

STUDIES ON INDIAN COPEPODS 6. THE POST-EMBRYONIC DEVELOPMENT OF TWO CALANOID COPEPODS, *PSEUDODIAPTOMUS AURIVILLI* CLEVE AND *LABIDOCERA BENGALENSIS* KRISHNASWAMY

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THE present communication contains the description of the life history of two calanoid copepods, *Pseudodiaptomus aurivilli* Cleve and *Labidocera bengalensis* Krishnaswamy. The development proceeds in the general calanoid pattern except that in both species there are only five free-living naupliar stages, the first being suppressed. A similar condition has been noted by earlier workers (*vide* Johnson, 1948).

PROCEDURE

The material used in the present study was obtained from the Gulf of Mannar from April 1959 to March 1961. Living as well as preserved specimens were examined for working out the successive stages. In the case of *P. aurivilli* the egg-carrying adult females were freely picked from plankton and kept individually in separate beakers of 250 cc. capacity. In most cases hatching took place within 24 hours. However, in majority of the cases all the nauplii in culture dishes died on the fourth or fifth day and none lived through all the stages. Consequently different stages freshly picked from plankton were reared through atleast one moult in the laboratory and thus the next higher stage determined. A total of five specimens of the last nauplius moulted into the first copepodite from which it was easy to trace to the adult stage.

During the months of April and May, 1960, numerous adults and earlier stages of *L. bengalensis* were found swarming the surface waters. These nauplii were freshly taken from plankton and reared in the laboratory establishing in all, five sequential stages. The correct identity of the larvae was then determined by rearing the last nauplius through the critical moult to the first copepodite which was traceable to the adult of *L. bengalensis*.

***Pseudodiaptomus aurivilli* Cleve**

This species is common in Indian waters and is taken in great numbers during the breeding periods. Johnson (1948) has described the post-embryonic development of *Pseudodiaptomus (Pseudodiaptallus) euryhalinus*, a species which he himself created a few years earlier (Johnson, 1939). The developmental history of *P. aurivilli* shows close relationship with that of *P. (P.) euryhalinus*, especially in the structure and segmentation of various appendages of both naupliar and copepodite stages and in the

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suppression of first nauplius, the egg hatching into a stage which is morphologically equivalent to the second nauplius of other calanoid species. However, profound differences exist in the pattern of segmentation of the body and in the fifth pair of legs. The most important specific features of the nauplii appear to be the length-breadth relationship, along with the structure of caudal armature and the number of setae borne on the antennule.

Nauplius II (Plate I, 1)

Average size 0.162. Body very opaque, eye red. General form oval without indication of hind body. Labrum is prominent in lateral view. Caudal armature in ventral view consists of the following: The posterior tip is bifurcated with the right lobe slightly at a higher level than the left one. A strong fairly long seta is borne on left lobe while an almost equally fragile seta is borne on right side. Tufts of small bristles are present at the bases of these two setae. Slightly in front of the caudal armature hairs are present in horizontal rows. Antennule is 3-segmented, the segments bearing one, two and five setae respectively. The last segment also bears a number of setules on its inner margin. There is a gradual increase in size from the short basal to the fan-like terminal segment. In antenna the protopodite is 2-segmented, the endopodite 1-segmented and exopodite 6-segmented. The basal protopodite bears a strong masticatory process and two short setae. The former is orientated in such a way that its free end is directed towards the labrum. Second protopodite segment also bears two short setae. Endopodite is short and stumpy, bears a single seta on the interlateral margin and three setae on the apex. Each of the segments of the exopodite is provided with one seta except the last which has two. The segmentation of protopodite and endopodite of mandible is similar to that of antenna, the exopodite, however, being only 4-segmented. The future masticatory blade is indicated in the basal protopodite by a stout spine. The second segment carries only two short setae. Two groups of setae are seen on endopodite. As the segment is more or less circular, these groups cannot be termed as inner and terminal. The 4-segmented exopodite is hardly longer than endopodite and bears five setae. There is no trace of other appendages.

Nauplius III (Plate I, 2)

Average size 0.186 mm. The length-breadth ratio of this stage is 62 : 38. The posterior tip tapers more acutely so that what may be termed the posterior body is indicated. In lateral view this is seen more sharply. In caudal armature the strong seta on left side is slightly reduced in comparative length. A short seta is added towards the left on the same lobe. The orientation of different setae is better observed in lateral view where the fragile seta on the right side is seen projecting posterodorsally, while the left side seta is projecting straight backwards. The newly added seta occupies an intermediate position. There is no change in the first and second segments of antennule. The fan-like third segment now carries seven setae which are arranged more or less equispaced on terminal subcircular margin. The masticatory process of first protopodite is stouter. An additional seta is present on second segment. In exopodite the full complement of eight setae is present, the first four segments with one seta each, last two with two each. Endopodite is one-segmented and has three setae on lateral and four on apical margins. The masticatory blade of mandible is toothed at its free end. In the second segment of protopodite one more seta is added, making a total of three. In endopodite also there are two additional setae, one in the proximal group and the other in the distal. Exopodite is 5-segmented, first four segments with one seta each and the last with two

setae. Maxillules are represented by two strong incurved spines, borne a little behind the mandibles.

Nauplius IV (Plate I, 3)

Average size 0.216 mm. In general shape there is not much change from the previous stage except that the dorsal side is more convex. In the caudal armature there are four setae now, two on each lobe. The spinous seta remains the longest and stoutest though its length compared to that of the body is much less. There are several bristles around the caudal setae, as well in front of it in posterior region of nauplius. The length-breadth ratio is 62 : 32. There are eleven setae and an aesthetask on the terminal segment of antennule, besides, again, a few hairs on the lower inner margin. The setae towards the apex are longer than those more proximal. The change in the structure of antenna consists of the addition of one seta each on the first copepodite segment and on lateral side of the still one-segmented endopodite and the transformation of the masticatory process of basal protopodite into a normal spine. In mandible the broad protopodite segment has a seta in addition to the fairly strong masticatory blade. There is also addition of one seta each both on the second protopodite and on the exopodite. Maxillule is now a bilobed structure, each lobe bearing three setae which are rather stout and arranged in a radiating manner.

Nauplius V (Plate I, 4)

Average size 0.246 mm. The length-breadth ratio is 63 : 37. The body shows traces of segmentation. The caudal armature is fully developed and differs from that of fourth stage in having one more short seta on the right lobe, besides a number of bristles and hairs. There are thirteen setae and an aesthetask in the last segment of antennule. Few setules are present on the inner lower margin. There is no change in antenna, mandible and maxillule. A rudimentary lobular maxilla with two setae is present a little beyond maxillule.

Nauplius VI (Plate I, 5-6)

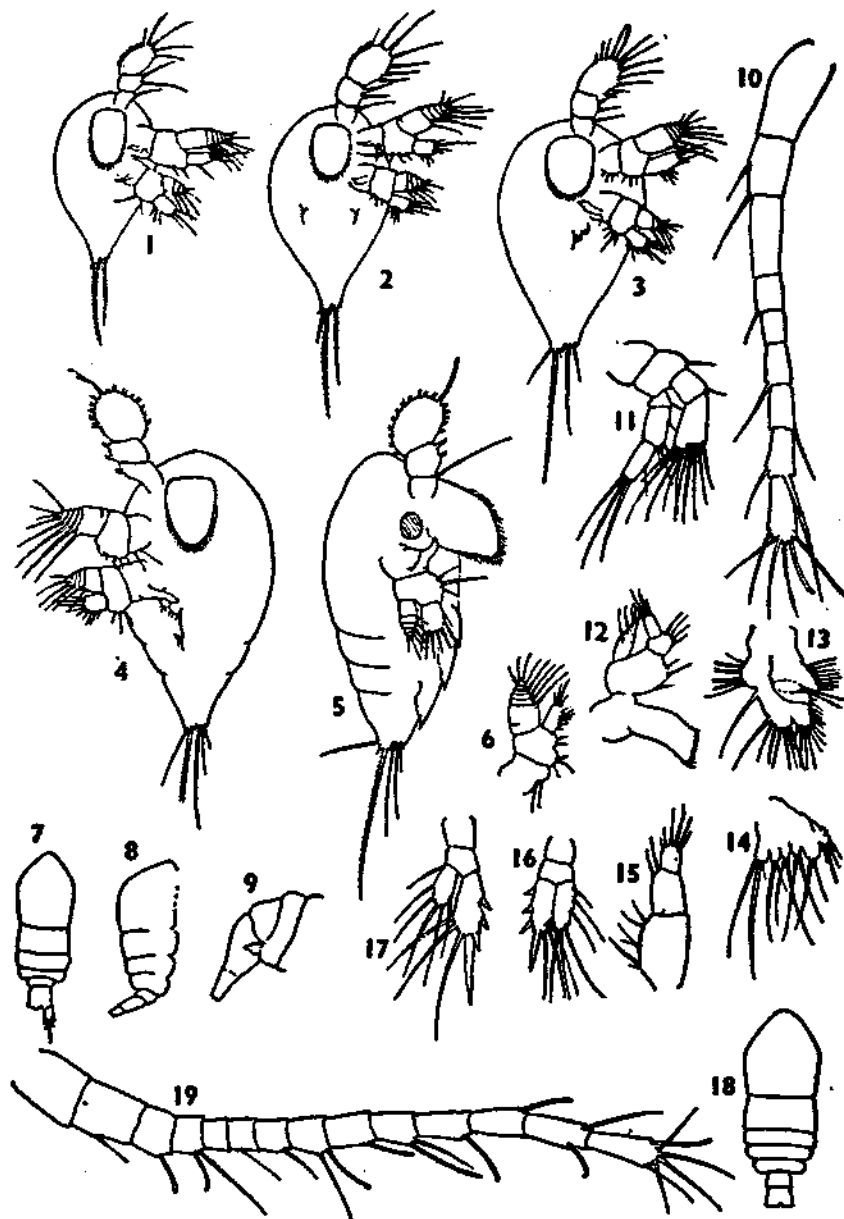
Average size 0.273 mm. Well-defined constituents of the future cephalosome, two pedigerous segments and the posterior body are present. The length-breadth ratio of the larva is 63 : 37. The last segment of antennule carries 16 setae and an aesthetask. There is no change in the structure of antennae, mandibles, maxillules and maxillae from that of the earlier stage. Maxilliped and first two pairs of legs are represented by rudimentary leaf-like structures.

Copepodite I (Plate I, 7-9)

Average size 0.45 mm. The body is composed of a prosome of four segments and a urosome of two segments. The cephalosomal segment is more or less rectangular with a broad anterior end. The posterior corners of prosome are rounded. The first and second thoracic segments bear a pair of legs each, while the third segment carries rudimentary third legs. First urosomal segment is short and at first looks a part of the prosome. But that this segment belongs to the urosome is clearly indicated by its fate in the subsequent stages. There are five caudal setae on each ramus.

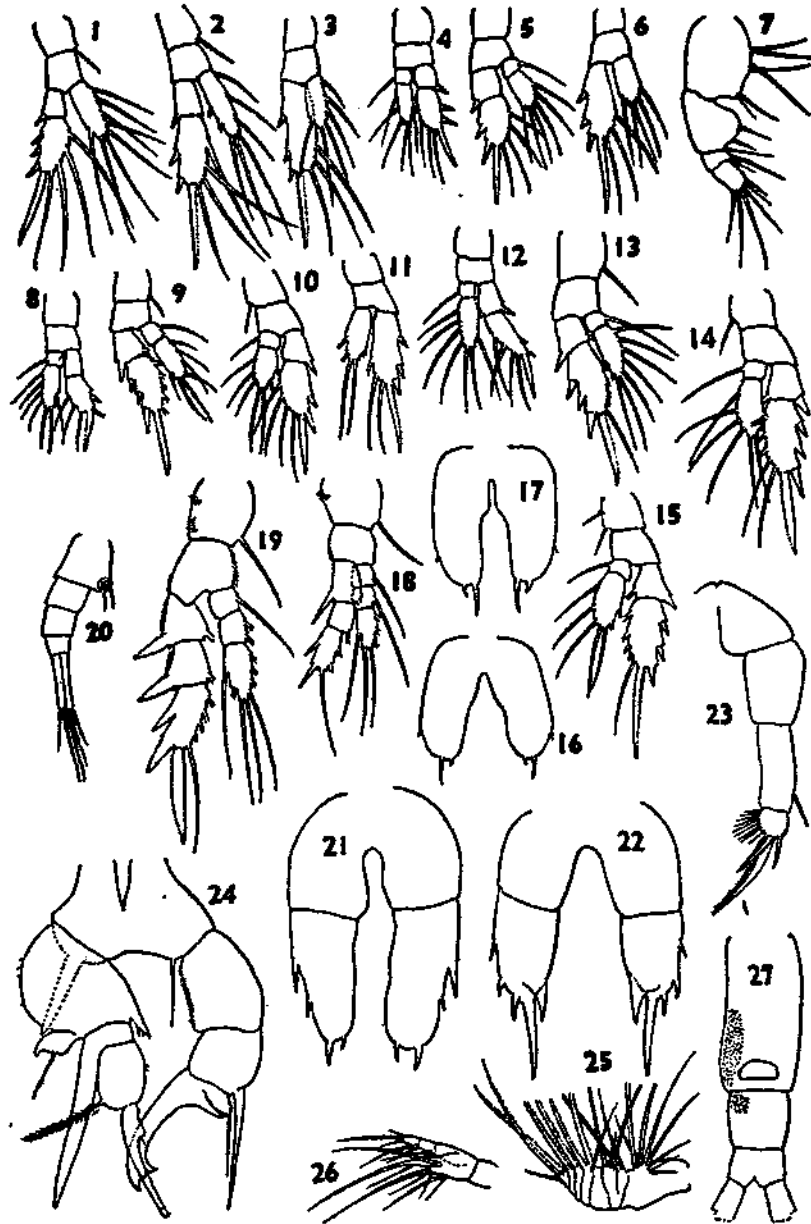
Antennule (Pl. I, 10) is composed of nine segments which have the following relative lengths :

1	2	3	4	5	6	7	8	9
18.5	12.0	16.0	7.25	6.75	8.0	9.0	9.5	13.0=100



Pseudodiaptomus aurivilli

FIGS. 1-5. Second to sixth naupliar stages; 6. Sixth nauplius antenna; 7-8. First exopodite, dorsal and lateral views; 9. First copepodite, posterior region enlarged; 10-15. First copepodite, cephalosomal appendages; 16-17. First copepodite, first and second swimming legs; 18. Second copepodite dorsal view; 19. Second copepodite antennule.



Labidocera bengalensis

FIGS. 1-3. Second coepodite, first to third legs.

Pseudodiaptomus aurivilli

FIGS. 4-6. Second coepodite, first to third legs; 7. Second coepodite maxilliped; 8-11. Third coepodite first to fourth legs; 12-15. Fourth coepodite first to fourth legs; 16-17. Fourth coepodite female and male fifth legs; 18-19. Adult first and second legs; 20. Adult urosome with genital spines; 21-22. Fifth coepodite male and female fifth legs; 23-24. Adult female and male fifth legs.

There are only very few setae and aesthetascs on the constituting segments, though they are abundantly present in the later stages. Antenna (Pl. I, 11) has a protopodite of two segments, an endopodite of two and an exopodite of three segments. This is also the pattern of segmentation noticed in adult. Mandible (Pl. I, 12) is formed by a biting ramus and a biramous palp. It is clear that there are two segments in protopodite, two in endopodite, and four in exopodite, as there are in adult. However, lines of separation between various segments are indistinct. The basic pattern of adult structure has also been developed in maxillule (Pl. I, 13). But here, the distal parts of appendage especially exopodite and endopodite are ill-formed without clear partitions. In maxilla (Pl. I, 14) the protopodite with four endites is clearly seen. Each endite bears only two setae except the first which carries three setae. The segmentation of endopodite is very indistinct as it is in all the stages, including the adults. Maxilliped (Pl. I, 15) is only 3-segmented. First segment is very large with three groups of setae. Second and third segments carry terminal setae, two and six respectively. Two pairs of swimming legs (Pl. I, 16-17) are biramous, each ramus being 1-segmented. The setal arrangements are shown in the figures. Third leg is rudimentary.

Copepodite II (Plate I, 18)

Average size 0.54 mm. An additional segment is present in prosome, urosome being only two-segmented. First three thoracic segments bear biramous legs while the last segment is provided with rudimentary fourth legs. Posterior corners of prosome are rounded. Antennule (Pl. I, 19) is 14-segmented, the segments having following comparative lengths :

1	2	3	4	5	6	7	8	9	10	11
9.63	9.63	5.30	4.70	3.77	4.30	5.01	5.66	7.20	6.40	8.30
12	13	14								
8.70	9.90	11.50=100								

Maxilliped (Pl. II, 7) is 4-segmented. First segment resembles the corresponding segment of the earlier stage. Second segment which is nearly half the size of first bears three equispaced setae in its distal half. Last two segments are rather small and bear two and six setae respectively. First three segments in fact represent the sympod while the terminal segment represents the endopodite which becomes segmented in later stages. There are three pairs of biramous swimming legs (Pl. II, 4-6) and a rudiment of fourth borne by four thoracic segments. In first two legs each ramus is 2-segmented while in the third it is only 1-segmented. The protopodite segments do not bear any seta in any of these legs.

Copepodite IV (Plate III, 3)

Average size female 0.81 mm. and male 0.78 mm. The fusion of cephalosome and first prosomal segment is indicated though the distinctness of various segments is still clear. Posterior corners of the last segment are clearly produced into symmetrical angular projections in both cases. Urosome is 3-segmented.

Antennule (Pl. III, 4) is 21-segmented in both sexes. The male right antennule, however, differs in the relative lengths of segments 13-17 (both inclusive). The segments of female antennule share the following proportionate lengths :

1	2	3	4	5	6	7	8	9	10	11	12
8.4	3.7	4.6	3.1	3.4	2.0	2.0	2.6	2.8	4.0	3.7	4.5
13	14	15	16	17	18	19	20	21			
4.2	7.9	4.9	4.6	5.1	5.5	6.7	7.6	8.7	=100		

Rami of first four pairs of legs (Pl. II, 12-15) are all 2-segmented. Fifth legs (Pl. II, 16-17) are similarly constructed in both sexes. Each leg consists of a single rather elongate segment on each side, continuous with each other at base. Each segment bears three spines, two at apex and one on outer margin at about two-third of distal length. The legs of two sides are symmetrical. But male legs differ from those of female in that they are slightly larger than female counterparts and that the terminal spines are comparatively of larger dimensions.

Copepodite V (Plate III, 5-6)

Average size female 1.0 mm. and male 0.90 mm. The fusion between cephalosome and pedigerous segments as well as that between last two prosomal segments are complete though traces of division still exist in the former case. The spines on posterior corners are well-developed and symmetrical, with margins between the two spines being characteristically wavy. Spines of last prosomal segment in female are rather divergent while those in male are projecting directly backwards. Urosome is 3-segmented in female and 4-segmented in male.

Antennule (Pl. III, 7-8) in both sexes consists of twenty apparently free segments. In female segments have the following relative lengths :

1	2	3	4	5	6	7	8	9	10	11	12
7.7	5.0	4.6	3.4	5.7	2.4	2.3	4.7	4.6	5.0	5.8	5.7
13	14	15	16	17	18	19	20				
5.8	4.6	4.7	5.7	5.1	5.0	5.8	6.4	=100			

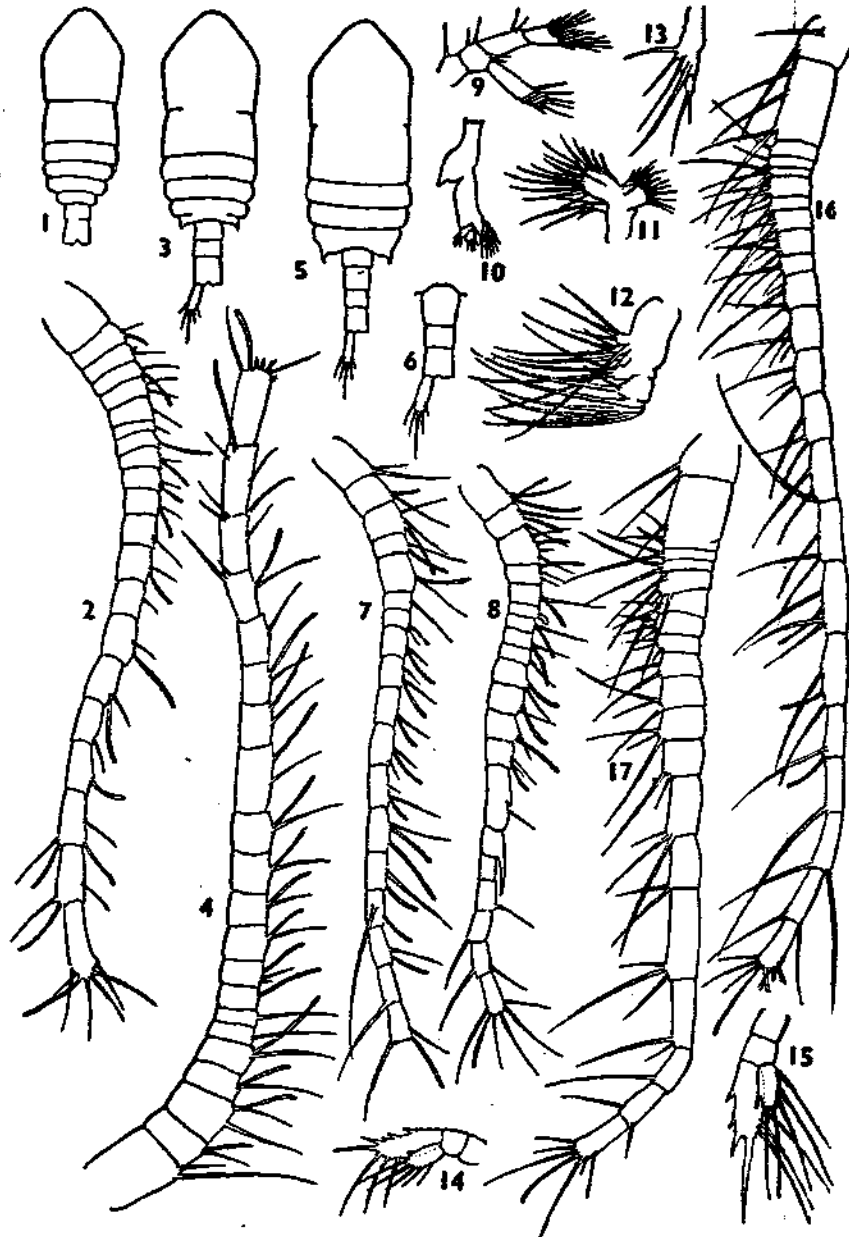
In male the antennular segments share the following lengths :

1	2	3	4	5	6	7	8	9	10	11	12
8.0	4.5	5.2	4.0	4.0	2.6	2.6	3.2	3.2	5.2	5.2	5.2
13	14	15	16	17	18	19	20				
4.5	10.3	5.2	4.5	5.2	5.2	5.2	7.0	=100			

All the four pairs of swimming legs are well-developed, the rami being three-segmented with final complement of spines and setae (Pl. II, 18-19). In female, fifth leg (Pl. II, 22) is 2-segmented, the basal segment of one side merging with that of the other side. While the basal segment is without any accessory parts, the distal segment bears five spines. Two of these are borne on apex while two other spines are set one on either side of this apical complex. Inner apical spine is very large, about four times larger than the outer apical. Fifth spine is borne on the outer margin of second segment at about its mid-length. Legs of the two sides are symmetrical. In male right leg (Pl. II, 21) is slightly larger than the left though both are constructed on the same pattern. The male fifth legs also consist of two segments. Basal segments of two sides are fused and do not carry spine or seta. The arrangement of spines on distal segment is as follows : Two spines on apex, a little separated from one another ; two spines on outer margin at about one-third and two-third lengths respectively. The proximal marginal spine and the outer apical spine are not of equal size and are larger than the other two spines. There is no trace of endopod either in right or left leg.

Adults

As in many sexually dimorphic species the advancements made by adults over fifth stage consist of the complete development and modification of antennules and fifth legs as well as in the addition of one more segment in urosome. There is complete fusion between cephalosome and first pedigerous segment as well as between the last two prosomal segments.



Pseudodiaptomus aurivilli

FIGS. 1. Third copepodite dorsal view; 2. Third copepodite antennule; 3. Fourth copepodite dorsal view; 4. Fourth copepodite antennule; 5. Fifth copepodite male dorsal view; 6. Fifth copepodite female urosome dorsal view; 7. Fifth copepodite female antennule; 8. Fifth copepodite male geniculate antennule; 9-13. First copepodite cephalosomal appendages; 14-15. First copepodite first and second swimming legs; 16-17. Fifth copepodite male and female antennule.



Labidocera bengalensis

FIGS. 1-5. Second to sixth naupliar stages; 6-7. First copepodite dorsal and lateral views; 8. First copepodite antennule; 9-10. Second copepodite dorsal and lateral views; 11. Second copepodite antennule.

Labidocera bengalensis Krishnaswamy

There are five naupliar stages, the first being suppressed. Nauplius is characteristically elongate rather spindle-shaped with posterior part tapering gradually and anterior part abruptly. Anteriormost part is constricted off from rest of the body in the form of a hood. The posterior end bears a number of setae, some of which are very long. General pattern of development of appendage is similar to that of the other two species of this genus whose developmental cycles are known (Johnson, 1935). However, specific differences are clearly expressed. An important character by which the nauplii of this specific could be separated from those of other species appear to be the enormous development of one of the setae on second protopod segment of antenna. In other species of *Labidocera* whose nauplii have been described, this seta is indistinguishable from others and is of no specific difference. Distinct differences are also noticed in the number of setae borne on posterior end of body and on various appendages. The increase in size from first to last stage is explicitly marked and can be used as a safe criterion for ready identification of various stages. Labrum is quite well-developed, narrow in the anterior half and is very sparsely armed with short weak setae.

Following the critical moult there are 6 stages, the last of which is the adult animal. Copepodites are only immature adults and the chief points of distinction between them consist in the segmentation of the body and metasomal appendages. In the first copepodite there is a total of five segments, four prosomal and one urosomal. Second copepodite possesses an additional urosomal segment. In third stage, urosome is still 2-segmented while one segment is added in prosome which now has reached its full development of five segments. Urosome becomes 3-segmented in fourth stage and remains thus thereafter in female. In male one more urosomal segment is added in fifth stage. This condition persists in adults also. The lateral hooks of prosome make their appearance in second stage and are present throughout the life cycle. Posterior corners of prosome become symmetrical in male only from fifth stage onwards. Sexual distinctions can be made out from the fourth stage.

Nauplius II (Plate IV, 1)

Average size 0.235 mm. Antennule is 3-segmented, first segment being the shortest and last the longest. Former bears only a single seta on distal margin. Second segment carries two setae, one about the mid-length and other on distal margin. There are three apical setae on third segment and they are much longer. Antennule is directed anteriorwards both in living and preserved specimens. In antenna protopodite is 2-segmented and much longer than exopodite and endopodite. First protopodite carries a masticatory hook and a seta, former being much stouter than the latter, although they are more or less of the same length. Second protopodite bears two setae at about the mid-length and a single seta at inner distal angle. The setae at mid-length are borne on a prominence and one of them is extremely large. It is always directed at a distal inner angle and appears to have a special masticatory or sensory function. Endopodite is 1-segmented with one lateral and three apical setae. The outermost apical seta is the largest. Exopodite is apparently 5-segmented. Each segment bears one seta except the terminal which bears two. Antenna is the longest of appendages and appears to play the leading role in locomotion of the nauplius. In mandible division of protopodite into segments is not yet clear although the constriction between the two future segments is clear enough. On the second half there are two setae. Endopodite is 1-segmented; however, the future segments are indicated only by arrangements of setae. Distal

segment is indicated by a group of four setae and proximal by three spines. Exopodite is 4-segmented, first and last segments bearing two setae each and others one each. Mandible is usually held in an exteroposterior direction. Caudal armature consists mainly of two setae, one long and heavily spinous and the other very short and spine-like. The point of origin of these setae is guarded by a row of four spines.

Nauplius III (Plate IV, 2)

Average size 0.323 mm. The structural advances of second stage over the first are as follows: Antennule has an additional seta on the terminal segment. The anteriormost of the apical setae is quite long and carries a number of bristles. First protopodite of antenna carries one masticatory hook and two setae, one of which is smaller than the other. In second protopodite one more seta is added, borne very close to the proximal group of two setae already found in the earlier stage. In exopodite an additional seta appears on proximal segment which still is undivided. Endopodite also bears an additional lateral seta besides the original one lateral and three apical setae. Protopodite of mandible is now clearly 2-segmented. First segment bears a single seta and a chewing process; second segment bears three spines, the distal two close together and the proximal separate. Endopodite has three spines on inner side (representing the proximal segment) and four slender setae on outer side. Exopodite has two setae on the proximal segment, indicating the latent 2-segmented nature of that segment. Bud-like structure with a few hairs appear as maxillules. There are two long setae besides a short one in the caudal armature. The longest seta is spinous while the shortest is very stout. Spinules guarding the base of caudal setae are reduced to two. However, a group of four spinules, two longer than the others, are present at some distance anterior to the base of caudal setae. Midway between maxillular bud and this group of spinules a few bristles are borne on either lateral side.

Nauplius IV (Plate IV, 3)

Average size 0.423 mm. Fourth stage exhibits the following morphological advances over the third: There is a total of 6 setae on terminal segment of antennule. Three of those might still be termed apical, but it will be more appropriate to state that the 6 setae are linearly arranged from about mid-length to apex of the segment. Segmentation of proximal segment of exopodite of antenna becomes deeper but still remains incomplete. In endopodite one more seta appears on the lateral side, the total now being three apical and three lateral. Masticatory process of mandible is larger and its apex is bifurcated. Second protopodite bears an additional spine making the total four. In endopodite also there is an increase of spine on proximal segment. Maxillule is a clearly defined structure, bearing three radiating setae. Caudal armature is more or less fully developed. There are four spines on posterior apex. The two setae on left side are much longer than the two on the right. The longest seta is heavily spinous. Outer of the two right side setae is spine-like and stout. The masticatory spines found in the earlier stage are highly reduced in size. The groups of spinules and bristles noticed earlier between maxillule and caudal setae are also present.

Nauplius V (Plate IV, 4)

Average size 0.466 mm. This stage differs from the fourth in the following: The second segment of antennule carries three setae while it was only two in the preceding stage. Two additional setae appear on last segment bearing now a total number of eight setae. All are much longer than before. Antenna reaches its full development. Six segments are clear in exopodite which bears eight setae, second and

last having two each and the others one each. In endopodite one more apical seta is added besides a few fine hairs on inner lateral margin. The masticatory process of mandible is well developed. There are five setae on second protopodite segment arranged in a radiating fashion. Spines on the side of endopodite are much longer and stouter, one of them carrying spinules on it. An additional seta appears on inner side of maxillule. Other posterior appendages are represented by blunt rudiments. The main change in caudal armature is in the group of spinules that were arranged across the ventral surface in front of caudal setae. These spines have been displaced to lateral positions, three being present on each side.

Nauplius VI (Plate IV, 5)

Average size 0.497 mm. Although several appendages have reached their full development in the preceding stage itself following structural advances are noticed in the sixth stage: There are ten setae on first segment of antennule, linearly set from proximal region to apex. This segment is much longer than other segments. There are also a few hairs near the base of some of the setae. The proximal portion of maxillule is constricted from the distal. There are six setae on each maxillule, all on distal half. Maxilla, maxilliped and first and second legs are clearly visible in rudimentary state. While these appendages are mere buds in the earlier stage, here they are flap-like with sharp processes on posterior margins. They can be snapped off by fine needle and mounted separately.

Copepodite I (Plate IV, 6-7)

Average size 0.553 mm. Prosome is composed of four segments and urosome of one segment. First prosomal segment is far larger than all other segments joined together. It is narrow in the middle than in anterior and posterior regions, thus indicating a future division in that region. There is no lateral hook on the cephalosome. Posterior corners of last prosomal segment are rounded. Urosome consists of only a single segment which is rather square, bearing the caudal rami. The latter are longer than wide and bear five setae each. The rostral spine on cephalosome is not yet developed. In lateral view the anterior end in front of antennule looks quite rounded. Eyes are prominent. Antennule (Plate IV, 8) consists of nine segments having the following relative lengths:

1	2	3	4	5	6	7	8	9	
6.0	10.4	12.3	16.6	9.1	10.4	10.4	11.6	13.2	=100

Third and fifth segments are devoid of seta while other segments carry one or more setae. Antenna (Pl. III, 9), mandible (Pl. III, 12) and maxillule (Pl. III, 11) have developed all the adult features and are sketched. In maxilla (Pl. III, 12) the distal portion is only 3-segmented while it is 4-segmented in all other copepodites and adults. A few smaller setae on the endites of various segments are also not fully expressed. Maxilliped (Pl. III, 13) is poorly developed. The sympod is unsegmented as is in adult and bears four setae, outermost of which is the longest. In endopod only two segments are formed, distal segment carrying two small setae. There are two pairs of biramous swimming legs (Pl. III, 14-15) and a rudiment of the third. Rami of the two legs are each 1-segmented. Protopodites are already divided but the constituent segments do not bear setae. Both first and second endopods carry 6 setae each while exopod carries three setae, four spines and a terminal blade in the case of first legs and three setae, three spines and a terminal blade in the case of second legs.

Copepodite II (Plate IV, 9-10)

Average size 0.680 mm. There is no change in the segmentation of prosome

except that traces of partition have appeared in first segment. An additional segment is present in urosome. The anterior urosomal segment is much smaller than the posterior. Lateral spines have appeared on the cephalosome and are situated at about one-third of its length from the anterior end. Rostral spines are also developed and can easily be seen projecting ventralwards. Antennule (Pl. IV, 11) is composed of twelve segments, sharing the following relative lengths :

1	2	3	4	5	6	7	8	9	10	11	12
8.8	9.2	5.0	6.3	7.1	9.6	10.5	6.7	7.9	9.2	9.6	10.1 =100

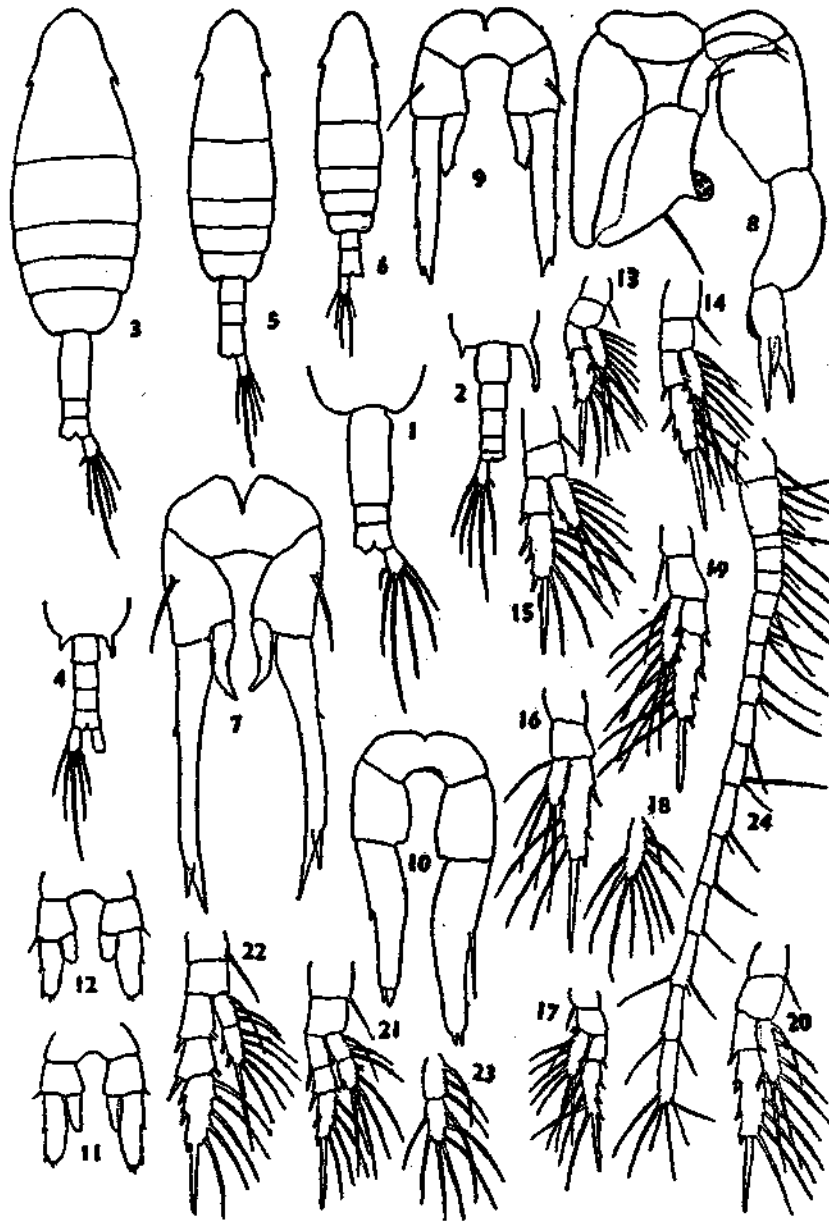
First segments are devoid of setae whereas one or more of them are borne by other segments. Maxilla (Pl. II, 25) has reached its full development and resembles that of adult. In maxilliped (Pl. II, 26) the sympod is fully grown with all seven setae arranged in three groups, first two segments containing two setae each and the last three. In endopod there are three segments, proximal two carrying two setae each and the distal three setae. The setae are all much long and widely stretched out. There are three pairs of biramous swimming legs (Pl. II, 1-3) and a rudiment of the fourth which resembles the rudimentary third leg of earlier stage. Exopods of first two legs and both rami of third leg are only 1-segmented. First and second endopods carry eight setae each while the third endopod has only six setae. Proximal segment of exopod carries one spine both in first and second legs and is without any seta. Second exopod segment in these two legs bears four setae and a terminal blade. However, the number of spines in first leg is three while it is two in second leg. In last leg endopod has six and exopod three setae, three spines and one terminal blade. First endopod carries one seta in the case of first two legs while it has no seta in the last leg. Second protopodite segment is devoid of any seta in any of the legs.

Copepodite III (Plate V, 6)

Average size 0.847 mm. Prosome has reached its full development of five segments, cephalosome and four thoracic segments, last of which is the result of the fusion of the fourth and fifth segments. Lateral hooks and rostral spines look like those of adult. Posterior end of prosome is symmetrical, but there is distinct increase in their comparative sizes. Antennule (Pl. V, 24) consists of seventeen segments with the following relative lengths :

1	2	3	4	5	6	7	8	9	10	11	12
6.1	10.3	2.0	3.2	3.0	4.0	4.2	4.4	4.2	6.2	6.0	8.3
13	14	15	16	17							
7.1	7.1	7.8	7.8	8.3 =100							

Second segment shows signs of division into three segments. Setal arrangement on that segment also is in agreement with this potential partition. All segments bear setae, but there is a profusion of it in the first seven proximal segments. All other cephalosomal appendages have reached the condition of adult structures. In maxilliped the sympod which is a massive structure now bears seven setae, three of them being of large dimensions. All these setae carry stiff setules on them. Endopod consists of four segments, first and second segments bearing two setae each, third one seta and the last three setae. The setae are all setiferous on one side. Between sympod and endopod there is a spine. Although it looks more a part of sympod, it has been interpreted as representing the first segment of endopod which can be distinguished only with difficulty. All four pairs of swimming legs (Pl. V, 13-16) are developed. Exopods of first three pairs of legs are 2-segmented while endopods of these legs as well as both rami of fourth legs are 1-segmented. Basal protopodite of first three legs bear one seta each, distal segment are devoid of any seta. First endopod bears eight setae ; second and third endopods nine setae each. Third



Labidocera bengalensis

FIGS. 1-2 Adult female and male urosome dorsal view ; 3. Fifth copepodite female dorsal view ; 4. Fifth copepodite male urosome dorsal view ; 5-6. Fifth and fourth copepodite dorsal view ; 7-8. Adult female and male fifth legs ; 9-10. Fifth copepodite female and male fifth legs ; 11-12. Fourth copepodite female and male fifth legs ; 13-16. Third copepodite first to fourth legs ; 17-20. Fourth copepodite first to fourth legs ; 21-22. Fifth copepodite first and second legs ; 23. Fifth copepodite endopod of fourth leg ; 24. Third copepodite antennule.

exopod bears only the spine. Three spines and one terminal blade are present on distal segment of first to third exopods. In the number of setae on distal segment the second and third exopods are similar, bearing five setae each ; in first exopod, distal segment has only three setae. The 1-segmented fourth exopod bears three setae, three spines and one terminal blade.

Copepodite IV (Plate V, 5)

Average size female 1.10 mm. and male 1.00 mm. Male is only a little longer than the third copepodite while female is much larger. Segmentation of body is similar in both cases. Antennule is 17 segmented and the segments have the following relative proportions :

1	2	3	4	5	6	7	8	9	10	11	12
3.9	10.6	4.3	2.6	5.3	3.6	4.3	4.3	6.3	6.6	7.3	7.0
13	14	15	16	17							
6.3	7.0	7.0	7.0	6.6	=100						

Second segment shows signs of division into four segments. These potential segments find their expression in fifth copepodite. In other mouth-parts the difference from the adult structures consists of only in size. Four pairs of swimming legs (Pl. V, 17-20) and fifth legs are present. Exopods in four pairs of legs are 2-segmented while endopods remain 1-segmented. The number of setae borne by four endopods are nine, ten, nine and seven respectively. In exopod first segment bears one seta and one spine in the case of first three legs and one spine alone in the case of fourth leg. Distal segment of exopod carries three spines and one terminal blade in all four legs. In the number of setae borne by that segment, however, the first leg differs from others. In the former it is only four while in the latter it is five setae. Fifth legs (Pl. V, 11-12) both in male and female are biramous and constructed more or less in the same pattern. First protopodite segment of both sides are confluent. Second protopodite segment bears a fine seta on its distal outer angle. Endopod, represented by a short smooth segment is devoid of any seta. Exopod is also 1-segmented and carries four short spines, two lateral and two apical. One of the lateral spines originates at about the middle of the segment while the spine is borne towards outer lateral angle. Fifth legs show slight signs of sexual distinction. In female the right and left legs are symmetrical and of equal dimensions. But in male the right leg is slightly larger than the left. This is particularly true of exopodite ; right exopodite is clearly broader and longer than that on the left.

Copepodite V (Plate V, 3-4)

Average size female 1.36 mm. and male 1.21 mm. Fifth copepodite has assumed practically all the structural peculiarities of the adult and the changes that follow this stage relate mainly to sexual maturation. In female the prosome has symmetrical posterior margin ; in male the right posterior corner is prolonged into a digitiform growth while that on left side is conical and much smaller. Female urosome is 3-segmented, first segment (genital) being much longer than the other two combined. It has also developed to some extent the characteristic curvature of right lateral margin of the segment. The numerous glandular openings present on right posterior area in adult female is also observed here. In male, urosome is 4-segmented. The small posteriormost segment is added only in the next stage. Segments of urosome diminish in size to posterior side. Caudal rami do not show differences in the two

sexes. Female antennule (Pl. III, 16) consists of 23 segments, the latter having the following relative lengths :

1	2	3	4	5	6	7	8	9	10	11	12
3.3	8.9	1.6	1.1	0.8	1.9	1.8	2.6	2.6	2.2	3.8	4.5
13	14	15	16	17	18	19	20	21	22	23	
4.8	5.3	6.1	6.4	6.7	6.4	5.3	6.1	6.1	6.5	5.2	=100

The number of setae borne by various segments are similar to that of the adults. Antenna, mandible, maxillule, maxilla and maxilliped have all attained the adult pattern of structure. Four pairs of swimming legs (Pl. V, 21-23) are also developed fully, exopods being 3-segmented and endopods 2-segmented. They are similar to that of the adults. In basic pattern of organisation the female fifth legs (Pl. V, 9) like those of the fourth stage resemble the fifth legs of adult. On each side it consists of a 2-segmented protopodite and 2 rami, both of which are uniramous and of different sizes. Endopodite is devoid of setae. However, its apex gives a split appearance. Exopodite which is longer than endopodite bears two equispaced lateral and two apical spines. The latter are much shorter and larger than the former. In protopodite the basal segments are still confluent, while the separate distal segment bears long slender seta on each side.

Male is smaller than female and shows sexual dimorphism, which is externally marked in the structure of antennules, fifth pair of legs, posterior corners of prosome and in segmentation of urosome. Right antennule (Pl. III, 17) is geniculate composed of nineteen segments. The partitions between second and fifth segments are not clear unless carefully examined. The constituent segments show the following relative proportionate lengths :

1	2	3	4	5	6	7	8	9	10	11	12
4.1	10.2	1.0	1.3	2.6	3.3	2.6	2.3	3.6	4.3	3.6	5.1
13	14	15	16	17	18	19					
7.6	7.1	12.3	9.2	6.1	6.6	7.1	=100				

Besides setae, the segments in the middle region of antennule also bears a number of aesthetascs. Male fifth legs (Pl. V, 10) differ from those of female not only in structural pattern but also in that they are highly symmetrical, the right leg being larger than that of female. Each leg consists of 2-segmented protopodite and a 1-segmented exopodite, the endopodite entirely lacking. Basal protopodite of two sides are confluent. Distal segments do not bear seta. Exopodite of left side bears a lateral spine which is conical and rather insignificant and two stout apical spines. Exopodite of right side bears two apical spines which correspond to those of left side and two lateral spines. One of these lateral spines is much long and is borne a little proximal to the middle of the segment while the other smaller spine is borne at midway between the large spine and the apex.

Adults (Plate V, 1-2)

Average size female 1.43 mm. and male 1.20 mm. Krishnaswamy (1952) who first described this species has given a detailed account of the adult male and female. However, few minor differences noticed are recorded below. Krishnaswamy in his text mentions that there are 22 joints in female but figures only 20. Probably it is because 'the joints between three and five are not very clear.' However, in the present case 22 joints are very clear and there is indication of a 23rd segment. Further, a comparison of the lengths of proximal 8 segments (6 segments in the figure given by Krishnaswamy) show that the proportionate sizes of these segments do not exactly correspond in the two cases. In the organisation of

male geniculate antennule there is full agreement between the present observations and the accounts given by Krishnaswamy.

SUMMARY

The post-embryonic development of two species of calanoid copepods, *Pseudodiaptomus aurivilli* Cleve and *Labidocera bengalensis* Krishnaswamy are described in detail. The identifying features of the various nauplii and copepodites of the two species are presented and figured.

There are only five naupliar stages, instead of the usual six met with in several other species of calanoids; the first stage is suppressed. Last nauplius metamorphoses into the first copepodite which moults five times to become adult, passing on the whole through five stages. In both species the sexual dimorphism sets in from the fourth stage onwards and the chief difference between the fifth stage and adults consists in the sexual maturation and the related changes.

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