

XIII. ON THE ANATOMY OF CERTAIN INDIAN UNIONIDAE.

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(With Plate XVI.)

INTRODUCTION.

The genera and species of Unionidae discussed in this paper are :—*Lamellidens marginalis* (Lamarck), *Solenaiia soleniformis* (Benson), *Physunio ferrugineus* and *Ph. micropteroides*, Annandale. These species resemble one another so closely in anatomical structure that I have considered it best to treat them together in a comparative manner.

The method of study was (1) simple dissection of the soft parts of the animals after removal from the valves, checked by (2) longitudinal (sagittal) section of the entire animal and (3) serial transverse section of the whole animal (into thin slices, 2-4 mm. thick) from one end to the other. The gills were studied microscopically after sectioning by the usual paraffin method. They have been specially studied with reference to the formation of the marsupium.

As regards the materials, the specimens of *Lamellidens* were procured from tanks about Calcutta, while the others were received from the Zoological Survey of India through the kindness of Dr. Annandale.

I. MANTLE-LOBES.

The *mantle-lobes* are free from each other from the antero-dorsal aspect of the anterior adductor muscle down along the ventral margins to the posterior margin as high as the postero-dorsal aspect of the posterior adductor muscle. Behind, the two lobes are joined to one another between the exhalent and inhalent apertures by a horizontal shelf formed by their fusion with the free dorsal margins of the outer lamellae of the outer gills and of the other lamellae of the gills to one another. The point of fusion of the mantle-lobes is placed just at the antero-dorsal aspect of the anterior adductor muscle in *Lamellidens* and *Solenaiia*, but at a higher level in *P. ferrugineus* and less so in *P. micropteroides*; further, this point forms the most anterior end of the lobes, and in the case of *Lamellidens* and *Solenaiia* is placed at the level of the ventral border of the anterior adductor muscle. A small gap between the margins of the mantle-lobes is left above the posterior adductor muscle, exposing the dorsal wall of the rectum in both *Lamellidens marginalis* and *Solenaiia soleniformis*. This gap is absent in both species of *Physunio*.

Above, each mantle-lobe is fused with the body-wall, the line of separation passing along the ventral aspect of the anterior adductor muscle, the base of the anterior lip of the mouth, and the attached dorsal margin of the anterior half of the outer labial palp; the line of

separation is then reflected forwards in an acute angle along the ventral aspect of a triangular membrane attaching the dorsal margin of the labial palps to the side of the visceral mass, and ultimately curves backwards round the anterior end of the inner and then the outer gill (the line of curvature forming about $\frac{1}{3}$ the circumference of a circle). It then passes obliquely downwards and backwards nearly in a straight line along the ventro-lateral aspect of the non-glandular portion of the kidney. Behind the foot, a canal¹ intervenes between the non-glandular portion of the kidney and the line of separation. In *Lamellidens* the line is placed on the dorsal aspect of the canal, whereas in both *Solenaia* and *Physunio* it lies on the outer side of the canal itself. Furthermore, the line of attachment of the outer lamella of the outer gill is placed below the line of separation in *Lamellidens* and *Solenaia*, but in *Physunio* in this line. This line is oblique and situated on the outer side of the kidney; it forms an acute angle with another line drawn from the anterior end of the outer gill to the posterior end of the attachment of the labial palps on their dorsal aspect in *Physunio* (more so in *P. ferrugineus* than in *P. micropteroides*), a right angle in *Lamellidens marginalis* and an obtuse angle in *Solenaia soleniformis*. Lastly, the line of separation passes along the ventral margin of the posterior adductor muscle to its posterior aspect, where it is joined to the opposite mantle-lobe through the intervention of the gills. It then curves round the posterior aspect of the posterior adductor muscle to join its fellow at the postero-dorsal aspect of the muscle.

The inhalent and exhalent apertures are bounded by the thick, pigmented margins of the mantle-lobes. The inhalent aperture is twice the exhalent aperture in height. The margin of the inhalent aperture is beset with tentacles in all the genera here described; in *Lamellidens* and *Solenaia* the tentacles are short and stout and are nearly of the same size, and are arranged in a single row, but in *Physunio* they are elongate and conical and of three sizes which are arranged irregularly in three rows, the largest ones (larger than those in *Lamellidens* and *Solenaia*) being placed internally.

The exhalent aperture is smooth in *Solenaia* and *Physunio*, but provided with a row of minute tubercles in its extreme lateral margins in *Lamellidens*. The margins of the aperture extend further downwards in *Physunio* than in *Lamellidens* and *Solenaia*.

II. LABIAL PALPS.

The *labial palps*, outer and inner, are continuous in front with the anterior and posterior lips of the mouth; they are elliptical in *Lamellidens* and *Solenaia*, but a little more elongate in *Physunio*. The point at which they are fused with the lips of the mouth forms a shallow concavity on the ventral margin in *Lamellidens* and *Solenaia*, but presents a slight flattening in *Physunio*. The labial palps are free from one another except in three-fourths the length of the dorsal margin from the anterior end; they are connected with the body by a triangular membrane attached to their fused dorsal margin. The apex of the membrane

¹ To be described with the kidney.

is directed forwards and the base forms a free margin behind ; the side fused with the wall of the visceral mass is overlapped by a small portion of the ventral margin of the inner gill.

III. MUSCLES.

(1) The *anterior adductor muscle* is irregularly triangular in shape in *Lamellidens* and *Physunio*, and rather obliquely pyriform in *Solenaiia*. The relative position of the muscle and the pseudocardinal tooth or teeth in the intact animal varies with the different species described. In *Lamellidens* the anterior end of the tooth or teeth is placed just above the middle of the attachment of the anterior adductor muscle, while in *Physunio* it extends to the antero-dorsal angle of the muscle with a gap between the two.

In all the species described here the muscle is divided into an upper and lower portion by an oblique septum extending between the two valves.

(2) The *posterior adductor muscle* is triangular (with the apex above and the angles rounded) in *Lamellidens* and *Physunio*. In *Solenaiia* it is elongated horizontally, with nearly parallel upper and lower borders and rounded ends ; in the anterior and upper corner there is a notch to receive the posterior end of the muscle.

(3) The *anterior retractor muscle* of the foot arises from the base of the foot on its side, just behind the mouth ; it passes obliquely upwards and forwards beneath the posterior lip of the mouth and on the inner side of the lower portion of the protractor muscle to be inserted into the valve just behind the anterior adductor muscle. In *Lamellidens* the surface of attachment lies along the lower two-thirds or more of the posterior margin of the adductor muscle, being widest below and tapering above. In *Solenaiia* it is placed behind the upper third of the posterior margin of the adductor muscle, and is nearly circular in shape. Lastly, in *Physunio* it is elongately triangular with the apex below, and is placed behind the upper half of the posterior margin of the anterior adductor muscle.

(4) The *protractor muscle of the foot* arises on each side from the visceral mass above the base of the muscular foot. The fibres radiate from an obliquely placed triangular area and are collected into a very short column, which passes obliquely downwards and forwards to be inserted into the valve near the anterior adductor muscle. In *Lamellidens marginalis* the muscle is placed below and behind the adductor at a little distance from it ; in *Solenaiia* it is placed behind and a little below the anterior retractor, at a distance behind its ventral aspect. In *Physunio* it is placed behind the adductor at the level of its lower end and also at a distance from it.

(5) The *posterior retractor muscle of the foot* on each side arises from the extreme posterior and dorsal aspect of the visceral mass ; the two muscles lie side by side in the middle line, pass obliquely upwards and backwards between the two kidneys (at their posterior portions) and are inserted into the valves above the level of the upper border of the kidneys and in front of the posterior adductor muscle. In *Lamellidens marginalis* the surface of attachment is more or less triangular in shape,

lying in contact with the upper end of the anterior aspect of the adductor muscle. In *Solenaiia* also, it is triangular, but lies in contact with the notch in the posterior adductor muscle. In *Physunio* again it is triangular, but is placed above and in front of the dorsal aspect of the adductor muscle.

(6) The *elevator muscles* are arranged in two patches one on each side, on the dorso-lateral aspect of the visceral mass.

In *Lamellidens marginalis* each patch is placed at the junction of the anterior one-third and posterior two-thirds of the body length and consists of very short columns of muscles 5—7 or more in number and arranged irregularly; they are at once inserted into that portion of the valve lying in front of the umbonal cavity. In *Solenaiia* they are placed behind the region of the umbo. In *Physunio* they are placed above and behind the anterior adductor muscle far forward in position as compared with those of *Lamellidens* or *Solenaiia*.

IV. GILLS.

The *gills* are more or less similar in *Lamellidens* and *Physunio*. They are elongated and placed obliquely, and are approximately 4 times as long as broad. The *inner gill* is wider and longer, and extends a little more forward than the outer one. The *outer gill* is narrow and pointed in front, narrow and tapering behind. The inner gill is wider than the outer and extends below the outer gill. In *Lamellidens* the outer gill is nearly of the same width all through except at the tapering posterior and rather abruptly narrowed anterior end. The inner gill projects downwards beneath the outer one more in the anterior two-thirds of its length than in its posterior one-third. In *Physunio* the outer gill is comparatively narrow, being widest near the middle of its length and tapering at both ends; it presents a notch in the ventral margin near the anterior end; the inner gill projects downwards most in front, slightly behind and least in the middle.

In *Solenaiia* the gills are much narrowed and elongated, being about ten times or more as long as they are broad; the inner gill extends a little more forward than the outer, as in the other species, and projects a little below the outer gill equally in its entire length except at the anterior end; the anterior and posterior ends of the outer gills are narrower and more pointed than those of the inner gill.

ATTACHMENTS OF THE GILLS :—

(1) The *outer lamella of the outer gill* is attached to the inner surface of the mantle-lobe. In *Lamellidens* the line of attachment lies a little below the separation of the mantle-lobes from the body-wall, so that the outer wall of the outer suprabranchial chamber is formed by a portion of the mantle-lobe; the case is similar in *Solenaiia*. In *Physunio*, however, the line of attachment lies at the line of separation of the mantle-lobe from the body-wall. The attached margin of the outer lamella is placed on a higher level than that of the inner lamella in *Lamellidens* and *Physunio*, but at a lower level (or at least in the same level) in *Solenaiia*.

(2) The *inner lamella of the outer gill* is attached to the side of the visceral mass, at its anterior end, the ventro-lateral aspect of the non-

glandular portion of the kidney and to the outer lamella of the inner gill behind the visceral mass and foot, from beneath the posterior adductor muscle.

(3) The *outer lamella of the inner gill* is similar to the preceding in its mode of attachment.

(4) The *inner lamella of the inner gill* is attached to the side of the base of the visceral mass and behind it to the inner lamella of the opposite inner gill to form the floor of the cloacal chamber. In *Lamellidens* the attached dorsal margin of the inner lamella is placed just below the glandular portion of the kidney, but towards the posterior end of the visceral mass it is displaced downwards from the kidney, so that the inner wall of the inner suprabranchial chamber in this region is formed by a portion of the side wall of the visceral mass; in *Solenaia* the case is exactly similar to that in *Lamellidens*. In *Physunio* the attached margin is placed beneath the glandular portion of the kidney near the posterior end of the visceral mass, where it is suddenly displaced downwards, as in the other forms.

Suprabranchial canals.—(a) The *outer suprabranchial canal* is placed on a higher level than the inner in *Lamellidens* and *Physunio*, but on a lower level in *Solenaia*. In *Lamellidens* the canal is small in the beginning, but gradually widens out posteriorly and opens into the cloacal chamber on the undersurface of the posterior adductor muscle in the middle of its antero-posterior thickness. Elongately triangular anteriorly, it widens out into an equilateral triangle behind in transverse section. In *Physunio* the canal is elongated and slit-like in front, but elongately triangular (with base directed upwards) behind the visceral mass in transverse section; it ends in the cloacal chamber at the anterior end of the ventral aspect of the posterior adductor muscle.

In *Solenaia* the canal is triangular in front, but quadrilateral at the posterior end of the visceral mass in transverse section, and terminates in the cloacal chamber in the middle of the antero-posterior length of the ventral aspect of the posterior adductor muscle.

(b) The *inner suprabranchial canal* in both *Lamellidens* and *Physunio* is slit-like in the beginning, becomes triangular posteriorly in transverse section and is nearly of the same height in its entire length. In *Solenaia* the canal is also slit-like in the beginning but becomes quadrilateral in transverse section at the end of the visceral mass; it is, however, of greatest width (from above downwards) anteriorly, forming about half the width of the inner gill, but becomes less so posteriorly.

The *renal aperture* is placed in the inner suprabranchial canal; in *Lamellidens* and *Physunio* at about the junction of the anterior one-third and posterior two-thirds of the line drawn from the anterior end of the inner gill to the posterior end of the visceral mass. In *Lamellidens* the aperture is slit-like and placed longitudinally, with a thick white rim; in *Physunio* it is rounded and without any thick white margin. In *Solenaia* it is slit-like and placed longitudinally some distance behind the middle of the length of the visceral mass.

The *genital aperture* is placed below and a little in front of the renal aperture in the same canal in both *Lamellidens* and *Physunio*. In *Solenaia* the aperture could not be made out.

The *common canal*, formed by the union of the two *suprabranchial canals* behind the visceral mass, is shorter than the antero-posterior length of the cloacal chamber in *Lamellidens* and *Solenaisia*, but nearly of the same length in *Physunio*.

STRUCTURE OF THE GILLS.—The specimens of *Solenaisia soleniformis*, Benson, and *Lamellidens marginalis*, Lam., supplied me with gravid females, while the specimens of the two species of *Physunio* were all sterile. In *Solenaisia* all the four gills act as marsupia, while in *Lamellidens* the outer gills only give rise to ovisacs. In *Physunio* the structure of the gills seems to show that the outer gills are concerned in carrying the embryos. The arrangement of the gill filaments and the formation of lateral tubes are shown in the following table :—

	Number of gill-filaments corresponding to one water tube or lateral tube.	Lateral tube.
<i>Solenaisia</i> —		
Outer gill, 20—22 Only outer lateral tube.
Inner gill, 12—18 Only inner lateral tube.
<i>Lamellidens</i> —		
Outer gill, 16—20 } Outer tube much more deve-
Inner gill, 12—15 } loped than the inner tube.
<i>Physunio</i> —		
<i>P. ferrugineus</i> —		
Outer gill, 25—28.		
Inner gill, 14—16.		
<i>P. micropteroides</i> —		
Outer gill, 20.		
Inner gill, 15—16.		

V ALIMENTARY CANAL.

(a) The *mouth* is a transverse slit-like aperture bounded in front and behind by anterior and posterior lips continuous with the outer and inner labial palps respectively.

(b) *Oesophagus*.—The course of the oesophagus is different in the three forms : in *Lamellidens* it is slightly curved or broadly S-shaped, passing obliquely upwards and backwards through the digestive glands. In *Solenaisia* it consists of a short nearly vertical portion (wide in the middle and narrow at both ends) and an elongated horizontal portion continuous behind with the stomach. In *Physunio* it consists of a vertical portion lying behind the anterior adductor muscle and a short horizontal portion (half as long as the vertical portion) continuous with the stomach behind.

(c) The *stomach* is surrounded by a digestive gland ; its cavity is very irregular with folds and furrows which are fairly constant in arrangement.

Behind the opening of the oesophagus and in the floor of the stomach is a transverse fold (tongue-like in *Lamellidens*, but rather conical and papilla-like in *Solenaisia* and *Physunio*), with a furrow behind ; the fold is directed upwards and backwards from below and produced laterally to the lateral walls of the stomach. In *Solenaisia* and *Physunio* there is another fold in front of the conical elevation at the junction of the oesophagus and stomach, which in *Solenaisia* extends backwards and up-

wards from below, and in *Physunio* only marked in the right side. Behind the conical elevation is another slight eminence which receives the opening of the intestine in *Solenaiia*. In *Lamellidens* the opening lies on or behind the eminence, while in *Physunio* it is placed behind it at the bottom of a cup-shaped depression itself surrounded by a raised margin. In all cases the opening of the intestine is placed to the left side of the middle line.

The posterior wall of the stomach is raised into a transverse fold in the middle of its width giving rise to two blind pouches; the fold is continued into the lateral wall of the stomach, more in the case of *Lamellidens* than in the two other genera. The dorsal pouch is directed upwards and backwards, while the ventral pouch is directed transversely backwards.

In *Solenaiia* there is another fold in the backwall of the dorsal pouch above the transverse one which passes obliquely outwards and downwards to meet the transverse fold at the side; this ridge is faintly marked or absent in *Lamellidens*, but in *Physunio ferrugineus* a similar ridge, arising from the dorso-lateral corner of the dorsal sac, passes downwards and forwards to meet the transverse ridge at the postero-lateral wall of the stomach; it is present only on the left side but a faint trace of it can also be made out on the right side. In this species also a fold arises from the right side of the cup-like depression (in which the opening of the intestine is placed), which passes obliquely upwards and to the right on the posterior wall of the stomach and ends below the transverse fold in the postero-lateral corner; two other smaller and less prominent ridges are seen, one arising from the postero-lateral aspect of the margin of the same cup-like depression to the right and the other a little above the preceding from the oblique ridge, both passing to the left. Another strongly marked ridge is also found in the right lateral wall of the stomach at the level of the margin of the cup-shaped depression, continued behind to the origin of the oblique ridge from the margin of the cup. It forms a deep pouch on the ventro-lateral aspect of the stomach, the lower boundary of which is formed by the raised lateral margin of the cup-shaped depression.

In all the three genera the transverse ridge from the posterior wall of the stomach, as it passes to the *left side*, fuses with one from the antero-dorsal wall above and with another from the ventral wall of the stomach at its junction with the oesophagus, with the formation of a separate portion of the dorsal pouch on the left side.

(d) *Intestine*.—The coils of the intestine in the visceral mass are similar in fundamental arrangement in all the genera considered here. They may be best described in a tabular form:—

Loop of the Intestine.	<i>L. marginalis.</i>	<i>Solenaiia soleniformis.</i>	<i>Physunio.</i>
(1) First loop, from the stomach to the posterior end of the visceral mass (course backward and downward on the left side of the middle line).	Course backward and downward.	Much more backward than downward.	Much more downward than backward.

Loop of the Intestine.	<i>L. marginalis.</i>	<i>Solenavia soleniformis.</i>	<i>Physunio.</i>
(2) Second loop, passing forwards and upwards to the dorsal aspect of the visceral mass.	Course nearly straight, half the first loop in length.	Course slightly curved, about half the length of the first loop.	Course curved with convexity upward and backward, about the same length as the first loop.
(3) Third loop, passing downward and backward and lying behind the second loop.	Course like that of the second loop and slightly longer than the same.		
(4) Fourth loop, passing forward and lying beneath the posterior portion of the first loop.	Course straight, slightly upward and about half the length of the first loop, lies below the first loop.	Like <i>Lamellidens</i> but not upward (or very slightly so).	Course rather short, less than half the length of the first loop.
(5) Fifth loop, passing backward and downward. The junction between the fourth and fifth loops crossing the first loop.	Course straight, slightly shorter than the fourth loop, lying above the first loop.	Course straight, about half the length of the fourth loop, lying above the first loop.	Course about half the length of the fourth loop.
(6) Sixth loop, passing upward and forward to end in the rectum.	About the same length as the fifth loop, lying above the fifth loop.	Very short, about half the length of the fifth loop.	

(e) The *rectum* is recognised by a thick, prominent typhlosole from the ventral wall. Beginning in the visceral mass, it passes forwards and upwards to reach the space between the digestive gland and the stomach in front and the pericardial sac behind. It then passes vertically upwards and at once bends backwards to enter the pericardial chamber; it passes through the chamber, being surrounded by the ventricle, and leaves the chamber at its posterior end. Lastly, the rectum passes backwards along the dorsal aspect of the posterior adductor muscle and ends in the anus placed at the summit of a conical papilla projecting into the cloacal chamber from above the posterior adductor muscle. In *Lamellidens* the course of the rectum through the pericardial chamber is straight and horizontal; furthermore, it presents two bulb-like swellings in front of and behind the ventricle; the conical papilla is flattened from side to side and the anus is a longitudinal slit with two lateral dentate margins which ordinarily keep the aperture closed. In *Solenavia* it is similar to that in *Lamellidens* in all respects except that the swellings are absent. In *Physunio* the course through the pericardial chamber is oblique (upwards and backwards from in front) and is slightly curved posteriorly with the convexity upward after it has left the pericardium; there is no bulbous swelling in the wall and the anus is more or less rounded, being surrounded by a fringe specially prominent on the dorsal aspect.

VI. DIGESTIVE GLAND.

The *digestive gland* forms a brownish mass round the stomach; it extends above and in front from the antero-dorsal aspect of the stomach to the postero-dorsal angle of the anterior adductor muscle above the oesophagus, and above and behind from the postero-dorsal aspect of the stomach to the rectum ventrally; the gland extends from the oesophagus in front to the first loop of the intestine behind. In all species, except *Physunio ferrugineus*, the ducts of the gland are not clearly seen under a magnification of ten diameters; there are numerous tubular crypts in the wall of the stomach into which the gland seems to open. In *Physunio ferrugineus* the racemose nature of the gland is quite distinguishable under a magnification of 10 diameters, and the gland is divisible into 4 lobes—one antero-dorsal, one postero-dorsal, and 2 ventral. A long duct from each lobe is distinctly seen to open into the cavity of the stomach.

VII. VASCULAR SYSTEM.

The *vascular system* has been studied in *Lamellidens marginalis* by injecting the blood vessels with a coloured fluid through the ventricle, as living and fresh specimens are available. In other forms only the heart, the vena cava, and a few other vessels could be studied properly.

(a) PERICARDIUM.—In *Lamellidens* and *Physunio* the pericardial sac is elongately oval, with rounded ends; the sac is slightly more flattened in *Lamellidens* than in *Physunio*. In *Solenaia* the sac is narrow and elongated, the anterior end being flattened from above downwards. A distinct gap is seen between the posterior end of the pericardial sac and the dorsal aspect of the posterior adductor muscle in which the rectum is placed, being surrounded by connective tissue. In all a longitudinal fold of integument rises vertically upwards from the mid-dorsal line of the wall of the pericardium; this is only slightly marked in the case of *Lamellidens* and *Solenaia*, being more prominent in the latter behind the pericardium and over the posterior retractor and anterior half of the posterior adductor muscle. In *Physunio* this membrane is extraordinarily developed, and is prolonged as a thin median flap between the dorsal wings of the two valves. The *reno-pericardial aperture* is placed on the ventro-lateral aspect of the rectum as the latter enters the pericardial sac.

(b) HEART.—The *ventricle* in *Lamellidens* seems to be bilobed when it is fully expanded and placed in the middle of the pericardial sac (occupying about the middle-third of the entire length of the sac); it is bounded in front and behind by the bulbous swelling round the rectum. In *Physunio* the ventricle is placed close to the posterior end of the pericardial sac. In *Solenaia* it is about half the length of the pericardium and is placed in the middle of the sac.

The *auricles*, *right* and *left*, are placed at the sides of the ventricle. Each auricle in *Lamellidens* is triangular in shape, with the apex directed forwards. The outer side is attached to the conjoined margin of the inner lamella of the outer and outer lamella of the inner gill, just external to the dorsal aspect of the kidney. It is attached to the ventricle in

the middle third of its length. The auriculo-ventricular opening is a slit-like aperture guarded by 2 semilunar valves, above and below. There are 3 to 4 apertures inside the outer border of the auricle to receive blood from the efferent branchial vessel. In *Solenaria* the auricle is trapezoid in shape ; of the two parallel sides the short one is attached to the ventricle and the long one to the gills. There seems to be a single aperture to receive blood from the gills. In *Physunio* the shape of the auricles is similar to that in *Lamellidens* ; the apertures inside the outer side to receive blood from the gills are 4 or 5 (?) in number.

The following blood vessels have been traced in *Lamellidens* by injecting them with carmine (suspended in water) through the ventricle.

The *anterior aorta* passes forwards along the dorsal aspect of the rectum and reaches the posterior end of the digestive gland where it divides into right and left *viscero-pedal* arteries. Each *viscero-pedal artery* runs forward and a little outward into the substance of the superficial portion of the digestive gland, and then curving downwards and forwards gradually comes to reach the postero-ventral aspect of the anterior adductor muscle at the corner of the mouth, where it divides into two branches, *pallial* and *palpal* arteries. The *pallial artery* passes forward in the substance of the mantle-lobe along the ventral margin of the anterior adductor muscle to reach the antero-ventral angle of the latter, where it divides into two branches again : the first, the *dorsal pallial artery*, curves upwards and backwards along the anterior margin of the anterior adductor muscle (in the substance of the mantle lobe), supplying small arteries to that portion of the mantle which lies in front of the muscle and to the muscle itself ; the other, the *anterior pallial artery*, curves downwards and backwards and then runs backwards along the dorsal aspect of the thick rim of the mantle lobe, to the posterior end near the inhalent margin where it seems to divide into a net-work of capillaries ; it gives rise to numerous branches from both sides in its course along the mantle margin.

The *palpal artery* passes through the anterior lip of the mouth to the outer side and divides into *outer* and *inner* palpal branches ; the *outer* branch passes into the outer labial palp in a conspicuously sinuous course lying in the outer lamella of the two, of which each palp is composed ; the inner branch passes into the inner labial palp in a slightly undulating manner lying in the inner lamella.

The *anterior aorta* in its course through the visceral mass gives off minute branches to the stomach, and the digestive gland ; it also gives rise to a large *pedal artery* near the posterior end of the stomach.

The *pedal artery* passes downwards and forwards through the visceral mass and reaches the muscular foot at the junction of the anterior and middle thirds of its length and then passes nearly to the extreme margin ; it supplies branches to the intestine, rectum and the genital organs.

The *posterior aorta* is a very small artery arising from the ventral aspect of the posterior end of the ventricle beneath the rectum. It passes along the ventral surface of the rectum between the two posterior retractor muscles of the foot where it divides into 2 branches, one on either side. Each branch gradually passes outwards along the posterior retractor muscle and reaches the posterior surface of the posterior

adductor muscle. Each supplies the corresponding half of the posterior adductor muscle, the posterior retractor muscle of its side and the posterior portion of the rectum.

The *pallial sinus (vein)* begins in the substance of the mantle flap at the level of the inhalent aperture just behind the thick rim of the lobe. It passes upwards and forwards in a curved manner below the posterior adductor muscle and ultimately opens into the auricle of its side at the postero-external corner. This sinus is also present in the other two genera.

The *vena cava (median ventral sinus)* at first lies between the two glandular portions of the kidneys, but gradually shifts downwards in its posterior course so as to lie at the point of union of the two glandular and non-glandular sacs; the ventro-lateral wall of the vena cava on either side is perforated with a row of apertures, the openings of vessels from the wall of the glandular portion of the kidneys; they are distinctly seen under a magnification of 10 diameters. In *Solenaia* and *Physunio* the relation between the vena cava and the kidney is similar to that in *Lamellidens*. In *Lamellidens* and *Solenaia* the transverse section of the vena cava is oval, with the short diameter vertical; in *Physunio* it is also oval but with the short diameter horizontal.

The two *afferent branchial veins* lie along the line of attachment of the inner lamella of the outer and outer lamella of the inner gill—in all the three genera.

The *single afferent branchial vein* lies along the base of the inner lamella of the inner gill in all the three genera. It is interesting to note that in *Anodonta* it lies along the base of the outer lamella of the outer gill.

VIII. EXCRETORY SYSTEM.

The *kidney* is doubled on itself, as usual, and is divisible into (a) glandular and (b) non-glandular portions.

The *glandular portion* of the kidney lies beneath the non-glandular; at its anterior end it communicates with the pericardium and is separate from its fellow by a distinct interval, and further behind by the interposition of the vena cava. In *Lamellidens* the sac is flattened from above downwards in front, lying on the ventral aspect of the non-glandular sac. Then the sac becomes oval in transverse section and, lastly, towards the posterior end of the visceral mass it is twisted on itself coming to lie on the inner side of the ureter, at first obliquely (*i.e.*, with the long diameter in a section placed downwards and outwards from above) and then vertically. The vena cava is now placed beneath the pericardial sac, with a small portion of the inner wall of ureter and glandular sac laterally and further back with the glandular sac only, the ureter being displaced to the outer side.

In *Solenaia* the glandular sac is separated at first from its fellow of the opposite side by the vena cava, and behind by the foot, which intervenes between the two. The inner wall of the sac is fused with the upper portion of the side of the foot, while the non-glandular portion placed dorsally at first is displaced to the outer side.

In *Physunio* the glandular sac lies beneath the non-glandular portion in the beginning, but is gradually placed on its inner side between it

and the foot and the posterior retractor muscle of the foot of its side ; the glandular sac is comparatively wider than the non-glandular. The walls of the non-glandular sac are generally seen applied to one another.

The glandular sac ends in front of the posterior adductor muscle. The nature of the communication between the glandular and non-glandular sac is rather different in the three genera.

In *Lamellidens* the glandular sac opens into the non-glandular by means of a slit-like aperture on the dorsal aspect at its posterior end ; a pigmented sac is found at the beginning of the ureter, open in front but blind behind ; it lies on the outer side, having its outer wall fused with the outer wall of the ureter and its inner wall lying free in the cavity of the same ; the blind posterior end of the sac lies just in front of the posterior adductor muscle, the inner surface of the sac is thrown into irregular folds and gives the appearance of a broad meshed spongy structure.

In *Solenaria* the glandular portion is placed on the inner side of the non-glandular sac. Towards the posterior end of the foot we get the beginning of a canal bounded externally by the mantle, internally by the non-glandular sac, above by the pericardial chamber and below by the outer suprabranchial chamber ; the canal widens out as it passes backwards. Behind the foot it forms a big sac lying on the outer side of the glandular sac, while the non-glandular sac narrows down into a small canal lying on the outer side of the posterior retractor muscle of the foot above the canal. Further backwards, the non-glandular sac terminates in a small blind sac just in front of the posterior adductor muscle. On reaching the under surface of the posterior adductor muscle the canal comes to lie on its ventro-lateral aspect and ultimately becomes continuous with the glandular sac by the disappearance of the septum between the two. In the lumen of the canal, as it lies at the level of the posterior retractors of the foot, there is an obliquely vertical septum, attached above to the outer wall of the canal a little below the dorsal aspect, and below to the inner wall a little above the ventral aspect. The free anterior and posterior borders of the septum is deeply concave. Above the upper attachment of the septum is an elongated aperture through which the ureter communicates with the canal. A similar arrangement but rather different in details has been described in *Anodonta*.

In *Physunio* the glandular portion is placed on the inner side of the ureter behind and both are flattened from side to side and slightly curved on themselves, with the convexity outwards ; in this situation it is separated from its fellow of the opposite side by the posterior retractor muscles of the foot. The glandular sac communicates with the non-glandular by an elongated aperture on its dorsal aspect, near the posterior end. The glandular sac in this situation is divided into two portions by an oblique partition, attached on the inner side to the ventro-internal corner, on the outer side to the outer wall a little below the dorsal aspect and behind to the outer wall just in front of the posterior end of the sac ; it is free anteriorly. Of the two sacs thus formed the upper one communicates with the ureter, while the lower one ends blindly.

(b) The *non-glandular portion* passes forwards beneath the pericardial chamber. The relation of the non-glandular to the glandular sac has already been described. At the anterior end, the non-glandular sac is separated from its fellow by the vertical portion of the rectum. The excretory aperture is placed at the outer ventro-lateral aspect of the sac. The interrenal aperture is elongated in *Lamellidens* and *Solenaiia*, but is less so in *Physunio*.

IX. REPRODUCTIVE SYSTEM.

The *gonads* are placed as usual amongst the coils of the intestine and a portion of the rectum in the visceral mass. In *Lamellidens marginalis* male specimens were available. The head of the spermatozoon is rod-shaped, about thrice as long as broad, rounded anteriorly, truncate or slightly concave, and widest posteriorly; there is a slight constriction in the middle. The tail is very fine and is about 3 or 4 times as long as the head.

X. NERVOUS SYSTEM.

The position of the ganglia is practically the same as that in *Anodonta*. The ganglia and the connectives could not be dissected out in *Solenaiia*.

The *cerebro-pleural ganglion* of each side gives off (1) an *intercerebral connective* in front of the mouth, (2) a *pallial nerve* from the anterolateral aspect, (3) a *cerebro-visceral commissure* and (4) a *cerebro-pedal commissure*. No other nerve was found arising directly from the cerebro-pleural ganglion.

The *pedal ganglion*, on each side, gives off 6 *nerves from the side* and receives the *cerebro-pleural commissure*. The otocyst lies inside the pedal ganglion.

The *visceral ganglion*, on each side, receives the cerebro-visceral commissure and gives off 3 nerves, a *branchial*, a posterior *pallial nerve*, and a small nerve to the posterior adductor muscle.

In *Lamellidens* the *branchial nerve* passes along the conjoined margin of the inner lamella of the outer and the outer lamella of the inner gill. It divides into two branches, one passing along the same margin and the other along the fused margins of the inner lamellae of the inner gills. The *posterior pallial nerve* divides into 3 branches:—(1) a small nerve to the mantle-lobe which passes to the attached margin of the outer lamella of the outer gill, a little in front of its posterior end; (2) a nerve to the mantle-lobe at the posterior end of the attached outer lamella of the outer gill; (3) a nerve to that portion of the mantle-lobe which forms the lateral wall of the cloacal chamber.

The *cerebro-visceral commissures* are placed side by side between the two glandular portions of the kidneys beneath the vena cava in *Lamellidens*. They are separated from one another by the lower end of the vena cava in *Physunio*.

SUMMARY.

The anatomy of the three genera of Unionidae dealt with in this paper agrees in general structure with that of *Anodonta* and *Unio* as

already described by various malacologists. The difference observed between the three genera and others consists mainly in the relative position of the different organs, a remarkable point being the arrangement of the various loops of the intestine which are practically identical in four species described here. Further, the main differences in general structure between the three genera described here are only due to the elongation of the body in the antero-posterior direction, this being greatest in *Solenaiia* and least in *Physunio*, with *Lamellidens* occupying an intermediate position between the two. Considering the individual organs, it is important to note that in *Solenaiia* all the four gills seem to give rise to ovisacs, and the kidneys also are more complicated than in the other two, somewhat resembling those of *Anodonta*.

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