ASCIDIACEA

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A. INTRODUCTION

The Danish Deep-Sea Expedition in 1950, 1951 and 1952 collected ascidians from the Pacific Ocean, the Tasman Sea, Indonesian waters, the Indian Ocean and the Atlantic Ocean, in depths from 2084 to 7000 metres. This material makes an important contribution to our knowledge of the abyssal ascidian fauna and its geographical distribution.

All the material, including type specimens, is deposited in the University Zoological Museum, Copenhagen.

B. LIST OF STATIONS WITH SPECIES FOUND AT EACH

Station

- 30. Bathystyeloides enderbyanus (Michaelsen). Molgula galatheae sp. n.
- 24. Bathystyeloides enderbyanus (Michaelsen).
- 52. Bathystyeloides enderbyanus (Michalesen). Molgula galatheae sp. n.
- 66. Bathystyeloides enderbyanus (Michaelsen).
- 190. Bathystyeloides enderbyanus (Michaelsen).
- 196. Styela milleri Ritter.
- 217. Culeolus suhmi Herdman.
- 233. Styela sericata Herdman.
- 234. Bathystyeloides enderbyanus (Michaelsen). Culeolus suhmi Herdman. Styela sericata Herdman.
- 235. Bathystyeloides enderbyanus (Michaelsen).
- 238. Bathystyeloides enderbyanus (Michaelsen). Styela sericata Herdman. Culeolus suhmi Herdman.
- 280. Hexacrobylus indicus Oka. Styela sericata Herdman. Polycarpa albatrossi (Van Name).

Station

- 281. Culeolus suhmi Herdman.
- 282. Polycarpa albatrossi (Van Name). Styela sericata Herdman. Culeolus suhmi Herdman. Hexacrobylus indicus Oka.
- 453. Molgula immunda (Van Name).
- 474. Polycarpa albatrossi (Van Name).
- 574. Styela sericata Herdman.
- 599. Bathystyeloides enderbyanus (Michaelsen).
- 601. Cnemidocarpa bythia (Herdman). Styela sericata Herdman. Bathystyeloides enderbyanus (Michaelsen).
- 602. Cnemidocarpa bythia (Herdman). Styela sericata Herdman.
- 607. Culeolus suhmi Herdman.
- 651. Cnemidocarpa bythia (Herdman).
- 653. Cnemidocarpa bythia (Herdman).
- 654. Abyssascidia wyvillii Herdman. Cnemidocarpa bythia (Herdman).
- 661. ? Culeolus suhmi Herdman.

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Station

663. Distaplia galatheae sp. n.
Styela sericata Herdman.
? Culeolus suhmi Herdman.
Molgula immunda (Hartmeyer) f. monocarpa n. f. Station

- 664. Styela sericata Herdman.
- 665. Dicarpa simplex Millar.
- 668. Octacnemus bythius Herdman. ? Culeolus suhmi Herdman.
- 716. Dicarpa simplex Millar.

C. DESCRIPTION OF SPECIES

Family CLAVELINIDAE Forbes and Hanley, 1848

Genus Distaplia Della Valle, 1881

Distaplia galatheae sp. n. (Fig. 1)

Material:

St. 663, $36^{\circ}31'$ S. $178^{\circ}38'$ W., Kermadec Trench, 24-2-1952, depth 4410 m. sandy clay; one specimen.

Diagnosis:

Test of a clear to somewhat milky appearance. Thorax at least as long as abdomen. Gonad beside intestinal loop. Larva with only one sensory pigment spot in cerebral vesicle.

Colony:

The single colony contains only three well-developed zooids. Test fairly firm, clear to milky in appearance, with the zooids showing through. The colony was attached by a broad base.

Zooid (Fig. 1A):

About 2.4 mm long. Thorax equal to or slightly larger than abdomen.

Siphons:

The oral siphon was not distinctly seen, but is apparently short. The atrial siphon is wider, conical or tubular and projecting dorsally, but the shape of the opening could not be seen in many zooids.

Oral tentacles:

The short finger-like tentacles probably number 12-16.

Branchial sac:

Four rows of stigmata with 3 quite prominent transverse bars between adjacent rows. No parastigmatic bars were seen. The dorsal languets, of which the second is larger than the first and third, are placed on the transverse bars a short distance down the left branchial wall. Gut:

A long narrow and slightly curved oesophagus leads to the ovoid or almost globular stomach. No folds or markings could be seen on the wall of the stomach. The proximal chamber of the intestine is short and leads to the curved ascending limb.

Gonad:

A large ovoid body lying beside the intestinal loop and stomach represents the gonad, but separate ovary and testis could not be distinguished.

Brood pouch:

The brood pouch is about as large as the thorax, but does not extend beyond the posterior end of the abdomen. It is joined to the thorax by a short narrow stalk. In the zooids examined two embryos were present in each brood pouch.

Larva (Fig. 1B):

About 1.2 mm. long from the anterior end of the papillae to the base of the tail. In the best developed larvae there are three anterior papillae, of which two are dorsal and one is ventral. The papillae are quite like those of other species in the genus. Four rows of small stigmata are present in the branchial sac, and the gut is well differentiated. Both oral and atrial siphons are developed. The cerebral vesicle is, however, abnormal since it possesses only one pigmented sensory organ. It could not be determined with certainty whether this was the ocellus or the otolith, but its shape suggested an otolith. The tail,



Fig. 1. Distaplia galatheae sp. n. A, zooid; B, larva.

when coiled round the larva, reaches the oral siphon.

Remarks:

No species of *Distaplia* has hitherto been found at great depths. The structure of the present species is little modified from that of species occurring in shallow waters. Only the larva, with its loss of one sensory organ from the cerebral vesicle, is modified and if the lost organ is in fact the ocellus, the modification is correlated with life in constant darkness.

Family OCTACNEMIDAE Herdman, 1888

Genus Octacnemus Moseley, 1876 Octacnemus bythius Moseley (Figs. 2, 3; Plate 1, figs. 1, 2)

Octacnemus bythius Moseley, 1876, p. 287, pl. 44, figs. 7-13.

Material:

St. 668, 36°23'S. 177°41'E., Kermadec Trench, 29-2-1952, 2640 m, clay; one specimen.

External appearance:

The body is cylindrical to ovoid and about 1.7 cm. long. At its upper end it bears a crown of 8 flat triangular lobes, and at its lower end there is a roughened surface by which the animal was apparently attached during life. The greatest diameter across the lobes, when they are fully extended, is about 5.5 cm. The crown is not quite symmetrical as the 3 or 4 ventral lobes are longer than the others. A soft, transparent and rather thin test covers the whole surface, including the lobes. There is an opening in the test at the upper end of the body, on the area enclosed by the crown of lobes, and situated a little towards the dorsal side. This is the outer end of the oral opening. The triangular lobes are, as will be shown later, nothing more than the greatly developed lobes of the oral siphon surrounding the oral opening. The exhalent opening in the test could not be seen in this specimen but Moseley found it on the postero-dorsal surface, outside the crown of lobes. As the test is transparent the red-brown muscles of the lobes and body wall can be seen without dissection.

Internal structure:

In the fixed specimen there is a large cavity between the test and the upper, or internal, surface of the oral lobes and another surrounding the body



Fig. 2. Octacnemus bythius Moseley. A, animal removed from test; B, body from left. Muscles in black.

and extending under the lobes. These two cavities have been wrongly called the oral or branchial cavity and the atrial cavity respectively, in several previous descriptions of Octacnemus. They may be artifacts and will be discussed later (see "Remarks"). The muscles of the body have already been carefully described in this and related species (MOSELEY, 1876; Herdman, 1888; Metcalf, 1900; Madsen, 1947). In the 'Galathea' specimen the muscles agree with existing accounts and are shown in fig. 2. On the oral lobes they consist of longitudinal muscles, which have generally been called radial muscles, and circular or transverse muscles. One longitudinal muscle lies between each two lobes and forks to send a branch along the margin of each adjacent lobe. The circular muscles are anatomically external to the longitudinal ones, lying on what has been called the aboral side of the lobes. Two rows of short stout muscles, one row on each side of the body, meet ventrally; these muscles appear to belong to the circular system. A few bands of muscle are also present on the dorsal side of the body, near the ganglion.

The ganglion is an ovoid white body which gives off a pair of large antero-lateral nerves, and a branched posterior nerve probably representing the paired posterior nerves and the median rapheal nerve. Immediately behind and slightly ventral to the ganglion is the globular neural gland, with a projecting funnel which has a simple opening. The



Fig. 3. Octacnemus bythius Moseley. A, ganglion and dorsal tubercle from ventral side; B, body from the right side, dissected, A. s., atrial siphon, B. o., branchial opening, D.l. dorsal line, P.a.o., pharyngo-atrial openings, Ph., pharynx, R., rectum, St, stomach; C, suggested evolution of Octacnemus from a simple enterogonid ascidian, A. c., atrial cavity.

external part of the oral opening, in the test, has been mentioned. The oral opening proper, which leads directly into the branchial sac, is moderately wide and is encircled by bands of muscle which are extensions of the mid-dorsal longitudinal muscle of the oral siphon. There is no trace of oral tentacles. The branchial sac is simple, its walls lacking stigmata, bars, and papillae. RITTER (1906), however, found a few vestigeal stigmata in his specimens of *O. herdmani*, a closely related, if distinct, species. There is a dorsal furrow representing the dorsal lamina of other ascidians, a wide endostyle, a retropharyngeal band and peripharyngeal bands encircling the oral opening. The pharyngo-atrial openings will be described later.

The oesophagus opens at the postero-dorsal corner of the branchial sac, but no details of the oesophagus, stomach or intestine were seen clearly. The rectum lies on the left of the stomach and opens into the atrial cavity.

Neither the atrial cavity nor the atrial siphon has been recognised in previous investigations of *Octacnemus*. The atrial cavity is a small pocket lying above and behind the postero-dorsal corner of the branchial sac and extending for a short distance in a ventral direction behind the sac. It is separated from

the branchial sac by a thin partition which is perforated by two groups of pharyngo-atrial openings, one group on each side of the dorsal line. Each group of openings consists of two or three adjacent oval slits. I do not know whether these openings are transformed stigmata or newly acquired structures. The atrial siphon, as seen in the 'Galathea' specimen, is short and turned back to lie along the posterior side of the body, but this attitude was probably produced after death. I believe that the structure described and illustrated by MOSELEY (1876, pl. 44, fig. 10, r) as the rectum was in fact the atrial siphon of his specimen, as it corresponds exactly in position with the siphon in the 'Galathea' specimen. The end of the rectum lies within and at the base of the atrial siphon.

The ovary and testis, each a single compact mass, lie beside the stomach and intestine, but their detailed structure could not be seen, nor the nature of their ducts.

Remarks:

Since it was first described by Moseley Octacnemus has been studied by several workers, but its structure has never been satisfactorily related to that of other ascidians.

The very characteristic crown of lobes has not been previously recognised as the greatly developed oral siphon, the lobes themselves being the 8 enlarged oral lobes. The two surfaces of the crown of lobes have commonly been called the oral and aboral surfaces; these correspond to the internal and external surfaces of the oral siphon.

This interpretation, that the crown of lobes represents the oral siphon, is supported by (1) the position of the lobes surrounding the opening to the pharynx; (2) the arrangement of the muscles in longitudinal and circular systems with the circular system external; (3) the number of lobes corresponding to the number of oral lobes in the less modified simple ascidians like Ciona and Ascidia; (4) the arrangement of the lobes with a space between lobes occupying the mid-dorsal and mid-ventral positions, as in Ciona; and (5) the presence of test on both surfaces of the lobes, as it is on both external and internal surfaces of the oral siphon in other ascidians. The only important difference is the position of the longitudinal muscles which in Octacnemus lie between the lobes whereas in Ciona they are in line with the lobes. But this change only involves a redistribution of the constituent strands of the muscles. By accepting this view of the crown of lobes

we see *Octacnemus* to be much less aberrant than has been thought.

The discovery of the atrial siphon and atrial cavity also brings Octacnemus into line with other ascidians. Hitherto the atrial cavity has either been thought to be absent or to be represented by the space between the test and the lower part of the body. Even without the discovery of the true atrial cavity the second interpretation would have been inadmissible since the space in question is bounded externally by the inner surface of the test and internally by the outer surface of the body wall. It is uncertain if this lower space and also the space above the lobes exist in the living animal or are artifacts as RITTER (1906) maintains, but I think that they are probably artifacts produced during fixation. As a living tissue the test must almost certainly maintain contact with the epidermis.

The peculiar structure of the branchial sac implies a method of feeding unlike that of most ascidians. It has been thought that Octacnemus is predatory since both RITTER (1906) and MADSEN 1947) found the remains of relatively large animals in the gut. The 'Galathea' specimen also contains, in the upper test space, a large copepod of the species Bradvidius armatus Giesbrecht. I am indebted to Dr. W. VERVOORT of the Zoological Laboratory, the University of Leiden, and also to Mr. R. V. GOTTO of the Department of Zoology, The Queen's University, Belfast, for identifying this copepod. The copepod was probably forced out of the branchial sac and into the upper test space by contraction of the body during fixation. It seems likely that quite large animals form most of the food of Octacnemus rather than the diatoms, unicellular algae and other small organisms commonly eaten by ascidians. Perhaps, as has been suggested, the large muscular lobes play some part in capturing living animals. It may be, however, that only dead animals are taken, and Dr. VERVOORT considers that the specimen of B. armatus found in the Octacnemus of the 'Galathea' collections may have been dead when engulfed. Whether or not Octacnemus captures animals in this way it certainly is not a filter feeder, as the branchial sac lacks stigmata and is therefore unable to strain small organisms out of a current of water. Indeed, it is probable that there is no constant current of water through the pharynx, and that the pharyngo-atrial openings serve only to allow the escape of water through the atrial siphon when the oral opening is closed and the body contracts. An intermittent current of water of this kind would be needed to remove faeces and the genital products.

With regard to the systematic position of Octacnemus several features, especially the unpaired gonads and the number of the oral lobes are characters found in the subclass Enterogona, and it is to this group that the genus should be assigned. The evolution of Octacnemus from an unspecialised enterogonid ascidian is suggested in fig. 3 C. The main changes involved are the great enlargement of the oral siphon, the simplification of the branchial sac and the reduction of the atrial cavity. These are all changes which are related to a changed method of feeding, the reduction of the atrial cavity probably having followed the loss of functional stigmata in the pharynx. In looking for a hypothetical ancestor of Octacnemus we must remember that although O. bythius and O. herdmani are solitary, there is one compound species, O. patagoniensis Metcalf. The genus may have derived from a primitive social enterogonid type with an organisation rather like that of Perophora, or from a solitary enterogonid type like Ciona.

Family CORELLIDAE Lahille, 1887

Genus Abyssascidia Herdman, 1880 Abyssascidia wyvillii Herdman. (Fig. 4)

Abyssascidia wyvillii Herdman, 1880, p. 470.

Material:

St. 654, 32°10'S. 175°54'W., Kermadec Trench, 18-2-1952, depth 5850-5900 m, pumice; two specimens.

External appearance:

The specimens measure 0.9 by 0.7 by 0.3 cm. and 1.0 by 0.7 by 0.2 cm. The body is somewhat compressed and smooth, being a little rougher only on the area of attachment.



Test:

Cartilaginous and moderately thick; firm; semitransparent.

Body Wall:

Very thin. The muscles are few, widely separated and run round the body mainly in a dorsi-ventral direction.

Siphons:

The oral siphon is short but was not distinctly seen. Atrial siphon placed far back, about or a little posterior to the middle of the body; conical and indistinctly lobed.

Oral tentacles:

Not seen.

Dorsal tubercle:

Not seen.

Branchial sac:

The margin of the dorsal lamina bears a row of moderately long languets. Longitudinal bars are present but their number could not be determined, owing to the collapsed state of the branchial sac. About 3 oval stigmata occupy each mesh.

Gut:

The oesophagus is bent sharply downwards and leads to a wide ovoid or barrel-shaped stomach. Sixteen low narrow folds were counted on the exposed right wall of the stomach, and the concealed left wall may bear a similar number so that the stomach probably has altogether about 30 folds. HERDMAN (1882) gives the number as about 12, in the type specimen. The intestine makes a loop on the right of the posterior part of the branchial sac, passes dorsally on the left of the oesophagus and leads to the rectum which extends forward to the base of the atrial siphon.

Gonads:

A group of many closely crowded testis follicles occupies the right side of the intestinal loop. The ovary is represented by a few ova scattered amongst the testis follicles. The sperm duct passes to the left of the oesophagus and forward beside the rectum.

Remarks:

These two specimens from the Kermadec Trench agree very closely with the description by HERD-MAN (1882) of the type specimen which was obtained by the "Challenger" Expedition south of Australia, at a depth of 4680 metres. Only in the number of folds on the stomach wall do they differ appreciably.

A. pediculata Sluiter which was collected by the "Siboga" Expedition between Australia and New Guinea, although rather similar, is distinguished by the possession of a stalk and by the arrangement of the gut.

Family STYELIDAE Sluiter, 1895

Genus Cnemidocarpa Huntsman, 1912 Cnemidocarpa bythia (Herdman) (Fig. 5)

Styela bythia Herdman, 1882, p. 63.

Material:

St. 601, $45^{\circ}51$ 'S. $164^{\circ}32$ 'E., Tasman Sea, 14-1-1952, depth 4400 m, Globigerina ooze; one specimen.

St. 602, 43°58'S. 165°24'E., Tasman Sea, 15-1 1952, depth 4510 m, bluish clay; three specimens.

St. 651, 32°10'S. 177°14'W., Kermadec Trench, 16-2-1952, depth 6960-7000 m, clay; three specimens.

St. 653, 32°09'S. 176°35'W., Kermadec Trench, 17-2-1952, depth 6180 m, pumice; four specimens.

St. 654, 32°10'S. 175°54'W., Kermadec Trench, 18-2-1952, depth 5850-5900 m, pumice; two specimens.



Fig. 5. Cnemidocarpa bythia (Herdman). A, a specimen without test hairs; B, a specimen with test hairs; C, dorsal tubercle and part of dorsal lamina; D, gonad; E, part of gonad to show arrangement of ovary and testis; F, transverse section of gonad. T., testis lobes.

External appearance:

The body is generally roughly rectangular in outline with the two siphons at the opposite corners of the upper edge. The surface is brown and rough, often coarsely wrinkled and in some specimens is provided with hair-like processes of the test near the basal area of attachment, although all specimens were fixed to hard objects.

Body wall:

Moderately thick, brown, and rather firmly adhering to the test. Longitudinal and circular muscles are quite strongly developed.

Dorsal tubercle:

A simple round, triangular or open horse-shoe shaped slit.

Branchial sac:

HERDMAN (1882) particularly noted that this species was distinguished by its dorsal lamina which has prominent teeth or languets. All of the specimens in the present collection which were examined showed this characteristic. The longitudinal bars of a specimen 7 mm. long were arranged thus:

dorsal lamina 1 (30) 7 (8) 3 (13) 7 (6) 3 endostyle.

Gut:

The gut lies far back in the body. About 10 longitudinal folds are present on the wall of the stomach. The pyloric caecum is curved, and swollen distally. The margin of the anus is almost plain.

Gonads:

On each side of the body there is one gonad, which varies from rather short to quite long and sinuous. The central part is occupied by the ovary and a number of rounded or pear-shaped testis follicles occupy the lateral and parietal parts of the gonad. The testis follicles are closely applied to the sides of the ovary, and give the gonads the form which distinguishes Cnemidocarpa from Styela. It has been suggested (SLUITER, 1914; HARTMEYER and MICHAELSEN, 1927; VAN NAME, 1945) that this species is closely related, or perhaps identical, to Styela tholiformis Sluiter and S. orbicularis Sluiter, both from deep water. But these two species have gonads typical of the genus Styela, in which the testis follicles are distinctly separated from the ovary. Moreover the dorsal lamina of S. tholiformis and S. orbicularis has a plain undivided edge quite distinct from that of C. bythia.

Genus Polycarpa Heller, 1877

Polycarpa albatrossi (Van Name) (Fig. 6)

- *Pandocia albatrossi* Van Name, 1912, p. 579, pl. 63, fig. 111, pl. 64, fig. 113, pl. 70, fig. 146; Hartmeyer, 1912, pp. 374, 378.
- Polycarpa albatrossi Hartmeyer 1923, p. 223; Van Name 1954, pp. 256, 257; pl. 2, fig. 5; text fig. 155.

Material:

- St. 280, 1°56'N. 77°05'E., Seychelles Ceylon,
 9-4-51, depth 4350 m, fine mud; one specimen.
 St. 282, 5°32'N. 78°41'E., Seychelles Ceylon,
- 11-4-1951, depth 4040 m, mud; 7 specimens.
- St. 474, 9°49'S. 114°13'E., Sunda Trench, 11-9-1951, depth 3840-3810 m; one specimen.

External appearance:

The largest specimen is 9 mm. long; all are ovoid with the low siphons on the upper surface. Apart from the siphons and the area immediately round them the surface of the body is covered with long branched hairs each consisting of a short stout stem from the end of which arise several slender filaments. Foreign matter adheres to the hairs.

Oral tentacles:

There are about 32 slender oral tentacles.

Dorsal tubercle:

This is small with a rather simple opening which is slightly curved and either transverse or longitudinal.

Branchial sac:

These specimens have two or three low folds on each side of the branchial sac. VAN NAME (1945) describes two folds on each side, the remaining two being rudimentary or absent.

The longitudinal bars of one of the "Galathea" specimens were arranged thus: –

dorsal line 2 (12) 12 (8) 5 (3) 5 endostyle.



Fig. 6. *Polycarpa albatrossi* (Van Name). A, a test hair; B, left half of body showing gut, the two gonads, and four endocarps.

Gut:

The stomach has only about 12 folds, a small number compared with that recorded by VAN NAME (1912) who notes 20 to 25. A quite large gastric caecum is present. The intestine forms a simple loop lying close to the stomach. A number of shallow lobes surround the anus.

Gonads:

Most specimens have three gonads on the right and two on the left side. The gonads are of the usual type found in the genus. VAN NAME (1912, 1945) does not say how many gonads he found in the type specimens, stating only that they were "not very numerous".

Remarks:

In spite of slight differences in the branchial sac, stomach, and number of gonads, there is little reason to doubt that the present specimens represent *P. albatrossi*. The species has previously been recorded only from deep water in the western North Atlantic.

Genus Styela Fleming, 1882 Styela milleri Ritter (Fig. 7).

Styela milleri Ritter, 1906, p. 21; van Name 1945, p. 308, text-fig. 204.

Material:

St. 196, 29°55'S. 31°20'E., off Durban, 13/14-2-1951, depth 425-430 m, sandy mud and stones; one specimen.

External appearance:

The specimen is 7 mm. in greatest diameter, with a brown and somewhat wrinkled surface. On the upper side are the two openings, rather close together.

Body wall:

This is thin and of a purple-brown colour. The muscles consist of many fine longitudinal and circular strands.

Oral tentacles:

There are about 24 tentacles of alternating lengths.

Dorsal tubercle (Fig. 7A):

The rather small tubercle has a simple slightly curved longitudinal opening.

Fig. 7. Styela milleri Ritter. A, dorsal tubercle; B, gut and left gonad, from left.



Branchial sac:

The dorsal lamina is a moderately wide plain edged membrane. Four folds are present on each side. The folowing is the arrangement of longitudinal bars on the right side:

dorsal line 6 (11) 3 (9) 3 (7) 4 (5) 3 endostyle.

Only 2 stigmata are usually present between adjacent bars.

Gut (Fig. 7B):

The stomach has 21 complete longitudinal folds and a small pyloric caecum. There is a constriction near the end of the rectum, the terminal part of which widens. The anus has a lobed margin.

Gonads (Fig. 7B):

One gonad is present on each side, consisting of a long curved ovary with a few testis follicles gouped round its lower end.

Remarks:

In two respects the specimen from the "Galathea" collection differs slightly from RITTER's description of the type material. Firstly, the test lacks hairs, and secondly, the dorsal tubercle is simpler. But VAN NAME (1945) neither mentioned nor illustrated test hairs; and the smaller size of the present specimen may account for the simpler form of the dorsal tubercle. The differences do not therefore seem sufficient to distinguish the specimen from *S. milleri*.

Previous records of this species are from deep water off the west coasts of North and South America.

Styela sericata Herdman (Fig. 8)

Styela sericata Herdman, 1888, p. 153, pl. 11, figs. 14-16.

Cnemidocarpa platybranchia Millar, 1955, p. 226, fig. 3.

Material:

St. 233, 7°24'S. 48°24'E., Madagascar-Mombasa, 9-3-1951, depth 4730 m, Globigerina ooze; several specimens.

St. 234, 5°25'S. 47°09'E., Madagascar-Mombasa, 10-3-1951, depth 4820 m, Globigerina ooze; one specimen.

St. 238, 3°23'S. 44°04'E., off Kenya, 3980 m, Globigerina ooze; 5 specimens.

St. 280, 1°56'N. 77°05'E., Seychelles – Ceylon,

9-4-1951, depth 4350 m, fine mud; one specimen.

St. 282, 5°32'N. 78°41'E., Seychelles – Ceylon, 11-4-1951, depth, 4040 m, mud; 7 specimens.

St. 574, 39°45'S. 159°39'E., Tasman Sea, 18-12-1952, depth 4670 m; one specimen.

St. 601, $45^{\circ}51'$ S. $164^{\circ}32'$ E., Tasman Sea, 14-1-1952, depth 4400 m, Globigerina ooze; three specimens.

St. 602, 43°58'S. 165°24'E., Tasman Sea, 15-1-1952, depth 4510 m, bluish clay; one specimen.

St. 663, 36°31'S. 178°38'W., Kermadec Trench, 24-2-1952, depth 4410 m, sandy clay; four specimens.

St. 664, 36°34'S. 178°57'W., Kermadec Trench, 24-2-1952, depth 4540 m, clay; one specimen.

External apperance:

The largest specimen is 1.8 cm. in length. In all specimens the body is ovoid and more or less depressed.

The branched test hairs are generally most abundant on the sides of the body, less so on the ventral surface and usually few or absent on the dorsal surface. The oral siphon is terminal and the atrial siphon near the posterior end of the dorsal surface. Each siphon is short and indistincly lobed.

Oral tentacles:

In a small specimen these number about 16, and in the largest 36.

Dorsal tubercle:

Very small with a simple oval or crescentic slit.

Branchial sac:

In the largest specimen and in a few others the branchial wall is thrown into folds, but these may be artifacts produced by contraction, as they vary in number and distinctness. Several well preserved specimens show no trace of folds.

Gut:

In the specimens from the Swedish Deep-Sea Expedition (MILLAR, 1955) no pyrolic caecum was found, but the additional material from the 'Gala-thea' shows a small curved caecum.

Fig. 8. *Styela sericata* Herdman. A, gut; B, gonad.



Gonads:

The gonads are of variable length, slightly sinuous, and are intermediate between the *Styela*-type and the *Cnemidocarpa*-type.

Remarks:

After examining the more abundant material from the present collection I have decided that the three specimens from the Swedish Deep-Sea Expedition on which I based the species *Cnemidocarpa platybranchia* (MILLAR, 1955) do in fact represent *S. sericata* Herdman. HERDMAN's description is not very detailed, but the shape of the body, the distribution of the test hairs, the branchial sac, and the number of gonads agree with the 'Galathea' specimens.

Genus Bathystyeloides Seeliger, 1905

Bathystyeloides enderbyanus (Michaelsen) (Fig. 9)

Bathyoncus enderbyanus Michaelsen, 1904, p. 226. pl. 10, fig. 1., pl. 13, figs. 45-48.

Bathystyeloides atlantica Millar, 1955, p. 229, fig. 5.

Material:

St. 24, 3°54'N. 8°22'W., Monrovia-Takoradi, 15-11-1950, depth 3200 m, mud; one specimen.

St. 30, 0°42'N. 5°59'W., Monrovia-Takoradi, 18-11-1950, depth 5160 m, mud; many specimens.

St. 52, 1°42'N. 7°51'E., San Thomé-Camaroon, 30-11-1950, depth 2550 m, muddy clay; one specimen.

St. 66, 4°00'S. 8°25'E., 5-12-1950, depth 4020 m, mud; 6 specimens.

St. 190, 29°42'S. 33°19'E., off Durban, 3-2-1951, depth 2760 m, Globigerina ooze; one specimen.

St. 234, 5°25'S. 47°09'E., Madagascar-Mombasa, 10-3-1951, depth 4800 m, Globigerina ooze; one specimen.

St. 235, 4°47'S. 46°19'E,, north of Madagascar, 11-3-1951, depth 4810 m, Globigerina ooze; 3 specimens.

St. 238, 3°23'S. 44°04'E., off Kenya, 13-3-1951, depth 3980 m, Globigerina ooze; 6 specimens. St. 599, 45°47'S. 164°39'E., Tasman Sea, 13-1-1952, depth 4390 m; one specimen.

St. 601, $45^{\circ}51'$ S. 164°32'E., Tasman Sea, 14-1-1952, depth 4400 m, Globigerina ooze; one specimen.

External appearance:

The specimens range in length from 6 mm. to 18 mm. The dorsal surface is fairly free of test hairs, but on the ventral surface and especially on a belt round the sides of the body there are many hairs. Most of these hairs are branched, having a short stout common stem from the end of which arise a number of fine tapering filaments.

Body wall:

A single large endocarp is present on each side.

Dorsal tubercle:

The opening is small and simple, in shape either a longitudinal oval slit or a transverse crescentic slit.

Branchial sac.:

In a specimen 16 mm. long there were about 135 longitudinal bars on each side of the branchial sac, but a specimen of length 12 mm. had only about 75 on each side.

Gut:

At least 12 folds on the wall of the stomach.

Gonads:

One on each side, straight or gently curved. Most of each gonad is occupied by the ovary. The testis follicles vary in their arrangement, being in some specimens regularly distributed along each side of the ovary, and in others grouped into large irregularly placed masses. The oviduct and common sperm duct are short and separate from each other.

Remarks:

The type specimen described by MICHAELSEN (1904) was from 4636 m in the Antarctic Ocean. A second specimen was collected by the Swedish Deep Sea Expedition, in the Atlantic Ocean, at a depth of



Fig. 9. Bathystyeloides enderbyanus (Michaelsen). Gonad.

5250-5300 m, and was described by me (MILLAR, 1955) as a new species *B. atlantica*. The diagnostic characters which I used to separate this species from *B. enderbyanus* were (1) the presence of test-hairs, (2) over 100 longitudinal bars on each branchial wall, (3) the even distribution of testis follicles round the ovary. In my account of *B. atlantica* I suggested that the type specimen of *B. enderbyanus* did in fact possess test-hairs which MICHAELSEN interpreted as filamentous algae, and that the separation of the two species may rest mainly on the number of longitudinal bars in the branchial sac and the distribution of the testis follicles.

The new and more plentiful material from the 'Galathea' provides, in both the gonads and the branchial sac, conditions intermediate between the two species. The separation of B. *atlantica* can no longer be maintained, and that name becomes a synonym of B. *enderbyanus*.

This species is apparently very widely distributed, having been recorded from the equatorial Atlantic Ocean, the western Indian Ocean, the Tasman Sea, and the Antarctic.

Genus Dicarpa Millar, 1955 Dicarpa simplex Millar (Fig. 10; Pl. 1, fig. 3)

Dicarpa simplex MILLAR, 1955, p. 225, fig. 2.

Material:

St. 665, 36°38'S. 178°21'W., Kermadec Trench,
25-2-1952, depth 2470 m, clay; many specimens.
St. 716, 9°23'N. 89°32'W., Acapulco-Panama,
6-5-1951, depth 3570 m, clay; 8 specimens.

External appearance:

The specimens in this collection are indistinguishable from those collected by the Swedish Deep-Sea Expedition, from which the type description was made.

Gut:

It is now possible to add detail to the incomplete description previously given (MILLAR, 1955). The oesophagus is a wide vertical slightly curved tube, leading down to the posterior end of the stomach. The stomach itself lies almost vertically, behind the branchial sac, and has 6 to 8 longitudinal folds on its wall. These folds are mainly developed on the right side of the stomach, the left side, which is adjacent to the intestine, being flat. The intestine leaves the lower anterior end of the stomach and



Fig. 10. *Dicarpa simplex* Millar. A, gut; B, transverse section of stomach.

bends upwards almost immediately to ascend vertically on the left of the stomach.

Gonads:

Most specimens examined showed the characteristic arrangement, with one polycarp-type gonad on each side of the body, but in one animal there were one small and two large gonads on one side, and one on the other side.

Remarks:

The only previous record of this species is from 4540-4600 metres in the north Atlantic Ocean. It is remarkable that it should also occur in the Kermadec area of the south Pacific Ocean.

The genus *Dicarpa* is obviously derived from the *Polycarpa* stock, as evidenced by the type of gonads. Specialization has taken the form of a reduced number of gonads and simplification in the branchial sac. These two characters are probably related to the very restricted space available in the small body.

Family PYURIDAE Hartmeyer, 1908

Genus Culeolus Herdman, 1881

Culeolus suhmi Herdman (Fig. 11)

Culeolus suhmi Herdman, 1882, p. 86.

Material:

St. 217, 14°20'S. 45°09'E., Mozambique Channel, 27-2-1951, 3390 m; two specimens.

St. 234, 5°25'S. 47°09'E., Madagascar-Mombasa, 10-3-1951, 4820 m, Globigerina ooze; many specimens.

St. 238, 3°23'S. 44°04'E., off Kenya, 13-3-1951, depth 3980 m; several specimens.

St. 281, 3°38'N. 78°15'E., SW of Ceylon, 10-4-1951, 3310 m, Globigerina ooze; one specimen.

St. 282, 5°32'N. 78°41'E., Seychelles - Ceylon, 11-4-1951, depth 4040 m, mud; several specimens.

St. 607, 44°18'S. 166°46'E., Tasman Sea, 17-1-1952, depth 3830 m; one specimen.

External appearance:

The proportions of body and stalk vary; one typical specimen has a body length of 2.5 cm. and a stalk length of 12.0 cm. The ventral edge of the body is nearly straight and the dorsal and posterior edges arched. Oral siphon projecting as a short tube; atrial opening moderately large and not projecting. An oblique line of prominent finger-like papillae completely encircles the atrial or posterior end of the body. The stalk is slender and marked with an irregular network of internal trabeculae.

Test:

The surface of the test is raised into small low rounded swellings, many of which have a short central papilla.

Oral tentacles:

Large and simply branched.

Dorsal tubercle:

The opening of the dorsal tubercle is of variable shape and in three specimens examined from Station 234 was a narrow longitudinal slit either curved to the right or left, or very slightly S-shaped and transverse. In the specimen from Station 607 the opening was horse-shoe-shaped, facing forwards.

Branchial sac:

The folds usually bear 10-14 longitudinal bars.

Gonads:

Two gonads are present on each side of the body, the ventral one on the left lying within the intestinal loop. The ovary is continuous along the whole length of the gonad, and is also enlarged at intervals to produce a number of rounded swellings. It is on these swellings alone that the testis is developed, forming a mass of follicles covering the dorsal side. Each gonad has a single short oviduct and sperm duct.

Remarks:

Culeolus is a very distinct deep water genus, but its subdivision into species is unsatisfactory as already noted by VAN NAME, (1945).

These specimens described above were taken from great depths in the Indian Ocean and Tasman Sea. They bear such a close resemblance to the original description of *C. suhmi*, given by HERD-MAN (1882) and the later description by VAN NAME (1945) that, although *C. suhmi* has hitherto



Fig. 11. Culeolus suhmi Herdman. A, specimen from St. 234;
B, specimen from St. 668; C, specimen from St. 661; D, part of stalk; E, dorsal tubercles of specimens from St. 234; F, dorsal tubercle of specimen from St. 668.

been recorded only from the Atlantic Ocean, I cannot doubt that we are dealing with the same species.

Specimens of this genus are also in the collection from:

(1) St. 661, 36°07'S. 178°32'W., Kermadec Trench, 23-2-1952, 5340-5230 m; one specimen.

(2) St. 663, $36^{\circ}31'$ S. $178^{\circ}38'$ W, Kermadec Trench, 24-2-1952, 4410 m; one specimen.

(3) St. 668, 36°23'S. 177°41'E., Kermadec Trench, 29-2-1952, 2640 m, clay; 4 specimens.

The material from Stations 663 and 668 appears to represent one species, but I am undecided whether it is *C. suhmi*. The most striking difference is that the fringe of finger-like papillae round the posterior end is incomplete, being absent from the dorsal part of the body. The stalk bends at a less acute angle on leaving the body than is usual in *C. suhmi*, and the stalk is longer and thinner. As far as I can judge the internal structure does not differ significantly. Since the range of variation in *C. suhmi* has never been defined, and the features distinguishing the specimens from the Kermadec Trench are all external ones, I am inclined to include those specimens also in *C. suhmi*, at least provisionally. But I should be prepared to remove them if further specimens showed the same constant characters.

The single specimen from Station 661, also in the Kermadec Trench, has the body 5.5 cm. long and stalk 7.5 cm. long. As there is a complete circle of finger-like papillae round the posterior end of the body, this specimen might be regarded as a large example of C. suhmi, but the stalk is relatively much shorter than in most of the specimens of that species. C. murrayi Herdman approaches this specimen in proportions and in the presence of a complete fringe of papillae, but according to HERDMAN (1882) C. murrayi has one gonad on each side. C. gigas Sluiter has similar proportions but it also has a single gonad on each side and it is possible that C. murrayi and C. gigas may be synonymous. I am inclined to include this specimen in C. suhmi, in spite of the apparent differences, at least until the whole genus can be reviewed. This solution is not entirely satisfactory because a review of the genus must depend on an examination of much more material, from different areas, and the difficulties of getting many specimens from very great depths are such that an opportunity for a complete survey of the genus may not occur for a long time.

Family MOLGULIDAE Lacaze-Duthiers, 1887

Genus Molgula Forbes and Hanley, 1848 Molgula immunda (Hartmeyer)

Caesira immunda Hartmeyer, 1909-1911, p. 1324.

Material:

St. 453, 3°56'S. 118°26'E., Macassar Strait, 24-8-1951, depth 2000 m, clay; one specimen.

External appearance:

The specimen is about 2 cm. in diameter, very soft and almost transparent, of a round outline and perhaps slightly flattened laterally.

Test:

Soft and clear, with short tag-like hairs scattered over the surface. In dissection the test separates into an outer tougher layer and an inner softer layer.

Siphons:

The siphons are quite widely separated. The oral siphon is short and conical, the atrial siphon long and gradually tapering.

Dorsal tubercle:

The opening is small, narrow and longitudinal.

Branchial sac:

The 7 folds on each side are tall, each with up to 20 longitudinal bars. In this specimen the infundibula are tall, narrow and finger-like, rising far into the folds. VAN NAME (1945) describes the infundibula as "rather low".

Gut:

The gut is confined to the postero-ventral part of the body, forming a rather open vertical S-shaped loop.

Gonads:

The position and structure of the gonads are characteristic of this species. On the left side a gonad lies within the primary loop of the gut which it almost completely fills. On the right is a similar gonad. Each gonad is almost circular in outline with a central ovary and radially arranged testis follicles which are pear-shaped and somewhat lobed or sub-divided.

M. immunda f. monocarpa n.f. (Fig. 12).

Material:

St. 663, 36°31'S. 178°38'W., Kermadec Deep, 24-2-1952, depth 4410 m, sandy clay; 2 specimens.

Diagnosis of form:

As species but with one gonad on the right side and none on the left.

External appearance:

Body ovoid and slightly depressed, covered with rather short test hairs which are most numerous on the lateral and ventral surfaces. Siphons not at all, or scarcely, visible externally.

Test:

Rather thin and flexible.

Body wall:

Thin and semi-transparent. The muscles, which are distinct but not specially strong, are best developed on the dorsal part of the body. They consist of longitudinal and circular muscles, both sets originating from the siphons.

Siphons:

The internal siphons are distinct but short, the oral siphon with 6 pointed lobes and the atrial



Fig. 12. Molgula immunda f. monocarpa n. f. A, intact animal;B, animal removed from test; C, part of a tentacle; D, dorsal tubercle; E, gut, with renal sac and gonad of right side;F, gonad.

siphon with 4 pointed lobes. On the oral siphon the three dorsal lobes are much longer than the ventral ones.

Oral tentacles:

About 12 tentacles, compound but not strongly branched.

Dorsal tubercle:

A simple slightly curved longitudinal slit.

Branchial sac:

The dorsal lamina is moderately long and increases in width towards the posterior end. Its margin is plain. In one specimen 8 tall folds were present on the left side; only 6 could be seen on the right side but there may have been more. The exact number of folds could not be determined in the other specimen, but there were about 7 on each side. The folds are peculiar as each seems to consist of up to 10 longitudinal bars but no stigmata, which are confined to the flat portion of the branchial wall, and arranged in double spirals.

Gut:

The gut is confined to the posterior part of the left side of the body. The short curved oesophagus leads into a rather small barrel-shaped stomach, and the intestine makes an S-shaped bend. The rectum is straight and moderately long.

Gonad:

The single gonad is on the right side. It consists of a central ovoid to circular ovary, and 4 to 7

pear-shaped lobed testis follicles radially arranged on the mesial surface of the ovary. Individual sperm ducts converge to a central point from which arises a short slender common sperm duct. The oviduct is very short and inconspicuous.

Renal vesicle:

The renal vesicle lies far back on the right side, immediately posterior to the gonad. It is sausageshaped and contains a large concretion.

Remarks:

I have given a full account of this form because further specimens might prove it to be specifically distinct from M. *immunda*. The only important difference that I find is the absence of a gonad on the left side. This is a feature which might have arisen within the species on account of the restricted space available for a gonad within the small primary loop of the intestine. As only two specimens are present in the collection I am not able to decide whether they represent a local variation or a separate species, but it seems best to regard them as a form of M. *immunda*.

Molgula galatheae sp. n. (Fig. 13)

Material:

St. 30, 0°42'N. 5°59'W., Monrovia – Takoradi, 18-11-1950, depth 5160 m, mud; one specimen.

St.5 2, 1°42'N. 7°51'E., San Thomé – Camaroon, 30-11-1950, depth 2550 m, muddy clay; several specimens.

Diagnosis of species:

Test soft, with very fine hair-like processes. Circular and longitudinal muscles thin and regular. Siphons toothed. Oral tentacles large and tri-pinnate. Dorsal tubercle with longitudinal slit. Dorsal lamina with plain edge. Branchial sac with 5 tall narrow folds on each side, each fold with one longitudinal bar. Tall transverse bars. Stigmata spiral, crossed by numerous radial vessels on each of which is a row of papillae. Gut confined to posterior end of body. One gonad on each side, each consisting of a mass of testis follilcles half enclosing an ovoid ovary. Renal sac postero-ventral to right gonad.

External appearance:

The specimens from St. 52 form a mat owing to the interlacing of their test hairs. The largest specimen is 2.0 cm. in greatest diameter. All have an ovoid form obscured by a thick coat of test hairs.



Fig. 13. *Molgula galatheae* sp. n. A, animal removed from test; B, oral tentacle; C, dorsal tubercle and part of dorsal lamina; D, part of branchial wall; E, stigma; F, branchial papilla; G, parietal aspect, and H, mesial aspect, of gonad.

Test:

This is soft and flexible, and almost completely covered with very fine processes to which are attached the shells of Foraminifera.

Body wall:

The body wall is thin. Its muscles consist of regular slender circular and longitudinal strands.

Siphons:

The siphons are short and conical, with toothed margins.

Tentacles (Fig. 13B):

There are 8 large oral tentacles and about the same number of smaller ones alternating with these. The largest tentacles are tri-pinnate.

Dorsal tubercle (Fig. 13C):

All specimens examined had a similar tubercle, which is small with a narrow longitudinal slit-like opening.

Branchial sac:

The dorsal lamina is a wide raised band with two low plain-edged membranes instead of one. Five narrow folds are present on each side of the branchial sac and each fold bears on its summit one tall longitudinal bar (Fig. 13D). There are no bars between folds. Below each fold is a row of spiral stigmata. Each stigma is long and regularly coiled (Fig. 13E). A series of up to 10 radial vessels crosses each stigma and these vessels bear papillae, which are short and finger-shaped with a slightly swollen end. No cilia were seen on the papillae but the preservation may not have been sufficiently good to show them, as very few can be seen on the stigmata themselves. Transverse bars are also present connecting adjacent folds and with the folds form a series of deep pockets on the branchial walls.

Gut:

This is confined to the posterior part of the body. The oesophagus is bent before joining the stomach, which is ovoid with wide longitudinal folds. The intestine and rectum are of uniform diameter. The intestinal loop is almost closed. The margin of the anus is plain.

Gonads (Fig. 13G, H):

One gonad is present on each side of the body. On the left side it is generally a short distance anterior to the intestinal loop but in some specimens it overlaps the intestine and occasionally appears to lie partly within the loop. The right gonad has a corresponding position on the right body wall. In most specimens the gonad is pear-shaped or almost globular. The central and parietal parts are occupied by the ovoid ovary ending in a short oviduct. The pear-shaped and lobed testis follicles form a compact mass on the mesial surface of the ovary and spread also round its lateral parts. The sperm duct arises from the mesial side of the gonad, at its narrow end, and projects freely. It is longer than the oviduct.

Renal sac:

The slightly curved renal sac lies on the right side of the body a short distance from the gonad and postero-ventral to it.

Remarks:

This species is distinguished from others in the family Molgulidae particularly by the nature of the branchial folds and by the presence of papillae on the radial vessels of the stigmata. The papillae of the radial vessels are not homologous with the branchial papillae of the Phlebobranchiata, which are present on the longitudinal bars. In *Molgula galatheae* the papillae are new structures whose function is not known. They may serve to hold the mucous sheet from the surface of the stigmata but I do not know what might be the significance of this device in the process of feeding.

Family HEXACROBYLIDAE Seeliger, 1906

Genus Hexacrobylus Sluiter, 1905 Hexacrobylus indicus Oka (Fig. 14)

Hexacrobylus indicus Oka 1913, p. 6, fig. 4. Hexacrobylus arcticus Hartmeyer 1923-24, p. 133, pl. 1, figs. 5, 6.

Material:

St. 280, 1°56'N. 77°05'E., Seychelles – Ceylon,
9-4-1951, depth 4350 m, fine mud; two specimens.
St. 282, 5°32'N. 78°41'E., Seychelles – Ceylon,
11-4-1951, depth 4040 m, mud; two specimens.

External appearance:

The body is ovoid and the largest of the specimens is 1.5 cm. long. In their shape, coating of test hairs, and nature of oral and atrial siphons the new specimens agree closely with Oka's type specimens. The most striking external feature is the group of six large lobes surrounding the oral siphon, two dorsal and four ventral. Each of these lobes is shaped like a hand with the fingers spread and curved.

Siphons:

When the test is removed the body wall of the oral siphon is seen to correspond in shape to the external appearance of the siphon. A strong circular muscle runs round the rim of the oral siphon immediately behind the lobes and each lobe has a longitudinal muscle passing along its internal face. The function of these muscles will be referred to later. The oral siphon is lined with test, the conspicuous sac-like lining of the siphon being left with the general test when the body is removed.

The atrial siphon is long and bent upwards. Its opening has no prominent lobes.

Body Wall:

The body wall is thin and transparent and has a sparse coating of small tag-like projections evidently



Fig. 14. *Hexacrobylus indicus* Oka. A, animal removed from test, from left side; B, one of the oral lobes seen from the opening of the siphon; C, end of the oral siphon. L, lobe of liver, Op.ph., opening to pharynx at base of oral siphon, Ov., ovary, Ph., pharynx, R.c., renal concretion, St., stomach, T., testis.

corresponding to the short hairs of the test. Slender circular muscles are present on each siphon. The longitudinal muscles of the oral siphon are divided into a ventral set of strong bands passing down towards the lower end of the body, and a dorsal set of finer strands reaching only to the base of the oral siphon. Longitudinal muscle strands are also present on the atrial siphon.

The internal organs correspond closely with Oka's description. The atrial cavity is comparatively small and extends from the base of the atrial siphon as a short pouch on each side of the pharynx.

Remarks:

The most interesting features of the species are the reduction of the pharynx with the complete elimination of stigmata, and the large size and complexity of the oral siphon. The two conditions are related, both being concerned with feeding habits. Examination of the stomach and intestine of two specimens in the 'Galathea' material shows that small swimming crustaceans, mainly copepods, are taken in, and these probably form a large part of the food of the species. The modified pharynx is of course unable to produce a water current or to filter out small organisms. Instead it seems likely that larger animals are captured individually by means of the oral siphon and passed by muscular action of the siphon back into the pharynx. It is not known whether the crustaceans are captured alive or whether they are already dead when taken in, having died and sunk to the bottom.

The oral siphon is adapted for the capture of comparatively large single organisms, by its large size, its greatly developed hand-like lobes, and its powerful muscles. The longitudinal muscles which lie on the internal face of the oral lobes are well placed to draw the lobes quickly across the opening of the siphon, which the terminal sphincter muscle also closes.

In addition to these anatomical adaptations there are probably also physiological adaptations to this method of feeding. In normal filter-feeding ascidians, for instance, a large and possibly active animal within the oral siphon would elicit the ejection reflex by which the stimulated siphon opens to allow the expulsion of the organism causing the stimulation. In *Hexacrobylus* this reflex might prevent feeding and may have been eliminated.

Hexacrobylus and the comparatively unrelated *Octacnemus* show remarkable convergence in the modified oral siphon and pharynx, both concerned with the change from filter-feeding to the intake of large single animals.

Three species have been described in this genus: *H. psammatodes* Sluiter from near the Celebes, *H. indicus* Oka from near Ceylon, and *H. arcticus* Hartmeyer from the North Atlantic Ocean. *H. psammatodes* differs from the other two species in a number of ways. *H. indicus* and *H. arcticus*, however, have much in common, and it has always been doubtful if they are distinct. When HARTMEYER (1923-24) established *H. arcticus* he admitted the difficulty of finding characters which clearly separated it from *H. indicus*, but he distinguished *H. arcticus* by (1) its smaller size, (2) the position of its siphons, and (3) the equal size and greater subdivision of the oral lobes.

Through the courtesy of the University Zoological Museum, Copenhagen, I have been able to examine six specimens from the original material collected by the 'Ingolf' Expedition, on which the species H. arcticus was based. The smaller size of the specimens taken by the 'Ingolf' is in itself not a good character, as the size may depend largely on the local environment. Moreover the specimens taken

by the 'Galathea' are intermediate in size between OKA's specimens of H. *indicus* and HARTMEYER's specimens of H. *arcticus*. The position of the siphons is not greatly different, but the atrial siphon of H. *arcticus* is shorter and straighter than that of H. *indicus*. I consider this also an insufficient character for separating the species. There is no important difference in the structure of the oral siphon, although H. *indicus* has the two dorsal lobes

enlarged whereas *H. arcticus* has six equal lobes as HARTMEYER remarked.

An examination of the new material collected by the 'Galathea' and a re-examination of the original material from the 'Ingolf' collections have convinced me that the similarities between *H. arcticus* and *H. indicus* are more important than the differences, and I therefore regard *H. arcticus* as a synonym of *H. indicus*.

D. DISCUSSION

The material in this collection establishes the presence of ascidians down to a depth of 7000 metres, and it is reasonable to suppose that they penetrate to the extreme depths of the ocean.

Of the species collected, six (Polycarpa albatrossi, Styela sericata, Bathystyeloides enderbyanus, Dicarpa simplex, Culeolus suhmi and Hexacrobylus indicus) are already known from areas geographically remote from those in which they were collected by the 'Galathea'. This is further evidence of the wide geographical distribution of species inhabiting very deep water. (See figs. 15-20).

The difficulties of collecting material from the abyssal region make it unlikely that many specimens would be taken in a single haul, and the number of individuals, for example of *Culeolus suhmi* at Station 234, probably represents a density of population comparable with that of shallow-water species.

Although moderately dense populations may occur, few species have succeeded in penetrating to great depths and these few species have been modified by the conditions of life there. The adaptive modifications are mainly of external form. Two common modifications are the possession of a stalk, and the development of filamentous processes on the test. Only those forms that live attached to a solid object lack one or other of these adaptations. Thus *Distaplia galatheae*, *Abyssascidia wyvillii*, and *Cnemidocarpa bythia*, all of which were, or are presumed to have been, attached to pumice or other solid object, lack both a stalk and test hairs. Even within this group some specimens of *Cnemidocarpa bythia* possess test hairs.

Most of the species in the collection are also remarkable for their rather small size; the only exception is in Culeolus, a genus which, significantly, has a very long stalk. We do not know the attitude of *Culeolus* in life, but the stalk is probably not rigid enough to hold the body off the bottom. It is however, sufficiently long and flexible to allow the body to move freely under the influence of water currents if these exist, or as the result of the periodic unstimulated contractions which have been observed in some ascidians. In either case the effect would be to prevent the body from sinking into the soft substratum, an event which would interfere with the filtering activity of the branchial sac. Those species which lie free on the surface of the ooze are able to stay on the surface by virtue of their coating of long test hairs. But as there may well be a limit to the



Fig. 15. Distribution of Polycarpa albatrossi (Van Name).



Fig. 16. Distribution of Styela sericata Herdman.



Fig. 17. Distribution of Dicarpa simplex Millar.

weight of body which this mechanism can support, these species are perhaps prevented from attaining a large size, and this, rather than a shortage of food, may be the limiting factor.

The larva of *Distaplia galatheae* shows, in the loss of the ocellus, the elimination of an organ which is no longer useful in the total darkness of deep water.

Another kind of adaptation concerns the method of feeding. The Ascidiacea evolved in comparatively shallow water and are adapted to life in waters rich in phytoplankton. The filter-feeding habit is related to these conditions and when certain ascidians started to penetrate greater depths the decreasing quantity of phytoplankton presented them with difficulties. Most deep water species, however, are still filter-feeders and must find enough suspended food in the water. The stomach contents of specimens of *Culeolus suhmi* taken from nearly 5000 metres have been examined for me by Dr. M.W. PARKE of the Plymouth Laboratory, to whom I am indebted for the following list of material identified.

- (1) many frustules of diatoms,
- (2) skeletons of Silicoflagellata, quite common,
- (3) Coccolithophoridaceae- cells still with cocco-

liths round them, loose coccoliths, and apparently cysts of Coccolithophoridaceae, fairly frequent,

(4) pieces of the skeletons of Radiolaria, quite frequent.

(5) brown walled cells, 3 to 10 μ , similar to nonmotile stages of the genus *Chrysochromulina*, very frequent.

(6) various plant cells, apparently naked, possibly cells which have lost their coccoliths, other Chryso-phyceae and occasional Dinoflagellates.

It appears from this list that *Culeolus* is a phytophagous filter-feeder and the same is probably true of many other deep water ascidians. The source of food material is presumably the slow rain of cells from the upper layers of water.

Most ascidians that have penetrated the depths have thus done so without fundamentally changing their method of feeding. The existence of quite different feeding methods in the two abyssal genera *Octacnemus* and *Hexacrobylus*, however, indicates that there exist considerable difficulties for filterfeeding animals at great depths, and that these difficulties have applied selective pressure favouring methods of feeding in which larger single organisms are taken. Although these two genera are the only



Fig. 18. Distribution of *Bathystyeloides enderbyanus* (Michaelsen).

Fig. 19. Distribution of Culeolus suhmi Herdman.



ones in which we have direct evidence, in the form of stomach contents, of a change from filter feeding, it is likely that some other abyssal genera showing similar anatomical modifications have similarly modified feeding habits. Thus in Dicopia and Megalodicopia the oral siphon is much enlarged and the pharynx has no true ciliated stigmata. These abyssal ascidians have probably the same feeding method as Octacnemus and Hexacrobylus. There is in addition one ascidian known from relatively shallow water, Oligotrema psammites Bourne, which feeds on quite large individual amphipod and copepod crustaceans and which shares with Octacnemus and Hexacrobylus the reduction of the pharynx and the enlargement of the oral siphon. It is possible that Oligotrema evolved in deep water where it acquired these adaptations and that it subsequently spread to shallower water.

Only one of the species in the collection is compound, and it appears that conditions in deep water favour solitary rather than compound forms.

Three possible reasons for this are suggested. The first is the relative scarcity of large solid objects over which compound ascidians can spread, an extended horizontal sheet being a common habit, especially in the *Didemnidae*, *Polyclinidae* and *Botryllinae*. The second possible reason concerns the interference with efficient filtering which the small zooids of compound forms might suffer living in the soft interface between ooze and overlying water. The solitary forms, having more powerful musculature, may be better able to deal with an excess of suspended matter in their feeding current.

The third factor which may act against compound forms is connected with their reproductive capacity. It is characteristic that the colonial habit involves reduction in size of the individual. It is also com-

monly associated with a diminished number of eggs in each zooid, although the eggs are given an increased chance of surviving to found a new generation by their retention within the zooid or colony until they have developed into advanced larvae. Retention within the parent is of positive survival value in shallow water where many pelagic larvae are lost through predation by plankton-feeding animals, or through their being carried by water currents away from localised favourable conditions. In deep water, however, loss by predation is small, and as the seafloor is uniform over large areas, larvae are unlikely to be carried by currents to an unfavourable place by the time they are ready to settle. Solitary forms retain their capacity to produce large numbers of eggs and the fact that there is a longer pelagic period before settlement is not a disadvantage in deep water. Therefore from this point of view also, compound species are at a disadvantage compared with solitary species. It may be that all three factors play a part in determining the relative scarcity of compound species.



Fig. 20. Distribution of Hexacrobylus indicus Oka.

	South Polar Sea	North Polar Sea	Atlantic Ocean	Indian Ocean	Pacific Ocean	Depth in metres
Family Clavelinidae		<u> </u>		·		
<i>Distaplia galatheae</i> sp. n.		—			+	4410
Family Polyclinidae Pharangodictyon mirabile Herdman			*****	+	_	2880
Family Didemnidae Leptoclinides faröensis Bjerkan	_	÷	+			0-2847
Family Octacnemidae Octacnemus bythius Herdman O. herdmani Ritter					++	1957-2640 4063-4087
Family Corellidae						
? Chelvosoma inaequale Redikorzev					-1-	985-3638
Abyssascidia wyvillii Herdman				+	+	4680-5900
Corynascidia suhmi Herdman	+			+	+	2475-4636
Benthascidia michaelseni Ritter					+	3927
Family Ameridaa						
Agnesia depressa Millar		_	+			5850-5860
					-	
Bathvascidia vasculosa (Herdman)	_			+		3510
Family Hypodytniidae		_			-1	5220
Hypobylnius cutycodes Moseley						5220
Family Styelidae						
Hemistyela pilosa Millar			+			5250-5300
Cnemidocarpa drygalskii (Hartmeyer)	_				+	3310
C. bathyphila Millar		-·	+			5250-5300
C. bythia (Herdman)				+	+	4510-7000
Polycarpa albatrossi (Van Name)				+	+	2599-4350
Styela sericata Herdman			+	+	+	3510-5860
S. milleri Ritter	*****			<i>—</i>		425-4080
S. pusilla Herdman					+	3090
S. squamosa Herdman				+		4680
S. bathybia (Bonnevie)						2195
Dicarpa simplex Millar			+		+-	2470-4600
Bathyoncus discoideus Herdman					+	4140
B. herdmani Michaelsen	+					4636
B. minutus Herdman					+	5625
B. mirabilis Herdman	and an address	_		+	×	2880
Bathystyeloides enderbyanus (Michaelsen)	+		+	_		2550-5300
Family Pyuridae						
Bathypera splendens Michaelsen	+	<u> </u>		_		350-4636
Fungulus antarcticus Herdman	+			<u> </u>		4473
F. cinereus Herdman				+		2880
Culeolus moselevi Herdman					+	4365
C. murravi Herdman	+				+	3397-4636
C. pyramidalis Ritter					+	4010-4066
C. recumbens Herdman					·	2475-3594
C suhmi Herdman	_	ومحمدين	+	+	+-	2894-4820
C willamaasi Herdman			1	1	4	4140
C. millemoest filoralitati					1	3500
C. nevlatus Herdman	_		_	 _L	1	2880
2. Hoterostiama singularo (Van Nama)			1.	T		5005
<i>i neterostigma singulare</i> (van iname)			+		. —	5005

List of species of ascidians recorded from depths of more than 2000 metres

Ε.

	South Polar Sea	North Polar Sea	Atlantic Ocean	Indian Ocean	Pacific Ocean	Depth in metres
Family Hexacrobylidae						
Hexacrobylus indicus Oka	—	+	+	+	—	891-4350
Family Molgulidae						
Molgula bathybia (Hartmeyer)	+		Appropriate a			4636
M. immunda (Hartmeyer)					+-	1788-4410
M. verrilli (Van Name)	-		-+-			3184
M. galatheae sp. n.	—		+			2550-5160

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Plate 1, fig. 1, Octacnemus bythius Moseley. Photograph of intact animal, from the dorsal side; fig. 2, photograph of intact animal, from the left side; fig. 3, Dicarpa simplex Millar, a group of intact animals.

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