

A REVISION OF THE SYSTEMATICS OF AUSTRALIAN SIPUNCULANS (SIPUNCULA)

by

S. J. EDMONDS

Honorary Associate, South Australian Museum, Adelaide, South Australia, 5000

ABSTRACT

EDMONDS, S. J. 1979. A revision of the systematics of Australian sipunculans (Sipuncula). *Rec. S. Aust. Mus.* 18(1): 1-74.

The author lists 57 species and subspecies of sipunculans reported from Australia and has examined Australian specimens of 43 of them. Three new species are described—*Phascolion cronullae* from the shell of *Gazameda gunnii* (Reeves), *Themiste variospinosa* and *Paraspidosiphon johnstoni*. The other species examined are redescribed. The Australian sipunculans belong to 4 families and 12 genera. The genus *Themiste* is considered to comprise 3 new subgenera: *Themiste s.s.*, *Lagenopsis* and *Stephensonum*. The genus *Centrosiphon* Shipley, 1903, because the type is thought to be a *Golfingia*, is considered to be invalid. Specimens identified by Edmonds (1956) as *Aspidosiphon klunzingeri* Selenka & de Man are now considered to be a new species, *Paraspidosiphon johnstoni*. Specimens identified by Edmonds (1956) as *Aspidosiphon steenstrupii* Diesing are now thought to be *Paraspidosiphon formosanus* (Sato, 1939). *Phascolosoma heronis* Edmonds, 1956 is now considered to be a junior synonym of *Phascolosoma stephensoni* (Stephen, 1942) and *Phascolosoma dunwichi* Edmonds, 1956 a junior synonym of *Phascolosoma scolops* (Selenka & de Man, 1883). *Aspidosiphon elegans elegans* (Chamisso & Eysenhardt, 1821) is considered to include *Aspidosiphon exilis* Sluiter, 1902. Suggestions about narcotising and dissecting specimens are given and the ecology and habits of the group are discussed. Maps showing the distribution of sipunculans in Australia are also included.

CONTENTS

I. INTRODUCTION	Page
Aim of the study	1
Characters of the phylum Sipuncula	2
Sipunculans, echiurans, etc.	2
Where sipunculans are found	2
The ecological role of sipunculans	2
Narcotising and dissection of sipunculans	4
Previous systematic studies of Australian sipunculans	5
Australian collections of sipunculans	7
Acknowledgments	7

II. SYSTEMATICS

Phylum Sipuncula and list of species reported from Australia	7
Key to families of Sipuncula	8
Family Sipunculidae and key to genera	8
<i>Sipunculus</i> and key to species	8
<i>Xenosiphon</i> and key to species	12
<i>Siphonosoma</i> and key to species	14
Family Golfingiidae and key to genera	18
<i>Golfingia</i> and key to species	18
<i>Phascolion</i> and key to species	29
<i>Onchnesoma</i>	32
<i>Themiste</i> and key to species	32
Family Aspidosiphonidae and key to genera	43
<i>Aspidosiphon</i> and key to species	43
<i>Paraspidosiphon</i> and key to species	49
<i>Cloeosiphon</i>	54
<i>Lithacrosiphon</i>	54
Family Phascolosomatidae and key to genera	55
<i>Phascolosoma</i> and identification of species	55

III. REFERENCES	71
-----------------	----

I. INTRODUCTION

Aim of the study

It is twenty years since the last general work on the systematics of the Australian sipunculans was published (Edmonds 1955, 1956). In the meantime more specimens have been collected and changes have been made in the systematics of the phylum. Some of the more recently collected specimens are new species and others are species not previously reported from Australia. Further, the additional specimens enable information about some of the previously described species to be extended and imperfections in their descriptions, and even errors in their identification, to be corrected. The aim of the study is to bring up to date, as far as it is possible, the systematics of the Australian sipunculans. Seeing that many parts of the coast, especially the northern ones, have still not been visited by collectors it seems almost certain that more species will be found in the future.

In identifying the animals I have relied mostly on the description of their external and internal anatomy. Little or no attempt has been made to use some of the more modern methods that are sometimes employed to separate closely related species and to determine new ones, for instance the

use of electrophoretic techniques (Manwell 1977 p. 331) or the study of chromosomes. The difficulties of using some of these methods when most of one's material is already fixed are great. As far as is possible I have worked with the concept in mind that a species consists of a population of animals and that it is not just a single animal or type specimen.

Most of the specimens have been collected intertidally or from the upper sublittoral zone and only a few have been dredged. I have included specimens from Lord Howe Island but not from Norfolk Island nor the eastern regions of the Tasman Sea, although it is possible that the range of the species may extend to the home waters of Australia. I have included the records of Australian species not seen by me but which have been identified by other workers. I have made little or no attempt to examine these records critically but I have included the species in the keys that are given in the paper.

Characters of the phylum Sipuncula†

Sipunculans are a group of unsegmented, coelomate, bilaterally symmetrical, marine invertebrates. Their body consists of two chief parts, a cylindrical, globular, flask- or sac-like, highly muscular trunk and a highly extensible and comparatively slender introvert, that is capable of complete retraction within the trunk. The mouth opens at the anterior extremity of the introvert and is usually wholly or partly surrounded by a group of tentacles or a tentacular fold. The introvert may be armed with hooks or spines (sometimes both); it may, however, be unarmed. Small glandular openings and hemispherical, conical or rather flat papillae are usually present on the trunk and introvert. Setae are absent. The alimentary canal is long and usually wound into a spiral for most of its length. The anus is usually situated dorsally on the anterior surface of the trunk. In most genera two nephridia open to the exterior on each side of the nerve cord near the anus but only one nephridium is found in the genera *Onchnesoma* and *Phascolion*. A contractile vessel is attached to the anterior region of the oesophagus. Anteriorly it branches into the tentacles but posteriorly it ends blindly. It is usually single but sometimes double; it may be simple or give off few to many tubules which may be long or short. The blood cells contain the respiratory pigment haemerythrin. The ventral nerve cord is unsegmented and the brain lies dorsally near the anterior extremity of the introvert. The gonads develop at the base of the retractors and the sexes, although separate, are indistinguishable externally. Fertilisation is external, cleavage of the zygote is spiral and the larva is a trochophore. No

segmentation appears during development. One species is known to be a protandrous hermaphrodite and two species are known to reproduce asexually.

Sipunculans, echiurans, holothurians etc.

Holothurians, sand-burrowing anemones, nemertines and especially echiurans are often mistaken for sipunculans. It is not difficult, however, to distinguish between them. The introvert of a sipunculan can be completely retracted into the body cavity but the proboscis of an echiuran cannot. The mouth of a sipunculan is placed at the anterior tip of the introvert but in an echiuran it lies on the trunk at the base of the proboscis. The anus of a sipunculan is usually situated anteriorly on the dorsal surface of the trunk but in an echiuran it is at the posterior extremity of the trunk. Tentacles are usually associated with the mouth of a sipunculan but are lacking in an echiuran. Setae are absent in sipunculans but usually a pair of them protrudes from the surface of an echiuran just posterior to the mouth.

Although they possess tentacles, anemones lack an introvert, a tubular alimentary canal and nephridia. Nemertines possess a posteriorly placed anus, they lack a body cavity and are usually without tentacles. Holothurians lack an introvert and the anus is posterior.

Where sipunculans are found

Sipunculans live in tropical, temperate and polar seas and their bathymetric range is wide. Many have been found intertidally and others have been dredged at depths of 6 860 m (Murina, 1964a p. 250; Stephen & Edmonds, 1972 p. 4 and 79; Cutler, 1977 p. 155). Fisher (1952 p. 371) thinks that, being soft bodied and defenceless creatures, they will probably live in any protected place that provides access to reasonably clear water and food.

In Australia most sipunculans have been collected intertidally or from shallow waters. They have been found in limestone reefs, in reef-forming and solitary corals, in mangrove flats, under stones, in fissures of non-calcareous rocks, in clumps of mussels, in masses of serpulid worms, in cracks in wooden jetty piles, in the holdfasts of algae, amongst the roots of marine angiosperms, in firm sand, in fine mud, in the empty shells of a number of molluscs and in the tubes and tests of larger foraminiferans.

Records of some species dredged off the Australian coast are given in Murina (1972) and Cutler (1977).

The ecological importance of sipunculans

Sipunculans perform a number of roles in the environment. Most are detritus feeders, some assist in the breaking down of limestone and

Footnote†. Based on the characters given in Stephen & Edmonds (1972): pp. 18-19.

coral reefs, some serve as food for other animals, some live commensally with solitary corals, anemones and molluscs, and others act as either the intermediate or final hosts of parasites.

The gut of sipunculans usually contains sand, mud, small particles of coral or limestone rock, pieces of algae or marine angiosperms, fragments of molluscan shells and echinoderm exoskeleton, the frustules of diatoms and the skeletal parts of foraminiferans. The information suggests that sipunculans are detritus feeders and that they extract any food contained in whatever they ingest. Chin and Wu (1950) claimed that diatoms were an important constituent of the food of a number of sipunculans collected at Amoy, China. In her experiments on the development of sipunculans Rice (1970: p. 142) fed the larvae on algal cultures of *Phaeodactylum tricornutum* and *Isochrysis galbana* and the larvae of *Phascolosoma agassizii* on "mixed diatoms and dinoflagellates collected from tidal pools" (Rice 1973 p. 3).

Very little experimental work, however, has been done on the feeding habits of the group. Peebles and Fox (1933) observed (1) that *Themiste* (= *Dendrotonum*) *zostericola* burrows in perfectly clean sand which contains no food but that in these conditions the animal does not ingest the sand, (2) that the tentacles are sensitive to small particles of food and to traces of chemicals and (3) that the anterior region of the introvert, the tentacles and the collar are the most sensitive to contact with foreign substances. It is possible, therefore, that sipunculans do not indiscriminately swallow their environment but that they are able to exercise some selection as to what they eat. Gardiner (1903: p. 333) claims that some sipunculans break down coral fragments into smaller particles. They do not, however, possess a crop and gizzard like earthworms or a gastric mill like some crustaceans.

Rice (1976 p. 126) reports that there are at least two patterns of feeding behaviour in rock-dwelling sipunculans. Species with long, extensible introverts and short digitiform tentacles feed by extending their introvert from the mouth of the burrow and grazing the surface of the rock near them. She says, "*Phascolosoma perlucens*, maintained in the laboratory in intact burrows has been observed to feed from the surface of the rock on sediment and detritus. Some particles adhere directly to the tentacles while others seem to be scraped off the rock by the small hooks of the introvert." On the other hand rock-dwelling species with long filiform tentacles and relatively short introverts such as *Phascolosoma antillarum* and *Themiste lageniformis* make use of a ciliary-mucus mechanism. "The tentacular crown is

extended above the mouth of the burrow and particles adhering to the sticky tentacles are directed by ciliary currents into the digestive tract."

Although sipunculans may inhabit the tubes and cavities made by other animals, it is known that some species, especially those belonging to the genera *Phascolosoma*, *Aspidosiphon*, *Paraspidosiphon*, *Cloeosiphon*, *Lithacrosiphon* and *Themiste* are able to construct their own homes in calcareous rock. Such species play an important part in the breaking down of coral and limestone reefs. The importance of sipunculans as members of a coral reef community is discussed in Rice (1976: p. 122). How soft bodied creatures are able to bore into hard rock is a baffling problem. The researches of Rice (1969), Rice and McIntyre (1972) and Williams and Margolis (1974) suggest that mechanical abrasion and chemical action are involved.

Sipunculans are a source of food for a number of different animals. Kohn (1975 pp. 313-331) has reviewed the topic in an article on predation on sipunculans. Pallas (1774) reported that *Siphonosoma edule* was used as food by the Batavians and Sato (1935) that *Sipunculus indicus* was eaten by the natives of Palau Is. Chin (1947) reported that *Sipunculus nudus* was eaten at Amoy, China and went as far as to supply a recipe for its preparation as a dish. Many fish eat sipunculans, Kohn (1975) lists two orders of elasmobranchs and six orders (17 families) of teleosts. He says that "the fishes are all generalized predators on benthic invertebrates but sipunculans, mainly *Aspidosiphon*, are the major prey of the stingray *Dasyatis americanus* and the margate *Haeumulon album* in the Caribbean. In the trunkfish *Lactophrys triqueter* and the economically important haddock, *Melanogrammus aeglefinus*, in the Barents Sea, *Aspidosiphon spinoscutatus* and *Golfingia marginacea* are only second to polychaetes in the diets in nature. In other fishes sipunculans represent subsidiary or incidental components of the diet." In South Australia small specimens of *Sipunculus robustus* are sometimes found in the stomach of the local King George (spotted) whiting *Sillaginodes punctatus*. Some sipunculans collected in such a way by W. Zeidler (3/1/76) are in the collection of the South Australian Museum (reg. no. E 1072).

Kohn says that only a few invertebrates are known to prey on sipunculans in nature. Kohn (1970, 1975) reports that the gastropod *Mitra litterata* preys on sipunculans that burrow in the intertidal limestone reef at Oahu, Hawaii. Sixteen of the 24 specimens of *Mitra* that he examined were each found to contain the remains of one sipunculan. The species eaten were *Phascolosoma scolops*, *P. stephensoni* (= *P. heronis*) and *Aspidosiphon elegans*. It is believed that the animals were eaten mostly during the night.

The sipunculan *Aspidosiphon jukesii* Baird lives commensally in the base of the solitary corals, *Heteropsammia* and *Heterocyathus*; the association is well documented and described (Bouvier 1895; Sluiter 1902; Stephen and Robertson 1952; Goreau and Yonge 1968; Yonge 1975; Rice 1976). Some of Rice's observations are referred to in the present paper on p. 49. Specimens of *Golfingia hespera* (Chamberlin) were found as commensals in the tubes of *Cerianthus* (Fisher 1952) and syllids are sometimes found in association with specimens of *Phascolin* (see p. 30). A list of some molluscs associated with sipunculans is given in Stephen & Edmonds, 1972 p. 342.

Sipunculans may contain parasites in their gut, body fluids or tissues. The most commonly found parasitic protozoans are sporozoans, especially gregarines. Some of the records are listed in Stephen & Edmonds (1972 p. 341) and further information is given in Jones (1975b p. 349). Rhabdocoelae have been reported from the gut of at least four different sipunculans and encysted metacercariae of unidentified trematodes from the intestine, brain, tentacles, gonads and contractile vessel of several species (Stephen & Edmonds 1972 p. 341). Nematodes have been reported from the body cavity of at least three species (Augener, 1903 p. 361; Edmonds, 1976 p. 222; Jones, 1975a p. 343).

Narcotisation and dissection of sipunculans

Sipunculans are usually much more easily indentified if they have been relaxed before they are preserved. The nature and arrangement of the tentacles and the presence of hooks and spines are readily observed if the specimen has been narcotised. One way of doing this is to place them in a dish containing sea water to which is carefully added (drop by drop) some 80% alcohol in which some menthol has been previously dissolved. It may take from a half to six hours before the animals do not respond to touch. The specimens should then be left overnight in 5% neutral formalin and stored in 70% alcohol.

Not many sipunculans can be identified from their external appearance; most require to be dissected. One method is to pin them out under water in a dish containing a layer of solidified paraffin wax about 20 mm thick. Place the dorsal (anal) side uppermost. With the aid of a sharp scalpel or fine scissors and forceps cut the body wall longitudinally along a line just to one side of the anus. Lift up the body wall ahead of the cut so that the incision does as little damage as possible to the structures underneath. Cut the whole length of the trunk and pin back the flaps. Wash away coagulated blood with the aid of a stream of water from a wash bottle.

In order to make a mount of the introvert hooks or body papillae, snip off a small section of the skin and place it on a slide with a drop of glycerine. Tease up the tissue containing the hooks with the aid of two fine needles. When the preparation is now examined under low power single hooks or groups of hooks can often be seen. Remove unwanted tissue and cover with a cover slip. Only hooks that lie flat should be drawn. There is no need to tease the piece of tissue containing the papillae.

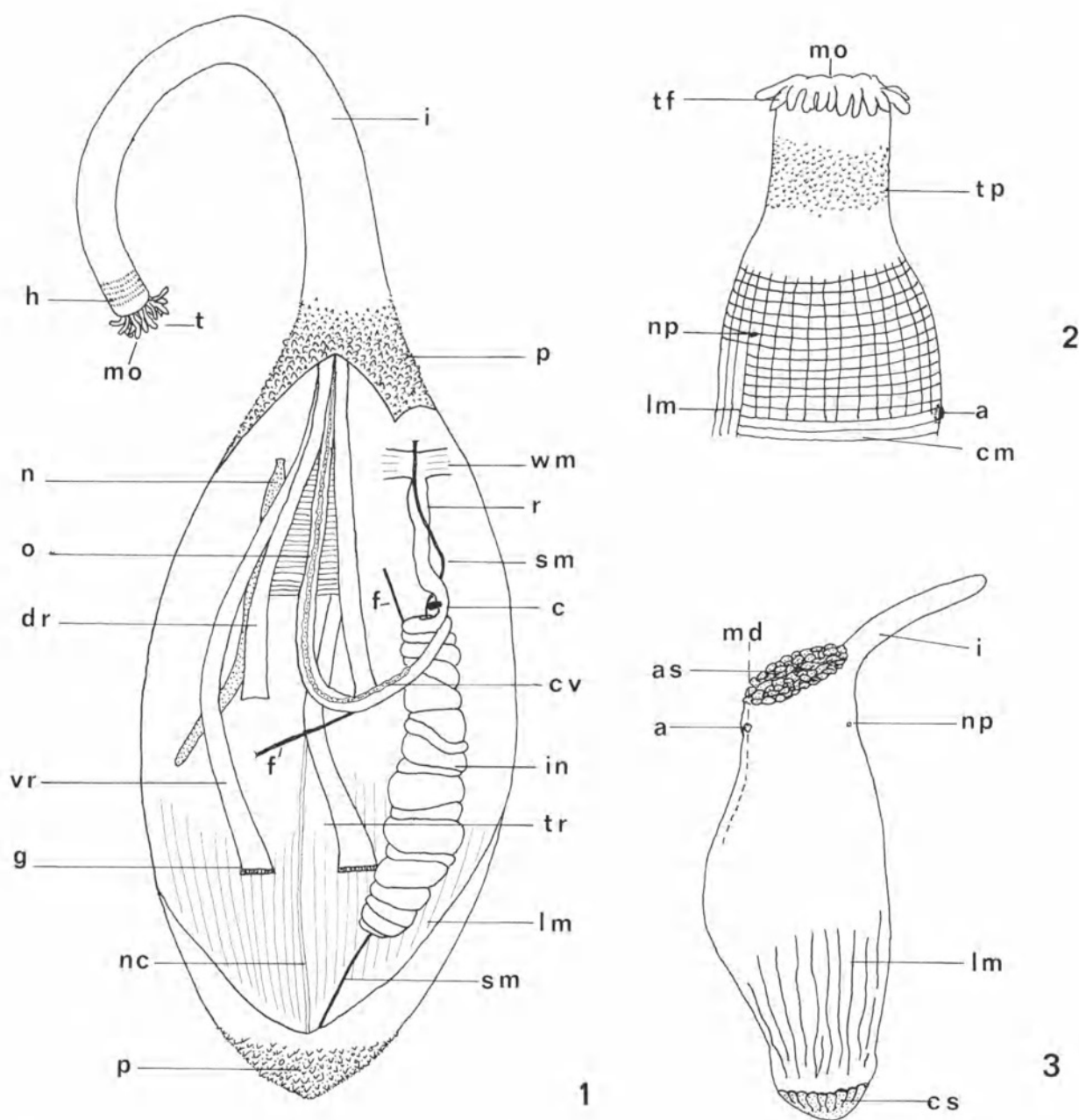
Figures 1-3 show some structures of a dissected sipunculan.

A glossary of terms used in sipunculan taxonomy is given in Stephen and Edmonds (1972 pp. 8-11).

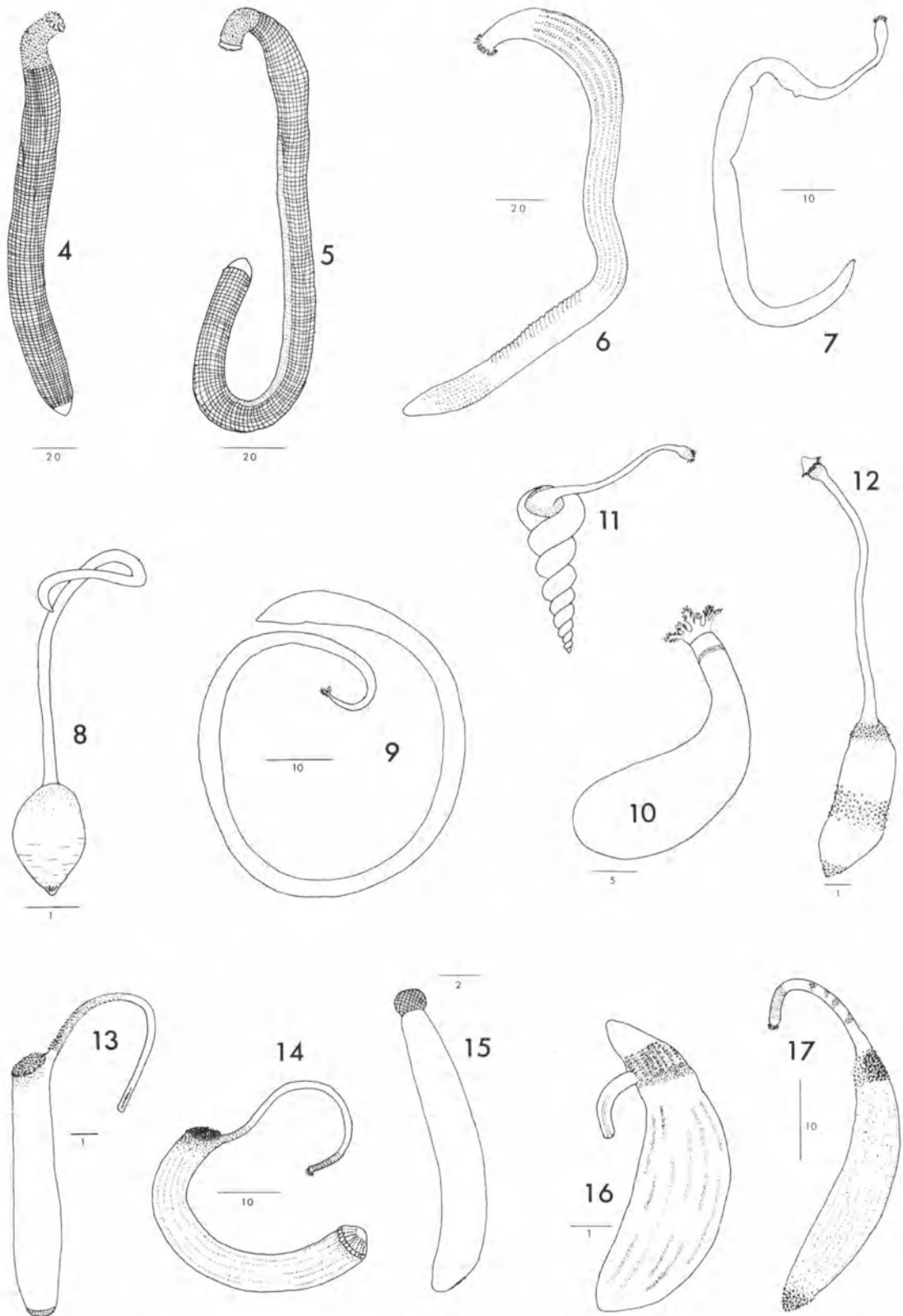
Previous systematic studies of Australian sipunculans

Records of sipunculans from Australia are contained in the following: Stimpson (1855), Keferstein (1865), Baird (1868), Selenka & de Man (1883), Augener (1903), Kesteven (1903), Fischer (1914, 1919a, 1921, 1927), Monro (1931), Wheeler (1938), Edmonds (1955, 1956), Murina (1964a, 1972), Cutler (1977) and Gibbs (1978).

More general information about the systematics of the phylum is given in Hyman (1959), Tétry (1959), Fisher (1952), Stephen & Edmonds (1972), Cutler (1973) and Cutler & Murina (1977).



FIGS. 1-3. Diagrams showing some of the external and internal characters of sipunculans. The specimen in Fig. 1 has been dissected from the dorsal side. a, anus; as, anal shield; c, caecum; cm, circular muscle; cs, caudal shield; cv, contractile vessel; dr, dorsal retractor; f, fastening muscles; g, gonad; h, hooks; i, introvert; in, intestine; lm, longitudinal muscle; m, mesentery; md, mid-dorsal line; mo, mouth; n, nephridia; nc, nerve cord; np, nephridiopore; o, oesophagus; p, papillae; r, rectum; sm, spindle muscle; t, tentacles; tf, tentacular fold; tp, triangular papillae; tr, trunk; vr, ventral retractor; wm, wing muscle.



FIGS. 4-17. Diagrams of Australian genera of sipunculans; 4, *Sipunculus*; 5, *Xenosiphon*; 6, *Siphonosoma*; 7, *Golfingia*, 8, *Onchnesoma*; 9 & 10, *Themiste*; 11, *Phascolion* (in shell); 12, *Phascolion* (removed from shell); 13, *Aspidosiphon*; 14, *Paraspidosiphon*; 15, *Cloeosiphon*; 16, *Lithacrosiphon*; 17, *Phascolosoma* (The numbers along the scale give its length in mm)

Australian collections of sipunculans

Collections of sipunculans are held in the Museums of all the States of Australia. The largest are those in the Australian Museum, Sydney and the South Australian Museum, Adelaide. A list of all the specimens in the latter Museum and their registered numbers is available on application to the Museum.

In the present paper the following abbreviations are used in referring to the collections: AMS—Australian Museum, Sydney; SAM—South Australian Museum, Adelaide; NMV—National Museum Victoria, Melbourne; WAM—Western Australian Museum, Perth; TM—Tasmanian Museum and Art Gallery, Hobart; QM—Queensland Museum, Brisbane. The number in brackets in the reference gives the number of specimens in the collection.

Acknowledgements

I am indebted to the following for the help that they have given me: Dr. P. Hutchings and Miss E. Pope (Aust. Mus., Sydney), Dr. B. Smith (Nat. Mus., Melbourne), Dr. A. Green (Tas. Mus., Hobart), Mr. W. Zeidler (Sth. Aust. Mus.), Dr. R. George and Mrs. L. Marsh (West. Aust. Mus.), Mr. A. Dartnall (Mus., Darwin), Mr. W. Green, Dr. D. Fielder, Prof. W. Stephenson and Mr. S. Cook (Dept. of Zoology, Univ. of Queensland), Miss I. Bennett (Univ. of Sydney), Prof. E. Cutler (Utica, U.S.A.), Dr. M. Rice (Smithsonian Instit., U.S.A.), Dr. V. G. Murina (Sevastopol, U.S.S.R.), Mr. R. Sims, and Mr. E. Easton (Brit. Mus. Nat. Hist., London), Dr. van der Spoel (Zool. Mus., Amsterdam), Dr. G. Harwich (Humbolt Mus., Berlin, D.D.R.) and particularly Dr. P. E. Gibbs (Marine Lab., Plymouth, England) who generously sent me duplicates of specimens collected by him at the Great Barrier Reef. Mr. P. Kempster (Univ. of Adelaide) took the photographs and Miss Lesley Howard drew some of the figures.

II. SYSTEMATICS

Phylum Sipuncula and list of species reported from Australia

The characters of the phylum are stated on p. 2. (Specific names are in alphabetical order and Australian specimens of the species marked * have not been seen by me).

Family Sipunculidae

Sipunculus indicus Peters

Sipunculus robustus Keferstein

Sipunculus titubans titubans Selenka & de Man

Xenosiphon mundanus (Selenka & de Man)

**Siphonosoma australe* (Keferstein)

Siphonosoma boholense (Selenka & de Man)

Siphonosoma cumanense cumanense (Keferstein)

Siphonosoma novaepommeraniae Fischer

Siphonosoma rotumanum (Shipley)

Siphonosoma vastum (Selenka & de Man)

Family Golfingiidae

**Golfingia coriacea* (Keferstein)

Golfingia herdmani (Shipley)

**Golfingia improvisa* (Théel)

Golfingia margaritacea adalaidensis Edmonds

**Golfingia minuta* (Keferstein)

Golfingia misakiana (Ikeda)

**Golfingia murinae murinae* Cutler

**Golfingia ohlini* (Théel)

**Golfingia pellucida* (Keferstein)

Golfingia schuettei (Augener)

**Golfingia semperi* (Selenka & de Man)

Golfingia trichocephala (Sluiter)

Golfingia vulgaris queenslandensis Edmonds

Phascolion collar Selenka & de Man

Phascolion cronullae n.sp.

**Phascolion dentalicolum* Sato

**Phascolion pacificum* Murina

Themiste cymodoceae (Edmonds)

Themiste dehamata (Kesteven)

Themiste fusca (Edmonds)

Themiste huttoni (Benham)

Themiste lageniformis Baird

Themiste variospinosa n.sp.

**Onchnesoma steenstrupii* Koren & Danielssen

Family Aspidosiphonidae

Aspidosiphon elegans elegans (Chamisso & Eysenhardt)

**Aspidosiphon exhaustus* (Sluiter)

Aspidosiphon gracilis Baird

Aspidosiphon hartmeyer Fischer

Aspidosiphon inquilinus Sluiter

Aspidosiphon jukesii Baird

**Paraspidosiphon cumingii* (Baird)

Paraspidosiphon formosanus (Sato)

Paraspidosiphon johnstoni n.sp.

**Paraspidosiphon steenstrupii* (Diesing)

Cloeosiphon aspergillus (Quatrefages)

Lithacrosiphon cristatus (Sluiter)

Family Phascolosomatidae

Phascolosoma albolineatum Baird

Phascolosoma annulatum Hutton

Phascolosoma arcuatum (Gray)

Phascolosoma nigrescens Keferstein

**Phascolosoma nigritorquatum* (Sluiter)

Phascolosoma noduliferum Stimpson

Phascolosoma pacificum Keferstein

Phascolosoma perlucens Baird

Phascolosoma rotnesti Edmonds

Phascolosoma scolops (Selenka and de Man)

Phascolosoma stephensoni (Stephen)

KEY TO FAMILIES OF SIPUNCULA

(based on Fisher, 1952 and Stephen and Edmonds, 1972)

1. Horny, chitinous or calcareous shield, cone or cap present at anterior extremity of trunk. Longitudinal musculature of body wall may form bands or be continuous
Aspidosiphonidae[†] (p. 43)
 No horny or calcareous shield, cone or cap present at anterior region of trunk. 2
2. Tentacles basically surround mouth and may be simple or branched, lie in groups, be reduced to a few lobes or even be absent but not lying in a horseshoe-shaped ring dorsal to mouth. Nuchal organ, if present, is dorsal to tentacles and not enclosed by them 3
- Tentacles arranged in a horseshoe-shaped ring which does not surround mouth but lies dorsal to it and which encloses the nuchal organ, if present. Longitudinal muscles grouped into bundles, except in one genus of four species. Skin usually bearing conical to hemispherical papilliform glands, usually largest and most prominent at anterior and posterior extremities of trunk. *Phascolosomatidae* (p. 55)
3. Longitudinal musculature of body wall thickened to form well defined bands. Integumentary canals or coelomic sacs present in body wall (except in that of one species)
Sipunculidae (p. 8)
 Longitudinal musculature of body wall continuous and not thickened into bands *Golfingiidae* (p. 18)

Family Sipunculidae and key to genera

Sipunculidae Baird, 1868 (in part); Sedgwick, 1898 (in part); Stephen and Edmonds, 1972.

Description: Adult specimens large and cylindrical. Longitudinal musculature always in bundles. Retractor muscles always four (except in *Siphonomecus*). Mouth surrounded by a ring of tentacles or a tentacular fold. Body wall of adults with integumental canals or coelomic sacs (except in *Phascolopsis*). Nephridia two. Type genus: *Sipunculus* Linnaeus.

Key to genera of the Sipunculidae

1. Introvert with sub-triangular, scale-like papillae but without hooks. Skin of trunk marked into rectangles by intersecting bands of longitudinal and circular muscles 2
- Introvert without sub-triangular, scale-like papillae. Hooks or spines may be present. Skin not strongly marked off into rectangles (except in *Siphonomecus*) 3
2. Four retractor muscles and an additional pair of protractor muscles, the latter arising from body wall near anus and connecting with introvert near brain. Spindle muscle arises anteriorly from wall of rectum. Gonad in form of a fine loop attached to body wall and rectum
Xenosiphon Fisher (p. 12)
 Four retractor muscles but no protractors. Spindle muscle arising from body wall anterior to anus. Gonads at base of ventral retractors and not in form of a filamentous loop
Sipunculus Linnaeus (p. 4)

3. Four retractor muscles 4
- Two retractor muscles *Siphonomecus* Fisher^{*}
4. Spindle muscle not fixed to body wall posteriorly. No coelomic extensions in body wall. Introvert without hooks or spines *Phascolopsis* Fisher^{*}
- Spindle muscle fixed posteriorly. Coelomic sacs or canals present in body wall. Introvert spines or hooks present or absent *Siphonosoma* Spengel (p. 14)

Genus *Sipunculus* Linnaeus

Sipunculus Linnaeus, 1776 p. 1078; Fisher, 1952 p. 375; Stephen & Edmonds, 1972 p. 21.

Description: Usually large animals, often stout. Trunk cylindrical and usually divided into squares or rectangles by intersection of longitudinal and circular muscles. Introvert short, clearly differentiated from trunk and carrying numerous, flat triangular papillae. Mouth surrounded by a tentacular fold, the margins of which in living specimens form more or less distinct tentacles. Introvert lacks hooks and spines. Spindle muscle attached anteriorly in front of anus. Coelomic extensions present in body wall. Contractile vessel double. Post-oesophageal or "sipunculus" loop present in alimentary canal anterior to intestinal spiral. Paraneural muscle well developed. Type species: *Sipunculus nudus* Linnaeus 1776.

Key to species of *Sipunculus* known from Australia

1. Longitudinal muscle in 37-43 bands, trunk very long and rather slender *S. indicus* (p. 9)
 Longitudinal muscles in less than 37 bands; trunk usually stout 2
2. Longitudinal muscles in 27-30 (usually 29) bands; digitate processes of brain rather threadlike and lateral in position *S. robustus* (p. 9)
 Longitudinal muscles in 23-26 bands; digitate processes short, finger- to leaf-like rather than threadlike
S. nubans nubans (p. 10)

Remarks: Triangular, scale-like papillae are always present on the introvert of *Sipunculus* and *Xenosiphon* but not *Siphonosoma*. In *Xenosiphon* two protractor muscles are present and the gonads lie on a filamentous loop but not in *Sipunculus* nor *Siphonosoma*. The spindle muscle of *Siphonosoma* arises anteriorly from three roots and is fixed posteriorly to the trunk wall. In *Sipunculus* and *Xenosiphon* it arises anteriorly from a single root and is not fixed posteriorly.

Fischer (1914 p. 1) and Murina (1972 p. 307) identified single specimens from St. Vincent Gulf, South Australia as *Sipunculus nudus* Linnaeus. Because *S. robustus* is commonly collected in this Gulf (see p. 10) there is some doubt about their records.

^{*}Species of this genus not reported from Australia.

[†]Dr. P. E. Gibbs of the Marine Laboratory at Plymouth, England has correctly pointed out to me (personal communication) that the tentacles of *Aspidosiphon* and *Paraspidosiphon* lie in a horseshoe-shaped ring dorsal to the mouth, as in *Phascolosoma*. The statements of Stephen and Edmonds (1972: p. 19, 215-216, 238) about the condition of the tentacles in *Aspidosiphonidae*, *Aspidosiphon* and *Paraspidosiphon* are therefore wrong and must be corrected. I am indebted to Dr. Gibbs for his information. Dr. Gibbs (1977: p. 30) has recently referred to the condition of the tentacles in *Aspidosiphon muelleri* Diesing.

***Sipunculus indicus* Peters**

Sipunculus indicus Peters, 1850 pp. 382-383; Keferstein, 1865 p. 421, pl. 31, fig. 1; Selenka and de Man, 1883 pp. 111-112; Edmonds, 1971 p. 137; Stephen and Edmonds, 1972 pp. 27-28.

Location of type: not known to author; specimen from Mozambique.

Description: Specimen long and cylindrical. Length of trunk 410 mm and width, almost uniform, 12 mm. Posterior extremity slightly rounded and swollen; invaginated terminal organ present. Surface of trunk divided into small rectangular areas by intersection of circular and longitudinal muscles. Circular annulations of trunk very noticeable. Surface of introvert bears sub-triangular papillae.

Longitudinal musculature in 37-42 anastomosing bands. Four retractor muscles arise at about the same level, the ventral pair from muscles 2-4 and the dorsal pair from 9-13 or 10-14. Alimentary canal with well developed post-oesophageal loop. Anus opens anteriorly to nephridiopores. Rectum long and fixed to body wall for most of its length. Small caecum attached to rectum. Two long nephridia, opening between muscles 4-5, extend back past point of fixation of retractors and are attached to body wall for most of their length. Brain simple and lacking a tufted organ. Contractile vessel double.

Systematic position: Johnston (1969: p. 43) described *Xenosiphon* (*Xenopsis*) *indicus* from the Laccadive Is. The species has two retractor and two protractor muscles arising from the body wall at different levels (Johnston 1969, fig. 3). Since he does not refer to *Sipunculus indicus* Peters and does not raise the question of synonymy it looks as if Johnson's "*indicus*" and Peter's "*indicus*" are different.

The Western Australian specimen, although it shows similarities with *Xenosiphon indicus* Johnson, is being described as *S. indicus* Peters because it lacks protractor muscles. Its four retractors arise from the body wall at about the same level. In addition the brain is simple and lacks the "tufted organs" described for *X. indicus*.

S. indicus is long and cylindrical. It possesses about 40 longitudinal muscles and the anus lies in front of the nephridiopores. Brain without processes, thus differing from *S. robustus* and *S. titubans*. Good illustrations of the species are given in Keferstein 1865, pl. 31, fig. 1 and in Sato 1939, pl. 19, fig. 4. No previous Australian record.

Distribution: (1) in Australia: Western Australia at Exmouth Gulf.

(2) elsewhere: Zanzibar, Madagascar, South Africa, Billiton, South China Sea, West Caroline Is., Coral Sea (AMS W5734).

Specimens examined and locality: Western Australia—Yardia Creek near Exmouth Gulf (1) AMS W9250.

***Sipunculus robustus* Keferstein**

(Figs. 18, 20-22)

Sipunculus robustus Keferstein, 1865 p. 421; Stephen and Edmonds, 1972 pp. 36-37.

Sipunculus angasii Baird, 1868 p. 80; Edmonds 1955 pp. 83-86, figs. 1-4, pl. 1.

Location of type: Hamburg Museum; specimen from Uvea (Wallis Is.), Pacific Ocean.

Description: Specimens long, cylindrical and often stout; frequently washed up on beaches near Adelaide after early winter storms. Colour pale pink and slightly iridescent. Trunk 60-260 mm long, 8-20 mm wide and usually divided into small, rectangular areas by intersection of circular and longitudinal muscles. Introvert short, clearly differentiated from trunk, 15-30 mm long and 5-10 mm wide, with numerous, posteriorly directed, scale-like papillae but no hooks. Mouth surrounded by a wrinkled fold, which in living specimens more closely resembles finger-like tentacles. Posterior extremity of trunk usually rounded and swollen but sometimes pointed. Terminal organ present.

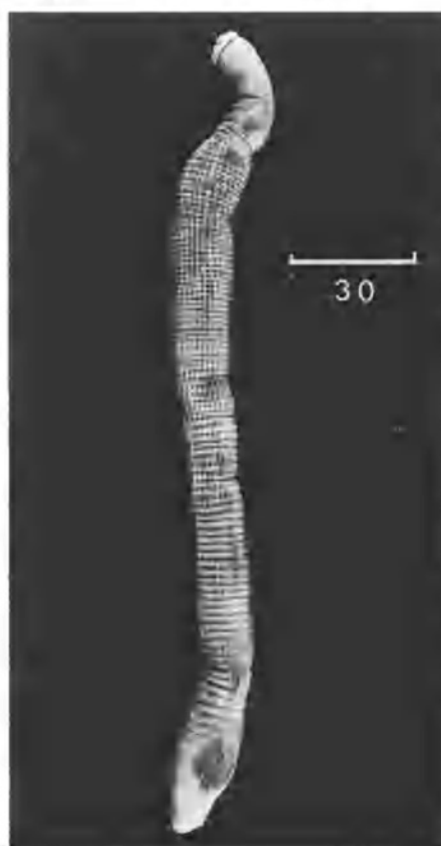


FIG. 18. *Sipunculus robustus*, (specimen from Tasmania), (scale measurements are in mm).

Longitudinal muscles in 27-30 (usually less than 30), sometimes anastomosing, bundles. Four stout, equal retractors arise at same level in anterior third of trunk, ventral pair from muscles 3-5 (2-5, 2-6, 3-6) and dorsal from 9-11 (9-12, 10-12, 8-13). Anterior region of oesophagus fastened to dorsal retractors by thin mesenteries and rest of gut to body wall by thin threads. Post-oesophageal or "sipunculus" loop present in foregut. Racemose glands and caecum present. Spindle muscle arises anterior to anus but not fixed posteriorly. Contractile vessel double. Nephridia attached between muscles 4 and 5 (5-6, 6-7) anterior to anus. Bilobed brain gives off dorso-laterally a number of delicate, thread-like digitate processes.

Systematic position and remarks: Edmonds (1955) identified a common South Australian sipunculan as *Sipunculus angasii* Baird 1868, a species described from Port Lincoln, South Australia. After an examination of the holotype of *S. robustus*, Stephen and Edmonds (1972: p. 37) concluded that *S. robustus* and *S. angasii* are conspecific, the name *robustus* having priority. *S. robustus* is well known in the Indo-Pacific region.

A comparison made between about 50 specimens of *S. nudus* collected by me at Morgat, Brittany (France) during 1961 and about 50 specimens of *S. robustus* collected from South Australian beaches confirms that the two species, although closely related, are different. In *S. nudus* there are 28-32 (usually over 30) longitudinal muscles while in *S. robustus* there are 27-30 (usually 28-29). In *S. robustus* the digitate processes are rather threadlike and somewhat lateral in position. In *S. nudus* they are fewer, short, rounded to fingerlike and situated more dorsally. The retractors in *S. nudus* usually span six or seven longitudinal muscles while in *S. robustus* it is usually three or four.

Fischer (1914 p. 1) identified *S. nudus* from St. Vincent Gulf, South Australia and Murina (1972 p. 307) *S. nudus* from Adelaide. Both records are of single specimens. It seems likely that the specimens are what I would call *S. robustus*.

S. robustus in South Australia lives below the level of low tide on sandy beaches. The gut contents are usually sand. Two small specimens were collected from the gut contents of a fish, *Sillaginodes punctatus*, caught at Marion Bay, South Australia (SAM E1072). The body fluid of *S. robustus* like that of *S. nudus* contains, in addition to blood cells and amoebocytes, free swimming, ciliated urn cells which are thought to help in the removal of some waste materials from the animal.

Previous Australian records: Monro (1931), Augener (1903), Edmonds (1955), Gibbs (1978).

Distribution: (1) in Australia: Queensland, Victoria, Tasmania, South Australia and West Australia.

(2) elsewhere: Palau, Wallis Is., West Caroline Is., Marshall Is., Philippines, Indonesia, Maldives and Laccadive Is., Madras, Madagascar, Zanzibar, off South Africa (at 2 720 m) and Malacca St. (at 1 140 m).

Specimens examined and localities: Queensland—Low Is. (1) SAM E1060 and (1) (Dr. P. Gibbs) SAM E1057; Turtle Is. (1) (Dr. P. Gibbs) SAM E1057; Townsville (1) E1052; Line Is. AMS G11388; Hayman Is. (1) AMS W3131. Victoria—Port Arlington (1) NM G1125; Black Rock (1) NM G1126; Hobsons Bay (1); Queenscliff (1) NM G1124; Rosebud (1) NM G1128; Brighton (1) NM G1123; Portland (1) SAM E1049. Tasmania—Seven Mile Beach (1) SAM E1048 and (2) TM K103/15530. South Australia—St. Vincent Gulf (washed up after storms), especially at Aldinga and Sellicks Beaches (80) SAM E1050, E1051, E1053 and E1055; Spencer Gulf at Minlacowie (2) SAM E1054; Aldinga Beach (2) AMS W3600. Western Australia—Rottnest Is. (1) WAM 125/76; Woodmans Point (1) WAM 172/76.

Sipunculus titubans titubans Selenka & Bulow

(Figs 23-25)

Sipunculus titubans Selenka & Bulow, 1883 pp. 100-101; Stephen & Edmonds, 1972 pp. 37-38.

Location of type: Zoological Museum, Humboldt-University of Berlin, DDR.; specimen from Puntarenas (coll. Grube), cat. no. 1036.

Description: This account is based on 12 specimens, two larger ones from the Gulf of Carpentaria and 10 smaller ones from Moreton Bay, Queensland. All are cylindrical with body wall divided into rectangles by the crossing of longitudinal and circular muscles. Body wall of larger specimen thick but of smaller pink and semi-transparent. Trunk of larger 80-120 mm long and 8-11 mm wide, of smaller 18-55 mm long and 2-5 mm wide. Posterior extremity pointed, rounded or formed into a glans. Invaginated terminal organ present in two. Introvert short (maximum length 10 mm), much narrower than trunk and bearing numerous, fleshy, sub-triangular papillae. Tentacles not exposed in any specimen but dissection shows that a tentacular fold is present.

Longitudinal muscles in 23-26 bands (usually 24 at base of retractors), anastomosis slight. Four introvert retractors arising at same level in anterior fourth of trunk. Base of retractors usually extended laterally by strands of muscular tissue (making it difficult sometimes to specify the span of the muscles). Ventral retractors arising from muscles 2-5, 1-4, 1-5 or 1-6, dorsal retractors from 6-10, 6-11, 7-11 or 8-11. Anterior oesophagus attached to dorsal retractors by thin mesenteries and post-oesophageal loop present in foregut. Rectum short and rectal caecum present in two larger specimens and two smaller ones. Two racemose glands attached to strands of tissue connecting rectum and base of dorsal retractors. Contractile vessel double with roughened or vesiculated surface but no tubular villi. Spindle muscle arises anterior to anus but not fixed posteriorly. Nephridia about one fourth or fifth as long as trunk, arising between muscles 4-5 well in front of anus and attached for about a fourth or fifth of their length. Brain bilobed with a number of short digitate processes along its antero-dorsal margin; processes may be simple, stubby or leaf-like and those laterally placed may branch slightly.

Systematics: At first I thought that these specimens might be *Sipunculus aequabilis* Sluiter, 1902 described from Indonesia. A re-examination of the holotype (Zoological Museum, Amsterdam)—an already dissected specimen—confirms that it has 21-22 longitudinal muscles, that its ventral retractors arise from muscle number 3 and the dorsal pair from 8-9. It has a small caecum but no racemose glands. The specimens from Queensland however, possess a greater number of longitudinal muscles and their retractors span more muscles. One point not previously reported is that at least three stout swellings or protuberances arise from the fore-brain of the holotype of *S. aequabilis*. I am inclined to think that they correspond to digitate processes.

Although resembling *Sipunculus norvegicus* (Danielssen, 1869) in many respects the Queensland specimens differ because they possess digitate processes. Recently I examined two specimens of *S. norvegicus* from the collection of the British Museum (Nat. Hist.)—one from Norway (1922-5-22-1) and the other from the Bay of Biscay (97-4-21-4). The brain of both lacks digitate processes. Confirmatory evidence on this point is given by Akesson (1958 p. 138); "At about the place where the other species (*S. nudus* and *S. robustus*) have digitate processes *S. norvegicus* has a muscular strand, a rudiment of the larval protractor muscle. There is certainly no histological similarity between the two structures and they are not connected in any way."

Sipunculus titubans Selenka & Bülow, 1883 was described from a single specimen collected at

Puntarenas. Recently I examined the holotype, a dissected specimen. The trunk is about 48 mm long and the introvert 6 mm. A tentacular fold surrounds the mouth and triangular papillae are present on the introvert. Longitudinal muscles 26 at base of retractors and 26 posteriorly. Ventral retractors arise from muscles 1-5, 1-6 (type description says 3-5 or 1-5) and dorsals from 8-11, 7-11. Racemose glands and caecum present. Contractile vessel double. Nephridia opening anteriorly to anus between muscles 4-5 and fixed for half their length. As stated in the type description, no spindle muscle is present but the intestine has been damaged and part of it is missing. Brain bilobed and giving off from its antero-dorsal margin a number of short tufted (possibly leaf-like) digitate processes, something not mentioned by Selenka (unless included in the statement "Nervensystem demjenigen *S. nudus* sehr ähnlich").

Consequently I consider the specimens from Queensland to be *S. titubans*. The chief differences are that in the holotype (1) the digitate processes seem to form a tufted or brush-like structure while in the others the processes are stouter and (2) the nephridia are fixed for half and not a fifth of their length. The absence of a spindle muscle in the holotype is so unusual in *Sipunculus* that it may reasonably be regarded as accidental and not general. Unfortunately no reference to the absence or presence of a spindle muscle in their specimens of *S. titubans* has been made, as far as I can see, by other authors.

The Queensland specimens differ from *Sipunculus robustus* Keferstein which has 27-29 longitudinal muscles and longer and more thread-like digitate processes and from *Sipunculus nudus* Linnaeus which has 30-33 muscles and finger-like processes. *Sipunculus zenkevitchi* Murina, 1969, dredged from the Pacific Ocean, has 25 longitudinal muscles, an oval brain with two eyespots but apparently no processes. *Sipunculus longipapillosus* Murina, 1968 has 24-26 longitudinal muscles but trunk papillae with long extensions. *Sipunculus delphinus* Murina, 1967 has 25 longitudinal muscles, retractors arising from muscles 2-5 (2-4) and 7-8 (8-11), a caecum and racemose glands and seems very closely related to *S. titubans*.

What evolutionary or adaptive value the different kinds of digitate processes have in the Sipunculidae is not known. Metchnikoff (1900) considered that the processes were sensory structures. Akesson (1958 p. 136) maintains that they are not sensory but "form a part of a secretory organ. In the organ is accumulated the neurosecretory substance from the bipolar neurosecretory cells in the anterior dorsal margin of the brain. From there the secretion is given off to the coelomic fluid".

Digitate processes have been found, at least, in the following *Sipunculus* species; *S. nudus* Linnaeus (finger-like), *S. robustus* Keferstein (thread-like), *S. titubans* Selenka & Bulow (brush-to finger-like), *S. galapagensis* Fisher (irregularly folded sheets of tissue), *S. marcusii* Ditadi (leaf-like), *S. natans* Fisher (numerous slender lobes forming a conspicuous tuft) and *S. polymyotus* Fisher (very slender, flattened, thin and digitate). Three or four swellings or protuberances on the forebrain of the holotype of *S. aequabilis* Sluiter are probably processes. The processes are lacking in *S. norvegicus* Danielssen.

Fischer, 1895 described a subspecies, *S. titubans diptychus*, from West Africa which has 30-33 muscle bands, retractor muscles attached to bands 2-5 and 11-14 and a spindle muscle.

No previous record from Australia.

Distribution: (1) in Australia: Queensland at Weipa and Moreton Bay.

(2) elsewhere: North-west Africa, Canary Is., Gold Coast Gulf of Guinea, Senegal, Zanzibar, Madagascar, Gulf of Siam, Thailand, West Indies, southern Chile.

Specimens examined and localities: Queensland—Weipa (Albatross Bay, Gulf of Carpentaria) (1) AMS W9241; mouth of Embley River (Albatross Bay) (1) WAM 231/76; Middlebanks (Moreton Bay) dredged in sandy mud at 10 m (10) SAM E1069.

Genus *Xenosiphon* Fisher

Xenosiphon Fisher, 1947 p. 360; 1954 p. 312; Stephen & Edmonds, 1972 p. 38; Johnston, 1969 p. 43.

Type species: *Xenosiphon branchiatus*: Fisher, 1947.

Description: Large, cylindrical and closely resembling *Sipunculus*. Unlike *Sipunculus* in possessing an extra pair of protractor or retractor muscles, arising from posterior border of introvert near brain. Introvert short and with flat, triangular papillae. Longitudinal and circular muscles banded as in *Sipunculus*. Rectum long and anus lies anterior to nephridiopores. Gonads form a filamentous loop. Integumental canals or saes present.

Type species: *Sipunculus mundanus branchiatus* Fisher, 1895.

Remarks: Four species have been described for the genus. They fall into three subgenera; (1) *Xenosiphon* (sensu stricto) Fisher, 1954 p. 312.

Subcutaneous coelomic system consists of independent, irregular sacs, some of which carry papilliform gills. No accessory intestinal loop.

Nephridia long and attached to body wall by mesentery. *X. caribae* Fisher, 1954 also belongs to this subgenus.

(2) *Austrosiphon* Fisher, 1954

Type species: *Xenosiphon mundanus* (Selenka & Bulow, 1883).

Subcutaneous system in form of longitudinal canals lying between longitudinal ridges of body wall. Accessory or "sipunculus" loop present in foregut. Nephridia small and free.

(3) *Xenopsis* Johnson, 1969

Type species: *Xenosiphon indicus* Johnson, 1969.

Subcutaneous system as in *Austrosiphon*. Two protractors and only one pair of retractors. "Sipunculus" loop present in foregut. No cephalic tube.

In Australia only one species, *Xenosiphon mundanus*, is known.

Xenosiphon (*Austrosiphon*) *mundanus* (Selenka and de Man)

(Figs. 26-27)

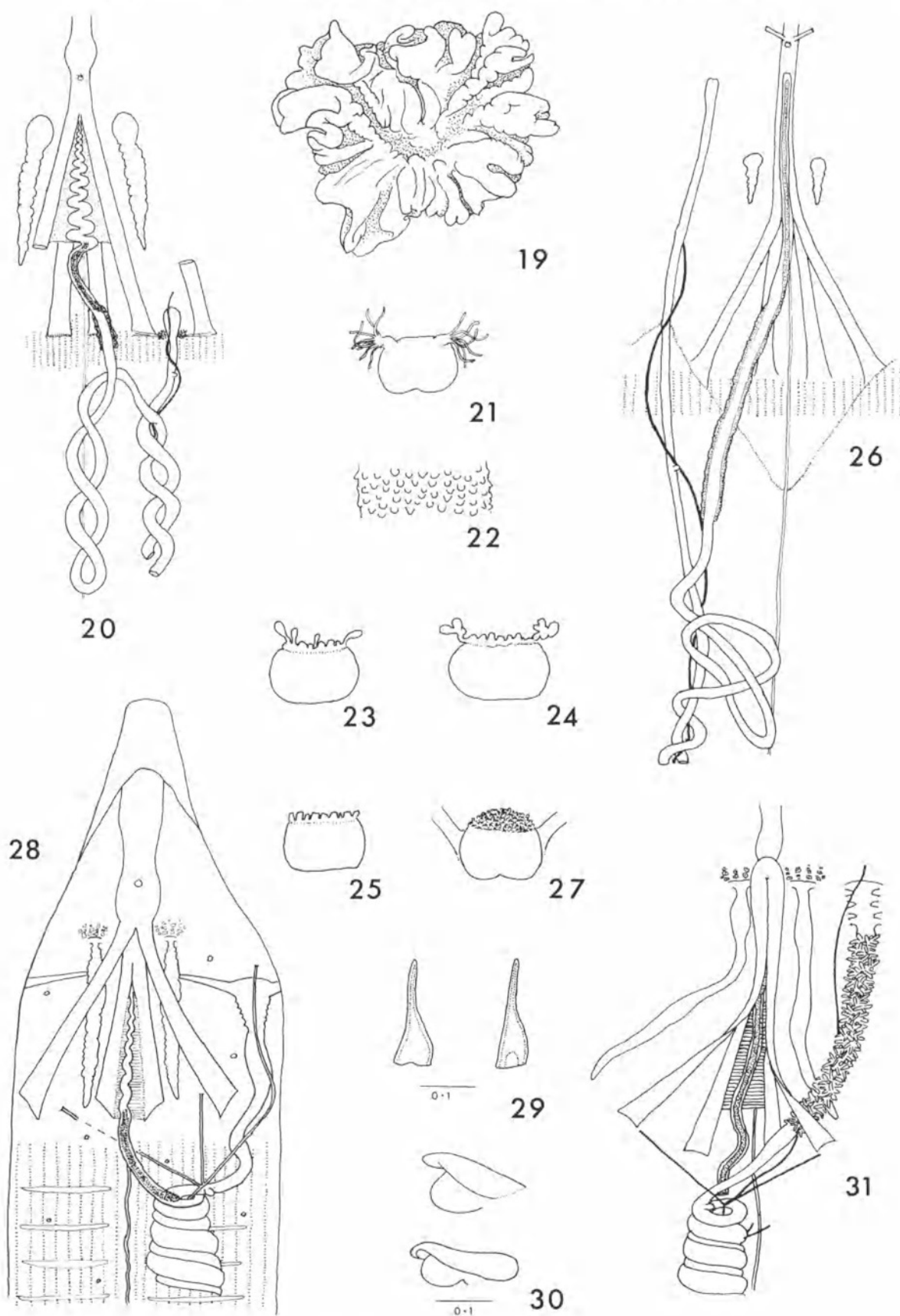
Sipunculus mundanus Selenka and de Man, 1883 pp. 108-109, pl. 12, fig. 174.

Xenosiphon mundanus Fisher, 1954 p. 314; Edmonds, 1955 pp. 87-89; Edmonds, 1960 p. 160; Cutler, 1977 p. 138.

Location of type: British Mus. (Nat. Hist.), London; specimen from Sow and Pig Shoal, Port Jackson, New South Wales.

Description: Specimens long, cylindrical and superficially resembling a *Sipunculus*. Trunk 130-270 mm long and 7-12 mm wide. Body wall divided into rectangular areas by intersecting bands of longitudinal and circular muscles. Introvert short, 10-20 mm long and 4-7 mm wide, bearing many, posteriorly directed, scale-like papillae and a tentacular pad or fold. Annulations caused by circular muscles usually less marked on dorsal surface of posterior third of worm. Longitudinal muscles in 28-31, slightly anastomosing bands. Terminal organ present at posterior extremity of trunk.

Four retractor muscles arise at about same level, a ventral pair from muscles 2-4, 1-3, 1-4 and dorsal pair from 7-10, 7-11, 8-11. Two ribbon-like protractor muscles arise from body wall of anterior part of trunk and are attached to introvert near brain. Oesophagus long and straight; short post-oesophageal or "sipunculus" loop present. Spirals of intestine fastened by many short mesenteric threads.



FIGS. 19-31. Fig. 19, tentacular fold of a *Sipunculus* (after Gibbs). Figs. 20-22, *Sipunculus robustus*; 20, anterior region dissected; 21, brain and digitate processes; 22, subtriangular papillae from introvert. Figs. 23-25, *Sipunculus titubans titubans*; brain and processes of three specimens from Queensland; Figs. 26-27, *Xenosiphon mundanus*; 26, anterior region dissected; 27, brain and tufted processes (after Fisher). Fig. 28, *Siphonosoma cumanense*; anterior region dissected. Fig. 29, *Siphonosoma australe*; hooks. Fig. 30, *Siphonosoma rotumanum*; hooks. Fig. 31, *Siphonosoma vastum*; anterior region dissected.

Anal aperture lies well anterior to nephridiopores. Rectum long and attached to body wall. Small caecum present. Contractile vessel double.

Gonads in form of a fine, delicate loop of tissue arising on each side of rectum and running across body wall to base of retractors and nerve cord. Nephridia short, stout and free, opening between muscles 4-5. Integumental canals lie longitudinally between ridges of muscles. Brain bilobed and capped anteriorly with a pad of tufted tissue.

Systematic position: This species is well known in south-eastern Australia and New Zealand. Its distinctive features are its two protractor muscles, its long rectum, its short nephridia (in *X. branchiatus* they are long) and the position of the anus well anterior to the nephridiopores. *X. indicus* Johnson, 1969 from the Laccadive Is. possesses 40-45 longitudinal muscles.

Previous Australian records: Selenka and de Man (1883); Edmonds (1955); Cutler (1977).

Distribution: (1) in Australia: New South Wales, Lord Howe Is., Victoria and off coast of South Australia at 1 320 m (Cutler 1977).

(2) elsewhere: New Britain; New Zealand; Chile (Tarifino and Tomicic, 1973).

Specimens examined and localities: New South Wales—Gunnamatta Bay (1) SAM E1083; Pig and Sow Shoal, Port Jackson (2) SAM E1080; Lord

Howe Is. (2) AMS G3950 and W1873; Bermagui (2) AMS W2534; Botany Bay (1) AMS W2535; Balmoral Beach (1) W1665, Victoria—Queenscliff (1) SAM E1085; Portland (1) NMM G1217; Port Fairy (4) AMS W9249. Tasmania—Binalong Bay (1) TM K825.

Genus *Siphonosoma* Spengel

Siphonosoma Spengel, 1912 p. 264; Fisher 1950a p. 805; 1952 pp. 380-381; Stephen and Edmonds 1972 p. 43.

Type species: *Siphonosoma australe* (Keferstein, 1865).

Description: Adults usually large and cylindrical. Introvert often not well differentiated from trunk and lacking scale-like, triangular papillae but sometimes possessing hooks and spines. Tentacles thread-or finger-like; no tentacular fold. Longitudinal muscles always divided into bands (sometimes not readily noticed from outside). Coelomic sacs in body wall. Four retractors. Spindle muscle arises anteriorly from three roots and attached posteriorly to body wall. Contractile vessel single and dorsal; small contractile tubules usually present. Two nephridia (usually with large crescentic nephrostomes). No post-oesophageal loop.

Subgenera: Fisher (1950a p. 805) divided the genus into three subgenera.

TABLE 1.

SUBGENERA OF *SIPHONOSOMA*

Subgenus	Transverse dissepiments	Numerous rectal caeca	Type species
<i>Siphonosoma</i> s.s.	absent	absent	<i>S. australe</i> (Keferstein)
<i>Hesperosiphon</i>	absent	present	<i>S. vastum</i> (Selenka & de Man)
<i>Damosiphon</i>	present	absent	<i>S. rumanense</i> (Keferstein)

Remarks: Species of *Siphonosoma* can be distinguished from those of *Sipunculus* because (1) the introvert lacks scale-like papillae (2) the tentacles do not form a fold (3) the spindle muscle arises anteriorly from three roots and is fixed posteriorly and (4) no post-oesophageal loop is present in the foregut.

KEY TO AUSTRALIAN SPECIES OF *SIPHONOSOMA*

1. Numerous transverse dissepiments attached to coelomic wall of trunk... *S. (Siphonosoma) cumanense cumanense* (p. 14)
No transverse dissepiments attached to coelomic wall 2
2. Rectum with very numerous, finger-like caeca or villi
S. (Hesperosiphon) vastum (p. 15)
Rectum without finger-like caeca or villi 3
3. Introvert with hooks, spines or spine-like papillae 4
Introvert without hooks, spines or spine-like papillae 5

4. Brown-black, slightly bent hooks present
S. (Siphonosoma) australe (p. 16)
Light-brown, blunt, papilla-like spines present
S. (Siphonosoma) rotumanum (p. 18)
5. Longitudinal muscles 30-32
S. (Siphonosoma) boholense (p. 17)
Longitudinal muscles about 20
S. (Siphonosoma) novaepommeraniae (p. 17)

Siphonosoma (Damosiphon) cumanense cumanense
(Keferstein)
(Fig. 28)

Phascolosoma cumanense Keferstein, 1867 pp. 53-55, pl. 6, figs 19-21.

Sipunculus deformis Baird, 1868 pp. 80-81, pl. 9, fig. 2; Edmonds, 1955 p. 90.

Siphonosoma cumanense: Edmonds 1955 pp. 90-92; Stephen and Edmonds, 1972 pp. 46-49.

Location of type: Not known by author; specimen from Venezuela.

Description: Specimens of various size and shape; usually long and cylindrical. Length of trunk and maximum width of two largest specimens 410 x (10-20) mm, 450 x (12-21) mm, and of smallest 50 x (4-6) mm. Anterior region of trunk usually swollen. Introvert not strongly differentiated from trunk and for such a large species comparatively short; maximum length 60 mm, minimum 10 mm and lacking hooks and spines. Mouth surrounded by finger-like tentacles which, although numerous, seem small for the size of the animal. Anterior surface of trunk may be divided by furrows into small areas enclosing flat, glandular openings. Hemispherical papillae, with diameter up to 0.6 mm, on anterior and posterior surfaces of trunk; lying more or less in longitudinal rows and composed of long narrow plates with their long axes placed along the radii of the papillae. Body wall thick except where it is not traversed by circular and longitudinal musculature, such areas containing prolongations or extensions of the coelom.

Longitudinal muscles in 18-25 (usually 20-22) anastomosing bands. Four retractors arise in anterior fourth of trunk at about same level (sometimes dorsal pair a little more anteriorly), a ventral pair from muscles 2-3, 3-4, 1-3, 1-4 and a dorsal from 6-8, 7-8, 8-9. Sometimes retractors may lie obliquely along one or two muscles rather than transversally across a wider band.

Anterior region of oesophagus fixed to ventral retractors by thin mesenteries. Stout spindle muscle arises anteriorly from 3 roots, one anterior to anus and two from muscles 8, 9 or 10 near point of fixation of dorsal retractors. Two fasteners, arising from muscle 1 on each side of nerve cord, run to last spiral of intestine. Rectal caecum usually situated near point where 3 roots of spindle muscle meet. Two strands of muscle arise from muscle 1 at about level of nephrostomes, stretch across body wall and attach to wing muscle. Contractile vessel with numerous small villi. A series of thin crescentic shaped dissepiments lie transversally on each side of nerve cord between base of retractors and posterior extremity of trunk, spanning muscles 1-8, 3-7, 4-10 or 3-9. Two nephridia, attached to body wall for about a fifth of their length and extending to the base of the retractors, open between muscles 2-3 or 3-4 just anterior to anus. Tufted organs on coelomic wall near nephrostomes. Oval bodies, 0.8-1.5 mm in diameter, attached to inner body wall. Gonads at base of ventral retractors. Terminal organ present. Brain without processes.

Systematic position: These specimens possessing body dissepiments but lacking introvert spines and numerous rectal caeca fall into the subgenus *Damosiphon* Fisher, 1950a. They are being identified as *S. cumanense cumanense*, a species originally described from Venezuela and since reported from other tropical and warm waters. *Siphonosoma edule* Pallas, 1774, however, is a very closely related species, so close that it is not easy to decide on a character that distinguishes the two. The introvert of *S. edule* is said to be shorter than that of *S. cumanense*. The differences are discussed but not resolved in Stephen & Edmonds, 1972 p. 46 and 51. As *S. edule* was described from Batavia it is possible that some of these Australian specimens are *S. edule* (especially the specimen SAM E1090). A careful study of specimens collected from Batavia and Venezuela needs to be carried out, I think, before a decision about the two species can be made.

Previous Australian records: Baird (1868), Fischer (1921), Monro (1931), Edmonds (1955) and Gibbs (1978).

Distribution: (1) in Australia: East coast from Cape York to the mouth of the Clarence River, including the Great Barrier Reef; North West coast near Broome; West coast near Fremantle.

(2) elsewhere: East coast of America, Venezuela, Florida; Indian Ocean, Madagascar, Zanzibar, Red Sea, Arabian Sea, Laccadive and Maldive Is., Amboina; Pacific Ocean, New Guinea, Loyalty Is., New Britain, Philippines, Japan, Tahiti and Indo-China.

Specimens examined and localities: Queensland—Dunwich (in mud flats) (1) SAM E1090; same locality (1) SAM E1091 (2) SAM E1092, (1) SAM E1093, (1) SAM E1094; Low Is., (4) SAM E1096; Sir Charles Hardy Is., (11° 55' S, 143° 28' E) British Museum. New South Wales—Shelly Beach (mouth of Clarence River) (1) AMS W3194; Port Denman (3) AMS W1006. Western Australia—Kwinana (1) WAM 196/76; Fremantle Harbor (1) WAM 199/76; North West coast (1) Dept. of Zoology, Univ. of W.A.

Siphonosoma (Hesperosiphon) vastum (Selenka & de Man)

(Fig. 31)

Sipunculus vastus Selenka & de Man, 1883 pp. 103-104, fig. 171, fig. 179.

Siphonosoma crassum Spengel in Fischer, 1919a p. 279.

Siphonosoma vastum: Fischer, 1927 p. 199; Edmonds, 1955 pp. 92-95, figs 8-9; Stephen & Edmonds, 1972 p. 55-56.

Location of type: Zoological Museum of Humboldt University of Berlin; specimen from Jaluit (Marshall Is., Pacific Ocean).

Description: Trunk of Queensland specimen about 260 mm long and 10-13 mm wide and of Western Australia 57 mm long and 7 mm wide. Introvert, retracted in both specimens, 15-50 mm long; armed with numerous rows of curved, yellow-brown, rather blunt hooks or spinelets, the largest of which is about 0.1 mm long. Skin between rows of spines divided by fine furrows into small rectangular areas, each containing a small glandular opening. Surface of introvert and trunk bears hemispherical papillae, the largest (at anterior of trunk) being up to 0.5 mm in diameter.

Longitudinal muscles in 22-26 anastomosing bands. Two stout ventral retractors arise from muscles 2-6 or 1-6, and two dorsal retractors more anteriorly from muscles 9 or 9-10. Oesophagus attached to ventral retractors by fine mesenteries and gut filled with calcareous fragments. Contractile vessel with numerous small tubules or villi. Numerous larger fingerlike villi or caeca 1-1.5 mm long, attached to rectum; their function is unknown. Anal aperture between muscles 11-12 at about level of nephridiopores. Wing muscle strong. Stout spindle muscle arises anteriorly from 3 roots, one from muscle 12 anterior to anus and others from muscles 11 and 8. Another fastener from last whorl of intestine bifurcates, each root being attached to muscle 1 on each side of nerve cord. Spindle muscle attached posteriorly to body wall. A sac-like, globular, rectal or intestinal caecum, readily distinguishable from the numerous fingerlike villi, also present. Two nephridia, possessing prominent semi-lunar nephrostomes open between muscles 3 and 4, are attached for about a third of their length. Brain small and lacking processes.

Systematic position: The internal anatomy of these specimens resembles more closely that of *S. vastum* as shown in fig. 171 of Selenka & de Man, 1883 rather than that of *S. parvum* Fischer, 1928.

Previous Australian record: Shark Bay, Western Australia (Fischer, 1919a, 1927); Queensland (Edmonds, 1955).

Distribution: (1) Australian: Queensland at Heron Is. and Great Barrier Reef; Western Australia at Pt. Cloates.

(2) elsewhere: Pacific Ocean; Marshall Is., Funafuti, Rotuma, New Britain, Guam and Solomon Is. Indian Ocean; Mauritius, Laccadive Is., Maldives, Indonesia.

Specimens examined and localities: Queensland—Outer Barrier Reef (1) AMS W1606; Heron Is. (1) NMV coll.; Gillet Cay (4) AMS W9245. Western Australia—Point Cloates (1) WAM coll., Ningaloo Exped.

Siphonosoma (Siphonosoma) australe (Keferstein)

(Fig. 29)

Phascolosoma australe Keferstein, 1865 pp. 422-3, figs. 12 and 13.

Sipunculus australis Selenka and de Man, 1883 p. 90, figs. 180-183.

Siphonosoma australe Fisher, 1950a p. 807; Edmonds, 1961 pp. 217-220.

Sipunculus aeneus Baird, 1868 p. 76; Edmonds, 1961 pp. 217-220.

Location of type: Not known by author; specimen from Sydney, Australia.

Description: Although specimens of *S. australe* from New Zealand, Solomon Is. and south India have been examined by the author none are available from Australia. The following information is based on that of Keferstein (1865), Selenka and de Man (1883), Fischer (1922), Fisher (1950a) and Edmonds (1961).

Specimens long and cylindrical; trunk 130 mm (Keferstein)—220 mm (Fisher). Ratio of length of introvert to that of trunk half (Keferstein), third to half (Fisher) and almost three-quarters (Fisher). Prominent, hemispherical papillae on surface of trunk. Introvert armed with numerous rows of dark brown hooks or spines, 0.45 mm long (Keferstein), 0.22-0.34 (Edmonds), 0.3 (Fisher) and 0.2 (Fisher). Longitudinal muscles in 15 bands (Keferstein) but 13-18 according to other authors. Four retractor muscles arising at different levels in anterior third of trunk, a ventral pair from muscles 1-3 or 3-5 and a dorsal pair from 5-6 or 4-6. Nephridia long and free. Spindle muscle arises anteriorly from 3 roots and fastened posteriorly to body wall. Rectal caecum present.

Systematics: This species lacks both body dissepiments and numerous rectal caeca. It possesses rather long, dark spines. The differences between *S. australe* and the closely allied *S. eniwetoki* are discussed and illustrated in Fisher, 1950a. The hooks of *S. rotumanum*, another allied species, are stubby and rounded while in *S. australe* they are longer and sharper. Previous Australian record: Sydney, New South Wales (Keferstein, 1865).

Distribution: (1) in Australia: Sydney, New South Wales.

(2) elsewhere: Pacific Ocean; New Zealand, Samoa, Fiji, New Britain, Solomon Is., Philippines and Tasman Sea (at 610 m). Indian Ocean; Zanzibar, Madagascar, India and Indonesia.

Siphonosoma (Siphonosoma) boholense (Selenka and de Man)

Sipunculus boholensis (Semper?) Selenka and de Man 1883 pp. 109-111, pl. 12, figs. 175-177.

Siphonosoma boholense Stephen and Edmonds 1972 p. 63.

Location of type: Not known; specimen from Bohol (Philippines).

Description: Specimens very large and very stout. Trunk 270-410 mm long and 15-25 mm wide; maximum width anteriorly. Three specimens dark purple and fourth yellow brown. Body wall very thick. Introvert completely or partly contracted in all specimens; its maximum length about 80 mm and width 10-13 mm. A dissected introvert shows that numerous rows of brown papillae ring the organ but that hooks are absent. Base of introvert usually more darkly pigmented than rest of body. Skin of trunk anterior to anus rough and warty.

Longitudinal muscles in 29-33 anastomosing bands. Prominent rather flat papillae or skin bodies present on surface of trunk. Posterior extremity of 2 specimens is slightly bulbous and a terminal organ present. Four strong retractors arise in anterior third of trunk, a ventral pair from bands 4-5, 6-7, 4-6 and a dorsal pair more anteriorly from 9-12, 8-11, 8-13. Contractile vessel, with numerous very small villi, appears bushy. Spindle muscle stout; arises anteriorly from three roots, one being fixed in front of anus and others near base of dorsal retractors. Wing muscle strong. Rectal caecum in one specimen but not in second. Two nephridia, fixed to body wall for about two thirds of their length, open just in front of or at about same level as anus. Nephrostomes prominent and surrounded by numerous, small, tufted projections of the body wall. Prolongations of coelom extend into body wall. No fastener to last whorl of intestine found.

Systematic position: This is one of the largest species of sipunculans. It differs from other species of the same genus most noticeably in the number of longitudinal bands. In addition it lacks transverse dissepiments and hooks. This is the first Australian record.

Distribution: (1) in Australia: Queensland.

(2) elsewhere: Bohol, North Borneo.

Specimens examined and localities: Queensland—Yule Point, Townsville (3) SAM E1123; Dunwich (1) SAM E1124.

Siphonosoma (Siphonosoma) novaepommeraniae Fischer

Siphonosoma novaepommeraniae Fischer, 1926 pp. 104-106, pl. 3, figs 2-4; Wesenberg-Lund, 1959b p. 55; Edmonds, 1971 p. 140; Cutler, 1977 p. 139.

Location of type: Not known; specimen from New Britain.

Description: Specimen stout, cylindrical, narrowing slightly towards posterior and dark purple in colour in preserved condition. Body wall thick. Trunk 190 mm long and about 12-15 mm wide. Specimen contracted and longitudinal muscle bands not apparent externally. Prominent hemispherical papillae scattered on anterior eighth and posterior third of trunk, their diameter being 0.27-0.55 mm. Introvert, in retracted condition, about 45 mm long. Dissection of introvert shows presence of numerous rows of flat, circular papillae but no hooks.

Longitudinal muscles 17-18, with only slight anastomosis. Four short retractor muscles arise from two levels, a ventral pair from muscles 2-3 or 3-4 and a dorsal pair more anteriorly from bands 4-5. Oesophagus short but coiled intestine very long. Spindle muscle arising anteriorly from three roots, one being attached in front of anus, one to muscle 7 on right side and another to muscle 5 on the left near base of dorsal retractors. Spindle muscle fixed posteriorly. A fixing muscle connects posterior region of intestine to body wall. Wing muscle very strong. Gut filled with tightly packed coral fragments. Caecum not observed but rectal region damaged during dissection. Two nephridia, free for most of their length, arise at about same level as anus or just anterior to it. Contractile vessel with very numerous short villi, giving it a tufted appearance. No transverse dissepiments in body cavity. Brain not noticeable.

Systematics: This species can be distinguished from other Australian species of the same genus because (1) it lacks transverse body dissepiments, (2) it lacks hooks, and (3) it has less (17-18) longitudinal muscles than *S. boholense* which possesses about 30.

Previous Australian record: Coral Sea (30° 05'S, 154° 33'E) at 1 560 m (3) (Cutler, 1977 p. 139).

Distribution: (1) in Australia: Queensland (Heron Is.); Coral Sea (at 1 560 m).

(2) elsewhere: New Britain; Guam; Mauritius.

Specimens examined and locality: Queensland—Heron Is., (1) SAM E1125.

Siphonosoma (Siphonosoma) rotumanum (Shipley)
(Fig. 30)

Sipunculus rotumanus Shipley, 1898 pp. 469-470, pl. 37, figs 1-3.

Siphonosoma hawaiiense Edmonds, 1966 pp. 386-388, figs 1-4.

Siphonosoma rotumanum: Edmonds, 1971 p. 143, fig. 4; Stephen & Edmonds, 1972 p. 71.

Location of type: British Museum (Nat. Hist.), London; specimen from Rotuma.

Description: Specimen cylindrical and slightly curved ventrally. Trunk about 65-67 mm long and 8 mm wide. Introvert about 30 mm long, armed with transverse rings of pale-coloured, blunt hook-like structures. Although they seem larger than those described by Edmonds (1966, 1971), hooks closely resemble those of *S. rotumanum*. Papillae of two kinds; one, found mostly on introvert, is small, circular, about 0.1 mm in diameter, with a clear pore at its centre and the other, found mostly on trunk and few in numbers, is larger, hemispherical and about 0.4 mm in diameter. None of papillae black, as reported by Edmonds (1971).

Longitudinal muscles 15-16 and slightly anastomosing. Four retractors arise at different levels, a long ventral pair in mid-region of trunk from muscles 2-3 and a shorter dorsal pair more anteriorly from muscles 4-5; all fuse anteriorly. Alimentary canal held in position by fine fastening strands and a spindle muscle. Spindle muscle attached anteriorly well in front of anus and posteriorly by several radial-like extensions. Spindle muscle with two very prominent lateral roots connecting with muscle 7 on each side of nerve cord. Additional fastener runs from muscle 1 (at a point mid-way between base of dorsal and ventral retractors) to penultimate spiral of intestine. Wing muscle strong. Rectal caecum present. Nephridia slender, fixed to muscle 2 for most of their length and opening at about same level as anus; nephrostomes prominent and crescentic. Tufted bodies present on body wall near nephrostomes.

Systematic position: The specimen corresponds closely with specimens of *S. rotumanum* in my possession from Rotuma, Hawaii and Guam. The "hooks" or adhesive structures on the introvert are a little larger than those previously described and only one fastener was found arising between the dorsal and ventral retractors.

Much of the internal anatomy of *S. rotumanum* is like that of *S. australe* (Keferstein). The hooks of the latter, however, are sharp. *S. rotumanum* differs from *S. novaepommeraniae* (Fischer, 1926) in the possession of hooks.

Previous Australian record: Low Is., Queensland (Gibbs, 1978).

Distribution: (1) In Australia; Queensland.

(2) elsewhere: Pacific Ocean at Rotuma, Hawaii, Solomon Is. and Guam.

Specimen examined: Queensland—Low Is. (1) SAM E1128.

Family Golfingiidae and key to genera

Golfingiidae Stephen & Edmonds, 1972 p. 77.

Description: Tentacles basically surround mouth and may be finger-like, thread-like, branched or dendritic; they may be reduced to a few lobes or even be absent. No coelomic extensions in body wall. Longitudinal and circular musculature continuous. Tentacles usually interrupted mid-dorsally by a nuchal organ. Type genus: *Golfingia* Lankester, 1885.

KEY TO GENERA OF GOLFINGIIDAE

1. One nephridium 2
Two nephridia 3
2. Anus on anterior region of introvert near mouth. Single retractor muscle. Introvert very long. *Onchnesoma* (p. 32)
Anus on trunk and not on introvert. One or two retractors. Animals usually inhabiting discarded shells of gastropods and scaphopods, sometimes the tubes of annelids and more rarely solitary corals *Phascolion* (p. 29)
3. Tentacles arising from 4-8 stems and branching or dendritic. Retractors usually two, very rarely four. Contractile vessel with well-developed tubules or villi *Themiste* (p. 32)
Tentacles usually finger- or thread-like and not branching; sometimes reduced to a few lobes or more rarely absent. Retractor muscles two or four *Golfingia* (p. 18)

Genus *Golfingia* Lankester

Golfingia Lankester, 1885 p. 469; Fisher, 1950b p. 548; 1952 pp. 388-9; Stephen and Edmonds, 1972 pp. 77-80; Cutler and Murina, 1977 pp. 173-187.

Description: Often bottle- or flask-shaped, sometimes cylindrical or sub-cylindrical. Longitudinal and circular musculature continuous. One or more rows of finger- or thread-like tentacles usually surround mouth; in few species tentacles much reduced or even absent. Nuchal organ usually present mid-dorsally in ring of tentacles. Hooks present or absent. One or two pairs of retractor muscles. Spindle muscle may or may not be attached posteriorly to body wall.

Type species: *Sipunculus vulgaris* de Blainville, 1827.

Remarks: The genus is large, containing more than 100 species. Only about six of these are present in collections in Australia; most of the species listed

in this paper are from the records of other workers. The genus has been divided into subgenera by Fisher (1950b), Wesenberg-Lund (1959a), Stephen (1964), Cutler and Murina (1977) and Murina (1967; 1975a; 1977). In dealing with the taxonomy of the genus I have largely followed Cutler and Murina (1977) who reviewed the group and synonymised a number of species. I received Murina's latest subdivision of the genus (Murina, 1977) only after the present paper had been typed.

KEY TO SUBGENERA OF *GOLFINGIA*

1. One pair of retractor muscles 2
Two pairs of retractor muscles 4
2. Spindle muscle not attached posteriorly 3
Spindle muscle attached posteriorly *Siphonoides*†
3. Contractile vessel without villi *Phascoloides* (p. 24)
Contractile vessel with villi *Thysanocardia* (p. 27)
4. Nephridia bilobed *Mitosiphon* (p. 22)
Nephridia single-lobed 5
5. Spindle muscle attached posteriorly *Golfingiella* (p. 27)
Spindle muscle not attached posteriorly *Golfingia* s.s. (p. 19)

Subgenus *Golfingia* s.s.

Golfingia sensu stricto Fisher, 1950b p. 549; 1952 p. 390; Stephen and Edmonds, 1972 p. 81; Cutler and Murina, 1977 p. 179.

Description: Two pairs of retractor muscles. Hooks may or may not be present. Contractile vessel simple and without villi. Spindle muscle not fixed posteriorly.

Type: *Sipunculus vulgaris* de Blainville.

KEY TO SPECIES OF SUBGENUS *GOLFINGIA* REPORTED FROM AUSTRALIA

1. No hooks or spines on introvert
G. margaritacea adelaidensis (p. 21)
Introvert with hooks or spines 2
2. Anterior and posterior extremities of trunk of unrelaxed specimens forming a cap or shield-like structure; globose papillae present on shield *G. herdmanni* (p. 19)
No cap or shield-like structure at extremities of trunk 3
3. Spines tend to be straight; small swelling at base of spine
G. vulgaris queenslandensis (p. 21)
Spines claw-like; no swelling at base of spines *G. ohlini* (p. 22)

Golfingia (*Golfingia*) *herdmanni* (Shipley)

(Figs. 32, 36-38)

Centrosiphon herdmanni Shipley, 1903 pp. 171-174, pl. 1, figs. 4-10.

Location of type: not known by author; type locality, Sri Lanka (= Ceylon).

Description: Specimens light to dark brown in colour and cylindrical. When freshly collected or fixed without relaxation they usually assume the

characteristic shape, anterior and posterior regions of trunk looking rather like aspidosiphonid caps or shields which are surrounded at their junction with trunk by a fold of body wall. Caps usually dark brown or rust coloured in contrast with light brown trunk. In relaxed specimens caps and folds less noticeable or may be difficult to discern, then resembling more closely a typical golfingiid. Caps covered with small, rather globose, glandular, dark rust-brown, slightly stalked papillae tending to lie on elevated, radial ridges of body wall which suggests that longitudinal musculature in these areas could lie in bundles. An examination of transverse sections of the area, however, shows that this is not so, and that the ridging is in layers external to the dermis. Nor do sections show hardened or cornified structures found in cap of some aspidosiphonids (Hyman 1959, fig. 219H).

Length of trunk of 20 unrelaxed specimens 25-65 mm, width 3-8 mm. Introvert about a quarter to half length of trunk, 2-3.5 mm wide and arising centrally from cap and not ventrally as in *Aspidosiphon*; anterior region slightly bulbous. Mouth surrounded by numerous finger-like tentacles. Anteriorly introvert armed with randomly arranged, light to dark brown hooks or spines 0.15-0.20 mm long. Associated with spines at or near their base is a small bulbous swelling of body wall which sometimes appears to lie between the wings of the spines. Papillae on introvert base and on anterior cap bulbous (with tendency to be stalked), dark brown and 0.12-0.19 mm in diameter. Papillae on trunk wall flatter, less pigmented, smaller and less noticeable. Trunk may feel and appear smooth although covered with small, white, glandular openings. On posterior cap papillae dark brown-rust coloured and about same size as those on anterior cap.

Four retractor muscles separate for most of their length; a strong ventral pair arising from about middle of trunk and a weaker dorsal pair more anteriorly. Oesophagus fastened for some of its length to ventral retractors by thin mesenteries. Intestine long (about 20 double spirals). Rectal caecum present. Three fixing muscles, either two to oesophagus and one to rectum or one to oesophagus, one to posterior spiral and one to rectum. Wing muscle strong, sometimes extending almost to nerve cord on each side. Spindle muscle strong, arising under rectum either from a triangular flap of tissue, the apex of which connects with spindle muscle or (more frequently) from two strong roots (perhaps the lateral parts of the triangular flap). Spindle muscle not fixed posteriorly. Nephridia tubular but may be swollen near nephridiopore, arising just in front of anus, about a third as long as trunk and free for most of their length.

† No species of this subgenus has been reported from Australia.



FIG. 32. *Golfingia herdmani*, (specimens from Proper Bay, South Australia).

Gonads at base of ventral retractors. Contractile vessel tubular and without villi. Nuchal organ present but not always readily noticeable. Two eyespots.

Systematic position: The specimens fit well the description of *Centrosiphon herdmani* Shipley, 1903 described from two specimens from Sri Lanka (formerly Ceylon). No other record of the species exists. Shipley placed them in a new genus because they possessed, anteriorly and posteriorly, thickened, "chitinoid" shields and because the introvert arose from the centre of the shield and not ventrally to it as in *Aspidosiphon*. Transverse sections of the "shields", however, show that structurally they are not differentiated from the rest of the body wall and that no chitinous bodies are present. When the specimens are relaxed the "shields" usually become less evident and sometimes disappear. Because the presence of the shields or caps is an uncertain character it seems unwise to use it to separate off a new genus. The tentacles are arranged like those in *Golfingia*, the papillae, the introvert hooks and the internal anatomy of the specimens are golfingiid and not aspidosiphonid-like. At present, it seems better to me to call the species *Golfingia* (*Golfingia*) *herdmani* rather than *Centrosiphon herdmani*. The transference of the type of the genus *Centrosiphon* to *Golfingia* makes the genus *Centrosiphon* invalid. I



FIG. 33. *Golfingia margaritacea adelaidensis*, (specimen from Aldinga Bay, South Australia).

have not been able to find Shipley's type; it is not deposited in either the Nat. Hist. Mus., London or the Museum of the Zool. Dept. of the University of Cambridge (U.K.), the places where most of his types were lodged.

For some time I was uncertain as to whether or not *G. herdmani* and *G. margaritacea adelaidensis* were conspecific. I have decided against this possibility because *G. margaritacea adelaidensis* lacks hooks (they are present in all my specimens of *G. herdmani*), its anterior and posterior trunk is not modified to look like shields and globose papillae are not present on its body wall.

The taxonomic position of the specimens, however, is still unsatisfactory. Species of *Golfingia* with shield-like structures at one or both extremities of the trunk have been previously described, *G. (Phascoloides) rutilofusca* (Fischer), redescribed by Murina (1967) and by Cutler (1977), being one. *Golfingia* sp. of Cutler (1977 p. 140) as shown in his fig. 2 is closely related to *G. herdmani* and matches some of my Australian specimens. Murina (1975a p. 1085) created *Dushana*, as a subgenus of *Golfingia* to contain *G. scutigera* and *G. adriatica* both of which she said, possessed shield-like modifications at the extremities of the trunk. *G. herdmani* might possibly fit in this subgenus. Both Cutler and Murina now appear to have doubts about the subgenus

because neither of them in their most recent reviews of the genus (Cutler & Murina 1977; Murina, 1977) mention *Dushana*. Murina (1977 p. 212) now places *G. scutigera* (Roule), the type of *Dushana*, in the subgenus *Golfingia* s.s. No previous Australian record.

Distribution: (1) in Australia: Proper Bay, near Port Lincoln, South Australia.

(2) elsewhere: Sri Lanka (Ceylon).

Specimens examined and localities: South Australia—Proper Bay (part of Port Lincoln at base of Eyre Peninsula); amongst roots of *Posidonia* about 25 m from base of low cliffs at point where railway line to Coffin Bay crosses road to Sleaford Bay. To find the animals it is necessary to dig up a square or sod of *Posidonia* and pull it apart. The animals are well camouflaged. (15) SAM E1149; (10) SAM E1158; (3) SAM E1143.

***Golfingia* (*Golfingia*) *margaritacea adelaidensis* Edmonds**

(Figs. 33, 39)

Golfingia margaritacea adelaidensis Edmonds, 1956 pp. 302-3, pl. 2, fig. 2.

Location of type: Australian Museum, Sydney; specimen from Aldinga reef, St. Vincent Gulf, South Australia.

Description: Specimens long, slender, cylindrical and rather active when alive; yellow-brown and tending to glisten. Trunk 60-100 mm long, maximum width 4-7 mm. Posterior extremity usually tapering to a sharp point. Anterior and posterior extremities of trunk show no sign of ridging and no tendency to form caps as in *Golfingia herdmanni*. Body surface bearing numerous small, rather flat papillae best developed and most thickly packed on anterior and posterior regions of trunk. They appear as white, circular to elliptical structures about 0.1-0.2 mm in diameter, in a yellow matrix of body wall. Introvert slender, comparatively short, 20-25 mm long, 2-3 mm wide and lacking hooks. Anterior extremity of introvert of living and dead specimens usually swollen into a bulb-like structure 3-6 mm in diameter. Tentacles short, digitiform, white and up to 80 in number. Body wall generally thin.

Two ventral retractors arise close to nerve cord in anterior third of trunk and two dorsal retractors more anteriorly near level of anus. Retractors separate for most of their length. Oesophagus fastened to ventral retractors by two mesenteries; intestine long, consisting in one specimen of 34 double spirals. Spindle muscle arising from a triangular flap of tissue beneath a strong wing muscle and not fastened posteriorly. Fastening

muscles three or four. One (F1) arises from body wall just below left dorsal retractor and connects with oesophagus. A second (F2), arising near origin of F1, connects with last spiral of intestine (and in a few specimens gives off a short branch to posterior oesophagus). In two specimens F1 and F2 arise from same point. F3 (when present) and F4 arise between right dorsal and ventral retractors and connect with the last and penultimate intestinal whorls.

These specimens differ from *Golfingia herdmanni* (Shipley) from Proper Bay because (1) they do not form a cap or ridge at the extremities of the trunk (2) they lack introvert spines and (3) they lack rusty coloured, globose papillae on the anterior and posterior surfaces of the trunk and the ridges on which they lie, both of which are present in *G. herdmanni*.

Edmonds (1956 p. 303) says that "a caecum is lacking or possibly rudimentary". Recent study of more specimens shows that a small caecum is usually present. The specimens are close anatomically to *G. margaritacea* (Sars), described from Norway and reported widely from the northern hemisphere and from the Antarctic and sub-Antarctic. Recently Cutler (1977 p. 139) has reported *G. margaritacea* from off the South Australian coast. Whether his specimen is the same as mine I do not know. Murina (1977 p. 230) has placed *G. margaritacea adelaidensis* in the synonymy of *G. margaritacea margaritacea*. I find it difficult, however, to lump the South Australian material with that described by Théel and Wesenberg-Lund from Norway and Greenland and that from Alaska described by Fisher (1952). The spindle muscle of my specimens is strong and arises from a triangular flap of tissue under and separate from the wing muscle and not from the rectum as shown in pl. 23 fig. 3 of Fisher (1952). Théel's fig. 174 shows only two fixing muscles (there are three or four in mine) and no stout fixing muscle runs to the rectum near the anus, as shown in Théel (1905) fig. 174. In addition the specimens are always yellowish-brown in colour.

Previous Australian records: Edmonds (1956).

Distribution: Known only from Aldinga, South Australia.

Specimens examined and locality: In sand and debris amongst the roots of the marine angiosperm *Amphibolis antarctica* on the reef at Aldinga Bay, St. Vincent Gulf, South Australia. (1) SAM E1159, (2) SAM E1148, (1) SAM E1176, (1) SAM E1177, (1) AMS W3603.

***Golfingia* (*Golfingia*) *vulgaris queenslandensis* Edmonds**

Golfingia vulgaris queenslandensis Edmonds, 1956 pp. 303-4, pl. 17.

Location of type: Australian Museum, Sydney; specimens from Heron Is., Queensland.

Remarks: No additional specimens have been collected since Edmonds' 1956 record. There is still doubt about the identity of these specimens. They possess two pairs of retractors, hooks, three fastening muscles and a spindle muscle not attached posteriorly. The introvert is swollen anteriorly and there is a weakly developed rim between the base of the introvert and the trunk, much like that found in *Golfingia herdmani*. The hooks, however, are different from those of the latter species.

Distributions: Known only from Queensland.

Specimens examined: (2) Heron Is., Queensland, AMS W3602.

****Golfingia* (*Golfingia*) *ohlini* (Théel)**

Phascolosoma ohlini Théel, 1911 p. 29, pl. 2, figs 21-23, pl. 3, figs 24-27, pl. 5, figs 69-70.

Golfingia ohlini: Fisher, 1950b p. 550.

Location of type: Not known; type locality South Georgia.

Description: I have not seen Australian specimens of the species. Théel's account of the type specimen reads, "Total length of body 16 or 17 mm. Body elongate, subcylindrical, with posterior extremity pointed. Tentacles slender, 16 in number, arranged in groups on each side of the median line. Distinct ciliated sense pads present, separating the dorsal tentacles. Skin whitish, shining with small cylindrical papillae, crowded at the posterior extremity of the body and scarce at its middle. Behind the tentacles mamillary wart-like papillae and scattered hooks, both directed backwardly. Two free segmental organs. Muscular layers of the body-wall continuous, not separated into bands. Two ventral and two dorsal retractors. Intestinal spiral composed of about 14 double turns and not attached posteriorly."

Australian record: New South Wales, off Broken Bay (33° 34'5 S, 152° 06'5 E) (1) Murina, 1972 pp. 301-302.

Distribution: (1) in Australia: off coast of New South Wales.

(2) elsewhere: Antarctica and sub-Antarctica; Mauritius and South Africa; Chile.

Subgenus *Mitosiphon* Fisher

Mitosiphon Fisher 1950b p. 550; 1952 p. 393; Stephen & Edmonds 1972 p. 113; Cutler & Murina 1977 p. 180.

Description: Two pairs of retractor muscles. Introvert hooks (if present) have accessory comb of

spinelets at base. Nephridia bilobed. Spindle muscle not attached posteriorly.

Type *Phascolosoma hesperum* Chamberlin.

KEY TO SPECIES OF SUBGENUS *MITOSIPHON* REPORTED FROM AUSTRALIA

1. Introvert hooks with 4-5 accessory teeth
G. misakiana (p. 22)
- Introvert without hooks *G. trichocephala* (p. 23)

(Murina, 1977 has now assigned *G. trichocephala* to a subgenus *Apionosoma* Sluiter, 1902; *G. misakiana* has been left in *Mitosiphon*).

***Golfingia* (*Mitosiphon*) *misakiana* (Ikeda)**

Phascolosoma misakianum Ikeda, 1904 pp. 7-9, pl. 1, fig. 3, pl. 3, figs 30-33; Fischer, 1919a p. 281; 1927 p. 204.

Golfingia misakiana: Fisher, 1952 p. 393; Cutler, 1973 p. 144; Murina, 1970 p. 66; 1977 p. 236.

Location of type: Not known to author; specimen from coast of Misaki Bay, Japan.

Description: Four specimens, two in very good condition and with introvert extended, were examined. Specimens small and slender and introvert almost thread-like. Trunk of largest 11 mm x 1.5-1.8 mm and introvert about 40 mm x 0.4-0.7 mm. Body wall thin and transparent enough to show most of internal anatomy without dissection. Mouth surrounded by 5 (26) swellings or protuberances, probably corresponding to tentacles. About 20 complete rows of clear, almost transparent hooks surround anterior region of introvert. Rows then become incomplete and ultimately hooks sparsely scattered. Hooks small, 0.022-0.027 mm tall, with sharply bent tips and with usually five sharp accessory teeth near base. More posteriorly placed hooks smaller and may lack accessory teeth. Introvert bearing very numerous, small urn-shaped glandular papillae. Posterior trunk papillae about 0.20-0.25 mm in diameter and rather flat, consisting of a few rounded plates arranged like the petals of a flower. In mid-trunk, papillae are larger (up to 0.1 mm in diameter) and the arrangement of plates less definite. One feature of specimens is that both trunk and introvert are covered by a very great number of very small "points" (possibly glandular pores), placed very closely to each other, lying in both longitudinal and transverse rows and making the surface appear striated.

The most transparent specimen shows four retractor muscles, two long, bilobed nephridia and a posteriorly fastened spindle muscle.

Systematic position: The specimens are considered to be *G. misakiana* (Ikeda). The question

arises whether *G. misakiana* and *G. trichocephala* (Sluiter), which is also being recorded in this paper from the eastern coast of Australia, are the same species, a species with a genetically determined set of hooks which for some reason concerned with the animals's environment may either be lost or never appear. Cutler (1973 pp. 139-144) discusses the question. He states that his specimens of *G. trichocephala* and apparently the type specimen (since he examined it) lack hooks. Murina (1970; 1977) describes *G. trichocephala* as being hookless. Neither can I find hooks on some specimens from Moreton Bay, Queensland which I have called *G. trichocephala* nor on some from Madagascar, sent to me by Dr. Thomassin. Murina must consider the two species valid because she described both of them in her 1977 paper and I think it best to regard them so, at present. If the two are the same it is remarkable that specimens with and without hooks have not been found together in the same collection. Nevertheless many characters of my specimens of *G. misakiana* correspond with those of *G. trichocephala* e.g., size and shape, anterior region of introvert and papillae (Murina, 1977, fig. 162), bilobed nephridia, four retractor muscles and even the fine striations on the surface of the trunk and introvert, which are present in both my specimens of the two species. The figures of the species were drawn from the specimen SAM E1161. The specimens lack the large papillae on the posterior surface of the trunk, present in *G. murinae* Cutler, 1969.

Previous Australian record: Western Australia (Fischer, 1919a).

Distribution: (1) in Australia: Western Australia at Shark Bay, 6-9 m (Fischer 1919a); N.S.W. at Broughton Is.

(2) elsewhere: Japan; New Guinea, Tanzania and Easter Is. (Murina 1977 p. 238).

Specimens examined and localities: N.S.W. at Broughton I., amongst roots of marine angiosperm *Posidonia* (Collet and Pat Hutchings) (2) AMS W13157, (1) AMS W12991, (1) SAM E1161.

***Golfingia* (*Mitosiphon*) *trichocephala* (Sluiter)**

(Figs. 34, 40)

Apionsoma trichocephalum Sluiter, 1902 pp. 42-44, pl. 4, figs. 8-11; Murina, 1977 p. 236.

Golfingia trichocephala Murina, 1972 p. 303; Cutler, 1973 p. 139; Cutler and Murina, 1977 p. 180.

Location of type: Zoological Museum, Amsterdam; specimen from near Surabaya, Java, Indonesia.

Description: Small, white-brown, slender species with a long, almost thread-like introvert. Trunk 3.0-5.1 mm long, maximum width usually less than

1 mm; curved ventrally in most specimens. Posterior extremity pointed. Body wall thin and internal structures often visible under strong light. Introvert 45 mm long in specimen with trunk 4.1 mm long; lacking hooks and tentacles.

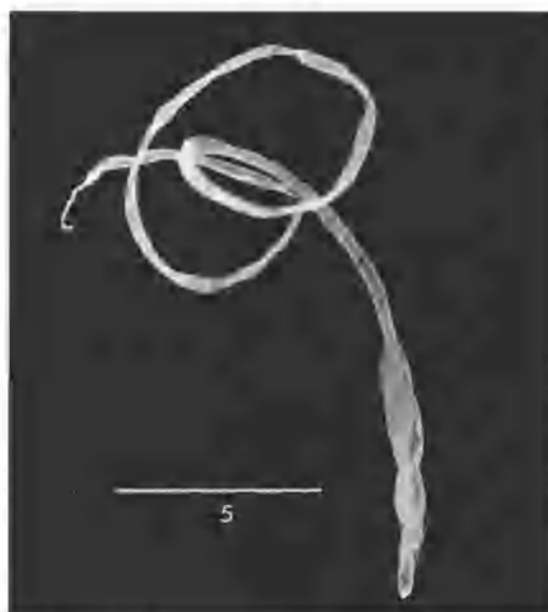


FIG. 34. *Golfingia trichocephala*, (specimen from Moreton Bay, Queensland). Scale measurements are in mm.

Longitudinal musculature continuous. Four slender retractor muscles, a ventral pair arising very close to nerve cord in middle of trunk and a dorsal pair more anteriorly. Intestine long, coiled and slender. No rectal caecum observed in 2 dissected specimens. Spindle muscle fixed posteriorly to body wall. Rectum attached to body wall near anus by a strand of tissue. Suspension at this point accounts for what Cutler (1973) described as a "genuflection in the rectum". Contractile vessel inconspicuous. Two yellow-brown, free, bilobed nephridia of equal length opening anteriorly to anal aperture.

Systematic position: *Apiosoma trichocephalum* Sluiter, 1902 was dredged at 56 m from Indonesia (lat. 7° 25' S, long. 113° 16'E) and described as possessing nephridia with single lobes. Cutler (1973 p. 138) re-examined Sluiter's type and found that the nephridia were bilobed. After a careful study of the type specimens he concluded that *G. tenuissima* Wesenberg-Lund, 1959a and *G. longirostris* Wesenberg-Lund 1959a were junior synonyms of *G. trichocephala*. Murina (1977 p. 180) removed it from the subgenus *Mitosiphon* and placed it in *Apiosoma* which she now regards as a subgenus.

Fischer (1919a) reported *Golfingia misakiana* (Ikeda) from Shark Bay, Western Australia. *G. misakiana* and *G. trichocephala* are alike in many respects. The former, however, is described as

possessing introvert hooks with accessory teeth. The specimens in the present collection from Rottneest Is., like those from Queensland, lack hooks.

G. trichocephala is identified by its small size, a very long slender introvert lacking hooks and tentacles, the presence of four retractors and two bilobed nephridia.

Previous Australian record: off coast of New South Wales (33° 34' S, 152° 16' E) by Murina (1972).

Distribution: (1) in Australia: Queensland, New South Wales and Western Australia.

(2) elsewhere: South Africa and West Africa (Wesenberg-Lund, 1959a, 1959b, 1963); Western Atlantic (Cutler, 1973); Indonesia (Sluiter, 1902); Coral Sea and Tasman Sea (Cutler, 1977); Gulf of Aden (Murina, 1970).

Specimens examined and localities: Queensland—Moreton Bay (8), dredged by S. Cook (Dept. of Zoology, Univ. of Queensland), SAM E1152; same locality (5) coll. W. Green (Univ. of Queensland) SAM E1150 and SAM E1154. Western Australia—William Bay, Rottneest Is. (2) AMS W10565.

Subgenus *Phascoloides* Fisher

Phascoloides Fisher 1950b p. 550; 1952 p. 395; Stephen and Edmonds, 1972 p. 131; Cutler and Murina 1977 p. 182; Murina, 1977 p. 180.

Description: One pair of retractor muscles. Introvert with or without hooks. Contractile vessel simple and without villi. Spindle muscle, if present, not attached posteriorly.

Type: *Sipunculus eremitus* Sars, 1851.

(Murina 1977 p. 180 has replaced *Phascoloides* Fisher, 1950b by *Nephasoma* Pergament 1946 on the grounds of priority. Her argument is that since *Nephasoma marinkii* Pergament, 1946 = *Golfingia glacialis* Danielssen and Koren, 1881 and because Fisher (1950b) placed *G. glacialis* in his subgenus *Phascoloides* the term *Nephasoma* is an older name in the group).

KEY TO SPECIES OF PHASCOLOIDES RECORDED FROM AUSTRALIA

1. Tentacles absent or reduced to leaf-like structures or lobular projections **G. minuta* (p. 24)
..... **G. improvisa* (p. 24)
- Tentacles numerous and finger-like 2
2. Wing muscle well developed and spindle muscle arising from two strong roots *G. schuettei* (p. 25)
- Wing muscle not well developed and spindle muscle not arising from two strong roots **G. pellucida* (p. 26)

**Golfingia* (*Phascoloides*) *improvisa* (Théel)

Phascolosoma improvisum Théel, 1905 pp. 82-83, pl. 5, figs. 51-58; pl. 12, figs. 177-182, pl. 14, figs. 202-3.

Golfingia improvisa Murina, 1958 pp. 1625-1628; Stephen and Edmonds, 1972 p. 145; Cutler, 1973 p. 155; Murina, 1977 pp. 184-6, figs. 122a-e.

Location of type: Not known to author; type locality, West coast of Sweden.

Description: Théel's account reads, "Total length of largest specimen 15 mm. Proboscis about half of the total length, or shorter. Trunk cylindrical, slightly tapering anteriorly and behind. Tentacles absent and replaced by some irregular, rounded prominences on the oral disc. Skin hyaline and provided with distinct papillae especially on the posterior end of the trunk and on the proboscis. A girdle of hooks always present. Two ventral retractors embracing the nerve cord with their roots, and varying greatly in length. They are attached to the body-wall either at the middle of the trunk, or at its anterior part or else considerably posteriorly. Two free segmental organs. Intestinal spiral composed of about 13 or more double turns and not attached posteriorly. Body cavity never contains eggs."

Remarks: This species has also been reported from New Zealand in the tube of a foraminiferan (Edmonds, 1976). *G. improvisa* is closely related to *G. minuta* (Keferstein) and thought to be synonymous with it by some workers (see under *G. minuta*). Murina (1977 pp. 184-8) discusses the question.

Australian record: Tasman Sea (39° 35' S, 153° 45' E) "in shell of a foraminiferan" (Murina, 1972 pp. 300) at 3 970 m.

Distribution: (1) in Australia: Tasman Sea.

(2) elsewhere: Sweden, Greenland, east coast of New Jersey, U.S.A., France, British Isles, north-west Pacific, South Africa.

* *Golfingia* (*Phascoloides*) *minuta* (Keferstein)

Phascolosoma minutum Keferstein, 1863: p. 40, pl. 3, figs 7-10; Théel, 1911 p. 32, pl. 3, figs 42-45, pl. 4, figs 46-49.

Golfingia minuta: Murina, 1957a pp. 994-995; 1958 pp. 1628-1634; 1977 pp. 186-188, fig. 123; Cutler, 1973 pp. 155-159.

Location of type: Not known to author; specimen from St. Vaast la Houge, Normandy, France.

Description: A small species. According to Keferstein trunk about 6 mm long and introvert 8

mm. Tentacles reduced to two leaf-like structures or 4-6 "lobular projections" (Cutler, 1973 p. 158). Musculature thin and continuous. Four retractors arising in posterior third of trunk (Cutler says "a wide variety of locations"). Spindle muscle not fixed posteriorly. Nephridia short, sac-like, free and opening a little behind anus. Small caecum usually present according to Cutler. Akesson (1958) says that *G. minuta* is hermaphroditic.

Systematics: *G. minuta* is very closely related to *G. improvisa*. Cutler (1973 p. 158) thinks that they are synonymous but Murina (1958 p. 1624; 1977 p. 186) considers them different.

Australian record: New South Wales, off Broken Bay (33° 34' S, 152° 06' E) (5) Murina, 1972 p. 300.

Distribution: (1) in Australia: off coast of New South Wales.

(2) elsewhere: Arctic Sea, North Sea, western-north Atlantic, Mediterranean, off South Africa, north-west Pacific, Chile, and Falkland Is.

****Golfingia* (*Phascoloides*) *pellucida* (Keferstein)**

Phascolosoma pellucidum Keferstein, 1865 p. 433, pl. 32, figs 26-27; Fischer, 1919a p. 281.

Golfingia pellucida: Fischer, 1950b p. 550; Cutler, 1973 pp. 159-162.

Location of type: Not known by author; specimen from St. Thomas, Antilles, West Indies.

Description: According to Keferstein the body is 8-9 times as long as wide, and the introvert is a half to three quarters as long as the body. Skin thin and transparent, often iridescent, with uniformly distributed small, wart-like papillae which posteriorly are pointed and yellow. Hooks few and irregularly distributed between the papillae and folds of skin on the anterior part of the introvert; they are seen only with the aid of a microscope and are 0.032 mm high and 0.044 mm long. Tentacles numerous and rather long.

Musculature thin, continuous and without banding. Two retractors arising in the middle third of the trunk. Two large eyespots. Intestine of about 14 spirals, without a posteriorly fastened spindle muscle. Three fasteners to the first spiral. Rectum short. Contractile vessel not observed. Nephridia short and free. Length of body 32-45 mm, of introvert 15-23.

Several specimens from St. Thomas, in coral at depth of 2 feet.

Remarks: Judging from the records of Keferstein (1865), Selenka & de Man (1883 p. 32), Augener (1903 p. 299), Fischer (1914 p. 8), Cutler (1973 p. 159) and Murina (1968 p. 421; 1977 p. 196), *G. pellucida* is a variable species. Fischer (1919 ap. 281) reported it from Cockburn Sound, Western Australia. Unfortunately he gave no information about the specimens. Recently I have examined two other specimens from Cockburn Sound and have decided that, although closely related to *G. pellucida*, they are different from it. I have referred them to *G. schuettei* (Augener, 1903), a species described from Sydney, New South Wales. Whether *G. schuettei* and *G. pellucida* are synonymous I am not able to say.

Australian records: Cockburn Sound, W.A. (Fischer, 1919a); Torres St., Q. (Selenka & de Man, 1883).

Distribution: Antilles, Costa Rica, Jamaica, eastern coast of South America, Amboina, western North Atlantic, Philippines, Singapore, Torres St., Gulf of Mexico, Gulf of Siam.

***Golfingia* (*Phascoloides*) *schuettei* (Augener)**

(Figs. 35, 44-45)

Phascolosoma schuttei Augener, 1903 pp. 335-337, figs 17-18.

Golfingia schuettei: Murina, 1964a p. 238, fig. 12; 1971: 43; 1973: 16; 1974 p. 235; 1977 pp. 191-2, fig. 128; Stephen & Edmonds 1972 p. 156, figs 18a and b.

Location of type: Not known; specimen from Sydney, Australia (coll. by Dr. Schutte in 1876).

Description: Specimens light to golden brown or grey, usually long and sub-cylindrical. Trunk 33-160 mm long (three are longer than 100 mm) and 5-10 mm wide. Introvert usually not well differentiated from trunk, 10-25 mm long. Mouth surrounded by numerous digitiform tentacles which are made to look complexly arranged by radially projecting extensions of the tissue from which the tentacles arise, much as is shown in figs. 191-3 of Théel (1905). Zone of brown to black, sharply pointed hooks, lies posterior to tentacles. Hooks either straight or curved slightly at tip and varying in size and direction. Anterior hooks usually largest, projecting almost at right angles to surface; posterior ones smaller, often just piercing surface. Small papilla-like swellings usually present near base of each hook. Field of hooks may be better developed on ventral surface and in one specimen whole field much reduced.



FIG. 35. *Golfigia schuettei*, (specimen from Port Jackson, New South Wales).

Trunk papillae may be plumply conical, globose or short and cylindrical, the first two sometimes arising from a narrowed base or stalk. Musculature of body wall continuous. Two strong retractors, separate for part or most of their length, arise in middle or posterior half of trunk. Contractile vessel prominent but without villi. Wing muscle strong. Spindle muscle arises anteriorly from two strong roots attached to body wall on each side of just anterior to anus. Roots, separate from wing muscle, run under rectum and join near caecum to form spindle muscle (much as in *G. margaritacea adelaidensis* and *G. herdmanni*). Spindle muscle free posteriorly. Three to five fastening muscles. F1, arising on left side of nerve cord runs to posterior oesophagus; F2, F3 and F4 (if present) connect with penultimate intestinal spiral and F5 with rectum. Nephridia two, usually tubular (sometimes swollen anteriorly), long free and opening at about same level as anus. Brain simple with two eyespots. Gonads at base of retractors. Twenty to thirty double intestinal spirals.

Systematic position: I am naming the specimens as *G. schuettei* (Augener) with some reservations, chiefly because I have not been able to compare them with the type specimen.

It is possible that the specimens, especially those from Cockburn Sound, W.A., are the same species

as those from Cockburn Sound which Fischer (1919 p. 281) called *G. pellucida* (Keferstein, 1865). The type locality of the latter species is in the Antilles but Fischer (1919 p. 281) says that it is "circumundang". Unfortunately Fischer gave no information about his specimens. *G. pellucida* (especially long specimens) have been reported from Indonesia, Malaysia and the Philippines several times, (1) by Selenka & de Man (1883) from the Philippines, Singapore (specimens with trunk 80 mm long, introvert 45 mm and without hooks) and Torres St. (hooks lacking) and (2) by Augener (1903) from Amboina (specimens 70 mm long). Selenka says that he was not able to find any real difference between specimens from the Antilles and Rio de Janeiro and from the Philippines etc. and gave all them all the same name.

After comparison with specimens of *G. pellucida* from the Western North Atlantic, which were named and sent to me by Prof. E. Cutler, and some from Curaçao, collected by C. J. van der Horst (Zool. Mus., Amsterdam) I am inclined to think that the Australian specimens are different. They are much larger, cylindrical rather than flask shaped, their tentacles are more complexly arranged, their wing muscle is strong and the spindle muscle arises either from a triangular flap or two strong roots. Concerning size, Cutler (1973 p. 159) found that the trunk of 834 specimens of *G. pellucida* from the Western North Atlantic was 3-25 mm long and 1-3 mm wide (most were 6-10 mm long). Murina (1968 p. 422; 1972 p. 302; 1977 p. 192) also reports small specimens. For these reasons I am reluctant to lump my specimens with those from Curaçao and the North Atlantic. A translation of Keferstein's description of *G. pellucida* is given in this paper (see p. 25).

Phascolosoma schuettei Augener, 1903 was described from a single specimen collected at "Sydney" by Dr. Schütte in 1876. Augener says that the specimen was with some others obtained from the Göttingen Museum. The type however, is not in the Museum today and there is no record that it was ever lodged there. The length of the trunk is about 70 mm and Augener figures its club-like papillae and its introvert hooks. Its tentacular crown consists of numerous, long, yellowish tentacles which surround the mouth in a single row. The single-rowed nature of the arrangement is obscured by the radially projecting folds of the tissue from which the tentacles arise (= "Tentakelgrundes") much as it is in *Siphonosoma cumanense*. The species possesses two retractors which arise in the posterior two-thirds of the trunk, three fasteners, 63 intestinal spirals, a caecum and a spindle muscle not attached posteriorly. There is no doubt that my Australian

specimen and Augener's description closely correspond and it is unfortunate that the type specimen cannot be found for a comparison. The main difference seems to be in the number of fasteners. Murina (1964a p. 238) records two specimens from the Tasman Sea (37° 31'S, 163° 59'E) at 1330 m and one from the N-W Pacific at 5397 m and in Murina (1973 pp. 69-70) several from the Peruvian-Chilean Trench at depths of up to 7 000 m. The specimens in my collection, however, were collected from shallow water, two from Port Jackson (= Sydney Harbor).

The trunk of *G. (Phascoloides) novaezealandiae* (Benham, 1904) may be long (up to 310 mm) and is sub-cylindrical; the species seems closely allied to *G. schuettei*. The four specimens so far described however, all lack introvert hooks. Sluiter (1902 p. 35) considered that his *G. subhamata*, dredged from two different localities in Indonesia, although closely related to *G. pellucida* was different from it. Recently I re-examined one of Sluiter's original specimens, a small one which I found difficult to work with. Whether *G. subhamata* and *G. schuettei* are the same I am unable to say.

G. schuettei differs from the other large Australian golfingiids (*G. margaritacea adelaidensis* and *G. herdmani*) in that it has only two retractors, while they have four.

Previous Australian records: New South Wales (Augener, 1903); Tasman Sea (Murina, 1964a).

Distribution: (1) in Australia: Port Jackson (N.S.W.); Cockburn Sound, Port Gregory and Dampier Archipelago (W.A.); Tasman Sea.

(2) elsewhere: N.W. Pacific Ocean; Peruvian-Chilean Trench.

Specimens examined: New South Wales—Port Jackson (1) AMS W3019 "under rocks" and (1) SAM E1171 (coll. P. Hutchings). Western Australia—Cockburn Sound (north of Jervis Bay) SAM 141/76; Cockatoo Is. (1) "under stones at low tide" WAM 149/76; Dampier Archipelago (1) coll. of WAM.

Subgenus *Golfingiella* Stephen

Golfingiella Stephen, 1964 p. 459; Stephen & Edmonds, 1972 p. 118; Cutler & Murina, 1977 p. 180; Murina, 1977 p. 240.

Description: Introvert without hooks but with tentacles or tentacular lobes. Two pairs of retractor muscles. Spindle muscle attached posteriorly. Nephridia single-lobed.

Type species: *Phascolosoma procerum* Möbius.

Remarks: I am following the lead of Cutler (1977 p. 141) in placing *G. murinae murinae* in this subgenus. Cutler (1969 p. 214), however, says that a few rows of transparent hooks are present on the introvert. It is difficult, therefore, to see how the species falls in *Golfingiella*. Murina (1977 p. 238), with some justification, has placed *G. murinae* in *Mitosiphon*. Perhaps the status of *G. murinae murinae* (= *unilobatae*) and *G. murinae bilobatae* needs investigation. Cutler and Murina (1977 p. 181) claim that, because its mouth lies outside the ring of tentacles, the species should be transferred to *Fisherana* (Phascolosomatidae).

**Golfingia (Golfingiella) murinae murinae* Cutler

Golfingia murinae murinae Cutler 1969 p. 214 (as amended by Cutler); 1973 p. 145; 1977 p. 141-2, figs 4 and 5; Cutler and Murina, 1977 p. 181.

Location of type: U.S.N.M. no. 38247; type locality, 37° 13'N, 68° 40'W, dredged at 4 540 m.

Description: Trunk 1.5-13 mm long. Introvert four to six times length of trunk, with few rows of transparent hooks (some of which have an accessory comb of spinelets at base). Large mammiform papillae at posterior end of trunk. Four retractors arising from posterior third of trunk. Nephridia free and sac-shaped. Anus posterior to nephridiopores.

Australian record: Cutler, 1977 p. 142.

Distribution: (1) in Australia: Tasman Sea (off Port Macquarie, N.S.W.) (31° 27'S, 153° 33'E) dredged at 4 530 m (6) (Cutler, 1977 p. 142).

(2) elsewhere: "A deep water species (1 000-4 750 m) in the north-western Atlantic and in the north-western Pacific Ocean (3 950 m)" according to Cutler, 1977; off Kenya (3 950 m), east of Seychelles (3 300 m), N-W Philippine Trench (1 000 m), Sunda Trench (2 810-2 990 m), south of Bali (780 m). All these records from Cutler, 1977.

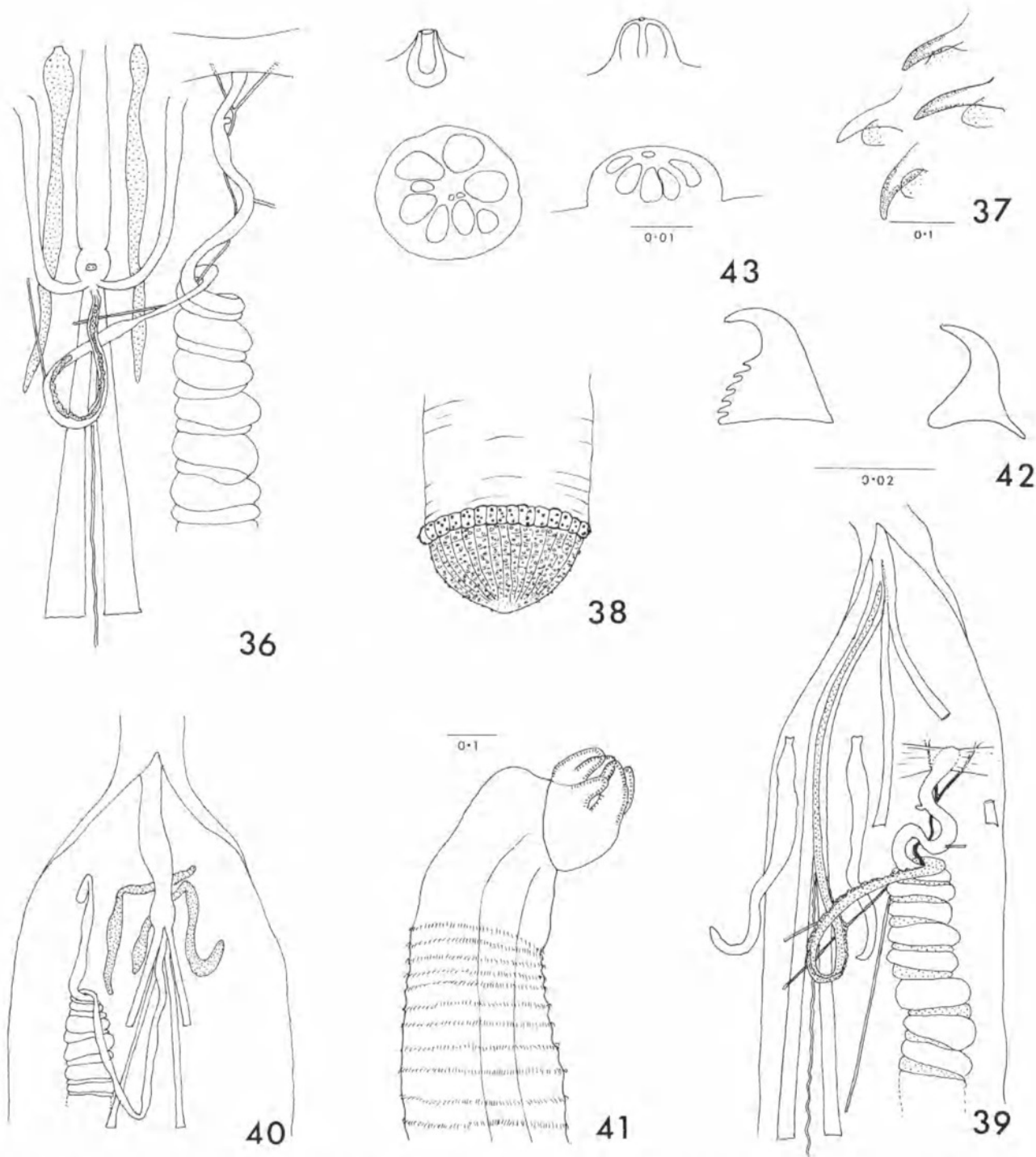
Subgenus *Thysanocardia* Fisher

Thysanocardia Fisher, 1950b p. 551; 1952 p. 400; Stephen & Edmonds, 1972 p. 120; Cutler & Murina, 1977 p. 181; Murina, 1977 p. 198.

Description: One pair of retractor muscles. Contractile vessel with branched or unbranched tubules. Nephridiopore usually opens in front of anus. No introvert hooks.

Type species: *Phascolosoma procerum* Möbius, 1875.

Remarks: The position of *G. coriaca* (Keferstein) in this subgenus is very uncertain because it possesses introvert hooks. Fisher (1950 p. 551; 1952 p. 395) placed it in the subgenus *Golfingia* s.s.



FIGS. 36-43. Figs. 36-38, *Golffingia herdmanni*; 36, anterior region dissected; 37, introvert hooks; 38, posterior region of trunk. Fig. 39, *Golffingia margaritacea adelaidensis*; anterior region dissected. Fig. 40, *Golffingia misakiana*; 41, anterior region of introvert; 42, introvert hooks; 43, papillae from trunk.

Keferstein's fig. 23 and his description "Contractiler Schlauch . . . , mit mehreren sehr langen, cylindrischen Aussackungen" indicates that long tubules are present. In which case the position of the species in *Golffingia* s.s. is also uncertain.

Specimens of neither of the two species reported from Australia have been seen by me. *G. coriacea* possesses hooks, *G. semperi* does not.

****Golffingia* (*Thysanocardia*) *coriacea* (Keferstein)**
Phascolosoma coriaceum Keferstein, 1865 pp. 432-3, pl. 32, figs. 23-4; Selenka and de Man, 1883 pp. 34-5, pl. 2, fig. 15, pl. 5, figs. 50-53.

Golffingia coriacea Fisher, 1950b p. 551; Cutler, 1973 pp. 160-161; Cutler and Murina, 1977 p. 181.

Location of type: not known specimen from St. Thomas, West Indies.

Remarks: Murina's single specimen from South Australia is small, cream and pyriform. Trunk 7 mm long and 5 mm wide and introvert 3 mm long and 1.5 mm wide. Introvert hooks 0.1 mm long. Two retractor muscles present and "fluffy" polian vesicles.

No specimens of this species are in the collection of the South Australian Museum. The only ones from St. Vincent Gulf in the Museum which are small, possess two retractors, fluffy polian vesicles and introvert hooks are those of *Themiste fusca* (see p. 40). The latter is common.

Cutler (1973 p. 159) places *G. coriacea* in the synonymy of *G. pellucida* (Keferstein) on the grounds that Keferstein's specimen must have been aberrant.

Australian record: South Australia, near Adelaide (Murina, 1972 p. 298).

***Golfingia (Thysanocardia) semperi** (Selenka and de Man)

Phascolosoma semperi Selenka and de Man, 1883 pp. 37-38, pl. 5, figs. 56-59.

Golfingia semperi Fisher, 1950b p. 551.

Location of type: ?; specimen from Uhoy, Philippines.

Description: Trunk 28 mm long and slim. Two stout retractors. Tentacles filamentous but hooks lacking. Contractile vessel with numerous tubules. Nephridia about half as long as trunk, free and opening anterior to anus. Spindle muscle not fixed posteriorly.

Remarks: No specimens seen by the author. Although it has been reported several times the species seems not to have been re-described. Fisher's 1921 account takes up only three lines. Australian record: Cape Jaubert, Western Australia (Fischer, 1921).

Distribution: (1) in Australia: Western Australia.

(2) elsewhere: Philippines, Red Sea, Zanzibar and Fernando Po.

Genus *Phascolion* Théel

Phascolion Théel, 1875 p. 13; Stephen and Edmonds, 1972 pp. 164-165.

Description: Specimens usually small, living in empty shells of gastropods or scaphopods, in tubes of annelids, in burrows in coral rock or in solitary corals. Body usually spirally twisted and internal organs asymmetrically arranged. Only one, usually the right, nephridium present. Usually only one

gonad. Musculature of body wall continuous. Characteristic adhesive or holding papillae usually present on surface of trunk.

Type species: *Phascolion strombi* (Montagu, 1804).

KEY TO AUSTRALIAN SPECIES OF *PHASCOLION*

1. Retractor single for all or most of its length 2
 Retractors double for all or most of their length 3
2. Retractor divided posteriorly near point of fixation into 3 short roots; caecum placed at a considerable distance from anus (half-third of way from anterior end of trunk) **P. pacificum* (p. 32)
 Retractor not divided posteriorly; caecum not reported *P. collare* (p. 29)
3. Some papillae on anterior surface of trunk near base of introvert with 2-4 points *P. cronullae* n.s.p. (p. 30)
 Papillae on trunk with single points. **P. dentalicolum* (p. 32)

Phascolion collare Selenka and de Man

(Fig. 52)

Phascolion collare Selenka and de Man, 1883 pp. 45-46, pl. 6, figs. 71-74; Fischer, 1922 p. 12; Cutler, 1977 pp. 144-5.

Type locality: Philippines; location of type not known to author.

Description: This description is based on two complete and two incomplete specimens. One intact specimen is spirally coiled but the other not. Estimated length of coiled specimen 14 mm and width 2.2 anteriorly; of other specimen 9×1.7 mm. Anterior extremity of trunk of coiled animal formed into a soft cap which is marked off from trunk by a rim; it is not an aspidosiphonid shield because it is not hardened and because introvert arises centrally and not ventrally to it. No shield-like structure in other specimen. Posterior region of introvert and anterior trunk bears flask-shaped papillae. Much of trunk carries numerous small hemispherical or rounded holdfasts, capped with a brown-black, forked structure of variable size, those on outer (dorsal?) side being largest. Single-pointed part of forked structure usually directed anteriorly.

Introvert about three quarters as long as trunk, bearing anteriorly numerous small, blunted hooks. One long nephridium. Intestine short and although convoluted seems not to be coiled. Retractor single, arising without bifurcation from posterior extremity of trunk.

Systematic position: There is no doubt that these specimens from *Heterocyathus* are a *Phascolion*. The single nephridium, the presence of holdfasts on the trunk and the absence of shields support this conclusion. The shape of the pointed structure of the holdfasts and the internal anatomy of the animal correspond to those of *Phascolion collare*, a species previously reported from shells. No three or five

pronged structures like those described for *P. tridens* Selenka & de Man are present in the Western Australian specimens. The specimens are closely related to *P. robertsoni* Stephen & Robertson, 1952, to *P. pacificum* Murina, 1957a and especially to *P. ikedai* Sato, 1930, reported from the coral *Stephanoceris*.

Distribution: (1) in Australia: north-west Australia.

(2) elsewhere: Philippines (Pangola, Uhoy, Bohol) in shells of *Strombus*, *Cerithium* and *Turbo*; Zanzibar in *Dentalium* shells; Makassar St. (at 2 000 m) and Bali Sea (at 1 951 m).

Specimens examined and localities: Western Australia—5 specimens in solitary coral, *Heterocyathus* sp. dredged at Norbill Bay, Dampier Archipelago WAM 36-73; also 2 specimens from *Heterocyathus* from Phillips Beach, Dampier Archipelago, AMS W5497. One retained in S.A. Museum (SAM E1188).

Phascolion cronullae n.sp.

Location of type: Australian Museum, Sydney; specimen in shell of *Gazameda gunni* (Reeves) off Cronulla, New South Wales.

Description: Trunk spirally twisted, about 9-20 mm long and with maximum width 3-4.5 mm. Introvert about as long as trunk and 1.5 mm wide. Body wall of introvert and anterior trunk is thick; that of part enclosed in shell of mollusc is thin, transparent and often fragile, except posteriorly where it is thicker.

Anterior extremity of introvert slightly bulbous and with small, scattered hooks 0.05-0.08 mm long. Anteriormost hooks are largest and straightest; more posterior hooks shorter and more recurved. Small papilla-like swelling present at base of hooks.

Introvert and trunk covered with papillae varying considerably in size and shape. Papillae on introvert smallest, with height greater than width, and with pointed and extended tips. Papillae on anterior trunk largest, 0.10-0.35 mm tall and 0.05-0.15 mm wide, some being urn-shaped and other more bulbous. Most terminate in a single tip, making papillae appear mamillate, but others, especially most anterior, may possess 2, 3 or 4 tips or prongs, then resembling to some extent the "four-armed cross" shown for *Phascolion convestitum* by Sluiter (1902: 32). Surface of trunk posterior to region with pointed papillae covered with numerous, closely packed, rather flat, pale coloured papillae, elliptical in shape. Thin walled part of trunk bears prominent, scattered holding or adhesive papillae about 0.1-0.2

mm tall and 0.15-0.25 mm wide, brown to dark red-brown in colour and usually lying with their blunted tips directed anteriorly. Between holding papillae and over rest of posterior surface lie numerous flat, pale, hemispherical to elliptical papillae.

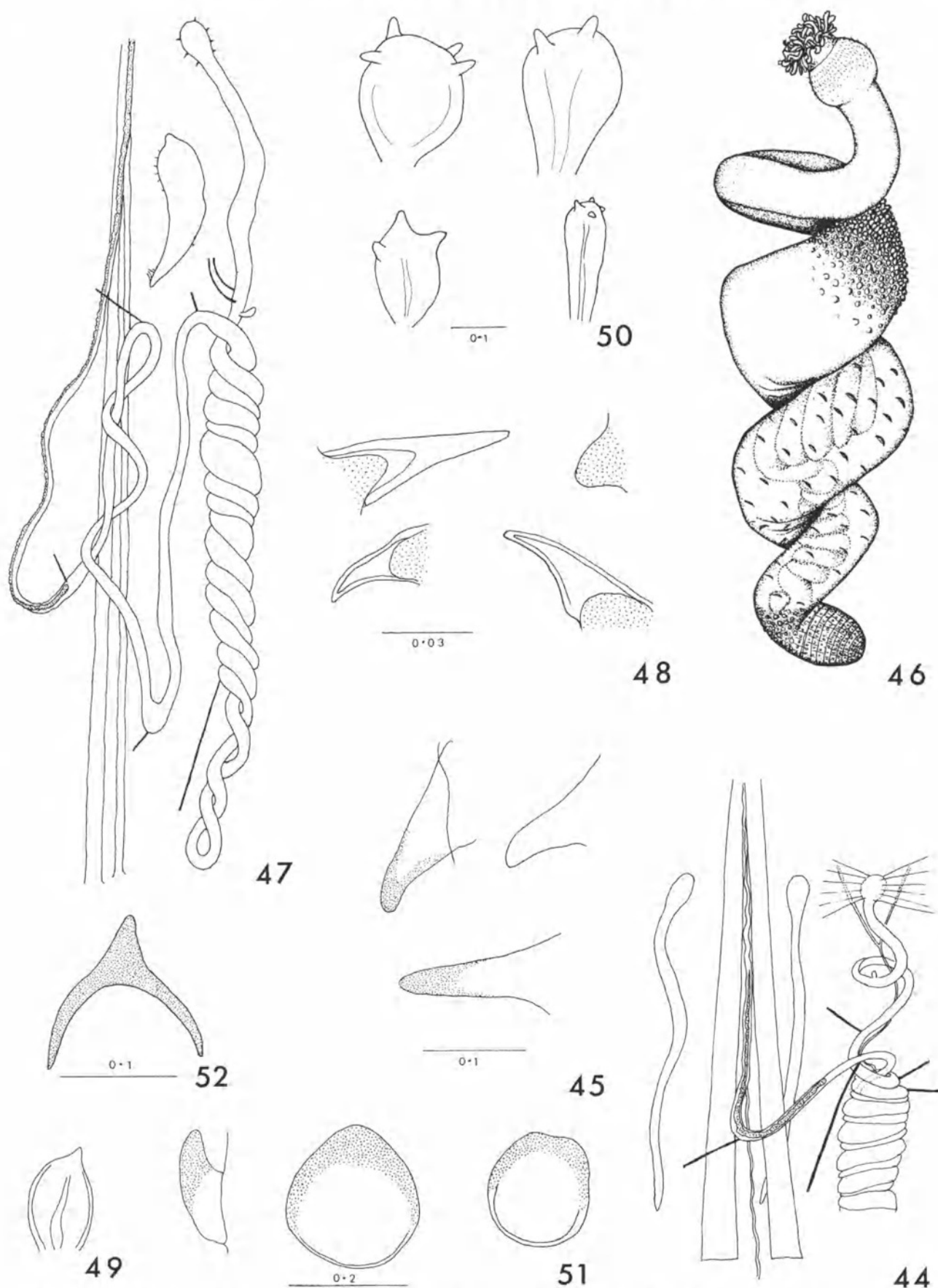
Longitudinal musculature continuous. Two retractor muscles, one usually stronger than other, arise separately at base of trunk. Alimentary canal complexly looped and coiled, with its oesophageal section fixed to the thinner retractor. Intestinal loops held in position by fixing muscles arising from anterior and posterior body wall. Posterior section of intestine may be wound into a loose spiral. Rectal caecum present and from nearby intestinal wall a pair of fastening muscles run to body wall (sometimes two strands may fuse before reaching body wall). Contractile vessel, without villi, attached to dorsal surface of oesophagus. No spindle muscle posteriorly. A single nephridium, fixed for most of its length.

Systematic position: These specimens resemble *P. convestitum* Sluiter, 1902 in possessing some anteriorly placed trunk papillae which possess 1-4 points. I have, however, compared them with Sluiter's type and consider them different. Sluiter's specimens, both labelled "types", are pyriform and bottle shaped and not coiled, and lack holdfast papillae with horny rims. The four-armed cross-like papillae are very numerous, more slender and extended than on the Australian specimens. Sluiter says that the nephridium of his species lies on the left side of the animal while in the Cronullan specimens it is clearly on the right. Sluiter does not mention the presence of a caecum nor of two fasteners that connect the rectum near the caecum and the body wall.

The Australian specimens differ from *P. strombi* (Montagu, 1804), in possessing anteriorly placed trunk papillae with 1-4 points. No such papillae are mentioned or illustrated by Théel (1905) where he redescribes the species, nor by Gerould (1913), nor in specimens collected by me at Roscoff, France (SAM E1183) nor in those dredged at 43° 03' N, 65° 30' W and sent to me by Dr. E. Cutler (Univ. of Utica, U.S.A.).

P. cronullae differs from *P. temporariae* Edmonds, 1976 from New Zealand in the shape of the introvert hooks and from *P. tortum* Edmonds, 1976, also from New Zealand, in the nature and position of the "ventral" retractor.

Commensal: I am indebted to Miss E. Pope of the Australian Museum, Sydney for the following information. "A polychaete of the family Syllidae was found in most of the shells containing a sipunculan. The polychaete seemed to be entwined with the *Phascolion* with its head near a point at the



FIGS. 44-52. Figs. 44-45, *Golfingia schuettei*; 44, anterior region dissected (specimen from Cockburn Sound); 45, introvert hooks. Figs. 46-51, *Phascolion cronullae*; 46, entire specimen; 47, anterior region dissected; 48, introvert hooks; 49-50, papillae from anterior trunk; 51, holdfasts from trunk. Fig. 52, *Phascolion collare*; hardened part of holdfast.

base of the introvert of the sipunculan. Of 74 randomly selected shells, 10 (13.3%) contained living molluscs, 46 (62%) contained *Phascolion* worms and 18 (24%) were empty. Syllids were present in 40 (87%) of the 46 tubes that contained the *Phascolion*." Dr. P. Hutchings of the Australian Museum has identified the polychaete as *Syllis* (*Toposyllis*) *armillaris* (Mueller).

Symbiotic associations between species of *Phascolion* and a number of other animals, including the syllid *Langerhansia cornuta* (Rathke) have been previously reported (Stephen and Edmonds 1972 p. 342).

Distribution: Known only from the type locality.

**Phascolion dentalicolum* Sato

Phascolosoma dentalicolum Sato, 1937 p. 165, pl. 4, figs. 20-21, text figs. 10-14; Cutler, 1977 p. 145, fig. 8.

Location of type: Saito Ho-on Kai Museum, Sendai, Japan; type locality, Onagawa Bay, north-east Honshu, at 23 m.

Description: Found in shells of *Dentalium* sp. Introvert 15 mm, trunk 15 mm. Small spines or hooks on introvert. Holding papillae on trunk low and laterally compressed. Two retractors. Single nephridium. Nephridiopore posterior to anus. Rectal caecum present.

Australian record: Great Australian Bight (off South Australia) 37° 28' S, 138° 55' E at 1 360 m (18) (Cutler, 1977). Specimens from small twisted gastropod shells.

Distribution: (1) in Australia: off South Australia.

(2) elsewhere: North-east Honshu, Japan.

**Phascolion pacificum* Murina

Phascolion pacificum Murina 1957b pp. 1777-1781, figs. 2a, 2b, 3a-e; 1972 p. 306; Cutler, 1977 p. 146.

Location of type: Not known to author; type locality Kurile-Kamchatka Trench at 6 156-6 860 m.

Description: Introvert with very small hooks. Trunk thin, small and grey-yellow. Single retractor with three roots. Caecum situated half or third of way from anterior end of trunk. Nephridia fastened to body wall for whole length.

Australian record: Great Australian Bight (off South Australia) 37° 28' S, 138° 55' E at 1 320-1 340 m (1) (Cutler, 1977 p. 146); specimen in empty gastropod shell.

Distribution: (1) in Australia: off South Australia.

(2) elsewhere: North-west Pacific Ocean, Peru-Chile Trench, Antarctica, Pacific and Indian Oceans.

Genus *Onchnesoma*

Onchnesoma Koren and Danielssen, 1875 p. 133; 1877 p. 142; Selenka and de Man, 1883 p. 130.

Description: Small sipunculans, usually pear or club-shaped. Introvert very long and without hooks and spines. Anus lies on introvert, well forward near mouth. Tentacles few or absent. Trunk covered with papillae of varying size and shape. Longitudinal musculature continuous. Single retractor arising from posterior of trunk. One nephridium.

Type species: *Onchnesoma steenstrupii* Koren & Danielssen, 1875.

**Onchnesoma steenstrupii* Koren & Danielssen

(Fig. 8)

Onchnesoma steenstrupii Koren & Danielssen, 1875 p. 133; 1877 p. 142, pl. 15, figs 28-36; Théel, 1905 pp. 93-96, pl. 10, figs 151-152, pl. 11, figs 157-172, pl. 13, fig. 185; Cutler, 1973 pp. 164-166.

Location of type: Not known to author; specimen from Kristiansund, Norway.

Description: Cutler (1973 p. 164) says that the worms have been aptly referred to as "a tiny football on a string". Trunk small, pyriform; length 1.0-2.5 mm, maximum 4 mm and width 0.8-1.3 mm (2 000 specimens sampled—Cutler, 1973). Introvert 5-10 times length of trunk, lacking tentacles and hooks. Only one introvert retractor. Anus lies well forward on introvert just posterior to mouth.

Remarks: The species is well known in the north Atlantic. It is distinguished from *Golfingia trichocephala* (Sluiter) by the position of its anus and the presence of only one retractor and one nephridium.

Australian record: New South Wales; off Broken Bay (33° 34'S, 152° 06'E) (7) Murina, 1972 pp. 164-166, 304-305.

Distribution: (1) in Australia: New South Wales.

(2) elsewhere: Iceland, Scandinavia, North Sea, North Atlantic, South-West Africa and Mediterranean.

Genus *Themiste*

Themiste Gray, 1828 p. 8, pl. 6, figs 4, 4a; Stephen, 1964 p. 458; Rice and Stephen, 1970 p. 66; Stephen & Edmonds, 1972 p. 193.

Dendrostomum Grube & Oersted, 1858 p. 118; Fisher, 1952 p. 404.

Dendrostoma Keferstein, 1865 p. 438; Selenka & de Man, 1883 p. 83.

Description: Trunk usually pear-shaped, sometimes elongate and slender; strongly contracted specimens may be globose. Tentacles surround mouth and branching; consisting of 4-8 stems which divide and sub-divide to form pinnately or palmately arranged tentacles. Hooks or spines may be present on introvert. Longitudinal musculature continuous. Retractor muscles two (rarely four). Spindle muscle not attached posteriorly. Two or more (usually three) fastening muscles to intestine. Two free nephridia. Contractile vessel usually well developed and bearing few to many villi which may be short or very long. Nuchal organ prominent in some species.

Type species: *Themiste hennahi* Gray (= *Dendrostomum peruvianum* Collin).

Remarks: Specimens of this genus have been collected along the coast of all the States of Australia. *T. lageniformis* is found in coral, in clumps of mussels and under stones. *T. cymodoceae* and *T. dehamata* are found in mud, in sand and in the roots of marine angiosperms. *T. huttoni*, *T. fusca* and *T. variospinosa* are often found in burrows in calcareous rocks or in cracks.

All the known Australian species have contractile vessels with numerous short villi. Specimens of *T. lageniformis*, *T. fusca*, *T. variospinosa*, *T. huttoni* and *T. cymodoceae* are usually pyriform, the last two and especially *T. cymodoceae* tending to be large and stout. *T. dehamata*, however, is more slender and elongate.

I am considering as one species the large specimens of *T. dehamata* collected in New South Wales (amongst them the type) and some smaller ones not uncommon in South Australia and Victoria. I have found it difficult to separate them other than on the basis of size. The relationship between them resembles in some ways that which Fisher (1952 p. 418) found between *T. dyscrita* (Fisher) and *T. zostericola* (Chamberlin). Eventually the larger New South Wales and the smaller southern forms may prove to be two species.

Subgenera of *Themiste*

On the basis of the number of retractor muscles and the length of the contractile tubules or villi the species of *Themiste* fall into three groups which I propose be regarded as sub-genera.

1. *Themiste* (*sensu stricto*) n. subg.

Diagnosis: Two retractor muscles. Contractile tubules or villi long and thread-like.

Type species: *Themiste hennahi* Gray.

Hooks or spines present	Hooks or spines absent
<i>T. alutacea</i> (Grube)	<i>T. dyscrita</i> (Fisher)
<i>T. blanda</i> (Selenka and de Man)	<i>T. hennahi</i> Gray
<i>T. hexadactyla</i> (Sato)	<i>T. lissa</i> (Fisher)
<i>T. peiricola</i> (Amor)	<i>T. perimeces</i> (Fisher)
<i>T. pyriformis</i> (Chamberlin)	<i>T. schmitti</i> (Fisher)
<i>T. rosacea</i> (Amor)	<i>T. zostericola</i> (Fisher)
<i>T. spinifera</i> (Sluiter)	

(hooks sometimes reported to be lacking in *T. alutacea*).

2. *Lagenopsis* n. subg.

Diagnosis: Two retractor muscles. Contractile tubules or villi short and finger-like.

Type species: *Themiste lageniformis* Baird.

Hooks or spines present	Hooks or spines absent
<i>T. fusca</i> (Edmonds)	<i>T. cymodoceae</i> (Edmonds)
<i>T. huttoni</i> (Benham)	<i>T. dehamata</i> (Kesteven)
<i>T. minor</i> (Ikeda)	<i>T. elliptica</i> (Sato)
<i>T. variospinosa</i> n. sp.	<i>T. fisheri</i> (Amor)
	<i>T. lageniformis</i> (Baird)
	<i>T. tropica</i> (Sato)
	<i>T. robertsoni</i> (Stephen and Robertson)

(in *T. robertsoni* the tubules are described as being "only of moderate length and fairly numerous").

3. *Stephensonium* n. subg.

Diagnosis: Four retractor muscles.

Type species: *Dendrostomum stephensoni* Stephen.

Hooks present	Hooks absent
<i>T. pinnifolia</i> (Keferstein)	<i>T. stephensoni</i> (Stephen)

Remarks: In *Themiste* s.s. the contractile tubules are usually few and in *Lagenopsis* they are numerous to very numerous. All *Themiste* species reported from Australia are members of the subgenus *Lagenopsis*.

KEY TO SPECIES OF *THEMISTE* (*LAGENOPSIS*) KNOWN FROM AUSTRALIA

- Specimens with introvert hooks 2
Specimens without introvert hooks 4
- Hooks of almost uniform size 3
Hooks of markedly different size, which are very irregularly directed *Themiste variospinosa* n. sp. (p. 42)
- Hooks few and scattered; specimens usually small (trunk less than 15 mm), body wall thin and sometimes nearly transparent, retractors not stout, intestinal spiral rather loosely wound *Themiste fusca* (p. 40)
Hooks many and prominent, extending over most of the introvert and even posterior to the anus; specimens may be large and stout, body wall thick, villi of contractile vessel crowded, intestinal spiral usually tightly wound *Themiste huttoni* (p. 36)
- Specimens slender, size medium to very long; two dorsal stems of tentacles usually longer than two ventral stems; tentacles plumose and flecked at their tips, nuchal organ usually prominent *Themiste dehamata* (p. 34)



FIGS. 53-54. *Themiste dehamata*, 53, retracted specimen from New South Wales (previously dissected), 54 specimen from Victoria.

Specimens stout rather than slender and pyriform or even sub-globular in shape; stems of tentacles about equal size 5

5. Specimens small to medium in size; tips of tentacles not pigmented; usually collected in clumps of mussels or in coral *Themiste lageniformis* (p. 41)

Specimens medium to large in size; tips of tentacles pigmented; usually collected in roots of marine angiosperms *Themiste cymodoceae* (p. 38)

***Themiste (Lagenopsis) dehamata* (Kesteven)**

(Figs. 53-57)

Dendrostoma dehamatum Kesteven, 1903, pp. 69-73, pl. 7, figs 1-6.

Dendrostomum dehamatum: Edmonds, 1956, p. 296, pl. 1, fig 1.

Themiste dehamata: Stephen & Edmonds, 1972, p. 198.

Location of type: Australian Museum, Sydney; specimen from Balmoral, Sydney Harbor, New South Wales.

Re-examination of three specimens: This redescription is based on three of Kesteven's original specimens from Balmoral, New South Wales (SAM E1210) but not the type material.

Specimens very long and slender. According to Kesteven (1903 p. 69) they were collected on the beach "at a time when there had been much rain and heavy storms". One cannot then discard the

possibility that the unusual shape of the specimens is the result of the changes which take place when sipunculans are placed in hypotonic solutions. Fisher (1952 p. 17) reported that three specimens of *Themiste perimeces*, washed up on the beach after a storm, were "unnaturally lengthened".

Body sub-cylindrical, slender, curved almost into a circle, tapering posteriorly and pointed. Trunk of largest 170 mm long and 7 mm wide posteriorly. Off-white to grey in colour with posterior region darker and almost black in one specimen. Skin smooth but marked into small rectangular areas by fine intersecting lines. Small, flat to slightly elevated papillae with small, white, centrally-placed glandular pores are present in the middle of the rectangular areas. Posteriorly placed trunk papillae black in one specimen.

Introvert, not well differentiated from trunk, with maximum length estimated as 50 mm; grey to yellow and without hooks. Tentacles plumose, flecked purple brown and, according to Kesteven, arranged "in four stems, two of two and two of three primary branches. In some specimens, however, the division between the branches extends right down to the circumoral muscular ridge, in which case there are eight branches". The individual tentacles seem arranged largely in a pinnate manner along the extended oral grooves (Kesteven, 1903, pl. 6, fig 2). Nuchal organ prominent.

Two very long retractors, arising in posterior half of trunk and separate for most of their length. Anteriorly, however, they are rolled to form two halves of a "tube" containing oesophagus and contractile vessel. Alimentary canal very long. Oesophagus runs to or near to base of retractors, where it is fastened, then loops up anteriorly and coils into a very long intestine with spirals extending into posterior third of trunk. Rectum very long and carrying a caecum. Anus and nephridiopores at about same level, although in Kesteven's fig. 1 the anus is just anterior. Rectal membrane present but not as prominent as that shown for *T. fisheri* (Amor, 1964, p. 4, fig. B).

There are three main fastening muscles and a spindle muscle. F1, arising at or just posterior to base of retractors (= mes⁺ and mes⁺ of Kesteven fig. 1), may be single or double; if double the roots may arise at slightly different levels. F1 is attached to oesophagus near posterior extremity of contractile vessel. F2, arising from left side of and near to nerve cord, runs to rectum near caecum, and usually supplies a well-developed series of connectives to posterior oesophagus near intestinal spirals (=spm⁺ of Kesteven's fig. 1). F3, arising from right side of nerve cord (more anteriorly than F2), runs to rectum at about level of caecum (=spm⁺ of Kesteven's fig. 1). Spindle muscle arising from rectum just posterior to caecum, traverses whole length of intestinal spiral but is not fixed posteriorly. Contractile vessel prominent, bearing very numerous, short villi (much like those of *T. lageniformis*, *T. cymodoceae* and *T. huttoni*) clustered along its dorsal surface. Posterior villi longer and forming short branches. Nephridia slender, free and about one third as long as trunk.

Remarks on some smaller specimens: After considerable deliberation I am referring a large collection of smaller specimens of *Themiste* from South Australia and Victoria to this species. They differ from the Sydney specimens most notably in size.

Trunk of largest 75 mm long but mostly 30-50 mm long and width 3-4 mm. Colour light grey to pale

pink but anterior region sometimes yellowish. Mouth surrounded by four groups or stems of branching tentacles, two larger stems being placed dorsally between a prominent nuchal organ and two smaller stems ventrally. Tentacles often dark purple, arranged pinnately along stems but at extremities of smaller branches more palmately. Introvert without hooks or spines and often not well marked off from trunk.

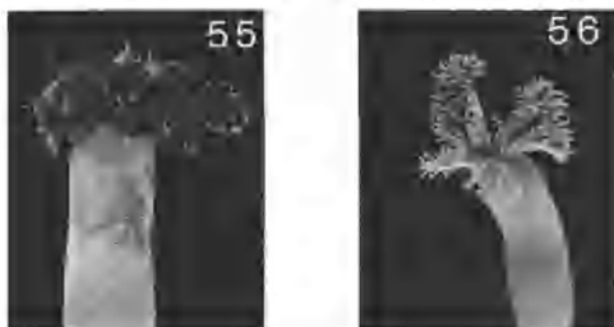
Internally as for *T. dehamata*. Two points of difference, however, sometimes noticed; (1) the rectal membrane is much more prominent than in the four specimens described above and (2) there are some variations in the points of attachment of the intestinal fasteners. F1 may consist of a membrane or three roots of different lengths. F2 may connect with upward loop of oesophagus more anteriorly and an additional F2a may connect the posterior oesophagus and rectum. F3 seems invariable. Spindle muscle as in Balmoral specimens. Spherical eggs 0.15-0.18 mm in diameter in some specimens.

Systematic position: I have not been able to distinguish satisfactorily between the larger specimens of *T. dehamata* from New South Wales and the smaller specimens of *Themiste* from South Australia, Victoria and Western Australia other than on their size. Eventually some other worker may be able to show that they are different. The relation between the large and small specimens is much like that between *T. zostericola* and *T. dyscrita* (Fisher, 1952 p. 418).

Themiste fisheri (Amor, 1964) from Argentina is closely allied to *T. dehamata*. Amor (1964 p. 469) considered that the tentacles of her specimens arose from six stems. While this may be so I contend that her fig. 3a could be interpreted to show the presence of four primary stems, her (1 & 2), 3, 4, her (5 & 6). The main differences between the two species are that *T. dehamata* has a caecum while *T. fisheri* has not, that F1 and F2 arise from different positions in the two and that the spindle muscle of *T. fisheri* seems to arise more anteriorly. None of these points is very significant taxonomically except for that of the caecum. Previous Australian record: New South Wales (Kesteven, 1903).

Distribution: in Australia: New South Wales, Victoria, South Australia and Western Australia.

Specimens examined and localities: New South Wales—Balmoral, Sydney Harbor (4) SAM E1210—part of Kesteven's collection. Victoria—Western Port Bay (2) SAM E1211 and (1) SAM E1212; Port Phillip Bay (4) SAM E1222. South Australia—chiefly amongst the roots of the marine angiosperms *Amphibolis*, *Posidonia* and *Zostera* Outer Harbor (7) SAM E1214 Aldinga reef (8) SAM E1216 and SAM E1217; Proper Bay, Port Lincoln



FIGS. 55-56. *Themiste dehamata*, tentacular crown of two specimens; 55 from Victoria, 56 from South Australia.

(10) SAM E1218; Coffin Bay (Eyre Peninsula) (3) SAM E1219; Cape Jervis (5) SAM E1221; Emu Bay (Kangaroo Is.) (6) SAM E1213; Sellick's reef "in roots of *Amphibolis*" (5) SAM E1225 Western Australia—Cottesloe (3) SAM E1248.

***Themiste (Lagenopsis) huttoni* (Benham)**

(Figs. 60-64)

Phascolosoma huttoni Benham, 1904, p. 307.

Dendrostomum huttoni: Edmonds, 1960, pp. 164-165, pl. 3, text figs. 5-6.

Themiste huttoni: Stephen & Edmonds, 1972, p. 204.

? *Dendrostoma signifer* (in part) Selenka & de Man, 1883, pp. 86-87; Augener, 1903, p. 337; Fischer, 1914, p. 11; Fischer, 1919a, p. 282.

Location of type: Not known by author; specimen from New Zealand.

Introduction: Selenka & de Man (1883, p. 87) considered a specimen from Sydney, with backwardly directed hooks 0.2 mm long, to be "an armed variety of *Dendrostoma signifer*" (= *T. lageniformis*). The same term was used by Augener (1903, p. 37) for some specimens from New Zealand, by Fischer (1914, p. 37) for some specimens from New Zealand and by Fischer (1919a, p. 282) for specimens from Albany, Western Australia. None of these authors discussed the taxonomic problem of the presence or absence of introvert hooks. Awati & Pradhan (1935, p. 10), however, in their account of "*D. signifer*" from India state that feebly developed hooks are found on the introvert of the younger stages but that they "fall off" in adults. This does not appear to be so for *T. lageniformis* in Australia. None of the specimens in my collection from Yeppoon, Dunwich and Darwin possess hooks, although they range from young to adult animals. On the other hand all the armed specimens of *Themiste* sent from New South Wales and Western Australia (including some with a trunk 40 mm long and others that contain eggs and consequently are adults) are heavily armed. At present I take the view that since all the specimens collected from any one locality are either armed or unarmed and not a mixture of the two they belong to closely related but different species. If in the future specimens with and without hooks are collected from the same habitat the decision would have to be reconsidered. Benham (1904) possibly took this view (although he did not explicitly state it) when he called the "armed variety" from New Zealand a new species, *D. huttoni*. Cutler (1973, p. 161) says, with justification, that the hooks of some species of *Golfingia* may be lost. While it is possible and even likely that some or all of the hooks may be lost from a specimen of

Themiste for reasons concerned with its environment or method of collection, my observations lead me to the hypothesis that *T. lageniformis* is one species and that the armed form is another.

The specimens of *Themiste* from some localities e.g. South Australia, are small and often almost transparent and the introvert hooks few in number, small, almost uniform in size and distributed over a small area of the introvert. Specimens from New Zealand, Tasmania, Western Australia and New South Wales are larger and more robust and the introvert hooks more numerous and larger but, while still almost uniform in size, they extend over much of the introvert, even to a point posterior to the anus. In another group of specimens from Queensland the hooks are noticeably different; some are very large and others almost rudimentary; they are irregularly arranged and point in different directions. For these reasons I regard the armed specimens of *Themiste* closely resembling the unarmed *T. lageniformis* as falling into three groups and, because any collection from one locality contains only one group and not two or more, I consider each group on morphological grounds to be a separate species. The specimens from New Zealand, Tasmania, Western Australia and New South Wales are *T. huttoni* (Benham), those from South Australia are *T. fusca* (Edmonds) and those with variable spines are a new species, *T. variospinosa*.

Description: The following description of *T. huttoni* is based on specimens from New Zealand, New South Wales, Queensland, Tasmania and Western Australia.

(1) Trunk of New Zealand specimens 16-35 mm long with maximum width about 6 mm, grey in colour, thick walled, smooth and pointed posteriorly. Estimated length of invaginated introvert about a quarter that of trunk. Dissected introvert shows that tentacles arise from a number of stems and that black, posteriorly directed hooks or spines are present. Hooks almost uniform in shape and size and their field does not extend as far as the anal aperture.

Two stout retractors arising from posterior half of trunk and separate for most of their length. Alimentary canal consisting of descending and ascending oesophageal loops, a long intestinal spiral and a rectum with a caecum. Contractile vessel attached to anterior oesophagus and bearing very numerous, short, finger-like villi, the most posteriorly placed of which often form short branches. Fixing muscles F1 and F3 well developed but F2 usually reduced. F1 arises from body wall anterior to and left of point of attachment of left retractor and is fastened to oesophagus just posterior to termination

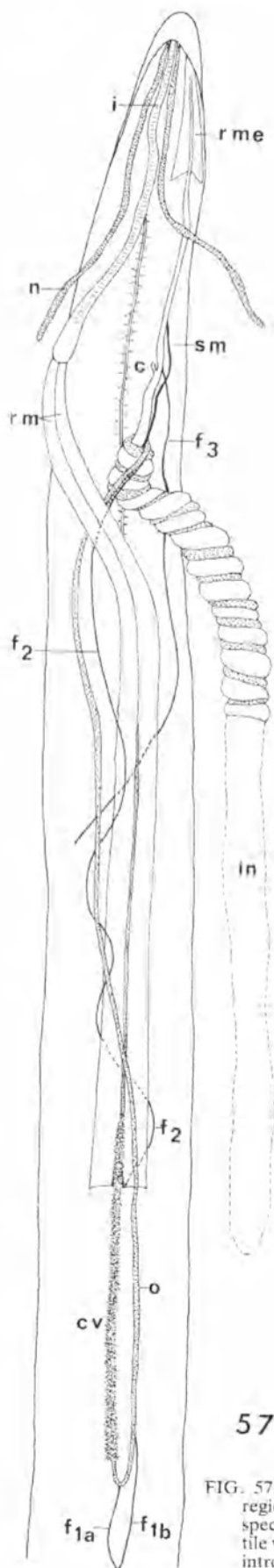


FIG. 57. *Themiste dehamata*, anterior region dissected (one of Kesteven's specimens), c, caecum; cv, contractile vessel; f1-f3, fastening muscles; i, introvert; in, intestine; n, nephridiopore; o, oesophagus; rm, retractor; rme, rectal membrane; sm, spindle muscle.

of contractile vessel. F3 attached to rectum near rectal caecum. F2 represented by a number of muscular threads arising from upward loop of oesophagus which converge and join rectum near caecum. Spindle muscle, arising anteriorly from rectum, not attached posteriorly. Wing muscle present. Two free tubular nephridia, opening just posterior to anus. Two eyespots near brain and a nuchal organ lying at dorsal extremity of introvert. Papillae on body wall small, flat with a small white pore centrally. Eggs spherical, 0.17-0.19 mm in diameter. Skin at posterior extremity traversed by fine lines.

(2) Trunk of Western Australian specimens 10-28 mm long and with maximum width 2.5-4.4 mm, curved inwards on the ventral side and with posterior extremity bluntly pointed. Tentacles as in New Zealand specimens but pigmented at their base. Introvert hooks dark brown to black, most pointing posteriorly. The field of hooks in all seven specimens, however, extends right round the introvert and well posterior to the anus (something very unusual in a sipunculan). F1 fixes oesophagus to body wall at a point between base of retractors. F2, F3, caecum, spindle muscle, nephridia and eyespots like those of New Zealand material.

(3) Specimens from New South Wales larger; trunk 12-55 mm long and maximum width 7-11 mm. Colour predominantly grey but with marked yellowish tinge. Armed area of introvert large but not extending posterior to anus as in specimens from Western Australia. F1 arises between retractors just to left of nerve cord. F2 not reduced, arising from body wall anterior to base of left retractor and running to posterior oesophagus; it may connect with rectum near the caecum. F3 as in New Zealand specimens. Hooks, diameter of base 0.15-0.25 mm and length 0.15-0.22 mm.

Systematic position: This species differs from *T. lageniformis*, *T. cymodoceae* and *T. dehamata* in the possession of introvert hooks. It differs from *T. fusca* which is smaller and in which the body wall is thinner, the nuchal organ more prominent, and the intestine shorter and more loosely wound. It differs from *T. variospinosa* in which the introvert spines vary very much in size, shape and orientation.

Previous Australian record: Sydney, New South Wales (Selenka & de Man, 1883).

Distribution: (1) in Australia: New South Wales, Tasmania, Western Australia and Queensland.

(2) elsewhere: New Zealand.

Specimens examined and localities: New Zealand—Stewart Is., (2) SAM E1228; east of Otago (1) trawled on "Tacaroa" SAM E1229. Tasmania—Coles Beach, near Devonport (1) SAM E1234;

Jacobs Boat Harbor (1) SAM E1235. Western Australia—Trigg Is., "in limestone reef" (7) SAM E1233 and (2) WAN 242/76; Cockburn Sound (2) WAM 32/73. New South Wales—Coffs Harbor (4) SAM E1236; Bottle and Glass Rocks (2) SAM E1237; Long Reef (1) SAM E1238. Queensland—Coloundra (6) "on exposed rocky shore" SAM E1239.

***Themiste (Lagenopsis) cymodoceae* Edmonds**

(Figs 58 and 63)

Dendrostoma cymodoceae Edmonds, 1956 pp. 297-301, figs 15-16; Akesson, 1958, pp. 147-151 figs 66-67 and 219-222.

Themiste cymodoceae Stephen and Edmonds, 1972, pp. 197-198, fig. 102.

Location of type: Australian Museum, Sydney; specimen from Aldinga Reef, South Australia, amongst roots of the marine angiosperm *Amphibolis* (= *Cymodocea*) *antarctica*.

Description: Adults large, robust and elongate to pyriform in shape; trunk 50-90 mm long with maximum width of 15-25 mm posteriorly. Colour light to dark grey with tendency to yellow brown anteriorly; posterior region usually darker. Introvert cylindrical, relatively short, about 5-8 mm in diameter and lacking hooks and spines. Surface of introvert just posterior to tentacles smooth, pale and shiny or sometimes purplish and glossy. A light brown or yellow band often surrounds introvert near its middle or towards base. Trunk of fixed specimens tends to curve inwards slightly on ventral side. Body wall smooth, although covered with numerous flat, white papillae, 0.04-0.08 mm in diameter, each of which bears a white glandular opening at its centre. Body wall thick, especially posteriorly. Longitudinal and circular musculature continuous but internal coelomic wall traversed by oblique muscle striations.

Tentacles arising from four primary stems any of which may subdivide so that tentacles sometimes appear to be in 4-8 stems. Subsequent division or redivision of stems gives rise to small, finger-like, straw to purple-brown pinnately arranged tentacles. Tip of tentacles always darker than remainder. Tentacles (= stems and tentacles), relative to length of trunk seem smaller than those of *T. lageniformis* and are more bushy.

Internal anatomy resembling that of *T. lageniformis*. Two long, stout retractors fixed in posterior third of trunk. Oesophagus thin-walled, running between retractors as far as their base and then looping sharply upwards to a point near rectum; intestine long and spirally coiled. Rectum short and carrying a caecum. System of intestinal fasteners variable. Oesophagus always fastened near base of



FIG. 58. *Themiste cymodoceae*, (specimen from Aldinga Bay, South Australia).

retractors by 1-4 short threads (F1), usually arising between bases of retractors on left side of nerve cord. F2, arising near left retractor and connecting with upward loop of oesophagus near the first spiral, may or may not be present, F2 may bifurcate or an additional fastener (F2a), arising close to F2, may also connect with oesophagus. In a few specimens F2 may connect solely or in part with last or penultimate intestinal spiral. F3, present in all specimens, is shorter and stouter than F2, arises on right side of nerve cord in anterior half of trunk and connects with last intestinal spiral or rectum where latter joins the intestine. Spindle muscle strong, arising anteriorly from beneath a rectal membrane, but not attached posteriorly. Contractile vessel attached to oesophagus as far as base of retractors and bearing very numerous short sometimes branching villi, which are larger and very densely clustered posteriorly. Nephridia thin, brown in colour, free, about one third as long as trunk and opening at about level of anus or usually just posterior to it. Gonads at base of retractors. Nuchal organ not as prominent as in *T. dehamata*.

Systematic position: *T. cymodoceae* is closely related to *T. lageniformis*. Although in 1956 I admitted that the two might be extreme varieties of the same species I now consider them different. *T. cymodoceae* grows to a larger size, its tentacles are more bushy and plumose and are pigmented at their

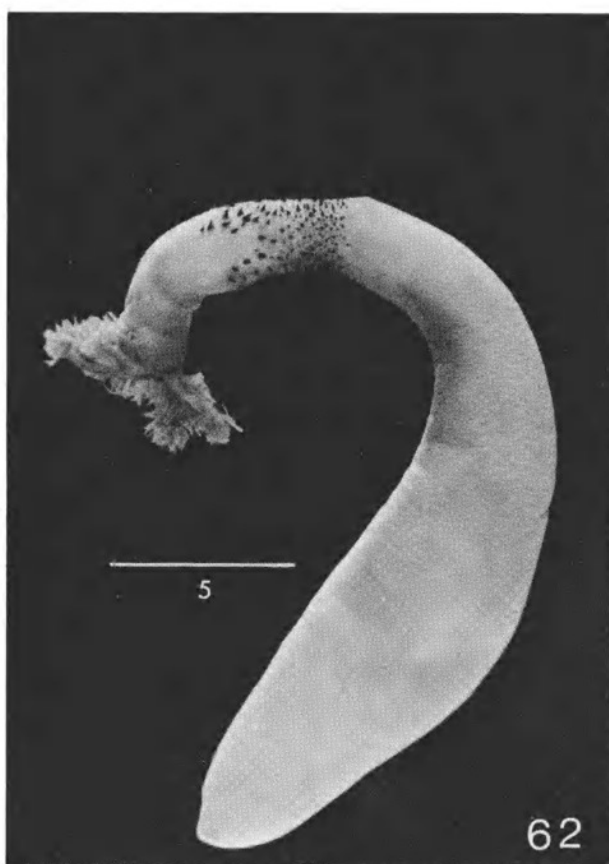
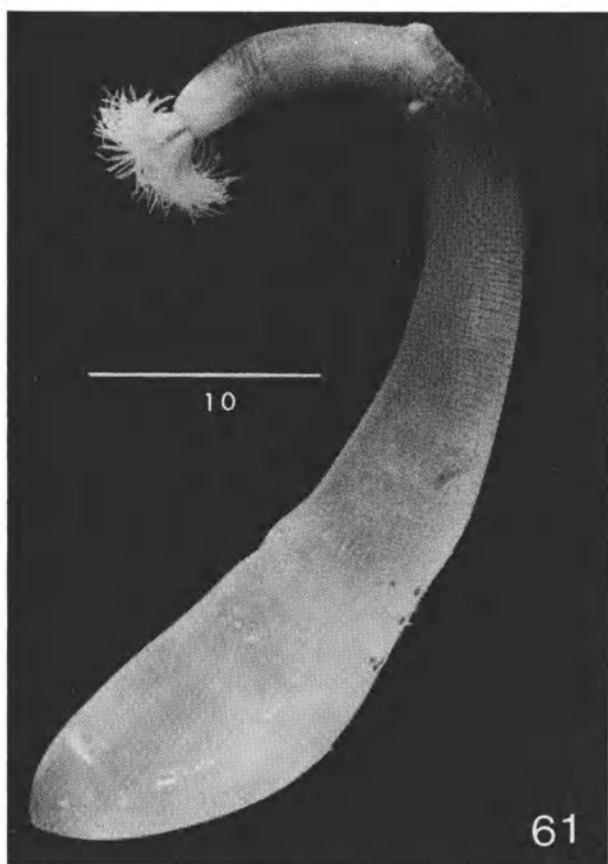
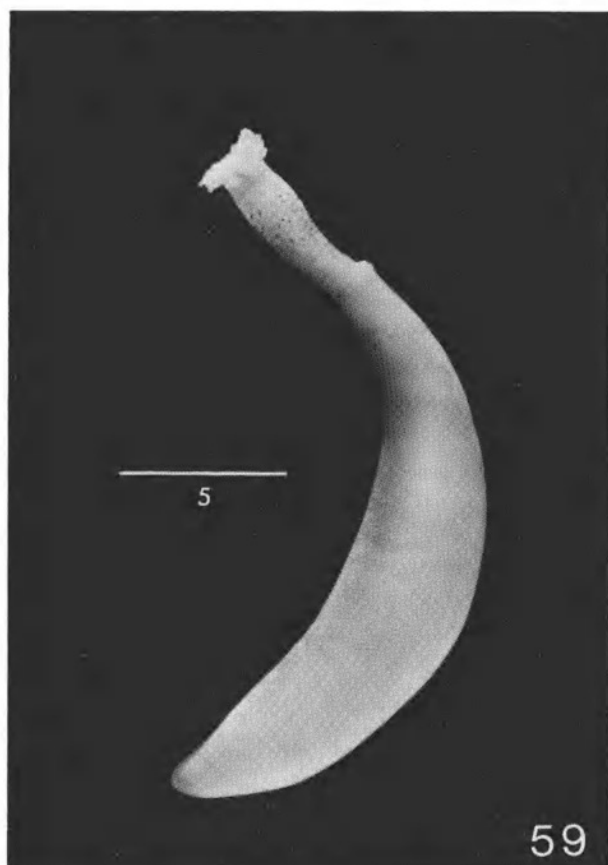


FIG. 59 *Themiste fusca*, (specimen from South Australia).

FIG. 61. *Themiste lageniformis*, (specimen from Curtis Is., Queensland).

FIG. 60. *Themiste huttoni*, (specimen from Long Reef, New South Wales).

FIG. 62. *Themiste variospinosa*, (specimen from Queensland).

tips and there is usually greater variation in the arrangement of its intestinal fasteners. There is, however, little difference in the internal anatomy of the two species. At Aldinga reef, St. Vincent Gulf, South Australia, the type locality, *T. cymodoceae* lives amongst the tangled roots of *Amphibolis* (= *Cymodocea*) *antarctica* and the sand and debris contained in them. It lives in a cavity which is formed as the animal grows in the roots. It seems to be almost sedentary; it scarcely moves and shows little inclination to burrow when it is placed on sand in an aquarium. *Amphibolis* normally lives below the level of inter-tidal reefs. Patches of it occur, however, on the outer edges of reefs which are well washed by waves and where there are tidal runs and drains. I have not found the species in burrows in rocks. *Themiste fusca*, however, occurs in burrows on the same reef at a higher level near the shore. Although I have collected about 400 specimens of *T. cymodoceae* at this locality I have not found any which carry introvert hooks. The specimens of *T. lageniformis* which I have identified from Australia have been associated with mussel clumps or coral rock.

The relation between *T. cymodoceae* and *T. lageniformis* is very much like that between *T. zostericola* and *T. dyscrita* as described by Fisher (1952 p. 418).

Akesson (1958) made a careful study of the nervous system of *T. cymodoceae* and Edmonds (1957a & 1957b) studied its respiration and excretion. It is a good experimental animal in that it is very hardy; it seems reluctant, however, to feed in the laboratory. Previous Australian record: South Australian (Edmonds, 1956).

Distribution: Known only from the shores of St. Vincent Gulf, South Australia.

Specimens examined and localities: South Australia—Aldinga reef (just north of Sellicks Beach), St. Vincent Gulf, "among roots of the marine angiosperm *Amphibolis* (= *Cymodocea*) *antarctica* (Labill.) Sonders & Ascherson", about 50 specimens comprising SAM E1191, E1193; Cape Jervis (2) SAM E1194.

***Themiste (Lagenopsis) fusca* (Edmonds)**

(Figs. 59, 65-67)

Dendrostomum fuscum Edmonds, 1960, pp. 165-167, figs 7-9, pl. 3.

Themiste fusca: Stephen & Edmonds, 1972, pp. 200-201.

Location of type: Australian Museum, Sydney; specimen from Proper Bay, near Port Lincoln, South Australia. Specimens burrowing in a calcareous, intertidal reef.

Description: Specimens usually small. Trunk rarely as long as 20 mm and usually less than 15 mm; white, cream or light brown in colour. Body wall thin and sometimes semi-transparent. Introvert short. Tentacles white and branching, sometimes flecked with brown and arising from four primary stems. Introvert hooks black, blunt, posteriorly directed, 0.05-0.10 mm long, few in number and scattered. Numerous very small, circular, pale coloured papillae, largest and most prominent at base of introvert and on posterior trunk. Skin usually smooth but sometimes furrowed into small square or rectangular areas.

Two slender retractors arising in posterior region of trunk. Oesophagus fastened to body wall at base of retractors, then looping anteriorly as in *T. lageniformis* and *T. huttoni*. Contractile vessel with fewer and simpler (less branched) villi. Intestinal spiral loosely and sometimes irregularly wound consisting of 6-10 double spirals. Rectal caecum small. Spindle muscle arising anteriorly from rectum but not fixed posteriorly. Two nephridia short, free and with external openings just posterior to anus. Rectal membrane present. Fastening muscle F1 connects base of oesophageal loop to body wall at point bear base of left retractor and F3 holds last spiral of intestine. F2 may be complete, reduced or absent; if complete, it holds posterior oesophagus and if reduced it joins only the posterior oesophagus and posterior intestinal spiral and not the body wall. Gonads at base of retractors. Two eyespots. Nuchal organ present.

Systematic position: This species is closely allied to *T. huttoni* (Benham) and *T. minor* (Ikeda), the latter from Japan. It differs from *T. huttoni* in that in *fusca* (1) the specimens are smaller (2) the body wall is much thinner and often nearly transparent (3) the hooks are smaller, fewer in number and more scattered in their distribution (4) the retractors are weaker (5) the villi are fewer (6) the intestinal coil is shorter and more loosely wound and (7) the nuchal organ is more prominent.

The smallest specimens are not easily distinguished externally from some of *T. minor* (Ikeda) kindly sent to me from Matsuyama, Japan by Dr. O. Ochi (Ehime University). The Japanese specimens, however, are smaller, their system of fastening muscles and their contractile vessel seem simpler.

Both *T. cymodoceae* and *T. fusca* are found at Aldinga and Sellicks Reefs, South Australia, the former amongst the roots of the angiosperm *Amphibolis* on the lowest levels of the reef and subtidally, and the latter in burrows in the calcareous rock at higher levels near the shore.

Previous Australian records: South Australia (Edmonds, 1960).

Distribution: (1) in Australia: South Australia.

(2) elsewhere: New Zealand.

Specimens examined and localities: South Australia—Point Wittelbee, Eyre Peninsula (15) SAM E1240; Coffin Bay (16) "in calcareous reef between tide levels" SAM E1241; Kellidie Bay (near Coffin Bay) (7) "in limestone reef"; Port Willunga and Aldinga (both south of Adelaide) (30) SAM E1243; Encounter Bay (in limestone reef in front of Yilkie Post Office) (20) SAM E1249; Proper Bay, near Port Lincoln "burrowing in limestone reef exposed at mid-tides" (8) SAM E1242.

Themiste (Lagenopsis) lageniformis Baird

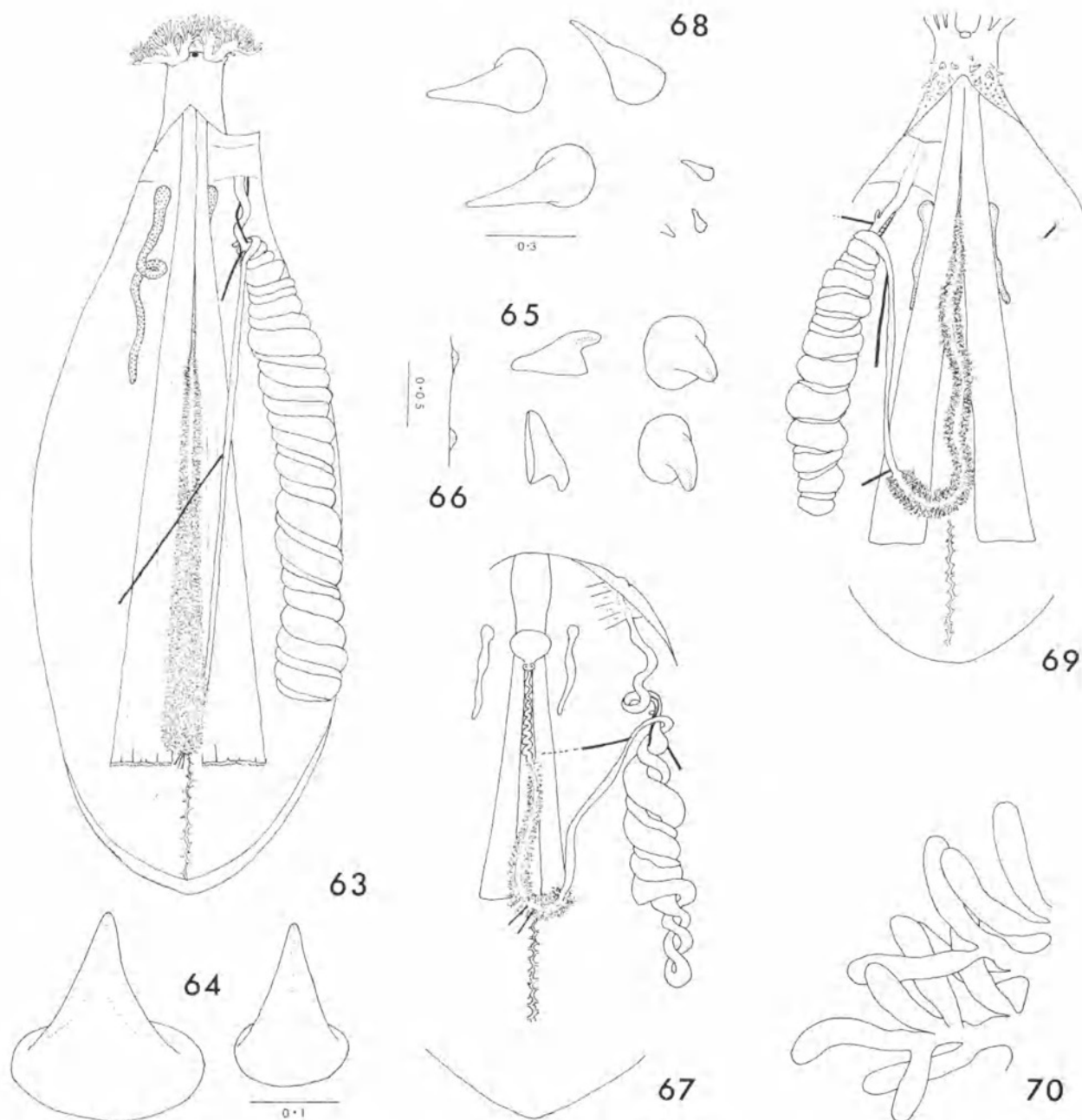
(Figs 61, 70)

Themiste lageniformis Baird, 1868, pp. 98-99, pl. 10, fig. 3; Rice and Stephen, 1970, pp. 66-67, pl. 3, figs 12-13; Stephen & Edmonds, 1972, p. 205.

Dendrostoma signifer Selenka & de Man, 1883, pp. 86-87, pl. ii, pl. 11, figs 163-164.

Dendrostomum signifer: Edmonds, 1956, p. 297, pl. 1, fig. 2.

Location of type: British Museum (Nat. Hist., London); specimen from Australia.



FIGS. 63-70. Fig. 63, *Themiste cymodoceae*; dissected specimen. Fig. 64, *Themiste huttoni*; introvert hooks. Figs. 65-67, *Themiste fusca*: 65, introvert hooks; 66, papillae on trunk (figs. 65 & 66 to same scale); 67, dissected specimen. Figs. 68-69, *Themiste variospinosa*: 68, introvert hooks; 69, dissected specimen. Fig. 70, *Themiste lageniformis*; branching contractile villi.

Description: Size and shape of specimens depending largely on whether or not they had been relaxed before fixation. Contracted specimens stout, pear-shaped or sub-spherical, relaxed ones longer and less stout. Trunk 5-33 mm long with maximum width in posterior third, flesh-coloured, light to dark grey or light to dark brown. Most tend to curve inwards on ventral side. Body wall appearing smooth although small, white, flat glandular pores present. Surface of unrelaxed specimens often divided into small rectangular areas by fine lines or ridges. Posterior extremity rounded or pointed.

Introvert short, 3-10 mm long, often darker in colour than trunk and often ringed anteriorly with a dark blue to black band. Tentacles white and not pigmented or flecked like those of *T. dehamata* and *T. cymodoceae*; arising from 4 primary stems any one of which may divide into two or more stems, the latter branching in turn to form tentacles. Consequently, if subdivision is near base of primary stem, number of stems may appear to be 5-8. Tentacles finger-like and relative to body length longer than those of *T. dehamata* and *T. cymodoceae*. Four primary stems form grooves along which food moves to mouth. Region of introvert just posterior to tentacles forming a smooth collar; a pigmented ring, if present, lying posterior to collar. All specimens listed below without introvert hooks, although collected at different times by different people.

Two very stout retractor muscles arising in posterior third of trunk. Oesophagus runs to base of retractors where it is held in position by a short, sometimes double, fastener (F1) and then loops anteriorly. Intestinal coil a well developed spiral; rectum short and carrying a caecum. In most specimens a second fastener (F2), arising near point of attachment of left retractor, is fixed to oesophagus near first intestinal spiral. F3, arising near right retractor, fixed to last or second to last spiral. Stout spindle muscle, arising anteriorly from beneath a rectal membrane, not fixed posteriorly. A tubular contractile vessel with numerous finger-like villi extending along the oesophagus to base of retractors; villi may form short branches near base of retractors but rarely extend a long upward loop of oesophagus. Two free, tubular nephridia, about one third as long as trunk, opening near anus or just posterior to it. Gonads at base of retractors; spherical eggs with diameter 0.18-0.20 mm. Nuchal organ not as prominent or as noticeable as in *T. dehamata* and *T. cymodoceae*. Brain with two eyespots.

Systematic position: *T. lageniformis*, probably better known as *T. signifer*, is a small to medium sized species, pyriform to sub-globose in shape and

often curved inwards on its ventral side. It lacks hooks and its tentacles are not pigmented at their tips. The body wall is usually stout and thick. A dark blue-black band may ring the introvert anteriorly.

Previous Australian records: Queensland (Edmonds, 1956), Cape York (Selenka & de Man, 1883). "Varieties" with hooks reported from Sydney (Selenka & de Man, 1883), from Tasmania (Fischer, 1914) and Albany, Western Australia (Fischer, 1926) are being referred to other species. Baird's 1868 record is from "Australia".

Distribution: (1) in Australia: Queensland, Northern Territory and Western Australia.

(2) elsewhere: widely in the Indo-Pacific Region; West Africa, South Africa, Madagascar, India, Gulf of Manar, Amboina, Japan, Philippines, New Zealand and Hawaii (SAM E1197).

Specimens examined and localities: Queensland—Dunwich (20) "in clumps of mussels, in front of the cemetery" SAM E1196 and (12) SAM E1207; Myora (10) SAM E1200; Cape Cleveland (2) SAM E1201; Cardwell (1) SAM E1202; Geoffrey Bay, Magnetic Is. (6) SAM E1203; Wellington Pt., Moreton Bay (8) SAM E1205; Wistari Reef, Capricorn Group (2) coll. of Prof. W. Stephenson; Yeppoon (5) coll. of Prof. R. Kenny; Rat. Is., near Pt. Curtis (7) AMS W2760. Northern Territory—Lee Point, near Darwin "in coral" (4) SAM E1208 and (4) SAM E1209. Western Australia—Broome (8) coll. from Hamburg Museum.

***Themiste (Lagenopsis) variospinosa* n.sp.**

(Figs. 62, 68, 69)

Location of type: Australian Museum, Sydney; specimen from "coral clumps", St. Helena Is., Moreton Bay, Queensland.

Description: This species is distinguished from *T. huttoni*, which it closely resembles, by the spination of its introvert hooks.

Trunk 9-27 mm long and maximum width 4-7 mm in posterior third, with posterior extremity bluntly pointed and with surface smooth, grey in some and pinkish brown in others. Small flat, circular papillae, with a very small clear or white pore at centre, almost uniformly distributed over surface. Tentacles branching and arising from 4-5 stems (shown in two well-relaxed specimens). Nuchal organ present between two stems of tentacles on dorsal side. Introvert hooks sharp and black; those most anteriorly placed largest, 0.15-0.30 mm long, with most points directed posteriorly. Hooks most posteriorly placed smallest, 0.02 mm long, with tips directed anteriorly, posteriorly or at right angles to surface (hence name *variospinosa*).

Internal anatomy much like that of *T. huttoni*. Two strong retractors, arising in posterior half of trunk. Alimentary canal consisting of downward and upward loops of oesophagus, a spirally coiled intestine and rectum. Contractile vessel attached to downward loop of oesophagus and bearing villi not as densely packed as in *T. huttoni*. Posteriorly placed villi forming short branches and extremities of villi sometimes expanded into a small knob. Fastening muscle F1 arising to left of base of left retractor (as it does sometimes in *T. huttoni*) and connecting with oesophagus just posterior to extremity of the contractile vessel. F2 arising more anteriorly than F1 and connecting with posterior oesophagus and rectum. F3 short and strong. Spindle muscle not fixed posteriorly. Rectal caecum present. Nephridia two, free, tubular and arising just posterior to anus.

Systematic position: In the retracted state these specimens look very much like a *Golfingia*. Some expanded specimens, however, show that the tentacles arise from at least four stems each of which divides and subdivides to form tentacles. The species is closely related to *T. huttoni* and *T. fusca*. It differs from both in the nature and arrangement of its introvert hooks.

No previous Australian record.

Distribution: in Australia: only from the type locality (St. Helena Is., Moreton Bay).

Specimens examined and localities: Queensland—St. Helena Is., Moreton Bay "in coral clumps" SAM E1245 and same locality (5) SAM E1246.

Family Aspidosiphonidae and key to genera

Aspidosiphonidae Baird, 1868, p. 100; Stephen and Edmonds, 1972, pp. 215-216.

Description: Rather small sipunculans with either a hardened, horny, usually brown shield or a white, calcareous cap clearly marked off on anterior region of trunk. A caudal shield may be present at posterior extremity of trunk. Introvert lies ventral to shield or cap in all genera, except *Cloeosiphon*, where it arises from centre of cap. Longitudinal musculature continuous or in bundles, the latter sometimes anastomosing considerably. Two nephridia.

Type genus: *Aspidosiphon* Diesing, 1851.

KEY TO GENERA OF ASPIDOSIPHONIDAE KNOWN FROM AUSTRALIA

1. Anterior (anal) shield or cap present and posterior (caudal) shield as well 2
- Anterior (anal) shield or cap present but no posterior (caudal) shield 3
2. Longitudinal musculature of trunk wall forming bundles, which may anastomose considerably 49

Paraspidosiphon (p. 49)

Longitudinal musculature of trunk wall continuous

Aspidosiphon (p. 43)

3. Longitudinal musculature of trunk wall continuous (anterior cap rounded, calcareous and pineapple-like). Introvert from middle of cap 54

Longitudinal musculature of trunk wall forms bundles, which may anastomose. Anterior cap has shape of a truncated cone. Introvert arising ventral to cap *Lithacrosiphon* (p. 54)

Remarks: Stephen (1964, p. 457) split off from *Aspidosiphon* a new genus, *Paraspidosiphon*, in which the longitudinal muscles are grouped into bundles, sometimes with much anastomosis. Stephen regarded the condition of the longitudinal muscles of considerable taxonomic importance in the phylum. Stephen and Edmonds (1972) followed Stephen's lead. Neither Cutler (1973, p. 173) nor Murina (1975b, p. 1748, 1752), however, considers that *Paraspidosiphon* is justified at the generic level, each preferring to regard *Aspidosiphon* as consisting of two subgenera, *Aspidosiphon* (*sensu stricto*) and *Paraspidosiphon*.

Centrosiphon (Shiely, 1903), which Stephen and Edmonds (1972) included in this family, is being omitted because it now seems to me that *C. herdmanni*, the type of the genus, is a golfingiid. The taxonomic position of the species is, however, still uncertain.

The tentacular arrangement in *Aspidosiphon* and *Paraspidosiphon* as stated by Stephen and Edmonds (1972, p. 217) is now known to be wrong, Gibbs (1977) pointing out that the tentacles lie in a near ring dorsal to the mouth, as in *Phascolosoma* (see remarks on p. 8). I am not certain how the tentacles are arranged in *Cloeosiphon* and *Lithacrosiphon*.

Genus *Aspidosiphon* Diesing

Aspidosiphon Diesing, 1851, p. 67 (in part); Stephen, 1964, p. 457.

Description: Anal and caudal shields usually prominent and longitudinal muscles of body wall continuous and not separated into bundles. Anal shield may be circular, elliptical or horseshoe shaped, darker in colour than the trunk, with its surface sometimes furrowed, grooved or covered with hard, irregularly arranged granules. Caudal shield may be flat, hemispherical, conical or truncate; it may or may not be furrowed or grooved. Sometimes the caudal shield is not strongly developed. Introvert arises from the ventral side of the anterior shield. Tentacles digitiform and arranged in a horseshoe-shaped ring dorsal to mouth (see foot-note on p. 8). One or two retractors. Two nephridia. Contractile vessel simple.

Type species: *Aspidosiphon muelleri* Diesing, 1851.

KEY TO SPECIES OF *ASPIDOSIPHON* FOUND IN AUSTRALIA

1. Introvert hooks—all with single points 2
Introvert hooks—some or all with two points 4
2. Hooks with long, bent points **A. exhaustus* (p. 46)
Hooks without long, bent points 3
3. A number of knobby papillae on anterior part of anal shield modified to form spine-like structure, *A. inquilinus* (p. 47)
No spine-like structures on anal shield; tendency for circular musculature of body wall to be striated *A. gracilis* (p. 46)
4. Surface of anterior shield furrowed or ribbed 5
Surface of anterior shield not furrowed
A. elegans elegans (p. 44)
5. Anterior shield with about 12 furrows, posterior shield with weaker striations (well known inhabitant of solitary corals) *A. jukesii* (p. 49)
Anterior shield with 5-6 furrows, posterior shield with 24-25 *A. harmeyeri* (p. 47)

A. elegans elegans and *A. gracilis* inhabit coral reefs and *A. harmeyeri* limestone reefs. *A. jukesii* lives in the solitary coral *Heteropsammia* and *A. inquilinus* inhabits the shells of *Dentalium* and other molluscs.

***Aspidosiphon elegans elegans* (Chamisso and Eysenhardt)**
(Figs. 71-76)

Sternopsis elegans Chamisso and Eysenhardt, 1821, p. 351 pl. 24, figs. 5a-e.

Aspidosiphon elegans Grube 1868a, pp. 645-647, pl. 8, fig. 5-5a-b; Selenka and de Man, 1883, pp. 124-6, pl. 1, figs. 10-10a, pl. 14, figs. 205-208; Sato, 1935, p. 316; Sato, 1939, p. 426-7

Aspidosiphon exilis Sluiter, 1886, p. 497, pl. 3, figs. 11-12.

Location of type: Not known to author; type locality, "small islands of the Pacific Ocean".

Description: Slender, delicate, pale to straw coloured and coral dwelling. Trunk more or less cylindrical, 8-14 mm long and 1.7-2.8 mm wide, thin walled and fragile and sometimes slightly curved so that ventral is slightly shorter than dorsal side. Longitudinal musculature continuous.

Anal shield prominent, elliptical, dark brown (although golden around edges) and usually warty; consists of brown polygonal plates placed closely together and usually lacking furrows (although edges may be ridged to some extent). Caudal shield more weakly developed and sometimes almost insignificant, usually hemispherical with chitinous structures around its periphery; furrows, if present are only marginal.

Papillae on trunk flat and usually restricted to (1) a narrow region just posterior to anal shield and (2) a narrow region at posterior of trunk, consisting of

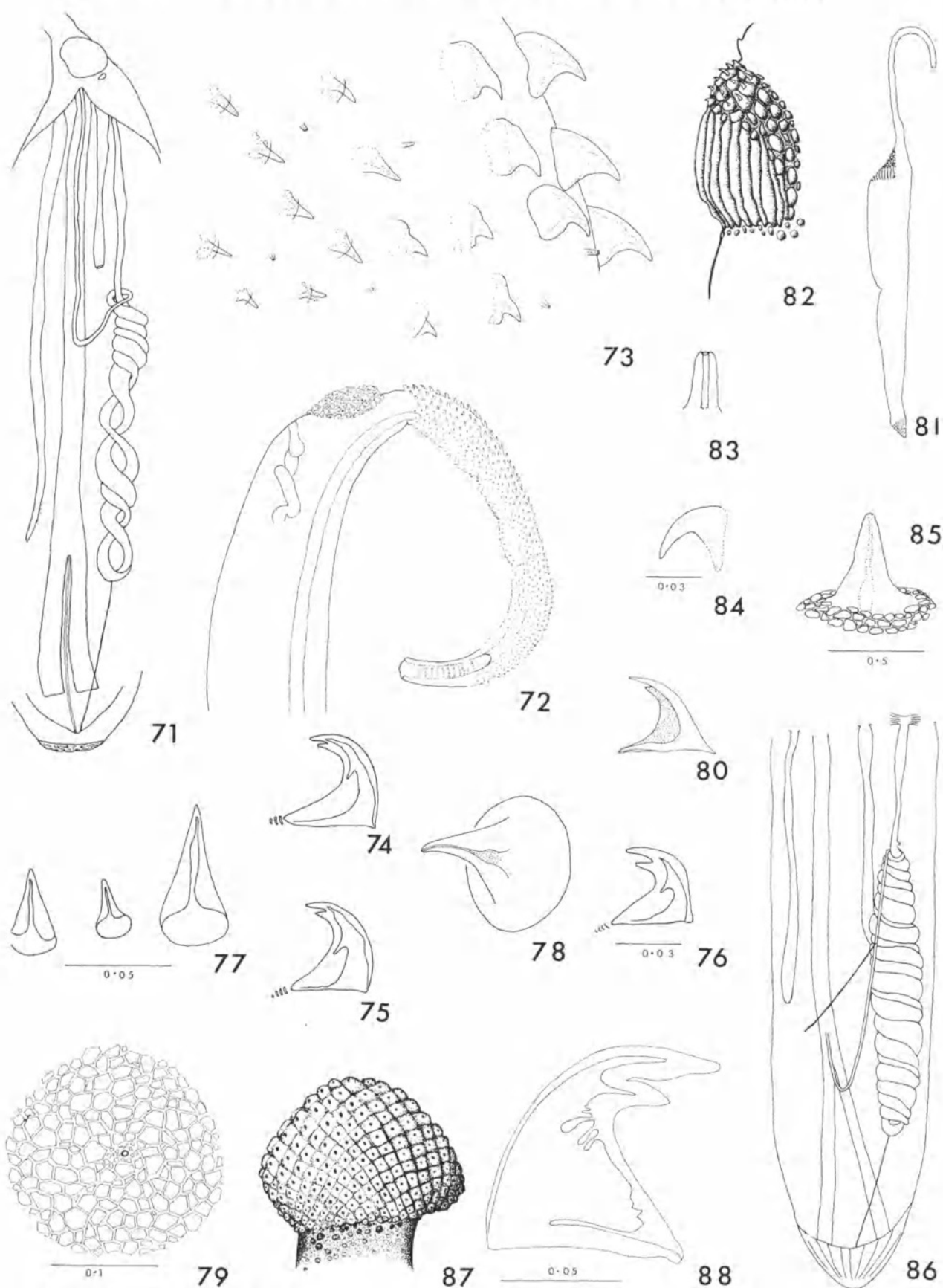
aggregates of flat polygonal plates grouped around a small circular opening. Caudal shield of some specimens consists of structures resembling closely set papillae.

Introvert of fixed specimens about as long as or a little longer than trunk, slender, thin walled, arising ventrally to anal shield and bearing anteriorly a few tentacular-like structures; armed with 15-30 rows of small dark hooks with two points. Clear area inside hook usually possesses a small, backwardly directed tongue or extension (slight variations of the angle at which the hook lies on a slide can cause considerable differences in its appearance). Hooks in most posterior rows of some specimens are smaller and lack internal markings—whether they are developing hooks or not is not known.

Dark, single pointed, closely set spines of varying size and shape lie on introvert posterior to hooks, their field extending to its base; spines (1) are larger and more closely set on dorsal surface of introvert and (2) become larger the more posteriorly they are placed. In some specimens, where spination is heavy, spines arise from strong bases or rooting processes and clearly possess a central, tubular canal.

Retractor muscle, arising from body wall well in front of caudal shield, consists of two short roots. Intestine loosely wound and frail. Rectum long and lacking a caecum. No intestinal fasteners observed. Two thin and delicate nephridia, about half as long as trunk, are fixed to body wall for most of their length. Spindle muscle fixed posteriorly.

Systematics and discussion: There is a group of aspidosiphonids in which the longitudinal musculature is continuous, which possess introvert hooks with two points, well developed introvert spines with single points (often with strong rooting processes) and which bear small truncated papillae on the introvert. They possess few or no papillae on the trunk except near the anal and caudal shields and the papillae are flat and consist of polygonal plates. They possess a single retractor muscle that arises from two roots which are fastened to the body wall well anterior to the caudal shield. Their nephridia are about half as long as the trunk and are fixed to the body wall for most of their length. Some of these species are *Aspidosiphon spinalis* Ikeda, 1904 (from Japan and Jaluit Is.), *A. spinosus* Sluiter, 1902 (from Indonesia), *A. homomyarius* Johnson, 1964 (from west coast of India), *A. exilis* Sluiter, 1886 (from Indonesia), *A. carolinus* Sato, 1935 (from West Caroline Is.), *A. bracki* Augener, 1903 (from Malaya), *A. elegans elegans* (Chamisso and Eysenhardt, 1821 (from Pacific Is., Philippines and the red Sea) and *A. elegans yapensis* Sato, 1935 (from West Caroline Is.).



FIGS. 71-88. Figs. 71-79, *Aspidosiphon elegans*; 71, dissected specimen; 72, introvert; 73, introvert hooks (from posterior region); 74-75, introvert hooks with two points; 76, hook from *Aspidosiphon exilis* Sluiter; 77, spines from introvert; 78, larger spine from posterior region of introvert; 79, papilla from anterior region of trunk (Figs. 74, 75 & 77 to same scale). Fig. 80, *Aspidosiphon hanimeyeri*; introvert hook (after Fischer). Figs. 80-86, *Aspidosiphon inquilinus*; 81, entire animal; 82, anal shield; 83, small papilla from introvert; 84, single pointed hook from introvert; 85, spiny papilla from anal shield; 86, dissected specimen. Figs. 87-88, *Cloeosiphon aspergillus*; 87, anterior cap; 88, introvert hook.

The first of these to be described was *A. elegans*. The description of Chamisso and Eysenhardt is very brief and deals with external features only. Their figures, however, show that their specimens are those of an *Aspidosiphon* with an anal and caudal shield, an introvert which arises ventral to the trunk, that the introvert is armed with hooks and spines, the latter increasing in size the more posteriorly they lie. Their specimens were collected "on the low-lying or small (= humiles) islands of the Pacific Ocean, in places that are washed by the tides, and boring in coral rocks, apparently by means of their shield (= scutum)", Grube's (1868) description of *A. elegans* from specimens from the Red Sea is fuller. The anterior shield is furrowed to some extent, the spines on the introvert are largest posteriorly and the papillae on the trunk are more prominent most posterior to the anal shield. His drawing of the bilobed hooks, however, is difficult to follow. The most detailed description of the species is that of Selenka and de Man 1883, their specimens having been collected from the Philippines and the Red Sea, the latter specimens showing some differences from those from the Philippines.

The specimens which I am describing from the Pacific Ocean (Hawaii, Solomons, New Hebrides and the Great Barrier Reef) resemble *A. elegans* in the following respects (1) the presence of double-pointed hooks with internal marking like those of *A. elegans* (2) flat papillae composed of polygonal plates (3) the spination of the introvert posterior to the hooks, the spines being largest on the dorsal surface and at the base of the introvert (4) the presence of a single retractor which stems from two roots attached to the posterior third of the body wall (5) the presence of two nephridia attached for most of their length.

Selenka's specimens, however possessed a caecum and a fastening muscle. Nevertheless, I am regarding my specimens as *A. elegans*.

An examination of Sluiter's specimens of *A. exilis* from (1) Siboga Stn. 172 (2 spec.) labelled "type" and (2) Diuzend Eil (Tausend Is.) (1 spec.) shows that they are identical with what I am regarding as *A. elegans*. The hooks, spines and papillae correspond in all respects. Consequently I have placed *A. exilis* Sluiter, 1886 in the synonymy of *A. elegans*. *A. homomyrius* Johnson, 1964, according to his description, is also very closely related to *A. elegans*.

A. elegans seem to have been found only in formations of coral.

No previous Australian record.

Distribution: (1) in Australia: Queensland at Three Is. and Lizard Is. (Gr. Barrier Reef).

(2) elsewhere: Pacific Is. (Chamisso and Eysenhardt, 1821), West Caroline Is. (Sato, 1935), Japan (Sato, 1939); Hawaii (in the present paper); Funafuti (Shiple, 1898); Indonesia (Sluiter, 1886); Philippines (Selenka & de Man, 1883); Gulf of Manaar (Gravelly, 1927); Mauritius (Wesenberg-Lund, 1959b); Red Sea (Grube, 1868, Herubel, 1904, Fischer, 1914, Wesenberg-Lund, 1957).

Specimens examined and localities: Queensland—Great Barrier Reef at Three Is. (4) coll. Dr. P. E. Gibbs SAM E1265, at Lizard Is. (5) coll. P. Wearne, at Heron Is. (1) coll. R. Reichelt.

The description of the species given above was based on these specimens and about 20 more from Hawaii.

**Aspidosiphon exhaustus* Sluiter

Aspidosiphon exhaustus Sluiter 1912, pp. 20-21, pl. 1, fig. 11.; Murina, 1972, pp. 295-298, 1977, p. 42-43, fig. 98.

Location of type: ? Zoological Museum, Amsterdam; specimen from off Morocco (36° 42' N, 8° 40' 30' W at 310-749 m).

Description (based on Sluiter 1912): Trunk 17 mm long and 2 mm wide. Introvert about as long as trunk and armed with numerous rows of very small, transparent hooks with long bent points. Anal shield oval and marked posteriorly with 12 radial furrows. Caudal shield with 10 furrows. Two retractor muscles, attached to caudal shield, join to form a single muscle. Two long nephridia attached to trunk for most of their length.

Murina (1972) gives the length of her Australian specimen as 15 mm and reports the presence of 20 furrows on the anterior shield.

Australian record: off coast of N.S.W., (33° 34' 5" S, 152° 06' 5" E) at depth of 425 m. 1 specimen: Murina 1972, pp. 295-298.

Distribution: (1) in Australia: off coast of New South Wales.

(2) elsewhere: off Morocco (Sluiter, 1912); Pacific Ocean at 27° 13' S, 109° 25' W and Atlantic Ocean at 5° S, 11° E (Murina, 1972).

Aspidosiphon gracilis Baird

(Figs 94-96)

Pseudaspidosiphon gracile Baird 1868, p. 103, pl. 10, figs 1, 1a.

Aspidosiphon gracilis: Selenka and de Man 1883, pp. 122-123, fig. 22, 209-213; Rice and Stephen 1970, p. 69.

Location of type: Natural History Museum, London, reg. no. 43.5.15, 58a-b; specimens from Philippine Is.

Description: Specimen long and slender. Trunk about 45 mm long and 2.5-3.0 mm wide, curved to resemble a horse-shoe, grey and bearing dark brown, hemispherical papillae which contrast with lighter coloured background of trunk. Because the darker papillae and the lighter areas of the trunk tend to lie in short longitudinal rows the trunk appears mottled.

Anal shield with 10 almost complete longitudinal furrows. Caudal shield sharply conical and with about 28 complete and a few incomplete radial furrows. Brown papillae, consisting of numerous closely set polygonal plates, are 0.10-0.22 mm in diameter and at their summit there is a white pore. Similar but smaller papillae lie on posterior surface of introvert and on body wall between radial furrows of caudal shield.

Introvert, light yellow in colour, about 40 mm long and 1.4 mm wide arising ventrally to anal shield; armed with small single pointed hooks, with width of base greater than height. Small conical papillae also present on surface. Prominent spines (fig. 00) scattered over much of introvert. A tendency for the musculature to be striated circularly is evident in the dissected specimen. Baird comments on a similar condition in his specimens, "Corpus gracile, ---- striis circularibus cinctum, ----."

Two retractors arise from body wall near posterior extremity of trunk. Alimentary canal very long and much coiled. Contractile vessel poorly developed. Neither an intestinal fastener nor caecum found. Two very long, free, almost black nephridia, nearly as long as trunk, arise at about same level as anus.

Systematic position: This specimen is one of the few which have been recorded and described.

No previous Australian record.

Distribution: (1) in Australia: Queensland at Low Is.

(2) elsewhere: Philippine Is.

Specimen examined and locality: Queensland—Low Is. (1) coll. Dr. P. E. Gibbs, SAM E1254.

Aspidosiphon hartmeyeri Fischer

(Fig. 80)

Aspidosiphon hartmeyeri Fischer, 1919a, p. 277; 1927, p. 204; Edmonds, 1956 p. 306, fig. 18; Cutler, 1977, pp. 147-148.

Location of type: Not known to author; type locality, Shark Bay, Western Australia.

Description: Trunk as long as 20 mm. Introvert about same length. Shields darker than trunk and composed of thick polygonal plates. Anterior shield with 5-6 furrows, posterior with 24-25. Introvert with hooks of two points and more posteriorly irregularly arranged spines. Tentacles 6-8. One retractor muscle with two long roots fixed near caudal shield. Strong spindle muscle fixed posteriorly. Nephridia more than half length of trunk, free for most of their length and opening just posterior to anal aperture. Longitudinal musculature continuous; circular muscles tend to form anastomosing bundles, most readily noticed in dissected animals. This probably accounts for the "Querstreifung" noticed by Fischer (1919). Two eyespots. Edmonds (1956) reports an intestinal fastener to last intestinal whorl and a caecum.

Systematic position: Although described from Australia the species is not well known in this country. The hooks of Edmonds' (1956) specimens are slightly different from those of Fischer. The species needs redescription from specimens collected at the type locality. I have used Fischer's figure of the hook.

Previous Australian records: Western Australia—Shark Bay (Fischer, 1919a); Rottnest Is. (Edmonds, 1956). South Australia—Great Australian Bight (37° 18' S, 138° 43' E at 795 m) (Cutler, 1977).

Distribution: (1) in Australia: Western Australia at Shark Bay and Rottnest Is.; off coast of South Australia.

(2) elsewhere: West African coast (Wesenberg-Lund, 1959a); Cuba (Murina, 1967).

Specimen examined and locality: Western Australia—Rottnest Is., (1) SAM E1250.

Aspidosiphon inquilinus Sluiter

(Figs. 81-87, 89)

Aspidosiphon inquilinus Sluiter, 1902, p. 29-30, pl. 2, figs 21-22.

Location of type: Zoological Museum, Amsterdam; specimen from Siboga Stn. 282 (8° 25.2' S, 127° 18' E, 27-54 m). In shell of *Dentalium* sp.

Description: Description based on three specimens found in shells of *Dentalium* sp. and one from shell of a nassariid mollusc. Specimens from *Dentalium* small, slender, sub-cylindrical becoming more slender posteriorly. Trunk 4-8 mm long, 0.7-1.0 mm wide anteriorly and 0.5-0.7 mm posteriorly. Colour off-white to pale yellow. Specimen from gastropod coiled.

Anal and caudal shields strongly differentiated from trunk and brown to dark brown in colour. Anal shield subtriangular with about 14-18 longitudinal furrows, surmounted by hard, warty and knobby papillae which are usually arranged so as to form approximately 3-5 transverse furrows. A feature of the shield is that 6-15 of the most anterior placed papillae are modified to form spine-like structures. Caudal shield conical with about 18 complete and incomplete furrows.

Introvert (not completely evaginated in any specimen) about as long as trunk or little longer, slender and about 0.5 mm wide. No tentacles observed in a dissected specimen but this point needs checking. Anteriorly introvert bears 25 or more rows of very small single-pointed hooks about 0.015-0.020 mm tall and wide. Between rows of hooks and over most of surface of introvert are numerous, small, tubular papillae or glands about 0.02 mm tall. Spines are also distributed over surface of introvert.

Papillae or skin bodies on trunk mostly elliptical in shape. Longitudinal musculature continuous. Introvert retractor single for over half its length but arising from two shorter roots attached to or near caudal shield. Oesophagus emerges from between roots of retractor and loops up; single fastening muscle attached to it. Spindle muscle fixed posteriorly and a wing muscle present. Rectum with small conical caecum. Two free nephridia, about half as long as trunk, attached to body wall at about level of anus.

Systematic position: I have compared these with the holotype of *A. inquilinus* Sluiter, described from a single specimen found in a *Dentalium* shell in the Timor Sea (8° 25' S, 127° 18' E) and consider them to be the same. The holotype is cylindrical and its shields are well defined. The anterior shield, however, is obliquely inclined to the longitudinal axis of the trunk but in the opposite way to the usual, its anterior region is tucked in and slopes down to the introvert (the effect is produced by the contraction of the longitudinal musculature nearby in the trunk). One important point, not mentioned by Sluiter, is that a few of the knob-like papillae which comprise the anterior part of the anal shield are modified to form sharply pointed hooks or spines which are obscured to some extent in the holotype by the introvert. The introvert retractor of the holotype (a dissected specimen) is single for well over half its length and arises from two shorter roots fixed to the trunk near the caudal shield. The specimens from Moreton Bay are smaller and so are their hooks. They possess a caecum and an intestinal fastener, neither of which is mentioned in the type description. Unfortunately, owing to the frail and

damaged condition of the gut, it is difficult to say whether the structures are now present in the holotype or ever were.



FIG. 89. *Aspidosiphon inquilinus*. (two specimens from Moreton Bay, Queensland; one in shell of *Dentalium*).

The Australian specimens are also closely related to *Aspidosiphon kovalenskii* Murina, 1964a collected from the shells of *Dentalium* sp. in the Adriatic and Aegean Seas. They differ, however, from *A. kovalenskii* in that (1) externally they possess spines and tubular papillae on the introvert and (2) internally they possess a caecum, only one fastening muscle and nephridia which are free and not attached.

Murina, 1972, p. 295 reported *A. exhaustus* Sluiter, 1912 living in the dead shells of gastropods (*Mitra* sp.) from the coasts of New South Wales and Western Australia. *A. exhaustus*, however, lacks the spine-like structures on its anal shield and is consequently thought to be different.

No previous Australian record.

Distribution: (1) in Australia: Moreton Bay, Queensland.

(2) elsewhere: Timor Sea (Siboga Stn. 282).

Specimens examined and localities: Three specimens from shells of *Dentalium* sp. collected during Moreton Bay Survey, Queensland by Stephen Cook

(Dept. of Zoology, Univ. of Queensland) at Stn. 28 in March, 1973. Two were dissected. One specimen also collected from shell of a nassariid at same locality; depth 10 m. SAM E1266.

Aspidosiphon jukesii Baird

(Figs. 97-99)

Aspidosiphon jukesii Baird, 1873, p. 97; Rice and Stephen, 1970, pp. 68-69.

Aspidosiphon corallicola Sluiter, 1902, pp. 19-25.

Location of type: Nat. Hist. Museum, London: reg. no. 1965.25.3; specimen from Lee Sandbanks (Great Barrier Reef), Queensland.

Description: All the specimens had been removed from the coral and fixed and the introvert was retracted except in two, where it was partly extended. Trunk either curved in a circle or coiled, with an estimated maximum length of 28 mm and maximum width of 5-8 mm. Anterior shield almost horseshoe-shaped, very dark in colour and warty, with radial furrows well developed on dorsal half. Furrows on ventral side of shield less strongly marked and run almost at right angles to radial ones. Anus prominent dorsally, just below anal shield. Posterior shield conical to hemispherical, light yellow and with radial furrows. Both shields correspond very closely to those of *A. jukesii* shown in figs. 21-23 of Rice and Stephen (1970).

Introvert (in retracted state) with length about three quarters that of trunk and bearing (1) small, doubly pointed hooks, (2) spines of variable size and (3) small, slender, sub-conical papillae which arise from hemispherical base. Papillae well developed on anterior and posterior fourth of trunk. A strong introvert retractor, dividing posteriorly into two stout roots, attached to body wall near caudal shield.

Longitudinal musculature continuous. Rectum long; without caecum and fastening muscle. Spindle muscle attached posteriorly. Nephridia slender, about half to three quarters as long as trunk and attached for about half of their length. Elliptical to spherical eggs 0.12-0.16 mm in diameter.

Systematics and remarks: These specimens from Queensland correspond very closely to Baird's *A. jukesii* as redescribed by Rice and Stephen (1970) and *A. corallicola* Sluiter 1902. Baird's specimens were obtained from Lee Sandbanks (Great Barrier Reef) and Sluiter's from solitary corals, including *Heteropsammia michelini* from Indonesia. Through the kindness of the authorities of the Zoological Museum of Amsterdam I have been able to compare my specimens with those of Sluiter (reg. no. V.Si.7.). The examination confirms the conclusion

of Rice and Stephen (1970), that *A. jukesii* and *A. corallicola* are synonymous. The species is well-illustrated in Rice and Stephen, 1970.

The association between the solitary corals *Heteropsammia* and *Heterocyathus* and the sipunculan *A. jukesii* was first reported by Edwards and Haime, 1848a and 1848b and has been redescribed by a number of writers, listed by Rice (1976). In a discussion on the matter Rice says, "The *Aspidosiphon* inhabits a spiral cavity in the base of the coral and, through an opening of the cavity on the under surface of the coral, the sipunculan extends its introvert into the surrounding substratum pulling the coral about as it probes and feeds in the sand. Through this association, the sipunculan is provided with a protective habitat and, by movements of the sipunculan, the coral is maintained in an upright position on the surface of the substratum and transported about to different feeding areas." The developmental history of the association has also been carefully studied. According to Rice, "The juvenile *Aspidosiphon*, when 1 mm or less in length, enters an empty gastropod shell, usually a small *Cerithium*. A coral planula settles on the shell, overgrowing and eventually enclosing it. Only those planulae settling on shells occupied by sipunculans have any chance of survival. Growth of the sipunculan and the coral are well synchronized, the sipunculan actively enlarging its cavity as a spiral tube in the base of the growing coral while maintaining an opening of the tube on the underside of the coral".

Previous Australian record: Queensland: Baird (1873); Goreau and Yonge (1968).

Distribution: (1) in Australia: Queensland at Heron Is. and Lizard Is.

(2) elsewhere: Malaysia, Gulf of Manar, Zanzibar and Madagascar.

Specimens examined and localities: Queensland—Lizard Is., (20) in the solitary coral *Heteropsammia michelini*; coll. D. Fisk (Dept. of Botany, Univ. of Queensland) SAM E1255 and E1256; Wistari Reef, Heron Is., "in solitary coral" AMS W5620.

Genus *Paraspidosiphon* Stephen

Paraspidosiphon Stephen, 1964, p. 457; Stephen & Edmonds, 1972, p. 237.

Description: Sipunculans with anal and caudal shields and with characters similar to those of *Aspidosiphon* Diesing but differing in that the longitudinal musculature of body wall is grouped into bands which may anastomose, sometimes considerably. Introvert, arising from ventral side of trunk, may be armed with hooks or spines, often

both. Tentacles as in *Aspidosiphon*. Introvert retractors one or two short roots. Spindle muscle attached posteriorly.

Type species: *Paraspidosiphon steenstrupii* (Diesing, 1859).

Remarks: Stephen considered that the condition of the longitudinal musculature warranted the separation of *Paraspidosiphon* from *Aspidosiphon* and *Fisherana* from *Phascolosoma*. Not everybody agrees with this. Both Cutler (1973) and Murina (1975b) consider that *Paraspidosiphon* warrants the status only of a subgenus. The genus contains about 25-30 species, most of which live in burrows in limestone or coral reefs.

Specimens of *Paraspidosiphon klunzingeri* and *P. steenstrupii* reported from Low Is. by Edmonds (1956) are now being referred to other species, the former to *P. johnstoni* n.sp. and the latter to *P. formosanus* (Sato).

KEY TO AUSTRALIAN SPECIES OF PARASPIDOSIPHON

1. Introvert hooks with a single point 2
Introvert hooks with two points 3
2. Numerous rectal appendages present *P. cumingii* (p.50)
Numerous rectal appendages absent *P. johnstoni* n.sp. (p.51)
3. Introvert hooks with a thin, posteriorly directed, tongue-like extension of clear area *P. steenstrupii* (p.51)
Introvert without tongue-like extension of clear area *P. formosanus* (p.50)

**Paraspidosiphon cumingii* (Baird)

Aspidosiphon cumingii Baird, 1868, p. 102; Selenka & de Man, 1883, pp. 113-115, pl. 13, figs 183-186; Rice & Stephen, 1970, p. 67.

Paraspidosiphon cumingii: Stephen & Edmonds, 1972, pp. 243-244.

Location of type: Nat. Hist. Museum, London: specimen from Philippines.

Remarks: This species is often reported from tropical and near tropical localities and is allied to *P. klunzingeri*. The introvert, however, is armed with single-pointed hooks and spines. The anterior shield has 12-13 furrows around its margin and the caudal has 30 of which only about 12-13 reach the centre of the structure. There are 27-28 longitudinal muscles anteriorly and 32-34 posteriorly. According to Selenka the posterior region of the rectum is thickly bordered with long, tufted villi ("Das letzte Ende des Mastdarmes ist dicht mit langen zottenartigen Gebilden besetzt"). There is one broad retractor which spans about 19 muscle bands; sometimes the retractor may split into as many as four roots. Two nephridia, attached for about two-fifths of their length extend to the posterior of the trunk. Selenka states that it has a strong fixing muscle.

Australian record: Low Is., Queensland (Monro, 1931).

Distribution: (1) in Australia: Low Is., Queensland.

(2) elsewhere: West Indies, Red Sea, Philippines, Zanzibar, Malaysia.

Paraspidosiphon formosanus (Sato)

(Figs 90, 92, 93)

Aspidosiphon formosanus Sato, 1939, pp. 421-424, text figs 55-57, pl. 21, fig. 23.

Paraspidosiphon formosanus: Stephen & Edmonds, 1972, p. 245; Edmonds, 1971, pp. 144-145.

Aspidosiphon steenstrupii: Edmonds, 1956, p. 307, fig 19.

Location of type: Not known to author; specimen from Sinko, Taiwan (Formosa).

Description: Specimens yellow to pink and tend to be slender. Trunk of largest 30-32 mm long and 2.5-4.0 mm wide and tending to curve inwards on ventral side. Anal shield elliptical, dark brown to black and composed of small knobby wartlike bodies to which white calcareous material may be attached; without furrows, although its periphery may be ridged. Caudal shield light brown, rounded, or conical and sometimes only weakly developed; if conical, weak radial furrows may be present but if rounded they do not appear. Papillae on trunk most prominent on surface adjacent to anal shield and are composed of small, closely packed, polygonal to rounded platelets; diameter of largest papillae 0.45 mm. Papillae near anal shield usually separated by grooves, which themselves are covered with small polygonal platelets. Papillae on mid-trunk region usually smaller, more rounded and scattered or even absent in some specimens. Papillae on posterior trunk larger and more prominent.

Introvert of retracted specimens about half as long as trunk; of expanded ones nearly twice as long. A few stoutly digitiform tentacles protrude adjacent to mouth in one specimen; surface of introvert just posterior to mouth is smooth and collarlike. Introvert armed with many rows of hooks with two points and spines with one point. Small truncated to cylindrical papillae lie between rows of hooks and among spines. Secondary or minor tooth of hooks tends to curve more strongly than primary one. Internally, clear area which at base of hook is half to three quarters as wide as hook, gradually tapers towards apex of hook. None of the mounted hooks show the posteriorly directed, tongue-like extension of the clear area like that shown for *P. steenstrupii* in fig. 192 of Selenka & de Man (1883) nor the



FIG. 90, *Paraspidosiphon formosanus*, (specimen from Queensland).

indentation on the right side of the clear area shown in fig. 59 of Sato (1939). Although all spines are single pointed, their shape varies considerably; some closely resemble single pointed hooks, some are more tetrahedral and others more slender and pointed. The variation is much like that shown for *P. grandis* in fig. 49 of Sato (1939).

Two introvert retractors, arising from muscles 2-5, 2-6, or 3-7 a short distance in front of caudal shield, remain separate for about one to two thirds of length of trunk before fusing to form a stout, single retractor. Oesophagus, carrying a simple contractile vessel, is attached to single retractor. Intestine with about 22 double spirals and rectum with a caecum. Spindle muscle strong and fixed posteriorly. No fixing muscle. Nephridia long (extending to posterior extremity of trunk), fixed for about half their length and opening at about same level or just posterior to that of anus. Brain simple with two eyespots.

Systematics: Although the internal anatomy is very much like that of *P. steenstrupii* (Diesing), the hooks of these specimens lack the thin tongue-like extension of the clear area shown in fig. 192 of Selenka & de Man (1883) and in pl. 1 fig. 4 of Augener (1903). The shape of the hooks is close to that of *P. ambonensis* (Augener, 1903). The shields of the latter, however, are furrowed. The specimens

are also close to *P. makoensis* (Sato, 1939) and *P. formosanus* (Sato, 1939), two species which themselves are allied. The shape of the hooks of the Australian specimens corresponds to those of the latter.

Edmonds (1956, p. 307 and fig. 19) described some specimens from Heron Is., Queensland as *P. steenstrupii*. I now think that this identification was wrong. The hooks, as shown in fig. 19, are like those of the specimens which I am now describing from Magnetic Is. and lack the tongue-like extension of the clear areas as shown by Selenka & de Man and Augener. Consequently the record of 1956 is now placed in the synonymy of *P. formosanus*.

No previous Australian record.

Distribution: (1) in Australia: Queensland.

(2) elsewhere: Formosa, Guam.

Specimens examined and localities: Queensland—Low Is., (2) SAM E1275; Magnetic Is. (2) SAM E1277.

****Paraspidosiphon steenstrupii* (Diesing)**

Aspidosiphon steenstrupii Diesing, 1859, p. 767, pl. 2, figs 1-6; Selenka & de Man, 1883, pp. 116-118, pl. 1, figs 12-13, pl. 13, figs 190-192.

Paraspidosiphon steenstrupii: Stephen & Edmonds, 1972, p. 254.

Location of type: Not known by author; specimen from St. Thomas.

Remarks: This species differs from *P. formosanus* in possessing introvert hooks in which the clear area carries a thin tongue-like extension, much like that of *Aspidosiphon elegans*. Edmonds (1956, p. 307, fig. 19) described some specimens from Low Is. as *P. steenstrupii*. I now think that they should have been called *P. formosanus* and am transferring the 1956 record to the synonymy of *P. formosanus*. *P. steenstrupii* has often been recorded from tropical and subtropical seas.

Australian record: Low Is., Queensland (Monro, 1931).

Distribution: (1) in Australia: Low Is., Queensland.

(2) elsewhere: West Indies; Brazil; Mauritius; Red Sea; Laccadive Is.; Japan; Philippines; New Hebrides; Indo China; Loyalty Is., and Cuba.

***Paraspidosiphon johnstoni* n. sp.**

(Figs. 91, 100-102)

Aspidosiphon klunzingeri: Monro, 1931, p. 34; Edmonds, 1956, pp. 308-9, fig. 20, pl. 3, fig. 1.

Location of type: Australian Museum, Sydney; specimen from coral in Moreton Bay, Queensland (coll. Prof. T. H. Johnston).

Description: Trunk usually cylindrical, sometimes curved ventrally, 20-45 mm long and 3-5 mm wide. Introvert, arising ventrally from trunk, is in fixed specimens about as long as or a little longer than trunk and armed anteriorly with very numerous (165) rows of single pointed hooks with a stout base and a curved tip. Hooks in posterior rows noticeably smaller than those in anterior rows. Posterior to rows of hooks is a narrow zone of scattered, single pointed "hooks" or "spines", closely resembling those more anteriorly, but which are much smaller and lack fine internal markings. Posterior part of introvert with out spines. Small, truncated to sub-conical papillae lie between rows of hooks and on surface of trunk. Tentacles short, few and finger-like lying in a part ring dorsal to mouth as in *Phascolosoma*.



FIG. 91. *Paraspidosiphon johnstoni*, (specimen from Queensland).

Shields dark gold to red brown in colour, wartlike in texture and appearance and prominent. Anal shield fan-like, lying obliquely to trunk and possessing 10-16 complete and incomplete furrows which radiate dorso-ventrally like ribs of a fan. Posterior shield conical, often carrying a rim at junction with trunk and possessing 22-28 complete and incomplete radial furrows. Furrows of both

shields may extend over lateral margins of shield, thus making surface of trunk joining shields appear furrowed. Furrows correspond approximately to tissue between longitudinal muscles.

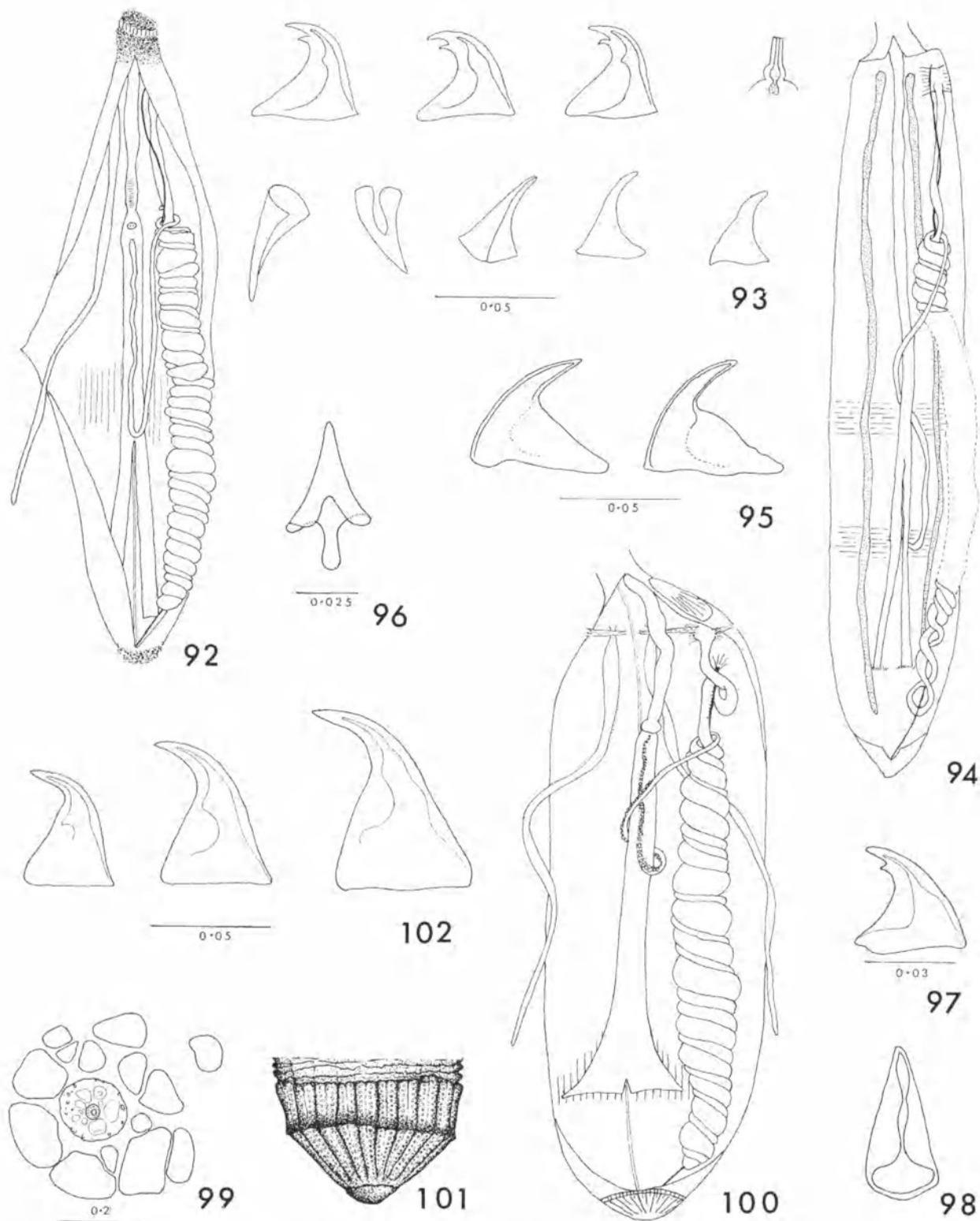
Body wall thick and longitudinal musculature in 25-32 anastomosing bundles. Circular musculature tends to form fascicles. Retractor muscle very strong, arising from two short roots each of which spans muscles 1-8, 2-7, 2-6 and 1-9 well in front of caudal shield. Oesophagus attached to retractor muscle for part length of latter. Intestinal spirals numerous and extend to posterior of trunk. Nephridia tubular, about three quarters as long as trunk and fixed for anterior quarter. No intestinal fastener and no rectal caecum. Wing muscle strong; in addition two strong muscles are attached to rectum near anus and run transversally across body wall to muscle 1 or 2 on each side of nerve cord. Spindle muscle stout, arising anteriorly from body wall under rectum, and fixed posteriorly. A strand of fine tissue connects rectum and body wall in some specimens. Contractile vessel without villi.

Systematic position: The specimens closely resemble *P. klunzingeri* (Selenka & de Man) in the shape and marking of the introvert hooks and in internal anatomy. They differ from it, however, in that (1) no rectal sac bearing numerous lobes on both sides is present ("am Rectum sitzt ein grosser, an beiden Seiten vielfach gelappter Blindsack") (2) they lack a well defined region of introvert spines and to a less extent (3) the spindle muscle arises from the body wall under the rectum and not in front of the anus ("Ein Spindelmuskel nimmt unmittelbar vor dem After seinen Anfang").

The Australian specimens also resemble *P. pachydermatus* (Wesenberg & Lund, 1937), *P. grandis* (Sato, 1939) and *P. cumingii* (Baird, 1868). They differ in that the last three species possess rectal appendages as clearly shown in Wesenberg-Lund 1937, fig. 9, Sato, 1939, fig. 50 and Selenka & de Man, 1883, fig. 186b. They also differ from (1) *P. angulatus* (Ikeda, 1904) in the internal markings of the hooks (2) *P. speciosus* (Gerould, 1913) in the shape of the hooks and the number of longitudinal muscles (3) *P. schnehageni* (Fischer, 1913) in which the shields are not furrowed, the longitudinal muscles 10-14 and in which there is no fastening muscle (Ditadi, 1975) and (4) *P. tenuis* (Sluiter, 1886) in which the hooks are long and slender.

Edmonds (1956, pp. 308-9) identified two specimens from Low Is. as *Aspidosiphon klunzingeri*, remarking at the time that they lacked rectal appendages. I now think that I was wrong in so doing. I have re-examined them and consider that they should be placed in the synonymy of *P. johnstoni*.

Specimens examined and localities: Queensland Raine Is. (11° 35' S, 144° 1' E) coll. I. M. Thomas, —Low Is., (2) coll. Dr. P. E. Gibbs, SAM 1274; SAM E1272; Moreton Bay, in coral (8) coll. T. H. Two Is., (4) coll. Dr. P. E. Gibbs, SAM E1273; Johnston SAM E1270.



FIGS. 92-102. Figs. 92-93, *Paraspidosiphon formosanus*; 92, dissected specimen; 93, introvert hooks, spines and papillae. Figs. 94-96, *Aspidosiphon gracilis*; 94, dissected specimen; 95, introvert hooks; 96, spine from introvert. Figs. 97-99, *Aspidosiphon jukesii*; 97, introvert hook; 98, introvert spine (same scale as 97); 99, trunk papilla. Figs. 100-102, *Paraspidosiphon johnstoni*; 100, dissected specimen; 101, posterior shield; 102, introvert hooks.

Genus *Cloeosiphon* Grube

Cloeosiphon Grube, 1868b, p. 48; Selenka & de Man, 1883, p. 126; Stephen & Edmonds, 1972, p. 267.

Description: Trunk surmounted by a rounded to pineapple shaped cap, consisting of numerous, small, white, calcareous plates. Introvert arises from centre of cap. Rows of two-pointed hooks present on introvert. No cap or shield at posterior of trunk. Longitudinal muscles continuous. Spindle muscle fixed posteriorly. Two nephridia.

Type species: *C. aspergillus* (Quatrefages, 1865).

Remarks: Although four species have been described in this genus most workers consider them to be synonymous. *C. aspergillus* is commonly found in coral formations in most tropical seas.

Cloeosiphon aspergillus (Quatrefages)

(Figs. 15, 87-88)

Loxosiphon aspergillus Quatrefages, 1865, p. 605, pl. 20, fig. 20.

Cloeosiphon aspergillus: Selenka & de Man, 1883, pp. 126-7, pl. 2, figs 23-24, pl. 14, figs 214-216; Edmonds, 1956, pp. 309-310, fig 21, pl. 3, fig 2; Stephen & Edmonds, 1972, p. 267-268.

Location of type: Not known by author: type locality: ??

Description: Trunk cylindrical, 10-45 mm long and 2.5-4.9 mm wide, bearing anteriorly a white, calcareous knob or cap, 2.5 mm in diameter and composed of small, white, polygonal plates of 4-6 sides, arranged in spiral rows. Each plate possesses a small brown pore. No cap, shield or knob at posterior extremity. Introvert slender, about as long as trunk, arises from centre of anterior cap and armed with double-pointed hooks. No spines on introvert.

Longitudinal musculature continuous. Trunk smooth although covered with glands, largest and most closely placed on anterior and posterior surfaces. Single retractor arising from two short roots. One fastening muscle. No intestinal caecum; spindle muscle fastened posteriorly. Nephridia dark, long (extending to base of retractor) and fixed for their entire length.

Systematic position: The identification of these specimens depends on the presence of the calcareous cap or knob and the shape of the introvert hooks. The cap is sometimes rounded, sometimes shaped like a pineapple or more flattened. The internal marking of the hook also varies to some extent. A number of authors consider that *C. japonicus* Ikeda,

1904, *C. japonicus* Sluiter, 1886 and *C. mollis* Selenka & de Man are synonymous. The matter is discussed in Stephen & Edmonds, 1972, p. 268.

Previous Australian records: Queensland: Munro, 1931; Edmonds, 1956.

Distribution: (1) in Australia: Queensland (in coral formations); Low Is., Heron Is., Lodestone Reef, One Tree Is.

(2) elsewhere: widely in the Indo-Pacific region.

Specimens examined and localities: Queensland—Heron Is., SAM E1292 (8), E1293 (1), E1294 (2), Low Is., SAM E1301 (4); Townsville SAM E1295 (1).

Genus *Lithacrosiphon* Shipley

Lithacrosiphon Shipley, 1902, p. 139; Fischer, 1919b, p. 289, Fischer, 1922, pp. 26-28; Stephen and Edmonds, 1972, p. 259; Cutler and Jurczak, 1975, p. 243.

Description: Anterior end of trunk surmounted by a hard, calcareous, cone-shaped cap borne on a pad of skin; longitudinal muscles fit into pad. Introvert arises on ventral side of trunk or cap and bears numerous rows of hooks with one or two points. Longitudinal muscles form bands which may anastomose freely. Two retractors and two nephridia. Spindle muscle fixed posteriorly.

Type-species: *Lithacrosiphon maldivensis* Shipley, 1902.

Remarks: All the species so far described have been found in formations of coral. Cutler and Jurczak (1975) have critically reviewed the genus and reduced the number of species from 9 to 3. The valid species are now *L. maldivensis* Shipley (the type), *L. cristatus* (Sluiter) and *L. uniscutatus* (Ikeda). Only *L. cristatus* has been found in Australia.

Lithacrosiphon cristatus (Sluiter)

(Fig. 16)

Aspidosiphon cristatus Sluiter, 1902, p. 26, pl. 2, figs. 15-16.

Lithacrosiphon cristatus Fischer, 1922, p. 26; Cutler and Jurczak, 1975, p. 243.

Location of type: Zoological Museum, Amsterdam; specimen from Malaysia (Siboga Stn. 53, Waingapu).

Description: Specimens small; trunk of largest 9 mm long and 3 mm wide. Anterior region of trunk with form of a truncated cone, the surface of which is marked with a number of almost longitudinal furrows. Posterior to furrowed area trunk bears

prominent, hemispherical swellings or papillae. Introvert estimated to be about as long as trunk. Longitudinal muscles in 17-22 anastomosing bands. Two introvert retractors. Two nephridia about half as long as trunk. Both uni- and bidentate hooks present on introvert, those most distally being bidentate.

The identification of these specimens depends on the facts that (1) the anal shield is furrowed and (2) the distally placed hooks have two teeth while the proximal ones have one. No previous Australian record.

Distribution: (1) in Australia: Lizard Is., Queensland.

(2) elsewhere: "wide tropical distribution" (Cutler); Malaysia, Timor, Saipan, Gilbert Is., Hawaii, Panama and the Caribbean.

Specimens examined and localities: Queensland—Lizard Is. (8) coll. P. Weate AMS and (3) SAM E1289; Yonge Reef, east of Lizard Is., (1) AMS W10542.

Family Phascolosomatidae and key to genera

Phascolosomatidae Stephen and Edmonds, 1972 p. 269.

Description: Specimens bottle- or flask-shaped, sometimes sub-cylindrical. Finger-like tentacles lying in a near circle dorsal to mouth and surrounding nuchal organ. Longitudinal muscles grouped in bands, except in one small genus. Papillae conical to hemispherical in shape, often mamillate and darkly pigmented and usually covered with small platelets; most prominent and most densely grouped at anterior and posterior extremities of trunk. Retractor muscles four, very rarely two.

Type genus: *Phascolosoma* Leuckart, 1828.

KEY TO GENERA OF PHASCOLOSOMATIDAE

1. Species in which longitudinal musculature forms bands
Phascolosoma (p. 55)
- Species in which longitudinal musculature is continuous
Fisherana[†]

Genus *Phascolosoma* Leuckart

Description: Trunk spindle-like sub-cylindrical, flash-shaped or fusiform. Longitudinal muscles always in bands, which may anastomose. Muscle bands not always visible externally but readily seen on dissection. Tentacles lie in a horse-shoe dorsal to mouth and enclose nuchal organ. Introvert and

trunk usually covered with prominent, conical to hemispherical papillae, often brown to dark red-brown in colour. Trunk papillae usually largest and most densely distributed on anterior and posterior surfaces (especially on dorsal side). Retractors four, very rarely two. Contractile vessel single and usually simple.

Type species: *Phascolosoma granulatum* Leuckart, 1828.

SUBGENERA OF PHASCOLOSOMA AND KEY TO SUBGENERA

Stephen & Edmonds (1972, p. 271) divided the genus into four subgenera. Of these, two, *Phascolosoma* s.s. and *Satonus*, are known in Australia.

1. One pair of retractor muscles *Rueppellisoma*
- Two pairs of retractor muscles 2
2. Contractile vessel with villi or tubules *Antillesoma*
- Contractile vessel without villi or tubules 3
3. Spindle muscle fixed to posterior of trunk
Phascolosoma s.s. (p. 56)
- Spindle muscle not fixed to body wall posteriorly
Satonus (p. 61)

Remarks: Specimens of *Phascolosoma* are the most commonly collected intertidal sipunculans in Australia. They are found in limestone and coral reefs (some species bore into the rock; Rice, 1969, 1976), in masses of tubiculous polychaetes, in clumps of mussels, in rock crevices, under stones and in mangrove flats. Most appear to be detritus feeders (Rice, 1976). The larval development of some species has also been studied by Rice (1970). A list of the species reported from Australia is given on p. 7 of the present paper.

Identification of species: I have not been able to construct a simple and satisfactory key to the Australian phascolosomatids.

P. nigritorquatum, however, differs from all the other species because (1) its spindle muscle, according to the type description, is not fixed posteriorly (2) its mouth is surrounded by a row of very dark granular swellings and (3) the introvert bears four rows of hooks. It is not a well-known species.

The shape and markings of the introvert hooks and the structure of the papillae are two characters most commonly used in the identification of species. Consequently I have figured the hooks of all the species.

The hook of *P. noduliferum* has a comparatively wide base, a tendency to narrow near its mid length and a fine clear streak running from the apex to the mid-base. The papillae of *P. noduliferum* are usually hemispherical and carry few platelets; they are not

[†] Specimens of this small genus have not yet been found in Australia. Cutler & Murina (1977, p. 183) consider *Fisherana* better placed in the family Golfingiidae.

heavily pigmented and tend to be uniformly distributed. Pigmented bands on the introvert are lacking.

P. arcuatum differs from other species in (1) the arrangement of its retractor muscles, (2) the presence of sub-epidermal coelomic extensions, (3) the tendency of its circular musculature to form small bundles and (4) its lack of fixing muscles. The clear area of the hook is very wide basally. The species has been found only in association with mangroves.

The papillae of *P. annulatum* are covered with large contiguous, polygonal plates which usually are darker in colour at the base of the papillae. Polygonal plates like those on the papillae are scattered on the body wall between the papillae. The hook of *P. annulatum* is "scolops-agassizi"-like and consequently not a very useful distinguishing character.

The hook of *P. albolineatum* is stout; its pointed part is strongly bent and lies almost parallel to the base of the hook. The central clear "streak" is wide and slopes sharply to a basal corner of the hook. There is a well developed clear, triangular area on the side of the streak away from the tip of the hook.

The papillae of *P. pacificum* tend to be sharply conical so that specimens may feel "bristle-like". The introvert hook is sharply bent, its clear streak widens basally and it possesses a clear triangular area. The nephridia extend almost to the extremity of the trunk and are fixed to the body wall for most of their length. Specimens are sometimes mottled in colour.

The hook of *P. stephensoni* has a clear triangular area on one side of the clear streak that runs from the apex to the base and on the other side a clear crescentic area. The latter is characteristic.

The hooks of *P. rotnesti* and *P. scolops* resemble each other closely except that the clear streak of *P. rotnesti* may sometimes be slightly swollen near its middle. A rectal caecum, reported to be absent in *P. scolops*, is present in *P. rotnesti*. The papillae of *P. rotnesti* consist of more numerous and smaller platelets than those of *P. scolops*.

In *P. perlucens* a number of claw-like papillae or spines are present at the base of the introvert (especially on the dorsal side) and on the posterior region of the trunk. The hook is bent rather sharply.

The clear streak of the hook of *P. nigrescens* is swollen slightly in its upper half and very much expanded posteriorly. The basal part of the expansion is indented slightly so as to form a bulge or a tongue which is directed towards the tip of the hook.

I now consider that *P. heronis* Edmonds, 1956 and *P. dunwichi* Edmonds, 1956 were incorrectly named; the former should have been called *P. stephensoni* (Stephen, 1942) and the latter *P. scolops* (Selenka and de Man, 1883). The reasons for the changes are given in the text.

Phascolosoma (Phascolosoma) albolineatum Baird

(Fig. 106)

Phascolosoma albolineatum Baird, 1868, pp. 91-92; Rice and Stephen, 1970, p. 59; Stephen and Edmonds, 1970, p. 293.

Phymosoma albolineatum Selenka and de Man, 1883, pp. 71-74, pl. 9, figs. 128-129.

Location of type: Nat. Hist. Museum, London, reg. no. 1925.25.1; specimen from Philippine Is.

Description: This description is based on the four specimens mentioned below and 16 others from the Solomon Is. Trunk off-white to pale straw in colour except at junction with introvert where it is dark brown; length 9-34 mm and width (in mid-region of trunk) 3-8 mm. Straw coloured introvert, about half to three quarters as long as trunk, with a number of black bands of varying size on its dorsal side. An almost complete ring of short, stubby, light tentacles (26 in one specimen) lies dorsal to mouth. Immediately posterior to mouth there is a smooth collar-like region. Posterior to collar, introvert is armed with rows (28 in one specimen) of dark coloured stout hooks, with a strongly bent tip. Central, clear region of hook wide and slopes sharply to basal corner. A triangular shaped, clear area lies basally on one side of central clear area.

Papillae on introvert brown, pointed, sub-conical or mamillate, becoming larger and more densely placed basally. Papillae on trunk largest anteriorly and 0.2-0.3 mm in diameter; in mid-trunk region they are smaller and more scattered and about 0.15 mm in diameter and posteriorly slightly larger and closer together.

Longitudinal musculature in about 20 anastomosing bundles. Four retractors, arising in posterior half of trunk; a stout ventral pair from muscles 2-6 or 2-7 and a more slender, dorsal pair more anteriorly from bands 4-6 or 5-7. Oesophagus fastened to retractors by thin mesenteries. A strong fastener arising from muscle 1 on left side near base of dorsal retractor runs towards junction of oesophagus and intestinal spiral, giving off one branch to posterior oesophagus and another branch to last spiral of intestine. No rectal caecum. Wing muscle strong. Spindle muscle attached near anus and at posterior extremity of trunk. Contractile vessel simple. Nephridia, about half as long as trunk, fixed for about half their length and attached at same level as anus.

Remarks: The shape of the hooks is a very useful specific character of this species.

No previous Australian record.

Distribution: (1) in Australia: Great Barrier Reef, Queensland.

(2) elsewhere: an Indo-Pacific species: Natal, Aboina, Java, Indo-China, Philippines, Japan, Tokara Is., Palau, West Caroline Is.

Specimens examined and localities: Queensland—Great Barrier Reef at Three Is., (2) SAM E1315 and at Casuarina Beach, Lizard Is., (2) WAM 220/76.

***Phascolosoma (Phascolosoma) annulatum* Hutton**

(Figs. 103, 107-8)

Phascolosoma annulatum: Hutton, 1879, p. 278; Benham, 1903, p. 174; Edmonds, 1960, pp. 160-2, text figs. 1-2; Stephen and Edmonds, 1972, pp. 296-297; Cutler, 1977, p. 151.

Physcosoma scolops var. *mossambicense* Augener, 1903, p. 339 (in part).

Physcosoma scolops var. *tasmaniense* Fischer, 1914, p. 3, pl. 1, figs. 4-6.

Physcosoma scolops Wheeler, 1938, p. 346.

Phascolosoma tasmaniense Edmonds, 1956, pp. 285-286, figs. 5-6.

Location of type: Not known by author; specimen from Campbell Is., New Zealand.

Description: Trunk 25-49 mm long and 4-7 mm maximum width. Introvert about as long as trunk (in fixed specimens), with 20-30 short finger-like tentacles lying in a near ring dorsal to mouth. Numerous rows of dark coloured introvert hooks, resembling those of *P. scolops* (Selenka and de Man) and *P. agassizii* Keferstein. The hook possesses (1) a clear streak (sometimes swollen near its middle) running down through the "centre" of the hook and (2) a clear triangular area on one side of the streak.

Specimens brown but anterior and posterior of trunk made dark- to red-brown or almost black by pigmentation of papillae. Papillae at base of introvert dark red, conical and closely packed, particularly on dorsal surface; those on anterior and posterior surface of trunk largest, most prominent, conical or hemispherical, about 0.2-0.4 mm in diameter and densely packed. Papillae may coalesce or run into one another; composed of polygonal plates set closely together. At base of papillae there is usually an almost complete ring of what appears to be darker plates, much as is shown for *Phascolosoma japonicum* (Grübe) by Sato (1939, fig 29). Papillae

on mid-region of trunk smaller and more scattered. A feature of the species is that dark-brown polygonal plates are scattered over the surface between papillae. Whether they are detached plates of the larger papillae is not certain. A number of pigmented bands, usually best developed on dorsal side, partly surround anterior surface of introvert. Pigmented patches sometimes appear on trunk.



FIG. 103. *Phascolosoma annulatum*, (specimen from South Australia).

Longitudinal muscles in 18-25 anastomosing bands, usually visible externally. Two stout ventral retractors arising from muscles 2-5, 2-6, 2-7, 3-5 or 3-6 and two more slender dorsal retractors from 5-6, 4-6 or 4-7 are attached to posterior half of trunk. One fastening muscle, connecting muscle 1 on left side to last spiral of intestine, may bifurcate giving a second root to oesophagus. Contractile vessel without villi. Spindle muscle arises anteriorly near anus and is fixed posteriorly. Nephridia, usually about half length of trunk fixed to body wall for about half to two thirds of their length and arising near anus. Gonads at base of ventral retractors. Largest sub-elliptical eggs 0.11-0.13 mm long. Rectal caecum present in some specimens from South Australia (SAM 1323), rudimentary or absent in others but present in those from New Zealand (SAM 1324 and 1325).

Sytematic position: *P. annulatum* differs from all other Australian phascolosomatids in the structure

of its papillae and in the presence of platelets on the body wall between the papillae. The platelets are polygonal and appear to be detached platelets from the papillae. It differs from *P. agassizii* Keferstein in the structure of the papillae and from *P. japonicum* Grube which lacks polygonal platelets on its surface.

In spite of the fact that the rectal caecum is better developed in New Zealand specimens I regard the specimens from southern Australia and New Zealand as the same species. According to Cutler (1977, p. 151), Wesenberg-Lund in an unpublished work disagreed with this. Although I have not examined Augener's, Fischer's nor Wheeler's specimens I have placed them in the synonymy of *P. annulatum*. Figs. 4 and 5 of Fischer (1914) are the papillae and platelets of *P. annulatum* and the Sir Joseph Banks Group of islands, where Wheeler's material was collected, lie off Port Lincoln, South Australia, a locality where *P. annulatum* is commonly collected.

Previous Australian records: Augener (1903), Fischer (1914), Wheeler (1938) and Edmonds (1956).

Distribution: (1) in Australia: along coast of South Australia from Baird Bay (Eyre Peninsula) to Kilcunda; Victoria; along northern and eastern coasts of Tasmania.

(2) elsewhere: New Zealand; Campbell and Stewart Islands.

Specimens examined and localities: South Australia—Nuyt's Archipelago (2) SAM E1529; Baird Bay (5) SAM E1231; Pearson Is. (12) SAM E1528; Grindel Is. (5) SAM E1334; Port Lincoln "in calcareous reef" SAM E1322; Cape Donnington (2) SAM E1333; West Is. (1) SAM E1329; Corny Pt. (8) SAM E1329; Pondalowie Bay (5) SAM E1396; Beachport (3) SAM E1527; Emu Bay, Kangaroo Is., (2) SAM E1537; Stokes Bay, Kangaroo Is., (4) SAM E1532; Elliston (10) SAM E1540. Victoria—Shoreham (5) SAM E1327 and (1) NMV G1218; Portland (1) coll. NMV; Cape Patterson (1) coll. NMV; Kilcunda (5) coll. NMV. Tasmania—Eaglehawk Neck (3) SAM E1331 and (1) TMH K101-1553; Port Latta (1) coll. NMV; Dunally (5) TMH K166; Fossil Is. (1) TMH K82-14482; Tarroona Beach (1) TMH K206; Bichenor (2) coll. NMV; Erith Is. (1) AMS W6562.

Phascolosoma (Phascolosoma) arcuatum (Gray, 1828)

(Figs. 104, 109-111)

Sipunculus arcuatus Gray, 1828, p. 8.

Phascolosoma arcuatum: Baird, 1868, p. 88; Rice and Stephen, 1970, pp. 50-52, pl. 1.

Phymosoma lurco Selenka and de Man, 1883, pp. 61-63, pl. 1, fig 5, pl. 8, figs 103-110.

Physcosoma lurco: Fischer, 1895, p. 12.

Phascolosoma lurco: Edmonds, 1956, pp. 290-291, text fig 10.

Location of type: Nat. Hist. Museum London; specimen from India.

Description: Trunk stout, almost uniformly cylindrical, 15-120 mm long and 6-10 mm wide; body wall light-brown to brown except at anterior and posterior of trunk where it is usually dark-brown to brown-black. Posterior extremity of trunk may be invaginated slightly.

Introvert of fixed specimens with length varying from half to same as that of trunk. Horseshoe-shaped ring of tentacles lies dorsal to mouth. More posteriorly as many as 75 complete or partially complete rows of dark coloured hooks, with a large expansion basally of clear streak which runs from apex to base. Papillae between rows of hooks small, about 0.02 mm in diameter, those at extremities of trunk larger, 0.5-0.6 mm in diameter, prominent and very dark, consisting of numerous polygonal plates. Their structure is clearly shown in pl. 1, fig. 2 of Rice and Stephen (1970).

Longitudinal muscles in 16-23 broad, anastomosing bands not always visible externally. Circular muscles tend to form fascicles, as shown in fig. 103 of Selenka and de Man (1883). Rice and Stephen (1970, p. 50) point out that small coelomic pockets extend into spaces between longitudinal and circular musculature. Four retractors fixed to body wall in posterior third of trunk, a strong ventral pair to muscles 1-2, 2-3, or 1-3 and a more slender dorsal pair more anteriorly to 1-2 or 2-3. Retractors fuse for most of their length into one, larger flat muscle. Thin walled oesophagus attached to fused part of retractor for most of length of latter. Spindle muscle fastened anteriorly near anus and posteriorly to body-wall. Rectum short and without a caecum. No fastening muscle. Wing muscle strong. Nephridia about half to three quarters as long as trunk and fixed for about three quarters of their length. Contractile vessel without villi. Gonads at base of ventral retractors. Brain, a white swelling with pigmented eyespots.

Systematic position and remarks: This species is distinguished from other Australian phascolosomatids by (1) the structure of the introvert hooks (2) the arrangement of the retractors and (3) the presence of subepidermal, coelomic extensions. It is associated with mangroves and was for a long time known as *P. lurco*. Harms and Dragendorf (1933) and Green and Dunn (1976) have studied the ionic and osmotic balance of the species.



FIG. 104. *Phascolosoma arcuatum*, (specimen from Rockhampton, Queensland).

P. arcuatum, according to Green and Dunn, lives from the highest to the lowest levels of mangrove swamps along the west coast of peninsular Malaysia and consequently is subject to extremely variable salinities. According to their researches *P. arcuatum* is physiologically an osmoconformer. Green (1975) has studied the reproductive cycle of Australian specimens.

Previous Australian records: Baird (1868), Fischer (1895), Edmonds (1956).

Distribution: (1) in Australia: in mangrove flats in Queensland at Sandgate, Townsville and Rockhampton and in Western Australia at Derby.

(2) elsewhere: Malaysia, Indo-China, Philippines and Java.

Specimens examined and localities: Queensland—mouth of Ross River "in mangroves" (8) SAM E1335; Sandgate (5) SAM E1336 and (3) AMS W3605; Calliope River (3) "amongst mangrove seedlings" SAM E1526; Townsville "in mangroves" (10) SAM 1337, Western Australia—Derby (King Sound) "in mangroves on tidal flat" (2) SAM E1388 and E1389.

***Phascolosoma (Phascolosoma) nigrescens* Keferstein**
(Fig. 112)

Phascolosoma nigrescens Keferstein, 1865, p. 424, pl. 32, fig. 14-15; Edmonds, 1956, p. 289, text fig. 9; Stephen and Edmonds, 1972, p. 315.

Phymosoma nigrescens Selenka and de Man, 1883, pp. 73-74, pl. 9, figs. 130-137.

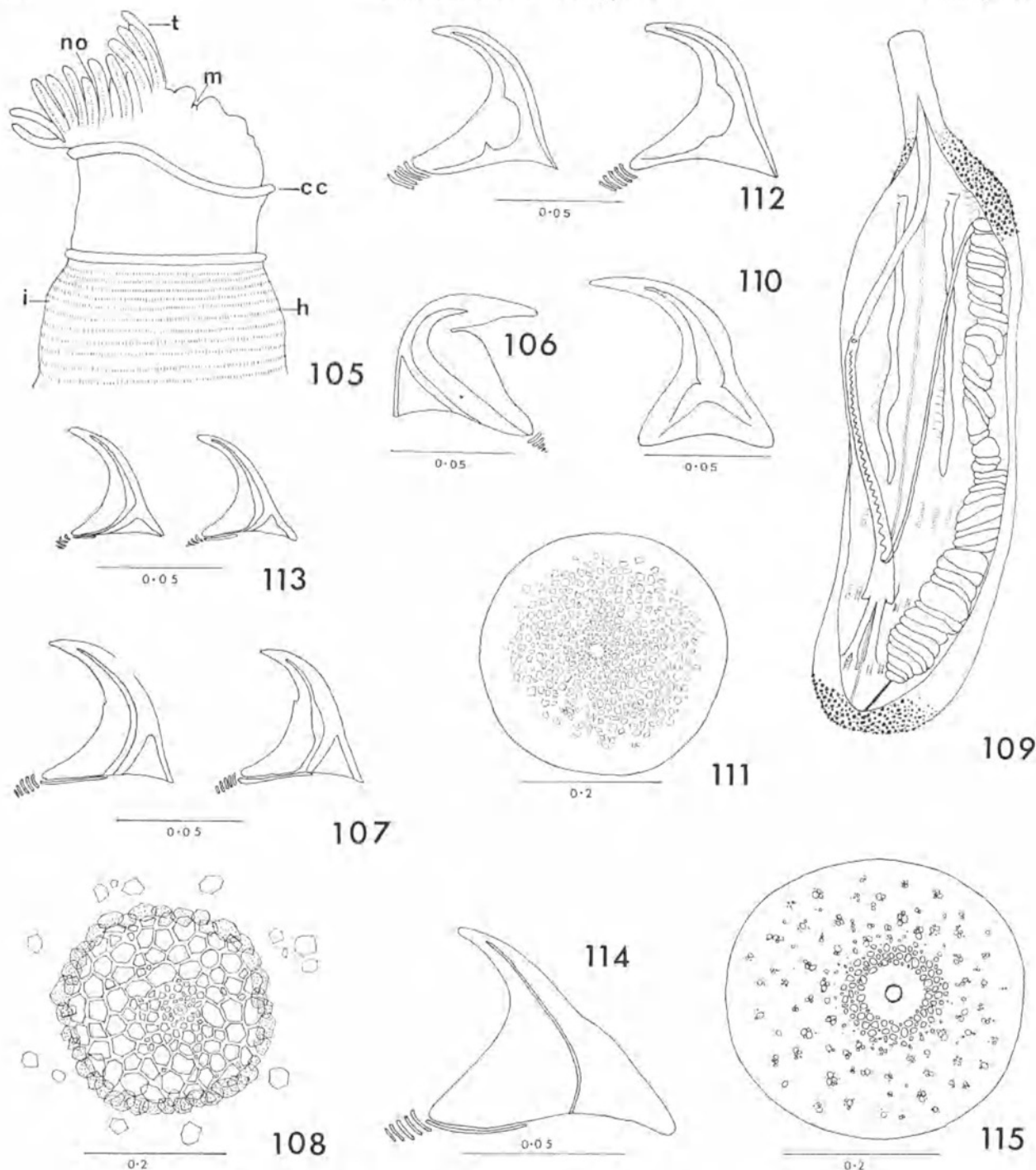
Location of type: Not known to author; specimen from Fiji.

Description: Trunk 15-45 mm long and 2.5-6 mm wide, light to dark-brown in colour. Introvert of fixed specimens may be as long as trunk but usually shorter, with group of short tentacles dorsal to mouth. Smooth collar present on introvert and more posteriorly 18-35 rings of light to dark-brown hooks (fig. 112). Although the clear area that runs from the apex of the hook towards its base is always expanded slightly in the middle, the shape of the clear area basally varies noticeably; in specimens from Broome there is a small hump but in those from Low Is. and Myora the hump is enlarged to a tongue-like protrusion. Introvert with stoutly conical papillae (0.05-0.07 mm in diameter) between rows of hooks, and usually with a number of pigmented bands on dorsal surface.

Papillae on trunk and introvert numerous, pointed and more uniform in shape and distribution than in most *Phascolosoma*. At posterior extremity of trunk papillae conical to mamillate, about 0.2 mm tall and 0.2 mm broad, with a pore at apex and consisting of dark coloured, elongate, radiating plates. A number of very dark papillae may be scattered randomly on trunk and introvert of specimens.

Longitudinal muscles in about 20 anastomosing bundles. Two stout ventral retractors arise in mid-third of trunk from muscles 1-7, 2-7, 2-8, or 3-9 and two slenderer dorsal retractors more anteriorly from 6-8, 5-8 or 7-9, the dorsal and ventral muscle on same side of nerve cord soon fusing. Strong spindle muscle attached near anus and at posterior extremity of trunk. Rectum and spindle muscle may fuse for part of length. A fastening muscle to posterior intestine may give a branch to oesophagus. Strong wing muscle and rectal caecum present. Contractile vessel simple. Nephridia fixed for half or third of their length, about half as long as trunk and arising at about level of anus.

Systematic position: This species is identified largely by the structure of its hooks as shown in figs. 130 and 135 of Selenka (1883) and in the present material. Edmonds (1956) mentioned that the contractile vessel of his specimens possessed very



FIGS. 105-115. Fig. 105, anterior region of introvert of a *Phascolosoma*, showing position of tentacles, mouth and nuchal organ (after Theel). Fig. 106, *Phascolosoma albolineatum*; introvert hook. Figs. 107-108, *Phascolosoma annulatum*; 107, introvert hooks; 108, trunk papilla. Figs. 109-111, *Phascolosoma arcuatum*; 109, dissected specimen; 110, introvert hook; 111, trunk papilla. Fig. 112, *Phascolosoma nigrescens*; introvert hooks. Fig. 113, *Phascolosoma nigritorquatum*; introvert hooks (from one of Sluiter's specimens). Figs. 114-115, *Phascolosoma noduliferum*; 114, introvert hook; 115, trunk papilla.

small villi. Although I have not been able to re-examine the same specimens I now think that I mistook some very small wrinkles or crenations of the muscular wall of the vessel to be villi.

It is difficult to find a satisfactory character which can be used to distinguish *P. nigrescens* from *P. puntarenae* Grube. The relationship between the two is discussed by Fisher (1952, p. 430-432). If they are the same, *P. puntarenae* Grube, 1859 has

priority. The species is often associated with coral formations.

Previous Australian records: Queensland—Low Is.; (Munro, 1931); Heron Is. (Edmonds, 1956). Western Australia—Cape Jaubert (Fischer, 1921); Shark Bay (Fischer, 1919a), Cape Dennison (Edmonds, 1956).

Distribution: (1) in Australia—Queensland; northern New South Wales; north west Australia.

(2) elsewhere; widely in Indo-Pacific region; West Africa.

Specimens examined and localities: Queensland—Low Is., "in coral" (2) SAM E1344; Magnetic Is., (1) SAM E1345; One Tree Is., (1) SAM E1346; Three Is., (1) SAM E1347; Cockle Bay (2) SAM E1350; Myora (1) SAM E1351; Wistari Reef (Capricorn Group) (2) SAM E1352. New South Wales—Woolgoga (1) coll. NMV; Lennox Head (3) AMS W10545 and (6) AMS W10544. Western Australia—Cable Beach (near Broome) (3) SAM E1349; Broome (Pt. Gantheaume) (3) WAM 10922; Dampier Archipelago (1) WAM 132/76 and (1) WAM 222/76.

***Phascolosoma (Satonus) nigritorquatum (Sluiter)**

(Fig. 113)

Phymosoma nigritorquatum Sluiter, 1882, pp. 151-152, pl. i, figs 3, 8, 11; Selenka and de Man, 1883, pp. 68-69.

Phycosoma nigritorquatum: Sluiter, 1902, p. 13; Fischer, 1919a, p. 280; 1921, p. 4-5, figs 1-2; 1927, p. 416.

Phascolosoma nigritorquatum: Stephen & Edmonds, 1972, p. 186.

Location of type: Zoological Museum, Amsterdam; specimen from Batavia "from coral islands".

Description: I have not examined any Australian specimens of the species. It has, however, been reported twice from Western Australia by Fischer (1919a, 1921). According to Sluiter the length of the body is 2.5-3 times its width. Posterior region pointed. Papillae very numerous, especially at anterior and posterior extremities of trunk. Longitudinal muscles in 20-22 bands and circular musculature continuous. Introvert about a quarter as long as body. Two anterior retractors weaker than two placed more posteriorly. A narrow papillae-free zone at base of introvert. A row of black granulated bodies? ("Körner") and swellings? ("Wülste") lie in a half ring around margin of mouth. The pigmented bands extend in successive rows around anterior part of introvert. Four rows of small, slender introvert hooks. Tentacles arising from two folds. Intestine with only a few, nine, spirals. No spindle muscle. Two anteriorly swollen nephridia. Colour of animals dark yellow to brown. Length without introvert 13 mm.

In a "discussion" that follows the description, Sluiter says that the black bands? or ridges? ("Leiste") on the introvert are characteristic of the species and that sometimes they anastomose. The first of the black bands is never completely invaginated and remains visible even if the introvert is retracted.

The account of Selenka & de Man is only a repetition of Sluiter's. Fischer (1921, p. 5) records that a specimen from Western Australia is 12 mm long and its introvert 8-9 mm. Skin yellow-white. Introvert hooks sickle-shaped and in 5-6 rows. Longitudinal muscles in 20-22 bundles. Two broad ventral retractors arise in posterior third from muscles 2-7. Intestine of 10-12 double spirals. Fischer says that a spindle muscle is present and that it is fixed posteriorly.

Systematic position: Recently I have re-examined two of Sluiter's specimens (V 51, 80, Baai v. Batavia) from the Zoological Museum, Amsterdam. The tube containing them bears the label "type"; one was partly dissected. Body small, trunk 5-8 mm long and 2.5-4 mm maximum width; pointed posteriorly. Introvert of each specimen almost completely retracted. Longitudinal muscles in 19-23 bundles visible externally; some anastomosis. Papillae most prominent on anterior and posterior surfaces of trunk; often sharply pointed and spine-like. Surface of papillae carries small rounded-polygonal platelets (much like those of *P. scolops*) and underlying there seem to be rather long radially arranged plates. In the specimen that I dissected a number of red-brown bands were found on the introvert, especially the dorsal surface. I was not able to find Sluiter's "intens schwarzer Körner und Wülste". A few rows of clear, unpigmented introvert hooks were present (fig. 113); they do not correspond very well with those drawn by Sluiter and Fischer and resemble closely those of *P. scolops* and *P. rotnestii*. Introvert retractors four, the dorsal and ventral pair on each side almost spanning the same number of muscles. The gut of the specimen which I dissected was thin, frail and not in good condition and that of the other (I extended the cut already present a little further anteriorly and posteriorly) was surrounded by coagulated material which was difficult to remove. In neither was I able to find a spindle muscle anteriorly nor the point of attachment of such a muscle near the anus. No sign of a posteriorly placed spindle muscle was present in one specimen but in the other a stout muscle emerges from the last intestinal spiral and is attached to the body wall. Consequently I have not been able to check conclusively whether a spindle muscle is present or absent in *P. nigritorquatum*. The answer is important because in the subgenus *Satonus* a spindle muscle is either absent or not attached posteriorly. *P. nigritorquatum* is the type of the subgenus. If *P. nigritorquatum* possesses a spindle muscle *Satonus* is invalid and another subgenus must be erected and a new type found. No information about the presence of a caecum or fastening muscle can be given. The two nephridia are free. Some sub-elliptical-shaped eggs (0.10-0.13 mm) long and (0.07-0.075 mm) wide.

with a nucleus about 0.025 mm in diameter were present.

Previous Australian records: Fischer, 1919a; 1921.

Distribution: (1) in Australia—Western Australia, Cape Jaubert and Shark Bay.

(2) elsewhere: Bay of Bantam, Indonesia.

***Phascolosoma (Phascolosoma) noduliferum* Stimpson**

(Figs 114-115)

Phascolosoma noduliferum Stimpson, 1855, p. 390;

Keferstein, 1865, p. 423, p. 32, figs 16-17;

Edmonds, 1956, pp. 286-288, text figs 7-8;

Cutler, 1977, p. 152.

Physcosoma grayi Baird, 1868, pp. 88; Rice &

Stephen, 1970, p. 52.

Location of type: Not known to author; specimen from Port Jackson, New South Wales.

Description: Trunk 12.65 mm long and 3.7 mm wide, brown or light brown in colour with only a slight darkening at its extremities. Introvert of fixed specimens about as long as trunk, lacking pigmented bands but possessing (1) about 20-25 short, digitiform tentacles and (2) a varying number of dark brown hooks (fig. 114). Shape of hook distinctive, with broad base and a thin clear streak, running from apex to base of hook.

Papillae usually hemispherical and more uniformly distributed on trunk than in *P. annulatum*; largest 0.3-0.4 mm in diameter, consisting of numerous small plates and scattered granules. Longitudinal musculature in 20-26 bands, not always visible externally because body wall is thick. Four retractors, a stout ventral pair attached to muscles 2-6, 2-7 or 1-6 in posterior half of trunk and a weaker dorsal pair more anteriorly to muscles 4-6, 5-7 or 6-7. Oesophagus fixed to retractors by two short mesenteries. Spindle muscle fixed anteriorly near anus and posteriorly to body wall. Wing muscle well-developed. A fastening muscle arising from muscle 1 or 2 near base of left ventral retractor runs to last or penultimate intestinal spiral; sometimes supplying a branch to oesophagus.

Nephridia half to three quarters as long as trunk and fixed for about three quarters of their length. Contractile vessel simple. No rectal caecum. Brain appears as slight swelling in some specimens; two eyespots. Elliptical eggs about 0.12 mm in diameter.

Systematic position: Edmonds (1956, p. 288) discussed at some length the status of this sipunculan commonly collected along the eastern and southern coasts of Australia and which has often been called *P. japonicum* (Selenka and de Man, 1883, p. 77; Dakin, 1952, p. 157 and Whitledge, 1899, p. 11). This probably stems from the identification of two specimens from New South Wales as *P. japonicum*

by Selenka and de Man, 1883. The two specimens, registered as 85.12.3.30 and 85.11.3.30, are in the British Museum (Natural History, London). They possess the hooks and papillae of *P. noduliferum* and not *P. japonicum*.

There is considerable overlap in the distribution of *P. noduliferum* and *P. annulatum* in Victoria and Tasmania. Specimens of both have been recorded from Eaglehawk Neck, Dunally and Bicheno (in Tasmania) and from Kilcunda and the Nobbies (in Victoria). The differences in their habitats at these places is not known. *P. noduliferum* occurs in New South Wales, Victoria, Tasmania and South Australia. Two specimens are also known from the South coast of Western Australia.

P. noduliferum differs from allied Australian species in the structure of its hooks and papillae. Pigmented bands on the introvert have not been described for the species.

Previous Australian records: Stimpson (1885); Edmonds (1956); Cutler (1977) (7 specimens dredged at 85-1340 m off South Australian coast).

Distribution: (1) in Australia—New South Wales, Victoria, Tasmania, South Australia and south coast of Western Australia.

(2) elsewhere—Malacca Sts. (at 1140 m), Mindanao (at 22 m), Pt. Moresby (New Guinea) (at 8 m), Campbell Is. (off south coast of New Zealand). All of these records are from Cutler (1977, p. 152).

Specimens examined and localities: New South Wales—Newport (6) SAM E1353; Long Reef (3) SAM E1354 and (1) AMS W10548; near Sydney (6) SAM E1356; Harbord (3) AMS coll.; Botany Bay (2) AMS W548. Victoria—the Nobbies, Western Port (8) SAM E1355 and (1) NMV G1129; Phillip Is. (2) SAM E1357; Godfrey reef near Lorne (1) NMV coll.; Cape Bridgewater (1) NMV coll.; Portsea Pier (1) NMV coll.; Malacoota (2) AMS W10547. Tasmania—Bicheno (2) NMV coll.; Jacobs Boat Harbor (1) TMH coll.; Dunally (2) TMH K/166; Eaglehawk Neck (8) TMH coll.; and (2) TMH K102/15532 and (5) SAM E1397; Erith Is. (1) AMS W10569. South Australia—Cape Northumberland (1) SAM E1390. Western Australia—10 miles east of Hopetown (1) SAM E1400; off south coast (35° 15' S, 126° 22' E) (1) WAM 145/76.

***Phascolosoma (Phascolosoma) pacificum* Keferstein**

(Figs. 120-121)

Phascolosoma pacificum Keferstein, 1866, pp. 8-9;

1867, pp. 49-50, pl. 6, Figs 1-2, Edmonds, 1956,

pp. 291-292, text fig. 11, Stephen and Edmonds,

1972, pp. 317-318.

Phymosoma pacificum: Selenka and de Man, 1883, pp. 63-65, pl. 2, fig. 6, pl. 7, figs. 111-112.

Location of type: Not known to author; specimen from Gilbert and Tarawa Is. (Kingsmill Group, Pacific Ocean).

Description: Trunk of largest specimen 102 mm long and maximum width (in posterior third of trunk) about 8 mm. Light brown to brown in colour with a darker mottling in some specimens. Mottling on anterior surface of trunk may be less irregular and more band-like, especially on dorsal surface. Body wall thick and banding of longitudinal muscles not usually visible externally.

Introvert in fixed specimens about as long as trunk, with a group of digitiform tentacles dorsal to mouth and with numerous complete and incomplete rows of large, dark-brown hooks, 0.07-0.10 mm wide basally and 0.07-0.09 mm tall.

Papillae on introvert and trunk numerous, closely packed, sharply pointed and conical so that animal feels rough and bristle-like (a fact mentioned by Selenka and de Man). On mid-region of introvert papillae 0.20-0.25 mm tall, 0.15-0.2 mm wide; on posterior of trunk becoming 0.3 mm tall, 0.3 mm wide. Papillae composed of very small granules with a pore at apex.

Longitudinal muscles in anastomosing bundles, about 20 anteriorly and 35-40 posteriorly. Four retractors, a stout ventral pair arising in mid-third of trunk and attached to muscles 2-7 or 2-8, and a dorsal pair more anteriorly and attached to same six or seven muscles. Retractors fuse anteriorly. Intestinal contents of coarse sand and coral fragments. One fastener to last or second to last spiral or intestine. Spindle muscle stout and attached posteriorly. No caecum in two dissected specimens. Contractile vessel simple. Nephridia pigmented brown or brown-black, very long (extending almost to extremity of trunk) and fixed to trunk wall for their whole length.

Systematic position: This species is identified by the size and shape of its introvert hooks and the presence of nephridia which extend almost to the posterior extremity of the trunk and which are fixed to the body wall for their whole length.

Previous Australian records: Queensland—Low Is. (Monro, 1931); Heron Is. (Edmonds, 1956).

Distribution: (1) in Australia—Great Barrier Reef, Queensland; Northern Territory.

(2) elsewhere: Indo-Pacific, Madagascar, Zanzibar, Mauritius, Red Sea, Amboina, Indo-China, Japan, Philippines, Guam, New Britain, West Carolines.

Specimens examined and localities: Queensland—Heron Is. (1) SAM E1358; Low Is. (1) SAM E1359; Turtle Is. (2) SAM E1360; Dunwich (1) SAM E1364; Michaelmas Reef, Cairns (2) AMS coll. Northern Territory—Fannie Bay Rocks, Darwin (1) AMS coll.

Phascolosoma (Phascolosoma) perlucens Baird

(Figs. 117-119)

Phascolosoma perlucens Baird, 1868, p. 90, pl. 10, fig. 2; Rice and Stephen, 1970, pp. 63-64.

Phymosoma dentigerum Selenka and de Man, 1883, pp. 67-68, pl. 1, fig. 7, pl. 9, figs. 118-123.

Phascolosoma dentigerum: Fisher, 1952, pp. 432-434, pl. 36, figs. 4-7.

Location of type: Nat. Hist. Museum, London, reg. no. 1847.12.30.11; specimen from Jamaica (in coral rock).

Description: Specimens tend to be slender and straw coloured in alcohol. Trunk of largest 45 mm long and 4.5 mm wide. Body wall thin and almost transparent in some regions. Introvert about half to three quarters as long as trunk (in fixed specimens) with (1) a number of very dark-brown bands on dorsal surface (2) prominent, dark-red-brown, spine-like papillae or tubercles on posterior dorsal surface and (3) rows of light- to dark-brown hooks anteriorly. Spine- or claw-like papillae mostly point backwards and vary in size, the largest being about 0.6-0.7 mm tall and about 0.5 mm wide basally (fig. 00). A fine tube runs from tip of spine to its base, the diameter of tube increasing basally. Anterior half or third of hook strongly bent and lying almost parallel to base of hook; central clear area expanded near its middle and a clear triangular area present basally. Papillae on posterior trunk darker than on trunk and tend to be claw-like; largest about 0.3 mm tall and 0.25 mm wide at base. Posteriorly placed claw-like papillae of two Australian specimens not as prominent as those shown in Fisher, 1952, pl. 39, fig. 5.

Longitudinal muscles in about 22 anastomosing bands. Retractor muscles four, a ventral pair attached to muscles 2-7 or 2-6 in mid-third of trunk and a dorsal pair more anteriorly to 5-8. Contractile vessel slender and without villi. One fastening muscle to last spiral of intestine. Caecum not observed (Fisher, 1952 claims that one is present). Nephridia fixed to trunk for about one third of their length and about one third as long as trunk.

Systematic position and remarks: The shape of the introvert hooks and the presence of large claw-like structures on the dorsal surface of the introvert make this one of the easier species of *Phascolosoma*

to identify. Fisher (1952) redescribed and figured it. The species is probably better known in the literature as *P. dentigerum*. The Australian specimens were collected in coral rock. Rice (1976) describes the feeding behaviour of the species.

Previous Australian record: Low Is., Queensland (Monro, 1931).

Distribution: (1) in Australia—Great Barrier Reef, Queensland.

(2) elsewhere—Baja California, Gulf of Panama, Rotuma, Funfuti, Marshall Is., Eniwetok Atol, Philippines, Laccadive Is., Batavia, Madagascar, and the West Indies.

Specimens examined and localities: Queensland—on Great Barrier Reef; Three Is., (1) SAM E1365; Tree Is.; (2) SAM E1366; One Tree Is., (1) AMS W5525; Lizard Is., "in coral" (3) SAME1395.

***Phascolosoma (Phascolosoma) rotnesti* Edmonds**

(Figs. 116, 124-126)

Phascolosoma rotnesti Edmonds, 1956, pp. 282-284, text figs. 1-4.

Physcosoma agassizii Fischer, 1919a, p. 277; Fischer, 1922, p. 7, pl. 1, figs. 3, 5 and 6.

Location of type: Australian Museum, Sydney; specimen from Rottnest Is., Western Australia, "from burrows in calcareous rock".

Description: Trunk 10-52 mm long and maximum width (in posterior third) 3-5 mm. Expanded introvert of fixed specimens about as long as trunk. Freshly collected animals pale to pink-brown in colour except at extremities of trunk which are dark-to red-brown. Red-brown bands, varying in number and width, usually present on dorsal surface of introvert. Trunk of few specimens is mottled by a number of red-brown spots. Partial ring of tentacles lies dorsal to mouth. From 15-45 rows of light to dark brown hooks, resembling those of *Phascolosoma scolops* (Selenka and de Man 1883, fig. 143) and *Phascolosoma agassizii* Keferstein, 1867, pl. 6, fig. 4 but not fig. 8, present on introvert anteriorly. A clear triangular area is always present on one side of the clear streak, which runs from the apex of hook to its base.

Papillae between rows of hooks very small and forming complete transverse rings; towards base of introvert they are larger, about 0.1 mm in diameter, pointed or conical and darker in colour. On anterior surface of trunk papillae larger, especially on dorsal side, 0.2-0.35 mm in diameter, more hemispherical, more densely packed and dark brown in colour. In mid-trunk region papillae smaller, rounded, more scattered and less prominent. On posterior surface



FIG. 116. *Phascolosoma rotnesti*. (specimen from Rottnest Island, Western Australia).

they are large, 0.2-0.45 mm in diameter, closely packed and dark brown. All papillae consist of small plates of almost uniform size.

Longitudinal muscles in 20-24 anastomosing bands, not always visible externally. Four retractor muscles, a strong ventral pair arising in posterior half of trunk from muscles 2-5, 2-6, 2-7 or 3-7 and a weaker dorsal pair more anteriorly from 4-6, 5-6, 5-7 or 6. Anterior oesophagus attached to dorsal retractors by thin mesenteries. Spindle muscle fastened near anus and at posterior extremity of trunk. Contractile vessel simple. One fastener arising from muscle 1 on left side joins last or penultimate spiral of intestine, sometimes giving off a branch to posterior oesophagus. Rectal caecum present. Nephridia, attached to body wall for about half their length, about two thirds as long as trunk and arising at about same level as anus. Brain sometimes observed as slight swelling with two eyespots. Gonads at base of ventral retractors.

Systematic position: The identity of the specimens was discussed by Edmonds (1956, p. 284). They resemble most closely *Phascolosoma scolops* (Selenka and de Man) and to a less extent *Phascolosoma agassizii* Keferstein, two very variable species. Edmonds (1956) considered that they differed from *P. scolops* (1) in the structure of the papillae (they have more uniformly distributed,

more closely set and rounded platelets) and (2) in the possession of a rectal caecum, a structure neither mentioned or figured by Selenka in the type description nor by Satō (1930) nor Wesenberg-Lund (1957) in their descriptions of specimens from Japan and Red Sea. There are two specimens of *P. scolops* in the Nat. Hist. Museum, London, both named and presented by Selenka. No caecum is present in the dissected specimen of the two. Just how important is the presence or absence of a rectal caecum in the systematics of *Phascolosoma* I am not sure. In the circumstances I prefer to specify (with some reservations) the specimens from Western Australia as *P. rotnestii* and not *P. scolops*.

From figs. 3 and 5 of Fischer, 1922 it seems likely his *P. agassizii* from Shark Bay and Rottnest Is. are *P. rotnestii*. I have not, however, been able to find his specimens.

The species is commonly found in limestone rocks, coral and lithothamnion and coralline mats.

Previous Australian record: Western Australia (Edmonds, 1956), ? Fischer, 1919a and 1922.

Distribution: (1) in Australia—Western Australia; as far north as Point Cloates and as far south as Albany. Whether these localities are at the extremities of its distribution is not known.

(2) elsewhere—no records.

Specimens examined and localities: Western Australia—Fremantle (3) "in calcareous rocks near railway bridge" SAM E1367; Rottnest Is. (Wilson Bay) (4) WAM 174/76; Rottnest Is. (Green Is.) (20) WAM 169/76 and (8) SAM E1368; Cottesloe (4) SAM E1369; Pt. Peron (2) WAM 180/76; Garden Is. (1) WAM 234/76; Abrolhos Group at Beacon Is. (2) WAM 237/76 and North Is., "in coral" (2) WAM 241/76; Yallingup Beach (2) AMS W9246; Cheyne Beach, Albany (2) WAM 239/76; Eagle Bay, Cape Naturaliste (2) WAM 174/76; Warroora (1) AMS 5470; Point Cloates (3) SAM E1370.

Phascolosoma scolops (Selenka & de Man)

(Figs 122-3)

Phymosoma scolops Selenka & de Man, 1883, pp. 75-76, figs 17, 138-144; Cutler, 1977, p. 152.

Phascolosoma dunwichi Edmonds, 1956, pp. 292-3, text figs 12-13; Stephen & Edmonds, 1972, pp. 300-301.

Location of type: Not known to author; specimen from Philippines.

Description: Trunk 15-34 mm long and maximum width (in posterior third) 3-6 mm light brown except at anterior and posterior extremities which are dark-

brown. Introvert of fixed specimens about as long as trunk with a variable number of dark-brown bands on dorsal surface. Tentacles 15-20 and digitiform, lying in a near ring dorsal to mouth. Surface of introvert just posterior to mouth smooth and collar-like.

Introvert hooks in 15-45 complete and incomplete rows, closely resembling those of *Phascolosoma scolops* as shown in fig 139 of Selenka & de Man (1883). Size of hook may vary in different specimens, smallest being 0.045 mm tall and largest 0.064 mm. Clear streak (running from apex to base of hook) (1) does not always form a uniform arc but may be bent in its middle (much like an Australian boomerang) and (2) is sometimes expanded at or just below bend. Most hooks with a small "secondary tooth", something not shown in Selenka's fig 139. A clear triangular area present on one side of clear streak at base of hook but lacking the clear crescentic area as found in *P. stephensoni*.

Papillae between hooks small, flat, circular to elliptical with diameter 0.02-0.03 mm. Papillae at base of introvert darker, conical (sometimes sharply) to hemispherical, consisting of an apical pore surrounded by almost contiguous, polygonal plates of about equal size. Papillae on trunk largest and most closely packed at anterior and posterior extremities, particularly on dorsal side; 0.2-0.35 mm tall and 0.2-0.3 mm wide. Papillae in mid-trunk region smaller, more scattered and less pointed. In some specimens number of papillae on middle and posterior surfaces may be reduced.

Longitudinal muscles in 20-25 anastomosing bands often clearly visible through body wall. Four retractors, a stout ventral pair attached to muscles 2-7, 1-6 or 2-6 in posterior half of trunk and a more slender dorsal pair more anteriorly to muscles 6-7, 5-7 or 6-8. Retractors on each side fuse anteriorly. One fastener runs from muscle 1 near base of left dorsal retractor to last spiral of intestine, sometimes giving a root to posterior oesophagus. Wing muscle well-developed. Spindle muscle fastened anteriorly near anus and posteriorly to body wall. Rectal caecum not present. Contractile vessel simple. Nephridia brown, about quarter to half as long as trunk, fixed for about half their length and opening at about same level as anus. Two eyespots present.

Systematic position: Edmonds (1956, p. 292) identified some specimens from Dunwich as *P. dunwichi* a new species allied to *P. scolops*. The main differences were that *P. dunwichi* possessed a caecum and that there were some differences in the size and distribution of the platelets of the papillae. More recently I have re-examined the specimens and consider that a caecum is not present. I must have mistaken a small outpocketing of the gut wall

containing some hard food particles for a caecum. In addition the size and distribution of the platelets of some of the newer specimens in my collection approach more closely those of the two specimens of *P. scolops* (named by Selenka) now in the Natural History Museum, London. The differences then between *P. scolops* and *P. dunwichi* then become insignificant and the latter becomes a junior synonym of the former.

What the distribution of the species is in Australia is not known. Very few phascolosomatids from northern and north-western Australia are available for study. However, all the specimens of *P. rotnestii* from south-west Australia that I have examined do possess a well-developed caecum.

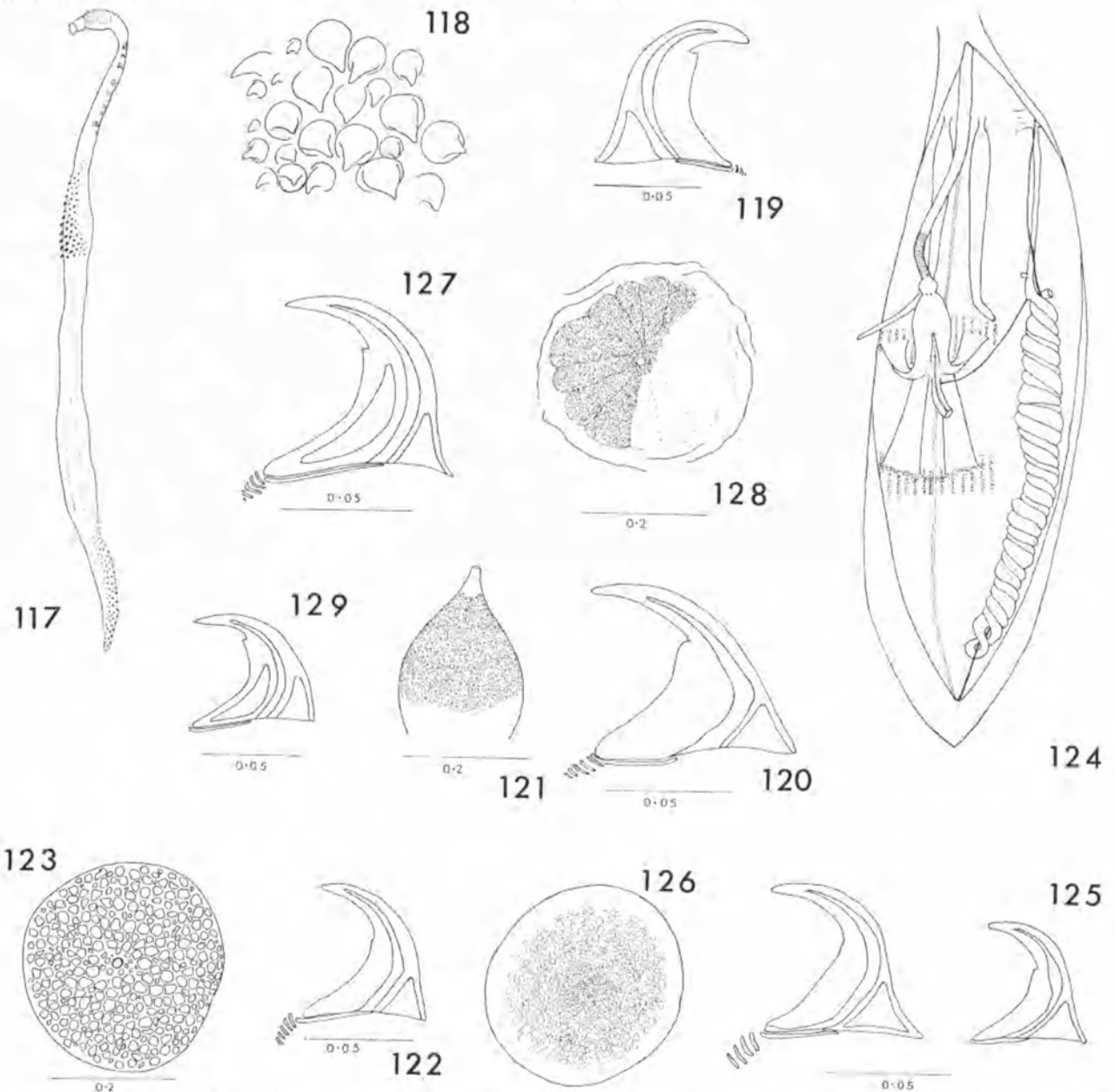
Superficially *P. scolops* and *P. stephensoni* are almost indistinguishable. The crescentic-shaped clear area present on the hook of *P. stephensoni*, however, is not present in *P. scolops*.

Previous Australian records: Queensland—Edmonds (1956); Monro (1931). Cutler (1977) reports one specimen off South Australia.

Distribution: (1) in Australia—Queensland.

(2) elsewhere—widely reported from the Indo-Pacific.

Specimens examined and localities: Queensland—Dunwich (on Stradbroke Is.) (1) in clumps of mussels SAM E1339; (3) SAM E1340; (6) SAM E1341.



FIGS. 117-129. Figs. 117-119, *Phascolosoma perlucens*; 117, complete specimen; 118, spine-like papillae from base of introvert (Figs. 117 & 118 after Fisher); 119, introvert hook. Figs. 120-121, *Phascolosoma pacificum*; 120, introvert hook; 121, papilla from introvert. Figs. 122-123, *Phascolosoma scolops*; 122, introvert hook; 123, trunk papilla. Figs. 124-126, *Phascolosoma rotnestii*; 124, dissected specimen; 125, introvert hook; 126, trunk papilla (same scale as Fig. 123). Figs. 127-129, *Phascolosoma stephensoni*; 127, introvert hook; 128, trunk papilla; 129, hook from one of Stephen's specimens.

***Phascolosoma* (*Pascolosoma*) *stephensoni* (Stephen)**
(Figs 127-129)

Physcosoma stephensoni Stephen, 1942, p. 250, pl. 11, figs 3-5.

Phascolosoma stephensoni: Wesenberg-Lund, 1963; pp. 121-126, text figs 7-9.

Phascolosoma heronis Edmonds, 1956, pp. 293-295, fig. 14.

Physcosoma scolops: Monro, 1931, p. 31.

? *Physcosoma agassizii*: Fischer, 1922, p. 7, pl. 1, fig. 6.

Location of type: Royal Scottish Museum, Edinburgh; specimen from Natal, South Africa.

Description: This account is based on the specimens below and a collection from Hawaii (SAM E1176). Trunk slender, 1.5-3.5 mm long and pale-straw to flesh coloured. Introvert of fixed animals about as long as trunk, with 5-9 brown to red-black bands of variable width on its dorsal surface. Closely packed pigmented papillae make base of introvert darker than surface of trunk. Rust coloured patches present in some places on trunk. Trunk of some Hawaiian specimens uniformly pale although some large papillae present posteriorly.

Introvert with almost complete ring of 20-24 digitiform tentacles lying dorsal to mouth and with a smooth, collar-like region just posterior to mouth. Introvert hooks in many complete and incomplete rows may vary in size even when taken from same animal, those more posteriorly placed being smaller. Hook always possesses a clear streak (running from apex to base), a clear crescentic area on one side of streak and a clear triangular area on other, a small secondary "tooth" and 4-6 bars basi-laterally. Rings of very small, subconical papillae, 0.02-0.04 mm tall and 0.025-0.05 mm wide basally, lie between rows of hooks.

Trunk papillae at posterior extremity of trunk usually conical, 0.3-0.5 mm tall and 0.25-0.4 mm wide basally, but sometimes a more rounded form is present as well. Conical form covered with small, brown polygonal plates but rounded form lacking small plates and possessing a number of curved petal-like plates radiating from an apical pore. It is possible that the rounded type is the result of the loss of the outer polygonal plates from the conical type. Papillae on dorsal surface largest. Mid-trunk papillae smaller, hemispherical, less pigmented and more scattered.

Longitudinal muscles in 20-25 anastomosing bands. Four retractors, a stouter ventral pair attached to muscles 1-5, 2-6, 2-7 or 2-8 near middle

of trunk and a more slender dorsal pair more anteriorly to 5-8, 6-7 or 6-8. One fastening muscle, attached to muscle 1 near base of left dorsal retractor, runs to last spiral of intestine, sometimes giving off a small root to posterior oesophagus. Rectal caecum present (dissected specimens SAM E1373 and E1531). Stephen in the type description did not mention the presence or absence of the structure. Wesenberg-Lund (1963, p. 124) states with emphasis that no rectal caecum is present. Dr. G. Smaldon (Royal Scottish Museum), however, informs me (personal communication) that a caecum is present in Stephen's dissected holotype. Contractile vessel without villi. Nephridia, about a third as long as trunk and fixed for about half their length, arise at about same level as anus.

Systematic position: *P. heronis* was described by Edmonds (1956) from some specimens collected at Heron Is. in the Capricorn Group, Queensland. Wesenberg-Lund (1963, p. 126) pointed out that the hooks of *P. heronis* closely resembled those of *P. stephensoni* (Stephen, 1942) from South Africa. Through the kindness of the Trustees of the Royal Scottish Museum I have been able to examine three of Stephen's specimens from Inhaca, Mozambique (1960.48.14), one a dissected specimen. I now consider that the two species are conspecific, Stephen's having priority. The hooks of the South African and Australian specimens are the same, although slightly different in size, and the papillae of Stephen's specimens are covered with fine plates, something not mentioned by him but reported for her South African specimens by Wesenberg-Lund (1963). I am grateful to the late Dr. Wesenberg-Lund for her observations. *Phascolosoma heronis* must be sunk.

It seems most likely that Fischer's (1922) record of *P. agassizii* from "Port Jackson near Sydney" is that of *P. stephensoni*; the drawing of the hook (pl. 1, fig 6) matches that of the latter species. Fischer's fig 6, however, in my opinion, differs from the books of *P. agassizii* as shown in plates 37 and 38 of Fisher, 1952. What I am now calling *P. stephensoni* is widely distributed in the Pacific Ocean. I have specimens from Hawaii, New Hebrides, Solomon Is., and Fiji. It is puzzling to know what name has been given to such specimens previously. I do not think that they are *P. scolops* because a re-examination of two specimens named by Selenka himself and now lodged in the British Museum (Nat. Hist) shows that the hooks lack the clear, crescentic area which is so prominent in *P. stephensoni*. The introvert hook of *P. fasciatum* Baird, 1868 as shown in fig 17 of Rice & Stephen (1970) also possesses a clear crescentic area. The current name of *P. fasciatum* is *P. granulosum* (Leuckart). I consider, however, that the hook of

these Australian specimens does not match that of *P. granulatum* as shown in Selenka & de Man (1883, fig 147).

Stephen considered that the distribution of *P. stephensoni* was localised along the coast of Natal (Wesenberg-Lund, 1963 p. 126). The occurrence of the species in Australia, Norfolk Is., Hawaii, etc. shows that its range is Indo-Pacific. What is difficult to account for is that it has not yet appeared anywhere else in the Indian Ocean nor on the western coast of Australia. In Australia, Hawaii and the Solomon Is. it is usually associated with coral formations.

The species differs from closely related species in the markings on its hooks.

Previous Australian record: Queensland—Heron Is., Low Is. (Edmonds, 1956).

Distribution: (1) in Australia—Queensland; New South Wales; Norfolk Is., Lord Howe Is.

(2) elsewhere—South Africa; Hawaii (SAM E1376-7); Solomon Is.

Specimens examined and localities: Queensland—Caloundra (5) SAM E1372 and (1) AMS W19550; Low Is. (3) SAM E1374; Albany Passage (North Queensland) (2) AMS G11224; Heron Is. (3) AMS W3597 (includes type of *P. heronis*) and (2) WAM 150/76; Norfolk Is. (2) SAM E1378. New South Wales—off Coff's Harbor (10) SAM E1373; Minnie Waters (2) AMS W9247; Lennox Head (6) AMS W10552; Arrawarra (2) AMS W10555; Lord Howe Is. (2) SAM E1375; Lord Howe Is. (Salmon Beach) (6) SAM E1531.

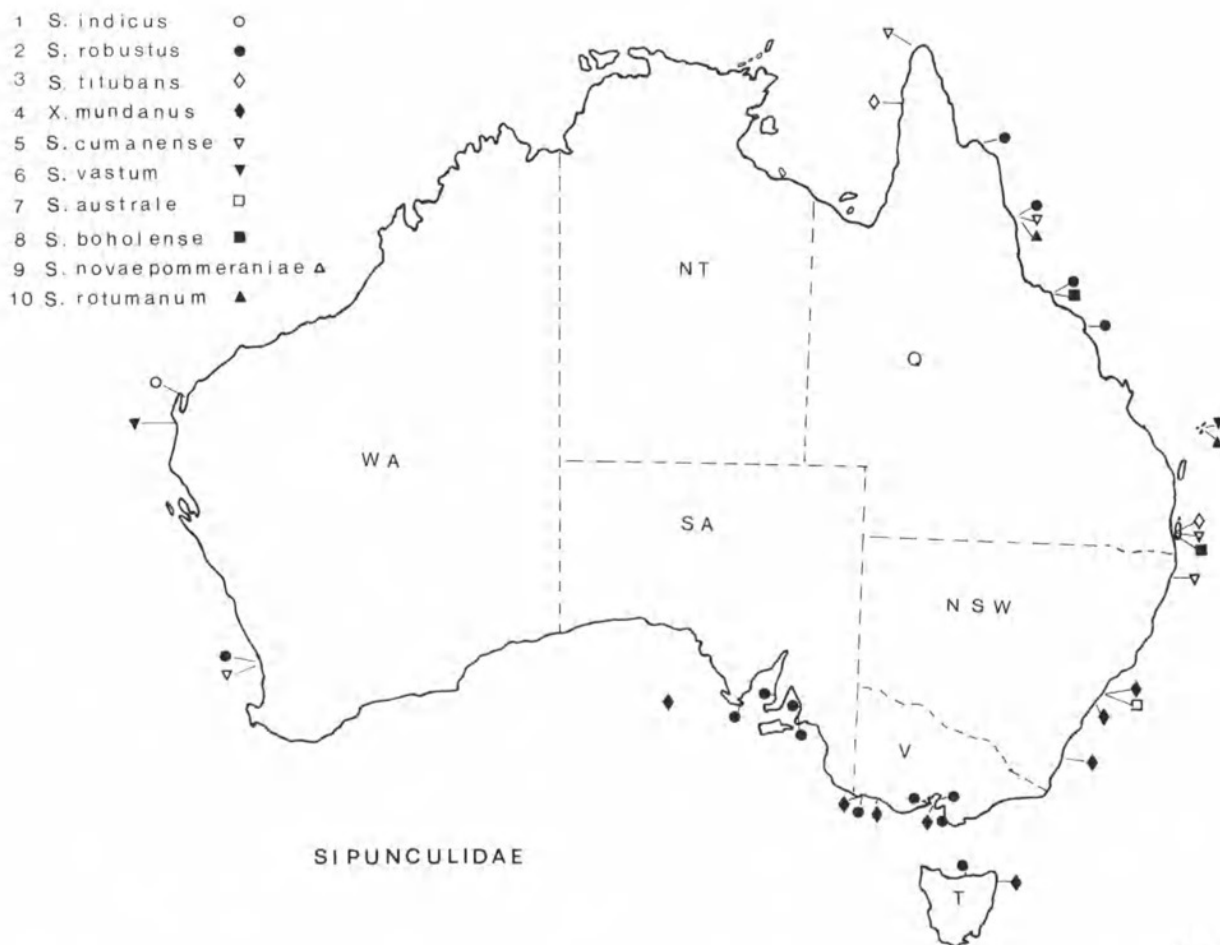


FIG. 130. Distribution of Sipunculidae in Australia.

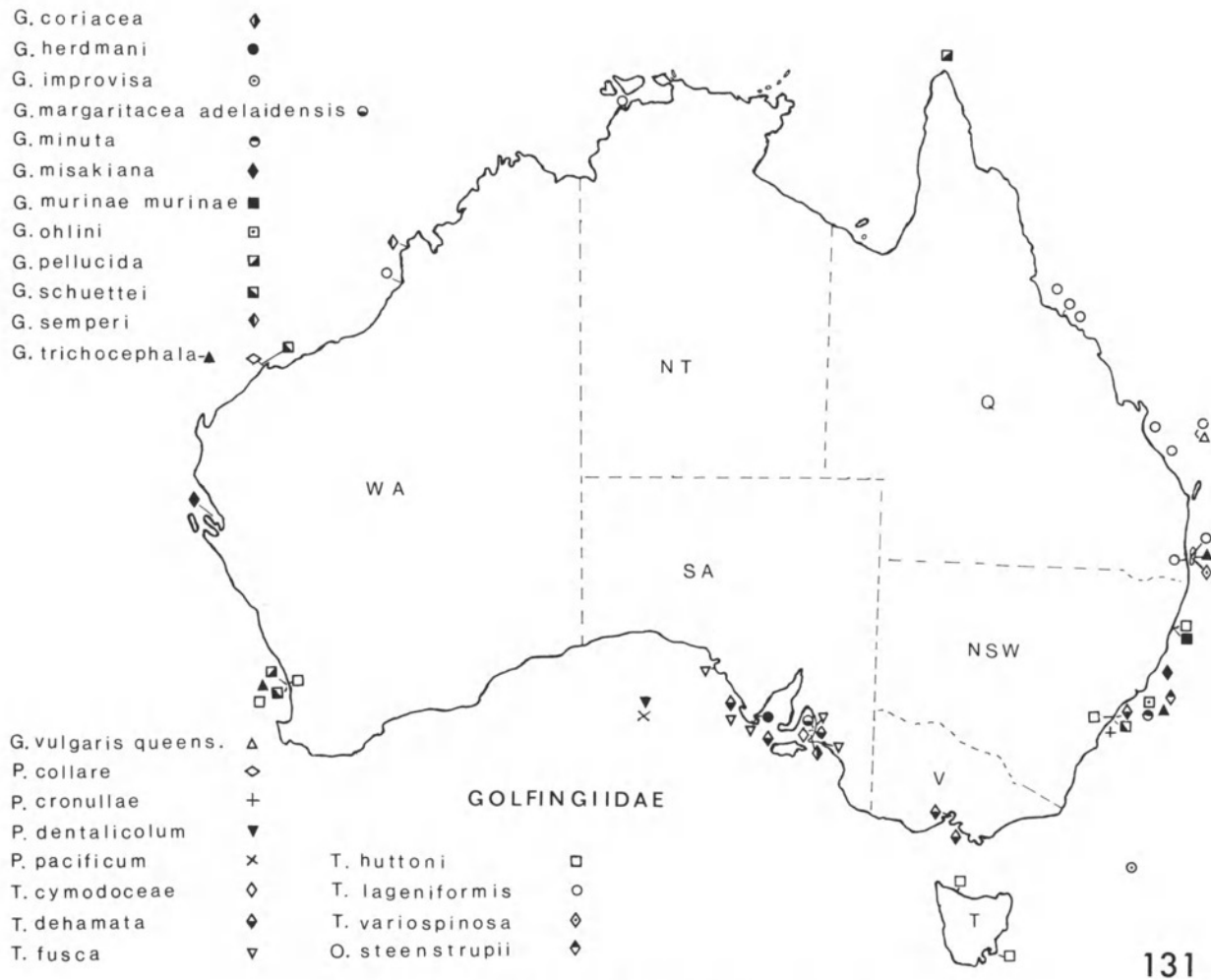


FIG. 131. Distribution of Golfingiidae in Australia.

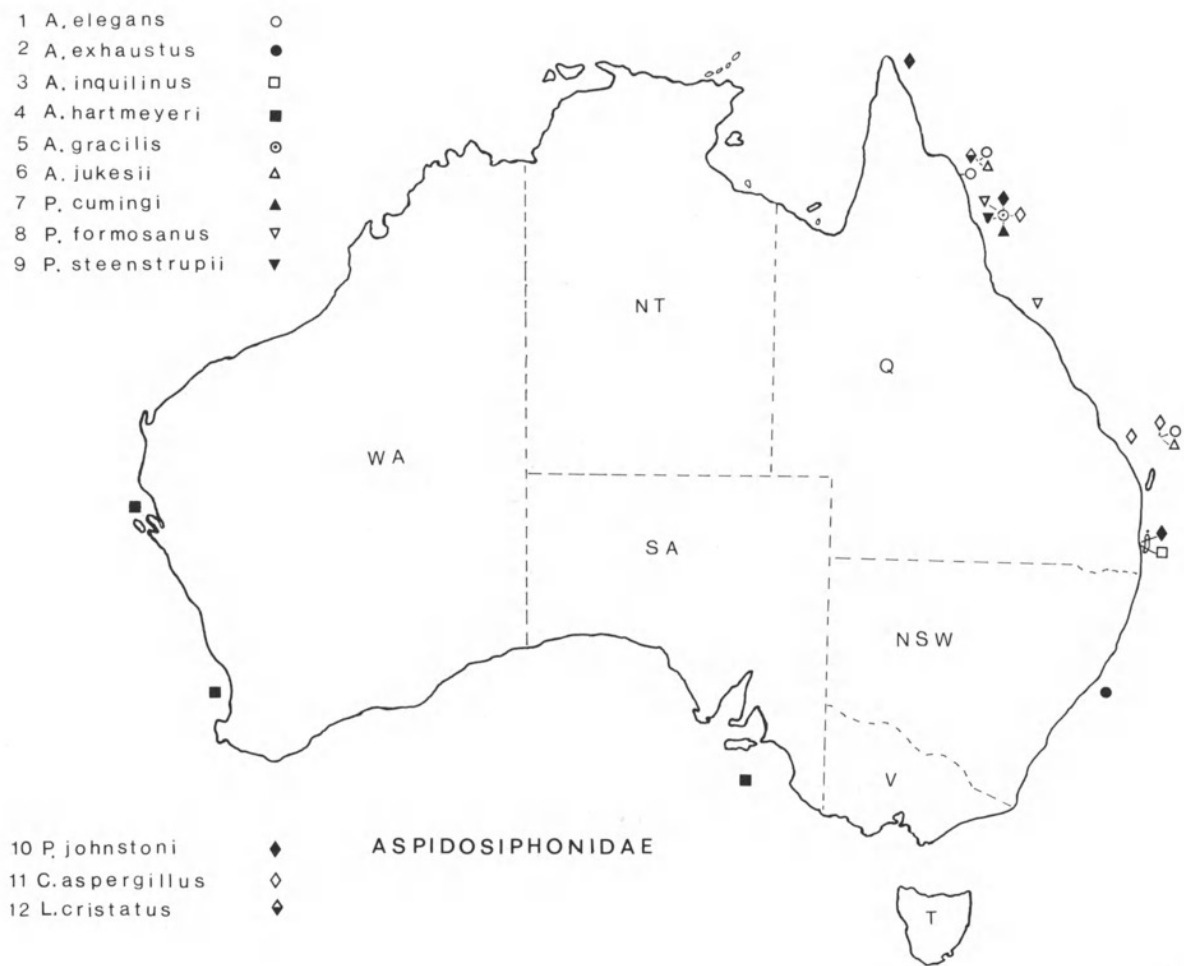


FIG. 132. Distribution of Aspidosiphonidae in Australia.

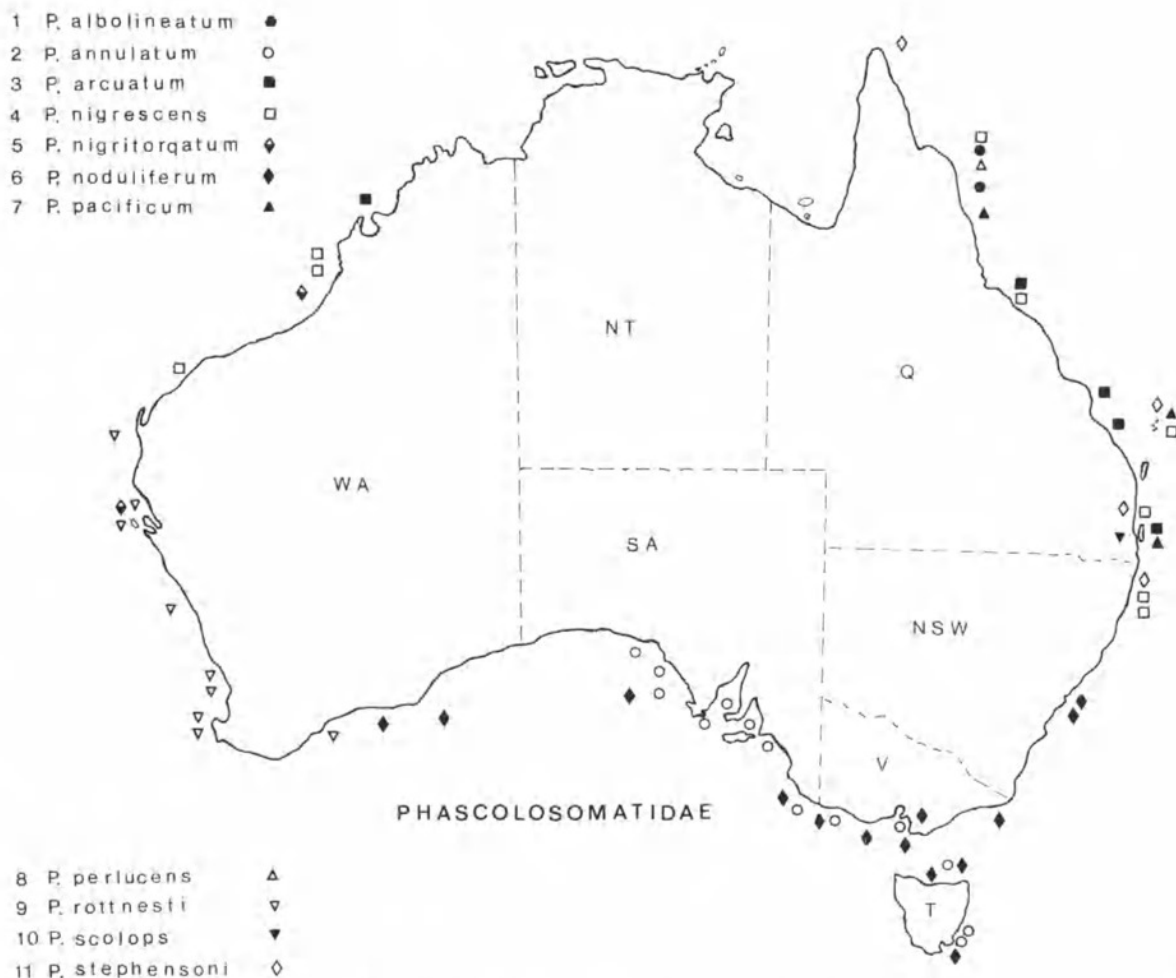


FIG. 133. Distribution of Phascolosomatidae in Australia.

133

REFERENCES

- AKESSON, B. 1958. A study of the nervous system of the Sipunculoideae, with some remarks on the development of the two species *Phascolion strombi* (Montagu) and *Golfingia minuta* (Kieferstein). (In) *Undersökningar över Öresund*. 38 Lund, C. W. K. Gleerup, 249 pp.
- AMOR, A. 1964. El genero *Dendrostomum* (Sipunculida) en la Argentina. *Physis*, **24** (68): 457-470, 5 figs.
- AUGENER, H. 1903. Beiträge zur Kenntnis der Gephyreen nach Untersuchung der im Göttinger zoologischen Museum befindlichen Sipunculiden und Echiuren. *Arch. Naturgesch.* **69**: 297-371, pls. 16-20.
- BAIRD, W. B. 1868. Monograph on the species of worms belonging to the subclass Gephyrea. *Proc. zool. Soc. London*: 76-114, pls. 9-11.
- BAIRD, W. B. 1873. Descriptions of some new species of Annelida and Gephyrea in the collections of the British Museum. *J. Linn. Soc. (Zool.)* **11**: 94-97.
- BENHAM, W. B. 1903. The sipunculids of New Zealand. *Trans. Proc. N.Z. Inst.* **36**: 172-184, 4 pls.
- BENHAM, W. B. 1904. Further notes on the sipunculids from New Zealand. *Trans. Proc. N.Z. Inst.* **37**: 301-308, 2 pls.
- BLAINVILLE, H. M. D. de. 1827. Dictionnaire des sciences naturelles. *Vers.* **49**: 305-313.
- BOSS, K. J. 1965. Symbiotic Erycinacean bivalves. *Malacologia* **3** (2): 183-195.
- BOUVIER, E. L. 1895. Le commensalisme chez certaines polypes madreporaires. *Annls. Sci. nat. Zool.* **20**: 1-32.
- CHAMISSO, A. de, and Eysenhardt, C. G. 1821. De animalibus quibusdam e classe vermium linneana. *Nova Acta Acad. Caesar Leop. Carol.* **10**: 343-374.
- CHIN, T. G. 1947. Studies of Fukien Sipunculoidea. *Biol. Bull. Fukien Christian Univ.* **3**: 97-104.
- CHIN, T. G. and WU, C. S. 1950. Diatoms in the intestine of Amoy sipunculids (Annelida, Gephyrea). The food of Sipunculida. *Lingnan Sci. J.* **23**: 43-52.
- CUTLER, E. B. 1969. New species of Sipuncula from the Western North Atlantic. *Proc. biol. Soc. Wash.* **82**: 209-218.
- CUTLER, E. B. 1973. Sipuncula of the Western North Atlantic. *Bull. Amer. Mus. nat. Hist.* **152** (3): 103-204, figs. 1-59, tables 1-13.
- CUTLER, E. B. 1977. The bathyl and abyssal Sipuncula. *Galathea Rep.* **14**: 135-156, 13 figs.
- CUTLER, E. B. and JURCZAK, E. 1975. The sipunculan genus *Lithacrosiphon* Shipley. A taxonomic review. *Zool. J. Linn. Soc.* **56**: 235-248, 3 figs.
- CUTLER, E. B. and MURINA, V. V. 1977. On the sipunculan genus *Golfingia* Lankester, 1885. *Zool. J. Linn. Soc.* **60** (2): 173-187.
- DAKIN, W. J. 1952. Gephyrea. (In) *Australian seashores*: 157-158. Angus and Robertson, Sydney.
- DANIELSSEN, D. C. 1869. *Sipunculus norvegicus*. *Ford. skand. Naturf. Kristiana Møte.* **10**: 541-542.
- DIESING, C. M. 1851. *Systema helminthum*. 2: 1-588. Vindebonae.

- DIESING, C. M. 1859. Revision der Rhyngodeen. *Sber. Akad. Wiss. Wien.* 37: 719-782, 3 pls.
- DITADI, A. S. F. 1975. *Aspidosiphon schneehageni* (Sipuncula) inhabiting *Tornatina* shells. *Veliger* 18 (2): 200-202.
- EDMONDS, S. J. 1955. Australian Sipunculoidea I. The genera *Sipunculus*, *Xenosiphon* and *Siphonosoma*. *Aust. J. mar. Freshwat. res.* 6: 82-97, 1 pl., 9 figs.
- EDMONDS, S. J. 1956. Australian Sipunculoidea 2. The genera *Phascolosoma*, *Dendrostomum*, *Golfingia*, *Aspidosiphon* and *Cloeosiphon*. *Aust. J. mar. Freshwat. res.* 7: 218-315, 3 pls, 21 figs.
- EDMONDS, S. J. 1957a. The respiratory metabolism of *Dendrostomum cymodoceae* Edmonds (Sipunculoidea). *Aust. J. mar. Freshwat. res.* 8: 53-63.
- EDMONDS, S. J. 1957b. The catabolism of nitrogen compounds in *Dendrostomum cymodoceae* Edmonds (Sipunculoidea). *Aust. J. mar. Freshwat. res.* 8: 131-135.
- EDMONDS, S. J. 1960. Sipunculids from New Zealand and the Chatham Islands. *N.Z. Dept. Sci. Industr. res. Bull.* 139: 159-167, 3 pls, 8 figs.
- EDMONDS, S. J. 1961. On *Sipunculus aeneus* Baird. *Ann. Mag. nat. Hist.*, (13) 4: 217-220.
- EDMONDS, S. J. 1966. *Siphonosoma hawaiiense*, a new sipunculid from Hawaii. *Pacific Sci.* 20 (3): 386-388.
- EDMONDS, S. J. 1971. Some sipunculans and echiurans chiefly from Guam (Sipuncula and Echiura). *Micronesica* 7: 137-151.
- EDMONDS, S. J. 1976. Three sipunculan species (two new) from New Zealand. *N. Z. J. mar. Freshwat. Res.* 10 (1): 217-224.
- EDWARDS, M. and HAIME, J. 1848a. Recherches sur les polypiers. II. Monographie des Turbinolides. *Ann. Sci. Natur.* (Ser. 3, Zool.) 9: 211-344.
- EDWARDS, M. and HAIME, J. 1848b. Recherches sur les polypiers III. Monographie des Eupsammides. *Ann. Sci. Natur.* (Ser. 3, Zool.) 10: 65-114.
- FISCHER, W. 1895. Die Gephyreen des Naturhistorischen Museums zu Hamburg. *Abhandl. d. naturwiss. Vereins, Hamb.* 13: 1-24, 1 pl.
- FISCHER, W. 1913. Über einige sipunculiden des naturhistorischen Museums zu Hamburg. *Jb. Hamb. wiss. Anst.* 30: 93-101.
- FISCHER, W. 1914. Weitere Mitteilungen über die Gephyreen des naturhistorischen Museums zu Hamburg. *Mitt. naturh. Mus. Hamb.* 31: 1-28.
- FISCHER, W. 1919a. Gephyreen der südwestküste australiens. *Zool. Anz.* 50: 277-285, figs 1-6.
- FISCHER, W. 1919b. Über die Gattung *Lithacrosiphon*, eine neue Sipunculiden-Gattung. *Zool. Anz.* 50: 289-293, 5 figs.
- FISCHER, W. 1921. Results of Dr. E. Mjöberg's Swedish scientific expeditions to Australia 1910-1913. 27. Gephyreen. *K. svenska Vetensk.-Akad. Handl.* 61 (8): 1-8, 6 figs.
- FISCHER, W. 1922. Gephyreen des Reichsmuseums zu Stockholm. *Ark. Zool.* 14 (19): 1-39, pl. 1-3, figs 1-42.
- FISCHER, W. 1926. Sipunculiden und Echiuriden der Hamburger Südsee-Expedition 1908-1909. *Mitt. zool. Staatinst. und. Zool. Mus. Hamb.* 42: 104-117, pl. 3, figs 5, 7-13.
- FISCHER, W. 1927. Sipunculoidea und Echiuroidea. (In) *Die Fauna Südwest-Australiens* 5: 199-216, pl. 2, figs 1-7.
- FISCHER, W. 1928. Über zwei neue *Siphonosoma*-Arten der Württembergischen naturlichen Sammlung zu Stuttgart. *Zool. Anz.* 76: 138-143, 2 figs.
- FISHER, W. K. 1947. New genera and species of echiuroid and sipunculoid worms. *Proc. U.S. natn. Mus.*, 97: 351-372, pls 8-15.
- FISHER, W. K. 1950a. The new subgenera and a new species of *Siphonosoma* (Sipunculoidea). *Ann. Mag. nat. Hist.* (12) 3: 805-808, 1 pl.
- FISHER, W. K. 1950b. The sipunculid genus *Phascolosoma*. *Ann. Mag. nat. Hist.* (12) 3: 547-552.
- FISHER, W. K. 1952. The sipunculid worms of California and Baja California. *Proc. U.S. natn. Mus.* 102: 371-450, pls 18-39, 87 figs.
- FISHER, W. K. 1954. The genus *Xenosiphon*. *Ann. Mag. nat. Hist.* (12) 7: 311-315, pls 7-8.
- GARDINER, J. S. The Maldive and Laccadive Groups, with notes on other coral formations in the Indian Ocean. The Fauna and Geography of the Maldive and Laccadive Archipelagoes, f: 333-341.
- GEROULD, J. H. 1913. The sipunculids of the eastern coast of North America. *Proc. U.S. natn. Mus.* 44: 373-437, 16 figs, pls 58-62.
- GIBBS, P. E. 1977. British sipunculans. *Synopses of the British fauna* (New Series), No. 12: 1-35.
- GIBBS, P. E. 1978. Macrofauna of the intertidal sand flats on low wooded islands, northern Great Barrier Reef. *Philos. Trans. Roy. Soc. (B)* 284: 81-97.
- GOREAU, T. F. and YONGE, C. M. 1968. Coral community on muddy sand. *Nature* 217: 421-423.
- GRAVELY, F. H. 1927. The littoral fauna of Krusadia Islands in the Gulf of Manaar, Gephyrea and Phoronis. *Bull. Madras Govt. Mus.* 16: 395-402, 1 fig.
- GRAY, J. E. 1828. *Spicilegium Zoologicum* (1): 1-8. London.
- GREEN, A. W. 1975. Annual reproductive cycle of *Phascolosoma luroo* (Sipuncula). *Proc. Int. Sympos. Biol. Sipuncula & Echiura* 1: 161-168.
- GREEN, J. P. & DUNN, D. F. 1976. Chloride and osmotic balance in the euryhaline sipunculid *Phascolosoma arcuatum* from a Malaysian mangrove swamp. *Biol. Bull.* 150: 211-221.
- GROBE, E. 1868a. Beschreibungen einiger von G. Ritter von Fraunfeld gesammelten Annelida und Gephyreen des rothen Meeres. *Verh. zool-bot. Ges. Wien.* 18: 629-650, pls 7-8.
- GROBE, E. 1868b. Tätigkeit der allgemeinen Naturwiss.—section der Schlesischen Gesellschaft im Jahre 1866. *Iber. Schles. Ges. Vaterl. Kult.* 45: 47-49.
- GROBE, E. & OERSTED, A. S. 1858. *Annulata oerstedianna*. *Vidensk. Meddr. dansk. Foren.* 1858: 105-120 (Gephyrea).
- HARMS, J. W. & DRAGENDORFF, O. 1933. Die Realisation von Genen und die consecutive Adaptation, 3 Mitteilungen. Osmotische Untersuchungen an *Physcosoma luroo*. *Z. wiss. Zool.* 143: 263-322.
- HÉRUBEL, M. A. 1904. Liste des Sipunculides et des Echiurides rapportés par M. Ch. Gravier du Golfe de Tadjourah. *Bull. Mus. Hist. nat. Paris* 10: 562-565.
- HUTTON, W. K. 1879. Additions to the list of New Zealand worms. *Trans. N.Z. Inst.* 12: 277-278.
- HYMAN, L. H. 1959. Phylum Sipunculids. (In) *The Invertebrates*. McGraw-Hill Book Company. N.Y. 5: 610-696, figs. 213-241.
- IKEDA, I. 1904. The gephyrea of Japan. *J. Coll. Sci. imp. Univ. Tokyo* 20 (4): 1-87, 4 pls.
- JOHNSON, P. 1964. Two species of *Aspidosiphon* (Sipunculoidea). *Ann. Mag. nat. Hist.* (13) 7: 331-335, pls 7-8.
- JOHNSON, P. 1969. A new subgenus of *Xenosiphon* (Sipunculoidea) and description of a new species from Indian waters. *J. Bomb. nat. Hist. Soc.* 66 (1): 43-46, figs. 1-7.
- JONES, I. 1975a. The occurrence of some intestinal and coelomic parasites of *Phascolosoma varians* of Puerto Rico. *Proc. Int. Sympos. Biol. Sipuncula & Echiura* 1: 343-348.
- JONES, I. 1975b. Further studies on the distribution and morphology of intestinal sporozoa of *Phascolosoma antillarum*. *Proc. Int. Sympos. Biol. Sipuncula & Echiura* 1: 349-355.
- KEFERSTEIN, W. 1863. Beiträge zur Kenntnis der Gattung *Phascolosoma* F.S. Leuckart Untersuchungen über niedere Seethiere. *Z. wiss. Zool.* 12: 35-51, pls. 3-4.
- KEFERSTEIN, W. 1865. Beiträge zur anatomischen und systematischen Kenntnis der Sipunculiden. *Z. wiss. Zool.* 15: 404-445, pls. 31-33.

- KEFERSTEIN, W. 1866. Untersuchungen über einige amerikanischen Sipunculiden. *Nachr. Ges. wiss. Göttingen* **1866**: 1-15.
- KEFERSTEIN, W. 1867. Untersuchungen über einige amerikanischen Sipunculiden. *Z. wiss. Zool.* **17**: 44-55.
- KESTEVEN, H. L. 1903. A new species of *Dendrostoma*. *Rec. Aust. Mus.* **5**: 69-73, 1 pl.
- KOHN, A. J. 1970. Food habits of the gastropod *Mitra literata* Lamarek. *Pacific Sci.* **24**: 483-486.
- KOHN, A. J. 1975. Predation on sipunculans. *Proc. Internat. Symp. Biol. Sipuncula & Echiura* I Kotor: 313-332.
- KOREN, J., and DANIELSEN, D. C. 1875. Bidrag til de norske Gephyreers Naturhistorie. *Nyt. Mag. Naturvid.* **21**: 108-138.
- KOREN, J., and DANIELSEN, D. C. 1877. Contributions to the natural history of the Norwegian Gephyrea. (In) Sars, M. *Fauna littoralis Norwegiae*. Christiania **3**: 111-156, pls. 14-15, figs. 18-46. Bergen.
- LANKESTER, E. R. 1885. *Golfingia macintoshi*, a new sipunculus from the coast of Scotland. *Trans. Linn. Soc. Lond. Zool.* (2) **11**: 469-474, pls. 55-56.
- LEUCKART, F. S. 1828. Breves animalium quorundam maxima parte marinarum descriptiones. Heidelberg: 9-23.
- LINNAEUS, C. 1766. *Systema naturae*, 12 ed.
- MANWELL, C. 1977. Superoxide dismutase and NADH diaphorase in haemerythrocytes of sipunculans. *Comp. Biochem. Physiol.* **58 B**: 331-338.
- METALNIKOFF, S. J. 1900. *Sipunculus nudus*. *Z. wiss. Zool.* **68**: 261-322.
- MONRO, C. A. 1931. Polychaeta, Echiuroidea and Sipunculoidea. *Sci. Rep. Gt. Barrier Reef Exped.* **4**: 1-37, 15 figs.
- MONTAGU, G. 1804. Descriptions of several marine animals found on the south coast of Devonshire. *Trans. Linn. Soc. London.* **7**: 61-85.
- MURINA, V. V. 1957a. Sipunculids collected on the first trip of the Antarctic Expedition of the "Ob" in 1956. *Zool. Zhurn.* **36**: 992-996.
- MURINA, V. V. 1957b. Abyssal sipunculids (genus *Phascolion*) of the north-western part of the Pacific Ocean collected by the "Vityaz" Expedition in 1950-1955. *Zool. Zhurn.* **36**: 1777-1791.
- MURINA, V. V. 1958. On the systematics of two closely related species of deep-water sipunculids of the genus *Golfingia*, according to the materials of the "Vityaz" Expeditions in 1949-1955. *Zool. Zhurn.* **37**: 1624-1634, 1 fig.
- MURINA, V. V. 1964a. New and rare species of sipunculids of the genus *Golfingia*. *Trudy Inst. Okeanol. Akad. nauk USSR*, **69**: 216-253.
- MURINA, V. V. 1964b. On the sipunculid fauna of the Mediterranean Sea. *Trudy Sevastopol' biol. Stat.* **17**: 51-76, 20 figs.
- MURINA, V. V. 1967. Report on the sipunculid worms from the sublittoral zone of Cuba and the Mexican Gulf. *Zool. Zhurn.* **46**: 1329-1339, 6 figs.
- MURINA, V. V. 1968. New discoveries from the fauna of Cuba and the Gulf of Mexico. *Rev. Roum. Biol. Zoologie* **13** (6): 421-423.
- MURINA, V. V. 1969. Two new species of sipunculids from the Pacific and Indian Oceans. *Zool. Zhurn.* **48**: 1732-1734.
- MURINA, V. V. 1970. Contributions to the fauna of sipunculid worms from the Gulf of Aden. *Vestnik Zool.* **2**: 65-72.
- MURINA, V. V. 1971. On the occurrence of deep-sea sipunculids and priapulids in the Kurile-Kamchatka Trench. *Trudy Inst. Okeanol.* **92**: 41-16.
- MURINA, V. V. 1972. Contributions to the knowledge of the sipunculid fauna of the southern hemisphere. (In) *Researches in Marine Fauna (Issledovani fauni morskoi XI (XIX))*: 294-314.
- MURINA, V. V. 1973. Sipunculids from the Peruvian-Chilean Trench. *Vestnik Zool.* **5**: 66-71.
- MURINA, V. V. 1974. Contributions to the knowledge of the fauna of sipunculid worms from the south Atlantic based on the data of the "Academic Kurchatov" Expedition of 1971. *Trudy Inst. Okeanol.* **98**: 228-239.
- MURINA, V. V. 1975a. New taxa of the genus *Golfingia*. *Zool. Zhurn.* **54**: 1085-1088.
- MURINA, V. V. 1975b. The evolution and the phylogeny of the Sipunculids. *Zool. Zhurn.* **54**: 1747-1758.
- MURINA, V. V. 1977. Marine Worms. Sipunculans of the Arctic and boreal waters of Eurasia. *Opredeliteli po Faune SSSR*, **111**: 1-282. *Adad. Nauk SSSR*, Leningrad.
- PALLAS, P. S. 1774. *Spicilegium Zoologicum*. Berolini (1) **10**: 1-15, 4 pls.
- PEEBLES, F. and FOX, D. L. 1933. The structure, functions and general reactions of the marine sipunculid worm, *Dendrostoma zostericola*. *Bull. Scripps Instn. Oceanogr.* (tech. ser.) **3**: 201-223, 11 figs.
- PERGAMENT, T. S. 1946. On a new genus and little known sipunculids from the northern Arctic Ocean. *Trudy Exped. "Sedov"*, Moscow-Leningrad, **3**: 189-193.
- PETERS, W. 1850. Über die Fortpflanzungsorgane des *Sipunculus*. *Arch. anat. physiol.* **1850**: 382-5, pl. 4, figs 1a-b.
- QUATREFAGES, A. de. 1865. *Histoire naturelle des Annelés marins et d'eau douce*. Paris, **2**: 1-794, pls 1-20.
- RICE, M. E. 1969. Possible boring structures of sipunculids. *Amer. Zool.* **9**: 803-812.
- RICE, M. E. 1970. Observations on the development of six species of Caribbean Sipuncula with a review of development in the phylum. *Proc. Intern. Sympos. Biol. of Sipuncula and Echiura* I Kotor: 141-160.
- RICE, M. E. 1973. Morphology, behaviour and histogenesis of the pelagosphera larva of *Phascolosoma agassizii*. *Smithson. Contrib. Zool.* **132**: 1-49.
- RICE, M. E. 1976. Sipunculans associated with coral communities. *Micronesica* **12** (1): 119-132.
- RICE, M. E. and MacINTYRE, I. G. 1972. A preliminary study of sipunculan burrows in rock thin sections. *Carib. J. Sci.*, **12**: 41-44.
- RICE, M. E. and STEPHEN, A. C. 1970. The type specimens of Sipuncula and Echiura described by J. E. Gray and W. Baird. *Bull. Brit. Mus. (Nat. Hist.) Zoology* **20** (2): 47-72, 3 pls.
- SATO, H. 1930. Report on the biological survey of Mutsu Bay 15. Sipunculoidea. *Sci. Rep. Tohoku Univ.* (4) **5**: 1-40.
- SATO, H. 1935. Sipunculoidea and Echiuroidea of the West Caroline Islands. *Sci. Rep. Tohoku Univ.*, (4) **10**: 299-329, pls 2-4.
- SATO, H. 1937. Echiuroidea, Sipunculoidea and Priapulidea obtained in North-West Honshu. *Res. Bull. Saito-Ho-on Kai Mus. (Zool)* **12**: 137-176, 3 pls, 14 figs.
- SATO, H. 1939. Studies on the Echiuroidea, Sipunculoidea and Priapulidea of Japan. *Sci. Rep. Tohoku Univ.*, (4) **14**: 339-460, pls 19-23, 60 figs.
- SEDGWICK, A. 1898. A student's textbook of Zoology. I Swanm. Sonnenschein. London.
- SELENKA, E., MAN, J. de, and BULOW, C. 1883. Die Sipunculiden Reisen im Archipel Philippinen von Dr. J. C. Semper. Leipzig & Wiesbaden, p. 2, 4 (1): 1-133, 14 pls.
- SHIPLEY, A. E. 1898. Report on the geophyrean worms collected by Mr. Stanley Gardiner at Rotuma and Funafuti. *Proc. zool. Soc. London.* **1898**: 486-473, pl. 47, figs. 1-2.
- SHIPLEY, A. E. 1899. A report on the Sipunculoidea collected by Dr. A. Willey at the Loyalty Islands and in New Britain. (In) A. Willey, *Zool. Res.* **2**: 151-160, pl. 18.

- SHIPLEY, A. E. 1902. Sipunculoidea, with an account of a new genus *Lithacrosiphon*. (In) Gardiner, J. S., *Fauna and Geography of the Maldive and Laccadive Archipelagoes*. 1: 131-140, pl. 7.
- SHIPLEY, A. E. 1903. Report on the Gephyrea collected by Prof. Herdman at Ceylon in 1902. *Herdman Rep. Pearl Oyster Fishery*, 1 (3) suppl.: 169-176, 1 pl., figs. 4-10.
- SLUITER, C. P. 1882. Beiträge zur der Kenntniss der Gephyreen aus dem Malayischen Archipel. *Naturrk. Tijdschr. Ned. Indie*. 41: 148-171, 2 pls.
- SLUITER, C. P. 1886. Beiträge zu der Kenntniss der Gephyreen aus dem Malayischen Archipel. *Naturrk. Tijdschr. Ned. Indie*. 45: 472-517, pls. 1-4.
- SLUITER, C. P. 1902. Die Sipunculiden und Echiuriden der Siboga-Expedition. *Siboga Exped. (Monographie)* 25: 1-53.
- SLUITER, C. P. 1912. Gephyriens provenant des campagnes de la Princesse Alice. 1898-1910. *Result. Camp. scient. Prince Albert I*, 36: 1-36, pl. 1, figs. 1-21.
- SPENGEL, J. W. 1912. Einige Organisationverhältnisse von Sipunculus-Arten und die Bedeutung für die Systematik dieser Tiere. *Verh. dtsch. zool. Ges.*, 22: 261-272.
- STEPHEN, A. C. 1942. Notes on the intertidal sipunculids of Cape Province and Natal. *Ann. Natal Mus.*, 10: 245-256, pl. 2.
- STEPHEN, A. C. 1964. A revision of the phylum Sipuncula. *Ann. Mag. nat. Hist.*, (13) 7: 457-462.
- STEPHEN, A. C., and EDMONDS, S. J. 1972. The phyla Sipuncula and Echiura. Trustees Brit. Mus. (Nat. Hist.) London, 528 pp.
- STEPHEN, A. C., and ROBERTSON, J. 1952. A preliminary report on the Echiuridae and Sipunculidae of Zanzibar. *Proc. R. Soc. Edinb.*, 64, B22: 426-444.
- STIMPSON, W. 1855. Descriptions of some new marine invertebrates from the Chinese and Japanese seas. Gephyrea. *Proc. Acad. nat. Sci. Philad.*, 7: 390-391.
- TARIFENO, E., and TOMICIC, J. 1973. Primer registro en el Pacifico sur Oriental para *Xenosiphon mundanum mundanum* (Selenka, de Man & Bülow, 1883). *Rev. Biol. mar. Valparaiso*, 15 (1): 107-110, 1 fig.
- THÉEL, H. 1875. Recherches sur le *Phascolion (Phascolosoma) strombi* (Montagu). *Bih. K. svensk. Vetensk. Akad. Handl.* 3 (3): 1-7.
- THÉEL, H. 1905. Northern and arctic invertebrates in the collection of the Swedish State Museum. Sipunculids. *K. svensk. Vetensk. Akad. Handl.* 39: 1-130, pls. 1-15.
- THÉEL, H. 1911. Priapulids and sipunculids dredged by the Swedish Antarctic Expedition 1901-1903, and the phenomenon of bipolarity. *K. svensk. Vetensk. Akad. Handl.* 47: 1-36, pls. 1-5, 8 figs.
- TÉTRY, A. 1959. Classe des sipunculien. (In) Grassé, *Traité de Zoologie* 5 (1): 785-854, 1068-1081, figs. 575-673, 9-16 suppl.
- WESENBERG-LUND, E. 1937. Gephyrea. *Bull. Mus. r. Hist. nat. Belg.* 13 (36): 1-23, 10 figs.
- WESENBERG-LUND, E. 1957. Sipunculoidea and Echiuroidea from the Red Sea. *Bull. Sea Fish. Res. Sm. Israel*, 14 (3): 1-15.
- WESENBERG-LUND, E. 1959a. Sipunculoidea and Echiuroidea from tropical West Africa. *Atlantide Rep.* 5: 177-210, 16 figs.
- WESENBERG-LUND, E. 1959b. Sipunculoidea and Echiuroidea from Mauritius. *Vidensk. Medd. fra Dansk. naturh. Foren.* 121: 53-73, 6 figs.
- WESENBERG-LUND, E. 1963. South African sipunculids from coastal waters. *Vidensk. Medd. fra Dansk. naturh. Foren.* 125: 101-146, figs. 1-12.
- WHEELER, M. B. 1938. The Sir Joseph Banks Islands. Reports of the expedition of the McCoy Society. *Proc. R. Soc. Vict.* 1 (50): 345.
- WHITELEGGE, J. 1899. List of the marine and freshwater invertebrate fauna of Port Jackson and neighbourhood. *J. Proc. R. Soc. N.S.W.* 23: 163-323.
- WILLIAMS, J. A. and MARGOLIS, S. V. 1974. Sipunculid burrows in coral reefs: evidence for chemical and mechanical excavation. *Pacific Sci.* 28 (4): 357-359.
- YONGE, C. M. 1975. A note on mutualism between sipunculans and scleractinian corals. *Proc. Internat. Symp. Biol. Sipuncula & Echiura Kotor I*: 305-311.



1980. "A revision of the systematics of Australian sipunculans (Sipuncula)."
Records of the South Australian Museum 18, 1–74.

View This Item Online: <https://www.biodiversitylibrary.org/item/127010>

Permalink: <https://www.biodiversitylibrary.org/partpdf/78715>

Holding Institution

South Australian Museum

Sponsored by

Atlas of Living Australia

Copyright & Reuse

Copyright Status: In copyright. Digitized with the permission of the rights holder.

License: <http://creativecommons.org/licenses/by-nc-sa/3.0/>

Rights: <https://biodiversitylibrary.org/permissions>

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at <https://www.biodiversitylibrary.org>.