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A NEW SPECIES OF ARGULUS, WITH A MORE  
COMPLETE ACCOUNT OF TWO SPECIES  
ALREADY DESCRIBED.

BY

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In a paper already published in these Proceedings<sup>a</sup> four new species of *Argulus* were described. But the diagnosis of each was necessarily very brief and only specific differences could be noted. Such accounts answer very well for preserved material, and may be allowed to stand until further information is obtained from a study of living specimens. But as soon as such information is obtained it becomes expedient to give a more detailed description together with as much of the habits and mode of life as may be of value.

Such an attempt has been made in the present paper upon two of the species previously described, *A. americanus* and *A. versicolor*, the only ones which have been obtained alive. In addition a diagnosis is given of a third species which proves to be new.

ARGULUS AMERICANUS Wilson.

*Argulus americanus* WILSON, Proc. U. S. Nat. Mus., XXV, p. 718.

Much of the anatomy of this interesting species has already been given in the paper referred to, but it was disconnected and mingled with that of many other species. It is here gathered together and completed and supplemented by an account of the development.

The species was obtained by Prof. Jacob Reighard at Ann Arbor, Michigan, from some *Amia calva* kept in aquaria and was sent to the author in the winter of 1901-2. It was diagnosed as a new species and described supposedly for the first time.

But shortly afterwards a manuscript upon The Vermine and Crustacean Parasites of Fresh-Water Fishes, by Dr. R. R. Gurley, was sent to the author from the U. S. Fish Commission. This manuscript was evidently prepared with considerable care and labor about ten years ago, but has never been published.

In it are included two new species of *Argulus*, one of which is evidently the same as *A. americanus*, since it corresponds in every detail.

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<sup>a</sup> Proc. U. S. Nat. Mus., XXV, pp. 635-742.

The account also includes a partial description of the eggs and larva, and it is unfortunate that the manuscript name could not have been given to the species, since this description so far antedates that of the author.

In the present account acknowledgment has been made of such facts as have been taken from Dr. Gurley's manuscript.

At present this species has been found only upon the dog-fish, *Amia calva*. Professor Reighard writes that it is found over the outside of the fish generally, the larger number on the anterior part of the body and the head, but some on the fins. They are most numerous on the ventral side of the body in front of the pelvic fins. They are never found on the gills or anywhere else internally. They are not noticeable until the fish have been for some time in the aquarium.

This is one of the largest of the American fresh-water species and is the best of any the author has seen for purposes of study, since it is particularly transparent when alive and also when cleared in clove oil. There is no difficulty in making out all the details of the internal anatomy even to the nervous system and its connections.

It is pale brownish white in color, sparsely covered on the dorsal and ventral surfaces with small pigment spots of a reddish hue. In all the living specimens seen by the author there were eight faint reddish bars running transversely across the dorsal surface. Gurley, however, says:

The ground color is faint grayish or grayish green. The most conspicuous markings are the rose to purplish red bars, which are most distinct marginally where they form well-defined spots.

Probably the color as well as the distinctness of the bars varies considerably in different lots of individuals.

The dorsal surface of the ovary and semen receptacles in the female and the abdomen of the male in the vicinity of the testes are heavily pigmented with circular spots of a rich dark brown. The structural details are as follows:

GENERAL FORM.—*Dorsal surface*.—The carapace is obovate and fully as wide as and often wider than long; the antero-lateral sinuses are distinct, leaving a well-defined frontal lobe which, however, does not project very far, since it is flattened anteriorly. The posterior sinus is narrow and about one-third the entire length of the carapace, and is squarely truncated at its base. Its sides converge rapidly in passing backward so that the broadly rounded lobes of the carapace overlap considerably at their tips (fig. 1).

The sutures dividing the carapace into its respective areas are characteristically arranged. The two central longitudinal ribs (*r*) are fairly close together for such a broad carapace and are almost parallel except at their anterior ends. The horseshoe suture (*hs.*) separating the cephalic from the other areas is comparatively short and narrow.

This makes the lateral areas wide anteriorly and leaves a thoracic area (*t*) posterior to the suture which is actually longer than it is wide, a condition rarely found among the Argulidæ. From the sides of the horseshoe suture near its anterior ends a well-defined secondary suture (*ss*) extends backward on either side in a broad outward sweep through the center of the lateral area nearly parallel with the margin of the carapace. These sutures divide each lateral area into an outer and an inner portion, the former of which can be flexed on the latter,

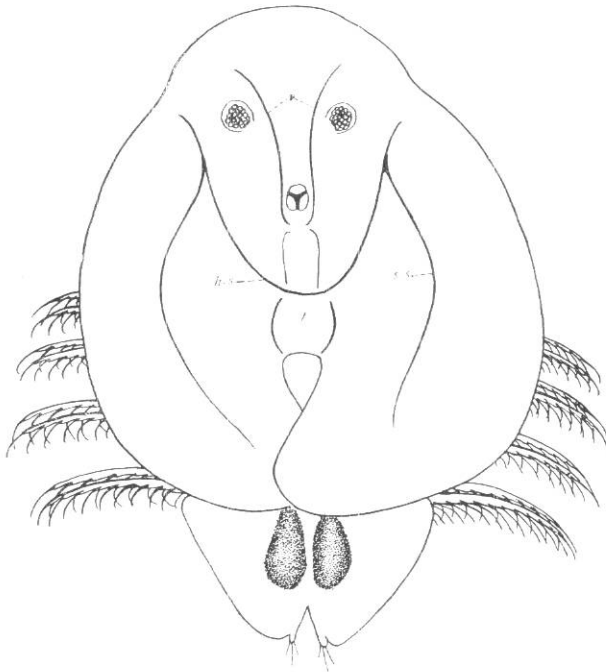


FIG. 1.—DORSAL VIEW OF MALE ARGULUS AMERICANUS.

thereby greatly increasing the mobility of the carapace. The free thorax is entirely concealed beneath the overlapping lobes of the carapace which also cover the anterior third of the abdomen, giving this argulid a very compact appearance in dorsal view. The abdomen is broadly triangular, one-half wider than long, with all its angles well rounded. The lateral margins project forward slightly, suggesting a heart shape. The anal sinus is triangular, cut less than a third the length of the abdomen and carries the anal papillæ upon its lateral margins close to the tips of the lobes. The papillæ are somewhat club-shaped, rather short and blunt, and each is tipped with three setæ of medium length.

*Ventral surface* (fig. 2).—The frontal lobe is plainly divided into an anterior and posterior portion by a line parallel with the edge of the carapace except at either end where it curves around abruptly to the base of the antennæ. From the center of this line there projects backward into the posterior portion a triangular area (the post-frontal triangle) whose ventral surface is on the same level as the rest of the carapace. But the remainder of the posterior portion on either side of the triangle is hollowed out for the antennæ. The ventral surface of the triangle, the anterior rim, and the anterior half of the lateral

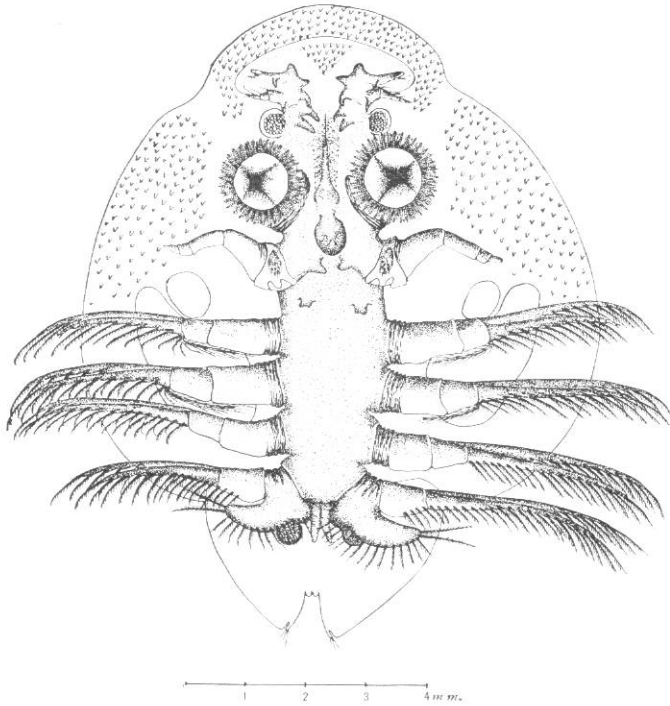


FIG. 2.—VENTRAL VIEW OF FEMALE ARGULUS AMERICANUS.

areas are thickly covered with sharp triangular spines of considerable size, which must hold the creature very firmly on its host.

*Antennæ* (fig. 3).—These are small but well armed with stout hooks and spines.

The proximal portion of the basal joint of the first pair carries two stout spines on its inner border, the posterior of which is strongly curved backward. The distal portion of this joint has the usual hooks on the outer and anterior margins and two spines upon its posterior margin, one of which is long and stout, while the other is very slender. The terminal portion of this antenna is two-jointed and projects considerably beyond the basal portion. The second antennæ are four-jointed, and each carries two large triangular spines on its inner

margin and a smaller and sharper one on the posterior margin of its basal joint. The latter is reinforced by several setae. All these hooks and spines are of a rich yellow color.

*Eyes.*—These are small, made up of numerous facets, and quite widely separated.

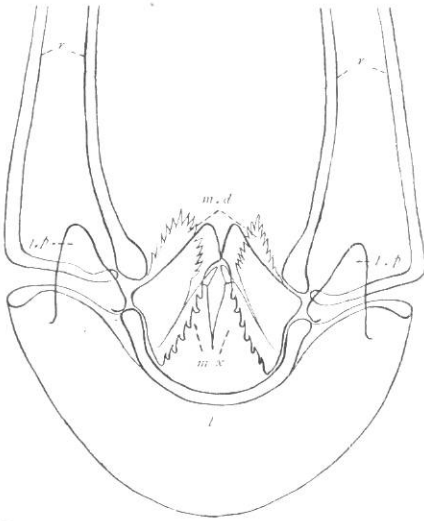


FIG. 4.—MOUTH PARTS OF ARGULUS AMERICANUS. *l*, LOWER LIP; *lp*, LABIAL PALP; *md*, MANDIBLES; *mx*, MAXILLÆ; *r*, CHITIN RIBS.

only, they are widened into a spatula form, with long and sharp teeth on both the inner and outer margins and around the end, twelve or fifteen of them in all. The maxillæ (*mx*) are also much stouter than in *foliaceus*, but the single tooth at the tip is shorter and blunter. As a whole the proboscis is only slightly club-shaped and is rather smaller than would be expected on so large an Argulus. The chitin framework, while agreeing in its general make-up with that of *foliaceus*, differs in several details. The longitudinal ribs (*r*) are not forked at their distal ends, and the transverse ribs are less complicated.

*Anterior maxillipeds.*—These are small, not more than one-sixth the width of the carapace, and close together. The shape of the chitinous rods which support the membranous edge and the arrangement of the fringe are peculiar. There

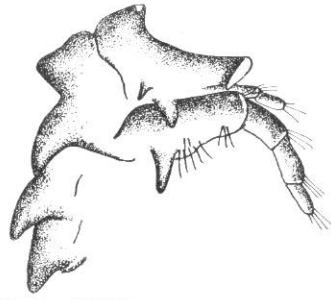


FIG. 3.—ANTENNÆ OF FEMALE ARGULUS AMERICANUS.

*Mouth* (fig. 4).—This organ has a peculiar, almost trapezoidal, form, and its lateral margins are strongly serrated. The lower lip (*l*) has a sharper curve than in *A. foliaceus* and the labial palps (*lp*) are relatively smaller. But the greatest difference is in the mandibles (*md*); instead of being broadly sickle-shaped, with teeth along the inner margin

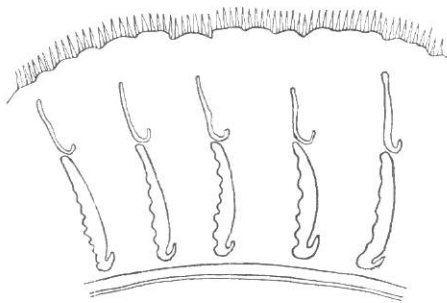


FIG. 5.—BORDER OF SUCKING DISK IN ARGULUS AMERICANUS.

are two concentric rows of the rods, the inner about twice the length of the outer, while outside of the latter is a wide free margin (fig. 5).

The rods in both rows are shaped like the letter J when viewed from the inside, the bases of those in the outer row articulating with the tips of those in the inner row. Around the edge of the membrane is a fringe of elongated finger-like papillae, each terminated by three or four slender hairs.

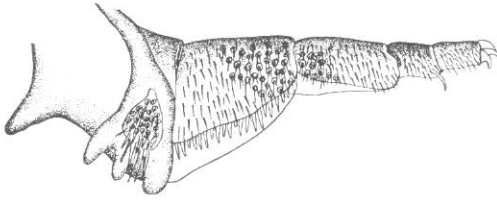


FIG. 6.—POSTERIOR MAXILLIPEDS ARGULUS AMERICANUS.

*Posterior maxillipeds* (fig. 6).—These are small but well armed. Of the five joints, the three terminal ones are much smaller than the two basal ones. The basal plate has an elongated triangular form and carries upon its posterior margin three teeth so wide and so squarely truncated as to be plates rather than teeth, as is also the case in *A. catostomi*. The plates are reenforced by a pair of stout, blunt spines near the median line just behind the mouth. The papillated area is small, but has a bunch of long and sharp setae on its posterior margin; the remainder of its surface and the entire ventral surface of the four terminal joints are covered with short, stiff hairs, each with a swollen base.

The terminal joint ends in three small, rather blunt claws of about the same size, arranged in a broken row anteriorly, while opposed to them posteriorly is a short, rounded papilla or thumb.

*Swimming legs*.—These are long and slender, projecting well beyond the edge of the carapace, the two anterior pairs with recurved flagella. The basal lobes on the posterior pair are large and boot-shaped, with a distinct heel. They are fringed along the posterior margin with a row of plumose setae, and the toe of the boot carries two much longer setae, also plumose.

*Tactile papillae*.—These, for ovipositing, are large, long, and quite widely flaring in the female, but reduced to mere stumps in the male.

*Circulation*.—This, while agreeing with that in other species, differs markedly in the structure and working of the heart (fig. 7). This is

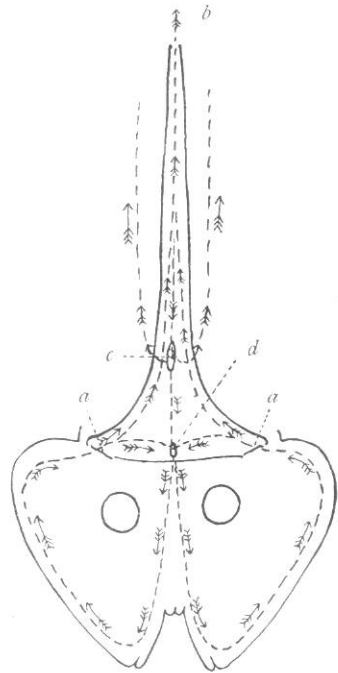


FIG. 7.—DORSAL VIEW OF THE HEART OF ARGULUS AMERICANUS (DIAGRAMMATIC). *a*, PAIRED LATERAL OPENINGS; *b*, ANTERIOR OPENING OF AORTA; *c*, ANTERIOR; *d*, POSTERIOR VENTRAL OPENING.

of the usual shape, but has only five openings instead of six, the ventral one consisting of a single longitudinal slit.

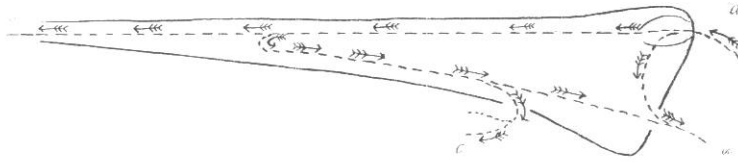


FIG. 8.—SIDE VIEW OF THE HEART OF ARGULUS AMERICANUS (DIAGRAMMATIC). FOR LETTERING SEE FIG. 7.

All the blood enters through the lateral valved openings (*a*); a part of it passes out of the aorta (*b*) anteriorly and another part out of the

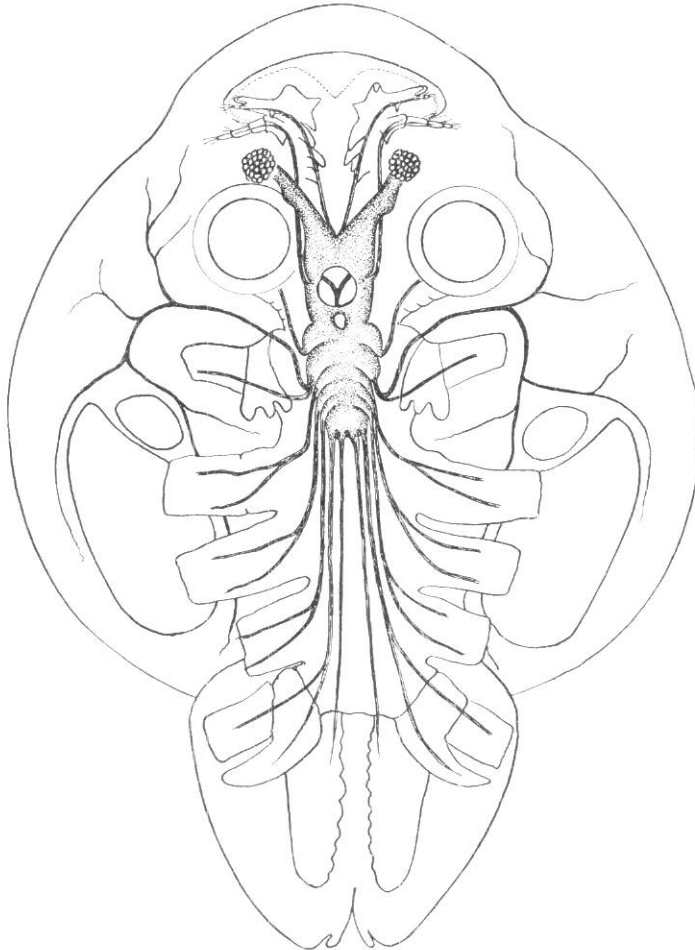


FIG. 9.—THE NERVOUS SYSTEM OF ARGULUS AMERICANUS.

posterior median aperture (*d*); each of these streams follows the usual course (fig. 8), but the greater bulk turns downward and passes out of the ventral median slit (*e*).



This stream pours around the intestine and separates naturally into two side streams running forward past the bases of the swimming legs and sending out lateral streams into each of them, finally joining the anterior streams from the aorta under the brain. On its return the blood percolates through the lateral sinuses of the carapace and, joining the streams from the borders of the abdomen, enters the openings at the sides of the triangular base of the heart.

*Nervous system* (fig. 9).—This consists of a dorsal brain and a ventral chain of six ganglia. The brain is rather small, but well pigmented,

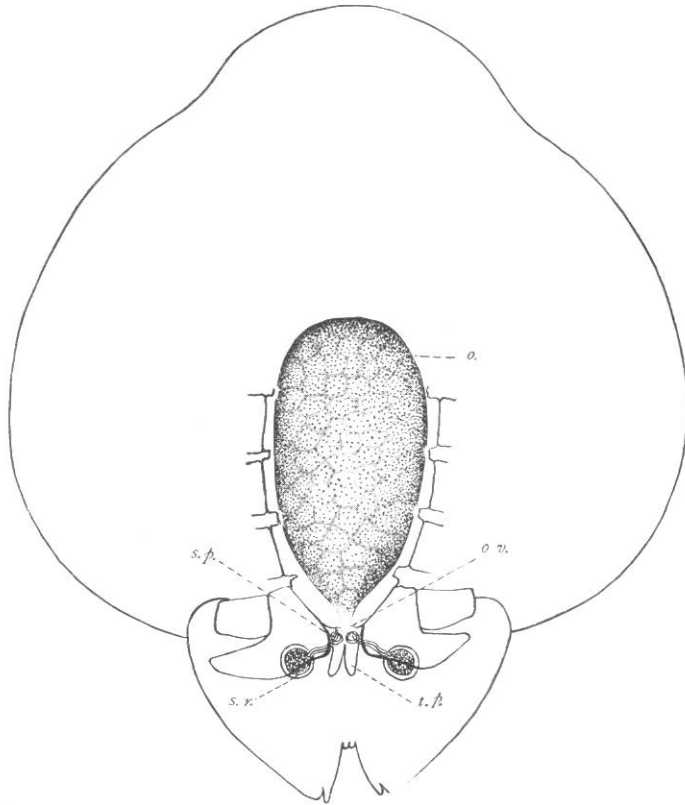


FIG. 10.—SEXUAL ORGANS OF FEMALE ARGULUS AMERICANUS. *o*, OVARY; *o. v.*, OVIDUCT; *s. p.*, SEMEN PAPPILAE; *s. r.*, SEMEN RECEPTACLE; *t. p.*, TACTILE PAPPILAE AT THE OPENINGS OF THE OVIDUCT.

so as to be prominent by contrast with the light-colored carapace. Its ventral portion extends quite a distance in front of the pigmented dorsal portion and is nearly three times as wide. From the anterior border of this ventral portion a pair of nerves extend forward to the anterior antennæ. Another pair arise from about the center of the lateral borders and lead to the posterior antennæ. These two pairs are the only cranial nerves. The ventral ganglia diminish in size rapidly; they are distinctly lobed along the sides, but fused through

the center. Each of the five anterior ones gives off a single pair of nerves, while the sixth and last one gives off two pairs. The nerves from the first ganglion, which is considerably the largest of the six, go to the sucking disks; a branch arises from this nerve very soon after it leaves the ganglion and passes forward to the mouth parts. The nerves from the second ganglion are a little larger than any of the others, which is fully accounted for when it is found that they quickly divide, one large branch going to the second maxillipeds and the other innervating the lateral areas of the carapace.

The nerves from the third, fourth, and fifth ganglia and the first pair from the sixth ganglion supply the swimming legs in order on either side. The last pair of nerves which are given off from the posterior border of the sixth ganglion innervate the reproductive organs.

*Reproductive organs* (fig. 10).—These are beautifully typical and can

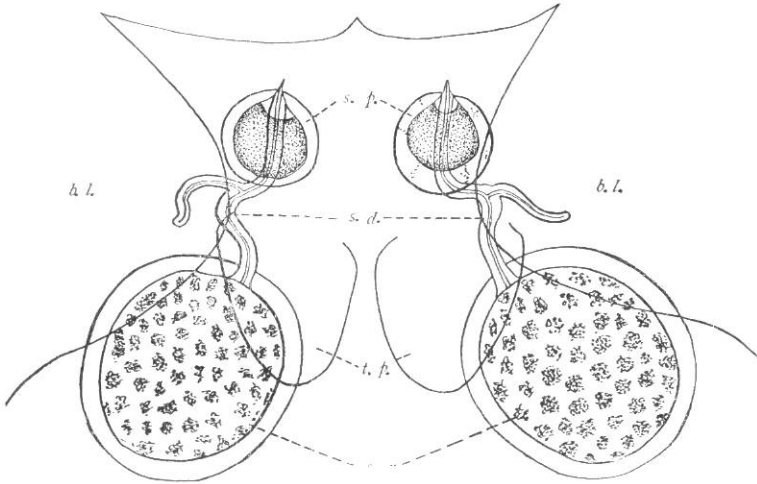


FIG. 11.—SEMEN RECEPTACLES AND PAPILLÆ OF ARGULUS AMERICANUS FEMALE UNDER GREATER ENLARGEMENT. *b. l.*, BASAL LOBES OF POSTERIOR LEGS; *s. d.*, DUCTS LEADING FROM THE RECEPTACLES TO THE PAPILLÆ; *s. p.*, SEMEN PAPILLÆ; *s. r.*, SEMEN RECEPTACLES; *t. p.*, TACTILE PAPILLÆ.

be plainly seen through the outer covering, even in preserved and mounted specimens. In the female the semen receptacles (*s. r.*, fig. 11) are large and close together; the semen papillæ (*s. p.*) are also large and the hardened chitinous tip of the duct which leads to them from the receptacles projects forward rather than inward toward its fellow on the other side. In the figure the tactile papillæ (*t. p.*) used for ovipositing are much smaller than the average, and the specimen was selected for this reason, since these papillæ would conceal the underlying organs as little as possible.

The relative size shown in the full-length figure of the female (fig. 2) is nearer the average.

In the male the essential organs (fig. 12) are quite typical, but the accessory organs surpass those of any species so far examined. In

addition to the regular peg and semen receptacle on the fourth and third legs, respectively, we find on the anterior surface of the third leg a long club-shaped projection, which arises from the outer end of the basal joint and projects diagonally forward and outward past the distal basipod joint and far out on the exopod (fig. 13). Its surface is smooth and even and it seems to be tactile in function. There is another conical projection, a trifle smaller, on the posterior surface

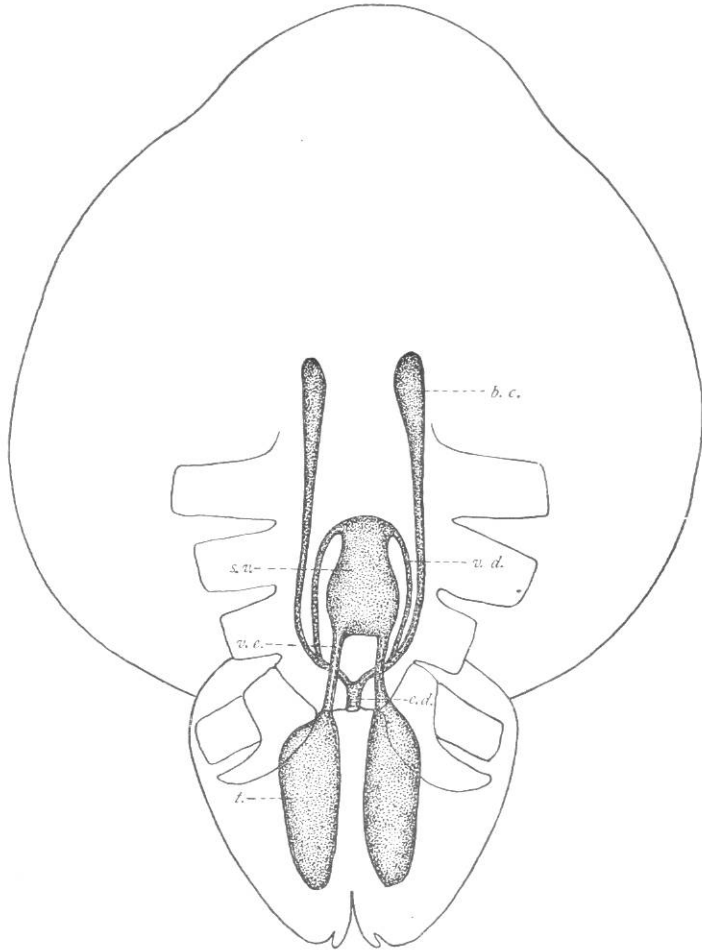


FIG. 12.—SEXUAL ORGANS OF MALE ARGULUS AMERICANUS. *b. c.*, BLIND CAPSULE; *e. d.*, EJACULATORY DUCT; *s. v.*, SEMEN VESICLE; *t.*, TESTES; *v. d.*, VAS DEFERENS; *v. e.*, VAS EFFERENS.

of the preceding pair of legs, exactly opposite the one just described. This also has a smooth surface and a probable tactile function. To increase this probability both projections are well innervated and their surfaces are plentifully covered with short setae. There are also small projections, varying considerably in different individuals, upon the opposite surfaces of the same joints as bear the large ones.

*Eggs and development.*—Gurley, in the manuscript already referred to, has given an outline of development, with a description of the larva. But, again, the present author had obtained ripe females from Professor Reighard at Ann Arbor, Michigan, and had successfully reared the larvæ before Gurley's manuscript was placed in his hands. It is a pleasure to find that these two accounts agree in every detail.

The eggs are laid in single rows (fig. 14), exactly as those of *A. megalops*, and not at all resembling either *A. foliaceus* or *A. catostomi*. But the eggs themselves are more like those of *A. catostomi* than of any other species whose eggs are known.

They are arranged end to end, the heads all pointing in one direction, but with every third or fourth one reversed. The jelly in which they are enveloped, on hardening in the water, assumes an appearance very similar to that on the eggs of *A. catostomi*—that is, it is raised into ridges running lengthwise of the egg, each ridge composed of a row of club-shaped papillæ standing out at right angles to the surface of the egg (fig. 15). There are about six of these rows on the free surface of the eggs, including those along the sides where the eggs are attached to

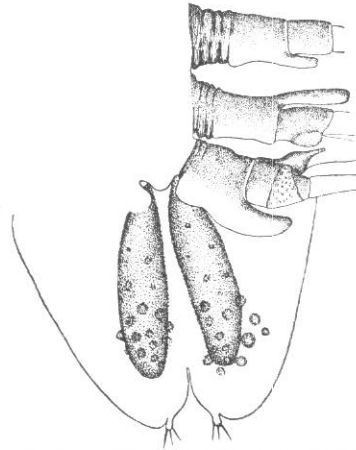


FIG. 13.—POSTERIOR LEGS AND ABDOMEN OF ARGULUS AMERICANUS.

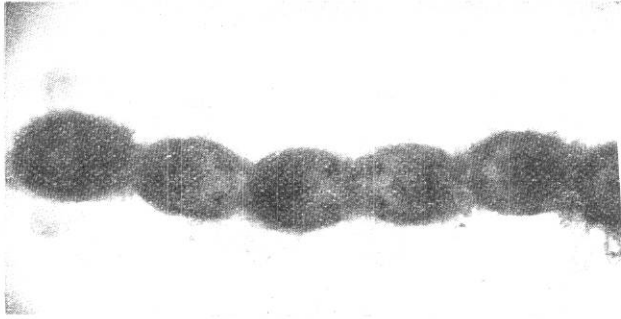


FIG. 14.—MICRO-PHOTOGRAPH OF EGG STRING OF ARGULUS AMERICANUS, SHOWING THE JELLY PROTUBERANCES AND THE LARVÆ PARTIALLY DEVELOPED.

the surface on which they are laid. The rows coalesce at the ends and are most widely separated at the center.

In addition to these crenated ridges there are also a few large scattered masses of jelly, some of which are nearly two-thirds as large as

the entire egg. They also stand out nearly at right angles to the surface of the egg, and while they are really attached at random, yet there is an average of about one on either side of each egg in the row, so that, viewed as a whole, they are at fairly regular intervals. This feature is sufficient to distinguish the eggs at once from any others that are known.

The eggs are small, measuring 0.375 by 0.275 mm. exclusive of the jelly, light yellow in color and quite clear when first laid. But they speedily turn darker in color and become opaque within the first two

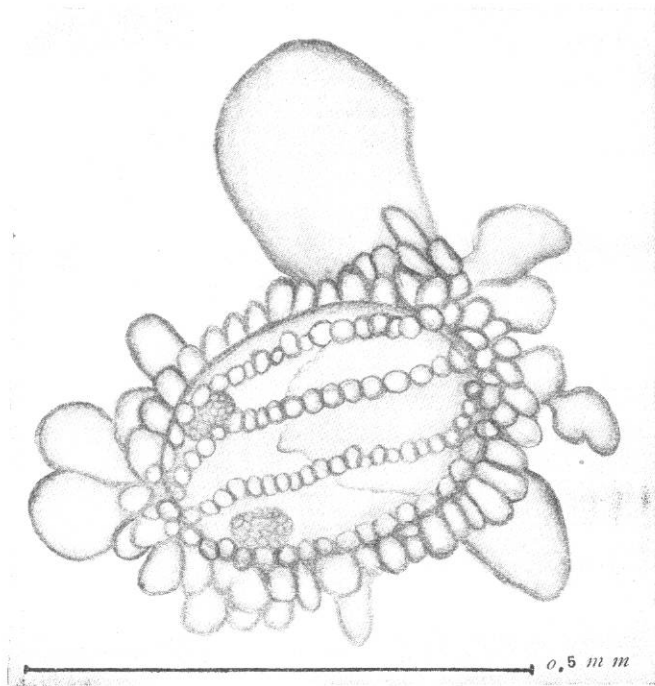


FIG. 15.—AN EGG OF ARGULUS AMERICANUS APPROACHING MATURITY. THE FULLY FORMED LARVA CAN BE SEEN THROUGH THE JELLY ENVELOPE.

days. Toward the middle of the second week, about the tenth day, the eyes appear as two jet black large-sized spots near one end of the egg. These spots are elliptical in shape, with their longer diameters inclined toward the central axis of the egg, which is also that of the embryo.

The egg now begins to clear and becomes more and more transparent up to the time of hatching. Through the membranes and the jelly can be seen the outline of the embryo's body and appendages. These can not be distinguished as plainly as in *megalops*, for many reasons. The jelly covering the egg is not as transparent as in *megalops* and the papillae render it still more opaque. Again, the partial development of the appendages renders it possible to pack the

embryo in a much smaller space, with a resultant confusion of the parts.

Such close packing explains, furthermore, the small size of the egg, and we are forced again to the conclusion that the size of a copepod's egg has very little to do with the size of the adult female. It is,

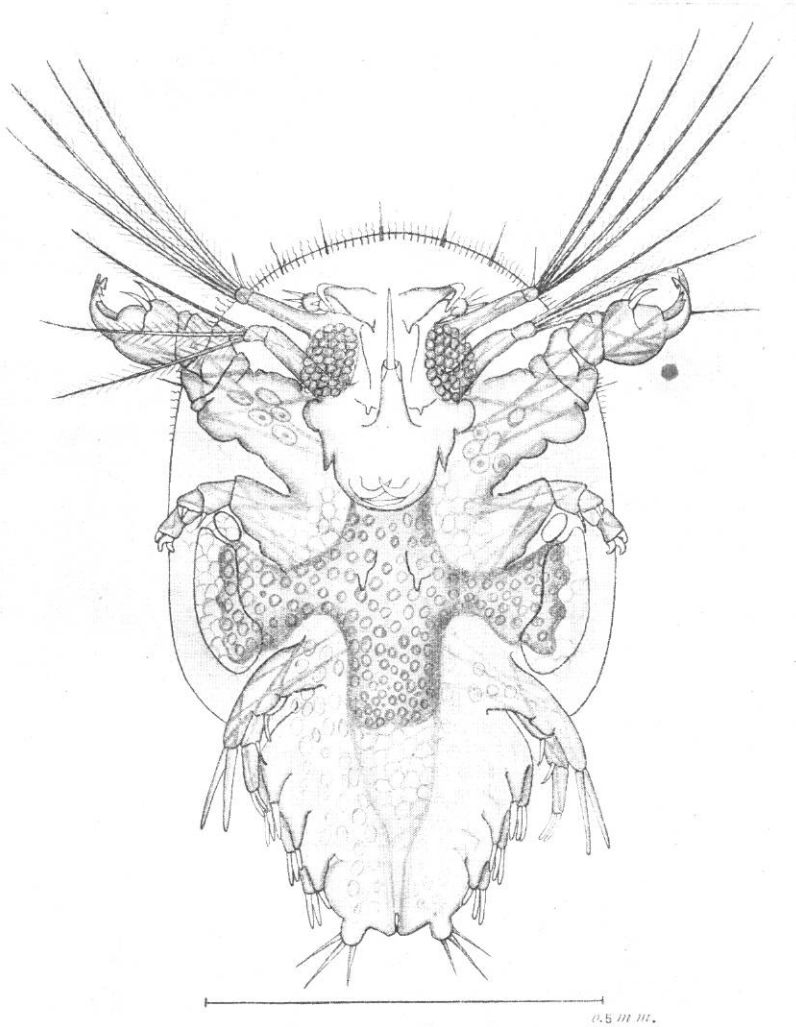


FIG. 16.—NEWLY HATCHED LARVA OF ARGULUS AMERICANUS.

rather, dependent upon the length of time the embryo is to remain within the egg and the degree of development it is to attain before hatching. An adult *americanus* is much larger than a *megalops*, and yet the eggs of the two are about the same size. This is explained by the fact that the *megalops* larva spends sixty days or more inside the

egg, and comes forth a miniature adult, while the *americanus* larva spends only sixteen or seventeen days in the egg and comes forth in a typical cyclops stage to undergo many subsequent transformations before reaching the adult form.

The temperature of the aquarium was about 72° F., or a few degrees warmer than our fresh-water ponds during the summer season. The eggs which were laid June 8 began to hatch the 25th, a period of only seventeen days, about half the length of time required by the eggs of *A. foliaceus* and *catostomi* and only one-fifth of that required by *A. stizostethii* and *megalops*.

The newly hatched larvæ (fig. 16) are not as lively as those of

*megalops*, which would be expected from the fact that they are not provided with as good organs of locomotion, but they are also more sluggish than the *catostomi* larvæ, which have exactly the same structure. Furthermore, when first hatched they stick to the bottom of the dish and do not swim up and toward the light until the third or fourth day. And when they do get up to the surface they prove to be negatively heliotropic, in sharp contrast with all the other *Argulus* larvæ thus far studied, which are positively heliotropic to a very marked degree.

Owing both to the position and incomplete development of the temporary locomotor organs, the motion of these nauplii is jerky and cyclops-like. They are not

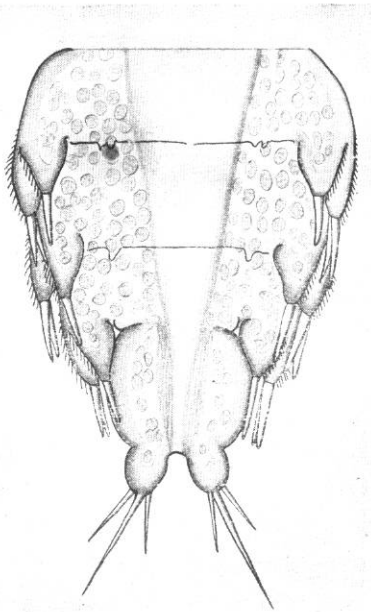


FIG. 17.—FREE THORAX AND ABDOMEN OF ARGULUS AMERICANUS LARVA.

as transparent as the other larvæ and do not furnish as favorable objects for study, owing to the presence of a large area of rust-colored pigment over the stomach and anterior intestine which hides much of the internal anatomy.

In general shape they are short and broad, the carapace being well rounded anteriorly, with a broad and shallow posterior sinus, while the free thorax and abdomen form a broad triangle, relatively shorter than that of *foliaceus* and *catostomi*. Around the anterior margin of the carapace can be seen large tactile hairs similar to those found upon other species. But they are much fewer in number and more scattered than in *megalops*, and the intervening cilia are very minute

and situated not at the very margin, but a little way back on the ventral surface.

The first free segment of the thorax (fig. 17) is about half the width of the carapace, while the succeeding segments diminish rapidly in size. The abdomen is about the same width as the last thorax segment, is well rounded at the sides, and terminates posteriorly in a pair of anal papillæ which are large, almost spherical in shape, and tipped with three long, sharp spines.

The first antennæ (fig. 18) are three jointed, as in other species, but the basal joint is relatively much smaller; in fact, it is but a trifle larger than the two spherical terminal joints, but is armed with the usual stout sickle-shaped hook. The bristles and spines on these terminal joints are rather more numerous than in other species.

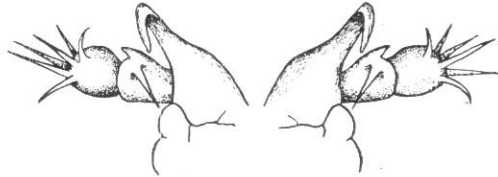


FIG. 18.—FIRST ANTENNAE OF THE NEWLY HATCHED LARVA OF ARGULUS AMERICANUS.

The second antennæ are modified into locomotor organs, and both in the segments and in the number and arrangement of the long plumose rowing setæ they are exactly like those of *foliaceus* and *catostomi* nauplii. The temporary mandibular palps are also like those of the species just named, but are attached somewhat farther forward relative to the other mouth parts.

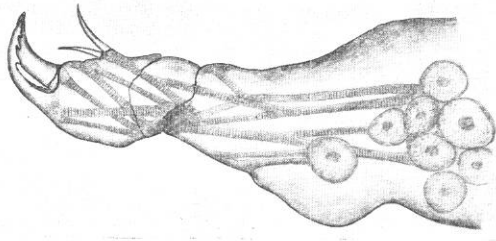


FIG. 19.—ANTERIOR MAXILLIPED OF THE NEWLY HATCHED ARGULUS AMERICANUS.

The anterior maxillipeds (fig. 19) are stout, four jointed, and terminate in the usual pair of sickle-shaped hooks, the ventral one of which is barbed. The basal joint of these appendages is very stout, and in its interior can be seen the group of large cells which are to form the sucking disks in later development.

The posterior maxillipeds (fig. 20) are much smaller, five jointed, and very rough on their ventral surface, while the outer border of every joint is armed with one and often two or more sharp spines.

These appendages terminate in two small but stout claws capable of independent motion and a conical papilla tipped with two short spines. The basal joint has no spine upon its posterior border.



The swimming legs are the same as in *foliaceus* and *catostomi*, the first pair only being developed, while the rest are immovable stumps. This first pair (fig. 21) consists of two basal joints well roughened and armed with numerous spines upon their ventral surface, a two-jointed endopod tipped with two short spines, and a one-jointed exopod tipped with two long rowing setae.

The only difference here from other larvæ already described is that the endopod has only two instead of three joints.

The leg stumps attached to the other thoracic segments all show the endopods and exopods clearly, the former being tipped with a single spine, the latter with two.

In their internal structure the most noticeable difference from other larvæ is the almost complete absence of skin glands.

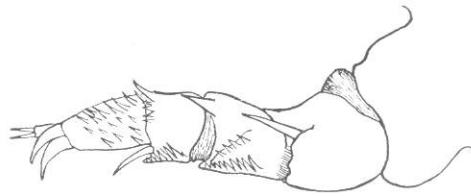


FIG. 20.—SECOND MAXILLIPED OF THE NEWLY HATCHED LARVA OF ARGULUS AMERICANUS.

The *megalops* larva, with its sixty days of incubation, came forth with a wonderfully well developed system of skin glands; the *foliaceus* and *catostomi* larvæ, with about half as long an incubation, showed a little more than half as many glands.

And now these *americanus* larvæ, with an incubation of only seventeen days, show almost no glands at all. We can not escape the conviction that these glands are developed quite slowly and that they do not appear until comparatively late in larval life. It would seem also that they must be developed independently of the incubation period, so that while the latter is changed greatly, being doubled in some species and halved in others, the glands apparently always require about the same time for development. In these *americanus* larvæ we find but a single small group of glands, six or seven in number, on either side near the posterior edge of the carapace lobes. They are much smaller than in *megalops*, and the ducts are not at all distinct. There are also a few scattered glands along the dorsal surface of the carapace, thorax, and abdomen, but they are all very small, and none of them show the structure given for *foliaceus* and *megalops*. They have rather the appearance of being in an immature and partially developed condition.

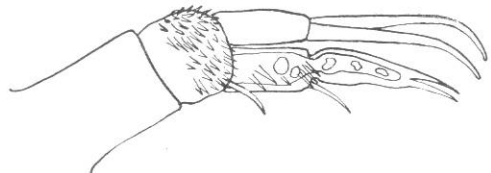


FIG. 21.—FIRST SWIMMING LEG OF THE NEWLY HATCHED LARVA OF ARGULUS AMERICANUS.

The paired shell glands are invisible, due to the opacity of the

surface pigment, which is so dense just in front of the side branches of the stomach where these glands are situated, and also in many other places, as to conceal all details of internal structure. The circulation is similar to that described in other larvæ except for the absence of a well-defined peripheral sinus in both the abdomen and the cephalo-thorax.

The internal cellular lacunæ appear about the same, but the currents are not as well defined, especially those of the abdomen. This larval circulation is carried on chiefly by means of certain muscles in the cephalo-thorax and abdomen, similar in both position and function to those already described for *megalops*. The heart has not yet appeared, and hence those differences which make the adult circulation peculiar can not yet be detected. The transverse dorso-ventral band or curtain at the place occupied later by the posterior wall of the heart is not as well developed as in *megalops* larvæ, another natural result of the differences in the period of development.

Furthermore, in view of the immature condition of all the swimming legs except the first pair, the muscles in the basipods of those appendages can not aid circulation to any appreciable extent. In fact, the undeveloped condition of most of the larval organs may well explain the feeble circulation.

As soon as the heart acquires definite form after the first moult we should expect to find the circulation showing the same peculiarities as in the adult.

The nervous and reproductive systems present no peculiarities worthy of special note, but are similar to those already described in the adult.

#### ARGULUS VERSICOLOR Wilson.

*Argulus versicolor* Wilson, Proc. U. S. Nat. Mus., XXV, p. 716.

This is a very clean-looking *Argulus* and by far the most beautiful of any American species. It can be distinguished from all others at a glance by its brilliant coloration, which is as variegated as that of an old-fashioned patch-work quilt or the traditional Joseph's coat. The ground color is a soft yellow-green, which forms a wide border around the edge of the carapace and extends inward in a series of bands and irregular spots, the former being a deeper green than the margin, while the latter have somewhat of a rusty tinge. One of these bands runs from the marginal border on either side just behind the sucking disks diagonally backward to the base of the central longitudinal ribs. From the center of each diagonal band another narrower one extends backward parallel with the edge nearly to the posterior margin of the carapace. These longitudinal bands are joined with the marginal border at about their center by a short radial band, which shows the same rusty tinge as the spots. These latter are found just outside the suck-

ing disks and also opposite the base of the first swimming legs in the lateral lobes.

The rest of the surface is filled in with orange-yellow of varying intensity, the posterior portion of the carapace lobes being tinged with brown, while the side branches of the stomach give more or less of a reddish hue to the parts overlying them.

Through this variegated groundwork the ribs, the digestive tube, and the reproductive organs stand out prominently. The ribs are a bright golden orange, the two central longitudinal ones being bordered with yellow green.

The digestive tube, when the parasite has taken a full meal, is deep wine red in the carapace and thorax, but fades to a green-yellow in the abdomen. It has a dark-green border on either side which occupies all the thoracic segments outside the intestine itself and extends forward anteriorly to the frontal border and posteriorly to the extreme tip of the abdomen lobes.

The testes and semen receptacles are a rich purple-red, so deep as to be almost opaque.

The eyes and brain are large and of a brilliant black.

With such a rich variety of color it would be natural to suppose that these copepods would fade quickly in preservatives, but such is not the case. After being hardened in chrome-acetic, corrosive-acetic, and Perenyi's, they have been kept nearly three years in alcohol with so little change as hardly to be distinguished from fresh specimens. They can also be run up through the alcohols, cleared in xylol or clove oil, and mounted in balsam without change of color. Indeed, eau-de-javelle is the only agent yet tried which will bleach the color. This removes it entirely and leaves the *Argulus* perfectly transparent.

Thus far the species has been found only upon the common pickerel (*Lucius reticulatus* Le Sueur), but is likely to be found upon other fish also at the breeding season.

Actual experiment has proved that they are capable of living on red-fin shiners, bream, etc., for a long time.<sup>a</sup>

This single host is, however, very widely distributed throughout the United States, and in all probability the parasite has an equal distribution. Not more than two or three specimens are found upon a single fish, and these are always in the gill cavity. Often also it is necessary to examine fifteen or twenty fish before finding a single parasite, so that they could be easily overlooked and a good summer catch of fish might not reveal their presence. For this reason winter is the best time to secure them upon fish caught through the ice, and as they remain alive for some time after the fish is dead an entire day's catch can be looked over. In this manner as many as thirty have been obtained in a single afternoon from three adjacent ponds. Thus far

<sup>a</sup>Proc. U. S. Nat. Mus., XXV, 1902, p. 647.

they have not been sought in a single locality without success. When kept in aquaria they are lively, moving about and changing from one fish to another more often than other species. The long plumose setæ upon the swimming legs make powerful oars and enable them to dart about with great rapidity. One of their favorite movements is to leave the side of the aquarium and, turning back downward, scuttle swiftly along the under side of the surface film of the water after the manner of the very much slower aquatic snails.

GENERAL FORM—*Dorsal surface* (fig. 22).—Carapace almost perfectly orbicular, the antero-lateral sinuses shallow, but leaving a well-rounded frontal lobe; the posterior sinus is one-third the length of the carapace and only one-sixth its width, so that the lateral lobes are broad

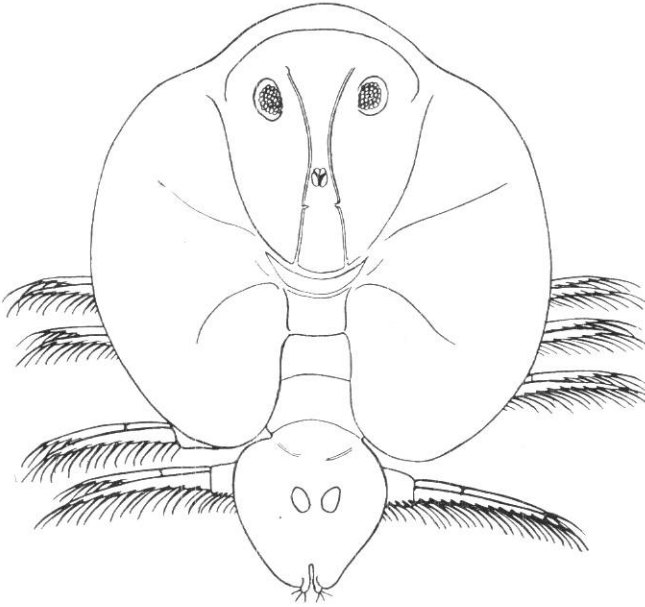


FIG. 22.—DORSAL VIEW OF FEMALE ARGULUS VERSICOLOR.

and well rounded. In the female they just reach the abdomen; in the male they overlap it somewhat. The free thoracic segments are twice as wide as long and are half concealed beneath the carapace lobes on either side. The abdomen has a very graceful oval outline in the female and is about three-sevenths the length of the carapace. In the male it is more nearly triangular, but narrows considerably anterior to the testes, and the lateral margins project forward in a well-defined and rounded lobe on either side. The anal sinus is very short and slit-like, with the papillæ subterminal.

The arrangement of the grooves dividing the carapace into its areas is very symmetrical. The longitudinal ribs are close together, and the joints in them just behind the brain can be clearly seen. The

horseshoe suture is longer and narrower than in *americanus*, and from near its base two sutures radiate outward into the lateral area. The thoracic area is separated into an anterior crescent-shaped and a pos-

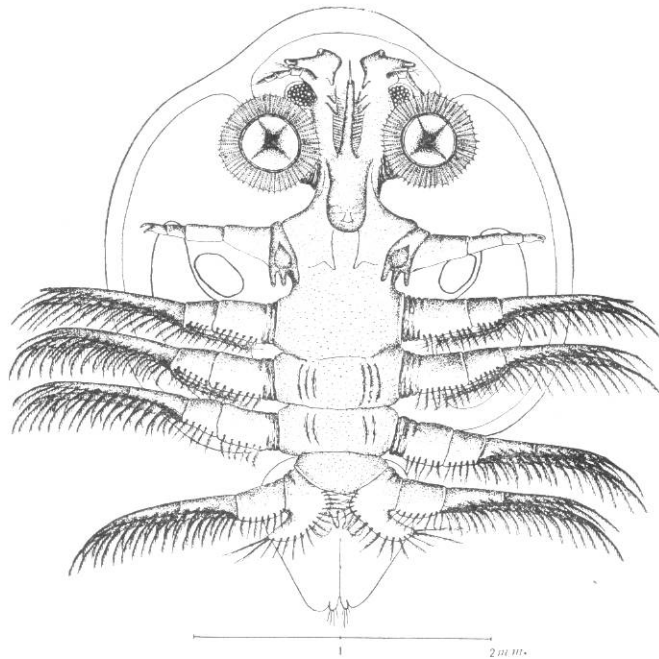


FIG. 23.—VENTRAL VIEW OF FEMALE ARGULUS VERSICOLOR.

terior rectangular portion, the former of which is much wider than the latter and follows closely the posterior curve of the horseshoe.

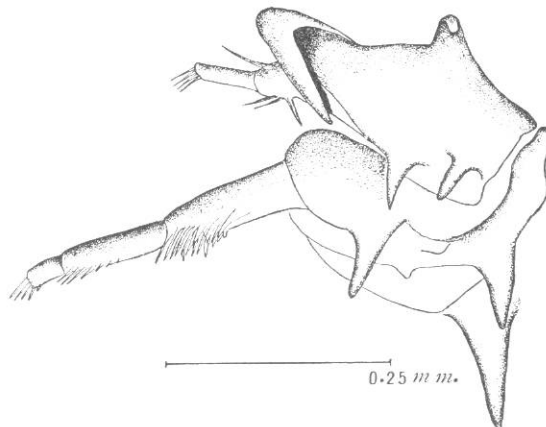


FIG. 24.—DETAIL OF ANTENNAE OF ARGULUS VERSICOLOR.

*Ventral surface* (fig. 23).—The frontal lobe is simple and, together with the anterior half of the lateral areas, is covered with inconspicuous triangular spines. The antennae are of good size and well armed;

the hooks upon the basal joint of the first pair are large and powerful, while the spines are very long and sharp. The two terminal joints carry numerous setæ, but do not project much beyond the lateral hook (fig. 24). The second antennæ are 4-jointed, the basal joint having a long spine on its posterior margin, while each of the remaining joints has a tuft of stout setæ at its distal end. The eyes are large, somewhat lunate, and inclined toward the longitudinal ribs; the facets are small and numerous and crowded closely together.

On the median line between the eyes and posterior to the large spines which arm the base of the second antennæ there is a groove for the reception of the stylet (fig. 25). It extends back as far as the base of the proboscis, and is lined on either side with a heavily corrugated layer of chitin.

The mouth differs considerably from that of other described species, and presents a peculiar appearance by reason of the arrangement of its chitin framework. The mouth opening is narrowed antero-posteriorly and elongated sidewise so as to appear like a narrow transverse slit, broken at the center by the protruding under lip (fig. 26). On examining the chitin skeleton, we find the same four longitudinal ribs connected at the latitude of the mouth by a transverse framework. But the structure and arrangement of this latter is very different from anything yet described, as can be readily seen in fig. 26. The most noticeable differences are the elliptical loops on either side of the mouth and a trapezoidal projection which extends down into the center of the upper lip to the very edge of the mouth opening.

The transverse rib also, which is situated at the junction of the upper and under lips on either side, turns outward at the joint nearest the mouth and protrudes like a knob through the side of the proboscis. The rudimentary palp alongside this joint is very small. Inside the lips may be seen a part of the long, sickle-shaped mandibles, edged with sharp saw teeth. The maxillæ have not yet been seen.

The anterior maxillipeds are large, well separated, and placed far forward close to the margin of the antero-lateral sinuses. The mem-

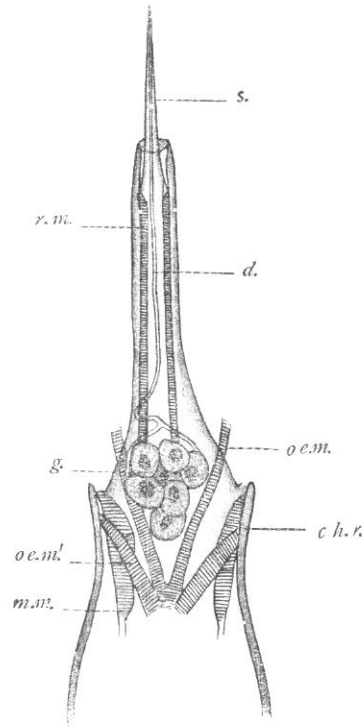


FIG. 25.—STING AND POISON GLAND OF ARGULUS VERSICOLOR. *ch.r.*, CHITIN RIB OF PROBOSCIS; *d.*, DUCTS OF POISON GLAND; *g.*, POISON GLAND; *m.m.*, MANDIBLE MUSCLES; *o.e.m.*, ESOPHAGUS MUSCLE; *o.e.m'*, SIDE MUSCLE OF ESOPHAGUS; *r.m.*, RETRACTOR MUSCLE; *s.*, STING.

branous edge is quite wide, and is supported by chitin ribs whose construction is peculiar. The stiffened circle which serves as an

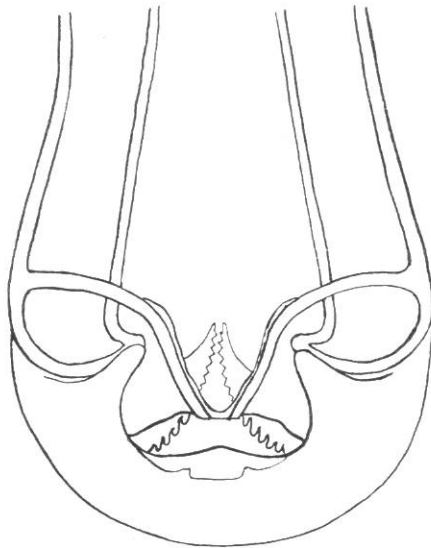


FIG. 26.—CHITIN SKELETON OF THE PROBOSCIS IN ARGULUS VERSICOLOR.

outer ones it is approximately symmetrical. The plates are arranged end to end and do not quite touch one another, but leave narrow open spaces of membrane. Thus, while strengthening the membrane they still leave it very flexible.

*Posterior maxillipeds* (fig. 28).—These are also large and well armed. The joints diminish in size much more regularly than those of *americanus*; the plate on the basal joint is triangular, with long, stout, and not very sharp teeth; the papillated area is comparatively large

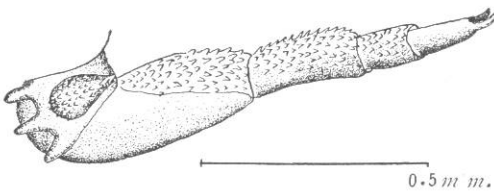


FIG. 28.—POSTERIOR MAXILLIPED OF ARGULUS VERSICOLOR.

and armed with strong setæ. The anterior half of the second joint and the entire ventral surface of the remaining three joints are covered with good-sized papillæ, each carrying a toothed scale. These papillated scales are similar to those on *americanus*, and consist of a hemispherical or hemiellipsoidal papilla, upon whose summit is borne the toothed scale. The latter is inclined at an angle of 10

as well as the membranous edge, is raised into knobs at equal intervals around its circumference (fig. 27). From each knob a chain of four slightly oblong chitin plates extends outward to the edge of the membrane. These are placed end to end and diminish regularly in size, the distal one being less than half as large as the proximal. Each is convex at the proximal and concave at the distal end, the convexity of one plate fitting into the concavity of the one next inside it. In the first and second plates the concavity is eccentrically situated, but in the two

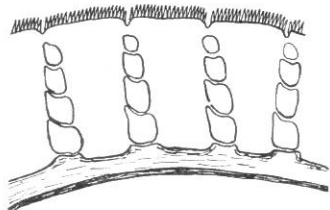


FIG. 27.—CHITIN RIBS IN THE MARGIN OF THE SUCKING DISKS OF ARGULUS VERSICOLOR.

or 15 degrees to the body and is an elongated ellipse in outline (see *a* in fig. 29). Its basal half, which is fused with the summit of the papilla, is solid, but the free half is cut into from two to six long and acuminate teeth. In general the scales nearer the anterior margin of the maxilliped have the larger number of teeth. Often one of the outer teeth is short and stands out at an angle from the others like a thumb. Evidently such an arrangement forms a surface which must give the copepod a firm hold even through the slimy coat of the fish's body.

The terminal joint of these maxillipeds ends in three hooks of unequal size; the anterior one is much the largest, with a thick, blunt tip armed with a single short, sharp seta. The other two are more slender and strongly curved (fig. 30).

*Swimming legs.*—These are long and slender and reach far beyond the edge of the carapace. They are fringed with stout plumose setae and enable this argulus to swim with great power and rapidity. The flagella upon the first two pairs have a double curve, as can be seen in fig. 31, which is a dorsal view looking through the carapace in a bleached specimen. The basal lobes upon the posterior legs are very long and their tips extend beyond

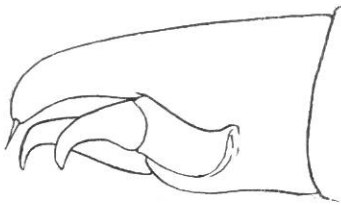


FIG. 30.—TERMINAL JOINT OF POSTERIOR MAXILLIPED OF ARGULUS VERSICOLOR.

the edge of the abdomen. They have the usual boot shape, with a single seta on the toe of the boot much longer than the rest. The chitin rings in the lateral lobes of the carapace extend farther forward than those in *americanus*, and the concavity in the posterior one into which the smaller ring fits is on the inner margin a short distance back from the anterior end instead of at the end itself.

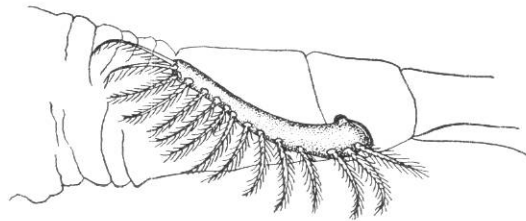


FIG. 31.—DORSAL SURFACE OF THE ANTERIOR LEG ON THE RIGHT SIDE OF ARGULUS VERSICOLOR, SHOWING SIZE AND ATTACHMENT OF NORMAL FLAGELLUM.

*Tactile papillæ.*—These are long and slender in the female and curve in toward each other at the tips, while in the male they are so rudimentary as to be almost invisible.

*Circulation.*—This is the same as that given for *A. foliaceus*.



FIG. 29.—SCALES ON VENTRAL SURFACE OF THE POSTERIOR MAXILLIPEDS OF ARGULUS VERSICOLOR.



*Reproductive organs.*—These are similar in position and arrangement to those of *americanus*, but the unpaired seminal vesicle in the male is quite different in shape, being nearly spherical, with an emarginate anterior border. Another difference was the fact that, after removing the pigment from several males, no trace of any accessory blind capsules could be seen. The second legs of the male have a large conical projection on their posterior surface at the outer end of the basal joint (fig. 32). There is a similar much smaller one in a corresponding position on the third legs, and these legs also have a rounded knob on the anterior surface of the second joint at the end next the body.

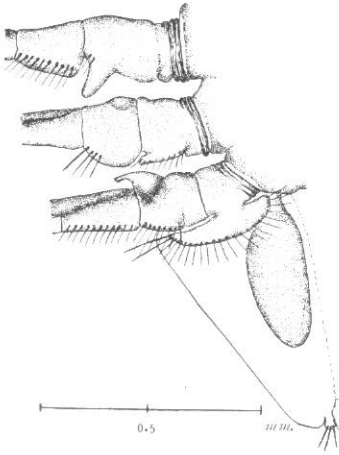


FIG. 32.—THREE POSTERIOR PAIRS OF LEGS IN THE MALE ARGULUS VERSICOLOR.

But the chief interest, both in this species and *americanus*, lies in the fact that it was possible to ascertain in them from actual observation the structure and exact function of the semen receptacle and peg upon the bases of the third and fourth legs, respectively.

The peg consists of two parts, basal and terminal; the basal portion is a blunt papilla whose walls are stiff and covered with rough tubercles (fig. 33). It does not appear to be hollow, but readily permits of the withdrawal of the terminal part inside itself. This terminal portion is a slightly curved conical tube, with walls as flexible as rubber and so thin as to be perfectly transparent and colorless. The tip of the tube is somewhat enlarged and surrounded by a row of minute hairs. Inside both tube and papilla can be seen a muscle strand which extends from the tip of the tube diagonally backward to the posterior margin of the leg. By means of this muscle, together with the circular muscles in its own walls, the tube can be withdrawn inside the papilla or protruded at pleasure.

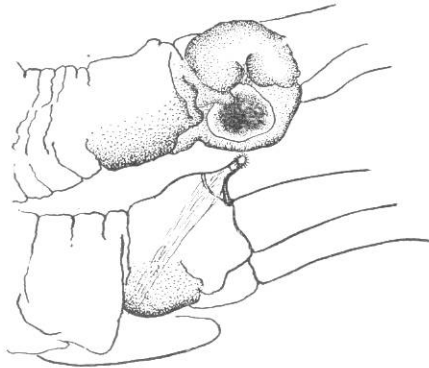


FIG. 33.—BASAL JOINTS OF THE TWO POSTERIOR LEGS OF MALE ARGULUS VERSICOLOR, SEEN FROM THE VENTRAL SURFACE.

The semen receptacle is a cavity in the posterior part of the distal end of the basal portion of the third legs; the opening into this cavity is on the ventral surface, near the posterior margin. This opening is guarded by a strong sphincter muscle.

Just in front of the opening, upon the anterior part of the ventral surface, are two rounded papillæ, covered with rough tubercles. This receptacle is filled with semen from the testes, probably through the agency of the peg, though this was not actually observed. Once filled, however, it operates as follows: The sphincter muscle around the opening relaxes enough to allow the entrance of the peg on the fourth leg. Being protruded as far as possible and the sides of the basal papilla being compressed by internal muscles, the peg tube acts like a pipette and becomes filled with semen from the receptacle. It is then withdrawn and inserted in the opening of the duct leading to the semen receptacle in the abdomen of the female. The sides of the basal papilla are again compressed, the internal muscles being aided by the rough papillæ on the ventral surface of the fourth leg, which bend over and seize the base of the peg securely, one on either side. By this means the peg is emptied of its contents again very similarly to a pipette.

ARGULUS TRILINEATA, new species.

The U. S. Fish Commission recently received from Messrs. King and Oliphant, pharmacists, of Macon, Georgia, a single specimen of a female *Argulus* taken from one of their goldfish. This was forwarded to the author for identification, and proves to be a new species, with characters as follows:

Carapace elliptical, reaching well beyond the base of the abdomen, with the longitudinal and transverse diameters in the proportion of 14:12.5 (fig. 34). The posterior sinus is three-sevenths the length of the carapace and a little more than twice as long as wide. The anterolateral sinuses are so shallow as to be scarcely perceptible, so that the cephalic area does not project appreciably. The central longitudinal ribs are close together and nearly parallel; the joints in them behind the brain are indistinct and easily overlooked. The horseshoe suture is long and narrow and comparatively pointed at the posterior end, leaving the lateral areas very symmetrical and about the same size anteriorly and posteriorly. The thoracic area of the carapace, behind this suture, is a short strip one-fourth as long as wide and only half the length of the first free thoracic segment.

These thoracic segments increase in length from in front backward, the posterior one being more than twice as long as the anterior. They also increase somewhat in breadth, and since the posterior sinus of the carapace is about the same width, the free thorax is almost entirely exposed.

The abdomen is very small and spindle shaped, one-quarter the length of the rest of the body and two-thirds as wide at the center as it is long. The anal sinus is cut just to the center, and is narrow but of uniform width, leaving stout, bluntly conical lobes; the anal papillæ are small and basal.

*Ventral surface* (fig. 35). — Both pairs of antennæ are relatively small and weak, but are fairly well armed with hooks and spines. The anterior and lateral hooks on the basal joint of the first pair are slender, but the spine on the posterior border is above the average size.

The terminal portion of these first antennæ is slender and does not project beyond the lateral hook (fig. 36).

The basal joint of the second antennæ is as long as, and much thicker than, the two terminal joints, and the latter are attached obliquely to

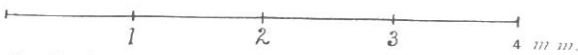
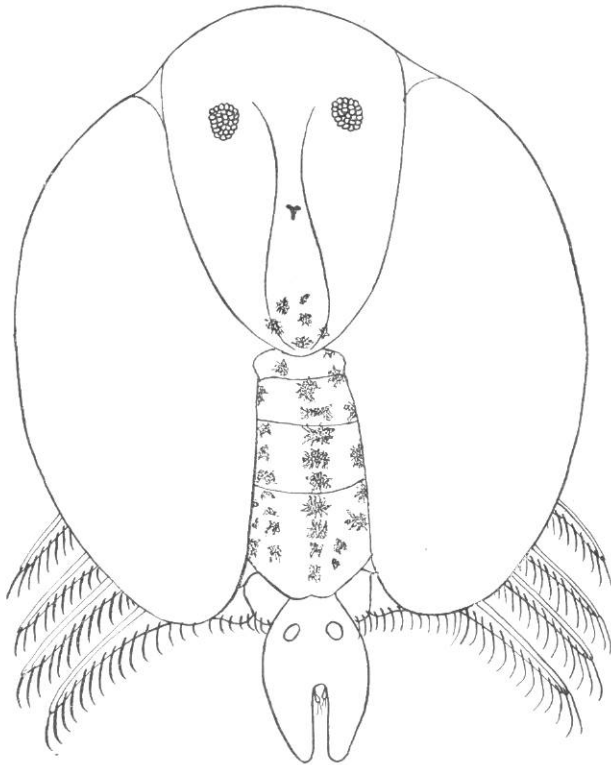


FIG. 34.—DORSAL SURFACE OF A FEMALE ARGULUS TRILINEATA.

one of its distal corners, so that the two portions of the antennæ stand nearly at right angles to each other.

The basal joint carries a stout spine on its posterior margin just where it joins the head, and two long, slender spines on the ventral surface at the distal end. The second joint has a single long spine on its anterior border at the distal end, while the terminal joint carries five or six large and stout spines. The spines along either side of the mid line of the body opposite the bases of the antennæ, those on the

posterior border of the basal joints of the antennæ, and the lateral hooks on the first antennæ are deep yellow in color and opaque; all the others are transparent and colorless.

The eyes are small, lunate, and more or less inclined to the central axis; they are situated well forward and widely separated.

The sucking disks are small, not more than one-eighth the width of the carapace; they are situated far forward and are widely separated.

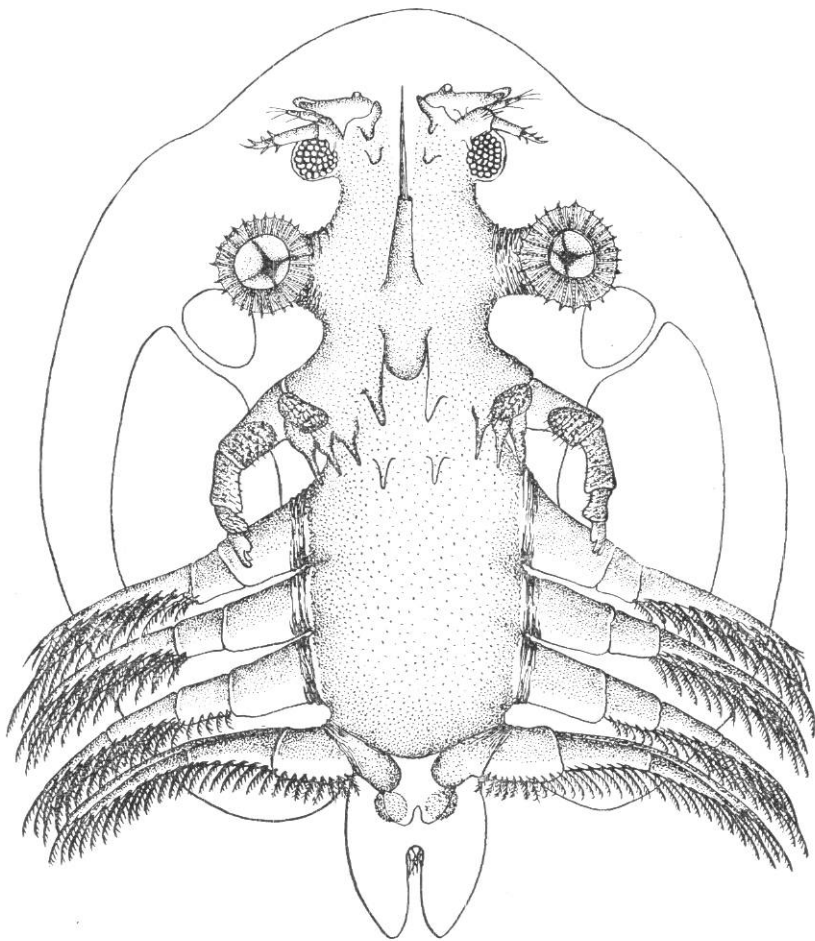


FIG. 35.—VENTRAL SURFACE OF A FEMALE ARGULUS TRILINEATA.

The chitin ribs, which support the membranous border, are made of trough-like scales overlapping one another, very similar to those in *A. megalops*.

*Posterior maxillipeds*.—These are large and very fully armed, to offset the slender antennæ (fig. 37). The basal joint has an oval papillated area, which is placed obliquely, is elevated considerably above

the surrounding surface, and entirely covered with short conical spines. The three teeth on the posterior border of this joint are very long, stout, and acute. The second joint carries on its distal end a papillated area even larger than that on the basal joint. The third and fourth joints are enlarged at their distal ends, and their whole ventral surface is covered with spines and papillae. The terminal joint is tipped with two curved claws and a fleshy

"thumb."

*Swimming legs.*—These reach well beyond the edge of the carapace, and the two anterior pairs have recurved flagella. The distal joints of all four pairs carry a row of plumose setae along their posterior border. The lobes on the basal joints of the last pair are small and well rounded.

The tactile papillae at the pretty thoroughly fused with

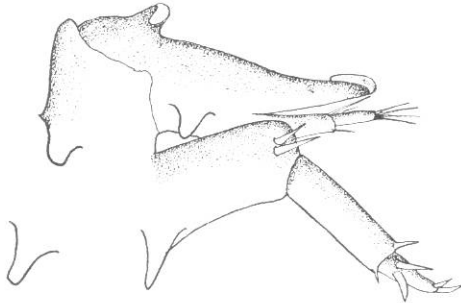


FIG. 36.—FIRST AND SECOND ANTENNAE OF ARGULUS TRILINEATA.

opening of the oviduct are broad and the ventral surface of the abdomen.

Of the chitin rings in the lateral lobes of the carapace the anterior one is small and egg shaped, and is situated very close to the base of the sucking disks, while the posterior one is large and so broad that its inner border reaches to the bases of the swimming legs. The contrast in the size of these two rings is greater than that of any other species so far examined. The ventral surface of the anterior portion of the carapace is covered with triangular spines as large and as numerous as those in *americanus*.

Nothing could be definitely ascertained with reference to the nervous and reproductive systems without danger of spoiling the specimen for a type, and therefore they are allowed to pass for the present. Of course the semen receptacles were visible. They prove to be large, spherical, and situated rather far forward. The papillae connected with them are close together on the median line, well concealed beneath the tactile papillae.

Total length, 4.5 mm.; length of carapace, 3.7 mm.; breadth of carapace, 3.3 mm.; length of abdomen, 1 mm.; breadth, 0.6 mm.

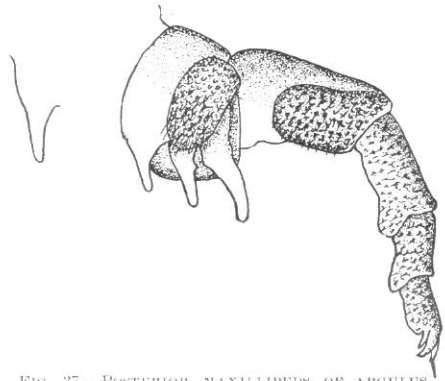


FIG. 37.—POSTERIOR MAXILLIPEDS OF ARGULUS TRILINEATA.

Color a uniform pale yellow, deeper along the central axis and lighter toward the margins. The dorsal surface of the thorax is ornamented with three well-defined rows of dark brown pigment spots which stand out prominently against the yellow background and catch the eye at once when the creature is viewed under a low power. The middle row is made up of a dozen large spots in single line along the central axis; the lateral rows are made up of numerous smaller spots arranged alternately in two broken lines. Under strong magnification these spots are seen to be transversely oblong and very irregular, the edges being cut repeatedly more than half the distance to the center (fig. 38). The large semen receptacles are also dark brown and show through the abdomen very prominently.

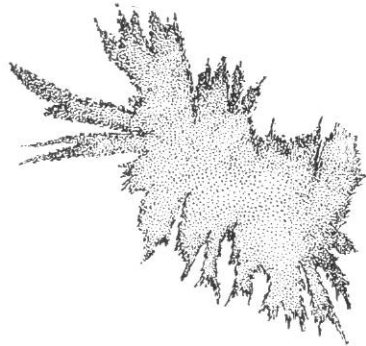


FIG. 38.—ONE OF THE PIGMENT SPOTS ON THE DORSAL SURFACE OF THE FREE THORAX OF ARGULUS TRILINEATA.

Locating this species in the artificial key already published<sup>a</sup> we should have:

- A. Carapace lobes overlapping the base of the abdomen.
  - B. Anterior swimming legs with a flagellum.
  - C. Carapace elliptical, considerably longer than wide.
7. *a*. Sucking disks only 0.12, far forward and widely separated; abdomen small, spindle shaped, cut to the center. Color light yellow, with three rows of dark pigment spots on the dorsal surface of the thorax ..... *trilineata*.

(*tres* = three, *lineatus* = arranged in lines.)

The author also desires to record the occurrence of *Argulus aloæ* at Casco Bay on the coast of Maine.

Several fine males were obtained from the common cunner (*Otenotobrus adspersus* Walbaum), and they seemed fairly numerous. This is the first instance where this species has been positively identified north of Woods Hole since its original discovery by Dr. Gould. And it will increase the probability that the habitat may extend to the Gulf of St. Lawrence as doubtfully recorded by Mr. J. E. Whiteaves. Incidentally also it is the first species of this family to be obtained from the cunner, but as no females were found it may be inferred that this was only a temporary host used during the breeding season.

<sup>a</sup> Proc. U. S. Nat. Mus., XXV, 1902, p. 701.

