XVII ON THE ANATOMY OF *ATOPOS* (*PODANGIA*) *SANGUINOLENTA* (STOLICZKA, M.S.).

By EKENDRANATH GHOSH, *L.M.S., B.Sc., Assistant Professor of Biology, Medical College, Calcutta.*

(Plates xxv–xxvii.)

INTRODUCTION.

The present article is based on several specimens of a slug collected more than forty years ago by the late Dr. F. Stoliczka in Penang [1] and at present in the possession of the Indian Museum. They have been placed at my disposal through the kindness of Dr. N. Annandale for anatomical investigation. Although left in alcohol for so many years, the animals were still in such a good condition as to allow me to make out the anatomical features in full detail with a few exceptions only. Having access to Simroth (12) and Collinge's (3, 4, 5, 6) publications, I took the opportunity of comparing the anatomy of other species of *Atopos* (of which *Podangia* is a subgenus) with that of the present species. As the animals had not been lately identified, it was necessary for me to consider the external characters fully and in minute detail, including the coloration. Unfortunately the colours of the animals have probably faded through long immersion in alcohol, but I have described them as they are at present.

Before passing on to the anatomy at once I shall try to find out the positions of the animals and the genus to which they most probably belong.

The specimens were placed in the family of Vaginulidae (Veronicellidae, Gray), order Pulmonata, under the name of *Veronicella sanguinolenta* by Stoliczka.[2] In 1891 Simroth in his admirable monograph (12) defined a new genus *Atopos* which he established for three species of *Vaginula*, Latrille,

---

[1] Apparently he obtained the specimens in the "more wild and deep ravines of the north-western part of the island." (Journ. As. Soc. Bengal (2) XLI, p. 261 (1872).

[2] Stoliczka probably referred to these specimens in his paper on the mollusca of Penang (1873), but he only named them in MS. Collinge in "A CHECK LIST OF THE SLUGS," published by Cockerell and himself (3), writes on page 223 "*Atopos pulverulentus* apparently includes a specimen in the British Museum from Penang (Theobold), marked '*V. sanguinea*, Stol.' It has the body beautifully marbled with black and grey, the sole pale orange-tinted. Length about 54 mm. Bluntly keeled." No date is assigned to *A. pulverulentus*, Benson, on page 195 of the same paper and I am unable to trace the description.

which is considered to be identical with *Veronicella*, Blainville (17). He also described the anatomy of these three species.

The genus *Atopos* is mainly defined by the following characters :—

The body is thickest at the junction of the anterior one-third and posterior two-thirds, with a median keel on the dorsal surface of the mantle (notum); the transverse section of the body forms an isosceles triangle with a short base (formed by the foot); the female generative aperture is situated close to the anus and the renal and respiratory apertures in the groove between the mantle and the sole, a little behind the male generative aperture (although a little distant from it); the male generative aperture is situated behind the right lower tentacle.

Simroth also separated a few other species of *Vaginula* and placed them in a new genus which he named *Prisma*. The genus is characterized by the body of the animal being prismatic in transverse section.

Before the publication of Simroth's paper (12), Heude founded another genus *Rathouisia* for *Vaginulus sinensis*, the name of which he changed to *R. leonina*. The characters of the genus *Rathouisia* are briefly as follows :—

The animals are elongated, limaciform; the mantle is not slimy; the upper tentacles are long; the lower tentacles are bifid; the posterior end of the foot is pointed, and extends beyond the mantle. The male generative aperture is placed behind the right lower tentacle. The female generative aperture rather approaches the male one, and is placed a little behind it, the anus and the excretory and respiratory apertures are placed close to the female generative aperture.

Later on, Heude united the genera *Atopos*, *Prisma* and *Rathouisia* to establish a separate family Rathouisiidae, characterized by a keeled mantle, male and female generative apertures distant and the anal and respiratory apertures placed near the female opening, in contradistinction to the absence of a keel, the position of the female generative aperture on the right in the middle of the body and that of the anal and respiratory apertures nearly at the posterior end of the body in the family of Vaginulidae (7, 11).

In 1900 Babor (2) established a new subgenus *Podangia* for *Atopos schildii* which differs from other species of *Atopos* in the following characters. The body of the animal is slender and high, with a distinct head separate from propodium. The foremost part of the notum is bent over the head covering it as a hood. The ommatophores (upper tentacles) are short, thick and distinctly annulated. Under each ommatophore is a crescent-shaped flap of integument produced into a process on each side and blended with the lower tentacle and the integument on the side of the mouth. The surface of the mantle is uniformly granulated with scattered tubercles in addition. The sole is small, with finely wrinkled border and with numerous

compact lobes. The groove between the foot and the mantle is shallow. The snout is elongated, with a small triangular mouth.

Taking the above characters into consideration, it seems to me that the animal belongs to the subgenus *Podangia*,[1] and as the colouring of the body differs from that of *P. schildii* it may be provisionally designated as *Atopos* (*Podangia*) *sanguinolenta*.

EXTERNAL CHARACTERS (pl. XXV, figs. 1 & 2).

GENERAL. The animal is elongated, limaciform. The body is compressed from side to side and is tapering to a point at the posterior end. The height and width of the animal is greatest at about one-fourth the length from the anterior end. The surface of the mantle is granulated uniformly and it also bears small scattered tubercles in addition. The tubercles are more numerous on the lateral aspect specially towards the margin of the mantle. The keel in the middorsal line is prominent but rounded. The margin of the mantle (perinotum) is sharp, wrinkled and inflexed. The foremost part of the mantle is bent over the head to form a hood-like covering. The anterior border of the hood is slightly notched. The posterior end of the mantle extends well beyond the foot. There is no distinct snout, the mouth being placed in a depression on the ventral aspect of the head. The head is distinctly separate from the propodium. The ommatophores are short, thick, and cylindrical, and are marked with annular wrinkles, they seem to be non-retractile (i.e. non-invaginable), as in all the specimens examined they were protruded to their full lengths although a little bit contracted. The lower tentacles are short, contractile and are each connected at the base with a flap of integument (precephalic flap) beneath. Each precephalic flap is a continuation forward of the head from the ventral aspect and is separated from its fellow of the opposite side by a long narrow gap extending behind to a little in front of the mouth. The anterior border of the flap is thin and convex; the outer border is broadly S-shaped, being concave in front and convex behind; the antero-external angle is pointed and the antero-internal rounded (pl. XXV, fig. 4). The anterior end of the foot is truncated and is produced in front to form the propodium. The posterior end of the foot is narrow and pointed and it does not extend beyond the mantle border. The margin of the foot is produced into a thin rim. The sole is wrinkled irregularly with small

[1] The colouring of *P. schildii*, as described by Babor (2), is as follows:—The dorsal surface of the mantle (notum) is dark brownish grey; the foremost part of the mantle which forms a hoodlike covering of the head is of course pale. The head and foot are hazel-nut brown in colour.

The anatomy of *P. schildii* having been compared with that of *A. semperi* and *Rathouisia* in a few lines only, is of little use for the determination of the species.

lobules. The foot is separated from the mantle border by a shallow groove.

COLORATION.—The dorsum of the mantle is now reddish buff with dots and blotches of purplish black; of the tubercles some are of the same colour as the blotches. The lateral surface of the mantle is purplish black above, forming a broad longitudinal band with irregularly sinuous margins and of about one-third the height of the notum in width; this band is continuous with that of the opposite side round the anterior hood-like portion of the mantle; below there is another bluish black band with irregular margins, this is also continuous with that of the opposite side round the anterior end of the mantle by a narrower band of the same colour. The margin of the mantle (perinotum) is yellowish grey, with bluish black dots just below the band above. The ommatophores, lower tentacles and the dorsal surface of the precephalic flap are slaty blue. In life the colour of the dorsal surface of the mantle was probably bright red and the lower lateral band was probably dark blue.

MEASUREMENTS.—The animals having contracted in different degrees, and having been distorted by long immersion in alcohol, it is very difficult to get an accurate measurement to be of any use afterwards. Still it was thought best to note down the different measurements of all the specimens so as to form an idea of an average dimension. The length is taken along the midventral line after straightening the animal but without stretching it. The figure thus obtained was then compared with that resulting from measuring the animal along the midventral line in the distorted condition, and it was seen to be practically the same in both the cases. Another measurement is also taken along the keel from end to end. The width of the notum is taken to be the longest distance between the two lateral surfaces of the animal, and this is found to correspond generally to the junction of the anterior one-fourth and the posterior three-fourths of the body. The height of the notum is the longest perpendicular distance between the keel and the margin of the notum.

The measurements are given below in a tabulate form; they are all taken in centimetres.

Number of specimens.	1	2	3	4	5	6
Length along the venter ..	7·8	7·6	7	6·9	6·9	6·4
Length along the dorsum ..		10·9	9·1	10 2	9	8·8
Width of the notum	1·1	1·0	1·0	1·0	1·0	1·0
Height of the notum	1·4	1·3	1·2	1·3	1·2	1·2
Width of the foot	·7	·6	·65	·65	·6	·5
Distance of the male genital aperture from the anterior end of the foot ..	·3	·3	·3	·3	·3	·3
Distance of the female genital aperture from the anterior end of the foot ..	1·3	1·3	1·25	1·3	1·3	1·2
Length of the ommatophore ..	·3	·2	..	..	·2	·2
Length of the lower tentacle	·15	·15	..	..	·15	·15
Length of the cephalic flap ..	·4	·3	..	..	·3	·3
Width of the flap ..	·3	·3	..	..	·3	·3

ANATOMY.

I. BODY WALL (pl. xxv, fig. 3).

Minute structure.—The body wall consists of the following layers :–

(1) The *epidermis* consists of a single layer of epithelium. The cells of the epithelium are columnar in shape and are placed side by side except at their extreme narrow ends of attachment, where they are a little separated from each other. The free borders of the cells are refractile and striated, but it is doubtful whether they are ciliated. The protoplasm is granular and is marked with faint longitudinal striations. The nuclei are large and oval, and are placed in the middle of the cells. The attached narrow ends of the cells probably contain brown pigment granules in some places. Between these epithelial cells are scattered fine ducts of unicellular

glands which are sometimes placed so close to the surface of the body that the epithelial cells over them become more or less flattened and displaced sidewise.

(2) The *dermis* or corium consists mainly of connective tissue with a few muscle fibres and unicellular glands. The glands are large flask-shaped cells generally placed beneath the epithelial layer. The cell-content consists mainly of the secreted materials with a little protoplasm and a small nucleus at the base. Immediately beneath the epithelial layer the connective tissue consists of large bundles of white fibres placed nearly at right angles to the surface and of smaller bundles which are branched off from the vertical ones and are spread horizontally in all directions. The fibres ultimately form a close network in the interstices of which lie the connective tissue cells. These are round, oval or fusiform cells with large nuclei. Some of these and others with branching processes contain brown pigment granules, which are densely placed beneath the epidermal layer. Beneath this are one or two layers of several muscle fibres scattered irregularly. The deeper layers of connective tissue consist of loosely arranged bundles of white fibres with a few yellow fibres and numerous connective-tissue cells. These cells are free from pigment granules.

II. RESPIRATORY SYSTEM (pl. xxv, fig. 5).

The pulmonary chamber is much atrophied; it forms a small oval sac lying in the anterior-third of the body beneath the right lateral wall of the mantle. It extends almost to the junction of the mantle with the foot below and stops short of the middle line above. The pulmonary chamber seems to open to the interior by an aperture placed at the antero-lateral corner to the right; the aperture is placed just behind the anus. The pericardium extends obliquely on the roof of the pulmonary chamber from the right antero-lateral towards the left postero-lateral corner. The kidney lies on the roof at the back. The roof of the pulmonary chamber is closely adherent to the inner surface of the mantle.

III. VASCULAR SYSTEM (pl. xxv, fig. 5).

The *pericardium* lies obliquely on the roof of the pulmonary chamber. The dorsal wall of the pericardium seems to be closely adherent to the body-wall.

The *ventricle* is placed in front of the auricle. The ventricle is a thick-walled pyriform sac with the ventral surface flattened

and the dorsal one convex. The *auricle* is thin-walled and is smaller than the ventricle.

Minute structure of the ventricle.—The ventricle is surrounded by a single layer of columnar epithelium. The muscles are arranged in various directions. The cavity of the ventricle is irregular and is traversed by numerous strands of muscle fibres. There is no epithelial lining in the cavity.

The *aorta*, just after its origin from the anterior end of the ventricle, divides into two; one passes forwards to the buccal bulb, while the other curves backwards and passes beneath the ventral aspect of the albumen gland closely applied to it, and seems to enter into the substance of the ovary; it also gives origin to several small vessels which supply the albumen gland.

The *pulmonary artery* (8) lies along the left side of the kidney, before it ends in the auricle; it receives numerous vessels from the kidney.

IV KIDNEY (pl. xxv, fig. 5).

The kidney is a flattened triangular body lying on the roof of the pulmonary chamber at the back. In position it lies just over the accessory digestive gland to the right. The surface of the kidney is provided with a network of vessels which open into the pulmonary arteries. The margins of the kidney are thinned out and is continuous with the membranous wall of the pulmonary chamber. The ureter could not be traced.

In *A. strubelli* (10), the pulmonary chamber is a more or less round sac with the heart placed transversely and kidney to the left extending over more than half of the pulmonary chamber.

Minute structure.—The kidney consists of a mass of tubules which converge to open into the ureter which seems to lie along the right (?) side of the kidney. The tubules are long and wavy with wide lumen. They are all placed side by side with thin layers of intervening connective tissue. The wall of the tubules consists of a single layer of polyhedral cells placed on basement membrane. The nuclei of the cells are oval, and are placed at the bases of the cells.

The sections of kidneys from two specimens show numerous cystic bodies contained in the cells of the tubules. These cystic bodies, which are doubtlessly parasitic, seem to be the oocysts of a sporozoon. They are mostly round or oval, although many are irregular in shape. The wall seems to consist of a thick layer of cuticle which did not allow the staining fluid to penetrate into the interior. The cysts contain from one to six spores with distinct round nuclei. The spores are spherical, or facetted when there are more than one in a single cyst. The oocysts were too little advanced to show the formation of sporozoits. This sporozoon seems to belong to the genus *Klossia* (fam. Polysporocystidae, order Coccidiidea).

V. Digestive system (pl. xxv, figs. 6–13, and pl. xxvi, figs. 14–16).

(i) The *buccal bulb* forms a tubular or elongated conical proboscis lying in a muscular sheath when retracted. The sheath opens on the ventral aspect of the head to form the mouth. The wall of the sheath is continuous behind with the wall of the buccal bulb just in front of the opening of the oesophagus into the latter.

(ii) The buccal bulb is continuous behind with a thick-walled conical sac which forms the *radula sac*. Collinge (3) describes the buccal bulb as divided into two portions lying respectively in front and behind the opening of the oesophagus. The radula sac is surrounded by a distinct muscular sheath.

The *radula* (pl. xxv, figs. 11–13) is a wide ribbon-like structure which does not seem to extend far forwards in the proboscis. The teeth are arranged in **V**-shaped rows with the apex of v directed backwards. There is no central. The lateral teeth are uniform in shape except the two median ones which are slightly different from others. There is no marginal. There are never less than 19 teeth on each side of the middle line. Each tooth is unicuspid and presents a shallow cup-like process in the middle.

The teeth of the radula in *A. strubelli* (10) are similar to those of the present species except that there is no cup-like process in the former.

(iii) The *salivary glands* could not be found in the specimens dissected. They were described in several species of *Atopos* by Collinge (3, 4) and Simroth (12). Each gland was described to consist of a glandular mass and a long duct opening into the bucca bulb just behind the attachment of the muscular sheath on the ventral aspect. In *A. sarasini* (4), the two glands unite to form a single mass, although the two ducts are separate.

(iv) The *oesophagus* (pl. xxv, fig. 6) is a narrow tube arising from the dorsal surface of the buccal bulb behind the proboscis-sheath in the middle line or a little to its left. It then takes a U-shaped curve the bend of which is directed to the left. The tube then curves to the right, and down the side and ventral aspect of the anterior end of the radula sac to the mid ventral line, and then sharply turns forwards for some distance beneath the proboscis-sheath. It again turns backwards and passes beneath the short intercerebral connective to the undersurface of the digestive gland into the cavity of which it opens a little in front of the junction of the anterior one-third and posterior two-thirds of its length.

In *A. maximus* (3), the oesophagus passes to the left and then takes a U-shaped curve to pass beneath the radula-sac, it then passes backwards and to the left beneath the intercerebral connective to the under surface of the digestive gland and opens into it at a point about one-fourth the length of the gland from the anterior end. In *A. sarasini*, the oesophagus takes a similar sigmoid curve, but passes to the right at first and

then to the left. In *A. leuckarti* and *A. strubelli*, it ends in the anterior end of the digestive gland.

Minute structure (pl. xxv, fig. 10).—The oesophagus consists of the following coats from without inwards :—

(1) A thin layer of connective tissue consisting of a few white fibres and elongated fusiform connective tissue cells. Just beneath this layer are seen two nerves (oval in transverse section) passing along the sides of the ventral surface of that portion of oesophagus which passes backwards from beneath the intercerebral commissure to the digestive gland.

(2) Alternate layers of longitudinal and transverse muscle-fibres with loose connective tissue intervening between them. The fibres do not form continuous bundles, but are arranged irregularly. The fibres of different layers often communicate with one another. The bundles become smaller and smaller as we pass inwards. The longitudinal fibres become predominant on the inner side and form several longitudinal folds, generally nine in number, which project into the cavity of the tube.

(3) The mucous membrane consists of a single layer of columnar epithelium. The cells seem to be ciliated.

(v) *The digestive gland, mid-gut gland* or *liver* (pl. xxv, figs. 6 and 8) is a large elongated conical (or fusiform) body wide and rounded in front, but tapering and pointed behind. It occupies more than the posterior two-thirds of the body. In front it lies in connection with another small gland, the accessory digestive gland, and it is connected at its hinder end to the terminal body-wall by strands of connective tissue. The outer surface of the gland is smooth, but presents some transverse fissures. The inner surface is raised into numerous folds and papillae which increase the absorbing surface to a great extent. The wall of the gland is thick, and the gland is circular in transverse section.

In *A. strubelli* and *A. semperi* (10), the outer surface of the gland is finely lobulated but the inner surface is smooth and circular in transverse section. In both the gland is of dark colour and is conical in shape. In *A. leuckarti* (10) the gland is irregularly lobed and presents a process to the left from near the anterior end.

Minute structure (pl. xxvi, figs. 14, 15).—The whole gland is surrounded by a thin layer of connective tissue (consisting of white fibres and connective-tissue cells). This ensheathing layer gives off numerous strands which converge and pass inwards to form the core of numerous papillae and folds which project into the cavity of the gland. These strands consist of connective-tissue fibres with a few muscle cells. These strands are surmounted by a single layer of cells which are placed side by side without any interspace between them. The cells are arranged to form

tubular spaces (simple tubular glands) between the contiguous connective tissue strands. Each space communicates with the cavity of the digestive gland by a wide mouth. The epithelium consists of elongated ciliated cells with the nuclei placed at the base. Numerous goblet cells are found between these ciliated cells. The bases of many of these ciliated cells are occupied by a number of amoeboid (?) corpuscles with large round nuclei.

The *accessory digestive gland* (pl. xxv, figs. 6, 8) is a small triangular body lying in front of the digestive gland. The ducts of this gland open into the intestine as the latter passes forward from the left side of the gland. In the drawing of the alimentary canal of *A. maximus* (5) ducts of two other glands (not represented in the figure) are shown to open into the digestive gland. Hence it might be inferred that the above gland opens into the digestive gland. No such glands seem to be present in *A. strubelli*, *A. semperi*, and *A. sarasini* (4.) The process from the digestive gland in *A. leuckarti* seems to be homologous with the accessory gland.

Minute structure (pl. xxvi, fig. 16.)—The gland is surrounded by a connective tissue-sheath. It consists of a large number of lobules held together by connective tissue. Each lobule consists of a group of irregularly polyhedral cells closely apposed to one another, although fine channels (with walls composed of connective-tissue cells only) are often found passing between the cells. The protoplasm of most of the cells is coarsely granular and is stained red with eosin. These are undoubtedly zymogen granules. The nuclei are oval or rounded, and are obscured in many cells by these granules. A small proportion of cells have clear protoplasm with finer granules and more distinct nuclei. The gland is richly supplied with blood vessels which are placed inside the lobules. They generally form bundles in the middle of the lobules.

(vi) The *intestine* is a stout but thin-walled tube arising from the left side of the digestive gland towards the ventral aspect and close to the opening of the oesophagus. It forms a U-shaped loop lying embedded on the dorsal surface of the gland and then passes along the left side or on the dorsal aspect of (figs. 6, 18) the accessory gland, over the groove on the albumen gland and vagina obliquely to end in the anus, which lies on the right side in the groove between the foot and the overhung margin of the mantle closely behind the female genital aperture.

In *A. strubelli* (10) and *A. leuckarti* (10), the intestine seems to be directly continuous with the oesophagus at the anterior broad end of the midgut gland, which opens into the gut by a wide aperture at the junction of the two. In *A. sarasini* (4) the intestine forms a M-shaped loop lying embedded in the wall of the gland and comes out from its anterior end. The oesophagus is continuous with the intestine with a wide aperture (at the junction) which communicates with the cavity of the midgut gland.

Comparing the alimentary canal of these slugs with that of the more typical groups of pulmonates, *e.g.* the land snails, it should be observed that in the present animal there is no distinct dilatation of the midgut in the form of stomach quite distinct from the liver, which opens into the gut by small ducts in contradistinction to the separate stomach and liver in the land snails. Here the stomach might be considered to have become incorporated with the cavity of the gland, the wall of which presents numerous tubular glands homologous with a separate digestive gland.

VI. REPRODUCTIVE SYSTEM.

As in other pulmonates, the male and female genital organs are united in the same individual. There is some difference in opinion about the connection between the male and female organs at their proximal ends. Simroth's (10) descriptions and figures of the genital organs of his three species show that there is a common hermaphrodite gland from which are given off the vas deferens and oviduct; this condition then corresponds to the second of three types of genital ducts described by Lang (8). Collinge (3, 4), however, could not find out any connection between the two in his specimens. Although I found the two organs separate from each other I have a good deal of doubt about the validity of Collinge's view for the reasons noted below. On examining under the microscope the stained sections of the organ which corresponds to what Collinge described as ovary, I observed spermatozoa in different stages of development to my full satisfaction in addition to immature ova. As I had only old spirit specimens to dissect, it occurs to me that the so-called ovary is really a hermaphrodite gland the fine vas deferens of which I could not trace. As the hermaphrodite and albumen glands lie over the penial sheath it seems to me that the vas deferens, being very fine and small, gets torn as the above glands are lifted up from their position and are separated from the penial sheath. Still as I could find out no connection between the two organs in the several specimens I dissected, I leave the question for further consideration in future.

(I) MALE GENITAL ORGANS (pl. xxvi, fig. 20).

(1) A fine thread-like tube (pl. xxvi, fig. 20a) opening into the posterior end of the penial sheath near the attachment of the retractor muscle of the penis. It lies along the left side of the penial sheath and the stout tube in front, and extends to near the external opening of the right Simrothian gland. The same arrangement is seen in both *A. maximus* and *A. sarasini* described by Collinge (4) who called the tube vas deferens. Considering the anatomy of the genital organs of other pulmonates, this tube seems to be homologous with the flagellum. This has

been described in *Helix pomatia* and other pulmonates of the same family (7, 8).

Minute structure (pl. xxvii, figs. 27 and 28).—The tube is composed of the following coats from without inwards :—

(1) A thin layer of connective tissue.
(2) A layer of longitudinal muscle-fibres.
(3) A layer of circular muscle-fibres.
(4) A submucous coat of connective tissue (with a few muscle-fibres) raised into a number of longitudinal folds, generally ten, projecting into the lumen.
(5) A single layer of columnar epithelium with numerous goblet cells (secreting cells).

(2) The *penial sheath* consists of two portions :—(1) A stout hollow spindle-shaped structure giving attachment to the retractor muscle at its proximal end ; (2) a stout tubular structure arising from the distal end of the first portion and ending in the external aperture at the base of the right lower tentacle.

Minute structure.—The tubular portion consists of alternate layers of longitudinal and transverse muscles arranged irregularly. The wall is thrown into large longitudinal folds, the core of which is formed mainly of longitudinal muscle fibres. The presence of these large folds shows the great extensibility of the penial sheath. The epithelium consists of a single layer of cubical (or short columnar) cells.

(3) The *penis* is a more or less cylindrical structure lying in the proximal portion of the penial sheath when retracted. The penis is attached to the sheath at the proximal end and is traversed by a fine channel continuous with the lumen of the tube described above, and opening into the tip by a small aperture.

(4) The *retractor penis muscle* is a short thick band extending from the inner side of the body wall on the right, a little behind the female genital aperture, to the proximal end of the penial sheath and penis.

(5) The *Simrothian glands* (pl. xxvi, figs. 19, 20a) are two tubular structures, one on each side, opening on the outer side of the lower tentacles, the right one being placed close to the male genital aperture. Each gland can be divided into four portions—(1) a long stout tubular portion coiled in various ways ; (2) a short narrow portion, also tubular in structure, coiled closely ; (3) an elongated slightly curved conical portion continuous with the second one at the tapering end and ending in the next in a broad base; (4) a very short narrow tube with a small cylindrical process from the outer side.

The structure of the Simrothian glands in *A. maximus* and *A. sarasini* resembles closely that of the present species except that there is no distinct fourth portion and the process arises from the proximal end of what corresponds to the third division

in the present species. There is no left Simrothian gland in *A. sarasini* (4).

Minute structure.—First portion (pl. xxvi, fig. 24).—The wall consists of the following layers from without inwards :—

(1) A thin layer of connective tissue forming a sheath round the tube.
(2) A layer of large granular cells more or less cylindrical in shape and with large nuclei placed on one side; they are arranged radially and obliquely, being attached to the first layer at their outer ends and to the next by the inner. In a transverse section one finds several oblique sections of the cells. These seem to be muscle-cells.
(3) A layer of muscle-fibres arranged longitudinally.
(4) A layer of transversely arranged muscle-fibres.
(5) A layer of submucous tissue. It forms numerous folds projecting into the lumen. Small muscle-fibres can be traced into it from the fourth layer.
(6) The mucous membrane consists of a single layer of columnar epithelium.

Second portion (pl. xxvii, fig. 26).—The different layers are :—

(1) An outermost layer of connective tissue.
(2) A thick transverse layer of muscular fibres intermingled with white and yellow fibres.
(3) A single layer of cubical cells with round nuclei. The epithelium is not folded.

Two or more loops of this portion of the tube may be held together in connective tissue.

Third portion (pl. xxvii, fig. 25).—The various layers are :—

(1) A layer of thick longitudinal muscle-fibres—the individual fibres are separated by connective tissue.
(2) A thin transverse layer of muscle-fibres; some of these are continued into the folds of submucous tissue.
(3) A submucous coat of loose connective tissue thrown into ten or twelve folds.
(4) The mucous membrane consists of a single layer of columnar cells with oval nuclei.

(6) The external aperture of the male genital organ seems to be situated on the inner side of a triangular process between it and the base of the right lower tentacle.

(II) FEMALE GENITAL ORGANS (pl. xxvi, figs. 17, 18).

(1) The *hermaphrodite* gland is a large lobulated body lying closely apposed to the posterior end of the albumen gland. The dorsal surface is marked with a longitudinal groove for the

intestine. The ventral surface is concave and rests on the penial sheath.

Minute structure (pl. xxvi, fig. 21).—The gland is composed of a number of lobules held together by connective tissue, which forms a thin sheath round the whole gland and also extends between the adjacent lobules. Each lobule is oval in shape and gives rise to a duct of its own which unites with others from the adjacent lobules to form the main duct of the gland. The lobular ducts could be distinctly followed to the oviduct by the naked eye. Each lobule consists of a single layer of flattened epithelium supported on a thin layer of connective tissue (forming the wall), with a central cavity filled with mature ova and spermatozoa. Each lobule gives origin to both ova and spermatozoa from its wall.

In the formation of an ovum, a cell of the wall enlarges and becomes fusiform in shape; its free surface is covered by a single layer of flattened cells continuous with those of the wall of the lobule. When mature the ovum seems to lie free in the cavity of the lobule.

The cells which ultimately form the spermatozoa seem to divide into a number of round cells (primary sperm-mother cells) which become aggregated on the surface of conical or round projections into the cavity of the lobule from its wall. In a section of the lobule one will see several projections, the centre of which consists of a mass of protoplasm with a large nucleus. The primary sperm-mother cells are arranged on the surface of the projections. What seems to occur is the proliferation of an epithelial cell so as to form a mass of round cells on the surface of one which grows more rapidly than others and forms the supporting cell. The protoplasm of this cell is highly granular, and it has got no distinct cell-wall. The primary mother cells seem to divide again to form groups of secondary sperm-mother cells for by careful examination of stained sections under the microscope one will find a second set of smaller cells grouped in a similar way and still attached to a supporting cell. The nuclei of these secondary sperm-mother cells become gradually elongated to form the head of the spermatozoa. The different stages of the change in shape of the round nucleus to a rod-shaped body could be easily followed in stained sections. The protoplasm of the cell then elongates to form the tail of the spermatozoon. The mature spermatozoa then separate from these papillae and lie freely in the cavity of the gland in bunches.

The mature *ovum* (pl. xxvi, fig. 22) is completely surrounded by a single layer of flattened cells (with distinct nuclei) attached end to end. The protoplasm is coarsely granular. The large nucleus lies in the centre and presents a conspicuous nucleolus.

The mature *spermatozoon* (pl. xxvi, fig. 23) consists of a hook-shaped head and a long fine tail. The head is curved and pointed at the tip, but broad and rounded at the base. It is also curved twice before it ends in the tail, which is many times longer than the head.

(2) The *albumen gland* is an elongated body with the posterior end flattened and attached to the ovary. The anterior end is narrow. The upper convex surface of the gland is smooth, but present numerous transverse fissures. It is indented with a longitudinal groove for the intestine. The inner surface is concave and presents a depression for the penial sheath over which it lies.

Minute structure (pl. xxvii, fig. 29).—The gland is composed of a number of lobules bound together loosely by connective tissue. Each lobule is formed by a group of tubular acini, each of which seems to end in a duct which unites with others to form a main duct opening into the oviduct. Each acinus is enclosed by a basement membrane. Inside it is the epithelium consisting of a single layer of polyhedral cells with large round nuclei placed towards the base. The inner free borders of the cells are broken and jagged. The inner two-thirds of the cells are filled with coarse granules. The cavities of the acini are filled with the secreted material which is stained deep blue with hæmatoxylin. The ducts of the acini are lined with columnar epithelium.

(3) The oviduct is a thin-walled tube passing through the substance of the albumen gland and emerges through its anterior extremity to end in the vagina.

Minute structure (pl. xxvii, figs. 30, 31).—The wall consists of a thin outer layer of connective tissue which is continued into the centre of the longitudinal folds projecting into the lumen. Inside this layer is a coat of connective tissue cells with a few fibres between them. These are also continued into the folds and surround the central strands of connective tissue. The mucous membrane consists of a single layer of ciliated columnar epithelium.

(4) The vagina is a stout tubular structure slightly curved with the convexity downward and to the right. The upper surface presents a groove for the intestine.

(5) The receptaculum seminis is an oval body with a fairly long tubular stalk opening into the middle of the vagina on its side.

(6) The female genital aperture in which the vagina ends, lies in the groove between the foot and right mantle border at a distance from the anterior end of the body already noted in a tabular form.

VII. Nervous system (pl. xxvii, fig. 32).

The nervous system is of euthyneurous type. The ganglia are closely united to form a mass round the oesophagus. The cerebral ganglia are closely connected to each other by a short thick intercerebral commissure. The cerebro-pedal and cerebro-pleural connectives are united to form a short thick band on each side. The buccal ganglia are placed on the ventro-lateral aspect of the hinder end of the proboscis-sheath at the junction with the radula-sac. The stomato-gastric connectives are long

The pedal and viscero-pleural ganglia of both sides are closely connected to each other to form a reniform mass. The aperture for the oesophagus is very small.

VIII. PEDAL GLAND (pl. xxvii, fig. 33).

Is a tubular structure lying beneath the central nervous system on the dorsal aspect of the foot. The external aperture of the gland lies in the middle line in the groove betwen the head and propodium.

LITERATURE.

1. Adams, H., and Adams, A. The genera of recent mollusca (1858).
2. Babor, J Fl. " Erste vorläufige Mittheilung zu einer Monographie der Gattung *Atopos* Simroth," Ann. d. k. k Nat. Hist. Hofmuseums Wien, 1900, Bd. XV, pp. 100—102.
3. Cockerell, T. D. A., and Collinge, W E. " A check-list of the slugs." The Conchologist, Vol. II, No. 8, Dec. 21st, 1893, pp. 195, 223.
4. Collinge, W E. " Report on the non-operculate land-mollusca." Fasciculi Malayenses Zool., part II, Skeat Expedition (1899—1900).
5. Collinge, W E. " On the non-operculate land and fresh-water molluscs," Journal of Malacology 1902, Vol. IX, pt. 3.
6. Collinge, W E. " Report on the slugs." A. Willey's Zoological results," 1899, pp. 429—438, pls. xl—xli.
7. Cooke, Rev. A. H. Article " Mollusca." Cambridge Natural History edited by S. F. Harmer and A. E. Shipley.
8. Gegenbaur, C. Elements of comparative anatomy translated into English by F. Jeffrey Bell.
9. Lang, A. Text-book of Comparative Anatomy, Vol. II. English translation by H. M. Bernard and M. Bernard.
10. Minchin, E. A. Article " Sporazoa (protozoa) " in text-book of Zoology edited by Sir E. Ray Lankester.
11. Pelseneer, P. Article " Mollusca " in text-book of Zoology edited by Sir E. Ray Lankester.
12. Simroth, H. " Uber das Vaginuliden genus *Atopos* n.g." Zeit. f. Wiss. Zool. 1891, Bd. iii, pp. 593—616, T. xxxvii le P R.
13. Stoliczka, F. " Land shells of Penang." Journal of Asiatic Society of Bengal, Vol. 42, part II, p. 35 (1873).