STRUCTURE, HABITS AND EARLY DEVELOPMENT OF A NEW SPECIES OF *STILIGER* EHRENBERG.

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INTRODUCTION.

While engaged in faunistic studies of the brackish waters of Madras, Professor R. Gopala Aiyar drew my attention to the occurrence of a small Eolid-like Mollusc. An examination of the brackish water pools near the mouths of the rivers Cooum and Adyar in Madras during August and September 1935, revealed this tiny Mollusc creeping on algae floating in the waters. A careful study of its external characters and anatomy convinced me that it was a new species of the genus *Stiliger* Ehrenberg, and a preliminary note on this form was read by me before the Zoology Section of the Indian Science Congress held at Indore in the month of January 1936.

Though the genus was discovered as early as 1831, our knowledge of its anatomy is incomplete in most respects while nothing is known about its life-history. I have therefore given in this paper a full description of the external morphology and internal anatomy of this new form, which I have named *Stiliger gopalai*, sp. nov., and a brief account of the bionomics and development. *Stiliger gopalai* is a hardy form and affords good scope for study under laboratory conditions. Captivity affects neither its normal activities nor its breeding habits.

The species is named after Professor R. Gopala Aiyar, Director of the University, Zoological Research Laboratory, Madras, to whom I express my warmest gratitude for his unfailing help and kind encouragement throughout this work. I wish to express my thanks to Dr. Baini Prashad, Director of the Zoological Survey of India, and Dr. H. S. Rao for having kindly gone through the manuscript and made useful suggestions ; and my indebtedness to the Syndicate of the Madras University for the award of a Research Studentship.

MATERIAL AND METHODS.

When salinity and temperature conditions were favourable and when the growth of a common alga, *Chaetomorpha*, was abundant, large numbers of the mollusc were collected by a careful search among the algal meshes from the brackish water pools near the mouth of the river Cooum and in the backwaters of Adyar. They continued to be active for a couple of months when kept in large glass vessels containing brackish water and algae (particularly *Chaetomorpha*) brought from their natural habitat. Under these conditions a study of most of its habits, especially the method of feeding, copulation and spawning was made. That these Opisthobranchs shrivel and lose their shape on sudden fixation has been repeatedly stated by previous writers, and it is not necessary therefore to refer to the importance of careful narcotisation prior to fixation for dissection as well as for section cutting. Menthol was used with success as a narcotising agent. As the animals are very small, their anatomical structure was studied by dissections with the aid of a Zeiss binocular microscope and by means of serial sections. Of the several fixatives used, Brasil's modification of Bouin's fluid and corrosive formol gave the best results. For staining, iron haemotoxylin and eosin or Meyer's acid haemalum and eosin were employed. For a study of the early development, water in the dishes was renewed at least twice a day. Some stages of development, in which the various parts were opaque, were fixed in glacial acetic acid and rendered transparent in increasing grades of glycerine for microscopic study. To prevent escape of the minute larvae while the water was changed, the siphon was plugged with a small quantity of cotton wool. Though unfortunately I was not able to observe the actual metamorphosis of the larvae, metamorphosed young ones of varying growth were obtained from the brackish water pools near the mouth of the river Cooum. The growth of these young forms was studied by keeping them in glass vessels containing brackish water and algae. The vessels were wrapped in thin cloth which was kept constantly moist.

HISTORY OF THE GENUS *Stiliger*.

For a tiny Opisthobranch mollusc found in the Red Sea, Ehrenberg[1] erected the genus *Stiliger* in 1831 and named the species ' *ornatus* ' with the following description : " Habitus Eolidae. Corpus oblongum,

[1] Symbolae Physicae—Decas I—1831, as referred by Allman **(8)**, Chenu **(17)**, Bergh **(9)** and Eliot **(26)**.
Mag. de Zool., 1837, also referred by the above-mentioned authors.

pallio discreto nullo. Latera Corporis branchiarum stiliformium seriebus longitudinalibus instructa. Tentacula duo tantum in medio dorso." Later in 1837 d'Orbigny gave the name *Calliopaea bellula* to an animal whose generic characters were identical with those of *Stiliger*. The description of *Calliopaea bellula* like that of *Stiliger ornatus* is incomplete ; and d'Orbigny not only mistook the rhinophores to be the buccal tentacles, but also made a serious mistake regarding the position of the anus. Milne-Edwards (**19**) described the digestive apparatus of *Calliopaea bellula* giving the correct position of the anus, but he assumed that the digestive system communicated with the vascular system in the region of the cerata and introduced the term ' gastrovascular system ' which later on led to a great controversy. Verany's *Calliopea souleyeti* (**60**) was described in fair detail by Souleyet (**57**). Alder and Hancock (**6**) established that *Calliopaea* of d'Orbigny was identical with *Stiliger* of Ehrenberg. They retained the name *Stiliger* which had six years' precedence over *Calliopaea*, and placed the genus in the family Hermaeidae (synonymous with Stiligeridae of O'Donoghue, 1928). Meyer and Moebius in 1865 in their *Fauna der Kieler Bucht* (p. 13) described a similar animal as *Embletonia mariae*. The figures of *Calliopaea bellula* of d'Orbigny and *Embletonia* of Meyer and Moebius agree so closely that the identity of these two forms was first pointed out by Fischer (**32**) and later by Bergh (**9**). Bergh referred both these forms to the genus *Stiliger* of Ehrenberg, but he preferred to retain the specific name '*mariae*' of Meyer and Moebius. Eliot (**22** and **26**) opined that, since d'Orbigny's description of the species *C. bellula* has undoubted priority over *E. mariae*, these forms should be named *Stiliger bellulus*, thus retaining the oldest generic and specific names. Eliot also believed that *Stiliger ornatus* might agree with *S. bellulus* but this could not be decided as the specific characters and the nature of the radula still remain unknown in that species. *Calliopaea dendritica* Alder and Hancock has no place in the genus *Stiliger* as it is identical with *Hermaea dendritica*. Loven's *Stiliger modestus* as shown by Allman (**8**) ceases to be a *Stiliger* and becomes *Alderia modesta*. Kelaart's description of *Pterochilus viridis* (**38**, p. 492) is too incomplete for recognition of the species, but Eliot (**23**) referred it to '*Stiliger viridis*.' Hutton's *Calliopaea felina* was redescribed by Eliot (**25**) as *Stiliger felinus*. Eliot (**21**) recorded two species, *i.e.*, *Stiliger varians* and *Stiliger irregularis* from the Zanzibar harbour, South Africa, and later (**29**) described *S. tentaculatus*—the only *Stiliger* with oral tentacles so far known collected by Annandale in Siam. *S. pica* of Annandale and Prashad (**56**) was yet another species of Hermaeid from the Chilka Lake. Labbe (**39**) described a variety of *S. bellulus*. Of the various authors who have described species of *Stiliger*, only Bergh and Souleyet have given a description of the anatomy ; and presumably for want of living material no one has described the bionomics and development of any of the species. Of the several species referred to above, *S. tentaculatus*, *S. pica* and the present species, *S. gopalai*, are inhabitants of brackish waters while the rest are marine.

It is worth mentioning here that the validity of Trinchese's *Ercolania* as a separate genus from *Stiliger* was questioned by Eliot (**20**) and

O'Donoghue (**43**). Vayssiere (**59**) treated *Ercolania* as a separate genus ; and Bergh[1] and Eliot (**20**) have described new species of *Ercolania*. In my view the genus *Ercolania* is distinct from *Stiliger* in that the former has canaliculated grooves in the rhinophores. This character, though minute, is quite distinct, and a similar difference in the nature of the rhinophores also distinguishes *Hermaea* from *Stiliger*.

EXTERNAL FEATURES OF *Stiliger gopalai*, sp. nov.

The animal (Pl. VII, figs. 1, 2 and 5) has the general appearance of an Eolid and measures when fully expanded 11 to 12 mm. in length and 4 to 4·5 mm. in breadth. The ground colour is deep brownish gray speckled with yellow here and there. The yellow colour completely disappears on preservation and the depth of the gray varies with the physiological condition of the animal. When kept in captivity without food for a couple of days, the gray fades into a pale colour. The dark gray colour of the dorsal part of the snout is striking with a pale yellow streak running on either side of this area beginning from the base of the dorsal tentacle and extending up to the anteriormost cerata. The rest of the dorsal surface and the sides are finely spotted yellow with the region surrounding the anus slightly pale. The yellow spots are very minute in the anterior half of the back and comparatively large in the posterior half.

The snout, 1·75 mm. in length, is more or less convex dorsally, and slightly notched in the anterior middle region over the mouth giving the appearance of two minute lumps, one on either side, which represent the thickenings of the outer lips (Pl. VII, fig. 3, *la.*). The snout bears antero-dorsally a pair of smooth, long, slender and pointed tentacles or rhinophores measuring about 3 to 3·25 mm. in length. A pair of dark, minute eyes is seen through the transparent integument covering the neck region behind the dorsal tentacles.

The part that follows the neck is conspicuously broad and bears the dorsal papillae or the cerata, which are arranged in two longitudinal bands, one on either side of the back leaving the middle region bare throughout its length. Each band appears at first sight to consist of two or more rows of cerata, but as in *Stiliger bellulus* the arrangement is irregular. The cerata are 3 mm. long, neither very slender nor very much inflated. They are dark gray with distinct white tips, and reveal all over their surface microscopical white dots representing the gland cells (Pl. VII, fig. 4, *o. gl.*). Such gland cells are also seen at the bases of the rhinophores. Each band consists of thirty to forty cerata, of which, as a rule, the anterior ones are the smallest and the posterior the longest ; but the autotomy of these organs and their subsequent regeneration are so common that small and minute cerata may appear occasionally at any region in the band. The hepatic ramifications (*d. gl. r.*) extending into the cerata show only one main stem which gives off but a few minute branches. When the animal is disturbed the gland cells secrete a copious, whitish, slimy, pungent-smelling fluid, and the

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[1] Beitr. Z. Kennt. der Aeolidiaden—*Ver. k.k. Zool. Bot. Gessel. Wien.*, V, (1878) referred by Eliot (**20**).

cerata break off spontaneously as in *Tergipes* and *Galvina.* The cerata thus cast off swim freely in water in all directions by means of their cilia and may continue to be active for nearly a week.

The foot, which is .1 mm. wide, is considerably narrower than the back and extends from one end of the body to the other, tapering posteriorly into a fine filamentous tail nearly as long as the rhinophore. It is pale yellow in colour and bears a few minute, yet distinct, white spots.

The middle of the anterior region of the foot is slightly grooved with its antero-lateral edges rounded into two small lobes. The narrow foot seems to be adapted to the habit of creeping on filamentous algae (*Chaetomorpha*) which form its chief food. Movements of the animal from place to place are effected by waves of muscular contractions characteristic of all Gastropods. When the animal creeps from one filament of the alga to another lifting up the anterior part of the body, the muscular contractions of the foot are clearly seen in the region which is raised above the substratum. The cilia of the foot are in constant action but they only play a secondary part in the locomotion of the animal.

The mouth, a vertical slit, is anterior and median and lies immediately above the median cleft of the foot ; and the anus (Pl. VII, fig. 1, *an.*), which opens out to the exterior on a minute papilla, is dorsal and median, lying in front of the pericardium. The genital openings are three in number and are situated on the right side of the body in the neck region. Of these the male genital or the penial opening (Pl. VII, fig. 5, *op. pen.*) lies foremost immediately beneath the right eye. The second in order is the oviducal opening (*op. ov.*) for the purpose of spawning, which lies close behind the male genital opening. The third, the vaginal (*op. va.*), is situated some distance from the other two beneath the first or the second cerata of the right side. The ampulla of the vagina, which lies closely pressed to the integument, shows an external demarcation as a pale white scar behind the vaginal opening.

Histology of the Body-Wall and the Foot.—The body-wall is thin, soft and smooth and consists of an outer ectodermal epithelium of varying thickness formed of pigment cells. The pigment is, however, absent in the cells lining the labial folds and the region immediately surrounding the anus. The lining epithelium of the rhinophores, the labial folds and the cerata is provided with vibratile cilia, but that of the back and the sides is without any cilia. Associated with the dermal epithelium are seen two types of glands, *i. e.*, the mucous and the odoriferous glands. The mucous glands are either unicellular or multicellular and stain darkly with haematoxylin. The comparatively large-sized, flask-shaped odoriferous glands are multicellular and are particularly numerous in the head region at the bases of the rhinophores and all over the cerata. They lie beneath the epithelium and open to the exterior by short necks. Beneath the dermal epithelium there is a loose connective tissue traversed by muscle fibres and blood sinuses.

The foot (Pl. VIII, fig. 1) has an outer ciliated epithelium of columnar ciliated cells (*ci.c.*) with a thin cuticle separating the cells from the cilia. Beneath this epithelium lies the dermal connective tissue penetrated by muscle strands (*m.f.*) and blood sinuses. The mucous glands are either unicellular (*m.g.*) and interspersed between the epithelial cells, or multicellular (*m.m.g.*) and sub-epithelial. They open to the exterior through minute crypts (*cr.*) and secrete a copious quantity of mucus which aids the animal to creep easily on any substratum or to cling to the surface of water with the ventral side upwards.

DIGESTIVE SYSTEM.

The digestive system of *Stiliger* was first studied in *S. bellulus* by Milne-Edwards (**19**). He observed a number of ramifications of the gut in the dorsal papillae and other external organs, and believed that there was a definite communication of the digestive organs with the vascular system in those regions. He accordingly termed this apparatus, the gastro-vascular system, which, as remarked by Alder and Hancock (**6**), " he compares to the system of vessels radiating from the stomach of the *Medusidae* on the one hand, and to the caeca connected with the digestive organs of the *Nymphons* among the *Crustacea* on the other." The work of Quatrefages (**48**) on *Eolidina paradoxum* confirmed the results obtained by M.-Edwards. His (**49, 50**) further investigations on the subject led him to establish the Order Phlebenterata, to include certain forms allied to *Stiliger* such as *Acteonia*, *Chalidis* etc., which were supposed to exhibit what he called ' phlebenterism ' He believed that the members of this order suffered a very great deterioration of the vascular system, the heart and the blood vessels being completely absent, and that the digestive system was likewise modified. He believed that the anus was absent in all these forms, and that the alimentary system discharged the double function of digestion and circulation. The researches of Alder and Hancock, and of Souleyet and others did not confirm Quatrefages' observations. After much controversy over the subject, the Biological Society of Paris proved definitely that the conclusions arrived at by Quatrefages were erroneous and that in all the Phlebenterata there is a definite circulatory system independent of the organs of digestion.

In *Stiliger gopalai* the mouth is a narrow slit placed on the inferior side of the head and bounded by a pair of fleshy lips (Pl. VII, fig. 3, *la.*), which are continuous with each other except for the presence of a deep furrow running in the median line above the mouth. The ectodermal epithelium of the lips is ciliated and is invaginated evenly into a short and narrow passage, the channel of the mouth. The epithelium (Pl. VIII, fig. 2, *epi.*) of the channel of the mouth has a number of small crypts (*cr.*) along which the numerous club-shaped glands (*b.gl.*) of varying sizes open by their slender ducts. These glands correspond to the buccal or oral glands of Opisthobranchiata described by several authors. Posteriorly the channel of the mouth leads into a pale white, muscular organ, the pharyngeal bulb or the bucco-pharynx (Pl. VII, fig. 7 and Pl. VIII, fig. 3, *ph.*), 0·7 mm. long, 0·6 mm. high. This organ, which is suctorial in function, is provided with a radula and an ascus (*as.*) and receives the discharge of a pair of salivary glands (*s.gl.*). The lumen of the pharyngeal bulb is lined by an epithelium of columnar non-ciliated cells, the secretion of which forms a thin cuticle lining the entire interior of the pharyngeal bulb.

At the base of the lips and guarding the entrance to the mouth there is a ring of circular muscles acting as a sphincter. From this region several strands of muscles forming the anterior retractors pass backwards to be attached to the anterior region of the pharyngeal bulb. The paired posterior retractors of the pharyngeal bulb proceed backwards from its sides to the foot. By the action of these two sets of muscles the pharyngeal bulb moves backwards and forwards.

The radula (Pl. VIII, fig. 4) measuring 0·6 mm. in length lies ventrally in the pharyngeal bulb. It is of the uniseriate type characteristic of all Ascoglossa. It shows (i) a straight ascending axis bearing five well formed teeth and one growing tooth surrounded by odontoblasts in a short horizontally placed radular sac, (ii) a descending axis of seven teeth proceeding towards the ascus and (iii) the ascus itself, a minute pouch antero-ventral to the pharyngeal bulb and containing a small heap of about twenty worn out teeth. Throughout the life of the animal the odontoblasts in the radular sac continuously secrete material for the formation of fresh teeth, while the worn out teeth are being stored in the ascus. The teeth (Pl. VIII, fig. 5) are all of the same shape and size. Each tooth is 0·125 mm. long, and has a wavy margin. One half of the tooth bears a spoon-shaped depression into which the tooth behind closely fits. The teeth closely resemble those of *Stiliger varians* and *Ercolania siottii*. On comparing the radula of this form with that of *S. bellulus* (syn. *S. mariae*, Bergh 1872, Taf. 26, fig. 6) we find that in the latter the descending axis is spirally coiled and shows a larger number of teeth, broad at their bases and narrow and pointed at their apices.

The animal possesses a pair of slender salivary glands (Pl. VII, fig. 7, and Pl. VIII, fig. 3, *s.gl.*) measuring about 1·1 mm. in length and 0·1 mm. in thickness. The great development of the anterior genital complex on the right side has pushed the glands to the left of the oesophagus. A pair of narrow salivary ducts nearly as long as the glands, and 0·017 mm. thick, pass through the nerve collar and open into the pharyngeal bulb, one on either side of the oesophagus. The gland (fig. 6) is composed of large cells (*gl.c.*) with small ciliated interstitial cells (*ci.c.*) wedged in between. The glandular cells are cubical, highly vacuolated and contain a large number of granules. The secretion of the gland is poured into the central lumen and is driven forwards by the ciliary action of the interstitial cells. The duct of the gland is formed of an inner layer of low ciliated cells and an outer layer of thin fibrous tissue.

The oesophagus (Pl. VII, fig. 7, and Pl. VIII, fig. 3, *oe.*), a thin semi-transparent slender tube 1·2 mm. long, starts from the postero-dorsal region of the pharyngeal bulb (immediately behind which it is encircled by the central nervous system) and running backwards beneath the spermatheca communicates with the stomach (*st.*). It has an inner layer of tall columnar ciliated cells and a thin outer muscular layer. There is no oesophageal caecum as in *Elysia viridis.* Souleyet (**57**) figured a caecum in *S. souleyeti* describing it as the first stomach. Neither Bergh nor Eliot has described an oesophageal caecum in any of the species of *Stiliger.*

The thin-walled and roughly triangular stomach (*st.*) which is shorter and wider than the oesophagus, lies medially above the ampulla of the hermaphrodite duct and in front of the pericardium. The inner wall of the stomach is longitudinally plicated and lined by a layer of low columnar ciliated cells. The stomach receives its nerve supply from the gastro-oesophageal plexus formed by the anastomosis of gastro-hepatic and gastro-oesophageal nerves from the visceral and the stomato-gastric centres respectively. A pair of diverticula (Pl. VII, fig. 7, *di.*) opens posteriorly into the stomach, one on either side ; and each of these gives two caecal prolongations (*ca.*), anterior and posterior, running along the sides of the body. These caecal prolongations in their turn communicate with the glandular ramifications (*d.gl.r.*) of the digestive gland present in the cerata. The lining of the diverticula and of the caecal prolongations is ciliated like that of the stomach, but has no folds, and its cells are very short.

The ramifications of the digestive gland of *Stiliger* penetrate into the cerata as in the allied genera *Hermaea* and *Ercolania*. In *S. gopalai* there is only a single main stem in each of the cerata (Pl. VII, fig. 4, *d.gl.r.*), with but a few minute short branches. In *S. bellulus* and *S. tentaculatus* a number of fairly long branches fill up the large space in the cerata. The digestive gland is grayish green in life, and though very much diffuse it has the same histological structure as in *Kalinga ornata* (Rao, **52**). The glandular epithelium (Pl. VIII, fig. 7) lining the ramifications, projects in the form of folds into the central lumen (*1*) and is formed of tall columnar and short cubical cells. The latter are few in number. Their cytoplasm is vacuolated and contains granular inclusions (*gr.*) of several kinds. The digestive gland in Mollusca is a hepato-pancreas, but it is supposed to discharge the function of excretion also.

The short intestine (Pl. VII, fig. 7, *int.*), 0·5 mm. long, arising antero-dorsally from the stomach, proceeds upwards and is continued as an extremely short rectum to the anus situated medially on the dorsal body wall in front of the pericardium. The intestinal walls are composed of an outer fibrous layer of sparse musculature and an inner glandular layer of tall columnar ciliated cells. The rectum does not differ to any extent from the intestine in histological structure.

S. gopalai, like the rest of the members of the Sub-Order Ascoglossa, is a vegetable feeder. Even in captivity the animal feeds voraciously on *Chaetomorpha* only, preferring starvation to feeding on other algae. In the act of feeding it rests on a thread of alga and applying its mouth to one of the cells, punctures it with the outermost tooth of the radula. This is brought about by the contraction of the anterior retractor muscles, which shortens the channel of the mouth. Immediately after the puncture is made the suctorial pharynx begins to work emptying the contents of the cell. When the feeding animal is watched under a binocular microscope, the pharyngeal bulb is seen through the translucent skin to contract and expand very rapidly sucking in the juice and driving it through the oesophagus into the stomach and the caecal prolongations of the digestive system. After emptying one cell of the algal thread it moves on to the next and repeats the same process. When young specimens without much pigment or the pale semi-starved adults are watched under the binocular microscope after feeding on the algae for about a quarter of an hour the course of the gut is clearly seen through the integument because of the bright green colour of the algal juice. It is also observed that the cerata expand and contract independently of one another driving the contents of the caecal prolongations into the ramifications of the digestive gland and back again into the former. The sphincter at the base of each of the cerata controls this action.

CIRCULATORY AND RESPIRATORY SYSTEMS.

The organs of circulation are very simple and consist of the heart, the blood vessels and the blood sinuses. The heart (Pl. VIII, fig. 8) is a two-chambered muscular organ consisting of an auricle (*au.*) and a ventricle (*v.*) enclosed in a thin transparent membranous sac, the pericardium (*pe.*). The oval pericardial chamber, about 2·25 mm. long lies behind the anus, immediately beneath the dorsal body wall. As is common in all Mollusca, it is coelomic in origin. It communicates with the renal organ by the reno-pericardial opening (*r.p.o.*) situated posteriorly on the right side. Through the semi-transparent wall of the dorsal surface the heart is seen to pulsate about forty times per minute. The walls of the auricle and the ventricle in the live animal are thin, muscular and transparent. There is no endothelial lining to the auricle or the ventricle. The auricle receives several minute veins (*vei.*) posteriorly and pumps the blood into the ventricle. The auriculo-ventricular opening is provided with a pair of valves, which prevent the flow of blood back into the auricle when the ventricle contracts. The aorta arises from the anterior part of the ventricle and runs forward supplying blood to all the visceral organs and the foot, from which it is brought into the general body cavity. From the general body cavity, which is a haemocoel in all Gastropods, the blood enters into a number of sinuses in the integument and the cerata. The blood brought to these organs is aerated and is collected by various small veins which join together to form a few main trunks that open into the auricle.

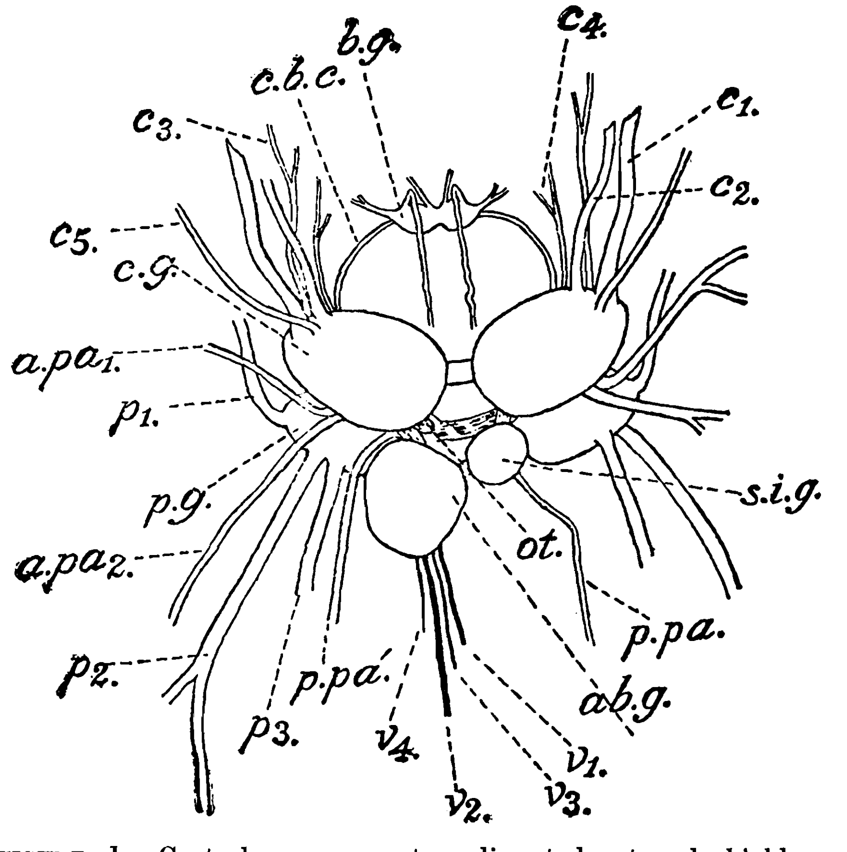
The function of respiration is performed by the entire integument and the cerata. The sinuses, filled with blood present in these organs, are bounded by loose connective tissue and are separated from the exterior only by a thin dermal epithelium. Aeration takes place effectively in these organs. The cerata do not, however, discharge exclusively the function of respiration as when all the cerata are lost the animal remains normally active. For this reason, some authors prefer the term dorsal papillae to cerata, which is a near approach to the ctenidium or the true gill.

RENAL SYSTEM.

The renal system (Pl. VIII, fig. 8.) consists of a thin-walled renal chamber or the kidney (*r.c.*) which is coelomic in origin like the pericardium (*pe.*). It is situated immediately behind the pericardium and extends almost to the posterior end of the body. From the anterior right corner it gives off a diverticulum (*di.r.*) which, after communicating with the pericardial chamber by means of the reno-pericardial opening (*r.p.o.*), runs forward on the right side of the pericardium close to the body wall, and turning to the left in front of the pericardium opens out medially on the dorsal body wall by the renal pore (*r.o.*) situated immediately behind the anus. The renal chamber and its diverticulum are lined with small cubical cells with vacuolated cytoplasm and basally placed nuclei. The reno-pericardial opening is without a funnel, and provided with short ciliated cells. The extremely minute renal pore can only be made out in serial sections of the kidney and is lined by a ciliated epithelium which is a continuation of the general epithelium of the body wall.

NERVOUS SYSTEM AND SENSE ORGANS.

Souleyet (**57**) remarked on the nervous system of *Stiliger souleyeti* (syn. *Calliopaea souleyeti*) as follows : " Le system nerveux resemble a cellui des *Tergipes ;* les ganglions qui composent dans des connextions un peu differentes, (fig. 27 et 28) Les yeux ne sont plu aussi en rapport immediant avec les ganglions cerebraux." His diagrams represent the dorsal and the ventral aspects of the brain alone, and indicate the origin of three nerves from the cerebro-pleural ganglion, one from the pedal, two from the abdominal and three from the supra-intestinal.



TEXT FIGURE. 1.—Central nervous system dissected out and highly magnified to show the various ganglia and the origin of nerves.

From his drawings it is, however, clear that the sub-intestinal ganglion is absent, but neither the ganglia nor the nerves are named. Later, Bergh (**9**) and Eliot (**25** and **26**) did not give any account of the nervous system in their descriptions of *Stiliger ;* and thus the nervous system in the genus remains practically unknown.

The animals being extremely small, the investigation of the various ganglia and the numerous delicate nerves in particular was very difficult. Dissections were made under a binocular microscope focussing a strong beam of light from an illuminator on the object. The methods adopted by Russel (**54**) for the investigation of the nervous system of *Elysia viridis* have been followed here with success.

The central nervous system of *Stiliger gopalai* consists of four pairs of oval, pale white ganglia placed immediately behind the pharyngeal bulb forming a ring round the oesophagus. There are a pair of cerebro-pleural ganglia (text fig. 1 and Pl. VIII, fig. 9, *c.g.*), a pair of pedals (*p.g.*), a pair of viscerals (*ab.g.* and *s.i.g.*) and a pair of buccals (*b.g.*). The cerebral and the pleural centres are fused together to form the cerebro-pleural ganglia, which are united above the oesophagus by a short cerebral commissure. The cerebral centres are also joined below the oesophagus by a very delicate connective, the cerebro-buccal commissure (*c.b.c.*), which bears a pair of minute and elliptical buccal ganglia (*b.g.*) lying posteriorly on the pharyngeal bulb. The pleural centres are likewise joined beneath the oesophagus by the visceral loop bearing a pair of visceral ganglia of unequal size. Of these two ganglia, the one to the left, the abdominal (*ab.g.*), is bigger and the other to the right, the supra-intestinal (*s.i.g.*), is comparatively small. The two are joined by a short connective between them. The supra-intestinal is joined to the right pleural centre by a short commissure, and similarly the abdominal to the left pleural centre. The pedal ganglia (*p.g.*), which are of the same size as the cerebro-pleurals, lie posteriorly beneath the cerebro-pleural ganglia and are joined by the pedal commissure lying beneath the oesophagus. The pedals are also connected to the cerebral and the pleural centres by means of the cerebro-pedal and the pleuro-pedal connectives respectively.

Eight pairs of nerves arise from the cerebro-pleural ganglia, of which the first six are cerebral nerves from the cerebral centres and the remaining two are the anterior pallial nerves[1] from the pleural centres. The first pair of cerebral nerves (text. fig. 1 and Pl. VIII, fig. 9, *cl.*), which is comparatively stout, arises from the antero-dorsal region of the cerebro-pleural ganglia and proceeding forward divides at the bases of the rhinophores into several branches to innervate these organs. This pair of nerves does not bear any discrete ganglia either at the proximal or the distal end. The second pair (*c*2.) arising in front of the first pair, reaches the labial folds and supplies them with several minute branches. The third pair (*c*3.) innervates the channel of the mouth and the retractors of the pharyngeal bulb. The fourth pair (*c*4.) is extremely delicate and supplies the pharyngeal bulb itself. The fifth (*c*5.) and the sixth pair of cerebral nerves supply the eyes and otocysts respectively. The optic nerve (*c*5.) bears a small optic ganglion (*op.g.*) as shown in Pl. VIII, fig. 9. The otocyst (text. fig. 1, *ot.*) being sessile, its nerve is extremely short. The anterior pallial nerves (*a.pa.*1 and *a.pa.*2.) arise from the junction of the pleural and the pedal centres. The first of these two pairs proceeds anteriorly and supplies the sides of the neck

[1] The terminology followed here with reference to the various nerves is essentially that adopted by Russel (**54**).

region, while the second pair turns behind to supply the sides of the animal immediately behind the neck. The first pallial nerve of the right side gives off a short branch (*n.p.*) to supply the penis-pouch and the vas deferens. Owing to the fact that this nerve arises from the junction of the pleural centres and that a few fibres pass from the pedal ganglia into this nerve, the innervation of the penis was believed by some authors to be pedal.

Three pairs of nerves arise from the pedal ganglia(*p*1, *p*2 and *p*3.) to supply the entire length of the foot. The pedal nerves, compared to other nerves, are fairly stout.

Three pairs of very delicate nerves take their origin from the buccal ganglia, of which the first pair (Pl. VIII, fig. 10, *b.n*1.) arises anteriorly from the buccal ganglia and innervates the radular sac. The second pair (*b.n*2.) arising laterally close to the cerebro-buccal connective (*c.b.c.*) supplies the pharyngeal bulb. The nerves forming the third pair (*b.n*3.), known as the gastro-oesophageal nerves, arise directly from the anterior middle region of the buccal ganglia (*b.g.*). There are no gastro-oesophageal ganglia. The gastro-oesophageal nerves (*b.n*3.) proceed hindward remaining in close contact with the oesophagus. Along with the oesophagus and the ducts of the salivary glands they pass through the nerve collar and proceed ventrally on the wall of the stomach ending in a pair of minute ganglia (*g.*). The gastro-oesophageal nerves in the region of the oesophagus and the stomach bear a number of small ganglion cells (*g'*). From all these ganglion cells nerve fibres start and ramify on the surface of these organs. Posteriorly this network joins a similar ramification derived from the gastro-hepatic nerve supply of the abdominal ganglion.

There are only two visceral ganglia, *viz.*, the abdominal and the supra-intestinal ganglia (Pl. VIII, fig. 9, *ab.g.* and *s.i.g.*). As in *Limapontia* the sub-intestinal ganglion is absent since it is fused with the pleural centre of the left side. A single nerve, the posterior pallial (*p.pa.*), arises from the supra-intestinal ganglion and passing beneath the spermatheca reaches the dorso-lateral region of the integument and innervates it. The corresponding nerve of the left side (*p.pá.*) takes its origin from the junction of the pleural and the abdominal centres since the sub-intestinal is absent as already stated. A branch from the main nerve of the supra-intestinal ganglion innervating the pericardium, the aorta and the kidney has been described by Russel (**54**). Owing to the minuteness of this branch I was unfortunately not able to trace it.

Four extremely delicate and ganglionated nerves, the visceral nerves, take their origin from the posterior face of the abdominal ganglion. The first of these nerves (*v*1.) proceeds beneath the oesophagus and reaching the mucous gland ends in a small ganglion (*ge.g.*) from which a ramification of nerve fibres spreads all over the surface of the mucous gland and the vagina forming thus the genital plexus. This nerve, before it ends in the genital plexus, gives a short branch, the right hepato-gastric nerve (*r.h.g.*), which supplies the right side of the stomach and its diverticulum of the same side. The second visceral nerve (*v*2.) from the abdominal ganglion is seen as a thin wavy line passing by the side of the oesophagus on its left side. It proceeds nearly to the posterior region of the left side of the stomach and forms the gastro-hepatic plexus. The third nerve (*v*3.) passes by the side of the intestine and after giving a short branch (*n.in.*) to that organ proceeds hindward to innervate the aorta, the heart, the pericardium and the renal chamber (*p.c.r.*). The fourth of the visceral nerves (*v*4.), which takes its origin from the lower surface of the abdominal ganglion, innervates the ampulla of the hermaphrodite duct.

The organs of special senses consist of the eyes, the otocysts, the rhinophores and the labial folds. Besides these the dorsal papillae and the whole of the external surface of the animal serve as organs of touch.

A pair of dark minute eyes (*ey.*) lies behind the rhinophores immediately beneath the integument covering the neck region. The optic nerves are long and bear the optic ganglia (*op.g.*). Each eye is enclosed in a thin membranous capsule and shows a black pigmented cup-shaped retina, a round globular lens and a thin transparent cornea. The optic nerve enters the eye from its lower surface and innervates the retinal cup. The otocysts (text. fig. 1, *ot.*) are a pair of minute bodies placed close to the pedal ganglia, but they receive their nerve supply from the cerebro-pleural ganglia. Each otocyst contains a single otolith. These are the earliest sense organs to make their appearance in the course of development and serve as the balancing organs.

The rhinophores are smooth, pointed at their tips, and without the grooves found in *Ercolania.* They are provided with a ciliated epithelium and receive their nerve supply from the first pair of cerebral ganglia. Their function has been believed to be olfactory by some authors [Alder and Hancock (**6**), Hancock and Embleton (**35**), and Eliot (**26**)], but Agersborg (**2**) is of opinion that they respond only to a general chemical stimulus.

The labial folds lie on either side of the mouth as fleshy thickenings. They are provided with vibratile cilia and receive their innervation from the second pair of cerebral nerves. They are supposed to be the seat of the sense of taste.

REPRODUCTIVE SYSTEM.

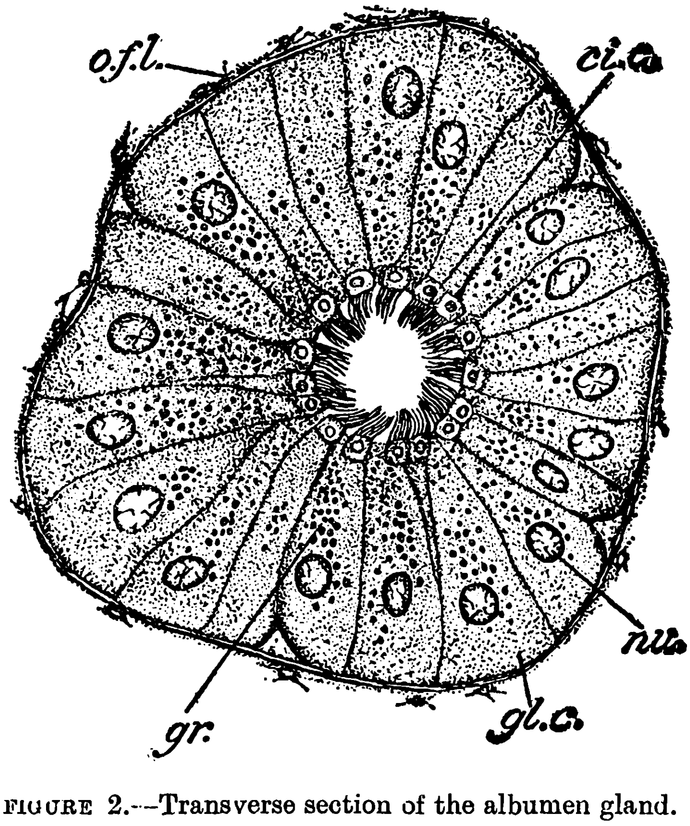
The organs of reproduction of *Stiliger* were first studied by Souleyet (**57**) and later on by Bergh (**9**). As the complicated ducts and their glandular annexes are imperfectly understood, I propose to describe them in this species in somewhat greater detail. The general arrangement of the ducts and the position of the glands are very much as in *Limapontia nigra* described and figured by Alder and Hancock (**5**).

In *S. gopalai* the reproductive organs (Pl. VIII, fig. 11 and Pl. IX, fig. 1) occupy by far the largest space in the peri-visceral cavity and consist of numerous follicles of the hermaphrodite gland, the hermaphrodite duct and the anterior genital complex. The follicles of the hermaphrodite gland (Pl. VIII, fig. 11, *hr.gl.*) are reniform and small in size, each measuring about 0·6 mm. along its long axis. Most of them lie close to the integument, and in life the yolk-laden eggs give a pale yellow colour to them. As in all Ascoglossa described by Pelseneer (**46**) and Eliot (**26**), each follicle produces spermatazoa as well as ova. Sections of the animal fixed in Brasil's modification of Bouin's fluid and stained with iron haematoxylin and eosin show the follicles clearly. Each of the follicles has a thin germinal epithelium close to which lie a number of spermatocytes and oocytes of all stages of growth. Besides these, there are always well developed sperms and eggs. Each ovum is filled with granules of yolk, and has a fairly large nucleus and a nucleolus. The sperms are found in clusters and each possesses a sinuous head (which is deeply stained by haematoxylin) and a long tail (stained red by eosin). The follicles have the same histological structure, but for convenience of description may be divided into (i) an anterior group placed in front of the left hepatic diverticulum and to the left of the oesophagus ; and (ii) a comparatively large posterior group occupying almost the entire posterior half of the body behind the hepatic diverticula. The thin, minute, transparent ductules (Pl. VIII, fig. 11, *du.*) arising from the follicles (*hr.gl.*) of each group form a small duct. The duct from the anterior group (*hr.d*1.) passes beneath the hepatic diverticulum and meets its fellow (*hr.d*2.) from the posterior group about the middle region of the body to form a common hermaphrodite duct (*hr.d.*). The hermaphrodite duct is very narrow and thin at its origin but has an abrupt, opaque, whitish dilatation in its course called the ampulla (*hr.am.*) about 2·5 mm. long and 0·5 mm. thick. After passing forwards beneath the stomach and the oesophagus it turns to the right becoming narrow again on reaching the anterior genital complex.

The anterior genital complex (Pl. VIII, fig. 11 and Pl. IX, fig. 1) is placed to the right side of the oesophagus and the stomach, and is disproportionately large in relation to the size of the animal. It consists of the male genital organs (*pen.*, *pen.s.*, *pr.d.*), the oviducal organs (*al.gl.* and *mu.gl.*) and the apparatus consisting of the vagina (*va.a.*), the vaginal canal (*va.c.*) and the spermatheca (*spt.*) for receiving and storing sperms during coitus. In order to show the narrow part of the hermaphrodite duct and its communication with the male genital and oviducal organs, it is essential to remove the entire spermatheca (with its outline shown in dotted lines in Pl. IX, fig. 1). The downward loop of the mucous gland is slightly twisted to the right so that the bulged part of the vaginal canal (*va.d.*) and the duct of the prostate (*pr.d.*), which lie normally ventral to the anterior region of the mucous gland (*mu.gl.*), come in direct view, with the short communication between them clearly seen.

The narrow terminal region of the hermaphrodite duct communicates anteriorly with the vas deferens (Pl. IX, fig. 1, *v.d.*) and ventrolaterally with the oviducal organs (*al.gl.* and *mu.gl.*). The vas deferens is an extremely narrow and short duct which swerves round the penis pouch (*pen.s.*). The latter lodges the penis, which, in a retracted condition lies inverted and in expanded condition becomes everted and pushed out through the male genital opening situated on the right side of the neck immediately behind the eye. It then assumes a conical form bearing at its tip a minute recurved crystalline stylet (Pl. IX, fig. 2).

The vas deferens is continued through the penis and opens out to the exterior by a small perforation present at the tip of the stylet. A duct (Pl. IX, fig. 1, *pr.d.*) from the prostate gland joins the vas deferens at the point where the latter communicates with the hermaphrodite duct. It runs backwards communicating with the vaginal canal, and at a point where the stomach receives the hepatic diverticula, it divides into two branches. Following the course of the hepatic diverticula the branches reach the body wall on either side, each dividing into two slender ducts (Pl. VIII, fig. 11, *pr.d*1. and *pr.d*2.). One proceeds anteriorly and the other posteriorly parallel to the caecal prolongations of the digestive system, communicating with the glandular ramifications of the prostate gland (*pr.r.*) in the cerata. The branch running anteriorly along the right side of the animal is much shorter than its fellow on the left and is supplemented by another branch that joins the main duct directly. In life the ramifications of the prostate are slender and pale white in contrast to the stout and grayish-green ramifications of the digestive gland found in the cerata. In transverse sections of the cerata the slender branches of the prostate are seen close to the outer wall with the granular contents of their cells stained deeply with eosin ; whereas the digestive gland occupies the central space with the granules of its cells stained densely with haematoxylin.



TEXT FIGURE 2.—Transverse section of the albumen gland. ×600.

A small translucent albumen gland (Pl. IX, fig. 1, *al.gl.*) and a large transparent mucous gland (*mu.gl.*) belong to the oviducal organs. The albumen gland lies ventral to all other parts of the anterior genital complex and is paired being divisible into two rami, each about 1·75 mm. long. The length of the gland varies with the numbers of eggs passing into it. In preserved specimens its surface is much lobed. There is a single short duct arising from the gland, which, along with the mucous gland communicates with the terminal region of the hermaphrodite duct as already stated. The albumen gland of *Stiliger* corresponds to the opaque and greatly coiled albuminous part of the muco-albumen gland of the Nudibranchs in general, but here it is much more simple. The gland is tubular in section (text fig. 2.) and has a thin outer layer (*o.f.l.*) of fibrous tissue with a few strands of muscles and a comparatively thick inner layer formed of groups of large glandular cells (*gl.c.*) alternating with small ciliated interstitial cells (*ci.c.*). The cytoplasm of the glandular cells reveals large granules (*gr.*) staining deeply with haematoxylin. There are indications that this gland provides the albumen that surrounds the egg and also the outer capsule. The mucous gland (Pl. IX, fig. 1, *mu.gl.*) is about 3·5 mm. long and 2·5 mm. wide and lies along the right side of the body. In dissecting specimens preserved in formalin the gland swells up on contact with water, frays out and loses its shape. Specimens preserved in alcohol are for this season preferred. The mucous gland is a simple wide roughly U-shaped tube lined with tall columnar glandular ciliated cells (Pl. IX, fig. 3) and opens out to the exterior by the oviducal opening (fig. 1, *op.ov.*) situated immediately behind the male genital opening. The nuclei (*nu.*) of the gland cells are basal, and the cells which stain deeply with eosin contain very little cytoplasm (*cy.*). The slimy transparent secretion of this gland exudes with the eggs at the time of oviposition through the oviducal opening.

The vagina (*va.a.*), its passage and the spermatheca (*spt.*) constitute the apparatus for receiving the sperms during copulation. These are collectively termed ' the androgynous organs ' by some authors [Alder and Hancock (**5**)]. In tracing back these organs from the vaginal opening (*op.va.*), we find that the latter leads into a small tubular passage, which at once dilates into what is called the ampulla of the vagina (*va.a.*) which is about 0·2 mm. long. The narrowed vaginal passage (*va.c.*) runs at a right angle to the ampulla on the surface of the mucous gland, and proceeds parallel to the main duct of the prostate (*pr.d.*) which is continued as a small dilatation (*va.d.*) at the anterior region of the mucous gland. In figure 1, this dilatation communicates on the right with the duct of the prostate (*pr.d.*), on the left with a short duct leading to the spermatheca (*spt.*) and ventrally with the oviducal organs (*al.gl.* and *mu.gl.*). The ampulla of the vagina and its long narrow passage are lined internally by a layer of low ciliated cells. The dilatation of the vaginal passage close to the mucous gland is likewise ciliated, but the cells lining it are peculiar in that they resemble the cells of the mucous gland, though they are much shorter in length. The spermatheca is large and spherical having a diameter of about 2·25 mm. It is situated behind the pharyngeal bulb and rests partly on the oesophagus and partly on the mucous gland. When full, its contents impart a brown colouration to it. It has an outer fibrous layer, and an inner glandular layer, the cells of which do not bear any cilia. The duct of the spermatheca is extremely short and arises ventrally on its right. Sections of the animal show spermatozoa in the vaginal ampulla, in the dilation of the vaginal passage and in the spermatheca.

Souleyet and Alder and Hancock mistook the hermaphrodite gland in many of the Elysioid forms for the ovarium and the prostate for the testis. Souleyet (**57**) was apparently not fully aware of the significance of the albumin gland and associated it with the male genitalia. This gland has been represented by Bergh (**9**) in *S. bellulus* as an unpaired structure ; but in *S. gopalai* it is paired as in *S. souleyeti*. In *S. bellulus* the penial stylet is slender and as long as the penis itself ; in *S. pica* [Annandale and Prashad (**56**)] it is extremely short, slender and minute ; in *S. gopalai* it is short, recurved and has the same shape as that of *Limapontia capitata* (Bergh **9**, Taf. 26, fig. 21.).

BREEDING AND SPAWNING HABITS.

Animals kept in captivity in brackish water amidst algae in glass dishes were often observed to copulate. The details may be observed with a hand lens. When two individuals approaching in opposite directions come in contact with each other their short, conical penis is usually exserted. Their right neck regions are brought close together, and as soon as the penis of one individual is thrust into the vaginal passage of the other, the animals come closer and curve in the manner shown in (Pl. VII, fig. 6). Muscular spasms pass over them as they lie curled up. The copulation does not last more than three minutes, after which the individuals separate. As a rule they do not feed until the spawn is deposited. But some animals have been observed to copulate more than once before spawning. A few hours after spawning their normal movements are resumed until the next stimulus of contact prepares them for copulation.

During copulation the sperms from the terminal region of the hermaphrodite duct find their way into the vas deferens. The duct of the prostate brings directly into the vas deferens a slimy secretion, together with which the sperms of each individual are conducted through the penis into the vaginal pasage of the other. The sperms thus received in the vaginal passage find their way into the spermatheca where they remain for some time. As the eggs pass from the hermaphrodite duct into the oviducal organs, the sperms from the spermatheca enter into the dilatation of the vaginal canal and from there into the oviduct. The eggs are then fertilized and are immediately directed into the albumen gland, where they receive a coating of albumen and are enclosed in small capsules. They next pass through the mucous gland to the exterior along with its secretion.

Copulation does not seem to be absolutely necessary for the production of fertile ova. Animals kept separately for about a fortnight in confinement produced perfectly healthy and fertile ova, but they were observed to deposit fewer strings of spawn at longer intervals. This was apparently a case of self-fertilisation. As the animals under laboratory conditions spawn an hour or two after receiving the sperms of other individuals, it is presumed that in separated individuals the sperms have not already been received and stored in some part of the reproductive system. If it is remembered that the dilated part of the vaginal passage communicates with the duct of the prostate (*vide* Pl. IX, fig. 2.), the passage of the sperms from the vas deferens into the region of the prostate duct and thence through the vaginal passage and the short connecting canal into the oviducal organs to fertilize the eggs is readily explained.

The spawn is usually attached to a clean thread of alga, but in captivity it is also deposited on the surface of the glass dish or of water. In spawning as observed under the binocular microscope, the oviducal opening becomes widened and the animal bends slightly to the right bringing the pressure of the blood to bear upon the anterior genitalia by a slight contraction of the posterior region of the body. The albumen gland is extended to twice its normal length and gets filled with eggs, which, provided with small enclosing capsules, pass to the mucous gland and thence to the exterior through the oviducal opening. As the eggs pass out they are arranged in a regular closed anti-clockwise spiral. The transparent and sticky secretion of the mucous gland covers the spiral egg-mass completely, giving it the appearance of a string and keeping the eggs in position. The secretion becoming slightly hardened in contact with water, also serves to fix the strings of spawn to the algae or to any other surface upon which they are deposited. While the spawn is being deposited on an algal thread the animal moves forward twisting it round. On a plane surface, however, it assumes the form of a crescent. When the spawn is deposited on the surface of water, the animal floats in the usual manner with its ventral side upwards, so that the eggs come to lie beneath the surface of water suspended by the secretion of the mucous gland. Each string of spawn (Pl. IX, fig. 4.) when stretched is 10 to 25 mm. long, 1·25 mm. thick and contains 700 to 1,500 minute eggs. Two individuals left together in water for a couple of days produce nearly a dozen such strings of spawn. As a result of repeated spawning the individuals are much reduced in size. The length of the string and the number of eggs in it vary with the external environmental conditions. It has been observed that while healthy individuals under favourable conditions deposit long strings of spawn with large number of eggs, those that are starved or exhausted deposit only short strings with fewer eggs.

NOTES ON DEVELOPMENT.

Of the various workers who studied the development of Opisthobranchs, Casteel (**16**) gave a detailed account of the cell-lineage and early development of the egg into a veliger in the Nudibranch, *Fiona marina*. In this paper I have attempted to describe the more important stages in the early development of *S. gopalai*. The egg (Pl. IX, fig. 5) is a pale yellow spherical body with a diameter of 70μ surrounded by an albuminous, viscous substance, and is enclosed in a thin, roomy, transparent capsule consisting of two laminae. The capsule is slightly oval, about 175μ long, but becomes rounded as the egg divides. Occasionally a capsule of unusually large size with two or three eggs is met with. Only one egg, however, grows into a larva at the expense of the others. The egg has an extremely delicate vitelline membrane and finely divided yolk globules distributed almost uniformly throughout the egg. Immediately after spawning, one or two minute polar bodies are seen loosely attached to the egg near the apical region.

Two hours after spawning, the first cleavage appears, dividing the egg into two almost equal cells, which are rounded at first, but later flattened at the point of cleavage as they press each other (fig. 6). The second cleavage appears two hours after the first at right angles to the latter resulting in four cells of equal size (fig. 7). At about the end of five hours after spawning, the four blastomeres divide giving rise to an upper group of four micromeres and a lower group of four megameres (fig. 8). Further cleavages are rapid with the result that about twenty hours after spawning the egg has divided into a mass of minute cells.

At the end of about twenty four hours after spawning, invagination followed by the formation of the blastopore begins in the central region of the mass of cells at the vegetative pole, (Pl. IX, figs. 9 and 10) resulting in a gastrula. When the invagination is complete, the gastrula has the appearance of an inverted cup with its longitudinal axis shorter than its transverse axis, and its apical region slightly flattened. Soon the gastrula becomes elongated with its apical region prominently pointed (fig. 11). Increased division of the cells near the blastopore causes the region surrounding it to become broader while the blastopore itself is narrowed gradually until it is reduced to a minute crescentic slit (fig. 12), which is probably finally closed[1].

At a later stage which it reaches in about forty five hours (Pl. IX, fig. 13), the gastrula is so far advanced as to pass on to an early veliger larva. In the region of the crescent of the blastopore the stomodaeum (*sto.*) is formed as a deep invagination of the ectoderm. Immediately above this region the velar lobes (*ve.*) make their appearance as two rounded lobes, one on either side, with minutely ciliated margins with the help of which the early veliger rotates inside the capsule. Ventral to the stomodaeum the foot (*ft.*) is formed as a broad median protuberance. The posterior region of this early veliger reveals a broad layer of glandular cells which secrete a thin, transparent shell (*sh.*). The preceding stages, however, show that the shell gland begins as an ectodermal invagination, which opens and extends over the posterior region followed by the thickening of its cells. In the early veliger stage the enteron appears below the shell gland. The anterior end of the enteron touches the stomodaeal invagination (*sto.*) but does not communicate with it. The region immediately behind this is slightly saccular and forms the stomach (*st.*). The liver appears in the form of two lobes of unequal size (fig. 13, *l.l.* and *r.l.*), the left being considerably larger than the right. The intestine (*int.*) is a narrow posterior prolongation of the stomach and joins the ectoderm near the base of the foot. Above the level of the intestine lies a group of vacuolated cells forming the larval kidney (*k.*). The otocysts (*ot.*) which are the earliest sense organs to appear in the larva are seen, one on either side, at the base of the foot below the ectoderm.

[1] As the cells are opaque in this region and as no sections of the gastrula have been taken, I cannot say with certainty that the blastopore closes completely after it is reduced to a minute slit. In *Fiona marina* and other Opisthobranchs the blastopore has been observed by several authors to close completely and in *S. gopalai*, which is an allied form, the same phenomenon may occur.

A typical veliger is formed before the completion of sixty five hours after spawning. During this period the velar lobes increase enormously in size followed by a thickening of their free edge with bigger cilia. The constriction between the two lobes of the velum grows deeper. The stomodaeum finally opens into the stomach where it communicates with the larger left liver lobe. The intestine gets elongated and slender and opens to the exterior. The shell gland thins out as it grows in extent, as a consequence of which the shell grows in size. The foot, which is merely a median protuberance beneath the stomodaeal region, now gradually becomes broadened and flattened. Its upper surface comes to possess minute cilia, while the cells lining its under surface secrete the operculum. The strongly pigmented larval kidney lies immediately above the terminal region of the intestine. At the end of sixty five hours the veliger is fully formed in its egg-capsule with its various organs still slightly opaque, and is seen to rotate inside with the help of its powerful velar cilia which strike against the wall of the enclosing capsule. By about the end of ninety hours or early on the fifth day after oviposition, the thinned-out enveloping membrane is ruptured liberating the larva. The sticky substance, which surrounds the eggs and keeps them in position, becomes soft enough to allow the larvae to escape into the surrounding water. All the larvae in a string of spawn do not escape simultaneously, some taking a longer time than the others.

The larva is a typical free swimming veliger, 120μ long and 85μ broad, (Pl. IX, figs. 14 and 15) with a transparent nautiloid shell (*sh.*) and an operculum (*op.*). The antero-dorsally situated velum (*ve.*), is much constricted in the middle region, dividing it into two large lobes with their upper surface hollow. The margins of the velar lobes bear big locomotive cilia and are continuous with those of the narrow constricted middle region. Lower down the velum lies the broad, flattened ciliated foot (*ft.*), which bears on its ventral side an operculum (*op.*). The dorsal retractor muscles (*d.r.*) runs forwards from the left posterior side of the larva behind the large liver lobe to about the middle region of the stomach, where it divides into two strands, which terminate in the antero-dorsal region of the larva. By the contraction of this muscle the velum is withdrawn into the shell. The retraction of the foot is caused by the right and the left retractor muscles of the foot (*r.f.*), which start from the dorsal middle region of the posterior half of the larva and turning along the sides pass anteriorly to terminate in the foot. The mouth lies between the velum and the foot and leads into a fairly long ciliated passage, the stomodaeum (*sto.*), the posterior end of which communicates with a large saccular stomach (*st.*). The latter bears a large liver lobe on the left side and a similar but a smaller one on the right. The intestine (*int.*), starting from the middle region of the stomach, passes forwards to open at the anus situated on the right side slightly below the level of the margin of the shell. The stomach and the intestine are internally ciliated like the stomodaeum. Green unicellular algal matter, which the animal has taken in, is seen in the stomach revolving with great rapidity by the action of cilia. The larva has a pair of large otocysts (*ot.*) placed at the base of the foot, one on either side. The eyes are absent in the just hatched larva, but four or five days later they make their appearance as two dark spots at the base of the velar lobes.

Our knowledge of the metamorphosis of the larvae of Opisthobranchs is inadequate. Nordman (**41**) and Schultze[1] have described briefly some aspects of the post-larval development of *Tergipes edwardsii* and *Tergipes lacinulatus* respectively. In spite of all precautions, Infusorians, which grew under laboratory conditions in dishes and attacked the larvae, could not be kept under check. The larvae that escaped the attack of Infusorians for a fortnight grew only in size.

Two or three days after a heavy shower in the first week of October and in the last week of December 1935, metamorphosed young ones in various stages of growth, exceeding 1·25 mm. in length, were obtained from the brackish water pools near the mouth of the river Cooum. In structure they did not differ much from the adults, but the gray and yellow colour of the integument characteristic of the adults was not developed. The young ones were all bright green owing to the presence of algal matter in the gut and the hepatic caeca, and without shell or operculum. The velum had completely disappeared, but the large cilia in the anterior region of the animal (Pl. IX, fig. 16) were still present. The rhinophores of the young ones had blunt tips in contrast to the pointed ones of the adult. The eye posterior to the base of each rhinophore was disproportionately large in relation to the size of the animal. The otocysts near the cerebral ganglia, were seen conspicuously through the transparent integument. The anterior cleft of the foot was not prominent, but the foot was extended into a tail like filament. The only two pairs of cerata were in the form of small protuberances, with the hepatic caeca extending into them. Under the binocular microscope the cerata were of a purple shade in colour, which, however, faded as more were formed. At the stage when five or six cerata were formed on either side, the gray pigment gradually appeared. In the laboratory, the young ones fed voraciously on *Chaetomorpha* and grew rapidly in size. Young forms, only 1·25 mm. in length, attained the full size of the adult within a period of twelve days, and began depositing spawn from the fifteenth or the sixteenth day.

Some points of interest in the breeding habits, early development and growth of *S. gopalai* need special mention here.

That there is no definite period of breeding is clear from the fact that sexually mature individuals were obtained throughout the year either from the Adyar or from the Cooum brackish water pools. Semper (**55**) and Orton (**45**) believed that in the tropics, where the temperature is high and remains constant or almost constant, most of the animals breed throughout the year. Aiyar[2] and Subramaniam[3] have observed continuous breeding in Madras in *Salmacis bicolor* and *Clibanarius olivaceus*.

[1] *Weigm. Arch.* 1849, i. p. 277, as referred by Eliot (**26**).
[2] *Proc. Ind. Acad. Sci.*, I, p. 726 (1935).
[3] *Journ. Royal Micr. Soc.*, LV, p. 14, (1935).

It has been observed by various writers that when the temperature is high the development of early larvae is accelerated. In *S. gopalai* the veligers escaped out of the spawn within a period of not more than five days after oviposition, whereas in allied Opisthobranchs of the British coasts the minimum time taken was not less than a fortnight (*vide* Reid, **53** and Eliot, **26**). Such a rapid development in this form is due probably to high temperature conditions which prevail in Madras.

In *S. gopalai* the young ones grow rapidly to adult size and attain maturity within a fortnight. Orton (**44**) recorded a similar phenomenon in the life-history of *Galvina picta*. A raft moored about six weeks after it was in the sea showed a number of Nudibranchs, particularly *Galvina picta* of varying sizes and their egg masses among a thick growth of *Obelia geniculata*, on which those animals were observed to feed. He observed that "the Nudibranchs had undoubtedly peopled the raft as veligers, rushed through their development at the expense of the Hydroids and were giving off veligers again to populate Hydroids elsewhere within a period of not longer than six weeks and two days" In *S. gopalai* the growth of the young ones is more rapid than in the case of *Galvina picta*. In the brackish waters of Madras where the environmental conditions are continually changing, an extremely rapid growth to attain maturity seems to be a necessity, as favourable conditions do not last long.

Behaviour of the Animal in Respect of Variations in Salinity.

Apart from other factors such as temperature and food supply, the salinity of the brackish water, which has been observed to be always changing, seems to exercise a great control over the animals. When the animals were first observed in the brackish water pools near the mouth of the Cooum about the end of August 1935 and in the backwaters of Adyar in the month of September, the waters in both the places had a low salinity as the localities were not in open communication with the sea and were flooded by freshets brought by the rivers. The bar near the mouth of the river Cooum opened during the last week of September 1935, much earlier than the one at the Adyar river mouth. As more and more sea water was brought into the brackish water pools, the salinity increased and the algae disappeared, the animals were no longer found. In the Adyar backwaters, however, the salinity remained low, and individuals of *S. gopalai* were still found. By about the middle of October 1935, the salinity in the pools at the mouth of the Cooum had been brought down by rainfall. Three days after the rain numerous young ones ranging from 1·25 mm. to 2·5 mm. in length appeared suddenly. But the low salinity condition was not maintained long with the opening of the bar. With the gradual rise in the salinity the animals began to diminish in numbers until they grew scarce. Up to the month of November 1935, adult animals were collected in Adyar, but none after the bar had been opened. The bar near the mouth of the river Cooum silted up very early ; and during the last week of December 1935, a few days after rains, metamorphosed young ones appeared again with the sudden fall in the salinity. The appearance of the young forms coincided with the growth of *Chaetomorpha* (on which they feed) on the sides of rocks and other hard surfaces. From the last week of December 1935, and as long as the bar remained closed near the mouth of the Cooum, the animals continued to occur.

The observations made seem to show that the animals live in water of salinity distinctly lower than that of the sea. Since they are rare when the bar remains open for considerable periods, I am led to believe that, due to the incoming sea water and the increase in salinity a large number perishes. When more fresh water accumulates in the brackish water pools reducing the salinity, the animals occur in large numbers and breed. As the metamorphosed young ones were obtained nearly always after a heavy shower, it seems probable that a lowered salinity is an essential condition for metamorphosis.

SYSTEMATIC POSITION OF *S. GOPALAI*.

The Sub-Order Ascoglossa, of the Order Opisthobranchiata, is characterised by the presence of a suctorial pharynx, of a uniseriate radula the teeth of which when worn out are retained in a sac or ascus, of a single otolith in each otocyst, of a penial spine, and of a visceral loop with two or three visceral ganglia. There are no jaws.

The family Hermaeidae of Ascoglossa includes *Stiliger*, *Ercolania*, *Hermaea* and *Alderia*. O'Donoghue (**43**) is of opinion that the family should be named Stiligeridae and not Hermaeidae, for the reason that *Stiliger* and not *Hermaea* is the oldest member of the family. According to strict rules of biological nomenclature he is correct, though the family is better known by the name Hermaeidae.

The general Eolidiform appearance of the body, the position of the anus in front of the pericardium and the presence of a single pair of long and smooth tentacles place the present form in the genus *Stiliger* of Ehrenberg.

The specific characters of *Stiliger gopalai*, sp. nov. may be summarized as follows: colouration of the body is deep brownish gray stippled with yellow; cerata, about forty on each side coloured dark gray with white tips, are neither very slender nor bulged out; the ramifications of the digestive gland in the cerata have a single main stem with a few minute branches; foot is narrow, pale yellow, with the anterior lobes rounded and the tail filamentous; the radula has five teeth in the ascending axis and seven in the descending axis; axes are straight but not spiral; margin of the teeth is wavy; penial armature is short and recurved; there is no pericardial prominence.

Stiliger gopalai differs from all other species described hitherto but combines in itself several characteristics of different species of the genus. The present form differs from *Stiliger bellulus* (syn. *S. mariae* **22**; **26**: and **9**, 1872) in the nature of the radula, cerata and penial armature. In *S. bellulus* the descending axis of the radula is a spiral showing a large number of teeth which have broad bases and narrow apices; the cerata are conspicuously bulged showing a large number of hepatic ramifications; and the penial armature is long and slender. In *S. souleyeti* (**57**) the presence of a uniform green colouration, of large and club-shaped cerata and of a radula resembling that of *S. bellulus*, clearly separate it out from the present species. The teeth of *S. gopalai* resemble very closely those of *S. varians* (**21**); but the marine habitat, the extremely small size of the body, the inflated cerata and the bladder-like pericardial prominence in the latter make it distinct from the former. *S. irregularis* (**21**) is marine, the general colouration is reddish gray, the oral veil is not notched and the margins of the teeth are less wavy than those of *S. varians*. These important features of *S. irregularis* distinguish it from the present form. The presence of a spirally coiled descending axis of the radula, a very prominent posterior prolongation of the pericardium and the probable absence of the penial armature in *S. felinus* (**25**) distinguish it from *S. gopalai*. *S. tentaculatus* (**29**) differs from all others of the genus in having well developed oral tentacles and tentacular prolongations of the foot. The absence of filamentous tail and of white spots in the foot, and the presence of a radula resembling that of *S. bellulus* and of the very slender cerata in *S. pica* (**56**) differentiate it from *S. gopalai*. *S. gopalai* and *S. pica*, however, agree in their brackish water habitat and short penial armature.

In Eliot's opinion *Stiliger ornatus* Ehrenberg, the specific characters of which are not given, agrees with *S. bellulus*. *Pterochilus viridis* of Kelaart (**38**) was, however, doubtfully referred as '*Stiliger? viridis*' by Eliot in 1906 (**23**); but the green colouration of the body and the capsular spawn distinguish it from the present species. The nature of the radula in *S. ornatus* and '*Stiliger? viridis*' is not known. *Custiphorus vesiculosus* of Deshayes was ascribed by Fischer (**32**) to the genus *Calliopaea* while in 1928 O'Donoghue (**43**) referred it to *Stiliger*. Apart from other characters, the colouration of *S. vesiculosus* and the presence of vesicles or globules in the cerata distinguish it from *S. gopalai*. Doubting the correctness of treating *Ercolania* as a genus separate from *Stiliger*, O'Donoghue (**43**) provisionally included under the genus *Stiliger* all the species of *Ercolania*, viz., *E. siottii*, *E. panceri*, *E. uzilli*, etc. As discussed in the history of this genus at the beginning of this paper (*antea* pp. 436-438) *Ercolania* can be distinguished as a separate genus from *Stiliger* on account of the absence of canaliculated grooves in the rhinophores of the latter.

SUMMARY.

1. The external and internal morphology of *Stiliger gopalai*, sp. nov. from the brackish waters of Madras is fully described with a brief account of the bionomics and early development.
2. The digestive system of *S. gopalai* while agreeing with that of several species of the genus, differs from that of *S. souleyeti* in having no oesophageal caecum. The radula closely resembles that of *S. varians* and *Ercolania siottii*. The hepatic ramifications are simple and give off very minute branches.
3. The central nervous system shows a primitive condition as in all Ascoglossa. The visceral loop bears only two ganglia, the abdominal and the supra-intestinal. The sub-intestinal ganglion is absent as in *Limapontia*. Gastro-oesophageal ganglia are absent.

4. The reproductive system is fully described including the histology of the accessory glands. The penial armature is extremely short unlike that of *S. bellulus* and closely resembles that of *Limapontia*.
5. The process of copulation and spawning has been observed. The course of the eggs from the hermaphrodite follicles to the exterior is described. The spawn is a cylindrical string and the eggs are closely arranged in anti-clockwise spiral within. Animals were observed to deposit spawn even without copulation. The animals breed throughout the year.
6. The eggs develop into veligers very rapidly. The metamorphosed young ones, collected from the natural habitat, attain the adult size and maturity within a period of fifteen days.
7. The animals become scarce with the increase in salinity in the brackish waters due to communication with the sea. Large numbers of animals were collected when the salinity was low. A sudden fall in the salinity seems to favour matamorphosis.

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KEY TO LETTERING

ab. g.	abdominal ganglion.
al. gl.	albumen gland of the anterior genitalia.
an.	anus.
a. pa 1.	1st anterior pallial nerve.
a. pa 2.	2nd anterior pallial nerve.
as.	ascus.
au.	auricle.
b. g.	buccal ganglia.
b. gl.	large buccal glands.
b. gl'	small buccal glands.
b. n 1.	1st pair of nerves from buccal ganglia.
b. n 2.	2nd pair of nerves from buccal ganglia.
b. n 3.	gastro-oesophageal nerves.
c 1.	1st pair of cerebral nerves.
c 2.	2nd pair of cerebral nerves.

c 3.	3rd pair of cerebral nerves.
c 4.	4th pair of cerebral nerves.
c 5.	5th pair of cerebral nerves.
ca.	caecal prolongations of the digestive system.
c. b. c.	cerebro-buccal commussure.
c. g.	cerebro-buccal ganglia.
ci.	cilia.
ci. c.	ciliated cells.
c. n. s.	central nervous system.
cr.	crypts through which the glands open.
ct. c.	connective tissue.
cy.	cytoplasm of gland cells.
d. gl. r.	glandular ramifications of digestive gland.
di.	diverticulum communicating with the stomach.
di. r.	diverticulum of the renal chamber.
d. r.	dorsal retractor muscle of the veliger.
du.	ductules from the follicles of hermaphrodite gland.
epi.	epithelium.
ey.	eye.
ft.	foot.
g. and g′	small ganglia of the gastro-oeseophageal nerves.
ge. g.	a small ganglion of the first visceral nerve situated in the anterior genitalia.
gl. c.	gland cells.
gr.	granules.
hr. am.	ampulla of the hermaphrodite duct.
hr. d.	common hermaphrodite duct.
hr. d 1.	hermaphrodite duct from the anterior group of follicles.
hr. d 2.	hermaphrodite duct from the posterior group of follicles.
hr. gl..	follicles of hermaphrodite gland.
int.	intestine.
k.	kidney of the veliger.
l.	central lumen.
la.	labial folds.
l. l.	left lobe of the liver in the larva.
l. ph.	lumen of anteriormost region of pharyngeal bulb cut in section.
m.	mouth.
m. f.	muscle fibres.
m. g.	unicellular mucous glands of foot.
m. m. g.	multicellular mucous glands of foot.
mu. gl.	mucous gland of the anterior genitalia.
n. in.	a branch of the third visceral nerve to intestine.
n. p.	a short branch from the first pallial nerve to penis pouch.
nu.	nuclei of the gland cells.
oe.	oesophagus.
o. f. l.	outer fibrous layer.

o. gl.	odoriferous glands.
op.	operculum of veliger.
op. g.	optic ganglion.
op. ov.	oviducal opening.
op. pen.	opening of the male genital organ.
op. va.	vaginal opening.
ot.	otocyst.
p 1.	1st pedal nerve.
p 2.	2nd pedal nerve.
p 3.	3rd pedal nerve.
p. c. r.	branch of 3rd visceral nerve to the pericardium, heart and renal chamber.
pe.	pericardium.
pen.	penis.
pen. s.	penis pouch.
p. g.	pedal ganglion.
ph.	pharyngeal bulb.
p. pa..	posterior pallial nerve of the right side.
p. pa′	posterior pallial nerve of the left side.
pr. d.	main duct of the prostate.
pr. d 1.	anterior lateral branch of the prostate.
pr. d 2.	posterior lateral branch of the prostate.
pr. r.	glandular ramifications of the prostate.
r. c.	renal chamber.
r. f.	retractor muscles of the foot of the Veliger.
r. h. g.	right hepato-gastric nerve.
r. l.	right lobe of liver in larva.
r. o.	renal pore.
r. p. o.	reno-pericardial opening.
s. gl.	salivary glands.
sh.	shell of the larva.
s. i. g.	supra-intestinal ganglion.
spt.	spermatheca.
st.	stomach.
sto.	stomodaeum of the larva.
v.	ventricle.
v 1.	1st visceral nerve.
v 2.	2nd visceral nerve.
v 3.	3rd visceral nerve.
v 4.	4th visceral nerve.
va.	vacuoles in the cytoplasm.
va. a.	ampulla of the vagina.
va. c.	vaginal passage.
va. d.	dilated bulb of the vaginal passage.
v. d.	vas deferens.
ve.	velum of the veliger larva.
vei.	veins.

MGIPC—M—III-8-12—20-12-37—400.