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THE  
VOYAGE OF H.M.S. CHALLENGER.

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ZOOLOGY.

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REPORT on the PHYLLOCARIDA collected by H.M.S. Challenger during the  
Years 1873-76. By Professor G. O. SARS, of the University of Christiania.

INTRODUCTION.

AMONG the numerous Crustacea brought home by the Challenger Expedition, there are two forms belonging to the above named interesting group, both of which represent new generic types. This addition is especially of high interest since only a single recent genus of Phyllocarida was hitherto known, viz., the genus *Nebalia*, all the other forms belonging to this group being Palaeozoic fossils. Thus, a closer investigation of the two new types added by the Challenger Expedition cannot fail to be of great importance in advancing our knowledge of this very remarkable and anomalous group of Crustacea.

One of the forms has already been roughly described by the late Dr. v. Willemoes Sulm under the name of *Nebalia longipes*, and in the last edition of Professor Claus' Zoology this form has been quoted with a new generic name as *Paranebalia longipes*. I fully agree with Professor Claus that this species ought to be regarded as the type of a new genus, which, however, is rather nearly related to the earlier known genus *Nebalia*. The other form contained in the Challenger collection seems to deviate much more from the typical genus, and may perhaps throw some light on the structure of certain fossil forms. But the very restricted material has unfortunately prevented me from instituting a satisfactory anatomical investigation of this interesting form. Besides these forms, according to a letter from the late Dr. v. Willemoes Sulm to Professor v. Siebold,<sup>1</sup> a

<sup>1</sup> *Zeitschr. f. wiss. Zool.*, Bd. xxiv.



species of *Nebalia*, closely related to *Nebalia geoffroyi*, was observed off the Kerguelen Islands. The specimens were, however, not preserved, apparently owing to their being regarded as identical with the above named common species.

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## GENERAL REMARKS ON THE MORPHOLOGY OF THE PHYLLOCARIDA.

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The views of zoologists as to the systematic position of the genus *Nebalia*, the only hitherto known recent form of this group, have been widely different. Leach, the founder of the genus, placed it among the Macrura, and was followed in this view by several other authors, as Lamarck, Bose, and Desmarest, whereas Milne-Edwards in his important work on the Crustacea put the genus among the Phyllopoda, placing it together with the genus *Apus* in his family Apusidæ. The great authority of the last named eminent naturalist seemed to have finally settled the question about the systematic position of *Nebalia*, it being by the general consent of carcinologists regarded as a true Phyllopod, though it was afterwards found necessary to remove it from the genus *Apus*, and to establish a distinct family, Nebaliadæ, for its reception. More recently, however, the phyllopodous nature of this form has been denied by several naturalists. Thus, Dr. E. Metschnikoff, in studying the development of *Nebalia*, was led to the result, that this form should more properly be referred to the Decapoda than to the Phyllopoda, and accordingly named it a "phyllopodiform Decapod." A similar view seems also to have been partly adopted by Professor Claus in transferring *Nebalia* from the Entomostraca to the Malacostraca. Finally, the late Dr. v. Willemoes Suhm, in describing a new form from the Challenger Expedition, places the family Nebaliidæ among the Schizopoda. Mr. Salter<sup>1</sup> was the first to point out the apparent affinity of the recent genus *Nebalia*, to certain Palæozoic fossils, and Claus also recognised the relationship of *Nebalia* to these old forms of Crustacea. In 1879 Dr. A. Packard established a distinct order, Phyllocarida, for the reception of *Nebalia*, together with the above mentioned fossil forms, which formerly had generally been regarded as true Phyllopoda most nearly related to the genus *Apus*; and in the following year Professor Claus in the third edition of his Zoology likewise referred the genus *Nebalia* to a distinct order, Leptostraca, removing it far from the Phyllopoda and placing it among the Malacostraca.

As to my own views, I fully agree with the above named authors, that the genus *Nebalia* ought to be removed from the Phyllopoda, but I am not prepared to agree with Professor Claus in transferring it to the Malacostraca, and still less can I entertain the

<sup>1</sup> On *Peltocaris*, a New Genus of Silurian Crustacea, *Quart. Journ. Geol. Soc. Lond.*, vol. xix., 1863.

view of the late Dr. v. Willemoes Suhm in placing it among the Schizopoda. In my opinion the genus *Nebalia* ought to be retained within the order of the Branchiopoda, though representing a distinct subdivision or suborder, for which the name Phyllocarida, proposed by Dr. A. Packard, as the older one, must be preferred to that proposed by Professor Claus. The order Branchiopoda will thus contain the following subdivisions:—Phyllocarida, Phyllopoda, Cladocera, Branchiura, the type of the last division being the genus *Argulus*, which in my opinion cannot properly be referred to the Copepoda, as proposed by Claus, but, in accordance with the views set forth by Thorell and others, may find its proper place among the Branchiopoda, though it deviates still more from the type of the order, the Phyllopoda, than is the case with the genus *Nebalia*.

It seems to be a generally adopted assumption, that the genus *Nebalia* forms a distinct transition between the Phyllopoda and the Podophthalmia, and that its affinity to the latter is even closer than to the former. I have been led to a rather different view as to the relationship of *Nebalia*, and I think we shall find, on closer examination, whether we consider the external or internal organisation, that this presumed affinity to the Podophthalmia is in reality only very slight, and that most of the characters adduced to show the decapodous nature of *Nebalia* do not hold good, since they are found fully as pronounced either in other Branchiopoda or in certain Crustacea not at all belonging to the Podophthalmian group. Thus, the stalked mobile eyes are not only met with in the Podophthalmia, but also, as is well known, in a section of true Phyllopoda, the Branchipodidæ, and as to structure the eyes in *Nebalia* evidently agree much more with those in the latter than in the former. The carapace in *Nebalia*, it is true, exhibits some resemblance to that in certain Schizopoda, as *Gnathophausia*, in being not connected with the trunk, but we must remember that this is also the case in the Phyllopoda, both in *Apus* and in the bivalved forms, and that this character in the Branchiopoda is universal, whereas in the Podophthalmia it is exceptional, only distinguishing a very restricted number of forms. Besides, the carapace in *Nebalia* shows both in its structure and especially in the presence of a distinct adductor muscle a much closer resemblance to the bivalved shell in the Phyllopoda. The form of the exposed part of the body in *Nebalia* is very unlike that met with in the Podophthalmia, whereas the resemblance in this respect to certain Phyllopoda and still more to the Copepoda is unmistakable. The internal organisation of *Nebalia*, though rather deviating from that in the Phyllopoda, does not show any marked resemblance to that in the Podophthalmia, being much more similar to that in the Amphipoda; neither in my opinion can the development be adduced as evidence of the decapodous nature of *Nebalia*.

As to the several limbs, their structure is in fact highly remarkable, indicating a peculiar mixture of characters found in very different groups of Crustacea, and on the whole their presumed resemblance to those in the higher Crustacea may on closer examination turn out to be only very slight. Thus, the structure of the two pairs of antennæ

and the oral parts certainly appears very different from that generally met with in the other Branchiopoda, but I think it will be fully as difficult to point out any closer resemblance in this respect to the Podophthalmia. The eight pairs of limbs succeeding the oral parts, on the other hand, are evidently constructed on the very same type as those in the Phyllopoda, agreeing, as they do, both as to structure and function with the so called "branchial feet" in these Crustacea. But in *Nebalia* these limbs are followed by four pairs of very differently formed appendages, constituting exceedingly powerful natatory organs, and as similar swimming legs, the pleopoda, are also found in the Podophthalmia, this character has likewise been adduced to show the decapodous nature of *Nebalia*. It must, however, be remembered, that such organs are not restricted to the Podophthalmia, but are also met with in several other Crustacea, as Amphipoda and Copepoda, and both as regards structure and number, the swimming legs in *Nebalia* apparently agree much more closely with those in the Copepoda than with those in any other group. This resemblance becomes still more striking by the presence in *Nebalia* of two additional pairs of rudimentary caudal limbs, evidently answering to the rudimentary legs found behind the swimming legs in several Copepoda. On the whole the general appearance of *Nebalia* bears a very striking resemblance to that in certain free living Copepoda, especially of the Harpactoid section. This similarity I do not regard as merely accidental, but as indicating a true consanguinity, and this has partly also been allowed by Dr. Packard. In order to understand the morphology of the Phyllocarida, it thus becomes necessary not only to pay attention to the higher Crustacea, but also to the lower forms, especially the Copepoda, which seem to be the most primitive of the recent Crustacea. To express shortly my opinion about the relationship of the genus *Nebalia*, I would call it, instead of a "phyllopodiform Decapod" as it has been termed by Metschnikoff, more properly a "copepodiform Branchiopod." At the end of this Report, when the Challenger forms have been described, I propose to enter more in detail into the question of the homology of the recent Phyllocarida with other known Crustacea.

As to the supposed affinity of the genus *Nebalia* to the fossil Palaeozoic forms referred to the order Phyllocarida, the general appearance of the carapace, and especially the presence in some of them of a similar jointed rostral plate as in *Nebalia*, seems in fact to point to some closer relationship, but as the limbs of these old Crustacea are still wholly unknown, and moreover, as the tail in most of them exhibits a rather different aspect, the degree of affinity must still be regarded as very doubtful. In any case these Palaeozoic forms cannot be placed within the same family as *Nebalia*, but ought to be separated as a distinct subdivision, and some of the forms exhibit such an anomalous aspect as hardly even to justify the view that they belong to the same order. On the other hand, it is quite evident, that the two new generic types from the Challenger collection, described below, are on the whole so closely related to *Nebalia* as to be properly classed together with this genus in the same family.

## DEFINITION OF THE FAMILY.

## NEBALIIDÆ.

Anterior part of body covered by a large compressed bivalvular carapace, connected with the body only along the cephalic part, its valves admitting of being moved by a distinct adductor muscle and extending down the sides so as to enclose between them all the oral parts as also the greater part of the other limbs. A tongue-shaped rostral plate present in front, movably articulated to the carapace. Trunk covered over by the carapace and composed of eight subequal segments. Posterior part of body tapering backwards and consisting of two more or less distinctly defined subdivisions, pleon and tail, each composed of four segments. Eyes pedunculated and mobile, but without faceted cornea. Both pairs of antennæ strongly developed, subpediform, with the peduncle geniculate; anterior pair, or antennulæ, with the peduncle four-jointed and bearing a setose lamella at the end, besides the flagellum; posterior pair with a single multiarticulate flagellum. Mandibles comparatively small, with the cutting part rudimentary, the molar tubercle well developed, palp very large, triarticulate. First pair of maxillæ with two incurved masticatory lobes and a very elongate and slender reflexed palp; second pair lamellar, with distinctly defined palp and exognath. Eight pairs of subequal phyllopodous legs present on the trunk posterior to the oral parts; endopodite more or less produced, with the inner edge and apex densely setiferous, but without projecting lateral lobes. Four pairs of powerfully developed biramose pleopoda on the succeeding part of the body, followed by two pairs of rudimentary caudal limbs. Penultimate segment without limbs. No telson. Caudal rami simple, forming two diverging plates edged with spinules and setæ. Ova deposited within the lower part of the carapace, and supported between the branchial legs. Development direct, without metamorphosis. Internal organisation on the whole rather similar to that in the Amphipoda.

*Remarks.*—As the fossil forms referred to the Phyllocarida are still very imperfectly known, none of the limbs having as yet been found preserved, it is rather difficult to point out the characters which should be regarded as exclusively distinguishing the recent family Nebaliidæ. There is however at least one character, well seen in the fossil forms, which seems to distinguish them very sharply from the Nebaliidæ, viz., the presence of a strongly developed telson, no trace of which is found in any of the recent forms.

As above stated the recent Phyllocarida were formerly only represented by a single genus, *Nebalia*. The two new genera, added by the Challenger Expedition, chiefly

differ from each other, as also from the typical genus, by the different development of the phyllopodous or branchial legs. While in the one form, *Paranebalia*, both the endopodal and exopodal parts of these limbs are very elongate, so as somewhat to approach the form of the legs met with in the Euphausiidae, these parts are in the other form *Nebaliopsis*, so very much reduced as to cause these limbs to appear as merely simple, slightly lobular plates. We have thus, as regards these limbs in the recent Phyllocarida, a series of modifications tending in the one case to render them apparently more adapted for the prehension of food, in the other case to restrict their function to solely respiratory purposes; the genus *Nebalia* occupying in this respect an intermediate position.

According to this difference in the structure of the branchial legs, the three recent genera of Phyllocarida may be characterised as follows:—

Branchial legs	well developed,	scarcely projecting beyond the edges of the carapace, endopodite narrow, indistinctly jointed, exopodite forming a broad rounded plate, epipodite very large, expanded at both extremities, . . . . .	<i>Nebalia</i> , Leach.
		projecting far beyond the edges of the carapace, endopodite very elongate and slender, almost pediform, exopodite also rather produced and ending in a narrow point, epipodite exceedingly small, nearly obsolete, . . . .	<i>Paranebalia</i> , Claus.
	imperfectly developed, lamelliform, endopodal and exopodal parts only slightly indicated as small triangular lobes, epipodite well defined, . . . .		<i>Nebaliopsis</i> , n. gen.



## DESCRIPTION OF GENERA AND SPECIES.

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Order BRANCHIOPODA.

Suborder PHYLLOCARIDA.

Family NEBALIIDÆ.

*Paranebalia*, Claus, 1880.

*Paranebalia*, Claus, Grundzüge der Zoologie, ed. 4, vol. i. p. 576.

*Generic Characters*.—General appearance much as in *Nebalia*. Carapace smooth, oval, lateral parts or valves produced posteriorly to broadly rounded lobes separated above by an angular incision. Rostral plate well developed. Trunk scarcely longer than pleon. Tail rather sharply defined from pleon, with the first segment smaller than the succeeding. Eyes well developed, with distinct visual elements. Antennulæ rather stout, with last joint of peduncle produced anteriorly to a serrate lamella; flagellum comparatively short, greatly dilated in male. Antennæ slender, with last joint of peduncle elongate and geniculate at the base, flagellum simple, cylindrical, of similar structure in both sexes. First pair of maxillæ with the outer masticatory lobe narrowly produced and abruptly truncate at the end; second pair with palp and exognath well defined but comparatively small. Branchial legs projecting far beyond the edges of the carapace; endopodite very elongate and slender, almost pediform; exopodite also very elongate and produced to a narrow point; epipodite exceedingly small, upper end produced. Pleopoda much as in *Nebalia*. The two succeeding pairs of rudimentary caudal limbs both inarticulate. Caudal rami much as in *Nebalia*.

*Remarks*.—This genus, founded by Professor Claus upon the description given by the late Dr. v. Willemoes Suhm of his *Nebalia longipes*, is chiefly distinguished from *Nebalia* by the structure of the branchial legs, as also by the male having only the antennular flagellum peculiarly modified, whereas the antennæ are quite alike in both sexes. Moreover the maxillæ exhibit some structural differences apparently of generic value. In all other respects it seems to agree very closely with the typical genus. Only one species is as yet known.

1. *Paranebalia longipes*, Willemoes Suhm (Pls. I., II.).

*Nebalia longipes*, Willemoes Suhm, On some Atlantic Crustacea from the Challenger Expedition, iii; Trans. Linn. Soc. Lond., ser. 2, vol. i. p. 26, pl. vi. 1879.

*Paranebalia longipes*, Claus, Grundzüge der Zoologie, ed. 4, p. 576.

*Specific Characters*.—Carapace as seen laterally, oval in form, covering besides the trunk also more or less completely the sides of the pleon; rostral plate oblong, narrowed in front and terminating in a spiniform projection. Posterior abdominal division or tail scarcely longer than pleon and suddenly much narrower, the two middle segments denticulate at the posterior edge. Eyes slightly curved and tapering to the end, upper side strongly denticulate. Antennulæ with the terminal expansion of the peduncle broadly lanceolate and armed with about twelve serrations along the outer edge; flagellum not attaining half the length of the peduncle, and composed of but five articulations, the first by far the longest. Antennæ with last joint of peduncle longer than the preceding and armed at the anterior edge with two recurved denticles, flagellum shorter than peduncle and six-articulate. Epipodite of last pair of branchial legs produced above to a slender flap. The three posterior pairs of pleopoda with the basal part strongly serrate at outer edge. The two pairs of rudimentary caudal limbs nearly equal in size. Caudal rami about as long as the three last caudal segments combined, outer edge minutely spinulose, inner setose, apex blunt, tipped with a fascicle of exceedingly long and slender setæ. Length of adult female 6 mm.

*Remarks*.—In the above diagnosis I have given some characteristics, to which I am inclined to believe should only be attributed the value of specific marks. As, however, the above named species is the only representative of the genus as yet known, a strictly specific diagnosis cannot of course be drawn up at present.

*Description*.—Among the material sent me for examination no male was found, all the specimens being either immature or adult females, partly laden with eggs or embryos. But the late Dr. v. Willemoes Suhm has shortly described and figured the adult male of this form, which exhibits some very interesting features not found in the male of *Nebalia*. Unfortunately the male specimens examined by that naturalist have been lost, and thus my investigations have been solely restricted to the female sex. The length of the adult female does not exceed 6 mm. and hence the present form is rather inferior in size to the known species of *Nebalia*.

All the specimens having been preserved in strong spirit, the body has become rather opaque and of a dark brownish colour, showing however in most of them, at the anterior part dorsally, a peculiar marking in the form of two symmetrical, slightly ramified patches of a whitish colour (see Pl. II. fig. 1). Whether this marking is due to a merely external colouring or indicates some underlying internal tissue, I have not been able to ascertain. By carefully preparing a specimen with absolute alcohol and

oil of cloves, and then mounting it in Canada balsam, I have succeeded in rendering the whole body sufficiently pellucid to admit a closer examination of the several parts in their natural connection with each other (see Pl. I. fig. 1).

As to the external appearance (see Pl. I. fig. 1; Pl. II. fig. 1) the present form exhibits on the whole a great resemblance to the common species of *Nebalia*, with this exception, however, that the terminal part of the body, comprising the four last segments, is comparatively more slender and also more distinctly marked off from the preceding part than is the case in *Nebalia*. In describing the body I find it advisable to distinguish four principal divisions, viz., the cephalic part, to which the carapace is connected, the trunk, the pleon, and the urosome or tail, the two latter parts answering to the so-called abdomen in the higher Crustacea, and to the abdomen and thorax in the Copepoda. All these four divisions are pretty well defined in the present form, and are of about equal length, but differ both in form and in the structure of their respective limbs.

The cephalic part is somewhat flattened, and along its whole dorsal surface firmly connected with the carapace. It bears the following appendages, enumerated from before backwards:—The eyes, the antennulæ, the antennæ, the anterior lip, the mandibles, the posterior lip, the first pair of maxillæ, and the second pair of maxillæ. Of these appendages only the eyes, the antennulæ, and the antennæ project to a certain extent beyond the free edges of the carapace, all the other parts being wholly concealed within its valves.

The trunk is almost cylindrical in form, and only slightly longer than broad. It is composed of eight short segments, well defined in their whole circumference, and nearly equal in size, each bearing a pair of branchial legs, the outer part of which projects beyond the free edges of the carapace.

The pleon is at the base fully as broad as the trunk, but tapers gradually, so as scarcely to be more than half as broad at the end. It is composed of four well-defined segments, each bearing a pair of powerfully developed natatory appendages or pleopoda. The last segment is provided with distinct, rounded, epimeral plates, partly covering the base of the corresponding pair of pleopoda.

The urosome or tail is rather slender, and very movably connected with the pleon, so as often to form an angular bend with it (see Pl. I. fig. 1). It is nearly cylindrical in form, and composed of four segments, the first of which is the smallest, and, properly speaking, corresponds to the last thoracic segment in the Copepoda. This and the succeeding segment bear each a pair of rudimentary caudal limbs, whereas the third segment is without any trace of limbs. The last segment terminates in two slender, diverging branches, evidently answering to the so-called "furca" in the Copepoda, and to the caudal lamellæ in the Branchipodidæ. The two middle segments of this division are denticulate at the posterior edge, and the last segment projects at the end, beneath the

terminal branches, as two triangular, pointed processes, having between them the anal orifice (see Pl. II. fig. 10).

The carapace (see Pl. I. fig. 1 ; Pl. II. fig. 1) is rather large, covering the greater part of the body, including the whole cephalic part, the trunk, and part of the pleon. It is highly compressed, the free lateral parts extending in the form of two valves perpendicularly along the sides, so as wholly to cover the oral parts, and to include between them the basal parts of the two pairs of antennæ, as also the greater part of the branchial legs. Above, the two valves pass immediately into each other by an even curve, without any intervening hinge. As seen laterally (Pl. I. fig. 1), the carapace exhibits a somewhat oval form, with the dorsal line slightly arched, the anterior edges strongly curved, and joining the inferior without any intervening angle. Posteriorly, each valve forms an obtusely rounded lobe, advancing to a more or less extent over the side of the pleon, without however covering the dorsal surface of that division. These lobes are separated above by a deep emargination, at the bottom of which a small and narrow incision is seen (see Pl. II. fig. 1). Owing to this emargination, the posterior edges of the carapace appear in a lateral aspect (Pl. I. fig. 1) obliquely truncate, and joining the dorsal line at an obtuse angle. The so-called rostrum (Pl. I. fig. 1, *R* ; fig. 2) forms an oblong tongue-shaped plate, movably articulated to the carapace in front, above the insertion of the eyes. It is slightly arcuate, with the upper side convex, the lower concave, and terminates in a sharp spiniform projection issuing from a slight longitudinal elevation running along the concave side of the rostrum. As seen from above or below (fig. 2) this plate appears broadest near the base and tapers slightly towards the end, whereas in *Nebalia* it is more regularly oblong—oval in form. When lowered and applied against the anterior part of the carapace, it almost reaches to the inferior edges, thus, as it were, closing the anterior aperture of the carapace as an operculum. The carapace is connected with the body dorsally along a rather restricted space, extending from the base of the rostral plate to about the middle of its length. The limits of this space are faintly traced both in the lateral and dorsal aspect of the animal (see Pl. I. fig. 1 ; Pl. II. fig. 1), and according to its position, this space may properly represent the gastric region in the higher Crustacea. Throughout this limited dorsal area the carapace forms the immediate body-wall, whereas elsewhere it only loosely covers the body, which admits of being moved to a certain extent within it. On each side of the anterior part of the carapace, immediately beneath the above-named region, and at a short distance behind the mandibles, an assemblage of lucid spots, forming together a well-defined, rounded, oval area (Pl. I. fig. 1, *Cm*) may easily be distinguished. This area is produced by the insertion of the strong adductor muscle, by the aid of which the valves of the carapace admit of being approached to each other to a certain extent. Both in form and position this muscle entirely agrees with the strong adductor muscle of the shell met with in the bivalved Phyllopoda, thus giving the carapace an evident phyllopodous character. As

to structure, the carapace is rather thin and pellucid and very flexible, not at all calcareous, and without any trace of external sculpturing. It is composed of two distinct layers, an outer chitinous coat, and a soft membrane lining the inside of the carapace. Between the two layers there is a system of hollow spaces anastomosing with each other, and forming together a complicated network of canals, in which the blood circulates.

The eyes (Pl. I. fig. 1, *O*; fig. 3) are movably articulated to a short segment, lying in front of the antennal segment, and are partly covered by the rostral plate, projecting obliquely at each side (see Pl. II. fig. 1). They are rather large, nearly as long as the rostral plate, slightly curved, and somewhat tapering, and not as in *Nebalia*, expanded at the end. The upper edge is slightly convex and densely denticulate, the denticles increasing somewhat in size toward the tip of the eye; the lower edge is almost straight and quite smooth. The eye-pigment is black, and does not completely fill up the outer part of the eye, forming a narrow, oblong central mass, from which the small, rounded crystalline cones project all around. There is no distinct faceted cornea similar to that found in higher Crustacea.

The antennulæ (Pl. I. figs. 1, *a*<sup>1</sup>; fig. 4) are rather powerful organs, almost pediform in character, and more or less projecting in front of the carapace, immediately below the eyes. They consist each of a strong, four-jointed peduncle, geniculate at the middle, and two terminal appendages movably articulated to the same. The first joint of the peduncle is rather firmly connected with the antennal segment and of a nearly quadrate form, without any spines or bristles. The second joint is almost twice as long, and rather movably articulated to the first, forming with it a more or less distinct elbow-shaped flexure. It is slightly dilated towards the end, which exhibits on the upper side an obtuse projection, at the base of which several slender bristles are affixed; from the lower side, close to the end of the joint, moreover, four rather strong and recurved ciliated setæ arise. The third joint is somewhat shorter than the second, constricted at the base, and likewise very movably articulated, so as generally to form with the preceding joint a strong geniculate bend. At some distance from the extremity there is a slight prominence, and between this prominence and the terminal edge a great number of slender, diverging bristles occur. The fourth joint is much shorter, and has only a very restricted mobility in relation to the preceding joint. It is produced along the anterior side to a compressed lanceolate expansion (fig. 6) freely projecting from its end, and strongly serrate along the outer edge. The serrations, from twelve to fourteen in number, are pretty regular, and increase in size toward the tip of the expansion, each of them being finely denticulate at the upper edge. At the base of this expansion a few slender bristles are affixed to the inner surface of the joint. Of the two terminal appendages, the outer one has the form of an oblong-oval lamella clothed along the anterior side and apex with a great number of unequal-sized slender bristles, forming together a dense brush. The inner appendage, representing the true flagellum, is more cylindrical in form, and also

considerably more elongate, though scarcely exceeding half the length of the peduncle. It slightly tapers towards the end, and is composed of five articulations, the first of which is nearly twice as long as the four others combined. All the articulations are densely beset with bristles, especially along the anterior edge, where the bristles are arranged in distinctly defined fascicles increasing in length toward the apex. On closer examination, some of the setæ are found to be densely ciliated along one of their edges, and besides there is found in each fascicle an exceedingly delicate and pellucid ribbon-shaped appendage (fig. 5), answering to the so-called olfactory cilia in other Crustacea. According to the statements of the late Dr. v. Willemoes Suhm, the flagellum in the adult male has a very different appearance from that in the female, being greatly expanded, and without any distinct articulations. In the male of *Nebalia*, the flagellum is also somewhat different from that in the female, but the difference here consists chiefly in this part being more elongate and having dense clusters of sensory bristles on the proximal joints.

The antennæ (fig. 1,  $a^2$ ; fig. 7) are somewhat more elongate and slender than the antennulæ, and affixed in close approximation to the latter, so as partly to cover them at the base. They are composed of an elongate, triarticulate peduncle, geniculate at the middle, and a single multiarticulate flagellum. The first joint of the peduncle is short and thick, somewhat similar to that of the antennulæ and without spines or bristles. The second joint is also quite smooth, but considerably more elongate, cylindrical in shape, and, like the antennulæ, forming a more or less distinct, elbow-shaped bend with the basal joint. The last joint of the peduncle is still more elongate and close to its base abruptly curved, so as to render the peduncle distinctly geniculate at the middle. The anterior edge of this joint is somewhat irregularly flexuous, forming above, at the curvature of the joint, a rounded, knee-shaped protuberance, beset with short bristles; two similar but less prominent setose protuberances follow further below, and, besides, two somewhat recurved dentiform projections are found at the same edge, the one nearly in the middle, the other at the end. The outer part of the anterior edge is, moreover, beset with slender ciliated setæ, rapidly increasing in length towards the end, and continued transversely on the inside of the joint, so as partly to project also on the posterior side; these setæ are very elongate, almost reaching to the end of the flagellum. The posterior edge of the joint has only a single seta at the middle, but this seta is very strong and more densely ciliated than the others. The flagellum is considerably shorter than the peduncle, cylindrical in form, and composed of six distinctly defined joints, the first of which is by far the longest, and about equals the three succeeding in length. At the end of each of the joints anteriorly, a dense fascicle of bristles occurs, and in addition the first joint has three similar fascicles along its anterior edge. According to the statements of the late Dr. v. Willemoes Suhm, the antennæ in the adult male do not differ materially from those in the female, whereas in the male of *Nebalia* the flagellum is extremely elongate, slender and filiform.

The anterior lip (fig. 8) forms a rounded fleshy prominence issuing from the antennal segment and projecting backwards so as to cover the masticatory parts of the mandibles. It is slightly emarginate at the free terminal edge and finely ciliated on each side of the emargination.

The posterior lip I have not succeeded in isolating from the surrounding parts. In *Nebalia* it constitutes a rather small bifid lobe, limiting the oral orifice posteriorly.

The mandibles (fig. 1, *M*; fig. 9) have the body comparatively small and tapering above to a narrow point reaching rather far up the sides of the body (see fig. 1). The masticatory part is strongly incurved so as to form a right angle with the body. It has the cutting edge quite rudimentary, only forming a small, undivided dentiform projection (see fig. 10), whereas the molar tubercle is well developed, cylindrical in form, and terminating in a large fluted molar surface. No difference whatever can be detected in the armature of the two mandibles. The palp (fig. 11) is very fully developed, being twice as long as the mandible (see fig. 9) and generally pointing obliquely anteriorly so as to reach the inferior edge of the carapace (fig. 1, *Mp*). It is rather slender and composed of three well-defined joints, the first comparatively short and unarmed, the second very elongate and somewhat curved, bearing at the posterior edge four slender bristles, and at the opposite side near the end another recurved seta. The last joint is nearly as long as the preceding and strongly compressed, forming an oblong vertical lamella, slightly dilated at the middle and provided along the outer part of the posterior edge with a double series of densely ciliated bristles arranged in a comb-like manner and increasing in length towards the tip. As to structure, the mandibles in the present form agree fairly well with those in *Nebalia*, excepting that the cutting edge is still more rudimentary, and that the last joint of the palp is somewhat differently formed.

The first pair of maxillæ (fig. 1, *m*<sup>1</sup>; fig. 12) exhibit two well-defined and rather dissimilar masticatory lobes, and a slender recurved palp. The outer masticatory lobe is rather narrow and strongly incurved, with the apex abruptly truncate and armed with a double row of strong equal-sized spines, besides a few slender bristles, one of which, affixed at a short distance from the apex anteriorly, is somewhat stronger than the others and finely ciliated. The inner masticatory lobe is considerably shorter than the outer and has the form of a rounded lamella, finely ciliated along the free edges and, besides, provided with a row of about twelve strong ciliated setæ, curved anteriorly and forming together a broad fan. The palp, which is movably articulated to the end of the basal part, at the base of the outer masticatory lobe, is very elongate and slender. It exhibits at the base two imperfectly defined segments, forming together a more or less sharp bend and followed by a very narrow setiform terminal part, projecting obliquely posteriorly along the sides of the trunk (fig. 1, *m*<sup>1</sup>). The latter part is provided along the lower edge with about fifteen extremely slender unciliated bristles, the posterior of which are rather regularly arranged, two issuing from the tip. In the structure of these maxillæ,

which has been wrongly represented by the late Dr. v. Willemoes Suhm, the present form exhibits some well marked differences from *Nebalia*. Thus, the outer masticatory lobe in the latter genus is very dissimilar, being not nearly so much produced, and its armature is also rather different; moreover the inner lobe is somewhat smaller, whereas the palp is comparatively more strongly developed.

The second pair of maxillæ (fig. 1,  $m^2$ ; fig. 13) are composed of a somewhat lamellar basal part, to the end of which two appendages are movably articulated, the inner one representing the palp, the outer the exognath. The basal part is divided into two segments, and juts out internally as three densely setose masticatory lobes, the posterior of which is by far the largest. In front of these lobes there is a slight expansion, bearing three slender ciliated setæ, the outer of which is very elongate. The palp is shorter than the basal part and rather narrow, biarticulate, with the first joint smooth, and the second tipped with three slender ciliated setæ. The exognath arising close outside the palp, has the form of a narrow lamella, somewhat shorter than the palp, and provided along the outer edge and apex with about nine finely ciliated setæ. The maxillæ above described differ from those in *Nebalia*, chiefly by the far inferior development of both the palp and exognath, which in the latter genus are considerably longer than the basal part, and provided with a much greater number of bristles.

The branchial legs (Pl. I. fig. 1, *brp*; Pl. II. figs. 2-4) in the present form are, as above stated, modified in a peculiar manner, so as at first sight to appear very different from those in *Nebalia*, this modification being apparently to make them more adapted for direct prehension of the food, whereas their original function as respiratory organs seems to be much less pronounced than in the typical genus. This is chiefly effected by the excessive prolongation of the endopodite, accompanied also by a peculiar transformation of the exopodite, and a considerable reduction of the epipodite. The branchial legs in the present form thereby acquire an appearance strongly reminding us of the true legs in some of the higher Crustacea, especially those of the Euphausiidae. As is also the case in *Nebalia*, these limbs are considerably more elongate in the adult females than in the young animals and in the males, and are moreover distinguished by the great development of the bristles affixed to them. In both sexes they project considerably beyond the free edge of the carapace (see Pl. I. fig. 1, *brp*), whereas this is not the case in *Nebalia*. All the legs present a rather uniform appearance, forming together a densely crowded double series along the ventral side of the trunk, and being extended straight downwards, parallel to each other, and with their outer projecting parts more or less distinctly curved. Their movements in the living animal are undoubtedly performed in a simultaneous and rhythmical manner as in *Nebalia*. As to structure (see Pl. II. figs. 2-4), the same principal parts as in *Nebalia* are easily found, though rather modified in form. On the main stem may be distinguished a somewhat expanded laminar basal part, and a slender terminal part or endopodite, the latter being more or less curved and divided into a

number of segments. These segments are, however, very imperfectly defined, and hence can only be exactly counted with great difficulty, except on the posterior pairs (fig. 4), where they appear more distinct, amounting to six in all. The inner edge of the stem does not show any trace of lateral lobes or endites, but is bordered by a regular series of rather elongate and slender ciliated setæ. Besides, at a short distance from the edge along the posterior surface, another similar series of slender setæ occurs, and this series on the last pair (fig. 4) successively passes over from the posterior surface to the outer edge, whereby the terminal part of the endopodite becomes densely setiferous on both edges. Finally, a third series of very minute hair-like bristles is found close inside the latter series along the posterior surface of the legs. The setæ of the basal part in all the legs are considerably shorter than those affixed to the endopodite, though arranged in a similar manner. The apical setæ in most of the legs (figs. 2, 3) differ somewhat from the rest, at least in the female, one of them being densely plumose, whereas the others are quite unciliated, very slender and strongly curved at the tip. On the last pair (fig. 4), however, the apical setæ do not differ materially from the lateral, but on close examination a very small spine, somewhat reminding one of the terminal claw in higher Crustacea, is found at the tip between the setæ. The exopodite, issuing from the base of the endopodite on the outer side, exhibits an appearance very different from that in *Nebalia*, having the form of a slender plate, somewhat shorter than the endopodite, and produced at the end into a very narrow flap. It is fringed along its whole outer edge with a single regular series of slender ciliated bristles, one of which issues from the tip. In the middle pairs (fig. 3) the exopodite is very elongate, and beyond the middle more or less distinctly geniculate, with an approach to a division into two parts, a basal and a very narrow terminal part, thus acquiring a certain resemblance to the natatory branch in higher Crustacea. In the posterior pairs (fig. 4) the exopodite becomes considerably shortened, and of a more simple form. The epipodite, which in *Nebalia* is exceedingly large and expanded both superiorly and inferiorly, is in the present form reduced to a very small appendage affixed externally to the end of the basal part. It has the form of a narrow recurved plate, very delicate in structure and finely ciliated along the outer edge. In the anterior pair (fig. 2) this plate is slightly bilobed, the inferior lobe being, however, very short and rounded; in the succeeding pairs (fig. 3) it is more simple and oblong in form, and in the last pair (fig. 4) the plate is considerably more produced above than in the other pairs, forming a narrow, slightly flexuous flap, which projects upwards beyond the base of the leg (see Pl. I. fig. 4).

The four succeeding pairs of limbs (Pl. I. fig. 1, *p*!; Pl. II. figs. 5-7), affixed to the pleon, constitute very powerful natatory organs or pleopoda, which admit of being moved with great force from before backwards, acting in much the same manner as the swimming legs in the Copepoda. They consist each of a broad and somewhat flattened basal part, to the end of which two diverging linear branches are affixed. The basal part is strongly muscular, and composed of two unequal segments, the proximal quite short, the distal

oblongo-quadrangular in form, and in the three posterior pairs having the outer edge regularly serrate. Of the branches the outer one is the shorter, and uniarticulate with the outer edge, and the apex strongly spinose, the inner edge being bordered by a regular row of ciliated setæ, two or three of which issue from the apex inside the terminal spines. The inner branch is somewhat more slender and distinctly biarticulate, the proximal joint very short, the distal elongate and slightly tapering to the apex, which juts out as a short dentiform projection and, inside the latter, bears a strong spine. Along both edges of this joint a dense series of ciliated setæ increasing successively in length toward the tip is affixed, and from the inner side of the proximal joint a linguiform lateral lobe (fig. 6*a*) arises, armed at the tip with three strongly chitinised hooks (fig. 6*b*). This lobe meets the one on the other side, and by the aid of the above-mentioned hooks both pleopods become thus, as it were, clasped together, so as only to admit of a quite simultaneous movement. In comparing the four pairs of pleopoda with each other, we find some slight differences in their armature and in the relative length of the branches. Thus, in the first pair (fig. 5) the outer edge of the basal part is quite smooth, without any trace of the regular serrations occurring in the other three pairs. Moreover, the outer branch in this pair is considerably shorter as compared with the inner, and the spines of the outer edge are much more numerous and also arranged in a different manner, being only in the distal part disposed in fascicles, whereas those of the proximal part form a dense comb-like series. In all the other pairs (figs. 6, 7) the spines of the outer branch are arranged in five distinct fascicles, two in each fascicle, besides a small seta, and to the obliquely truncate apex three somewhat stronger spines increasing successively in size are affixed. The last pair of pleopoda (fig. 7) are somewhat smaller than the preceding pairs, and have the inner branch only very slightly longer than the outer, and the spines of the latter branch are also considerably smaller.

The two pairs of rudimentary caudal limbs (Pl. I. fig. 1, *cp*<sup>1</sup>, *cp*<sup>2</sup>; Pl. II. figs. 8, 9) succeeding the true pleopoda are both of a very simple structure, forming narrow uniarticulate plates, scarcely at all movable. They are setose at the inner edge and armed at the obliquely truncate apex with three spines. Those of the first pair (fig. 8) are somewhat larger and more densely beset with bristles than the posterior pair (fig. 9), with the apical spines successively increasing in length, whereas on the latter pair the middle spine is the longest.

The caudal rami (Pl. I. fig. 1, *ur*; Pl. II. fig. 10) have the form of two more or less diverging narrow plates, movably articulated to the end of the last segment, and about as long as the two posterior caudal segments taken together. They are minutely spinous along the outer edge, and along the inner they are provided with a row of short ciliated bristles, besides a series of minute spines. From the obliquely truncate apex a dense fascicle of very long and slender setæ arises, which, however, were mostly broken in the specimens examined.

*The internal organs* I have not succeeded in isolating by dissection, owing to the small size of this form. In the previously mentioned specimen, rendered pellucid by preparation in Canada balsam, and represented on Pl. I. fig. 1, the intestine can, however, be easily traced running through the axis of the body and terminating in a strongly muscular rectum, which traverses the last caudal segment (see also Pl. II. fig. 10). At the sides of the intestine the ovaries (Pl. I. fig. 1, *Or*) appear very distinctly, owing to their being rather more opaque than the surrounding parts. They have the form of two very elongate and narrow tubes running through the whole trunk and pleon, and, moreover, projecting anteriorly to some extent within the cephalic part and posteriorly almost reaching to the end of the second segment of the tail. They were each filled by only a single series of ovarian ova, each with a very distinct germinal vesicle in the centre.

The musculature of the body may also be rather distinctly traced in the specimen. Thus, in the cephalic part several strong muscular bundles are seen passing from the dorsal side to the several appendages belonging to that division, and in the succeeding part of the body, besides the muscles moving the respective limbs, there is another group of very powerful muscles running parallel to the axis, and by the aid of which the body admits of being moved in relation to the cephalic part or to the carapace, as does also the tail upon the pleon. Of these muscles the dorsal, or extensores, are the more numerous, passing from the one segment to the other and apparently forming several layers, whereas the ventral musculature is chiefly restricted to two strong muscles running backwards beneath the intestine, and in the tail dividing into separate bundles for each segment. The heart, distinctly visible in living animals from its rapid pulsations, quite escapes attention in dead specimens owing to its very thin and pellucid walls, and the nervous system, as also the caeca of the intestine are very difficult to see even in fresh specimens. That all these parts on the whole may agree with those in *Nebalia*, I cannot but believe, as these two genera are otherwise very nearly related.

*Development.*—As above stated, some of the specimens in the collection were laden with eggs and embryos. On Pl. II. figs. 11, 12, I have represented one of the embryonic stages in a ventral and lateral aspect, having found it somewhat different from the corresponding stage of *Nebalia*, as figured by Metschnikoff. The length of this embryo is nearly 1 mm. As may be seen, it is still provided with the so-called larval cuticle, forming a pellucid homogeneous sheath investing the greater part of the body, and terminating in a slightly bilobed extremity. The anterior part of the body, constituting the cephalic division, is very considerably dilated, almost globular, and to a great extent filled up with the remainder of the yolk, whereas the succeeding part gradually tapers posteriorly. The latter does not exhibit any trace of the strong dorsal curvature found in the corresponding stage of *Nebalia*, according to the statement of Metschnikoff, but is quite straight, or with the terminal part even slightly curved

ventrally (fig. 12). Of the several divisions of the body which are distinguished in the adult animal, the anterior or cephalic part is, as above stated, very massive and about as long as the succeeding division or trunk, which exhibits, within the larval cuticle, all its segments well defined. The posterior part of the body, on the other hand, including the pleon and the tail, is still rather imperfectly developed and scarcely longer than the trunk. It consists of only five segments besides the caudal rami, and if the four anterior of these segments be referred to the pleon, the tail will then only be represented by a single segment. The free edges of the developing carapace (fig. 12, *C*) can easily be traced on each side as a curved line extending backwards from the base of the eyes and meeting above at the most anterior part of the trunk. The carapace is thus in this stage chiefly confined to the cephalic part, the greater portion of the trunk being exposed behind it. The rostral plate (*R*) is also readily detected as an obtuse protuberance curving inferiorly in front and not yet marked off from the carapace. The several appendages belonging to the cephalic division are all visible, though still rather imperfectly developed. The eyes (*O*) constitute two rather large recurved prominences, which, however, as yet show no trace of either pigment or visual elements, and are also quite smooth, not as in the adult animal denticulate. The antennulæ (*a*<sup>1</sup>) and antennæ (*a*<sup>2</sup>) are of a very similar appearance, forming simple digitiform recurved processes projecting freely from beneath the anterior part of the head, the former slightly diverging the latter extending straight backwards along the ventral surface. Between the base of the antennæ a rounded prominence (*L*), still invested by the larval cuticle, is seen, representing the anterior lip. Somewhat posterior to this prominence, three pairs of rather small and closely crowded processes occur, the two anterior pairs exhibiting a slender terminal appendage, distinctly marked off from the proximal part, and somewhat recurved. Of these processes the anterior pair (*M*) represent the mandibles, and their terminal appendage the mandibular palp; the succeeding pair (*m*<sup>1</sup>) are the first pair of maxillæ, and their terminal appendage, which is considerably narrower than that of the preceding pair, is easily recognised as the slender recurved palp of these maxillæ; the third pair (*m*<sup>2</sup>), finally, are as yet quite simple, conical in form and represent the second pair of maxillæ. On each of the eight segments of the trunk there are a pair of bilobular appendages (*brp*) pointing posteriorly and each partly covering the one succeeding it. These appendages represent the developing branchial legs and are all exactly alike and slightly extended laterally. They are succeeded by three pairs of appendages (*p*<sup>1</sup>), which are also distinctly bilobular at the tip, but much smaller and quite concealed by the larval cuticle. These appendages are the three anterior pairs of pleopoda. No trace can as yet be detected of either member of the fourth pair of pleopoda, or of the two succeeding pairs of rudimentary caudal limbs. The caudal rami (*ur*) form simple obtusely conical processes, lying within the symmetrically formed bilobular extremity of the larval cuticle and being well defined from the last segment, but as yet without any

trace of spines or bristles. The young, when fully developed and ready to escape from the incubatory cavity of the mother, have much the same appearance as the adult animal, with this exception, however, that the last pair of pleopoda, as is also the case in the young of *Nebalia*, are not yet developed, but only indicated as a slight projection of the last segment of the pleon.

*Habitat*.—According to the statement of the late Dr. v. Willemoes Suhm, the present interesting form was obtained during the stay of the Expedition at the Bermudas, by Mr. John Murray, who took it in Harrington Sound, a bay which only communicates with the sea through a narrow passage. Afterwards the late Dr. v. Willemoes Suhm also collected the animal in the same bay, where it occurred not rarely under stones and Corals. But among twenty females he only succeeded in finding two male specimens.

*Nebaliopsis*, n. gen.

*Generic Characters*.—Carapace distinctly sculptured, very large and produced along the dorsal line so as to cover over the whole trunk and the greater part of the pleon; valves not expanded posteriorly nor separated above by any emargination. Rostral plate very small, tongue-shaped. Trunk much larger than pleon and rather dilated. Tail very small with the segments subequal. Eyes rudimentary, without pigment or visual elements. Antennulæ not very strong, last joint of peduncle produced anteriorly to a narrow projection, terminal lamella comparatively small, narrowed at the tip, with scattered spines at the edge, flagellum well developed. Antennæ with last joint of peduncle divided into two segments, flagellum slender, multiarticulate. Mandibular palp very strong, subpediform. Second pair of maxillæ with palp and exognath imperfectly developed and not defined from basal part. Branchial legs very small and simple in structure, forming oblong lanceolate lamellæ, setose on the inner edge and slightly lobular at the outer, endopodal and exopodal parts only very faintly indicated, epipodite distinctly defined, narrow, elliptical, upper extremity more produced than lower. Pleopoda well developed, outer branch lamellar, expanded, inner lanceolate. The two succeeding pairs of rudimentary caudal limbs subequal, unarticulate. Caudal rami lamellar expanded, outer edge spinous, inner setose.

*Remarks*.—The present new genus is chiefly distinguished by the peculiar form and sculpture of the carapace, and by the structure of the branchial legs. In both these respects, as also, it would seem, in the structure of the oral parts, it differs very considerably from the two other known genera of recent Phyllocarida. The relative development of the several divisions of the body is likewise rather different, especially when compared with the typical genus *Nebalia*, the trunk occupying the far greater part of the body, whereas the terminal part or tail—greatly developed in *Nebalia*—is very much reduced in size. In the form of the carapace, the present genus shows a certain resemblance to

the Devonian genus *Dictyocaris*, Salter, in which a distinct external sculpturing has also been described; but whether this resemblance is only accidental or points to some nearer relationship between the two genera, it is impossible at present to say with any approach to certainty.

2. *Nebaliopsis typica*, n. sp. (Pl. III.).

*Specific Characters*.—Carapace thin and flexible, somewhat compressed, with a slight dorsal keel running along the middle, its form, as seen laterally, oblongo-triangular, dorsal line very faintly curved, anterior extremity narrowly rounded, posterior obtusely produced above, inferior edges strongly curved in front of the middle. Rostral plate exceedingly small, oval in form, with a slight carina running along the middle and terminating in a blunt point. Surface of carapace sculptured by elevated narrow ridges anastomosing with each other and forming together a somewhat irregular open network, less distinct on the anterior part, where a somewhat flexuous transverse elevation passes down the sides for a short distance from the anterior edge. Trunk very large, about as long as pleon and tail combined. Tail scarcely longer than the three posterior segments of pleon taken together, very narrow, with the posterior edge of the segments indistinctly denticulate. Eyes exceedingly small, cylindrical, smooth, apex rounded. Antennulæ with the two first joints of peduncle rather strong and subequal in length, third much smaller, lamellar appendage about as long as first joint of flagellum. Antennæ with the peduncle scarcely longer than that of the antennulæ, first joint the largest. Pleopoda with basal part smooth, outer branch shorter than inner and having the outer edge strongly curved and armed with a single row of small denticles. Caudal lamellæ about as long as tail, expanded in the middle, extremity tapering and slightly incurved, outer edge apparently armed with seven spines, increasing in size posteriorly, tip with two spines (or strong setæ). Length reaching about 40 mm.

*Remarks*.—The specific diagnosis given above is of course only provisional, the present form being the only one of the genus as yet known. Most of the characters mentioned above may, however, from analogy with other forms prove to be really specific in value. It is apparently this form that was mentioned by the late Dr. v. Willemoes Suhm in a letter to Professor v. Siebold,<sup>1</sup> as a gigantic Ostracode. This strange mistake may be readily explained by the incompleteness of the first specimen obtained, of which only the carapace and a small fragment of the body was brought up in the dredge.

*Description*.—Of this remarkable form there is in the collection an apparently young specimen with most of the limbs preserved, and also the carapace of a much larger and in all probability adult specimen, together with a fragment of the cephalic part. The former specimen has a length of 22 mm. excluding the caudal rami, which are wanting

<sup>1</sup> *Zeitschr. f. wiss. Zool.*, Bd. xxiv, p. xiii.

in the specimen. Its carapace measures 16 mm. in length. The carapace of the other specimen is fully 29 mm. long and 16 mm. high, and thus the total length of this specimen may have been about 40 mm.—a very large size, indeed, as compared with that of the other known recent Phyllocarida.

The form of the body (see Pl. III. figs. 1, 2) differs considerably from that in the species of *Nebalia* and *Paranebalia*, not to speak of the peculiar shape of the carapace, by the large size of the middle division, the trunk, whereas the posterior part of the body, including the pleon and the tail, is comparatively far less developed and scarcely at all longer than the trunk.

The carapace is exceedingly large and of a form distinctly deviating from that met with in the other two genera. It is slightly compressed, though somewhat less so than in *Nebalia*, and covers the greater part of the body, including the cephalic part, the trunk and the greater portion of the pleon, without, however, being connate with the body except along a very limited space in front. As seen from the side (figs. 1, 5) it exhibits an oblong triangular form, with the dorsal line only very slightly arched, the anterior extremity narrowly rounded, and the posterior extremity produced above to an obtuse angle. The inferior edges exhibit somewhat in front of the middle a strong, almost angular curvature, and behind this curvature they ascend obliquely, without forming any projecting lateral lobe, but joining immediately the posterior edges by a very slight curve. The free edges meet above at an obtuse angle, no intervening incision or emargination, similar to that found in the other known forms, being present (see fig. 6). The rostral plate (see figs. 1, 5) is exceedingly small, but distinctly defined from the carapace. As seen from above (fig. 7) it exhibits a quite regular oval form, with a slight keel running along the middle and terminating in front in a small angular projection. In both specimens it curves straight downwards between the free anterior edges of the carapace, partly closing the anterior opening of the shell as an operculum, but in the living animal it undoubtedly may admit of being raised and lowered to a certain extent, as is the case with the other known forms. As to structure, the carapace is very thin and flexible, almost membranaceous, and semitransparent, but provided with a well-marked external sculpturing, especially very distinct on the carapace of the larger specimen (figs. 5, 6). This sculpturing consists of a system of narrow elevated ridges anastomosing with each other, and forming together a somewhat irregular open network, limiting a great number of angular depressed areas of different size and form. Towards the anterior part of the carapace this sculpturing becomes gradually less distinct, and at last wholly disappears, whereas at a short distance from the anterior edge a rather coarse transverse elevation passes down the sides, making at its upper part a sharp curve backwards. In the middle of the dorsal surface (fig. 6) a straight ridge or low keel runs along the carapace from its anterior extremity to the posterior, dividing it into two symmetrical halves, and at the end of the anterior fourth part of the length of the carapace a well-defined obliquely transverse line crosses the ridge

and marks off in front the very small space where the carapace forms the immediate body-wall, at the same time dorsally defining the anterior division of the body,—the cephalic part. Immediately below this area, on each side, the insertion of the adductor muscle of the valves is distinctly seen as an assemblage of small lucid spots.

The division of the body behind the cephalic part is very large, occupying more than the third part of the length of the body. It is at once seen to answer to the comparatively small part described above in *Paranebalia* as the trunk, and is, as in that genus, composed of eight well-defined segments, slightly increasing in size posteriorly, and each bearing a pair of branchial limbs. The ventral surface of this division bulges out as it were in its posterior part, so as to project further down than the pleon, whereas the contrary is the case in the two other known genera.

The pleon is considerably shorter than the trunk and rapidly tapers posteriorly. It is composed of the normal number of segments, none of which, however, exhibits any traces of distinct epimera.

The tail is very small and narrow, cylindrical in form, and about as long as the three posterior segments of the pleon taken together. It is composed, as in the other genera, of four segments about equal in size, the three anterior being slightly denticulate at the posterior edge. The last segment is somewhat dilated at the end, and wants the dentiform projections found in the preceding genus on each side of the anal orifice.

The eyes (figs. 8, 9, *O*) exhibit a quite rudimentary condition, wanting, as they do, every trace of pigment and visual elements. They are very small, so as easily to escape attention, and nearly cylindrical in form, or very slightly dilated towards the end, which is obtusely rounded and quite smooth.

The antennulæ (fig. 8, *a*<sup>1</sup>) are constructed upon the very same type as in *Nebalia* and *Paranebalia*, but appear comparatively shorter and stouter. The first joint of the peduncle is rather massive, irregularly angulated, and, as in the latter genera, very firmly connected with the head. The second joint is scarcely longer than the first, dilated in the proximal part, and rapidly tapering to the end, forming with the succeeding joint a strong geniculate bend. It bears on the inner side near the end a few recurved setæ, but is otherwise, like the first, quite smooth. The third joint is scarcely more than half as large as the preceding, constricted at the base and somewhat dilated toward the end, with the terminal edge forming on the outer side an obtuse angle. The fourth joint is still smaller but rather broad, and juts out anteriorly as a slightly curved narrow process, strongly compressed and very finely denticulate at the anterior edge. As in *Nebalia* and *Paranebalia* a lamellar appendage is articulated outside at the base of this process. This appendage is, however, rather small and of a somewhat fusiform shape, with a few small spines along the anterior edge, two of which are affixed to an angular projection about the middle. Of the numerous slender bristles which clothe the corresponding lamella in the two other genera, there is no trace to be detected. The flagellum seems

to have been rather elongate, in all probability much longer than the peduncle, but the outer part is wanting in both specimens. The preserved proximal part is composed of eight joints, the first of which, as usual, is by far the largest and about as long as the lamellar appendage, whereas the succeeding joints are very short. The bristles, which may have clothed these joints anteriorly, were broken off in the specimen examined.

The antennæ (fig. 8, *a*<sup>2</sup>) are somewhat more slender than the antennulæ, and comparatively rather smaller than those in *Nebalia* and *Paranebalia*. The peduncle is scarcely longer than that of the antennulæ and geniculate at the middle. Its first joint is the largest, irregularly quadrangular in form, and exhibits on the outer side at the base a rounded prominence, slightly overlapping the basal joint of the antennulæ. The second joint is, like the first, quite smooth, and has the distal extremity obliquely truncate, forming with the succeeding joint a sharp geniculate bend. The latter joint is considerably more slender than the two preceding, and divided into two segments by a well-marked transverse suture. It is provided along the anterior edge with a number of small slender bristles, forming on the proximal segment a double row. The flagellum in both specimens is imperfect, the outer part being broken off, but, to judge from the form of the proximal part, it may have been rather elongate and slender.

The anterior lip (figs. 8, 9, *L*) projecting posteriorly between the bases of the antennæ, is rather large and almost pentagonal in form, the terminal edge being not, as in the two other genera, emarginate, but on the contrary produced in the middle as an obtuse angle, and without any visible ciliation.

The mandibles (fig. 8, *M*) are very small, more so even than in *Nebalia* and *Paranebalia*. The structure of their masticatory part could not be more closely examined, but this part seems to be far less developed than in the genus *Paranebalia*. The palp (*Mp*), on the other hand, is very large, almost pediform, and composed of three distinctly defined joints forming angular bends with each other. The basal joint is rather massive, and forms with the succeeding joint apparently a very movable articulation. Both these joints are quite smooth and nearly uniform in size, whereas the terminal joint is considerably smaller and of a narrow elliptical form; it is moreover strongly compressed, and provided along the posterior edge with a dense row of ciliated bristles, arranged in a comb-like manner.

Of the maxillæ I have only been able to examine the second pair more closely, the first pair being so much damaged in the specimen examined as not to admit of any satisfactory description. The former pair (fig. 10) are very small and look rather dissimilar to those in *Nebalia* and *Paranebalia*, whereas, on the other hand, they show an unmistakable resemblance to the maxillæ in certain Copepoda. As in the latter group the inner masticatory lobe is very strongly developed and does not extend in the same plane as the others; it is, moreover, provided at the free edge with a dense row of strong spine-like bristles, which are ciliated at one of their edges and recurved, so as to form together a dense comb-like fan projecting towards the oral orifice. The three other

masticatory lobes are much smaller, and very narrow, and arise from a common lamellar expansion lying outside the principal lobe. They were devoid of any armature, but it may be that a few bristles have been originally affixed to their obtusely rounded extremities. Neither the palp nor the exognath are distinctly defined from the basal part but appear only as simple expansions of it. The palp has the form of a rather large oval projection extended in the axis of the maxilla, and provided with numerous slender ciliated setæ on both edges, those of the outer edge being the longest and arranged in several rows. The apex is evenly rounded and unarmed, whereas a row of very small spine-like bristles is found along the inner edge, inside the slender ciliated setæ. The exognath is exceedingly small, constituting only a very slight lamellar expansion of the outer edge, and provided with four densely plumose and somewhat flexuous setæ increasing in size towards the base.

The branchial legs (fig. 3) are at first sight very unlike those in the two other known genera, and comparatively far inferior in size, as also much more widely separate from one another (see figs. 1, 2). They are very simple in structure, forming, as they do, merely delicate membranous lamellæ of oblongo-lanceolate form and slightly lobular at the outer edge. There is no marked limit between basal and terminal part, nor are the endopodite and exopodite distinctly defined, the epipodite being the only part distinctly marked off from the plate. The inner edge of the plate forms a very slight and even curve, and is bordered by a single row of slender setæ, continued also on the narrowly rounded extremity. Beyond the middle there is outside a very slight lobiform expansion, the distal end of which is somewhat produced and separated from the terminal part of the plate by a narrow incision. This expansion, which is quite smooth, may, from its position, answer to the exopodite, and the part of the leg projecting beyond the above mentioned incision of course corresponds to the terminal part of the endopodite in the other Nebaliidæ. The epipodite forms a narrow elliptical lamella affixed on the outer side nearer to the base, and separated from the exopodite by another narrow incision. It is connected to the leg by a narrow neck, and has the upper extremity considerably more produced than the lower, the former even reaching somewhat beyond the base of the leg. The substance of the branchial legs is very soft, almost parenchymatous, and between the two investing cuticles there is accumulated a granular opaque mass disposed in small patches, apparently coagulated blood. All parts of the leg, indeed, seem here to be equally well adapted for respiratory purposes. Moreover, in the proximal part several thin muscular bundles are seen, partly crossing each other and disappearing at about the middle of the length of the leg.

The pleopoda (fig. 4) are rather powerful and, as in the other genera, composed of a large lamellar basal part, to the end of which two unequal branches are affixed. The basal part is oblongo-quadrangular in form and quite smooth, though projecting at the end externally as an acute angle. Of the branches the outer one is unarticulate and

distinguished by its lamellar structure and peculiar expanded form, the outer edge bulging out as a strong curve, whereas the inner is quite straight. The latter bears a row of short setæ, whereas the outer edge is armed with numerous small denticles, arranged pretty regularly in a single series. The inner branch is considerably longer than the outer, but much narrower and lanceolate in form. It is composed of two distinctly defined joints, as in the other genera, the first quite short and bearing inside the usual linguiform lobe, the second evenly tapering to the apex, and all around the edges fringed with ciliated setæ. The first pair of pleopoda only differ from the other three by the outer branch being somewhat less expanded. The last pair, as in the other genera, are somewhat shorter than the preceding pairs, but otherwise of the very same structure.

The two pairs of rudimentary caudal limbs succeeding the pleopoda (see fig. 1) are very small, and quite alike, forming simple narrow plates, setose at the edges and pointing directly backwards.

The caudal rami were broken off in the specimen examined, and are only conjecturally indicated in fig. 1 by dotted lines. When, however, recently preparing the specimen for retransmission, I detected at the bottom of the tube in which it was originally preserved, a part, which, in spite of its anomalous appearance, I cannot but believe to be one of the caudal rami, detached from the specimen. In the accompanying cut I give a figure of this part, drawn to the same scale as figs. 3 and 4 on Pl. III., which represent limbs from the same specimen. In its general appearance it somewhat resembles the outer branch of the pleopoda, but is very much larger, measuring nearly 5 mm. in length and thus about equalling that of the posterior division of the body, or tail. It has the form of a rather broad lamella, somewhat expanded in the middle and drawn out to a slightly incurved extremity, which is narrowly truncate. The edge, which I regard as the outer, is sharpened and evenly curved, with seven angular notches, to which as many spines may have been affixed, one of which, the most proximal, still remains. The latter is very small, but in all probability the others successively increased in size posteriorly. The inner edge is evenly convex in its proximal part, but becomes slightly sinuous towards the end. It is considerably thickened and exhibits two distinct lips, limiting a narrow

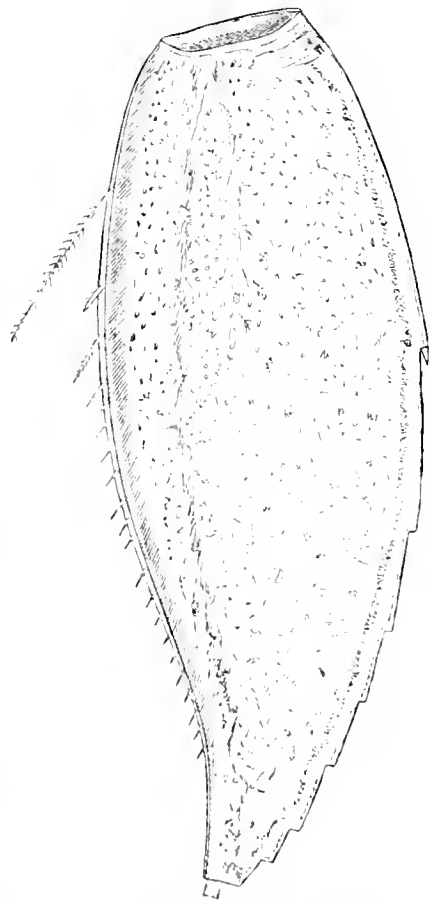


FIG. 1.—Caudal rami of *Nebelopsis typica*.

sulcus, to the bottom of which a series of slender ciliated setæ seems to have been affixed, the bases of most of them being still present. From the tip of the lamella a fragment of what may have been either a strong spine or a very elongate seta projects, and external to this another similar spine or seta may have been affixed. The whole lamella exhibits a delicate parenchymatous structure similar to that of the branchial legs.

As the younger specimen is rather pellucid, some of the internal parts can also be faintly made out through the integuments. Thus, in a lateral view (fig. 1), a dark string is seen running from the cephalic part through the whole trunk and part of the pleon, at some distance from the dorsal surface. On examining the animal from the dorsal side, this string is found to be composed of two symmetrical narrow tubes filled with an opaque granular mass, and having between them another tube somewhat wider and more transparent. It therefore seems evident that the string referred to must represent the intestine, together with two elongate cæca accompanying it in the greater part of its length. But, besides, the anterior part of the body contains another internal organ of far greater dimensions, constituting a large opaque mass slightly tapering posteriorly and extending through the greater part of the trunk at a short distance from the ventral surface. The significance of this body I am unable to state with certainty. It cannot represent the generative organs, since it apparently forms an unpaired mass, and, moreover, its situation would seem to forbid such an assumption. I am more inclined to regard it either as a kind of liver, or perhaps more properly an accumulation of fatty deposits, answering to the adipose body which in *Nebalia* envelops the whole intestine together with its cæca. The ventral ganglionic cord—only with great difficulty examined in the two other genera—is here immediately visible when the animal is examined from the lower side (fig. 2), lying, as it does, immediately inside the ventral cuticle and not being concealed by the branchial legs. The ganglia of the trunk, placed in the two other genera so closely together as almost to be coalescent, are in this animal wide apart and connected by very long commissures, in close proximity to each other. The ganglia of the pleon, of which at least the anterior is very distinctly seen, are considerably larger than those of the trunk, and furnish several nerve-trunks to each side, from which numerous fine nerves arise, partly innervating the musculature of the pleon and partly entering the pleopoda.

*Habitat.*—The first specimen obtained, which, as above stated, was only represented by the carapace and a fragment of the front part of the body, was taken with the dredge in the Southern Ocean between Prince Edward Island and the Crozets.

Station 146, December 29, 1873; lat.  $46^{\circ} 46'$  S., long.  $45^{\circ} 31'$  E.; depth, 1375 fathoms; bottom, Globigerina ooze; bottom temperature,  $35^{\circ} 6$ .

The other more complete specimen came up in the trawl from a very considerable depth in the South Pacific, about midway between New Zealand and Chili.

Station 289, October 23, 1875; lat.  $39^{\circ} 41'$  S., long.  $131^{\circ} 23'$  W.; depth, 2550 fathoms; bottom, red clay; bottom temperature,  $34^{\circ} 3$ .

## HOMOLOGY OF THE RECENT PHYLLOCARIDA.

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In the following pages I propose to discuss more in detail the homologies of the several parts in the Nebaliidae, as compared with those in other recent Crustacea. As has been indicated at the beginning of this Report, my view as to the relationship of the genus *Nebalia* to other known Crustacea somewhat differs from that set forth by most other naturalists, and the examination of the two related new generic types procured by the Challenger Expedition, and described above, has confirmed me still more in the opinion at first adopted from a thorough investigation of our common northern form, *Nebalia bipes*, Fabricius.

It is certainly astonishing that the great resemblance of *Nebalia* to certain Copepoda,

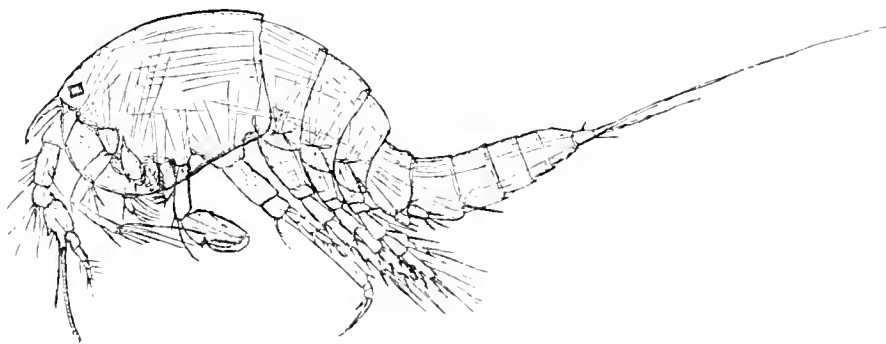


FIG. 2.—*Dossicus laqueatus* (Claus), male.

has escaped the attention of most naturalists who have subjected this genus to a closer examination, whereas the much more remote affinity to the Podophthalmia has always been dwelt upon, and even Professor Claus, to whom we are, as is well known, indebted for an admirable work on the free living Copepoda, does not seem to have been aware of this unmistakable resemblance; I think it may be readily found by a closer comparison, that the affinity of *Nebalia* to the Copepoda is in fact much greater than to the Podophthalmia, both as regards the external appearance and the structure of the several appendages. In some other important points it exhibits, on the other hand, an evident agreement with the Phyllopoda, and for that reason it ought to be, in my judgment

placed within the same order, the Branchiopoda, though representing the type of an anomalous suborder, the Phyllocarida.

In order to facilitate a closer comparison of the Nebaliidæ with the Copepoda, I subjoin a cut of a male specimen of one of our most common marine forms of the Harpactoid group, viz., *Diosaccus tenuicornis* (Claus).

*Homology of the Body-Divisions.*—In examining the body of a Nebaliid, its general resemblance to that of a Copepod, especially of the Harpactoid group, may at once be recognised. But it is at the same time readily seen that there is in the Nebaliidæ a distinct division of the body which is only faintly indicated in the Copepoda, viz., the trunk, or, as it is generally termed, the thorax. What is described as thorax in the Copepoda does not at all answer to the thorax in the higher Crustacea, but undoubtedly is homologous with the anterior part of the "abdomen" in these Crustacea, or the division in the Nebaliidæ described above as the pleon, whereas the so-called abdomen in the Copepoda evidently answers to only the posterior part of the abdomen in the higher Crustacea or the division in the Nebaliidæ succeeding the pleon, and described above as the tail. This is especially distinctly seen in the above described form, *Paranebalia longipes* (Pl. I. fig. 1; Pl. II. fig. 1), where the latter division is very sharply marked off from the pleon, both exhibiting a form very similar to that in the Copepoda, and, moreover, quite agreeing in function, since the tail here evidently admits of being moved as a whole upon the pleon, in the very same manner as in the Copepoda. A closer comparison between the Nebaliidæ and Copepoda thus clearly shows that the terminology generally adopted in describing the higher Crustacea has been wrongly applied as regards the lower forms (Copepoda), since the divisions "thorax" and "abdomen" in the former do not answer to the similarly named divisions in the latter. This misapprehension may indeed have been the cause why the affinity of *Nebalia* to the Copepoda has not been recognised. Thus, in order to explain the supposed abnormal number of segments in the "abdomen" of *Nebalia*, Professor Claus has set forth an hypothesis, which seems to me very unreasonable, viz., that the two last segments together with the caudal rami in *Nebalia* answer to the telson in the Podophthalmia, which latter part, he suggests, has been originally formed by several segments. The fact is, however, that the so-called abdomen in *Nebalia* does not show any similarity at all to that division in the higher Crustacea, whereas it is constructed upon the very same type as in the Copepoda, the number of segments being in full accordance with that found in a great number of these Crustacea, admitting the above given explanation of the homology of the body-divisions in both. As to the limit between the two divisions in the Nebaliidæ, described above as pleon and tail, it should be remembered that the first segment of the latter division, properly speaking, answers to the segment in the Copepoda generally described as the last thoracic segment, but which in most of the forms evidently has a much closer relation to the succeeding division, the tail, or, as it is wrongly termed, the abdomen.

*Homology of the Carapace.*—As above mentioned, the carapace in *Nebalia* has been adduced as a character showing the affinity of this genus to the Podophthalmia, and especially the Schizopoda. On closer examination we shall, however, find that according to this character it might with quite as good reason be classed among the Phyllopoda; for both the finer structure of the carapace and the manner in which it is connected with the body are rather more in accordance with the latter Crustacea than with the Podophthalmia. Moreover, the presence of a well-developed adductor muscle, never found in any Podophthalmia, gives the carapace in the Nebaliidæ a very marked phyllopodous character. As to form and relation to the body, it exhibits, as it were, an intermediate condition between the carapace in *Apus* and the bivalved shell in *Limnadia*. The jointed rostral plate is a character neither found in the Podophthalmia nor in the Phyllopoda, whereas a quite similar movable rostral projection is met with in some Copepoda of the Harpaetoid group, and in the latter forms, moreover, the lateral parts of the so-called cephalic segment are found to extend more or less down the sides, so as to include between them the bases of the antennæ and most of the oral parts, thus assuming the character of a bivalvular carapace, though being still connate with the body along the dorsal surface. The greatly developed carapace, by which the Nebaliidæ at first sight seem to be so very sharply distinguished from the Copepoda, may thus be found to have in fact its homologue also in the latter Crustacea.

*Homology of the Eyes.*—The eyes form another character wrongly adduced to show the affinity of *Nebalia* to the Podophthalmia. In reality the eyes in the Nebaliidæ, though properly termed stalked and mobile, differ essentially from those in the Podophthalmia by their much simpler structure and by the want of a distinct faceted cornea. On the other hand, they are found to agree, both as to form and structure, very closely with the eyes in a well-known family of the Phyllopoda, the Branchipodidæ.

*Homology of the Antennulae.*—These limbs certainly exhibit a structure very different from that met with in other Branchiopoda, but they are also quite dissimilar to the corresponding limbs in the Podophthalmia, differing essentially as well by the abnormal number of joints in the peduncle, this being in all higher Crustacea invariably but three, as also by the peculiar setose lamella appended to the end of the peduncle. To compare this lamella, as proposed by some authors, to the so-called antennal scale belonging to the succeeding pairs of limbs, the antennae, in Decapods and Schizopods, is, in my opinion, quite unreasonable. Neither can it properly be regarded as homologous with the inner flagellum in these Crustacea or to the accessory flagellum in the Amphipoda, since it is affixed outside the true flagellum, which latter undoubtedly answers to the outer flagellum in other Crustacea, bearing, as it does, the characteristic sensory appendages, generally termed olfactory cilia. Thus the lamella under consideration cannot properly be compared to anything met with in the higher Crustacea, but apparently represents a characteristic feature peculiar to the Nebaliidæ. I think we may better understand the

structure of the antennulæ in the latter forms by instituting a comparison with the corresponding limbs in the Copepoda. Thus, in the Harpactoidea we find that the anterior pair of antennæ, which undoubtedly answer to the antennulæ in the Nebaliidæ, are composed each of two rather distinctly defined divisions, a thicker proximal part and a much narrower distal part, the former consisting pretty constantly of four articulations, the last of which forms anteriorly a lateral expansion bearing a slender, ribbon-like appendage, the latter composed of a varying number of articulations but always very sharply marked off from the proximal part. There cannot in my judgment be any doubt that the proximal part of the anterior antennæ in these Copepoda answers to the antennular peduncle in the Nebaliidæ, and the distal part to the flagellum. The lateral expansion of the last joint of the proximal part in the former is also well seen in the Nebaliidæ, and, moreover, in all probability the ribbon-like appendage affixed to that expansion in the Harpactoidea is a homologue of the setose lamella in the Nebaliidæ. Thus, all parts of the antennulæ in the latter forms seem to be in fact represented in the Copepod antennula, and the apparently abnormal number of joints in the peduncle as compared with that in the higher Crustacea, will turn out to be quite normal in relation to the Copepoda.

*Homology of the Antennæ.*—In comparing the antennæ in the Nebaliidæ with those in the higher Crustacea, we find at once their structure very different from that in any known form of the Podophthalmia, whereas they at first sight somewhat resemble the lower antennæ in the Amphipoda. On closer examination, however, it is easily found that they differ materially also from those in the last named group of Crustacea by the peduncle being only triarticulate, whereas in all known Malacostraca the number of joints is far greater, generally amounting to five in all. Moreover, the peculiar geniculate bend at the middle of the peduncle is rather different from what is generally met with in the Malacostraca. I think we may also in the case of these limbs more properly derive their structure from that met with in the Copepoda, especially those of the Harpactoid group. In these Copepoda the posterior antennæ are, as is well known, very small but composed of three distinctly defined segments, the last of which forms with the preceding a strong geniculate bend, and it may readily be found, by comparison, that these three segments together perfectly agree in form with the antennal peduncle in the Nebaliidæ. At the tip of the last joint, moreover, in some forms a small imperfectly defined terminal joint may be distinguished, representing a rudiment of the flagellum. The accessory branch generally found affixed to the middle of the second segment is sometimes quite obsolete, whereby the accordance becomes still more pronounced. The peculiar modification of the flagellum in the male of *Nebalia*, somewhat similar to what is met with in the Amphipoda and Cumacea, does not seem to have any more general significance, since in the nearly related genus *Paranebalia* there is no difference whatever to be found in the antennæ of the male and female, whereas it

is here only the antennulæ which are peculiarly modified, as is also the case in the Copepoda.

*Homology of the Oral Parts.*—These appendages appear on the whole very dissimilar to those in other Branchiopoda, and their structure has consequently been adduced to show the closer affinity of *Nebalia* to the Podophthamia. Especially is the great development of the mandibular palp certainly a very characteristic feature, since such a palp is never met with in any adult Branchiopod. In form this palp, however, exhibits, as has also been pointed out by Professor Claus, a much closer resemblance to that in the Amphipoda than to the palp in the Podophthamia, and the structure of the mandible itself is also rather different, showing, by the reduction of the cutting edge and the great development of the molar surface, more similarity to that met with in the greater part of the Branchiopoda. In the Copepoda the mandibles are, as is well known, in most cases provided with a well-developed palp, but this palp is generally biramose or bears a so-called branchial appendage, which however is often very reduced in size and in some forms even quite obsolete, whereby the palp acquires a certain similarity to the mandibular palp in the Nebaliidæ. The very slight development of the posterior lip or metastoma in the Nebaliidæ is a character apparently more in accordance with the Entomostraca than with the Malacostraca, in which latter this part is always well developed and rather large. As to the structure of the maxillæ, both pairs seem to me to be essentially different from those in the higher Crustacea, and especially is the structure of the first pair quite peculiar and only admits of a very general comparison with those in other Crustacea. In the structure of the second pair I find, however, a well-marked resemblance to the maxillæ in a great number of Copepoda, and this resemblance is especially very striking in the case of the genus *Nebaliopsis*, as stated above. In the Copepoda, it is true, only a single pair of maxillæ are present, but this pair I think may more properly be regarded as homologous with the second pair in the Nebaliidæ, the first pair not being developed in the former Crustacea. The number of maxillæ in the Nebaliidæ cannot be adduced as showing their affinity to the Malacostraca, since we find at least in all Phyllopoda both pairs distinctly developed, though of a rather simple structure.

*Homology of the Branchial Legs.*—These limbs, in my opinion, undoubtedly stamp the Nebaliidæ as true Branchiopoda, agreeing, as they do, both in structure and function with the so-called branchial feet in other forms of this order. This has, however, been partly combated by some naturalists, who regard them as more closely agreeing with the thoracic legs in the Schizopoda; and, in fact, if we had confined our examination to the structure of these limbs in the above described genus *Paraneubalia*, such a view might perhaps to a certain extent be advocated, as in this form they certainly exhibit an appearance somewhat approaching that of the legs in the Euphausiidæ. On the other hand, I think, that no one will find any trace of similarity between the simple lamelli-

form branchial legs in *Nebaliopsis* and the thoracic legs of any Schizopod or other Malacostracan. In both these genera, however, these limbs are constructed upon the same general plan, the chief agreement being found in their adaptation for solely respiratory purposes, and in so far they very materially differ from the thoracic legs in the Malacostraca. In *Nebalia* the branchial legs hold an intermediate position and consequently exhibit the most typical structure, whereas in the two above named generic types they represent, as it were, the extremes of a series of modifications, apparently standing in some connection with the very different conditions of life in the two, the one being a shallow-water form, the other a very marked deep-water form. That these limbs in *Nebalia* are much more closely related in structure to the branchial legs in other Branchiopoda, than to the thoracic legs in the Malacostraca, cannot in my opinion be disputed. It is true that they somewhat differ from the branchial legs in the Phyllopoda by the want of the so-called endites or lateral lobes of the endopodite. But it must be remembered, that these endites are only peculiar to the Phyllopoda, whereas in other undoubted Branchiopoda, as the Cladocera, they are more or less completely obsolete. Nor can it properly be adduced in support of the assumption of the nearer relationship of *Nebalia* to the Schizopoda, that the "thoracic" legs in the former exhibit the same principal parts as in the latter, since these parts, viz., the endopodite, exopodite, and epipodite, may easily be distinguished in Crustacea belonging to very different groups, and in most other Branchiopoda are quite so well definable as in *Nebalia*. The number of these limbs in all the known recent Phyllocarida is eight pairs, and if we consider the anterior pair as homologous with the maxillipeds in the Malacostraca, the number will certainly answer to that of the thoracic legs in these Crustacea, whereas their number in other Branchiopoda is very variable and at least in the Phyllopoda is much greater. But on closer examination we shall find that the anterior pair of branchial legs in the Nebaliidae evidently belong to the trunk and not to the cephalic part, as do the maxillipeds in all the known Malacostraca, and even in the Euphausiidae, where the maxillipeds are constructed upon the very same type as the succeeding legs, the development shows them clearly to belong to the head and not to the trunk.<sup>1</sup> It thus results that the maxillipeds are wanting in the Nebaliidae, and that the number of the limbs belonging to the trunk is in reality greater than in the Malacostraca. In the Copepoda these limbs are only represented by the so-called maxillipeds, which according to the suggestion of Professor Claus may properly be regarded as the outer and inner branches of a single pair of limbs.

*Homology of the Pleopoda and Caudal Limbs:*—The great agreement both in form and composition between the two posterior divisions of the body in the Nebaliidae and the so-called "thorax" and "abdomen" in the Copepoda, has been stated above. This agreement becomes still more evident by a comparison of the respective appendages.

<sup>1</sup> See my Report on the Challenger Schizopoda, Zool. Chall. Exp., pt. xxxvii.

Thus, the pleopoda in the Nebaliidæ undoubtedly agree very closely with the swimming legs in the Copepoda both as to structure and number, whereas their affinity to the pleopoda in the Malacostraca is much more remote. To compare them to the caudal limbs or the so-called saltatory legs in the Amphipoda, as proposed by Professor Claus, is, I think, objectionable, since the latter limbs belong to a different division of the body and more properly answer to the rudimentary caudal limbs in *Nebalia*. As to the mode in which the pleopoda are moved, we find also the greatest resemblance between *Nebalia* and the Copepoda, especially those of the Harpactoid group, the movements being not at all rhythmical nor performed in the same rapid and almost vibratile manner as in the Amphipoda and most Podophthalmia (Euphausiidae). The two rudimentary caudal limbs in the Nebaliidæ likewise find their homologues in the Copepoda. The first of these pairs are thus evidently homologous with the generally very small and imperfectly developed so-called last thoracic legs in the latter Crustacea, and on closer examination we shall find that also the second pair of these limbs are represented in the Copepoda, though in a very rudimentary state. Thus, on the segment succeeding the so-called last thoracic segment in the latter Crustacea, and generally described as the first abdominal segment, there occur in most of the forms on each side, close to the genital orifice, a small tubercle provided with a few spine-like bristles. This tubercle, more distinct in the males, is undoubtedly the rudiment of a pair of limbs, evidently answering to the second pair of rudimentary caudal limbs in the Nebaliidæ. The succeeding segments in the Copepoda as also in the Nebaliidæ are entirely devoid of any trace of limbs, and in most of the Harpactoidea these segments exhibit a denticulate armature on the hinder edge quite similar to that in the Nebaliidæ. Finally, the caudal rami appended to the last segment in the Nebaliidæ are undoubtedly homologous with the so-called "furea" in the Copepoda, as also with the caudal lamellæ in the Branchiopodidæ, being not true limbs but more properly representing a bipartite terminal segment. These terminal appendages in the Nebaliidæ are therefore not at all homologous with the so-called uropoda in the Malacostraca, the latter being true ventral limbs.

*Homology of the Internal Organs.*—The internal organisation of *Nebalia*, which I have also thoroughly studied in the northern form *Nebalia bipes*, may on the whole be said to be much more advanced than in any other of the known Entomostraca, but I do not find in this respect any closer resemblance to that of the Podophthalmia, whereas it exhibits some points of apparent affinity to that met with in the Amphipoda.

The nervous system seems in fact to differ essentially in structure from that generally met with in the other Branchiopoda by the ganglionic cord being not double but forming a single median series of ganglia, as in most Malacostraca. It must, however, be remembered, that the peculiar double ladder-like ventral cord, though very characteristic of the Branchiopoda, does not form a universal character of these Crustacea. Thus, among the Cladocera we find the nervous system in *Leptodora* wholly dissimilar from

that in the other forms, and also in the Branchiura the nervous cord is constructed upon a quite different type.

The intestine in *Nebalia* is markedly distinguished by the presence of a chitinous visceral skeleton never found in any Branchiopoda; but this skeleton does not show any resemblance to that found in the Podophthalmia, whereas its similarity to that found in the Amphipoda is unmistakable. With the latter Crustacea *Nebalia* also apparently agrees in the two pairs of elongate caeca arising from the gastric part and accompanying the intestine in the greater part of its length, and more especially in the presence of another pair of elongate caecal appendages originating from the terminal part of the intestine and running anteriorly along its dorsal side. On the other hand, the occurrence of two short curved caeca, projecting forwards within the head, is a character pointing rather more to the Branchiopoda, in some of which, as in the genus *Daphnia*, we find two quite similar curved caeca arising from the anterior part of the intestine.

As to the structure of the heart the genus *Nebalia* may equally well be compared with the Branchiopoda as with other Crustacea, since the structure of this organ in the former is very variable, being in some forms quite short and sac-like with only a single pair of lateral venous fissures, in other forms more or less elongate with a varying number of such fissures. As in the Branchiopoda the vascular system is imperfectly developed, though a pair of short arteries may be traced at each end of the heart.

The generative organs in both sexes, as in most of the Branchiopoda, are rather similar and very little complicated in structure, forming merely a pair of simple cylindrical tubes extending along the sides of the intestine, and opening by a short excretory duct on the ventral surface of the last segment of the trunk. In the Podophthalmia these organs are, as is well known, much more complicated, and, moreover, always exhibit a very marked difference in their structure in the two sexes.

*Development.*—The development of *Nebalia* cannot in my judgment be adduced as showing any close affinity between this form and the Decapoda, as suggested by Metschnikoff; and this has partly also been admitted by Professor Claus, in so far, at least, that he has pointed out that the stage of the *Nebalia*-embryo, termed by Metschnikoff the Zoca-stage, and on which this author chiefly bases his suggestion of the decapodous nature of *Nebalia*, does not in reality correspond to that stage in the Podophthalmia, but more properly to the earliest stage of the *Cyclops*-form in the Copepoda. Neither can I find that the supposed agreement between the development of *Nebalia* and that of *Mysis* points to any true consanguinity between these genera. As is well known, we find a very similar direct development also in a great number of other Crustacea not at all belonging to the Podophthalmia, as in the Cumacea and Isopoda, and even in the Phyllopoda I have recently had an opportunity of stating an instance of a quite direct development, without any metamorphosis, and agreeing, more-

over, in all essential points rather well with that found in *Nebalia*.<sup>1</sup> The apparent agreement with the Schizopoda in the mode in which the ova and embryos are borne in *Nebalia* during their development, is considerably lessened by the circumstance that there is in the latter form no trace of any true incubatory pouch, the ova being simply received within the valves of the carapace and kept in place by the aid of the branchial legs.

*Concluding Remarks on the Phylogeny of the Nebaliidæ.*—Owing to the suggestion made by most naturalists, that *Nebalia* forms a direct transition between the Phyllopoda and Podophthalmia, it has generally been supposed that the Nebaliidæ have descended from the Phyllopoda, and that, on the other hand, all the Podophthalmia should be regarded as descendants from *Nebalia*-like ancestors. In his interesting treatise on the phylogenetic relationship of the Malacostraca, Dr. Boas has sought to strengthen the latter supposition by instituting a close comparison of the limbs in *Nebalia* with those in the Malacostraca, and has thereby been led to the result, that the connecting link between *Nebalia* and the great bulk of the Podophthalmia is represented by the Euphausiidae, from which again all the other forms of that division are supposed to have descended. It would seem that the chief reason that has led Dr. Boas to this view as to the supposed close relationship between *Nebalia* and the Euphausiidae, is the apparent agreement in the number of segments composing the anterior division of the body (cephalothorax), and the uniformity in structure of the eight pairs of limbs succeeding the oral parts in both. For in all other points the difference is in reality so very great, as in most cases only to admit of the statement of a very general homology, such as could also be made by comparing almost any forms of Crustacea. It has been stated above that the resemblance of the branchial legs to the legs in the Euphausiidae is in the genus *Paranebalia* considerably more pronounced than in *Nebalia*. But notwithstanding this agreement, I still believe that there is no true relationship between the Nebaliidæ and the Euphausiidae, and that the above mentioned apparent conformity in the construction of some of the limbs in both is merely accidental, a view that seems also to be confirmed by the fact that in an otherwise closely related genus, *Nebaliopsis*, these limbs exhibit a form showing no similarity whatever to the corresponding limbs in the Euphausiidae. If any true consanguinity had existed between the Nebaliidæ and the Euphausiidae, the agreement between the two would certainly not be restricted to the above named limbs, but might have been traced also in the rest of the organisation. But this is by no means the case. On the contrary, it may easily be found on closer comparison, that the Euphausiidae in so far differ from the Nebaliidæ even considerably more than is the case with a great number of other Malacostraca.

As to my own view on the probable phylogenetical relation of the Nebaliidæ to other

<sup>1</sup> On *Cyclestheria hislopæ* (Baird), a New Generic Type of Bivalved Phyllopoda, *Forhauell. Vidensk. Selsk. Christ.* 1887 (to be shortly published).

Crustacea, I am inclined to agree on the whole with the suggestion set forth by Dr. A. Packard in his valuable treatise on the Phyllopod Crustacea of North America, believing that the Nebaliidæ may have descended from some Copepod-like ancestors, whereas they do not show any relation whatever to the Podophthalmia, the latter having in all probability developed independently by a separate line from some Nauplius- or Zoea-like form. From the same stem that gave origin to the Nebaliidæ, I think that also the other Branchiopoda may be derived, the latter having apparently become rather considerably modified in various ways to adapt them to the somewhat exceptional conditions under which they live, whereas the Nebaliidæ have still preserved much of the external appearance which may have distinguished the progenitors of the order, while their internal organisation has become much more modified.

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PLATE I.

PLATE I.

*Paranebulia longipes* (Willemoes Suhm).

- Fig. 1. Adult female, seen from the left side; magnified about thirty-four diameters. The specimen has been rendered pellucid by mounting in Canada balsam, so as to exhibit *in situ* the several limbs covered by the carapace, as also some of the internal organs. *R*, rostral plate; *O*, eye; *a*<sup>1</sup>, antennula; *a*<sup>2</sup>, antenna; *M*, mandible; *Mp*, mandibular palp; *m*<sup>1</sup>, maxilla of first pair; *m*<sup>2</sup>, maxilla of second pair; *brp*, branchial legs; *pl*, pleopoda; *ep*<sup>1</sup>, *ep*<sup>2</sup>, rudimentary caudal limbs of first and second pairs; *ur*, caudal rami; *Cm*, adductor muscle of carapace; *Ov*, ovary.
- Fig. 2. Rostral plate, seen from below; magnified fifty diameters.
- Fig. 3. Left eye, lateral view.
- Fig. 4. Left antennula.
- Fig. 5. One of the olfactory filaments from the flagellum of same; highly magnified.
- Fig. 6. Serrate projection of last segment of peduncle of same.
- Fig. 7. Left antenna.
- Fig. 8. Anterior lip, seen from below.
- Fig. 9. Mandibles, together with the palps and adductor muscle; front view.
- Fig. 10. Masticatory part of a mandible; more highly magnified.
- Fig. 11. Mandibular palp, lateral view.
- Fig. 12. Maxilla of first pair.
- Fig. 13. Maxilla of second pair.





PLATE II.

PLATE II.

*Paranebalia longipes* (Willemoes Subm)—*continued*.

Fig. 1. Adult female, viewed from above ; magnified about thirty-four diameters.

Fig. 2. Branchial leg of first pair ; magnified fifty diameters.

Fig. 3. Branchial leg of fifth pair.

Fig. 4. Branchial leg of last pair.

Fig. 5. Pleopod of first pair.

Fig. 6. Pleopod of second pair.

Fig. 6*a*. Lateral lobe of inner branch of same ; more highly magnified.

Fig. 6*b*. One of the chitinous hooks from the same lobe ; magnified three hundred and eighty diameters.

Fig. 7. Pleopod of last pair.

Fig. 8. First pair of rudimentary caudal limbs.

Fig. 9. Rudimentary caudal limb of second pair.

Fig. 10. Last caudal segment, together with right caudal ramus, seen from below.

Fig. 11. Embryo taken from the incubatory cavity of an adult female specimen, seen from below ; magnified seventy-eight diameters. *R*, rostral plate ; *O*, eyes ; *a*<sup>1</sup>, antennule ; *a*<sup>2</sup>, antennæ ; *L*, anterior lip ; *M*, mandibles ; *m*<sup>1</sup>, maxillæ of first pair ; *m*<sup>2</sup>, maxillæ of second pair ; *brp*, branchial legs ; *pl*, pleopoda ; *ur*, caudal rami.

Fig. 12. Same embryo, viewed from the right side. *C*, carapace ; remaining letters as in fig. 11.



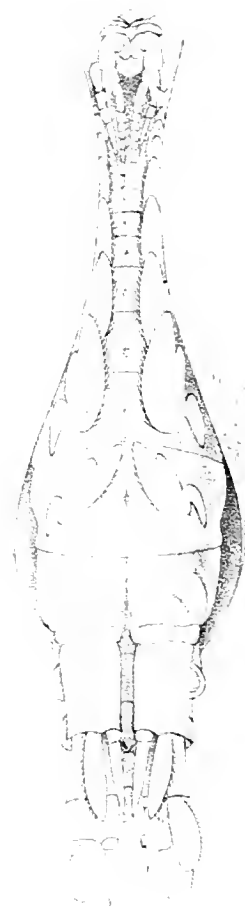


PLATE III.

PLATE III.

*Nebaliopsis typica*, n. gen. et sp.

- Fig. 1. Young specimen, viewed from the left side ; magnified about five diameters.
- Fig. 2. Same specimen, ventral aspect.
- Fig. 3. Right branchial leg of seventh pair from same specimen ; magnified twenty-four diameters.
- Fig. 4. Pleopod of third pair from same specimen.
- Fig. 5. Carapace of another, apparently adult specimen, seen from the left side ; very slightly magnified.
- Fig. 6. Same carapace, viewed from above.
- Fig. 7. Rostral plate of same specimen, seen from above ; somewhat more magnified.
- Fig. 8. Fragment of the cephalic part of same specimen together with its several appendages, viewed from the left side ; magnified about five diameters.  
*O*, eye ; *a*<sup>1</sup>, antennula ; *a*<sup>2</sup>, antenna ; *L*, anterior lip ; *M*, mandible ; *Mp*, mandibular palp.
- Fig. 9. Same fragment, front view. The terminal part of the antennulae as also the antennae and mandibles are omitted. *O*, eyes ; *a*<sup>1</sup>, bases of the antennulae ; *L*, anterior lip.
- Fig. 10. Maxilla of second pair from same specimen ; magnified fourteen diameters.







































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