ON *CHONDROCLOEA VARIANS*, A NEW APODOUS HOLOTHURIAN FROM THE MADRAS HARBOUR.

By R. VELAPPAN NAIR, *M.Sc.*, *University Zoological Research Laboratory, Madras.*

(Communicated by Rai Bahadur S. L. Hora, D.Sc., F.N.I.)

(*Received November 26, 1945; read April 17, 1946.*)

CONTENTS.

INTRODUCTION.

The present paper is a continuation of the work on Echinoderm types carried out at this Laboratory by Aiyar (1938) on *Salmacis bicolor*, Moses on *Pentaceros hedemanni* * and Anantaraman on *Temnopleurus toreumaticus*.* *Chondrocloea varians* n.sp. forms the subject matter of this paper. Our knowledge of the anatomy of the genus *Chondrocloea* is meagre and the occurrence of this species in large numbers in the Madras Harbour afforded an excellent opportunity for a detailed study.

HISTORICAL RÉSUMÉ.

The generic name *Chondrocloea* was established in the year 1898 by Östergren in his revision of the Synaptidae, but it was not recognised by subsequent workers until 1938, when Clark established the validity of the genus. Semper (1868) who discovered the genotype, *Chondrocloea recta,* included it under *Synapta* Eschscholtz, 1829. Similarly, the earlier workers, like Lampert (1885), Theel (1886) and Ludwig (1892), included the form under *Synapta* in their classification. Östergren, in his revision, included also the viviparous West Indian species belonging to the genus *Synaptula* Oersted, 1849, in the genus *Chondrocloea*. Clark (1907), in his monograph on the Apodous Holothurians, gave precedence to the genus *Synaptula* over

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* Unpublished.

Chondrocloea and included all the forms under the former genus. Further, he suggested the possibility of inclusion of two groups of species under *Synaptula*. Since the descriptions of a few of the species were imperfect, Clark considered *nigra, hydriformis, psara, indivisa, recta, virgata, lactea* and *reticulata* as the only valid species under *Synaptula* and the remaining four species of *Synaptula*, namely, *reciprocans, striata, aspera* and var. *maculata* as synonymous with *S. nigra, S. recta, S. virgata* and *S. reticulata* respectively. Heding (1928), in his paper on the Synaptids collected by Mortensen on his different expeditions, described 17 new species of *Synaptula* (*rosea, albolineata, alba, jolensis, denticulata, minima, tualensis, neirensis, ostergreni, madreporica, rosetta, lamperti, purpurea, bandae, membrana, ater* and *violacea*). He further redescribed the four species of *Synaptula* which Clark considered synonymous, and considered them as valid species. He suggested the transfer of *S. nigra* to the genus *Polyplectana* on the ground that the miliary granules in this species are branching rods and not rosettes, a differentiating feature between the two genera. He also suggested the desirability of using the generic name *Chondrocloea* for the oriental species of *Synaptula* in case *S. hydriformis* should prove to be generically different and considered *S. indivisa* (genotype of *Chondrocloea*) as a doubtful species. Based on his study of a rich material of *Synaptula*, Heding divided the subfamily Synaptinae Östergren, 1898, into two sections, the Micrournae and the Heterournae, according to the nature of the ciliated funnels and included *Synaptula* in the former. Later, he added to it three more species, *S. mortenseni* (1930), *S. rubra* and *S. boweniensis* (1931). Clark (1938) described a new species, *Chondrocloea macra*, but retained only the West Indian species *hydriformis* under the genus *Synaptula* and removed all the other species to *Chondrocloea* and considered the genotype *Chondrocloea indivisa* as a juvenile form of *Chondrocloea recta* which he designated as the genotype. Altogether 30 species of *Chondrocloea* are known.

The characters of the majority of the species are fairly well known; a few of the species described by Heding, like *C. tualensis, C. rosea, C. ostergreni* and *C. minima*, are apparently juvenile forms and may in the end prove to be young ones of some of the more common forms. The descriptions of *C. albolineata, C. neirensis, C. rosetta, C. lamperti, C. purpurea, C. minima* and *C. rosea* are based on single specimens. Further, *C. ater* and *C. violacea* are described from posterior fragments alone. Our knowledge of the anatomy of the genus is far from satisfactory and what little is known is due to the descriptions of the species given by Semper (1868), Sluiter (1888), Heding (1928, 1930 and 1931) and Clark (1938).

Of the two closely related genera, *Polyplectana* and *Synaptula*, the anatomy of the latter genus alone has been satisfactorily worked out. The first anatomical and developmental study was by Oersted (as shown by Heding) on *Synaptula vivipara* investigated by him in the year 1845 during his stay at Jamaica. The only other noteworthy contribution on this genus is by Clark (1897) who worked out also some features of the anatomy of *Synapta vivipara* along with the development of the species.

The general anatomy of the European forms belonging to the other genera is very well known and though the contributions on the morphology are many and varied the important investigations of workers like Müller (1850), Baur (1864), Semper (1868), Semon (1887), Hamann (1883 and 1884), Cuénot (1891), Clark (1907) and Becher (1910) added much to our knowledge of the Synaptidae in general.

Previously only few specimens of Synaptinae have been collected from Indian waters and the records of the occurrence of the genus *Chondrocloea* from the Indian coast are very few. *Synapta recta* and *Synapta striata* have been recorded from Ceylon (Pearson, 1903). The 'Investigator' Expedition collected a few specimens of *Chondrocloea striata* from the Mergui Archipelago and the Straits of Malacca (Koehler and Vaney, 1908). A single specimen of *Synapta recta* was collected by Gravely (1927) from under the Pamban Bridge in the Gulf of Manaar. He also recorded the abundant occurrence of smaller, similar looking specimens at Rameswaram.

Material and Methods.

The specimens for this study were obtained in large numbers from the Madras Harbour. Specimens brought from the Harbour were removed to clean sea water in the Laboratory Aquarium Tanks where several of them lived in an apparently healthy condition from six to eight weeks feeding on the organisms on the sides of the Tanks. For narcotisation equal volumes of ether and sea water gave excellent results. Magnesium sulphate could also be employed, but takes a longer time to bring about the desired result. Fixatives such as Bouin's, Brasil's modification of Bouin, Flemming's without Acetic, Corrosive sublimate, Kleinenberg's Picro-sulphuric and Susa's were tried; the last four gave good results. Materials fixed in Picro-sulphuric and stained with Heidenhain's Iron Haematoxylin gave the best preparations. Bielschowsky's method was also tried for the nervous system but without much success. Vital staining with Methylene Blue was adopted for the study of the tactile organs on the surface of the body. Injection with Indian Ink was also attempted to study the process of excretion. The details of the blood and water vascular systems were made out from dissections of preserved material and supplemented in certain cases with whole mount preparations stained with Borax Carmine.

Bionomics.

Like most of the known species of *Chondrocloea* this species is littoral in habits, found living in large numbers amongst Sponges, Polyzoa, Mytilus, etc. on the pillars of the quay inside the Madras Harbour. It has also been collected from underneath the submerged stones below the Pamban Bridge in the Gulf of Manaar. Large numbers of individuals have been observed to form communities and migration from place to place has also been observed. Fresh specimens brought to the Laboratory are fairly active and in the Aquarium Tanks they invariably cling horizontally to the wall by means of the anchors and keep themselves near the surface of the water. The animal climbs on the sides of the Tanks with the help of the adhesive papillae present in large numbers on the outer side of the tentacles and the anchors on the surface of the body. The specimens are more or less semi-transparent and have an average length of 150 mm. and a breadth of about 7 mm. in the expanded condition. A giant specimen was found in the collection brought from the Harbour on the 5th November, 1942, measuring about 320 mm. in length and 10 mm. in breadth. The highly looped alimentary canal, the calcareous ring and the gonads are fairly visible through the thin body wall in spite of the prominent striated coloration. The body is highly contractile and it may shorten up to a third of the original length. No voluntary amputation by means of muscular contraction has been observed. The tendency for voluntary amputation, however, is sometimes shown when the animals are removed from the sea water and held in a pendent position; almost immediately violent contraction takes place resulting in the breaking off of the part of the body below the point of seizure. This, however, cannot be considered as a normal happening. The capacity for regeneration has not been observed and is probably absent.

The coloration of the animal is pinkish red and the regions between the five radii of the body, each characterised by a band running from the anterior to the posterior extremity of the animal, are marked by longitudinal interrupted stripes of a deeper shade (Fig. 1). The coloration of the tentacles is the same as that of the body. Some specimens are darker with a violet tinge and at first sight appear to be different. But these are generally found amongst the brown Polyzoan, *Crisia*, and the colour may, therefore, be a variation to suit the immediate surroundings.

External Characters.

The body is elongated, vermiform and more or less cylindrical. The surface of the body is beset with numerous small projections or true verrucae containing

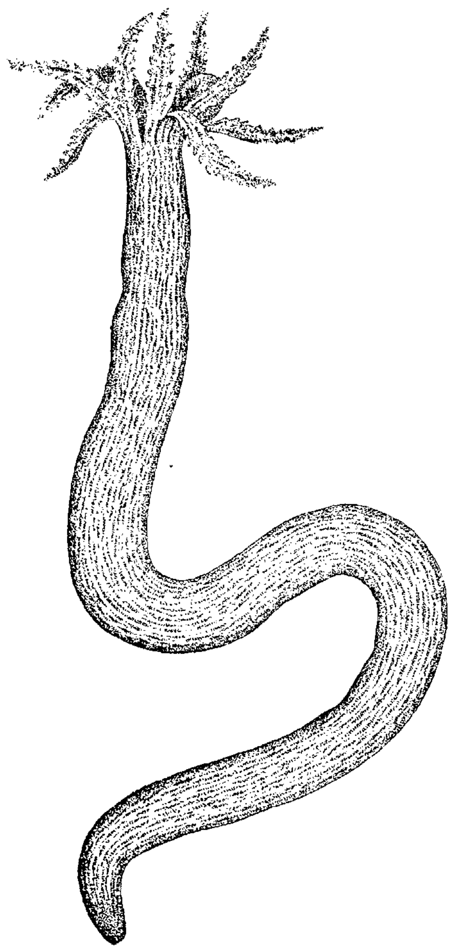

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FIG. 1. *Chondrocloea varians* n.sp. × 2.

the calcareous deposits. Sometimes the body wall of the animal in each inter-ambulacral region projects into a regularly arranged longitudinal row of large verrucae brought about by the contraction of the body muscles. Even though these two types of verrucae are not of any taxonomic value, the presence of both kinds in the same species is interesting. The largest verrucae occur in the genera *Synapta* and *Euapta*, while the smaller type is found in *Leptosynapta*, *Synaptula* and *Taenio-gyrus*. In the other genera they are generally wanting. The larger verrucae in *Synapta maculata* number 10 in each transverse row. But in *C. varians* there are only five such verrucae. The mouth is terminal and is in the form of a circular opening in the centre of the oral disc around which the feathered tentacles are arranged in a single circle. The anus is at the posterior end of the body. The anchor and anchor plates could be seen as very minute specks on the surface of the animal. As already mentioned, the five ambulacral regions of the body are clearly seen as narrow streaks indicating the position of the longitudinal muscles and the radial nerves. The number of the tentacles is not constant and is variable from ten to fifteen.* The variation in the number of the tentacles in forty specimens is as follows:—

16	specimens	with 10	tentacles.
8	,,	,, 11	,,
6	,,	,, 12	,,
4	,,	,, 13	,,
6	,,	,, 15	,,

In the living animal each tentacle is regularly and gracefully curved down towards the mouth and this movement is repeated by every tentacle in turn. The tentacles are highly contractile. The anterior two-thirds of the tentacle is more or less flattened and is provided with two rows of digits on either side which show great variation in numbers. At the apex could be seen small and newly formed digits. On the outer side of the tentacle, all over the flattened portion, are numerous adhesive papillae about 50μ in diameter, specially numerous along the stalk and the digits. The adhesive papillae are used exclusively for the movement of the animal. During locomotion the tentacles are pressed so firmly that the adhesive papillae are flattened against the substratum. Towards the basal portion of each tentacle and situated on either side of the base is a pair of dark red eyes.

TENTACLES.

The importance of the number and nature of tentacles in the classification of the genera and species has been emphasised by Clark (1907 and 1924) and Heding

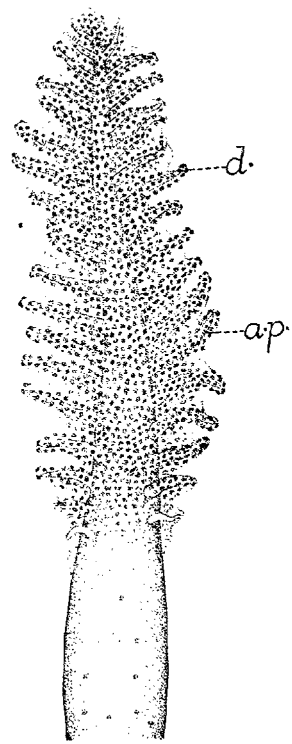

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FIG. 2. A tentacle showing the adhesive papillae and the digits. ×8.

* Such wide variation has not been recorded for any of the known species. It is to indicate this character that this form has been named *Chondrocloea varians*.

(1928). Heding holds that the number of tentacles within the species is usually very constant and that the variation is limited to one tentacle more or less. The variation within the genus according to Clark may be ten to fifteen. Variation up to three tentacles has been noted in *C. mortenseni*. The present species is remarkable for its very great variation in the number of tentacles. The fact that there is such a wide variation in this species should make one hesitate in accepting the importance which Clark and Heding attach to the tentacle number as a specific character.

The tentacles are about 12 mm. in length in the extended condition and all of them are of the same size. They are pinnate with an average of about 20 pairs of digits arranged on either side of the main stalk (Fig. 2). The number of digits in the tentacles is also of not much classificatory value for it varies according to the age of the animal. The digits are united by a thin membranous web as in the majority of the species of *Chondrocloea*. As mentioned previously, the outer side of the tentacle is studded with numerous rounded adhesive papillae. It is beyond doubt that they are adhesive in function and help in the locomotion of the animal. But how the adhesion is effected, whether by any secretion or otherwise, has not been satisfactorily ascertained. No mucous gland has been noted nor any muscle fibre which could bring about a cupping action of the parts concerned. Gustatory organs are absent. The tentacles are devoid of calcareous deposits. Miliary granules and rods with irregularly branching ends have been noticed on the tentacles of *C. alba* and *C. mortenseni* respectively.

The structure of the tentacle is essentially the same as in the other species of Synaptinae. The main stalk of the tentacle is hollow, being traversed by the tentacular canal of the water vascular system. Externally, there is a very thin cutis, below which lies the epithelium composed of a single layer of thin cells with small and rounded nuclei (Fig. 3). The epithelial cells of the outer side of the

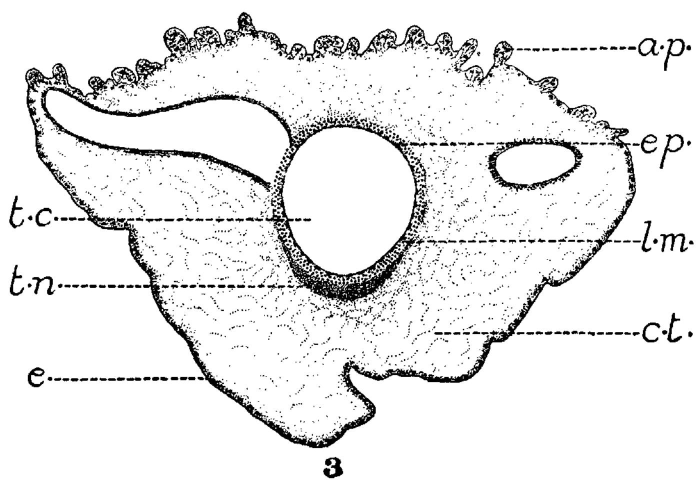

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FIG. 3. Transverse section of the tentacle. ×60.

tentacle form the adhesive papillae. The cells of the adhesive papillae are bigger with well-defined cell walls and prominent nuclei. Below the epithelium is the connective tissue layer which occupies nearly the whole of the section and consists of irregularly arranged strands. The tentacle nerve, which is crescent-shaped in sections, passes along the inner side of the tentacle, internal to the connective tissue layer and innervates the muscle layer of the tentacle. The muscle layer consists of only the longitudinal muscle fibres situated next to the connective tissue layer. Quatrefages (1842) and Baur (1864) mention the presence of circular muscle fibres in the tentacles of *Synapta*, but recent workers have not confirmed their findings. No trace of any circular muscle fibres has been noticed in the tentacles of *C. varians*. Lining the lumen of the tentacle is the innermost layer of epithelium, composed of flat cells with very small nuclei. The digits have the same structure as the tentacle, but the central cavity of the digit is completely cut off from the main tentacular canal as in *S. vivipara*.

Body Wall and Body Cavity.

As in all other Synaptids, the body wall is thin and translucent and, in sections, circular in outline with the longitudinal muscles appearing in the radii as five short rays directed towards the centre.

Externally there is a thin and transparent layer of cutis secreted by the epithelial cells. Inner to this is the epithelium composed of a single layer of cells (Fig. 4).

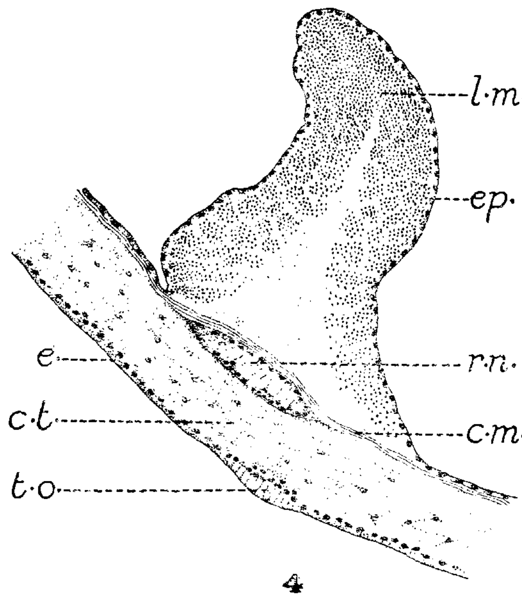

Fig. 4. Transverse section of the radial portion of the body wall. ×120.

These are of two kinds: the ordinary irregularly shaped cells with clear and oval nuclei and the sensory cells. The former occur in plenty and their inner ends taper and merge with the connective tissue layer below. The sensory cells, which are tactile, are grouped in clusters on the surface of the body wall; they are long and columnar and of about twice the length of the ordinary epithelial cells. The nuclei are basal and similar to those of the epithelial cells. The tactile organs will be described more fully under the sense organs.

Below the epidermis is the connective tissue layer, which occupies the major portion of the thickness of the body wall. This is composed of a homogeneous matrix with numerous fibres which are the prolongations of the stellate cells. The pigment cells and the calcareous bodies occur in this layer.

Two types of pigment cells have been noticed to be abundant in *C. varians*, one light yellowish brown and the other violet. The yellowish brown pigment cells are spread uniformly while the violet pigment cells are massed to form the longitudinal stripes present on the body of the animal.

The shape and size of the four types of calcareous particles of Synaptinae, viz. the anchors, anchor plates, supporting rods and miliary particles or granules, show considerable diversity in the different genera. But they are remarkably constant among the members of a species and for that reason afford excellent taxonomic basis. As a rule, each species has a characteristic deposit of each kind and in certain cases one or even two may be absent. Only the genus *Anapta* is known to be without anchors. In *C. varians*, the anchors, anchor plates and miliary granules are abundantly found in the connective tissue of the body wall. Supporting rods are absent in the species. Further, the tentacles are free from calcareous deposits of any kind.

The anchors are bilaterally symmetrical structures lying over the anchor plates with their long axes at right angles to the long axis of the animal, and having the usual shape of the anchors of other species of *Chondrocloea* (Fig. 5). The anchor

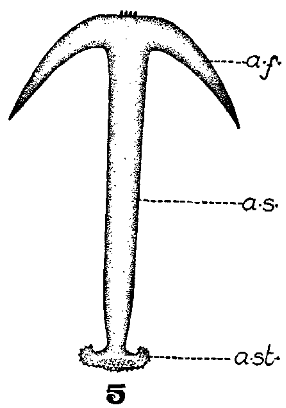

FIG. 5. Anchor. ×200.

consists of the anchor stock, the shaft and the smooth and tapering anchor flukes or arms. There are a number of minute teeth present on the outer side of the anchor stock along its entire length. The stock is connected to the bridge of the anchor plate with connective tissue fibres. The posterior end of the shaft together with the anchor stock is slightly curved upwards. The anchor flukes are not articulated on the same plane as that of the shaft; and their pointed ends are raised towards the outside. On the vertex where the two arms fuse with the shaft, three to five minute knobs are present. The anchors measure 210μ in length and 135μ in breadth. Anchors with two pairs of flukes, one pair below the other, have been noticed to be very common in the species (Fig. 6). These are of about the same size as the normal anchors. Whether these are abnormal anchors, as has been found in *C. ater*, is very difficult to say. They are, however, so constant in their occurrence that it is difficult to regard them as not having some specific value. Abnormal anchors, malformed with three flukes, have been occasionally noticed (Fig. 7).

The anchor plates are perfectly symmetrical structures having an oval shape (Fig. 8). The broader anterior end is provided with six large toothed holes of uniform size. Below these holes are three smaller ones: a median articular hole and two paired holes to the outer margin of which are attached the ends of the arched bridge. The posterior end is provided with three very small holes, of which the central one is slightly larger. The edges of the articular hole and the other five holes are perfectly smooth. Similarly, the bridge is also smooth without any serrations on it. The

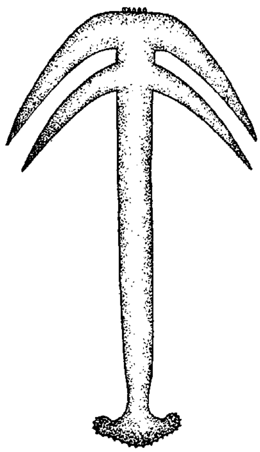

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FIG. 6. Anchor with two pairs of flukes. ×210.

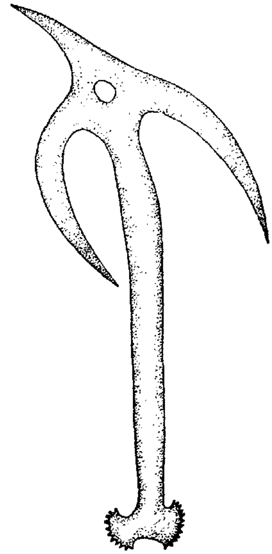

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FIG. 7. Malformed anchor with three flukes. ×300.

anchor plates measure 180μ in length and 140μ in breadth. Malformed anchor plates are rarely seen in the species (Fig. 9).

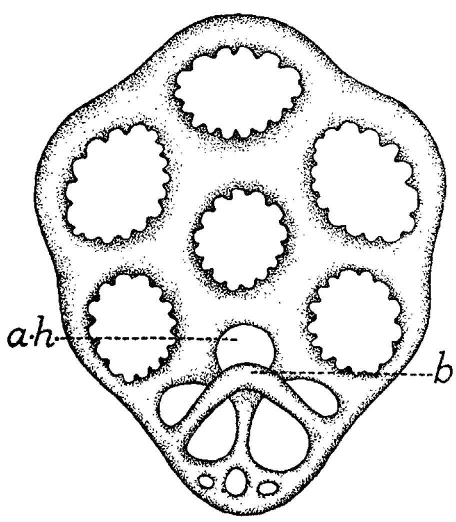

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FIG. 8. Anchor plate. ×300.

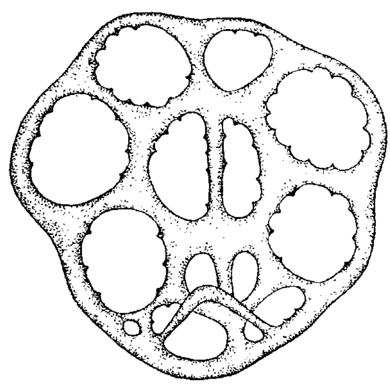

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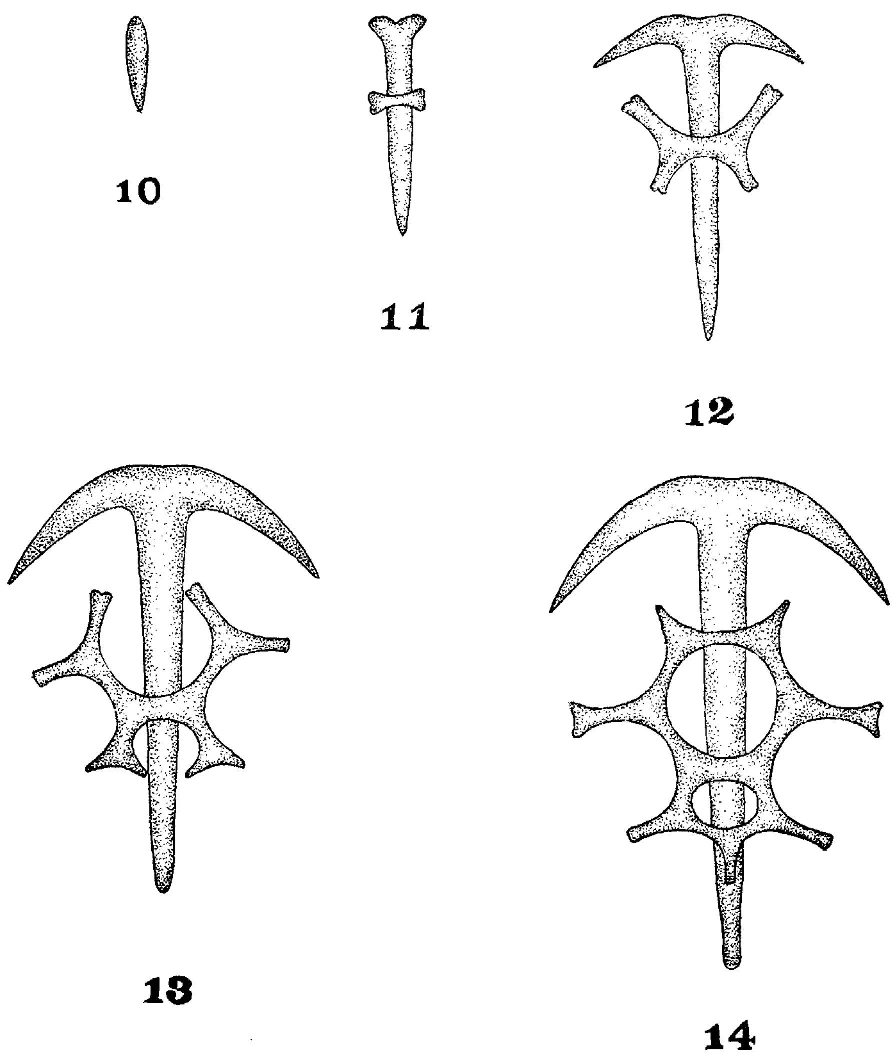
FIG. 9. Malformed anchor plate. ×300.

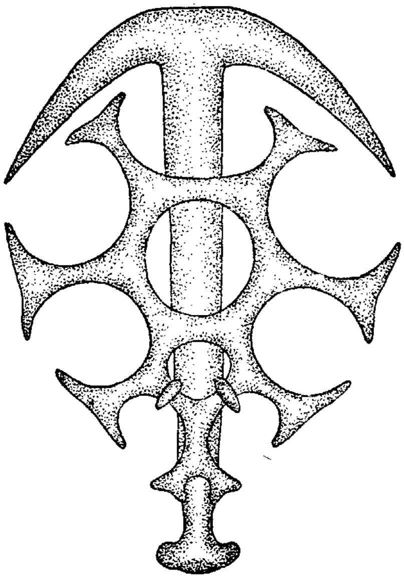
The anchors and anchor plates are nearly of the same size at both ends of the animal without any appreciable difference. These are lodged in sac-like spaces in the cutis and are worked by the contraction of the body wall. The 'stickiness' of the animal is mainly due to the anchors, the flukes of which adhere to the fingers. The anchors aid the adhesive papillae in locomotion.

The histogenesis of the anchor and the anchor plates has been the subject of investigation by earlier workers. As early as 1845 Oersted figured the developmental stages of the anchor and the anchor plates of *Synaptula vivipara*. Later workers like Semon (1887), Woodland (1907) and Domantay (1933) made detailed studies on the method of formation of the spicules in other forms. These calcareous deposits are formed by special mesenchyme cells in the connective tissue of the body wall. In the development of the anchor and the plate, the rudiment of the anchor is the first to make its appearance as a short rod formed across the long axis of the body. Later on, the plate arises as a short rod placed across the middle of the rudiment of the shaft of the anchor, the free ends of which soon fork. The forked ends grow and divide dichotomously with regularity. Due to the unequal growth of the branches of the third and subsequent forks, the branches meet and fuse enclosing



FIGS. 10–14. Stages in the formation of anchor and anchor plate. × 280.

open spaces which ultimately form the toothed and smooth perforations of the completed plate. Figures 10 to 16 illustrate the formation of the anchor and anchor plate in *C. varians*.



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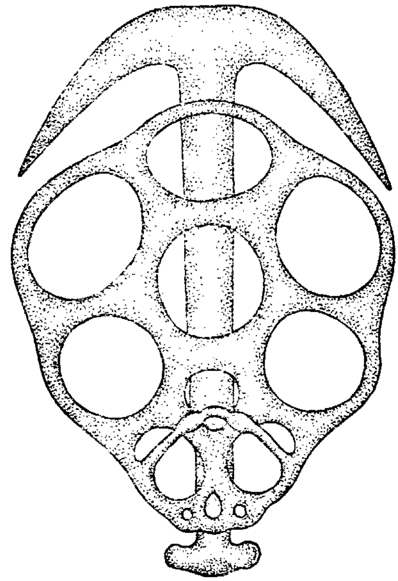

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FIGS. 15-16. Further stages in the formation of anchor and anchor plate. ×280.

In most genera minute rods and grains or particles of lime, called the miliary granules, are present; they are characteristic and furnish one of the most reliable means of identifying the species. The miliary granules in *C. varians* are irregular rosettes of varying shape and size, the biggest measuring 10μ (Fig. 17). These are

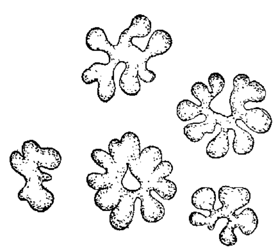

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FIG. 17. Miliary granules. ×900.

scattered uniformly in the body with a tendency to be concentrated in the interspaces between the longitudinal stripes.

The layer of connective tissue is followed on the inside by the circular muscle layer. This layer, as in all other Synaptids, runs round the body cavity as a continuous layer composed of wavy muscle fibres. In the region of the radius the muscle fibres are less in number. Near the cloacal opening this layer becomes somewhat better developed to form the sphincter muscle.

In the radial portion between the cutis and the circular muscle layer runs the radial nerve. This nerve, like the nerve ring, takes a comparatively deep stain as also the nuclei in the nerve.

The longitudinal muscles are confined to the radii, being situated on the inner side of the circular muscle layer and covered by the endothelium. The longitudinal muscle band is like a strip attached by one side to the radial portion of the body wall with the other side free and projecting into the body cavity; the muscle fibres being arranged in groups are clearly seen in sections. The muscle fibres are numerous on the free side and few at the attached side.

The innermost layer of the body wall is the simple epithelial layer consisting of polygonal cells which in sections show very faint cell walls similar to the epithelial cells, but they are very much flattened and have oval nuclei. The presence of cilia on these cells is a disputed point. Hamann (1884) found cilia on the endothelial cells, but later investigators failed to notice them. In *C. varians* the endothelial lining is provided with well-developed cilia. The cilia on the Polian vesicles, the gonads and the alimentary canal are fairly long and measure about 25μ in length and are best seen with dark ground illumination.

The body cavity, as in all other Synaptids, is very spacious in *C. varians* extending from the anterior to the posterior extremities. It is partially divided by the mesenteries supporting the intestine and in the anterior region by the radiating strands of tissue connecting the oesophagus with the calcareous ring. The body cavity maintains its communication with the water vascular system through the madreporic holes. The body cavity is filled with a fluid, probably identical with the fluid of the water vascular system, and composed mainly of water in which three types of corpuscles float (Fig. 18). Some are colourless and amoeboid with

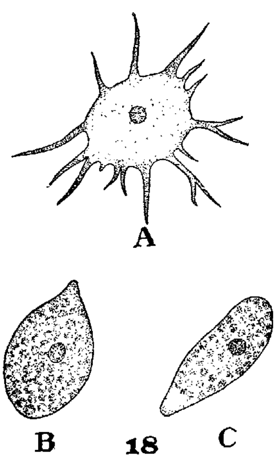

FIG. 18. Coelomic corpuscles. ×1200.
A, Amoebocyte; *B*, Granulated corpuscle; *C*, Pigment corpuscle.

a rounded nucleus and slender and anastomosing pseudopodia. Sometimes these amoebocytes mass together into clusters and form plasmodia. The others are also amoeboid, but with densely packed granules, single nucleus, and with a single small blunt pseudopodium. The third type includes the pigment corpuscles resembling the second in general appearance, but they are deeply pigmented and are red in colour. The amoebocytes are excretory in function.

CALCAREOUS AND CARTILAGINOUS RINGS.

The calcareous ring could be seen in the living condition as a white structure surrounding the oesophagus just below the circlet of tentacles. It is composed of a number of distinct plates which correspond in number with the number of tentacles (Fig. 19). There are five radials and a varying number of interradials. The highly

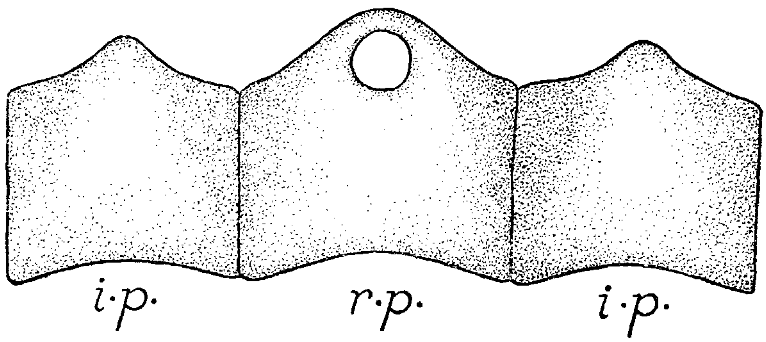

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FIG. 19. A portion of the calcareous ring. ×40.

convex anterior end of the radial is provided with a fairly large hole through which the radial nerve passes out after emerging from the nerve ring. The anterior end of each interradial is also convex with a blunt median conical projection. The posterior ends of all the plates are concave. Each plate, when seen under high magnification, is found to be composed of an anastomosing network of branching calcareous bodies. The anterior ends of the longitudinal muscles are attached to the outside of the radial pieces.

The cartilaginous ring found in all the species of *Chondrocloea* is weakly developed in this species. This ring is closely attached to the posterior margin of the calcareous ring and is provided with holes at the free margin.

ALIMENTARY CANAL.

The tubular alimentary tract is partially visible through the body wall of the living animal. The alimentary canal is looped near the middle portion. The mouth is situated at the anterior end in the centre of a prominence surrounded by the ring of tentacles and leads into the sac-like oesophagus. The oesophagus is attached to the calcareous ring by a number of radiating bands of connective tissue. The oesophagus leads into a narrow tube, the stomach, which is continued as the wider intestine. At the place where the stomach passes into the intestine, the alimentary canal bends and runs forward for a short distance and then resumes its course backwards to end in the rectum which opens terminally (Fig. 20). According to the nature of the attachment to the body wall the alimentary canal can be divided into three regions. The oesophagus and the stomach are attached to the dorsal interradius, the middle short region between the two curves of the alimentary canal to the left dorsal interradius and the posterior region up to the rectum to the right ventral interradius. The various parts of the alimentary canal have essentially the same structure. The wall of the stomach is thick and muscular. The intestine is thin-walled and the folds of the inner epithelium are large and very prominent.

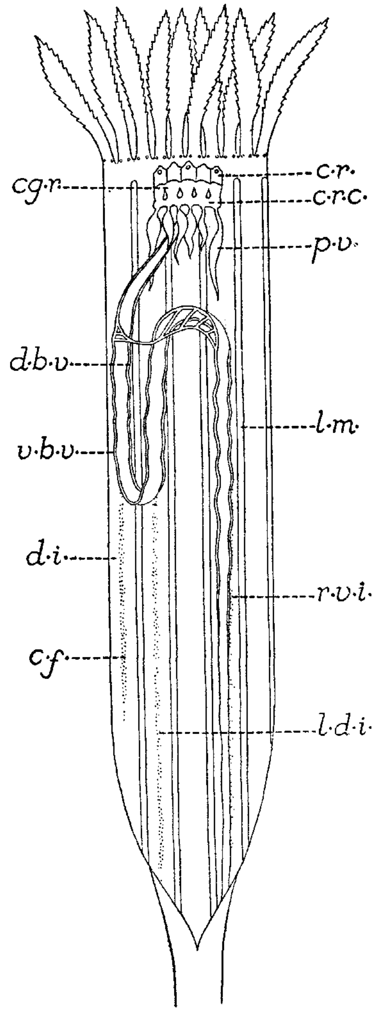

FIG. 20. Diagrammatic figure showing the internal organs.

The structure of the alimentary canal is the same as that of other Synaptids. Externally there is the coelomic epithelium of the body cavity (Fig. 21). This is composed of a single layer of ciliated cells with prominent nuclei. The cell boundaries are not clear. This layer is followed by a layer of connective tissue followed by the muscle bands. The musculature is composed of an external longitudinal and an internal circular layer of muscles. The longitudinal muscles appear in sections as a single row of muscle bundles, each of which is composed of about four to six longitudinal muscle fibres. The circular muscle layer is uninterrupted and the fibres have a wavy appearance. Occupying nearly half the thickness of the wall of the alimentary canal is the connective tissue layer situated on the inner side of the muscle layer. On the outer region of this layer are present a number of interspaces or lacunae. Next to the connective tissue layer is the innermost layer of the wall of the alimentary canal, namely, the inner epithelium. The cells of this region are long and compactly arranged. These cells occupy the whole portion of the fold projecting into the lumen of the alimentary canal. The cell walls of this layer are clearly seen and the nuclei are mostly oval and elongated in shape with dark and

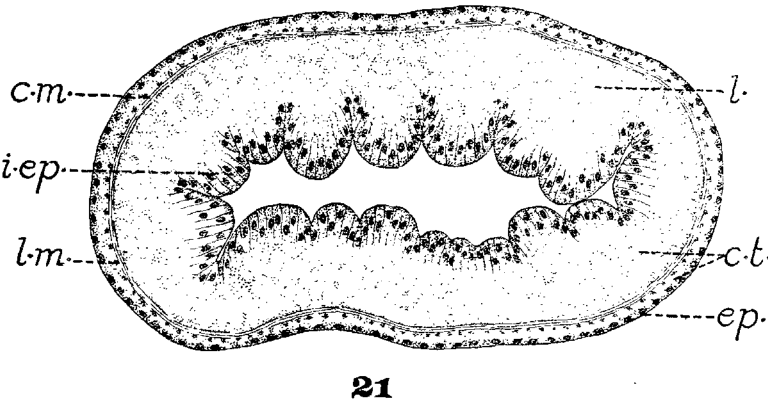

FIG. 21. Transverse section of the alimentary canal. ×160.

deeply staining nucleoli and chromatin granules. These cells are glandular and secretory vacuoles are present in almost all of them.

CILIATED FUNNELS.

In *C. varians*, the ciliated funnels, which are characteristic of the family, are arranged in three longitudinal rows along the bases of the mesenteries which connect the alimentary canal with the body wall. They are present on the dorsal interradius, right ventral interradius and left dorsal interradius (Fig. 20). They are attached to the mesenterial bases by means of short stalks and hang freely into the body cavity. Each ciliated funnel is cup-shaped and measures 46μ in length excluding the stalk. The stalk is short and slender and consists of a core of connective tissue covered by the body cavity epithelium (Fig. 22). The ciliated funnel consists of a continuation

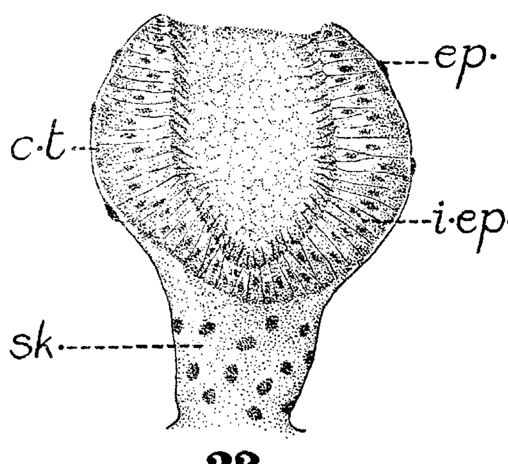

FIG. 22. Ciliated funnel. ×900.

of the flattened epithelium of the stalk followed by an extremely thin layer of connective tissue. The innermost layer of epithelium is thick and occupies the greater part of the thickness of the ciliated funnel. This layer consists of closely packed columnar cells with narrow elongated nuclei. They are provided with long cilia which project freely into the lumen of the ciliated funnel. By the collective action of the cilia of these organs the body fluid of the animal is kept constantly in motion.

Our knowledge of the function of the ciliated funnels is not altogether satisfactory. Clark (1907) says that the solid particles of waste matter are swept into the ciliated funnels from where they are seized by the coelomic corpuscles to be carried into the tissue of the body wall. Experiments carried out with *C. varians* show that the process of excretion is different from that described by Clark. Examination of specimens injected with Indian Ink particles shows the corpuscles in the body fluid loaded with these particles and such corpuscles are found in large numbers crowding in the lumen of the ciliated funnels. The coelomic corpuscles evidently collect the waste particles from the coelomic fluid itself and the ingested corpuscles are swept into the ciliated funnels by the action of the cilia present inside them. The fate of these wandering cells, whether they are retained in the connective tissue of the body wall to form the pigmentation of the animal or whether they pass to the outside, could not be determined, for the animals die a few hours after injection with Indian Ink.

Water Vascular and Blood Systems.

Owing to the extremely membranous nature of the organs composing these systems difficulty was experienced in studying their detailed structure and only a brief account can be given.

The water vascular system consists of the circular ring canal, the tentacular canals, the Polian vesicles and the stone canal with the madreporic holes. The circular canal is in the form of a tube surrounding the oesophagus situated below the calcareous and cartilaginous rings. From the anterior side of this canal, the tentacular canals, corresponding in number with the tentacles, arise and pass along the inner side of the calcareous ring. As in *Synaptula hydriformis*, the outer part of the lower region of each tentacular canal forms a blind sac—a tentacular ampulla—external to the calcareous ring. The Polian vesicles arise from the posterior region of the circular canal as tubular or saccular structures which float freely in the body cavity fluid of the animal (Fig. 23). The number of Polian vesicles varies in different individuals. From ten to fifteen Polian vesicles of different sizes and shapes have been noted in this species. Further, Polian vesicles arising as buds from the circular ring canal have been noted in almost all the specimens dissected. The Polian vesicles contain the corpuscles of the body fluid in large numbers. Pigment cells, similar to those found in the connective tissue of the body wall, are present on the Polian vesicles.

There is only a single stone canal which is attached to the common duct of the gonad by means of a mesentery and the latter is attached to the dorsal interradius of the body wall. The stone canal is tube-like placed anterior to and connected with the circular canal of the water vascular system. There is no connection between the stone canal and the body wall or the exterior. The madreporite is represented at the tip of the free end of the stone canal by four to five holes situated in slight depressions. It is through these apertures that communication is established between the body cavity and the water vascular system.

In sections, one side of the wall of the stone canal, i.e. the side away from the body wall, is thick and appears crescent-shaped (Fig. 24). Occupying the major portion of the thickness of the stone canal is the inner ciliated epithelium consisting of highly elongated cylindrical cells arranged compactly with long narrow nuclei. The cells of the thicker side of the stone canal are provided with long cilia extending right up to the other side of the lumen. The cilia on the cells composing the thinner side are few and short. External to the ciliated epithelium is the compact connective

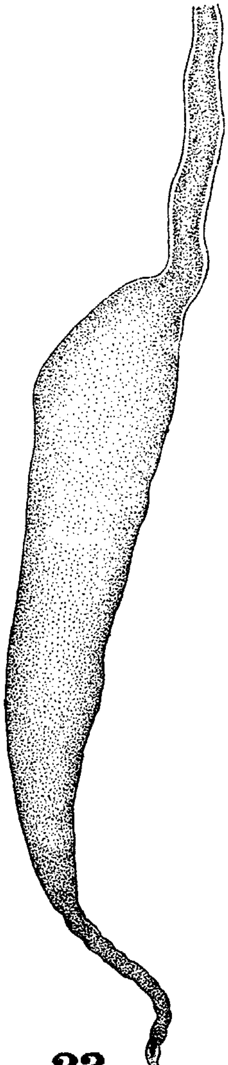

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FIG. 23. Polian vesicle. ×21.

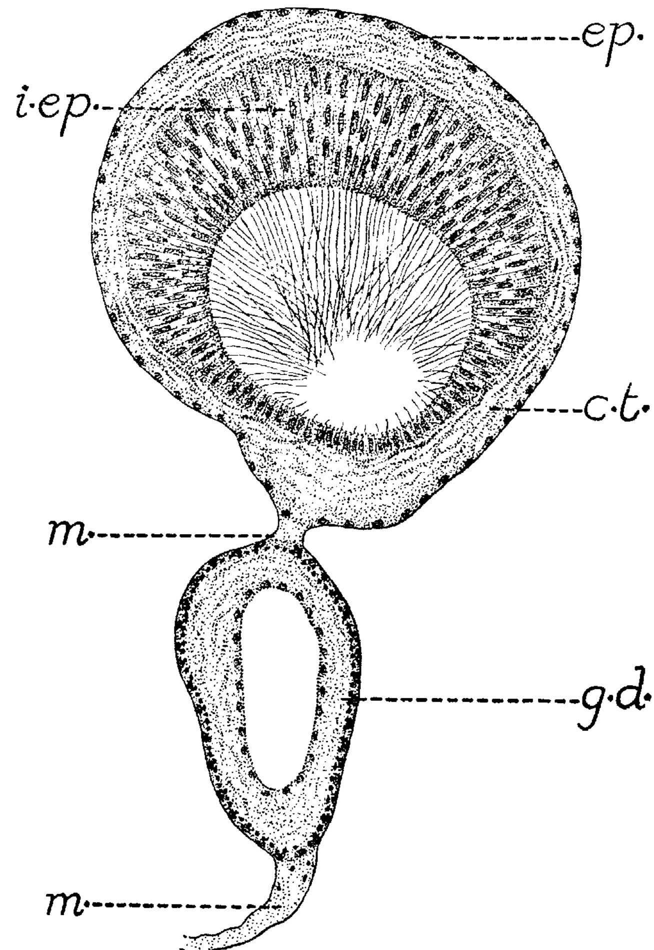

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FIG. 24. Transverse section through the stone canal and the gonadial duct. ×400.

tissue layer. External to this is the layer of outer epithelium composed of a single layer of cells with indistinct cell walls and rounded or oval nuclei.

The vascular system has not been studied in detail owing to the difficulty in getting satisfactory sections. What follows has been chiefly made out by dissection. The blood system in *C. varians*, as in other Synaptids, consists mainly of two longitudinal vessels closely attached to the alimentary canal; the dorsal vessel situated at the place of union of the mesentery with the alimentary canal and the ventral vessel on the opposite free side of the alimentary canal (Fig. 20). They run intimately attached to the alimentary canal throughout their courses, and the vessels communicate with each other by the lacunar spaces present in the wall of the alimentary canal. The ventral blood vessel starts from the lower end of the oesophagus and is continued as far as the middle of the third section of the alimentary canal with the two extremities merging in the lacunar spaces. The ventral blood vessel of the first section of the alimentary canal, at a level with the second loop, gives off a prominent connecting vessel to the ventral vessel of the third section of the alimentary canal. The connecting vessel usually maintains association with the ventral vessel of the first and the third sections of the alimentary canal by two and four smaller branches respectively. The dorsal and the ventral vessels run posteriorly to about the same distance along the alimentary canal.

Nervous System.

The nervous system consists of the circumoral nerve ring, the radial nerves and the tentacle nerves. Surrounding the anteriormost part of the oesophagus and situated on the inner anterior side of the calcareous ring is the circumoral nerve ring. The five radial nerves emerge from the circumoral nerve ring and pass through the holes in the radial pieces of the calcareous ring to take an abrupt downward course. These nerves run up to the posterior end of the animal between the circular muscle fibres and the connective tissues of the body wall. The radial nerves, soon after emerging from the radial pieces of the calcareous ring, supply the two positional organs of that radius with a pair of nerves. Further, the radial nerves innervate the tactile organs and the muscles of the body wall. The tentacular nerves arising from the circumoral nerve ring correspond in number with the number of the tentacles present in the animal. The optic nerves, corresponding in number with the eyes, take their origin from the base of the tentacle nerves. Each tentacle nerve passes between the longitudinal muscle layer and the connective tissue layer of the inner surface of the tentacle and gives off branches to the digits. The circumoral nerve ring, the radial nerves and the tentacle nerves have the same structure, and consist of a peripheral region containing the ganglion cells and an inner region which is chiefly fibrous in nature (Fig. 25).

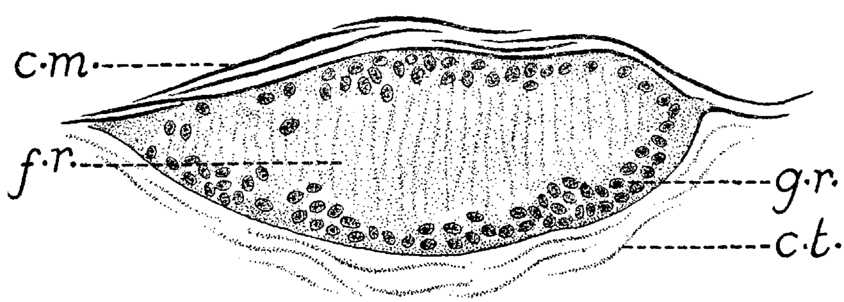

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Fig. 25. Transverse section of the radial nerve. ×400.

Sense Organs.

Four different kinds of sense organs have been described in Synaptids. They are the light detecting, positional, gustatory and tactile organs. Of these only the gustatory organs are wanting in *C. varians*.

The light detecting organs or the eyes are known in most of the species of *Chondrocloea*. A pair of these is situated at the base of the tentacle, one on either side, and the number of pairs of eyes corresponds with the number of tentacles. Each eye measures about 80μ in sections and is composed of a distinct horny mesodermal layer which is pigmented dark red in the living animal with scattered nuclei, overlying the swollen end of the nerve to the eye (Fig. 26). The swollen end of the nerve has a vacuolated appearance. The nerves supplying the eyes take their origin from the base of the tentacle nerve. In *Synaptula hydriformis* the optic nerves start direct from the circumoral ring at the base of the tentacle nerve.

The positional organs generally called the otocysts occur in all Synaptids. There are five pairs of them, each pair being in relation with a radial nerve, placed close to the calcareous ring. The radial nerves supply nerves to the otocysts. In *C. varians* each otocyst is of about 160μ in diameter; it is a spherical vesicle composed of a single layer of ciliated cells filled with a fluid in which is suspended a single sphere measuring 20μ in diameter.

The tactile organs are present only on the body, being absent from the tentacles even though one or two have been noticed at the bases of the stalk of the tentacles. They generally protrude from the general contour of the integument and about four such structures are present in a complete section of 10μ thickness. The tactile organs are composed of small groups of epithelial cells which are columnar and about twice the length of the ordinary epithelial cells (Fig. 27). The nuclei of these cells are basal in position and are slightly bigger than those of the ordinary

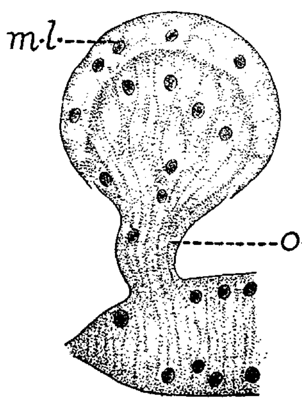

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Fig. 26. Section through the light detecting organ. ×360.

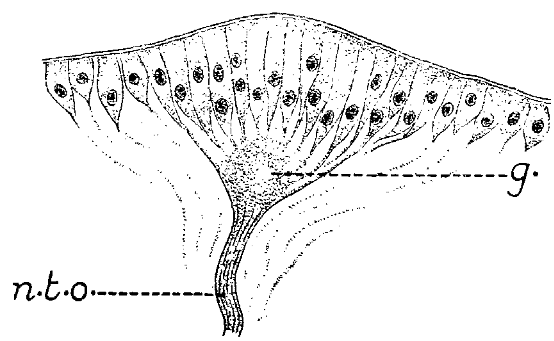

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Fig. 27. Section through the tactile organ. ×504.

epithelial cells. At the base of the tactile organ is a ganglion situated at the end of a small nerve arising from the radial nerve. The inner tapering ends of the cells composing the tactile organ are connected with the ganglion.

Reproductive System.

The gonad is creamy white in colour and is situated at the anterior end of the body on the dorsal side of the oesophagus. The gonad consists of a branched tuft with two main branches and a common short and thin-walled duct. The duct is attached to the dorsal interradius by means of a mesentery and opens through the body wall to the exterior by a single small genital aperture on the dorsal interradius immediately below the ring of tentacles. The genital aperture is very small and inconspicuous and could be made out only in sections. As mentioned already the stone canal of the water vascular system runs in close proximity with this short gonadial duct and is attached to it by the same mesentery. Each branch of the gonad is divided into a number of short tubules and the size of these tubules varies according to the state of maturity of the specimen. The two main branches of the gonad hang freely in the body cavity on either side of the alimentary canal. The gonad, like many other internal organs, is also pigmented, especially in the immature and spent conditions. The gonadial tubule consists of the following parts: a thin layer of coelomic epithelium of the body cavity provided with fairly long cilia, a very thin layer of longitudinal muscle fibres and the inner germinal epithelium (Fig. 29).

C. varians, like many other Synaptids, is hermaphrodite. Though the eggs and the sperms are developed inside the same tubule of the gonad, the species is protogynous. Active motile sperms have been noted only during September to November, the rainy season at Madras. During the other seasons of the year the gonadial tubules contain only large numbers of eggs and a few sperm cells. The motile sperms are fairly long and measure 55μ in length and the head measures 3μ. The heavily yolked eggs are spherical measuring 250μ in diameter with a circular centrally placed nucleus.

In the young condition of the tubule, the oogonia are the first to make their appearance on the outer side of the germinal epithelium. Later, the oocytes get pushed into the tissues immediately surrounding them (Fig. 28). Owing to the

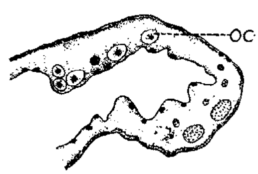

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FIG. 28. Longitudinal section through a young gonadial tubule. ×225.

growth of the oocytes, the germinal epithelium gets pushed into the lumen in the form of folds which fill almost the entire space inside the tubule. When the eggs have grown to about half their size, the spermatogonia appear on the inner side, situated at the base of the folds of the germinal epithelium. Sections of the tubules of all the specimens with fairly ripe eggs show a few sperm cells in between the folds (Fig. 29).

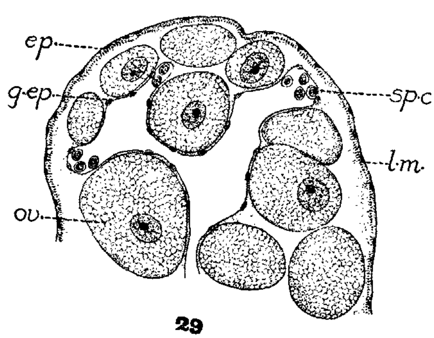

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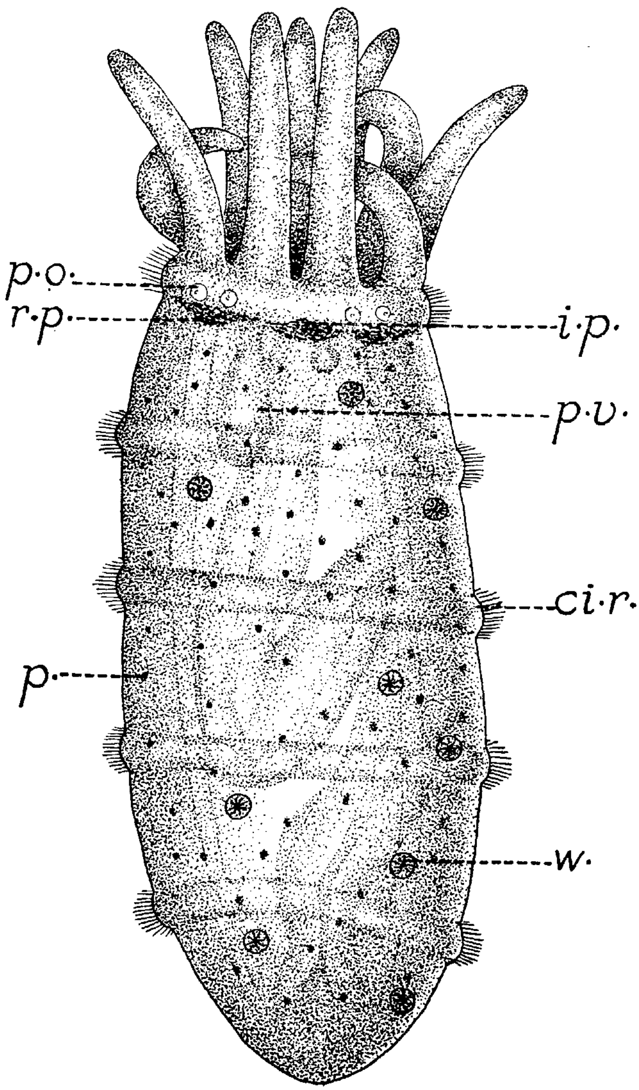
FIG. 29. Transverse section of a gonadial tubule showing the sperm cells. ×225.

During the rainy season when the eggs become fully mature and are ready for extrusion, the spermatogonia which were remaining inactive begin to divide and develop into spermatids. At this time the spermatids are seen to line the entire inner region of the germinal epithelium. The spermatids are transformed into the spermatozoa only after the extrusion of almost all the ripe eggs. The gonadial tubules when they contain only the sperms are white in colour and become enlarged in regions by the accumulation of large quantities of actively motile sperms.

Various attempts have been made to obtain the larvae by artificial fertilisation; but these have not been successful. Unlike other groups of Echinoderms difficulties



30

FIG. 30. Pupa obtained from the Madras Plankton. ×80.

in regard to artificial fertilisation of Holothurian eggs have been experienced by other workers as well. An attempt was made, therefore, to collect Synaptid pupae from the Madras Plankton and though this proved successful, the larvae were not obtained in sufficient numbers to establish a correlation. The Plankton collection made on the 4th September, 1942, contained a few advanced pupae of the same size and stage of development (Fig. 30). The pupa has the typical barrel-shaped appearance with five closed ciliary rings and ten simple tubular tentacles. Red pigment spots are scattered uniformly on the surface of the pupa. Only a few wheels have been noticed in the pupa. The looped alimentary canal and the growing Polian vesicles can be made out through the transparent body wall. The rudiments of the radial and interradial pieces of the calcareous ring are present as also are the positional organs. It is possible that the pupa may belong to *C. varians* when we consider the abundant occurrence of the species in the Madras Harbour.

SYSTEMATIC POSITION.

From a comparison of the description given in the foregoing pages with that of the other known species of *Chondrocloea*, it is clear that the Madras form is new to Science. The variation in the number of tentacles is an important feature of the present species; only variations up to three tentacles have been noted in *C. mortenseni*. The latter is a small species with ten to twelve free digits in the tentacles. Further, the tentacles are provided with rods having irregularly branched ends. Miliary granules are absent in *C. mortenseni*. The anchor plates of *C. varians* resemble those of *C. maculata*, *C. reticulata* and *C. bandae*. But in these three species, though the articular hole of the plate is smooth and the posterior end of the plate is provided with three holes as in *C. varians*, knobs have been noted on the bridge of the anchor plates. The weak calcareous ring in *C. maculata* is tinged green and the cartilaginous ring is well developed and is dark purple in colour. *C. reticulata* is a small species with a red calcareous ring. *C. bandae* also is a small species with only four to five digits in each tentacle. Further, the shape of the calcareous ring in these forms differs considerably from that of the Madras form. The miliary granules of *C. varians* resemble those of *C. reticulata* in having irregular rosettes of different shapes and sizes.

Family SYNAPTIDAE Burmeister, 1837.
Subfamily SYNAPTINAE Östergren, 1898.
Section Micrournae Heding, 1928.
Genus *Chondrocloea* Östergren, 1898.

Chondrocloea varians n.sp.

Average length of animals 15 cm. General body coloration, pink with red longitudinal interrupted stripes. Tentacles, ten to fifteen with about twenty pairs of digits with connecting web and adhesive papillae. Eye spots, visible on the oral disc. Calcareous ring, white with muscle impressions; cartilaginous ring, weakly developed. Anchors and anchor plates, of nearly the same size at both ends; anchors, $210\mu \times 135\mu$, with finely dented anchor stock and three to five knobs on the vertex, anchors with two pairs of flukes common; anchor plates, $180\mu \times 140\mu$ with the articular hole and bridge smooth, posterior end provided with three holes. Miliary granules, irregular rosettes of varying size and shape. Stone canal, single with madreporic holes at its free end. Highly looped alimentary canal; ciliated funnels of uniform size measuring 46μ; hermaphrodite and protogynous, provided with light detecting, positional and tactile sense organs.

Localities: Madras Harbour. Living amidst Polyzoa, Sponges, Mytilus, etc.
Pamban, Gulf of Manaar. On submerged stones under the Pamban Bridge.

ACKNOWLEDGEMENTS.

I take this opportunity to express my gratitude to Prof. R. Gopala Aiyar, Director, University Zoological Research Laboratory, for his unfailing help and valuable criticisms. I am thankful to Dr. N. Kesava Panikkar, the present Director of the Laboratory, for going through the manuscript and for his helpful suggestions. My thanks are also due to the authorities of the University of Madras for the award of a Research Studentship.

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NOTE.—References marked with an asterisk have not been referred to in the original.

KEY TO LETTERING.

a.f.	anchor flukes.
a.h.	articular hole.
a.p.	adhesive papillae.
a.s.	anchor shaft.
a.st.	anchor stock.
b.	bridge.
c.f.	ciliated funnels.
cg.r.	cartilaginous ring.
ci.r.	ciliary rings.
c.m.	circular muscle.
c.r.	calcareous ring.
c.r.c.	circular ring canal.
c.t.	connective tissue.
d.	digits.
d.b.v.	dorsal blood vessel.
d.i.	dorsal interradius.
e.	epidermis.
ep.	epithelium.
f.r.	fibrous region.
g.	ganglion.
g.d.	gonadial duct.
g.ep.	germinal epithelium.
g.r.	ganglion cell region.
i.ep.	inner epithelium.
i.p.	interradial piece.
l.	lacunae.
l.d.i.	left dorsal interradius.
l.m.	longitudinal muscle.
m.	mesentery.
m.l.	mesodermal layer.
n.t.o.	nerve to tactile organ.
oc.	oocyte.
o.n.	optic nerve.
ov.	ovum.
p.	pigment.
p.o.	positional organ.
p.v.	Polian vesicle.
r.n.	radial nerve.
r.p.	radial piece.
r.v.i.	right ventral interradius.
sk.	stalk.
sp.c.	sperm cells.
t.c.	tentacular canal.
t.n.	tentacle nerve.
t.o.	tactile organ.
v.b.v.	ventral blood vessel.
w.	wheels.