been ascertained. A common mode of propagation of Urnatella appears to be by budding, the formation of branches with their terminal polyps, and the detachment of these branches to establish stocks elsewhere. The different specimens apparently indicate this process, though it was not actually observed.

Though the stem of Urnatella is invested with a firm, chitinous integument, it still retains its flexibility; so that, when the polyp is disturbed, it not only closes its bell, and bends its head, but the entire stem bends, or even becomes revolute. Sometimes the polyps suddenly twist the stems from side to side, as if they had become wearied of remaining longer in the same position.

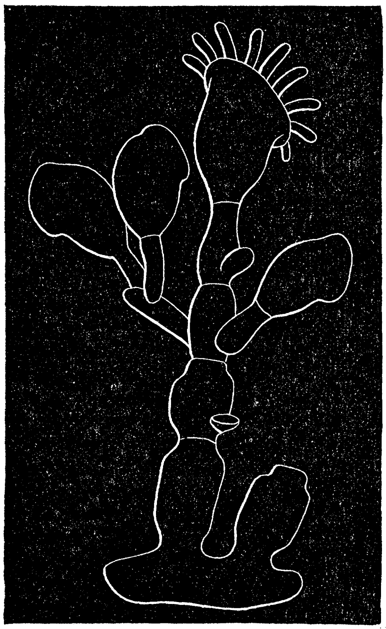


FIG. 2.—Urnatella gracilis, with the main stem of four segments, and a terminal expanded polyp. Branches are given off by the third segment, and a bud from the fourth.

The interior of the polyp is mainly occupied by the alimentary apparatus. From the mouth of the bell a funnel converges as the pharynx; and the tube of the former, as the oesophagus, occupies the shorter side of the bell. At the bottom of the latter the oesophagus opens into a capacious retort-like stomach, which occupies two-thirds of the capacity of the polyp. The stomach towards the mouth of the bell has an alembic-like pylorus, from which a short intestine turns ventrally to expand in an oval colon. From this a short rectum opens about the centre of the mouth of the bell. The pharynx, oesophagus, and stomach are lined with ciliated epithelium. The ventral side of the stomach has the epithelium colored brown, indicating, as in other polyzoa, an hepatic function. The polyp feeds on vegetable particles mainly, including diatoms, desmids, etc.; and the food may be observed in an incessant whorl in the axis of the stomach, induced by the action of the cilia lining the latter. The polyp is almost constantly infested with parasites, often in large numbers, which mingle with the food, and accompany this in its movement. The parasite is a ciliated infusorian, distinguished with the name of Anoplophrya socialis. From time to time, remains of the food are passed into the colon, and here accumulated into an oval pellet, which is then quickly discharged from the mouth of the bell.

Generative organs, or provision of any kind for the production of ova, were not detected, nor were eggs observed.

Urnatella differs from the marine genus Pedicellina mainly in not having an attached and creeping rootstalk, and in having free, pendent, and jointed stems, instead of simple pedicles.

THE PHYLOGENY OF THE HIGHER CRUSTACEA.

THE class Crustacea is one of the dominant groups of the animal kingdom, and it includes a very considerable proportion of our living animals. Its representatives are extremely diversified in structure; and a single order, such as the Decapoda, includes a much greater variety and diversity of forms than the whole class of insects. It is very rich in primitive and transitional forms; and when we add to this, that there is no group in which our embryological knowledge is more rich and varied, or in which the embryological history of the individual throws so much light upon the evolution of the race, its importance as a means for tracing the actual history of the evolution of species is obvious. In fact, most of the problems in the logic of morphological reasoning, are, in great part at least, problems in the morphology of the Crustacea.

Since the awakening in natural science which followed the publication of the Origin of species, many naturalists have attempted to disentangle the story of the phylogeny of the Crustacea. Some of these attempts, such as Müller's 'Für Darwin' and Huxley's 'Crayfish,' are familiar to all; while others, such as Claus' 'Crustaceen system,' are known to none except specialists. The latest attempt in this field ("Studien über die verwandtschaftsbeziehungen der Malakostraken," by Dr. J. E. V. Boas, *Morph. jahrb.*, viii. 4, 1883) is, to say the least, a very valuable addition to crustacean morphology, as well as an interesting study in scientific logic. Its results seem to be a close approximation to the true natural classification of the higher Crustacea, and it should therefore receive the careful attention of all naturalists, and of all who wish to be informed regarding the methods of thought in morphology; but as it is from necessity filled with minute details, which would be formidable to all except specialists, the general reader must be contented with a summary of the results.

The proof that the crabs are descended from long-tailed decapods is familiar to all naturalists; and no one can doubt, that, among these, the swimming decapods, such as Penaeus, are the most primitive. So far, the phylogeny of the decapods may be regarded as definitely settled, and Boas proposes no modification of the accepted view; but his opinion regarding the origin of the swimming decapods from the lower Crustacea is novel, and the evidence which he furnishes seems to be conclusive. The Decapoda are generally regarded as the modified descendants of the schizopods; but Boas points out that the order Schizopoda is not a natural group, since the animals which have been included in it belong to two widely separated orders.

According to this author, the Euphausiacea and the Mysidacea are not at all intimately related. The latter are not in the line which leads to the Decapoda, and there is no natural group Schizopoda. He therefore divides the group into two orders, — the Euphausiacea and the Mysidacea: the former including the primitive unspecialized forms through which the Decapoda have been evolved from the lower Crustacea; and the latter containing highly specialized forms, which have been evolved from the Euphausiacea along an independent line, and which have no direct relationship to the Decapoda. He holds, that the Euphausiacea are a synthetic group of Crustacea which has given rise to several divergent groups of descendants. Of these, the decapod stem has undergone the least modification. A second stem, the Mysidacea, has diverged in an entirely different direction, has departed very widely from the primitive form, and has, in its turn, given rise to the Cumacea, and through these to the amphipods and isopods, the latter being the most highly modified of the Malacostraca. A third line of descent from the Euphausiacea has given rise to the Squillacea.

The recognition by Boas of the fact, that the group Schizopoda is not a natural one, and the discovery that the animals which have been thus associated may be divided into a very primitive group, the Euphausiacea, and a highly specialized group, the Mysidacea, seems to be a very great advance in crustacean morphology.

He gives the following definition of the Euphausiacea: —

Malacostraca, with the mid-body and abdomen compressed, with a well-marked bend in the abdomen; carapace well developed; the last segment of the mid-body a complete ring; eyes stalked; antenna with a large scale; mandible simple; first maxilla with broad, one-jointed palp, and with well-developed exopodite; second maxilla with a similar palp, and with exopodite, and a cleft lacinia interna. The appendages of the mid-body or cormopods all have a well-developed exopodite, and an epipodite which is subdivided in all except the first pair, where it is simple. The endopodite is thin and weak, and it does not end in a sharp point: it is more or less rudimentary on the last two pairs. The first cormopods are not specialized as maxillipeds, but are like the others. The abdominal feet are powerful swimming-organs, with an appendix interna. In the male the first or most anterior ones are specialized as copulatory organs. The tail-fins are well developed. The liver is composed of a great number of small lobes. The heart is short and wide. The halves of the reproductive organ are united by a transverse unpaired portion. Spermatophores are present, and the spermatozoa are simple round cells. There is an antennary gland. The young leaves the egg as a free-swimming nauplius, and the carapace of the older larva is a great phyllopod-like mantle.

It is easy to trace the relationship between this group and the decapods, on the one side, and, on the other side, through Nebalia, to the phyllopods and lower Crustacea.

The Decapoda natantia resemble the Euphausiacea in many conspicuous and highly important particulars. In these two groups alone, among the Malacostraca, we have a free-swimming nauplius; and in both the carapace of the larva is a great mantle. The abdomen is bent in both, and the integument is horny. The carapace, the abdominal appendages, the large tail-fin, and the pointed telson, are alike in both. The endopodite of the first pleopod is a copulatory organ in the decapods as well as in the Euphausiacea; and spermatophores are almost universal in these two groups, while they are found in no other Malacostraca.

The close relationship between these two groups can hardly be questioned; nor is it difficult to show that the Euphausiacea are the primitive, and the Decapoda the derived, form. In the presence of simple epipodites, and of a four-jointed palp on the first maxilla, the Penaeadae are nearer to the phyllopods than Euphausia; but in all other respects Euphausia is the most primitive, and it shows its close relationship to the lower Crustacea by many characteristics, among which are the following. The terminal joint of the cormopods is rounded and blunt, as it is in Nebalia, instead of being pointed, as it is in all the Malacostraca except Nebalia. There are no specialized maxillipeds; but the first cormopod is like all the others, as it is in Nebalia, and all the cormopods are furnished with exopodite and epipodite: while in all other Malacostraca there are true maxillipeds; and either the exopodites or the endopodites, or both, are absent on some or on all the cormopods. The antenna has a well-developed exopodite; and in the young this is flabellum-like, and very similar to that of the adult Limnadia or Estheria. This feature of resemblance to the lower Crustacea is shared by the young of the Decapoda natantia. The first maxilla has a large exopodite; while this is rudimentary in the Decapoda and Mysidacea, the only other Malacostraca where it occurs at all. The pleopods are much like those of Nebalia: they are efficient swimming-organs, and they are provided with an appendix interna. The spermatozoa, like those of the phyllopods, are simple round cells without tails; and this is true of no other Malacostraca except the squillas.

While the Euphausiacea are thus seen to be very much like the phyllopods in so many important features, they are true Malacostraca; and they have deviated greatly from their phyllopod ancestor, and have acquired a small carapace, differentiated cormopods with long slender endopodite, small exopodite divided into shaft and flabellum, and an epipodite which is purely respiratory. They also differ from Nebalia in the possession of that distinctively malacostracan organ, a tail-fin, made up of a telson and a pair of swimmerets.

The relationship of Nebalia to the Malacostraca on the one hand, and to the phyllopods on the other, has long been recognized, and Claus has even gone so far as to hold that this form is a true malacostracan; but Boas believes that it is neither a true malacostracan, nor the phyllopod from which the Malacostraca originated, but simply the nearest living ally of this ancestral form.

He believes that the presence of a great mantle-like carapace, of eight unspecialized, broad cormopods with leaf-like exopodites, of a furcated abdomen without tail-fins, and of eight abdominal somites, show that it is not a malacostracan, but a phyllopod. As many phyllopods, such as Limnetis and the Cladocera, have, like the Malacostraca, an exopodite on the second antenna, we must believe that the Malacostraca have inherited this feature from their phyllopod ancestor; and, as it is absent in Nebalia, this form cannot be the direct ancestor of the Malacostraca. So, too, the fifth and sixth pairs of abdominal feet are rudimentary in Nebalia, while they are well developed in nearly all Malacostraca. As most of the phyllopods, and some of the Malacostraca, leave the egg as a free-swimming nauplius, we must believe that this was true of the phyllopod ancestor of the Malacostraca; but as Nebalia does not pass through a free nauplius stage, but leaves the egg in a more advanced condition, it cannot be in the direct line of evolution. Boas therefore concludes that Nebalia is a true phyllopod, and that the Malacostraca have originated from a form somewhat different, although Nebalia is the closest living ally of this ancestral form.

Having thus traced the decapods back through the Euphausiacea to a phyllopod ancestor very similar to the recent Nebalia, we have now to trace the ancestry of the other Malacostraca. Boas holds that the squilloids are a branch from the Euphausiacea, and that the Mysidacea have been derived from the Euphausiacea along still another line of descent, and have, in their turn, given rise to all the remaining groups of Malacostraca.

The Mysidacea differ from the Euphausiacea and the decapods in many features which they show in common with the Cumacea and the amphipods and isopods; and it is not difficult to show, that, in these points of difference, the Euphausiacea are the primitive group, and the Mysidacea the modified group.

In Euphausia, as in the swimming decapods, the body and abdomen are compressed; while they are flattened and rounded in the Mysidacea, and the tip of the abdomen is directed backwards, lacking the peculiar bend of Euphausia and Penaeus.

The structure of the mandible is very instructive. In Mysis, as well as in the Cumacea and amphipods and isopods, the mandible is forked, the cutting part being widely separated from the crushing part; and between the two there is a row of setae, and a peculiar accessory appendix. In Euphausia and the decapods the appendix and row of setae are absent, and the chewing part is hardly separated from the crushing part. In Mysis, as in Cuma and the amphipods and isopods, the palp and exopodite of the first maxilla are absent, and the laciniae are turned forwards as well as inwards; and in all these forms the laciniae of the second maxilla are directed forwards. They overlap, and the lacinia interna is undivided. In Euphausia, the decapods, and squillas, there are no brood-pouches; but these structures are present in Mysis, as well as in the Edriophthalmata, and they are formed in essentially the same way in all, — by plates which are developed on the basal joints of certain of the cormopods. In all these forms the young pass through a long metamorphosis within these pouches. The liver is comparatively simple. There are no spermatophores, and the spermatozoa have tails. The Cumacea are regarded by Boas as a greatly modified offshoot from the Mysidacea; and the amphipods and isopods are derived from an ancestral form somewhat like, but more primitive than, the living Cumacea.

As regards the position of the amphipods and isopods, Boas's view is directly opposite to that which has been generally accepted; as he regards these as the most highly specialized and divergent of the Malacostraca, instead of low and primitive forms. The conspicuous segmentation of the nervous system, the absence of a carapace, the sessile position of the eyes, the great number of similar somites, the worm-like shape of the body, and the elongation of the heart, — all seem at first sight to show that these forms are ancient and low. Boas points out that the nervous system gives no proof of a primitive condition, as there are as many independent ganglia in Mysis as there are in the sessile-eyed Crustacea. It is true that the heart is longer than it is in Mysis; but there are only three pairs of ostia, and the length of the heart, as compared with that of the mid-body, is no greater than it is in Mysis. As the eyes are stalked in Nebalia, the nearest ally of the Malacostraca, all of the latter must have inherited stalked eyes from their phyllopod ancestors, and the sessile eyes of the Edriophthalmata must be due to secondary modification. So, too, regarding the absence of a carapace. As the Malacostraca inherit this structure from the phyllopods, those forms in which it is absent must have lost it by secondary modification. The same thing is true of the absence of a scale on the antenna. There is, therefore, no proof that these animals are primitive; and the many points of resemblance to the Mysidacea which we have just noticed show the close relationship between these groups. But as the Mysidacea, like Euphausia and the decapods, have stalked eyes, a carapace, and a fused mid-body, exopodites in first maxillae, exopodites and palpi in second maxillae and on cormopods, and as a seventh abdominal segment is present, we must believe that the Mysidacea are the more primitive group, and the Edriophthalmata their recently modified and highly specialized descendants.

Boas believes that most of these differences are due to the fact that the Edriophthalmata have become adapted for running instead of swimming; and he thus explains the loss of the exopodites of the cormopods, the strengthening of the endopodites, the shortening of the abdomen, the loss of power in the pleopods, the flatness of the body and abdomen, the thickening of the integument, and the loss of eyestalks and of the antennary scale. The respiratory function of the pleopods he attributes to the loss of the carapace, and the thickening of the integument.

The general conclusions of this highly suggestive and interesting paper may be summarized as follows.

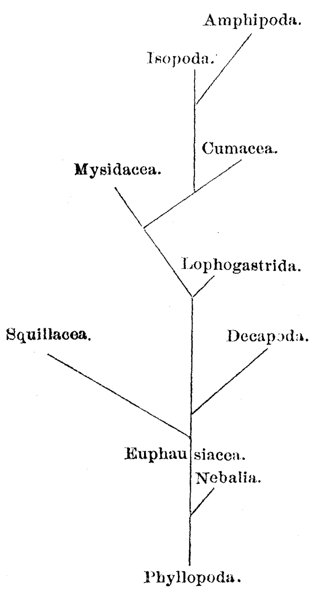
The Malacostraca are descended from the phyllopods, among which Nebalia is their nearest relative.

The Euphausiacea are the most primitive Malacostraca. The decapods originated from the Euphausiacea, although the most primitive decapods, the Natantia, are now widely separated from this ancestral form. The Squillacea stand by themselves, their nearest, although distant, allies being the Euphausiacea. They show in certain points a more primitive condition than any other Malacostraca; although, as a whole, they are highly modified.

The Mysidacea are also derived from the Euphausiacea; although they are so different from them that they must be placed in a distinct order, and the group Schizopoda must be abandoned. The Mysidacea have no close relationship to the decapods.

The Cumacea arise from the Mysidacea, and the amphipods and isopods from a form between the Mysidacea and the Cumacea. The amphipods and isopods are not a primitive group distantly related to the Podophthalmata, but they are the most highly specialized of the Malacostraca.

He gives the following as his phylogenetic classification of the Crustacea: —



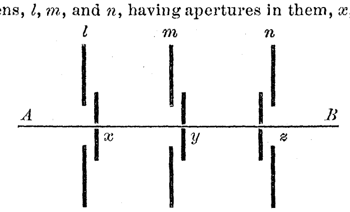
W. K. Brooks.

LETTERS TO THE EDITOR.

Radiant heat.

Mr. Fitzgerald has favored me with a paper [1] in which he takes exception to my views respecting radiant heat,[2] wherein he says, —

"Suppose that two regions, A and B, be separated by three parallel screens, l, m, and n, having apertures in them, x, y, z, capa-



ble of being opened and closed from the centre, so as to make every thing perfectly symmetrical round the line AB, perpendicular to the screens. Now, if x be opened for a very short time, a certain quantity of radiant energy will escape out of A into the region between l and m; and if y be opened when this heat reaches m, it can certainly be let on into the region mn; and if z be similarly opened when it reaches it, this radiant heat will get into B. While z was open, however, some heat left B; but, as Dr. Eddy observes, y may be closed so as not to let this even get through the screen m, and it can be all returned into B by reflection through z or some other aperture. So far I entirely agree with Dr. Eddy, and so far it seems as if the result had been to transfer heat from A to B without B's losing any heat by having it transferred to A. As I warned Dr. Eddy when I heard his paper, there are, however, other bodies and regions to be considered besides A and B. There are more than two bodies considered: there is the region of the screens. Consider what happens when the heat that escaped out of B into the mn region tries to get back into B. Some door must be opened to let it pass; and, while it is passing in, an at least equal amount of heat will be passing out of B into the mn region, so that you can never really get the heat that has once left B back into B again. This is true, whether you adopt doors over fixed apertures, such as I have supposed, or moving apertures, such as Dr. Eddy proposed. What really takes place is this: a certain quantity of heat escapes out of A and reaches B; and a not less quantity of heat leaves B, and is kept entangled in the region of the screens, and it is only possible to let the heat pass from A to B by means of this third region. Hence this only really comes to the same thing as letting A radiate some of its heat into the screen region, while B is kept closely shut up. Now, be it observed that Dr. Eddy practically postulates that this screen region is at least colder than A — in fact, he assumes it to be perfectly cold, i.e. to contain no radiant heat except what is admitted from A and B, so that it is by no means contrary to the theory of exchanges that A might cool by radiating into this region."

Now, Mr. Fitzgerald has stated only two of the three things which occur while the door z is open. He omits to state, that in my process a certain amount of heat which has come from A also passes through the door z every time it is opened, into the region B; and this is all which is proposed to be accomplished by the process which is at all unusual or peculiar. Thus the fact remains, that although a definite amount of heat from B remains entangled in the region mn, which is not increased with the lapse of time, there is a continued passage of heat through this region into B, that being the very object sought to be accomplished by my process. It is not easily seen how the arrangement of screens and apertures proposed by Mr. Fitzgerald could be so manipulated as to bring the heat coming from A into a position such

[1] On Dr. Eddy's hypothesis that radiant heat is an exception to the second law of thermodynamics. By George F. Fitzgerald, M.A., F.T.C.D., *Sc. proc. roy. Dubl. soc.*, iv. pt. i.

[2] *Sc. proc. Ohio mech. inst.*, July, 1882.