INTRODUCTION

The sea cucumbers or the holothuroidea of the Phylum Echinodermata comprise approximately 10 families and about 700 species occurring in the world oceans. Of these, in the Indian ocean more than 160 species have been recorded of which 6 species are from shallow and littoral region of the seas around India. Many of these species are edible and some of them are utilized for preparation of "beche de mer" in the Trepang industry.

Our knowledge on the holothurian fauna of the Indian seas is derived from the works of Bell (1886), Theel (1882 and 1886), Pearson (1903), Hornel (1917), Gravely (1927), Clark and Rowe (1971), Koehler and Vaney (1905, 1908, 1910), Nair (1946), James (1967, 1968*b* and 1969), Gopalakrishnan (1969), Daniel and Halder (1974) and Mary Bai (1977). An illustrated key to the identification of these holothurians in general is essential so as to enable the easy identification of the species of economic importance. The first part deals with a brief resume of taxonomy with keys to identify the common species occurring in the seas around India. Published information on the ecology of the holothurians is scarce, therefore notes on the ecology of 38 species studied by the author and collected from the literature are also given.

Although considerable anatomical information of the Japanese and European species of holothurians (*Stichopus japanicus* and *Caudina arenata*) is known there is no comprehensive account of detailed anatomy including histological detail of the several external and internal systems of any holothuroid species occurring in Indian seas. Therefore teachers of Zoology in the Indian Universities have always followed types described from Japanese and European seas. The need for a comprehensive anatomical-histological publication on a holothurian, commonly occurring in the east coast of India was felt. The second part of this publication therefore deals with the external characters, the digestive, haemal, respiratory, water vascular, nervous, reproductive systems, coelom and evisceration and regeneration of *Holothuria* (*Metriatyla*) *scabra* Jaeger.

ACKNOWLEDGEMENTS

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PART I

HOLOTHURIANS IN THE SEAS AROUND INDIA

The Echinoderms (Gk. ekhinos, hedgehog ; derma, skin ; spiny skinned animals) are marine coelomate animals having radially symmetrical construction both in their external and internal organisation derived from an original bilateral condition.

The phylum Echinodermata includes five classes, Crinoida (sea-lillies), Echinoidea (sea-urchins) Asteroidea (starfishes), Ophuiroidea (brittle stars) and Holothuroidea (sea cucumbers). They are found in all seas. But two species of holothuroidea are recorded from brackish water. *Synaptula similis* enters the brackish water in the mangrove swamps of the tropics,. while the other holothurian *Haplodactyl molpadiodes* is obtained at the mouth of Ganges (Annandale, 1923).

Class HOLOTHUROIDEA (Sea cucumbers)

Echinoderms elongated in the oral aboral axis with secondary bilateral symmetry usually lying on one side which may be differentiated ; mouth at or near one end and the anus at or near the other end ; mouth surrounded by a set of tentacles attached to the water vascular system, endoskeleton in the form of microscopic ossicles embedded in the body wall ; podia in the form of locomotory tube feet, usually occupying five ambulacral areas but may spread over the entire surface ; special organs like respiratory trees and cuverian organs present in most of the typical members of the class, gonad single, larvae known as auricularia ; evisceration and regeneration of internal organs very common ; in general creeping and burrowing in their habit but a few forms like *Pelagothuria* and *Planktothuria* are pelagic.

The classification adopted in this paper is according to the one given by Clark and Rowe (1971). Podia, shape of tentacles and spicules are the three characters used in the identification of holothurians. Presence or absence of podia and shape of tentacles constitute characters of ordinal value whereas spicules are of paramount importance in species identification.

HOLOTHURIANS FROM THE SEAS AROUND INDIA

Phylum ECHINODERMATA

Class HOLOTHUROIDEA

Order ASPIDOCHIROTIDA

Family HOLOTHURIIDAE

Actinopyga echinites (Jaeger)
Actinopyga lecanora (Jaeger)
Actinopyga mauritiana (Quoy and Gaimard)
Actinopyga miliaris (Quoy and Gaimard)
Actinopyga serratidens Pearson
Bohadschia argus Jaeger
Bohadschia marmorata Jaeger
Bohadschia vitiensis (Semper)
Bohadschia tenuissima (Semper)
Labidodemas rugosum (Ludwig)

Labidodemas semperianum Selenka
Holothuria (Selenkothuria) erinaceus Semper
Holothuria (Selenkothuria) moebii Ludwig
Holothuria (Semperothuria) cinerascens (Brandt)
Holothuria (Semperothuria) imitans Ludwig
Holothuria (Halodeima) atra Jaeger
Holothuria (Halodeima) edulis Lesson
Holothuria (Acanthotrapeza) pyxis Selenka
Holothuria (Platyperona) difficilis Semper
Holothuria (Thymiosycia) arenicola Semper
Holothuria (Thymiosycia) hilla Lesson
Holothuria (Thymiosycia) impatiens (Forskal)
Holothuria (Thymiosycia) remollescens Lampert
Holothuria (Mertensiothuria) fuscocinerea Jaeger
Holothuria (Mertensiothuria) leucospilota (Brandt)
Holothuria (Lessonothuria) pardalis Selenka
Holothuria (Holothuria) prompta Koehler and Vaney
Holothuria (Theelothuria) spinifera Theel
Holothuria (*Theelothuria*) *kurti* Ludwig
Holothuria (*Metriatyla*) *ocellata* Jaeger
Holothuria (*Metriatyla*) *scabra* Jaeger
Holothuria (*Microthele*) *nobilis* (Selenka)

Family STICHOPODIDAE

Stichopus chloronotus Brandt
Stichopus variegatus Semper

Order DENDROCHIROTIDA

Family CUCUMARIDAE

Pentacta cucumis (Semper)
Pentacta quadrangularis (Lesson)
Trachythyone alcocki (Koehler and Vaney)
T. typica (Theel)
Aslia forbesi (Bell)
Staurothyone rosacea (Semper)
Pseudocolochirus violaceus (Theel)
Pseudocnus echinatus (Von Marenzeller)
Leptopentacta javanicus (Sluiter)
Leptopentacta bacilliformis (Koehler and Vaney)
Thorsonia investigatories (Koehler and Vaney)
Stolus buccalis (Stimpson)
Stolus conjugens (Semper)

Stolus rapax (Koehler and Vaney)
Hemithyone semperi (Bell)

Family PHYLLOPHORIDAE

Actinocucumis typicus Ludwig
Cladolabes acicula (Semper)
Ohshimella ehrenbergi (Selenka)
Afrocucumis africana (Semper)
Phyllophorus (*Phyllophorella*) *parvipeds* H. L. Clark
Phyllophorus (*Urodemella*) *brocki* Ludwig

Order MOLPADIDA

Family MOLPADIIDAE

Molpadia australis (Semper)
Acaudina molpadioides (Semper)
Paracaudina chilensis (J. Muller)

Order APODIDA

Family SYNAPTIDAE

Opheodesoma grisea (Semper)
Synapta maculata (Chamisno and Eysenhardt)
Synaptula striata (Sluiter)
S. recta (Semper)
S. varians (Nair)
Protankyra pseudodigitata (Semper)

Family CHIROTIDAE

Polycheira rufescens (Brandt)

The class Holothuroidea includes four orders ; Aspidochirotida, Dendrochirotida, Apodida and Molpadida. Altogether 65 species under 28 genera are dealt here with.

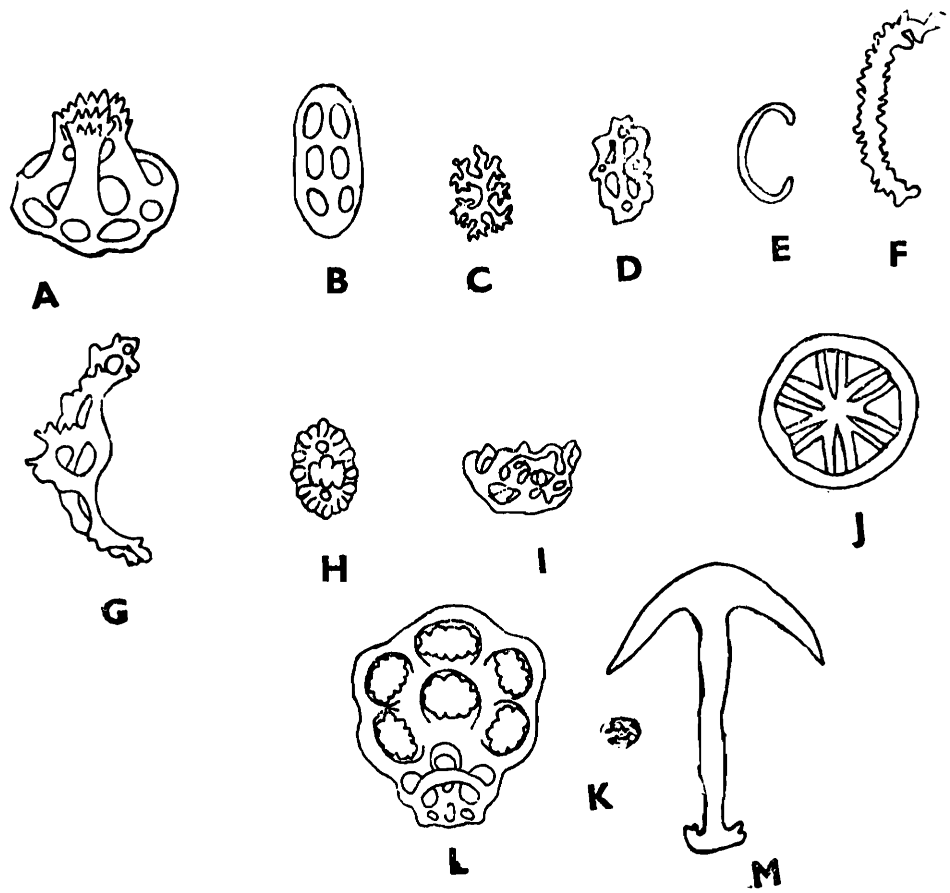
Key to the orders of Class HOLOTHUROIDEA

1. Podia present ; body stout ; body wall thick and muscular ranging from 1-15 mm. thickness (inc. s.*), spicules in the type of buttons, cups, perforated plates, rosettes or rods (Text-fig. 1A-J) Podia absent ; body either vermiform or stout and sauage shaped with a caudal appendage ; body wall thin 1 mm. thickness or less, smooth, rough or warty surface ; spicules in type of anchors with anchor plates, (Text-fig. 1 L, K, M) wheels and grains (Text-fig. 1 J) perforated plates irregular tables, irregular rods/cups (Text-fig. 7A, B) or as modified anchors without associated plates. 3

* contracted specimen.

2. Tentacles leaf-shaped (Text-fig. 2A) ; no true interovert with associated retractor muscles. ... ... ASPIDOCHIROTIDA

Tentacles bushy or tree-shaped, much branched (dendritic) (Text-fig. 2B) ; true interovert with associated retractor muscles. ... ... DENDROCHIROTIDA



Text-fig. 1. Spicules in general

3. 15 digitate tentacles ; body stout and sauage-shaped, with distinct caudal appendage ; anal papillae, tentacle ampullae and respiratory trees present ... MOLPADIDA

10-20 or more pinnate tentacles ; body vermiform with smooth rough or warty surface. Anal papillae, tentacle ampullae and respiratory trees absent. ... ... APODIDA

The order Aspidochirotida includes two families namely Holothuriidae and Stichopodidae.

Key to the Families of order ASPIDOCHIROTIDA

1. Gonads in a single tuft to the left of the dorsal mesentery. Spicules ; tables, branched rods and 'S' or 'C' shaped rods not present. ... ... HOLOTHURIIDAE

2. Gonads in two tufts, one on each side of the dorsal mesentery. Spicules ; tables, branched rods, and 'S' or 'C' shaped rods (Text-fig. 1 E), or slender dichotomously branched rods (Text-fig. 3A) buttons rarely, if ever, present. STICHOPODIDAE

Family HOLOTHURIIDAE

Under this family four genera, *Actinopyga,* Bronn, 1860 ; *Bohadschia* Jaeger, 1833 ; *Labidodemas* Selenka, 1867 and *Holothuria* Linnaeus, 1767 are dealt with.

Key to the Indian genera

1. Spicules : rods only, usually dichotomously branched or lobed (Text-fig. 1C), tables and buttons never present ; Calcareous ring very stout both radial and interradial plates with their anterior margin scalloped and sometimes with their sutures, indistinct, radial plates usually about twice as large as the interradials and possessing a median anterior ampullary notch, interradial plates with a short anterior median tooth-like projection ; 20-30 tentacles, body wall very thick ; pedicels and papillae small and numerous, indistinguishable from each other, scattered ventrally and dorsally ; size moderate to very large, upto 40 cm. long. 2

— Spicules : tables nearly always present, buttons, rods, perforated plates and rosettes present or absent, minute dichotomously branched or lobed rods rarely present and if so then only in combination with tables (Text-fig. 1A, B, D, F) other characters exhibiting a wide range. 3

2. Calcified anal 'teeth' (papillae) present ; 20-30 tentacles. ... ... *Actinopyga* Bronn 1860

— Calcified anal 'teeth' (papillae) not present ; 20 tentacles. ... ... *Bohadschia* Jaeger 1833

3. Spicules : tables scattered variously developed either with disc reduced and spire low and ending in a ring of spines or disc well developed and spinose, with spire of moderate height and smooth and irregular spinose buttons and clumsy 'C' shaped bodies ; Calcareous ring ribbon like radial plates usually shorter than broad, interradial plates also shorter than broad, tending to be curved (Text-fig. 4A) body wall fairly thick, usually about 1.5 mm. (1-2 mm.), soft and leathery body cylindrical or vermiform with pedicels and papillae confined to the five ambulacral areas : size moderate upto C. 15 cm. long. ... ... *Labidodemas* Selenka 1867.

— Spicules : variously developed and in various combinations : calcareous ring never ribbon like, radial plates either as long as broad or longer, interradial plates usually half as long as broad but never curved (Text-fig. 4B) body form showing a wide range but pedicels usually irregularly arranged on a more or less flattened ventral 'sole' and papillae irregularly arranged on the arched dorsal surface : size ranging from small to massive upto 45 cm. long. ... ... *Holothuria* Linnaeus 1767.

Genus **Actinopyga** Bronn, 1860

This is represented by five species namely, *A. echinites* (Jaeger) *A. lecanora* (Jaeger), *A. mauritiana* (Quoy and Gaimard), *A. serratidens* (Pearson) and *A. miliaris* (Quoy and Gaimard).

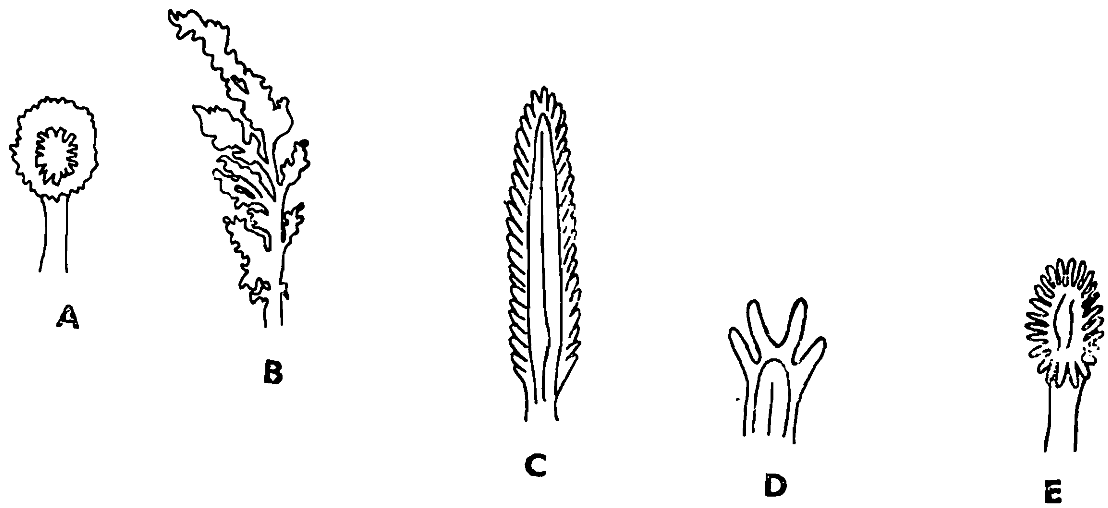
Key to the Indian species

1. Spicules : rods richly branched and small dichotomously branched rosettes and simpler rods dichotomously branched at both ends (Text-fig. 8A). ... *A. echinites* (Jaeger)

   Distribution : Islands of West Indian ocean, E. Africa and Madagascar, S. E. Arabia, Sri Lanka area, Bay of Bengal, East Indies, N. Australia, Philippine islands, China and S. Japan and S. Pacific islands. *Colour* : grayish-brown with dark irregular blotches within grooves of bivium lighter shade in trivium.

2. Rods slightly branched. No large rods, rosettes on the ventral side are larger and thicker than that of dorsal side (Text-fig. 8B). ... ... *A. lecanora* (Jaeger)

Distribution : Indo-pacific. *Colour* : Upper surface dark brown, speckled with lighter color or tiny spots. Ventral surface yellowish.



Text-fig. 2. Tentacles of : A. an aspidochirotid, B. a dendrochirotid, C. Synaptula, D. Protankyra, E Polycheira.

3. Spicules : rods of irregular shapes with many small processes along sides and small variable dichotomous x-shaped rosettes (Text-fig. 8C). ... ... *A. mauritiana* (Quoy and Gaimard)

Distribution : Indo-pacific. *Colour* : Dorsal and lateral surfaces dark brown or light chocolate brown with bases of papillae slightly lighter in color. Tips of pedicels dirty white.

4. *Spicules* : rods dichotomously branched at both ends, some with racemose ends, few with dichotomous side branches from middle of shaft and at both ends, giving appearance of perfect rosettes (Text-fig. 8D) ... *A. serratidens* Pearson

Distribution : Red sea, Sri Lanka area, Bay of Bengal, East Indies and Philippine islands. *Colour* : Black or purplish black.

5. Spicules : rosettes, the stem of which are widely spread. The stem of rosettes in skin are short and have slight protrubrances at sides and ends (Text-fig. 8E) ... ... *A. miliaris* (Quoy and Gaimard)

Distribution : Indo-pacific.

Genus **Bohadschia** Jaeger, 1833

This is represented here by four species namely *B. argus* Jaeger, *B. mormorata* Jaeger, *B. vitiensis* (Semper) and *B. tenuissima* (Semper).

Key to the Indian species

1. Spicules : rosettes and rods. rosettes of ventral side slender and much branched while that of dorsal side are thick and slightly branched. Podia with only few rods whose ends are thorny and branched with some of the rods in 'H' shaped (Text-fig 8F) ... ... *B. argus* Jaeger

Distribution : Islands of west Indian ocean, Sri Lanka area, Bay of Bengal, East Indies, North Australia, Philippine islands, China and South Japan and South Pacific islands, ...

Colour : Brown, dull, gray or purplish, with conspicuous white encircled spots of a different contrasting shade of brown, resembling the spots of a leopard.

2. Spicules : rosettes and granules. rosettes are very rarely branched. The granules are round, oval and dumb-bell shaped, sometimes branched at the ends. (Text-fig. 8G) ... *B. marmorata* Jaeger

   Distribution : Mascarene Islands, Indo-Pacific, E. Africa and Madagascar and Red Sea.

3. Spicules : rosettes and granules. rosettes are more delicate than that of *B. mormorata* granules are round or oval or dumb-bell shaped but smaller than that of *B. mormorata* (Text-fig. 8H) ... ... *B. vitiensis* (Semper)

   Distribution : Bay of Bengal, East Indies, North Australia, Philippine islands, S. Pacific islands and Hawaiian islands.

   Colour : Dorsal side dark orange, ventral side lighter.

4. Spicules : rosettes and granules. rosettes are delicate and slightly branched. granules are branched, round oval or dumb-bell shaped No perforations. ... *B. tenuissima* (Semper)

   Distribution : Red sea, Sri Lanka area, Bay of Bengal, East Indies, Philippine islands, China and S. Japan, and South Pacific islands.

   Colour : Dorsal side brownish, ventral whitish with dark spots.

Genus **Labidodemas** Selenka, 1867

This genus is represented here by two species, *L. rugosum* (Ludwig) and *L. semperianum* Selenka.

Key to the Indian species

1. Spicules : tables, disc well developed and spinose with spire of moderate height and usually very spinose, buttons smooth and irregular, often incomplete (Text-fig. 8I) ... ... *L. rugosum* (Ludwing)

   Distribution : Maldive area, Bay of Bengal, East Indies, N. Australia. Philippine islands and South Pacific islands. *Colour* : White or grey.

2. Spicules : tables few in number. stout or delicate and few buttons. Deformed or incomplete clumpsy C-shaped bodies (Text-fig. 8J) ... *L. semperianum* Selenka

   Distribution : Bay of Bengal, East Indies, Philippine islands and S. Pacific islands. *Colour* : Whitish but the pedicels and tentacles are brownish.

Genus **Holothuria** Linnaeus, 1767

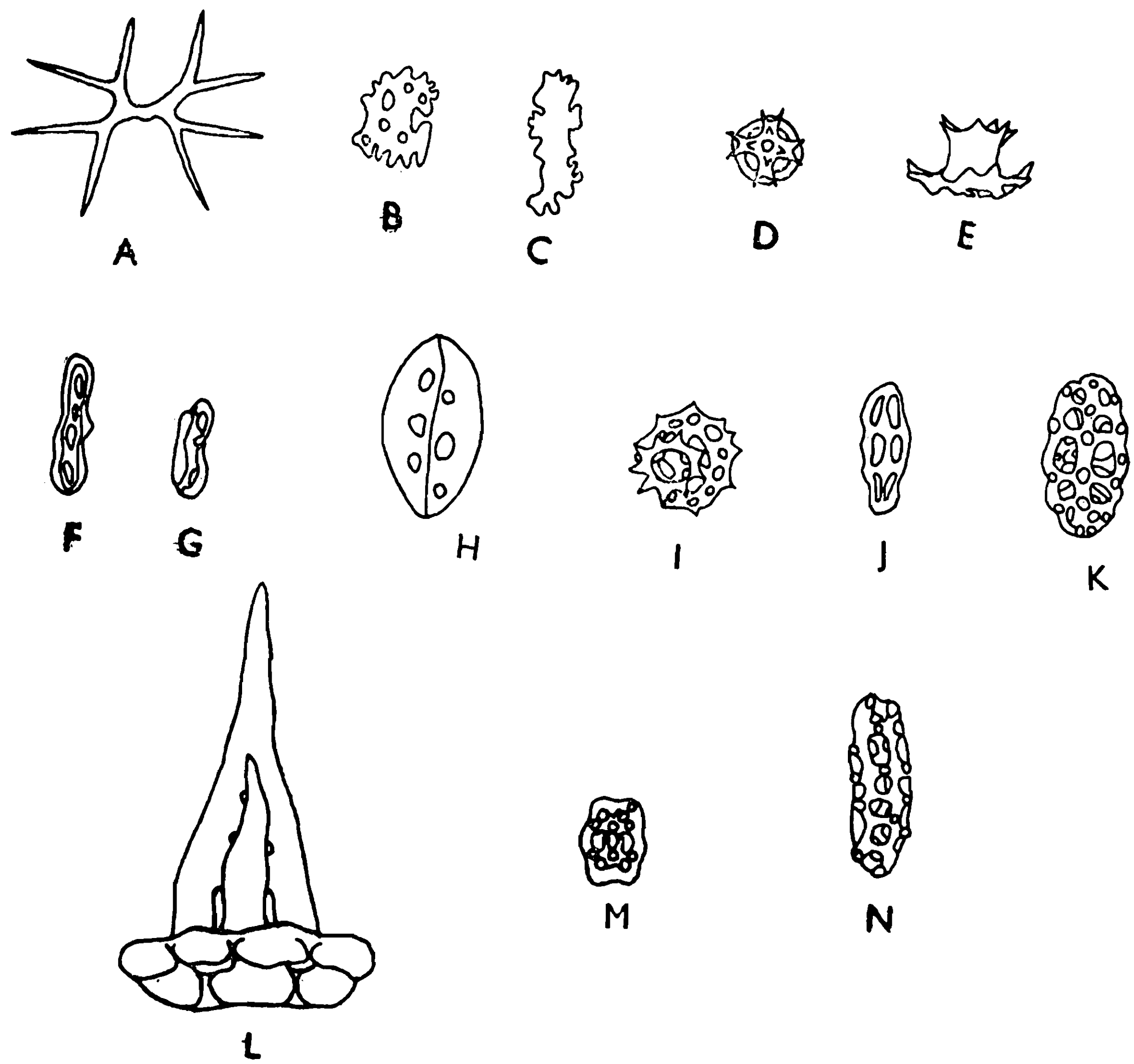
This is represented here by twelve subgenera namely *Selenkothuria*, *Semperothuria*, *Halodeima*, *Acanthotrapeza*, *Platyperona*, *Thymiosycia*, *Mertensiothuria*, *Lessonothuria*, *Holothuria*, *Theelothuria*, *Mertriatyla* and *Microthele*.

Key to the Indian subgenera

1. Spicules : tables only present in combination of rosettes, rods or perforated plates buttons never present, 20 tentacles 2

   Spicules : tables always present, alone or in combination with buttons, rods or rosettes never present. 18-30 tentacles 5

2. Spicules : perforated plates or thorny rods (Text-fig. 3B,C) tables present in some species if so always very reduced in form and sparsely distributed in the body wall. ... ... *Selenkothuria* Deichmann 1958



Text-fig. 3. Spicules of aspidochirotids

—Spicules : tables always present usually well developed, either in combination with rosettes or rods. 3

3. Spicules : tables in combination with rods, former usually with disc reduced or absent, spire moderately high, terminating in a few spines which form a single or double maltese cross when viewed from above (Text-fig. 3D) rosettes never present. ... ... *Semperothuria* Deichmann 1958

— Spicules : tables in combination with rosettes. Rods never present. ... 4

4. Spicules : usually with reduced disc, spire moderate to high, ending in a few spines forming a maltese cross when viewed from above. ... ... *Halodeima* Pearson 1914

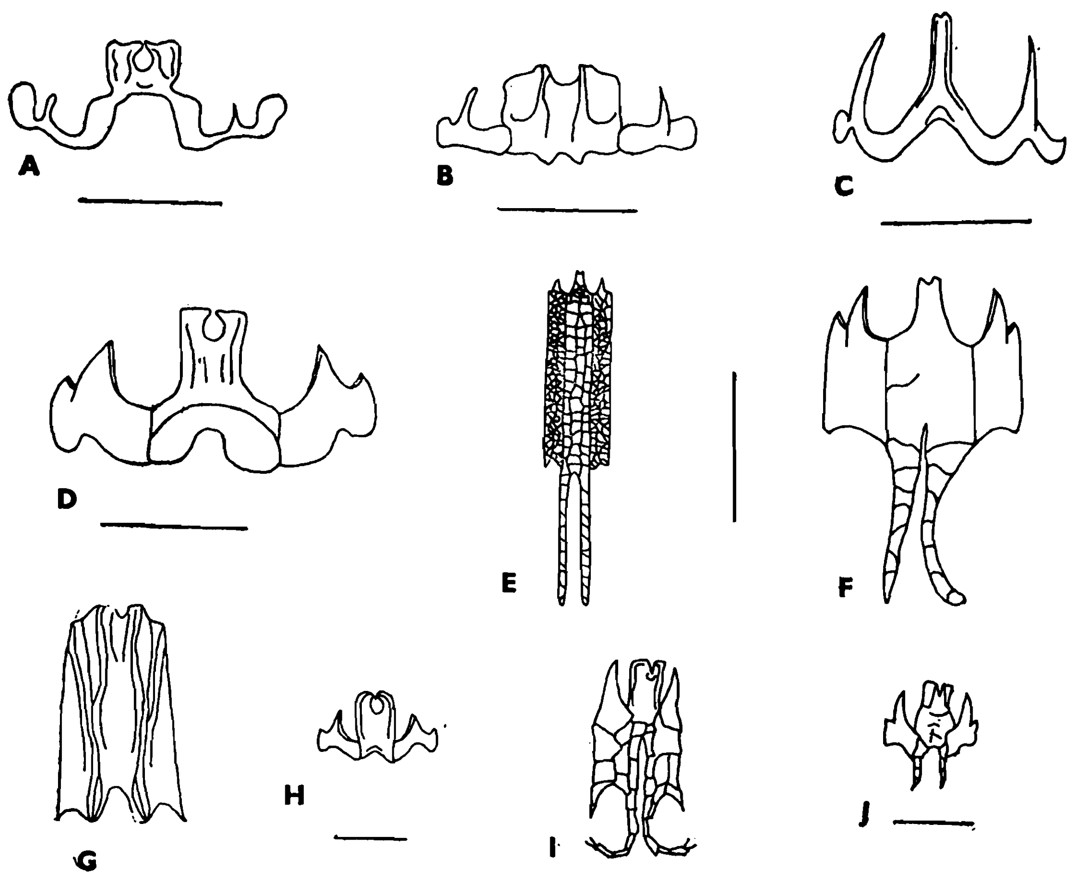
— Spicules : tables usually with large and well developed disc and low to moderately high spire, the rim of the disc often turned up to give the table a 'cup and saucer' appearance in side view. ... ... *Acanthotrapeza* Rowe 1969

5. Spicules : tables well developed, disc smooth and round with varying number of peripheral holes, spire of moderate height ending in several

spines, buttons oval, thin with three to six pairs of small holes (Text-fig. 3H), flat and having a median optical discontinuity. ... ... *Platyperona* Rowe 1969

— Spicules : tables fairly stout, disc smooth, squarish with eight to ten peripheral holes, spire of moderate height ending in a cluster of small spines (Text-fig. 1A), buttons regular or irregular in outline with three or more pairs of comparatively large holes except in *H* (T) *arenicola* which has comparatively small holes, not flattened, and no median optical discontinuity (Text-fig. 1B). ... ... *Thymiosycia* Pearson 1914

6. Spicules : tables not strongly developed disc with rim usually spinose, spire low ending in a ring (Text-fig. 3I) ; buttons irregular usually with three pairs of holes (Text-fig. 3J). ... ... *Mertensiothuria* Deichmann 1958



Text-fig. 4. Parts of calcareous rings of : A—*Labidodemas rugosum*, B—*Holothuria discrepans*, C—*Holothuria squamifera*, D—*Aslia forbesi*, E—*Pentacta quadrangularis*, F—*Thyone papuensis*, G—*Havelockia versicolor*, H—*Cladolabes aciculus*, I—*Actinocucumis typicus*, J—*Semperiella tenera*

— Spicules : tables clumpsy, disc well developed spinose, often turned upto give a 'cup and saucer' appearance to the table in lateral view (Text-fig. 3E), spires low to moderate, terminating in a ring or cluster of small spines, pseudo-buttons abundant, smooth usually irregular and often reduced to a single row of three or four holes (Text-fig. 3F). ... *Lessonothuria* Deichmann 1958

7. Spicules : tables simple, irregular with! spinose and reduced disc, buttons simple large with numerous small rounded or pointed knobs, giving the

button a very rugose appearance, three to ten pairs of holes which sometimes become obliterated by the thickening of the button. ... ... *Holothuria* Linnaeus, 1767

8. Spicules : tables well developed, disc smooth or spinose, sometimes multi-armed, spire either moderate or high, terminating in a cluster of small spines, modified tables with spire perfectly smooth and tapering to end in a point, giving the whole table a tack-like appearance, also present (Text-fig. 3K), buttons either simple with irregular, moderate-sized knobs or modified into hollow fenestrated ellipsoids (Text-fig. 3L). ... *Theelothuria* Deiehmann 1958

— Spicules : tables well developed with smooth disc spire of moderate height or high, terminating in several small spines, buttons simple, with moderate size, irregularly arranged knobs, three to six pairs of relatively large holes (Text-fig. 3M) never modified into hollow fenestrated spheres. *Metriatyla* Rowe, 1969

9. Spicules : tables stout and well developed with smooth squarish disc spire of moderate height terminating in many small spines, buttons usually always hollow fenestrated ellipsoids (Text-fig. 3N). ... ... *Microthele* Brandt, 1835

Subgenus **Selenkothuria** Deichmann 1958

This is represented here by two species namely, *H.* (*S.*) *erinaceus* Semper and *H.* (*S.*) *moebii* Ludwig.

Key to the Indian species

1. Spicules : predominatly short flat rods, often with forked ends and few lateral or terminal holes (Text-fig. 9A). ... ... *H. (S.) erinaceus* Semper

   Distribution : East Africa, Madagascar, Sri Lanka area, Bay of Bengal, East Indies, N. Australia, Philippine and South Pacific islands. *Colour* : dull grey with two rods of dark spots.

2. Spicules : rods usually with spinulated surface, mostly simple with a small hole in each end, rarely with a series of lateral projections sometimes forming a series of holes. ... ... *S. moebii* Ludwig

   Distribution : Mascarene Islands, Sri Lanka area, Bay of Bengal, East Indies, N. Australia, Philippine islands, China and South Japan and South Pacific islands.

Subgenus **Semperothuria** Deichmann 1958

This is represented here by two species namely *S. cinerascens* (Brandt) and *S. imitans* Ludwig.

Key to the Indian species

1. Spicules : tables in combination with rods, the former with reduced disc, spire moderatly high terminating in a few spines which form a single or double maltese cross when viewed from above. Rosettes never present (Text-fig 9B) ... ... *H. (S). cinerascens* Brandt

   Distribution : Indo-pacific, Mandapam, Vizingam, Minicoy, (Laccadives) and Rangat Bay (Andamans). *Colour* : Yellowish green.. *Nature of habitat* : Rocky, found attached to the rocks.

2. Spicules : tables with flattened base ; pillars parallel ending in eight spienes forming a single flat maltese cross. Supporting rods in tube feet and papillae mostly narrow, with perforated euds, occasionally with lateral holes (Text-fig, 9C) ... ... *H. (S). imitans* Ludwig

Distribution : South Indian and Sri Lanka area. *Colour* : Purplish brown. *Nature of habitat* : Shallow water, usually under flat rocks in low tide, tidepools, coral area O-1 fathom depth.

Subgenus **Halodeima** Pearson 1914

This is represented here by two species namely *H.* (*H.*) *atra* Jaeger and *H.* (*H.*) *edulis* Lesson.

Key to the Indian species

1. Spicules : rosettes and tables. Rosettes scattered chiefly derived from forked rods, often forming oval plates with four holes. Tables have a small disc with a hole (Text-fig. 9D). ... ... *H.* (*H*) *atra* Jaeger
   Distribution : Indo-pacific. *Colour* : Uniformly dark brown or black. *Habitat* : Shallow w.:ter in lagoons, mostly lying freely exposed.
2. Spicules : tables and rosettes. The disc of the table is in the form of a small ring the inner ends of which is folded. The crown resembles a narrow beam. The rosettes are closed and have three pairs of regular holes, two pairs on the side and one pair at the end (Text-fig. 9E). ... ... *H.* (*H.*) *edulies* Lesson
   Distribution : Indo-pacific. *Colour* : Bluish white with some reddish blue veins on the dorsal anterior and posterior regions.

Subgenus **Acanthotrapeza** Rowe 1969

This is represented by only one species, *H.* (*A.*) *pyxis* Selenka, which can be identified by the following characters.

Spicules ; tables and rosettes. The ring shaped crown of the tables carries few thorns which are in the form of cone and projected outwards, the rosettes are thickly built like a ring around the base of the tube feet (Text-fig. 9F) ... ... *H.* (*A.*) *pyxis* Selenka
Distribution ; Bay of Bengal, East Indies, Andaman Islands and Java Islands. *Colour* : Dorsal side greyish brown without whitish spots, ventral side brown with white spots.

Subgenus **Platyperona** Rowe 1969

This is represented by a single species, *H.* (*P.*) *difficilis* Semper, which can be identified by the following diagnostic character.

Spicules : tables and buttons. Buttons are oval, smooth, Prominent at the borders with perforations arranged in lines (Text-fig. 9G). ... ... *H.* (*P.*) *difficilis* Semper
Distribution : Indo-pacific. *Colour* : usually dark brown, sometimes almost purplish black rarely yellow. *Habitat* : Shore mostly under flat rocks and in pools.

Subgenus **Thymiosycia** Pearson 1914

This is represented by four species namely *H.* (*T.*) *arenicola* Semper, *H.* (*T.*) *hilla* Lesson, *H.* (*T.*) *impatiens* Forskal and *H.* (*T.*) *remollescens* Lampert.

Key to the Indian species

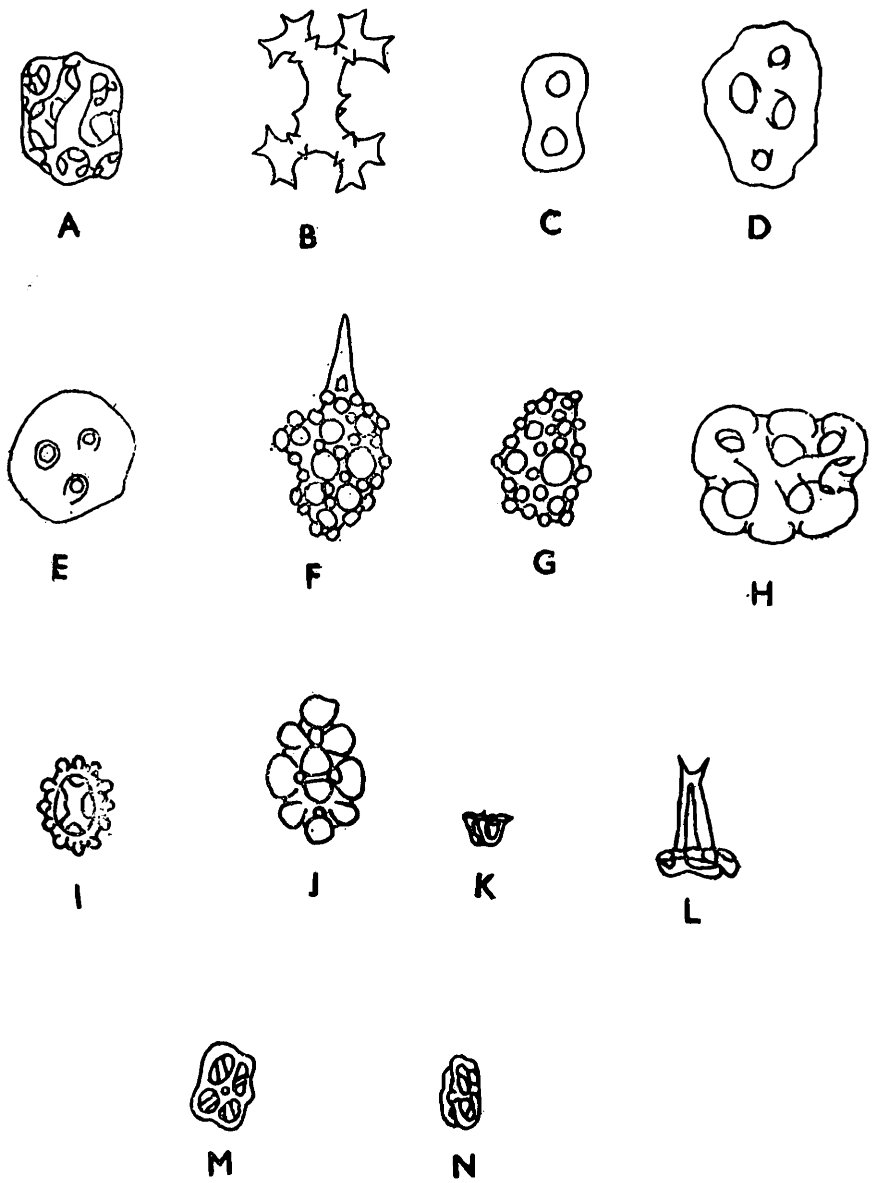
1. Spicules : tables are wide, the disc with numerous holes and smooth wavy ends. Spire is of moderate height. The crown is flat and irregular with a number of thorns. The buttons are oval with 3 pairs of comparatively small holes (Text-fig. 9H) ... ... *H.* (*T*). *arenicola* Semper

Distribution : Almost circum tropical. *Colour* : White to grey with a varying amount of dark pigment flecks. Some are almost black. *Habitat* : Shore. mostly hidden in sand or mud, rarely among rocks.

2. Spicules : tables fairly stout, disc smooth squarish in outline, usually with eight to ten peripheral holes, spire of moderate height ending in a cluster of small spines. Buttons irregular in outline with usually 3 pairs of comparatively large holes (Text-fig. 9I). ... ... *H. (T.) hilla* Lesson

Distribution : Indo-pacific.

— Spicules : tables and buttons. Tables are stout, disc large with many holes, smooth edge. The spire moderate height and has one to two cross ridges, crown is bulky with a number of thorns. Buttons regular in outline with three or more pairs of comparatively large holes (Text-fig. 9J). *H. (T.) impatiens* Forskal



Text-fig. 5. Spicules of cucumarids

Distribution : Almost circumtroprical, Indo-pacific. *Colour* : Mottled grey or brown. Sometimes almost uniformly reddish brown. *Habitat* : Shallow water to a few fathoms usually well concealed among rocks more rarely in sand.

3. Spicules : tables, buttons and rods. The spire high and has several transverse ridges. Buttons have three or more pairs of holes. The rods are enlarged at their ends, have two or three perforations. ... ... *H. (T.) remollescens* Lampert
Distribution : Red Sea, Bay of Bengal and N. Australia. *Colour* : Brown with dark brown spots.

Subgenus **Mertensiothuria** Deichmann 1958

This is represented here by two species namely *M. fuscocinerea* Jaeger and *M. leucospilota* Brandt.

Key to the Indian species

1. Spicules : tables with round to squarish disc, with 3 or 4 central holes and some marginal holes, spire low, often reduced to one rod ; the crown consists of one to four spires. Buttons complete or incomplete with two narrow holes. (Text-fig. 10A) ... ... *H. (M.) fuscocinerea* Jaeger
Distribution : Ranges from Sri Lanka, Australia, Navigator island Philippine island to Panamic region. *Colour* : Ash grey or brownish more or less mottled, ventral side pale grey with a velvet black ring, *Habitat* : Sandy, rocky or corralline bottom 8-15 fathoms.
2. Spicules : tables and buttons. Tables with low spire, ending in a flat circle of 8 to 12 short. Blunt teeth. Buttons variously developed from almost regular to twisted or irregular or incomplete, with large narrow holes (Text-fig. 10B) ... ... *H. (M.) leucospilota* Brandt
Distribution : From eastern coast of Africa to panamic regions, Indo-pacific. *Colour* : Faded reddish or brown, often paler on the ventral side. *Habitat* : shallow water to a few fathoms, rocky shore, tide pools and lagoons.

Subgenus **Lessonothuria** Deichmann 1958

This is represented here by a single species, *H.* (*L.*) *pardalis* Selenka, which can be identified by the following characters.

Spicules : tables, stout with round disc edge smooth or dentate, often incomplete spire low with 8 to 12 teeth, often reduced. In some individuals buttons in inner layer, numerous, composed of regular six holed buttons, in other almost all deformed, twisted, incomplete or with a few knobs on the surface (Pseudo-buttons) (Text-fig. 10C). ... ... *H.* (*L.*) *pardalis* Selenka
Distribution : Almost circum tropical. *Colour* : Extremely variable in colour. *Habitat*: From tide mark down to a few fathoms under rocks at low tides.

Subgenus **Holothuria** Linnaeus 1767

This is represented here by a single species, *H. prompta* Koehler and Vaney, which can be identified by the following diagnostic characters.

Spicules : tables and rods. Two types of tables are present. One has pillars very elongated, parallel, reunited one to the other by numerous transverse ridges and are crowned by well developed thorns. The other have very short pillars, oblique, reunited by only one layer of transverse ridge converging to one mass of thorns. All these tables have a base with rounded outline which has a central large hole, surrounded by eight peripheral holes. The pedicels have tables and some bent rods (Text-fig. 10D). ... ... *H. (H.) prompta* Koehler & Vaney

Distribution : Bay of Bengal and Andamans. *Colour* : Body wall transparent with pigmented spots of greenish black colour, more numerous and compact on the dorsal surface.

Subgenus **Theelothuria** Deichmann 1958

This is represented here by two species namely *H.* (*T.*) *spinifera* Theel and *H.* (*T.*) *kurti* Ludwig.

Key to the Indian species

1. Spicules : tables well developed, disc smooth sometimes multiarmed, spire moderate terminating in a cluster of small spines. Some tables modified with spire perfectly smooth and tapering to end in a point, giving the whole table a tact-like appearance, buttons either simple with irregular moderate sized knobs or modified into hollow fenestrated ellipsoids (Text-fig. 10E). ... ... *H.(T.) spinifera* Theel

   Distribution : Red sea, Persian gulf, Sri Lanka area and East Indies. *Colour* : Varying from black to yellow. *Habitat* : Burrowing forms rarely taken at low tides.

2. Spicules : tables, disc rounded, spire variable height certain pillars are elevated and terminate in a point. The pillars are united by transverse ridges. ... ... *H.(T.) kurti* Ludwig.

   Distribution : Red sea, Sri Lanka area and East Indies. *Colour* : Yellow.

Subgenus **Metriatyla** Rowe, 1969

This is represented here by two species namely *H.* (*M.*) *ocellata* Jaeger and *H.* (*M.*) *scabra* Jaeger.

Key to the Indian species

1. Spicules : tables with smooth, wavy disc with low spire ending with a crown with cluster of spines, buttons small with 3 pairs of holes (Text-fig. 10F). ... ... *H.*(*M.*) *ocellata* Jaeger

   Distribution : Red sea, Bay of Bengal, East Indies, North Australia and China and South Japan. *Colour* : Dorsal side brown with few darker spots ventral side whitish except on the median part, the colour is darker.

2. Spicules : tables well developed with smooth disc, spire of moderate height terminating in several small spines, buttons simple with moderate sized, irregularly arranged knobs, three to six pairs of relatively large holes (Text-fig. 10 G) ... ... *H.* (*M.*) *scabra* Jaeger

   Distribution : Indo-Pacific. *Colour* : Dorsal side dark (black) with yellow or white spots while ventral side is pale with minute dark spots. *Habitat* : Sandy or muddy bottom, Found burried partly or wholly or freely exposed in sandy or muddy bottom.

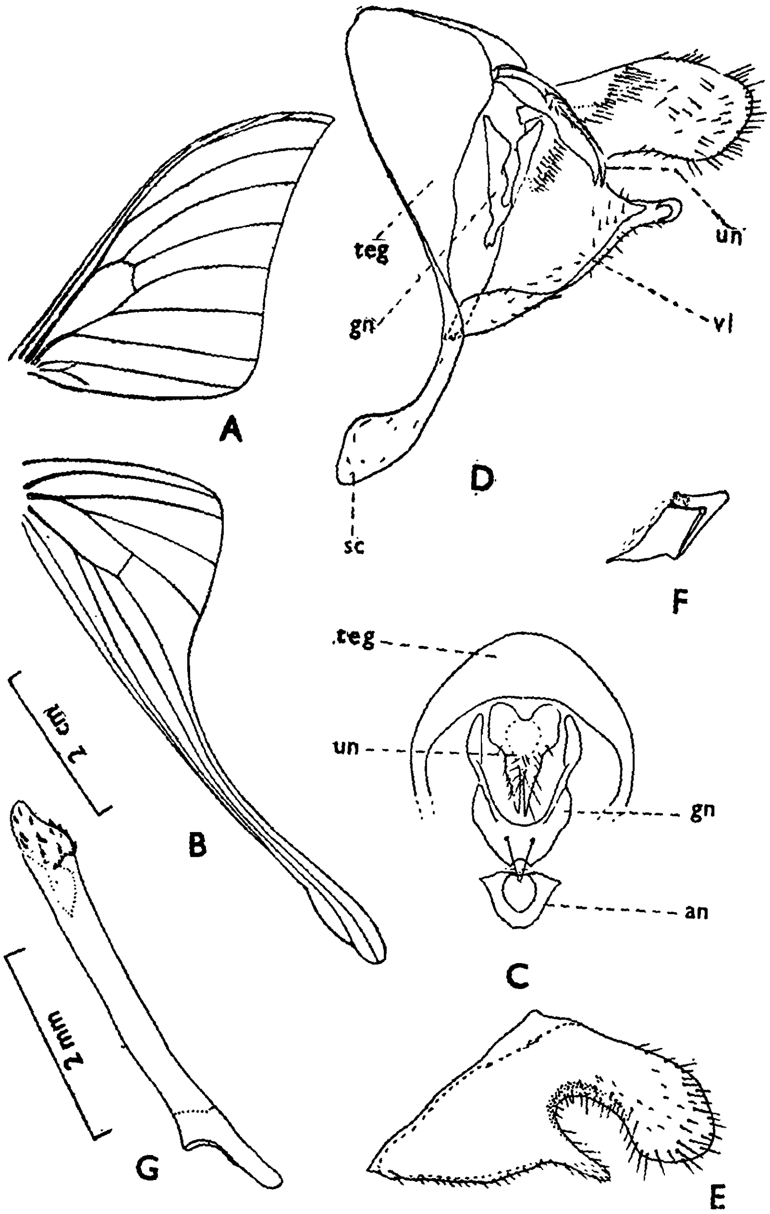
Subgenus **Microthele** Brandt 1835

This is represented here by a single species, *H.* (*M.*) *nobilis* (Selenka), which can be identified by the following distinguishing features.

Spicules : tables, stout with smooth squarish disc, spire of moderate height terminating in many spines. Buttons always hollow fenestrated ellipsoids (Text-fig. 10 H). ... ... *H.*(*M.*) *nobilis* (Selenka)

Distribution : Indo-Pacific.

Male.—Upperside : Frontal tufts pale yellow. Antennae pale brown, with their bases pale yellow. Labial palpi dark brown. Collar greyish-brown. Thorax and abdomen from pale yellowish to yellowish. Fore wings yellowish ; costal fascia brown, irrorated with grey up to basal two-thirds ; antemedial line indistinct, with only traces present across the middle of cell ; ocellus present on the discocellulars, the latter with black lunule, bluish scaling on inner side and pinkish suffused with fuscous on the outer side ; a reddish pink triangular spot



Text-fig. 5. *Proactias sinensis* ; A, fore wing venation ; B, hind wing venation ; C, inner view of genitalia shcwing uncus, gnathos and anellus ; D, lateral view of genitalia (without left valva) ; E, outer view of left valva ; F, lateral view of anellus ; G, aedeagus (A and B, of same mag ; C-F of same mag.).

below the costal fascia is continued with the outer line of ocellus ; postmedial line highly angulated, brown from costa to inner margin ; submarginal line faintly marked from subapical area to vein M_3 beyond which it is prominent and irrorated with grey and fuscous up to inner margin ; margin dark brown. Hind wing with the markings as on fore wing except for the absence of costal fascia, triangular spot and postmedial line ; submarginal line well developed from below subcosta to M_2 beyond which it is running close to margin up to the base of tail and irrorated with fuscous grey and pinkish scales. *Underside* : Thorax and abdomen as on upper side. Legs greyish fuscous, tinged with pink on the upper side.

Frons smooth. Antennae quadripectinate from base to apical seven segments which are bipectinate with shorter ramii ; ramii in general long and equal, the longest being equal to the length of six segments of the shaft at the middle. Labial palpi short and not projecting beyond the frontal tuft. Fore wing acute at apex, with the outer margin nearly straight. Legs with spurs, spines, claws and pulvilli as given in genus.

Venation.—Fore wing (Text-fig. 5, A) and hind wing (Text-fig. 5, B) mainly as given in *Actias selene.*

Male Genitalia (Text-fig. 5, C—G).—Uncus broadest at the base, gradually narrowing towards apex, the latter pointed and bifid ; the dorsal part only slightly raised and membranous. Gnathal arms narrow and incurved, meeting midventrally with a notch at the base. Tegumen broad and short, continued with vinculum, the latter narrow, ending in a moderately long saccus. Valva short and narrow, beset with setae, rather densely at the middle and sparsely near the ventral margin ; the mid ventral part deeply incised and produced outwardly into a well defined short and incurved sclerotised process ; anellus membranous mid-dorsally, the sides sclerotised. Aedeagus cylindrical throughout except at the apical area which is slightly broader, about twelve times as long as its width at the middle ; apical margin serrated on one side.

Wing expanse.—Males, 103-111 mm.

Material examined.—Two ♂♂ : INDIA : Arunachal Pradesh, Lohit Dist., Roing, 300m., 1 ♂, 6. iii. 1969, 1 ♂, 7. iii. 1969 (*S. K. Tandon* coll.).

Distribution.—INDIA ; BHUTAN ; and N. CHINA.

Remarks.—For remarks see under the genus *Proactias.*

Genus **Rhodinia** Staudinger

1872. *Rhodia* Moore, *Proc. zool. Soc. Lond.* : 578 (*nom.* preoccup.).
1892. *Rhodinia* Staudinger, In Rom., *Mem. sur les Lep.*, **6** : 327.
1933. *Rhodinia.* Schüssler, *Lepid. Cat.*, **56** : 87-88.

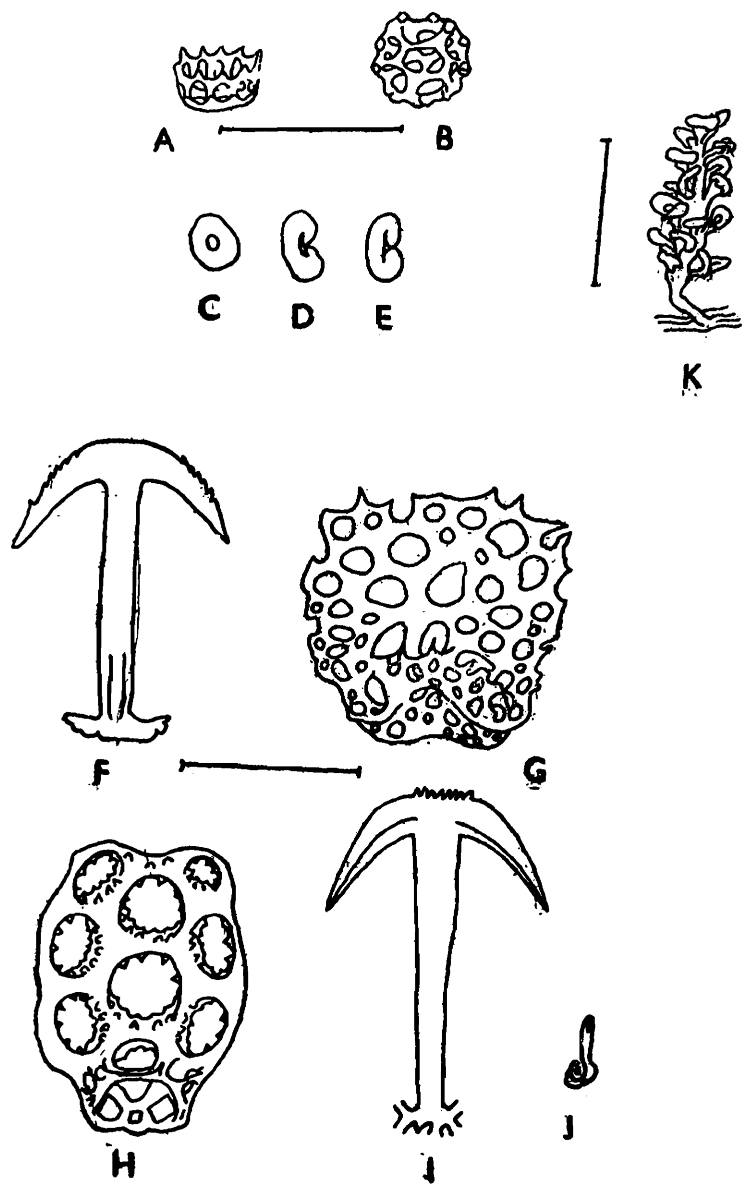
Type-species.—*Rhodia newara* Moore (1872) from NEPAL.

Frons flat at sides next to eyes, so that laterofrontal sutures distinct. Eyes small. Antennae quadripectinate in male, basal and distal ramii long and equal ; in female ramii unequal. Labial palpi three segmented, with the third segment being shortest. Fore tibia with the epiphysis reaching nearly three-fourths apically ; mid and hind tibiae with a pair of short terminal spurs, the latter bulbous or dilated basally, with the apical half chitinised and outer margins serrated ; tarsi with spines on 1-4 segments ; claws with well developed arolium and pulvilli.

Venation. —Fore wings with all the radials present ; vein R_5 stalked with M_1 and arising from beyond the upper angle of cell ; discocellulars incurved, obsolescent in middle. Hind wing with the upper discocellular absent, lower discocellular partly developed and incurved, *Distribution* : Bay of Bengal.

—Spicules : buttons swollen rather nodulated but smooth and perforated and small baskets (Text-fig. 11 D). ... ... *T. typica* (Theel)

Distribution : Bay of Bengal, China and South Japan.



Text-fig. 7. (A-E) Spicules of molpadids, (F-J) Spicules of Apodids, K—Ciliated funnel in *Polycheira rufescens*

Genus **Aslia** Rowe, 1970

This is represented here by one species, *Aslia forbesi* (Bell), which can be identified by the following diagnostic features.

Spicules : small regular four holed knobbed buttons and baskets (Text-fig. 11 E). *A. forbesi* (Bell)

Distribution : West India, Pakistan, Bay of Bengal.

Genus **Staurothyone** Clark. 1938

This is represented here by a single species, *S. rosacea* (Semper), which can be identified by the following characters.

Spicules : Cruciform plates and minute branched rods (Text-fig. 11 F). ... *S. rosacea* (Semper)

Distribution : South east Arabia, Sri Lanka area.

Genus **Pseudocolochirus** Deichmann, 1930

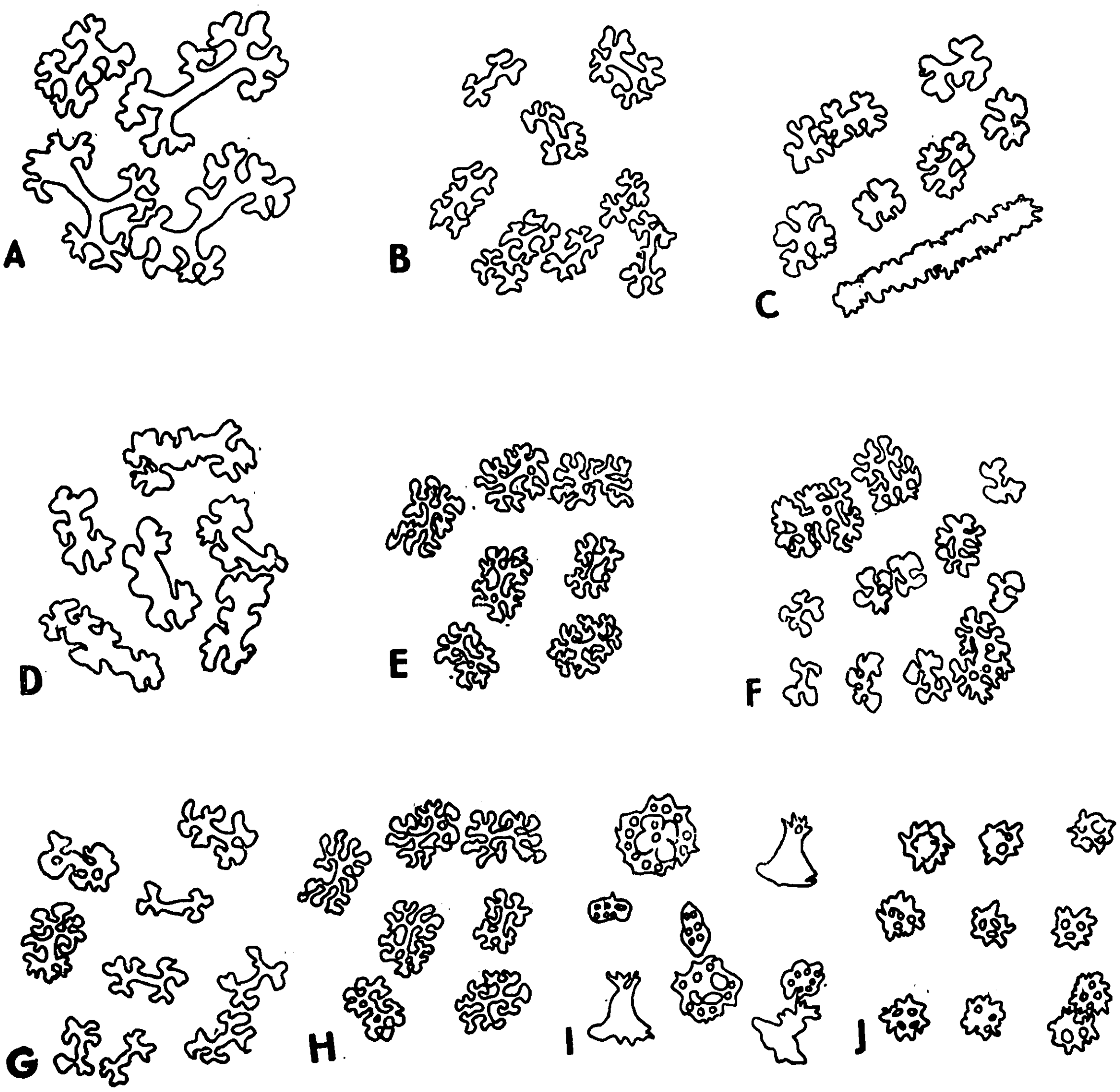
This is represented here by a single species, *P. violaceus* (Theel), which can be identified by the following features.

1. Small smooth swollen perforated plates (Text-fig. 5 C, D, E). ... ... *P. violaceus* (Theel)

Distribution : Bay of Bengal, East Indies, Philippine islands and China and S. Japan.

Genus **Pseudocnus** Panning, 1949

This is represented by a single species, *P. echinatus* (von Marenzeller), which can be identified by the following features.



Text-fig. 8. Spicules of : A—*Actinopyga echinites* (Jaeger), B—*A. lecanora* (Jaeger), C—*A. mauritiana*, (Quoy and Gaimard), D—*A. miliaris* (Quoy and Gaimard), E—*A. serratidens* Pearson, F—*Bohhadschia argus* Jaeger, G—*B. marmorata* Jaeger, H—*B. viliensis* (Semper), I—*Labidodemas rugosum* (Ludwig), J—*L. semperianum* (Selenka).

Spicules : in two layers, upper of fircone shaped smooth or knobbed buttons and lower :of more regularly rounded smooth or knobbed buttons with fewer holes (Text-fig. 5 F, G) ... ... ***P. echinatus*** **(Von Marenzeller)**

Distribution : Bay of Bengal (Orissa), China and South Japan, Tavoy and Mergui archipelago.

Genus **Leptopentacta** Clark, 1938

This is represented here by two species namely *L. bacilliformis* (Koehler and Vaney) and *L. javanicus* (Sluiter).

Key to the Indian species

Spicules : Oval plates which attains around 1 mm. in their greatest dimension. Small tubular spicules are also present (Text-fig. 11 G). ... ... ***L. bacilliformis*** **(Koehler and Vaney).**

Distribution : Bay of Bengal and Andaman Islands. *Colour* : Greyish yellow or maroon. *Habitat* : Coral area.

2. Spicules : smooth nodular buttons with usually only four holes and baskets (Text-fig. 11 H). ... ... ***L. javanicus*** **(Sluiter)**

Distribution : Bay of Bengal, East Indies.

Genus **Thorsonia** Heding, 1940

This is represented here by a single species, *T. investigatories* (Koehler and Vaney), which can be identified by the following features.

Spicules : Star shaped with four branches of which the central part is slightly raised. The arms show one or two series of perforations. At the centre two small projections are seen. The arms of spicules of pedicels atrophy and take the shape of perforated plate. Small spicules of 'rafter' shape with central part and extremities enlarged and perforated plates are also present (Text-fig. 11 I). ... ... ***T. investigatories*** **(Koehler and Vaney)**

Distribution : Bay of Bengal and mouth of Hugli.

Genus **Stolus** Selenka, 1867

This is represented here by three species namely *S. rapax* (Koehler and Vaney), *S. buccalis* (Stimpson) and *S. conjugens* (Semper).

Key to the Indian species

Spicules : perforated round plates and incurved tables in pedicels whose centre supports two pillars. ... ... ***S. rapax*** **(Koehler and Vaney)**

Distribution : Bay of Bengal (Hugli),

Colour : Body whitish and pedicels yellow.

2. Spicules : small nodular buttons with many holes (Text-fig. IIJ) ... ... ***S. buccalis*** **(Stimpson)**

Distribution : Indo-pacific.

3. Spicules : nodular buttons with few holes (Text-fig. 12k) ... ... ***S. conjugens*** **(Semper)**

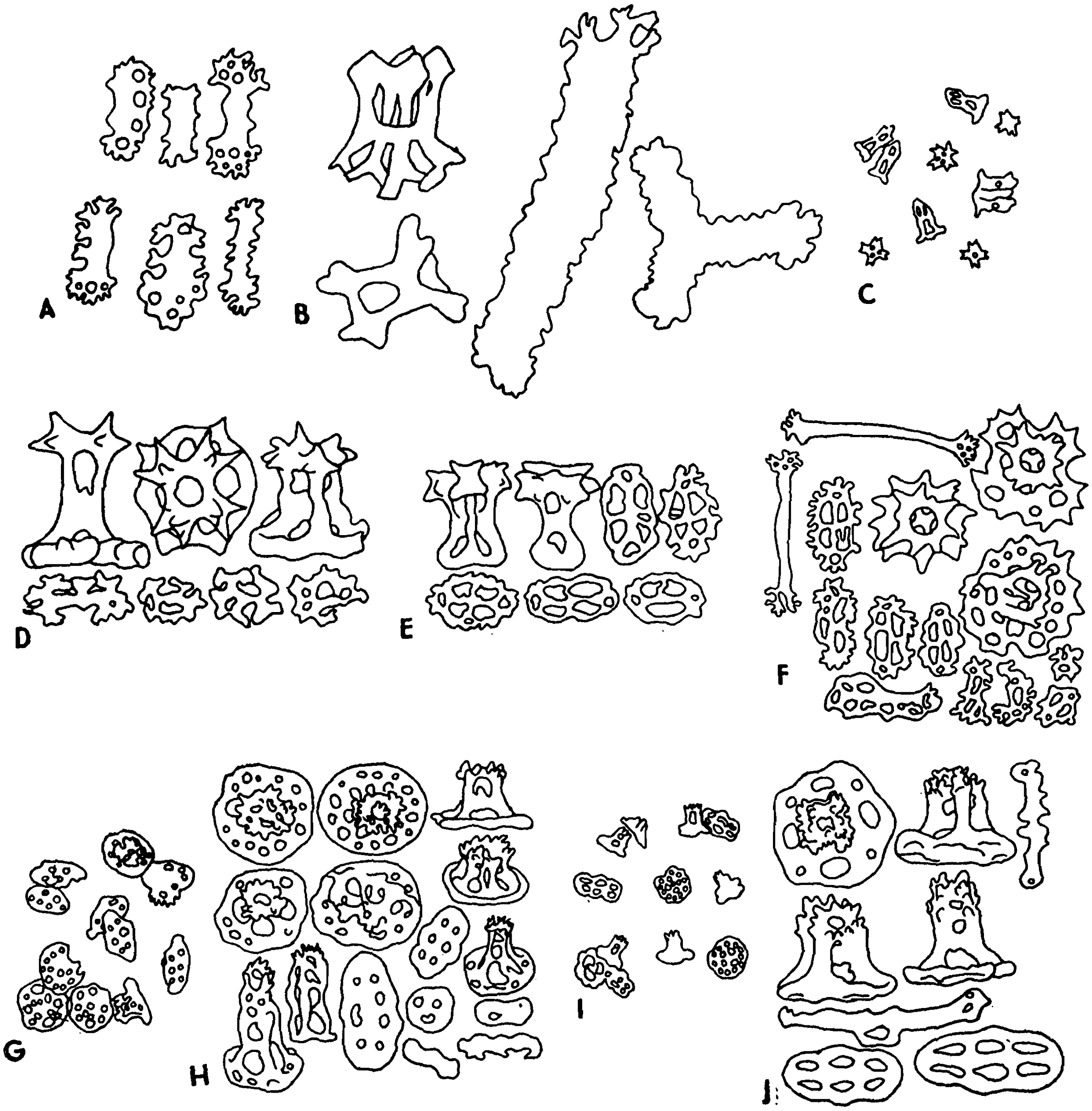
Distribution : West India, Pakistan, Sri Lanka area and Philippine islands.

Genus **Hemithyone** Pawson, 1963

This is represented by a single species, *H. semperi* (Bell), which can be identified by the following diagnostic features.

Spicules : Fenestrated ellipsoids and perforated fusiform plates (Text-fig. 12B) ... ... *H. semperi* (Bell)

Distribution ; E. Africa and Madagascar, West India and Pakistan, Sri Lanka area, Bay of Bengal, East Indies and North Australia.



Text-fig. 9. Spicules of : A—*Holothuria* (*Selenkothuria*) *erinaceus* Semper, B—*H.* (*Semperothuria*) *cinerascens* (Brandt), C—*H.* (*Semperothuria*) *imitans* Ludwing, D—*H.* (*Halodeima*) *atra* Jager, E—*H.* (*Halodeima*) *edulis* Lesson, F—*H.*—(*Acanthotrapeza*) *pyxis* Selenka, G—*H.* (*Platyperona*) *difficilis* Semper, H—*H.* (*Thymiosycia*) *arenicola* Semper, I—*H.* (*Thymiosycia*) *hilla* Lesson, J—*H.* (*Thymiosycia*) *impatiens* Forskal.

Colour : Whitish to light brown, tube feet slightly darker.

Habitat : Sandy and muddy—13 metres depth.

Family PHYLLOPHORIDAE

This family is represented here by five genera namely *Actinocucumis* Ludwing, 1875; *Cladolabes* Brandt, 1836; *Ohshimella* Heding and Panning, 1954; *Afrocucumis* Deichmann, 1944 and *Phyllophorus* Grube, 1840.

Key to the Indian genera

1. Spicules: contracted, approximately figure eight-shaped hollow fenestrated ellipsoids (Text-fig. 6C) and irregular tables with strong, aften eccentric four pillared spire, rosette-like plates are also present in the pedicels ... *Aotinocucumis* Ludwig, 1875

2. Spicules: rods derived from tables, with small disc and enormous spire ending in a single spine (Text-fig. 6a) or a cluster of spines (Text-fig. 6b), tables in the interovert with larger disc and shorter spire of two pillars, branched or delicate simple rods present in the interovert and tentacles. Calcareous ring simple, seperate pieces sometimes distinct, no posterior bifurcate prolongations on the radial plates (Text-fig. 4 G, H) ... *Cladolabes* Brandt, 1835

3. Spicules: tables absent. Spinose, often cruciform rods with spines usually around the middle and at each end of the rod. Compact branched rods also present in the tentacles. Calcareous ring with short or long bifurcate prolongations on the posterior margin of the radial plates having apparently fused along their lengths, radial and inter radial plants often composed of few large or many small pieces giving the appearance of a mosaic pattern (Text-fig. 4 I, J.) ... ... *Ohshimella* Heding and Panning 1954

— Spicules: thick plates, simple and branched rods; large lenticulate perforated plates, perforations almost or completly obliterated (Text-fig. 6E) *Afrocucumis* Deichmann 1944

— Spicules: four pillared tables or derivatives of these. ... ... *Phyllophorus* Grube, 1840

Genus **Actinocucumis** Ludwig, 1875

This is represented here by a single species, *A. typicus* Ludwig, which can be identified by the following characters.

Spicules: Eight shaped hollow fenastrated ellipsoids and irregular tables with strong four pillared spire, rosette-like plates also present in the pedicels (Text-fig. 12C) ... ... *A. typicus* Ludwig

Distribution: West India, Pakistan, Sri Lanka area, Bay of Bengal East Indies, North Australia and China and South Japan.

Genus **Cladolabes** Brandt 1835

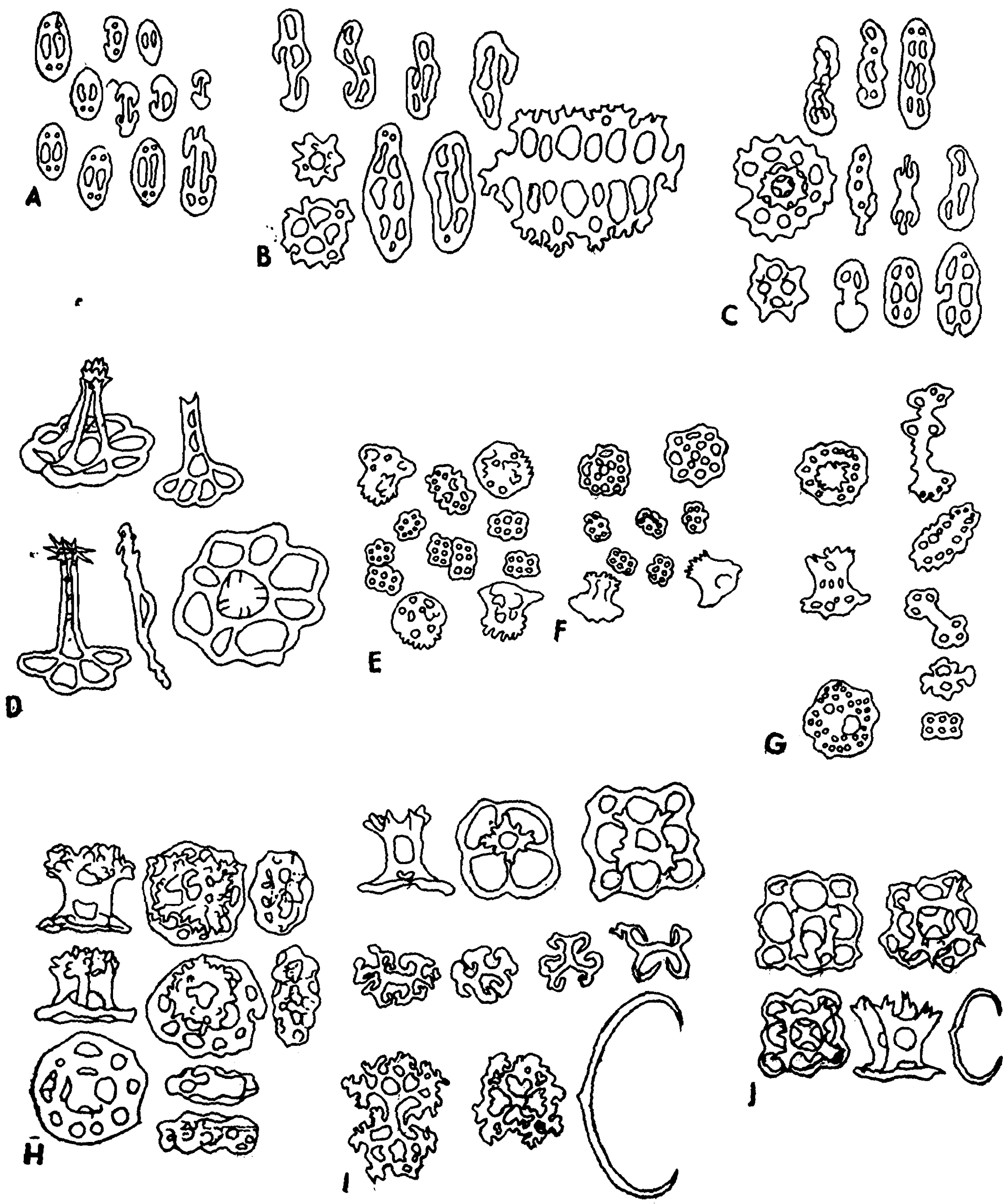
This is represented here by a single species, *C. acicula* (Semper), which can be identified by the following characters.

Spicules: rods derived from tables, with small disc and enormous spire ending in a single spine (Text-fig. 12D) ... ... *C. acicula* (Semper)

Distribution: Mascarene islands, Bay of Bengal, East Indies, North Australia and Phillippine islands

Genus **Ohshimella** Heding and Panning, 1954

This is represented here by a single species, *O. ehrenbergi* (Selenka), which can be identified by the following features.



Text-fig. 10. Spicules of : A—*Hololhuria* (*Mertensiothuria*) *fuscocinerea* Jaeger, B.—*H.* (*Mertensiothuria*) *leucopilota* Brandt, C—*H.* (*Lessonothuria*) *pardalis* Selenka, D—*H.* (*Holothuria*) *prompta* Koehler and Vaney, E—*H.* (*Theelothuria*) *spinifera* Theel, F—*H.* (*Metriatyla*) *ocellata* Jaeger, G—*H.* (*Metriatyla*) *scabra* Jaeger, H—*H.* (*Microthele*) *nobilis* (Selenka), I—*Stichopus chloronotus* Brandt, J—*S. variegatus* Semper.

Spicules : Spinose, often cruciform rods with spines usually around the middle and each end of the rod. Compact branched rods in the tentalces (Text-fig. 12E) ... ... *O. ehrenbergi* (Selenka)

Distribution : Indo-pacific.

Genus **Afrocucumis** Deichmann, 1944

This is represented here by a single species, *A. africana* (Semper), which can be identified by the following diagnostic features.

Spicules : Large lenticulate perforated plates, perforations almost or completly obliterated. The tube feet has big rods the ends of which have holes (Text-fig. 12F) ... ... *A. africana* (Semper)

Distribution : Islands of West Indian Ocean, Mascarene islands, E. Africa, Madagascar, Bay of Bengal, East Indies, N. Australia, and China and South Japan, *Colour* : reddish violet.

Genus **Phyllophorus** Grube, 1840

This is represented here by two sub genera namely ; *Urodemella* Deichmann, 1944 and *Phyllophorella* Heding and Panning, 1954.

Key to the subgenera

Spicules : reduced tables or thorny plates(Text-fig. 6G). ... ... *Urodemella* Deichman, 1944

Spicules ; four pillared tables with low spire, the four pillars joined by only one bridge or poorly developed. ... ... *Phyllaphorella* Heding & Panning, 1954

Subgenus **Urodemella** Deichmann, 1944

This is represented here by a single species, *P. (Urodemella) brocki* (Ludwig), which can be identified by the following characters.

1. Spicules : tables, the disc has only four holes aud its edge carries long spines. The crown is extensively folded and have spines (Text-fig. 12G). ... *P.* (*Urodemella*) *brocki* Ludwig

Distribution : Sri Lanka, East Indies, N. Australia and Philippine island

Subgenus **Phyllophorella** Heding & Panning, 1954

This is represented here by a single species, *P.* (*Phyllophorella*) *parvipeds* H. L. Clark, which can be identified by the following distinguishing features.

Spicules : tables, supporting plates, miliary granules and end plates. Margins of disc wavy to spinous, spire short and supported by four rods ; supporting plates found in the tuet feci, having wavy to spinous margins and are provided with numerous holes, some are dumb-bell shaped ; miliary granules are oval in shape with a rough surface ; end plates round with numerous holes and found in the tip of the tube feet (Text-fig. 12H) ... ... *P.* (*Phyllophorella*) *parvipeds* H. L. Clark

Distribution : Sri Lanka area, Bay of Bengal, East Indies and North Australia.

Order MOLPADIDA

This is represented here by two families namely Molpadidae and Caudinidae.

Key to the families of the order MOLPADIDA

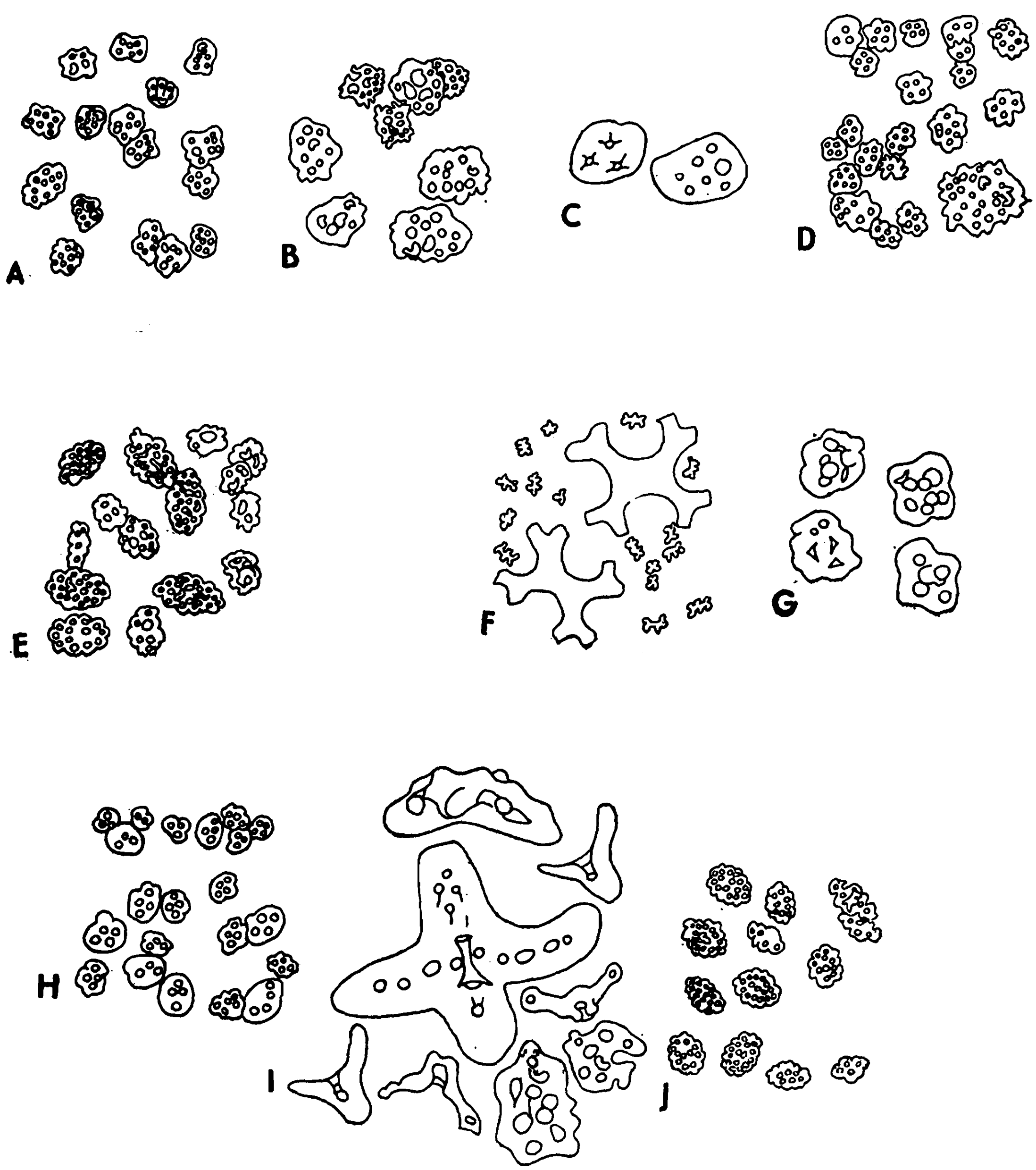
Tables and Modified anchors. ... ... MOLPADIIDAE

Cups, perforated plates often doughnut like with only one hole or irregular rods. ... ., CAUDINIDAE

Family MOLPADIIDAE

This is represented by a single genus, *Molpadia* Cuvier, 1817 which can be identified by the following features.

Spicules : irregular tables and anchors fusiform or fenestrated plates phosphotic bodies present. ... ... *Molpadia* Cuvier, 1817



Text-fig. 11. Spicules of : A—*Pentacta cucumis* (Semper), B—*P. quadrangularis* (Lesson), C—*Trachythyone alcocki* (Koehler and Vaney), D—*T. typica* (Theel), E—*Aslia forbesi* (Bell), F—*Staurothyone rosacea* (Semper), G—*Leptopentacta bacilliformis* (Koehler and Vaney), H—*L. javanicus* (Sluiter), I—*Thorsonia investigatories* (Koehler and Vaney), J—*Stolus buccalis* (Stimpson).

Genus **Molpadia** Cuvier, 1817

This is represented by a single species, *M. australis* (Semper), which can be identified by the following characters.

Spicules : Anchors and fusiform plates ... ... *M. australis* (Semper)

Distribution : Bay of Bengal (Hugli), Andaman Islands.

Colour : Marron.

Habitat : Coral area.

Family CAUDINIDAE

This is represented by two genera namely *Acaudina* H. L. Clark, 1907 and *Paracaudina* Heding, 1931.

Key to Indian genera

1. Smooth or spinose thick plates usually with one or few holes. ... ... *Acaudina* H. L. Clark, 1907
2. Spicules : Cups, perforated plates ; often three dimensional (Text-fig. 7A) and irregular rods. ... ... *Paracaudina* Heding

Genus **Acaudina** H. L. Clark, 1907

This is represented by a single species, *A. molpadioides* (Semper), which can be identified by the following features.

Spicules : Smooth or spinose thick plates with one or few holes (Text-fig. 13A) ... ... *A. molpadioides* (Semper)

Distribution : Sri Lanka area and Bay of Bengal.

Colour : Variable brown or marron.

Genus **Paracaudina** Heding, 1931

This is represented here by a single species, *P. chilensis* (Muller), which can be identified by the following characters.

Spicules : Cups, perforated plates, often three dimensional and irregular rods. ... ... *P. chilensis* (J. Muller)

Distribution : Bay of Bengal, N. Australia and China and South Japan.

Order APODIDA

This is represented here by two families namely : Synaptidae and Chiridotidae.

Key to the Indian families

1. Spicules : anchors and anchor-plates (Text-fig. 1L, K), rods and granules (Text-fig. 1M) never wheels or sigmoid particles. ... ... SYNAPTIDAE

—Spicules ; wheels with not more than six spokes (Text-fig. 1J) sigmoid bodies (Text-fig. 8C) no anchors or anchor-plates. ... ... CHIRIDOTIDAE

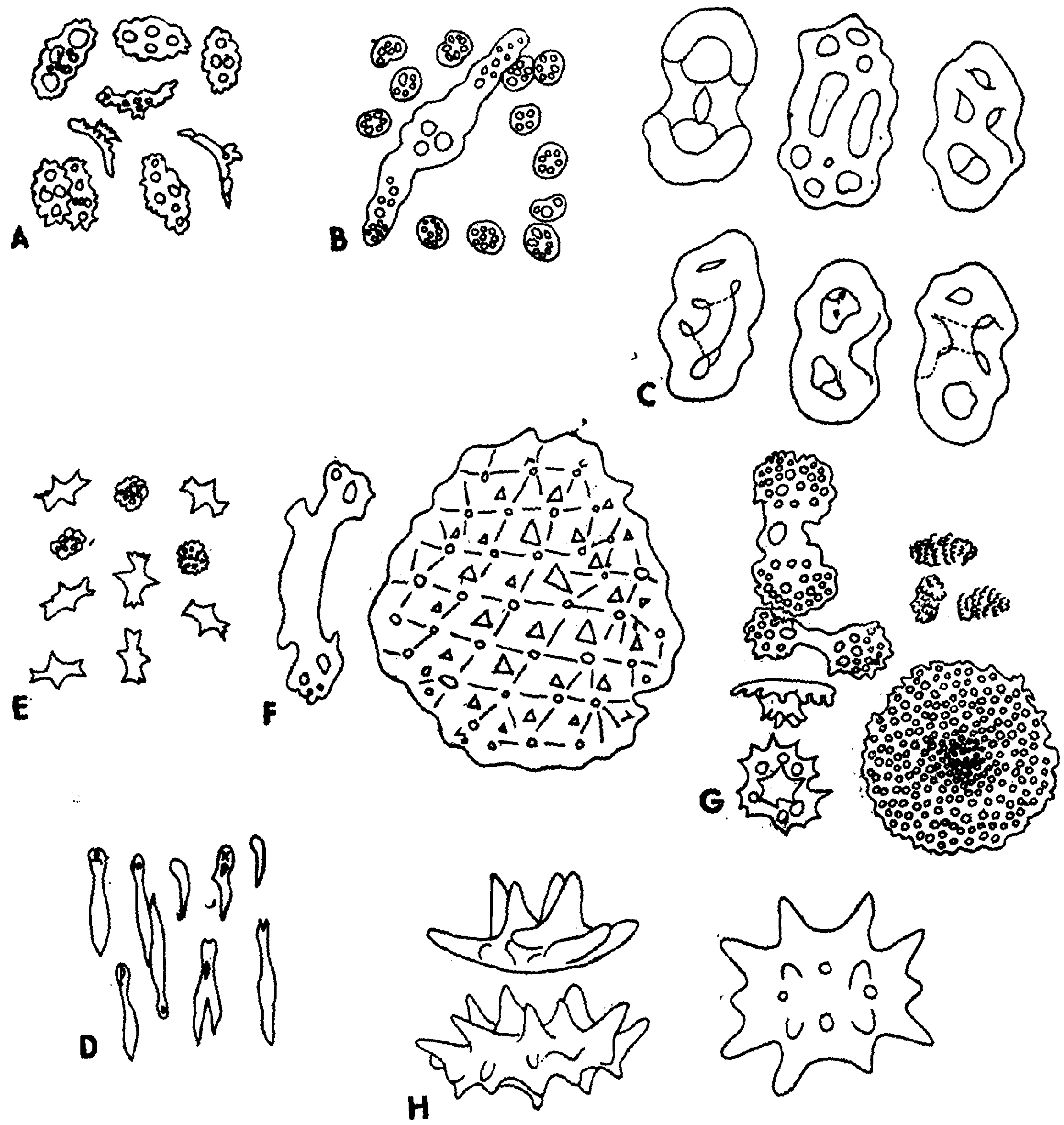
Family **Synaptidae**

This is represented here by four genera namely *Opheodesoma* Fisher, 1907 ; *Synapta* Eschsholty, 1829 ; *Synaptula* Orsted, 1849 and *Protankyra* Ostergren, 1898.

Key to the Indian genera

1. Spicules : large anchors, anchor plates sub rectangular and broad posteriorly with numerous smooth holes. ... ... *Synapta* Eschscholtz, 1829,
2. Spicules : anchors and anchor plates. Anchor plates abruptly contracted posteriorly thus lacking a large smooth hole on each side (Text-fig. 7H) ... ... *Opheodesoma* Fisher, 1907.

3. Spicules : Miliary granules when present having the form of curved knobbed rods (Text-fig, 11I) never resembling irregularly dichotomously branched granules. ... ... *Synaptula* Orsted, 1849
4. Spicules : anchor plates ovate and irregular with numerous, small, smooth or toothed holes (Text-fiig. 7A) not allowed into a handle posteriorly. ... ... *Protankyra* Ostergren, 1898



Text-fig. 12. A—*S. conjugens* (Semper), B—*Hemithyone semperi* Bell, C—*Actinocucumis typicus* Ludwig, D—*Cladolabes acicula* (Semper), E—*Ohshimella ehrenbergi* (Selenka), F—*Afrocucumis africana* (Semper), G—*Phyllophorus* (*Phyllophorella*) *parvipeds* H. L. Clark, H—*Phyllophorus* (*Urodemella*) *brocki* Ludwig.

Genus **Opheodesoma** Fisher, 1907

This is represented here by a single species, *O. grisea* (Semper), which can be identified by the following characters.

Spicules : anchors and anchor plates. Anchor plates abruptly contracted posteriorly thus lacking a large smooth hole on each side stalk of anchors irregularly branched (Text-fig. 13 B) ... ... *O. grisea* (Semper)

Distribution : E. Africa, Madagascar, Red Sea, S. E. Arabia, Bay of Bengal, E. Indies, North Australia, Philippine Islands and Hawaiian Islands.

Colour : Rose colour.

Genus **Synapta** Eschsholtz, 1829

This is represented here by a single species, *S. maculata* (Chamisno and Eysenhardt), which can be identified by the following specific features.

Spicules : Anchors and anchor plates, both very large, anchor plates broad posteriorly with numerous smooth holes (Text-fiig. 13C). ... ... *S. maculata* (Chamisno & Eysenhardt)

Distribution : Indo-pacific

Genus **Synaptula** Orsted, 1849

This is represented here by three species namely *S. recta* Semper, *S. striata* (Sluiter) and *S. varians* (Nair).

Key to the Indian species

1. Spicules : anchors, anchor plates and miliary granules. Miliary granules are in the form of curved knobbed rods never resembling irregularly dichotomously branched granules (Text-fig. 13 D). ... ... *S. recta* (Semper)

   Disiribution : Red sea, Sri Lanka area, Bay of Bengal, East Indies, N. Australia, Philippine islands and S. Pacific islands.

2. Spicules : anchors and anchor plates. The stalk of the anchor was always more or less incurved. ... ... *S. striata* (Sluiter).

   Distribution : Sri Lanka area, Bay of Bengal, East Indies and Mergui Archipelago. *Colour* : Yellowish brown.

3. Spicules : anchors, anchor plates supporting rods and miliary granules. The anchors are bilaterally symmetrical, minute teeth are present or the entire outer side of the anchor stock. The posterior end of the shaft together with the anchor stalk is slightly curved upwards. Anchors with double arms one below the other are very common. The anchor plates are symmetrical and oval in shape. The anterior end is broader and provided with six large toothed holes of uniform size. Below these holes are three smaller ones. The posterior end is provided with three very small holes of which the central one is larger. The miliary granules are irregular. ... ... *S. varians* (Nair)

   Distribution : Bay of Bengal common in Madras coast. *Colour* : Yellow. *Habitat* : Sandy and muddy 5—10 fathoms.

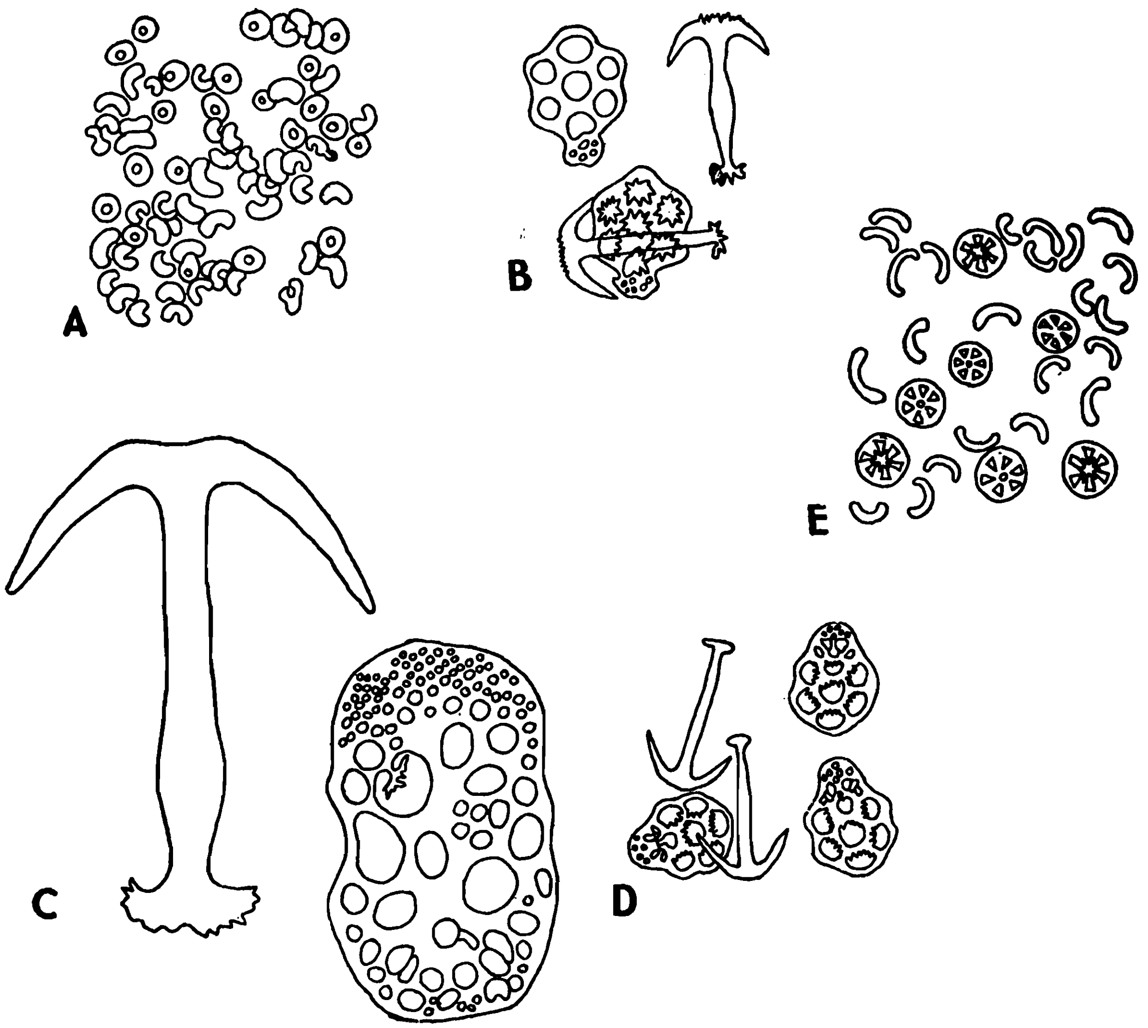
Genus **Protankyra** Orsted, 1869

This is represented by a single species, *P. pseudodigitata* (Semper), which can be identified by the following features.

Spicules ; Anchors, anchor plates and miliary granules. The anchor plates show some notable variations in size. The anchors have denticulations on almost all their length, The miliary granules are in the form of short stick rounded at their extremities and sometimes bifurcated. ... ... *P. pseudodigitata* (Semper)

Distribution : Red sea, Persian gulf, Bay of Bengal, East Indies and Philippine Islands.

Colour : White.



Text-fig. 13. Holothurian spicules : A—*Acaudina molpadioides* (Semper), B—*Opheodesoma grisea* (Semper), C—*Synapta maculata* (Chamisno and Eysenhardt), D—*Synaptula recta* Semper, E—*Polycheira rufescens* (Brandt).

Family CHIRIDOTIDAE

This is represented here by a single genus, *Polycheira* H. L. Clark, 1907, which can be identified by the following distinguishing characters.

Spicules : Wheels present in small papillae, no sigmoid bodies present. ... ... *Polycheira* H. L. Clark, 1907

Genus **Polycheira** H. L. Clark, 1907

This is represented here by a single species, *P. rufescens* (Brandt), which can be identified by the following distinguishing features :

Spicules : wheels (Text-fig. 13E), no anchor or anchor plates. Wheels present in small papillae ; no sigmoid bodies present. Ciliated funnels always collected into stalked cluster which are often quite large (Text-fig. 7 K) ... ... *P. rufescens* (Brand)

Distribution : Islands of West Indian ocean, E. Africa, Madagaskar, Sri Lanka area, Bay of Bengal, E. Indies, North Australia, Philippine islands and China and S. Japan.

PART II

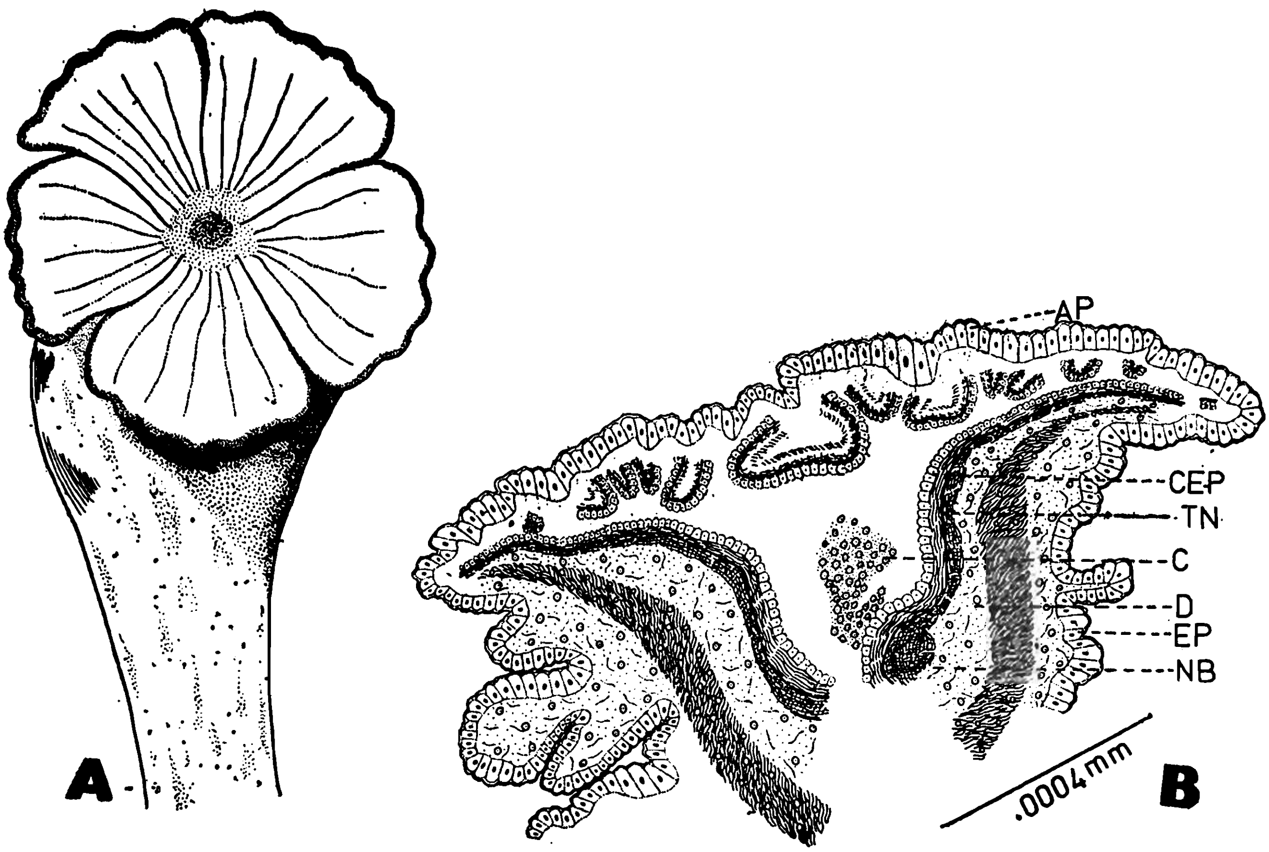
HOLOTHURIA (METRIATYLA) SCABRA JAEGER

I. EXTERNAL CHARACTERS

The body of *Holothuria Metriatyla scabra* Jaeger is elongated and cylinderical with the mouth at the antero-ventral end, surrounded by a ring of twenty peltate tentacles, and an anus at the postero-dorsal end. The total length ranges from 10 to 30 cm ; the body weight ranges from 25 to 2000 gm. It habitually lies on one side which is differentiated as the ventral creeping surface or sole. This surface is rough and bears locomotary podia. The dorsal surface is smooth, has fewer number of podia and is dark with yellow or white spots at irregular intervals, while the ventral side is pale with minute dots. (Pl.I, Figs. 1 & 2). The shape of the body is like that of a cucumber and hence the popular name the 'sea cucumber'.

The different type of tentacles of holothurians are recorded by Hyman (1955) and Boolootian (1966). The tentacles contain extensions of the water vascular system as branches from the radial canals. These are twenty in number. They vary from 1-15 cm. in length in the extended condition and all of them are of the same size. The shape of the tentacle is peltate, with central short stalk giving off five short horizontal branches (Text-fig. 14A). The tentacles are retractile and can be withdrawn into the mouth and are devoid of calcarious deposits. They are employed in showelling the muddy substratum on which the animal lies into the mouth.

Structure of the tentacle.—Externally there is a very thin cuticle, below which lies the dermis consisting of tall cells with large nuclei (Text-figs. 14B & 15). Glandular cells with secretory granules are present among the epithelial cells. At the surface of the tentacle, the epithelial cells from the adhesive papillae, the cells of which are compactly arranged and are tall with prominent nuclei. Glandular cells are more in this region. Below the epidermis is the dermis layer, composed of very soft and loose strands of connective tissue in the form of a net. Thick sensory fibres are distributed among the meshwork of connective tissue strands. Few coelomocytes are present in the dermis. Following the dermis is a very thick band of connective tissue which is the compact and well pronounced part of the tentacular wall. Vacuoles are present in the connective tissue. Beneath the connective tissue is a thin layer of dermis followed by nerve plexes. There is some space between the connective tissue and nerve plexes. A thick tentacular nerve is present beneath



Text-fig. 14. A—Tentacle, B—L. S. of a tentacle.

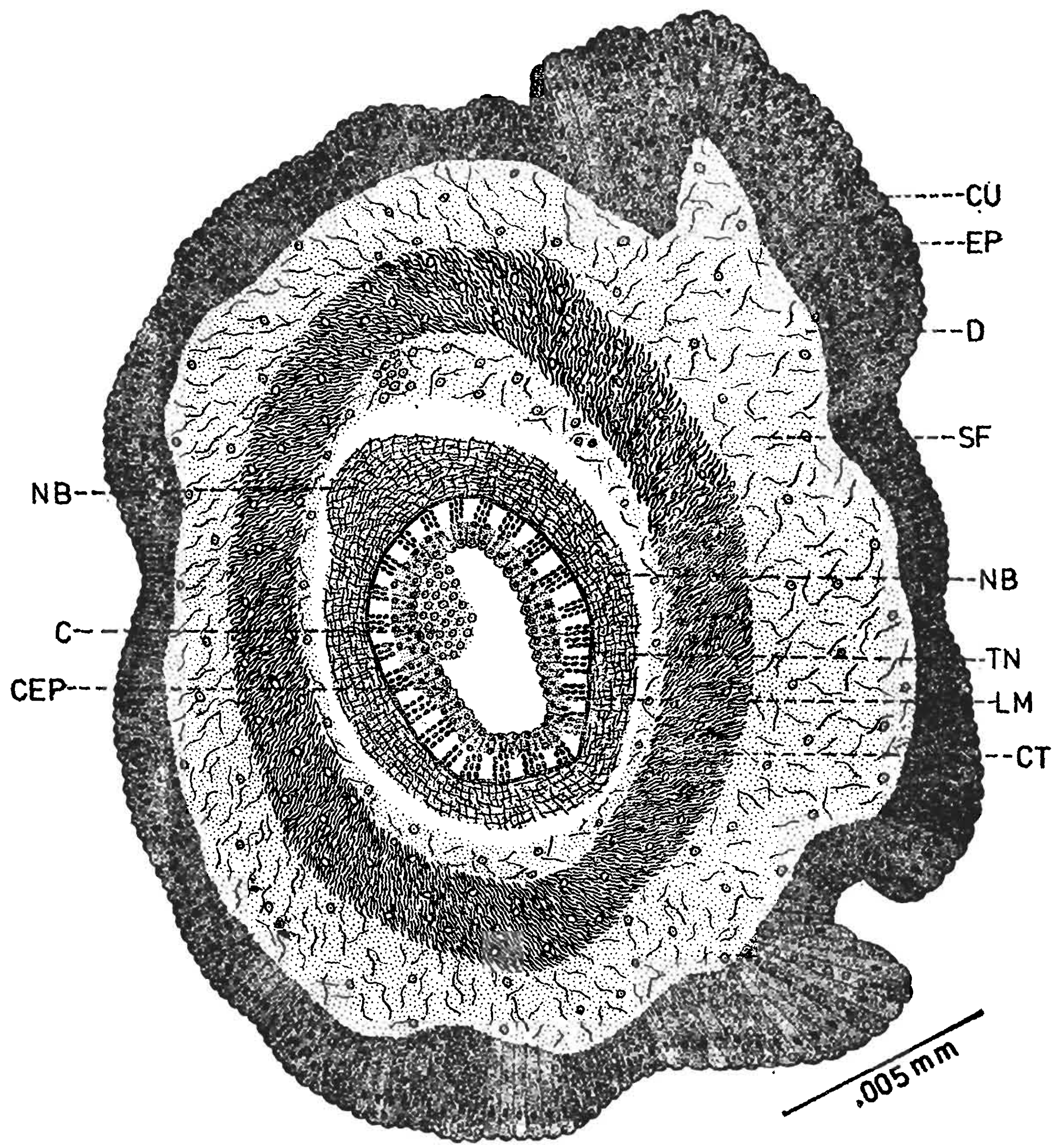
the nerve plexes. The tentacular nerve at the base of the tentacle is thickened to form a nerve band. The tentacular nerve and nerve plexes are closely associated. Following the tentacular nerve is the longitudinal muscle layer which at the base of tentacle is very thick. The lumen of the tentacle is called tentacular canal which is bordered by a thin layer of coelomic epithelium, the cells of which are sparsely distributed. Coelomocytes are present both in the coelomic epithelial cells and in the fluid which occupies the tentacular canal.

Structure of the body wall.—The histology of the holothurian body wall, described in detail by Hamann (1883), has been reviewed by Hyman (1955). The structure of the body wall of *Stichopus tremulus* (Gun) and *S. badionotus* is reported by Rollefsen (1965) and Cowden (1968) respectively. The fine structure of body wall of *S. japonicus* was studied by Kawaguti (1966). Recently, the structure of body wall of *Thyone briareus* is reported by David *et al.* (1973).

The body wall of *Holothuria scabra* is thick, tough, leathery and slimy. Podia are present abundantly in the ventral surface. These are hollow projections of the body wall.

The body wall surface is covered with a thin cuticle composed of structureless dead cells beneath which is found the epidermis (Text-fig. 16). The epidermis consists of clumped cuboidal or oval epithelial cells with spherical, deeply staining nucleus. Empty vesicles and few gland cells with granular inclusions are present among the epidermal cells. These may be the mucous secreting glands and the vesicles may be mucous vesicles. There is neither a basement membrane nor a compact layer which demarcates the epidermis from the underlying dermis.

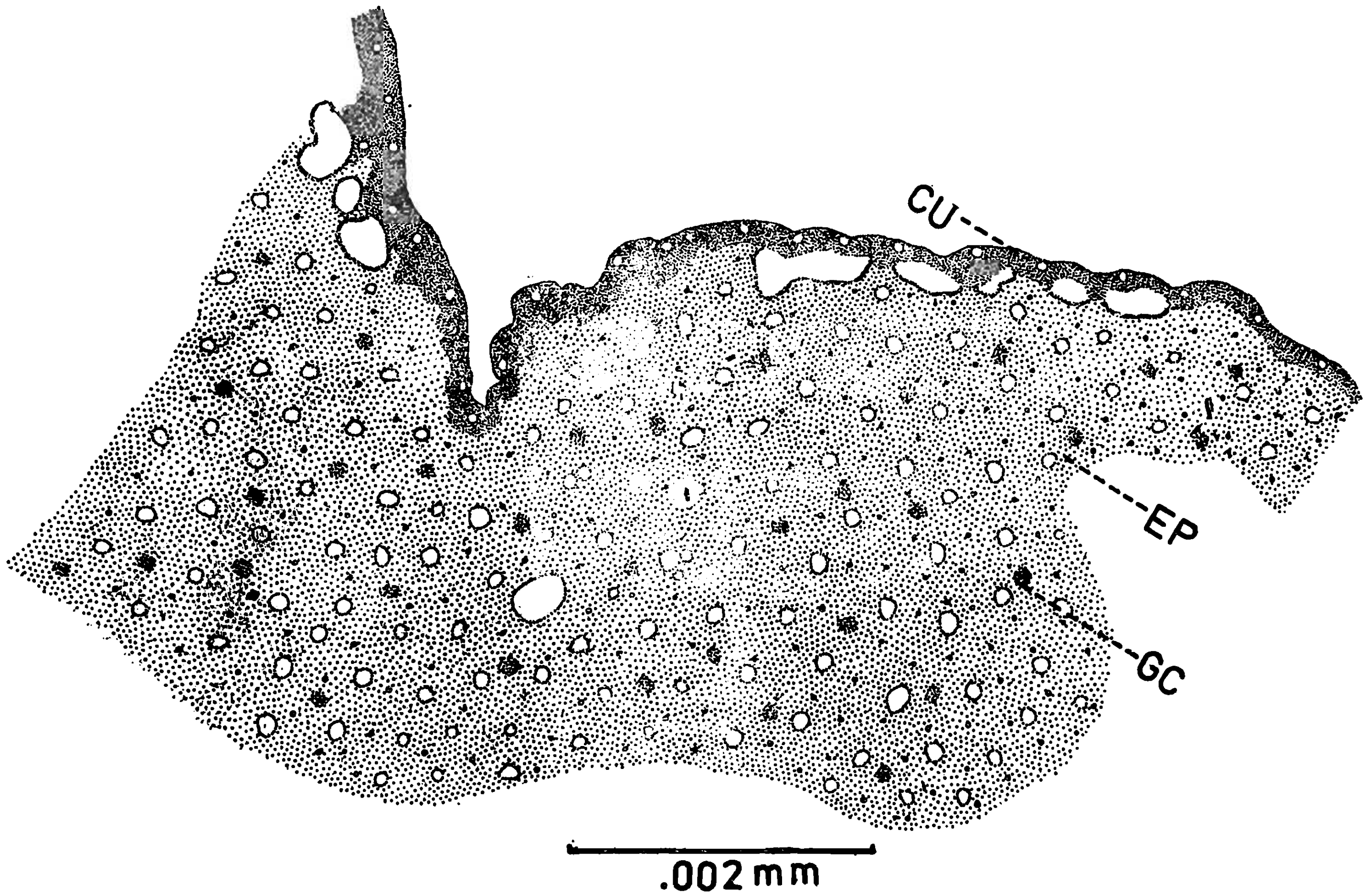
The dermis constitutes the major portion of the thickness of the body wall (Text-figs. 17 & 18). The dermis consists of two regions, an outer layer composed of strands and an



Text-fig. 15. T. S. of a tentacle.

inner region with more closely packed thick connective tissue fibres. There are numerous empty spaces which enclose the endoskeletal ossicles. Pigment granules, to which the body owes its colouration, occur as free granules both in the epidermis and dermis among the meshwork of connective tissue strands. Sensory neurons are distributed throughout the dermis. At the area of radial canals, there is a space between the dermis and circular muscle layer known as haemal lacunae. Amoebocytes are seen in this sinus (Text-fig. 17).

Following the dermis is a layer of undulated compact circular muscle fibres closely attached to the dermis. From the circular muscle layer thin strands of muscles in the form of supporting strands emerge out and traverse through the dermis and end in the epidermal

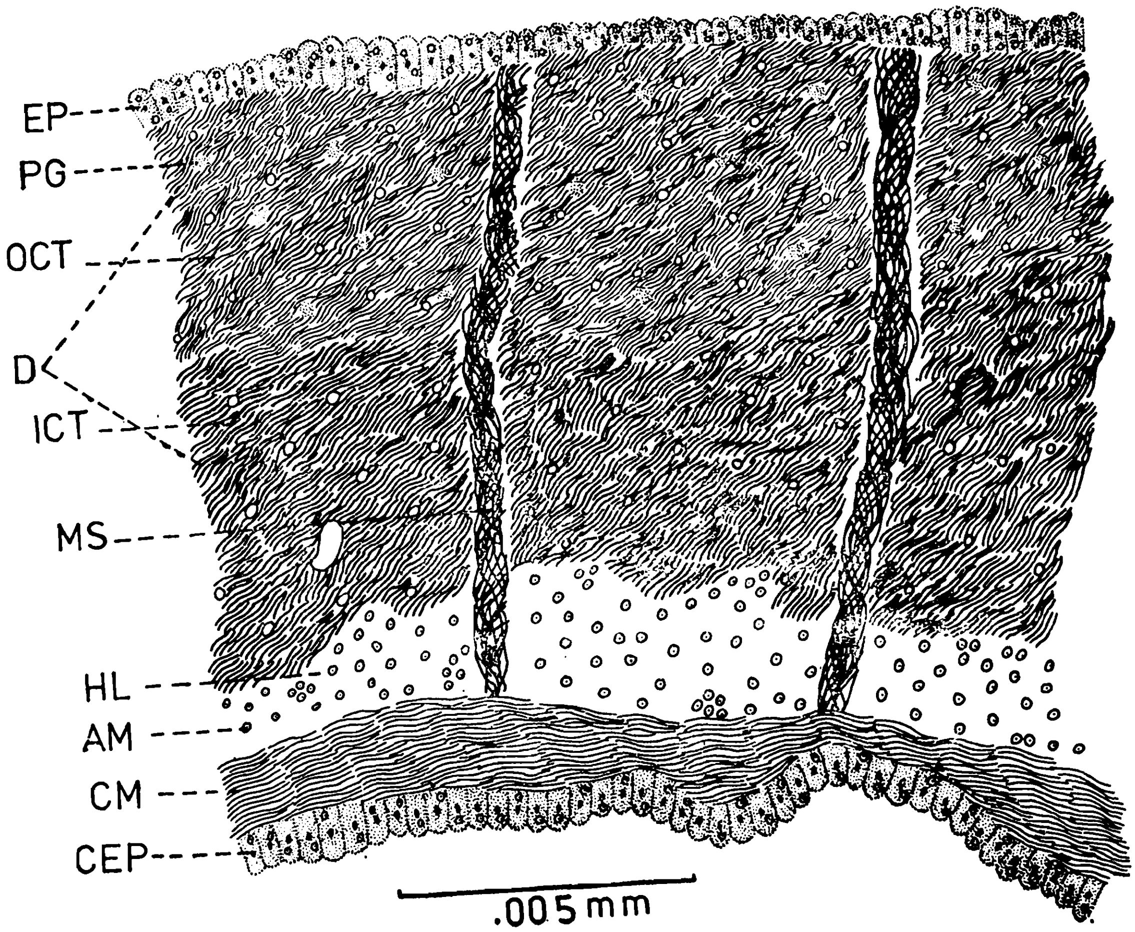


Text-fig. 16. Epidermis of the body wall.

layer of the body wall (Text-fig. 17). These strands may help in the compression and relaxation of the body wall. Beneath the circular muscle layer bordering the coelomic cavity lies the thin layer of coelomic epithelium, where the cells are loosely distributed in the soft connective tissue. Coelomocytes are seen in coelomic epithelium.

From the coelomic cavity glandular structures in the form of a canal penetrates into the dermis through the coelomic epithelium and circular muscle layer (Text-fig. 18). The end part of the glandular structure resembles an expanded pouch in which a number of coelomocytes are present. At certain places the pouch like portion lacks a wall. It seems possible that the coelomocytes could have entered the pouches through such structures.

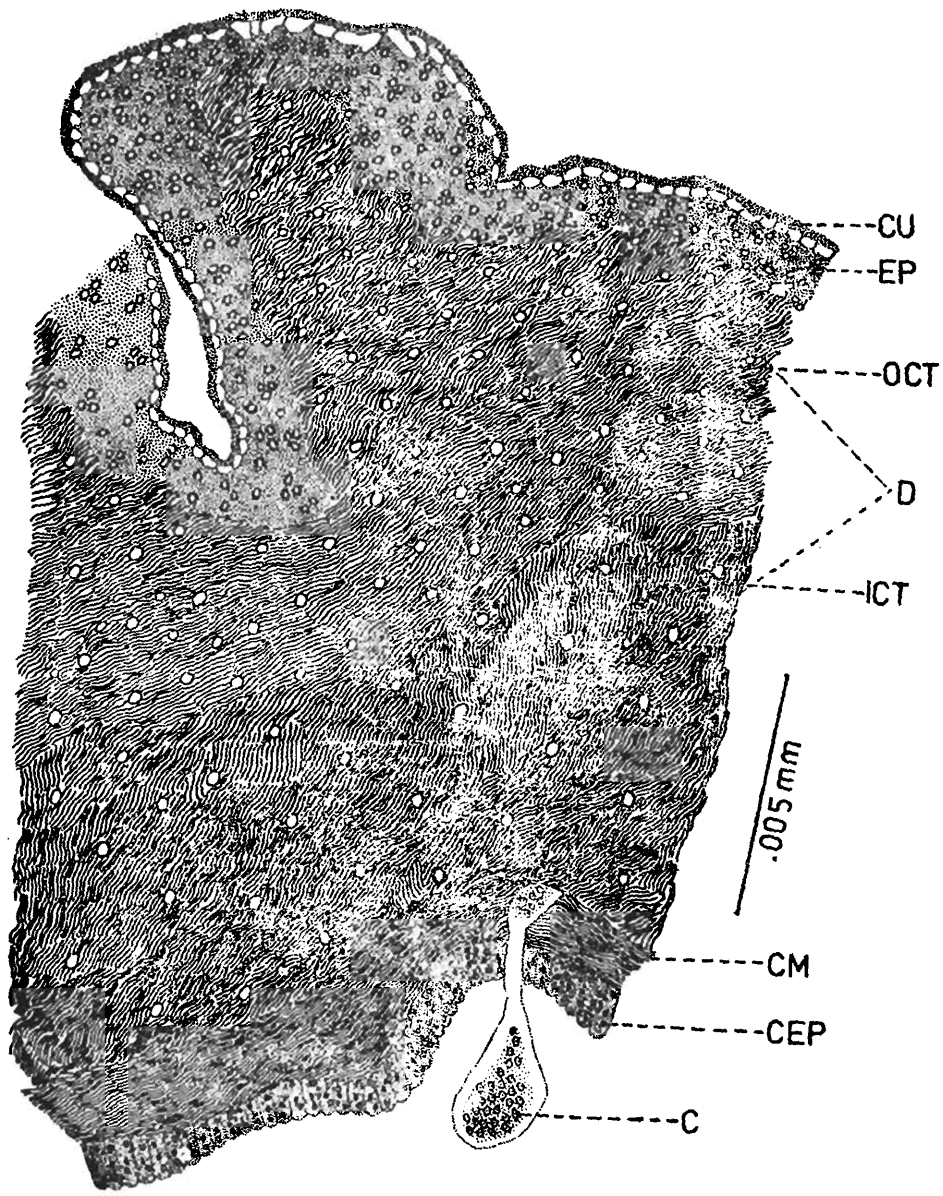
Longitudinal muscle band.—The structure of longitudinal muscle bands and the pharyngeal retractor muscles of holothurians are described and reviewed by Hyman (1955) and Boolootian (1966). The histology of longitudinal muscle bands of the holothurian, *Stichopus mollis* was reported by Freeman and Simon (1964). The fine structure of longitudinal muscle band of *S. japonicus* has been studied by Kawaguti and Ikemoto (1965). The distribution of K^+ and Cl^- in the longitudinal muscle of *Thyone* sp. was studied by Steinbach (1940). The presence of carbohydrate has been suggested by Gay and Simon (1964). The



Text-fig. 17. T. S. of the body wall at the place of radial water canal.

oxygen uptake of longitudinal muscle band of *S. mollis* was studied by Gay and Simon (1964). Bacq (1939*a* & *b*) and Welsh (1954), have studied the sensitivity to acetylcholine of the longitudinal muscle band of certain holothurians. The cholinergic transmission in the holothurian muscles has been reported by Bacq (1941 & 1947). The action potential of longitudinal muscle band of *Thyone briareus* has been studied by Prosser *et al.* (1951) and Prosser (1954). Euler *et al.* (1952) has reported the relaxation of the longitudinal muscle of holothuria by histamine. The response to stimuli in the longitudinal muscle of *Holothuria nigra* and *Caudina chilensis* has been studied by Hill (1926) and Tao (1927) respectively.

In *Holothuria scabra* there are five paired longitudinal muscle bands running along the length of the body occupying the radial positions attached by one side to the radial position of the body wall with the other side free and projecting into the body cavity. The muscle fibres are entirely covered by a very thin coelomic epithelium as is the inner surface of the body wall (Text-fig. 19A). Beneath this epithelium is a thin but distinct, connective tissue, which thins out to form a diffuse matrix between the muscle cells. In transverse sections the muscles are arranged in rosette shaped bundles, each bundle consisting of muscle fibres of varying numbers from four to ten. In longitudinal sections the muscle cells appear as laterally compressed fibres ; most of them run almost straight along the longitudinal axis of the muscle but some take a zig-zag course (Text-fig. 19B). These fibres extend into the neighbouring bundle, giving a complicated appearance to the whole structure. The muscle cells are mononucleate, the nucleus being placed external to the fibres.



Text-fig. 18. T. S. of the body wall.

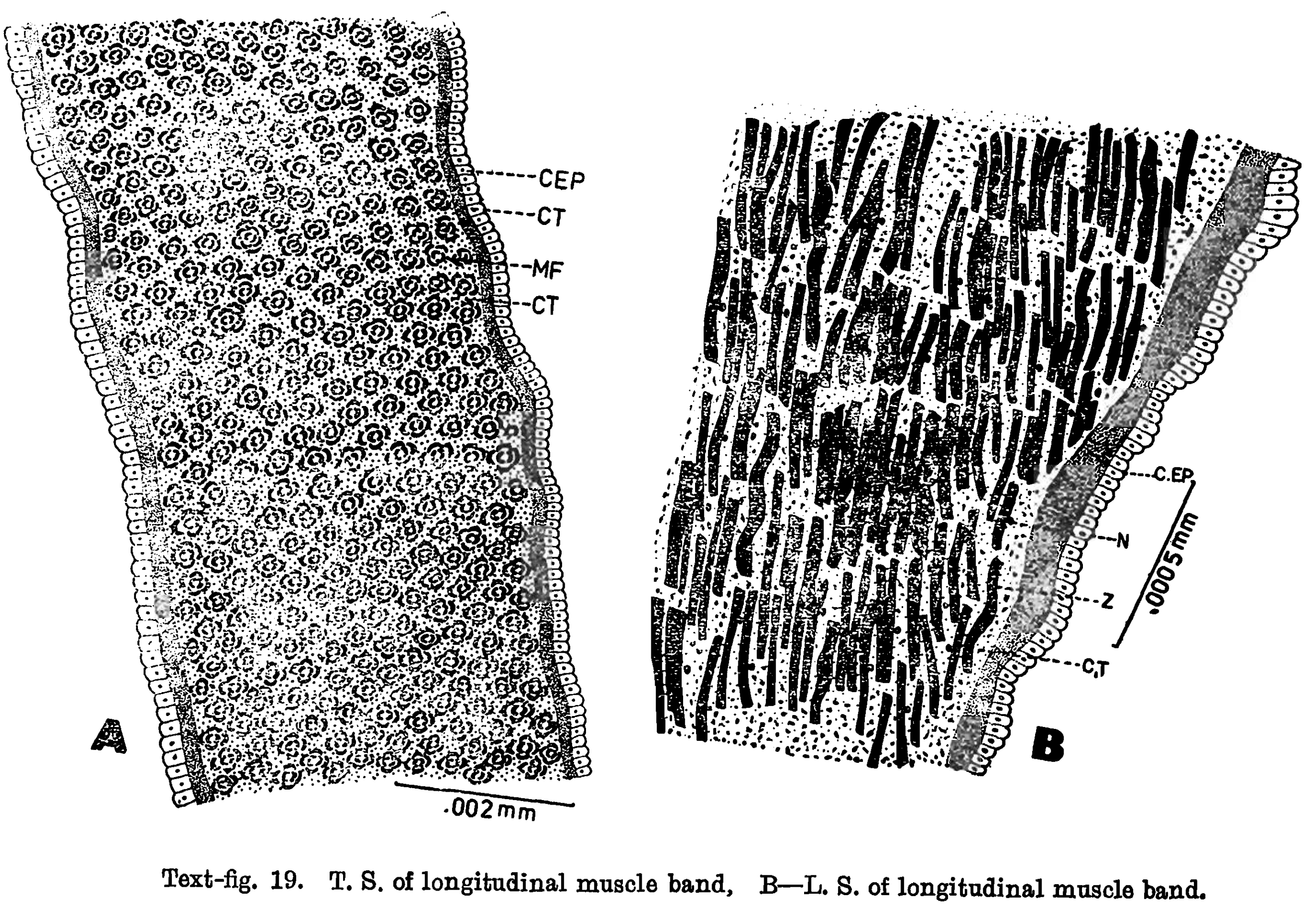
Each longitudinal muscle band is attached to the body wall radially by connective tissue. The muscle cells are innervated through this connective tissue attachment. The nerve fibres are seen closely associated with the muscle cells as very thin fibres.

II. THE SKELETON

The classification of holothurians is based mainly on the type of skeletal elements (Hyman, 1955) and the skeletal structures, made of calcareous substance, are called 'spicules' or 'ossicles'. These are found embeded in the connective tissue of the body wall. The calcareous plates, called 'calcareous ring' (Text-fig. 20E), encircle the oesophagus. The skeleton of *H. scabra* consists of four types of spicules. Based on their shape and size, they are known as tables, buttons, perforated plates and branched rods (Text-fig. 20 A-D).

Table type.—This type of spicules are present in the dosral and ventral part of the body and are more abundant towards the oral end (Text-fig. 20A). They are small ranging from 0.07 to 0.1 mm in length. The number of perforations varies from 8 to 32. The margins of the discs are wavy and in some, spine like projections are seen. A centrally placed four pillared spine having an average length of 0.05 mm is usually present and the pillars are united by several cross bars on the top of each spine. Normally 6 to 8 spines are present in each.

Button type.—These are perforated oval plates with 2 to 16 perforations in double rows. Those with six or more perforations are the most dominant ones. Some of them



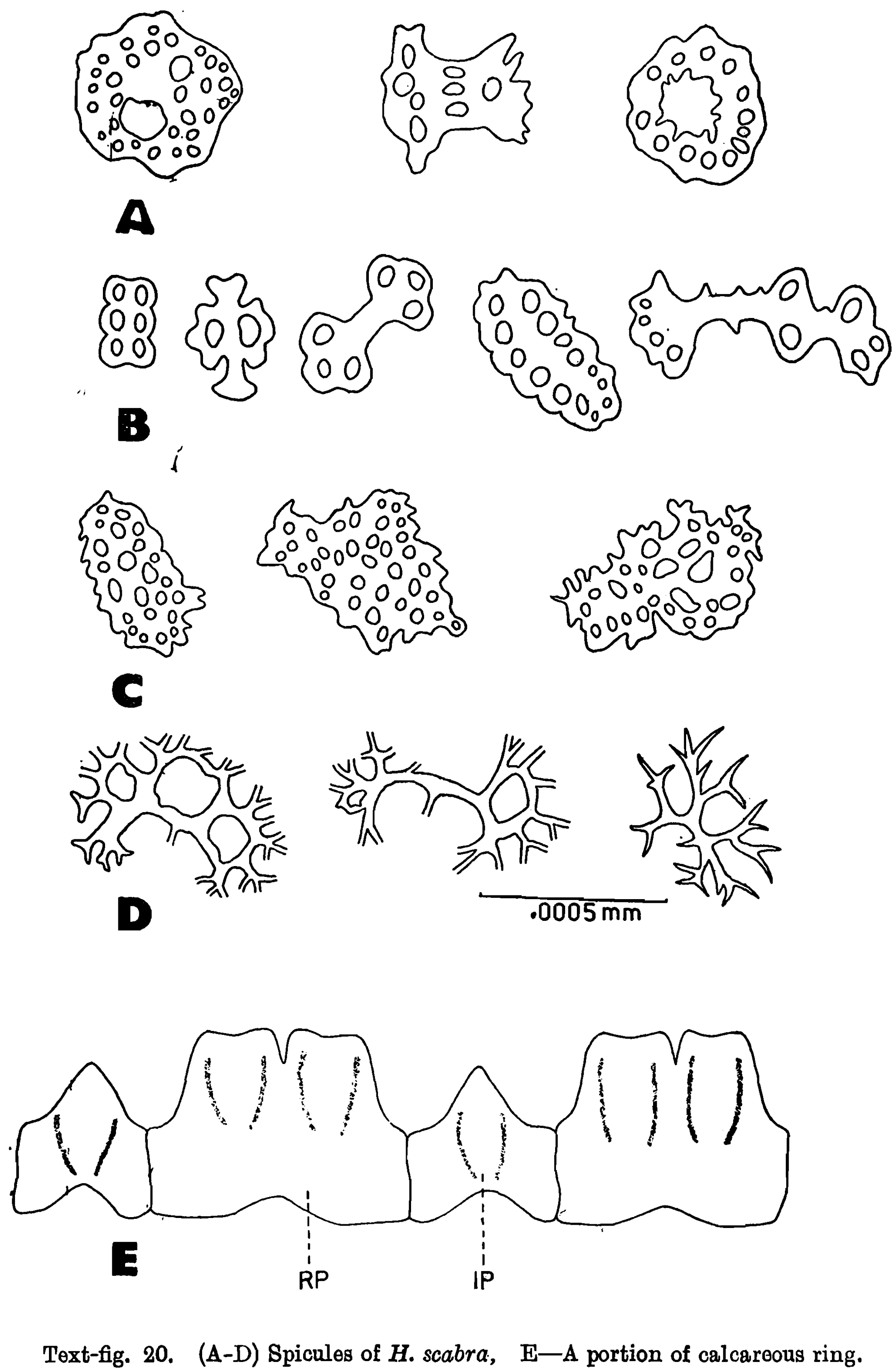
Text-fig. 19. T. S. of longitudinal muscle band, B—L. S. of longitudinal muscle band.

are smooth plates but a majority of them carry knobs. The length of the button types varies from 0.004 to 0.19 mm. The podia are supplied with button type spicules which are regular and dumb-bell shaped and these types are not common in other regions (Text-fig. 20B).

Perforated plates or supporting plates.—These are present in the podia or tube feet (Text-fig. 20C). The size of each spicule varies from 0.1 to 0.14 mm in length and 0.07 to 0.1 mm in breadth. These plates are broad and have numerous perforations in them. The central perforations which vary from one to many are larger than the marginal ones. The margins are wavy and some of the outermost perforations are incompletely closed.

Branched rods.—These are spicules with many branches and are present only in the ventral portion of the body (Text-fig. 20D). The average length is 0.1 mm.

The spicules consists of calcium and strontium carbonate. When examined under a polarising microscope they are anisotropic and show a definite orientation. The endoske-

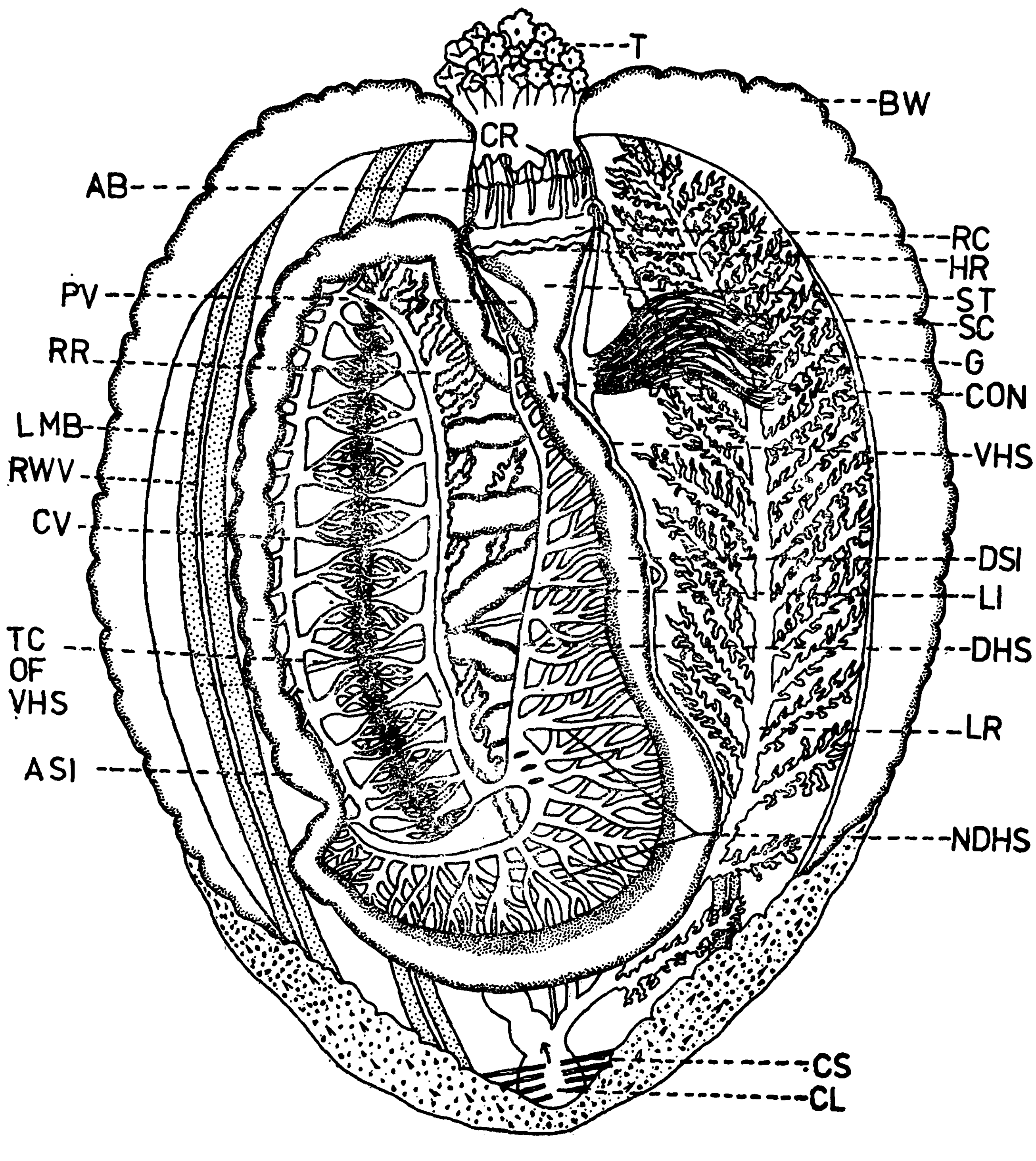


Text-fig. 20. (A-D) Spicules of *H. scabra*, E—A portion of calcareous ring. Diagramatic representation.

letal elements afford rigidity and at the same time pliability to the body, since they are not fused together. According to Nichols (1962) the fenestrate structure of spicules serves to produce a light but strong framework, and at the same time, conserves calcium carbonate.

Again the open pores on the exterior surface of the skeletal elements provide space for the connective tissue necessary to hold together adjacent parts. Nichols (1962) further suggests that the fenestrate structure prevents development of fractures along natural cleavage surfaces in the calcite and thus contributes to skeletal strength.

Calcareous ring.—Surrounding the oesophagus, lying below the tentacles, is a ring of calcareous plates called the calcareous ring consisting of five radial and five interradial pieces.

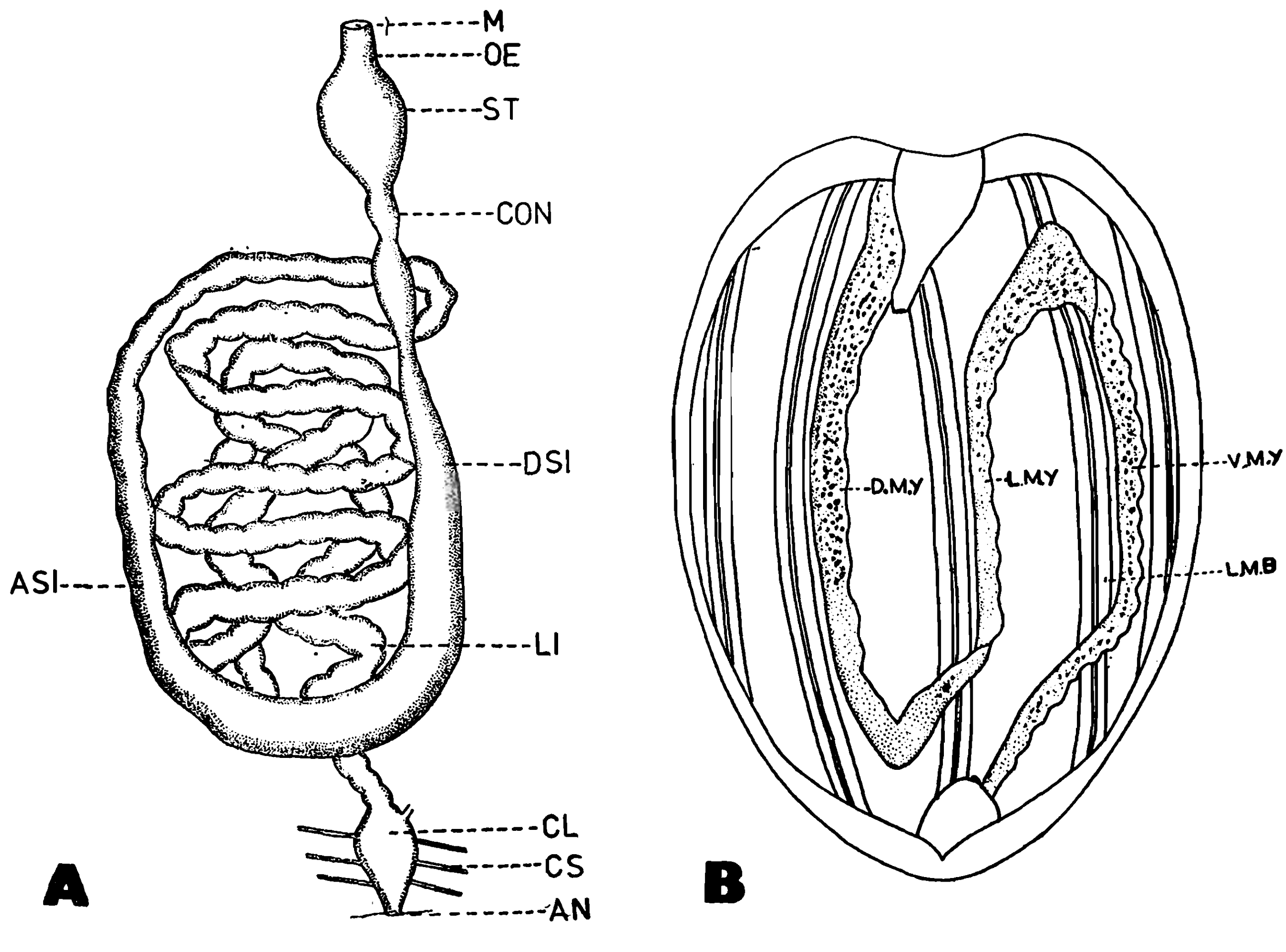


Text-fig. 21. Viscera of *H. scabra*.

The radials are larger than the interradials (Text-fig. 20E). The calcareous plates are square, with the anterior end notched for the passage of the radial water canal. The intersurface of these plates bears a groove into which the stems of the radial canals fit. The calcareous pieces are bound firmly together by means of connective tissue. The longitudinal muscle terminate anteriorly on the anterior part of the outer surface of the radial pieces belonging to calcareous ring. The calcareous ring protects the oesophagus, nerve ring and water vascular canals and it is the point of insertion of the longitudinal muscle bands.

III. THE DIGESTIVE SYSTEM

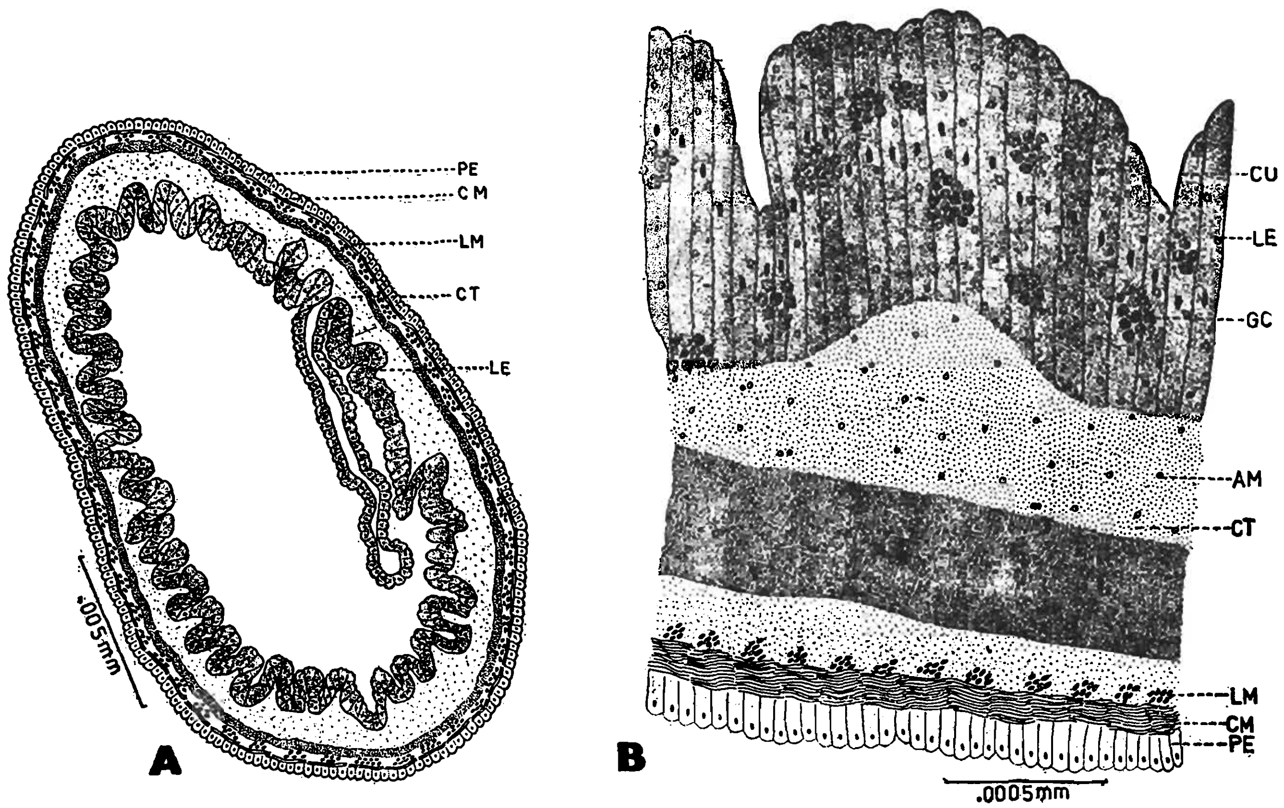
Investigations carried out on the digestive systems of holothurians have been summarised by Anderson (1966), Choe (1962), and Hyman (1955). The morphological and histological features of the alimentary canal have been studied in *Cucumaria elongata* (Fish, 1967*a* & 1967*b*) *Holothuria forskali* (Stott, 1957) and *Stichopus japonicus* (Choe, 1962). The histochemistry of the intestine of *Holothuria scabra* has been studied by Krishnan (1968). The ultrastructure of the gut has been described in *Stichopus japonicus* by Kawaguti (1966*a*), in *Thyone* by Farmanfarmaian (1969) and in *Holothuria tubulosa* by Rosati (1968). The anatomy, diet and



Text-fig. 22. A—Alimentary canal, B—Diagramatic representation of the course of mesentery.

tentacular feeding of dendrochirote holothurian *Cucumaria curata* was studied by Brumbaugh (1964). The physiology of digestion of *Holothuria atra* has been studied by Trefz (1958) and Lawrence (1972).

Mouth is circular or slightly oval, situated in the centre of the circlet of tentacles. This whole complex represents the morphological anterior end of the animal. The mouth leads into 'oesophagus' that occupies the centre of the aquapharyngeal bulb (Text-fig 21). The oesophagus is attached to the calcareous ring by a number of radiating bands of connective tissue. It leads to the 'stomach', obvious as an enlarged region of limited length (1-1.5 cm) (Text-fig. 22A). Following the stomach is a short, thin walled region, approximately 1 to 2 cm long, the 'constriction' which is pinkish red in colour. It is followed by a long intestine (15 to 40 cm), two to three times longer than the body, consequently looped within the coelom. The intestine is divisible into two regions ; a 'small' and a 'large intestine'. The small intestine consists of a descending and an ascending portions which ascends anteriorly along the left side to nearly the level of the aquapharyngeal bulb. It then turns agian and runs as the large intestine along the mid ventral region directly backward terminating at 'anus'. The terminal part of the large intestine, 'cloaca' is an expanded region in which the respiratory tree opens. The cloaca is attached to the surrounding body wall by radiating strands, the 'cloacal suspensors' composed of connective tissue and muscle fibres (Mary Bai, 1971a).



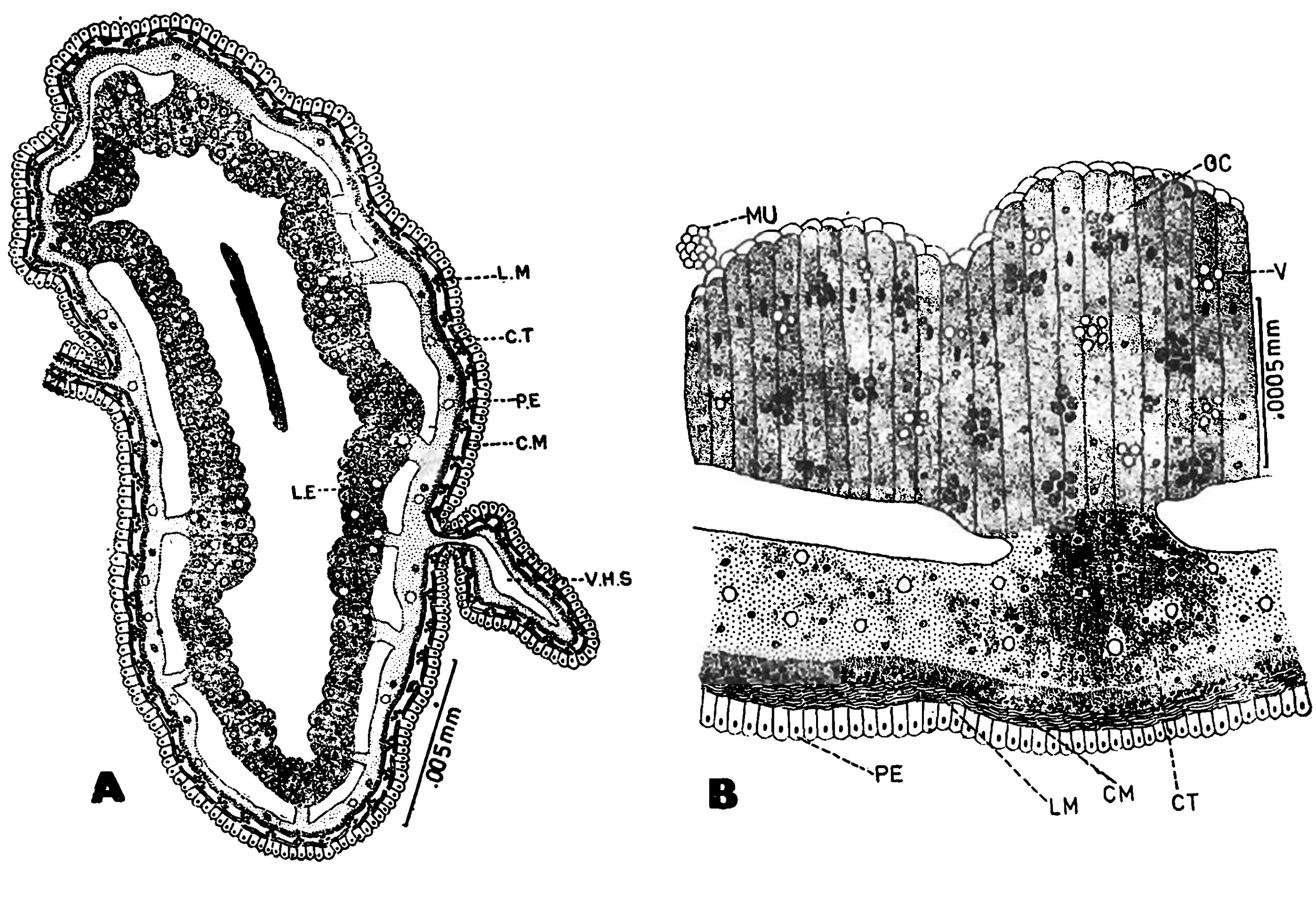
Text-fig. 23. A—T. S. of oesophagus, B—A portion of the T. S. of oesophagus.

The digestive tract is supported by a mesentery, divisible into three portions (Text-fig. 22B). The first part of dorsal mesentery attached the anterior part of the digestive tract (oesophagus, stomach and constriction) to the mid dorsal interradius. The dorsal mesentery also supports the gonoduct and stone canal. The second part or lateral mesentery supports and attaches the ascending part of the small intestine to the body wall in the left dorsal interradius. The ventral mesentery, springing from the ventral body wall supports and attaches the large intestine to the ventral interradius.

The wall of the oesophagus consists of an outer ciliated layer of columnar peritoneal epithelium, a layer of muscle fibres consisting of an outer circular and inner longitudinal muscle fibres, a layer of connective tissue divisible into an outer dense and inner fluid like portions and an inner lining epithelium (Text-fig.23 A & B). Amoebocytes are seen in the connective tissue layer and also in the inner lining epithelium. Mucous gland cells and secretory granules are present in the inner lining epithelium. It is thrown into simple villi which have connective tissue frame work. A very thin cuticle is seen covering the lining epithelium.

The stomach consists of : (a) a thin peritoneal epithelium, (b) a thick layer of longitudinal muscles which is often intermingled with circular muscle, (c) alayer of connective tissue and (d) a thin inner lining epithelium thrown into simple villi. The amoebocytes are seen in the connective tissue. Vacuoles are interspersed among the typical lining epithelial cells (Text-fig. 24 A & B).

In the constriction, the peritoneal epithelium is composed of closely packed columnar cells, the nuclei of which lie towards the surface (Text-fig. 25A & B). A point to be noted is that the longitudinal muscle fibres are found outside the circular muscle. The reverse is



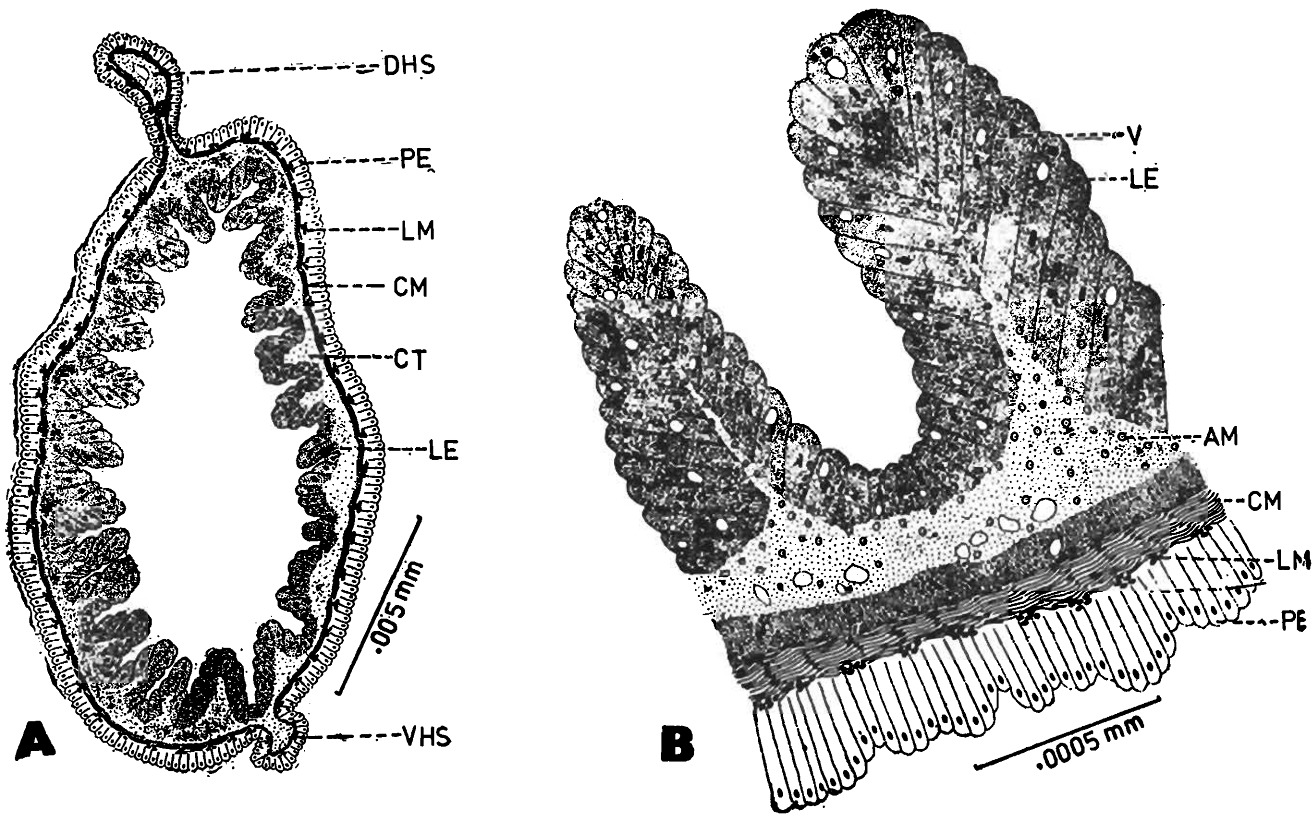
Text-fig. 24. A—T. S. of Stomach, B—A portion of the T. S. of stomach.

the case in the stomach and oesophagus. The posterior part of the constriction from where the rupture takes place during evisceration is completely devoid of longitudinal muscle fibres (Text-fig. 26A). The connective tissue layer is thin and vacuolar. Vacuoles and amoebocytes are present in the lining epithelium. Mucous globules are found to stream out through the free border (Text-fig 25B). Three dimentional view of the free constriction is given in (Text-fig. 26B).

The ascending and descending small intestine consists of four layers of tissue. The villi of the descending small intestine is very long and there is a gradual lengthening from the anterior to the posterior part, thereby obliterating the lumen posteriorly (Text-figs. 27 & 28). Mucous secretion is seen at the tip and in between the villi (Text-fig. 28A). However, the villi of the ascending small intestine are short (Text-fig. 29A & B) and mucous secretion is completely absent. Longitudinal muscles are absent.

The wall of the large intestine apart from the general structure consists of longitudinal muscle layer external to the circular muscle layer. Villi are very simple and glands are sparcely distributed (Text-fig. 30A & B).

In cloaca, the longitudinal muscle is absent at the anterior region from where the rupture takes place during evisceration (Text-fig. 31A). In other regions a dense circular muscle layer and a feeble longitudinal muscle layer are present (Text-figs. 31 B & 32A). Amoebocytes are less in number and are scarcely distributed in the lining epithelium.



Text-fig. 25. A—T. S. of constriction, B—A portion of the T. S. of constriction.

Physiology of feeding and digestion.—Holothurians are omnivorous in nature. In *Holothuria scabra*, feeding is effected by the tentacles. It shovels the surrounding substrate into its mouth by means of the tentacles. The stomachs of freshly collected animals were found to contain marine algae, copepods, spicules, diatoms, Navicula, Elphidium and sand with molluscan shells. Such organic food as the substrate contains is then digested and the remainder, not appreciably diminished in bulk, is voided after a considerable sojourn in the large intestine. When these holothurians are opened shortly after collection the small intestine appears relatively empty, whereas large intestine is distended with a load of bottom material. Thus a marked functional difference between the two parts of the intestine is indicated.

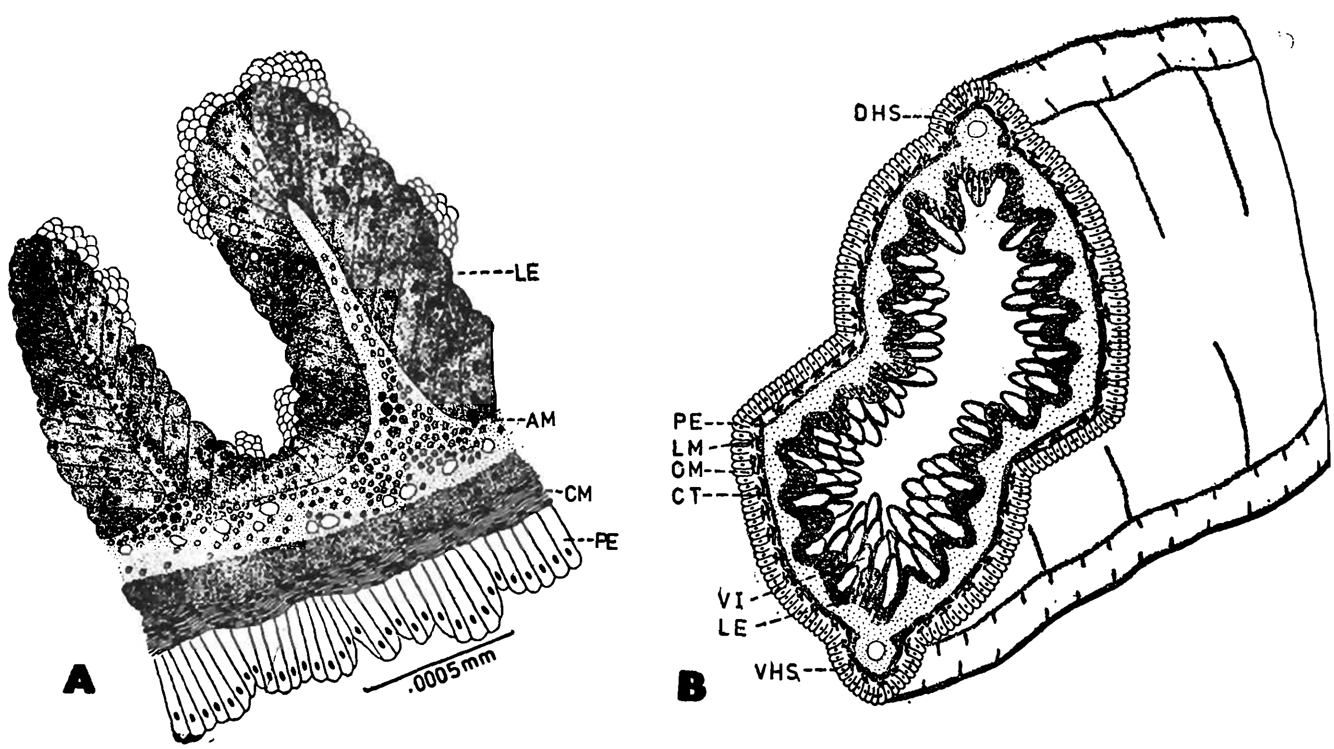
In undistributed conditions the ejected substrate forms a pellet around the posterior end of the animal.

Enzymes like proteinase, lipases and carbohydrates are present in oesophagus, descending and ascending part of the small intestine which forms the secretory and digestive region of the gut (Hyman, 1955). The presence of mucous glands and mucous secretion in the lining epithelium indicate their part in the digestion and absorption of the organic food material in the muddy sand.

Histology of the mesentery.—The mesentery consists of thick connective tissue covered by a distinct circular muscle layer and peritoneal epithelium (Text-fig. 32 B). The epithelium of the mesentery is continuous with the peritoneal epithelium of the alimentary canal and the inner lining of the body wall.

IV. THE HAEMAL OR BLOOD LACUNAR SYSTEM

The morphology and histology of the haemal system of various holothurians have been studied by several investigators; Prosser and Judson (1952) have reported on the histology and pharmacology of the haemal vessel of *Stichopus californicus* ; a brief description of the histology of haemal vessels of *Psolus chitonoides* is given by Hetzel (1965) ; Fish (1967a)



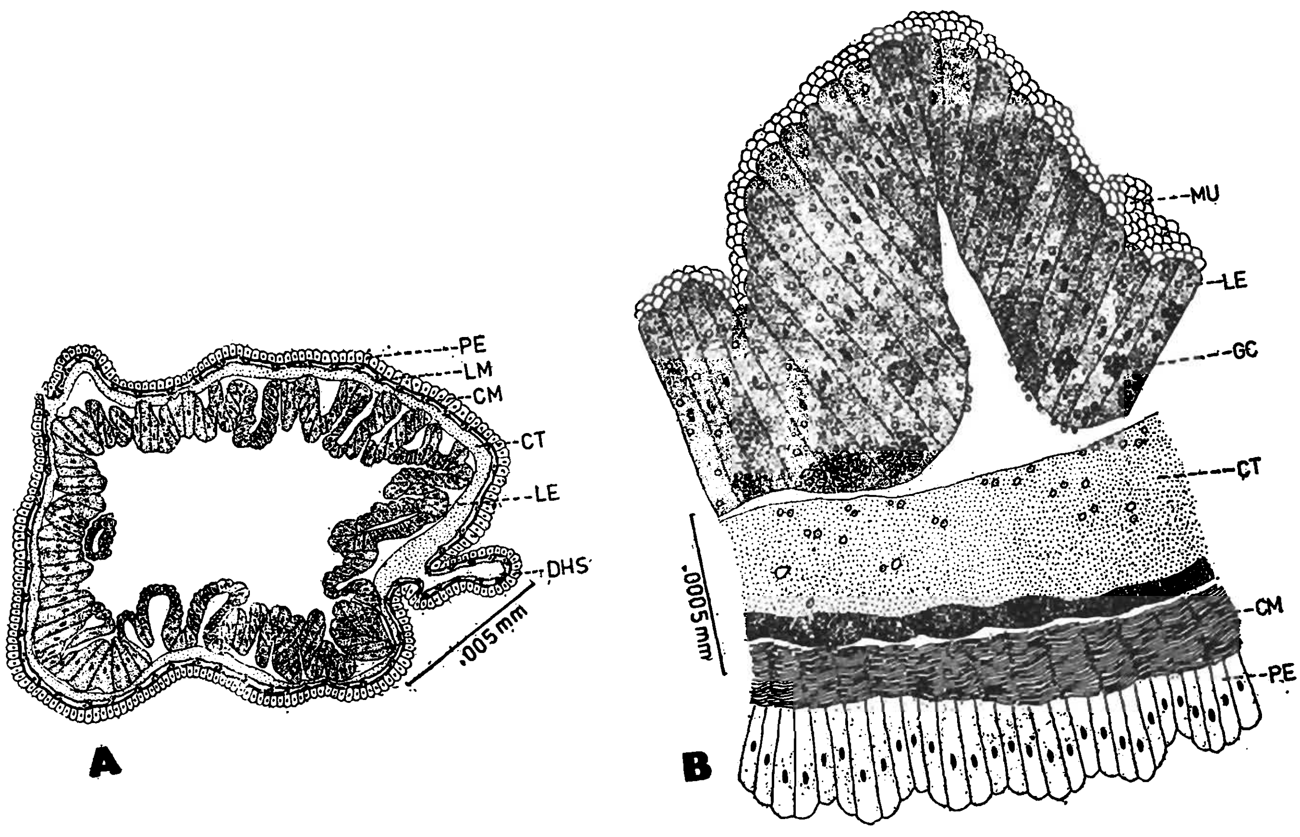
Text-fig. 26. A—A portion of the T. S. of constriction of the place of rupture during evisceration, B—A view of the constriction.

has described the histology of haemal system of *Cucumaria elongata*. A brief account of the fine structure of these vessels in *Thyone sp.* has been presented by Bell and Farmanfarmaian (1967). Doyle (1967) has given an elaborate account of the fine structure of the haemal system in the holothurian *Cucumaria frondosa*. The rate of pulsation of haemal vessels in *Caudina chilensis* has been studied by Kawamoto (1927).

The haemal system in *H. scabra* is well developed and a digramatic representation of this is shown in (Text-fig. 33A). It consists of a 'haemal ring', encircling the oesophagus, directly behind and closely attached to the water vascular ring (Text-fig. 33B). Two main sinuses, a dorsal and ventral, run along the small intestine (Mary Bai, 1971*a*). From the haemal ring five radial sinuses ascend along the aquapharyngeal bulb accompanying the radial water canals. They run along the body wall and lie between the hyponeural sinus and radial water canals of the body wall.

The 'ventral sinus' extends along the entire length of the stomach, constriction and small intestine, finally merging with the posterior part of the ascending small intestine. In the oesophageal region the ventral sinus is very thin and opens into the haemal ring. The ventral sinus is in close association with the gut wall. During its course along the descending and ascending small intestine, it is connected transversely by a simple horizontal vessel, the ventral haemal connective.

The 'dorsal sinus' runs along the whole length of the small intestine on the side where it is attached to the dorsal mesentery. It is connected to the intestinal wall by numerous branches. It gives off long branches to the loop of the intestine. Thereafter, the dorsal



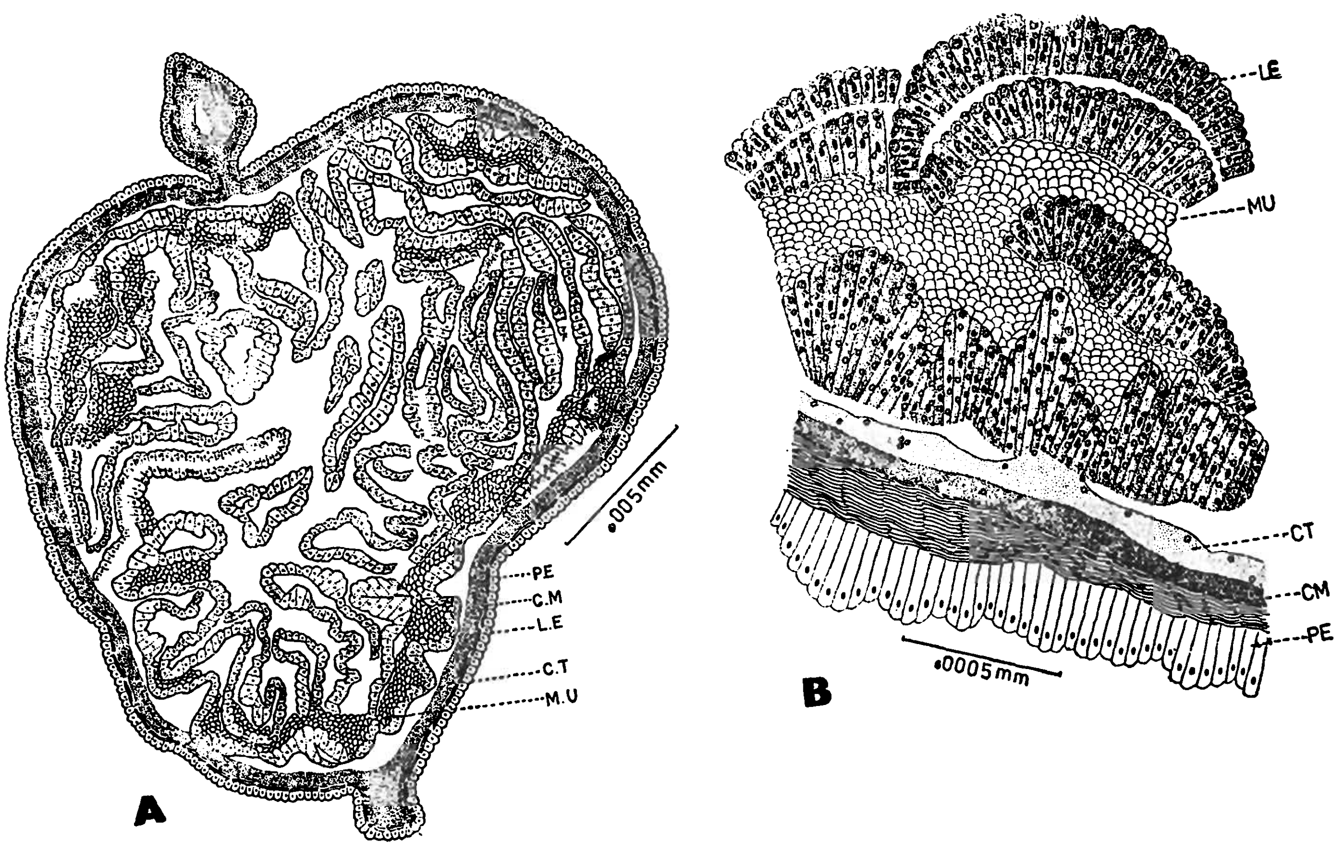
Text-fig. 27. A—T. S. of descending small intestine, B—A portion of the descending small intestine.

sinus is connected to the ascending small intestine through tufts of lacunae forming the 'rete mirabile' (Text-fig. 33A).

Between these network of lacunae and the wall of the ascending small intestine there is a collecting vessel, connecting the lacunar tufts and ascending small intestine. This vessel is continuous with the main dorsal sinus and is connected to the anterior and posterior end as shown (Text-fig. 33A). The lacunar tufts of the 'rete mirabile' are closely connected with the terminal ends of the left branches of the respiratory tree (Text-fig. 21). The dorsal sinus does not open anteriorly into the haemal ring and therefore both the stomach and constriction are devoid of it (Text-fig. 33A). At the anterior part the small intestine, the dorsal sinus ceases to exist as a separate canal and serial sections at this point show that it merges with the connective tissue of the intestine.

Structure of the haemal vessel.—The dorsal and ventral haemal sinus consist of an outer peritoneal epithelium, composed of columnar cells with deeply staining nuclei, a thick, uninterrupted circular muscle layer and a thick connective tissue with scattered amoebocytes. A distinct lumen is present in the dorsal vessel and in the ventral transverse connecting vessels, which in some portions contain fewer amoebocytes (Text-fig. 34 A) (Mary Bai 1971a).

The structure of the vessels of the dorsal sinus that are connected with the looped region of the small intestine differs from that of the dorsal sinus. The connective



Text-fig. 28. A—T. S. of descending small intestine, B—A portion of T. S. of descending small intestine.

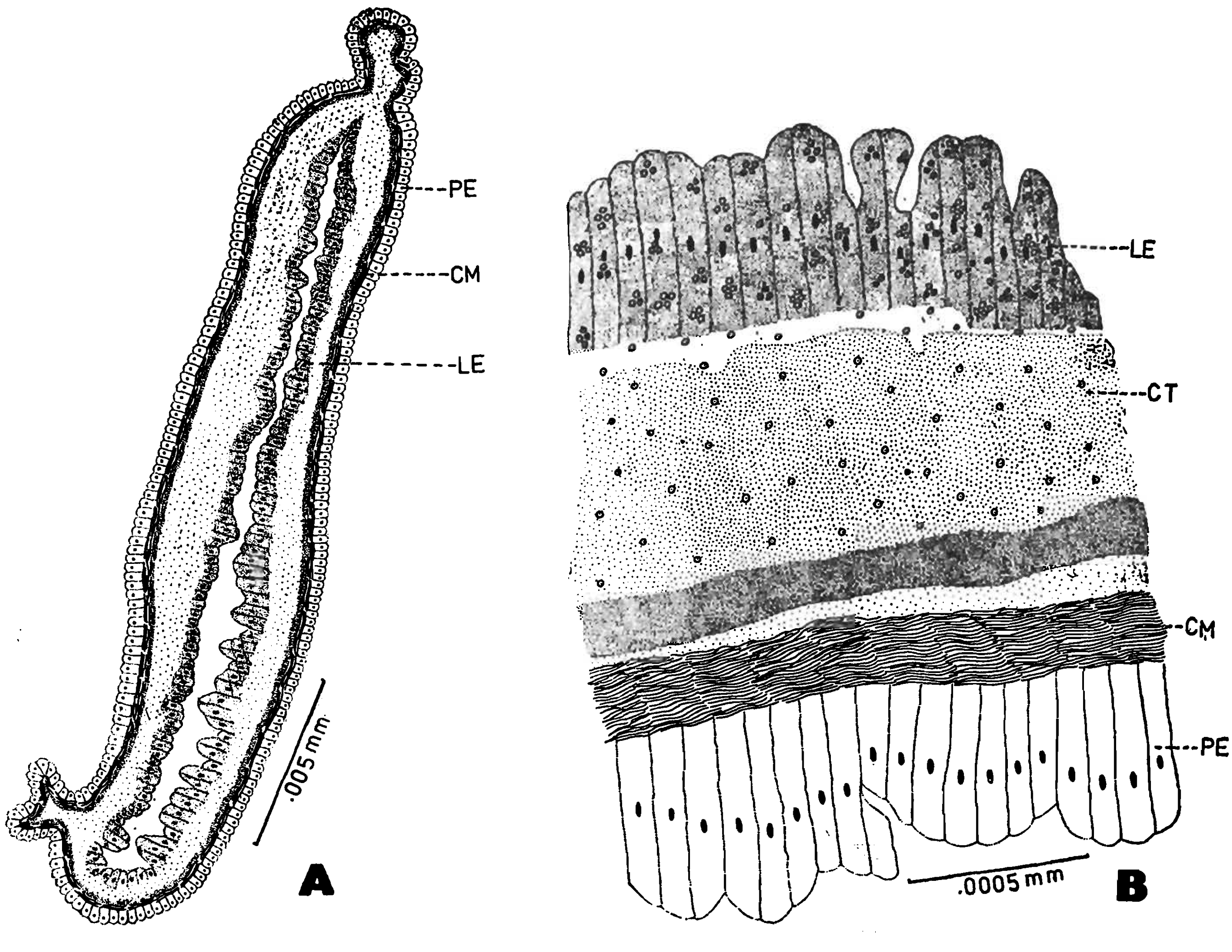
tissue is thick and occupies most of the area of the vessels with numerous lacunar spaces either empty or filled with granular amoebocytes (Text-fig.34 B). Lymphocytes like cells, the 'haemocytes' emerge from the connective tissue into the lumen of the vessel (Text-fig. 34B).

The structure of the 'rete mirabile' consiste of a thick peritoneal epithelium composed of elongated columnar cells, thin circular muscle layer and connective tissue. The lumen is found with fewer amoebocytes (Text-fig. 35A).

The haemal ring encircling the oesophagus consists of an outer thin peritoneal epithelium, a thin circular muscle layer and a thick connective tissue which is folded into villi like projections, located close to the peritoneal epithelium of the oesophagus. Numerous amoebocytes are seen in the connective tissue (Text-fig. 35 B).

Sections of the body wall at the place of radial water canal show distinct haemal lacunae filled with amoebocytes in between the dermis and the circular muscle layer (Text-fig. 17).

The function of the haemal system in echinoderms have been a controversy for a long time. In *H. scabra* the haemal vessels pulsate at 8-10 beats per minute at room temperature (28°C). The histological studies suggest that the amoebocytes are produced in the



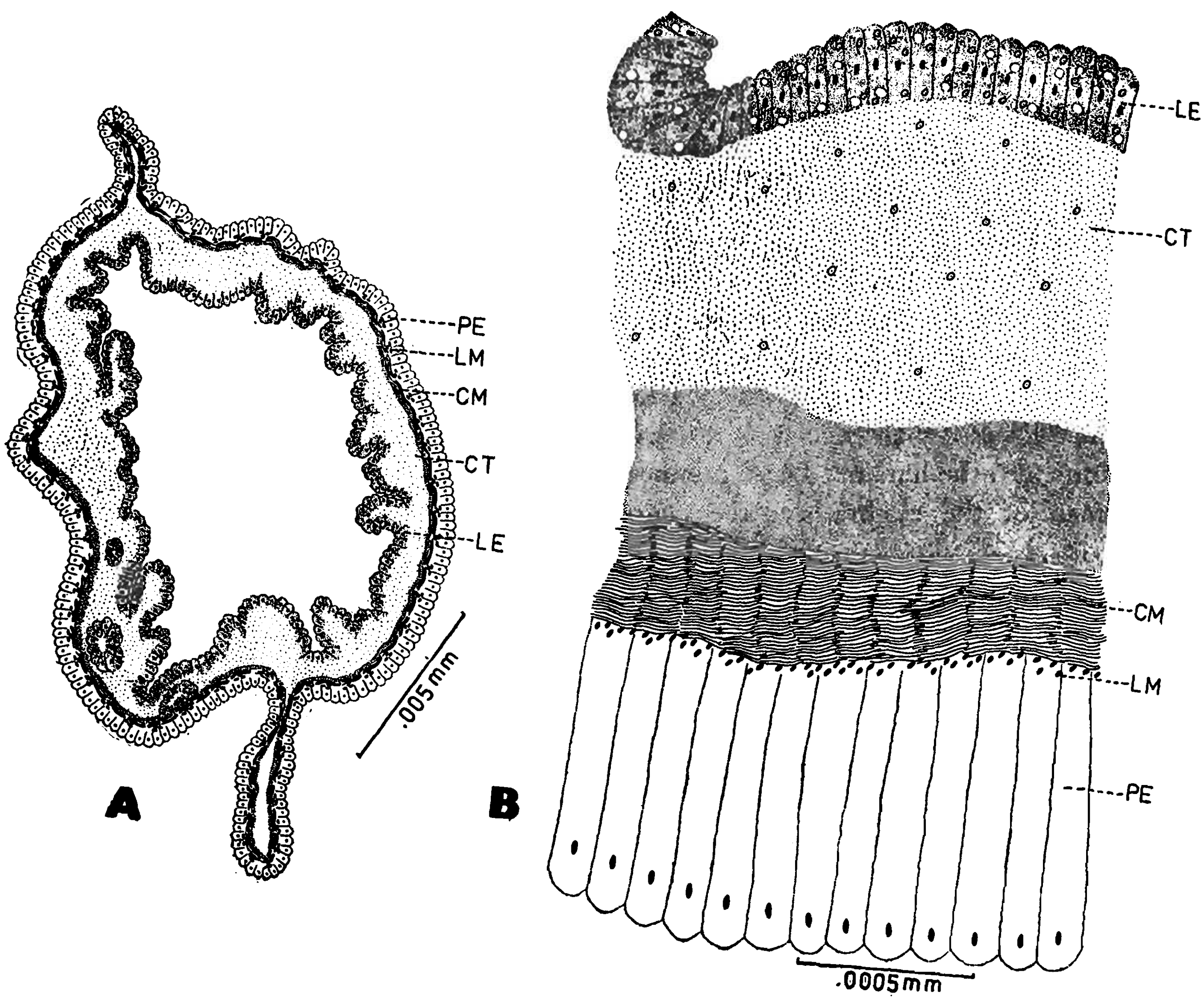
Text-fig. 29. A—T. S. of ascending small intestine, B—A portion of T. S. of ascending small intestine.

connective tissue of the branches of the dorsal haemal sinus and are carried through them to the gut from where they carry away the products of digestion to different tissues of the body (Mary Bai, 1971*a*). Studies using labelled sugars also support the view that the haemal system do play a role in the transport of nutrients (Krishnan and Krishnaswamy, 1970).

V. THE RESPIRATORY SYSTEM

Compared to the studies made on the gut and haemal system, those on the respiratory tree are scanty. The first description of the histology of the respiratory tree was given by Gerould (1896) and later by Bertolini (1933) for the holothurians, *Caudina arenata* and *Holothuria* sp. respectively. Apart from this, the only other recent work on this system is that of William and Mc Neill (1964) for *Cucumaria frondora.*

The respiratory physiology of holothurians is reviewed by Farmanfarmaian (1967). The respiratory function of respiratory trees in *Holothurian tubulosa* has been suggested dy Winterstein (1909) and demonstrated in the same animal by Bertolini (1933). The rate of oxygen consumption in *Paracaudina chilensis* has been studied by Nomura (1926), in *Thyone briareus,* by Heistand (1940), *Stichopus japonicus* by Choe (1962) and in *Holothuria forskali* by Newell and



Text-fig. 30. A—T. S. of large intestine, B—A portion of T. S. of large intestine.

Courtney (1965). The oxygen tension of the coelomic fluid of the *Holothuria poli* was reported by Fredericq (1911) and of *Holothuria tubulosa* by Buddenbrock (1938). The oxygen equilibrium of haemoglobin in *Cucumaria miniata* was studied by Manwell (1959). The function of red haemocytes of holothurian, *Thyonella gemmata*, in transport and storage of oxygen has been clearly demonstrated by Manwell (Personal Communiation to Farmanfarmaian, (1967).

The principal organ involved in respiration in *Holothuria scabra* is the respiratory tree which originates from the anterior part of the cloaca near the region where the large intestine opens into it and is attached to the body wall by irregular strands of connective tissue. It is further divided into a right and a left arborescent tube which project anteriorly into the coelom extending upto the aquapharyngeal bulb (Text-fig. 36). The two arms give rise to finer branches of tubules which fill the entire coelomic cavity, surrounding the internal organs. The tubules are colourless, transparent and terminate into small thin-walled vesicles. The left tree is intermingled with the lacunar network or rete mirabile of the ascending small intestine (Text-fig. 21). Apart from these two main branches, there are two to three short, branched tubes originating from the base of the common stem of the respiratory tree.

The structure of the respiratory tree

Since the respiratory tree is an evagination of the cloacal portion of the gut it has the same basic structure as other portions of the gut with certain simplifications. The stem and the tubles of respiratory tree consists of four layers, a peritoneal epithelium, a layer of circular muscle fibres, connective tissue and a lining epithelium. The peritoneal epithelium consists of columnar epithelial cells, with centrally placed nucleus (Text-fig. 37B).

The muscle layer is composed of continuous thick circular muscle fibres closely resembling the fibres seen in the region of the cloaca and a thin longitudinal muscle layer. Inner to these is the layer of broad connective tissue consisting of two distinct zones : an outer thicker and an inner fibrous, vacuolar, thin and fluid-like zone. Numerous amoebocytes are seen in the connective tissue. The inner lining epithelium consists of closely packed columnar cells with their nuclei at different positions. This layer is thrown into finger-like projections into the lumen. Large number of amoebocytes are seen in the lining epithelium. The lumen of the respiratory tree contains a fluid in which amoebocytes occur (Mary Bai, 1971*a*).

The terminal branches consist of a single or double layer of epithelial cells (Text-fig. 37B).

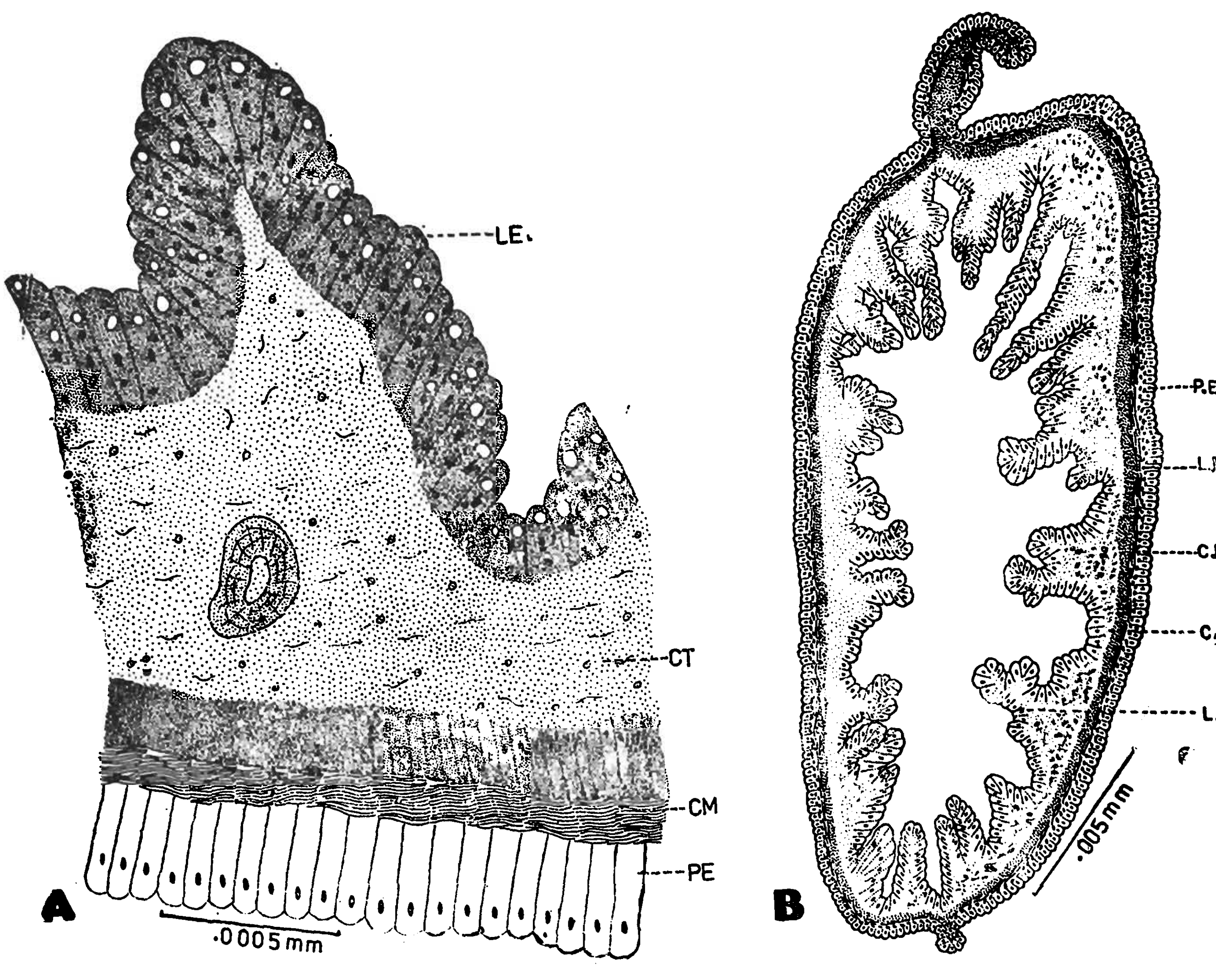
The cloaca of holothurians pump rhythimically which is called cloacal pumping. This action of the cloaca results in alternate filling and emptying of the respiratory trees with sea water. The course of events in briefly as follows : when the anal sphincter opens, water enters into the cloaca and travels anteriorly along the cloaca through the contraction of the cloacal suspensors and relaxation of the circular muscle fibres of the cloacal wall. Then the anus closes, the suspensors relaxes and the cloacal wall contracts. The water is forced into the lumen of the respiratory tubes. At this time the terminus of the digestive tract is closed. Thus, the pumping mechanism oscillates to maintain inflow and outflow of sea water alternately. Oxygen and CO_2 exchanges take place across the membrane of the terminal vesicles and epithelial layer of the *rete mirabile* of the haemal system. The de-oxygenated sea water is expelled out by the contraction of the body wall musculature. The respiratory trees, the digestive tract and finally the anal spincter are all open through which deoxygenated water and faeces are thrown out. Exchange of gases may also take place through the podia and the integument.

Accumulation of coelomocytes in the layers of respiratory tree may play some significant role in respiration and excretion.

Apart from the respiratory function the respiratory trees regulate the body turgor which is the very important factor in all activities (Mary Bai, 1971*a*).

VI. THE COELOM AND COELOMOCYTES

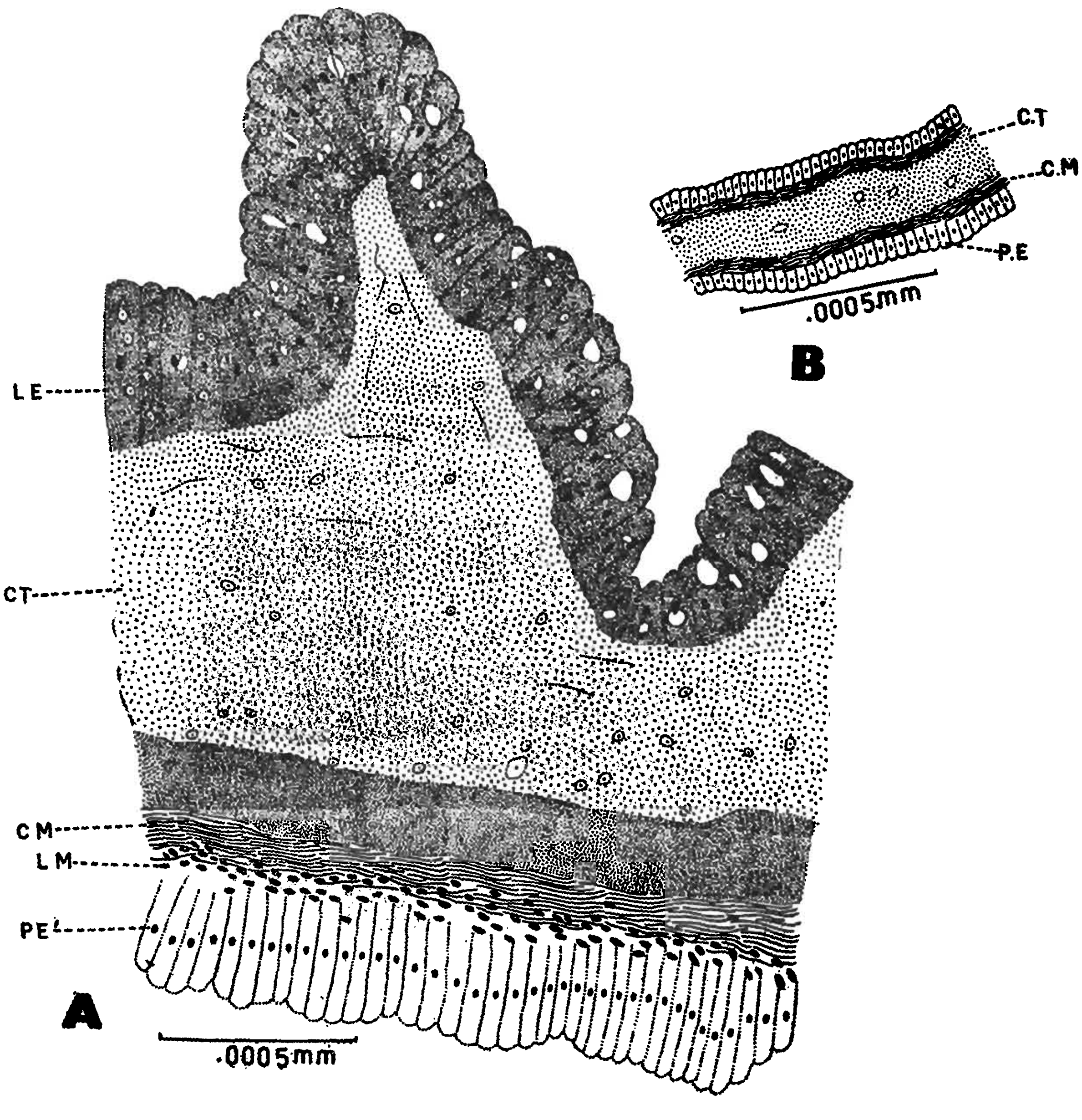
Several investigators have studied the morphology of holothurian coelomocytes (Semper, 1868 ; Hamann, 1883 ; Jourdan, 1883 ; Howell, 1885 ; Herouard, 1889 ; Cuenot, 1891, Frenzel, 1892 ; Knoll, 1893 ; Gerould, 1896 ; Dendy, 1898 ; Becher, 1907 ; Kollmann, 1908 ; Haanen, 1914 ; Theel, 1931 ; Van der Heyde, 1922*a* ; Kindred, 1924 ; Kawamoto, 1927 ; Hogben and Van der Lingen, 1928 ; Dawson, 1933 ; Ohuye, 1934, 1936, 1938 ; Crescitelli, 1945 ; Endean, 1958 ; Boolootian and Giese, 1958 ; Boolootian, 1962 ; Hetzel, 1963, 1965 ; Rollefsen, 1965 ; Cowden, 1968 ; and Fontaine and Philip 1973).



Text-fig. 31. A—A portion of the T. S. of cloaca at place of rupture during evisceration, B—T. S. of cloaca.

Holothurians possess a spacious coelom between the body wall and the digestive tract extending from the calcareous ring to the cloaca. It is partially divided by the mesenteries supporting the digestive tract and the bands of tissue connecting with the water vascular system through the madreporic holes. The hyponeural sinuses, water vascular system and the haemal system are also coelomic in nature. The coelom is lined by thin ciliated peritoneal epithelium.

The coelom is filled with coelomic fluid which is circulated by the cilia of peritoneal epithelium. It is less alkaline than sea water and contains a variety of free cells known as coelomocytes. The coelomocytes occur in the haemal fluid and the fluid of all the coelomic



Text-fig. 32. A—A portion of T. S. of cloaca, B—T. S. of mesentery.

compartments except the hyponeural sinuses. Microscopic examination of freshly drawn coelomic fluid shows the following types of corpuscles (Text-fig. 38).

A. *Lymphocytes* :

These are small spherical cells, typically 4 to 6 μ in diameter. Each consists of a large nucleus which occupies the major portion of the cell. The nucleus contains granular inclusions and chromatin. In a few Lymphocytes two nucleoli are present. They possess few pseudopodial outgrowths.

B. *Phagocytes* :

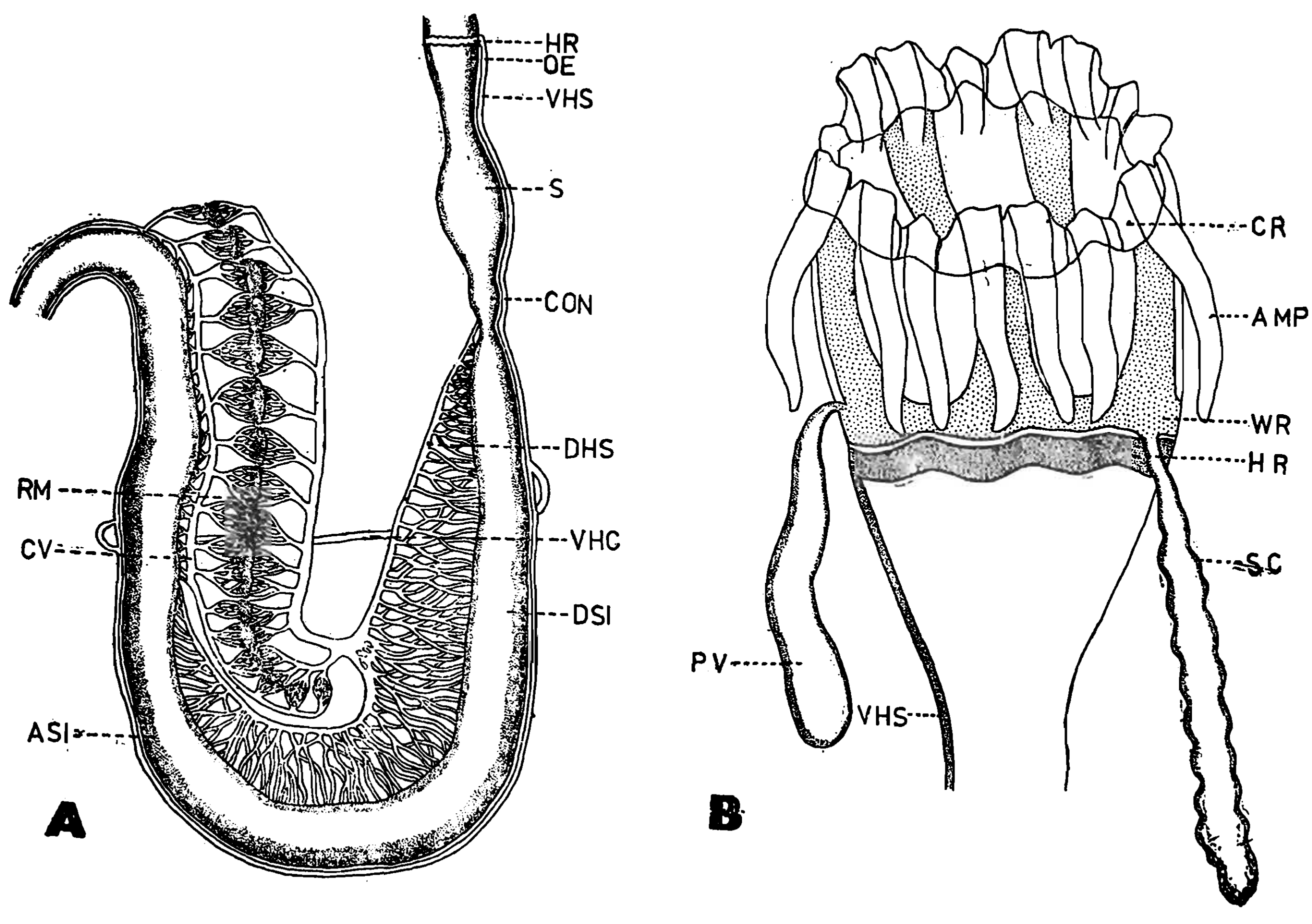
They are of different shapes ranging from 4 to 20 μ in diameter, and are provided with inner granular and outer thin cytoplasm. Vacuoles as well as granules are often found in them. The nucleus is large. Each cell possesses bladder-like filiform pseudopodia.

C. *Morula cells* :

These are found in aggregation of small cell-like structures. Their sizes range from 3 to 12 .. in diameter. These cells contain a number of spherules and certain other inclusions. Thesecells exhibit amoeboid movements and sometimes they freely float in the coelomic fluid.

D. *Haemocytes* :

The haemocytes resemble the lymphocytes except in the size of the nucleus which is



Text-fig. 33. A—The haemal system of *H. scabra*, B—Aquapharyngeal bulb. Diagramatic representation.

smaller and more granular. The cytoplasm is filled with granules and vacuoles. The size ranges from 2 to 6 μ in diameter.

E. *Fusiform cells* :

These are elongated in shape, typically 4 to 6 μ in diameter with an eccentrically placed nucleus and are few in number. The cytoplasm is provided with few granules.

F. *Crystal cells* :

These are characterised by the possession of refractive bodies which appear to be crystalline. Typical cells possessed by crystal cells are 6 to 9 μ in length.

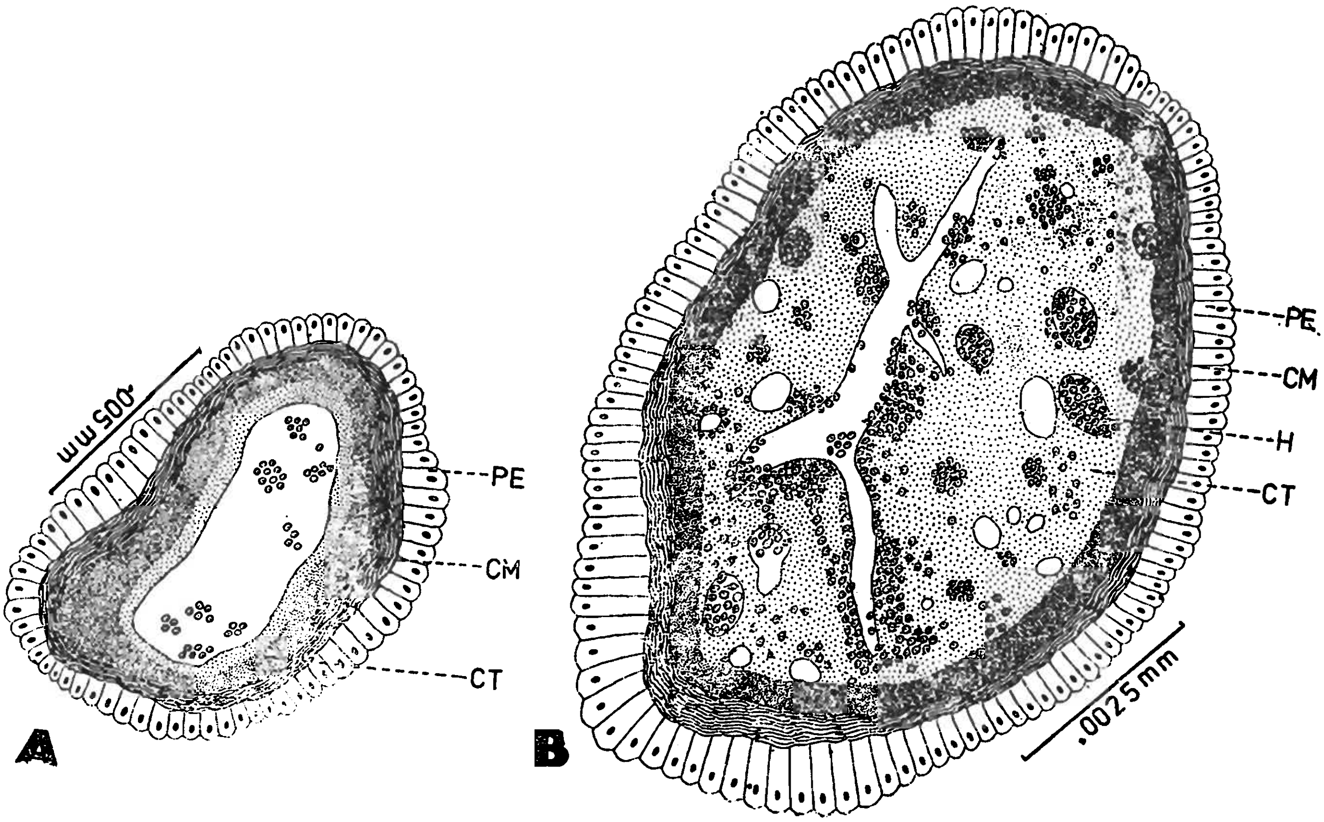
The fluid in the water vascular system contains all types of coelomocytes which occur in the body fluid. However the lymphocytes and phagocytes are found to be more common, The haemal system also contains a large number of floating morula cells. The abundance, variety and inclusions of the coelomocytes suggest that they serve vital roles such as nutrition, transport of wastes and phagocytosis.

VII. Water Vascular System

Apart from the perivisceral body cavities the echinoderms have a series of tubular systems and one such tubular derivatives of coelom is the water vascular system. The main function of the water vascular system is to maintain a sufficient hydrostatic pressure within its coelom in order to maintain turgidity. A detailed account of the water vascular system in holothurians is given by Hyman (1955).

The water vascular system in *H. scabra* consists of a circular ring canal or water ring, polian vesicle and stone canal (Text-fig. 33B).

The water ring or ring canal is a wide tubular structure surrounding the oesophagus



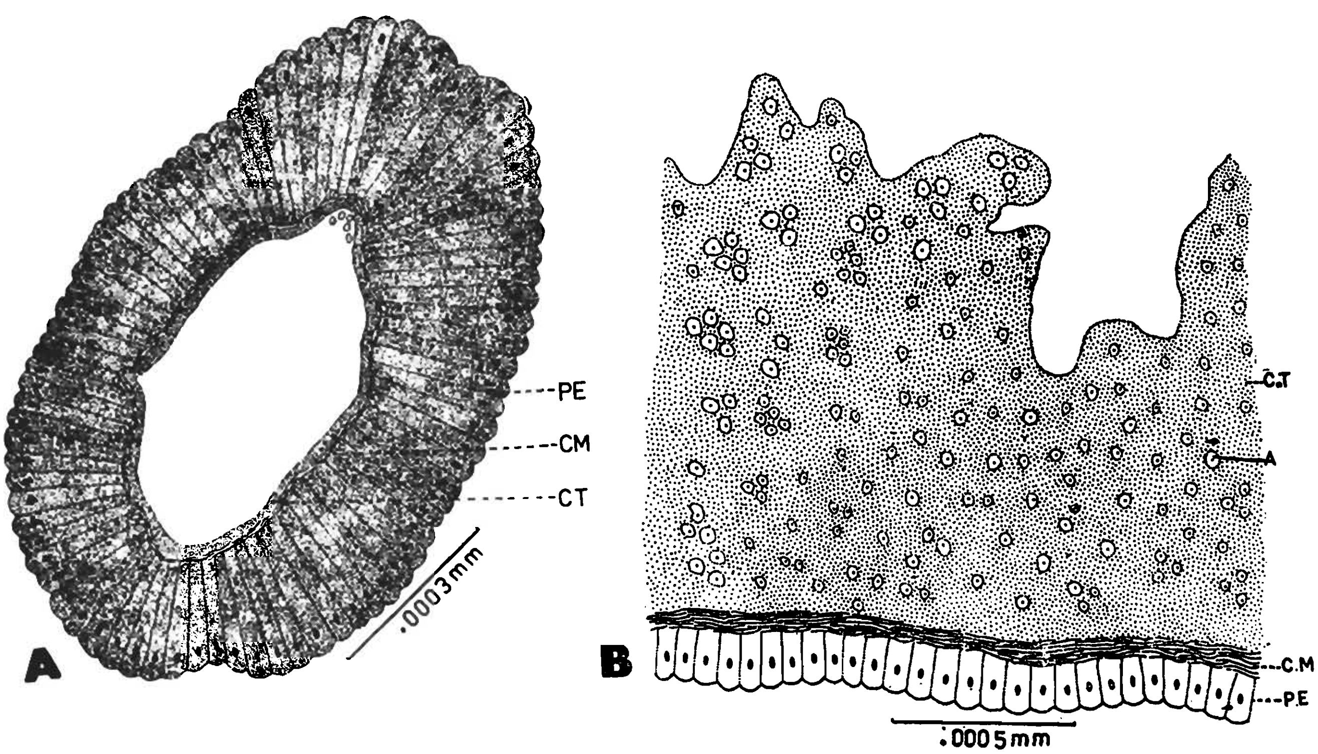
Text-fig. 34. A—T.:S. of dorsal haemal sinus, B—T. S. of haemal vessels of dorsal sinus.

posterior to the calcareous ring with the superimposition of folds on its wall externally. The histology of ring canal consists of an outer peritoneal epithelium, a layer of circular muscle fibres and a thick layer of connective tissue (Text-fig 39c).

From the ring canal five large radial canals ascend anteriorly along the oesophagus and pass to the inner side of the radial pieces of calcareous ring and gives off a branch to the tentacles. Then the reduced canals pass through the notch of radial pieces of calcareous ring and run backward along the inner surface of the body along the ambulacra between the radial nerve and the longitudinal muscle bands. The radial water canals are lined by coelomic epithelium and mesenchyme in which few longitudinal muscles are embedded.

The outer parts of the lower region of the tentacular canals form blind sacs projecting backward on the calcareous ring called ampullae.

The polian vesicle is an ovoid or elongated sac, its length varying between 1 and 2.5 cm, and arising from the left ventral part of the ring canal. Usually the number is one but very rarely two polian vesicles occur. The wall of the vesicle consists of the following layers. Externally it is clothed by a prominent peritoneal epithelium consisting of a single row of tall cells (Text-fig. 39A). Underneath the peritoneal epithelium is a longitudinal muscle



Text-fig. 35. A—T. S. of rete mirabile, B—T. S. of haemal ring.

layer. Major portion is occupied by the connective tissue composed of fibres. Numerous vacuoles and coelomocytes of various types are seen in this region. The lumen is lined by a layer of ciliated lining epithelium, the cilia of which are numerous and freely project in to the lumen. The lumen contains coelomic fluid with coelomocytes.

The stone canal springs from the right dorsal part of the ring canal and freely float in the coelom. It is an elongated structure whose length ranges from 1 to 5 cm. The wall of the stone canal is highly distended with folds. The canal is lined externally by a coelomic epithelium composed of columnar and closely packed cells (Text-fig.39B). Due to the presence of folds, the layer appears wavy. Thin and fibrous connective tissue with coelomocytes and cell inclusions, traversed by canals, follows the coelomic epithelium. The lumen is lined by a layer of ciliated columnar lining epithelial cells. Those cells away from the mesenterial attachment are ciliated while the cells on the other side are devoid of cilia. The madreporite is represented at the tip of the stone canal by 3 or 4 holes situated in slight depressions. It is through these apertures that communication is established between the body cavity and the water vascular system.

VIII. The Nervous System

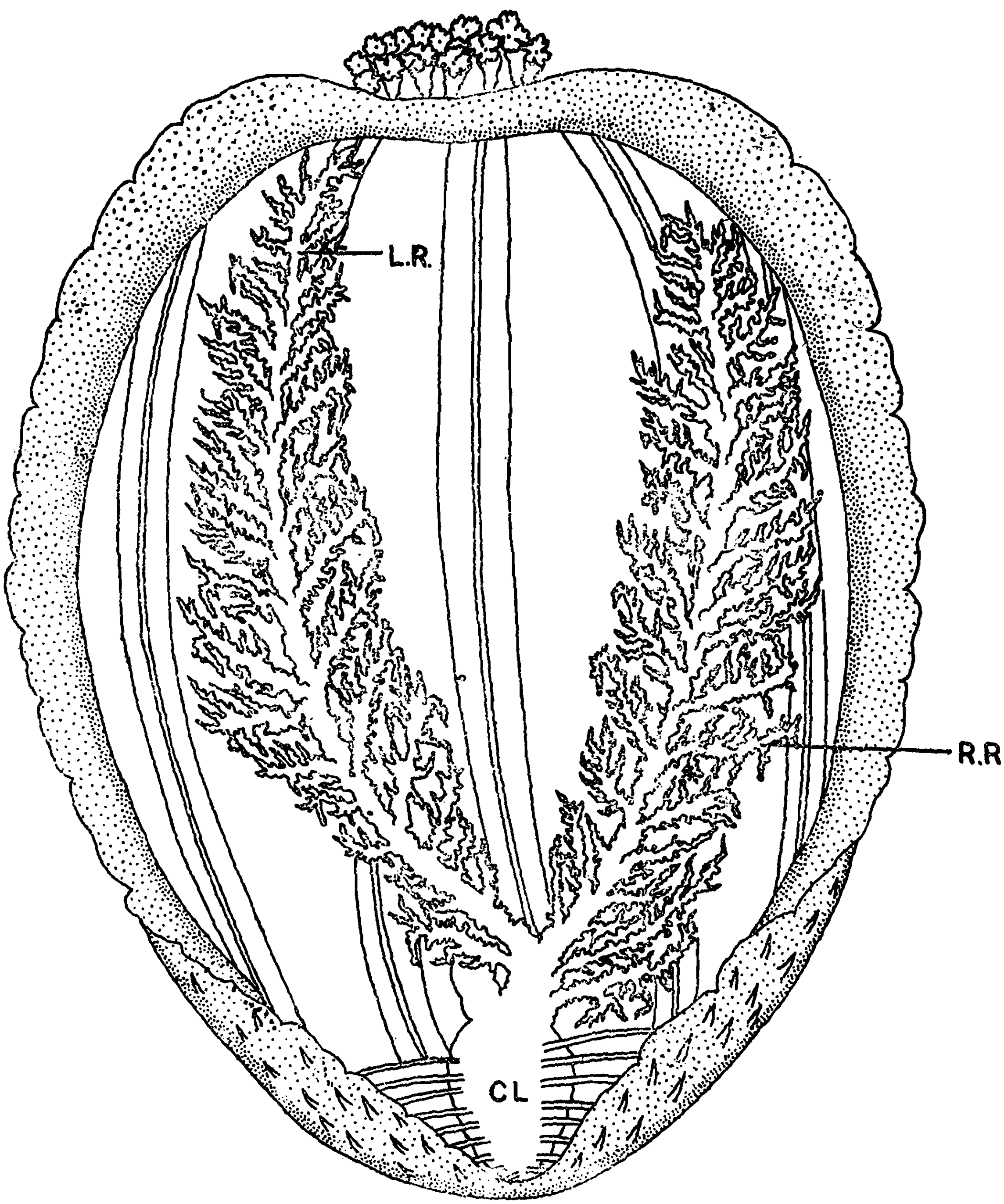
The nervous system of the Echinoderms is primitive, resembling that of coelentrates in basic construction. It consists of networks concentrated into ganglionated radial nerve cords and is divided into 3 divisions : 1) oral or ectoneural, 2) deeper lying hyponeural and 3) aboral or entoneural. The sensory ectoneural system is connected with the motor hyponeural and aboral systems. All the three divisions are not equally well developed in all the echinoderms. The general pattern of nervous system in holothurians is given by Hyman (1955).

In *Holothuria scabra* the ectoneural system is represented by the main nerve ring and outer oro-ectoneural part of the radial nerve. The nerve ring is a circular band surrounding the anterior most part of the oesophagus and situated on the innerside of the calcareous ring (Text-fig. 40A). Five radial nerves emerge from the nerve ring and pass through the notch of the radial plate of the calcareous ring. These nerves run lengthwise along with the radial canal of water vascular system and the innermost fibres of the dermis of the body wall, just external to the radial water vessel (Text-fig 40B). On either side of the radial nerve there are two spaces, the upper one is epineural canal or sinus, and lower one is the hyponeural canal or sinus, which is separated by a thin partition from the underlying radial water vessel. Tentacular nerves corresponding to their number arise from the nerve ring and innervate the tentacle. Each tentacle nerve passes between the connective tissue and the longitudinal muscle of the tentacle and gives off branches to adhesive papillae.

The radial nerve is divided by a thin longitudinal partition into a thicker outer ectoneural part and thinner hyponeural part (Text-fig. 40C). The radial nerve consists of bipolar and multipolar nerve cells with their fibrous axons and dendrites which form a network of a distinct layer. They are a few neurosecretory cells which are slightly larger with prominent axons. The neurosecretory substances are found among the nerve cells. A few bipolar and multipolar neurons themselves contain a secretory substance in the form of granules. These may be transformed into substances like acetylcholine. They are found among the neurons of the ectoneural and hyponeural band of the radial nerve. Eccentrically placed spherical nucleus occupy the major portion of the cytoplasm. The ectoneural band is sensory and gives off nerves to podia and ramifies into a general plexes in the body wall, while the hyponeural band is motor supplying the muscle fibres of the body wall and also participating in general plexes of the body wall. Thus it corresponds to the deeper oral or hyponeural system of other echinoderms. The aboral system is not represented in *H. scabra*.

IX. The Reproductive System

Hyman (1955) has given an account of morphology and histology of the reproductive system of different holothurians and Boolootian (1966) has summarised the reproductive cycles, biochemical changes throughout the reproductive cycle and breeding behaviour of holothurians. The reproductive physiolgy of the holothurian, *Stichopus japonicus* is given by Choe (1962). Gonadial pigments of the sea cucumber. *Holothuria leucospilota* has been studied by Takav et al. (1970). Rutherford (1973) has reported on the reproduction and growth of the holothurian, *Cucumaria pseudocurata.* Recently Krishnan and Dale (1975) and Atwood (1974) have studied the ultrastructure of the testis of the sea cucumber *Cucumaria frondosa* and *Leptosynapta clarki* respectively.



Text-fig. 36. Indicating the position of the respiratory tree.

Sexes are separate in *H. scabra* but morphological differentiation of sex is not easy. A single gonad, consisting of numerous thin, filamentous tubules united basally into one tuft, it attached to the left side of the dorsal mesentery and hangs freely in the coelom (Text-fig. 41A). The tubules are elongated and branched. From the gonodal base, the gonoduct proceeds in the mesentery and opens to the outside on the oral end at the base of the tentacles. In the case of females the filaments are coloured brown (uniformly thick and long) in which the eggs or oocytes are visible as small white spots (Text-fig. 41B). The testis consists of white (long beaded) uniformly thick and long filaments (Text-fig. 41B). However, such variation cannot be seen in early stages. The gonad is clothed by an external layer of the coelomic epithelium, which consists of two or three layered cuboidal cells beneath which is a thin circular muscle layer and a thin connective tissue layer. The lumen of the tubule is surrounded by germinal epithelium.

In the case of males (Text-fig. 42A) the spermatogonial cells are found attached to the germinal epithelium. The spermatogonial cells are larger and more or less spherical in shape with a distinct nucleus in the centre. Just after the spermatogonial cells and more towards the lumen of the tubules are the paimary and secondary spermatocytes which are much smaller with deeply staining nucleus. The mature spermatids and sperms are found in the centre of the lumen.

In the case of females, germinal epithelium gives rise to numerous oogonial cells which are small and found embedded in the germinal epithelium (Text-fig. 42B). The oogonial cells have prominent lightly staining neculeus with a distinct deeply staining nucleolus. Primary, secondary and mature oocytes are seen in the lumen. A mature ova is characterised by the presence of very large nucelus with a distinct nucleus in it.

The gonoduct consists of a ciliated epithelium, the cells of which are regularly with long cilia, directed towards the lumen, a broad connective tissue and externally a layer of coelomic epithelium continuous with the dorsal mesentery (Text-fig. 42C).

During spawing the sperms or ova are released through the gonopore by the ciliary action of the gonoduct. Fertilization is external and the embryo develops into an auricularia larva.

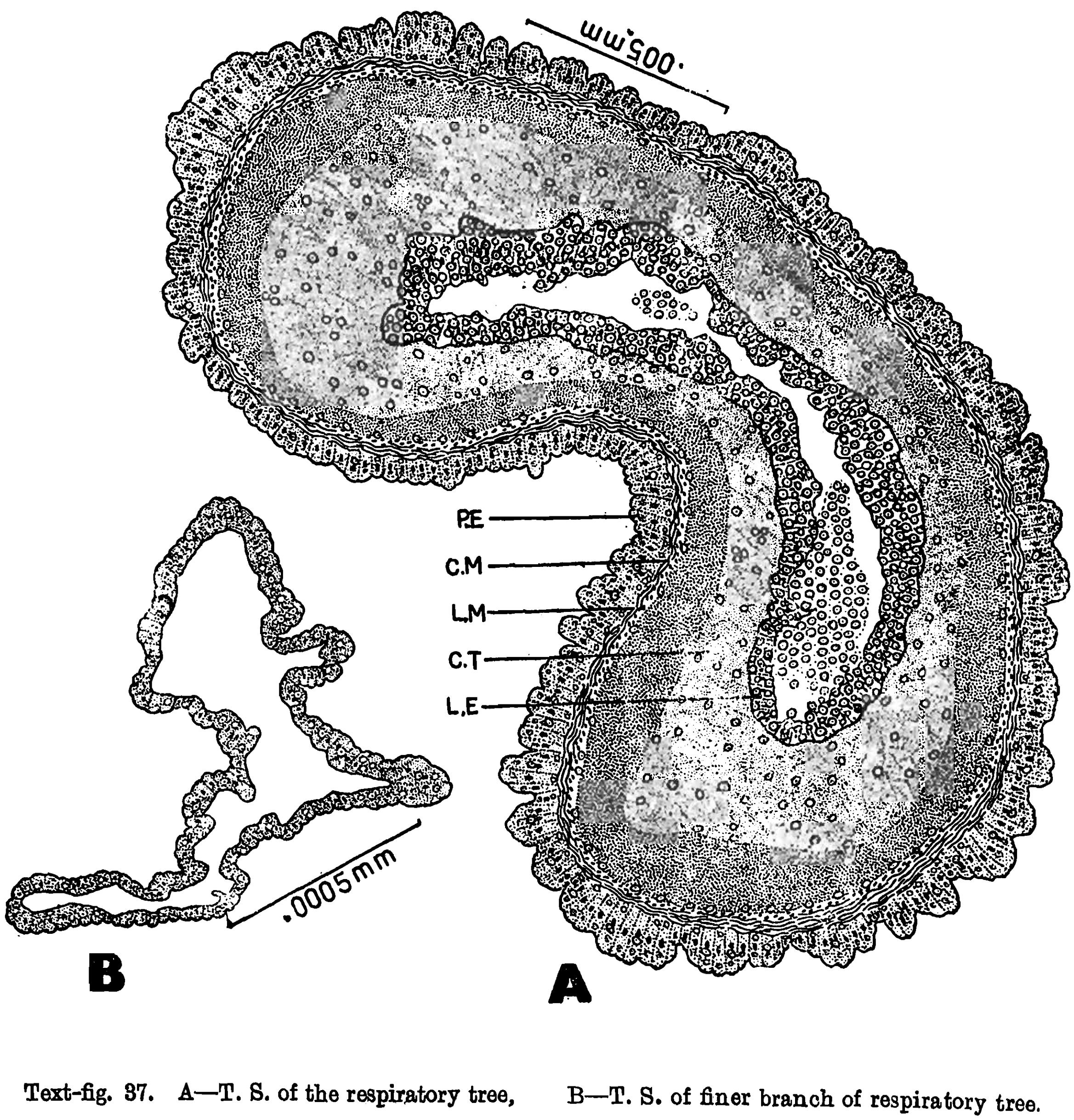
The reproductive cycle of *H. scabra* has been studied using the 'gonad index' method. Four stages of maturity; immature, maturing, mature and spent have been recognised based on the microscopic examination of both fresh and sectioned permanent mounts of reproductive tissues (Krishnaswamy and Krishnan, 1967). The animal breeds biannually, once in March-April and again in September-October. Both males and females spawn simultaneously. The biochemical and histochemical studies reveal the accumulation of carbohydrates and lipids in gonads during the peak breeding activity (Krishnan, 1968). A direct relationship between the protein content and the advancement of maturity is evident in the ovary whereas in testis an inverse relationship is found (Krishnan, 1968).

The role of the tissues other than gonodal, such as gut and body wall, during the reproductive cycle, exhibits a sex wise pattern of synthesis and translocation of nutrient materials (Krishnan, 1968).

The environmental factors such as salinity, rain, temperature and concentration of food during those periods induce breeding in *H. scabra.* Salinity appears to be the primary trigger to induce breeding (Krishnaswamy and Krishnan, 1967).

X. EVISCERATION AND REGENERATION

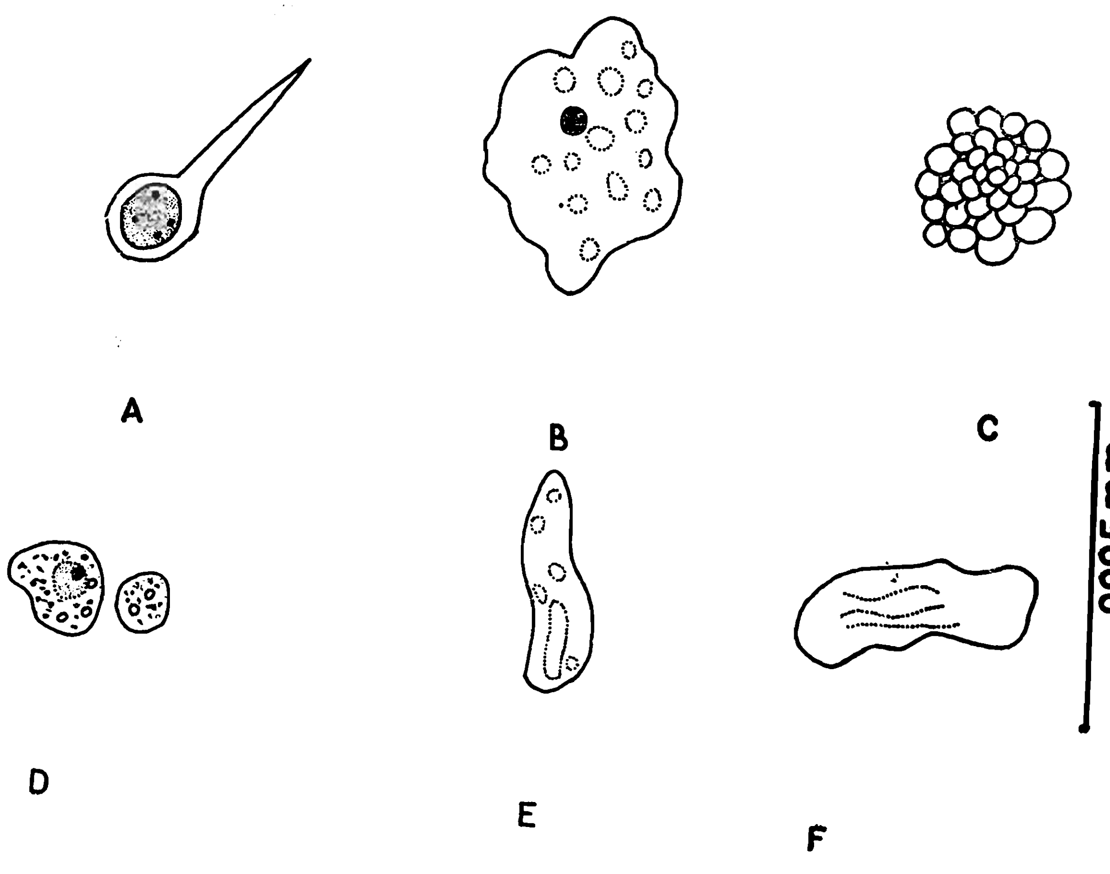
The holothurians possess an unique feature of eviscerating or ejecting out their inner organs under adverse conditions and regenerating the lost organs in the course of time. The process of evisceration and regeneration has been studied as early as 1851 by Dalyell. This process is reported to be a normal and spontaneous event (Kille, 1935 & Mosher, 1965), seasonal (Bertolini, 1932 & Swan, 1961) or defensive to tide over an adverse environmental condition (Pearse, 1909 & Domantay, 1931). The investigations in a larger number of *H. scabra* during various seasons of the year have not shown a single eviscerated or regenerating individual in the field. This shows that in *H. scabra* evisceration does not occur in nature either spontaneously or seasonally (Mary Bai, 1971*b*). Apart from evisceration, transverse fission of



Text-fig. 37. A—T. S. of the respiratory tree, B—T. S. of finer branch of respiratory tree.

the body and regeneration of the reciprocal parts in the body of the holothurians has been shown in experimental conditions by Dalyell (1851) and Chadwick (1891) and in natural conditions by Monticelli (1896), Crozier (1917), Deichmann (1922), Kille (1936), Frizell and Exline (1955) and Bonham and Held (1963).

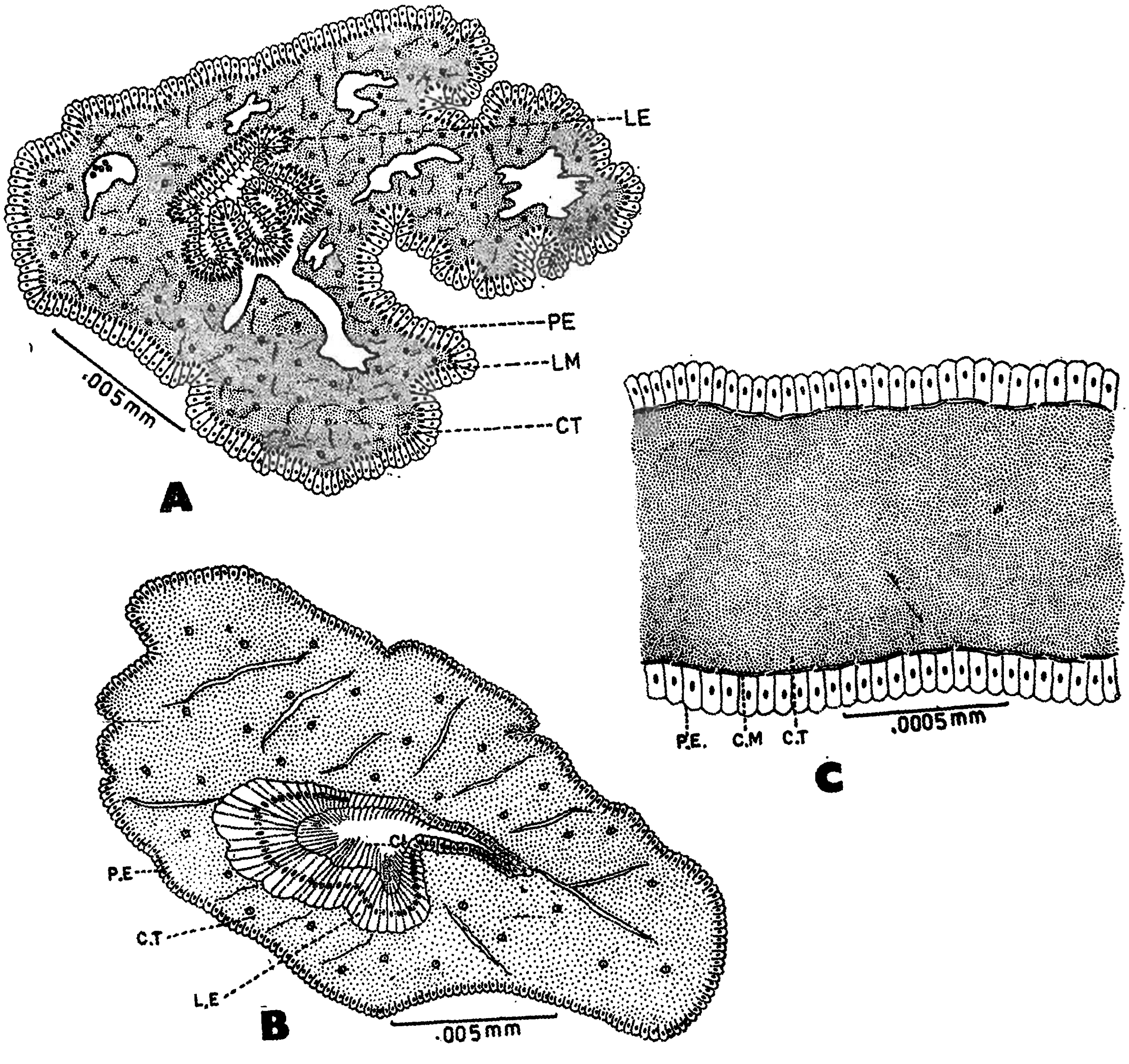
Regeneration of alimentary canal. —The results of the process of regeneration are given in (Text-figs. 43-45). During the first two days of regeneration the anterior and posterior ruptured ends were closed and the free edge along the length of the mesentery was uniformly thickened. This thickening consists of an outer peritoneal epithelium and an inner mass of mesenchyme with spindle or oval shaped dedifferentiated muscle fragments and morula cells. This thickening continued to increase by mitosis upto 3 to 5 days. The primordium of the alimentary canal was a rod-like straight thickening along the entire length of the mesentery. On the sixth day a complete tubular alimentary canal was formed by the formation of a lumen in the mesenterial thickening connecting the old and regenerating alimentary canal. The newly formed alimentary canal consisted of an outer peritoneal epithelium, a thin layer of circular muscle fibres, a connective tissue layer with amoebocytes and morula cells and a thin lining epithelium (Text-fig. 45 A). After seven days of regeneration the animals started feeding. From 9 to 32 days of regeneration the length and diameter of the alimentary canal increased. By 32 days the normal structural pattern was attainded.



Text-fig. 38. The coelomocytes.

Regeneration of haemal system. —The haemal system also developed from the mesenterial thickening. The ventral haemal vessel appeared as a projection consisting of an outer peritoneal epithelium covering a mass of mesenchymatous tissue with dedifferentiated muscle fibres and few morula cells at the free edge of the mesenterial thickening. The dorsal haemal vessel developed as a mesenterial thickening at the junction of the alimentary canal and mesentery on seventh day of regeneration. From 8 to 32 days the regeneration of haemal system involved the formation of lumen, branching, lengthening and differentiation of the different vessels so as to reach the normal condition.

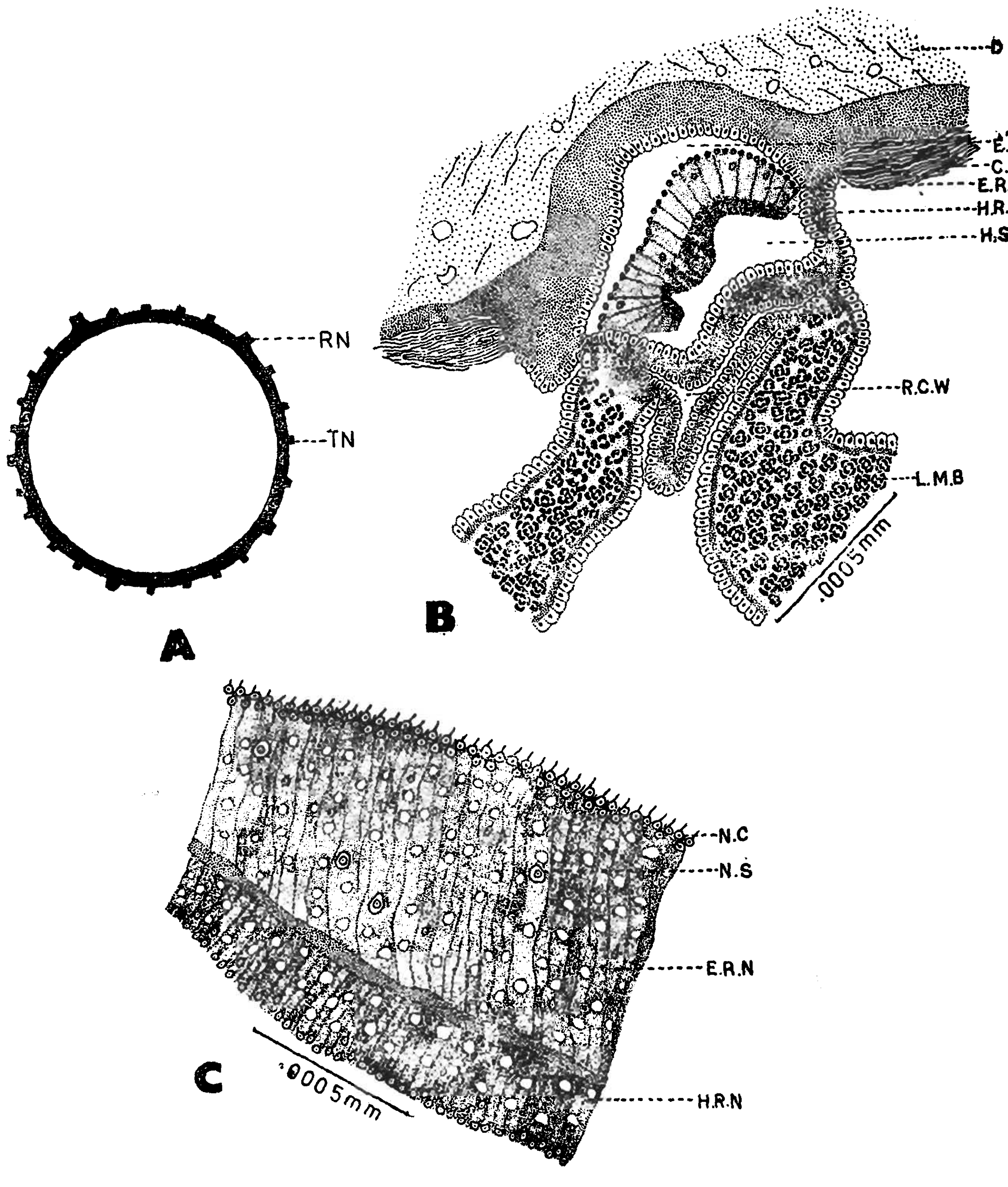
Regeneration of respiratory tree. —The ruptured end of the respiratory tree was closed within 24 hours after evisceration. The respiratory tree originated as a solid anterior



Text-fig. 39. A—T. S. of polian vesicle, B—T. S. of stone canal, C—T. S. of water ring.

projection from the ruptured end on the second day. On the fifth day, small buds as evidence of branching was noticed. Between 6 to 32 days the length and diameter of the respiratory tree increased and on 32nd day the normal bulk was attained.

There are two contradictory views regarding the process of regeneration of the alimentary canal in the holothurians. One is that it is replaced by tubular outgrowth, one growing from the posterior end and uniting in the middle forming a continuous structure (Bertolini, 1933) and Kille, 1936). The second view is that the alimentary canal is regenerated from mesentery (Scott, 1914 ; Kille, 1935 ; Dawbin, 1949*a* & *b*, Mosher, 1956 ; Smith and Greenberg, 1966 ; Smith, 1971 and Tracey, 1972).



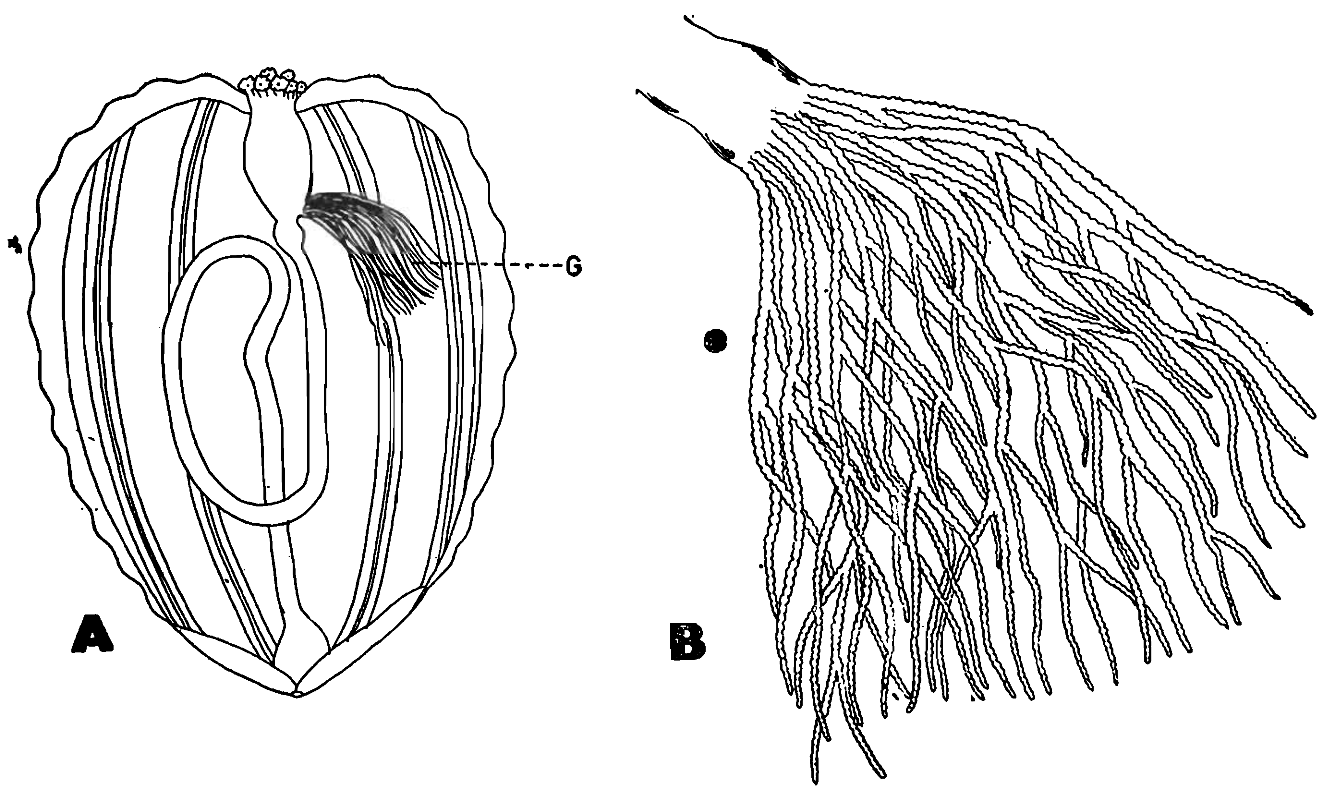
Text-fig. 40. A—Nerve ring. A diagramatic representation, B—T. S. of body wall showing radial nerve, C—T. S. of radial nerve.

Direct observations as well as autoradiographs made from sections of regenerating tissues after injection of tritiated thymidine revealed that the alimentary canal regenerates by the latter method from the mesenterial thickening (Mary Bai, 1971*a*).

XI. BIONOMICS

The holothurians are exclusively marine animals with the exception of two brackish water forms namely, *Synapta similis* and *Haplodactyla malpadioides*. The holothurian *H. scabra* is a sluggish form lying burried partly or wholly in muddy or sandy bottom. These are very common holothurians inhabiting the Pamban Islands and form a bed along the coast. They move by their ventral creeping side with the help of the tentacles and muscular action of the body wall and they even climb the walls of the aquarium tanks. These are omnivorous, and with the aid of the tentacles they shovel the substrate into their mouth.

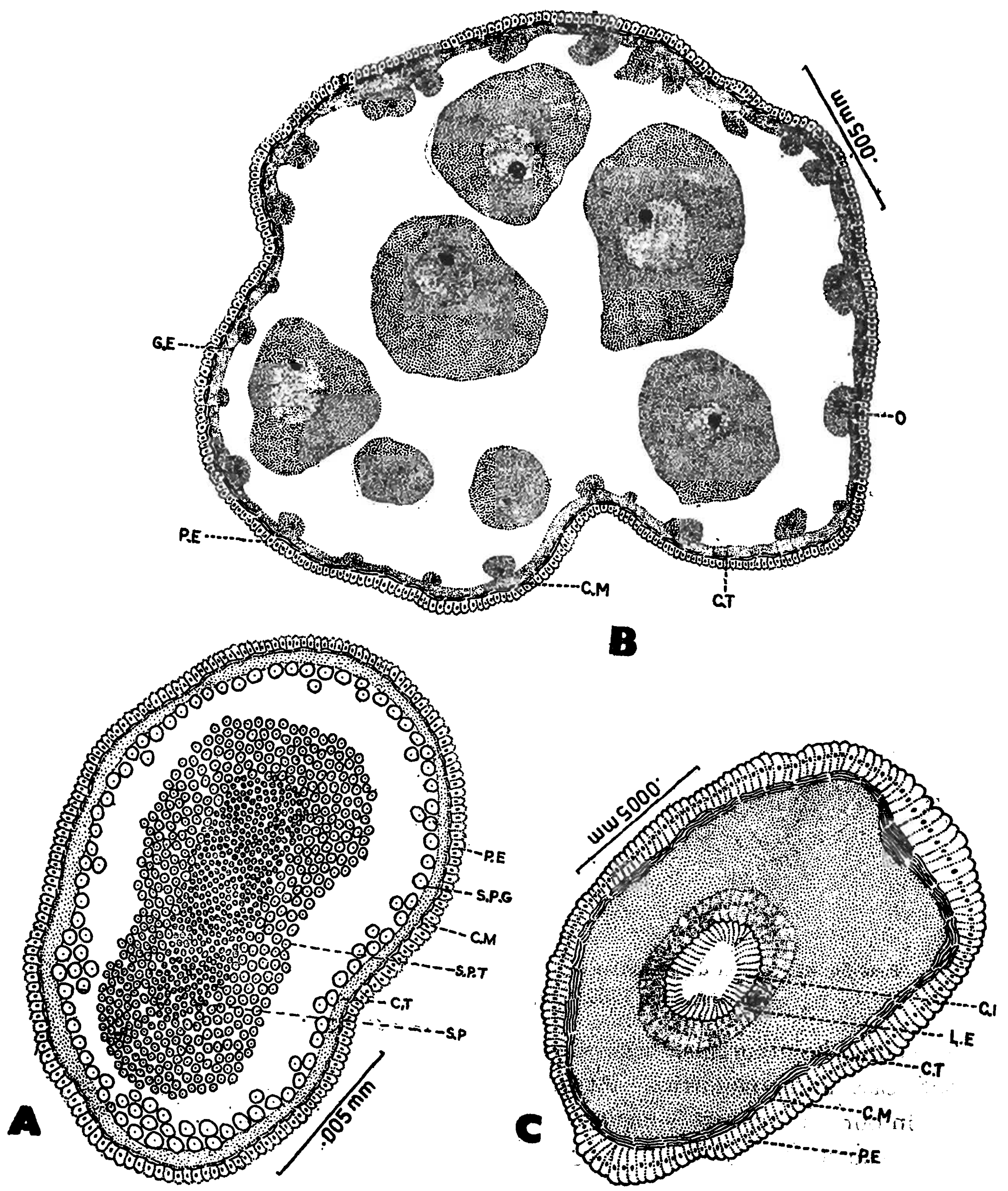
The sluggish and almost passive nature of the holothurians make them hosts to many commensals and parasites. A variety of commensals from protozoans to fish have been reported to be present in them. It has been reported that the Pea crab, *Pinnotheres doceannensis*, mostly females, were found to remain inside the lower part of the respiratory tree above the cloaca (Jones and Mahadevan, 1966).



Text-fig. 41. A—A diagramatic representation indicating the testis, B—A diagramatic representation indicating the ovary.

The cured holothurians, 'beche-de-mer' or 'trepang' is considered a delicacy in some of the south-east asian countries. At present about 30,000 kg of beche-de-mer is produced annually in our country and is exported, since it is not consumed locally. The industry is restricted to some of the fishing villages bordering the Gulf of Mannar and the Palk Bay along the south east coast of India (James, 1968*a*). *H. scabra* is the species that is almost exclusively used in this country for this purpose. The method of preparation of beche-de-mer is as follows. First an antero-posterior incision is made at the dorsal part of the anal region to cause them to eviscerate and to shorten and thicken. The body wall is boiled in fresh water and then they are kept in pits in the ground for overnight. Again on the next day they are boiled in fresh water and dried in the sun. This dried object is cut into small pieces which are added to soups and stews which impart a delicate flavour and swell into a gelatinous condition and are eaten as tit bits.

In Japan even the salted entrails (intestines) 'kenowata' is consumed by the people as food. The regeneration of the alimentary canal of *Stichopus japonicus* is used as a means to



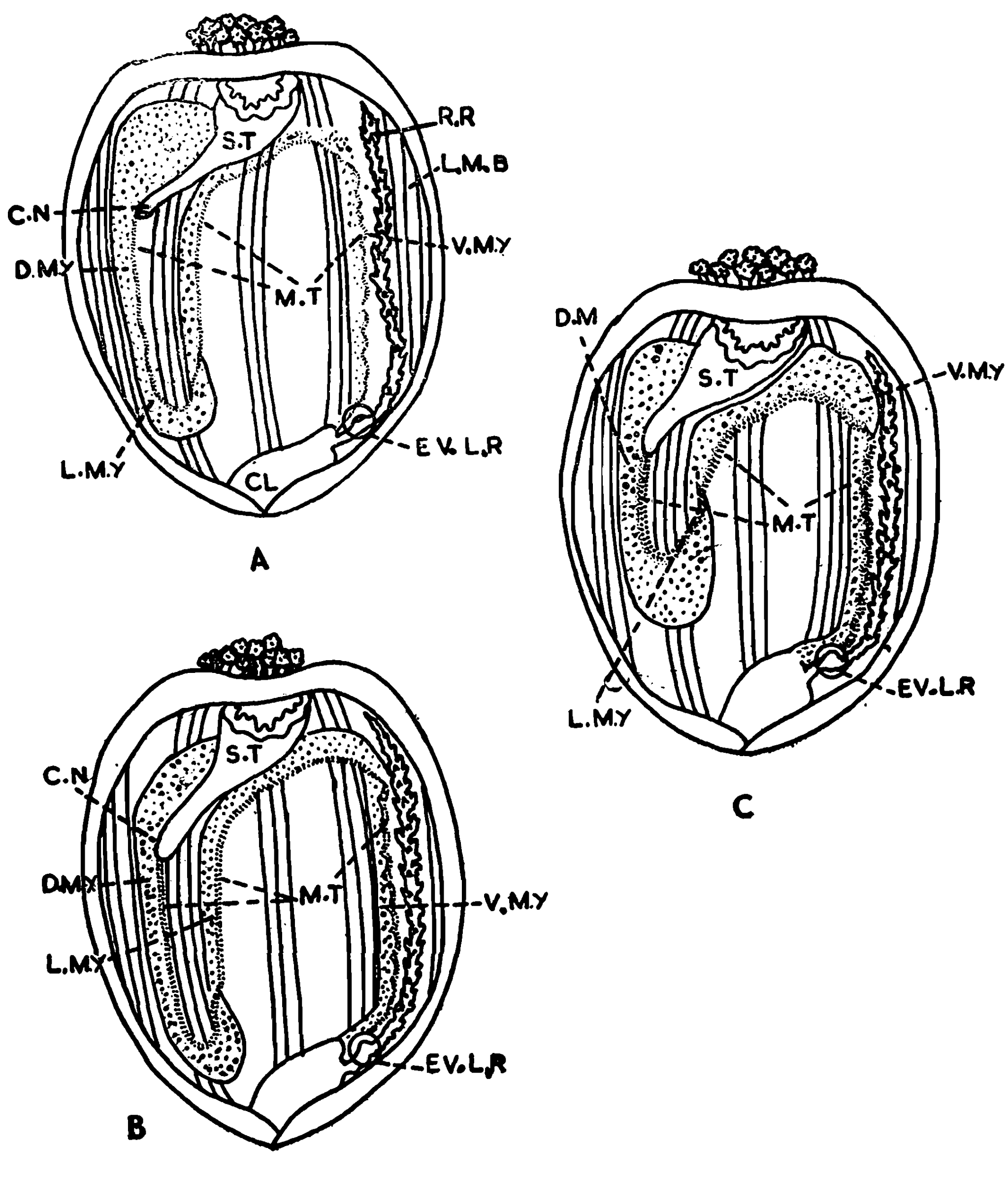
Text-fig. 42. A—T. S. of testis, B—T. S. of ovary, C—T. S. of gonoduct.

increase the production of kenowata. After inducing evisceration, the holothurians are kept in the fishing grounds. Within three months the regenerated alimentary canal is equal to the normal one (Choe, 1962). The studies on evisceration and regeneration in *Holothuria scabra* may help to launch holothurian culture in the coastal areas as in Japan which in turn may be of great economic importance. (Mary Bai, 1971*a*).

XII. DIRECTION TO PRACTICAL WORK

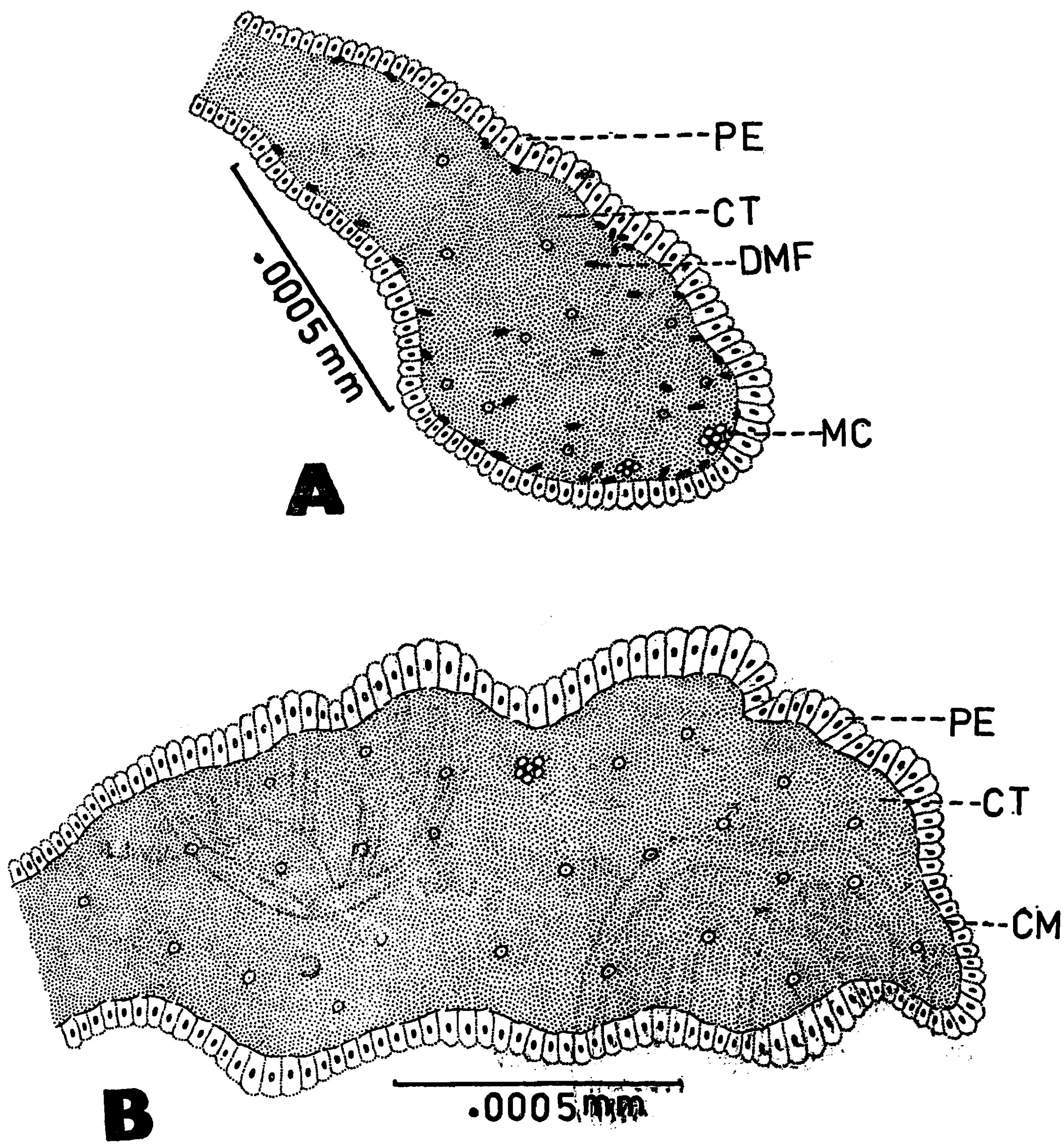
Collection, maintenance and preservation

The holoturians are available in large numbers in Gulf of Mannar near Krusadi Island and Rameswaram Islands on the east coast of south India. It is a shallow area, the bottom being sandy/muddy. They can be easily collected either by handpicking or by diving in



Text-fig. 43. Stages of regeneration.

that area. The living specimens should be transported to the laboratory in well oxygenated polythene bags. In laboratory they can be maintained at room temperature in cement concrete tanks of 120-1250 litres capacity. Make arrangements to aerate and circulate the sea water continuously as shown in (Text-fig. 46). The system mainly consists of an air-lift siphon, operated with compressed air and an alkathine or glass cylinder of 60 cm long with a diameter of 7 cm filled with shore jelly plugged with glass wool. Water, pumped by the air-lift recirculates through the glass wool and pebbles becomes cleared off the debris and excreta of the animals. The device acts also as biological filter, since the bacteria which



Text-fig. 44. A—T. S. of mesenterial thickening after one day regeneration, B—T. S. of mesenterial thickening after three days.

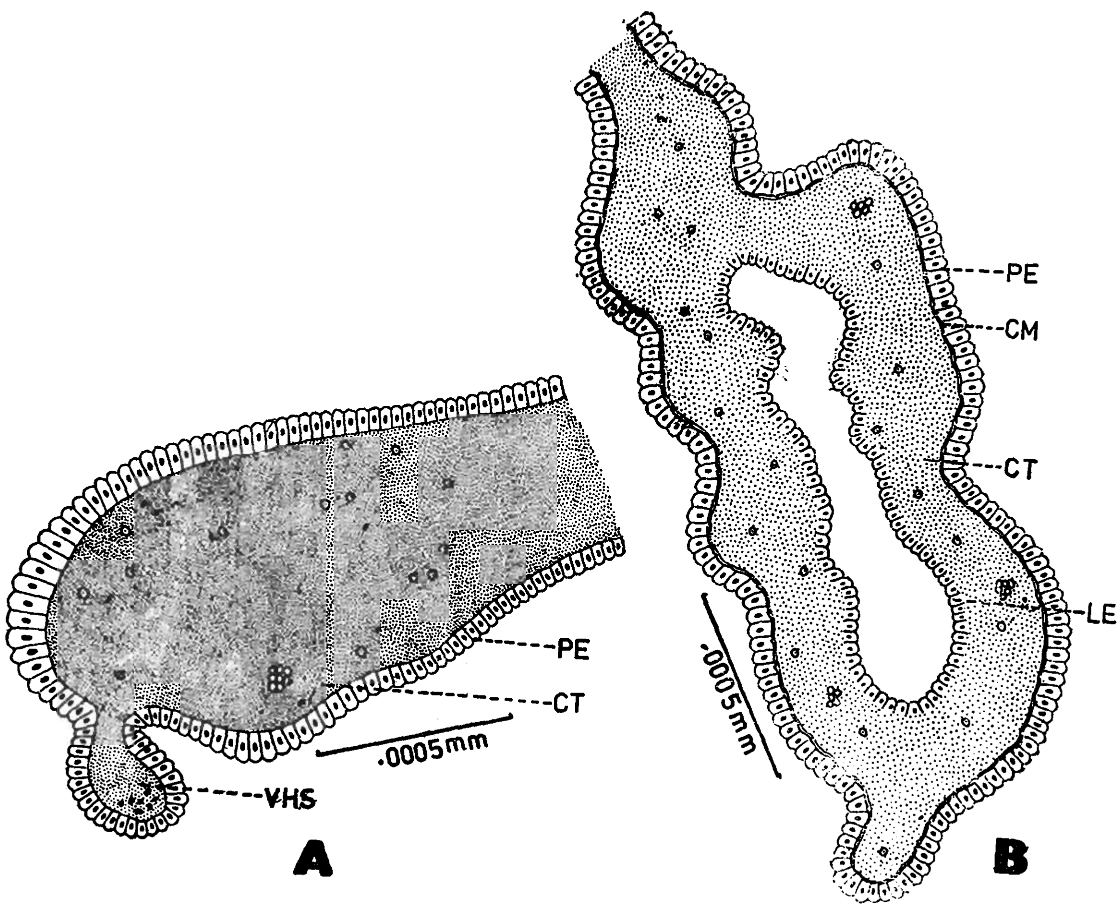
inside the column fix the ammonia excreted by the animals for the water which would otherwise be toxic to them (Saeki, 1958 and Kutty, 1968). Alternately few other methods are given by Mariscal (1974) for filteration/aeration systems in aquarium tanks.

The animals for anatomical work should be slightly anesthetised in 8% $MgCl_2$ in tap water solution for 30 minutes and thoroughly rinsed in sea water to prevent movement or evisceration. If they are to be preserved for future work, the specimens should be subsequently kept in 10% formalin. It has been found that if the fresh specimens are dropped directly into a specimen jar containing formalin they eviscerate the internal organs. This could be avoided if each specimen is injected slowly with formalin and then dropped into the specimen jar containing formalin.

External characters

Examine the following characters :

1. The shape, colour, dorsal and ventral sides, anterior and posterior end of the animal, and compare with the figure in the text,



Text-fig. 45. A—T. S. of mesenterial thickening after five days, B—T. S. of intestine after six days of regeneration.

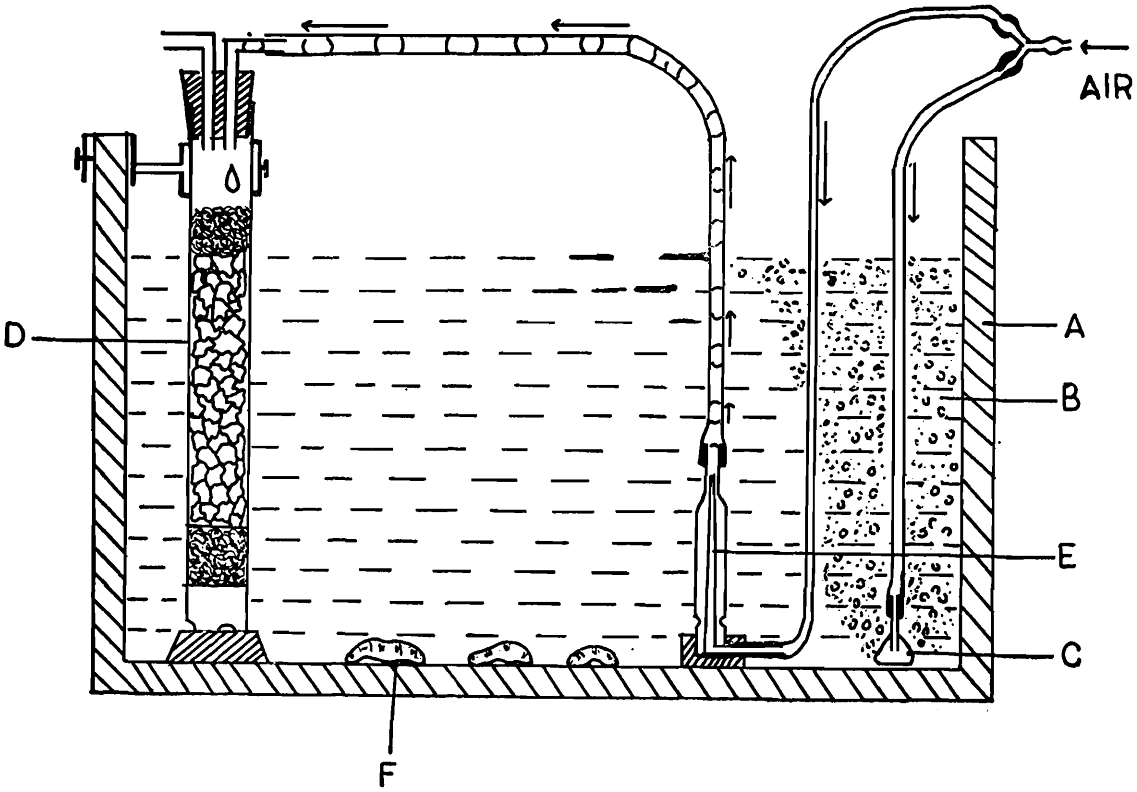
2. The structure of the tentacle and the podia as shown in (Text-fig. 14A) should be studied with a hand lens.

The skeleton

Prepare the skeleton of the body wall as follows : boil pieces of the body wall in 40% KOH in a test tube for a few minutes until the tissues disintegrate. Wash the fluid (with spicules) with distilled water and mount them on the slide with glycerol jelly. Study the types, length and diameter of the spicules under the microscope (Text-fig. 20A-D), *Internal anatomy*

Make a longitudinal cut in the middle of the dorsal body wall, pin the specimen onto a dissection board, dip in a tray of water and note the following.

1. Examine the alimentary canal starting from the owsophagus to cloaca (Text-fig.22A).
2. Note the type of calcareous pieces of the calcareous ring (Text-fig. 20E).
3. Examine the water ring, stone canal, polian vesicle, radial water vessel and ampulla (Text-fig. 33B).
4. Note the haemal ring below the water ring and its continuation as the dorsal and the ventral haemal vessel and its branches (Text-fig. 33A).
5. Note the nature of the respiratory tree and its brancehs (Text-fig. 36).
6. Note the structure of the gonadial tubules, its, attachment and its duct (Text-fig. 41).
7. The longitudinal muscle bands should be studied.
8. Locate the position of the nerve ring and its branches to the tentacles by slowly teasing out the tissues inside the calcareous ring with mounted needle.



Text-fig. 46. Diagramatic representation of the aquarium tank with filtering -cum-aerating system.

Coelomocytes

Syringe out samples of coelomic fluid from the perivisceral coelom of a fresh specimen with a 10ml hypodermic syringe with a stainless steel needle. Changes in the morphology of the coelomocytes, presumably due to contact with glass and metal surface can be kept to a minimum by repeated previous exposures of the inner surfaces of the syringe, needle, the surfaces of the slides and coverslips to the coelomic fluid of the same species of holothurian. Use vital stains such as Neutral Red, Janus Green B, Briliant cresyle blue, methylene blue, Bismark brown and toluidine blue.

Histology of viscera

For sectioning the soft tissues, fix them in various fixatives such as 10% formalin, Susa fluid, Bouin's fluid and Alcoholic bouin for 24 hours. Keep the material in running water for 24 hours and then transfer to 70% alcohol, dehydrate and embed in paraffin wax. Prepare sections of 5 μ thick with the aid of microtome. For sectioning the body wall, fix pieces of body wall in various fixatives as mentioned before and decalcify in Jenkin's fluid (Pearse, 1968). Study the intestinal contents from freshly collected specimens. Study the general histological structures by using Mallory's tripple stain, Masson's trichrome, Heidehhain's haematoxylin and Heidenhain's azan. For the nervous system, use Peter's silver-gold-chloride impregnation method.

Evisceration and regeneration

Induce evisceration of the internal organs in the holothurians weighing 80-2000 g. by injecting 10-100 ml of distilled water into the coelom. Maintain them in cement tanks as described earlier and feed them with sea mud. Take sections of the regenerated tissue samples of 2 cm length from different regions and stain them as described earlier.

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ABBREVIATIONS USED

A B. — Aquapharyngeal bulb.
A S I. — Asending small intestine
A M. — Amoebocytes
A M P. — Ampulla
A N. — Anus
A P. — Adhesive papilla
B W. — Body wall
C. — Coelomocytes
C. I. — Cilia
C E P. — Coelomic epithelium
C U. — Cuticle
C M. — Circular muscle layer
C T. — Connective tissue
C R. — Calcareous ring
Con. — Constriction
C S. — Cloacal suspensors
C L. — Cloaca
C V. — Collecting vessel
D. — Dermis
D H S. — Dorsal haemal sinus
D M. — Dorsal mesentery
D M F. — Dedifferentiated muscle fibres
D S I. — Descending small intestine
E R N. — Ectoneural part of the radial nerve
EV. L R. — Eviscerated left respiratory tree
E P. — Epidermis
E. S. — Epineural sinus
G. — Gonad
G C. — Glandular cells
G E. — Germinal epithelium
H. — Haemocytes
H R. — Haemal ring
H R N. — Hyponeural part of the radial nerve
H L. — Haemal lacunae
H S. — Hyponeural sinus
I P. — Inter radial piece
I C T. — Inner connective tissue
L E. — Lining epithelium
L R T. — Left respiratory tree
L M. — Longitudinal muscle layer
L I. — Large intestine
L M B. — Longitudinal muscle band
L M V. — Lateral mesentery
M. — Mouth
M C. — Morula cell
M F. — Muscle fibre
M T. — Mesenterial thickening
M S. — Muscle strand
M U. — Mucus
N. — Nucleus
N B. — Nerve band
N C. — Nerve cell
N D H S. — Net work of the dorsal haemal sinus
N S. — Neurosecretory cell
O. — Oocyte
O E. — Oesophagus
O C T. — Outer connective tissue
P E. — Peritoneal epithelium
P G. — Pigment granules
P V. — Polian vesicle
R C W. — Radial canal of water vascular system
R M. — Rete mirabile
R N. — Radial nerve
R P. — Radial piece
R W V. — Radial water vessel
S C. — Stone canal
S F. — Sensory fibre
S P G. — Spermatogonia
S P T. — Spermatids
S P. — Spermatozoa
S T. — Stomach
T. — Tentacle
T N. — Tentacular nerve
T Con.
V H S. — Transverse connective of ventral haemal sinus
V. — Vacuole
V I. — Villi
V H C. — Ventral haemal connective
V H S. — Ventral haemal sinus
V M Y. — Ventral mesentery
W R. — Water ring
Z. — Zig Zag