The Metamorphosis of Penæus. By W. K. Brooks.

Scarcely another fact in morphological science, standing alone, exceeds in interest the discovery that *Penæus*, a Decapod, passes through a Nauplius stage.

Those familiar with the literature of the subject will recollect that Fritz Müller kept under observation until it changed into a Protozoea a Nauplius which he captured at the surface of the ocean.

He also secured, in the ocean, a very complete series of larvæ, through which he identified his Protozoea with a young Macrouran with the characteristics of the genus *Penæus*.

He did not rear the Nauplius from a *Penæus* egg; nor did he actually observe the transformation into the young *Penæus*. Certain over cautious naturalists have therefore refused to accept his conclusions until more conclusive proof should be furnished.

A number of stages in the development of *Penæus* have been figured and described by Claus; but as he also relied upon surface-collecting, his evidence is open to the same objection.

Although I have shown, by tracing from end to end the life-history of *Lucifer*, that this Macrouran undergoes a series of changes almost perfectly parallel to those which Fritz Müller describes in *Penæus*, it is still desirable, as a matter of history, and in order to set at rest those critics who refuse to give any weight to deductive reasoning in morphology, to trace the life-history of *Penæus*, by actually witnessing the changes.

I have been able this summer, at the marine laboratory of the Johns Hopkins University, to obtain the youngest Protozoea stage of *Penæus*; the stage which Fritz Müller actually reared from the Nauplius. I have had the good fortune to rear this larva in the house, and to witness in isolated captive specimens every one of the five moults between the first Protozoea and the young *Penæus*. During June and July, the breeding-season, the mature females cannot be found inside the Sounds of our coast; and as our boat is too small for outside work during these windy months, I have not been able to secure the eggs or Nauplii; but this, the only gap in my series, is filled by Fritz Müller's observation. The whole metamorphosis of *Penæus* has therefore been actually witnessed, and there is no longer any room for criticism.

Protozoeas apparently identical with the youngest one figured by Müller, and which a comparison with *Lucifer* shows to be in the "first Protozoea" stage, were captured at the surface of the inlet by the hand-net.

They were carefully drawn and measured, and were then placed in tumblers, one in each tumbler, and were kept thus isolated and under observation until they assumed the characteristics of the genus *Penæus*, which they did after five moults.

The first Protozoea has an ocellus, a very short rostrum, and traces of the compound eyes, which are not yet movable. The first and second antennæ are Nauplius-like; and the biramous second antennæ are the chief organs of locomotion. The labrum has a short spine;

the mandibles are stout cutting-blades, with no trace of a palpus, or of the swimming-branches of the appendage. The first maxilla is small and jaw-like, while the second is long and slender, with a very small scaphognathite. There are three pairs of maxillipeds, all of them biramous. The first pair are large, fringed with long swimming-hairs, and they are efficient swimming-organs. The second pair are much smaller and of less functional importance; and the third pair are rudimentary and scarcely visible. The long slender hind body shows only very faint traces of a division into segments; and no ganglia could be made out. The tip of the abdomen forms a forked telson, with seven pairs of plumose hairs—one short one on the inside edge, another short one on the outside edge, and a terminal row of five much longer ones, the middle one being the longest of all.

After moulting, the "second Protozoea" is essentially like the first, the chief differences being that the compound eyes are now movable, and the hind body is sharply divided into segments. No joint as yet separates the telson from the sixth abdominal segment; but, with this exception, all the segments of the hind body are now well defined.

In the species which was studied, probably *Penæus brasiliensis*, the rudimentary thoracic and abdominal appendages described by Claus at this stage were not visible. I did, however, find a few specimens of another species which agreed in this respect with Claus's figure.

After the next moult the larva becomes what I have called in my paper on *Lucifer* a "Protozoea with preparations for the Schizopod stage."

It might, perhaps, be spoken of as a Zoea. The ocellus is still present, although the compound eyes are large and quite movable.

The rostrum is lengthened. The two pairs of antennæ retain the Nauplius characteristics.

The mandible has no trace of a palpus; and the metastoma consists of a pair of broad flat plates, separated from each other on the middle line, and placed in the same series with the other appendages.

The maxillæ and maxillipeds are as they were at the stage before, except that the third pair of maxillipeds are a little larger although they are still rudimentary.

The five thoracic somites are now cemented together; and each bears a pair of buds or pouches, the rudimentary appendages.

The telson is separated by a joint from the sixth abdominal segment; and the latter carries a pair of rudimentary swimmerets. There are no traces of appendages on any of the other abdominal segments, although all the ganglia are conspicuous and well developed. The halves of the fork of the telson diverge from each other a little more than they did during the earlier Protozoean stages.

After the next moult the animal reaches the Schizopod stage, so far as the anterior half of the body is concerned, although the abdo-

minal appendages are still absent. The ocellus is still present, as in the first Protozoea; but the character of the antennæ has changed completely. The ear has appeared in the basal joint of the first antennæ, and contains diatoms and other foreign bodies. The two-jointed basal portion of the second antennæ carries a short pouch, the rudimentary flagellum, and a long scale with plumose hairs and a single spine.

The palpus has appeared on the mandible. The exopodites of all five pairs of legs are large, and are now, with the swimmerets, the locomotor organs. The endopodites of the fourth and fifth pairs are somewhat less developed than those of the first, second, and third pairs, which now end in chelæ. The abdomen carries only one pair of appendages, those of the sixth segment: but these are now larger, and are used in swimming.

The tip of the telson is now almost square, with a very slight notch in the middle line.

After the next moult the chief change consists in the formation of the first five pairs of abdominal appendages. The endopodites are absent; and the whole appendage is rudimentary, and is not used for locomotion until the next stage.

After the next moult the animal reaches the *Penæus* stage. The scale of the antennæ becomes broad and triangular; the flagellum is greatly elongated and is divided into twelve joints. The mandibular palpus is greatly enlarged, and covers up the bases of the antennæ. The exopodites disappear from all five pairs of legs; and the abdominal appendages are now functional, although the endopodites are still absent.

This stage is reached by the first Protozoea in about three weeks; and all the changes have been actually witnessed in isolated captive specimens.

Our boat is too small for work outside during the windy months of June and July; and as the ripe females do not come into the inlets and sounds, I have not been able to obtain the eggs or the newly hatched young; but this is the less important, as Fritz Müller reared his "first Protozoea" from a *Nauplius*, so that we now have the entire metamorphosis from actual observation.—*Johns Hopkins University Circulars*, November 1882, p. 6.

On the Growth of the Molluscan Shell. By H. L. Osborn.

The structure of the molluscan shell has been studied by means of sections of adult shells by Carpenter and others; and they have found that it presents an outer membranous horny epidermis and an internal stony portion. Such a method could not give any idea of the actual process of shell-formation; a knowledge of this could be gained only by study of the first steps. To this end edges of the shell were snipped away, and a thin glass circle thrust between the animal and its shell, care being taken to prevent injury to the mantle. After the lapse of twenty-four hours the shell was