VII ON THE ANATOMY OF A BURMESE SLUG OF THE GENUS *ATOPOS*

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(Plates xvi—xix.)

Two specimens of this slug were collected by Mr. F H. Gravely, Assistant Superintendent, Indian Museum, from the base of Dawna Hills near Thingannyinaung, about 900 ft. above sea-level, on the 27th November, 1911.

They belong to the genus *Atopos*, Simroth, and are made the type of a new subgenus (*Parapodangia*) under the name of *A. (P.) gravelyi.*

Subgenus **Parapodangia**, nov.

An anterior portion of the mantle (notum) (about $\frac{1}{6}$th the body length) along the middle line separate from the thin dorsal wall of the body beneath. An H-shaped fold of the integument beneath the mouth between the precephalic flap and the foot. The lower tentacles fused with the precephalic flap as in *Podangia.*

Atopos (Parapodangia) gravelyi, n. sp.

Colour of notum sepia (with a slight brownish tint) with blotches and pinpoint dots of dark brown above, and of slaty gray (bluish) with blotches and spots of slaty black below; in the middle, a longitudinal row of pale buff blotches above and a continuous dark clove-brown band below. The anterior portion of the head (with ommatophores, lower tentacles and precephalic flaps) is slaty blue, while the posterior portion is ochraceous yellow behind. Foot sole pale yellow. Keel prominent, rounded and of dark clove-brown colour.

Length of notum (along mid-dorsal line) 14·7 cm. Height of notum 1·4 cm. Breadth 1·3 cm. Female genital aperture 1·35 cm. from male genital aperture.

ANATOMY.

I Body wall.

The inner surface of the thick mantle in its anterior portion where it is separate from the dorsal integument beneath, is very vascular and appears to share a prominent part in respiration.

The vessels are connected to the dorsal sinus in the mid-dorsal line of the body wall. In other respects, the body wall is quite similar to that in other species.

II Pallial Complex.

The *pallial complex* forms a circular area extending from the right side at the junction of the inner surface of the mantle and the dorsal surface of the foot to within 6 cm. of the margin of the mantle on the left side. It lies at about 2·4 cm. distant from the anterior margin of the mantle. The *pericardium* lies in the anterior two-thirds of the pallial complex and to the right, the *kidney* occupying the remainder. There is no distinct pulmonary chamber at all. The whole pallial complex is adherent to the thick mantle and is roofed by a thin membrane which is fused with the inner surface of the latter. The ventral wall lies over the anterior end of the liver.

The *heart* is placed in the long axis of the pericardium. The auricle is placed behind the ventricle.

Minute structure of the ventricle.—The outer surface is lined by a single layer of cubical-cells with oval nuclei. There is no distinct epithelial lining of the cavity. The superficial layers form a thin continuous coat of transversely-arranged muscle fibres. Beneath this, the muscle fibres form thick bundles which are disposed irregularly in different directions. Just beneath the superficial layer, the thick bundles are arranged circularly in a transverse direction, being separated from the former widely in many places by thick bundles which pass inwards, some radially and others obliquely, from the superficial bundles to these circular ones with which they seem to unite. More internally the disposition of the fibres are mainly longitudinal with a few oblique ones. The cavity of the ventricle is traversed by these muscle bands which extend through the cavity in various directions.

Minute structure of the auricle.—The wall is lined externally by a layer of rectangular cells with their long axis parallel to the surface. The superficial muscles form a transversely circular layer. The inner bundles form a longitudinally circular layer. Between these two layers, there are a few bundles which are arranged obliquely and seem to pass from one layer to another.

III. Digestive System.

(i) The *buccal bulb* forms a protrudable proboscis which, when retracted, is placed inside a proboscis sheath having a narrow funnel-like shape at its outer aspect. The proboscis forms the acrecbolic (pleurembolic) introvert of Sir E. R. Lankester.

As seen in a longitudinal section, the proboscis, when retracted, lies in the tubular space formed inside the proboscis sheath, which is folded a little behind its middle in such a way that its posterior portion is invaginated into the anterior portion;

the morphologically inner surface of the posterior portion of the sheath now becomes external and lies in contact with the inner surface of the anterior portion. On the dorsal surface and the lateral aspects of the anterior portion of the proboscis sheath are numerous flattened muscular strands which pass upwards and backwards to be inserted into the thin dorsal integument. The presence of these strands prevents this tubular anterior portion of the proboscis sheath from being protruded with the proboscis. Again the posterior division of the sheath, which, owing to the doubling of its wall, is placed inside the anterior division, is prevented from being straightened out behind by the presence of fine strands of connective tissue, which extend from its morphologically outer side (inner side in the present condition) to the outer surface of the proboscis in a direction backwards and inwards from the wall of the sheath.

It is remarkable to note that in *A.* (*P.*) *kempii*, Ghosh, owing to the absence of special muscle strands from the outer surface of the proboscis sheath to the dorsal integument, the proboscis can be extended to its full extent so that the wall of the sheath is seen to become continuous with the anterior end of the head in the position of the mouth. A partial protrusion of the proboscis is only possible in the present case. Again a simpler condition exists in *A.* (*P.*) *sanguinolenta* (Stol. MS.). Here the proboscis is attached behind to the posterior end of the sheath surrounding it, just in front of the beginning of the oesophagus, so that after the proboscis has been fully protruded it drags from behind the sheath which then becomes gradually everted and forms a covering of the radular portion of the proboscis, so that the proboscis sheath becomes continuous with the proboscis in front.

Hence the present species shows an intermediate condition as regards the structure of its protrudable buccal bulb.

Minute structure of the proboscis.—The inner surface is raised into transverse folds; the ridges on the upper half fit into depressions on the lower half like the teeth on the blades of a pair of forceps. The inner surface of the organ is lined by a single layer of cubical epithelium which secretes a layer of hard homogenous cuticle, as thick as the cells themselves. On the outer side of the epithelium are placed the muscular layer, the bundles being arranged in various directions.

(ii) The *radula sac* is a club-shaped body curved somewhat like the letter **S**, the narrow end of which is attached to the posterior end of the proboscis. The sac is surrounded by a thin outer coat of muscular tissue within which is a thick muscular coat. Both these two coats are continued behind to form the retractor muscle. Beneath the thick inner coat and lying in the ventral and lateral aspect of the cavity of the sac, is a thick flap of muscular tissue which is attached to the inner surface of the muscular sheath behind and laterally, but projects anteriorly into the cavity about half the length of the sac from its posterior

end; this free anterior end of flap gives attachment to the radula. Inside the muscular sheath and lying over the flap is a bilobed hollow fibrous cushion with a thick and hard wall. This cushion is free at its round anterior end and ventral aspect, but is attached to the muscular sheath behind and laterally towards the dorsal aspect. Ventrally between the two lobes is a deep transverse fissure into which the anterior end of the ventral flap fits. The dorsal surface of the cushion is convex in the middle line, but concave at the sides, where it is continuous with the inner surface of the muscular sheath. A little anterior to the middle of its length is a transversely placed crescentic aperture leading into the radula sac proper. The *radula* is attached to the anterior end of the ventral flap and passes over the anterior rounded end of the cushion to its dorsal surface over which it is traced backwards into the radula sac proper. The portion of the radula lying over the dorsal surface of the cushion extends laterally on the concave lateral portions of the surface and the inner surface of the muscular sheath, so that in a longitudinal section a little to one side of the middle line we get two sections of the radula—one lying on the dorsal surface of the sac, and another beneath the inner surface of the inner muscular sheath at a higher level than the first.

Minute structure of the radula and the radula sac proper.—The *radula* consists of the following layers :—

(1) A thin fibrous membrane lined beneath by a single layer of pavement epithelium. The membrane consists of white fibres alternating with single rows of connective tissue corpuscles.

(2) A single layer of cubical epithelium over the fibrous layer.

(3) A thick homogeneous corneous layer with fine longitudinal striation. To this are attached the bases of the teeth which are all unicuspid and are arranged in V-shaped rows.

The *radula sac* lies in the middle of the bilobed cushion in its dorsal aspect. The crescentic aperture (mentioned above) leads into the narrow cavity which is directed downwards and backwards, and which ends blindly after curving a little backwards and outwards. At the sides the cavity extends downwards and outwards and then upwards and inwards again for a short distance, where it ends blindly abutting on the wall of the hollow mass on the dorsal aspect. In a longitudinal section of the sac, a little to the side of the middle line, we get a sort of horse-shoe-shaped appearance as the cavity extends for some distance on the anterior aspect where the two portions become continuous. In a transverse section through the middle of the sac we get a reniform outline with the middle third of the convex side absent.

The sac is surrounded by a sheath of connective tissue. The ventral and the outer walls of the sac are thin; the lower

surface of the radula is applied on these surfaces. A little in front of the posterior blind end of the cavity, the lower and outer walls of the sac is lined by a single layer of large granular cells with round or oval nuclei. This layer is continuous with the cubical epithelium of the radula. At the extreme posterior end of the cavity of the sac lies a mass of cells arranged obliquely and probably in several rows. These are placed on a thin layer of connective tissue, and seem to be continuous in front with the layer of granular cells just mentioned, while the connective tissue layer is continued in front to that of the radula.

The corneous layer on which the teeth are placed becomes suddenly narrowed down, just behind the point where the cubical epithelium ends, and is continued backwards as a thin layer to the tip of the cavity where it ends above the upper tiers of cell of the cellular mass just mentioned. The dorsal and inner lining of the cavity is convex and have the teeth of the radula embedded in them. The cavity of the sac is thus so narrow as to keep the radula between its two surfaces, there being no space left between the radula and the lining of the cavity of the sac. The postero-dorsal wall of the sac is thick and projects into the cavity of the sac. The base of the projecting mass consists of a curved stratum of connective tissue in front of which lies an oval mass of large muscular fibres, arranged transversely and separated widely from each other by connective tissue fibres and cells. Still in front lies an elongated mass of connective tissue cells embedded in a gelatinous matrix traversed by a few fine fibres, on the lower aspect of this wall lies a row of much elongated obliquely-placed cells, continuous round the blind end of the cavity to the cellular mass on the upper and outer aspect of the cavity. On the lower surface of this cellular layer are seen two or three transverse rows of teeth one before another and placed flatly on the homogeneous layer. In front of these rows, the teeth are arranged obliquely on the thick homogeneous layer between rows of cells continued to the posterior and inner wall of the sac, and filling up the space between the successive rows and probably between the individual teeth of the same row. The cells are probably concerned in the secretion of the teeth of the radula.

(iii) The two *salivary glands* are fused to form a single oval mass, but there are two salivary ducts which pass to their destination as usual.

(iv) The *oesophagus* ends in the substance of the liver. Its course is exactly similar to that in other species.

(v) The *digestive gland* is elongately conical in shape and rounded in front. It ends about 1·5 cm. in front of the posterior end of the mantle. The upper surface is convex from side to side; it presents the S-shaped curve of the rectum in its anterior portion about $\frac{1}{4}$th the length of the gland from this end. The cavity of the liver is a C-shaped slit in transverse section.

(vi) The *intestine* forms a S-shaped curve lying partially embedded in the substance of the liver on the dorsal aspect. It begins on the left lateral aspect of the liver and, taking the curve just mentioned, emerges out of its wall from near the anterior end to the left. It then passes along the anterior border of the liver forwards and outwards to the right, being surrounded by a coil of the oviduct in its course, to end in the anus in the groove between the foot and the mantle. The portion which lies beyond the liver may be conveniently named *rectum*.

IV Reproductive System.

(i) The *hermaphrodite gland* is an oval mass—more or less flattened from side to side and placed on the right side of the anterior end of the liver. The organ is connected to the liver by a flat strand of fibrous tissue. The *retractor penis* muscle passes over the outer side of the gland.

Minute structure.—Under the low power the true glandular portion of the body lies in its distal end. It consists of a flattened mass of more or less rounded acini held together by loose connective tissue. Each acinus gives rise to a duct which unites with others to form the oviduct. The oviduct is coiled and looped in various ways as it passes on, and then emerges from the glandular mass after having received the vas deferens in the same. The vas deferens seems to arise from the centre of the glandular mass, and passes outwards nearly to its proximal end where it opens into the oviduct.

(ii) The *albumen gland* forms an elongated mass along the upper border of the hermaphrodite gland with which it is inseparably fused from the distal end.

Minute structure —The gland consists of numerous irregular lobules separated somewhat widely from each other by loose connective tissue. Each lobule consists of an irregular mass of acini held together by a thin layer of connective tissue. The acini open together into a short duct which ends in the main duct of the gland. The main duct passes along the upper border of the hermaphrodite gland and then turns downwards between the glandular mass and the coiled mass of oviduct to the lower border, where it seems to open into the oviduct. It also receives several ducts of lobules scattered along its course.

(iii) The *hermaphrodite duct* is a short tube which forms a V-shaped loop as it emerges from the glandular mass and coils itself round the intestine to pass outwards, downwards and a little backwards, where it ends in the external genital aperture placed just behind and internal to the anus.

(iv) The *penis* is enclosed in a penial sheath, which opens on the outer side of the base of the lower tentacles. There is one *simrothian gland*, on the right side only. The *penial sheath* as usual gives attachment to a retractor penis muscle. A fine thread-like tubule, the *flagellum*, also opens into the penis, at its distal end.

The *penial sheath* consists of two portions: (1) A stout reniform mass containing the penis when the latter is fully retracted, the wall of the penis being continuous with that of the penial sheath at their distal ends. (2) A narrow tubular portion, which ends in the external aperture with the *right simrothian gland.*

(v) The *right simrothian gland* consists of two portions: (1) A narrow tubular portion coiled in various ways in its distal two-thirds. (2) A stout portion (also looped once) ending in the external aperture. At the junction of the two, is a fine tubular blind-sac (coecum) directed towards the outer end. The base of the sac gives attachment to a few muscle fibres. These correspond to the first and fourth portions of the simrothian glands of *A.* (*P.*) *sanguinolenta.*

V Nervous System.

The general arrangement of the ganglia is similar to that in other species. As the system has not yet been studied in detail in other species, it is convenient to deal with them rather fully in the present species.

(i) *Cerebral ganglia.* Each ganglion contains numerous groups of ganglionic cells arranged correspondingly to the origin of nerves from it. Three such rows can be recognized as follows:—

(1) An elongated row of cell-group in the inner third of the ganglion along the whole length.
(2) A similar row in the outer third.
(3) A narrow elongated group in the middle third in its anterior fourth.

The nerves (C 1-5) from the cerebral ganglion:—

(1) A stout nerve on the inner side lying close to the nerve of the opposite side. It arises from the ventral aspect and supplies the ommatophore.
(2) A stout nerve dividing into three branches immediately after its origin. These supply the cephalic flap and its retractor muscle. One of these communicate with the buccal ganglion of the same side.
(3) A stout nerve from the antero-external corner of the ganglion; it supplies the outer side of the head.
(4) A fine nerve on the dorsal aspect of the nerve (3) supplying the dorsal integument of the head.
(5) Several small nerves on the outerside supplying the sides of the head and the muscular strands in connection with the proboscis and proboscis-sheath.
(6) A few fine nerves from the ventral aspect to the body wall at the base of the proboscis, one of which supplies the retractor muscle of the tentacle (C 6).

(ii) *Buccal ganglia.*—Each ganglion gives off (1) a number of nerves which spread over the proboscis and its radular portion; (2) one long nerve which passes along the oesophagus and serves

to supply this portion of the alimentary canal. It gives off a fine nerve to the salivary gland.

(iii) *Viscero-pleural ganglia.*—The nerves (VP 1-5) are:—

(1) Two stout nerves arising side by side from the outer side. The outer one can be traced to the V-shaped process at the anterior end of the foot of the same side. The inner one seems to supply the anterior end of the foot. These two nerves arise from the oval group of ganglionic cells on the outer and anterior portion of the ganglia.

(2) A fine nerve arising from the outer aspect of the left ganglion at its posterior end. It passes along the gullet and ends in the liver a little behind the antero-inferior surface of the liver.

(3) A nerve from the right ganglion which supplies the female genital organs.

(4) A fine nerve from the right ganglion to the penis, penial sheath and the simrothian gland.

(5) Nerves to the side of the mouth above the pedal groove (VP 5).

(iv) *Pedal ganglia* (P 1-3).—The nerves are:—

(1) A nerve to the pedal gland.

(2) Nerves to the lateral wall of the mantle just above the groove round the foot.

(3) The long pedal cord which passes backwards along the dorsal surface of the foot to its posterior end. It gives off numerous nerves from its outer side to supply the foot.

VI. Eyes and Head Appendages.

The *eyes* are of rhipidoglossate type. Each forms a vesicle which is closed anteriorly forming a cornea composed of an external layer of epithelial cells, continuous with the tegumentary epithelium, an internal layer of epithelial cells (continuous with retina) and an intervening layer of transparent connective tissue. There is an oval crystalline lens with a surrounding layer of vitreous humour.

Ommatophore.—The cylindrical body of the ommatophores is hollow with a thick wall. Just behind the optic vesicle is a thin septum of connective tissue stretching transversely across the cavity. The wall consists of the following layers:—

(1) A single layer of cubical epithelium on the outer side.

(2) A thick layer of connective tissue with numerous cells. This layer contains some mucous glands placed at distant intervals. There are numerous pigment granules along the course of the connective tissue fibres.

(3) A layer of circular muscle fibres with a few radial fibres from the next internal coat.

(4) A layer of longitudinal muscle fibres.

VII. Pedal Gland.

(i) The *pedal gland* is a tubular body. The anterior portion is somewhat flattened from above downwards, while the posterior portion is triangular in transverse section.

Minute structure.—The pedal gland agrees in minute structure with that in *Atopos* (*Podangia*) *kempii*, Ghosh, except in the following points:—

(1) In the present species there is a blood-sinus on the dorsal aspect of the lumen of the gland in the middle line. Its wall consists of longitudinal muscle fibres bounded on the outer side by a layer of connective tissue.

(2) Owing to the interposition of a blood-sinus, the lumen of the gland comes to lie more or less in the centre and has become flattened out a little, instead of lying more towards the dorsal aspect and of being circular in transverse section as in *A.* (*P.*) *kempii*.

(ii) The *supra-pedal gland* is a small tongue-shaped body lying between the proboscis sheath and the pedal gland, and opening into the exterior just above the aperture of the pedal gland.

Minute structure.—The anterior portion forms a wide U-shaped cavity with the curve of the U continued in front to open into the exterior. The posterior two-thirds form a glandular mass, which consists of numerous lobules held together by connective tissue. Each lobule consists of a number of many-sided cells with spherical nuclei placed on one side. The ducts of these glands seem to open into the cavity of the body. On the outer aspects of the cavity, there are also numerous glands of similar structure with ordinary mucus-secreting cells in addition. The cavity of the gland is lined by a single layer of cubical cells. Immediately on the outer side of the epithelium is a thin layer of connective tissue which is prolonged outwards between the lobules.

LITERATURE

For references see my paper "Mollusca, I", in the Zoological Results of the Abor Expedition (*Records of the Indian Museum*, VIII, part III, No. 15).