NORTH AMERICAN PARASITIC COPEPODS BELONGING TO THE LERNAEIDAE WITH A REVISION OF THE ENTIRE FAMILY.

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INTRODUCTION

The present is the thirteenth[1] paper in the series dealing with the parasitic copepods in the collection of the United States National Museum, and comprises the family of the Lernaeidae.

This is the oldest family of the parasitic copepods and includes some of the most eccentric and bizarre forms. The genera composing the family have often been wrongly interpreted, and their systematic position and arrangement have been mere conjectures. This was largely because they were imperfectly understood and nothing was known of the male sex or of the life history.

The development of *Pennella* consists of a broken series of larval forms described by different authors—Steenstrup and Lütken (1861), Lubbock (1860), Wierzejski (1877), Brady (1883), Lütken (1893), and M. T. Thompson (1905).

The development of *Lernaeocera* (*Lernaea*) was worked out in admirable shape by Pedaschenko in 1898 and by A. Scott in 1901. That of *Sarcotretes* was published by Jungersen in 1911, and the life history of *Lernaea* (*Lernaeocera*) has just been completed by the present author. We thus have now a life history for each of the four subfamilies. These have all been included in a condensed form

[1] The 12 preceding papers, all of which were published in the Proceedings of the United States National Museum, are: 1. The Argulidae, vol. 25, pp. 635–742, pls. 8–27. 2. Descriptions of Argulidae, vol. 27, pp. 627–655, 38 text figures. 3. The Caliginae, vol. 28, pp. 479–672, pls. 5–29. 4. The Trebiinae and Eurypliorinae, vol. 31, pp. 669–720, pls. 15–20. 5. Additional Notes on the Argulidae, vol. 32, pp. 411–424, pls. 29–32. 6. The Pandarinae and Cecropinae, vol. 33, pp. 323–490, pls. 17–43. 7. New Species of Caliginae, vol. 33, pp. 593–627, pls. 49–56. 8. Parasitic Copepods from the Pacific Coast, vol. 35, pp. 431–481, pls. 66–83. 9. Development of Achtheres ambloplitis Kellicott, vol. 39, pp. 189–226, pls. 29–36. 10. The Ergasilidae, vol. 39, pp. 263–400, pls. 41–60. 11. Descriptions of New Genera and Species, vol. 39, pp. 625–634, pls. 65–68. 12. The Lernaeopodidae, vol. 47, pp. 565–729, pls. 25–56.

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in the present paper, because of the opportunity thus afforded for comparison and inference.

A. Scott (1901) and Sir William Turner (1905) are the only authors who have verified the internal anatomy of the species they described by means of sections; the others have relied entirely upon what could be seen through the body walls. Scott described *Lernaeocera branchialis*, while Turner portrayed *Pennella balaenopterae*, representatives of two of the four subfamilies. In the preparation of the present paper various species of the genera *Lernaea*, *Lernaeenicus*, *Peniculus*, and *Collipravus* have been studied by means of serial sections, thus supplementing and completing the work of Scott and Turner.

It was further found after trial with various reagents that if specimens were properly dehydrated in absolute alcohol and entirely cleared in clove oil, they became so transparent that the internal anatomy in all its details was clearly visible without sectioning. Nearly every species described in the present paper has been treated in this manner, and the internal specific and generic characters have been thus determined.

Hence the systematization here proposed is the result of a careful study of the life history and of both external and internal morphology, and is substantiated by serial sections.

Much of the work was done at the laboratory of the Bureau of Fisheries at Fairport, Iowa, during the summers of 1914, 1915, and 1916.

That portion of the work which concerned the genus *Lernaea*, which is parasitic upon fresh-water fishes, and the material for which was collected at Fairport, has already been reported to the United States Bureau of Fisheries. The remainder of the work is incorporated in the present paper, and as here constituted the family Lernaeidae includes 17 genera, three of which—*Cardiodectes*, *Collipravus*, and *Trifur*—are new to science, and 80 species, of which 15 are new. There are seven generic names which have been introduced into this family, each of which is composed of the name *Lernaea* or the corresponding adjective *Lernaios* and some other word. Two of these compound names, *Lernaeopoda* and *Lernaeomyzon*, belong in the family Lernaeopodidae; two others, *Lernaeonema* and *Lernaeopenna*, are synonyms; the remaining three, *Lernaeenicus*, *Lernaeocera*, and *Lernaeolophus*, are still valid genera in the present family. In the author's opinion, the first part of all these names should be spelled alike, since each represents the same word which was in existence and whose spelling had been determined long before any of the compounds were formed.

HISTORY.

Early literature and natural history.—Most of the genera and species belonging to this family are buried in the flesh of their host, with the posterior portion of the body and the egg tubes hanging free in the surrounding water so as to be readily seen when the fish are handled. Many of the species also are of exceptionally large size, reaching 4 and sometimes even 6 inches in length. Such remarkable size and prominence called them to the attention of fishermen at a very early date, and we find mention of these parasites in several of the classical writers, the stories about them doubtless being derived from the fishermen.

Aristotle, Pliny, Oppianus, and Athenaeus all described the sufferings of the tunny and swordfish in the Mediterranean in consequence of the irritation caused by these pests. Two of the early natural histories, Aquatilium Animalium Historiae by Salviani (1554, p. 126) and Libri de piscibus marinis by Rondelet (1554, p. 249), repeated these accounts, and the latter author gave a figure of a tunny with one of the copepods fastened near the pectoral fin. Conrad Gesner, in his Historia Animalium—De Aquatilibus (1560, p. 112), gave a more extended account of the parasite, described its structure and appearance, and presented an enlarged figure of it, besides repeating the figure given by Rondelet. But his description and figure resemble a Lernaeopod far more than they do a Lernaean. Boccone, in his Recherches et Observations naturelles (1671, p. 284), tells us that the fishermen on the coast of Messina knew of another parasite which they called "Sanguisuca," and which buried itself in the flesh of the swordfish; and he adds with reference to it . . . "This sangsue appears to be tormented by a louse which I have never seen on any other animal. It is of the size of a pea and attaches itself firmly to the animal" (p. 292). Boccone considered his species the same as that of Gesner, but the figures he gave proved it to be a *Pennella*, while the "louse" on it was doubtless a goose barnacle similar to those shown in figure 147.

Lernaea and *Lernaeocera*.—Linnaeus obtained from a European carp, to which he gave the name "*Cyprinus carassius*," a parasite upon which he established the genus *Lernea* in 1746,[1] calling the species simply "*Lernea tentaculis quatuor*." In the following year he described another species, from the gills of a *Gadus*, under the designation "*Lernea cauda duplici tereti*."[2] In the tenth edition of his Systema Naturae (1758, p. 655) he designated the first of these species as *Lernea cyprinacea*, the second one as *L. asellina*, and he transferred to this genus *Lernaea* a third species, *salmonea*, which

[1] Fauna Suecica, p. 367, fig. 1282.
[2] Iter Westrogotha, 1747, p. 171, pl. 3, fig. 4, *a* and *b*.

had been described by Gissler under the name *Pediculus salmonis*,[1] arranging the three species in the order named.

Accordingly the species *cypinacea*, upon which the genus was originally founded, and which stands first in this tenth edition, becomes the oldest species in the family. It was the ostensible genus type for nearly a century, and it may well be restored to that position.

The second species, *asellina*, is a typical Chondracanthid, while the third, *salmonea*, is as typical a Lernaeopod, so that neither of them can be even retained in the family.

In the twelfth edition another new species, *branchialis*, was added to the genus and was placed first, but the genus diagnosis remained unchanged.

For many years every newly discovered parasite, whatever its structure might be, was referred to the genus *Lernaca*, which thus came to include a large number of heterogeneous species. Many of these have since been established as distinct genera. The first to be thus established was the species *branchialis*, which was made the type of a genus called "*Lerneocera*" by Blainville in 1822 (p. 376). Blainville included in his genus, besides the species *branchialis*, Müller's *Lernaca cyclopterina*, a new species which he named *surriraiis*, and unfortunately Linnaeus's *Lernaea cyprinacea*. If he had only omitted this last species, which of course he had not the slightest excuse for including, since it was Linnaeus's type species, the two genera would never have been exchanged, but, as it was, his mistake was copied by Desmarest (1825), Nordmann (1832), Burmeister (1833), Krøyer (1837), and Milne Edwards (1840). The latter explained that Nordmann, Burmeister, and Krøyer had restricted Blainville's generic name to such species as had soft symmetric horns on the head and straight multiseriate egg strings, and he adopted their restriction. Blainville, however, distinctly stated in his genus diagnosis that *Lernaeocera* had three immovable and branched chitin horns, two lateral and one dorsal (p. 375). And under the type species he said, "The egg sacks arise from just in front of the posterior extremity of the body and are much twisted or coiled" (p. 376). Furthermore, he stated plainly that he had never seen the species *cyprinacea*, but only the figure published by Linnaeus, which did not show the egg sacks.

In other words, the authors above quoted deliberately exchanged the two genus names to suit their own fancy, took away from Linnaeus's genus *Lernaea* the species which had served as its type for 90 years, and substituted for it the species which Blainville had made the type of his genus *Lernaeocera*, and forced upon Blainville, as a

[1] Kongl. Svensk. Vetensk. Acad. Handlingar, 1751, vol. 12, p. 185, pl. 6, figs. 1 to 5.

substitute type, a species which did not agree with his genus diagnosis and which he had never seen.

In such a dilemma only one course is possible, and that is to restore the two genera to their proper places, in spite of the great inconvenience which will result, and this has been done. The author sincerely regrets the necessity for such a change, especially when the genera are so widely known and so often quoted, but the evidence is so convincing as to leave no choice in the matter, and both Linnæus and Blainville have claims for justice which far outweigh any temporary embarrassment.

Location of the Lernaeans.—The early Lernaeans were so eccentric and apparently lacked so many of the usual crustacean appendages that Linnaeus did not suspect them of being crustacea, and placed them amongst the worms, characterizing them by the softness of their body and the absence of a shell. Hans Ström in the first part of his Physisk og Oeconomisk Beskrivelse (1762, p. 167), under the heading of insects, described both sexes of "*Lernaea salmonis*" and the females of "*L. uncinata.*" On page 209 he described *Lernaea corpore tereti flexuosa*, which Linnæus afterward identified as *L. branchialis* and placed with his other species among the worms.

O. F. Müller, in Zoologiae Danicae Prodromus (1776, p. 226), gave 11 species of *Lernaea;* Fabricius, in Fauna Groenlandica (1780, p. 336), gave 7 species; Hermann (1783), Schrank (1786), Lamartinière (1787), Brugières (1792), and Holten (1802) all added species of *Lernaea* and all adopted Linnaeus's system of classification. Cuvier, in his Tableau elementaire (1798, p. 389), placed the Lernaeans under "Mollusques gasteropods" in the division of those having free motion in water. Lamarck, in his Systême des Animaux sans vertèbres (1801), also placed them under the mollusks but under "Mollusques cephales."

Bosc published an Histoire Naturelle des Crustacés in 1802, but although he gave an excellent historical summary and a good account to date of *Caligus*, *Argulus*, *Cecrops*, *Dichelestium*, etc., he included none of the Lernaeans, which was equivalent to saying that he did not consider them as crustaceans. In an Historia Vermium (n. d.) published shortly afterwards he described (p. 51) 15 Lernaean species, placing them among the mollusks, but stating that they approached the intestinal worms. Lamarck, dissatisfied with his first attempt, removed the Lernaeans from the mollusks in his Philosophie Zoologie, 1809, and placed them among the annelids. Three years later, in Extrait du Cours de Zoologie and again in Histoire Naturelle des Animaux sans Vertèbres (1816), he showed the need of forming a separate class to receive these animals, which he named "Epizoaires," and which, he said, "may properly fill up the great void which exists between insects and worms."

In 1815–16 Oken published a Lehrbuch Naturgeschichte, in which he placed the Lernaeans as the third family in the order of "Erdleche oder Geschlechtsleche," and in this family were included all the parasitic copepods then known (p. 181). Later, in the same book (p. 357), he revised his classification, which contained many errors and called the group "Armwurmer," dividing it into two tribes, the Lernaeans containing four genera, *Axine*, *Clavella*, *Pennella*, and *Lernaea*, and the Argulids, containing also four genera, *Inops*, *Dichelestium*, *Caligus*, and *Argulus*. Thus was shown for the first time the relations between the Lernaeans and the other copepod parasites. In 1817 Cuvier, in his Regne Animal, adopted the view taken by Bosc, placing the Lernaeans among the intestinal worms, while he located the other parasitic copepods among the crustacea.

Soon afterwards Surriray made the important discovery that the long filaments suspended from the body of these animals contained eggs and that the young when hatched bore no resemblance to the adults, but were very similar to the young of *Cyclops*—that is, they were crustaceans and not worms.

Blainville, in his Mémoire sur les Lernées (1822), admitted the truth of Surriray's statement and fully established the Lernaeans among the crustacea, where they have remained ever since.

ECOLOGY.

Sexual dimorphism.—The females of the Lernaeidae are fixed parasites, and consequently there is a complete loss of the power of locomotion, although the swimming legs are usually retained, and there is great diversity in the means of prehension. Since the male does not finally become a fixed parasite, but remains upon his first host or swims about freely until his death, there is not the sexual dimorphism which was seen in the Lernaeopodidae. Indeed, it can not be said that there is any real dimorphism at all, because so long as the two sexes remain together and during the period of sexual union they are of the same size, and it is only after the female has become a fixed parasite for the second time and the male has perished, that the former increases enormously and becomes misshapen.

The body of the female is always a little longer than that of the male, and just before as well as for some time after fertilization the genital segment increases greatly in length, but remains of the same width, thus giving the female larva an exceptionally elongated form. A considerable portion of this increase takes place during the second free-swimming period, so that by the close of this period there is a marked difference in the length of the fused genital segment and abdomen between the female and such males as still survive; but in other respects the two sexes are alike.

Consequently the only dimorphism would be one of length and not of structure, a difference which is common to all copepods, but is here carried a little farther than usual.

Locomotion.—Judging by the size one would say that the larvae alone possess the power of locomotion, and that the adults are fixed parasites.

But we must remember that sexual union takes place during the first parasitic period, and that it is followed by a second period of free swimming during which both the male and female must be sexually mature.

Moreover, the male never develops any farther, so that he is as fully matured as he will ever become, and the subsequent development of the female is a retrograde metamorphosis rather than an evolution. Accordingly, we are justified in saying that both the larvae and the sexually mature adults are capable of free swimming, and in proof of this both are frequently taken in tow. The majority of males remain attached to their host after sexual union, but all the females and a small percentage of the males (4 per cent) disengage themselves and become free swimmers for a second time. Each of these free-swimming periods is fully as long as that of the Lernaeopod larva, so that the two together give the Lernaeid larva twice as much free swimming as is enjoyed by the Lernaeopodidae.

In the nauplius and metanauplius larvae the swimming motion is jerky and more or less spiral in direction; in the copepodid larvae it becomes faster and more continuous, although it still remains somewhat spiral.

These larvae dart about by spasmodic contractions of the swimming legs and search for something to which they can fasten themselves. If they find nothing suitable they swim about until tired, come to rest upon their backs on the bottom of the aquarium, and remain thus for long periods.

Prehension.—On seeking its first or temporary host the larva uses its second antennae and maxillipeds for prehension. After settling upon the gills in this manner it either continues to use these appendages like *Lernaea*, or fastens itself by a broad frontal filament to the tip of the gill filament like *Lernaeocera*, *Sarcotretes*, and *Pennella*. In the former case no change is produced in the host's gills, but in the latter case the attachment of the parasite's frontal filament to the fish's gill causes the gill to swell up and become tumid, while the filamentous plates disappear on both sides for some distance from the tip.

One or the other of these two modes of prehension, or both of them, are the only ones ever practiced by the male; but the female when she searches out a final host adopts a third method. She bur-

rows or pushes her cephalothorax into the host's flesh until it is completely buried and only the genital segment and abdomen are left on the outside.

From the sides of the head and anterior thoracic segments horns and processes of various sorts now grow out into the flesh of the host and eventually anchor the parasite so firmly that it can not be removed except by cutting away the flesh. The irritation produced by the horns develops a tough membrane or skin immediately around them, which adds considerably to the security of prehension. This tough membrane also envelops the free thorax or neck of the parasite and reaches as far as the real skin of the host. In addition to the horns there also grow out on the front of the head in *Pennella*, *Perodema*, and *Cardiodectes* curious misshapen warts and excrescences. In *Haemobaphes* there are no real horns but only laminate processes, flattened dorso-ventrally, and the free thorax is reflexed upon itself so that the head points backward instead of forward, and the sides of the cephalothorax and the first two or three thorax segments are prolonged laterally.

Baudouin writes (1905*c*, p. 720) that *Lernaeenicus sardinae* is able to cling with its cephalothorax to the vertebral column of its host as a woodpecker clings to the trunk of a tree, which would be still another or fourth method of prehension. He does not explain this prehension any further than to say that it is * * * "de façon a s'assurer d'un solide point d'appui sur ce poisson très mobile et très agile" (the sardine). However, from text figures accompanying his paper we can see that the grip upon the backbone is obtained by the short horns which grow out from the cephalothorax. The anterior horn is curved over ventrally around the ventral surface of one of the fish's vertebrae, the lateral horns are curled into the spaces between this vertebra and the one next to it on either side, while the ventral surface of the parasite's cephalothorax is applied to the side of the vertebra. The horns being cartilaginous and rigid furnish a secure grip, which holds the parasite's head in close contact with the fish's aorta.

Furthermore, in the case of *Pennella*, in addition to the tough membrane around the head and thorax, the irritation penetrates the surrounding tissue and causes the formation of an enormous cyst as large as an English walnut or even sometimes attaining the size of a lemon, and having the consistency of cartilage. Inside of this the head and neck of the parasite is often twisted in corkscrew fashion, thereby greatly increasing the difficulty of extracting them uninjured.

Whichever method of prehension may be adopted by the adult female can not afterwards be broken, but is kept throughout her life, and may even continue longer. The author has repeatedly cut out

of swordfish the chitin horns and portions of the cephalothorax of females of the genus *Pennella*, which had been dead so long that the remainder of their bodies had decayed and dropped off. The same may be said of *Lernaeocera branchialis*, whose chitin horns are often found in the throat of codfish and other Gadidae. By thus burying the cephalothorax in the flesh of the host the mouth of the parasite is brought close to some large blood vessel, from whence it can derive nourishment.

Burrowing.—The different genera choose different blood vessels and also different points on the outside of the host's body from which to commence their burrowing. These differences will be found stated for each genus under the generic characters. Of course the larger the fish infested by the parasite the greater the distance it must penetrate. In the case of *Pennella* on a large swordfish this distance sometimes reaches 15 or 20 cm.

It seems probable that this burrowing through the flesh is what causes the intense irritation mentioned by Aristotle, Pliny, and others in the tunny and swordfish, when the latter leap out of the water and often fall on board of ships.

The actual method of burrowing has never been witnessed, nor from the nature of the case is it likely to be, but there are certain inferences with reference to it which are inevitable. In the first place we know that it is not accomplished by any special or temporary organs, for no indications of anything of this sort have ever been discovered in the larvae.

On examining the regular appendages with a view of selecting those best adapted for burrowing, attention is at once drawn toward the second antennae and also the maxillipeds in such species as possess them.

The antennae are exceptionally large and powerful at the very time when the burrowing begins, and are armed with strong chelae. Moreover they are on the frontal margin of the head at first and are then transferred to the dorsal surface. Inasmuch as this is true of every one of these burrowing genera but is found in no other family of copepods there must be some significance in it. At least it would seem to show that these antennae are used in burrowing.

The burrowing is preceded and may be accompained by an elongation of the thorax and abdomen of the parasite. In the gill parasite *Lernaeocera* A. Scott stated that the genital segment elongates to fully 15 times its original length. The increase is probably much greater in *Pennella*, *Lernaea*, and other body parasites; Brian figured a young female *Pennella* in which the cephalic horns had not yet begun to develop as being 65 mm. in length. Ordinarily the burrowing must be completed before the horns and processes on the

cephalothorax begin to grow, since it would be manifestly impossible to move a set of long branched horns through flesh.

Torsion.—Baudouin (1905*b*), Quidor (1912), and some other observers have called attention to the torsion or twisting of the body of the adult females, which may be due to several causes. The anterior portion of the parasite's body is buried in the tissues of the host, and is held rigidly in place by the horns and lateral processes of the cephalothorax, and by the tough cyst that forms around them. The posterior portion of the body hangs freely in the water and can be moved in any direction.

When the parasite takes a position on its final host we may assume that its own long axis is parallel with that of the host (external parasites), or with the water current (gill parasites). The body of these female parasites is greatly elongated, while the antennae and mouth parts are close to the anterior end. Consequently when the parasite attaches itself to the fish and begins to burrow its way into the flesh the long body will trail backward in the water in such a way as to offer the least resistance. Furthermore the fish's scales are arranged in such a way that if the external parasite is to burrow under them, as is often the case, it must assume this position. At first the posterior portion of the body would have a tendency to stand out from the surface of the fish, but it is quickly bent by the resistance of the water and thus the body of the parasite comes to have a curve or bend just where it leaves the body of the host. The angle of this bend varies with the direction taken by the burrowing copepod. If the latter bores its way into the host at right angles to the surface (*Sarcotretes*) the bend in its body will be approximately a right angle; but if the parasite bores in obliquely the angle will be larger (*Lernaeenicus*); and in the case of very oblique boring there may be no bend at all (*Lernaea*, species).

In those parasites whose point of entrance is on the median line of the host this simple flexion of the body seems to be the only result produced. Specimens of all three of the genera mentioned above have been taken by the author from the median line of various hosts, and their bodies showed no torsion whatever. This fact seems to have escaped the observation of Baudouin and Quidor; at least they make no mention of it. But when, as usually occurs, the point of attachment is on the right or the left side of the host, then there follows a torsion or twisting of the body of the parasite upon its long axis in addition to the flexion.

Of course the body may turn either to the left or the right, and Quidor has defined as *direct* that torsion in which the body is turned from the left over toward the right when viewed from the anterior end, and as *inverse* when it turns from the right over toward the left. The amount of torsion is measured by standing the parasite

upon end in a circle so that the long axis of the parasite will, if produced, pass through the center, and at right angles to the plane of the circle. Radii are then drawn through the center of the anal and mouth apertures and projected upon the plane of the circle. The angle between these radii is the angle of torsion and is expressed in degrees. There are almost always longitudinal ridges or stripes or something of the sort which indicate clearly the direction of torsion, whether to the right or left.

So far as observations have gone there seems to be considerable regularity in the torsion, not only as to the direction, but also as to the amount. Furthermore if the torsion of any given species is direct on the right side of the host it is more often inverse on the left side, and the opposite. But the present author is by no means prepared to go as far as Quidor does and say that the kind and amount of torsion possesses specific value. On the contrary both prudence and actual observation strongly prohibit any such conclusion. In view of the extremely meager data at present available it seems presumptuous to assume that two given specimens of any genus are distinct because they were found on the same side of their host, and the one showed direct torsion while in the other it was inverse. And the distinction between a direct torsion of 45° in one specimen and 90° in another possesses still less value.

Subsequent observations may show that such distinctions ought to be considered in connection with certain genera, but the following tables prove conclusively that in the genus *Lernaeenicus* they are not worth considering.

Sixteen tomcod heads were preserved by Mr. V. N. Edwards at Woods Hole, each of which was badly infested on the side of the head, along the margin of the gill covers, and behind the pectoral fins with *Lernaeenicus affixus*, the number of specimens varying from 2 to 24 and the total reaching 138. The direction and amount of torsion of each parasite was carefully noted and is recorded in the tables, together with the position on the host.

It is assumed that in its normal position the dorso-ventral axis of the parasite is at right angles to the surface of the host's body and that the ventral surface of the parasite is next to the skin of the fish. This position is indicated in the tables by the term "dorsal 0°," and shows that there has been no torsion. When the parasite has been turned 180° in either direction its dorsal surface will be next to the skin of the fish, and this position is indicated by the term "ventral 180°." In case of doubt as to the direction of torsion the entire parasite was removed. The tomcod heads are numbered consecutively, the numbers appearing in the first column of the tables.

	Right side.	Center.	Left side.
1	direct..... 90° inverse.... 90°	ventral..... 180° ventral..... 180° dorsal..... 0°	
2	inverse.... 90° direct..... 10° direct..... 60° inverse.... 10° dorsal..... 0° inverse.... 90° inverse.... 30° inverse.... 10° direct..... 90° inverse.... 120° inverse.... 10°	dorsal..... 0°	
3	ventral.... 180° dorsal..... 0°	inverse.... 45° direct..... 45° inverse..... 60°	
4	inverse.... 60°	dorsal..... 0°	inverse.... 45° direct..... 90° dorsal .... 0°
5	inverse.... 45° inverse.... 10°	direct..... 90° inverse..... 45° dorsal..... 0° inverse..... 45°	ventral ... 180° inverse.... 100°
6	inverse ... 45° inverse.... 90° inverse.... 135°	direct..... 30°	
7		direct..... 135° inverse..... 45° dorsal..... 0°	inverse.... 90° inverse.... 45°

	Right side.	Center.	Left side.
8	direct..... 90° inverse.... 90° inverse.... 60° direct..... 90°	dorsal..... 0° inverse..... 135° direct..... 135° direct..... 90°	inverse.... 90° direct..... 90° dorsal..... 0° inverse.... 45° dorsal..... 0° inverse.... 90°
9	direct..... 135° dorsal..... 0° inverse.... 90° direct..... 60° inverse.... 135° inverse.... 135° ventral.... 180° inverse.... 100° ventral.... 180°		dorsal..... 0° inverse.... 90° direct..... 45° dorsal..... 0° direct..... 135°
10	direct..... 90° inverse.... 90° ventral.... 180° inverse.... 45° inverse.... 45° inverse.... 45° direct..... 90°	direct..... 90° direct..... 135°	direct..... 45° direct..... 90°
11			direct..... 90° direct..... 90° direct..... 100° inverse.... 45° inverse.... 90° direct..... 90° inverse.... 45° direct..... 90° direct..... 90°
12		inverse..... 90° ventral..... 180° dorsal..... 0°	
13	inverse.... 90°	direct..... 90°	

	Right side.	Center.	Left side.
14		inverse..... 45° direct..... 100°	inverse.... 60° dorsal..... 0° dorsal..... 0° direct..... 45° inverse.... 135°
15	inverse.... 90° inverse.... 90° inverse.... 135° inverse.... 90° direct..... 45° direct..... 90° dorsal..... 0° ventral.... 180°	direct..... 10° ventral..... 180° dorsal..... 0° ventral..... 180° ventral..... 180° direct..... 135° direct..... 90° inverse..... 90° ventral..... 180° ventral..... 180°	ventral.... 180° direct..... 90° direct..... 45° direct..... 45° direct..... 135° ventral.... 180°
16		dorsal..... 0° dorsal..... 0° inverse..... 135° direct..... 90° direct..... 45° inverse..... 90° dorsal..... 0° inverse..... 90° dorsal..... 0°	ventral.... 180°

In these tables there are 50 parasites from the right side of the host, 44 on the median line, and 44 from the left side—a remarkably even distribution. Of the 50 from the right side 29 (57 per cent) showed inverse torsion, 13 (26 per cent) showed direct torsion, and the remaining 8 either showed no torsion or were twisted through 180°. Of the 44 from the left side 19 (44 per cent) showed direct torsion, 14 (32 per cent) showed inverse torsion, and the remaining 11 either showed no torsion or were twisted 180°. Of the 44 from the median line 20 (44 per cent) showed no torsion or were twisted 180°, and the remaining 24 were evenly divided between direct and inverse torsion.

From these tables we may safely draw certain conclusions:

1. In the majority of instances the torsion is inverse on the right side and direct on the left side, but there is altogether too large a minority in each case to warrant us in attaching any specific value to the direction of torsion.

2. On the fifth head the necks of the four parasites from the center all entered the same opening in the skin of the host, and yet one showed no torsion, two showed inverse torsion, and one showed direct torsion.

On the eighth head the first three parasites from the center all entered the same opening in the fish's throat; one of them showed no torsion, while the other two were strongly twisted in opposite directions.

On the ninth head the first three parasites all entered a single opening in the right operculum of the fish, on the eleventh head the first three similarly entered a single opening in the left operculum, and on the fourteenth head the last three also came from one opening. Hence we are forced to the conclusion that the position of the parasite upon its host can not be the chief cause in determining either the direction or the amount of torsion. There must be some other influence so much stronger than the position that it can completely overcome the latter and produce its own effects in spite of opposition.

3. With reference to the amount of torsion four or five successive figures anywhere in the tables will show that for this species it possesses no significance whatever.

But Quidor, in the article already referred to and in another later one, went even further and argued that the genus *Sphyrion*, which has been placed with the Chondracanthidae, and a new genus *Hepatophilus*, which he had just established, should be transferred to the Lernaeidae, because they both showed torsion. He stated that the males of the two genera were unknown, and that the females showed distinct torsion, "which is found only in the Lernaeidae" (p. XL). There can be no question that they show torsion, but such a twisting of the body is merely mechanical, and there is no reason why any fixed parasite should not exhibit it, provided the anterior end of the body is firmly anchored in the flesh of the host while the posterior part hangs free in the water. On the contrary, there is every reason why all such parasites should show torsion quite irrespective of their morphology and ontogeny. But obviously we can not bunch them all in one family on the basis of torsion alone, when there are good morphological and developmental reasons why they should be separated.

With reference to the disposition of the above-mentioned genera and others which have been crowded into the Lernaeidae, a full discussion will be found on page 34.

Causes which produce the torsion.—Quidor stated that "This torsion is the result of the mode of fixation of the parasite, of the habits of the host, and of the mechanical action of the external medium" (1912*c*, p. 87).

We can readily understand how the resistance offered by the water produces both flexion and torsion in the body of the parasite, and how the amount of each might be varied by the habits of the host. But neither of these causes explains the differences enumerated in the above tables, especially the different kinds and amounts of torsion in specimens attached at the same point and on the same host. Again we are forced to the conclusion that there must be another cause, stronger than any of those already mentioned. Quidor did not explain what he meant by the "mode of fixation of the parasite," but rightly interpreted this evidently becomes the controlling cause, and is worthy of careful consideration.

First comes the choice of a location on the body of the host; some genera choose the gills or gill chamber, while others select some place on the outside of the fish's body, a few species even preferring the eye.

Attention has been elsewhere called to the burrowing of the parasite into the tissues of the host, which varies greatly according to the locality selected. In the throat it is only a short distance from the outside surface or from the gill arches to the ventral aorta or to the heart, and it is an easy matter for the parasite to find those blood vessels.

From the back or the sides of the fish it is a much greater distance, varying with the size of the fish, and the parasite, after burrowing through the tissues, will be fortunate if it strikes at once the blood vessel that it started for. Then, too, the knowledge of the fish's anatomy possessed by the parasite is not infallible, and it frequently happens that the burrow strikes a rib or the backbone, around which it must turn before reaching the desired goal. In such a case the parasite may have to hunt around for some little distance before it finds the blood supply. This turning aside of the anterior end of the body and the adjusting of the mouth to the blood supply is what produces the torsion. Jungerson told (1911, p. 7) of a young *Sarcotretes scopeli* fixed on the back of its host on a line with the root of the pectoral fin. "It went nearly straight down through the muscles, curved in front of the right pronephros over the upper pharyngeal bones, and had its anterior end lying in front of the left pronephros, with the sucking apparatus close to the jugular vein." Such a twisting of the anterior part of the body would have produced torsion even if there had been no external resistance.

Similarly, Baudouin described the mode of fixation of *Lernaeenicus sardinae*, in the back of the sardine near the dorsal fin: "The cephalothorax buries itself almost perpendicularly to the axis of

the body of the sardine, and crosses over in the midst of the muscles to the lateral portion of the vertebral column, going along one of the faces of the series of spinous hypophyses to a distance of about 1 cm" (1905, p. 326).

Here the cephalothorax seems to be able to cling to the bony framework, as a woodpecker clings to a tree, and in order to do this the cephalothorax must be definitely adjusted to the framework. The crossing over to the hypophysis and the adjusting of the cephalothorax again produce torsion.

In the case of *Pennella* on the swordfish there is a more marked twisting about before the final adjustment. The distance to be penetrated through the flesh is always several inches, and it seldom happens that the parasite gets very near to a blood vessel at first. Like the sardine Lernaean it starts perpendicularly to the axis of the fish's body, but often meets some obstruction around which it must turn aside. And when it has reached the body cavity it is compelled to move backward or forward, to the right or to the left before it can find a suitable food supply.

The result is that the head and neck of the *Pennella* is often twisted in corkscrew fashion or even thrown into a coil inside of the enormous cyst. The author has two of these cysts, taken from a 200-pound swordfish, in one of which the cephalothorax of the parasite describes a complete circle, 1½ inches in diameter, while in the other it takes the form of an ellipse 1¾ by 2¼ inches.

Such a coiling of the cephalothorax and neck must be accompanied by a considerable torsion of the body, and would very easily overcome the external resistance of the water. We are forced, therefore, to the conclusion that the real cause of torsion is internal, inside the tissues of the host, and not external. In the fresh-water genus *Lernaea* it sometimes happens that the torsion accidentally proceeds much farther than usual. Thus one specimen showed a direct torsion of 315°, or seven-eighths of a complete revolution, while another showed four complete revolutions, 1,440°.

Food.—Whatever may be the case with parasites of other families there can be no doubt that these Lernaeidae feed upon the blood of their host.

The simple fact that they burrow through the flesh until their head and mouth are brought into close proximity with some large blood vessel, and sometimes penetrate into the heart itself, leaves us no choice but to conclude that the parasite is making sure of a copious food supply. During the first free-swimming period the larvae of both sexes may, and probably do, obtain food from the plankton like other copepod larvae. But during the parasitism which follows this free-swimming period it is just as probable that

they feed upon the blood of their temporary host. Upon this food the various appendages develop and the sexes reach maturity. The male undergoes no further change and usually remains parasitic upon this first host. A few males, however, sometimes join the females for the second free-swimming period, but it is highly improbable that either sex takes any plankton food during this period. Their mouth parts are only suited for obtaining food parasitically. The male has completed his life work, he does not increase at all in size, and dies in a very short time.

The female is seeking a final host, to which she fastens as soon as it is found, and the copious supply of blood obtained from this host seems to be necessary for the formation and ripening of the eggs. No females of any genus produce egg strings until after this final food supply has been secured. The female does not increase in size during this period nor undergo any other changes, but awaits for a suitable food supply.

Hosts.—This family, like the Lernaeopodidae, is found upon fishes in both salt and fresh water. In consequence of the fact that the first or temporary host is always a different species from the final one, the number of hosts is greatly increased. We find these parasites also upon fishes at all depths from near the surface down to 2,000 fathoms and over.

Lernaeocera seems to prefer the gills of the Gadidae for a final host and the gills of the Pleuronectidae for a temporary host; *Lernaeolophus* is found upon the gills of the parrot fish, the barracuda, and the groupers of tropical seas; *Peroderma* often frequents the lateral muscles of the sardine, the goby, and Cuvier's genus *Scopelus* as its host; *Pennella* for its final host burrows deeply into the swordfish, the tunny, the sunfish, the dolphin, and the flying fish; *Peniculus* is found upon the fins of the Gadidae; *Lernaeenicus* penetrates the flesh of the Mugilidae, the Clupeidae, the dolphin, and the barracuda; *Lernaea* chooses the gars and pike perches for its temporary host, and the basses, the catfish, and the carp for its final host.

Parasites.—The Lernaeidae are notable examples of the fact that one parasite often serves as the host for another. Many of them are attached to the outside of the body of the fish, where they can catch all that floats in the water, and they very quickly become covered with algae, ciliate infusoria, hydroids, and even barnacles (fig. 147). The striped goose barnacle, *Conchoderma virgatum*, has been found upon several species of *Pennella*, and Fowler, in his Report on the Crustacea of New Jersey (1912, p. 91), stated that many of the specimens of *Pennella filosa* were parasitized with this barnacle and with the hydroid *Eucope parasitica*.

Other Lernaeans from both salt and fresh water are often so covered by algae that it is difficult to see any portion of the para-

site's body. Jungersen (1911, p. 1) found the external portion of the body of the new copepod which he described completely covered with a gymnoblastic hydroid, so that "the parasite at first sight appears made up of a stem and a large number of branchlets," the latter being the hydroids.

Kellicott (1880, p. 66), in speaking of the adult *Lernaea cruciata*, said that "the chitinous exterior, together with the external load of confervae and infusorial life which they usually bear, render them too opaque for satisfactory examination."

Cunnington (1914, p. 827), in his remarks upon *Lernaea haplocephala*, a new species from the ganoid fish, *Polypterus*, taken in Lake Tanganyika and the White Nile in Africa, said: "Vorticellids infest many of these Lernaeids from the Nile to such a degree as to render difficult the study of their anatomy. Among a considerable number of specimens taken on a *Polypterus senegalis* almost all are infested, some of them as markedly as the one photographed (fig. 7). The region where the vorticellids are most thickly attached is about the junction of the thin anterior third of the body with the more dilated posterior portion. It seems highly probable that the manner in which these parasitic copepods can be so densely encrusted by such organisms is directly related to the peculiar fact that after fixation to their host they appear no longer to undergo ecdysis."

Jungersen also mentioned several other examples of triple association between a hydroid, a parasitic copepod, and a fish. He himself had seen *Obelia geniculata* "flourishing on a *Lernaea*[1] *branchialis* attached in the gills of the common cod: a similar case is mentioned by Saemundsson" (p. 28).

Alexander Agassiz (1865, p. 87) found the hydroid *Eucope parasitica* "on a species of *Pennella* parasitic on *Orthagoriscus mola*." Later the same hydroid was taken by Leidy (1889, p. 165) on another Lernaean, "*Lerneonema*[2] *procera*," parasitic on *Odontaspis littoralis*."

Many of the specimens of *Lernaeenicus longiventris* and *L. radiatus* in the United States National Museum collection are well covered with hydroids and algae.

Ciliate infusoria are also often attached to *Pennella* and *Lernaeenicus*, sometimes in company with algae, sometimes alone. The Lernaeans which fasten to the gills or on the inside of the gill chamber for the most part escape these Epizoans, but specimens of *Lernaeolophus* and *Haemobaphes* are occasionally obtained with algae fastened to the posterior processes or the abdomen. Indeed *Peniculus* is the only genus upon which none of these forms have been recorded, and this is probably an omission.

[1] A synonym of *Lernaeocera branchialis*.
[2] A synonym of *Lernaeenicus procerus*.

Among them all there has not yet been found a true superparasite. They are merely inquilines; that is, none of them use the copepods for anything further than a means of anchorage or support. They all provide their own food, and they neither give anything to nor take anything from the copepods. The food which they take from the water can not affect the copepod in any way, since the latter is sucking the blood of the fish.

The only influence they can have is a mechanical one, loading the copepod down with a comparatively heavy weight, and increasing considerably the surface of water resistance.

If they are distributed evenly over the copepod's body they do not affect the torsion, but if there is only a single goose barnacle, or tuft of algae, or colony of hydroids, they must of necessity have more or less influence on torsion according to their position.

EXTERNAL MORPHOLOGY.

General body form of adult female.—During the copepodid stages when fertilization takes place the different body regions are as clearly defined as in the Caligidae. Indeed these stages show such a marked likeness to the corresponding ones in the Caligidae as to leave us in no doubt of the close relationship of the two. But as soon as the female has fixed herself to her final host a retrogressive metamorphosis begins. Horns or processes begin to develop on the sides of the cephalothorax and sometimes (*Pennella*, *Cardiodectes*, *Peroderma*) over the anterior end. In *Peniculus*, *Phrixocephalus*, and *Collipravus* the anterior thoracic segments remain fairly distinct and each carries a pair of swimming legs. In *Lernaea* while the segments are fused the swimming legs remain separated by a considerable distance and still indicate the thoracic divisions. In the other genera the swimming legs are bunched together close behind the head and there is a corresponding fusion of the thorax segments. The antennae do not increase in size with the growth of the rest of the body, but remain minute, and the same is true of the swimming legs; the eyes are buried by the growth of new tissue over them and become invisible, and in some genera (*Pennella*, *Lernaeolophus*) the mouth parts disappear or are possibly represented by small chitin knobs.

In general, therefore, the body of the Lernaean is unsegmented, but may be more or less distinctly separated into three parts—a cephalothorax made up of the head and one or two anterior thorax segments, a neck or free thorax, and a swollen posterior portion or trunk, consisting of the fused genital segment and abdomen.

In *Phrixocephalus* the first two thorax segments are fused with the head; in other genera only the first one. The resulting cephalothorax is globular in *Lernaeocera*, *Pennella*, and *Lernaeolophus*, while it is more or less flattened dorso-ventrally in *Peniculus*, *Ler-*

naecnicus, and *Lernaea;* and in *Peroderma* it is conical. Furthermore, in this latter genus the head and neck are attached at right angles to the trunk, while in other genera the head alone stands at an angle with the neck.

In *Pennella* the anterior surface and often the entire cephalothorax is covered with small globular or irregular processes which help to anchor the parasite firmly in position. In *Peroderma* and *Cardiodectes* branched processes are developed from the front of the head alone, while in *Phrixocephalus* these anterior processes take the form of small lobed and chitinous horns.

Again in most of the genera processes, flattened dorso-ventrally, are sent out from the lateral and sometimes from the dorsal margins of the head and anterior thorax segment. These afterwards develop into horns, which complete the anchorage of the parasite to its host.

There are no horns on *Peniculus*, *Haemobaphes*, *Cardiodectes*, or *Peroderma*, the anchorage being accomplished by the strong claws on the second antennae, by the frontal processes, or by a flexure of the neck.

In *Lernaeocera* and *Lernaeolophus* the horns are well developed and often branched dichotomously; in the other genera they are nearly always simple.

These horns are outgrowths of the epidermal tissues and at first are short and wide and soft in texture; subsequently they elongate, become more or less cylindrical, and are gradually hardened into chitin.

Too much systematic value must not be given either to the number or the arrangement of the horns in any genus or species, although a certain number and arrangement may be typical in each species; for example, the five radiating horns in *Lernaecnicus radiatus*. But there is always so much variation that no dependence can be placed upon negative evidence; positive evidence is more conclusive. No specimen of any other species has thus far been found which possesses five horns radiately arranged, but there are many specimens of *Lernaecnicus radiatus* which do not show them. The number and arrangement of the horns depend more upon the difficulties encountered by the parasite in attaching itself to its host, and upon the kind of configuration of the tissue of the host surrounding the point of attachment, than upon any specific inheritance in the parasite itself. When the head of *L. radiatus* is buried in the muscles of the menhaden there is no trouble in developing five radiating horns, but the result is very different when the head is wedged between two of the bony plates of the operculum. The horns, therefore, must be given an insignificant place in the determination of the species, and it would be extremely rash to establish a new genus simply upon the possession of two extra horns, as Fowler has done.

The neck or free thorax is usually cylindrical and much narrower than the other two regions; it is sometimes straight (*Lernaeenicus* and *Lernaea*) and sometimes flexed (*Lernaeolophus* and *Haemobaphes*).

In *Peniculus* it is short and flattened dorsoventrally, while in some species of *Pennella* it is 100 mm. or more in length. Its length is largely determined by the thickness of the skin and underlying tissue that must be penetrated in order to bring the mouth of the parasite into close contact with some large blood vessel. Even the same species will have a longer neck on a thick-skinned and thick-muscled fish like the sunfish and a shorter neck on a thinner-skinned and thinner-muscled fish like the swordfish. The neck often becomes hardened into chitin like the horns and is always much firmer in texture than the following region, especially at the point where it emerges from the skin of the host.

Usually it is not segmented, the moniliform appearance of such species as *Lernaeenicus sprattae* being something very distinct from segmentation.

In *Lernaea* the neck and body are the same width where they come together, and the point of union is indistinguishable; but the segments are indicated by the attachment of the swimming legs. From these it can readily be seen that all the thorax segments have shared in the elongation of the body. In *Peniculus* the neck is very much narrower than the body, where the two come together, and is distinctly segmented, with a pair of legs attached to each segment. These show us that while all the thorax segments share in the elongation of the body the size of the shares increases rapidly from in front backwards.

In *Lernaeocera* and *Pennella* the swimming legs are found at the anterior end of the neck, packed together as closely as possible just behind the head. This may possibly be a real migration in some of the genera—that is, the legs may have moved from the segment where they originally appeared onto preceding segments, as happens to the maxillipeds in the Lernaeopodidae. But the lengthening of the genital segment during the second free-swimming larval period indicates that the anterior thorax segments contribute very little to the neck and that the great bulk of the latter is made up of the anterior end of the fused fifth and genital segments.

The swollen trunk is made up of the fifth and genital segments and the abdomen, and is much softer in texture than the preceding regions. It is usually greatly elongated as well as swollen, but is rarely short and stout. In *Lernaeocera* and its close relatives it is also convoluted or bent in the form of the letter S. The abdomen is the portion behind the attachment of the egg strings, it is always

narrower than the genital segment, and is often reduced to a mere knob. To this abdomen are attached various kinds of appendages in some of the genera. In *Pennella* and *Pegesimallus* there are very long rows of branched barbules, from which the former and better known genus derives its name. In *Lernaeolophus* there are similar appendages massed together closely, so that they bear more resemblance to a yarn mop than to the barbules of a feather. In *Haemobaphes* and *Haemobaphoides* there are two or three large knobs or processes along either side. In the other genera the abdomen is without appendages.

The egg strings vary greatly in the different genera, not only in their general makeup, but also in the arrangement of the eggs inside the string. In the Lernaeinae the cases are sacklike and the eggs are multiseriate; in all the other genera the cases are threadlike and the eggs are uniseriate. The multiseriate egg strings are shorter than the body and straight, while the uniseriate egg strings are often many times the length of the body, and are either cylindrical and straight, or coiled into a loose snarl, or flattened laterally and curled into a tight spiral.

The appendages.—These are the same as those of the Lernaeopodidae, namely, two pairs of antennae, a pair of mandibles, two pairs of maxillae, a pair of maxillipeds, and four or five pairs of swimming legs. These are all present in the sexually ripe male, but some of them are usually wanting in the female.

The first or anterior antennae are simple jointed cylinders, well armed with short setae, and are evidently tactile sense organs. The second or posterior antennae are also simple jointed cylinders, short, stout, and strongly chelate. They serve as the principal organs of prehension during the larval stages and often maintain that function in the matured female (*Peniculus*, etc.).

The proboscis is made up of a fusion of the upper and under lips, often combined with a considerable portion of the ventral surface of the head.

In this latter form it is very extensile and may be protruded a considerable distance from the head and moved about freely, the movements being controlled by numerous powerful muscles. When strongly retracted, as sometimes happens during preservation, it is drawn in so far as to produce a saucer-shaped or bowl-shaped depression of the ventral surface of the head. When protracted the maxillae are carried along with it and are then found near the tip of the proboscis, a considerable distance from the ventral surface of the head. In those genera (*Lernaeolophus*) where the ventral surface of the head is chitinized and takes no part in the movements of the mouth tube, the latter is always withdrawn in preservation

and forms a pit or shallow depression. In *Haemobaphes* the proboscis is apparently confined to the mouth tube proper and the maxillae are attached to the ventral surface of the head at its base.

The mandibles are simply curved claws or spines, one-jointed and entirely devoid of teeth. The first maxillae are also one-jointed and armed with short setae; the second maxillae are two or three jointed and terminate in one or two stout claws. There is also usually a stout spine on the inner or outer margin of the basal joint. These appendages are important organs of prehension in the copepodid larvae, and doubtless assist in the burrowing of the female into the flesh of her final host.

The maxillipeds are found in both sexes of *Lernaea*, but so far as known only in the males of other genera, and are made up of a large swollen basal joint, a smaller distal joint, and from one to five terminal claws.

The swimming legs, as Claus pointed out, do not increase in size from the larval condition and, therefore, appear rudimentary and degenerate upon the greatly enlarged body of the adult. There is, however, no actual degeneration or retrogression in their structure, but it often, perhaps usually, happens that the rami or even the entire legs get broken off. This may result either from the movements of the parasite itself or during its removal from its host and subsequent separation from the cyst which envelops it. But in such cases there is always left the scar at either end of the chitin rib which connected the legs or the stumps of the rami. We can not, therefore, regard the swimming legs as having actually degenerated or retrogressed, but simply as having failed to increase in size with the rest of the body. And we must not conclude from an examination of one or two specimens that the legs are destitute of rami, when further search will likely yield a specimen on which they are still retained.

In general we may say that the genus *Lernaea* possesses five pairs of swimming legs, of which the first four pairs are biramose with three-jointed rami, while the fifth pair is uniramose and unsegmented.

In most of the other genera there are but four pairs, even in the larval form—the first two pairs biramose, the third and fourth pairs uniramose, all the rami two-jointed. In *Peroderma* and *Sarcotretes* there are but three pairs—the first two pairs biramose, the third pair uniramose, and all the rami two-jointed. In *Haemobaphoides* there are only two pairs of legs, both biramose with two-jointed rami.

The copepodid larvae of *Sarcotretes* possess only three pairs of swimming legs in contrast to the four pairs found in the larvae of *Lernaeocera* and *Pennella*, and the five pairs in the larvae of *Lernaea*.

It will be of great interest to find the larvae of *Peroderma* and *Haemobaphoides* and ascertain if they also show a reduction in the number of legs, the latter genus having only two pairs.

INTERNAL MORPHOLOGY.

The body wall.—The body wall is composed of two layers—an outer transparent layer, which may or may not become chitinous, and an inner opaque and cellular layer, the chitinogen membrane of Claus and other authors.

The outer layer is made up of thin lamellae, lying one upon another, with no intervening spaces. In *Lernaea barnimii* Hartmann described quite a complicated pattern of raised sculpture on the external surface of the outer layer. This may be seen on fresh and living specimens but usually disappears during preservation. Through this outer layer run pore canals, which vary in proximity in different parts of the body, being closest together along the center of the body and farthest apart on the antennae, swimming legs, and furca. These canals are connected more or less intimately with the soft inner layer of the wall and probably function in excretion.

The inner layer of the body wall is softer than the outer and is never hardened into chitin. It is composed of polyhedral cells, which vary greatly in thickness, those lining the posterior body and abdomen being much thicker than those found in the anterior body and arms. The cells are not much flattened but are more or less inflated and filled with a fine-grained brownish substance, glandular in nature, and having spherical nuclei with small nucleoli. This layer normally lies in contact with the inside surface of the outer layer, but in alcoholic specimens the two layers are often separated. In the living animal the cells of the inner layer undergo certain changes, thus described by Hartmann: "Some cells break loose, stretch out, become narrower, take on the appearance of threads, anastomose with one another, and send out many irregular processes" (p. 736). This wandering of the cells takes place in all parts of the body, in the horns, and in the appendages. As a result they form a meshwork of active protoplasm over the inside surface of the inner layer and fill such spaces as the inside of the abdomen around the intestine.

This meshwork is particularly thick inside the posterior body of the copepodid larva and probably contributes greatly to the nourishment and increase of that part of the body during its rapid development.

The muscular system.—In the copepodid stages the muscular system is well developed and very closely resembles that of the Caligidae, thus furnishing another evidence of the close relationship of the two families. But as soon as the female has fastened herself to her final

host and has begun her retrogressive metamorphosis the muscles share in the changes produced. As the body fuses and becomes swollen and tumid and the appendages cease to be used the muscles also fuse and disappear until there is nothing left in the adult female but a simple network between the integument and the alimentary canal to be noted under the digestive system (p. 27).

There are still the usual muscles connected with the antennae, especially the second pair, with such of the mouth parts as are still used, with the swimming legs of those genera in which they are better preserved, and with the anal papillae in *Lernaea*, *Peniculus*, etc., and in even the most retrogressive genera there are still muscles connected with the external openings of the oviducts, which control the passage of the eggs into the external sacks. But the other muscles, including all those which flexed or moved the body of the copepodid larva, entirely disappear. In *Lernaeenicus* the proboscis is highly developed and possesses a complicated system of muscles whereby each part of it, as well as the mouth parts connected with it, can be moved independently.

But the swimming legs are less well preserved and their musculature is correspondingly reduced. In *Peniculus* the jointed thorax retains more or less of its capability of motion, and with this most of the muscles.

The alimentary canal.—The mouth opens into a short esophagus, which is usually straight or but slightly curved, and is inclined to the axis of the head. It opens into the stomach on the ventral surface of the latter, near or at the anterior end, and the opening is guarded by a powerful sphincter muscle. In those genera (*Lernaeenicus*, *Peniculus*, etc.) in which there is a protrusible proboscis the extension and retraction take place principally in the mouth tube, and are shared only incidentally by the esophagus and at its anterior end. The muscles, which control these movements, are attached chiefly to the base of the mouth tube (fig. 69) and draw it in or push it out without affecting the esophagus very much.

When the proboscis is protruded the stomach is drawn forward by the muscles at its anterior end, and this shifts the position of the esophagus and allows it to follow the movement of the mouth tube without itself undergoing much change of length or diameter. Its walls, however, are elastic and are probably stretched a little during the extension of the proboscis and recover their normal form when it is retracted.

The stomach is abruptly enlarged behind the sphincter muscle and is sometimes straight and sometimes convoluted. In the genus *Lernaea* it also sends out a lobe on either side, but these lobes are not connected in any way with the horns, nor can they be said to enter the base of the horns, as Claus, Hartmann, and some others have

declared. There are always two of them, no matter what the number of the horns may be, and sometimes they are not opposite the base of the horns. Furthermore, they are present in the larva long before the horns have started to grow. The stomach is lined with a digestive epithelium of very irregular thickness, from which scattering spherical cells project into the central cavity. These contain the digestive fluids and also a large nucleus with distinct nucleoli.

The stomach passes insensibly into the intestine, which, in most of the genera, is narrowed to a mere thread where it passes through the neck and then widens again in the trunk. Sometimes (*Lernaeolophus*) the intestine is convoluted in the lower portion of the neck, but it is usually straight. In the trunk it lies nearer the dorsal surface, between the ovaries and the oviduct, and is sometimes flattened dorsoventrally (*Sarcotretes*), again laterally (*Lernaeolophus*), or may even assume a three-cornered shape (*Pennella tridentata*), but is usually cylindrical.

In species like *Phrixocephalus triangulus*, where the trunk is short and wide, the intestine becomes baglike, and in the new genus *Collipravus* it is looped and folded back on itself, owing to the misplacement of the neck. The intestine passes into the abdomen in those genera (*Lernaeolophus*, *Pennella*, etc.) which have a comparatively large abdomen, and is bluntly rounded near the posterior end of the latter. In the genera (*Sarcotretes*, *Peniculus*, etc.) with a small abdomen it does not leave the trunk, but is bluntly rounded just in front of the vulvae, and the rectum is given off from its upper posterior corner. The rectum is very narrow and threadlike, and is connected with the side walls of the abdomen by numerous muscles. It is straight when the abdomen is large, but in the other genera is inclined dorsally.

In every genus thus far examined there is an anal lamina on either side of the external opening of the rectum, sometimes fair sized and armed with setae, sometimes minute and destitute of setae. But no matter how small the lamina may be there is an opening through the body wall into its interior that shows its real nature (fig. 57).

The anterior end of the stomach is suspended from the dorsal wall of the head by two long and narrow muscles, and in the genus *Lernaea* there are additional sets of muscles on each of the lateral lobes. The posterior end of the intestine is similarly connected with the dorsal wall of the abdomen or trunk. The alternate contraction and expansion of these muscles produce a forward and backward movement of the entire digestive canal. This is most marked in the copepodid larvae, but persists to some extent in those adults whose bodies are straight and not bent into a sigmoid loop. In addition to these

muscles the digestive canal is suspended by connective tissue from the dorsal or lateral walls of the various regions of the body through which it passes.

The walls of the stomach and intestine also contain both longitudinal and transverse muscle fibers, which produce strong peristaltic movements, so that the food is moved about and pushed back and forth over every portion of the digestive epithelium.

The nervous system.—The copepodid larva has a nervous system almost the same as that of the Caligidae, which has been described in detail elsewhere; but, like the muscular system, this, too, gradually disappears, and but little of it can be found in the adult female. There is enough of it left, however, to control such movements as persist, and especially the working of the reproductive organs.

In a median section of the head (fig. 69) the remains of the supra and the infra esophageal ganglia can still be seen, with scattered nuclei representing the nerve centers. Even the nerves themselves may be detected, but only those leading to muscles and organs which are active in the adult. Of the other nerves and even of the ventral chain of ganglia only traces are left, which are difficult to detect.

In all the genera the tripartite eye of the larva persists in the adult, and there is usually a more or less distinct nerve connecting it with the supra-esophageal ganglion. But it is buried deeply in the tissues over the base of the esophagus and has evidently been covered with the surrounding tissues during the growth of the various horns and cephalic processes. The lenses are usually no longer visible and, indeed, the eye itself can not be seen except in specimens which have been cleared in oil or some similar medium. The nervous system, therefore, shows the greatest retrogression of any portion of the body; it not only fails to increase proportionally to the growth of the body, like the various appendages, but it really diminishes and partially disappears.

The male reproductive organs.—The male reaches sexual maturity during the fourth copepodid stage, and the sex organs consist of a pair of testes situated in the posterior part of the cephalothorax and separated some little distance from each other, a pair of straight vasa deferentia, and a pair of sperm receptacles, containing the spermatophores and located in the genital segment. Each testis is an ovoid or ellipsoid and is somewhat flattened dorsoventrally; the vas deferens leads from the testis directly back alongside the intestine and into the genital segment, where it is enlarged into a receptacle to hold the spermatophores. In the fifth segment the vas deferens is convoluted once, and this fold has glandular walls which supply the cement material for the outside covering of the spermatophores. The opening through which the latter are extruded is on the ventral surface of the genital segment.

The female reproductive organs.—In the copepodid stage, when fertilization takes place, the ovaries of the female are ovoids or ellipsoids, like the testes of the male, and are similarly situated in the posterior portion of the cephalothorax, near the dorsal surface. The oviducts correspond in every particular with the vasa deferentia, leading back alongside the intestine to an enlargement in the genital segment, which is to receive the sperms from the spermatophores deposited on the outside of the segment by the male; and in the genus *Lernaea* the posterior portion of the oviduct secretes cement substance, like the vasa deferentia.

During the retrogressive metamorphosis which follows the fixation of the female to her final host a great change takes place in both the location and structure of the reproductive organs. The ovary migrates from the cephalothorax through the entire length of the free thorax into the genital segment, where it assumes a position near the dorsal surface at the anterior end of the segment, except in the new genus *Collipravus*, where it is near the posterior end at the base of the abdomen. In most of the genera the ovary also reverses its position, the anterior end becoming posterior and the posterior end anterior, so that the oviducts in the adult always arise from the anterior end. Furthermore, in some genera (*Lernaeocera*, *Pennella*, etc.) the two ovaries move inward toward the midline and finally come together and fuse, leaving only a pair of anterior and posterior horns to mark their dual origin.

The oviducts now pass down around the intestine to the ventral surface and strait back to the vulvae without convolutions, except in *Pennella*, where there is a single fold just as they leave the ovaries.

A pair of cement glands is also formed, whose anterior glandular portion originates at the anterior end of the genital segment at the base of the neck and ventral to the oviducts. Each gland is cylindrical and without convolutions, and the two lie side by side along the midline. At about its center each gland is contracted and passes into a duct which empties into the oviduct of the same side just inside the vulva. These ducts are also without convolutions in all the genera except *Lernaeolophus* and *Lernaeocera*, in which they are vertically convoluted.

In the genus *Lernaea* the cells at the posterior end of the ovary gradually loosen themselves from the epithelium and become associated in longer or shorter filaments or strings, each of which is made up of many cells flattened together like a row of coins and which increase in size toward the anterior end of the ovary and there break up into separate eggs as they pass into the oviducts, the conditions being thus similar to those found in the Lernaeopodidae.

In all the other genera thus far studied the ovary consists of a mass of tiny nucleated cells, with no arrangement into filaments or

strings but with all the eggs separate and in close contact one with another. Those near the opening of the oviduct are about twice the size of those at the center and these in turn are much larger than those at the posterior end. The increase in size is accomplished by the absorption of food material or yolk, which goes on with much greater rapidity at the anterior end just as the eggs pass out into the oviducts. In the latter the eggs are arranged in a single row and are strongly flattened, so that they look like coins standing on edge.

The external egg sacks are short and bag-shaped in the Lernaeinae, and the eggs are piled loosely into them, with almost no flattening and without definite arrangement. In the oviducts also of this subfamily the eggs are spherical instead of being flattened, and they do not quite touch one another. In the other genera the egg sacks are filiform and very long, reaching 12 to 15 inches in the genus *Pennella*, and the eggs are arranged in a single row and flattened as they were in the oviducts; but there is this difference: In the oviducts the eggs are in actual contact, while here in the external sacks each is separated from its neighbor on either side by a partition formed of the egg membranes.

In the Lernaeinae the developing larvae are not arranged in any order with reference to the walls of the egg sacks, but in the other subfamilies there is the same arrangement as in the Caligidae—namely, the body of the nauplius appears on one of the flattened sides of the egg, with the head on the edge of the egg that is nearest the outer lateral margin of the sack. The long axes of the nauplii are usually parallel, but occasionally one is reversed in position; and, similarly, while most of the nauplii are on the proximal surface of each egg, occasionally one will be found on the distal surface.

Fertilization, as already stated, occurs during the last copepodid stage; the spermatophores are attached by the male in pairs to the ventral surface of the genital segment of the female, their openings being brought into contact with the vulvae. The contents of the spermatophore then pass into the enlarged end of the oviduct inside the vulva and the emptied sack drops off. According to A. Scott in *Lernaeocera branchialis* the first pair of spermatophores are replaced by others in succession until the receptacula are filled, each receptaculum holding the contents of four spermatophores. At first the four lots remain separate in the oviduct, but they soon mix and become one homogeneous mass.

A. Scott concluded that in *Lernaeocera* "the spermatozoa at once pass up the rudimentary oviduct to the ovary and fertilize the eggs." (1901, p. 43.) But there are several considerations which render such an action highly improbable:

1. The eggs are not ripe at the time the spermatozoa are introduced into the oviduct, and it requires at least four to six weeks for them to reach maturity. It is hardly possible for an egg to be fertilized so long before it is fully developed.

2. Segmentation does not begin until the eggs pass out into the external sacks; consequently if they were fertilized in the copepodid stage they must then lie dormant during the four to six weeks before they could begin to segment—an extremely improbable procedure.

3. If the spermatozoa swarmed up the rudimentary oviduct they would go in sufficient numbers to fertilize every egg and leave a considerable surplus.

We could hardly concede to the spermatozoa that were left after fertilization the ability to pass back down the oviduct, and they would have to remain in the ovary; but an ovary filled with dead spermatozoa, or for that matter with living ones, would hardly be a favorable place for egg development.

4. The fact that no sperm receptacle can be definitely made out in the adult is what would naturally be expected. It has already been stated that the spermatozoa pass out of the spermatophores into the enlarged end of the oviduct when the copepodid female is fertilized. There is never, therefore, any separate sperm receptacle and none ought to be expected in the adult. Again, this enlarged end of the oviduct in a larva only 1 or 2 millimeters in length is of necessity very small, and it could easily persist in the adult and still escape detection.

In every genus examined there are convolutions in the oviduct, where it is narrowed before passing out of the vulva, that are posterior to the last egg. Any one of these convolutions is large enough to hold several sperm receptacles the size of the one in the copepodid larva, and it would seem more reasonable to conclude that one of them serves such a purpose.

5. But we are not confined wholly to negative evidence. In a young *Pennella filosa*, examined by the present author, the ovaries have already migrated from the cephalothorax into the genital segment, although the larva was only 18 mm. in length. But at the posterior end of this segment, a short distance inside of the vulvæ, there is an enlargement in each oviduct filled with a mass of something that has every appearance of being spermatozoa. This specimen could not be sectioned to complete the proof, but there would seem to be but little doubt that this is the same enlargement into which the spermatozoa were originally introduced, and, if so, they did not pass up into the ovary.

Consequently we can only conclude that the spermatozoa remain near the vulva, and that each egg is fertilized not in the ovary

when it is immature but after it has acquired its yolk material and become fully ripe, just before it passes out into the external sack.

SYSTEMATIC TREATMENT.

Family LERNAEIDAE.

Family characters of female.—The largest of the parasitic copepods, sometimes reaching a length of 200 to 250 mm., exclusive of the egg strings. Body more or less cylindrical, elongate, and unsegmented; separable into three regions—a cephalothorax furnished with horns or processes, a free thorax in the form of a narrow cylindrical neck, and a trunk comprising the rest of the body, more or less swollen and either straight or sigmoid; anal laminae present but often minute; egg strings paired, either short club-shaped sacks or long threads, straight, coiled into loose masses, or twisted into regular spirals. Antennae distinctly dorsal, second pair chelate; mouth in the form of a sucking tube, more or less protrusible; a tripartite eye buried in the tissues above the esophagus; mandibles and two pairs of maxillae, but no maxillipeds except in *Lernaea;* three, four, or five pairs of swimming legs; at least the first two pairs biramose, rami two or three jointed, the others uniramose with jointed rami.

Adult female with the head and part of the neck buried in the tissues of the host and firmly anchored in such a way as to bring the mouth in contact with some copious blood supply.

Family characters of male.—Not developed beyond the fourth copepodid stage, at which time it becomes sexually mature. Body like that of *Cyclops*, comprising a cephalothorax covered dorsally with a carapace, a free thorax, a genital segment, and a jointed abdomen armed with a pair of large anal laminae; antennae and mouth parts like those of the female; proboscis also more or less protrusible; sometimes a sixth pair of rudimentary legs on the genital segment; a pair of large prehensile maxillipeds a little distance behind the mouth tube.

The male never bores into the tissues of its host nor becomes permanently anchored in any way, nor is it ever found attached to or in company with the adult female.

KEY TO THE SUBFAMILIES AND GENERA.

1. Trunk straight; swimming legs widely separated, the posterior pair close to the vulvae; egg cases sacklike; eggs multiseriate.....*Lernaeinae* 2
1. Trunk straight; first two pairs of swimming legs close together and near the head, the others at short intervals; egg cases filiform and straight or coiled into regular spirals; eggs uniseriate.....*Lernaeenicinae* 3
1. Trunk with sigmoid curve; all the swimming legs close together and near the head; egg cases filiform and convolute or coiled into spirals; eggs uniseriate and very numerous.....*Lernaeocerinae* 8

1. Trunk straight; all the swimming legs close together and near the head; egg cases filiform, straight, and very long; eggs uniseriate; abdomen with a row of feather-like processes on either side_____*Pennellinae* 11
2. Head with 2, 3, or 4 soft and swollen horns symmetrically arranged; neck and trunk smooth and without transverse grooves, the one passing gradually into the other_____*Lernaea* Linnaeus, 1758, p. 36.
2. Head with irregular protuberances; neck and trunk transversely wrinkled, the one passing into the other abruptly with a great difference in diameter_____*Leptotrachelus* Brian, 1903, p. 40.
2. Dorsal portion of head extended straight forward, longer than the body, and bearing on its swollen tip the antennae; head and trunk the same diameter without a neck_____*Thorodamus* Krøyer, 1863, p. 41.
3. Head and thorax smooth, without processes or horns, and in line with the axis of the trunk_____*Peniculus* Nordmann, 1832, p. 44.
3. Cephalothorax with horns or processes, or both, and often bent at an angle with the neck_____ 4
4. Bilateral symmetry perfect; branched frontal processes covering the anterior head, but no horns or lateral processes; egg strings straight_____ 5
4. Bilateral symmetry perfect; lateral horns or cushion-like processes, but no frontal processes; egg strings straight_____ 6
4. Bilateral symmetry considerably distorted; head and neck attached to the side of the trunk; egg strings coiled into spirals_____ 7
5. Cephalothorax and neck straight and attached at right angles to the side of the trunk some distance behind the anterior end.
Peraderma Heller, 1865, p. 49.
5. Cephalothorax and neck with a sigmoid curve and attached to the anterior end of the trunk_____*Cardiodectes*, new genus, p. 50.
6. Two to ten chitinous horns, or two or three small posterior knobs on the cephalothorax; neck not enlarged behind the swimming legs; one pair of maxillae_____*Lernaeenicus* Le Sueur, 1824, p. 56.
6. Two lateral horns on the cephalothorax, soft and unbranched; neck enlarged behind the swimming legs; two pairs of maxillae.
Sarcotretes Jungersen, 1911, p. 69.
7. Neck attached to a lateral anterior corner of the trunk; abdomen minute and hemispherical_____*Phrixocephalus* Wilson, 1908, p. 74.
7. Neck attached to the center of the dorsal surface of the trunk, abdomen as long as the trunk and turned sidewise_____*Collipravus*, new genus, p. 78.
8. Egg strings looped into loose masses_____ 9
8. Egg strings coiled into regular tight spirals_____ 10
9. No abdominal processes; trunk soft and fleshy; cephalic horns very irregular.
Lernaeocera Blainville, 1822, p. 83.
9. Five or six branched processes along either side of the abdomen; integument of every part of the body thick and chitinized; cephalic horns regularly branched_____*Lernaeolophus* Heller, 1865, p. 89.
10. Head and neck with lateral processes, simple and soft; neck reflexed upon itself; abdomen two-thirds as long as the trunk and regularly tapered.
Haemobaphes Steenstrup and Lütken, 1861, p. 93.
10. Cephalothorax with branched chitin horns; neck very short and not reflexed; abdomen as long as the trunk and expanded at the tip.
Haemobaphoides T. and A. Scott, 1913, p. 100.

10. Cephalothorax with three simple chitin horns, two lateral, one dorsal; neck much longer than the trunk, not reflexed; abdomen half the length of the genital segment, without processes_____*Trifur*, new genus, p. 101.

11. Abdomen with a row of feathery processes along either side; cephalothorax with numerous frontal processes and two or three horns, chitinous and usually simple_____*Pennella* Oken, 1816, p. 105.

11. Abdomen twisted spirally and covered with papilliform villi; neck with small excrescences attached by threads; no horns or frontal processes. *Pegesimallus* Krøyer, 1863, p. 126.

Remarks.—At first the genus *Lernaea* was the only one in the entire group of parasitic copepods, and everything that was parasitic and that seemed likely to be, or even to become, a copepod was placed in this genus by the early investigators. One after another of these species have been removed and made the types of new genera, until all that are left are those included in the present paper. But even after they began to separate new genera investigators still placed them all with *Lernaea* in the family Lernaeidae, which thus became the final dumping ground for everything that was bizarre in form and that could not be located elsewhere. Many of these genera have already been removed and correctly located elsewhere, and it is proposed now to remove all the others that do not show sufficient relationship in morphology and development. Accordingly the five genera, *Sphyrion*, *Strabax*, *Trypaphylum*, *Opimia*, and *Rebellula*, which have heretofore been included in the Lernaeidae, must be dropped for the following reasons: The adult females of these genera have processes at the posterior end of the genital segment in addition to the egg strings, from a single pair (*Opimia*) up to large bunches (*Sphyrion*); the second antennae are neither dorsal nor chelate; there are no swimming legs or anal laminae, and the female carries a pigmy male attached to the posterior end of her body. This last proves at once that the life history is entirely different from that here set forth for the Lernaeidae. These genera will be taken up in a future paper.

The genus *Ive* which was provisionally placed in the Lernaeidae by its founder, Mayer (1879), can not possibly be left there, since it is not a fixed parasite at all and the two sexes are found together moving about freely, with the male 5 mm. in length, or half the size of the female.

The genus *Lernaea* presents so many differences from the other genera that it might seem a question whether it ought to be included with them or established in a family by itself. But from the account of that genus already given (see Bibliography under Wilson) it will be found that the resemblances far overbalance the differences, especially in the matter of the peculiar life history, and the genus is accordingly retained in the present family.

LERNAEINAE, new subfamily.

Subfamily characters of female.—Cephalothorax armed with soft horns or processes, two, three, or four in number and unbranched; trunk straight without a sigmoid curve; genital segment enlarged on the ventral surface, just in front of the vulvae, into a pregenital prominence; egg cases short and sacklike, eggs multiseriate. Two pairs of antennae, second pair uncinate; a pair of curved and spine-like mandibles; two pairs of maxillae; one pair of maxillipeds; swimming legs widely separated with a fifth pair close to the vulvae.

Subfamily characters of male (genus *Lernaea*).—Body like that of *Cyclops*, composed of a cephalothorax covered with a dorsal carapace, three free thorax segments, a genital segment, and a three-jointed abdomen; anal laminae each armed with a single jointed seta, more than half the length of the whole body. Antennae and mouth parts like those of the female; a fifth and often a sixth pair of swimming legs on the genital segment. Parasites of fresh-water fishes exclusively.

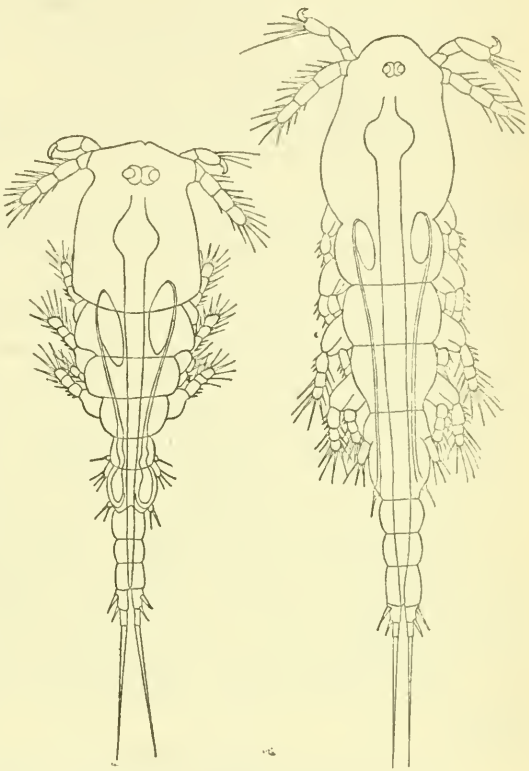

FIG. A.—THE MALE (LEFT) AND FEMALE (RIGHT) COPEPODID LARVAE OF LERNAEA VARIABILIS; ACTUAL LENGTH OF FEMALE, 1.50 MM., INCLUDING THE LONG ANAL SETAE.

Ontogeny of genus Lernaea.—The genital protoplasm at the posterior end of the ovary gradually forms onto long threads or filaments, transversely segmented into cells. These increase in size toward the anterior end of the ovary, and as they pass into the oviduct the filaments break up into their separate cells, each of which forms an egg. The eggs pass down the oviduct to its posterior portion, which serves as a cement gland. Just before entering this portion they are fertilized, and after entering they are covered with an egg membrane composed of the cement substance.

In the external egg sacks development takes place up to the nauplius stage. The larva hatches as a typical nauplius with the usual three pairs of appendages and one pair of balancers. It swims about freely in the plankton during the nauplius and metanauplius stages, undergoing several molts. On reaching the first copepodid stage it seeks as a temporary host some fish other than the one which is to serve as the final host of the female, and both sexes cling to the gill filament by means of their second antennae and maxillipeds, and feed on the fish's blood.

Four copepodid stages are passed here on the gills, the genital segment and abdomen becoming gradually perfected, the reproductive organs being developed, and the swimming legs increasing in number and in the number of segments in the rami. During the fourth copepodid stage both sexes become sexually mature and fertilization occurs. After fertilization the female leaves the gills and swims about freely again in the plankton in search of a final or permanent fish host. She fastens to the skin on the outside of the fish's body by means of her second antennae and maxillipeds, and burrows into the underlying tissues with the aid of these organs and the powerful maxillae. Soft horns or processes then develop from the sides of the cephalothorax, the body is greatly elongated and enlarged, the ovaries migrate back into the genital segment, and the mature adult stage is reached, in which she continues until death.

The male remains upon the gills of the first fish host until death, without further increase in size or other transformation, or he may sometimes leave and swim about freely in the plankton; but he never attains a length of more than a millimeter and a half, does not seek another host, undergoes no changes corresponding to those of the female, and is never found subsequently in the company of the female.

Genus LERNAEA Linnaeus.

Lernaea LINNAEUS, Fauna Suecica, 1746, p. 367.
Lernaea LINNAEUS, Systema Naturae, 10th ed., 1758, p. 655.
Schisturus (part) OKEN, Lehrbuch Naturgeschichte, 1816, p. 182.
Lernaeocera (part) BLAINVILLE, Journ. de Physique, vol. 95, 1822, p. 375.
Lernaeocera (part) NORDMANN, Mikrographische Beiträge, 1832, p. 123.
Lernaeocera BURMEISTER, Acta Acad. Caes. Leop. Carol. Nat. Cur., vol. 17, 1833, p. 309.
Lernaeocera (part) MILNE EDWARDS, Histoire Naturelle des Crustacés, vol. 3, 1840, p. 526.
Lernaeocera, all subsequent authors.

External generic characters of female.—Head a rounded knob projecting from the anterior margin of the cephalothorax and placed nearly at right angles to the body axis, with a deeply buried, tripartite eye near the center of the dorsal surface; one or two pairs of horns, simple or forked, on the lateral margins of the cephalothorax; sometimes an unpaired horn on the center of the dorsal

margin; all the horns conical and soft; neck soft, slender, and cylindrical, enlarging gradually into the trunk which is also cylindrical; trunk with a pregenital prominence in front of the vulvae; abdomen short and bluntly rounded, terminating in a pair of minute anal laminae; egg strings elongate-conical or ovoid, eggs multiseriate.

Two pairs of antennae, second pair uncinate; proboscis conical and very short; mandibles claw-shaped and without teeth; two pairs of maxillae; one pair of maxillipeds; four pairs of biramose swimming legs, first pair just behind the head, others at increasing distances posteriorly; a fifth pair of one-jointed stumps just in front of the vulvae.

Internal generic characters of female.—Esophagus short, nearly straight, and diagonal to the body axis; anterior stomach with lateral lobes and more or less convoluted; posterior stomach passing insensibly into the intestine, which is straight, of the same diameter throughout, and abruptly contracted into a short rectum; ovaries paired, close to the dorsal surface and near the posterior end of the trunk; matured oviducts with two long posterior and two shorter anterior loops; eggs remaining spherical and never flattened anteroposteriorly; no separate cement glands, the thickened glandular walls of the posterior oviducts serving that purpose.

No separate excretory glands, the chitinogen layer of the skin apparently serving for excretion through the pore canals.

Genus habitat.—This genus fastens to the outside surface of the fish's body, usually in the vicinity of the fins, and bores into the underlying tissues a short distance until it finds an adequate blood supply without seeking any particular organ or blood vessel.

Generic characters of the copepodid male.—The external generic characters have already been given under the subfamily. Internally the esophagus is long and nearly parallel with the body axis; stomach passing insensibly into the intestine and that into the rectum, the entire tube lined with digestive cells filled with black granules; supra ganglion comparatively small, infra ganglion very large and stout and extending back into the genital segment; testes paired, but not always side by side, situated in the head and anterior thorax above the stomach and intestine, spindle-shaped with the sperm ducts leading from their anterior ends back to the large spermatophore receptacles in the genital segment.

Type of the genus.—*Lernaea cyprinacea* Linnaeus, first species.

(*Lernaea*, Λέρνη, a fabled abode of the hydra.)

Remarks.—In a monograph of this genus by the present author, submitted to the United States Bureau of Fisheries and soon to be published, will be found the complete morphology and life history, together with a full revision of all the known species.

KEY TO THE SPECIES OF LERNAEA.

1. Two cephalothoracic horns, a lateral pair 2
1. Three cephalothoracic horns, a lateral pair and one dorsal and unpaired 3
1. Four cephalothoracic horns, a dorsal pair and a ventral pair 5
2. Horns directed laterally at right angles to body axis; trunk not much wider than neck; pregenital prominence inconspicuous (8.40 mm.)[1]
dicrocephala (Cunnington), 1914.
2. Horns diagonal to body axis, directed posterodorsally; trunk suddenly enlarged to four times the diameter of neck; pregenital prominence very large (8 mm.) ..... new species[2].
3. Lateral and dorsal horns all dichotomously branched 4
3. Lateral horns simple, dorsal one bifid at apex; pregenital prominence inconspicuous; abdomen short (10 mm.) ..... new species[2].
3. Lateral horns three or four pronged, dorsal horn bifid at apex; pregenital prominence conspicuous; body clubshaped; abdomen long and wide (7.50 mm.) ..... *pectoralis* (Kellicott), 1882.
4. Lateral horns once bifid, dorsal horn twice bifid; body spindle-shaped; no pregenital prominence (8 mm.) ..... *lagenula* (Heller), 1865.
4. All three horns twice bifid; body clubshaped; pregenital prominence divided, its two lobes and the abdomen the same size (10 mm.)
catostomi (Krøyer), 1863.
4. Lateral horns twice bifid, dorsal horn simple or once bifid; trunk clubshaped; pregenital prominence simple and much smaller than the abdomen (12 mm.) ..... *tortua* (Kellicott), 1882.
5. Dorsal and ventral horns about the same size 6
5. Ventral horns much smaller than the dorsal 9
6. Pregenital prominence simple and shorter than the abdomen 7
6. Pregenital prominence divided, its lobes as long as the abdomen 8
7. Abdomen short and plump; pregenital prominence forming a distinct "heel"; ventral horns bifid (5.70 mm.) ..... *phoxinacea* (Krøyer), 1863.
7. Abdomen short and plump; pregenital prominence not forming a distinct "heel"; dorsal horns bifid (13.50 mm.) ..... *esocina* (Burmeister), 1835.
7. Abdomen long and stout; pregenital prominence forming a distinct "heel"; all the horns simple (14.30 mm.) ..... *haplocephala* (Cunnington), 1914.
8. Pregenital prominence divided into three broadly rounded lobes; horns long, slender, straight (13.50 mm.) ..... *pomotidis* (Krøyer), 1863.
8. Pregenital prominence twice bifid, forming four narrow lobes; horns short, plump, curved (10 mm.) ..... *cruciata* (Le Sueur), 1824.
9. Pregenital prominence divided into distinct lobes; dorsal horns simple and undivided 10
9. Pregenital prominence simple or only slightly indented; dorsal horns distinctly forked 11
10. Abdomen a short and broad triangle; dorsal horns cylindrical and standing out laterally at right angles to the body axis (9 mm.)
tenuis (Wilson), 1916.
10. Abdomen long and plumply conical; dorsal horns flattened dorso-ventrally and curved forward in front of the head and parallel to the body axis (11.50 mm.) ..... *variabilis* (Wilson), 1916.
11. Abdomen short and inclined to body axis; egg cases broadly elliptical; ventral horns mere knobs (14 mm.) ..... *barnimii* (Hartmann), 1870.

[1] Average total length of species.
[2] Named and described in the monograph mentioned under remarks, p. 37.

11. Abdomen short and inclined to body axis; egg cases narrow and elongate-cylindrical; ventral horns half the length of the dorsal (22.50 mm.) *cyprinacea* (Linnaeus), 1758.

11. Abdomen long and parallel with body axis; ventral horns very short and slender spikes (10 mm.)_____*temnocephala* (Cunnington), 1914.

As would naturally be inferred a great many species that were originally ascribed to this genus have subsequently been transferred to other genera. These may be most easily recorded in the form of a table giving first the original species of the genus, then the author, and finally the present genus and species. It will be noted that some of the transferences are not merely from one genus to another, but also into a new family, which may be not even very closely related to the Lernaeidae.

Species.	Author.	Present genus.	Present species.
adunca	Ström, 1762	*Clavella*	*uncinata.*
anomala	Abildgaard, 1794	*Clavella*	*anomala.*
asellina	Linnaeus, 1761	*Medesicaste*	*asellinum.*
cirrhosa	La Martinière, 1787	*Pennella*	*filosa.*
clavata	Müller, 1776	*Peniculus*	*clavatus.*
cornuta	Müller, 1776	*Chondracanthus*	*cornutus.*
cyclophora	Blainville, 1822	*Lernaeenicus*	*sprattae.*
cyclopterina	Müller, 1776	*Haemobaphes*	*cyclopterina.*
dalmanni	Retzius, 1831	*Charopinus*	*dalmanni.*
diodontis	Oken, 1816	*Pennella*	*diodontis.*
elongata	Grant, 1827	*Lernaeopoda*	*elongata.*
encrasicholi	Turton, 1807	*Lernaeenicus*	*encrasicholi.*
exocoeti	Holten, 1802	*Pennella*	*exocoeti.*
gadina	Müller, 1776	*Lernaeocera*	*branchialis.*
gobina	Müller, 1776	*Diocus*	*gobinus.*
hemirhamphi	Kroyer, 1863	*Lernaeolophus*	*hemirhamphi.*
huchonis	Schrank, 1786	*Basanistes*	*huchonis.*
lavareti	Fabricius, 1794	*Ergasilus*	*sieboldii.*
marionis	Blainville, 1822	*Pennella*	*sagitta.*
merluccii	Holten, 1802	*Chondracanthus*	*merluccii.*
nodosa	Müller, 1776	*Chondracanthus*	*nodosus.*
oculuris	Cuvier, 1830	*Lernaeenicus*	*sprattae*
pectoralis	Müller, 1776	*Lepeophtheirus*	*pectoralis.*
pinnarum	Fabricius, 1779	*Clavella*	*uncinata.*
radiata	Müller, 1776	*Chondracanthus*	*radiatus.*
salmonea	Linnaeus, 1761	*Salmincola*	*salmonea.*
spratta	Sowerby, 1806	*Lernaeenicus*	*sprattae.*
tentaculis quatuor	Linnaeus, 1746	*Lernaea*	*cyprinacea.*
uncinata	Müller, 1776	*Clavella*	*uncinata.*

In addition to the above species, which can be located with reasonable certainty, there are also others which have never been described with sufficient accuracy to enable one to locate them with any certainty, nor even with any probability.

LERNAEA BASTERI Blainville, 1822, p. 437.

"The body is white and divided into two parts by a constriction; the abdomen is very large and oval; the cephalic enlargement is globular; the mouth is inferior and provided with a double pair of

hooks, by means of which the animal fastens itself. I know this species only through Baster, who observed that this animal bore considerable resemblance to that figured by Gissler. (Acta Holmiae, 1751, p. 90; pl. 6, figs. 1–5.)"

This is the only description ever given, and while it shows that the creature can not belong to the genus *Lernaea*, it does not tell us where it can be placed.

LERNAEA GADUS-MINUTUS Hesse, 1891, p. 191.

In the text Hesse spoke of this "Lernée du Gade petit" as though it were a new species, but in the explanation of the plate (pl. 7, figs. 1–9) he distinctly called it the larva of "Lernaea branchialis du Gade petit," which seems to be what it really was.

LERNAEA LOTAE Hermann, 1783.

Oken in 1816 separated the genus *Schisturus*, in which the body was soft, from the genus *Lernaea*, in which it was covered with a horny skin. He placed the species *lotae* in this new genus and gave for it the following description: "Vier ungleiche Eierschnüre, am Mund zwei Häkschen."

This was probably some genus that possessed paired posterior processes, since none of the copepod parasites have four egg strings. At all events it was not a Lernaean.

LERNAEA MULTICORNIS Cuvier, 1830, p. 256.

"Il y en a une a cornes petites, inegales et tres nombreuses (*L. multicornis*, Cuv.) sur les ouies d'un serran des Indes." This has never been seen or mentioned by any other author, and its attachment to the eye renders it highly improbable that it belongs to the genus *Lernaea*.

Genus LEPTOTRACHELUS Brian.

Silvestria Brian, Atti del Soc. Ligustica di Scienze, vol. 13, 1903, 6 pp. 1 text fig.

Leptotrachelus Brian, Zool. Anz., vol. 26, 1903, p. 547.

External generic characters of female.—Cephalothorax with two or three soft, cushionlike protuberances or horns, varying in size and shape; head considerably swollen; neck long, straight, and slender, or sometimes bent into a U-shape, covered anteriorly with a cutaneous sheath, monilliform posteriorly; trunk abruptly enlarged, subcylindrical, thickest anteriorly, tapering posteriorly, with numerous transverse wrinkles but without a pregenital prominence, straight or slightly curved; no abdomen; egg strings, antennae, mouth parts, and swimming legs unknown; male also unknown.

Type of the genus.—*Leptotrachelus truchae* Brian, monotypic.

(*Leptotrachelus*, λεπτός, slender and τράχηλος, neck.)

Remarks.—Brian established this odd genus upon several specimens sent to him by the Italian investigator, Filippo Silvestri, and obtained from "*Percichtys trucha*," taken in the Santa Cruz River, Patagonia. He first named the genus *Silvestria*, but this name being preoccupied he changed it to *Leptotrachelus*. It apparently bears more resemblance to the Lernaeinae than to the other subfamilies, and, as it came from fresh water, we may leave it here until further data are obtained.

Genus THERODAMAS Krøyer.

Therodamas Krøyer, Bidrag til Kundskab om Snyltekrebsene, 1863, p. 316, pl. 15, fig. 4, *a—f*.

External generic characters of female.—Body divided into two parts, the anterior one resembling a slender neck ending in a swollen spherical head, the posterior one considerably wider, distinctly segmented, and tapering backwards. Anterior portion really a median dorsal process, but carrying on its swollen tip a pair of stout uncinate second antennae. First segment of the posterior portion the true head, bearing the proboscis and mouth-parts on its ventral surface. First, second, third, and fourth thorax segments the same width as the head and each bearing a pair of swimming legs. Genital segment strongly tapered posteriorly; abdomen short and deeply parted in the center; anal laminae small and armed with stout setae; egg strings spindle-shaped; eggs small, multiseriate, and not definitely arranged. First antennae unknown; second pair stout and uncinate; proboscis short and blunt; one pair of mandibles, two pairs of maxillae, no maxillipeds; swimming legs well separated, all four pairs biramose, rami 3-jointed and armed with plumose setae.

Type of the genus.—*Therodamas serrani* Krøyer, monotypic.

(*Therodamas*, Θερσδάμας, a Scythian king who fed lions with human flesh.)

Remarks.—Krøyer obtained a goodly number of adult females from the gills of a species of *Serranus* in the Danish West Indies. The present author searched long and carefully for this odd genus upon various genera and species of the groupers at Jamaica in 1910, but without success.

The chief peculiarity of the genus is the curious median and dorsal prolongation of the head, which looks exactly like a slender neck, and to complete the resemblance its anterior end is enlarged like a head and carries on its dorsal anterior margin a pair of uncinate second antennae like those of the other Lernaean genera. The first antennae are apparently lacking, but possibly Krøyer overlooked

them. The mouth being on the ventral surface of the first segment of the part posterior to this apparent neck shows that it is not a neck at all and that the swollen anterior end of it is not a head. But in spite of such an anomalous arrangement this genus admirably supplements the others in the family. In most of the genera (*Lernaeocera*, *Pennella*) the excessive elongation of the body of the adult female takes place in the fifth and genital segments, the first four thorax segments having no share in it. In *Peniculus* the third and fourth segments are elongated a little but not nearly as much as the fifth and sixth segments. In *Lernaea* all the thorax segments share in the elongation, the posterior ones more than the anterior. And here in *Therodamas* also all the thorax segments share in the elongation, but the anterior ones are elongated more than the posterior, and the head, which in other genera has only sent out lateral and dorsal processes, is here elongated anteriorly. The wide separation of the swimming legs and the multiseriate, sack-like egg strings place the genus in the subfamily of the Lernaeinae.

LERNAEENICINAE, new subfamily.

Subfamily characters of female.—Cephalothorax armed with hard chitin horns, more or less profusely branched, or with soft cushion-like lateral processes, or with branched frontal processes, sometimes two of these combined; neck cylindrical and usually very slender and chitinous; trunk straight, without a sigmoid curve; genital segment enlarged but destitute of a pregenital prominence; egg strings long and thread-like; neither in coils nor spirals, eggs uniseriate. Two pairs of antennae, the second pair chelate; mandibles in the form of straight spines; one or two pairs of maxillae; no maxillipeds; first two pairs of swimming legs close together just behind the head, one or two other pairs at short intervals.

Subfamily characters of male (*genus Sarcotretes*).—Body like that of *Cyclops*, composed of a cephalothorax covered with a carapace and furnished anteriorly with a stout attachment filament; three free thorax segments, and a fused, one-jointed, genital segment and abdomen; anal laminae rather small, each armed with four or five tiny setae of varying length. Antennae and mouth parts like those of the female with the addition of the rudiments of a pair of maxillipeds; two pairs of biramose swimming legs with two-jointed rami, a third pair uniramose, rami also two-jointed.

Parasites of salt-water fish exclusively.

Ontogeny of genus Sarcotretes.—The genital protoplasm in the posterior end of the ovary gradually forms into egg mother-cells and these into egg daughter-cells, which are uniformly distributed throughout the anterior half of the ovary without forming filaments.

Each egg daughter-cell as it passes into the oviduct accumulates yolk and food material and becomes a mature egg. In the oviduct these eggs are strongly flattened antero-posteriorly and packed together like a row of coins. The cement glands are entirely separate from the oviducts and open into the latter close to the vulvae, covering each egg with an external membrane just before it passes out into the egg strings. Here the eggs are again packed like a row of coins, but are now separated by the membranes. The nauplius and metanauplius stages have not been seen, but in all probability are passed as free-swimming larvae in the plankton.

In the genus *Sarcotretes* the first copepodid larvae sought as a temporary host the same fish to which the fertilized female afterwards fastened as a permanent host. But these copepodid larvae fasten not to the gills but to the fins of the fish by means of their strong chelate second antennae. At the close of this stage the larva fastens itself to the fish by firmly cementing to the fish's skin the terminal disk of a stout frontal filament developed in the anterior part of the cephalothorax, and remains thus attached during the subsequent copepodid stages. These stages are called pupal, because during them the antennae, mouth parts, and swimming legs all lose their distinct segmentation and often their setae and become swollen and clumsy. The reproductive organs, however, are developed so that at the close of the last pupal stage, when the appendages are restored to their former condition, the young males and females shed their frontal filaments and swim about again freely in the plankton where fertilization occurs. After fertilization the males die and the females seek again the same species of fish for their final host, fastening to its skin by the chelate second antennae. They then bur-

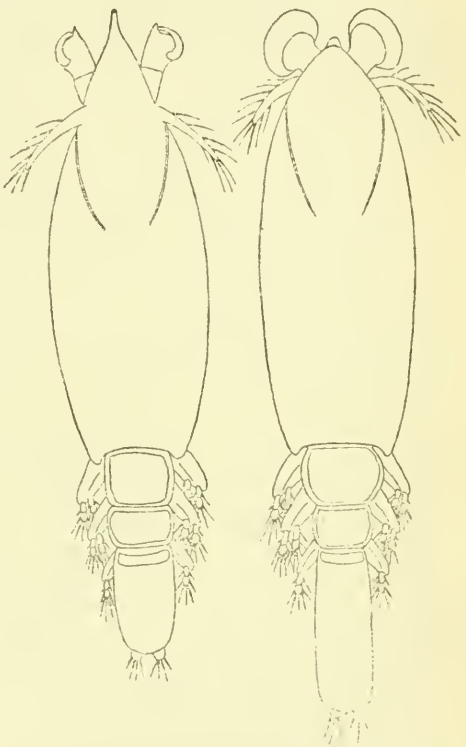

FIG. B.—THE MALE (LEFT) AND FEMALE (RIGHT) COPEPODID LARVAE OF SARCOTRETES SCOPELI. AFTER JUNGERSEN: ACTUAL LENGTH OF FEMALE, 2MM.

row into the tissues of the host by means of the antennae and the mouth parts and finally reach the intestines, where they are permanently anchored by the outgrowth of processes or horns from the sides of the cephalothorax.

Genus PENICULUS Nordmann.

Peniculus NORDMANN, Mikrographische Beiträge, 1832, p. 107, pl. 6, figs. 8 to 14.

External generic characters of female.—Cephalothorax distinctly separated from the rest of the body, elliptical, flattened dorso-ventrally, covered with a carapace which often shows lateral lobes, and destitute of horns or processes; neck composed of second and third thorax segments, much narrowed, flattened dorso-ventrally, and chitinized; fourth segment more or less spherical and much widened; trunk composed of the fifth and genital segments fused and a minute abdomen; egg strings slender and much longer than the trunk; eggs uniseriate. Second antennae strongly chelate; eye tripartite and deeply buried; probosis long, conical, and retractile; two pairs of maxillae; second pair uncinate.

Internal generic characters of female.—Esophagus strongly inclined to the body axis; stomach only slightly enlarged and without convolutions; intestine straight, much wider than the stomach, dorsal and abruptly contracted into a very short rectum (fig. 14); well-defined supra and infra esophageal ganglia with distinguishable nerves; ovaries dorsal to the intestine and near the anterior end of the trunk; oviducts passing from the anterior ends of the ovaries around the intestine to the ventral surface and straight back to the vulvae; oviducts long and comparatively narrow; cement glands close together and ventral to the oviducts, the glandular portion as wide as, or wider than, the oviducts and usually distinctly segmented, the ducts sometimes parallel, sometimes convergent posteriorly and opening into the oviducts near the vulvae; paired digestive glands on either side of the esophagus and anterior stomach; paired excretory glands on the ventral surface of the fourth thorax segment.

Genus habitat.—This genus does not burrow into the tissues of its host, but is always found upon the fins, usually the dorsal fins. It fastens itself to the bone of one of the fin rays by means of its second antennae, and the chelae of these antennae are usually so covered with osseus tissues whose growth is induced by the irritation, that it is impossible to separate them from the ray.

Type of the genus.—Peniculus fistula Nordmann, monotypic.

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

Remarks.—This genus was established and meagerly described by Nordmann but was not definitely located. Milne Edwards placed it

in the Chondracanthidae, while Claus (1858) was the first to recognize it as a Lernaean. Krøyer (1863) added two new species, *clavatus* and *furcatus*, having only a single specimen of the latter, and Nordmann in 1864 added the new species *calamus*, which was not figured and has never been seen by any investigator since, but whose description and size are sufficient to warrant its validity.

Claus in 1868 described in much greater detail Nordmann's type species and the present author did the same for Krøyer's species *furcatus* in 1906, still retaining it in the genus and among the Lernaeidae. But after the present detailed study of this family and especially of their internal anatomy the species *furcatus* can no longer be kept in the genus, and there are many good reasons for transferring it to another family. Chief among these reasons are the following:

1. While the second and third thorax segments are narrower than the carapace there is no formation of a definite chitinized neck.

2. The fourth thorax segment is indistinguishably fused with the fifth and genital segments, the only indication of its presence being a pair of fourth legs on the ventral surface of the trunk.

3. The trunk is much too short and too strongly flattened dorso-ventrally for a Lernaean; it has large posterior processes, as long as itself, into which the body cavity extends; it has a distinct abdomen, also strongly flattened dorso-ventrally, and also with posterior processes into which the body cavity extends.

4. The second antennae are distinctly ventral and are not chelate, there is no retractile proboscis, and all four pairs of legs are biramose with one-jointed rami.

5. The ovaries extend forward nearly to the anterior end of the fourth thorax segment; the eggs in the oviducts are more or less spherical and not packed like a row of coins; the egg strings are very short and stout and there are only 10 or 15 eggs in each string.

Such cumulative differences necessitate the separation of this species from the others in the present genus and the new name *Peniculisa furcata* is proposed for it. Furthermore, the majority of these differences are just as effective for separating it from the Lernaeidae, and as they all correspond with the characters of the Dichelestiidae the present author would transfer the species to that family.

This leaves in the genus *Peniculus* three species already described, to which is here added a fourth that is new to science.

KEY TO THE SPECIES.

1. Trunk short, twice as long as wide; proboscis also short and slender; second antennae enlarged into disks at the tips (5 mm.)[1] *calamus* Nordmann, 1864.

[1] Average total length of species.

1. Trunk three and a half times as long as wide; proboscis long and stout; fourth segment two-thirds as wide as the trunk (9 mm.)
clavatus Krøyer, 1863, p. 46.

1. Trunk five times as long as wide; proboscis short and slender; fourth segment less than half the width of the trunk (9mm.) *fistula* Nordmann, 1824.

1. Trunk seven times as long as wide; proboscis short and stout; fourth segment only slightly narrower than the trunk (6.25 mm.)
fissipes, new species, p. 47.

PENICULUS CLAVATUS (Müller).

Plate 1, figs. 1–7.

Peniculus clavatus Krøyer, Bidrag til Kundskab om Snyltekrebsene, 1863, p. 266, pl. 14, fig. 8, *a–g*.
Lernaea clavata Müller, Zoologia Danica, 1779, p. 38, pl. 33, fig. 1.

Host and record of specimens.—Eleven specimens were obtained from the fins of *Sebastes marinus* by the United States Bureau of Fisheries steamer *Speedwell* during the summer of 1878 at stations 138, 184, and 198 off Cape Ann, Massachusetts. These 3 lots have received respectively Cat. Nos. 47782, 38028, and 47781, U.S.N.M.

A single female was taken from the dorsal fin of the same host off Salem, Massachusetts, in August, 1877, and has been given Cat. No. 47783, U.S.N.M..

Specific characters of female.—Cephalothorax subspherical, as wide as long, a little pointed anteriorly where it forms a bluntly rounded rostrum, to whose lateral margins are attached the first antennae, and to whose anterior margin are attached the larger chelate second antennae; no horns or processes of any description; ventral surface circular in outline and deeply concave, the long proboscis being attached to the bottom of the depression.

The second and third thorax segments form a slender neck, flattened dorso-ventrally, chitinized, somewhat enlarged through the bases of the third legs, and bent forward at an angle of 45° just in front of the enlargement.

Fourth segment two-thirds the width of the trunk, from which it is separated by a deep groove; the fourth legs are attached to its posterior margin. The trunk is cylindrical, three and a half times as long as wide, of the same diameter throughout, and abruptly rounded posteriorly. The abdomen is a minute tubercle close to the dorsal surface, but showing distinct anal laminae, each of which is armed with three long setae and two shorter ones. The egg strings are one-fourth the width of the trunk and nearly twice the length of the entire body.

The first antennae are turned backward along the lateral margins of the cephalothorax; they are three-jointed, the basal joint the shortest, the second joint the longest, the two terminal joints well armed with setae. The second antennae are stout and unguiculate,

with their basal joints large, considerably inflated, and fused only at their origin, while the terminal claws are stout, strongly curved, and folded downward and inward against the basal joints and toward each other.

The proboscis is as long as the neck and of medium diameter, somewhat narrowed at the tip with an intricate supply of muscles for retraction and protrusion. The mouth opening is terminal and circular and is surrounded by a delicate fringed membrane. The first maxillae are minute and one-jointed, tipped with a small seta and situated on the sides of the proboscis just at the base of the terminal narrowing. The second pair are also on the sides of the proboscis, posterior and ventral to the first pair; they are slender and two-jointed, the terminal joint half the length of the basal and tipped with a short curved claw. Only the basal plates are present in the four pairs of legs, the rami having disappeared; these plates are notched on the outer margin near the distal end.

Total length, 9 mm. Trunk, 7.50 mm. long, 2 mm. wide. Egg strings, 17 mm. long, 0.50 mm. wide.

Color (preserved material). Head and neck a grayish yellow, trunk a dark cinnamon brown, egg strips a lighter brown.

(*clavatus*, club-shaped.)

Remarks.—This species was originally described by Müller and referred to the genus *Lernaea*, but when Krøyer rediscovered it he recognized at once that it did not belong to that genus but to Nordmann's *Peniculus*.

Claus suggested (1868, p. 12) that Krøyer's *clavatus* and Nordmann's *fistula* were the same species, but the present description and figures make it certain that the two species are distinct. The general body proportions are very different, as can be seen from the key (p. 46), especially the length of the proboscis and trunk, the width of the fourth segment, and the relative size of the abdomen. These differences are carried still farther in the details of the appendages, none of which correspond with those given by Claus for *fistula*.

Claus recorded that the first antennae were broken on all the specimens at his disposal, but fortunately they were present on several of the present specimens and are given in detail in figure 3.

As distinctive characters in the internal anatomy of this species we may notice the comparatively narrow oviducts and wide cement glands, the glandular portion of the latter being actually wider than the oviducts and distinctly segmented. The ovaries also are short and broadly ovate or heart-shaped.

PENICULUS FISSIPES, new species.

Plate 2, figs. 8–14.

Host and specimens.—Seven females were obtained from the fins of an unknown fish by the United States Bureau of Fisheries

steamer *Albatross* at Laredo Bay, in the Straits of Magellan, January 22, 1888. These have received Cat. No. 47784, U.S.N.M, and become paratypes of the new species; from them a single female was selected to serve as the species type with Cat. No. 47785, U.S.N.M.

Specific characters of female.—Cephalothorax elliptical, a little less than twice as long as wide and flattened dorso-ventrally, with a well-defined lateral lobe on either side at the posterior end; rostrum short and wide and broadly rounded; tripartite eye large and so deeply buried as to be nearer the ventral than the dorsal surface. Neck comparatively wide and bent ventrally at an angle of 45°; third thorax segment elongated, but not much widened posteriorly; fourth segment relatively long and nearly as wide as the trunk, from which it is separated by a deep groove.

Trunk narrow-cylindrical and seven times as long as wide, squarely truncated posteriorly; abdomen hemispherical and half the diameter of the trunk, with well-defined anal laminae, each armed with three long plumose setae and two smaller, non-plumose ones; egg strings one-third the diameter of the trunk and two-thirds longer than the entire body, with narrow masses of cement substance at their tips.

First antennae slender and three-jointed, basal joint the shortest, the other two about equal and well armed with setae; second antennae with a stout basal joint and a short and strongly curved terminal claw; proboscis short and wide, mouth opening large, circular, and terminal, surrounded by a narrow stiff rim; first maxillae minute, one-jointed, tipped with two tiny setae and fastened to the lateral wall of the proboscis; second maxillae comparatively large, basal joint long and stout and armed with a short spine on the posterior margin near the center, second joint half as long and tipped with a short curved claw; the distal end of the basal joint and the proximal end of the second joint are tapered so that the appendage is narrowed at the joint. The basal laminae of the first three pairs of swimming legs are rounded triangular, with a narrow sinus on the inner margin near the base, each one split diagonally from the apex of the triangle to the base of this sinus. The fourth pair has a knob in place of the sinus and the split extends only to the center of the lamina.

Total length, 6.25 mm. Length of trunk, 5.12 mm.; width, 0.75 mm. Length of egg strings, 10.50 mm.; width, 0.25 mm.

Color (preserved material), a uniform light yellow, the carapace and swimming legs with spots of dark brown pigment more or less symmetrically arranged.

(*fissipes*, *fissus*, cleft and *pes*, foot, alluding to the diagonal split in the basal laminae of the swimming legs.)

Type.—Female, Cat. No. 47785, U.S.N.M.

Remarks.—It is unfortunate that the name of the host of this interesting species was not known or at least was not recorded. Its chief external distinguishing characters are the long and narrow trunk, the long and wide fourth thorax segment, and the split basal plates of the legs. In the internal anatomy especial attention is called to the exceptionally long ovaries, which are conical, extend nearly the entire length of the trunk, and taper to a sharp point posteriorly. The oviducts are a little wider than the ovaries and also a little longer, since they extend to the vulvae. The glandular portion of the cement glands is relatively short and very indistinctly segmented, the ducts are longer than the glandular portion and straight. The intestine is comparatively narrow.

Genus PERODERMA Heller.

Perodcrma HELLER, Reise der Fregatte *Novara*, 1865, p. 250.
Taphrobia CORNALIA, Atti della Societa Italiana di Scienze Naturali, vol. 18, 1875, pt. 2, pp. 197–200.

External generic characters of female.—Cephalothorax globular, without horns but with a dense tuft of ramifying tubules on the frontal margin of the head; the bases of these tubules are swollen into flasks and their tips are somewhat tumid; neck cylindrical, joining the trunk at right angles about one-third the distance from its anterior end; trunk an elongated ovoid, narrowing posteriorly; egg strings attached to the posterior end and four times the length of the trunk, slender and straight; eggs numerous, uniseriate, and tightly packed like a row of coins; no abdomen.

First antennae three-jointed, setiferous; second antennae two-jointed, chelate; proboscis short and conical, inclosing a pair of mandibles; two pairs of maxillae, the second pair tipped with stout claws; three pairs of swimming legs, first two pairs close together and biramose, third pair removed some distance and uniramose, all the rami two-jointed and bearing plumose setae (adapted from Richiardi, 1876).

Internal generic characters of female.—No exact description can be given through lack of material, but from the analogy of the new genus *Collipravus* (p. 78) it is certain that the insertion of the neck into the side of the trunk instead of at the anterior end profoundly modifies the arrangement of the generative organs and the digestive tube. And hence the internal morphology, when obtained, will differ markedly from that of *Lernaeenicus*, *Sarcotretes*, and *Cardiodectes*. But since the neck is inserted in the center (laterally) of the trunk and at right angles to its axis it does not seem probable that there will be any disturbance of the bilateral symmetry, as there is in *Collipravus* and *Phrixocephalus*.

Genus habitat.—This genus burrows into the lateral muscles of its host and penetrates to the vertebral column; the tubular cephalic processes adhere to the vertebrae, pass through the apertures in the lateral hypophyses, and finally reach the peritoneum.

Type of the genus.—*Peroderma cylindricum* Heller, monotypic. (*Peroderma*, πείρω, to pierce, and δέρμα, the skin.)

Remarks.—The distinctions which separate this genus from *Lernaeenicus* and *Cardiodectes* are given elsewhere (p. 51). Richiardi, from whose description and figures the above genus diagnosis is taken, afterward (1881) briefly described a second species, *petersi*, and a year later a third species, *bellottii*, for neither of which were any figures given. This third species, again described and figured by Jungersen in 1911, is here referred to the new genus *Cardiodectes* (p. 52).

With reference to the species *petersi* Richiardi said that it differed from *cylindricum* in the greater development of the cephalothorax, in the larger number of tubular cylindrical appendages, disposed regularly in tufts, in the fact that the neck was straplike instead of cylindrical, in the subterminal insertion of the neck in the trunk, in the curvature of the trunk, and in the fact that the egg strings were four in number instead of two, were coiled into a tight spiral, and were separated a little distance from one another. Whatever may have been the form which he thus described, it is reasonably certain that it did not belong to the genus *Peroderma*.

The species *branchiata* proposed by Bassett-Smith[1] was not described in sufficient detail to warrant its separation from *cylindricum*, and it can not be established as a valid species until such distinguishing characters are forthcoming.

Thus we are left with only the original type species.

CARDIODECTES, new genus.

External generic characters of female.—Cephalothorax ellipsoidal, with a tripartite eye at the anterior end over the base of the esophagus and not very deeply buried; entire anterior portion covered with dichotomously branched processes, subcorneous in texture, which radiate chiefly from a pair of anterior horns and which form a spherical mass nearly equal in diameter to the trunk; horns continued along the lateral margins; neck hardened but remaining one-third the diameter of the trunk, bent twice at right angles, first backward at the base of the cephalothorax, then forward at about the center; trunk cylindrical and straight; abdomen hemispherical and dorsal, with a pair of minute anal laminae; egg strings long and straight, eggs tightly packed. Two pairs of minute antennae, second pair chelate; one pair of tiny maxillae; four pairs of swimming legs, first two pairs

[1] Ann. Mag. Nat. Hist. (7), vol. 1, 1898, p. 13.

close together and biramose, third pair removed a little distance and uniramose, fourth pair still farther back and destitute of rami; all the rami present are two-jointed and heavily armed with setae.

Internal generic characters of female.—Esophagus at right angles to the axis of the cephalothorax; stomach without convolutions; intestine passing to the dorsal surface of the trunk; rectum short and inclined toward the dorsal surface; ovaries situated near the anterior end of the trunk, dorsal to the intestine; oviducts straight and flattened laterally; cement glands straight, narrow, and parallel, glandular portion shorter than the ducts; chitinogen layer of body wall especially well developed in the anterior thorax and neck, where the outer layer shows numerous pore canals.

Genus habitat.—This genus penetrates from the outer surface of the isthmus of the host through the intervening tissues and buries its head with the anterior processes in the bulbus arteriosus of the fish's heart.

Type of the genus.—Cardiodectes medusaeus (Wilson), first species.

(*Cardiodectes*, καρδία, the heart, and δηκτής, a biter or torturer.)

Remarks.—This new genus is established to include the species originally described by the present author as *Lernaeenicus medusaeus* in 1909, and noted by Brian in 1912, and a species described by Richiardi in 1882 as *Peroderma bellotti* and noted by Jungersen in 1911.

For the original description of *medusaeus* there was but a single specimen available, and it could not be injured. Hence, investigation was confined to what could be seen from the outside without removing the branched processes. In the present instance these processes were removed and the cephalothorax was cleaned of everything except the lateral horns. In this way the antennae and mouth parts were laid bare.

This genus differs from *Lernaeenicus* in that it has these processes in place of hard chitin horns, it shows no body torsion, the proboscis is not extensile, and there are but three pairs of legs with rami instead of four.

The two species mentioned above do not belong to the genus *Peroderma*, as suggested by Jungersen, first because that genus does not possess the soft and laminate lateral horns, which here appear behind the processes. Again, in *Peroderma* the processes are tubular, and their interior communicates with the general body cavity; they also cover the entire head and conceal the antennae and mouth parts. Here they are solid and the swimming legs and antennae are left free.

In *Peroderma* the neck is at right angles to the trunk and opens out of the side of the latter, as in the new genus *Collipravus*, but

here the neck is a continuation of the trunk in line with the body axis, as in *Lernaeenicus*.

This must produce a great difference in the internal anatomy and alone is sufficient to distinguish the genera. The swimming legs are smaller and less developed in the present genus, and only the cephalothorax is buried in the bulbus arteriosus of the fish's heart, while in *Peroderma* the entire body is buried in the lateral muscles of the host, leaving only the egg strings hanging free, and the tubular cephalic processes adhere to the vertebral column. The species may be distinguished as follows:

KEY TO THE SPECIES.

Egg strings much longer than the body; soft lateral horns entirely confined to cephalothorax ..... *medusaeus* (Wilson), 1908, p. 52.
Eggs strings only a quarter the length of the body; lamellar wings on the thorax also ..... *bellottii* (Richiardi), 1882, p. 55.

CARDIODECTES MEDUSAEUS (Wilson).

Plate 3, figs. 15–23.

Lernaeenicus medusaeus WILSON, 1908, p. 458, pl. 76, figs. 99 and 100.—BRIAN, 1912, p. 27, pl. 10, figs. 1–5.

Host and record of specimens.—Two females were obtained from the throat of *Nannobrachium leucopsarum* on the Pacific coast at stations 4434 and 4541 by the United States Bureau of Fisheries steamer *Albatross* in 1904.

One has received Cat. No. 47786, U.S.N.M., while the other was sacrificed to obtain the data given below. Both specimens, as also the one obtained in 1908, were fastened to the throat of their host, with the head and frontal processes buried in the bulbus arteriosus of the heart, the body turned back at right angles outside the fish's skin, with the ventral side of the parasite toward its host. Naturally there would be but a single specimen on each fish, since there would be no room for a second parasite's head within the fish's heart. A third specimen was obtained by the Bureau of Fisheries' steamer *Albatross* at Misaki, Japan, in the throat of *Diaphus glanduliferus*. As the host is small the two have been preserved together with Cat. No. 47823, U.S.N.M.

Specific characters of female.—Cephalothorax ellipsoidal, nearly as wide as long and evenly rounded; a pair of soft horns extending forward from the anterior margin and a second pair extending outward and ventrally from the postero-lateral margin, the bases of the two pairs running together along the sides of the head. The posterior pair are divided into lobes, more or less swollen into spheres, while the anterior pair are strongly flattened dorso-ventrally, and from them chiefly, but also to some extent from the ante-

rior surface of the head, radiate the dichotomously branched soft processes, whose tips are tumid and swollen into spheres.

These processes radiate backward along the surface of the head as well as forward and sidewise, and entirely cover the anterior cephalothorax, extending back dorsally to the second antennae and ventrally to the base of the posterior horns. They thus form an ovoid mass (fig. 16), the point of the oval anterior and the long axis inclined to the axis of the head.

Anterior thorax enlarged and bent dorsally at right angles to the head, then narrowed posterior to the fourth pair of legs into a cylindrical and chitinized neck, which is again bent at right angles, this time ventrally, bringing the axis of the trunk parallel to that of the head.

Trunk cylindrical, increasing gradually to its full diameter and then continuing that size throughout its entire length, with a slight lobe on either side around the vulva. Abdomen hemispherical, inclined dorsally, and about one-third the diameter of the genital segment and one-half longer than wide. Egg strings one-fourth the diameter of the trunk and one-half longer than the entire body.

First antennae two-jointed, the terminal joints well armed with setae and turned outward and downward parallel with the dorsal surface of the head and at right angles to the head axis. Between the bases of these antennae and projecting from the dorsal surface is a small rostrum. Second antennae three-jointed, thickset, and chelate. Proboscis turned down ventrally between the bases of the anterior horns and consisting of a short tube somewhat enlarged at the tip and nonretractile, judging by the lack of muscles. Dorsal to the base of the proboscis and anterior to the end of the stomach is a well-defined tripartite eye, which is not very deeply buried. On either side of the proboscis near the tip is a minute two-jointed maxilla, the terminal joint tipped with a short claw.

Of the four pairs of swimming legs the first two are close together and just behind the bases of the posterior horns of the head, the third pair is removed a greater distance and is attached in front of the groove between the third and fourth segments, while the fourth pair is at a still greater distance and just in front of the beginning of the neck. Each leg consists of a triangular basal joint joined to its fellow by a chitin framework across the midline; each leg of the first two pairs has two short rami, the third leg has but one, while the fourth leg has none; the rami are indistinctly two-jointed and rather heavily armed with setae.

None of the chitin fragments of the sterna can be seen between the base of the legs, as noted in *C. bellottii* by Jungersen (1911, p. 13), and no furca or longitudinal ribs similar to those found in *Peroderma* by Richiardi.

Total length, not accounting for curves, 8 mm. Length of head, including processes and horns, 2.50 mm. Length of trunk, 7 mm.; diameter, 1.30 mm. Length of egg strings, 14 mm.

Color (preserved material), a uniform light yellow.

(*medusaeus*, medusa-like, alluding to the anterior processes.)

Internal anatomy.—The chitinogen layer of the body wall is somewhat thickened in the second, third, and fourth thorax segments, and also in the anterior end of the fifth segment. While there are no definite skin glands as in *Sarcotretes*, there are many large conical or funnel-shaped pores through the outer chitin layer in these regions, which communicate with the chitinogen cells and may well serve as excretory ducts (fig. 21).

Esophagus inclined ventrally to the axis of the head and opening into a stomach which is somewhat unsymmetrical as can be seen from figure 19, which has no convolutions, and which sends out no lateral processes. The ovaries are comparatively short and narrow, while the oviducts are very wide, filling nearly the whole cavity of the trunk (fig. 15).

The cement glands do not reach the anterior end of the oviducts, and are somewhat flattened dorsoventrally between the latter and the body wall, while the oviducts are a little flattened laterally.

Remarks.—This description is intended to supplement and in a few particulars to correct the one previously given. The former specimen was evidently injured on removing it from the fish. These two specimens were sent still attached to their host and were removed uninjured.

The characters which distinguish the species from Richiardi's *bellottii* are in the position and arrangement of the frontal processes and the posterior soft horns. In *bellottii* the frontal processes extend backward on the ventral surface a considerable distance beyond the base of the head and the soft posterior horns, while there is an additional pair of laminate processes or wings on the sides of the second thorax segment, as Richiardi stated.

In *medusaeus* the frontal processes only extend to the anterior margin of the posterior horns, the latter are distinctly on the cephalothorax, and there is nothing on the sides of the second thorax segment (fig. 18).

Moreover, in *medusaeus* there are no vestigial second maxillae anterior to the first legs, as noted by Jungersen for *bellottii*.[1]

The species found by Brian on *Myctophum affine* and referred to *medusaeus* appears to be correctly located, as will be seen by comparing his plate 10, figure 5, with plate 3, figure 15, of the present paper.

[1] Vidensk Meddel, fra den Naturh. Foren., vol. 64, 1911, p. 13, fig. 1, text, pl. 2, fig. 27.

CARDIODECTES BELLOTTII (Richiardi).

Plate 21, figs. 161 and 162.

Peroderma bellottii RICHIARDI, Atti della Soc. Tosc. Processi Verbali, vol. 3, 1882, p. 149.

Peroderma bellottii JUNGERSEN, Vid. Medd. fra den Naturh. Foren., Kiøbenhavn, vol. 64, 1911, pp. 11 and 13.

Host and record of specimens.—Two specimens of *Scopelus glacialis*, each infested with a single parasite of this species, were kindly sent to the author by Prof. F. E. Jungersen. They were collected by the Danish steamer *Thor* at the Straits of Gibraltar in 1910. One of the parasites was removed from its host, cleared, and mounted; the other, still attached to its host, has been placed in the United States National Museum, with Cat. No. 49701, U.S.N.M.

Specific characters of female.—Cephalothorax ellipsoidal, as wide as long, and smoothly rounded; soft horns on the anterior margin folded and turned inward toward each other; base of posterior horns extending across the second and onto the third thorax segment; each horn is flattened into a soft lamina, projecting ventrally, and somewhat enlarged at the tip; there is no division into lobes and no swollen spheres as in *medusaeus.*

Frontal processes longer than the others and projecting far in front of the head; those which radiate backward along the ventral surface of the head also project beyond the tips of the posterior soft horns; the entire mass of processes is thus an elongate ellipsoid, a little narrower anteriorly than posteriorly. The separate processes are considerably flattened, and are lobed and branched so that they closely resemble the fronds of the common seaweed *Fucus.*

The neck is bent twice as in *medusaeus*, first dorsally posterior to the base of the soft horns, and again ventrally behind the fourth legs.

Trunk cylindrical or somewhat spindle-shaped, being widest at the center and narrowing toward the posterior end; no lobes at the bases of the egg strings; abdomen hemispherical and inclined dorsally, less than a quarter of the diameter of the genital segment; egg strings one half wider than the abdomen and a quarter of the length of the entire body.

First and second antennae similar to those of *medusaeus;* proboscis somewhat larger, but apparently nonretractile; maxillae two-jointed and tipped with a small claw; maxillipeds rudimentary, consisting of a small basal joint tipped with a seta, and situated about halfway between the proboscis and the first swimming legs.

Four pairs of swimming legs, first two pairs biramose, rami two-jointed, third pair uniramose and two-jointed, fourth pair consist-

ing of only the basal joints, without rami or setae; first three pairs well armed with setae.

These legs are arranged like those of *medusaeus*, the first and second pairs close together, the second pair about opposite the center of the posterior soft horns, the third pair at a greater distance near the posterior margin of the third segment, the fourth pair at a still greater distance near the posterior end of the fourth segment.

Scattered chitin fragments which probably represent the original thoracic sterna are found in the spaces between the legs.

Color (preserved material), a uniform light yellow.

Total length, not estimating the curves, 6 mm. Length of head, including processes and horns, 2 mm. Length of trunk, 5 mm.; diameter, 1.15 mm. Length of egg strings, 1.50 mm.

(*bellottii*, to the Milanese ichthyologist, C. Bellotti.)

Internal anatomy.—The internal anatomy is very similar to that of *medusaeus*, with the following differences. The chitinogen layer is much thickened in the genital segment as well as in the anterior thorax segments. There are the same large conical or funnel-shaped pores in the outer skin, communicating with the inner chitinogen cells. The ovaries are somewhat longer and wider while the oviducts are not quite as wide, but the latter are still comparatively very wide and are flattened laterally like those in *medusaeus*. The cement glands are longer and reach in front of the anterior ends of the oviducts; they are cylindrical and are not flattened. These specific distinctions will supplement those already given under *medusaeus*, and may serve to establish the two species upon a more substantial basis.

Genus LERNAEENICUS Le Sueur.

Lernaea (part) Sowerby, Turton, Blainville, Cuvier, etc.

Lerneocera (part) Blainville, Journ. de Physique, vol. 95, 1822; *Lerneocera surriraiis*, third species, p. 376, a synonym for *Lernaeenicus sprattae*.

Lerneaenicus (part) Le Sueur, Journ. Acad. Nat. Sci., Philadelphia, vol. 3, 1824, p. 289. Type *Lerneocera radiata* Le Sueur, second species.

Lerneonema (part) Milne Edwards, Hist. Nat. des Crustacés, 1840, vol. 3, p. 524; *L. monillaris*, second species, p. 525, a synonym for *Lernaeenicus sprattae*.

Foroculum Wm. Thompson, Cat. Museum College of Surgeons, 1843; *Foroculum sprattae*, single species, a synonym of *Lernaeenicus sprattae*.

Lerneaenicus Fowler, Report New Jersey State Museum for 1911 (1913), p. 87.

External generic characters of female.—Head not separated from the thorax, in line with the body axis, or bent forward at right angles, with a deeply buried tripartite eye over the base of the esophagus; horns slender, cylindrical, chitinous, 2 to 10 in number, simple or branched; anterior thorax enlarged through the bases of the swim-

ming legs, then becoming filiform and chitinous, twisted and usually flexed; trunk cylindrical and straight; abdomen straight, narrower than trunk and of varying lengths; anal laminae minute and destitute of setae; egg strings filiform and very long, eggs uniseriate and strongly flattened. Two pairs of antennae, second pair chelate; proboscis large and extensile; mandibles without teeth; one pair of maxillae, no maxillipeds; four pairs of swimming legs close together behind the head, first two pairs biramose, third and fourth pairs uniramose.

Internal generic characters of female.—Esophagus short, straight, and inclined to the body axis; stomach without lateral lobes but with one or two convolutions, passing insensibly into the intestine, which is very narrow in the neck, but wider than the stomach in the trunk, abruptly contracted at the posterior end of the abdomen into a narnow rectum; ovaries paired, short, wide, and strongly flattened between the intestine and the dorsal body wall at the anterior end of the trunk; oviducts passing around the intestine to the ventral surface and then straight back to the vulvae, eggs tightly packed like a row of coins; cement glands slender, cylindrical.

Genus habitat.—This is a genus of muscle borers; they penetrate from the outside surface of the host's body into the underlying tissues, sometimes from the throat, sometimes from the sides of the body, sometimes from the vicinity of the fins. In some species there are peculiar frontal processes by means of which they fasten themselves to a bone, but they are usually anchored by the cephalic horns, and a cyst is formed around the horns, the head, and the anterior neck.

Type of the genus.—*Lernaeenicus radiatus* Le Sueur, type by elimination.

(*Lernaeenicus*, *Lernaea*, and *enico*, to torment or torture.)

KEY TO THE SPECIES OF THE GENUS LERNAEENICUS.

1. 3 to 9 or 10 horns, cylindrical, chitinous, branched 2
1. Only 2 horns, a lateral pair, short and unbranched 3
1. No horns, but instead 2 or 3 small and soft knobs 4
2. Horns usually 5, arranged radially in one set; head in line with thorax; no attachment plates (40 mm.)[1] ..... *radiatus* Le Sueur, 1824, p. 59.
2. Horns in two sets, one at posterior end of head, the other behind the fourth legs; head at right angles to thorax; four attachment plates in front of antennae (12 mm.) ..... *polyceraus*, new species, p. 62.
2. Horns, 3, triangular or conical, in one set; no attachment plates; head at right angles to thorax (13 mm.) ..... *cnerasicholi* (Turton), 1807.
3. Horns pointed backward; no attachment plates in front of antennae; neck often moniliform (25 mm.) ..... *sprattae* (Sowerby), 1804.
3. Horns pointed laterally; four attachment plates in front of antennae; neck never moniliform (25 mm.) ..... *affixus*, new species, p. 64.

[1] Average total length of species.

4. Abdomen more than half the length of the trunk 5
4. Abdomen short and blunt 6
5. Posterior horn half the length of the head, lateral horns much shorter; abdomen twice the length of the trunk (45 mm.)
longiventris, new species, p. 66.
5. Posterior and lateral horns the same length; abdomen a little longer than the genital segment (70 mm.) ..... *procerus* (Leidy), 1858, p. 69.
5. Posterior and lateral horns the same length as the head; abdomen as long as the genital segment (50 mm.) ..... *vorax* Richiardi, 1877.
5. Posterior and lateral horns one-third the length of the head; abdomen much shorter than genital segment (70 mm.) ..... *polynemi* Bassett-Smith, 1898.
6. Head subtriangular, with no lateral horns, but with a single dorsal tubercle; neck three times the length of the trunk; abdomen very minute (28 mm.)
gracilis Heller, 1865.
6. Head hastate, bluntly pointed anteriorly; two lateral and a dorsal knob; neck shorter than the trunk; abdomen of medium size (40 mm.)
sardinae Baudouin, 1904.
6. Head club-shaped, with lateral but no dorsal knobs; abdomen lacking, the trunk ending in a point (60 mm.) ..... *lesucurii* Milne Edwards, 1840.

Remarks.—Three species, *abdominalis* Milne Edwards, 1840, *labracis* and *sargi* Richiardi, 1880, ascribed to this genus have never been figured, and the last two have not even been described, so they are of necessity omitted.

Four species, *inflexus* and *nodicornis* Steenstrup and Lütken, 1861, *gempyli* Horst, 1878, and *cristaliformis* Brian, 1912, are transferred to the new genus *Sarcotretes* established by Jungersen in 1911. With reference to the horns we may notice that in the genus *Lernaea* they are always soft, while in *Lernaeenicus* those of the first two species in the key (*radiatus* and *polyceraus*) are as chitinous as in *Lernaeocera*, those of *sprattae* and *affixus* are only partially chitinized, while the horns, or better, the knobs of the remaining species are usually soft.

The two species, *vorax* and *neglectus*, described and figured by Richiardi in 1877, are probably identical. The only difference which Richiardi could find in them was that *neglectus* averaged only two-thirds the size of *vorax*. He himself said of the former species, "It is impossible to find in its general form any characters which will distinguish it from *vorax*. It does not differ in the form and position of the antennae, the buccal apparatus, the maxillipeds, the number and conformation of the segments or in the form of young individuals, and hence in the progressive deformation of the testa as also in the mode of attachment to the body of the host" (p. 206). In other words, we have to conclude that it does not differ at all, but is the same species and hence *neglectus* is made a synonym of *vorax*. In his profile view Richiardi represented the eye of *vorax* as actually protruding from the dorsal surface of the head.

In all the species examined by the present author the eye is just above the esophagus and a considerable distance beneath the dorsal surface, as is shown in figure 69.

In dealing with this genus Fowler[1] said in the key to the genera of the Lernaeidae (p. 86):

"b. No vestiges of feet on under surface of body, nor any appendages representing them ----------*Lerneaenicus.*"

and again (p. 87), in the genus diagnosis of *Lernaeenicus*, "Thoracic limbs placed close together just behind head, first two biramose, third and fourth uniramose, and all with two joints." The latter of course is the correct statement. The spelling "*Lerneaenicus*" is too obviously a printer's error to be worthy of a second thought.

LERNAEENICUS RADIATUS LeSueur.

Plate 4, figs. 24–35, plate 5, figs. 36–41.

Lerneocera radiata LeSueur, Journ. Acad. Nat. Sci. Philadelphia, vol. 3, 1824, p. 288, pl. 11, fig. 1. The new genus *Lernaeenicus* proposed, p. 289.

Lernea radiata De Kay, New York Fauna, Crustacea, vol. 6, 1844, p. 60.

Lernaeonema radiata S. I. Smith, Rep. Comm. Fish. for 1871 and 2, p. 578 (284), pl. 7, fig. 30.

Lernaeonema radiata R. Rathbun, Proc. U. S. Nat. Mus., vol. 7, 1884, p. 491.

Lernaeocera psis septemramosus Fowler, Rep. N. J. State Museum, 1911 (1913), p. 92, pl. 24.

Lernaeenicus radiatus Fowler, Rep. N. J. State Museum, 1911 (1913), p. 87, pl. 21; Proc. Acad. Nat. Sci. Philadelphia, vol. 65, 1913, p. 62.

Host and record of specimens.—There are in the United States National Museum collection 48 vials containing specimens of this species as follows: From the tomcod, *Microgadus tomcod*, Cat. Nos. 6146, 8283, 8285, 8687, 12298, 12299, 12300, 38025, 42318, 42321, 42338, 42339; from the menhaden, *Brevoortia tyrannus*, Cat Nos. 6001, 6002, 6063, 8282, 11617, 18369, 42323, 42331, 42337, 42345, 47790, 47791; from the killifish, *Fundulus heteroclitus*, Cat. Nos. 42311, 42317, 42335, 42343, all so far mentioned taken at Woods Hole, Mass.; from the eel, *Anguilla bostonensis*, Cat. No. 12293 from Woods Hole, and Cat. No. 42322 from Charleston, South Carolina; from the bluefish, *Pomatomus saltatrix*, at Woods Hole, Cat. No. 47787; from the glut herring, *Pomolobus aestivalis*, at Woods Hole, Cat No. 12313; from the shad, *Alosa sapidissima*, no locality, Cat No. 47789; from the old-wife, *Leiostomus xanthurus*, at Beaufort, North Carolina, Cat. No. 47788; from the smelt, *Osmerus mordax*, at Woods Hole, Cat No. 42350; from the hake, *Urophycis tenuis*, at Woods Hole, Cat. Nos.

[1] Crustacea of New Jersey, 1913.

12303 and 12304; from the alewife, *Pomolobus pseudoharengus*, at Woods Hole, Cat Nos. 13069 and 42327; from the pursey minnow, *Cyprinodon variegatus*, at Woods Hole, Cat. No. 8287; from the anchovy, "*Engraulis vittatus*," in New York City market, Cat. No. 42349; from the white perch, *Morone americana*, at Woods Hole, Cat. Nos. 8286 and 8288; no host and no locality given, Cat. Nos. 6176 and 35252.

The eight specimens in lot No. 12313 are heavily infested with algae, but were removed from their host with exceptional care and are finely preserved. Since Le Sueur's original specimens have been lost these may well serve as surrogate types of the species.

Specific characters of female.—General body form elongate slender, and graceful, the three body regions distinctly separated. Head terminal and globular, with a conical proboscis as large as itself attached to the ventral surface at right angles to the long axis. Cephalothorax furnished with slender, filamentous, radiating chitin horns, usually five in number and unbranched. But there may be any number of these horns from 2 to 9; when there are only two they are on a level with the dorsal surface at the extreme anterior end of the head (fig. 29); when there are five they are arranged radiately around this portion of the head like the spokes of a wheel (fig. 27). But there may also be a smaller horn on either side of the base of the second antennae, and two others, one on either side of the thorax, on a level with the dorsal surface and opposite the fourth pair of legs (figs 28 and 40). These horns may be of any length or they may be reduced to mere knobs. When there are five, the typical number, they are nearly equal and are arranged one dorsal, two lateral, and two latero-ventral. When they differ in length the two lateral are usually the longest and the dorsal one the shortest.

The free thorax or neck is somewhat enlarged immediately behind the head through the bases of the legs, then quickly becomes filiform and has the same diameter back to the trunk. The latter is elongate-conical, the point of the cone at the base of the neck, the outer surface smooth and without any traces of segmentation. Normally a section of this trunk would present a circular outline, but in preserved material it often becomes flattened laterally. The egg strings are the same diameter as the neck and one-half longer than the body. In immature specimens the trunk is greatly reduced in length and width, while the neck is proportionally increased in length, and the egg strings then are often three times the length of the whole body (fig. 26). The abdomen is a short, stout, and blunty rounded cone, on a level with the dorsal surface of the genital segment, one-third the length and three-fourths the width of the latter, and destitute of anal laminae or setae.

The first antennae are short, slender, cylindrical, and three-jointed, sparingly armed with setae, one at the tip of the distal joint and one on the side of the second joint. The second antennae project from the anterior margin of the head on either side of a short and pointed rostrum. They are long, stout, and two-jointed, the joints about the same length, the distal one ending in a stout chela, the claw shutting down past a spiny projection on the inner side of the distal joint.

Proboscis a bluntly rounded cone, soft and fleshy in texture, as large at the base as the whole ventral surface of the head, and constricted at about the center of its length. It is well supplied with striated muscles, by means of which it can be protruded and withdrawn, or moved from side to side. At the tip there is a large lobe on either side and a central oval plate on the ventral surface. This plate is convex ventrally and covered at the center with minute three-cornered spines. Above this plate and between the lateral lobes the slender cylindrical mouth-tube projects a short distance. This is a very thin-walled, transparent tube, wrinkled transversely, and held open by circular chitin ribs. It flares somewhat at the tip, where it is surrounded by a delicately scalloped membrane. It is extensile and can also be moved from side to side independently of the rest of the proboscis.

On either side of the base of the ventral plate is a maxilla, which is three-jointed, the terminal joint narrower and longer than the other two, which are about equal. At the outer distal corner of the basal joint is a short spine; the terminal joint ends in a short, stout, and blunt claw.

The swimming legs each consist of flattened oval basal plate and very short and blunt rami, destitute of setae; the first two pairs are biramose, the last two pairs uniramose.

Color.—The head and proboscis are a deep fish-blood red when freshly taken from the host, the neck a light horn color slightly greenish, the central digestive canal more or less red when filled with blood; trunk dark red internally, surrounded by the yellowish-white ovaries and oviducts; egg strings a light greenish yellow.

Entire length, without egg strings, 40 mm. Length of trunk, 20 mm. Diameter of trunk, 1.50 mm. Greatest spread of horns, 6 mm. Length of egg strings, 28 mm.

(*radiatus*, radiate, alluding to the usual arrangement of the horns.)

Remarks.—The beautiful figures illustrating this species were drawn some time ago by Richard Rathbun, now assistant secretary in charge of the Smithsonian Institution, and were generously turned over to the present author together with valuable notes and de-

tailed descriptions, so that the present account must be credited to him practically in its entirety.

The two figures of the adult female were drawn by J. H. Blake and are by far the best that have ever appeared of the species, since they show a wealth of detail which is specifically accurate.

Mr. V. N. Edwards of the Bureau of Fisheries' station at Woods Hole, who collected most of the specimens of this species mentioned above, told the author that it was very common in the spring when menhaden are abundant, but is found only occasionally during the summer when these fish are much less plentiful.

The parasite is found on the sides and back of its host, usually not far from, and often quite close to, the dorsal fin, and is sometimes attached to the throat under the tongue, or to the edges of the operculum. They bury deeply in the flesh, with the cephalic horns wrapped around some portion of the bony framework of the fish, or held firmly between two bony plates of the operculum, and they make a bad sore.

The species can be readily recognized by the radiating cephalic horns, the large fleshy proboscis, and the projecting second antennae, which stand out prominently from the anterior margin of the head. The number of horns as well as their arrangement varies considerably, but a careful examination of all the oddities in the 200 specimens belonging to the United States National Museum failed to reveal a single one that could be separated specifically. They all possessed the same large fleshy proboscis, projecting second antennae, and swimming legs.

Consequently the new genus "*Lerneocceropsis*" proposed by Fowler in his Crustacea of New Jersey (p. 92) can hardly stand, since the only point in which it differed from *raditaus* was in the possession of two extra horns on the sides of the neck. There are at least a dozen such specimens in the National Museum collection from the same host that Fowler mentioned, but every one of them belongs to the present species. Furthermore, Fowler's specimens show their likeness ("opsis") not to *Lernaeocera* but to *Lernaeenicus*.

LERNAEENICUS POLYCERAUS, new species.

Plate 5, figs. 42–47.

Host and record of specimens.—Two specimens were obtained from the red goat fish, *Upeneus maculatus* by Dr. Edwin Linton at Beaufort, North Carolina, in 1902, and are numbered Cat. No. 47807, U.S.N.M. A third specimen was obtained by Mr. V. N. Edwards from the tomcod, *Microgadus tomcod*, at Woods Hole in 1885. It has been given Cat. No. 6147, U.S.N.M., and is made the type of the species, the two others becoming paratypes.

Specific characters of female.—General form comparatively short and stout; head bent forward at right angles to the thorax, with four attachment plates at its anterior end, in front of the antennae; a pair of long, branched lateral horns at the posterior end of the head; two other lateral and a posterior horn, all dichotomously branched, on the thorax behind the fourth legs; thorax much widened between the two sets of horns; neck comparatively thick, flexed behind the horns and again where it joins the body; trunk a short ellipsoid, slightly flattened laterally; abdomen three-fifths the diameter of the trunk and nearly the same length, somewhat enlarged through the center; egg strings the same diameter as the neck and longer than the trunk.

First antennae minute, three-jointed, sparsely armed with setae; second pair two-jointed and chelate; four attachment plates like those in *affixus*, but each is deeply bilobed and the distal margins curl over inwards.

Maxillae small and three-jointed, the terminal claw short and blunt; proboscis large and long, protruded from the ventral surface of the head and parallel with the axis of the thorax; two large lateral lobes at the tip, but no ventral plate visible; mouth-tube much swollen between the lateral lobes, then abruptly contracted to less than half the basal diameter; first three pairs of legs with a single ramus indistinctly segmented, the fourth legs without a ramus.

Color (preserved material).—Neck and horns a yellowish cartilage-gray; head red from the contained blood; body and egg strings a brownish yellow.

Total length, without egg strings, 12 mm. Length of head and neck, 6 mm.; of trunk, 3 mm.; of abdomen, 3 mm.; of egg strings, 8.50 mm. Greatest diameter of the trunk, 1 mm.

(*polyceraus*, πολύς, many, and κέρας, a horn.)

Remarks.—Doctor Linton recorded in his notes that this species was attached to the gill cover of its host and that the surrounding tissues were congested and inflamed. The single goatfish from which his specimens were obtained was the only one examined by him, so there are no data as to the abundance of the species. It will be seen that this species resembles *radiatus* in the number and hardness of its horns and *affixus* in the possession of attachment plates, but its general makeup and the details of the appendages are quite different from both.

In general it may be recognized by its small size and its short and stout trunk, the abdomen being as long as the genital segment.

LERNAEENICUS AFFIXUS, new species.

Plate 6, figs. 48–61.

Host and record of specimens.—The tomcod, *Microgadus tomcod*, seems to be the most frequent host of this species, and the United States National Museum collection contains the following series of specimens obtained at Woods Hole, Massachusetts. A single female to serve as the type of the new species, Cat. No. 47792; a dozen females, Cat. No. 12311; 8 entire tomcod heads, with about 50 parasites attached, Cat. No. 47797; 8 tomcod heads, with 100 parasites attached, Cat. No. 47798; 40 females from the same host, at Fire Island Beach, Long Island, Cat. No. 35982; 8 females, Cat. No. 47794.

It has also been found upon a few other hosts—three vials, containing 2, 3, and 8 specimens, respectively, from the killifish, *Fundulus heteroclitus*, with Cat. Nos. 47793, 47795, and 47796; a single female from the white perch, *Morone americana*, Cat. No. 12301; two females from the glut herring, *Pomolobus aestivalis*, Cat. No. 42296.

Specific characters of female.—General body form very similar to *radiatus*, with the three regions as distinctly separated; head turned ventrally at right angles to the thorax, cylindrical, slightly larger at the base and tip than in the center. No horns on the head, but a single pair, short and unbranched, on the sides of the thorax opposite the fourth legs; occasionally these horns may be branched, and rarely there is a second pair posterior to the first, which are reduced to mere stumps.

This species attaches itself to a bone, and hence the horns are not used for anchorage. The organ of fixation is on the anterior end of the head, just in front of the second antennae, and is made up of two lamellae on either side, whose bases are attached along the midline of the front of the head. At their bases these lamellae lie flat upon the surface of the head and point away from each other; they then gradually curve forward until their tips are parallel, thus assuming the shape of half a cylinder.

The anterior surface of the lamellae or the inside of the half cylinder is applied directly to the bone, and cements itself so firmly to the latter that the two can be separated only by cutting, the long axis of the bone being parallel with the body axis of the copepod.

The edges of the lamallae are often thickened to make the fastening more secure. The thorax, genital segment, and abdomen are like those of *radiatus*, except that the trunk is relatively longer and wider, being from 10 to 15 times the diameter of the neck. The egg strings are about one-third the diameter of the trunk and a little longer, and are usually fairly straight. First antennae short and stout, two-jointed, with two small spines on the terminal joint; sec-

ond antennae one-jointed, the joint long and conical and furnished on the inner margin with a cup-shaped socket, into which the tip of the stout and strongly curved terminal claw shuts, forming a chela. Proboscis long and narrow and parallel with the body axis in consequence of the turning forward of the head; it is shorter and much narrower than in *radiatus*, and is not constricted at the center. It terminates similarly in a pair of large dorso-lateral lobes and a subquadrangular plate, from under whose base project the maxillae. These are two-jointed, the basal joint the stouter and the longer, and armed on its anterior margin near the center with a short spine.

The terminal joint is much shorter and narrower and is somewhat enlarged at the distal end, to which is hinged the short and strongly curved claw. First two pairs of swimming legs with triangular basal plates carrying two rudimentary rami; third pair with an elliptical basal plate, reduced in size and carrying but one ramus; fourth pair with an elliptical basal plate, still further reduced and without any ramus.

The anal laminae are greatly reduced in size also, and consist of tiny knobs, one on either side of the anus, and destitute of setae.

Color (preserved material), a uniform orange yellow; the head, neck, and egg strings brownish, the body often spotted with brown.

Total length without egg strings, 20 to 30 mm. Length of trunk, 12 to 18 mm.; diameter, 1.50 mm. Length of egg strings, 15 to 20 mm.

(*affixus*, fastened or attached, that is, to a bone.)

Remarks.—This species seems to be a parasite chiefly of the tomcod, which it often infests in great numbers (see tables, p. 12). Its favorite point of attachment is on the isthmus of the fish's throat, between the opercula, but it is also often found along the ventral margins of the opercula. It can be readily recognized by the fact that it is always attached by the front of the head to a bone, and this one character will separate it from *radiatus* when, as often happens, the two are found together upon the same fish. Further distinctions are the attachment lamellae, the forward flexure of the cephalothorax, and the very short horns, only two in number. From *polyceraus*, which also possesses attachment lamellae and a forward flexure of the head, it may be distinguished by its larger size, by the relatively longer and narrower trunk, and by the one pair of unbranched horns instead of two pairs of branched ones.

The bunching of this parasite on the throat of the tomcod is remarkable, three or four of them often using the same opening through the skin of the fish, but attaching themselves to different bones and showing great differences in both the direction and amount of torsion (see p. 15).

LERNAEENICUS LONGIVENTRIS, new species.

Plate 7, figs. 62–70.

Host and record of specimens.—The collection of the National Museum contains 15 vials of this species from widely different hosts and localities, as follows:

Specimens.	Host.	Locality.	Cat. No. U.S.N.M.
1 female	*Caranx crysos*	New England coast	2107
Do	*Palinurichthys perciformis.*	Woods Hole	6058
Do	*Pomatomus saltatrix*	Long Island Sound	6190
Do	*Cybium maculatum*	Woods Hole	6192
2 females	*Caranx* species	Vineyard Sound	6194
3 females	*Caranx crysos*	Woods Hole	19727
Do	*Pomatomus saltatrix*	do	42312
1 female	*Caranx hippos*	do	42346
1 female type	Dolphin	Atlantic Ocean	47800
7 females	*Coryphaena equisetis*	Beaufort, North Carolina.	47801
2 females	*Scomberomorus maculatus.*	Woods Hole	47802
Do	*Mugil cephalus*	Beaufort, North Carolina.	47803
3 females	*Caranx crysos*	do	47804
2 females	do	Woods Hole	47805
12 females	Dolphin	Atlantic Ocean	47806

Specific characters of female.—Cephalothorax smoothly rounded and elongated at right angles to the body axis, without horns but with three protuberances or knobs. One of these is median, projecting from the posterior end of the cephalothorax and in line with it, about two-thirds its length and half its diameter. The other two are lateral, one on either side opposite the base of the larger median knob, and are short and wide, little more than a slight swelling or tubercle.

The neck is long and narrow, but relatively much thicker than in *radiatus*, nearly straight and decreasing in diameter to the point where it joins the trunk. The latter widens abruptly from this narrowed point and is cylindrical; the portion representing the genital segment is of the same diameter throughout and about one-quarter as long as the neck. To its posterior end is attached the abdomen, which is cylindrical, of the same diameter as the egg strings, and nearly twice as long as the genital segment; the anal laminae are minute and destitute of setae.

The egg strings are one-third the diameter of the genital segment and but little longer than the abdomen. As they approach ripeness the embryos are colored a beautiful maroon, and this gradually becomes more apparent in the strings.

The first antennae are turned back along the surface of the head and are indistinctly three-jointed, the terminal joint chelate, a strongly curved claw shutting down against a short projection on the inner margin of the second joint. The basal joint is a trifle wider and nearly twice as long as the second joint. There is apparently no protrusible proboscis, since none can be seen in any of the specimens, but fortunately those from Beaufort, North Carolina, were examined alive and a proboscis could then be seen projecting from the ventral surface. The numerous muscles also connected with the mouth opening must be used for protrusion and retraction. And sections of the head of one of these preserved specimens show clearly that the only reason why no proboscis is seen is that it was tightly withdrawn into the head at the time of death. The mouth is a simple opening and is surrounded by a narrow and ciliated membrane. On the inside of the mouth tube and projecting from its dorsal surface into the lumen can be seen two large and stout spines, bipartite near their tip, which probably represent rudimentary mandibles. On either side of the mouth are the maxillae, which are two-jointed, the basal joint stouter than the terminal and nearly twice as long, somewhat swollen at the center, and armed on its ventral surface with two short knobs placed side by side; the terminal joint is tipped with a rather stout claw, longer than the joint itself and slightly curved.

Upon the ventral surface of the neck where it joins the head are the four pairs of swimming legs. These diminish in size regularly backward, the first two pairs being biramose and the last two pairs uniramose, all the rami two-jointed. The basal plates are broadly triangular, the base of the triangle jointed to the thorax, while to the apex are attached the rami. The joints of these rami are of about the same size and the terminal one is tipped with seven setae, the central three of which are considerably longer than the others.

Internal structure.—Inside of the anterior end of the genital segment may be seen the ovaries, which are strongly flattened between the intestine and the dorsal wall of the segment. They are oval in outline, the broad ends anterior, from which the oviducts extend obliquely downward and backward to the ventral surface. There they increase in diameter, become straight and cylindrical, and extend back to the vulvae. The cement glands are straight and narrow and do not show any segmentation; the duct is about the same length as the glandular portion.

The esophagus is slightly enlarged at either end and contracted at the center; the anterior enlargement is probably temporary and due to the pulling up of the dorsal wall during retraction; the posterior enlargement is permanent. The stomach is narrow and at its posterior end, where it passes into the neck, it is bent at right angles. The intestine fills the whole lumen of the neck and abdomen,

but in the genital segment, where it is somewhat enlarged, it lies near the dorsal surface and leaves room for the oviducts and cement glands.

Color a dull, yellowish-white, often becoming transparent in the neck and abdomen, head a bright pink red, egg strings a beautiful maroon on ripening; large blotches of the same maroon on the basal joints of the legs, the rows thus formed continued forward onto the head; oviducts dark brown.

Total length, excluding egg strings, 40 to 50 mm. Length of head, 2.35 mm.; of neck, 25 mm.; of genital segment, 5.50 mm.; of abdomen, 10 mm.; of egg strings, 13 mm. Diameter of neck, 0.45 mm.; of genital segment, 1.30 mm.; of abdomen, 0.35 mm.; of egg strings, 0.30 mm.

(*longiventris*, *longus*, long and *venter*, abdomen.)

Nauplius.—Body spindle-shaped, the posterior half considerably narrower than the anterior, both ends evenly rounded, the length to the width at the center as 10 to 7. The eye spot is comparatively large and shaped like the section of an ordinary T rail. There are four color spots, a large one at the center on either side close to the lateral margin and a pair of smaller ones near the posterior end, each about half way between the margin and the midline. These four and the eye spot are the same rich maroon red as is found on the basal joints of the legs of the adult.

In the center of the body are oil globules, sometimes a single large spherical one filling the whole center, as in figure 70, sometimes a pair of smaller ones with their adjacent sides flattened along the midline.

Occasionally there is a group of small drops irregularly disposed, but always chiefly at the center. The balancers are large and stout, and are curved forward on either side.

Length, 0.25 mm.; width at the center, 0.175 mm.

Remarks.—This species was first found upon the crevalle or hard tail, *Caranx crysos*, the genital segment and egg strings showing on one side or the other of the dorsal or ventral fin near the tail. Afterwards a single specimen was taken from the operculum of the common mullet, *Mugil cephalus*, and several specimens near the dorsal and anal fins of the small dolphin, *Coryphaena equisetus*. The head is buried in the tissues close to the backbone, where it forms a fibrous membrane or sheath, very tough and fitting so tightly that it is difficult to remove it without injury to the head of the parasite. The neck is contractile and upon irritation can be withdrawn, pulling half or two-thirds of the genital segment in with it. When the irritation stops the body returns to its normal position. The species is not at all common and only a single specimen has been found upon any fish.

The only other species which closely resembles it is *polynemi* Bassett-Smith, but in that species the head is in line with the neck instead of at right angles to it, the basal joints of the legs are narrow-oblong instead of triangular and have no pigment spots, the abdomen is shorter than the genital segment, while the egg strings are two or three times as long as the abdomen and bright green in color.

LERNAEENICUS PROCERUS (Leidy).

Lernaeonema procera LEIDY, Proc. Acad. Nat. Sci. Phila., 1888, p. 165.—FOWLER, Report of New Jersey State Museum, 1911 (1913), p. 125.

Host and record of specimens.—Several of these parasites were obtained by Leidy from the shark, *Carcharias littoralis*, caught at Beeseleys Point, New Jersey. They were hanging from the upper lip on either side of the mouth, and were thickly covered with hydroids, *Eucope parasitica.*

Specific characters of female.—Head horizontal, semioval, convex above, with three short and blunt occipital tubercles; anterior part well rounded, excavated beneath and inclosing the mouth, antennae, and maxillipeds; neck long, linear, and cylindrical; trunk short, fusiform, and truncated posteriorly; abdomen longer than the genital segment, linear, cylindrical; egg strings long, linear, and cylindrical.

Color, a uniform pale yellow.

Total length, 70 mm.; including the egg strings, 90 mm. Length of head, 3 mm.; of neck, 30 to 45 mm.; of genital segment, 10 to 12 mm.; of abdomen, 12 to 15 mm.; of egg strings, 20 mm. Diameter of neck, 0.375 mm.; of genital segment, 1.75 mm.; of abdomen, 0.50 mm.; of egg strings, 0.25 mm.

(*procerus*, long.)

Remarks.—This parasite is known only from Leidy's description and the original specimens have been lost. Fowler in the reference given above repeated Leidy's description, placing the species for some unaccountable reason in the family of the Ergasilidae, although he speaks of the parasites as "lerneans." Since the original specimens are lost we must be guided by the above description (no figures were published) and the species must remain as Leidy left it until rediscovered at some future time. It is closely related to *longiventris*, *vorax*, and *polynemi*, but does not agree well enough with either of them to be identified with it.

Genus SARCOTRETES Jungersen.

Sarcotretes JUNGERSEN, Vidensk. Meddel. fra naturh. Foren., vol. 64, 1911, 33 pages, 2 plates, 6 text figures.

External generic characters of female.—Cephalothorax in line with the body axis and considerably enlarged; eye so deeply buried as to be invisible; two lateral horns ventral to the carapace, large,

soft, and thin-walled; dorsal carapace and two or three anterior terga and sterna often fully preserved; neck constricted just behind the horns, then enlarged and constricted again into a narrow chitin stalk where it joins the trunk and usually flexed; trunk claviform with a minute abdomen on the dorsal surface; egg strings long, straight, and uniseriate.

Two pairs of antennae, second pair chelate; mandibles spine-like and without teeth; two pairs of maxillae; three pairs of swimming legs, first two pairs biramose, third pair uniramose, all the rami two-jointed and armed with setae.

Internal generic characters of female.—Esophagus in line with body axis and nearly straight; anterior stomach neither lobed nor convoluted; intestine enlarged in the anterior neck, then constricted through the narrow stalk, enlarged again and flattened dorso-ventrally in the trunk, and abruptly constricted at the posterior end into a short rectum.

Ovaries paired and dorsal to the intestine at the anterior end of the trunk, only a little flattened; oviducts nearly straight and much wider than the ovaries or intestine; cement glands not reaching the anterior ends of the oviducts, glandular portion shorter than the ducts and not segmented. Chitinogen layer of the skin especially well developed at the anterior and posterior ends of the genital segment; a longitudinal row of skin glands along either side of the ventral surface, some distance from the midline.

Genus habitat.—This genus burrows into the cephalic or cephalothoracic muscles of its host and brings its head in contact with the apophysis of the vertebral column. The head and enlarged portion of the neck are surrounded by a cyst formed in the tissues of the fish.

External generic characters of Copepodid male (genus *Sarcotretes*).—Head and first thorax segment fused into a cylindrical cephalothorax, three times as long as wide; second, third, and fourth thorax segments free; fifth and genital segments and abdomen indistinguishably fused and without lobes; anal laminae short and wide, each armed with four or five minute, nonplumose setae. First antennae with indistinct joints; second antennae two-jointed and chelate; mouth tube conical, at right angles to the axis of the head; mandible a single slender spine; first maxilla a fingerlike process, without joints; second maxilla uncinate; maxilliped reduced to a mere knob; three pairs of swimming legs, first and second pairs biramose, rami indistinctly two-jointed, third pair uniramose, without joints.

Type of the genus.—*Sarcotretes scopeli* Jungersen, monotypic.

(*Sarcotretes*, Σάρξ, flesh, and τρητής, a borer or piercer.)

KEY TO THE SPECIES.

1. Neck but little enlarged anteriorly and not flexed; lateral horns at right angles to the body axis 2
1. Neck much enlarged anteriorly, then constricted and flexed at the constriction; tips of the horns turned backwards 3
2. Lateral horns swollen and bluntly rounded; proboscis conical and strongly tapered (49 mm.)[1] ..... *nodicornis* (Steenstrup and Lütken), 1861.
2. Lateral horns cylindrical and sharply pointed; proboscis cylindrical or spherical (85 mm.) ..... *gempyli* (Horst), 1878.
3. Proboscis short and fully as wide as long; carapace, terga, and sterna distinctly visible 4
3. Proboscis twice as long as wide; no carapace, terga, nor sterna visible (26 mm.) ..... *inflexus* (Steenstrup and Lütken), 1861.
4. No constriction behind the legs; mouth tube turned ventrally; rami of legs armed with setae (13 mm.) ..... *scopeli* Jungersen, 1911.
4. A marked constriction behind the legs; mouth tube in line with head; rami of legs without setae (44.50 mm.) ..... *cristaliformis* (Brian), 1912.
4. No constriction behind the legs; mouth tube in line with head; upper lip bilobed (22 mm.) ..... *lobatus*, new species, p. 72.

Remarks.—The only reason given by Jungersen for establishing the present genus was the fact that it possessed but three pairs of swimming legs, while the closely allied genera possess four pairs. There are, however, several other characters of equal or greater value, such as externally the presence of first maxillae on the sides of the mouth tube in front of the second pair, the softening of the horns and the anterior portion of the thorax, and the persistence of the larval carapace, terga, and sterna.

Internally there is the peculiar arrangement and character of the chitinogen layer of the body wall, which covers the inner surface of the neck as well as the genital segment, the wheel-like skin glands, and the dorso-ventral flattening of the intestine. Taken accumulatively these characters establish the genus beyond any dispute, and there should be transferred to it such species as show these characters, or a convincing majority of them. Accordingly that has been done in the key above given. It is worthy of note that Steenstrup and Lütken recognized that the species described by them differed materially from the *Lernaeenicus* type, and suggested in a footnote the possibility of a subsequent generic separation. Horst stated definitely that his species had but three pairs of legs and an extra pair of mouth-parts, while the "hard chitin parts of the cephalothorax" which he mentioned were probably the persistent carapace, sterna, and terga. Brian showed the same details in the excellent figures of his species, all of which have been confirmed upon a specimen in the United States National Museum collection (see p. 72).

Furthermore this species is not gregarious like *Lernaeenicus* but is solitary, only a single specimen being found upon a host.

[1] Average total length of species.

Doctor Jungersen very kindly presented the author with a fine specimen of his species, *Sarcotretes scopeli*, which has been of great service for comparison.

SARCOTRETES ERISTALIFORMIS (Brian).

Lernaeenicus cristaliformis BRIAN, Copépodes parasites des Poissons et des Échinides provenant des campagnes scientifiques de S. A. S. le Prince Albert I^er^ de Monaco, 1912, p. 20, pl. 4, figs. 1 and 2; pl. 9 and 10.

Host and record of specimens.—A single female was obtained from *Gastrostomus bairdii* by the Bureau of Fisheries steamer *Albatross* at station 2206, off the coast of New Jersey, in August, 1884. It has been given Cat. No. 8349, U.S.N.M.

Remarks.—This specimen is somewhat injured but not enough to affect its identification. It agrees in every particular with the two large specimens so fully and excellently described by Brian. And it was even obtained from the same host, a rare deep-sea Eupharyngid, but from a different locality. It exceeds Brian's specimens somewhat in size, the trunk measuring 33 mm. in length and the neck and cephalothorax 25 mm.; this latter portion of the body has shriveled somewhat in the preservative and was probably a few millimeters longer when taken from the fish.

SARCOTRETES LOBATUS, new species.

Plate 8, figs. 71–79.

Host and record of specimens.—Two specimens were obtained from *Benthosema* (*Scopelus*) *mulleri* in slightly different localities, one by the Fisheries steamer *Fish Hawk* in 1882 at station 1140 off Marthas Vineyard, the other by the Fisheries steamer *Albatross* in 1883 at station 2001 off Block Island. The former has been given Cat. No. 6123, U.S.N.M., and is made the type of the species, the latter was cleared in clove oil for the internal anatomy.

External specific characters of female.—Cephalothorax short, cylindrical, and strongly inflated, covered dorsally with a well-defined carapace, and sending out on either side a large cushionlike process or horn, which curves posteriorly and ends in a sharp point; combined width of head and horns much greater than the length. Neck behind the horns considerably inflated and showing the remains of the two anterior terga and sterna, then narrowing gradually with a thickening and increasing chitinization of the skin, and forming a narrow stalk just in front of the trunk, where it is bent ventrally at a right angle. Trunk thickening rapidly beyond the bend, cylindrical, the same diameter throughout and abruptly truncated at the posterior end. Abdomen a small spherical knob on a level with the dorsal surface and inclined dorsally; neither specimen carried egg strings and so they are unknown.

First antennae short, slender, curved sharply backward, and very indistinctly segmented, if at all, rather well supplied with setae at the tips and along the outer margins. Second antennae large and stout and three-jointed, basal joint the narrowest, terminal joint strongly flattened and in the form of an equilateral triangle, whose apex is articulated with the second joint and whose base is distal, twice the width of the basal joint, and armed with a powerful chela, made up at the outer angle of a long sickle-shaped claw whose tip shuts down inside a stout process at the inner angle; this claw is operated by strong muscles which fill the interior of the joint. Proboscis cylindrical, of about the same diameter as the carapace and strongly protrusile (fig. 72). It is usually extended straight in front of the head, but can be moved about in various directions.

At the tip the upper lip divides into two lobes, which stand out prominently when the proboscis is retracted, but are folded over tightly against its side when it is extended. The underlip forms a single median lobe, which is also more prominent in the retracted proboscis.

Between these lobes extends the mouth tube, much as in *Lernaeenicus;* it is very short and less than half the diameter of the proboscis, and the opening is surrounded by a deeply fringed membrane. Beneath the center of the upper lip and dorsal to the esophagus lies a tripartite eye, which is very distinctly visible in the cleared specimen.

This eye is still farther out toward the tip of the proboscis than in *Lernaeenicus*, but otherwise its general relations are the same.

On the sides of the mouth tube are the second maxillae, three-jointed, the basal joint long and slender, the second joint three-fifths as long and carrying a small process on the inner margin, the terminal joint in the form of a curved claw, nearly as long as the second joint.

Just above the bases of these second maxillae there is on either side a tiny, one-jointed process, tipped with two minute setae, which represents the first maxilla. These can only be seen in an end view since they are in the bottom of the groove between the lips and the mouth tube, and are entirely concealed by the lobes in a side view.

The three pairs of legs are close together on the ventral surface of the thorax: the basal plates of the first two pairs are broadly triangular, those of the third pair are narrow oblong; the two former are biramose while the latter is uniramose, and the rami are each two-jointed and tipped with two or three long setae.

Internal specific characters of female.—Esophagus nearly in line with the head axis; stomach considerably enlarged, but not sending out processes laterally and not convoluted. Intestine narrowed through the neck, then enlarged in the anterior trunk, where it passes

at once to the dorsal portion below the ovaries and is strongly flattened dorso-ventrally between the ovaries and oviducts; rectum fairly long and inclined dorsally.

Ovaries two-third as long as the oviducts and not much flattened, but cylindrical and pointed at the posterior end; oviducts slightly flattened and in about the center of the trunk dorso-ventrally; cement glands relatively narrow, the lumen of the glandular portion scarcely wider than the duct, the two about the same length and both reduced to a mere line.

The chitinogen layer of this species would have been extremely satisfactory to Claus in his search for "subcutaner Drusen." It is thin and uniform along the midline dorsally and ventrally and for some distance on either side, especially between the ovaries and the dorsal surface. But along the sides of the body and more particularly around the anterior and posterior ends of the trunk it is greatly thickened, as shown in figure 78, and nearly every cell communicates with the exterior through a pore canal in the chitin layer. Along either side ventrally, where the chitinogen layer begins to thicken, there is a row of 12 large glands, whose central lumen opens through a pore.

These glands are seen in section in figure 78, and in surface view enlarged in figure 79. Each consists of five or more cells arranged radially around the central lumen, and in the cleared specimen they are dark cinnamon brown in color and so opaque as not to show their nuclei.

It is especially worthy of note that this chitinogen layer covers the enlarged portion of the neck and the soft horns of the cephalothorax, thus offering a sharp contrast with the genus *Laernaeenicus*, whose horns and neck are completely chitinized.

Color (preserved material), a brownish yellow, darker on the cephalothorax and trunk, lighter on the neck.

Total length, 22 mm. Length of cephalothorax, 1.35 mm.; width, 2 mm. Length of trunk, 9 mm.; width, 2 mm.

(*lobatus*, lobed, alluding to the upper and lower lips.)

Genus PHRIXOCEPHALUS Wilson.

Phrixoccphalus Wilson, Proc. U. S. Nat. Mus., vol. 35, 1908, p. 461.

External generic characters of female.—Cephalothorax a short cylinder, somewhat flattened and chitinized, sending out from one to three pairs of lateral cylindrical horns, more or less branched and chitinized, and a few frontal processes in the form of knobs or short horns. Neck cylindrical and hardened, with one or more sets of horns, simple or branched, the last set opposite the fourth legs; inserted in the trunk eccentrically, to one side of the midline, and some-

what twisted. Trunk abruptly enlarged and slightly twisted, at right angles with the neck; abdomen small and hemispherical, with a pair of rudimentary anal laminae destitute of setae; egg strings attached laterally and nearer the dorsal surface; tightly coiled into a spiral; eggs numerous and uniseriate.

Two pairs of minute antennae, second pair chelate; mouth parts reduced to mere chitin knobs; proboscis small and nonretractile. Four pairs of swimming legs, first two pairs close together, biramose, rami one-jointed, third and fourth pairs removed a considerable distance and uniramose, all the rami armed with setae.

Internal generic characters of female.—Bilateral symmetry distorted; esophagus inclined to the head axis and very short; stomach without lateral lobes or convolutions. Intestine very narrow through the neck, but much enlarged in the trunk; rectum short, given off from the dorsal, posterior corner of the intestine and somewhat inclined dorsally.

Ovaries on the dorsal surface, nearer the posterior end, diagonal to the trunk axis, and not much flattened; oviducts also diagonal to the trunk axis but in the opposite direction to the ovaries, the one on the side to which the neck is attached close to the ventral surface, the other considerably elevated above it, but the two pass down around the intestine on opposite sides. Cement glands both on the side of the elevated oviduct and not parallel to each other either laterally or vertically, but deviously curved, the glandular portion much longer than the ducts and indistinctly segmented. Chitinogen layer of the body wall most developed in the trunk, especially at the posterior end; no definite skin glands.

Genus habitat.—This genus fastens to the eye of its host, burrowing in from the outer surface and bringing the mouth in contact with the blood vessels at the back of the eye. The head and neck are completely chitinized and covered with a thick cyst, they show both torsion and flexion.

Type of the genus.—Phrixocephalus cincinnatus Wilson, monotypic.

(*Phrixocephalus*, φριξός, a bristling of the hair, and κεφαλή, the head.)

KEY TO THE SPECIES.

1. Head with three pairs of lateral horns; neck with two sets of horns, all branched; trunk narrow oblong (30 mm.)[1]____*cincinnatus* Wilson, 1908.
1. Head with one pair of lateral horns, profusely branched; neck with one set of simple horns; trunk broadly triangular (11 mm.)
triangulus, new species, p. 76.
1. Head unknown; neck with one set of tripartite horns and inserted in the side of the trunk; the latter semioval in outline; egg strings widely divergent (5 mm.)_____*diversus*, new species, p. 77.

[1] Average total length of species.

Remarks.—This genus was founded upon a single specimen, which could be examined only superficially for its external characters. The new material here presented has slightly modified some of the characters and has added many new ones. Especial attention is called to the asymmetry of the body, which is comparatively slight in this genus, but which forms an initial step leading up to the complete distortion exhibited in the new genus *Collipravus* (p. 78). The elevation of the vulvae toward the dorsal surface is also worthy of note; in the new species, *diversus*, they are practically on a level with the dorsal surface.

The discovery of the two pairs of antennae and the two additional pairs of legs is particularly gratifying, since it makes this genus completely analogous with the others in the family. It is also very pleasing to find that the internal anatomy fully corroborates the asymmetry of the exterior.

PHRIXOCEPHALUS TRIANGULUS, new species.

Plate 9, figs. 80–84; plate 10, fig. 85.

Host and record of specimens.—Three females with egg strings were obtained from the eyes of *Neopercis multifasciata* at Owari Bay, Japan, by the Bureau of Fisheries steamer *Albatross* in 1906. One of these was a perfect specimen and is made the type of the new species, with Cat. No. 47799, U.S.N.M. The others become paratypes, with Cat. No. 47808, U.S.N.M.

Specific characters of female.—Cephalothorax barrel-shaped, a little longer than wide, made up of the head and first two thorax segments fused, and separated from the third thorax segment by a distinct groove. Anterior end squarely truncated and giving off three frontal processes in the form of short, lobed, chitin horns; a pair of large lateral horns curve over dorsally and send off rows of long posterior branches, more or less anastomosed. Third segment separated from the fourth by a groove; fourth segment somewhat enlarged, especially on the ventral surface, and armed with two lateral and a ventral horn in the form of large chitin spines. Neck behind the fourth segment considerably narrowed, chitinized, and joined to the anterior end of the trunk at a right angle; in the two larger specimens it is at the extreme right anterior corner, in the smallest specimen, about half the size of the other two but with egg strings, the neck is on the midline of the dorsal surface, but a short distance behind the anterior end. The head and neck are also twisted through an arc of 90°, so that the ventral surface of the neck faces inward toward the midline of the trunk. The latter is triangular in side view, considerably flattened laterally, and thickest at the posterior end; dorsal surface flat and nearly straight, ventral surface strongly convex; abdomen a small hemisphere at the posterior end

on the dorsal surface and inclined dorsally; egg strings attached near the dorsal surface, large in diameter, and coiled into a wide spiral.

Antennae reduced to mere knobs on the dorsal surface of the head, comparatively wide in diameter but elevated very little. Mouth parts also reduced to rounded chitin knobs, one on the midline in front of the base of the median frontal process, and behind this two on either side of the midline. First two pairs of swimming legs toward the posterior end of the cephalothorax biramose, the rami very indistinctly jointed; third pair posterior to the center of the third segment, uniramose, the ramus also indistinctly jointed; fourth pair on the posterior margin of the fourth segment also uniramose, but with a single joint; all the rami are well armed with setae. The basal joints of the first two pairs of legs are close together on the midline, those of the third pair are a little farther apart, while those of the fourth pair are widely separated, one on either side of the ventral horn.

Color (preserved material) a uniform dark brown, almost black, the frontal processes and lateral horns lighter brown.

Total length, 11 mm. Head and neck, 5 mm. long; third thorax segment, 0.80 mm. in diameter. Trunk, 6 mm. long, 2 mm. wide, and 3 mm. thick at the posterior end. Egg strings, 3.50 mm. long, 1.35 mm. wide.

(*triangulus*, triangular, alluding to the outline of the trunk.)

Remarks.—In the type-specimen it is possible that the antennae may have been broken off, since these minute appendages, when chitinized, are extremely brittle, but no scars of such a break could be found.

One of the lateral horns was broken, leaving a short stump, but it is assumed that this horn corresponded to the one on the opposite side.

In both the other specimens the head and anterior neck were lacking.

PHRIXOCEPHALUS DIVERSUS, new species.

Plate 10, figs. 86 and 87.

Host and record of specimens.—A single female with egg strings was taken from the eye of *Callionymus virgis* Jordan, at a depth of 65 fathoms in Totomi Bay, off Hamamatsu, Japan, at station 3713, by the Bureau of Fisheries steamer *Albatross*.

This is made the type of the new species with Cat. No. 47809, U.S.N.M.

Specific characters of female.—Head, first, second, and third thorax segments missing; fourth segment present and armed with two pairs

of forked horns, one pair lateral and one ventral, and a pair of uniramose swimming legs between the bases of the ventral horns. Trunk triangular, the dorsal margin nearly straight, the ventral margin strongly convex, these two forming the sides of the triangle; posterior margin or base of the triangle also nearly stright. Neck attached a short distance behind the anterior end or apex of the triangle, on the dorsal surface and not on the median line. Neck also twisted at right angles to the trunk, as in the other species, so that the ventral surface faces the lateral surface of the trunk. Egg strings attached on a level with the dorsal surface and standing out on either side so that they almost form a straight line at right angles to the trunk axis. Each string is comparatively long and thick, and the coils of the spiral are separated a little from one another.

Color (preserved material), neck and trunk a brownish yellow, egg strings orange yellow.

Length of trunk, 3 mm.; greatest diameter, 2 mm. Length of egg coils, 3.50 mm.; diameter, 1 mm. Diameter of egg strings, 0.33 mm.

(*diversus*, divergent, alluding to the egg coils.)

Remarks.—Since there is but a single mutilated specimen, it seems at first sight presumptuous to establish a new species for it. But it presents so many striking differences as to leave no doubt of its being a new species, and supplements the characters of the genus in such a way as to demand recognition. In *cincinnatus* the fourth thorax segment carried two pairs of profusely branched horns, with the fourth legs entirely concealed between their bases so that they escaped notice. In *triangulus* there were but three horns in the form of simple spines, and the unpaired ventral horn stood between the widely separated fourth legs. Here in *diversus* there are again two pairs of horns, but the ventral pair are only forked once, and the fourth legs are close together between their bases and are only partially concealed.

Again, in *cincinnatus* and *triangulus* the neck is attached to the extreme anterior corner of the trunk; here it is removed a short distance from the anterior end on the dorsal surface and is still attached to one side of the midline. Finally the egg strings which are parallel in all the other genera and species in which they are coiled are here so widely separated as almost to form one straight line at right angles to the axis of the trunk.

COLLIPRAVUS, new genus.

External generic characters of female.—Cephalothorax oblong, nearly cylindrical, sending out laterally two pairs and ventrally one pair of cushion-like processes. Second, third, and fourth thorax segments distinctly separated, each with a pair of cushion-like lateral processes. Neck narrow and chitinized, bent just behind the fourth

segment and armed with small branched chitin horns. The neck is joined to the trunk on the dorsal surface of the latter and considerably away from the midline.

Trunk ellipsoidal, the anterior end bluntly rounded, the posterior end with lobed processes over the bases of the egg strings. Abdomen as long as the trunk, flattened dorso-ventrally, and bent sidewise at right angles to the trunk axis. Egg strings coiled in tight spirals, eggs uniseriate.

Two pairs of antennae, second pair chelate; one pair of maxillae; four pairs of swimming legs, first two pairs close together and biramose, third and fourth pairs separated a short distance and uniramose, all the rami two-jointed.

Internal generic characters of female.—Bilateral symmetry completely distorted; esophagus inclined to the head axis, with a tripartite eye buried in the tissues at its base; stomach not sending out lateral lobes nor convoluted; intestine looped once in the trunk; rectum short and straight; an anal lamina, destitute of setae on either side of the anus.

Ovaries at the extreme posterior end of the trunk on the dorsal surface, each a flattened sphere inclined to the trunk axis; oviducts separated by the neck, then coming together again, running forward diagonally to the anterior end of the trunk, then backward on the ventral surface to the vulvae. Cement glands also separated by the neck, then closing together again; they start between the ovaries at the posterior end and run diagonally forward the whole length of the dorsal surface, then backward on the opposite diagonal on the ventral surface, with no differentiation between the glandular portion and the ducts.

Chitinogen layer of the body wall thickest in the posterior lobes of the trunk and in the abdomen, elsewhere very thin.

Genus habitat.—This genus, like *Haemobaphes*, burrows from the bases of the gill arches into the throat and buries its head and the four anterior thorax segments in the bulbus arteriosus of its host. The abdomen is bent outward, away from the fish's throat, on whichever side the parasite may be attached, and the egg strings project through the gill opening.

Type of the genus.—*Collipravus parvus*, new species. monotypic.

(*Collipravus*, *collum*, neck and *pravus*, irregular, misplaced.)

COLLIPRAVUS PARVUS, new species.

Plate 11, figs. 89–97.

Host and record of specimens.—Five females were obtained from the gill arches of *Jenkinsia stolifera* at Nassau, in the Bahamas, by the Bureau of Fisheries steamer *Albatross* in 1886. One of these is made the type of the new species with Cat. No. 47810, U.S.N.M.;

the others become paratypes with Cat. No. 12327, U.S.N.M. A single female, without a head, was obtained from the same host in the Florida Keys and was cleared in clove oil to obtain the internal anatomy.

Specific characters of female.—Specific characters the same as the generic, with the addition of the following details: Cephalothorax and anterior thorax segments all very soft and fleshy, the cushion processes much inflated, forming on the dorsal surface three longitudinal ridges, the central one the cephalothorax proper, the others the lateral processes.

On the fourth segment the lateral processes are conical and extend backward on either side of the neck. That portion of the neck which is inclosed in the bulbus arteriosus is also soft, but becomes gradually chitinous and where it passes out through the wall of the artery is armed with two or three branched chitin horns, which are buried in the adjacent tissue. The neck then softens again before it joins the trunk and is twisted somewhat upon its long axis, but just how much it was impossible to tell, because the two heads were packed so tightly together inside the bulbus arteriosus (see "*Remarks*" below). The anterior end of the trunk points forward toward the fish's mouth and the abdomen is turned outward away from the bulbus arteriosus, so that when there is a parasite on both sides of the fish the one is the reverse of the other.

The long egg coils reach out through the gill opening and are visible from the exterior when the operculum is closed; each, if uncoiled, would be at least three times the length of the trunk.

The first antennae are two-jointed and setiferous; the second pair are also two-jointed and comparatively minute; they project very little and the tooth of the chela is nearly as large as the claw. The maxillae are attached to the ventral surface of the head at the base of the mouth-tube, which can not be protruded very far, if at all; each maxilla is made up of two slender joints and a long needlelike claw, slightly curved. Only the first thorax joint is fused with the head, and this is fairly well differentiated on the sides by the lateral processes. The first and second swimming legs are close together, the second pair much larger than the first; the third and fourth pairs are separated by considerable intervals, each on the posterior margin of its segment. In the preserved material the basal lamina of every leg is heavily pigmented with black, which makes them stand out prominently.

Color (preserved material), head, neck, and trunk a light yellowish gray, egg strings orange yellow.

Length of trunk, 3.50 mm.; diameter, 1.50 mm. Length of head and neck, 2.50 mm. Length of egg coils, 4.50 mm.; diameter, 0.60 mm.

(*parvus*, small.)

Remarks.—In the material collected by the Bureau of Fisheries steamer *Albatross* there were three specimens which had been removed from their host and two which were still attached, one on either side, to the gills of a *Jenkinsia stolifera* 40 mm. long. As is usual in such cases the torsion in these parasites was in opposite directions, as was also the flexion of the abdomen. On dissecting out the parasites their necks were found to enter the ventral aorta of the host at about the same point, just in front of the two arteries that supply the posterior gill arch. Both necks turned backward inside the aorta and the heads of the parasites were found closely packed together and filling the entire cavity of the bulbus arteriosus.

One head (*a*) was superimposed upon the other (*b*), the dorsal surfaces of the two facing the ventral wall of the aorta and the ventral surface of (*a*) packed against the dorsal surface of (*b*). The head (*a*) was longer than (*b*), thus bringing its anterior ventral surface with the mouth-tube in front of the frontal margin of (*b*). Both mouths were thus unobstructed and could take in blood freely; the free anterior end of (*a*) was inflated into a cylinder the full size of the lumen of the bulbus, the remainder of (*a*) and the whole of (*b*) were much flattened dorso-ventrally.

This leads to the conclusion that under normal conditions, when there was but a single head inside the bulbus, its form would be cylindrical and but little flattened. Both heads have been used in the details here presented, and in the figures a dorsal and lateral view of (*a*) (figs. 90 and 91) and a dorsal and ventral view of (*b*) (figs. 92 and 93) are given.

How the tiny fish could live and apparently thrive with two such parasites literally sucking its heart's blood is a mystery.

The genus can be easily recognized by the flexion of the comparatively large abdomen and by the misplacement of the neck on the dorsal surface of the trunk. The complete distortion of bilateral symmetry in the internal morphology follows as a result of this misplacement.

LERNAEOCERINAE, new subfamily.

Subfamily characters of female.—Cephalothorax armed with hard chitin horns, more or less branched; neck and trunk curved, usually in the shape of the letter S; genital segment enlarged; no pregenital prominence but often lateral processes over the bases of the egg strings; the latter filiform, very long and coiled in loose masses or twisted into a tight and regular spiral; eggs uniseriate and packed like a row of coins.

Two pairs of antennae, second pair chelate; manibles unknown; no protrusible proboscis; two pairs of maxillae, second pair uncinate;

no maxillipeds; all the swimming legs close together and near the head.

Subfamily characters of Copepodid male (genus *Lernaeocera*).—Body like that of *Cyclops*, composed of a cephalothorax covered with a carapace; three free thorax segments, a fused fifth and genital segment, and a short, one-jointed abdomen; anal laminae small, each armed with 4 or 5 minute setae. Antennae and mouth parts as in the female, with the addition of a pair of well-developed uncinate maxillipeds; two pairs of biramose swimming legs, with two-jointed rami, third and fourth pairs uniramose, rami also two-jointed.

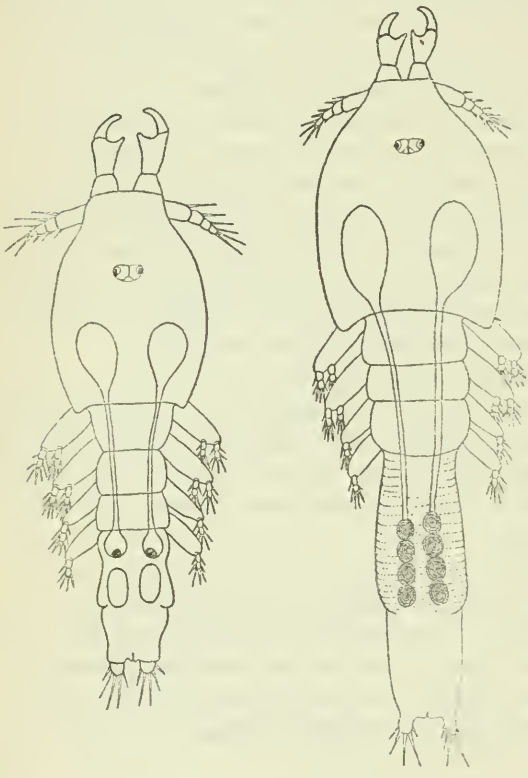

FIG. C.—THE MALE (LEFT) AND FEMALE (RIGHT) COPEPODID LARVAE OF LERNAEOCERA BRANCHIALIS, AFTER A. SCOTT: ACTUAL LENGTH OF FEMALE, 2.30 MM.

Ontogeny of genus Lernaeocera.—The genital protoplasm in the posterior end of the ovary forms egg mother cells and egg daughter cells, the latter filling the anterior end of the ovary without definite arrangement. These oocytes acquire food and yolk material as they pass into the oviduct, and are there strongly flattened and packed tightly in a single row. The cement glands are entirely separate from the oviduct and open into the latter just inside the vulvae. Each egg is surrounded by an external membrane of cement material as it passes out through the vulva into the external sack, where it is again flattened and arranged with the others like a row of coins. The larva hatches as a typical nauplius with the usual three pairs of appendages, and one pair of posterior balancers. The nauplius is transformed into a metanauplius while swimming about freely in the plankton. At the first copepodid stage it seeks out as a temporary host some fish other than the one which is afterwards to serve

the female for a permanent host. To this fish's gills it adheres by means of the chelate second antennae and proceeds to fasten itself to the apex of the gill filament by a broad frontal band of chitin. While thus attached it passes through two or three pupal stages during which there is the same disappearance of segmentation and of setae in the appendages as occurs in the Lernaeenicinae (see p. 43). But the reproductive organs develop, the body of the female elongates considerably, both sexes reach maturity, and fertilization takes place. The female, and sometimes also the male, then sever their connection with the gill filament and swim about again freely in the plankton.

The male soon dies, but the body of the female elongates still more and she then seeks out a final host and fastens to its gill arches with her chelate second antennae. She finally burrows through the intervening tissues to the immediate vicinity of the heart or the ventral aorta, where the head is securely anchored by the outgrowth of branched chitin horns. Here the female remains as a fixed parasite during the remainder of her life, which probably lasts a year or more.

Genus LERNAEOCERA Blainville.

Lernaea (part) LINNAEUS, Systema Naturae, ed. 12, 1767, vol. 1, pt. 2, p. 1092.
Lernaeocera BLAINVILLE, Journ. de Physique, vol. 95, 1822, p. 375.
Lernaeocera (part) NORDMANN, Mikrographische Beiträge, 1832, p. 130.
Lernaea BURMEISTER, Acta Acad. Caes. Leop. Nat. Cur., vol. 17, 1833, p. 319.
Lernaea (part) MILNE EDWARDS. Histoire Naturelle des Crustacés. vol. 3. 1840, p. 528.
Lernaea, all subsequent authors.

External generic characters of female.—Cephalothorax globular, comparatively small, and furnished with three branched chitinous horns or anchor processes, the dorsal one usually a little longer than the lateral ones; second, third, and fourth thorax segments in the form of a slender neck of moderate length and of about the same diameter throughout; fifth and genital segments fused and more or less swollen, and with the abdomen bent into the form of the letter S; abdomen distinctly separated from the genital segment in immature stages, but completely fused in the mature adult; egg strings filiform, many times the length of the body, and coiled into irregular masses. First antennae three-jointed and well supplied with setae: second pair chelate and two-jointed; two pairs of maxillae, but no maxillipeds; first two pairs of swimming legs biramose, two posterior pairs uniramose, all the rami two-jointed.

Internal generic characters of female.—Mouth really terminal, but appearing lateral, owing to the inclination of the head; esophagus nearly in line with head axis; stomach without lateral processes or

convolutions, bent at right angles when it enters the neck and passing insensibly into the intestine, which is enlarged in the posterior neck and trunk; rectum very short and narrow. Ovaries fused on the midline of the dorsal surface, in the small of the back, and folded around the sharp curve in the body wall; oviducts passing around the intestine to the ventral surface and thence to the vulvae; cement glands ventral to the oviducts and plainly convoluted.

External generic characters of copepodid male.—Head and first thorax segment fused; second, third, and fourth thorax segments free; fifth and genital segments fused; abdomen one-jointed; anal laminae armed with short setae. Two pairs of antennae, second pair chelate; a pair of mandibles; two pairs of maxillae, second pair uncinate; a pair of stout maxillipeds.

Internal generic characters of Copepodid male.—Mouth tube at right angles to the head axis; stomach and intestine straight and indistinguishable; rectum very short; large digestive glands along either side of the cephalothorax. Testes paired and situated in the posterior portion of the cephalothorax; sperm ducts straight and dorsal to the intestine; spermatophore receptacles in the genital segment large and elliptical.

Type of the genus.—*Lernaeocera branchialis* (Linnaeus), first species.

(*Lernaeocera*, *Lernaea*, and κέρας, a horn).

KEY TO THE SPECIES.

1. Head without anchor processes, simple, and filiform; body not flexed; egg strings not coiled; no appendages (13.50 mm.)[1]
abyssicola (Brady), 1883, doubtful.

1. Head with simple unbranched processes; neck long and slender; body with a strong curve or simple flexure; egg strings sometimes regularly coiled 2

1. Head with branched processes; neck short and stout; body with double sigmoid flexure; egg strings always loosely coiled 3

2. Head small, subspherical; genital segment and abdomen covered with a dense filamentous growth; egg strings coiled in a regular spiral (20 mm.)
lotellae (Thompson), 1889.

2. Head small, funnel-shaped, joined to the neck at an acute angle; genital segment and abdomen covered with scattered tufts of setae (22.50 mm.)
rigida (Krøyer), 1863.

2. Head large and spherical; genital segment only slightly wider than the neck and separated from the abdomen by a constriction; no setae or filaments (50 mm.) ..... *lumpi* (T. Scott), 1901.

3. The posterior horn the only one developed, as long as the whole body, in line with it and profusely branched; egg strings in a few loose coils (15 mm.) ..... *branchialis*, var. (Hesse), 1891.

3. Genital segment with but a single curve; processes flat and short, but much branched; egg strings stout and their coils larger than the entire genital segment (8 mm.) ..... *minuta* (T. Scott), 1900.

[1] Average total length of species.

3. All three processes or horns developed; genital segment with a double sigmoid curve; egg cases coiled but slender 4
4. Horns slender and cylindrical, all about the same length; abdomen completely fused with genital segment (40 mm.)
branchialis (Linnaeus), 1767, p. 85.
4. Horns flattened and laminate, posterior one three times the length of the lateral ones; abdomen not recurved; coils of the egg strings very large (14 mm.) ..... *lusci* (Bassett-Smith), 1896.
4. Horns very short, bilobed but not branched; abdomen boot-shaped and strongly narrowed where it joins the genital segment (32 mm.)
godfroyi (Quidor), 1912.

LERNAEOCERA BRANCHIALIS (Linnaeus).

Plate 10, fig. 88; plate 12, figs. 98–107; plate 17, fig. 140.

Lernaea branchialis Linnaeus, Systema Naturae, 1767, vol. 1, pt. 2, p. 1092.—Claus, Gesellschaft zur Beförderung der gesammten Naturwissenschaften zu Marburg, vol. 9 supplement, 1868, p. 16, pls. 3, 4.—Metzger, Archiv für Naturgeschichte, vol. 34, 1868, p. 106.—A. Scott, Liverpool Marine Biology Committee Memoirs, No. 6, 1901, p. 33.—T. and A. Scott, British Parasitic Copepoda, Ray Society, London, 1913, p. 142, pls. 42, 43.

Lernaea gadina Fabricius, Fauna Groenlandica, 1780, p. 336.

Lernaeocera branchialis Blainville, Journ. de Physique, 1822, vol. 95, p. 376, 1 plate.

Lernaeocera branchialis Nordmann, Mikrographische Beiträge, 1832, heft 2, p. 130.

Host and record of specimens.—This parasite is very common upon various species of Gadidae, especially the common cod, as the following list of specimens in the National Museum collection will show. It is always found near the base of the gill arches with its head buried in the underlying tissues close to the heart or the ventral aorta.

From the Greenland cod, *Gadus ogac*, 2 females, Cat. No. 6211, from Disco Bay, Greenland. From the common cod, *Gadus callarias*, 1 female, Cat. No. 6145, from Georges Banks; 1 female, Cat. No. 8488, from Harpswell, Maine; 4 females, Cat. No. 12910, from Woods Hole, Massachusetts; 2 females, Cat. No. 12911, from Browns Banks; 2 females, Cat. No. 12912, from Casco Bay, Maine; 1 female, Cat. No. 14324, from Harpswell, Maine; 5 females, Cat. No. 42329, from Casco Bay, Maine; 1 female, Cat. No. 47811, from Harpswell, Maine; 3 females, Cat. No. 47812, from Woods Hole, Massachusetts; 3 females, Cat. No. 47813, from Woods Hole, Massachusetts; 2 females, Cat. No. 47814, from Harpswell, Maine; 3 females, Cat. No. 47815, no locality.

Cat. No. 42300 contains 2 females with no host given; it came from the Omaha Exposition.

External specific characters of female.—Cephalothorax globular and provided with three branched horns, two lateral and one median

and dorsal; horns chitinous and profusely divided, the tips of the subdivisions usually somewhat swollen. Neck about the same diameter throughout and often showing transverse wrinkles. Trunk considerably enlarged and elongated, the portion representing the genital segment of about the same diameter, the abdomen tapering to a bluntly rounded end. In the full-grown adult there is no groove or other indication of the point of junction of the genital segment and abdomen as there is in immature specimens, but the two are indistinguishably fused and are bent into the form of the letter S .

A pair of minute anal laminae can be easily detected in half-grown specimens, and they persist in the mature adult, each being tipped with a single seta. The egg strings are voluminous and each is drawn into a loose and irregular coil which, if straightened, would be several times the length of the entire body; eggs minute and strongly flattened.

Two pairs of antennae on the dorsal surface of the head as in all the Lernaeidae, the first pair three-jointed, with a tuft of setae at the tip, the second pair two-jointed, the joints about the same size, the terminal one bearing a stout chela. Proboscis strongly protrusible; when fully extended (fig. 101) it forms a bluntly rounded cone on the front of the head, pointed backward parallel with the axis of the neck, and carrying on its tip the two pairs of maxillae. In preserved specimens the proboscis is usually withdrawn so completely that it pulls in with it the whole front of the head and causes the latter to assume a cup shape, as represented in Emerton's excellent figures (figs. 98–100).

The muscles which control this proboscis are evidently arranged like those in *Peniculus* (fig. 2), so that the mouth tube proper can be withdrawn a long distance. At the tip of the mouth tube are the two pairs of maxillae, the first pair (*mx*, fig. 103) short finger-like papillae, divided at the tip and each portion armed with a single large seta. On the outer margin of the papilla near the base is a small, rounded palp-like protuberance. The second maxillae are two-jointed, the basal joint stout and armed at its distal end on the dorsal surface with the two claw-like processes noted by Claus as characteristic of the same appendages in the copepodid female. The terminal joint is also stout but smaller than the basal joint, and it ends in a stout claw.

Behind the cephalothorax come the four pairs of swimming legs, the first two pairs close together and biramose, the third and fourth pairs removed a very short distance and uniramose, all the rami two-jointed and well supplied with setae. Color, a dark brownish red, due to the contained blood; horns dark brown; head and egg strings a light orange yellow.

Total length, if the body were straightened, about 40 mm. Greatest diameter of trunk, 8 to 10 mm. Length of egg strings if straightened, 150 to 200 mm.

(*branchialis*, pertaining to the gills, which are its habitat.)

Internal specific characters of female.—Esophagus short and inclined at an angle of about 60° to the axis of the neck, entering the stomach at the anterior end with little or no sphincter muscle at the junction.

Stomach increased to about 2 diameters in the neck, passing insensibly into the intestine, which is abruptly enlarged in the genital segment.

The fused ovaries are produced into horn-like projections anteriorly and posteriorly, which are strongly flattened dorsoventrally and fit down on the dorsal surface of the intestine like a saddle, the flaps extending nearly to the center of the side of the intestine. Each anterior horn tapers to an apex which lies dorsal to the intestine and from which the oviduct leads around the outside of the intestine to the ventral surface and follows that surface back to the vulva. These oviducts are exceptionally narrow compared with the size of the parasite and along the ventral surface are wholly ventral to the intestine. Each cement gland is about the same diameter as the oviduct, along whose inner ventral surface it extends, the two glands being in contact with the ventral body wall and close to the midline. The anterior end of the gland turns up with the oviduct for a short distance on the outside of the intestine at the base of the neck and terminates in a blunt point. The chitinogen layer of the body wall is poorly developed.

Specific characters of the Copepodid male.—Cephalothorax elliptical, narrow anteriorly through the bases of the antennae, almost squarely truncated posteriorly, and covered with a dorsal carapace. Second, third, and fourth thorax segments about the same length and width, which latter is half that of the carapace. Line of demarkation between the fifth and genital segments indicated by lateral notches. Abdomen short, much narrower than the genital segment; anal laminae each armed with 4 or 5 setae. First antennae four-jointed, the basal joint much longer than any of the others, each joint well armed with setae; second antennae comparatively small, two-jointed, the joints about the same size and triangular, the terminal joints tipped with a stout chela. Proboscis long and fairly stout; mandible in the form of a long and slender spine; first maxilla a short papilla tipped with two long setae; second maxilla two-jointed, joints the same width but the basal one somewhat the longer, terminal claw short and stout; two-jointed maxillipeds present behind the maxillae, the terminal joint the same length as the basal but much narrower, terminal claw short and pointed.

Internally there is a large tripartite eye a little in front of the center of the cephalothorax. The testes are paired and at the extreme posterior margin of the cephalothorax; the sperm ducts open out of their posterior ends and run back to the genital segment where each is enlarged into a pair of receptacles within which are formed and stored the spermatophores.

Total length, 1.75 mm. Diameter of cephalothorax, 0.45 mm.

Nauplius.—General outline diamond-shaped, considerably flattened dorso-ventrally, a trifle longer than wide, all the corners well rounded, Three irregular patches of pigment on the dorsal surface, one at each of the lateral angles and the third at the posterior angle. The anterior angle is filled by the large compound eye, whose pigment is the same color as that of the dorsal patches, a yellowish purple. Behind the eye may be seen the first traces of the nerve ganglion, not as yet clearly developed. And behind the ganglion, occupying the bulk of the center of the body, is a single large oil globule similar to that noted in *Lernaeenicus longiventris* (p. 68). First antennae armed with a bunch of short spines on the dorsal surface near the distal end and the usual two long terminal plumose setae. Second antennae and mandibles of the typical pattern, biramose, the exopod four-jointed, each joint bearing a plumose seta, the endopod with a single joint tipped with two setae. Balancers slender and curved, turned at right angles to the body axis so that the two are in the same straight line.

Total length, 0.45 mm. Greatest width, 0.40 mm.

Metanauplius.—General outline an elongated oval, the pointed end posterior, the margin evenly rounded. The posterior pigment spot has increased in size while the lateral ones have fused across the midline. The eye is relatively smaller and not as close to the anterior margin. The appendages remain approximately as before except that the endopods of the second antennae and mandibles are now distinctly jointed, and the terminal joint of each is armed on the inner margin with a stout spine. At the posterior end of the body inside of the skin may be seen the beginnings of two free thorax segments, a fused fifth and genital segment, and a one-jointed abdomen with anal laminae. The balancers turn forward as before, but are now jointed close to their base, while the terminal portion is flattened dorso-ventrally and bluntly rounded at the tip. Between these from the posterior end of the body projects a short conical process, with a pair of blunt rounded spines on either side at its base.

This is the posterior body of the metanauplius, while that which is seen inside of the skin is to become the posterior body of the first copepodid larva after the next molt.

Total length, 0.55 mm. Greatest width, 0.25 mm.

Remarks.—The present is one of the longest known and most frequently mentioned species amongst the parasitic copepods. Every zoologist has become familiar at least with its name and some of its reputed characteristics. It has long served as one of the stock examples used to illustrate degeneration and retrogression, and the average opinion with reference to it has been well expressed by Dr. Andrew Wilson in an article on Degeneration in the Popular Science Monthly for June, 1881, in which he said "Beginning life as a three-legged 'nauplius,' the lernean retrogresses and degenerates to become a mere elongated worm, devoted to the production of eggs, and exhibiting but little advance on the sacculina" (p. 227).

The appendages have been variously reported as rudimentary or entirely obsolete, even up to the very latest publications with reference to them. At the time of the first discovery of the male by Metzger and Claus (1868), the latter called particular attention to the presence of a compound eye, of anal laminae, and of the various appendages in the adult female, but the significance of his discoveries were overlooked and soon forgotten. As far as the appendages are concerned, the present species shows neither retrogression nor degeneration. The adult female retains all the appendages that she ever possessed, and they are as fully developed in the adult as they were in the copepodid stage. The only change that has been made is that the parasite has ceased to use some of them, and they have consequently become brittle and are easily broken off. And even if we apply to them the term rudimentary, we must remember that they are no more imperfectly developed in the adult than they were in the larva. In the body form there is an elimination of joints, more or less fusion of various body regions, and considerable distortion, so that here we do find retrogression. In the future, therefore, in dealing with this species we should remember that the appendages can not be classed with the body form, but that the two are distinctly separate.

Genus LERNAEOLOPHUS Heller.

Pennella (part) Nordmann, Galerie du Muséum d'Hist. Nat. de Paris, 1839; *P. sultana*, afterward made the type of Heller's genus; Bull. de la Soc. Imp. des Nat. Moscou, 1864, vol. 37, p. 485, *P. sultana*, var. *sigmoida*.

Penellus (part) Milne Edwards, Histoire Naturelle des Crustacés, vol. 3, 1840, *P. sultana*, p. 523.

Lernaea (part) Krøyer, Naturhistorisk Tidsskrift, 3 Raekke, 2 Bind, 1863, *L. hemiramphi*, p. 318, afterwards transferred to Heller's genus.

Lernaeolophus Heller, Reise der *Novara*, 1865, p. 251, *L. sultanus*, monotypic.

Lernaeolophus Wilson, Proc. U. S. Nat. Mus., vol. 44, 1913, *L. recurvus*, p. 252, pl. 46; *L. striatus*, p. 254, pl. 47, figs. 260, 261.

External generic characters of female.—Cephalothorax inclined ventrally to the neck axis; a pair of lateral and an unpaired dorsal

horn, chitinous; neck cylindrical, heavily chitinized, and showing considerable torsion, attached to the trunk on the midline. Trunk bent in a sigmoid curve, also heavily chitinized; abdomen large, with rudimentary anal laminae, armed with a double row of dichotomously branched processes; egg strings coiled in a loose mass like those of *Lernaea* and concealed by the processes.

Two pairs of antennae, second pair chelate; proboscis somewhat protractile; mouth parts replaced by small knobs; first two pairs of swimming legs biramose, third and fourth pairs uniramose, all the rami two-jointed and setiferous; the four pairs close together behind the head.

Internal generic characters of female.—Bilateral symmetry complete; stomach without lobes; intestine wide and much convoluted in the neck, greatly enlarged in the trunk, then narrowed in the abdomen; rectum short; ovaries extending from the bend some distance forward into the neck, nearly as long as the oviducts, strongly flattened posteriorly, but nearly cylindrical anteriorly; oviducts very wide, somewhat flattened laterally, and at the sides of the intestine rather than ventral to it; in fact the ovary and oviduct almost come together and completely cover the lateral surface of the intestine. Cement glands between and ventral to the oviducts, glandular portion much longer than the duct, curved dorsally at the interior end around the outside of the oviduct, or sometimes passing up inside of the oviduct and curving over the top and down on the outside; duct of cement gland convoluted. Chitin layer of body wall much thickened and very hard; chitinogen layer thickest along the sides of the body and in the abdomen; no definite skin-glands.

Genus habitat.—This genus burrows into the underlying tissues from various places in the mouth and throat of their fish host, on the jaw, the roof of the mouth, gill arches, etc. The entire body is strongly chitinized and shows both torsion and flexion.

Type of the genus.—*Lernaeolophus sultanus* (Nordmann), monotypic.

(*Lernaeolophus*, *Lernaea* and λόφος, a crest or tuft.)

KEY TO THE SPECIES.

1. Body straight or only slightly curved; a distinct groove at the base of the neck; abdominal processes 20 or more on either side and unbranched; (27 mm.)[1] ..... *striatus* Wilson, 1912.
1. Body folded back upon itself once at the base of the neck; abdominal processes 10 or more on either side, very slender and profusely branched; (20 mm.) ..... *recurvus* Wilson, 1912.
1. Body with a regular sigmoid curve 2
2. Abdominal processes 20 or more on either side, divided into numerous fine hairs at the tips (16 mm.) ..... *hemiramphi* (Krøyer), 1863.
2. Abdominal processes 10 or more on either side, dichotomously branched from the very base (15 mm.) ..... *sultanus* (Nordmann), 1864, p. 91.

[1] Average total length of species.

LERNAEOLOPHUS SULTANUS (Nordmann).

Plate 13, figs. 108–113.

Pennella sultana Nordmann, Bull. Soc. Impérlale des Naturalists de Moscou, 1864, vol. 37, p. 485, pl. 5, figs. 12–16.

Penellus sultana Milne Edwards, Histoire Naturelle des Crustacés, vol. 3, 1840, p. 523.

Lernaeolophus sultanus Heller, Reise der *Novara*, 1865, p. 251, pl. 25, fig. 7.—Brian, Copepodl parassiti dei pesci d'Italia, 1906, p. 91.

Host and record of specimens.—Two females were obtained from the gill arches of the orange file fish, *Alutera schoepfii*, in Vineyard Sound in 1874, and have received Cat. No. 6186, U.S.N.M. Two other females were found by the present author in the upper jaw on the inside of the mouth of the garfish, *Tylosurus marinus*, at Woods Hole, Massachusetts, in August, 1903, and have received Cat. No. 47816, U.S.N.M. A single broken specimen was obtained from *Haemulon plumieri* by Dr. Edwin Linton at the Carnegie Institution, Tortugas, Florida, in July, 1908, and has received Cat. No. 47817, U.S.N.M.

Specific characters of female.—Cephalothorax spherical, at right angles to the neck axis, and covered with a hard chitin skin, divided by a shallow median groove on the anterior and ventral surfaces into two cushion-like halves or pads, each of which is prolonged on the ventral surface into a series of three short, rounded, and often lobed processes, which project from the pad-like fingers. These processes are covered with a thin chitin skin and their lumen is in connection with the cavity of the head. Posteriorly are given off a pair of lateral horns and an unpaired dorsal one, all three cylindrical, composed of hard chitin, and more or less branched.

These horns are also hollow to their very tips and, like the processes their lumen opens into the cavity of the head. Behind the horns the neck narrows a little, but remains comparatively wide and of about uniform diameter down to the trunk; its walls are very thick and hard.

The head and neck show a torsion of from 135° to 180°, bringing the ventral surface almost, if not quite, over the dorsal surface of the trunk. The latter enlarges gradually from the base of the neck and with the neck and abdomen is bent into a vertical sigmoid curve. The concave bend on the back of the trunk is narrow and sharp and is strengthened by a thick chitin ridge which runs across it, transverse to the trunk axis, and flattens out and disappears on either side. The convex ventral margin sweeps in a broad curve from the base of the neck to the vulvae. The abdomen is on a level with the dorsal surface, is fully two-thirds as long as the trunk, and is more than half as wide and deep. Along either side of the abdomen and

extending onto the posterior end of the genital segment are two rows of dichotomously branched processes. The upper row of six processes is a little below the dorsal surface of the abdomen and is still further depressed on the trunk. The lower row of five processes is parallel to the upper one, the last process standing on the median line of the genital segment (vertical median).

The branching of these processes varies considerably in different individuals, and probably in the same individual at different stages of development; the older the individual the more profuse the branching, the younger the individual the simpler the processes. As might be expected these branched processes furnish excellent anchorage for various fixed forms of animal and plant life, and they are often found covered with algae or protozoa. The processes in the two rows alternate with one another, and the tip of the abdomen is left free. This tip is slightly bilobed and on either lobe, close to the anus, is a rudimentary anal lamina, destitute of setae. The egg strings are curled into a loose and irregular coil, as described by Kroyer and Nordmann, and are not in a regular convolute spiral as stated by Heller.

The first antennae are minute, two-jointed and tipped with setae; the second pair are also two-jointed and tipped with a strong chela, the nearly straight claw shutting down behind a catch on the opposite margin of the terminal joint. Proboscis in the bottom of a groove on the ventral surface of the head, of softer tissue than the surrounding parts, and apparently capable of being somewhat protruded; mouth parts lacking.

Four pairs of swimming legs close together in the curve of the neck just behind the head. The basal joints of these legs are rounded oblong, the first two pairs with a basal projection on the inner margin. The rami are usually broken off, but occasionally a leg will be found with the rami intact, when we can see that the first two pairs are biramose, the third and fourth pairs uniramose, the rami all two-jointed and well armed with setae.

Color (preserved material), the uniform reddish brown characteristic of chitin in alcohol.

Total length, including the sigmoid curvature, 15 mm. Cephalothorax, 1.50 mm. long, 1.50 mm. wide. Neck, 1 mm. in diameter. Genital segment, 2.50 mm. in diameter.

(*sultanus*, like a sultana).

Remarks.—The discovery of the two pairs of antennae on these specimens necessitates a different interpretation of the knobs found on the ventral surface of the head.[1]

[1] See Proc. U. S. Nat. Mus., vol. 44, p. 252–255.

These can no longer be regarded as rudiments of the antennae and mouth parts for several reasons:

1. The true antennae have been found in their proper position on the dorsal surface of the head. In creatures as thoroughly chitinized as this genus of parasites the minute appendages break off with especial ease, and the present author has never before seen specimens to which they remained attached. And when once broken off it is practically impossible to find any scars showing their former presence.

2. On comparing different specimens of *sultanus* the form and size of these knobs is found to vary far more than would be probable if they were the rudiments of appendages.

3. The interior of the knobs is in connection with the cavity of the head, which is manifestly unlike the condition of appendages.

They must be regarded, therefore, as mere processes, corresponding to the frontal processes in other genera, but in this genus restricted in number and confined to the ventral surface. In this genus then, as in *Pennella*, the maxillae have apparently disappeared.

The distinctive characters in the morphology of the species are the chitinization of the entire body so that its form remains the same however poorly it may be preserved, the two rows of branched processes on the sides of the abdomen and genital segment, the pushing of the ovaries and oviducts forward into the base of the neck, and the convolution of the ducts of the cement gland.

Genus HAEMOBAPHES Steenstrup and Lütken.

Haemobaphes Steenstrup and Lütken, Kongelige Danske Videnskabernes Selskabs Skrifter, 5te Raekke, 1861, p. 405.

External generic characters of female.—Cephalothorax subspherical, much inflated and soft, with a tripartite eye buried in the tissues over the base of the esophagus; produced laterally into a cushionlike process on either side, with a short, rounded point extending diagonally forward and outward; anterior margin with a rounded knob on either side of the midline.

Second, third, and fourth thorax segments distinctly separated, the first two nearly as wide as the cephalothorax and sometimes produced laterally into cushionlike processes, the fourth segment narrower with short, bilobed processes on the venterolateral surface like those in *Chondracanthus;* similar processes sometimes found on the third segment.

Neck long, slender, cylindrical, and flexed upon itself a little in front of the center, where it is completely chitinized and armed with numerous short chitin horns, simple or branched.

Trunk much swollen, bent into a sigmoid curve, the ventral surface on the convex side, with a pair of short, swollen processes over the bases of the egg strings; abdomen relatively large, swollen, and cylindrical, with a pair of lateral processes near its base; egg strings long, each coiled in a tight spiral; eggs uniseriate and closely packed.

Two pairs of antennae, second pair uncinate; proboscis short, conical and nonretractile; first maxillae apparently lacking, second pair uncinate; four pairs of swimming legs, first two pairs biramose, rami two-jointed and setiferous; third and fourth pairs uniramose, rami one-jointed and setiferous.

Internal generic characters of female.—Bilateral symmetry completely preserved; intestine narrowed through the neck, moderately enlarged in the genital segment, and occupying the entire lumen of the abdomen; rectum long and conical; ovaries on the dorsal surface just in front of the concave flexure, their anterior third more or less cylindrical, their posterior two-thirds much flattened and spread out laterally over the dorsal surface of the intestine; oviducts on the ventral surface of the intestine and narrow; processes over the bases of the egg strings filled with muscles which probably give the latter their coiled form; glandular portion of the cement glands longer than the ducts, both glands and ducts parallel but removed a little distance from the midline; chitinogen layer of body wall well developed along the sides of the trunk and in the two pairs of lateral processes at the posterior end.

Genus habitat.—This genus inserts its soft head and anterior neck into the ventral aorta or bulbus arteriosus of its host, burrowing in from the gill arches. The neck is flexed sharply where it enters the aorta, and usually turned to one side, but there is no torsion.

Type of the genus.—*Haemobaphes cyclopterina* (Fabricius), monotypic.

(*Haemobaphes*, αἷμα blood, and βαφή dipped or dyed).

KEY TO THE SPECIES.

1. A series of lobed but unbranched processes on either side of the head and four anterior thorax segments; trunk with sigmoid flexure and lateral processes (34 mm.)[1]_____*cyclopterina* (Fabricius), 1780, p. 95.
1. A series of profusely branched processes on either side of the head and four anterior thorax segments; trunk nearly straight and without lateral processes (16 mm.)_____*cnodis*, new species, p. 97.
1. A single pair of bilobed processes on either side of the cephalothorax, none on the free thorax; trunk with sigmoid flexure and lateral processes (20 mm.)_____*dicraus*, new species, p. 98.

[1] Average total length of species.

HAEMOBAPHES CYCLOPTERINA (Fabricius).

Plate 14, figs. 114–118.

Lernaca cyclopterina Fabricius, Fauna Groenlandica, 1780, p. 337.—Krøyer, Naturhistorisk Tiddskrift, 1837, p. 502, pl. 5, fig. 4, *a—c*.—Baird, Proc. Zool. Soc. London, 1861, p. 239.

Schisturus cyclopterinus Oken, Lehrbuch Naturgeschichte, 1816, p. 183.

Lernecocera cyclopterina Blainville, Jour. de Physique, vol. 95, 1822, p. 376.

Haemobaphes cyclopterina Steenstrup and Lütken (given under genus above).—T. and A. Scott, British Parasitic Copepoda, Ray Society, 1913, p. 147, pl. 44, figs. 5–7.—Wilson, Contrib. Canadian Biology, 1906–1910 (pub. 1912), p. 99.

Host and record of specimens.—Fifteen females with egg strings were obtained from the gills of *Cyclogaster ingens* Gilbert, in the Sea of Japan off the Korean coast at station 4863 of the fisheries steamer *Albatross* in July, 1906, and have been given Cat. No. 47818, U.S.N.M. Three single females were obtained from the gills of *Lycenchelys* (*Lycodes*) *verrillii*, the first two by the steamer *Speedwell* in the Gulf of Maine in August, 1877, the third "near La Have" in 1888. These have been given, respectively, Cat. Nos. 6137, 38331, and 47819, U.S.N.M.

Specific characters of female.—The specific characters are the same as the generic characters already given, but to them we may add the following details.

The entire cephalothorax and that portion of the neck in front of the flexure was very soft and easily lacerated, which contrasted strongly with the firm and solid condition of the remainder of the body. This is the portion which hangs free within the fish's aorta and doubtless remains soft for that reason. On the dorsal surface the cephalothorax proper is distinctly indicated by a central longitudinal ridge, which narrows anteriorly over the mouth parts, but there are no visible traces of a carapace.

On either side is a long cushion-like process, which narrows into a small knob anteriorly and curls downward and inward over the ventral surface almost to the median line. Dorsally these processes are on a level with the central cephalothoracic ridge, ventrally they project considerably. In front of them two other cushion processes are given off from the ventrolateral surface, which also project ventrally.

Between the rounded anterior ends of these processes are found on the anterior margin the two pairs of antennae and on the ventral surface the mouth parts. The cephalothorax is separated from the second thorax segment by a distinct groove, and the second, third, and fourth thorax segments are similarly defined dorsally but are less distinct ventrally. The second and third segments are nearly as wide as the head, including the lateral processes; the fourth seg-

ment is abruptly narrowed to less than half that width. The second and third segments each have a pair of lateral cushion processes, as wide as the segment itself and smoothly rounded, those of the third segment having on the posterior ventral surface a small knob. The fourth segment sends out on either side a soft bilobed process, the lobes thick and bluntly rounded, and inclined a little ventrally.

Behind these lobes the neck narrows and becomes rapidly chitinized until it reaches the flexure, beyond which it is slightly enlarged and armed with chitin horns of varying numbers and patterns, but usually short and somewhat flattened. Behind these horns the neck is again narrowed until it reaches the trunk, which it enters exactly on the median line so that there is no distortion of the bilateral symmetry.

The antennae and mouth parts are at the extreme anterior end of the cephalothorax; the first antennae are stout, three-jointed, and well armed with setae; the second pair are made up of two stout joints, furnished with strong muscles and tipped with a chela, whose long and rather slender claw shuts down past a projection on the opposite margin of the terminal joint. The mouth tube is short and but little, if at all, retractile, with a well-defined ventral plate; no first maxillae could be detected; the second pair are three-jointed, the basal joint the shortest, the second joint the longest and stoutest and armed on its outer margin with a short spine; the third joint is tipped with a short and weakly curved claw. Only the two pairs of legs described by Steenstrup and Lütken could be detected; each of these is biramose and the rami are two-jointed and setiferous. With the three anterior joints of the free thorax so well differentiated we should look for four pairs of legs instead of two, and a perfect specimen will probably reveal them. (See *Remarks*, below.)

Color (preserved material) of the body, the soft portion of the neck, and the head grayish yellow, chitinous portions of the neck and egg strings darker orange yellow.

Total length, including curves, 34 mm. Cephalothorax and neck, 14 mm. long, 0.75 mm. in diameter. Greatest diameter of trunk, 4 mm. Egg coil, 14 mm. long, 2 mm. in diameter. Each egg string, if straightened, would be approximately 125 mm. long.

(*cyclopterina*, from the genus of fish on which it was first found.)

Remarks.—Fortunately the specimen numbered 38331 included a mutilated head; the neck had been broken at the flexure and the anterior portion was again broken between the cephalothorax and the second segment. But the broken parts could be placed together while they were being drawn, and it was much easier to orient them when thus separated from the trunk than it would have been when attached to it. The antennae and mouth parts were uninjured, but one leg of

each pair was gone and the remainder of the ventral surface was more or less lacerated, so that if the parasite originally possessed four pairs of legs the two posterior pairs might easily have been destroyed. The discovery of the antennae and mouth parts brings this species, and through it the genus up to a better analogy with the rest of the family. Steenstrup and Lütken, the founders of the genus, examined several specimens which they reported as perfect, but the best they could say of the cephalothorax was that it presented considerable likeness to that of *Pennella*. They found neither antennae, proboscis, nor mouth parts, and as far as is known no investigator since their day has even seen the parasite's head.

The internal morphology is peculiarly interesting since it shows that, in spite of the sigmoid curvature of the body, there has been no disturbance in the bilateral symmetry. In this particular it presents an important contrast to *Phrixocephalus* and *Collipravus*, in both of which there is more or less distortion.

HAEMOBAPHES ENODIS, new species.

Plate 20, figs. 156 and 157.

Host and record of specimens.—A single perfect female with egg strings was obtained from the gills of *Lycodapus fierasfer*, a small deep-sea fish, 4 inches in length, by the Bureau of Fisheries steamer *Albatross* 11 miles off Point Pinos Lighthouse, on the California coast, May 26, 1904. It is made the type of the new species, with Cat. No. 49702, U.S.N.M. Like all other species of this genus the head and anterior thorax are buried inside the bulbus arteriosus of the host, and there is but a single specimen on each fish.

Specific characters of female.—Cephalothorax and the three anterior free thorax segments about the same width, all four covered with numerous profusely branched cauliflower processes, which do not show any definite arrangement; these give this part of the body a peculiarly rough and swollen appearance; the head, the thorax, and these processes are exceedingly soft and fragile. Neck quickly becoming chitinous and armed with a single pair of short horns in front of the flexure; the portion behind the flexure enlarged in diameter and shorter than the portion in front of the flexure. Trunk almost straight with only a hint of the sigmoid curve; genital segment enlarged to four times the diameter of the neck, the dorsal margin only slightly concave, the ventral margin broadly convex, with no knobs or processes. Abdomen in line with the genital segment, about half the length and width of the latter, the same diameter throughout, and also without knobs or processes. Egg strings loosely coiled, the coils a little wider than the abdomen and about the length of the genital segment.

First and second antennae in the same position and similar in structure to those of *cyclopterina;* maxillae and proboscis also similar in position and structure; swimming legs entirely concealed by the cauliflower processes so that it would be necessary to remove the latter in order to ascertain their exact number and arrangement.

Color (preserved material), a uniform brownish yellow except the head and anterior thorax and their processes which are white.

Total length, 16.50 mm. Head and anterior thorax, 2 mm. long, 1.50 mm. wide.

Genital segment, 6 mm. long, 2.33 mm. wide. Egg coils, 6 mm. long, 1.50 mm. wide.

(*enodis*, destitute of knobs or processes.)

Remarks.—This species is so radically different from the others in the genus that it can be readily recognized by its general form without the details of the appendages. The absence of all knobs and processes on the trunk, the almost complete suppression of the sigmoid curve, and the profusion of cauliflower processes on the head and anterior thorax are the distinguishing characters. The size is also more in accord with the miniature host on which it lives.

HAEMOBAPHES DICERAUS, new species.

Plates 19 and 20, figs. 148 to 155.

Host and record of specimens.—Two females with egg strings were taken from the gill arches of *Chaeturichthys sciistius* at Hakodate, Japan. The more perfect of the two is made the type of the new species, with Cat. No. 49703, U.S.N.M. The other becomes a paratype, with Cat. No. 49735, U.S.N.M. They were taken from separate fish, and each was fastened in the fish's throat at the base of the gill arches and had bored through the intervening tissues and buried its head inside the bulbus arteriosus.

Specific characters of female.—Head and all of the thorax inclosed within the bulbus arteriosus very soft and easily torn or crushed; cephalothorax with a single pair of lateral cushion processes, each of which is bifid; the anterior branch is on a level with the dorsal surface of the head, is short, cylindrical, bluntly rounded at the tip, and pointed directly forward parallel with the axis of the head; the posterior branch is enlarged into a circular cushion, evenly rounded and slightly flattened dorso-ventrally, and extends diagonally downward and backward to the ventral surface.

The second, third, and fourth thorax segments are distinctly differentiated; the second and third segments the same width as the head without the lateral horns, the fourth segment a little narrower; all three segments perfectly smooth, without knobs or processes. Neck a little more than half the width of the fourth segment, becoming rapidly chitinized, and armed with a single pair of short

spinelike horns just in front of the flexure. Beyond the flexure it enlarges gradually until it joins the trunk on the ventral surface and at the median line.

There is a large spherical swelling on either side of the genital segment at the anterior end, which starts on the dorsal surface and reaches almost to the ventral surface. It may even be said that it does reach that surface since its contour is indicated by a slight notch on the ventral margin. There are two small knobs on the ventral surface just in front of the egg coils, and a pair of lateral fleshy flaps or processes over the bases of the egg strings, which are elongated dorso-ventrally.

The genital segment passes insensibly into the abdomen, which is short, nearly straight, and twisted on its axis, so that the anal sinus shows in a side view of the trunk. Over the base of the abdomen two large processes are fused across the dorsal midline like a large saddle.

The egg coils are a little longer than the abdomen and taper toward their tips. The first antennae are three-jointed and well armed with setae; the second antennae are stout and two-jointed, the terminal joint a little narrower than the basal and armed at the tip on the outer margin with a stout curved claw, which shuts down inside a raised semicircle on the opposite inner margin.

Proboscis well developed and projecting from the ventral surface of the head; upper lip split lengthwise through the center, each half considerably wider than the mouth tube; the latter divided and grooved on the ventral surface and a little flattened on the dorsal surface; maxillae three-jointed, with a short and bluntly-pointed terminal claw.

Four pairs of swimming legs, the first and second pairs close together and a short distance behind the mouth, each biramose, the rami one-jointed, the endopod considerably smaller than the exopod, both well armed with plumose setae. The third and fourth pairs are on the posterior margins of their respective thorax segments; each is uniramose, the ramus one-jointed and armed, the third pair with five, and the fourth pair with four, large plumose setae. The relative distances of the three posterior pairs behind the first pair are represented by the numbers 1, 6, and 11.

Color (preserved material), a uniform orange yellow, the egg strings brown, the head and anterior thorax white.

Total length, if straightened, 20 mm.; from the flexure in the neck to the tip of the abdomen, 11 mm. Diameter of head through lateral processes, 1.25 mm. Diameter of genital segment, 4 mm. Diameter of abdomen behind the saddle. 2 mm. Length of egg coils, 6 mm.; diameter, 1.50 mm.

(*diceraus*, δις, two and κέρας, horn.)

Remarks.—This species is considerably smaller than *cyclopterina*, and may be recognized at once by the single pair of bifid processes on the cephalothorax, while the second, third, and fourth thorax segments are destitute of processes. This distinction may then be substantiated by the differences in the appendages, especially the maxillae and the swimming legs.

The head of this species was much better preserved than those of *cyclopterina*, and the details of all the appendages are distinctly shown. The long plumose setae upon the swimming legs are especially worthy of notice. Being buried inside the bulbus arteriosus of the host they have no chance to get broken or injured, and thus are preserved intact, as they were when the copepodid female first found her host.

The fact that the only head amongst the 15 females belonging to the species *cyclopterina* was mutilated, while in the single specimen of the species *enodis* both the cephalothorax and the free thorax were so covered with cauliflower processes as to effectively hide the swimming legs, makes it advisable to take the present species as our standard in the matter of the number and arrangement of the swimming legs.

Accordingly the genus diagnosis given above (p. 94) assigns four pairs of swimming legs to the genus, and there is every reason to believe that this will prove to be the correct number when more specimens of the other two species are obtained.

Genus HAEMOBAPHOIDES T. and A. Scott.

Haemobaphoides T. and A. Scott, British Parasitic Copepoda, Ray Society, 1913, p. 148, pl. 44, fig. 8.

External generic characters of female.—Cephalothorax subspherical and furnished with terminal branched chitin horns similar to those found in *Lernaea;* second, third, and fourth thorax segments not differentiated, but fused into a short neck, which is straight and not reflexed, and which carries neither horns nor processes. Trunk much swollen, bent into a sigmoid curve, with a pair of simple processes over the bases of the egg strings; abdomen longer than the genital segment, covered with irregular processes along the sides and on the dorsal surface at the base, and considerably enlarged at the tip. Egg strings coiled into a tight spiral which tapers toward the distal end. No details with reference to any of the appendages nor to the internal anatomy.

Genus habitat.—This genus bores into the gill arches of fish and anchors itself in the surrounding tissues by means of its chitin horns. It does not bury its head in the aorta or the bulbus arteriosus like the preceding genus.

Type of the genus.—*Haemobaphoides ambiguus* (T. Scott), monotypic.

(*Haemobaphoides*, *Haemobaphes* and the ending εἶδος denoting likeness).

Remarks.—T. and A. Scott established this new genus in 1913 for the species which T. Scott had described in 1900 as *Haemobaphes ambiguus*. It certainly seems to be a distinct genus, but it is unfortunate that neither in the original description nor in the new genus diagnosis are any of the appendages even mentioned. The internal anatomy is probably very similar to that of *Haemobaphes* and this makes the lack of external detail all the more regrettable.

TRIFUR, new genus.

External generic characters of female.—Cephalothorax enlarged nearly at right angles to the neck, and armed with a dorsal posterior median horn and two shorter conical lateral horns. Neck moderately thick, completely chitinized, and three times the length of the trunk, curved but not flexed, and smooth. Trunk only slightly swollen, bent into a sigmoid curve at right angles to the curve of the neck, the ventral surface on the convex side, with a pair of short and wide fleshy processes over the bases of the egg strings. Abdomen slender, half as long as the genital segment, and continuing the S-curve, destitute of processes; egg strips coiled into tight spirals, which are one-half longer than the abdomen; eggs uniseriate and flattened into thin disks.

Two pairs of antennae, second pair chelate; four pairs of swimming legs, two pairs close together just above the base of the cephalothorax, the others removed to some distance on the neck itself.

Internal generic characters of female.—Digestive tube occupying the center of the neck, the dorsal portion of the genital segment, and the center of the abdomen, abruptly contracted into a short rectum. Ovaries paired on the dorsal surface of the digestive tube at the anterior end of the trunk; oviducts running forward a long distance into the neck on the dorsal surface, then curved around the outside of the intestine to the ventral surface, following the ventral curve of the genital segment for half its length, then rising gradually to the center of the lateral surface.

Cement glands on the lateral surface of the genital segment at its anterior end and dorsal to the egg strings, running this way for half the length of the segment, then curving around outside of the egg strings to the ventral surface of the latter and following that surface back to the vulvae. The transition from gland to duct occurs just where it curves around the outside of the egg string. Chiti-

nogen layer very thick over the entire inner surface of the genital segment and abdomen.

Genus habitat.—Muscle borers, penetrating from the outside surface of the host into the underlying tissues, usually near a fin; anchored in the muscles themselves by the cephalic horns, the surrounding tissues forming a cyst around the head.

Type of the genus.—*Trifur tortuosus*, monotypic.

(*Trifur*, a notorious rascal in Plautus.)

Remarks.—This genus is so markedly different from the others in the family as to warrant its establishment, even upon the scanty material here recorded. The trunk is almost exactly like that of *Haemobaphes*, except that it is relatively much smaller, but the head and neck are totally different and resemble those of *Lernaeenicus*. The entire head, including the horns, and the neck are fully chitinized, instead of being soft, and the thorax segments are so completely fused as to be indistinguishable. The new genus thus combines the characters of the two older genera and becomes a connecting link between them. All the characters essential for its establishment are present, including the antennae and swimming legs, the only things lacking are the proboscis and maxillae, whose future discovery can not affect the systematic position of the genus.

TRIFUR TORTUOSUS, new species.

Plates 20 and 21, figs. 158 to 160.

Host and record of specimens.—Two females with egg strings were obtained from the outside of the body near the pectoral fin of *Salilota australis*, at Otter Bay, Smith Channel, South America. One specimen lacked the head and was cleared in clove oil to show the internal anatomy; the other was perfect, except the proboscis, and is made the type of the new genus and species, with Cat. No. 49704, U.S.N.M.

Specific characters of female.—In addition to the generic characters already given, the cephalothorax with its horns is fully chitinized like *Lernaeenicus* and *Phrixocephalus*, but totally unlike *Haemobaphes*. The long posterior horn is slightly curved, conical, and bluntly rounded at the tip; the lateral horns are smaller and shorter but also conical and blunt.

The neck is comparatively much thicker than in *Haemobaphes* and is curved in two or three different directions, chiefly sidewise at right angles to the median plane of the trunk. It is perfectly smooth, without knobs or horns, and in the cleared specimen is more than twice the length of the trunk; it does not continue the S-curve but is straight for a very short distance and then turns sidewise.

The genital segment is not much enlarged (2½ diameters), is flattened a little laterally, and is perfectly smooth except for the two wide fleshy processes over the bases of the egg strings. The abdomen is about the same diameter as the coils of the egg strings, is enlarged a little at the tip, and is without knobs or processes. It is bent in a half circle where it leaves the genital segment and is straight for the rest of its length. At the center of the posterior end is a slight sinus which indicates the position of the anus and on either side of this is a rudimentary anal lamina, without setae.

The two pairs of antennae are on the dorsal surface of the head, in a position corresponding to that in the other genera. The first antennae are short and indistinctly jointed and are turned outward away from the midline; the second antennae are rather large, are two-jointed and chelate. The majority of the rami on the swimming legs are lacking, but the basal joints indicate distinctly the position of the legs; the first two pairs are close together on the ventral surface of the head and just in front of the neck and are biramose; the third and fourth pairs are on the ventral surface of the neck, at distances behind the second pair represented by the numbers 3 and 8; the third pair is biramose and the fourth pair uniramose. From the muscles and a portion of the chitin framework left in the front of the head it is probable that the missing proboscis was similar to that in *Lernaeenicus*.

Color (preserved material), a brownish yellow, more of a brown on the head and neck, more of a yellow on the trunk; egg strings cinnamon-brown.

Total length, if straightened, 50 mm. Length of head, including posterior horn, 10 mm.; diameter, 3 mm. Diameter of neck, 1 mm. Length of genital segment, 12 mm.; diameter, 3 mm. Length of abdomen, 7 mm.; diameter, 1.50 mm. Length of egg coils, 8.50 mm.; diameter, 1.50 mm.

(*tortuosus*, full of curves and windings, alluding to the body form.)

Subfamily PENNELLINAE.

Subfamily characters of female.—Cephalothorax armed with hard chitin horns, two or three in number and unbranched; neck and trunk straight, no sigmoid curvature; genital segment only slightly enlarged and without a pregenital prominence; abdomen with branched, feather-like processes in a row along either side, often running onto the posterior end of the genital segment; anal laminae very rudimentary and destitute of setae; egg strings filiform, very long and straight, eggs uniseriate and minute, packed like a row of coins. Two pairs of antennae, the second pair chelate; a tripartite eye deeply buried over the base of the esophagus; proboscis small and

capable of but little protrusion; mandibles unknown; no maxillae or maxillipeds; four pairs of swimming legs close together just behind the head.

Subfamily characters of copepodid male (genus *Pennella*).—Body, like that of *Cyclops*, composed of a cephalothorax covered with a carapace having lateral and posterior lobes; three free thorax segments, a fused fifth and genital segment, and a one-jointed abdomen; anal laminae very short and armed with minute setae. Two pairs

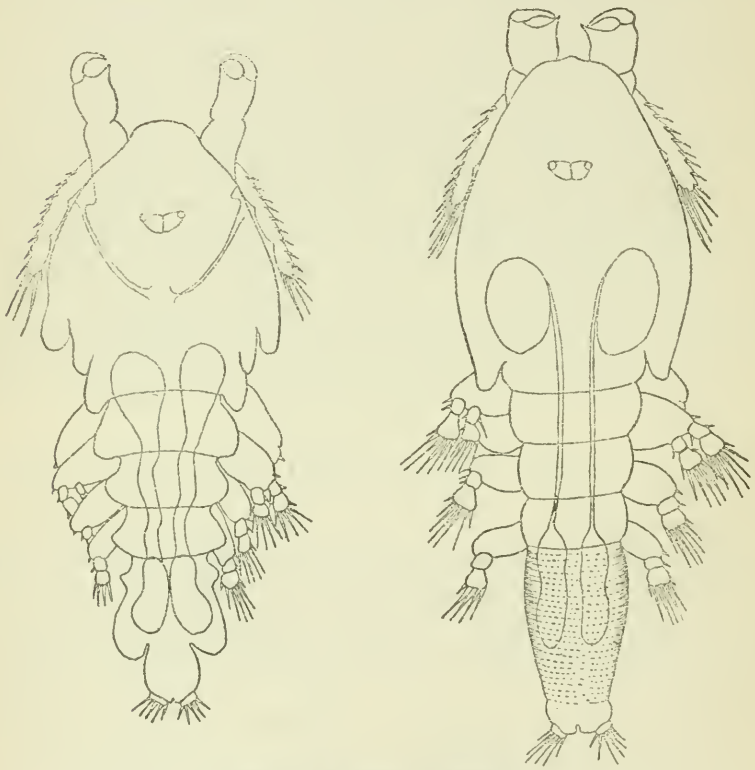

FIG. D.—THE MALE (LEFT) AND FEMALE (RIGHT) COPEPODID LARVAE OF PENNELLA VARIANS AFTER WIERZEJSKI; ACTUAL LENGTH OF FEMALE, 0.80 MM.

of antennae, second pair chelate; compound eye in the shape of a transverse spindle; mandibles stilet-shaped; two pairs of maxillae, second pair uncinate; one pair of stout, clawed maxillipeds; first two pairs of swimming legs biramose, third and fourth pairs uniramose, all the rami two-jointed. Parasites of salt-water fish exclusively.

Ontogeny of the genus Pennella.—The genital protoplasm forms egg mother cells and egg daughter cells as in the Lernaeocerinae. The oocytes acquire food and yolk material as they pass into the oviduct, in which they are strongly flattened and packed in a single row. The cement glands are separate from the oviduct and empty

into the latter just in front of the vulvae. Here each egg is covered with a membrane of the cement substance and then passes into the outer case, where it is again flattened and packed with its fellows in a single row. These eggs are much smaller in diameter than those of the other subfamilies, and as a rule there are many more of them than in the Lernaeenicinae and about the same number as in the Lernaeinae. The larva probably hatches as a typical nauplius, although this has never been observed, and is transformed into a metanauplius while swimming freely in the plankton. At the first copepodid stage the larva seeks its temporary host, which in the present instance is a cephalopod, upon whose gills are passed this and the subsequent copepodid stages. At first the larva fastens with its chelate second antennae, but with the first molt it develops a frontal filament by which it is securely anchored to the gill of the cephalopod.

Then follow pupal stages in which the segmentation of the body and its appendages becomes indistinct, the setae lose their plumes, and the various appendages become misshapen, swollen, and incapable of use. But sexual ripening goes on just the same and fertilization takes place here on the cephalopod's gills. Then comes a final molt for the female in which she acquires again well-formed appendages capable of good service. She then swims away in search of a final host, into whose flesh she burrows and is anchored by chitin horns growing out from the cephalothorax.

It is worthy of note that some species of this subfamily have been found upon whales and become thus the only copepods parasitic upon a warm-blooded animal. It may also be noticed that the members of this subfamily are the largest of the Lernaeidae, sometimes attaining the comparatively enormous length of nine or ten inches.

Genus PENNELLA Oken.

Pennatula Linnaeus, Systema Naturae, 1758, p. 819. *P. sagitta*, third species.

Pennella Oken, Lehrbuch Naturgeschichte, 1816, p. 358. Type, *P. diodontis*, monotypic, a synonym of *P. sagitta*.

Lernaopenna Blainville, Journ. de Physique, 1822, vol. 95, p. 378. Type, *L. bocconii*, first species.

Baculus Lubbock, Trans. Linn. Soc. London, 1860, vol. 23, p. 190. Type, *B. elongatus* monotypic. A larval form of *Pennella*.

Hesselia Brady, *Challenger* Copepoda, 1883, vol. 8, p. 136. Type, *H. Cylindrica*, monotypic. A larval form of *Pennella*.

Penella, Penellus, Lernaeopinna, various authors.

Reasons for retaining the name Pennella.—Linnaeus, mistaking entirely the nature of these parasites, placed them in the genus *Pennatula* or Sea pens, and this genus name was subsequently used by Ellis (1763), Gmelin (1788), Lamarck (1818), Pallas (1772), Cuvier (1817), and others.

But *Pennatula* was the name of a genus of alcyonarian coral polyps, which gradually came into general use, and which is still retained in the group of sea fans known as Pennatulacea, with the type genus *Pennatula.*

Hence Oken, on establishing the new species *diodontis* in 1816, suggested *Pennella* as a new name for the genus and it has been universally adopted.

Thus although Linnaeus antedated Oken by many years we can not use his name for this copepod genus, but must adopt the one given by Oken.

External generic characters of female.—Cephalothorax globular, hemispherical, or semielliptical, usually somewhat flattened dorsoventrally and often with the anterior end squarely truncated and covered with short and tumid processes; the rounded posterior end gives off two or three cylindrical chitin horns, unbranched. Neck very long, cylindrical, and comparatively wide, increasing gradually in diameter and passing insensibly into the trunk. The latter is cylindrical, often transversely ridged, and straight; abdomen long and tapering to a bilobed tip, with a pair of tiny anal laminae armed with long setae; a row of appendages along either side of the abdomen, nearer the ventral surface, and branched so as to resemble the barbs and barbules of a feather. Egg strings from once to several times the length of the body, straight and filiform; eggs numerous and uniseriate. Antennae persisting in the mature adult while the two pairs of maxillae apparently disappear; first two pairs of legs close together, third and fourth pairs removed a short distance.

Internal generic characters of female.—Bilateral symmetry completely preserved; mouth tube on the anterior end of the head or on the ventral surface near the anterior margin; proboscis with a meager supply of muscles; esophagus inclined to head axis and supported by a rigid chitin framework suspended from the ventral wall of the head; stomach without convolutions or lobes; intestine straight, nearer the dorsal surface, and considerably narrowed in the abdomen; rectum short and straight.

Ovaries two-thirds the length of the trunk, tapered posteriorly, the ends distinct, the central portion more or less completely fused; oviducts with a short loop where they leave the anterior ends of the ovaries, and comparatively narrow; cement glands extending the entire length of the trunk, the ducts the same length and diameter as the glandular portion.

Chitinogen layer of body wall forming an opaque network of pigmented fibers over the inner surface of the thick chitin skin.

Genus habitat.—This genus burrows from apparently any locality on the outer body surface of its host through the skin and tissues,

and buries its head in some vital organ, forming an enormous cyst, which becomes very hard and remains a long time after the death of the parasite; it always shows torsion and sometimes flexion.

External generic characters of Copepodid male.—Cephalothorax made up of head and first thorax segment fused; second, third, and fourth segments free and diminishing gradually in width; fifth and genital segments fused; abdomen one-jointed, anal laminae short and wide.

First antennae indistinctly jointed and well armed with setae; second pair two-jointed with a stout chela; mouth tube long and barrel-shaped; mandibles without teeth; first maxillae on the outside of the tube at its base, bilobed; second maxillae on the ventral surface of the head, two-jointed and tipped with a claw; maxillipeds near the posterior margin of cephalothorax, also two-jointed and tipped with a claw; swimming legs corresponding exactly with those of the female; no fifth legs.

Internal generic characters of Copepodid male.—Esophagus short and strongly inclined to the body axis; stomach much widened in the cephalothorax, tapered posteriorly and passing insensibly into the narrow intestine. Supraesophageal ganglion comparatively small, connected dorsally with a wide tripartite eye and anteriorly with a large frontal gland secreting an attachment filament. Infra ganglion almost as large as the stomach and extending back into the second thorax segment. Testes paired and opposite each other above the stomach in the first and second thorax segments, ovate, with wide sperm ducts leading back to large spermatophore receptacles in the genital segment.

Type of the genus.—*Pennella sagitta* (Linnaeus), first species.

(*Pennella*, diminutive of *Penna*, a feather).

Remarks.—This genus has been probably the least understood of any in the entire family and scarcely any two authors have described their species similarly. This is partly due to the fact that specimens are often mutilated in order to save the host, since the removal of a *Pennella* in its entirety is almost certain to involve the destruction of its host as a museum specimen. It is also partly due to the presence of a much larger and tougher cyst around those portions of the body which are buried in the host; this is very difficult to remove without injury to the parasite. Again the short and stubby frontal processes, like those on a cauliflower, entirely cover the mouth and surrounding regions, and several heads must be sacrificed before gaining an adequate idea of the structure of the buccal region. In the present instance there has been an abundance of material for clearing in clove oil, for dissection, and for sectioning, and the facts here presented have been ascertained in all these ways as well as by ordinary methods.

With reference to the "male" of this genus described by Milne Edwards, Steenstrup and Lütken, Thomson, Bassett-Smith, and T. and A. Scott, it may be said that Milne Edwards briefly described a genus male but did not even mention one in connection with any of the species. He was evidently describing something which no other investigator has ever seen and which had no connection with this genus at all. Steenstrup and Lütken thought it probable that his description was not derived from his own observation, but that he mistook Nordmann's figure of a male *Anchorella* (*Clavella*) for *Pennella* and based his description upon that. Thomson, Bassett-Smith, and Scott simply translated his mistake and no one of them claimed to have seen a male.

Steenstrup and Lütken figured under *Pennella exocoeti* something which they called "The presumable pigmy male of the species." In their genus diagnosis they said that this "gave some idea of the males which had hitherto been sought in vain." But they did not mention it at all in their description of the species; evidently they were not certain that it was a male, and had no idea of its structure. Whatever it may have been, it certainly was not a pigmy male of this genus, for the males of *Pennella* are like those of the other genera in the Lernaeidae. They do not live beyond the copepodid stages, and hence are not to be found attached to the body of the adult female, nor even upon the same fish.

If one will compare carefully the copepodid males obtained by Wierzejski from the gills of three cephalopod species with the copepodid males of *Lernaeocera* described by A. Scott (1901), with those of *Sarcotretes* described by Jungersen (1911), and with those of *Lernaea* here described (p. 35), there will be no doubt that they were really what Wierzejski claimed them to be, the sexually ripe copepodid males of some *Pennella* species.

Here is the true male of the present genus, and it is one that corresponds in every particular with the other Lernaeid males already discovered. Upon Wierzejski's description and excellent figures are based the generic characters given above.

The adult females are found everywhere upon the body of their hosts and can not be said to prefer any especial locality. The large trunk of the parasite stands out from the surface of the skin, while the head and long neck are buried in the tissues of the host's vital organs. The tissue with which they come in immediate contact forms a thick and tough covering or cyst around them, which is often as large as an English walnut and sometimes attains the size of a lemon.

These cysts are usually flattened in one direction, and with age they become nearly as hard as cartilage. Inside of them the head

and neck of the *Pennella* are frequently twisted in corkscrew fashion, thereby increasing the difficulty of withdrawing them and giving the copepod a more secure hold upon its host. These cysts may be found almost anywhere in the fish's body, in the stomach and intestine walls, the mesentery, the liver, the caeca, etc. When the copepod dies the cyst simply shrivels and hardens still more, and such lumps, nearly as hard as bone, may be cut out of the liver or elsewhere alongside of the living ones.

The portion of the parasite which hangs free in the water outside the fish's skin is frequently infested with goose barnacles, hydroids, or algae. One specimen was obtained, 4 inches in length, to which were attached 18 *Conchoderma virgatum*, the mass of the barnacles being many times that of the copepod's body.

Quite recently (1912*b*) Quidor has published a paper on copepod parasites, in which he gave a diagnosis of the genus *Pennella* and then discussed its life history and specific characters. After showing that various other data did not furnish favorable specific characters, he advocated the structure of the plumose abdominal appendages and the individual torsion as a ready and infallible means of distinguishing species (pp. 202–3).

The structure of the abdominal appendages was quite thoroughly discussed by Steenstrup and Lütken in connection with *Pennella sagitta*.

While it may be possible to select plumules from the different species which will show the distinctions portrayed by Quidor, it is also possible to find on the same fish two Pennellas of the same species, fastened side by side, but whose plumules show very different structure. So long as this is likely to occur it is evident that something else must be used to separate the species. With reference to the value of torsion, if Quidor's observations were based upon the statements contained in his description of the genus, they must be profoundly modified before they will possess any scientific value. He stated: "La tête . . . présente ventralment deux antennes rudimentaires et une région buccale couverte d'appendices chitineux plus ou moins ramifiés" (p. 197); and, again: "Il (the genital segment) porteen arrière, sur la face dorsale, les orifices de ponte d'on sortent deux longs sacs ovigières filiformes." (P. 198.)

The two pairs of antennae are dorsal and not ventral, and the egg strings are ventral and not dorsal, as in every Lernaeid genus. By placing the antennae with the mouth on the ventral surface Quidor is reduced to the unhappy situation of calling the swimming legs dorsal, since they are on the opposite surface.

As a consequence all the torsion which he called direct is really inverse and his inverse torsion is really direct, because he was hold-

ing the animal with its ventral side uppermost so that right and left were reversed. Furthermore by placing the mouth on the same surface as the antennae, whether he called it dorsal or ventral, he has altered the true amount of torsion, that is, the angle between the buccal and anal orifices.

Hence what he gave as a direct torsion of 135° might well be an inverse torsion of 45°. Again his statement that "the value of the angle of torsion in the adult furnishes very precise specific characters" (p. 203) can not be proved in actual experience. No species shows anything like constancy in either the amount or the direction of torsion. We have just stated that the neck of *Pennella filosa* is often twisted in corkscrew fashion inside the cyst, but this is by no means always or even usually the case. It is evident, however, that the torsion of these corkscrew specimens will be very different from that of normal specimens, and even amongst the latter there is a wide variation. In most Pennellas the direction of torsion is clearly shown by the twisting of the color pattern on the neck. Interpreting on this basis, the torsion of five specimens of *Pennella filosa* taken from the same swordfish are: Direct 90°, inverse 180°, direct 360°, direct 360°, inverse 180°. Manifestly when two torsions are in the same direction and one is four times the other, they do not furnish a "very precise" specific character.

The only rational conclusion is that torsion in this genus has comparatively little specific value. We are forced, therefore, in making a key of the species, to rely upon an accumulation of characters, rather than upon any one or two characters alone.

Furthermore it has been found necessary to exclude the following species from the key for the reasons stated after each:

Penella anthonyi and *P. cettei* Quidor. In his attempt to use the mode of branching of the plumose appendages as the chief characteristic of the various species Quidor gave figures showing these appendages in the two species here named (1912b, pl. 1, figs. 9, 11, and 12). He also gave photographs of the two parasites, half the natural size (pl. 4, figs. 30 and 31), and a few additional facts in his key to the species. But he does not even mention them in his text, and we are left in absolute ignorance of the details of all their appendages, as well as of their general morphology.

Consequently while they may very likely prove to be new species, we can not accept them upon present evidence.

Lerneopenna blainvillii LeSueur (1824, p. 289, pl. 11, figs. 2 and 3). A synonym of *Pennella exocoeti* (see p. 115).

Pennatula bocconii Lamartinière (1798, p. 51, pl. 20, fig. 6). Milne Edwards made this a distinct species, but Steenstrup and Lütken said it was not well enough described to warrant separation and made it a synonym of *Pennella diodontis*. It was the first species (type) of

Blainville's "new genus" *Lerneopenna.* But Steenstrup and Lütken's statement holds good to-day; it has never been described with enough detail to enable it to stand as a separate species.

Lerneopenna brachiata Blainville (1822, p. 446, pl. 1, fig. 4). A synonym of *Pennella sagitta* (see p. 113).

Penella costai Richiardi (1880, p. 150). This is a *nomen nudum* and probably identical with *Pennella filosa.*

Pennella diodontis Oken, Chamisso, and Eysenhardt (1821, p. 350, pl. 24, fig. 2). A synonym of *P. sagitta* (see p. 113).

Pennella gracilis and *P. intricata* A. Costa. Carus in his Prodromus Faunae Mediterraneae (1885, p. 374) mentions these two species and ascribes them to A. Costa, but adds "Hospites, loci, descriptio?". He himself was as badly at fault since he did not give the reference in which A. Costa mentioned these species, and all efforts to find such a reference have failed.

Lerneopenna holteni Desmarest (1825, p. 347). When Desmarest transferred Holten's species, *Lernaea exocoeti*, to Blainville's genus *Lerneopenna*, he also changed the specific name. But of course there was no warrent for this and so his name, *holteni*, becomes a synonym.

Penella plumosa DeKay (1844, p. 60). DeKay described (1822, p. 87, 1 text figure) a mutilated specimen of a parasite from "*Diodon pilosus*" sent to him by Doctor Mitchill, which he was satisfied did not belong to any genus as yet established. Afterward in his Zoology of New York he evidently redescribed the same creature and gave it the above name.

Either he himself or the printer made an error in the name of the host, and gave it as "*Diodon plumosus* of this report." Fowler (1913b, p. 91) suggested that, as such a fish was not named in DeKay's report, it was proably a mistake for DeKay's "*Diodon fuliginosus*," which does appear in the report, and he made DeKay's species a synonym of *P. filosa.*

But it seems more probable that the specific name of the parasite was in some way substituted for that of the host, the two being very similar, and that DeKay was redescribing and naming the same species that he had in 1822, of which during the intervening years he had obtained better specimens. This would make it a synonym of *P. sagitta*, which infests *Diodon*, and not of *P. filosa*, which has never been found on that genus of fishes.

Penella remorae Murray (1856, p. 299, 5 text figures). This species was found attached to the sucking disk of "*Echeneis remora*," and all that was described and figured was the portion outside the disk, the part buried in the tissues of the fish having been destroyed in an attempted dissection. But this posterior portion of the parasite showed plainly that the specimens were immature, the plumose appendages having only just started to grow. A remora

could easily obtain such immature specimens while attached to some larger fish which was the regular host of the parasite.

At all events, with no data on the anterior two-thirds of the body, including all of the appendages, the species can not be accepted.

Pennella rubra Brian (1906, p. 86, pl. 7, fig. 3). This was a single specimen, without egg strings and lacking all that part of the anterior body which had been buried in the tissues of the host. This lack of egg strings, as well as the condition of the plumose appendages, show it to have been an immature stage of some species infesting the sunfish on which it was found. Brian himself afterward recognized this, and in 1912 (p. 16) placed the species as a synonym under *P. filosa*.

Pennella sultana Nordman (1864, p. 485, pl. 5, figs. 12–16). This species was first described briefly by Milne Edwards (1840, p. 523) and ascribed to Nordmann in accordance with manuscript in the Paris Museum. The manuscript was afterward published by Nordmann as above, but the species does not belong to the genus *Pennella*, and in the following year was established by Heller (1865, p. 251) as the type of the new genus *Lernaeolophus*.

KEY TO THE SPECIES OF THE GENUS PENNELLA.

1. Length 50 mm. or less, exclusive of the egg strings 2
1. Length 100 mm. or more, exclusive of the egg strings 3
2. Head spherical, the same width and length, covered with minute and regular excrescences; two soft, slender horns, 2 to 3 times the length of the head, pointed backward (10 to 20 mm.)[1] ..... *sagitta* (Linnaeus), 1758, p. 113.
2. Head much wider than long, flattened dorsoventrally, deep cut at the center, covered with large irregular excrescences; two slender horns a little longer than the head and pointed backward (40 to 50 mm.) *exocoeti* (Holten), 1802, p. 115.
2. Head wider than long, flattened dorsoventrally, squarely truncated anteriorly, not cut at the center, but covered with irregular excrescences; three soft, slender horns, the lateral ones at right angles to head and branched (30 mm.) ..... *liouvillei* Quidor, 1912, p. 116.
2. Head much longer than wide, with wing-like excrescences on either side; two stout conical horns much shorter than head and at right angles to it (15 to 25 mm.) ..... *varians* Steenstrup and Lütken, 1861.
3. Three horns, long and slender, at right angles to head, the dorsal one shorter than the lateral ones; neck slender and much longer than trunk 4
3. Two horns, short and blunt, at right angles to head; neck shorter than the trunk and nearly of the same diameter 5
3. Two horns, long and soft, pointed backwards; neck thick and as long as the trunk or longer 6
4. Neck 3 times as long as trunk; abdomen two-fifths length of genital segment; egg strings half the length of whole body; head minute and spherical (175 to 225 mm.) ..... *antarctica* Quidor, 1912, p. 116.

[1] Average total length of species.

4. Neck 2 times as long as trunk; abdomen half the length of genital segment; egg strings half the length of whole body; head flattened, much wider than long (200 to 320 mm.)_____*balaenopterae* Koren and Danielssen, 1877.
4. Neck and trunk the same length; abdomen two-fifths length of genital segment; egg strings twice the length of whole body; head flattened, much wider than long (140 mm.)_____*tridentata* Listowsky, 1893.
4. Neck 2 to 3 times as long as trunk; abdomen three-fifths length of genital segment; head cup-shaped anteriorly (90 to 125 mm.)
crassicornis Steenstrup and Lütken, 1861.
5. Horns chitinous, at right angles to head, and both in the same straight line; abdomen half the length of genital segment; egg strings no longer than abdomen (90 to 100 mm.)_____*histiophori* Thomson, 1889.
5. Horns fleshy and very short, terminating in a small red knob; abdomen half the length of genital segment; egg strings much longer than whole body (100 mm.)_____*pustulosa* Angas, 1847.
5. Horns chitinous, slender, and scarcely projecting beyond the margins of the head; abdomen stout and less than half the length of genital segment; egg strings twice the length of whole body (150 to 200 mm.)
filosa (Linnaeus), 1758, p. 119.
6. Head squarely truncated anteriorly, with concave sides; horns parallel with the neck; neck and trunk the same length; abdomen half the length of genital segment (225 mm.)_____*instructa*, new species, p. 122.
6. Head cup-shaped anteriorly, with convex sides; horns extending diagonally ontward; neck one-fifth shorter than trunk; abdomen a third the length of genital segment (180 mm.)_____*orthagorisci* Wright, 1870, p. 124.
6. Head shaped like a clove, largest anteriorly; horns parallel with neck; neck 3 times as long as trunk; abdomen half as long as the genital segment (275 mm.)_____*charcoti* Quidor, 1912.

PENNELLA SAGITTA (Linnaeus).

Pennatula sagitta Linnaeus, Systema Naturae, 1758, p. 819, pl. 3, fig. 13.—Ellis, Philos. Trans., vol. 53, 1763, p. 419, pl. 1.—Cuvier. Regne Animal, vol. 4, 1817, p. 36.—Dekay, Amer. Journ. Science, vol. 4, 1822, p. 87, 1 text fig.

Lernaeopenna sagitta Blainville, Journ. de Physique, vol. 95, 1822, p. 379, pl. 1, fig. 5.

Lernaeopenna brachiata Blainville, Journ. de Physique, vol. 95, 1822, p. 446, pl. 1, fig. 4.

Pennatula bocconii Lamartinière, Atlas du Voyage de la *Pérouse*, 1798, pl. 20, fig. 6.

Lernaea diodontis Oken, Lehrbuch Naturgeschichte, 1816, p. 184.

Pennella sagitta Nordmann, Mikrographische Beiträge, 1832, p. 121, pl. 10, figs. 6–8.—Steenstrup and Lütken, Kong. Danske Videns. Skrifter, 1861, p. 409, pl. 14. fig. 31.

Pennella diodontis Oken Lehrbuch Naturgeschichte, 1816, p. 358.

Pennella diodontis Oken, Chamisso, and Eysenhardt, Nova Acta Acad. Caes. Bonn, vol. 10, 1821, p. 350, pl. 24, fig. 3.

Pennella diodontis Quidor, Deuxième Expédition Antarctique, Charcot, 1912, p. 205, pl. 1, fig. 2; pl. 2, figs. 19–22; pl. 4. fig. 38.

Remarks.—As the above synonomy shows, various authors have attempted to establish 4 or 5 different species upon the material obtained from the genus *Diodon*. Linnaeus made the mistake of

placing this copepod among the sea fans, and this error was copied by Ellis, Lamarck, Esper, and others, each of whom described the creature simply from a figure given by one of the others. Cuvier recognized that it did not belong with the polyps, but he went too far in the opposite direction and declared that it must be considered as belonging to the genus *Caligus* of Müller.

In a later edition (1830) he adopted Oken's genus *Pennella* under the Lerneans (vol. 3, p. 256), but included in it only the single species, *filosa*.

However, on page 320 in a footnote under the polyp genus *Pennatula* he said: "*Pennatula filosa*, et *Pennatula sagittata*, sont des animaux parasites, du genres des lernèes (les *Penelles*, Oken); mais nullement des pennatules. Le *Penn. sagitta*, Esper, Pennat., pl. V, est tout autre chose que celui de Linn.; peutètre est-ce un *Nephthys*."

De Kay, after noting the above treatment of the parasite, said: "This animal has been first ranked as a *Lernea*, a parasite, then considered as a pennatule or polype, afterwards placed in the genus *Calygus* as a crustaceous animal, and finally, it has been decided that it shall occupy a new genus as an Annelide." (p. 88.) He then gave an incomplete description of a mutilated specimen from "*Diodon pilosus*," sent to him by Doctor Mitchill, together with a text figure. The head, the neck, and the anterior portion of the genital segment were lacking, the specimen having evidently been broken off on a level with the outside surface of the host's skin.

Consequently the only portion of his description of any scientific value was that of the "plumulae" and the name of the host. And it is not surprising that he finally concluded to place the animal in one of the four genera established by Lamarck under the order of "Polypes tubiferes," thus restoring it to the polyps.

Blainville described in his text a species which he claimed was the *sagitta* of Linnaeus, Ellis, Esper, Lamarck, and DeKay (p. 379), But he manifestly never saw the creature; his description is borrowed from those of the other authors, and for a figure he copied the imperfect wood cut of DeKay. Indeed, he comprehended so little about the size and structure of the species that he described it again in the explanation of his plate (p. 446) as a new species, to which he gave the name *brachiata*.

Nordmann gave us the first really scientific description of this parasite, accompanied by excellent colored figures. He identified his species with that described by Linnaeus and the others, and if his identification was correct, as we have no reason to doubt, it established the species of those early writers beyond question. And since it was the first parasite described by Linnaeus it becomes the

oldest of the parasitic copepods. With reference to the host, Linnaeus's specimens were taken from the sargassum fish, *Pterophryne histrio*, that of DeKay was from a *Trichodiodon* (*Diodon*) *pilosus;* Blainville's *sagitta* was from a species of *Lophius* in the Sea of China, while his *brachiata* was from a *Diodon* at Manila, Philippine Islands; Nordmann's species was taken from *Lophius marmoratus*, but he identifies it with DeKay's specimen from *Diodon.*

The species thus becomes a parasite of the two genera, *Lophius* and *Diodon.*

PENNELLA EXOCOETI (Holten).

Lernaea exocoeti Holten, Skrivter af Naturhistorie-Selskabet, vol. 5, 1802, p. 136, pl. 3, fig. 3.

Lernaeopenna holteni Desmarest, Crustacés, 1825, p. 347.

Lernaeopenna blainvillii LeSueur, Journ. Acad. Nat. Sci. Phila., vol. 3, 1824, p. 289, pl. 11, figs. 2 and 3.

Penellus blainvillii Milne Edwards, Hist. Nat. des Crustacés, 1840, p. 523.—Flower, Proc. Zool. Soc. London, vol. 26, 1858, p. 372.

Pennella exocoeti Steenstrup and Lütken, Kong. Danske Videns. Selskabs Skrifter, vol. 5, 1861, p. 415, pl. 14, fig. 33.

Penella exocoeti Quidor, Deuxième Expédition Antarctique, Charcot, 1912, pl. 1, fig. 3; pl. 4, fig. 39.

Remarks.—Holten gave a fair description and figures of this species, which were copied by Desmarest without any additions from original investigation, but with a change of name to correspond with Blainville's newly established genus. Steenstrup and Lütken obtained three specimens from an *Exocoetus* species captured in the tropical Atlantic, which they positively identified with Holten's species, and of which they gave excellent figures, but added nothing to Holten's description. So far as can be judged from a comparison of the respective figures and descriptions, their identification was correct, but neither description gives us very much in the way of details. They also discovered just above the base of the egg strings two tiny objects which they called pigmy males, and which they said "were fastened to the skin of the female so tightly by their maxillipeds that it was not possible to loosen them without tearing them in pieces" (p. 419). These were not placed with the females under the species *exocoeti*, but were put in the general remarks after all the species, and without any description. The simple fact that they could not be removed from the female without tearing them in pieces indicates that they were not males. The two sexes are never welded together in any such manner as that, and the only injury that would be possible would be the loss of the claws on the maxillipeds or perhaps of the entire appendages. Steenstrup and Lütken further stated that "the *P. blainvillii* described by LeSueur was also taken

from an *Exocoetus* (*E. volitans*) but differs from ours (namely from *exocoeti*) both in the older and the younger stages so much that we may regard it as quite distinct" (p. 415).

A careful comparison of LeSueur's figures and description with those of Steenstrup and Lütken does not show any differences of specific value.

Blainvillii has three horns, all of a length and quite short and the neck is short and stout; *exocoeti* has only two horns while the neck is long and threadlike. But neither of these differences nor both of them are sufficient to separate the two species; much more accurate and detailed descriptions must be given before we can definitely establish them as distinct species, infesting the same host and in the same locality.

PENNELLA LIOUVILLEI Quidor.

Penella liouvillei QUIDOR, Deuxième Expédition Antarctique Française, Charcot, 1912, p. 209, pl. 1, fig. 1; pl. 2, fig. 26; pl. 3, fig. 28; pl. 4, fig. 37.

Remarks.—This species of Quidor differs from *exocoeti* only in the possession of a dorsal cephalic horn, in the branching of the lateral horns, and in the fact that the inflated lateral portions of the head do not project in front of the central portion. Quidor added that the torsion was direct in *exocoeti* and inverse in *liouvillei*, and if we can judge from his text this is the difference which induced him to establish his new species. But it has been shown elsewhere (p. 109) that torsion has no specific value, and the other differences might all result from different conditions encountered while the parasite was penetrating the tissues of its host. Hence there is need of more details here also before the species can be definitely established.

PENNELLA ANTARCTICA Quidor.

Plate 15, figs. 119–124.

Penella antarctica QUIDOR, Deuxième Expédition Antarctique Française, Charcot, 1912, p. 206, pl. 1, figs. 15–17; pl. 4, figs. 29, 34.

Host and record of specimens.—Two females out of a lot that were taken from the Sei whale, *Balaenoptera borealis*, off northern Japan by Dr. R. C. Andrews of the American Museum of Natural History, New York City, were presented to the National Museum and have received Cat. No. 47820, U.S.N.M.

Specific characters of female.—Head distinctly separated from the first thorax segment by a deep groove, ellipsoidal with the long diameter transverse, and flattened somewhat dorsoventrally; divided into two halves by a longitudinal furrow, which is wide and shallow, beginning at the antennae on the dorsal surface, extending around

the anterior margin, and running the whole length of the ventral surface to the neck. Ventrally the anterior two-thirds of this furrow is filled with the small horny frontal processes, those along the margin of the groove larger than those along the bottom. First two thorax segments as wide as the head, fused and separated from the third and fourth segments by a groove; they give off a pair of long and slender lateral horns and a much shorter dorsal horn.

Third and fourth segments also fused, narrower than the two first segments and tapered posteriorly; neck very long and threadlike, only the extreme anterior portion being yellow and chitinous, while the rest is softer and the same color as the trunk. The latter is comparatively short and not much enlarged, its surface being raised into irregular transverse ridges, lighter in color than the intervening grooves. Posteriorly its dorsal portion passes into the abdomen, which is short, tapering, transversely ridged like the trunk, and bluntly rounded at the tip.

Each barb of the plumose appendages is single and branched on only one side; the first one or two branches (barbules) are much larger than the others and are themselves dichotomously divided; the egg strings are comparatively short and slender.

The first antennae are removed some distance behind the second pair, are three-jointed, and well armed with setae. The second antennae are two-jointed and tipped with a chela; the basal joint is triangular, the apex of the triangle being attached to the dorsal surface of the head and the base being articulated with the terminal joint; the claw of the chela is stout and strongly curved, the peg is short and considerably inclined inward toward the opposite antenna.

The mouth tube is reduced to a mere fringe around an opening on the ventral surface of the head, in the bottom of the groove and near the sinus in the anterior margin. No mouth parts can be seen, but instead the groove around the mouth is filled with the corneous frontal processes.

Buried deeply in the tissues over the base of the esophagus is an eye which still retains the two lateral lenses found in larval forms.

The four pairs of swimming legs are all present, the three posterior pairs placed at distances behind the anterior pair represented by the numbers 5, 17, 28; the first two pairs are biramose, the last two uniramose, all the rami two-jointed and bearing setae.

The structure of the mouth framework is clearly shown in figure 123; the esophagus is surrounded by a chitin ring (*cr*) oblong in shape, somewhat angular and attached to the inside of the wall of the head. From each of its four corners and from the center of either side a short and wide chitin band (*cb*) projects dorsally into the cavity of the head.

To the ends of each band and all over the dorsal surface of the ring numerous muscle bands are attached, which have their origin on the dorsal and posterior walls of the head. Similar muscle bands are inserted all over the ventral wall of the head around the mouth, on the soft membranes as well as on the harder chitin parts. These also have their origin on the dorsal, lateral, and posterior walls of the head, so that the entire cavity, except for the digestive tube, is filled with these muscle bands.

Their contraction pulls in the ring and the portions of the ventral wall around the mouth as far as the elasticity of the chitin and the soft membranes will permit. The entire front of the head thus takes the place of the protrusible proboscis in other genera.

The esophagus, after passing through the ring, turns forward and opens on the ventral surface of the head in the space between the anterior bands (*oe*). There is a posterior prolongation (*p*) which extends backward between the ring and the ventral wall of the head, and ends blindly between the posterior bands. Behind this prolongation posteriorly and along either side of the ring are irregularly rounded areas (*m*) in the ventral wall of the head, which are covered with a fairly thin, soft membrane instead of the hard chitin. Between these areas and outside of them the walls are thick and hard; the frontal processes cover both the hard chitin and the soft membranes indiscriminately, and can be removed from the latter as well as the former without injury. The number, size, and arrangement of these soft membranes furnish good specific characters.

Color (preserved material), head and anterior fifth of the thorax dark yellowish brown; remainder of thorax and trunk light yellow on the dorsal and ventral surfaces and dark brown along the sides; plumose appendages silver gray; egg strings light yellow.

Total length, 235 mm. Head, 4 mm. long, 5 mm. wide. Lateral horns, 35 mm. long. Genital segment, 50 mm. long, 4 mm. wide. Abdomen, 18 mm. long. Egg strings, 100 mm. long.

(*antarctica*, the region from which the original specimens came.)

Remarks.—One of the specimens was an exceptionally fine one, and the above description has been given in order to supplement the one presented by Quidor and to correct certain errors.

Quidor found but a single pair of antennae and he designated as first maxillae two chitin knobs, one on either side, in the sinus of the frontal margin, and thus in front of the mouth, between it and the antennae; two others on the ventral surface were designated as second maxillae, and only three pairs of legs were found.

The species may be recognized by the exceptionally long and slender neck and by the three horns on the first thorax segment, the two lateral ones being long and inclined forward.

PENNELLA FILOSA (Linnaeus).

Plate 15, figs. 125–127; plate 16, figs. 128–133; plate 17, figs. 134–139.

Pennatula filosa LINNAEUS, Systema Naturae, 1758, p. 819.

Lernaea cirrhosa LA MARTINIÈRE, Atlas du Voyage de la *Pérouse*, 1798, pl. 2, fig. 6.

Penellus filosa MILNE EDWARDS, Hist. Nat. des Crustacés, 1840, vol. 3, p. 523.

Penella filosa QUIDOR, Deuxième Expédition Antarctique Française, Charcot, 1912, pl. 1, figs. 5–8; pl. 4, figs. 35, 36.

Pennella filosa CUVIER, Règne Animal, 1830, vol. 3, p. 257.—M. T. THOMPSON, Biological Bulletin, 1905, vol. 8, p. 296, 6 text figs.—BRIAN, Résultats Scientifiques Prince de Monaco, fasc. 38, 1912, p. 16, pl. 3, figs. 2–4; pl. 6, fig. 10.

Pennella rubra BRIAN, Copepodi parassiti dei Pesci d'Italia, 1906, p. 86, pl. 7, fig. 3.

Host and record of specimens.—The following specimens of this parasite appear in the United States National Museum collection; Cat. No. 3155, one female from a swordfish captured off the coast of Nova Scotia; Cat. No. 6143, two females from *Mola rotunda*, off Marthas Vineyard; Cat. No. 6144, two females from a swordfish, Woods Hole, Massachusetts; Cat. No. 42298, twelve females much infested with barnacles from an unknown locality and host; Cat. No. 42307, seven females from swordfish at Woods Hole; Cat. No. 42313, ten females from swordfish, Woods Hole; Cat. No. 47754, five females from sunfish, Woods Hole, much infested with barnacles; Cat. No. 47755, eight heads only from swordfish, Woods Hole; Cat. No. 47821, one female from *Mola rotunda*, Woods Hole; Cat. No. 47822, two females from *Tetrapturus albidus*, north Atlantic.

Specific characters of female.—Cephalothorax subspherical, wider than long, slightly flattened dorsoventrally, and almost squarely truncated at the anterior end, which is covered with short processes. These processes are usually branched like those on a cauliflower, especially around the edges, but some of them are simple. Where the head joins the neck a pair of short, straight, and unbranched horns are given off on the dorsal surface, and there is often a shorter third one between them.

On the dorsal, lateral, and ventral surfaces of the head, near the beginning of the processes at the anterior end, there are usually several small knobs, irregularly disposed and never alike in any two specimens.

Neck comparatively thick, about the same diameter throughout, and considerably shorter than the genital segment. The latter is about twice the diameter of the neck and transversely ridged, increasing gradually from the neck and then remaining the same diameter for the rest of its length.

Abdomen half the length of the genital segment, plumes large and profusely branched, usually with tertiary plumules. Egg strings very slender and often several times the length of the body; one of the specimens in lot No. 42313, which was itself 120 mm. in length outside the fish's body, had egg strings 350 mm. long.

First antennae slender and three-jointed, close to the bases of the second pair and turned forward, the joints of about the same size and heavily armed with setae. Second antennae two-jointed, joints the same size, the terminal one chelate, a stout and strongly curved claw shutting past a large peg on the inner margin of the joint. Between the basal joints is a short, pointed rostrum, with the usual pigment spot at its center, and a tripartite eye is deeply buried in the tissues over the base of the esophagus; there are no visible mouth parts. The basal plates of the swimming legs are slender and elongated-triangular in shape, the intervals between the successive pairs being represented by the numbers 10, 30, 35 respectively.

The structure of the mouth framework is shown in figures 130–131. The chitin ring around the esophagus is short and wide, concave anteriorly and bluntly rounded posteriorly, with only four chitin bands projecting into the cavity of the head, one at each anterior corner and one at the center of either side. There is but a single semielliptical area on either side covered with thin and soft membrane; each of these areas starts just in front of the lateral chitin band and extends backward nearly to the posterior margin of the head. It is surrounded by a wide chitin band or ridge, the bands on the inner sides of the areas meeting along the median line, except for a short distance posteriorly. The arrangement of the muscles and frontal processes with reference to these areas and bands is similar to that in *Pennella antarctica*.

Immature stages.—A young *P. filosa*, 18 mm. in length, taken from a swordfish, is shown in figures 135–139. The antennae and swimming legs are the same as in the adult, but in contrast to the latter all the mouth parts are present and are very distinct. The proboscis projects considerably from the ventral surface of the head and is evidently retractile. Inside of it at its base lie the mandibles, which are made up of a broad lamellate basal joint, tipped with a curved spine without teeth. The stout muscles connecting the basal joint with the inner walls of the head show that these organs take a prominent part in the early activities of the parasite, and may even assist in burrowing through the flesh of its host. The first maxillae are tiny projections on the side walls of the proboscis, each tipped with two long setae. The second maxillae are long and stout; each consists of a basal joint armed with two strong claw-like spines, one on the ventral surface near the distal end and the other at the end on the lateral margin, and a distal joint armed with two claws, one

terminal and slightly curved, the other on the inner margin near the base. These appendages are also furnished with very powerful muscles and are probably used in burrowing. The maxillipeds are reduced to mere spines, with which are still connected two or three weak muscles whose only service seems to be to show that the spines are really rudiments of mouth parts. In the posterior end of the genital segment, just inside the vulva, can be seen the enlargement of the oviduct on either side which serves as a receptaculum seminis. The entire abdomen is monilliform and terminates in two large anal laminae, each well supplied with setae.

In an older specimen, 35 mm. long, the rudiments of the mixillipeds have disappeared, but the other appendages remain intact; the genital segment is ridged transversely, and the plumose appendages of the abdomen have started as broad bluntly rounded processes, one on either side of each monilliform division of the abdomen.

Color.—Head and neck, or buried portions of the body, pale yellow, often with a reddish tinge from the contained blood; genital segment and abdomen dark cinnamon brown, banded transversely with yellow; egg strings dark orange yellow.

Total length, 150–200 mm. Head, 8 mm. long, 10 mm. wide. Neck, 50–60 mm. long, 3 mm. wide. Genital segment, 70–80 mm. long, 6 mm. wide. Abdomen 40–50 mm. long. Egg strings 200–350 mm. long.

(*filosus*, thread-like.)

Remarks.—The history of this species is rather complicated. Linnaeus described his *Pennatula filosa* as follows: "P. stirpe rachi utrinque pennata: basi tentaculis duobus. Bocc. mus., 1674, p. 286, t. 286. Habitat in M. Mediterranei Xiphiis. Setae 2, rubrae, ad basin rachios pennatae insertae, ipsaque rachi longiores."[1]

Stebbing pertinently remarked[2] that the only thing of any specific value in this description was the name of the host. But, fortunately, subsequent investigators have added useful characters that do possess specific value.

Guerin-Meneville published[3] a figure of *Pennatula filosa* that shows enough details to identify the species. Cuvier said,[4] "There is one species (*Pennella filosa*) in the Mediterranean, 7 or 8 inches long, which penetrates the flesh of the swordfish, the tunny, and the sunfish, and torments them horribly." Milne Edwards added,[5] "Body very long, slender, and straight; head swollen, carrying behind two short and obtuse horns. Appendages of the abdomen penniform, slender, and joined two by two at their base."

[1] Systema Naturae, ed. 10, 1758, p. 819.
[2] South African Crustacea, 1905, pt. 3, p. 188.
[3] Regne Animal, 1837, vol. 2, pl. 9, fig. 3.
[4] Idem, 1830, vol. 3, p. 257.
[5] Histoire Naturelle des Crustaces, vol. 3, p. 523.

Steenstrup and Lütken[1] said that if it should prove that several closely related species had been combined under the single name *filosa*, the species from the Mediterranean swordfish must be considered as the type, which is obviously true. But these authors attempted no further identification of the species.

No other investigator did more than to mention the species until Brian in the Bulletin de l'Institut Oceanographique (No. 110, 1908, p. 8) described at considerable length and illustrated with text figures both the development stages and the adult female. In this paper he placed a question mark after the species, but in a subsequent paper[2] he dropped the question mark and was satisfied with the identity of the species. His specimens were obtained from *Orthagoriscus mola* in the Atlantic west of the Azores. The present author has found both adults and development stages of the same parasite upon the swordfish.

Finally Quidor[3] has given us photographs of the entire animal and careful drawings of the plumose appendages of the abdomen from which we can easily identify the species. His specimens were found both on the swordfish and the sunfish on the northern coast of France.

With the details here added in reference to the antennae, the chitin framework supporting the esophagus, and the mouth parts of the development stages this species ought to be securely established.

PENNELLA INSTRUCTA, new species.

Plate 18, figs 141–147.

Host and record of specimens.—The United States National Museum collection includes the following specimens, all taken from the swordfish, *Xiphias gladius:* No. 3691, two females, by steamer *Lookout* from Atlantic off New England; No. 6159, one female, by the fisheries steamer *Albatross*, northern Atlantic; No. 14574, one female, from Maine coast; No. 47750, a single female with the cyst which enclosed its head and neck, from Woods Hole, Massachusetts, made the type of the species; No. 47751, eight females with their cysts, from Woods Hole; No. 47752, five females, from Woods Hole; No. 47753, four heads with horns intact, taken from cysts found inside the body of a swordfish, Woods Hole.

Specific characters of female.—Cephalothorax swollen, considerably longer than wide and squarely truncated anteriorly, with the lateral walls slightly concave. This hollowing in of the sides of the head is due to large swellings at the bases of the horns posteri-

[1] Kong, Danske Videns, Salskabs, Skrifter, 1861, vol. 5, p. 416.

[2] Campagnes scientifiques due Prince de Monaco, fasc. 38, 1912, p. 16.

[3] Deuxième Expédition Antarctique Française, Charcot, 1912, pl. 1, figs. 5–8; pl. 4, figs. 35, 36.

orly and an elevated ridge around the margin of the anterior truncated end. Frontal processes arranged in a definite pattern, consisting of a semicircle on either side around the margin, two shorter bunches inside of them curved like parentheses marks, and two narrow straight masses through the center dorsoventrally. (See fig. 143.) There is a wide, open space without processes between the semicircle and the parenthesis mark on either side, and a narrower space between the parenthesis mark and the central mass, so that the pattern stands out very distinctly.

At the posterior end of the cephalothorax nearer the dorsal surface there is a single long horn on either side, which tapers gradually to a bluntly rounded point, extends directly backward alongside the neck, and is curved considerably forward toward the ventral surface. The chitin skin over these horns is very thin, and in consequence the horns are soft and pliable. The neck is not enlarged anteriorly, but starts abruptly from the back of the head between the horns, is the same diameter throughout, and is much longer than the trunk. The latter is twice the diameter of the neck and is transversely ridged; abdomen half the length of the genital segment; plumules about 24 in number along each side of the abdomen, quite long and dichotomously branched; egg strings very slender and longer than the entire body.

First antennae four-jointed, each joint heavily armed with setae, separated from the second pair by a considerable distance (fig. 145); the third joint is the shortest and narrowest, while the fourth or terminal joint is the longest and widest. Second antennae large and stout; basal joints triangular, considerably smaller than the terminal joints and widely separated across the midline; second or terminal joints swollen, with a stout and strongly curved claw, which shuts against a medium-sized peg on the inner margin of the joint. Between the basal joints is a wide chitin plate, in the center of which is a large and bluntly pointed rostrum with a pigment spot in its base. The chitin ring surrounding the esophagus is diamond-shaped, with the two obtuse angles lateral, and each of them giving off a wide chitin band; the other two bands are on either side of the anterior point. The arrangement of the chitin ribs and soft membranes is exactly like that of the frontal processes, the soft membranes under the open spaces, the ribs under the processes.

The swimming legs each have a large spot of pigment on the basal joint and the different pairs are separated by distances corresponding to the numbers 1, 5, 6.

Color.—Head and buried portion of the neck brownish yellow; trunk dark cinnamon brown with interrupted transverse bands of yellow; plumose appendages dark steel-gray.

Total length, 225 mm. Head 7 mm. long, 8 mm. wide, 7 mm. thick. Neck, 110 mm. long, 2.50 mm. in diameter. Genital segment, 75 mm. long, 6 mm. in diameter. Abdomen, 40 mm. long. Egg strings, 330 mm. long.

(*instructus*, arranged in definite order, alluding to the frontal processes.)

Remarks.—This species may be recognized by the peculiar pattern in which the frontal processes are arranged and by the two curved horns given off from the posterior margin of the cephalothorax. The long distance between the first and second antennae, and the comparatively long distance to which the third and fourth legs are removed are also characteristic. This is undoubtedly the "*Penella* sp?" described by Brian in his preliminary note on the parasitic copepods taken during the scientific voyages of the Prince of Monaco[1]; his figures, especially of the head and horns, are unmistakable. This species infests the swordfish together with *filosa*, and has not thus far been found upon any other host. The cysts formed around the head and neck in the tissues of the host are very large, and inside of them there is more or less twisting and flexure.

While the part of the body outside of the host does not apparently afford as good lodgement for *Conchoderma* as was the case in *filosa*, it does prove attractive to hydroids and algae, and is often very heavily loaded with one or both of them.

PENNELLA ORTHAGORISCI Wright.

Pennella orthagorisci WRIGHT, Ann. Mag. Nat. Hist., ser. 4, vol. 5, 1870, p. 43, pl. 1.

Host and record of specimens.—A single lot of 10 females were obtained from *Mola mola* at Woods Hole, Massachusetts, and have received Cat. No. 42299, U.S.N.M.

Specific characters of female.—Wright fully described this species in the reference above given, but he had only two specimens obtained in the harbor of Cork, Ireland. The following notes by Mr. Richard Rathbun upon the 10 specimens obtained at Woods Hole will therefore be of interest by way of comparison:

Cephalic horns generally three in number, but sometimes only two, as in Wright's figure; they originate from the base of the cephalic region, close to the neck, and often so exactly between the two that it is difficult to say to which they properly belong. When only two they originate much farther apart than in Wright's figure, very near or quite at the sides of the head toward the dorsal surface. When three in number the third one springs from the dorsal surface midway between the other two, sometimes reduced to a mere knob, at others attaining a length two-thirds that of the lateral horns, but

[1] Bull. de l'Instit. océanog., No. 110, 1908, p. 6.

never equaling them. None of the lateral horns were as long as in Wright's figure, and they were usually slender, the stoutest ones measuring 2 mm. in diameter. They sometimes taper and sometimes enlarge toward the tip, are of about the same size and length on the two sides, and usually project at an angle of 45°.

The head varies in the proportion of length to breadth, but is always wider than long, rarely twice as wide as long; it is generally divided into two lobes, though sometimes obscurely, by a groove which runs the length of the ventral surface, makes a slight depression on the frontal margin, and disappears on the dorsal surface. The anterior end of the head is more or less flattened, rarely slightly concave, and is inclined toward the ventral surface. This flattened portion is covered with frontal processes branched like cauliflowers, which are packed closely together, are quite uniform in size, and present an even contour.

The proboscis is elongated dorso-ventrally and is completely hidden by the frontal processes, which form a double ring or band about it, the separation between the two rings being only slightly but usually distinctly indicated. Along the anterior margin of the head are a number of small protuberances similar to, but larger than, the frontal processes, with which they are usually continuous. There is one on each side of the longitudinal groove, those on the ventral side being nearer together, those on the dorsal side farther apart. On the sides of the head there may be anywhere from one to eight of these processes, not regularly placed, and often more or less digitate like cauliflowers.

The antennae are situated somewhat in front of the center of the dorsal surface, about one-third of the distance from the anterior margin. The integument covering the head is very thin and yielding to the touch; the horns and the anterior thorax are much more rigid.

The thorax varies considerably in length; anteriorly it joins the head abruptly, retains a uniform width for most of its length, and enlarges gradually at the posterior end to meet the trunk. The latter is ribbed transversely, the ribs being sometimes quite prominent, at others but faintly indicated. It is of uniform diameter (twice that of the neck) as far back as the vulvae, where it is abruptly constricted to two-thirds its former diameter, and from thence tapers gradually to a bluntly rounded tip.

The filamentous appendages are very numerous and dense, and are directed backward and ventrally, leaving the dorsal side of the abdomen clear; they extend slightly beyond the anus.

The swimming legs are just behind the head, where they occupy one and a quarter to one and a half millimeters of linear space. The two anterior pairs are close together and overlap more or less, while

the interspaces between the second and third and the third and fourth pairs are comparatively large and subequal.

Color.—Head and horns light brown, trunk dark olive brown, the grooves between the ribs lighter in color; egg strings gray white; plumose appendages a deep black.

Total length, exclusive of egg strings, 160 to 180 mm.

(*orthagorisci*, the former generic name of the host.)

Remarks.—This species differs from *instructa*, just described, in the following particulars: The head in the present species is always wider than long, while in *instructa* it is always longer than wide; the horns are usually three and are chitinous, while in *instructa* there are never but two, which are soft in texture; the trunk is comparatively three times the length and twice the diameter of that in *instructa;* the first antennae are so close to the second pair that their bases touch, while in *instructa* they are far removed; Wright represents the second antennae as definitely three-jointed and slender, while in *instructa* they have but two joints and are fully as wide as long.

Genus PEGESIMALLUS Krøyer.

Pegesimallus KRØYER, Bidrag til Kundskab om Snyltekrebsene, 1863, p. 332, pl. 18, fig. 7.

Generic characters of female.—Body made up of five distinct parts: First, an elongate-ovate head, destitute of antennae and mouth parts, but with a small proboscis; second, a short and slender neck; third, a thicker posterior neck covered with excrescences resembling bunches of grapes; fourth, a vermiform anterior trunk, transversely ridged, with a ventral row of soft processes along either side of the midline; fifth, a posterior trunk, in three coils, and covered with villous processes.

Remarks.—The above is adapted from Krøyer's generic diagnosis and gives the principal characters of this parasite. He had but a single specimen which was found amongst some Greenland crabs that were sent to him.

There is nothing in the description or in the figures to show that this is a copepod and not a worm, as there were no egg strings.

It may be a copepod not fully developed and covered with Gymnoblastic Hydroids like those described by Jungersen.[1] But we must have many more details of its structure before we can decide where to place it; meanwhile it may be left here among the Lernaeans where Krøyer located it, with the understanding that its presence is very questionable.

[1] Vidensk. Meddel. fra naturh. Foren., vol. 64, 1911, p. 21.

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1916. ————. The Feathers of the Flying Fish. Agricultural News, West Indies, vol. 15, No. 360, p. 63, 1 text figure.

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1905. Anthony R. and Calvet L. Recherches faites sur la Cétacé capturé à Cette le 6 octobre 1904 (Balaenoptera physalus [Linné]). 1re. Partie. IV, Parasites extérieurs. Bull. de la Soc. phil. Paris (9), vol. 7, pp. 80–85, 1 text figure. *Pennella balaenopterae.*

1905*b*. ————. Note sur les Penella balaenopterae (K. and D.) recueilles sur le Balaenoptera physalus (Linn.) de Cette (octobre 1904). Bull. Mus. Hist. nat., Paris, 1905, pp. 198–200.

330 B. C. Aristoteles. De Historia Animalium. Published in 50 volumes.

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Proved the presence of eyes and anal laminae in various genera of the Lernaeidae.

1868. ————. Beobachtungen über Lernaeocera, Peniculus, und Lernaea. Ein Beitrag zur Naturgeschichte der Lernaeen. Schrift. Gesellsch. Beförd. ges. Naturw. Marburg, vol. 9. Supplement, Heft 2. 32 pp., 4 plates.

The first detailed account of the development of *Lernaea (Lernacocera) branchialis,* pp. 16–27, pl. 3, figs. 3–9; pl. 4, figs. 1–18.

1868*b*. ————. Ueber die Metamorphose und systematische Stellung der Lernaeen. Sitzungsb. Gesellsch. Beförd. ges. Naturw. Marburg, 1868, No. 2, pp. 5–13.

A careful study of the development stages shows the closest relationship between the Lernaeidae and the Caligidae.

1868*c*. ————. Ueber Lernaeocera esocina. Zeitschr. ges. Naturw. Halle, vol. 31, pp. 530–531.

An abstract of what was published in 1868. *Lernaea esocina.*

1905. Cligny, A. Sur un Lernaeenicus parasite du Spratt. Compt. Rend. Soc. Biol. Paris, vol. 59, pp. 165–166.

1885. COBBOLD, T. SPENCER. Notes on Parasites collected by the late Charles Darwin, Esq. Jour. Linnaean Soc. London, Zoology, vol. 19, pp. 174–178.

Lernaea (Lernaeocera) branchialis and two allied forms mentioned, p. 178.

1856. COCKS, W. P. Lernaea branchialis. Ann. Mag. Nat. Hist., ser. 2, vol. 18, p. 186.

A large specimen (*Lernaeocera b* —.) found on the gills of *Gadus eglefinus*.

1875. CORNALIA, EMILIO. Sulla Taphrobia pilchardi, nuovo genere di Crostacei parassiti. Atti Soc. Ital. Sci. Nat., vol. 18, pt. 2, pp. 197–200, pl. 6.

The new genus is the same as Heller's *Peroderma cylindricum*.

1847. COSTA, A. Note sur la Circulation des Pennelles. Compt. Rend. Acad. Paris, vol. 25, pp. 368–369. Also L'Institut, vol. 15, No. 714, p. 291.

1871. CUNNINGHAM, ROBERT O., M. D. Notes on the Reptiles, Amphibia, Fishes, Mollusca, and Crustacea obtained during the voyage of H. M. S. *Nassau* in the years 1866–69. Trans. Linnaean Soc. London, vol. 27, pp. 465–501, pls. 58, 59.

Lernaeocera, species, p. 500, pl. 59, fig. 11. *Lernaea*, species, p. 500, pl. 59, fig. 10.

1914. CUNNINGTON, WILLIAM A. Zoological Results of the Third Tanganyika Expedition. Report on the parasitic Eucopepoda. Proc. Zool. Soc. London, 1914, pp. 819–829, pl. 1.

Enumerated and gave a key to all the known species of *Lernaeocera* (*Lernaea*) and described and figured three new species, *L. dicraccphala*, p. 824, pl. 1, figs. 1–3; *L. haplocephalo*, p. 826, pl. 1, figs. 4–7; *L. temnocephala*, p. 827, pl. 1, figs. 8 and 9.

1798. CUVIER, GEORGES LEOPOLD. Tableau élémentaire de l'Histoire naturelle des Animaux. 1 vol. 8vo. Paris, An. 6 (1798).

Placed the Lernaeidae amongst the Mollusca gasteropoda with those of the latter which have free motion in the water.

1817. ————. Règne Animal, ed. 1, Paris, 4 vols.

The Lernaeans were discussed in vol. 4, p. 37, and it was for the first time noted that many small animals living on the gills of fishes had been wrongly placed in the Lernaeidae.

1830. ————. Règne Animal, ed. 2, Paris, 5 vols.

Placed the Lernaeans in the second class of Zoophytes, the Entozoa, vol. 3, pp. 255–258 and divided them into 7 groups, Les Lernées propres, Les Pennelles, Les Sphryions, Les Anchorelles, Les Brachielles, Les Clavelles, and Les Chondrachanthes.

1822. DE KAY, JAMES E. Observations on the "Pennatule flèche" (P. sagitta of Lamarck) in the Cabinet of Dr. Mitchill. Amer. Journ. Sci., vol. 4, pp. 87–8, 1 text figure.

Described and figured a mutilated specimen, and called attention to the fact that it had been ranked first as a Lernaean, then as a Pennatula or polyp, afterwards as a *Caligus* or copepod, and finally as an annelid. He himself restored it to the polyps.

1844. ————. Zoology of New York or the New York Fauna. Part VI, Crustacea. Albany, 1844.

Parasitic copepods, pp. 57–60, pl. 10, figs. 44–47. *Lernaea cruciata*, p. 59; *Lernaea (Lernaeenicus) radiata*, p. 60; *Penella plumosa* and *P. filosa*, p. 60. He made this *P. plumosa* a new species, but it was probably the same as the *P. sagitta* described in 1822 (see p. 111).

1823. DESMAREST, ANSELME GAETAN. Article Malacostracés. Dictionaire des Sci. Nat., vol. 28, pp. 138–425.

An effort to supply the omissions in the articles on the Crustacea in the Dictionaire occasioned by the death of Leach, to whom they had been intrusted.

1825. Desmarest, Anselme Gaetan. Considérations générales sur la Classe des Crustacés, et Description des Espèces de ces Animaux, qui vivant dans la mer, sur les côtes ou dans les eaux douces de la France. 8vo. Paris, Strasbourg. 1825, 447 pp. 5 tables, 56 plates.

A reprint of 1823 with many additions. Contained a useful history of the group, their structure, functions, habits, and economy, and a brief review of the classifications previously published, illustrated by five synoptic tables. First referred the Lernaeidae to the Crustacea, p. 343.

1763. Ellis, John, Esq. F. R. S. Of the Sea Pen or Pennatula phosphorea of Linnaeus; also a Description of a new species of Sea Pen, found on the Coast of So. Carolina, with Observations on Sea Pens in general. Philos. Trans., vol. 53, p. 419 seq., pl. 1.

Pennatula (*Pennella*) *filosa* and *P. sagitta*, p. 433.

1780. Fabricius, Otho. Fauna Groenlandica. 8vo., Hafniae et Lipsiae, 452 pp., 1 unn. plate.

All the species are placed under the one genus *Lernaea* and include *gadina*, p. 336; *cyclopterina* and *salmonea*, p. 337; *uncinata*, p. 338; *gobina*, p. 339; *radiata*, p. 340; *nodosa*, p. 341. The Latin descriptions are very accurate in their details but there are no figures.

1858. Flower, W. H. Exhibition of Penellus blainvilli, M. Edwds, on Flying-fish. Proc. Zool. Soc. London, vol. 26, p. 372.

1913. Fowler, Henry W. Notes on the fishes of the Chincoteague region of Virginia. Proc. Acad. Nat. Sci., Philadelphia, vol. 65, pt. 1, pp. 61–65.

"*Lernaeacnicus radiatus*" found on *Brevoortia tyrannus*.

1913*b*. ————. The Crustacea of New Jersey. Report New Jersey State Mus. for 1911 (1913), pp. 29–650, pls. 1–150.

Lernaeacnicus radiatus, p. 87, pl. 21. *Pennella filosa*, p. 90, pl. 22. *Pennella sagitta*, p. 91, pl. 23. *Lernaeoceropsis septemramosus*, n. gen.; n. sp., p. 92, pl. 24; a synonym of *Lernaeacnicus radiatus*. *Lernaeocera* (*Lernaea*) *cruciata* and *L. tortua*, p. 477.

1876. Friederichsen, L. Kleine Mittheilungen aus dem Museum Godeffroy. Journ. Mus. Godeffroy, vol. 12, pp. 160–175.

Lernaeacnicus abdominalis found upon *Boreogadus productus* Günther, on the Peruvian coast, p. 160.

1904. Gadd, Pehr. Parasit-Copepoder i Finland. Acta Soc. Fauna Flora Fennica, vol. 26, No. 8, 60 pp., 2 plates.

Lernaeocera (*Lernaea*) *esocina*, pp. 42–44.

1895. Garbini, A. Appunti di Carcinologia veronese. Mem. Accad. Verona, vol. 71, ser. 3, fasc. 1, 94 pp., 1 plate.

Lernaeocera (*Lernaea*) *esocina* and *L. cyprinacea*.

1560. Gesner, Conrad. Historia Animalium-De Aquatilibus. 5 vols. folio. Zurich.

Described *Pennella* and the Lernaeans, vol. 5, chap. 8, and gave the history of the parasites. The *Pennella* was seldom to be seen except at the time of the rising of the dogstar, and then not on many fishes, but only on the tunny, swordfish, and occasionally on the dolphin. He gave a text figure, p. 112, and repeated (p. 115) the figure given by Rondeletius.

1888. Giard, Alfred. Sur le Peroderma cylindricum (Heller), Copépode parasite de la Sardine. Compt. Rend. Acad. Paris, vol. 107, pp. 929–931. Also in Bull. Sci. de la France et le Belgique, ser. 3, vol. 2, pp. 312–314.

1889. ————. Sur l'association de Pennella orthagoriscî Percival Wright, et de Conchoderma virgatum Spengler. Le Naturaliste (2), vol. 11, No. 50, p. 82.

The *Pennella* of *Balaenoptera rostrata* often shows specimens of *Conchoderma* attached to its thorax. Mayer had also seen them on *P. filosa* from the swordfish, and Giard added the finding of them on *P. orthagoriscî*.

1790. Gmelin, Johann Friedrich. Linnaeus Systema Naturae, Editio decima tertia, aucta, reformata, cura. Lipsiae, 1790.

All the parasitic copepods are bunched under the genus *Lernaea*, pp. 3144–3147.

1784. Goeze, Johann A. E. Von der Fischlernaeen. Leipziger Mag. Naturk., 1784, pp. 39–49, pl. 1.

1879. Goode, G. Brown. The Natural and Economic History of the Menhaden. Rep. U. S. Comm. Fish. for 1877, pp. 1–529.

Mentioned (p. 104) one or more species of Lernaeans on the gills and *Lernaeenicus* upon the external surface, and figured the latter, pl. 10, fig. 15.

1883. ————. Materials for a History of the Sword-fish. Rep. U. S. Comm. Fish. for 1880, pp. 289–394.

Described, p. 346, *Pennella filosa* and *P. costaii* and three other parasitic copepods which infest this fish.

1870. Hartmann, Robert. Beiträge zur anatomischen Kenntniss der Schmarotzer-Krebse. 2. Lernaeocera barnimii. Arch. Anat. Physiol., 1870, pp. 726–752, pls. 17, 18.

Detailed morphology of the female, considerable histology, and some of the larval development. *Lernaea barnimii.*

1871. ————. Ueber d. v. Poren durchsetzte Chitinskelet der Caliopus, Cecrops und gewisser Lernaeoceren. Sitzungsb. Gesell. Naturf. Freunde, Berlin (Oct. 1870), 1871, pp. 60–61.

1865. Heller, Dr. Camil. Reise der österreichischen Fregatte *Novara*. Zoologischer Theil, Zweiter Band. III Abtheilung. 1. Crustaceen, Wien, 4to, 280 pp., 25 plates.

Lernaeocera (Lernaea) lagenula, n. sp., p. 246, pl. 24, fig. 9. *Lernaeonema (Lernaeenicus) gracilis*, n. sp., p. 249, pl. 25, fig. 5. *Peroderma*, n. gen., p. 250. *Peroderma cylindricum*, n. sp., p. 250, pl. 25, fig. 6. *Lernaeolophus*, n. gen., p. 251. *Lernaeolophus sultanus*, n. sp., p. 251, pl. 25, fig. 7.

1783. Hermann Jean. Helmintologische Bemerkungen. Der Naturforscher (J. E. I. Walch), No. 19, pl. 2.

Described *Lernaea squamicola* and *L. lotae* (see p. 40).

1863. Hesse, Eugène. Recherches sur quelques Crustacés rares ou nouveaux des Côtes de France. 2me Mémoire. De le Lernée branchiale et de celle qui vit sur le Gade barbu. Ann. Sci. Nat. (4), Zool., vol. 20, pp. 101–121, pl. 1.

1870. ————. Description d'une nouvelle espèce de Crustacé parasite de l'ordre des Lernéidiens de la famille des Lernéocériens, et du genre Lernée, Lernée du Gade-petit. Lernaea gadi minuti (nobis). Ann. Sci. Nat. (5), Zool., vol. 13, 30 pp., 1 plate.

A larval *L. branchialis.*

1891. ————. Description d'une nouvelle Lernée branchiale du Chaboisseau de Mer a longues Épines (Cottus bubalis, nobis). Ann. Sci. Nat. (7), Zool., vol. 11, pp. 187–195, pls. 6, 7.

Advocated a cirriped origin for *Lernaea (Lernaeocera)*. Neither figures nor description locate the species with any satisfaction.

1904. Hofer, Dr. Bruno. Handbuch der Fischkrankheiten. 8vo. München. 359 pp., 222 text figures, 18 colored plates.

Parasitic copepods on the skin and gills, pp. 144–190.

1802. Holten, H. S. Anmaerkninger till Beskrivelsen over Zeus guttatus samt Beskrivelser over tvende nye Arter Lernaeer. Skrivt. Naturh. Selsk., vol. 5, pt. 2, pp. 129–137, pl. 3.

Lernaea (Chondracanthus) merluccii, p. 135, pl. 3, fig. 2. *Lernaea (Pennella) exocoeti*, p. 136, pl. 3, fig. 3.

1878. Horst, Dr. R. Ueber zwei neue Schmarotzerkrebse. 1. Lernaeenicus gempyli, ein Schmarotzerkrebs von einem Fische (Gempylus serpens). 2. Ein Schmarotzerkrebs von eine Annelide (Polynoe rarispina). Tijdschr. Nederlandsche Dierk. Vereen. (Haag), Leyden, vol. 4, pp. 51–55, pl. 3, figs. 1–5.

L. gempyli here referred to the genus *Sarcotretes*.

1835. Johnston, George, M. D. Illustrations in British Zoology. Loudln's Mag. Nat. Hist., vol. 8, pp. 565–569, fig. 53, text.

Lernaea (Clavella) uncinata.

1888. Joubin, L. Note (contenue dans un pli cacheté) sur les ravages causés chez les Sardines par un Crustacé parasite. Compt. Rend. Acad. Paris, vol. 107, pp. 842–844.

Lernaeenicus, species.

1888*b*. ————. Sur un Copépode parasite des Sardines. Compt. Rend. Acad. Paris, vol. 107, pp. 1177–1178.

Lernaeenicus, species.

1911. Jungersen, Hector F. E. On a new Gymnoblastic Hydroid (Ichthyocodium sarcotretis) epizoic on a new parasitic Copepod (Sarcotretes scopeli) infesting Scopelus glacialis, Rhdt. Vid. Meddel. Naturh. Foren, Kjøbenhavn, vol. 64, pp. 1–33, pls. 1, 2, 6 text figures.

Gave the larval development of the copepod as well as the morphology of the adult female. Condensed reprint in Nature, London, vol. 88, No. 219b, p. 25.

1880. Kellicott, David S. Observations on Lernaeocera cruciata. Proc. Amer. Soc. Microscopists, vol. 1, pp. 64–68, pls. 1 and 2.

Lernaea cruciata.

1881. ————. Lernaeocera tortua, n. sp. Proc. Amer. Soc. Microscopists, vol. 2, pp. 41–43, 1 unn. plate.

Lernaea tortua.

1882. ————. On Certain Crustaceans Parasites of Fresh-water Fishes. Proc. Amer. Soc. Microscopists, vol. 4, pp 75–78.

Lernaeocera (Lernaea) pectoralis from axilla of redfin shiner, *Luxilus cornutus*.

1858. Kneeland, Dr. On the Parasites of a Sunfish. Proc. Boston Soc. Nat. Hist., vol. 6, p. 396.

A species of "*Lernaea*" (*Pennella ?*) was attached in large numbers around the dorsal and anal fins.

1860. Koch, C. L. Collezio Adriatico del Museo di Storia naturale di Trieste. Trieste, 1860.

Lernaeolophus sultanus.

1775. Koelreuter, Jos. Gli. Lernaeae forsan adhuc incognitae Gadi callarii L. branchiis firmiter inhaerentis descriptio. Comment. Acad. Theod. Palat., vol. 3, Phys., pp. 57–61.

Probably *Lernaeocera branchialis*.

1877. Koren, J. and Danielssen, D. C. A new Species of the Genus Pennella, Pennella balaenopterae, nobis. Fauna Littoralis Norvegiae, pt. 3, pp. 157–163, pl. 16, figs. 1–9.

An excellent description and figures showing the internal as well as the external morphology.

1835–8. KRØYER, HENRIK. Om Snyltekrebsene, isaer med Hensyn til den Danske Fauna. Naturh. Tidsskr., vol. 1, pt. 2, 1835, pp. 172–208, pl. 2; pt. 3, 1835, pp. 252–304, pl. 3; pt. 5, 1837, pp. 476–504, pl. 5; pt. 6. 1837, pp. 605–628, pl. 6; vol. 2, pt. 1, 1838, pp. 8–52, pl. 1; pp. 131–157, pl. 3.

A review of the entire group giving its distinguishing characters and a systematic synopsis based upon that of Burmeister (1833), dividing the group into five classes, the first of which was the Penellina, including the genera *Lernaca, Lernaeoccra, Peniculus, Pennella,* and *Sphyrion.* The only species described belonging to this class were *Lernaea (Lernaeoccra) branchialis,* p. 293, pl. 3, fig. 10, and *Lernaca (Haemobaphes) cyclopterina,* p. 502, pl. 5, fig. 4.

1863. ————. Bidrag til Kundskab om Snyltekrebsene. Naturh. Tidssk. (3), vol. 2. pp. 75–426, pls. 1–18.

Also as a reprint with pages numbered 1–352. The following references are to the latter. *Therodamas serrani,* n. gen.; n. sp., p. 316, pl. 15, fig. 4. *Lernaca (Lernacolophus) hemiramphi,* n. sp., p. 318, pl. 15, fig. 7. *Lernaea (Lernaeoccra) rigida,* n. sp., p. 320, pl. 18, fig. 2. *Lernaeoccra (Lernaca) catostomi,* n. sp., p. 321, pl. 18, fig. 4. *Lernaeoccra (Lernaca) pomotidis,* n. sp., p. 323, pl. 15, fig. 5. *Lernaeoccra (Lernaca) phoxinacca,* p. 325, pl. 18, fig. 3. *Pegesimallus spiralis,* n. gen.; n. sp., p. 332, pl. 18, fig. 7. *Peniculus elavatus,* p. 266, pl. 14, fig. 8.

1801. LAMARCK DE, JEAN B. P. Système des Animaux sans vertèbres. 1 vol. 8vo. Paris, An IX (1801).

Placed the Lernaeidae among the mollusks.

1809. ————. Philosophie-Zoologie. 8vo. Paris.

Removed the Lernaeidae from the mollusks and placed them with the annelids.

1812. ————. Extrait du Cours de Zoologie sur les Animaux sans Vertèbres. 8vo. Paris.

Formed a separate class to receive the Lernaeans which he named the "Epizoaires".

1816. ————. Historie Naturelle des Animaux sans Vertèbres. 7 vols. 8vo. Paris. Another edition, 1838.

Placed the Lernaeans with the "Epizoaria" and said "These animals approach near to the worms and insects without belonging to either".

1798. LAMARTINIÈRE. Atlas du Voyage de *La Peyrouse.*

Gave a figure, pl. 20, fig. 6, of *Pennatula bocconii,* probably *Pennella sagitta.*

1889. LEIDY, JOSEPH. Parasitic Crustacea. Proc. Acad. Nat. Sci., Philadelphia. 1888. p. 165.

Described *Lerneonema (Lernaeenicus) procera,* n. sp., attached to the sides of the mouth and upper lip of "*Odontaspis littoralis,*" and thickly covered with a hydroid parasite.

1890. ————. Parasites of Mola rotunda. Proc. Acad. Nat. Sci., Philadelphia, 1890, pp. 281–282.

Pennella filosa mentioned and described.

1824. LE SUEUR, C. A. On three new species of Parasitic Vermes belonging to the Linnaean Genus Lernaea. Journ. Acad. Nat. Sci., Philadelphia, vol. 3, pp. 286–293, pl. 11. fig. 1–4.

Lerneocera cruciata, n. sp., p. 286, pl. 11, fig. 4; *Lerneocera radiata,* n. sp., p. 288, pl. 11, fig. 1. *"Lerncaenicus,"* n. gen., p. 289. *Lerneopenna blainvillii,* n. sp., p. 289, pl. 11, figs. 2 and 3 (see p. 115).

1825. ————. Sur trois nouvelles espèces du genre Lernaea. Féruss. Bull. Sci. Nat., vol. 4, pp. 285–286. French translation of 1824 paper.

1746. LINNAEUS, CAROLUS. Fauna Suecica Sistens Animalia Suecica Regni. Ed. 1, 1 vol. 8vo. Stockholm. Ed. 2, 1 vol. Stockholm, 1761.

Described a parasite found upon *Cyprinus carassius,* and established from this species the genus *Lernaea.*

1758. Linnaeus, Carolus. Systema Naturae. Tenth Edition, 8vo., Stockholm.

The genus *Lernaea* contained here three species, *cyprinacea*, the original type, *asellina*, afterward made the type of the genus *Oralicu*, and *salmonca*, which now belongs to the genus *Salmincola* (p. 655). Genus *Pennatula* (p. 818) changed to *Pennella* by Oken in 1815. *P. filosa* and *P. sagitta*, p. 819.

1893. Listowsky, E. Penella tridentata, neuer Art der parasitirenden Crustaceen. Tradui Kazan. Univ., vol. 25, pt. 2, 19 pp., 1 unn. plate.

Russian prefaced by a three-line Latin diagnosis.

1860. Lubbock, Sir John. On some Oceanic Entomostraca collected by Captain Toynbee. Trans. Linnaean Soc., vol. 23, p. 190, pl. 29, figs. 40 and 42.

Baculus elongatus, n. gen.; n. sp., which was afterward proved to be a larval stage of *Penncila* species (compare Mrazek, 1895, and Thompson, 1890.)

1893. Lütken, Christian. Slaegten Baculus Lubbock et udviklingstrin af Penella. Vidensk. Meddel. Naturh. For. Kjøbenhavn (5), vol. 15, pp. 73–76.

Shows that Lubbock's *Baculus* is an undeveloped *Penncila* species.

1879. Mayer, Paul. Carcinologische Mittheilungen. V. Pennella und Conchoderma. Mitth. Zool. Stat. Naples. vol. 1, p. 53.

Pennella filosa from a swordfish and infested with a goose barnacle.

1868. Metzger, A. Ueber das Männchen und Weibchen der Gattung Lernaea vor den Eintritt der sogen. ruckschreitenden Metamorphose. Arch. Naturg., vol. 34, pp. 106–110.

Translated in Ann. Mag. Nat. Hist., ser 4, vol. 3, pp. 154–157, 1869.

1840. Milne Edwards, Henri. Histoire Naturelle des Crustacês. 3 vols. 8vo. **Paris.**

A standard work containing a summary of everything previously published and much new material. The Lernaeans, pp. 521–529, pls. 40, 41. *Lernconema*, n. gen., p. 524, the same as LeSueur's *Lernaeenicus*.

1881. Moreau, Emile. Histoire Naturelle des Poissons de la France. Paris, 3 vols.

Mentioned, vol. 3, p. 460, *Lernaeenicus sprattae* fastened to the eye of a spratt.

1895. Mrázek, Al. Ueber Baculus Lub. und Hessella Br. Ein Beitrag zur Anatomie der Lernaeiden. Sitzungsb. königl. böhmischen Ges. Wiss., Math.-Naturw. Classe, vol. 44, 17 pp., pls. 1, 2.

Both of these so-called new genera are really development stages of a *Penncila* species. The description of *Baculus* includes the internal anatomy as shown in serial sections.

1776. Müller, Otho F. Zoologiae Danicae Prodromus. 1 vol. 8vo. Copenhagen.

Afterwards published in full in four volumes, German and Latin, from 1779 to 1784. The Lernaeans were placed with the worms and mollusks.

1682. Muraltus. Miscellania curiosa sive Ephemeridum Medico Physicarum Germanicarum Academiae Naturae Curiosum. 8vo. Nuremberg.

While dissecting *Mustela fluviatilis* he found "an insect" inserted into the eye of the fish and hanging out from it. It was so firmly fixed by its arms that no doubt it caused the humours of the eye to escape and rendered the fish blind (p. 126). Probably *Trypaphylum musteli*.

1856. Murray, Andrew. Description of a new species of Echeneis (E. tropicus) and of a new Lernean of the genus Penella (P. remorae), infesting the Echeneis remora; with some remarks on the economy of the Remora. Edinburgh New Philos. Jour., n. s., vol. 4, pp. 287–301, 5 text figures.

This *P. remorae* is almost certainly the young of some described species.

1878. NARES. Narrative of a voyage to the Polar Sea during 1875–76 in H. M. Ships *Alert* and *Discovery*. 2 vols. London.

Haemobaphes cyclopterina, vol. 2, p. 247.

1832. NORDMANN, ALEX VON. Erster Beitrag zur Naturgeschichte der Lernäen. Mikrogr. Beitr. Naturg. wirbel. Thiere, pt. 2, pp. 49–144, pls. 1–10.

Peniculus fistula, n. gen., n. sp., p. 107, pl. 6, figs. 8–13. *Pennella sagitta*, p. 121, pl. 10, figs. 6–8. *Lernaeocera* (*Lernaea*) *cyprinacea*, p. 123, pl. 6, figs. 1–7. *Lernaeocera branchialis*, p. 130.

1864. ————. Neue Beiträge zur Kenntniss parasitischer Copepoden. Erster Beitrag. Bull. Soc. Imp. Nat. Moscou, vol. 37, No. 4, pp. 461–520, pls. 5–8.

Begins with a bibliography of the subject and then gives a classification of the known genera. *Pennella sultana* with var. *sigmoidea*, p. 485, pl. 5, figs. 12–16. *Peniculus fistula* and *P. calamus*, n. sp., p. 515.

1759. ODHELIUS, J. L. Chinensia lagerstromiana. Amoen. Acad. (of Linnaeus), vol. 4, p. 257, fig. 3, text.

A description of *Pennella sagitta*.

1816. OKEN, L. Lehrbuch der Naturgeschichte. Dritter Theil, Zoologie. 2 vols. 8vo. Jena, with Atlas.

Parasitic Copepods, vol. 2, pp. 181, 357.

1821. OKEN, CHAMISSO, and EYSENHARDT. Ueber Pennella diodontis. Nova Acta Acad. Caes. Leopold. Bonn, vol. 10, p. 350, pl. 24, fig. 3. Also published in Actes nouv. Acad. Curieux Nature, vol. 10, pt. 2, pl. 24, fig. 2.

120 A. D. OPPIANUS. Ἁλιευτικά, On Fishing.

Repeated Aristotle's description of the sufferings of the tunny and swordfish and declared that the fish are frequently killed by these parasites, liber 11, p. 24.

1867. PACKARD, ALPHEUS S., Jr. Observations on the Glacial Phenomena of Labrador and Maine, with a View of the Recent Invertebrate Fauna of Labrador. Mem. Boston Soc. Nat. Hist., vol. 1, pp. 295–303, pl. 8.

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A simple list without descriptions or figures.

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Lernaeocera branchialis.

1897. ————. Ueber die Entwickelung des Nervensystems und der Genitalzellen und die Dorsalorgane von Lernaea branchialis. Arbeit. Nat. Ges. Petersburg, vol. 37, 11 pp. Condensed and reprinted in Trav. Soc. Impér. Nat. St.-Pétersbourg, vol. 27, No. 6, pp. 187–194.

Lernaeocera branchialis.

1898. Pedaschenko, D. D. Die Embryonalentwickelung und Metamorphose von Lernaea branchialis. Trav. Soc. Impér. Nat. St.-Pétersbourg, vol. 26, pt. 4, No. 7. Section Zool. et Physiol. Russian text, pp. 1–246; German text, pp. 247–307, pls. 1–6.

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78 A. D. Plinius Secundus, Caius. Historia Naturalis. 37 Books.

Repeated, Book 9, Section 16, what Aristotle had said with reference to the sufferings of the tunny and swordfish from the parasites infesting them.

1910. Quidor, Auguste. Note préliminaire sur Penella balaenopterae Koren et Danielssen. Bull. Mus. Hist. Nat., Paris, 1910, pp. 97–98.

A mutilated specimen identified by mode of insertion and branching of abdominal appendages.

1912. ————. Affinités des genres Sphyrion (Cuvier) et Hepatophilus (g. n.). Arch. Zool., Paris, (5), vol. 10, pp. xxxix–l, 6 text figures.

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1912*b*. ————. Deuxième Expédition Antarctique Française (1908–1910). Copépodes Parasites. Sciences Naturelles: Documents Scientifiques, pp. 197–214, pls. 1–4.

Penella antarctica, n. sp., p. 206, pl. 1, figs. 15–17; pl. 4, fig. 29, 34. *Penella charcoti*, n. sp., p. 207, pl. 1, fig. 13; pl. 2, fig. 25; pl. 4, fig. 33. *Penella liouvillei*, n. sp., p. 209, pl. 1, fig. 1. *Penella diodontis*, pl. 1, fig. 2. *Penella exocoeti*, pl. 1, fig. 3. *Penella sagitta*, pl. 1, fig. 4. *Penella anthonyi*, n. sp., pl. 1, fig. 9. *Penella cetti*, n. sp., pl. 1, figs. 11, 12. *Penella balaenopterae*, pl. 1, fig. 14. *Lernaea (Lernaeocera) godfroyi*, n. sp., p. 210, pl. 2, fig. 23.

1912*c*. ————. Sur la torsion des Lernaeidae et les affinités du genre Sphyrion (Cuvier) et Hepatophylus (n. g.). Compt. Rend. Acad. Paris, vol. 154, pp. 87–89.

The torsion is the result of the mode of fixation, the habits of the host, and the mechanical action of the external medium. It plays an important rôle in systematization as it enables us to distinguish the Chondracanthidae from the Lernaeidae, and to transfer the genus *Sphyrion* from the former to the latter. (See p. 10.)

1913. ————. Affinités des Caligidae et des Lernaeidae; Caligodes lamarcki. Bull. Soc. Zool. France, vol. 38, No. 6, pp. 191–196, 7 text figures.

The genera *Echetus*, *Sciaenophilus*, and *Caligodes* bury themselves deeply in the tissues of the host, they have a slender and cylindrical neck, and they show the flexion and torsion characteristic of the Lernaeidae, but the appendages and mouth-parts are like those of *Caligus*.

1913*b*. ————. Sur Lamarckina caligusa, n. gen.; n. sp. et l'évolution des Lernaeidae. Compt. Rend. Acad. Sci. Paris, vol. 156, pp. 1096–1097.

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1905. Rathbun, Mary J. Fauna of New England. 5. List of the Crustacea. Occas. Pap. Boston Soc. Nat. Hist., No. 7, pp. 86–103.

1884. Rathbun, Richard. Annotated List of the described Species of Parasitic Copepoda (Siphonostoma) from American Waters contained in the United States National Museum. Proc. U. S. Nat. Mus., vol. 7, pp. 483–492.

1843. Rathke, Heinrich. Beiträge zur Fauna Norwegens. I. Crustacea. Nova Acta Acad. Caes. Leopold, vol. 20, pt. 1, pp. 1–132, pls. 1–5.

Lernaea (Lernaeocera) branchialis, p. 129.

1876. RICHIARDI, S. Intorno al Peroderma cylindricum dell' Heller, e sopra due specie nuove dell' genere Philichthys. Atti Soc. Toscana Sci. Nat. Pisa, vol. 2, pt. 2, pp. 189–201, pl. 6.

1877. ————. Descrizione di due specie nuove di Lernaeenicus con osservazione intorno a questo ed ai generi Lernaeocera Bl., e Lernaeonema, M. Edwds. Atti. Soc. Toscana Sci. Nat. Pisa, vol. 3, pt. 1, pp. 195–206, pl. 7.

Lernaeenicus vorax, n. sp., p. 203, pl. 7, figs. 1–21. *L. neglectus*, n. sp., p. 206, pl. 7, figs. 23–43.

1878. ————. Del nuovo genere di crostaceo Trypaphylum e delle nuove specie Phyllophora crassa, e Lernanthropus foliaceus. Atti. Soc. Toscana Sci. Nat., Pisa, Proc. Verb., vol. 1, p. xx.

Trypaphylum musteli from the muscles of the hyoid apparatus of *Mustelus plebejus* Bp. No description or figures.

1880. ————. Contribuzione alla Fauna d'Italia. Catalogo sistematico dei Crostacei che vivono sul corpo degli animali acquatici. Exposizione internazionale di Pesca in Berlino, 1880, pp. 147–152.

A list of 130 species of parasitic copepods without any descriptions or figures, 57 of them being new species, which thus become mere *nomina nuda*.

1880*b*. ————. La Clupea sprattus ed il Lernaeenicus sprattae. Atti Soc. Toscana Sci. Nat. Pisa, Proc. Verb., vol. 2, p. 101. Also in Zool. Anz., vol. 3, p. 642.

1881. ————. Intorno a due specie nuove di Crostacei parassiti. Atti. Soc. Toscana Sci. Nat. Pisa, Proc. Verb., vol. 2, p. 247.

Peroderma petersi, n. sp., p. 247. Abstract in Zool. Anz., vol. 4, pp. 386–387.

1882. ————. Intorno ad una nuova specie del genere Peroderma. Atti Soc. Toscana Sci. Nat. Pisa, Proc. Verb., vol. 3, p. 149. Abstract in Zool. Anz., vol. 5, pp. 475–476.

Peroderma belottii in the muscles of the hyoid apparatus of *Scopelus benoiti*. Species here transferred to new genus *Cardiodectes*.

1903. RICHTERS, FERDINAND. Lernaeonema encrasicoli, Baird, ein Parasit der Sprotte. Prometheus, vol. 14, pp. 267–268, 1 text figure.

Lernaeenicus encrasicholi.

1886. RIDLEY, STUART O. Animal Life in High Latitudes on the Norway Coast. The Zoologist, Oct., 1886, 6 pp.

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1554. RONDELET, GUILLAUME. Libri de piscibus marinis. 1 vol. folio, Lyon.

Repeated Aristotle's and Pliny's account of the parasites of the tunny and swordfish in the Mediterranean, p. 249.

1911. SAEMUNDSSON, B. Bidrag til Kundskaben om de islandske Hydroider. Vidensk. Medd. Naturh. Foren., Kjøbenhavn, vol. 63.

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1850. SALTER, JAMES. Description of Lerneonema bairdii. Ann. Mag. Nat. Hist., ser. 2, vol. 6, pp. 85–87, pl. 7, figs. 1–5.

Lernaeenicus sprattae.

1554. SALVIANI, HIPPOLYTE. Aquatilium Animalium Historiae. 1 vol. folio, Rome.

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1886. Sars, George O. The Norwegian North Atlantic Expedition (1876–1878). vol. 6, pt. 2, Crustacea et Pycnogonidia nova in Expeditione Norvegicae 1876–78 collecta. Christiania.

Parasitic Copepods, p. 80.

1896. Schimkewitsch, Wlademir. Sur les premiers Stades du Développement des Copépodes parasitaires. Compte Rendu des Séances du troisième Congrès International de Zoologie, Leyden, 1896, pp. 503–504.

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1898. ————. Zu einen Referat des Herrn Prof. Dr. R. S. Bergh (Ueber Entwickelung von Lernaea). Zool. Anz., vol. 21, No. 550, p. 48.

1910. Schneider, Guido. Verletzungen an Cyprinus vulgaris. Riga Korrblatt. Naturf. Ver., No. 53, pp. 112–113.

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1901. Scott, Andrew. Liverpool Marine Biological Committee Memoirs on typical British Marine Plants and Animals. VI. Lepeophtheirus and Lernaea. London, Royal 8vo, 1 vol., 54 pp., 5 plates, 1 text figure. Also in Trans. Liverpool Biol. Soc., vol. 15, pp. 188–241, pls. 1–5.

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A simple list without descriptions or figures.

1900. Scott, Thomas. Notes on some Crustacean Parasites of Fishes. 18th. Ann. Rep. Fish. Board Scotland, pt. 3, pp. 144–187, pls. 5–8.

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1904. ————. On some Parasites of Fishes new to the Scottish Marine Fauna. 22nd. Ann. Rep. Fish. Board Scotland, pt. 3, pp. 275–280, pl. 17.

Lernaea (*Lernaeocera*) *lusci*, p. 277, pl. 17, figs. 12, 13.

1905. ————. III. Observations on some Parasites of Fishes new or rare in Scottish Waters. 23rd. Ann. Rep. Fish. Board Scotland, pt. 3, pp. 108–119, pls. 5–6.

Pennella filosa and *Lernaea* (*Lernaeocera*) *lusci*, p. 113.

1909. ————. Some Notes on Fish Parasites. 26th Ann. Rep. Fish. Board Scotland, pt. 3, pp. 73–92, pls. 3–7.

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1874. SMITH, SIDNEY I. Invertebrate Animals of Vineyard Sound and adjacent Waters. Rep. Comm. Fish. for 1871 and 2, pp. 295–747, pls. 1–38.

Parasitic Copepods, pp. 574–578.

1874*b*. ————. The Crustacea of the Fresh Waters of the United States. B. The Crustacean Parasites of the Fresh-water Fishes of the United States. Rep. Comm. Fish. for 1872 and 3, pt. 2, pp. 661–665.

Mentioned *Lernaeocera* (*Lernaea*) *cruciata* and *L. catostomi*, p. 665.

1884. ———— Review of the Marine Crustacea of Labrador. Proc. U. S. Nat. Mus., vol. 6, pp. 223–232.

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1905. STEBBING, REV. T. R. R. South African Crustacea. Part III. Marine Investigations in South Africa, vol. 4, pp. 21–120, pls. 17–26.

Pennella orthagorisci, p. 119.

1861. STEENSTRUP, J. J. S. Det aabne Havs Snyltekrebs, etc. (Copepoda parasita et Lernaea oceani Atlantici et Arctici). Arch. Soc. Phys. Nat., Genève (nouv. pèri.), vol. 12, pp. 190–192.

1860. STEENSTRUP, J. J. S. and LÜTKEN, CH. Uddrag af Bidrag til Kundskab om det aabne Havs Snyltekrebs og Lernaeer. Overs. Kongl. Dansk. Vidensk. Selsk. For., 1860, pp. 185–193.

1861. ————. Bidrag til Kundskab om det aabne Havs Snyltekrebs og Lernaeer. Kongl. Dansk. Vidensk. Selsk. Skrift., 5te Raekke, naturh. og mathem. Afdeling, vol. 5, pp. 343–432, pls. 1–15.

Lernaeonema and *Lernaeenicus*, p. 398. *Lernaeenicus nodicornis*, n. sp. and *L. inflexus*, n. sp., p. 401, pl. 13, figs. 26 and 27; both are here referred to Jungersen's genus *Sarcotretes*. *Lernaea* (*Lernaeocera*) *branchialis*, *var. sigmoida*, new, p. 404, pl. 13, fig. 29. *Haemobaphes*, n. gen., p. 405; *H. cyclopterina*, type species, pl. 13, fig. 30. *Pennella sagitta*, p. 409, pl. 14, fig. 31. *P. varians*, n. sp., p. 413, pl. 14, fig. 32. *P. exocoeti*, p. 415, pl. 14, fig. 33. *P. crassicornis*, n. sp., p. 416, pl. 14, fig. 34.

863. ————. Recherches sur les Siphonostomes et les Lernées de la haute mer et sur d'autres Copépodes parasitaires nouveaux ou peu connus. Extrait. Arch. Soc. Phys. Nat., Genève, (nouv. pèr.), vol. 16, p. 235.

1853. STIMPSON, WILLIAM. Synopsis of the Marine Invertebrata of Grand Manan, or the Region about the Mouth of the Bay of Fundy, New Brunswick. Smithsonian Contr. Knowl., Jan. 1853, pp. 1–67, pls. 1–3.

Lernaea (*Lernaeocera*) *branchialis* on young codfishes.

1915. STOCK, V. On some of the Parasitic Copepods of the Bay of Fundy Fish. Supplement, 47th Ann. Rep. Dept. Fish., Canada, fasc. 1, Marine Biology, pp. 69–71.

1839. STORER, D. H. Report of Fishes and Reptiles of Massachusetts. 8vo. Boston, 1 vol.

Pennella sagitta from the sunfish, p. 172.

1762. STRÖM, HANS. Physisk og Oeconomisk Beskrivelse over Fogderiet Søndmør, beliggende i Bergens Stift i Norge. Første Part, Copenhagen, 8vo.

Lernaea corpore tereti flexuoso, tentaculis tribus subramosis, which is evidently *L. branchialis*, p. 209–210, pl. 1, fig. 18.

1886. Tarr, Ralph. Parasitism among Marine Animals. Science, vol. 7, p. 17.

Pennella, a parasite of the swordfish, is itself infested with parasitic barnacles.

1893. Thompson, I. C. Report on the Copepoda of Liverpool Bay. Trans. Liverpool Biol. Soc., vol 7, pp. 175–230, pls. 15–35.

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1905. Thompson, M. T. Immature Specimens of Pennella filosa. Biol. Bull., vol. 8, pp. 296–307, 6 text figures.

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1843. Thompson, William. Report on the Fauna of Ireland. Division Invertebrata. Rep. British Assoc. Adv. Sci., 1843, p. 270.

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1844. ———. Additions to the Fauna of Ireland. Ann. Mag. Nat. Hist., ser. 1, vol. 13, pp. 430–440.

Lernaeonema monillaris from the sprat.

1849. ———. Crustaceen der Brittischen Fauna. Arch. Naturg., vol. 15, pt. 6, pp. 318–340.

Pennella pustulosa, p. 339.

1889. Thomson, Geo. M. Parasitic Copepoda of New Zealand. Trans. New Zealand Inst., vol. 22, pp. 353–375, pls. 25–29.

Pennella histiophori, n. sp., p. 368, pl. 28, fig. 2. *Lernaea* (*Lernaeocera*) *lotellae*, n. sp., p. 369, pl. 28, figs. 3, 3*a*.

1905. Turner, Sir William. On Pennella balaenopterae; a Crustacean parasitic on a Finner Whale, Balaenoptera musculus. Trans. Roy. Soc. Edinburgh, vol. 41, pt. 2, No. 18, pp. 409–434, pls. 1–4.

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1807. Turton, William. The British Fauna. 2 vols. 8vo. London.

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1886. Underwood, Lucien M. List of the Described Species of Fresh Water Crustacea from America North of Mexico. Bull. Illinois State Lab. Nat. Hist., vol. 2, p. 323–386.

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1859. White, J. C. On the Parasites of Orthagoriscus mola. Proc. Boston Soc. Nat. Hist., vol. 6, p. 404.

Pennella filosa, covered with polyps.

1877. Wierzejski, A. Ueber Schmarotzerkrebse von Cephalopoden. Zeit. wiss. Zool., vol. 29, pp. 562–582, pls. 32–34.

The copepodid stages, male and female, of some species of *Pennella*, probably *varians*, found upon *Sepia*, *Elcdone*, and *Loligo* at Trieste.

1908. Wilson, Chas. B. North American Parasitic Copepods. A List of those found upon the Fishes of the Pacific Coast, with Descriptions of New Genera and Species. Proc. U. S. Nat. Mus., vol. 35, pp. 431–481, pls. 66–83.

Haemobaphes cyclopterina, p. 458. *Lernaeenicus* (*Cardiodectes*) *medusaeus*, n. sp., p. 458, pl. 76, figs. 99, 100. *Phrixocephalus cincinnatus*, n. gen.; n. sp., p. 461, pl. 76, fig. 101.

1908. WILSON, CHAS. B. The Morphology, Development and Economic Relations of the Genus Lernaea.

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1881. WILSON, DR. ANDREW. Degeneration. Pop. Sci. Mon., vol. 19, pp. 218–229, 382–394, 19 text figures.

The Lernaeans, pp. 227–228.

1870. WRIGHT, E. P. On a New Species of the genus Pennella. Ann. Mag. Nat. Hist., ser. 4, vol. 5, pp. 43–47, pl. 1.

Pennella orthagoriscl.

EXPLANATION OF THE PLATES.

an^1	first antennae.
an^2	second antennae.
ba	bulbus arteriosus.
cb	chitin band.
cg	cement gland.
ch	chitinogen layer.
cr	chitin ring.
dg	digestive gland.
e	eye.
eg	excretory gland.
fp	frontal processes.
ig	infra esophageal ganglion.
in	intestine.
l^1	first swimming legs.
l^2	second swimming legs.
l^3	third swimming legs.
l^4	fourth swimming legs.
lb	labium.
lm	labrum.
m	soft membrane.
md	mandible.
mo	mouth.
ms	muscle.
mx^1	first maxilla.
mx^2	second maxilla.
mxp	maxilliped.
od	oviduct.
oe	esophagus.
ov	ovary.
p	posterior prolongation of esophagus.
pb	proboscis.
pc	pore canal.
re	rectum.
sg	supra esophageal ganglion.
sr	semen receptacle.
st	stomach.

PLATE 1.

Female of *Peniculus clavatus*.

Fig. 1. Side view; actual length of egg strings 17 mm. Fig. 2. Head and neck, enlarged, showing antennae, mouth-parts, and musculature of proboscis. Fig. 3. First and second antennae, ventral view. Figs. 4, 5. First and second swimming legs. Fig. 6. Anal laminae. Fig. 7. Ventral view of cleared specimen, showing arrangement of reproductive organs.

PLATE 2.

Female of *Peniculus fissipes*.

Fig. 8. Side view; actual length of egg strings 10.50 mm. Fig. 9. Head and anterior thorax much enlarged. Figs. 10, 11, 12. First, second, third, and fourth swimming legs. Fig. 13. Anal laminae. Fig. 14. Side view of cleared specimen, showing arrangement of reproductive organs.

PLATE 3.

Female of *Cardiodectes medusaeus*.

Fig. 15. Side view of cleared specimen, showing reproductive and digestive systems; frontal processes removed from head. Fig. 16. Side view of head and anterior thorax, with processes in place. Fig. 17. First and second antennae and

rostrum, dorsal view. Fig. 18. Dorsal view of head, processes removed except those on the sides. Fig. 19. Ventral view of head, showing the peculiar entrance of the esophagus into the side of the stomach. Fig. 20. Proboscis enlarged. Fig. 21. Section of body wall, showing pore canal and chitinogen layer. Fig. 22. First three pairs of swimming legs. Fig. 23. Ventral view of cleared specimen, showing reproductive organs.

PLATE 4.

Female of *Lernaeenicus radiatus*.

Fig. 24. Side view, drawn by J. H. Blake. Fig. 25. Posterior view of head, also drawn by J. H. Blake. Fig. 26. Side view, drawn by R. Rathbun. Fig. 27. Top view of head. Fig. 28. Side view of head, showing proboscis and posterior plate at base of antennae. Fig. 29. Dorsal view of head with only two horns. Fig. 30. Diagonal view of same cut open to show the digestive tube. Fig. 31. Side view of proboscis. Fig. 32. Tip of proboscis, showing central plate and maxillae. Fig. 33. Maxilla. Fig. 34. First and second antennae and rostrum. Fig. 35. Side view of posterior trunk with egg strings; figs. 27 to 35 drawn by R. Rathbun.

PLATE 5.

Females of *Lernaeenicus radiatus* and *L. polyceraus*.

Figs. 36 to 39. Swimming legs of *L. radiatus*. Fig. 40. Head and neck, with two sets of horns. Fig. 41. Ventral view of maxilla. Fig. 42. Side view of *L. polyceraus*. Fig. 43. Ventral view of head and neck. Fig. 44. Side view of head. Fig. 45. Attachment lamellae. Fig. 46. Tip of proboscis with maxillae. Fig. 47. Swimming legs.

PLATE 6.

Female of *Lernaeenicus affixus*.

Fig. 48. Side view. Fig. 49. Side view of head fastened to the ray of a fin. Fig. 50. Side view of head with attachment apparatus. Fig. 51. Anterior view of attachment lamellae. Fig. 52. First antenna. Fig. 53. Second antenna. Fig. 54. Tip of proboscis. Fig. 55. Mandibles. Fig. 56. Maxilla. Fig. 57. Anal laminae. Figs. 58 to 61. Swimming legs.

PLATE 7.

Female of *Lernaeenicus longiventris*.

Fig 62. Side view. Fig. 63. Side view of head. Fig. 64. First and second antennae. Fig. 65. The same on another specimen. Fig. 66. Mandibles. Fig. 67. Maxilla. Fig. 68. Swimming legs. Fig. 69. Longitudinal section of head and anterior neck. Fig. 70. Newly hatched nauplius.

PLATE 8.

Female of *Sarcotretes lobatus*.

Fig. 71. Diagonal view, partly dorsal, partly lateral. Fig. 72. Dorsal view of head. Fig. 73. Tip of proboscis, dorsal. Fig. 74. Tip of proboscis, ventral. Fig. 75. First and second antennae. Fig. 76. Maxilla. Fig. 77. Swimming legs. Fig. 78. Lateral view of cleared specimen, showing reproductive organs. Fig. 79. Ventral row of excretory glands.

PLATE 9.

Female of *Phrixocephalus triangulus.*

Fig. 80. Dorsal view of head and neck, side view of trunk. Fig. 81. Ventral view of head and neck with swimming legs. Fig. 82. Diagonal view of head, showing antennae. Fig. 83. Anterior view of head with processes. Fig. 84. Lateral view of cleared specimen, showing reproductive organs.

PLATE 10.

Phrixocephalus triangulus, P. diversus, and *Lernaeocera branchialis.*

Fig. 85. Ventral view of cleared specimen of *P. triangulus,* showing bilateral symmetry. Fig. 86. Diagonal view of *P. diversus.* Fig. 87. Side view of same, showing asymmetrical position of neck. Fig. 88. Metanauplius of *Lernaeocera branchialis;* actual length, 0.55 mm.

PLATE 11.

Female of *Collipravus parvus.*

Fig. 89. Ventral view of head, side view of body. Fig. 90. Side of head (*a*). Fig. 91. Dorsal view of same. Fig. 92. Ventral view of head (*b*). Fig. 93. Dorsal view of same. Fig. 94. Dorsal view of second antennae. Fig. 95. Proboscis and maxillae. Figs. 96, 97. Dorsal and ventral view of cleared specimen, showing asymmetrical arrangement of reproductive organs.

PLATE 12.

Female and nauplius of *Lernaeocera branchialis.*

Fig. 98. Side view. Fig. 99. Central view of head. Fig. 100. Anterior view of head; these three figures drawn by J. H. Blake. Fig. 101. Side view of head with proboscis protruded. Fig. 102. First and second antennae. Fig. 103. Mouth tube and first maxillae. Fig. 104. Second maxilla. Fig. 105. Swimming legs. Fig. 106. Anal laminae. Fig. 107. Newly hatched nauplius; actual length, 0.45 mm.

PLATE 13.

Female of *Lernaeolophus sultanus.*

Fig. 108. Side view. Fig. 109. First and second antennae. Figs. 110, 111. Swimming legs. Fig. 112. One of the abdominal plumules. Fig. 113. Side view of cleared specimen, showing digestive tube and reproductive organs.

PLATE 14.

Female of *Haemobaphes cyclopterina.*

Fig. 114. Side view of trunk, dorsal view of posterior neck, ventral view of anterior neck and head. Fig. 115. Dorsal view of cephalothorax. Fig. 116. Ventral view of same. Fig. 117. Ventral view of anterior head. Fig. 118. Side view of cleared specimen showing reproductive organs.

PLATE 15.

Females of *Pennella antarctica* and *P. filosa.*

Fig. 119. Side view of *P. antarctica.* Fig. 120. Pieces of whale blubber with parasites in place; the piece on the right shows the scar left after the disappearance of the parasite; photograph by Dr. Roy C. Andrews. Fig. 121.

Dorsal view of first and second antennae. Fig. 122. Ventral view of head, showing frontal processes. Fig. 123. Inner surface of ventral wall of head. Fig. 124. Swimming legs. Fig. 125. Side view of *P. filosa*, drawn by J. H. Blake. Fig. 126. Anterior view of head. Fig. 127. Dorsal view of same, both drawn by J. H. Blake.

PLATE 16.

Female of *Pennella filosa*.

Figs. 128, 129. Dorsal and ventral views of head, with frontal processes and internal muscles. Figs. 130, 131. External and internal views of anterior end of head with frontal processes removed. Fig. 132. Dorsal view of first and second antennae. Fig. 133. Side view of cleared specimen, showing reproductive organs.

PLATE 17.

Females of *Pennella filosa* and *Lernaeocera branchialis*.

Fig. 134. Swimming legs of adult *P. filosa*. Fig. 135. Side view of head of young female of *P. filosa*, 18 mm. long. Fig. 136. Second maxilla. Fig. 137. Diagonal view of thorax, with swimming legs. Fig. 138. Posterior end of genital segment, showing enlargement in oviduct which serves as a receptaculum seminis. Fig. 139. Posterior end of abdomen, with anal laminae. Fig. 140. Side veiw of cleared specimen of *Lernaeocera branchialis*, showing digestive tube and reproductive organs (after A. Scott).

PLATE 18.

Female of *Pennella instructa*.

Fig. 141. Side view, drawn by J. H. Blake. Fig. 142. Ventral view of head and anterior neck. Fig. 143. Anterior end of head, internal view. Fig. 144. Anterior end of head, external view showing frontal processes. Fig. 145. Dorsal view of first and second antennae. Fig. 146. Swimming legs. Fig. 147. A specimen of *P. instructa* infested with goose barnacles.

PLATE 19.

Female of *Haemobaphes diceraus*.

Fig. 148. Side view of adult with egg strings. Fig. 149. Ventral view of head and anterior thorax, cleared in clove oil. Fig. 150. Dorsal view of head and anterior thorax, showing single pair of horns. Fig. 151. Ventral view of proboscis.

PLATE 20.

Haemobaphes diceraus, *H. cnodis*, and *Trifur tortuosus*.

Fig. 152. First and second antennae of *H. diceraus*. Fig. 153. First and second swimming legs. Figs. 154, 155. Third and fourth swimming legs. Fig. 156. Side view of adult *H. cnodis*, with egg strings. Fig. 157 Ventral view of head and anterior thorax, showing the profusion of soft processes. Fig. 158. Side view of cleared specimen of *T. tortuosus*, showing the arrangement of the internal organs.

PLATE 21.

Females of *Trifur tortuosus* and *Cardiodectes bellottii*.

Figs. 159 and 160. Side view of head and anterior thorax, and of trunk of *T. tortuosus*. This is drawn from an entire specimen but the long neck is so twisted in different directions that it does not give a satisfactory view of the entire creature in any one position. Fig. 161. Side view of *C. bellottii*, showing the lobed frontal processes. Fig. 162. Side view of head and anterior thorax, showing the four pairs of legs; the thoracic process on the side nearest the observer has been removed.

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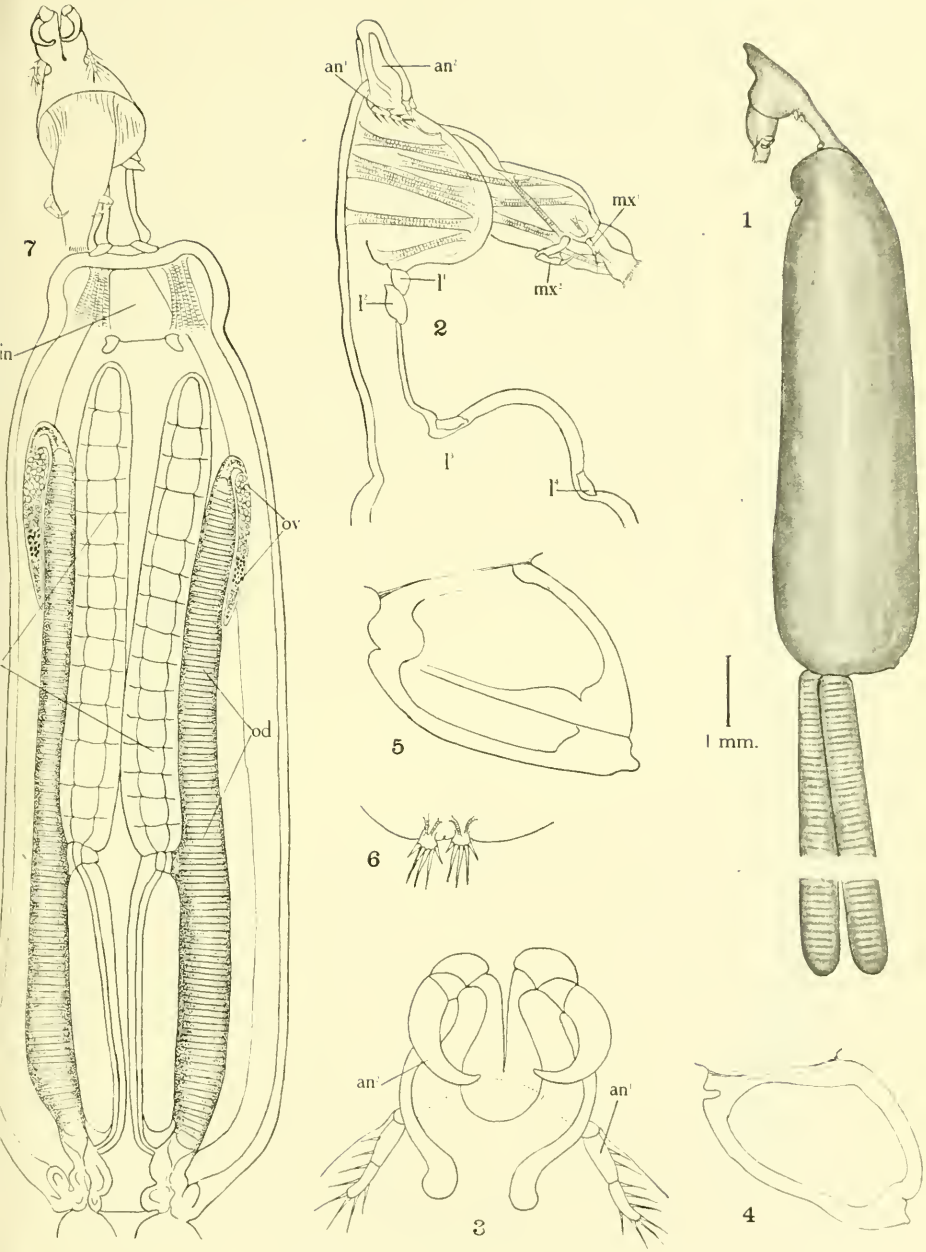

FEMALE OF PENICULUS CLAVATUS.

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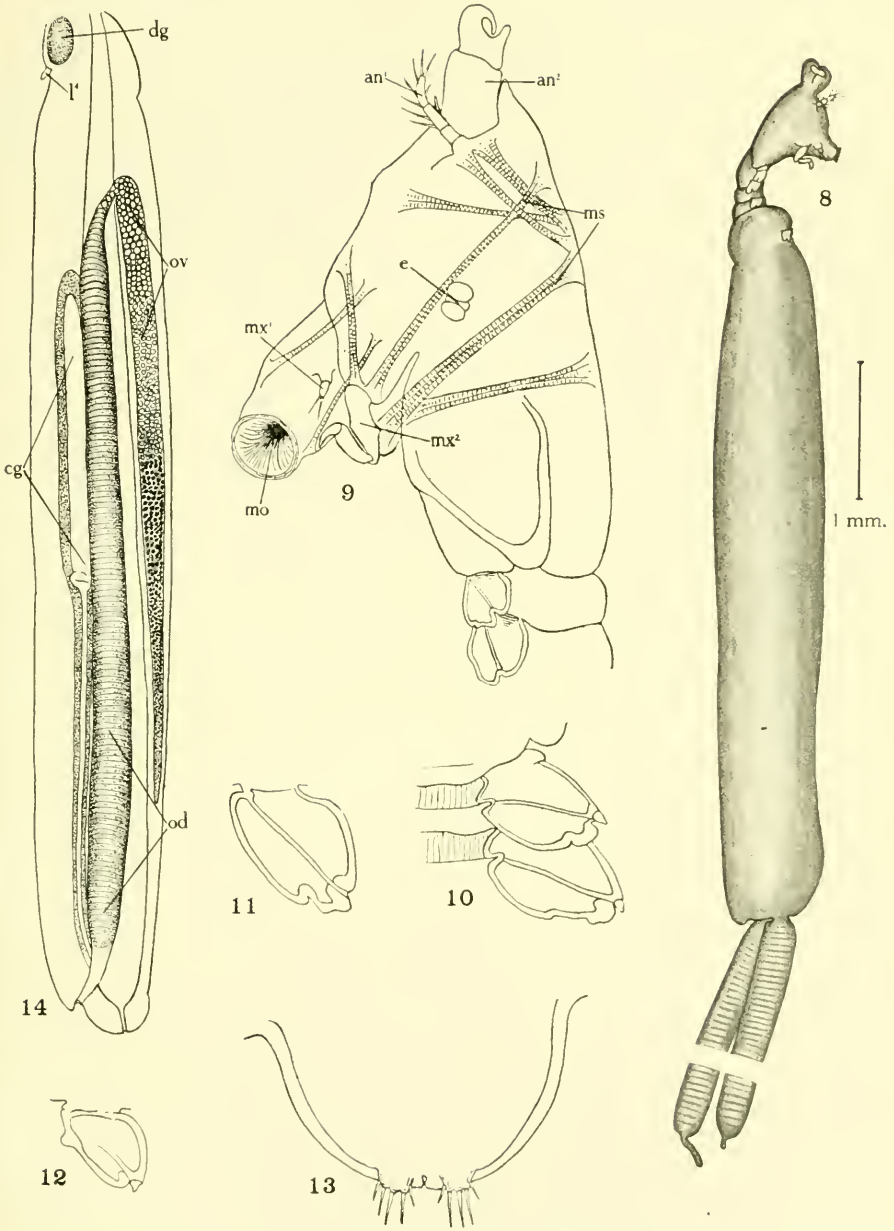

FEMALE OF PENICULUS FISSIPES.

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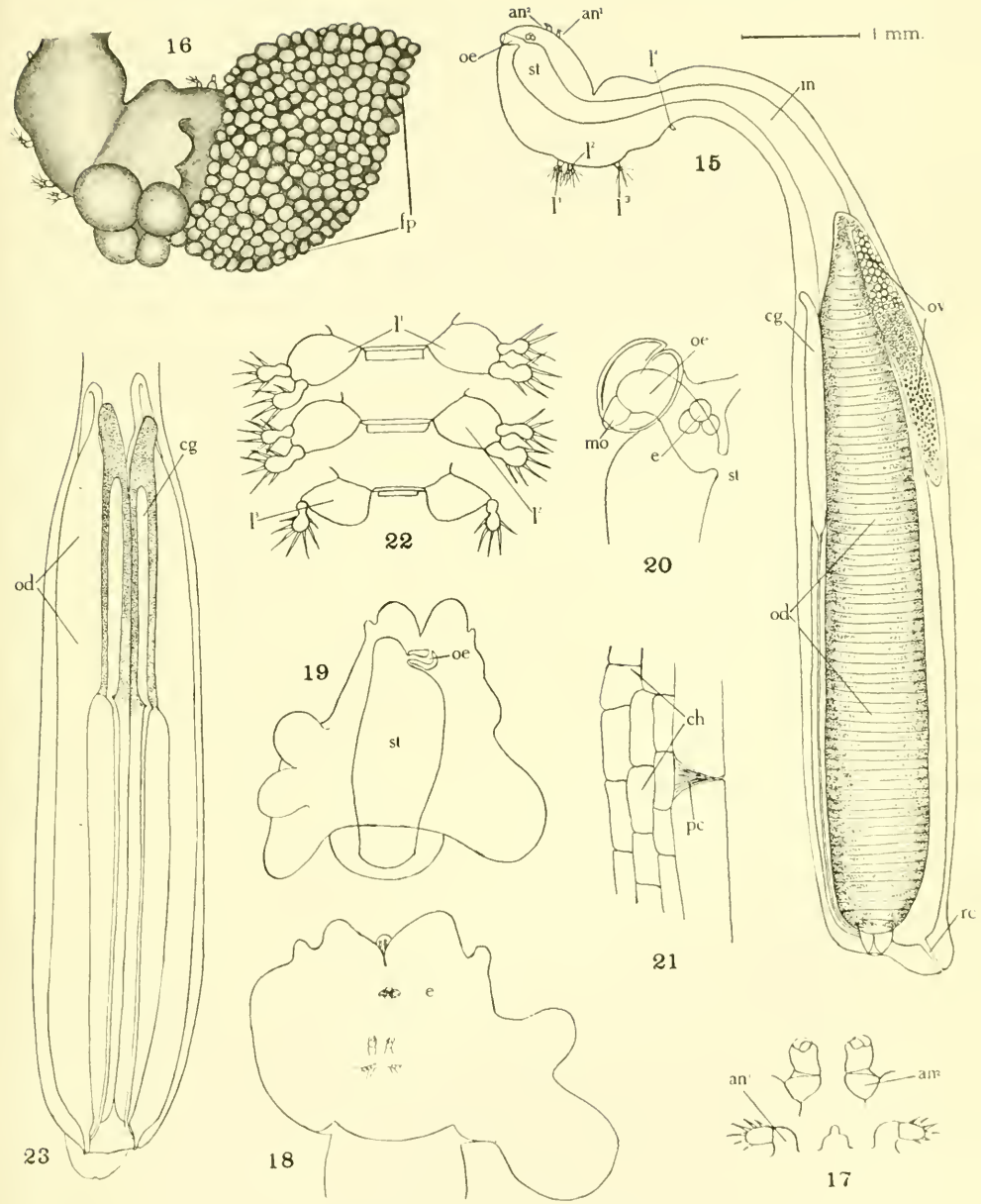

FEMALE OF CARDIODECTES MEDUSAEUS.

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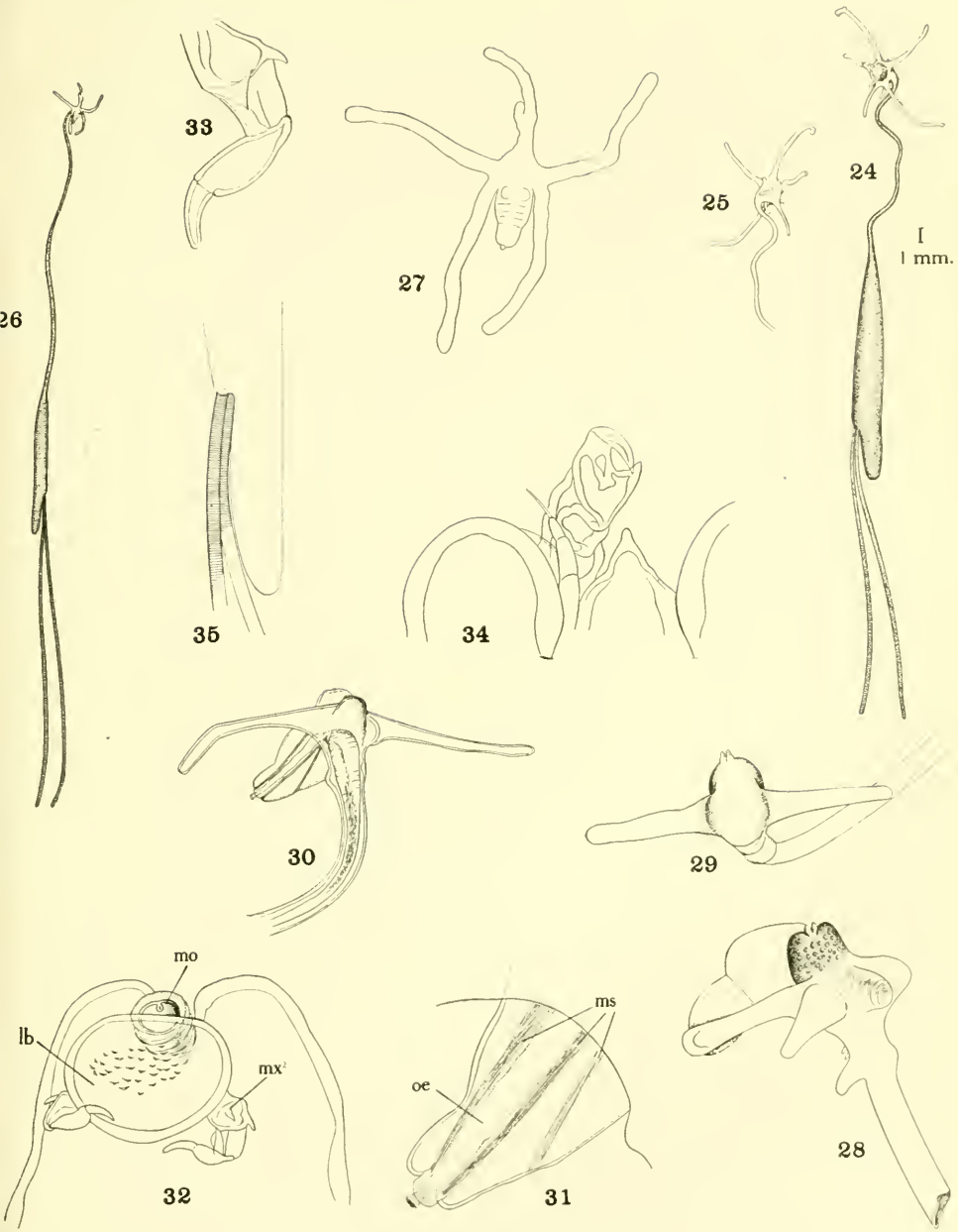

FEMALE OF LERNAEENICUS RADIATUS.

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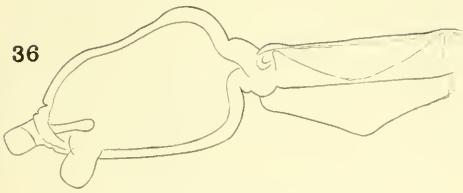
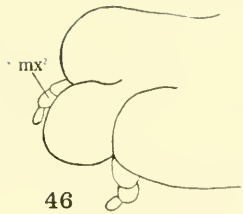
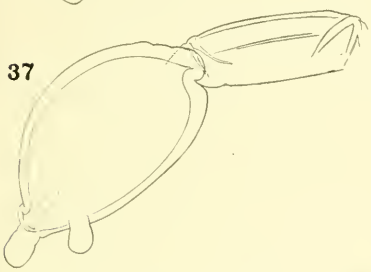
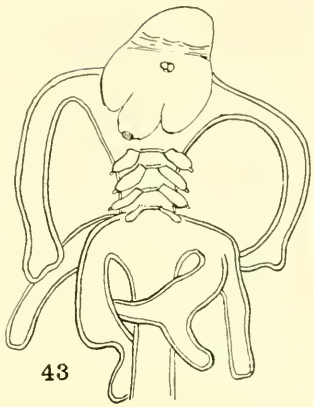
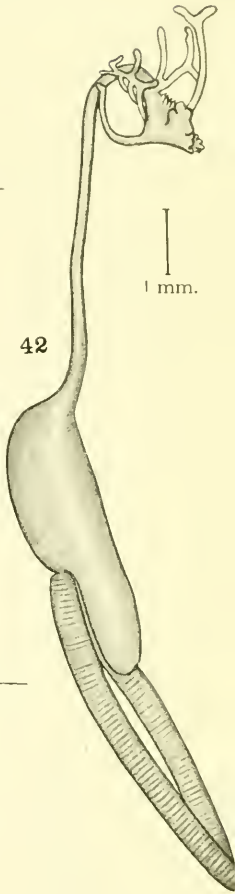
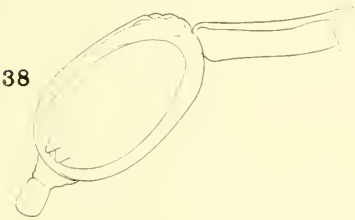


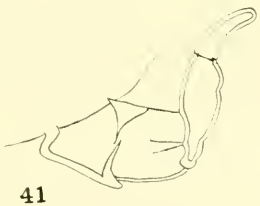


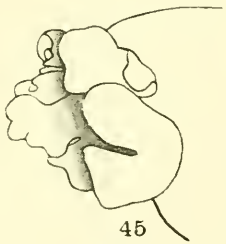


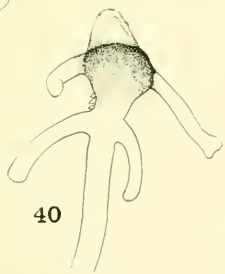


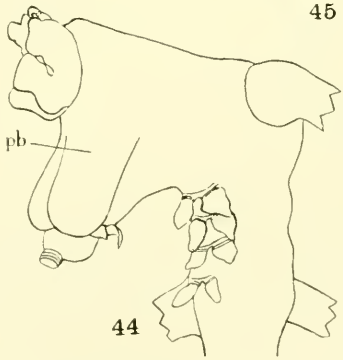


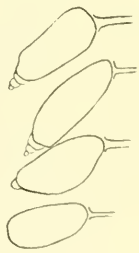






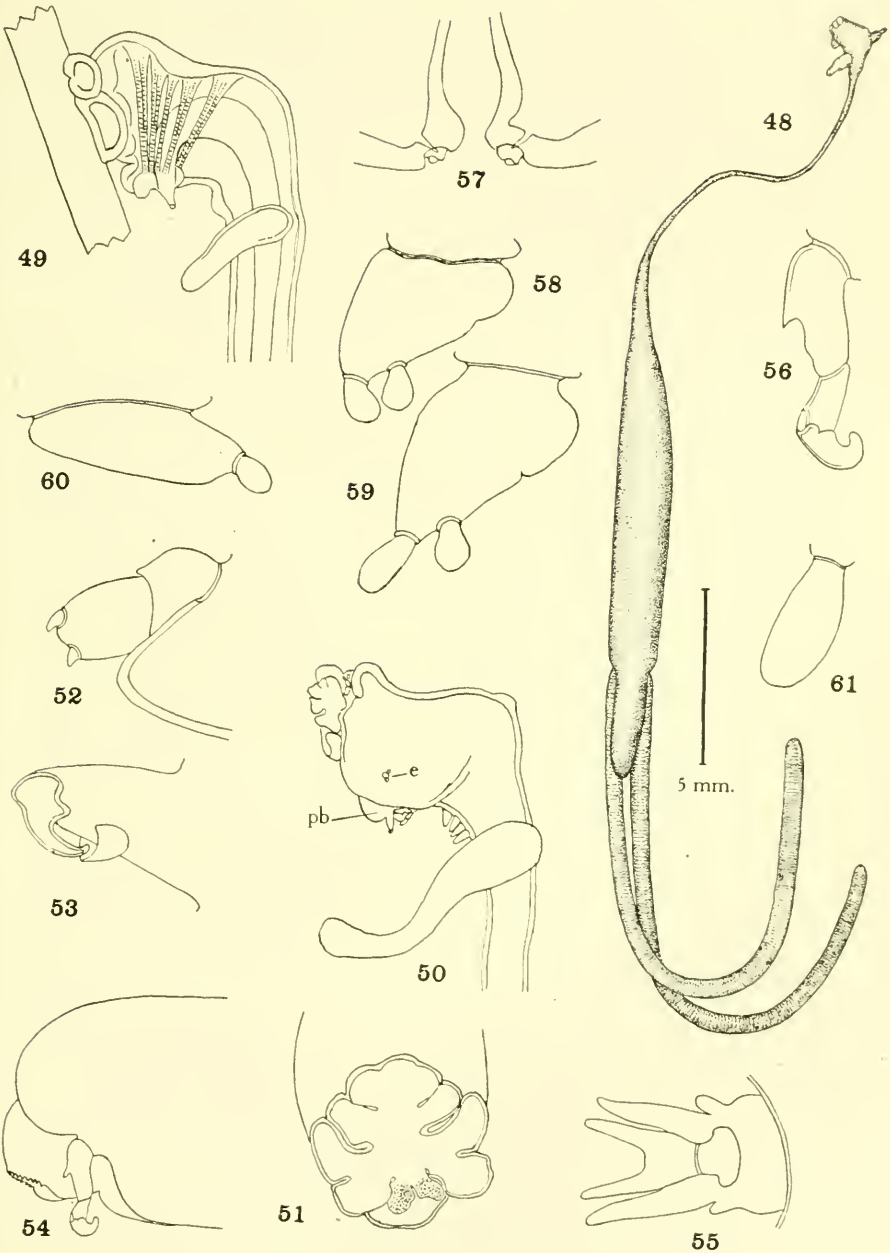






FEMALES OF LERNAEENICUS RADIATUS AND L. POLYCERAUS.

FOR EXPLANATION OF PLATE SEE PAGE 145.



FEMALE OF LERNAEENICUS AFFIXUS.

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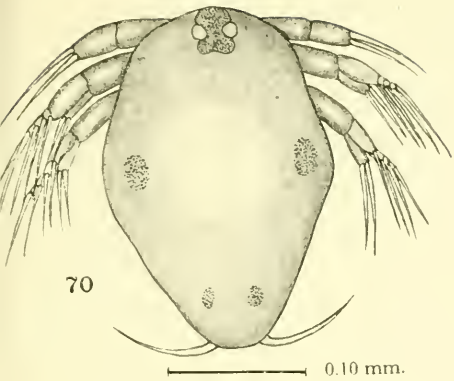

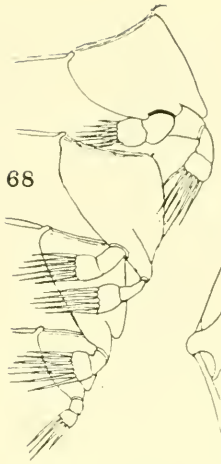

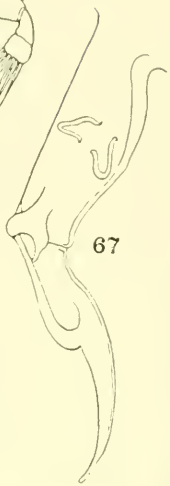

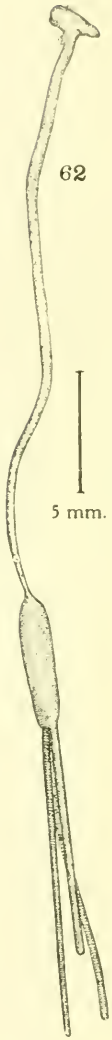

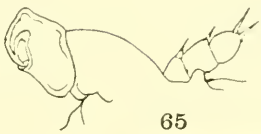

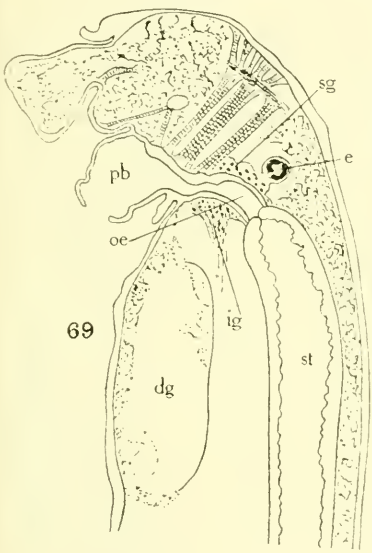

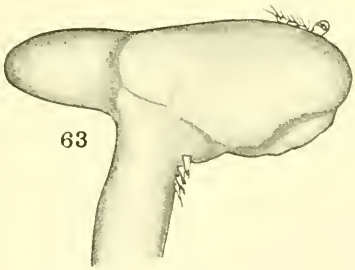

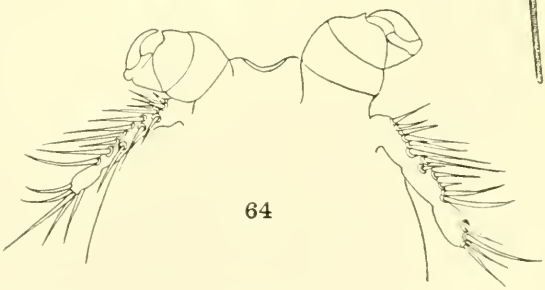

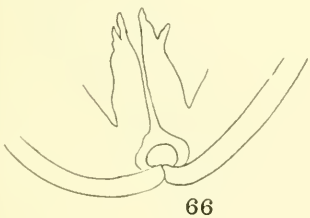

FEMALE OF LERNAEENICUS LONGIVENTRIS.

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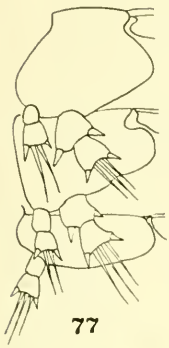

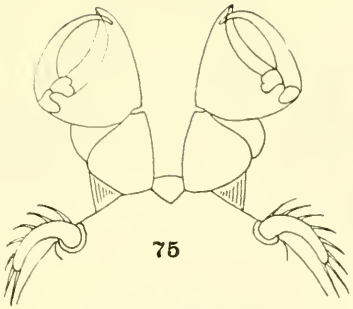

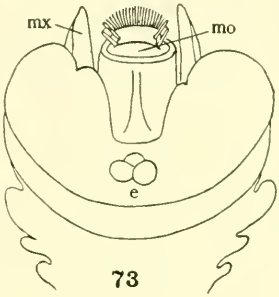

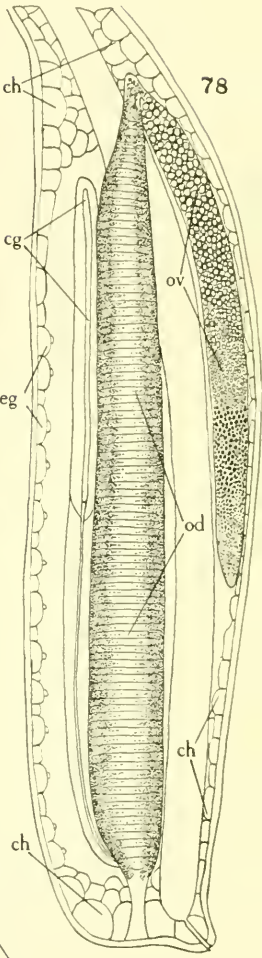

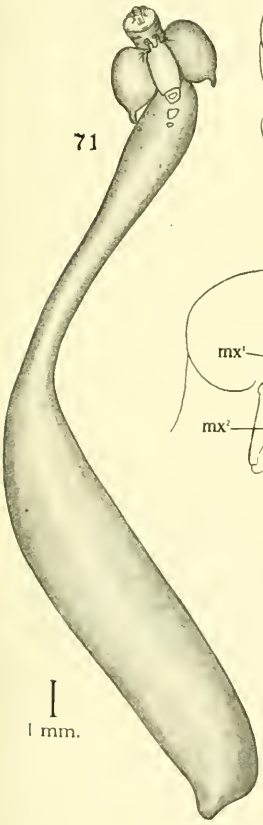

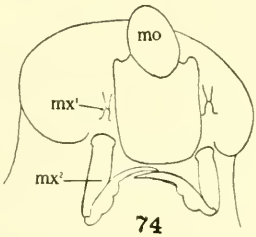

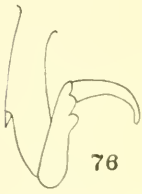

FEMALE OF SARCOTRETES LOBATUS.

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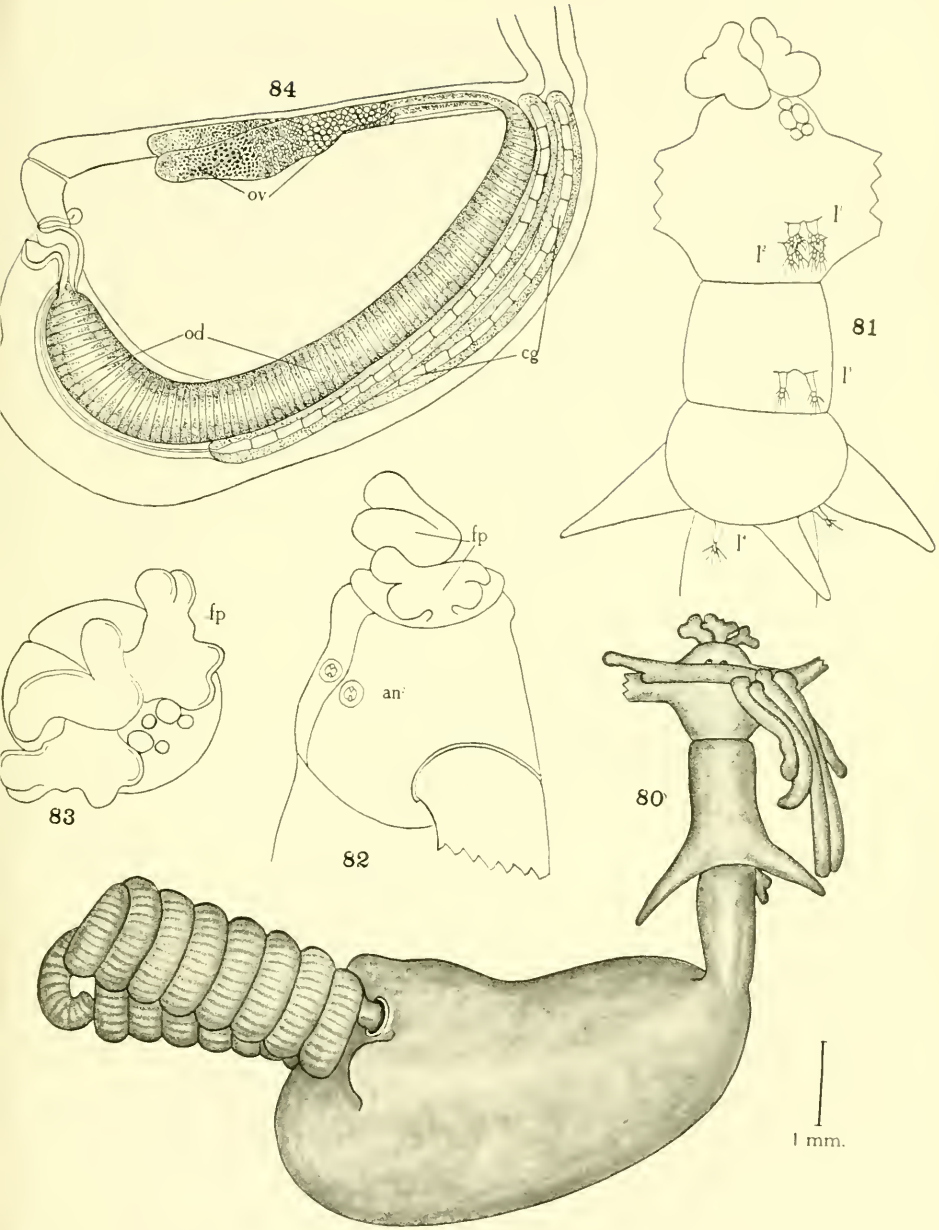
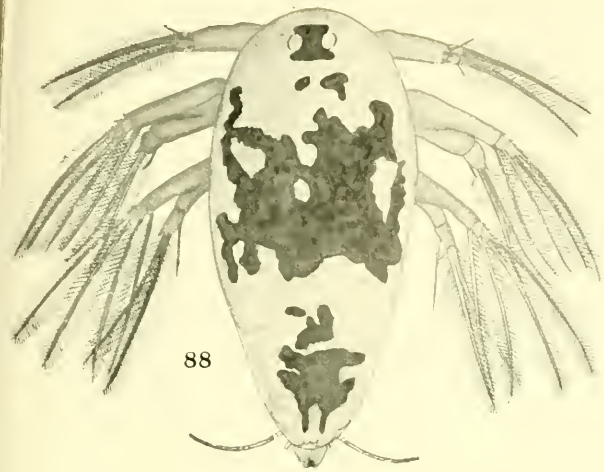
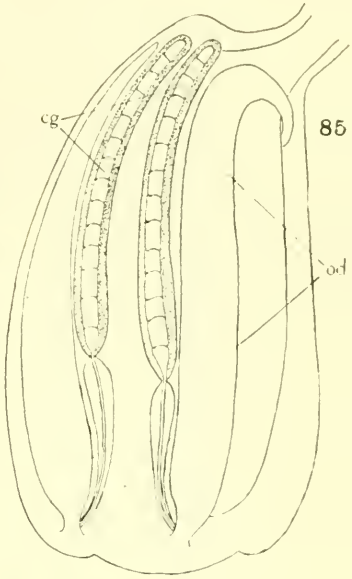
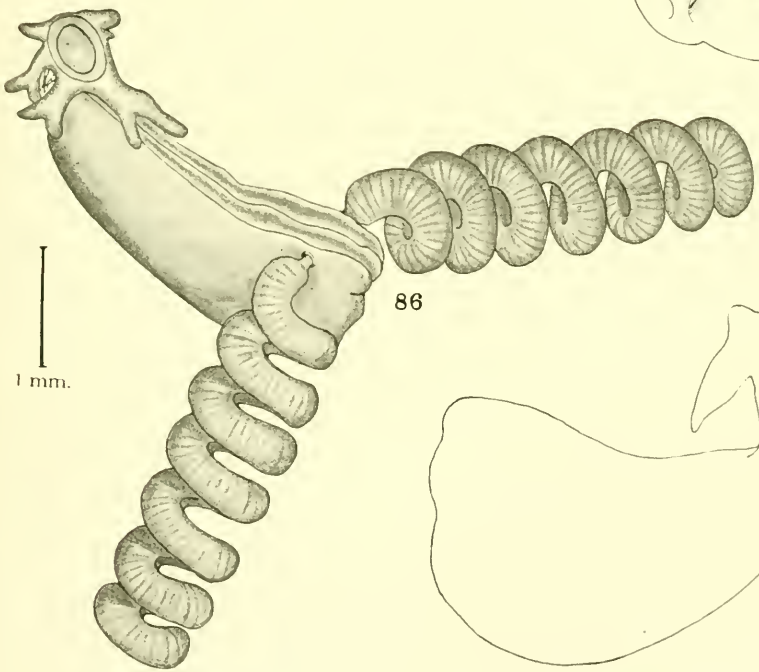


FEMALE OF PHRIXOCEPHALUS TRIANGULUS.

FOR EXPLANATION OF PLATE SEE PAGE 146.







PHRIXOCEPHALUS TRIANGULUS, P. DIVERSUS, AND LERNAEOCERA BRANCHIALIS.

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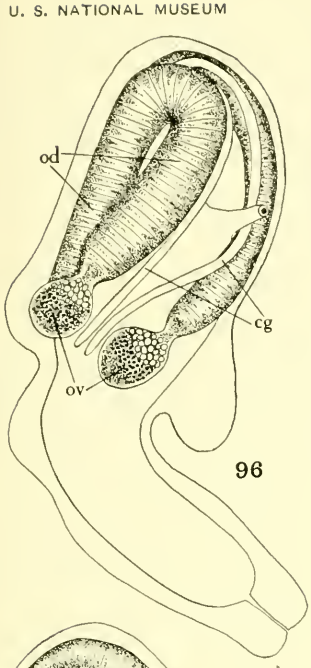

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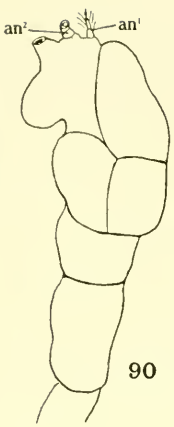

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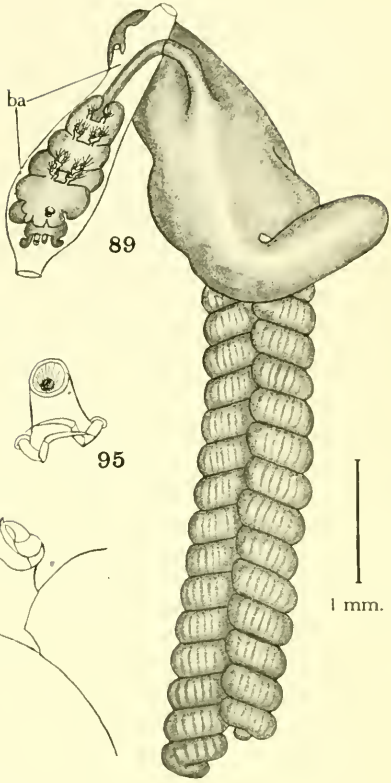

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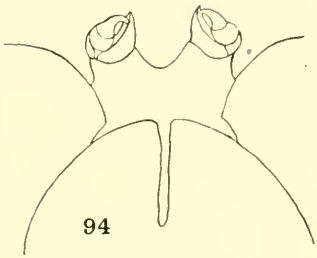

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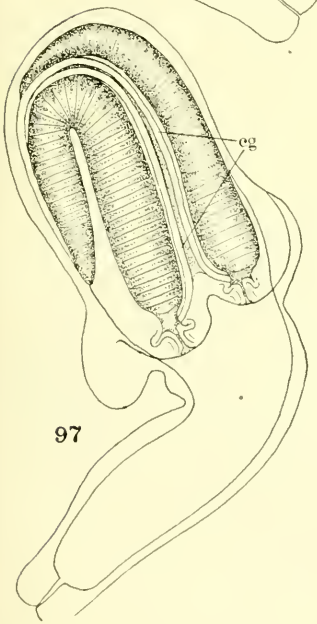

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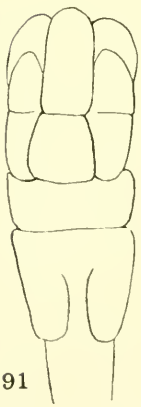

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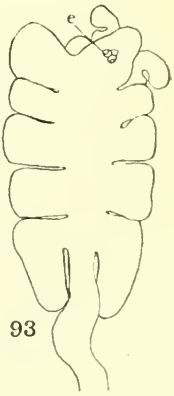

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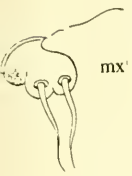
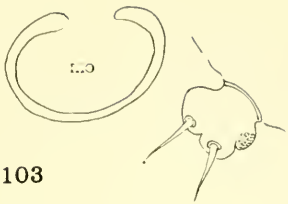
FEMALE OF COLLIPRAVUS PARVUS.

FOR EXPLANATION OF PLATE SEE PAGE 146.





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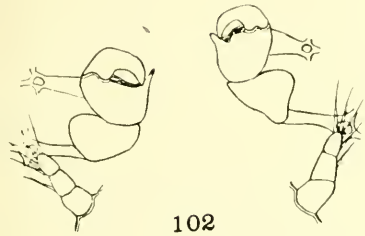

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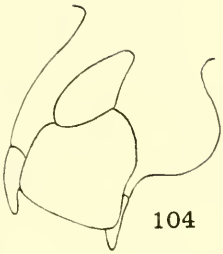

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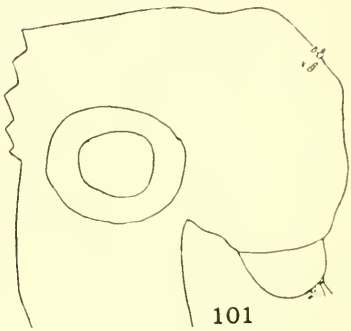

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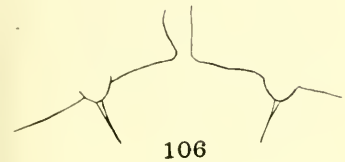

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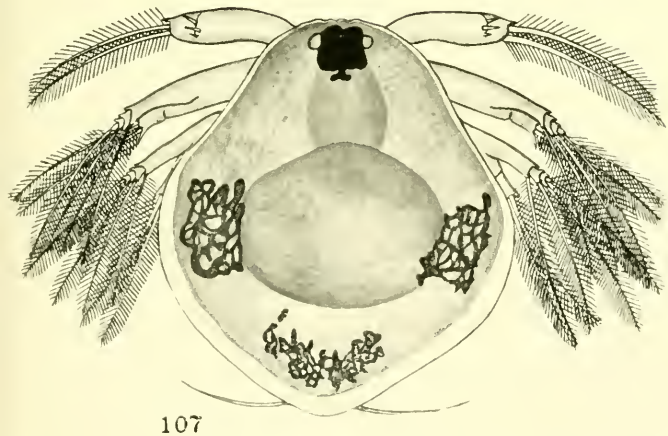

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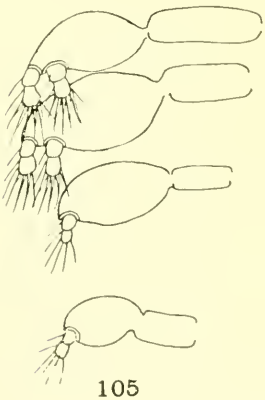

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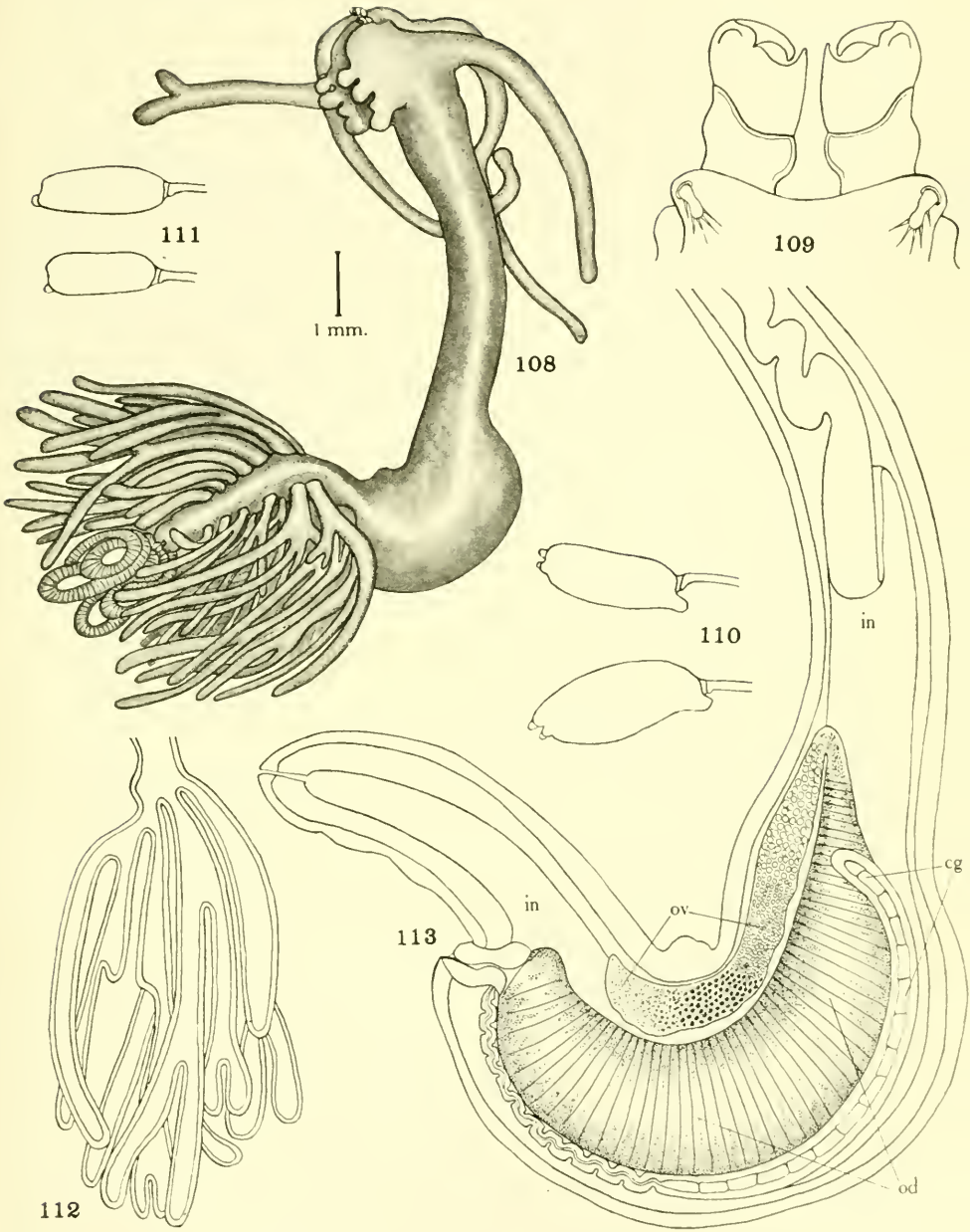
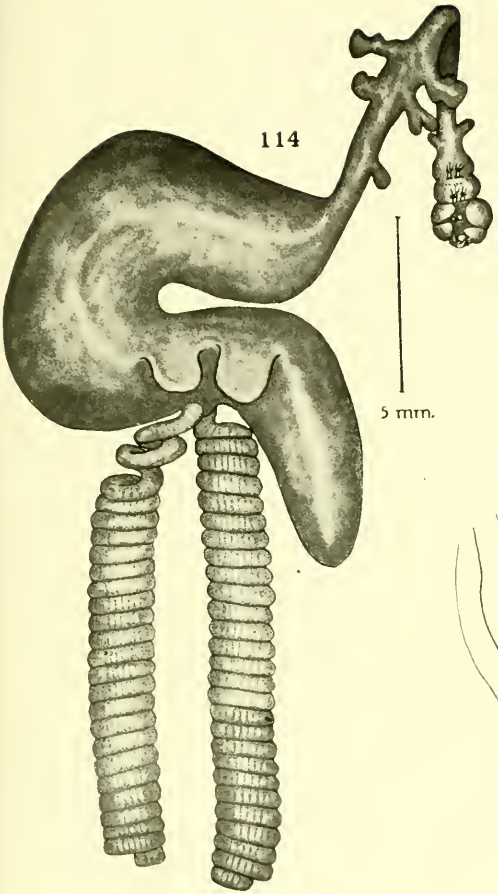
FEMALE AND NAUPLIUS OF LERNAEOCERA BRANCHIALIS.

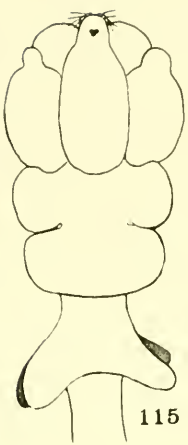
FOR EXPLANATION OF PLATE SEE PAGE 146.

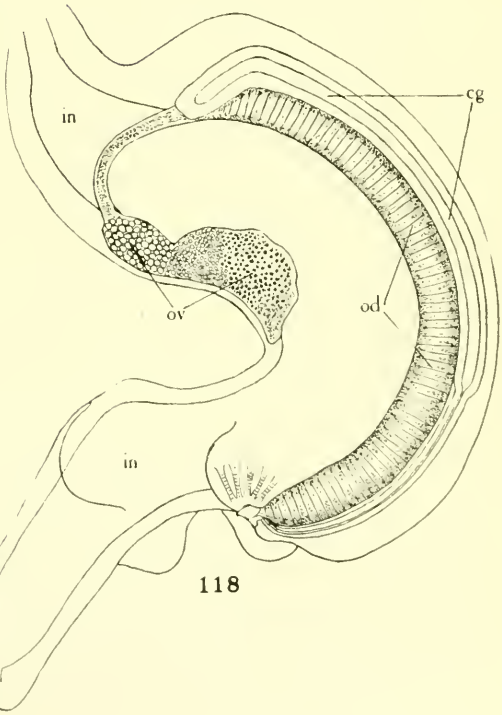


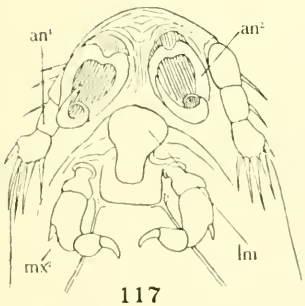
FEMALE OF LERNAEOLOPHUS SULTANUS.

FOR EXPLANATION OF PLATE SEE PAGE 146.



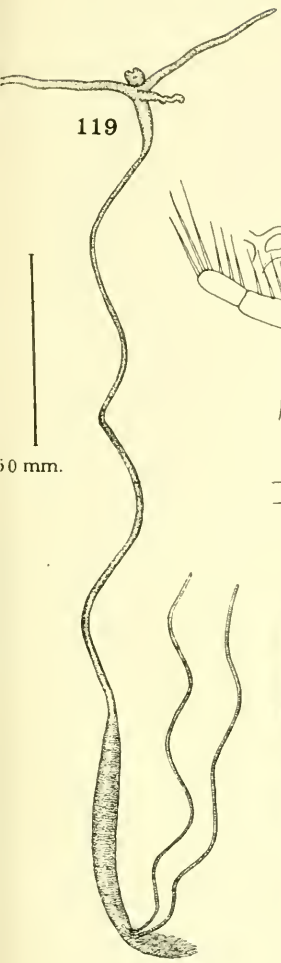


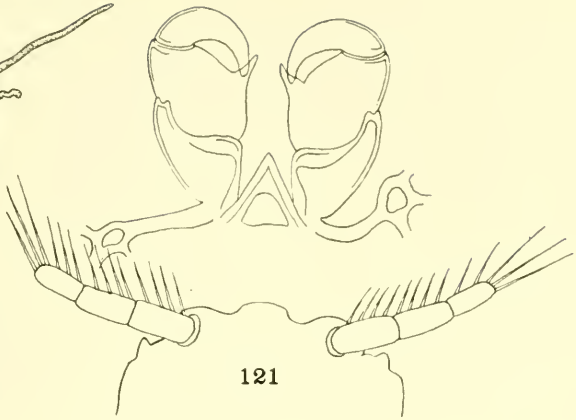


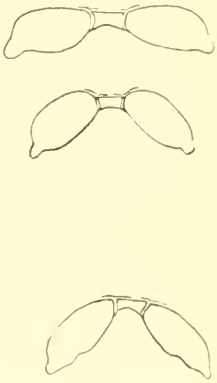


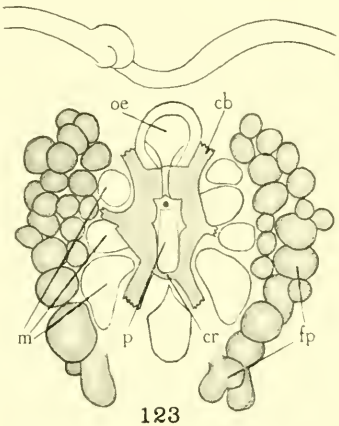
FEMALE OF HAEMOBAPHES CYCLOPTERINA.

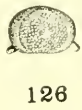
FOR EXPLANATION OF PLATE SEE PAGE 146.

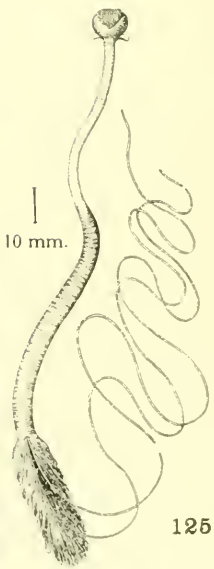


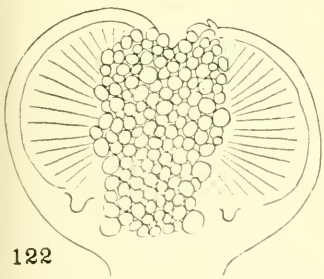


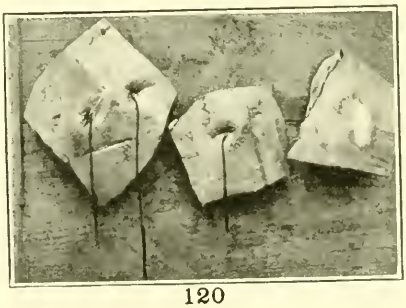






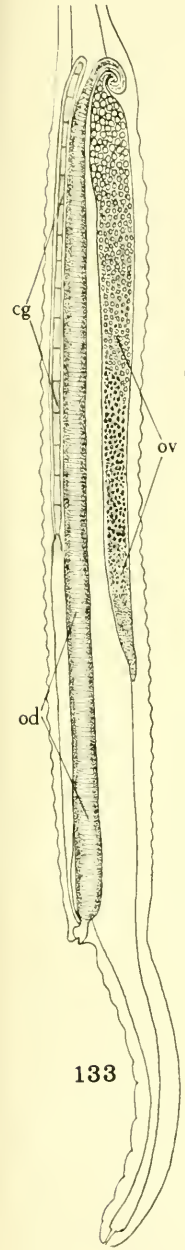




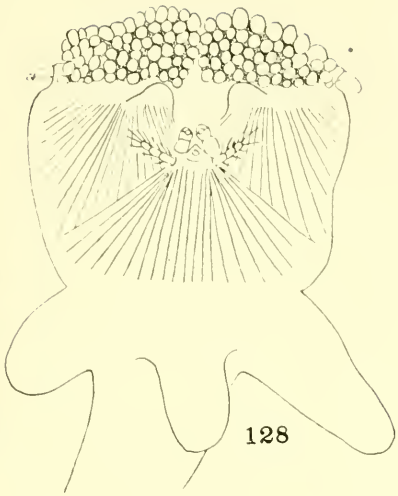


FEMALES OF PENNELLA ANTARCTICA AND P. FILOSA.

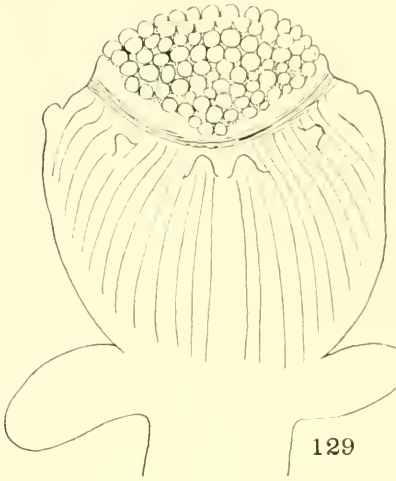
FOR EXPLANATION OF PLATE SEE PAGES 146, 147.



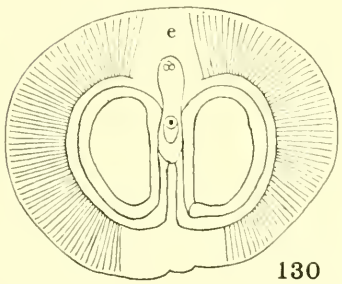
133



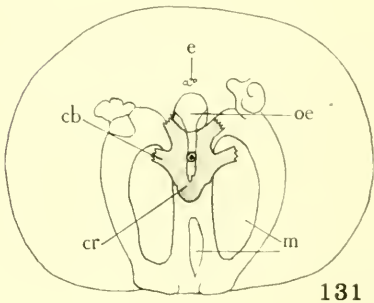
128



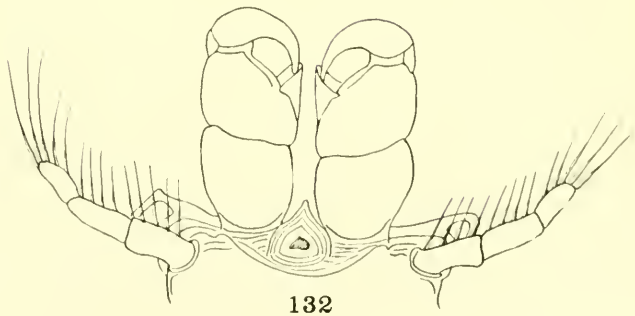
129



130



131



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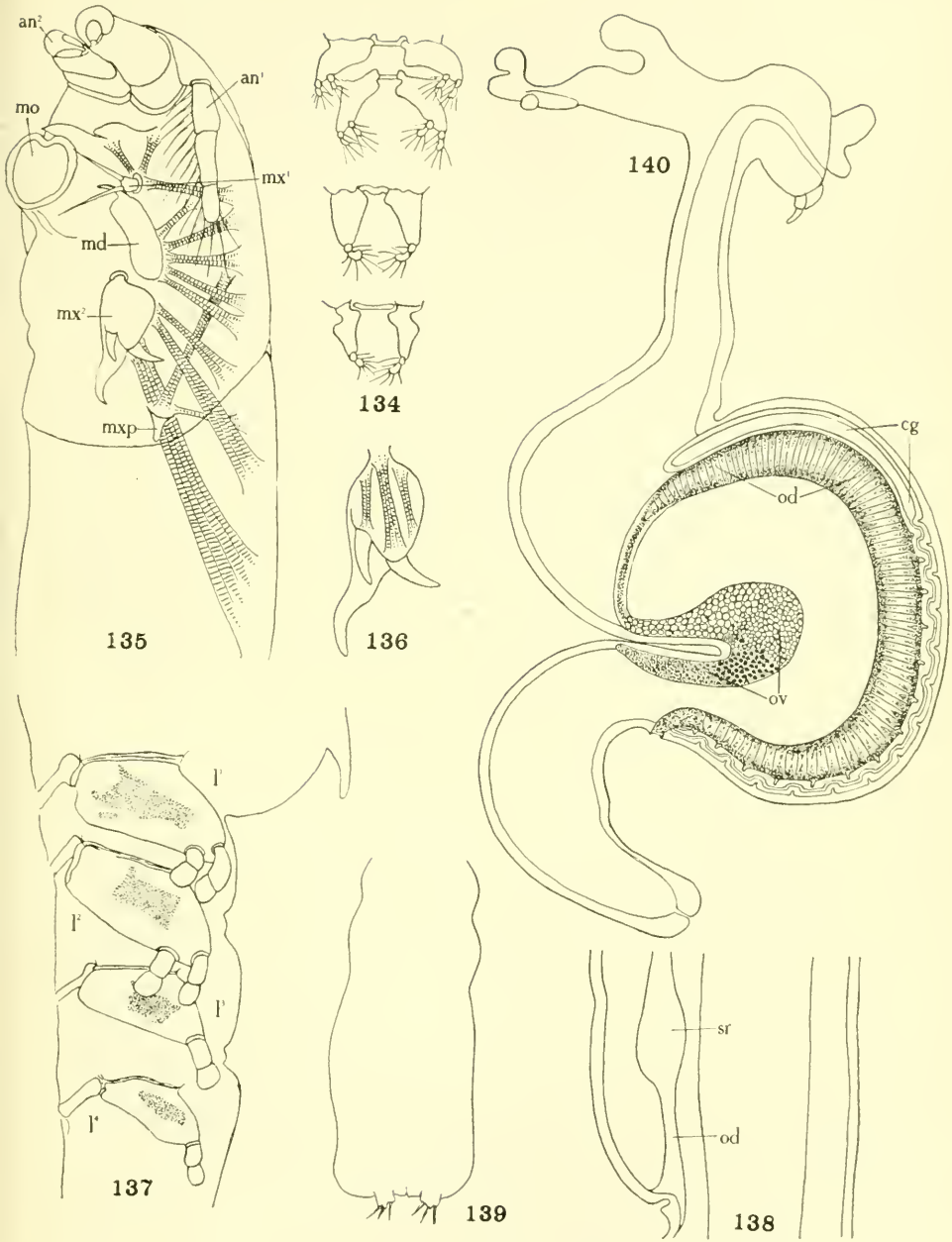
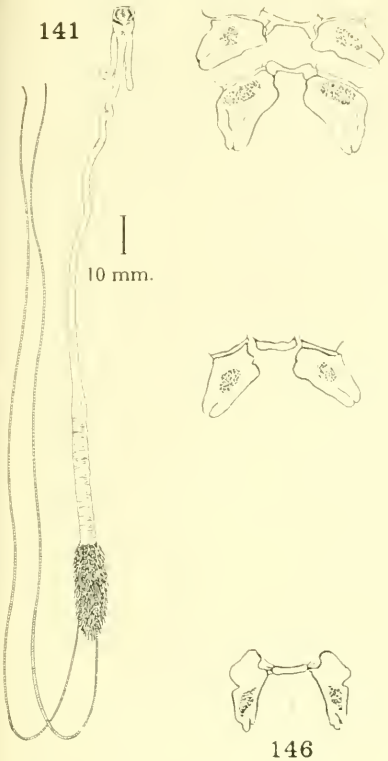
FEMALE OF PENNELLA FILOSA.

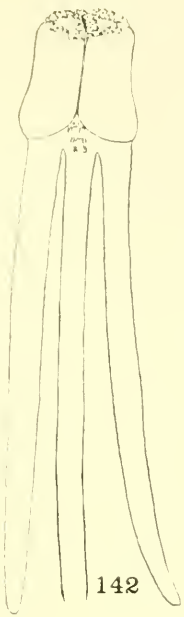
FOR EXPLANATION OF PLATE SEE PAGE 147.

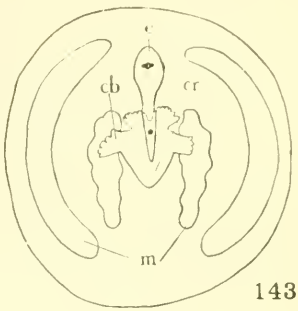


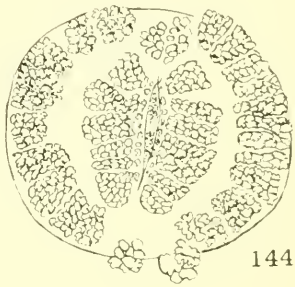
FEMALES OF PENNELLA FILOSA AND LERNAEOCERA BRANCHIALIS.

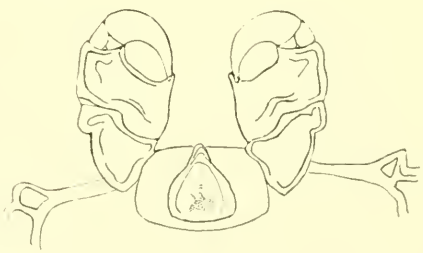
FOR EXPLANATION OF PLATE SEE PAGE 147.

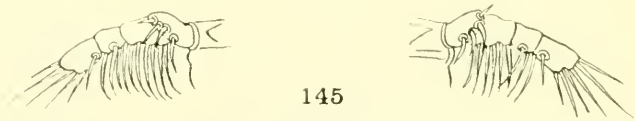






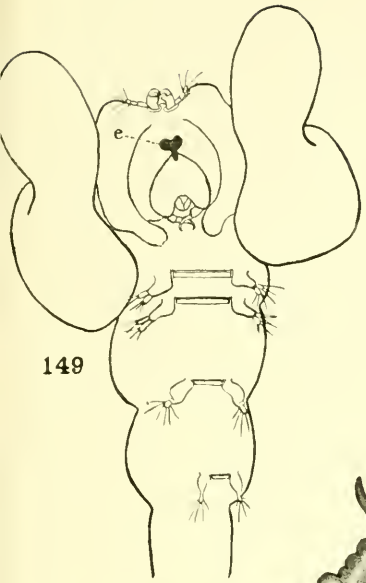




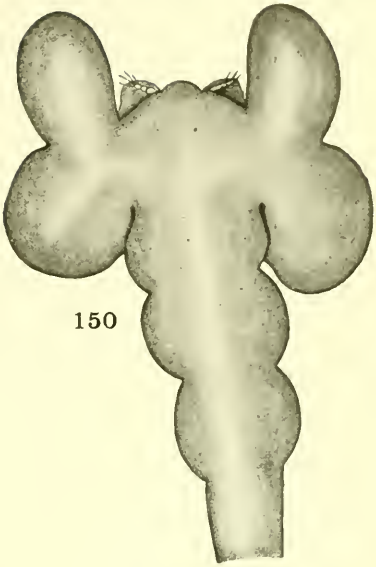


FEMALE OF PENNELLA INSTRUCTA.

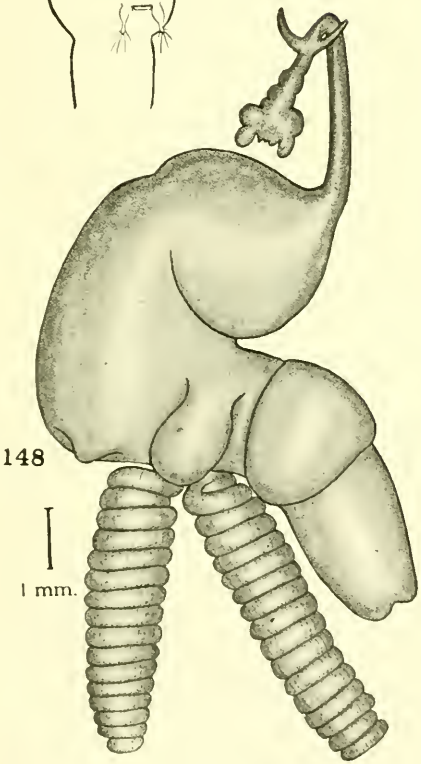
FOR EXPLANATION OF PLATE SEE PAGE 147.



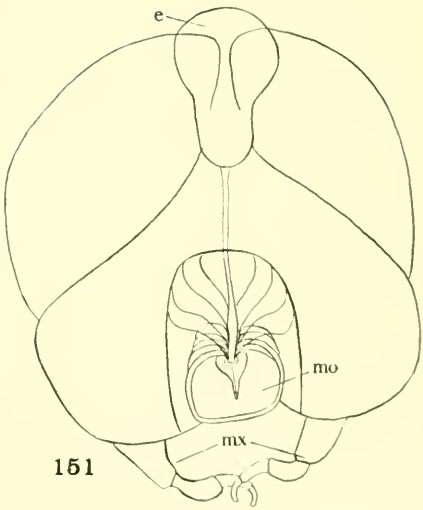
149



150



148



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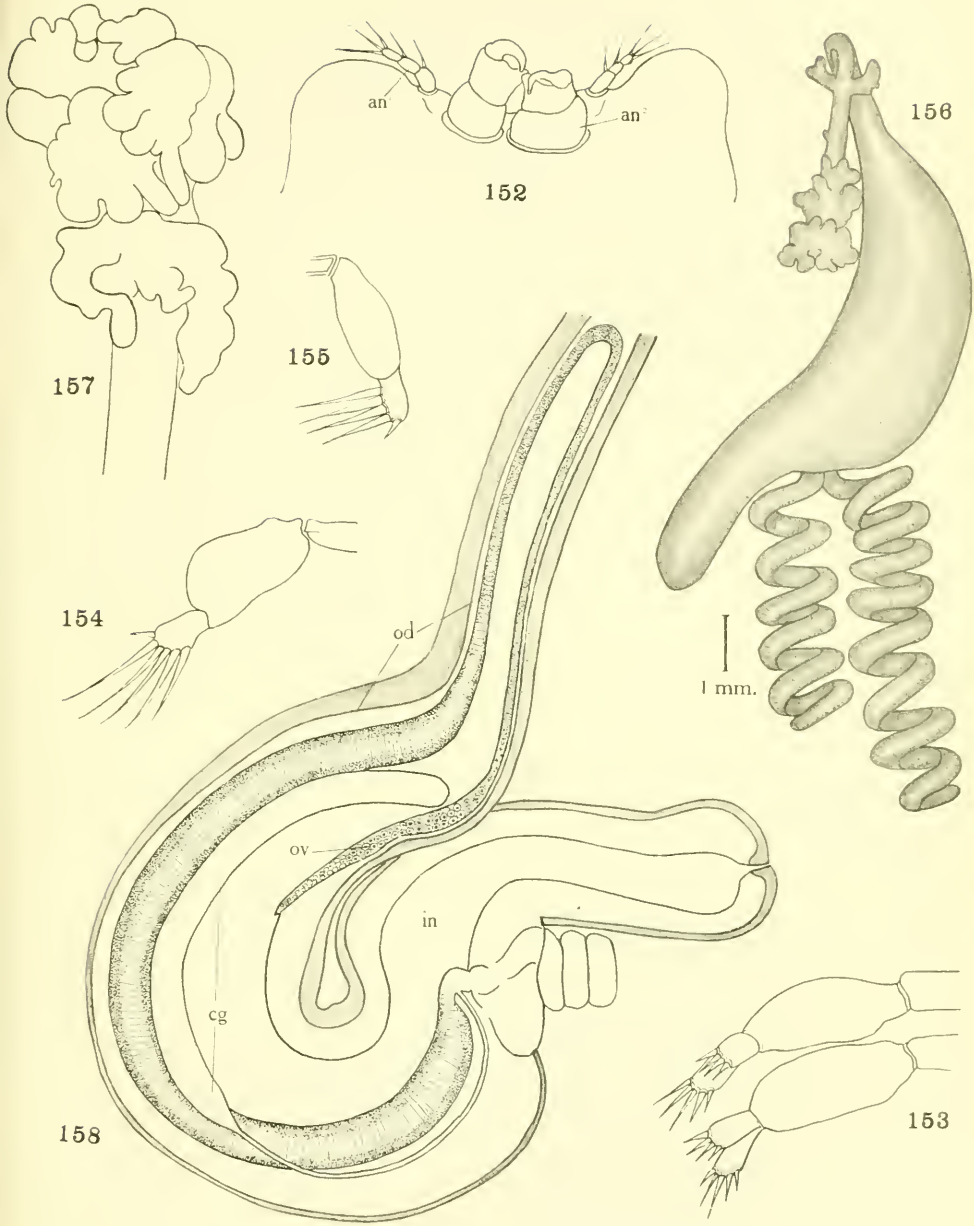
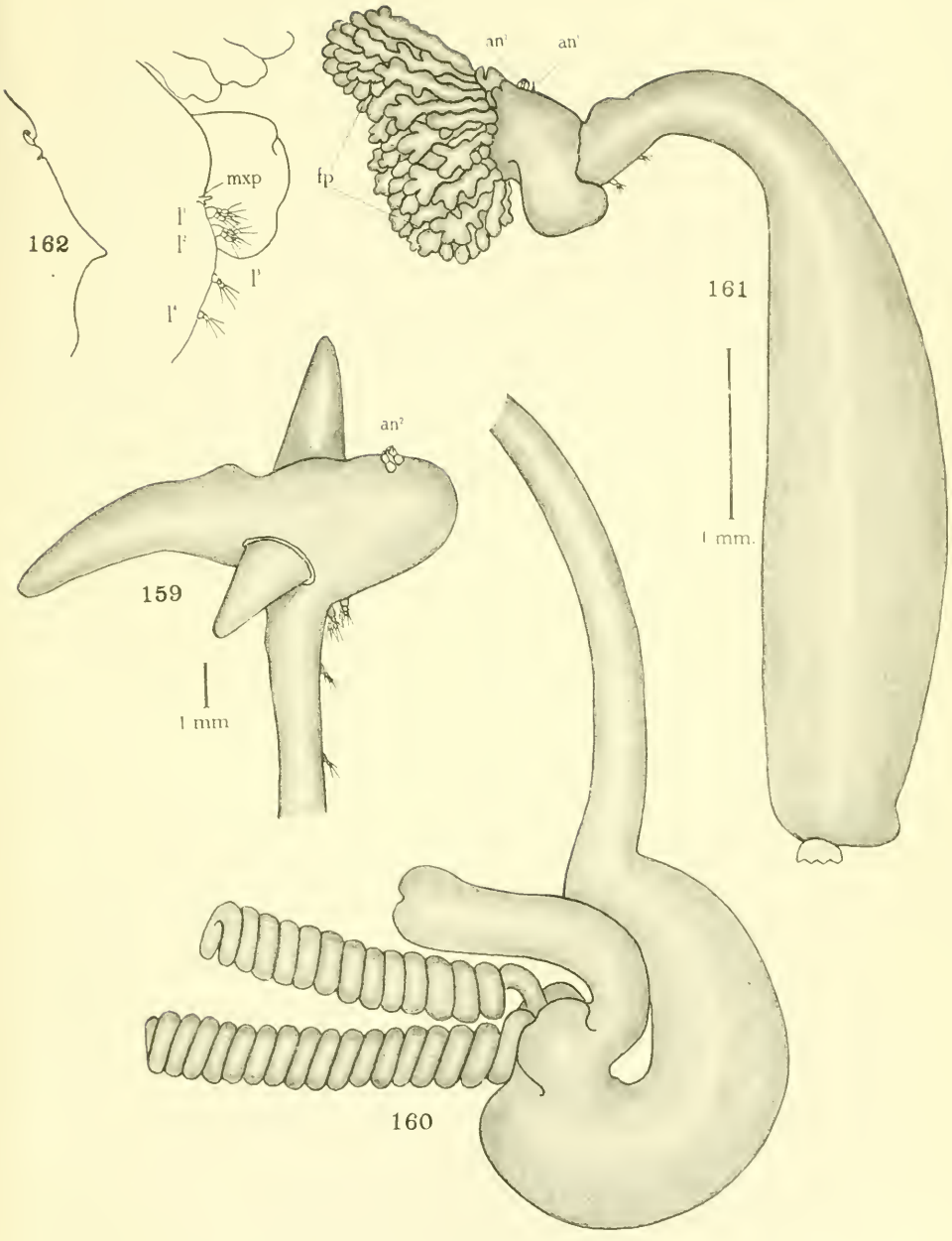
FEMALE OF HAEMOBAPHES DICERAUS.

FOR EXPLANATION OF PLATE SEE PAGE 147.



FEMALES OF HAEMOBAPHES DICERAUS, H. ENODIS, AND TRIFUR TORTUOSUS.

FOR EXPLANATION OF PLATE SEE PAGE 147.



FEMALES OF TRIFUR TORTUOSUS AND CARDIODECTES BELLOTTII.

FOR EXPLANATION OF PLATE SEE PAGE 147.