J. Zool. Soc. India 40-41 : 7-22 (1988-89)

ON THE ANATOMY OF THE COMMON SEA URCHIN *Stomopneustes variolaris* (LAMARCK)

D. B. JAMES

Central Marine Fisheries Research Institute, Kochi - 682 031

Abstract : In this paper the anatomy of the common sea urchin of the Indian coast *Stomopneustes variolaris* (Lamarck) is presented. The external characters and all the systems are described in detail. Notes on the habits of the sea urchin are also provided.

Key words : Anatomy, Sea urchin, *Stomopneustes variolaris*.

INTRODUCTION

Information on the anatomy of echinoderms is scanty, more so from the Indian side. Aiyar (1938) published a memoir on the anatomy of the sea urchin *Salmacis bicolor* . James (1967, 1968) gave the gross anatomy of the holothurians *Phyllophorus (Phylophorella) parvipedes* and *Stolus buccalis* respectively. Rao (1968) described the anatomy of the interstitial holothurian *Psamothuira ganapati*. Mary Bai and Ramanathan (1977) have published the internal anatomy of the holothurian *Holothuria (Semperothuria) cinerascens* from the Kanyakumari coast. Mary Bai (1978, 1980) published on the anatomy and histology of the commercially important holothurians *Holothuria (Netriatyla) scabra*. Except for the papers of Aiyar (1938) and Mary Bai (1980) the other papers cited give stray observations on the anatomy of holothurians.

The sea urchin *Stomopneustes variolaris* (Lamarck) (Pl. I) is a large, conspicuous, often gregarious sea urchin in the intertidal region in the seas around India. It occurs right from the low water mark to 20 metres depth. It has a wide distribution and is reported from the Mascarene Islands East Africa and Madagascar,

* Present address : TRC of CMFRI, 90 North Beach Road, Tuticorin-682001.

S.E. Arabia, Maldives and Lakshadweep, Sri Lanka, Bay of Bengal, East Indies, North Australia, China, Southern Japan and South Pacific Islands. (AM. Clerk & Rowe, 1971). It is well distributed in the Seas around India. It is reported from Ratnagiri (West Coast) by Ranade (1979) and from the Lakshadweep by Nagabhushanam and Rao (1972) and James (1969, 1989). It is widely distributed in the Gulf of Mannar and Palk Bay and reported by Bell (1888), Thurston (1894), H. L. Clark (1925), Gravely (1927), James (1969, 1986, 1988), Satyamurti (1976) Joseph (1978) and Rao *et al.* (1985). It is reported from the East Coast (Madras, Visakhapatnam and Kanyakumari) by H. L. Clark (1925), Gravely (1941) by Giese *et al.* (1964) from Madras, James (1969) from Waltair (Visakhapatnam). Ganapati and Sastry (1972), Reuben et al. (1980) an Sastry (1985) have reported this species from Visakhapatnam. This species is recorded from the Andaman and Nicobar Islands by Tikader *et al.* (1985, 1986) and James (1986).

Since this is a large, conspicuous and easily available sea urchin it is often given to the students for dissections and also for mounting of various types of pedicellariae. The anatomy worked out in detail and presented here will be useful to them.

EXTERNAL CHARACTERS

The test of the sea urchin is more or less globular with large, smooth and pointed spines. In very large specimens the test appears to be slightly pentagonal in shape. The test is arched on the aboral side and more or less flattened on the oral side and scarcely sunken towards the peristomial edge. The spines at the ambitus are very large and those on the oral side and some of them surrounding the mouth are flattened which aid in shovelling the food into the mouth. At the centre of the oral side there is a circular opening, the mouth through which project the free ends of five teeth.

Surrounding the mouth there is a circular area of soft skin the peristomial membrane. The peristomial membrane is supported by many fenestrated plates (Fig. 1). Such spicules have been reported from *Salwaa's bicolor* and *Stomopneustes variolaris* by Aiyar and Menon (1934). Midway between the edge of the peristome and the teeth there are five pairs of special tubefeet called buccal tube feet. Just outside the peristome and amongest the spines are situated five pairs of branched and fleshy structures called dermal branchiae which are arranged in five groups in the interradial areas. At the aboral pole there is a small aperture the anus which is surrounded by a area of leathery skin called the periproct.

The entire surface of the body except the peristome and the periproct is covered by spines. The spines are of various sizes; the large ones are called primary spines and the smalled ones are called the secondary spines. The spines are attached to the test by something like a ball and socket arrangement. At the base of each spine there is a cup-shaped concavity which fits over a ball-like tubercle on the test. As the tubercle is larger than the base of the spine, the spine has a large range of movement. Around the base of the spine there is a circular ridge formed by a ring of minute projections; the base and this ridge of the spines are connected with tubercle by a cylindrical sheath of muscle-fibres. By the contraction of these fibres the spine moves in any direction.

Besides the spines the surface of the sea urchin is beset with fine double rows of delicate tansverse cylindrical structures bearing suckers at their ends. These are known as tubefeet. Each of the double row runs from oral to aboral side in the ambulacral areas. They are locomotory, sensory and respiratory in function.

Among the spines there are outgrowths of small peculiar structures, the pedicellariae arising from the surface of the integument. Three types of pedicellariae are found in this sea urchin. They are known as tridentate, triphyllous and ophiocephalous pedicellariae. Each pedicellariae consists of three blades or jaws mounted on a long stalk and a well developed musculature for opening and closing of the jaw. The stalk contains a calcareous rod which articulates with a minute tubercle on the test. The pedicellariae are covered with ciliated epithelium which is modified to form special receptor organs on the inner surface of the blades.

Tridentate Pedicellariae : In tridentate pedicellariae the calcareous supporting rod in the stalk does not extend to the base of the blades. The upper portion of the pedicellariae is mounted on an elastic tube which enables it to move in any direction and also to reach the site of offence easily. The three blades touch only at the base and at the tip (Fig. 2, A & B). The blades are dumb-bell shaped.

Ophiocephalous pedicellariae : These are more numerous than any other type of pedicellariae found in this sea urchin. They are scattered all over the test and the stalk is supported proximally by a calcareous rod extending to half its length; the distal *half is devoid* of the rod but contains an elastic band in the axis and is therefore flexible and mobile. The blades (Fig. 2, B) are of various forms with short or elongate blades. The margin of the blade is serrated and the serrations are large and appear like teeth. The apophysis of the larger forms terminate rather bluntly at the base of the blade, not continuing on to the edge of the blade which is the usual condition in ophiocephalous pedicellariae.

Triphyllous pedicallariae : The triphyllous pedicellariae are the smallest in size. The supporting rod extends for about half the distance of the stalk, the distal portion of which contains elastic tissue and is highly flexible.

Pedicellariae serve for the purposes of offence and defence. The sea urchins being provided with a body encased in a rigid skeleton and leading a sedentary life have to constantly protect themselves from other organisms settling on them or attacking them. They have to also get rid of the showers of mud and sand. The various larvae of the sedentary organisms form a menace to the sea urchin.

The two blades of the triphyllous pedicellariae hold the particles of sand while the third blade hammers the particle into dust and is finally swept by the cilia. The ophiocephalous pedicellariae grip the larger prey which brush against the urchin and hold fast the prey till the tubefeet take it up and convey it to the mouth. Thus different types of pedicellariae function in different ways and keep the delicate skin of the urchin clean.

There are minute, glassy, club-shaped structures covered with cilia and possessing a rich supply of nerves at the bases mainly in the radii of the oral surface. These glassy spheres, called the spheredia are attached to the ambulacral plates by means of short stalks. The sphaeridia serve the purpose of balancing.

THE SKELETON

When the spines and pedicellariae are removed the body is seen to be enclosed in a firm immovable skeleton called the test. The test is composed of twenty rows of calcareous dermal plates fitting closely and rigily by means of sutures. The dermal plates lie beneath the epidermis and below these plates lie the nervous and water vascular system. The skeleton is divided into three parts. 1. the plates of the globular shell or corona 2. the plates of the apical system embedded in the periproct and 3. the plates of the peristome. The corona is formed by ten double rows of coronal plates arranged meridionally from the periproct to the peristtome. Five of these double rows are radial in position and constitute the ambulacra and the other five of them are in the interradial position and constitute the interambulacra.

The outline of the corona as viewed from the aboral pole is called ambitus. The adambulacrral plates can be easily made out in the living condition because of the presence of two rows of tubefeet running all along its length along one margin of the plate. The tubefeet are absent in the interambulacral plates. The line dividing each ambulacral area from the adjoining interambulacral area is more or less straight but the row that divides ambulacral and interambulacral plates from the adjoining row of similar plates is zig-zag. In a large specimen of 95 mm. test diameter there are 17 plates and a in a small specimen of 55 mm. test diameter there are 14 plates in the interambulacra. Both kinds of plates are more or less rectangular in shape. The plates carry tubercles on their outer surfaces for the articulation of spines and pedicellaria.

The outlines of the plates cannot be made out in large speciimens. The ambulacral plates (Fig. 3) are more or less square-shaped each having one prinmary tubercle. In the young specimens it is seen that the plates are orginally trigeminate with three pairs of pores arranged in an arc. The trigeminate plates combine to form compound plates upto 6 trigeminate plates covered by a large primary tubercle. The pore zones are arranged in three verticle series. This is clearly seen on the oral side. At the aboral side and at the ambitus of the test there is one row of pores at the outer edge of the ambulacral plate. This row is distinctly verticle and the next two rows are wavy. The pore zones do not widen at the peristomial edge but they are somewhat constricted.

The primary tubercles are of the same size as the interambulacral primaries. They are not confluent but separated even at the ambitus by a series of miliary tubercles. On the oral and aboral sides the primary tubercles are rather irregularly developed and it is difficult to say which are primary tubercles and which are secondary tubercles. In the pore zones there are small tubercles which may form on the oral side two distinct longitudinal series.

The interambulacral plates (Fig.4) are one third broader than the ambulacral plates at the ambitus. They become narrower adorally whereas the ambulacral plates have the same width. Thus the ambulacra at the peristome is twice as broad as the interambulacra.

The peristome is distinctly larger than the apical system and it is one fourth the diameter of the test. The peristomial membrane contains numerous elongated plates embedded in the skin. (Fig. 1) In larger specimens some of the plates carry pedicellariae. Of these, five pairs are large and found opposite the ambulacral areas. These are known as buccal plates.

The apical system is small and is 1/5 to 1/7 of the diameter of the test. There are a number of scattered plates in the periproct at the aboral end. Amongst the plates the anus is placed slightly excentrically. Surrounding the periproct there ae ten plates, five of which are radial in position and the other five in the interradial position. The plates placed in the radial position are small and called the occulars. Occulars I and V are broadly insert. The occular poe is almost situated at the centre of the plate. The plates placed in the interradial position are large and are called the genitals or basals. The genital plates are pierced by well defined pore known as genital pore. One of the genital plates is larger than the other and is known as madreporite. The madreporite has a pitted appearence. Both the occulars and genitals carry a single large tubercle in addition to several small tubercles. The occulars and genital plates and the scattered plates embedded in the periproct constitute the apical system.

At the centre of the peristome lies the mouth through which projects five white teeth which are keeled. The mouth leads into pharynx which is surrounded by masticatory apparatus called the Aristotle's lantern. In consists of five pyramids, five radial teeth, five rotulae and five compasses twenty pieces in all. In case of *Salmacis bicolor* in addition to the above plates there are five epiphyses. All these ossicles and the muscles attached to them are inserted in the outer walls of five sac-like cavities which are collectively termed the lantern coelom.

Aristotle's lantern is situated near the pharynx. It is pentamerous structure of general conical shape with the apex formed by five teeth usually seen protruding from the mouth opening. The main portion of the Aristotle's lantern is made up of the pyramids (Fig. 6, P) or alveoli which are interradial and vertical in position. Each alveolus is made up of two halves which are united along the greater part of their length through a longitudinal suture but diverge from each other at the anterior end so as to leave a triangular space between them. The outer lateral surface of each alveolus has a verticle groove for the attachment of the masticatory muscles. Each tooth (Fig. 6, T) is long, slightly curved and lies closely attached to the middle of the inner surface of an alveolus. The upper end of the tooth is soft nd flexible and the lower end which projects through the mouth is strong and firm with a ridge on the outer side. The upper ends of the alveoli are connected by a dumb-bell shaped ossicle known as rotula (Fig.6, R). Besides these fifteen pieces there are five slender rods laying above and parallel to rotulae and known as compassess (Fig. 6, C).

The Aristotle's lantern is operated by a complex set of muscles. At the flat distal end of the Aristotle's lantern there is a pentagonal muscle known as the elevator off the compass (Fig.7, EC). The elevator of the compass is a broad muscle and is attached to the compasses at the base. By the contraction of the muscles the compasses are raised. The compasses (Fig. 7, C) are bifid and on each side of them a narrow muscles is attached known as the depressor of the compass. The other end of the muscle is attached to the test between two perignathic girdles. At the upper end of each pyramid on either side there is a muscle known as protactor muscle (Fig. 7, PM). It broadens at the lower end and is attached to the test between the depressor of the compass and the perignathic girdles. There is a third pair of short muscles known as lantern retractors (Fig.7, LR). They are attached at one end to the auricles and at the other end to the base of the pyramid. Between the pyramids there are five pairs of muscles known as masticatory muscles.

As a result of the contraction of the elevator of the compass, the compassess strech out pulling the lantern into the coelom. As a result of this the lantern coelom is pushed into the general coelom. The dermal branchiae are outgrowths of the lantern coelom and when the lantern is raised the fluid in the gills is drawn out and they collapse. The depressor of the compasses when they contract they pull the lantern down to its original position expelling the fluid of the lantern coelom back into the gills which consequently become distended.

There is a circular verticle ridge on the inner surface of the test and encircling the Aristotle's lantern known as the perignathic girdle (Fig.7, P). The perignathic girdle is made up of five arches called the auricles. Each auricle is composed of two halves united by means of a suture. Each half of the auricle arises as an internal projection from interambulacral plate arising close to the edge of the peristome. The two adjcent halves of an auricle meet in each ambulacral area and form an arched bridge beneath which pass the radial water vascular canal, radial blood vessel and the radial nerve cord.

DIGESTIVE SYSTEM

The mouth is situated at the centre of the peristome on the oral side. Surrounding the mouth there are five teeth of the Aristotle's lantern. The mouth leads to pharynx which runs vertically upwards as a narrow tube and emerges from the top of the lantern and passes at once into the oesophagus (Fig.8, 0) which reaches almost aboral pole where it is suspended by suspensory ligaments from the plates of the periproct. The oesophagus passes into the small intestine (Fig.8, SI) which runs round on the inner side of the test at the ambitus in a clock-wise direction. The inner border of the small intestine is constricted off as a slender tube siphon from its proximal to its distal end. The siphon is believed to keep a stream of sea water that passes through the gut for the purposes of respiration. After making an almost complete circle the small intestine twists on itself into a small loop and then runs round in an anti-clockwise direction as large intestine (Fig.8, LI) when viewed from the aboral pole. The large intestine is aboral to the small intestine and makes almost a complete circle and ascends up as the rectum (Fig. 8, R). The rectum opens out as the anus which is situated in the midst of the periproct. The walls of the small and large intestines are very delicate and distensible. The large intestine is highly sacculated and has red colour. They are pressed against the test and are supported by mesenterial strands from the outer coelomeic walls. As a result of this the large and small intestines are thrown into flattened festoon-like lobes in each radius.

The walls of the rectum are smooth and are attached at the distal end to the inner surface of the test by means of large number of strands.

The Coelom and Its Derivatives : At a very early stage in the development of the sea urchin the coelom becomes divided into four separate compartments which lead to the formation of various parts of the coelom in the adult. In the adult sea urchin the coelom consists of general body cavity or perivisceral coelom, peri-pharyngeal or lantern coelom, water vascular system, axial coelom, the aboral ring, madreporic vesicle and the gonads which are outgrowths of the coelomeic wall.

Perivisceral coelom : The general body cavity is very spacious and occupies the greater part of the body of the animal inside the test. It is filled with coelomeic fluid which is slightly alkaline in reaction.

THE LANTERN COELOME AND ITS PERIHAEMAL CANALS :

The lantern coelom surrounds the pharynx and the Aristotle's lantern. The lantern coelome is cut off from the general coelome by a membrane known as lantern membrane. At an early stage five double perihaemal canals are given off radially from the five corners of the lantern coelome which run outwards between the radial nerve and the radial water vessel. In adults the two perihaemal canals of each radius fuse into one and are completely closed off from the lantern coelome. Each radial perihaemal canal becomes independent part of the coelome extending the whole length of the radius. The lantern coelome is in communication with the external gills or branchiae which lie at the margin of the periostome on the oral side. Branches are given off to the podia that accompany the podial branches of the water vascular canal.

There are two conspicuous sinuses that accompany the festoons of the small intestine. The larger of these, the inner marginal sinus arises from the haemal ring and runs along the oseophagus and accompanies the inner side of the festoons of the intestine branching richly into the intestinal wall. The outer or dorsal marginal sinus is found along the outerside of the small intestine. It also gives off a net work into the intestinal wall.

Water vascular system is of the usual type found in the echinoderms. At the base of the oesophagus there is the main water vascular ring (Fig.9, WVR) from which the stone canal (Fig. 9, SC) ascends vertically through the coelome to the madreporite (Fig. 9, M). The stone canal is accompanied by a conspicuous axial organ (Fig.9, AO). From the water vascular ring five small structures arise in the radial regions known as polian vesicles (Fig.9, PV). Hyman (1955) is of the opinion that they are of the lymphoid nature and should be designated as spongy bodies. They are present just beneath the rotulae.

From the water vascular ring five radial water vascular canals (Fig.9, RVC) arise and these alternate with the polian vesicles. The water vascular canals first run downwards for a very short distance and then turn outwards passing beneath the rotulae. They emerge through the bridges of the auricles and run outwards and upwards along the middle of each ambulacral area on the inner surface of the test. At the aboral end each canal ends blindly in a small terminal tentacle. Each radial vessel gives of a series of transverse vessels beyond the peristomial region. Each of these transverse vessels on the two sides ends in a tubefoot. A tube-foot consists of a rounded ampulla (Fig.8, A) and a stalk which ends in a sucker supported by a calcareous sucker plate. The ampullae lie within the test while the stalk and the sucker are outside through a pair of aperatures in the ambulacral plates.

From one of the five sides of the water-vascular ring the stone canal arises. The stone canal is a narrow tube which ascends up and situated very close to the oesophageal region of the elimentary canal. Aborally the stone canal opens into a closed coelomeic space known as madreporic ampulla which is situated just below the perforated madreporite.

The entire system is ciliated and current of water constantly enters the madreporic plate into the madreporic ampulla from where it passes through the stone canal into the water-vascular ring. From this ring canal water passes into the five radial water vessels and then to the ampullae and the tubefeet. The walls of the ampullae and the tubefeet are muscular. When the ampullae contract the water in them is pumped into the tube-feet which consequently become tense and stretch out. The suckers of the tube-feet come into contact with the substratum and the central plate of each sucker is raised and a vaccum is formed between the sucker and the point of attachement. This brings about a firm attachement of the sucker to the substratum. When the ampulla relaxes, the water from the tube-feet rushes back into the ampulla as a result of which the tube-feet becomes shorter and pulls the anumal towards the point of attachment of the sucker. The process of contraction and relaxation of the ampullae bringing about the extension and shortening of the stalks off the tube-feet is repeated in the successive tube-feet of the animal. Movement is brought about by the concerted and repeated action of the ampullae, tube-feet and their suckers. Locomotion in this sea urchin is slow and is effected by a series of jerks.

THE RESPIRATORY AND EXCRETORY ORGANS

Respiration is effected chiefly by branchiae and the tube-feet. The lantern coelome, the siphon and to some extent the alimentary canal also aids in respiration.

Sea water is continuously drawn into the body through the perforated madreporite and stone canal and this water enters the tube-feet. The tube-feet are constantly expanding and contracting and are always bathed in sea water. When the tube-feet are distended their walls become thin and the water in the stalks absorbs oxygen from the sea water and the oxygenated water is conveyed in to the perivisceral coelome and is carried by the coelomeic fluid for respiration to all parts of the body.

There are groups of highly branched thin walled, hollow structures placed interradially around the peristome and they are always immersed in sea water. The structure of the walls of the gills are similar to those of the tube-feet with the difference that the muscular layers in the gills are poorly developed. The lumina of the gills communicate with lantern coelome by means of openings at the base of the gills and these openings can be widened or narowed to regulate the passage of fluid from the lantern coelome. By the contraction and relaxation of the depressor muscles of the Aristotle's lantern the coelomeic fluid in the lantern coelome is forced into the branchiae where it absorbs the oxygen from the sea water. On contraction of the radial muscles the oxygenated fluid in the gills goes back into the lantern coelome and oxygen diffuses into the surrounding tissues and into the general coelome.

The amoebocytes which are generally distributed throughout the body are believed to have an excretory function as well. They are phagocytic in nature and ingest the bacteria and other foreign bodies and also take up liquid waste substances. It is believed that the amoebocytes laden with excretory material either pass out to the exterior through the walls of the branchiae or degenerate with the dermis and form pigment.

THE NERVOUS SYSTEM

In echinoderms the nervous system is of three types, *viz.*, the ventral or ectoneural, the deep oral or hyponeural and the apical nervous system. The first type of the nervous system is sensory in function while the other two are motor. It is now being recognised more and more than the sensory ectoneural system must be connected with the motor hyponeural and apical systems. All the three types of nervous systems are not equally developed in the different classes of the phylum.

The ectoneural nervous system is well developed in *Stomopneustes variolaris* and consists of circumoral nerve ring, five radial nerve strands and subepithelial nerve-plexus. The circumoral nerve ring surrounds the mouth and lies between the peristomial membrane and the Aristotle's lantern. The circumoral nerve ring gives off five radial nerve strands each running along the inner surface of the ambulacrum. From these radial, nerve strands, transverse nerve strands are given off known as the pedal nerves which go and supply the tube-feet while others become merged into the sub-epithelial nerve plexus beneath the skin which inervate the spines, pedicellariae. Each radial nerve ends in a tentacle-like termination.

The hyponeural system is very poorly developed in the echinoids. It takes the form of five nerve patches which are radial in position and lie partly on the circumoral nerve ring and partly at the places of origin of the five radial nerves. There are no radial extensions of these nerve patches along the ambulacra. These nerve patches consist of nerve cells and fibres and separated from the extoneural nerve ring by a layer of connective tissue. The hyponeural system supplies nerves to muscles that work the lantern apparatus. The apical nervous system is also coelomeic in orign and motor in function but it is absent in echinoids.

THE REPRODUCTIVE SYSTEM

The sexes are separate. The gonads (Fig.10, G) are placed in the interradial position in five bunches. The five bunches of the gonads are not separate but are connected at the centre. The gonads hang freely into the perivisceral cavity from the apical part of the test by means of coelomeic membrane. Each gonad consist of large number of branching tubules. Each tubule has a minute ductile and several of these ductiles join to form a main duct. The five main ducts open to the outside through the five genital pores which are situated on the genital plates. The openings of the genital pores are guarded by minute papillae. Mature gonads are orange in case of females and white in case of males.

ACKNOWLEDGEMENTS

I am most greatful to Dr. S. Jones, former Director of C.M.F.R. Institute for suggesting to me to work out the anatomy of this sea urchin and also for his guidance and suggestion. I am also greatful to Dr. P.S.B.R. James, Director, C.M.F.R. Institute for his kind interest and encouragement.

REFERENCES

AIYAR, R. G. and M. MENON 1934. Observations on the spicules of *Salmacis bicolor* (Agassiz) and *Stomopneustes variolaris*. *Ann. Mag. nat. Hist.* (10) 13: 468-473.

AIYAR, R. G. 1938. *Salmacis* (The Indian Sea Urchin). *Indian Zool. Mem.*, 7: 1-68.

BELL, F. J. 1888. Report on a collection of Echinoderms made at Tuticorin, Madras by Mr. E. Thurston. *Proc. Zool. Soc. Lond.*, 1888: 383-389.

CLARK, A. M. and F.W.E. ROWE 1971. *Monograph of shallow-water Indo-West Pacific echinoderms*. British Museum (Natural History), London, Publication No. 690: 238 pp.

CLARK, H. L. 1925. *A Catalogue of the recent sea urchins in the collection of the British Museum (Nat. Hist.)*. London. 250 pp.

GANAPATI, P. N. and D. R. K. SASTRY 1972. Record of *Athanas indicus* (Coutiere) (Decapoda : Alpheidae) associated with *Stomopneustes variolaris* (Lamarck) (Echinodermata : Echinoidea) from Visakhapatnam coast. *Proc. Indian Acad. Sci.*, 38: 367-372.

GIESE, A. C., S. KRISHNASWAMY, B. S. VASU and J. LAWERENCE 1964. Reproductive and biochemical studies on sea urchin *Stomopneustes variolaris* from Madras Harbour. *Comp. Biochem. Physiol.*, 13: 367-380.

GRAVELY, F. H. 1927. Littoral fauna of Krusadai Island in the Gulf of Mannar. Echinodermata. *Bull. Madras Govt. Mus.*, 1: 163-173.

——— 1941. Shells and other animal remains found on the Madras beach. *Ibid.*, 5: 86-90.

JAMES, D. B. 1967. *Phyllophorus (Phyllophorella) parvipedes* Clark (Holothuroidea), a new record to the Indian Seas. *J. mar. biol. Ass. India.* 7: 325-327

———— 1968. Studies on Indian Echinoderms-2. The holothurian *Stilus buccalis* (Stimpson) with notes on its systematic position. *Ibid.*,

———— 1969. Catalogue of echinoderms in the reference collection of the Central Marine Fisheries Research Institute. *Bull. cent. Mus. Fish. Res. Inst.*, 7: 51-62.

———— 1983. Sea cucumber and sea urchin resources. *Bull. cent. mar. Fish. Res. Inst.*, 34: 85-93.

———— 1986. Zoogeography of shallow-water echinoderms of Indian Seas. *In:* P.S.B.R. James (Ed.) *Recent Advances in Marine Biology*. Today and Tomorrow's Printer's and Publishers, New Delhi. pp. 569-591.

———— 1988. Echinoderm fauna of the proposed National Marine Park in the Gulf of Mannar. *Proc. Sym. Endangered Marine Animals and Marine Parks*. 1: 403-406.

———— 1989. Echinoderms of Lakshasweep and their zoogeography. *Bull. cent. mar. Fish, Res. Inst.* 43: 97-144.

———— 1990. Sea urchin roe-a potential resource for export. *Seafood Export Jour.*, 21(6) : 36.

Mary Bai. M. 1978. The anatomy and histology of *Holothuria scabra* Jaeger *J. mar. biol. Ass. India*. 20 (1&2) : 22-31.

———— 1979. Occurence of the sea urchin *Stomopneustes variolaris* (Lamarck, 1816) along the coasts of Kanyakumari, S. India. *Zool. Surv. India*, pp. 103-104.

———— 1980. Monograph on *Holothuria (Metriyatyla) scabra* Jaeger. *Mem. Zool. Surv. India.* 16(2) : 1-75.

Nagabhushanam, A. K. and G. C. Rao 1972. An ecological survey of the marine fauna of Minicoy Atoll (Laccadive Archipelago, Arabian Sea). *Mitt. zool. Mus. Berlin,* 48(2) : 265-324.

Ranade, M. R. 1979. Studies on the marine fauna of Ratnagiri (West coast, India). I. Echinodermes. *Bull. Fish. Fac. Konkan. Agri. Univ. India.* 1(1) : 21-26.

Rao, G. C. 1968. Psamothuria ganapati n.gen., n. sp. an interstitial holothurian from the beach sands of Waltair coast and its autoecology. *Proc. Indian Acad. Sci.* 67(5) : 201-206.

Rao, D. S., D. B. James, K.G. Girijavallabhan, S. Muthuswamy and N. Najmuddin 1985. Biotoxicity in echinoderms. *J. mar. biol. Ass. India.* 27: 88-96.

Reuben, S., T. Appa Rao and P.E. Samson Manickam 1980. Sea urchin resources of Waltair coast. *Symposium on Coastal Aquaculture*. Organised by the Marine Biological Association of India, Cochin. p. 113 (Abstract).

Sastry, D. R. K. 1981. On some crustacean associates of Echinodermata from the Bay of Bengal. *Rec. zool. Surv. India*. 79: 19-30.

———— 1985. Observations on the distribution of *Stomopneustes variolaris* (Lamarck) (Echinodermata : Echinoidea) along the Visakhapatnam coast *Second National Seminar on Marine Intertidal Ecology. Department of Zoology*, Andhra University, Waltair. Abstract No. 42.

Satyamurti, S. T. 1976. The Echinodermata in the collection of the Madras Government Museum. *Bull. Madras Govt. Mus. nat. Hist. New Series* 7(3): 1-284.

Tikader, B. K. and A. K. Das 1985. *Glimpses of animal life of Andaman and Nicobar Islands*. Zoological Survey of India. 170 pp.

Tikader, B. K., A. Daniel and N. V. Subba Rao 1986. *Sea shore animals of Andaman and Nicobar Islands.* Zoological Survey of India, Calcutta. 188 pp.

Thurston, E. 1894 *Rameswaram Island and fauna of the Gulf of Mannar. (Madras Government Museum Sci. ser.)* No. 1: 78-138.

EXPLANATION TO PLATE

Stomopneustes variolaris (Lamarck)

EXPLANATION TO FIGURES

Figure 1

Fenestrated plates from the peristomial membrane.

Figure 2

A. Tridentate pedicellaria B. Valve of tridentate pedicellaria

C. Valve of ophiocephalous pedicellaria

Figure 3

Figure showing the arrangement of ambulacral and interambulacral plates AM-Ambulacral plates IAM-Interambulacral plate

Figure 4

Figure showing the arrangement of Interambulacral plates x 10

Figure 5

Apical system GP-Gonopore AN-Anus I-V (Occular plates) x 10

Figure 6

Aristotle's lantern T-Tooth C-Compass P-Pyramid R-Rotula x 4

Figure 7

Muscles of Aristotle's lantern EC-Elevator of compass T-Tooth C-Compass PM-Protractor muscle LR-Lantern retractors LP-Lantern Protractor x 1

Figure 8

Dissection seen from the oral side. O. Oesophagus SI-Small Intestine LI-Large intestine R-Rectum G-Gonad HS-Haemal Sinus RVC-Radial Vascular Canal A-Ampulla x 1½

Figure 9

Watervascular system M-Madreporite G-Gonopore A-Ampulla PV-Polian vesicle AO-Axial organ SC-Stone canal WVR-Water Vascular Ring RVC-Radial Vascular Canal TV-Transverse Vessel x 4

Figure 10

Reproductive system G-Gonad

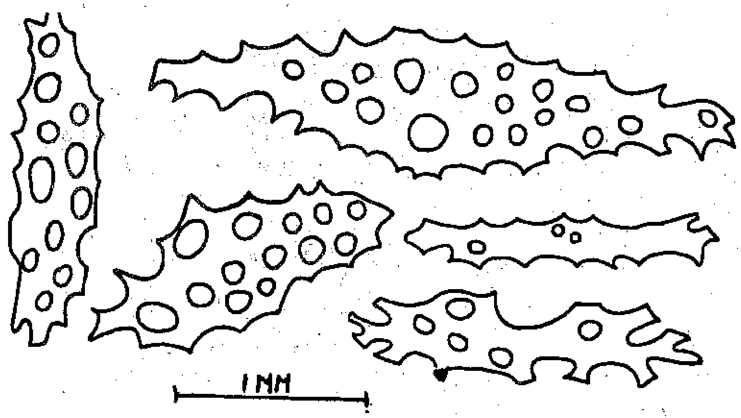

FIG. - 1

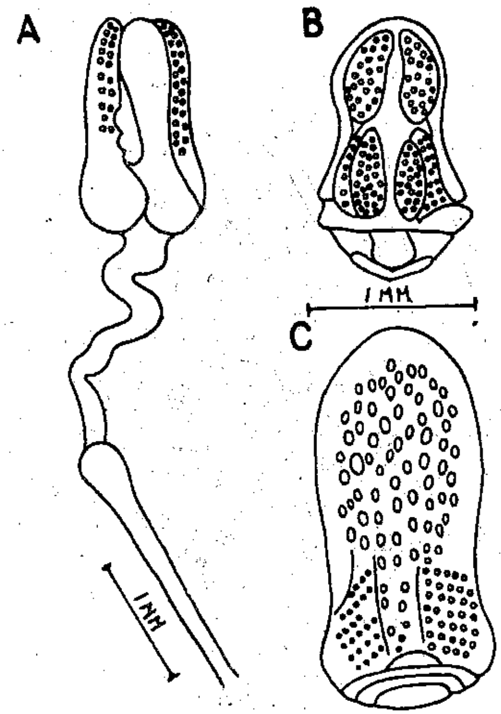

FIG. -2

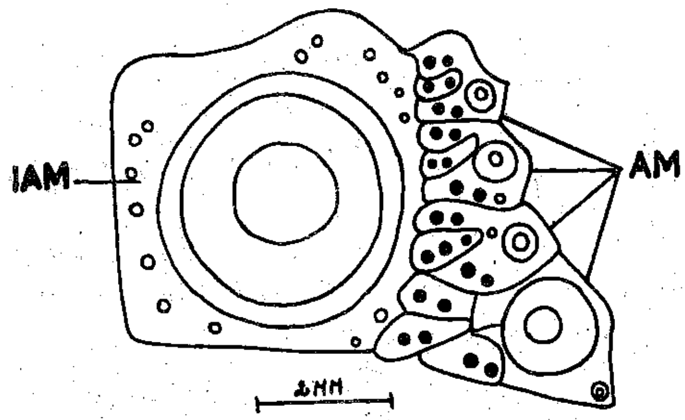

FIG. -3

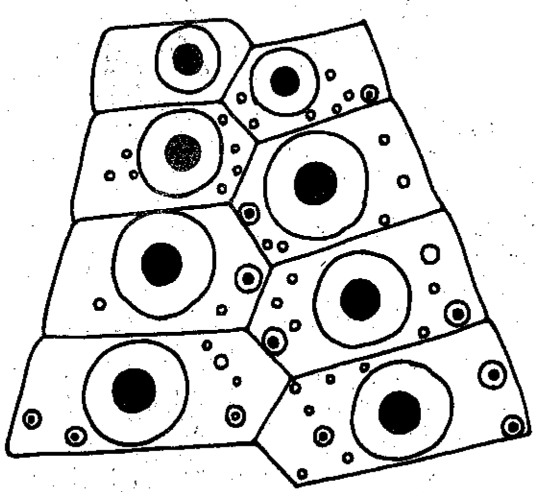

FIG. -4

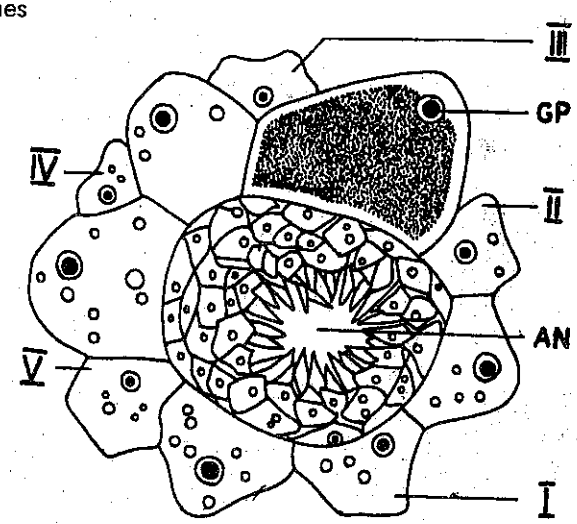

FIG. -5

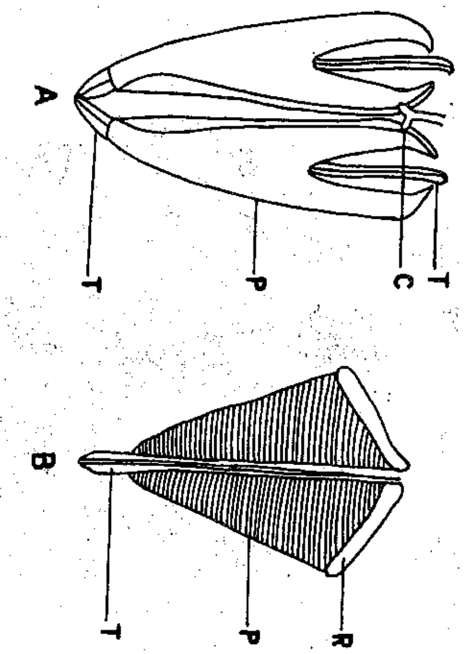

FIG. -6

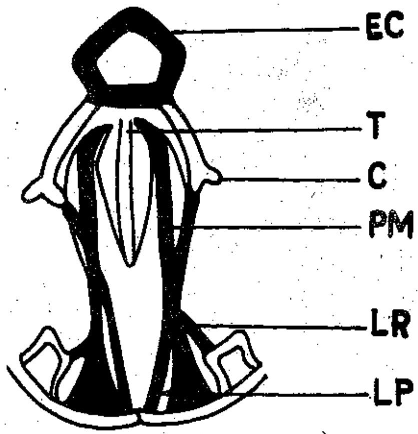

FIG. -7

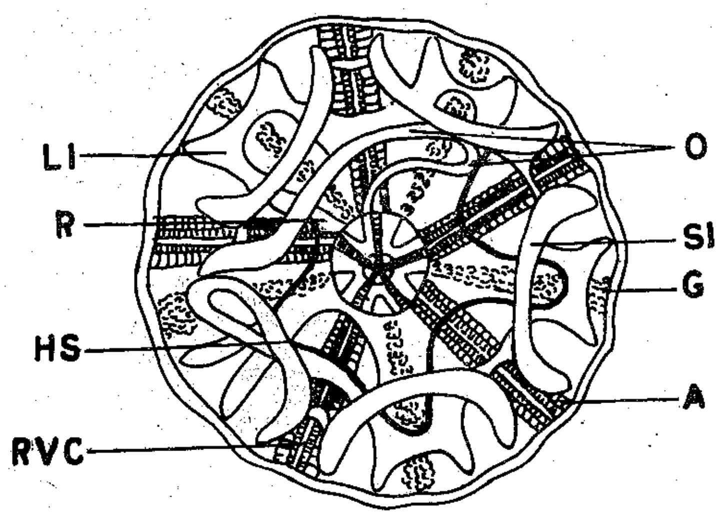

FIG. -8

J. Zool. Soc. India 40-41 : 7-22 (1988-89)
James

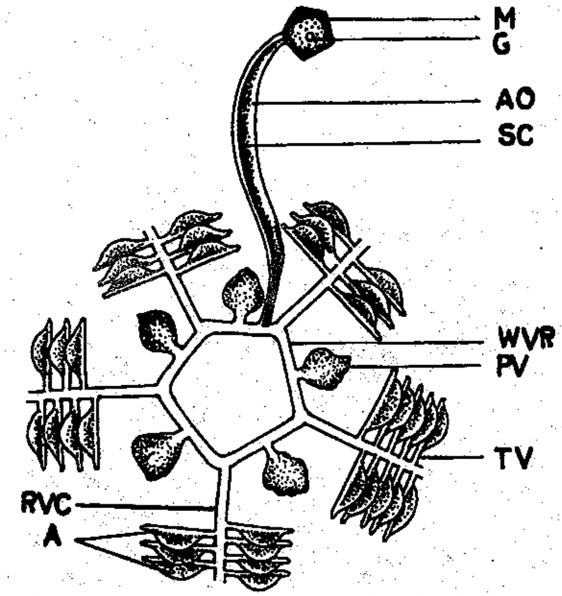

FIG. -9

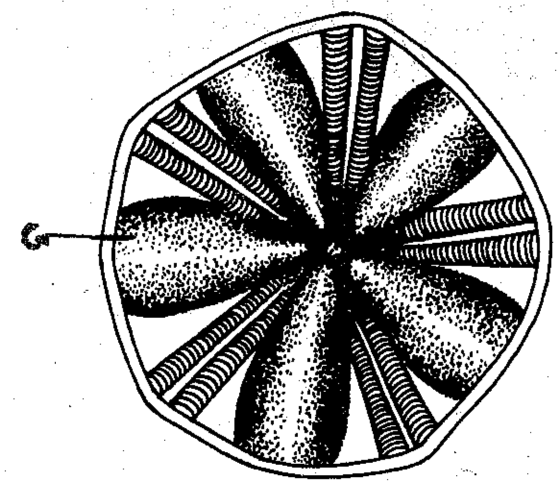

FIG. -10

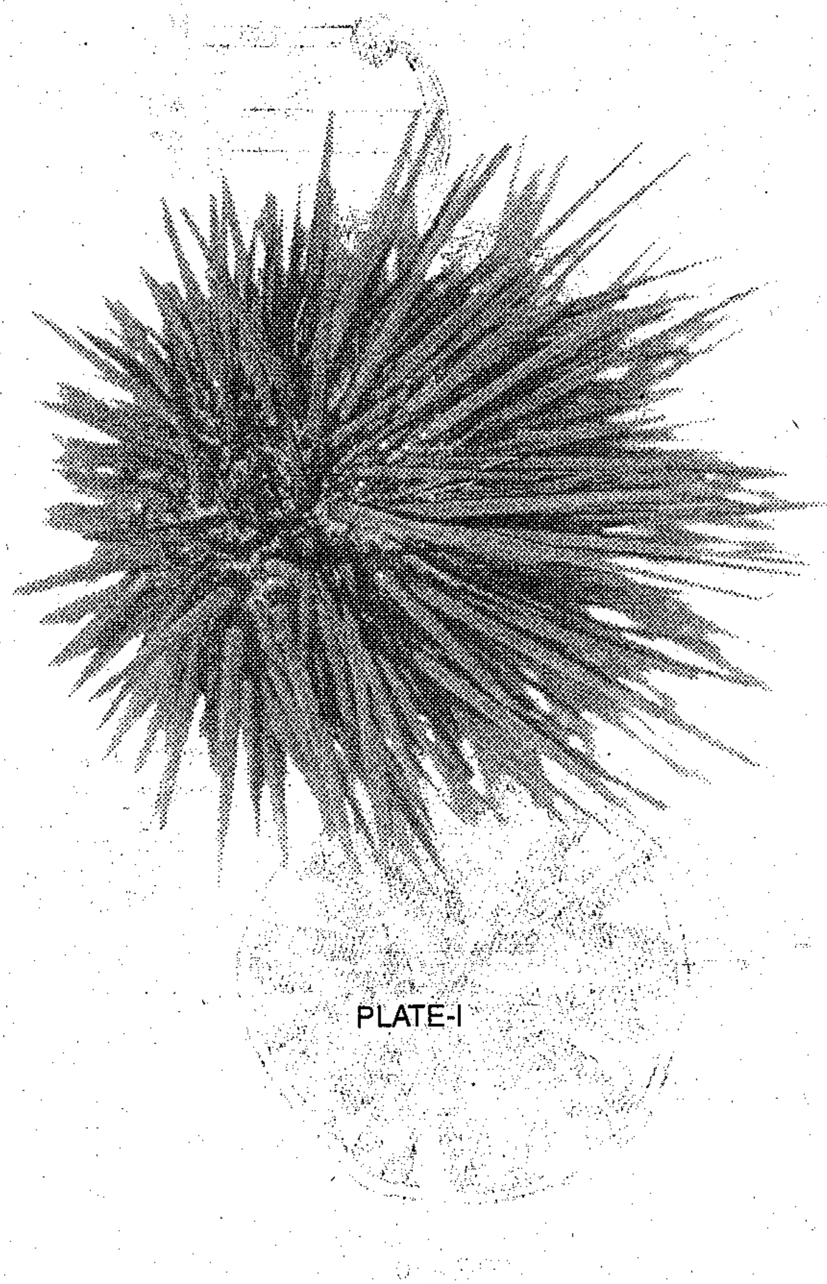

PLATE-I