

The Development Stages of *Oithona helgolandica* and *Oithona spinirostris*, with a Note on the Occurrence of Body Spines in Cyclopoid Nauplii.

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With 1 Figure in the Text and Plates 1-3.

INTRODUCTION.

IN recent years the development stages of Copepoda have been the subject of study by various workers. Their attention, however, has been mainly directed to fresh-water species, presumably because the material is more readily available, and it seems desirable that our knowledge of the development of marine Copepoda should be extended. The material utilised for the present work was collected on the periodic and comprehensive fishery cruises carried out by the F.R.S. *Explorer*, and we are indebted to the Fishery Board for Scotland for permission to undertake this detailed study. Since the appearance of Grobben's standard work on *Cetochilus septentrionalis* Goodsir (*Calanus finmarchicus* Gunn.), the only important publication dealing with the life-histories of marine Copepoda, so far as we have been able to ascertain, is that of Oberg, who, in *Die Metamorphose der Plankton-Copepoden der Kieler Bucht*, describes the development stages of seven common marine forms. Oberg's choice of species, which are all more or less neritic, was again obviously dictated to him by the material at his disposal, and it is hoped that our collections, which cover not only the northern part of the North Sea, but also the Faroe-Shetland Channel, and part of the Atlantic itself, will furnish material for the establishment of the life-histories of some of the more oceanic forms.

A careful checking of Oberg's drawings and tables, however, has shown that, as far as his account of *Oithona similis* (hereinafter referred to as *Oithona helgolandica*, which, as Sars points out, is the first name under which it was described) is concerned, he has missed several points in the six nauplius stages which, from the point of view of comparison with other

species, may be considered of some importance. His work on this species was therefore carefully revised, and criticised where necessary before the corresponding stages of *Oithona spirostris* were attacked. It will be seen that the differences separating the nauplii of these two species are nowhere very pronounced, and the first and second nauplius stages are to be distinguished chiefly by size and shape, together with a certain small feature to be observed in the armature of the labrum. The important part that the labrum might play in determining species must have been overlooked by Oberg, since his figures of this organ are extremely rough and inaccurate.

The development stages of *Oithona spirostris* have not, so far as we are aware, been described hitherto.

OITHONA HELGOLANDICA CLAUS.

Syn. *Oithona similis* Claus.

„ *spiniifrons* Boeck.

„ *pygmæa* „ .

„ *spirostris* Giesbrecht (not Claus).

As Oberg has already shown, *Oithona helgolandica* retains the full number of six nauplius stages in its development, but as the armature of the appendages appears to differ somewhat from that described by him, a full description is given here.

The First Nauplius Stage. Length, .115 mm. (Plate 1, Fig. 1).

Body egg-shaped, and considerably flattened dorso-ventrally. The furcal armature at this stage consists of a single pair of long thin bristles which tend to be directed outwards and dorsally. The ventral body spines to which reference will be made later are already visible at this stage. The labrum, well seen in a ventral view of the whole animal, is distinct in form, and retains the same appearance throughout all the six nauplius stages. It is rounded anteriorly, and three very fine forwardly directed bristles can be seen in this region on either side. Posteriorly it is produced laterally to a three-spined point on each side, the outermost spine being the largest and the innermost the smallest. On the posterior margin, on either side of the median line, is a group of four spines, of which the innermost and outermost are both fairly small, while the other two are larger, the one nearest the inside being very long and strong.

Appendage 1, The Antennule. (Plate 1, Fig. 1.) This appendage is three-jointed. The first joint is unarmed; the second joint bears three bristles, the third of which is very much longer than in Oberg's figure, reaching well beyond the end of the third joint. The third joint bears

four bristles, two at the extreme distal end, and one, which is directed dorsally, immediately behind, while the remaining bristle is very small and thin, and is to be seen on the dorsal side of the segment, nearer the proximal end. These last two bristles do not appear in Oberg's description.

Appendage 2, The Antenna. (Plate 1, Fig. 1B.) The coxopodite has a sharp masticatory process with a short bristle arising at its base. The basipodite has two fine bristles and a very small accessory bristle which is not shown in Oberg's figures. The endopodite is simple, and has two inside bristles and two end bristles. The exopodite is six-jointed, the second joint being the longest. The first joint is unarmed, the second to the fifth joints have one bristle each, while the sixth joint has one lateral and one end bristle, making six bristles in all for the whole exopodite.

Appendage 3, The Mandible. (Plate 1, Fig. 1C.) The coxopodite bears a small sharp bristle. The basipodite has one strong short inside bristle. The endopodite is in two joints, the first of which bears two inwardly-directed strong masticatory processes, and is so short that it appears almost as a part of the basipodite. The second joint of the endopodite has two small inside bristles and two end bristles of unequal length. The exopodite is four-jointed, the first joint being the longest, and each joint is furnished with one bristle. There is no sign of the maxillæ at this stage.

The Second Nauplius Stage. Length, .130 mm.

In appearance this stage is difficult to distinguish from the preceding stage, as the difference in size is so small as not to be readily noticed. A careful examination shows that two fine long bristles, which are the rudiments of the coming maxillæ, can be seen in the postero-ventral region, and the presence or absence of these is the best key for the separation of Stages 1 and 2. The furcal armature has undergone no change. (Plate 1, Fig. 2E.)

Except in the matter of size, the labrum in this stage is identical with that in the preceding stage.

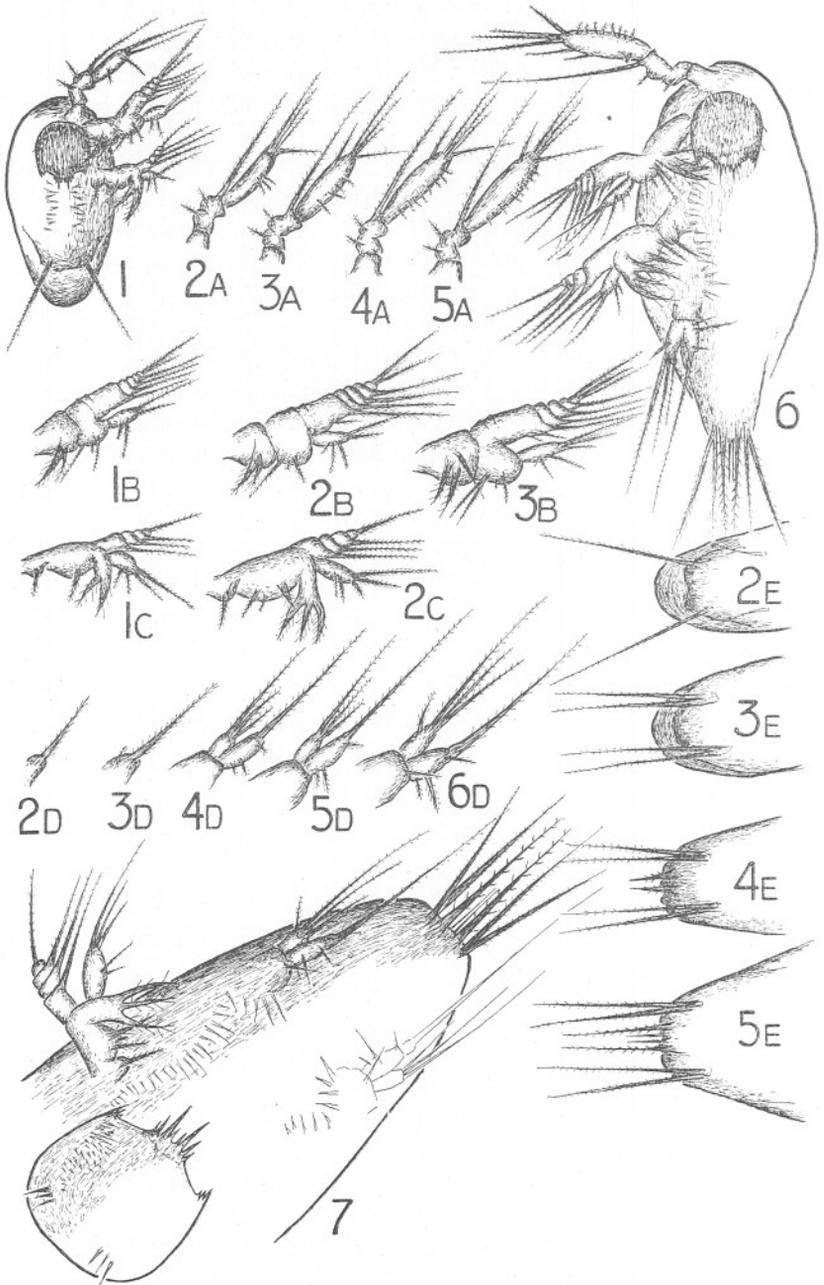
Appendage 1, The Antennule. (Plate 1, Fig. 2A.) Proximal and second joints exactly as in Stage I.

The distal joint has three end bristles, a dorsally directed one just behind them, and three fine dorsal bristles in the middle of the segment, making seven bristles in all for the third joint of the antennule. Here again Oberg figures only the three end bristles.

Appendage 2, The Antenna. (Plate 1, Fig. 2B.) Coxopodite and basipodite as in Stage I.

The endopodite has five bristles, two at the distal end and three on the inner margin. (Oberg figures three at the distal end and two on the

PLATE 1.



inner margin.) The exopodite is similar to Stage I, except that the second joint bears a small accessory bristle in addition to its single long bristle.

Appendage 3, The Mandible. (Plate 1, Fig. 2C.) The coxopodite as in Stage I. The basipodite has two small bristles and a third smaller bristle on the inner edge. The endopodite is two-jointed, the first joint very short, and bearing the masticatory processes, now three in number. Second joint of the endopodite with two inner and three end bristles. The exopodite is exactly as in the preceding stage.

Appendage 3, The Maxillule. (Plate 1, Fig. 2D.) These appear at this stage only as rudiments represented by a protuberance on each side, bearing a single long, well-developed bristle.

The Third Nauplius Stage. Length, .140 mm.

The general shape of the body is still oval, but slightly longer in proportion to its width. The posterior end of the body does not yet protrude beyond the cephalothoracic shield. (Plate 1, Fig. 3E.)

This stage can be easily recognised by the furcal armature which is distinctive. It consists of a pair of long bristles on either side. They are of more or less equal length, and seem to have a common origin at the point where the single bristles of the preceding stage were to be seen.

The labrum is again unchanged in appearance.

Appendage I, The Antennule. (Plate 1, Fig. 3A.) The first and second joints are again as in Stage I. The distal joint has three end bristles and a dorsally-directed bristle just behind them as in the preceding stage, but in addition a ventral bristle is now seen on the distal end of the ventral margin of the segment, while there are four very fine dorsal bristles, making nine bristles in all on the third segment of the antennule. Oberg only figures four bristles for this segment at this stage.

EXPLANATION OF PLATE 1.

Oithona helgolandica. Nauplius Stages.

FIG. 1. First Nauplius Stage.

In the subsequent figs. the numbers 1-6 refer to the successive Nauplius stages, and the letters A-E to the parts figured:—

A=Antennule.

B=Antenna.

C=Mandible.

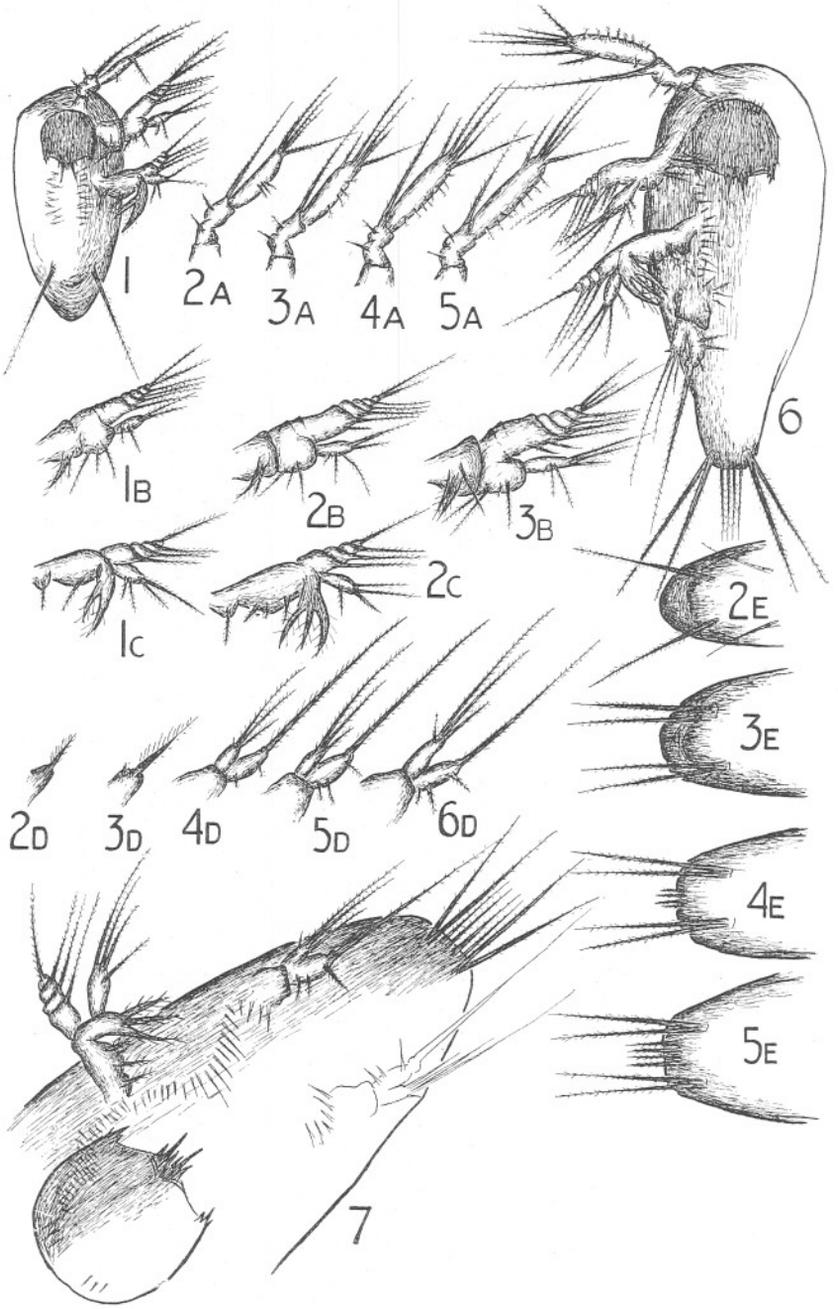
D=Maxillule.

E=Posterior part of body, ventral view.

FIG. 7. Stage 6, ventral view, showing arrangement of body spines.

All figures drawn to the same scale at a magnification of about 600 diameters, except Fig. 7, which is somewhat larger.

PLATE 2.



Appendage 2, The Antenna. (Plate 1, Fig. 3B.) The coxopodite has now two strong masticatory processes of approximately equal size, and in addition a long fine bristle. The basipodite resembles that of the preceding stage except that the proximal bristle is now paired, both bristles arising in the same position.

The endopodite resembles that of the previous stage, but has now three end bristles in place of two. The exopodite is still six-jointed, but the second joint has two small accessory bristles in addition to its long bristle, making three bristles in all for the second segment, while the distal segment has now three end bristles in place of the two of the preceding stage.

Appendage 3, The Mandible. (Plate 1, Fig. 2C.) This appendage is in all respects the same as that of the last stage.

Appendage 4, The Maxillule. (Plate 1, Fig. 3D.) No great change is yet to be seen in this appendage from the previous stage, but there is a tendency for a two-lobed structure, as shown by the presence of a second small bristle close to the first, which is itself somewhat longer than in Stage II.

The Fourth Nauplius Stage. Length .165 mm.

Considerable difference in size can now be made out, but the whole of the body is still under the cephalothoracic shield. The furcal armature consists of the paired lateral spines as in the last stage, but in addition there are to be seen two small but stout end spines, one on each side of the median line at the extreme posterior end of the body. (Plate 1, Fig. 4E.) The labrum remains the same as in Stage III.

Appendage 1, The Antennule. (Plate 1, Fig. 4A.) The proximal and second joints remain the same as in the previous stage, and the distal end of the last joint with its three end bristles and the dorsally directed one is also unchanged. The ventral edge shows distally the bristle which

EXPLANATION OF PLATE 2.

Oithona spinirostris. Nauplius Stages.

FIG. 1. First Nauplius Stage.

In the subsequent figs. the numbers 1-6 refer to the successive Nauplius stages, and the letters A-E to the parts figured:—

A=Antennule.

B=Antenna.

C=Mandible.

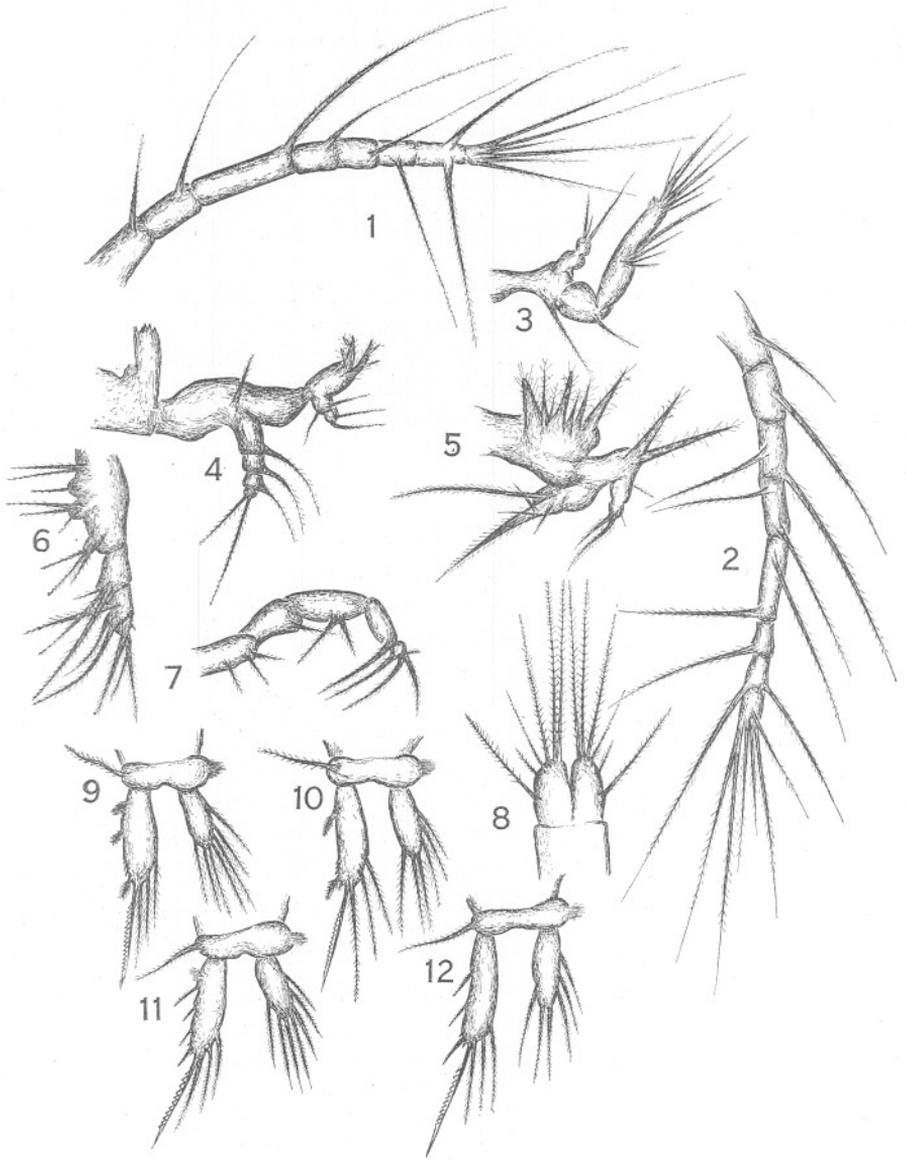
D=Maxillule.

E=Posterior part of body, ventral view.

FIG. 7. Stage 6, ventral view, showing arrangement of body spines.

Magnification slightly less than in Plate I to make the figures correspond in size.

PLATE 3.



first appeared in Stage III, but the dorsal edge of this third joint bears eight fine bristles which are not easily distinguished. This is the first stage in which Oberg figures these fine bristles, and he does not state the number seen.

Appendage 2, The Antenna. (Plate 1, Fig. 3B.) This appendage remains unchanged from the preceding stage in all respects.

Appendage 3, The Mandible. (Plate 1, Fig. 2C.) No change is to be seen from the preceding stage.

Appendage 4, The Maxillule. (Plate 1, Fig. 4D.) This appendage is now distinctly biramous, endopodite and exopodite being clearly separated from one another. The exopodite has three end bristles of which the outermost one is the longest. The endopodite has one very long and strong bristle and three very small inside bristles. The coxopodite and basipodite, as yet scarcely distinguishable, bear no visible armature.

The Fifth Nauplius Stage. Length .190 mm.

In this stage the body, now becoming more markedly elongated, is seen to project beyond the end of the cephalothoracic shield. The furcal armature has been increased by a pair of very small fine end bristles which are to be seen inside the two end spines first mentioned in the last stage. These two fine bristles are placed parallel to the stronger spines, but inside them, one on each side of the median line, so that they are very close together. The two short strong spines seen in the last stage have now become much longer, and are only slightly shorter than the paired bristles at each side, which, however, are somewhat shorter than when they were first seen in Stage I. It is to be doubted if any actual reduction in their length has taken place, but they have not appreciably increased in length during the successive stages, so that in proportion to the

EXPLANATION OF PLATE 3.

First Copepodid Stage.

- FIG. 1. *Oithona helgolandica*. Antennule.
 ,, 2. *O. spinirostris*. ,,
 ,, 3. Antenna
 ,, 4. Mandible
 ,, 5. Maxillule
 ,, 6. Maxilla
 ,, 7. Maxillipede
 ,, 8. Furca
 ,, 9 & 10. 1st and 2nd pleopods of *O. helgolandica*.
 ,, 11 & 12. 1st and 2nd pleopods of *O. spinirostris*.

Magnification as in Plate I.

increasing body-length they appear shorter. (Plate 1, Fig. 5E.) The labrum shows no difference from the preceding stage.

Appendage 1, The Antennule. (Plate 1, Fig. 5A.) Except for a very slight increase in size this appendage shows no change from the corresponding one in the previous stage.

Appendage 2, The Antenna. (Plate 1, Fig. 3B.) This appendage has undergone no change from that of the fourth nauplius stage.

Appendage 3, The Mandible. (Plate 1, Fig. 2C.) No change from that of the last two stages.

Appendage 4, The Maxillule. (Plate 1, Fig. 5D.) No change from the preceding stage.

The Sixth Nauplius Stage. Length .215 mm.

The posterior end of the body now projects well beyond the cephalothoracic shield, and the whole animal is more elongated in general form, having its greatest width about the middle. The furcal armature is the same in design as that of the previous stage, but the two end spines are somewhat longer, and the two fine bristles found inwards from them are about twice as long as in the fifth stage, though still very thin and weak in appearance. The labrum which has remained the same in pattern throughout all the stages shows no difference from that of the last stage.

Appendage 1, The Antennule. (Plate 1, Fig. 6.) The proximal and second joints are still unchanged, but there are differences in the distal joint. A second smaller bristle is added on the ventral edge distally, just behind the first one seen in the previous three stages, and there is also a short thorn-like bristle on the ventral border of the segment near the proximal end. Neither of these two is figured by Oberg. The end bristles and the eight bristles on the dorsal edge remain the same as in the last stages.

Appendage 2, The Antenna. (Plate 1, Fig. 3B.) This appendage still shows no change in its appearance from that of the third nauplius stage.

Appendage 3, The Mandible. (Plate 1, Fig. 2C.) In appearance and armature this appendage is the same as in all the preceding stages since the second nauplius stage.

Appendage 4, The Maxillule. (Plate 1, Fig. 6D.) This appendage has grown in size somewhat, but presents only small differences from that of the fifth nauplius stage. A small bristle has been added to the basipodite, and a very small extra bristle can be made out on the exterior edge of the expodite; otherwise there is no visible change in the armature.

From this stage the animal moults into the first copepodid stage. This was isolated and examined carefully, the various appendages being dissected off from the trunk, and, as in the case of the nauplii, examined under the oil immersion lens to obtain the fullest detail.

The First Copepodid Stage. (Plate 3.) Length .36--37 mm.

As good figures of the appendages of this stage are wanting in Oberg's paper, they are shown here in some detail. Oberg has seemed more intent on the fate of the various bristles in the nauplius stage in the moult to the first copepodid than in giving a clear description of the armature of the appendages in this stage.

It must be mentioned here that the body spines which have been present in all the nauplius stages and to which reference is to be made later in this paper, disappear on the moult to the copepodid and no trace of them has been seen in this stage.

The furca, which is bifurcated from this stage onwards, has on each side three long end bristles, a shorter lateral bristle, and, between these two groups in a postero-lateral position, two small bristles of unequal length, the exterior one of which is the smaller. Both these bristles are directed postero-laterally and can be seen in dorsal or ventral view of the furca.

Appendage 1, The Antennule. (Plate 3, Fig. 1.) Consisting of eight segments, the third being the longest. Each of the first six bears a single bristle, that on the long third segment being longer than any of the others. The seventh joint has two large bristles, one at each side. The end joint has six bristles, five originating at the distal end, the sixth about half-way down the joint. Of these six bristles four are very long and strong, while the remaining two are about half the length of the others.

Appendage 2, The Antenna. (Plate 3, Fig. 3.) The exopodite in this appendage is greatly reduced, and consists only of a two-lobed rudiment, the distal lobe of which bears three bristles, one of which is very small. The basipodite is long and thin, and has one bristle at its distal end. The endopodite forms the adult antenna, and bears three sets of bristles, one bristle proximally, three small and one large bristle at the constriction in the middle of its length, and six end bristles, three of which are large and three small. Just behind the end bristles are to be seen numbers of very fine hairs on the inner margin of the segment.

Appendage 3, The Mandible. (Plate 3, Fig. 4.) The coxopodite exhibits a strong toothed process. The basipodite is furnished with one medium-sized bristle. The endopodite is of curious shape, having a large basal joint bearing two strong bristled spines distally and two bristles proximally on a protuberance from which the second joint of the appendage arises. This second joint also bears two bristles. The exopodite is four-jointed, joints one to three having one bristle each, while the end joint has two bristles.

Appendage 4, The Maxillule. (Plate 3, Fig. 5.) The coxopodite is

greatly enlarged with seven masticatory spines, of which three, the two outer ones and the middle one, are particularly powerful. The endopodite bears two strong spines on an inner lobe. The exopodite is in two small portions, the proximal having one very small bristle and the distal two end bristles and a very small accessory bristle. The basipodite bears on its outer margin a large lobe, the epipodite, on the distal portion of which are to be seen two large and three very small bristles.

Appendage 5, The Maxilla. (Plate 3, Fig. 6.) Coxopodite with three groups of bristles, two in the first, one in the second, and three in the third. The basipodite with a lobe bearing three bristles. Endopodite of three segments, the first and second each with two very long and one smaller bristle, the third with three end bristles and one very small accessory bristle. Except for one more articulation which is not yet apparent, this appendage is the same as in the adult animal save in point of size.

Appendage 6, The Maxillipede. (Plate 3, Fig. 7.) The coxopodite appears divided into two parts, the first with three stout bristles, two of which are close together, and the second with one stout bristle distally. The basipodite with two stiff bristles about the middle of its length and directed inwards. The endopodite of two segments, the first with one bristle distally, the second with three long bristles and a very short bristle.

Appendage 7, The First Pleopod. (Plate 3, Fig. 9.) The basipodite has a long external bristle and some fine hairs on the inside. The endopodite is unsegmented and has seven bristles. The exopodite has three inside bristles, a terminal serrated spine, and two strong short spines on the outside edge. Near the most distal of these are two or three much smaller spines close together. Close to the proximal end of the exopodite on the exterior edge are to be seen some fine hairs.

Appendage 8, The Second Pleopod. (Plate 3, Fig. 10.) The basipodite as in the first pleopod. The endopodite is unsegmented and bears six bristles. The exopodite resembles that of the anterior pleopod, except that the fine hairs are absent at the proximal end, and there is an additional small spine between the distal short spine and the long serrated spine.

It is not deemed necessary here to describe the ensuing copepodid stages up to the adult animal. The changes which take place are for the most part of a minor nature, and in the first copepodid stage all the principal characteristics of the adult animal can be easily recognised.

OITHONA SPINIROSTRIS CLAUS.

- Syn. *Oithona challengerii* Thompson.
 ,, *plumifera* Scott (not Baird).
 ,, *atlantica* Farran.

As already stated, no account of the development stages of this species has as yet been seen in the literature examined, and for this reason a comparison of the stages with those of the preceding species is of considerable interest.

Throughout the development stages of these two Cyclopoids one cannot but marvel at the similarity between the corresponding stages, especially in the case of the first two nauplius stages. In actual detail of structure regarding the appendages there is practically no difference at all to be seen, and indeed the antennule and antenna are the same throughout the nauplius stages for both the species. The chief distinguishing points are those of size, general shape, and in the older nauplii the armature of the hind end of the body, while the mandible and maxillule furnish two minor differences between the species.

The First Nauplius Stage. Length .130 mm. (Plate 2, Fig. 1.)

Body oval in shape, but slightly more pointed posteriorly and broader anteriorly than Stage I of the preceding species. The labrum shows two small but nevertheless distinct points of difference. Its central group of strong spines on the posterior margin of the organ consists of three on each side of the median line in place of four on each side as in *O. helgolandica*. Of these three spines the middle one is by far the longest and strongest. In addition the three spines which form the postero-lateral termination of the labrum are of unequal size as in the last species but the middle one and not the outermost is the longest, while the outermost itself is small and more outwardly directed.

Appendages. (Plate 2, Figs. 1, 1B, and 1C.) In this, the first nauplius stage, all the three appendages are exactly similar to the corresponding appendages in the first stage of *O. helgolandica*.

The Second Nauplius Stage. Length .150 mm. (Plate 2, Figs. 2A, B, C, D, and E.)

The body is similar in shape to that of the first nauplius stage but slightly more elongated, and the difference in size between the two species at this stage is more pronounced, though it is as yet insufficient to enable them to be distinguished without the aid of careful measurements.

Appendages. With the exception of the mandible the appendages of the second stage are again the same as those of the corresponding stage of the preceding species. The armature of the hind end of the body, too, is in no way different. The mandible itself, however, shows one small point of difference which from now on persists through all the remaining nauplius stages. It is seen in the endopodite, on the inner margin of which only one bristle is now to be seen, whereas in *O. helgolandica* there are two small bristles on the inner margin of the mandibular endopodite in all the stages. The first nauplius stage of *O. spinirostris* also shows these two small bristles, but, curiously enough, the second, and all later stages in this species show only one bristle in this position.

The Third Nauplius Stage. Length .170 mm. (Plate 2, Figs. 3A and B, 2C, 3D and E.)

The difference in size from *O. helgolandica* is now becoming still more pronounced, and with a high power the two species can sometimes be separated by size alone, though there is still a very considerable overlap if they are examined in quantity.

Appendages. With the exception of the difference in the armature of the mandibular endopodite mentioned in the last stage, the appendages and armature of the hind end of the body are the same as for the former species.

The Fourth Nauplius Stage. Length .200 mm. (Plate 2, Figs. 4A, 3B, 2C, 4D, and E.)

In this stage the animal is now distinctly larger than in the same stage of the preceding species. General body shape is not essentially different, but in *O. spinirostris* there is a tendency for the greatest breadth to lie more anteriorly than in *O. helgolandica*. The armature of the furca at this stage, too, becomes distinctive, and from this stage on the species can be isolated at once by this means. In place of the two stout short medianly placed end spines of *O. helgolandica* there are to be seen four short thinner spines occupying exactly the same position. There is no other difference in the armature.

Appendages. Again, excepting the mandible, which is the same at this stage as in the second stage, the appendages show no difference from the fourth stage of the last species.

The Fifth Nauplius Stage. Length .230--235 mm. (Plate 2, Figs. 5A, 3B, 2C, 5D, and E.)

The difference in size at this stage can clearly be seen. The body is distinctly broader anteriorly than in the last species. With the exception of the mandible the appendages are again identical in armature with

those of *O. helgolandica*. The furcal armature is the same as in the last stage, but the spines are about double the length of those in the fourth stage, and still four in number. The long lateral bristles show no change.

The Sixth Nauplius Stage. Length .265–.270 mm.

The size difference is now obvious.

The body shape, as shown in Plate 2, Fig. 6, is stouter anteriorly than that of *O. helgolandica*, and is correspondingly more slim posteriorly. Other than the mandible, which is again the same as in the earlier stages, the maxillule is the only appendage that differs in any way from those of the previous species. The small bristle seen on the basipodite of the maxillule in *O. helgolandica* does not appear in the present species at this stage. (Plate 2, Fig. 6D. cf. Plate 1, Fig. 6D.) The furcal armature resembles that of the fifth stage, but the four median spines are now quite long, though not much more than half the length of the lateral bristles.

This is the last of the nauplius stages, and the animal now moults into the first copepodid stage. As in the preceding species, six nauplius stages have been retained in the development, and the similarity in all the stages is certainly striking. The body spines referred to above are to be seen equally well in both the species, and no differences in the number or arrangement of them have been noticed. Though the differences in the labrum are not great between the two species, they are at least common to all the stages and seem to supply a quite sound assistance in the identification of these two Oithonas.

The First Copepodid Stage. Length .42 mm.

Save in the matter of size, which is, of course, now the chief distinguishing feature, there is remarkably little difference between the first copepodid stages of these two species. Plate 3 shows the appendages of this stage. The pleopods and the antennule are the only appendages which show the least difference in the armature, so that in Plate 3, Figs. 3, 4, 5, 6, 7, and 8 apply equally well to both species. Fig. 2 shows the antennule of *O. spinirostris*, and can be compared with that of *O. helgolandica* in Fig. 1. The only difference is that in *O. spinirostris* there are two bristles on each of the third, fourth, and fifth joints in place of one. The end bristles are the same in both cases. In the pleopods the basipodites and the endopodites are the same in both, but the exopodites show a distinct difference. The bristles and end blades, or serrated spines, are the same in both species, but the armature of the exterior edge is characteristic. In the first pleopod of *O. spinirostris* (Plate 3, Fig. 11) there are four outer spines in place of the two in *O. helgolandica*. These

spines are somewhat longer, and are not so heavily bristled as in the former case (Fig. 9). Also the small accessory spines seen between the two in this figure do not appear in *O. spinirostris* and in the exopodite of the second pleopod (Fig. 12) the same state of affairs is seen except that there are in the present species three definite long spines instead of the four of the last pleopod, and in place of the two shorter spines of the preceding species.

As in the former case, it is not thought necessary to enter into the copepodid stages further here. As in *O. helgolandica*, all the characteristics of the adult can now be recognised.

MEASUREMENTS OF NAUPLII.

In order to show how a careful series of measurements could separate the species the following results of such a series, have been included in this work :—

NUMBERS MEASURED.

Length mm.	Stage I.	Stage II.	Stage III.	Stage IV.	Stage V.	Stage VI.
.100	5	—	—	—	—	—
.105	16	—	—	—	—	—
.110	32	—	—	—	—	—
.115	52	—	—	—	—	—
.120	24	11	—	—	—	—
.125	16	16	2	—	—	—
.130	32	40	9	—	—	—
.135	20	27	22	—	—	—
.140	3	27	40	—	—	—
.145	—	12	26	—	—	—
.150	—	47	20	—	—	—
.155	—	17	7	8	—	—
.160	—	3	10	20	—	—
.165	—	—	14	34	—	—
.170	—	—	28	28	—	—
.175	—	—	16	12	—	—
.180	—	—	4	4	6	—
.185	—	—	2	—	17	—
.190	—	—	—	—	44	—
.195	—	—	—	6	28	—
.200	—	—	—	14	19	—
.205	—	—	—	48	5	8
.210	—	—	—	22	—	25
.215	—	—	—	4	—	46
.220	—	—	—	—	6	30
.225	—	—	—	—	14	11
.230	—	—	—	—	18	—
.235	—	—	—	—	26	—
.240	—	—	—	—	14	—
.245	—	—	—	—	3	—
.250	—	—	—	—	—	4
.255	—	—	—	—	—	9
.260	—	—	—	—	—	15
.265	—	—	—	—	—	16
.270	—	—	—	—	—	24
.275	—	—	—	—	—	9
.280	—	—	—	—	—	3

In measuring large numbers it was found impossible to employ sufficiently high magnification to make a detailed examination of each specimen, and the difficulty presented itself that while it was a comparatively simple matter to separate the species in Stages IV, V, and VI, in Stages I, II, and III this was not so easy, although the stages themselves could be fairly readily distinguished. For this reason a large number of specimens of each stage was measured regardless of species, and in every case two modal points appeared clearly which corresponded to the two species at the size at which each most frequently occurred. Two hundred specimens at each stage were measured, and the species were then separated out by the maxima in the table. Where there was obvious overlap between the modes the overlapping numbers were divided between the two species in proportion to the modal maxima. This was done because *O. helgolandica* was more abundant in the material than *O. spinirostris*.

This separating out of the species is shown in the following table, which shows the range of size at each stage to be considerable.

OITHONA HELGOLANDICA—NAUPLIUS STAGES.

Stage.	Range of Length (mm.).	Modal Length (mm.).	Number measured at :—(mm.).							Total No.
I.	·100– ·125	·115	·100	·105	·110	·115	·120	·125	–	125
			5	16	32	52	16	4	–	
II.	·120– ·140	·130	·120	·125	·130	·135	·140	–	–	115
			11	16	40	27	21	–	–	
III.	·125– ·155	·140	·125	·130	·135	·140	·145	·150	·155	123
			2	9	22	40	26	20	4	
IV.	·155– ·180	·165	·155	·160	·165	·170	·175	·180	–	106
			8	20	34	28	12	4	–	
V.	·180– ·205	·190	·180	·185	·190	·195	·200	·205	–	119
			6	17	44	28	19	5	–	
VI.	·205– ·225	·215	·205	·210	·215	·220	·225	–	–	120
			8	25	46	30	11	–	–	

OITHONA SPINIROSTRIS—NAUPLIUS STAGES.

Stage.	Range of Length (mm.).	Modal Length (mm.).	Number measured at :—(mm.).							Total No.
I.	.120—	.130	.120	.125	.130	.135	.140	—	—	75
	.140		8	12	32	20	3	—	—	
II.	.140—	.150	.140	.145	.150	.155	.160	—	—	85
	.160		6	12	47	17	3	—	—	
III.	.155—	.170	.155	.160	.165	.170	.175	.180	.185	77
	.185		3	10	14	28	16	4	2	
IV.	.190—	.200	.190	.195	.200	.205	.210	—	—	94
	.210		6	14	48	22	4	—	—	
V.	.220—	.235	.220	.225	.230	.235	.240	.245	—	81
	.245		6	14	18	26	14	3	—	
VI.	.250—	.270	.250	.255	.260	.265	.270	.275	.280	80
	.280		4	9	15	16	24	9	3	

From these tables the graphs shown in Text-Fig. 1, are constructed. The former of these two tables gives us Graph 1, the first part of which is not very explicit, because the early stages of *O. spinirostris* tend to coincide in size with the next later stages of *O. helgolandica*.

From the second table Graphs 2 and 3 are plotted, allowance having been made for overlapping of the stages in the manner already described. In this way it becomes clear that the first peaks of Graph 1 are the result of the overlapping, not of different stages of one species, or of corresponding stages of the two species, but of two or more non-corresponding stages of the two species, e.g., Stage I—*O. spinirostris* and Stage II—*O. helgolandica*. From Stage IV onward there is no appreciable overlap of the stages or species.

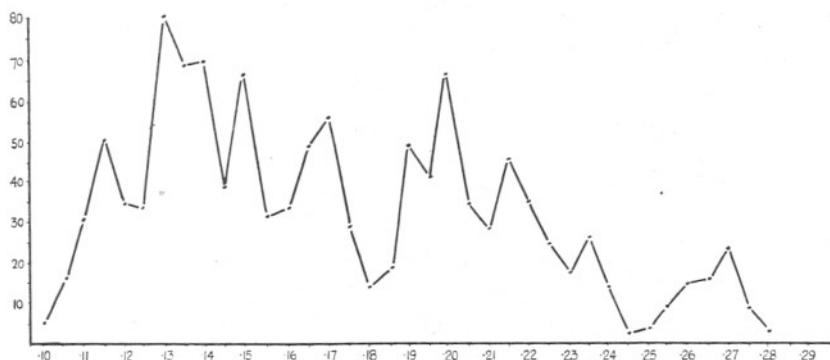
COPEPODID SIZES.

A large number of the first Copepodid stage of both species was measured, and the range of size was found to be considerable. The modal size for *O. helgolandica* was .36 to .37 mm., and for *O. spinirostris* .42 mm.

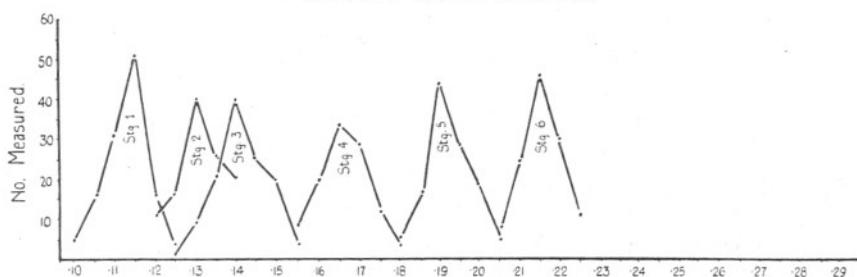
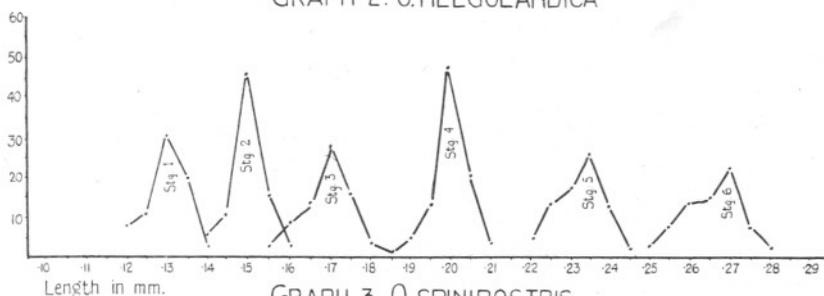
THE BODY SPINES.

The body spines referred to above were first seen in the fifth nauplius stage of *Oithona helgolandica*. The specimen under examination was well

displayed with the appendages extending straight out from the body, affording a good view of the ventral body surface. Three or four spines were observed ventro-laterally, slightly anterior to the developing maxillule, and it was indeed at first thought that they were part of the



GRAPH 1. BOTH SPECIES

GRAPH 2. *O. HELGOLANDICA*GRAPH 3. *O. SPINIROSTRIS*

TEXT FIG. 1.

maxillary rudiment. A careful scrutiny revealed the fact that they were not attached in any way to the maxillule, but arose from the body wall itself, being directed ventrally and slightly inwards. By following them carefully a row of spines fifteen to sixteen in number and varying in size

was disclosed, passing up from the region of the maxillule towards the labrum on each side of the body. They were at first to be discerned only with an oil immersion lens, and even then the fact that they were only slightly inclined to the vertical, and supported by the water in which the nauplius was mounted, made them appear for the most part only as points. As the preparation became less moist they could be seen lying inwards at an angle, but on being further depressed they became almost indistinguishable as they lay flat on the body surface.

All six nauplius stages were subsequently seen to possess these body spines. In the first nauplius stage only six or seven spines could be seen on each side, but in the last nauplius stage about twenty were visible. These spines do not arise in a straight line, but in two definite curves on each side of the body, as shown in Plates 1 and 2, Fig. 7. Although the spines are not all of equal length they vary but slightly from one to the next, their size diminishing and increasing gradually. In the later nauplius stages they are seen to extend beneath the labrum to a point where, diminishing in size, they terminate in an indefinite cluster. The closest examination of the first copepodid stage fails to reveal a trace of any such structures, so that they are to be regarded as peculiar to the nauplius alone.

A careful study of the existing literature has shown that though several workers have seen spinules and hairs on various parts of the body, and have used their presence or absence as a means of identification of species, yet there appears to be no mention of spines of anything like the size seen in this case. Their position down the sides of the body, too, is different from that shown for most of the groups of body hairs, which seem as a rule to show a transverse arrangement. Then again there appears to be no reference to any body spines in the case of marine Cyclopoida, probably because fresh material is too scanty and not easily obtained.

Since there seemed to be no exact parallel to these spines, it was decided that the investigation might be carried further with advantage. We therefore directed our attention to the study of other marine Cyclopoids in the nauplius stage in order to ascertain whether the spines were confined only to the one genus *Oithona*. Here the difficulty of obtaining material was encountered, inasmuch as marine Cyclopoids are by no means common even in the adult stage. However, a large marine Cyclopoid nauplius of greater dimensions than that of *Oithona* was found in the Firth of Forth. Its species is as yet in doubt, but it evidently belongs to one of the largest of the Cyclopoida. The chief point concerning it at present, however, is that all the specimens seen, in all stages of development, show the same arrangement of body spines as does the nauplius of the *Oithonas*. They were, as in the previous case, very difficult to see,

but under the same mounting conditions as were used in the case of the *Oithonas* they appeared fairly distinctly, showing the same relative position as in that genus. In order to show that these spines were really attached to the body, and not merely seen through the cuticle, a cast of each of the species of nauplius was picked out from the material and examined under the oil immersion lens. The spines in the ventro-lateral body region were now clearly to be seen, showing that they did project from the body wall in life, and were withdrawn from their sheaths in ecdysis.

As a natural consequence of these results it occurred to us that possibly the nauplii of fresh water Cyclopoids would exhibit the same structure, although among the vast collection of literature on these species no reference to any such spines was to be found. Accordingly, after a spell of warm weather in February an expedition was made to a small fresh-water loch in the vicinity of Aberdeen, and a fine silk net was towed across it to a depth of two or three feet. On examining the resulting collection in the laboratory a number of Cyclops species was found, in varying copepodid stages, and also a few nauplii, which, from their structure, were easily identified as Cyclopoid nauplii. Some of these were carefully mounted ventral side up in a drop of water with a light coverslip placed on top. The oil immersion lens was again requisitioned for the examination. At first little could be seen owing to the rather dense character of the body of the animal, but as the preparation became less moist body spines of exactly the same type as those in the preceding species became visible, occupying the same relative positions, and directed inwards towards the middle line of the body.

Thus in three genera of Cyclopoids these spines occur in the nauplius stages, and since two, at any rate, of these genera are widely separated, one being marine, the other fresh water, it appears probable that these body spines are common to most of the nauplii of Cyclopoid Copepoda. Such a statement as this cannot be definitely made until more species have been examined, but it is in our opinion more than a possibility.

As to the meaning or function of a double row of such relatively large spines it is hard to give any accurate solution, but the probability seems to us that, from their position and distribution, they form some kind of channel leading towards the mouth, and that they assist in some way the feeding processes, or act as a guide for a feeding current. Owing to their situation an examination of the spines in a live condition is next to an impossibility. Further Cyclopoid nauplii are to be examined as soon as the material can be obtained, and the results of this extended examination will, it is hoped, be made known at a later date.

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