THE ANATOMY OF PHARELLA ORIENTALIS, DUNKER AND TAGELUS RUFUS, SPENGLER.

By H. H. BLOOMER.

(Plate x.)

I wish first to acknowledge my indebtedness to the director of the Natural History Department of the British Museum, Professor E. Ray Lankester, F.R.S., and to Mr. Edgar A. Smith, I.S.O., by whose courtesy I have been enabled to examine a specimen of each of the above species.

Pharella orientalis, Dunker.

External Characters.

The specimen measures 14.5 c.m. long, 4.7 c.m. deep, and along the dorsal surface is slightly curved upwards. The mantle lobes from a position over the posterior part of the anterior adductor muscle, take a deep curve and pass some distance posteriorly before their concrescence, thus the pedal aperture though lying anteriorly extends over the anterior adductor muscle, and on the ventral surface still further posteriorly. The muscles of the pallial edge (Fig. 1, *P.M.*) form a deep band, and the exterior margins of the lobes are crenulated all round them. The periostracum passes from the pallial edges to the valves of the shell and is abundant at the posterior end. The flaps on the mantle lobes bordering the pedal aperture are very narrow. There is no fourth aperture. The proximal portion of the siphon is strongly developed, while the free portions are extremely short. The tentacles bordering the siphonal openings are very long, particularly the outer ones (Fig. 1, *S.T.*), some measuring as much as 8 millim. long. The smaller tentacular fringe extends a considerable distance anteriorly along the concresced portion of the mantle lobes, both dorsally and ventrally.

The foot (Fig. 1, *F.*) is long, of a nearly uniform depth and axe-shaped at the distal end.

The retractor pedis posterior muscle (Fig. 1, *P.R.P.*) is long, thereby shortening the distance between the posterior adductor and the siphon. At the posterior end the inner parts of the bases of the gills are joined together for about only one-third of the distance between the siphon and the foot.

The labial palps are relatively short and wide, the outer ones being especially wide.

Musculature.

i. The Pallial Muscles (Fig. 1, *P.M.*).—These form a deep band round each mantle lobe, and ventrally lie chiefly at right angles to the pallial edge. They obtain their maximum thickness at the line of adhesion to the valves of the shell. At the posterior end they form the proximal siphonal portion and are much more strongly developed (Fig. 1).

The anterior adductor muscle (Fig. 1, *A.A.*) is a large and nearly circular muscular plate, joined dorsally and anteriorly with the dorsal integument and mantle lobes, and posteriorly with the foot by the muscular ventral integument.

The posterior adductor muscle (Fig. 1, *P.A.*) is a large and deep plate of muscles, curving anteriorly and posteriorly towards the flattened dorsal surface. Anteriorly it is connected with the retractor pedis posterior muscle, and posteriorly with the proximal portion of the siphon and the dorsal integument.

ii. The Pedal Muscles.—The muscular arrangement of the foot is similar to that of *Solen* and is strongly developed. The three kinds of muscles found in this genus are also present, but in *Pharella orientalis* there is a large increase in the number of rows of the transverse muscles. Briefly, on each lateral side are two groups of longitudinal muscles, and between these there is a semi-circular band passing from the dorsal to the ventral surface. Between the two inner and much larger layers of longitudinal muscles, are a number of rows of transverse muscles, the fibres of which pass through the longitudinal muscles to the semi-circular layers, and they either continue, or other muscular fibres pass from these latter through the outer longitudinal bundles to the muscular pedal integument.

The pedis retractor anterior muscles (Fig. 1, *P.R.A.*) are short and thick, and in the foot proceed mostly in a posterio-ventral direction over instead of under the longitudinal pedal muscles. There does not appear to be any bifurcation of the free portions.

The pedis retractor posterior muscle (Fig. 1, *P.R.P.*) is a comparatively long muscle, narrow at the sides and increasing in depth towards the median line. The bifurcated parts are short and connected with the posterior adductor muscle. Anteriorly the muscle continues as a portion of the longitudinal muscles of the foot.

Alimentary Canal.

The lips (Figs. 1, 2 and 3, *A.L.* and *P.L.*) formed by the union of the labial palps are wide, especially the upper or anterior one, which is of considerable width. The oesophagus (Figs. 2 and 3, *Oe.*) first runs a little dorsally, then turns posteriorly and opens into the stomach.

The stomach (Fig. 1, *St.*) is a long and irregularly shaped sac, consisting of a number of divisions which, for convenience, I have termed Anterior-oesophagael, Posterior-oesophagael, Cardiac, Central, and Pyloric.

The anterior oesophagael division (Figs. 2 and 3, *A.Oe. St.*) is long and narrow and divided from the posterior oesophagael one by a muscular ridge passing round the stomach.

The posterior oesophagael division (Figs. 2 and 3, *P. Oe. St.*) lies between the anterior oesophagael and the pyloric divisions. At its posterior end is the central division (Fig. 2, *C.D.*) bordered by a muscular ridge (Fig. 2, *C.D.R.*).

The dorsal side of this ridge is more developed and represents the muscular papilla of *Solen* (Fig. 2, *M.P.*). It separates the central from the cardiac division (Figs. 2 and 3, *C. St.*). Continuous with it is also a ridge (Fig. 2, *Oe. C.R.*) which divides the posterior oesophagael from the cardiac division. In the anterior part this muscular tissue extends right across, thus completely separating these two divisions.

The pyloric division (Figs. 2 and 3, *P. St.*) is large and occupies the whole of the posterior portion of the stomach. On the right side is a muscular ridge (Fig. 3, *P.D.R.*) running from the posterior oesophagael ridge nearly round this pyloric division. The ventral portion of the pyloric division narrows and continues as the caecum of the crystalline style (Figs. 1, 2, and 3, *C.C.*). The caecum is very long and large. It first passes ventrally, then curving, extends a considerable distance along the pedal cavity.

The intestine (Figs. 1 and 3, *In.*) leaves the ventral surface of the left anterior part of the pyloric division, the typhlosole commences, and the intestine proceeds first a little anteriorly, curves, and goes ventrally running just anterior to the caecum of the crystalline style, from which it is separated by a row of transverse muscles. It then turns anteriorly and forms a number of large folds, in the last of which the typhlosole disappears and the intestine proceeds posteriorly, passing over the right side of the caecum, then going dorsally, passes in a large loop over the posterior part of the pyloric division, and turning posteriorly continues as the rectum (Fig. I, *R.*). It is shortly afterwards encircled by the ventricle (Fig. I, *V.*), then passes over the posterior adductor muscle into the exhalent siphonal chamber, terminating in a bi-lobed anus (Fig. I, *A.*).

The liver (Fig. I, *L.*) lies laterally, ventrally, and partly dorsally around the stomach. The large bile duct enters on the ventral surface of the posterior oesophagael division and the smaller bile duct into the central division.

Circulatory System.

Apparently closely resembles that of *Solen*.

As regards the gill structure, Dr. Ridewood[1] states:—"In the five species of *Solen* examined the lamellæ are heterorhabdic and plicate, the plication being shallower in *Solen orientalis* than in the others. The numbers of filaments in a plica are nearly the same in the two demi-

1. Phil. Trans. Roy. Soc., 1903 (ser. B), vol. 195, pp. 147-284.

branchs and run approximately 26 in *Solen vagina*, 17 in *Solen ensis*, 12 in *Solen fonesi*, 22 in *Solen* (*Solena*) *rudis* and 16 in *Solen* (*Pharella*) *orientalis*. . . . . The two or three filaments at the apex of the plica are enlarged in *Solen fonesi* and *Solen orientalis*. . . . . In *Solen orientalis* there is every gradation from a shallow frontal groove to a shallow frontal ridge, even in filaments cut at the same horizontal level. In all five cases the frontal groove disappears at the ventral edge of the demibranch, where the principal filament presents a distinct frontal ridge."

Nervous System.

The cerebro-pleural ganglia lie lateral to the mouth, under the retractor pedis anterior muscles, and between them and the ventral integument. The commissure connecting the two ganglia goes in front of the mouth. Each ganglion apparently gives rise to only one anterior nerve, the anterior pallial nerve, which passes gradually outward to the posterio-ventral edge of the anterior adductor muscle, but divides shortly before reaching it, the inner branch going underneath and innervating the muscle, the outer one passing across the mantle lobe and again dividing, the anterior part once more proceeds and divides; both branches join the outer circumpallial nerve, while the posterior part goes posteriorly as the inner circumpallial nerve.

Posteriorly each cerebro-pleural ganglion communicates with the viscero-parietal ganglion by a connective. The connective first proceeds between the retractor pedis anterior muscle, and the pedal wall, then emerging, runs between the latter and the viscera, and, reaching the anterior portion of the retractor pedis posterior muscle, passes through the pedal integument to the lateral surface of the muscle and then underneath to the viscero-parietal ganglion.

The cerebro-pedal connective leaves the cerebro-pleural ganglion on the inner side of the cerebro-visceral connective, and passing partly through and then along the pedal muscles, gives off a nerve to the viscera and afterwards joins the pedal ganglion.

The pedal ganglia are situated in the centre of the foot, midway between the dorsal and ventral surfaces, just over the anterior end of the anterior folds of the intestine. The ganglia give off on each side a number of nerves which innervate the foot.

The viscero-parietal ganglia are situated under the posterior adductor muscle. From each ganglion arises a branchial nerve which first goes some distance anteriorly and curving outwards passes to the gills. Posteriorly each viscera-parietal ganglion gives off a nerve, the posterior pallial nerve. It passes latero-posteriorly across and under the posterior adductor muscles, then there arises from it a nerve which crosses the mantle lobe and joins the inner circumpallial nerve, and afterwards the outer circumpallial nerve. The main nerve goes along the proximal

portion of the siphon, innervating it and the dorsal integument, and apparently joining the outer circumpallial nerve.

Tagelus rufus, Spengler.

External Characters.

The specimen measures 5.7 c.m. long and 2 c.m. deep. The mantle lobes (Fig. 4, *M.L.*), which take a slight curve forwardly from the anterior margin of the anterior adductor muscle, are not concresced along their ventral surface, but are joined together below the extreme siphonal end by a round transverse muscle (Fig. 4, *M.C.*), the ends adhering to the valves of the shell, and thus resembling the adductor muscles, consequently the pedal aperture extends from the anterior adductor muscle to the siphon. There is no fourth aperture. At the posterior end the mantle lobes proceed some distance beyond the proximal portion of the siphon, giving off close to their posterior edges lateral processes (Fig. 4, *P.L.P.*) which encircle and are connected, with the siphon, thus completely enclosing the posterior end of the pallial chamber.

The teeth of the shell are not very prominent, and do not penetrate into the viscera as in *S. strigillatus*. The proximal portion of the siphon is short, while the free portions (Fig. 4, *In. I'.* and *Ex. S'.*) are of considerable length, the exhalent being longer than the inhalent one, but the openings by which they communicate with the pallial chamber are small. Large siphonal retractor muscles (Fig. 4, *S.R.M.*) are present and from a large surface adhere to the valves of the shell. The edges of the mantle lobes and the siphon are not characterised by carrying a tentacular fringe. The foot (Fig. 4, *F.*) is large, comparatively short, and very deep. The inner parts of the bases of the gills are joined together.

Musculature.

i. Pallial Muscles.—The muscles of the pallial edge commence at the anterior adductor muscle as a deep band. This band, after taking a slight curve, anteriorly, passes posteriorly and gradually decreases in depth until it reaches the proximal siphonal end, where the two mantle lobes are joined together by a round transverse muscle, the musculus cruciformis (Fig. 4, *M.C.*) described by von Ihering [2], and stated by him as being an important character of the super-family *Tellinacea*, confirming the views of Dall. He believes this cruciform muscle is a special development of the fibres of the mantle edge, and functionally may serve as a secondary adductor.

The siphonal retractor muscles (Fig. 4., *S.R.M.*) run a short distance anteriorly along the mantle lobes, they pass through them, and spreading

2. Proc. Acad. Nat. Sci. Philad., 1900, pp. 480, 481, 2 figs.

out dorsally and ventrally, extend in a deep semi-circular direction, forming large surfaces from which they adhere to the valves of the shell.

The anterior adductor muscle (Fig. 4, *A.A.*) is a plate of muscles of greater length than depth, and divided into two unequal parts by the ventral integument passing between them to the dorsal surface. Anteriorly the muscle is connected with the mantle lobes, and posteriorly with the pedal and the dorsal integument.

The posterior adductor (Fig. 4, *P.A.*) muscle is a deep plate of muscles flattened anteriorly, and from this side is joined with the bifurcated parts of the retractor pedis posterior muscle and dorsal integument, and at the posterior side with the proximal portion of the siphon, the *dorsal integument and the mantle lobes.*

The pedis retractor anterior muscles (Fig. 4, *P.R.A.*) run ventrally, apparently over the longitudinal pedal muscles. There is no bifurcation of their free parts.

The pedis retractor posterior muscle (Fig. 4, *P.R.P.*) is very narrow and of considerable length, the posterior parts of the bifurcated portions being connected with the posterior adductor muscle.

From the specimen examined it was not possible to trace the pedis elevator or branchial retractor muscles, present in *S. strigillatus.*

Alimentary Canal.

The lips (Figs. 5 and 6, *A.L.* and *P.L.*) formed by the junction of the labial palps, point anteriorly. The oesophagus (Figs. 5 and 6, *Oe.*) is very short, it passes posteriorly and soon opens into the stomach. In shape the stomach (Fig. 4, *St.*), though similar to that of *S. strigillatus*, [3] is longer, shallower, and the divisions are not so pronounced. I have, however, used the same terminology for the respective divisions. In the left part of the stomach and anterior to the centre lies the central division (Fig. 5, *C.D.*), bordered by a muscular ridge (Fig. 5, *C.D.R.*), which on its dorsal side is developed into a muscular papilla (Fig. 5, *M.P.*). From this central ridge, proceeds another one (Figs. 5 and 6, *A.D.R.*) which separates the dorso-central from the anterior division, then passing around the stomach in an irregular manner, divides the anterior from the posterior division.

The anterior (Figs. 5 and 6, *A.D. St.*) is larger than the posterior division (Figs. 5 and 6, *P.D. St.*), and its dorsal surface consists of a very muscular layer. The dorso-central division (Fig. 5, *D.D.*) is shallower and not so readily distinguished. The posterior division (Figs. 5 and 6, *P.D. St.*) is larger, depressed dorsally, and deeper at the posterior end.

From its ventral surface proceeds the caecum of the crystalline style (Figs. 5 and 6, *C.C.*), which goes ventrally, then curving terminates near the dorsal surface of the pedal cavity. As in *S. strigillatus* the intestine

3. Journ. Malac., 1903, vol. x, p. 36,

(Fig. 5, *In.*) is only partly separated from the caecum and appears as an irregular groove on the side of the latter. Near the distal end of the caecum the intestinal walls unite, thus completely enclosing it. The intestine (Fig. 4, *In.*) returns along the dorsal surface, and becoming free passes to the posterior part of the proximal portion of the foot, and makes a large number of folds (Fig. 4, *F.In.*) at and over the posterior division, then turning posteriorly continues as the rectum (Fig. 4. *R.*). It passes round the posterior adductor muscle, and on the posterio-ventral surface ends at the anus (Fig. 4, *A.*). The liver (Fig. 4, *L.*) surrounds the anterior portion of the stomach with a considerable part lying underneath it. The large bile duct enters on the ventral surface of the anterior division, just in front of the intestine, and the smaller bile duct into the central division.

Circulatory System.

The circulatory system generally resembles that of *S. strigillatus.*

As regards the structure of the gills, Dr. Ridewood remarks [4]:

"The gills of the three species of *Solenocurtus* examined agree tolerably closely in their general structure. The lamellæ are highly plicate, the plicæ being flattened antero-posteriorly so as to resemble the leaves of a book. The number of filaments in a plica are about 30 in the outer and 40 in the inner demibranch in *Solenocurtus strigillatus*, and *Solenocurtus* (*Tagelus*) *rufus*, while in *Solenocurtus* (*Macha*) *philippinarum* the numbers are about 24 and 30. In *Solenocurtus rufus* all the interlamellar septa rise high up the demibranch but in the other two species alternate septa are of small vertical extent. *Solenocurtus rufus* also has in the apex of the plica, a blood tube which is not noticeable in the other two."

Nervous System.

The nervous system is very similar to that of *S. strigillatus*, the chief differences being in *T. rufus*, a smaller number of branches of the posterior pallial nerves and more particularly the absence of the large ones crossing the siphonal retractor muscles.

Reference Letters.

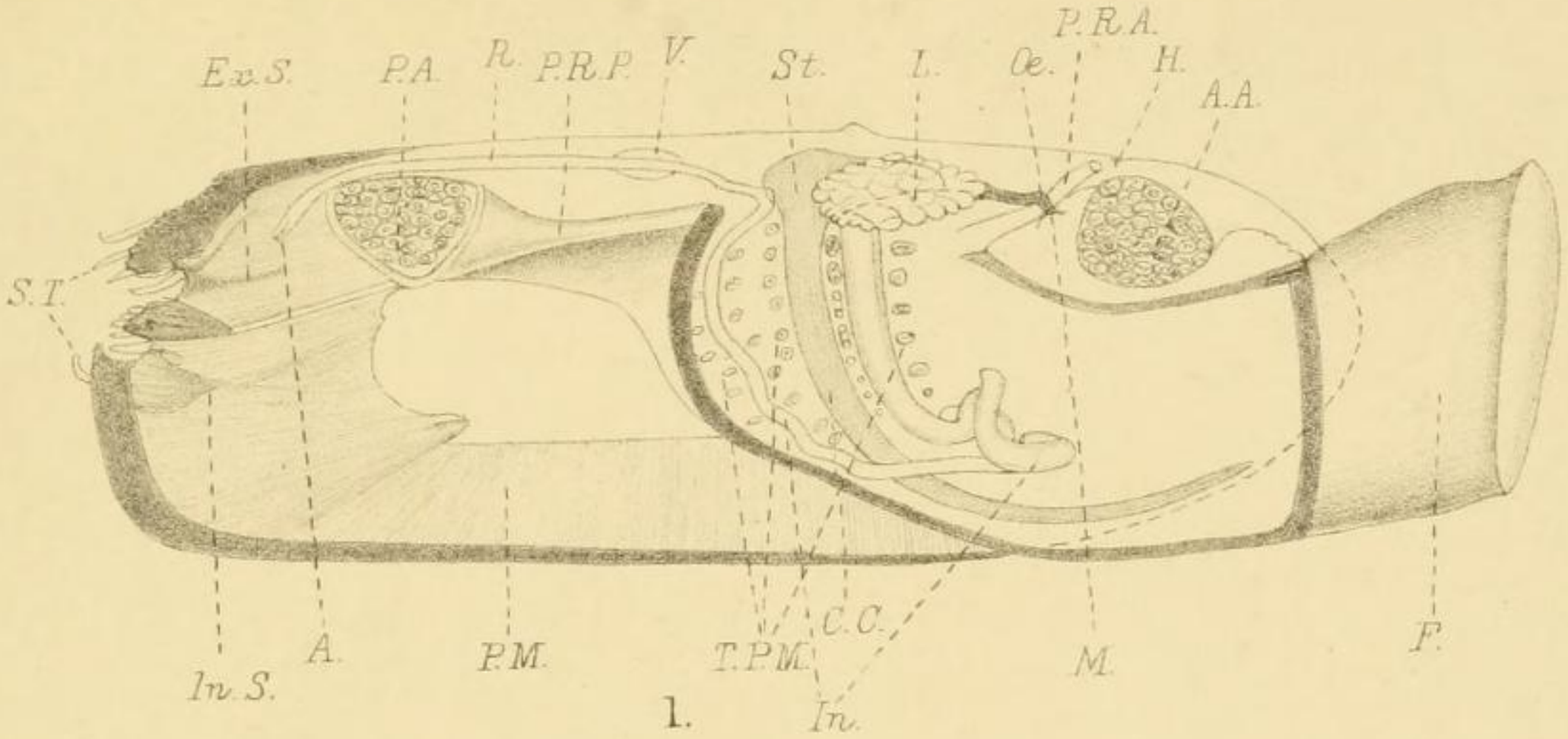
A. Anus.
A.A. Anterior adductor muscle.
A.L. Anterior or upper lip.
A,D.R. Ridge separating the anterior from the other portion of the stomach.
A.D.St. Anterior division of the stomach.
A.Oe.St. Anterior oesophagael division of the stomach.
C.C. Caecum of the crystalline style.
C.D.R. Muscular ridge bordering the central division of the stomach.
C.D. Central division of the stomach.
C.St. Cardiac division of the stomach.

4. *Op. cit.*

D.D. Dorso-central division of the stomach.
Ex.S. Proximal portion of the exhalent siphonal chamber.
Ex.S'. Free portion of the exhalent siphonal chamber.
F. Foot.
F.In. Folded portion of the intestine
H. Point where the dorsal integument is connected with the teeth of the shell.
In. Intestine.
In.S. Proximal portion of the inhalent siphonal chamber.
In.S'. Free portion of the inhalent siphonal chamber.
L. Liver.
M. Mouth.
M.C. Musculus cruciformis, a transverse muscle, situated ventrally to the siphon.
M.P. Developed portion of the muscular ridge, representing the muscular papilla of *Solen*.
M.L. Left mantle lobe.
Oe. Oesophagus.
Oe.C.R. Ridge dividing the posterior oesophagael from the cardiac portion of the stomach.
P.A. Posterior adductor muscle.
P.D.St. Posterior division of the stomach.
P.L. Posterior or lower lip.
P.M. Muscles of the pallial edge.
P.D.R. Muscular ridge of the stomach running from the oesophagael ridge nearly around the pyloric division.
P.L.P. Lateral processes from the posterior edges of the mantle lobes, which encircle and are connected with the siphon.
P.Oe.St. Posterior oesophagael division of the stomach.
P.R.A. Retractor pedis anterior muscle.
P.R.P. Retractor pedis posterior muscle.
P.St. Pyloric division of the stomach.
R. Rectum.
S.T. Tentacles bordering the siphonal apertures.
St. Stomach.
S.R.M. Siphonal retractor muscle.
T.P.M. Transverse pedal muscles.
V. Ventricle.

EXPLANATION OF PLATE X.

Fig. 1. *Pharella orientalis*, Dunker. View from the right side, showing the alimentary canal, &c., × $\frac{2}{3}$.
Fig. 2. *Pharella orientalis*, Dunker. Longitudinal section of the stomach, showing the internal structure of the left side. × $1\frac{1}{2}$.
Fig. 3. *Pharella orientalis*, Dunker. Longitudinal section of the stomach, showing the internal structure of the right side. × $1\frac{1}{2}$.
Fig. 4. *Tagelus rufus*, Spengler. View from the right side, showing the alimentary Canal, &c. × $1\frac{1}{2}$.
Fig. 5. *Tagelus rufus*, Spengler. Longitudinal section of the stomach, showing the internal structure of the left side. × 2.
Fig. 6. *Tagelus rufus*, Spengler. Longitudinal section of the stomach, showing the internal structure of the right side. × 2.



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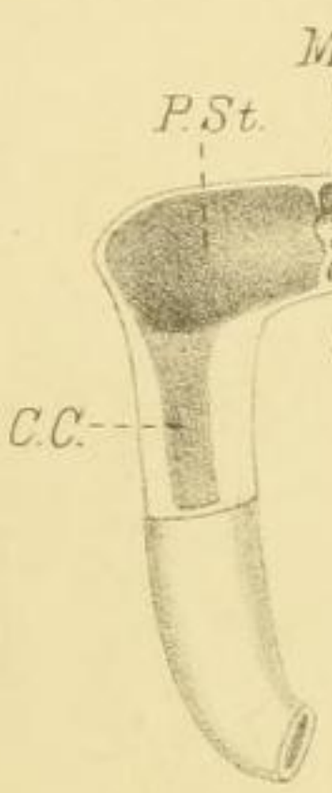

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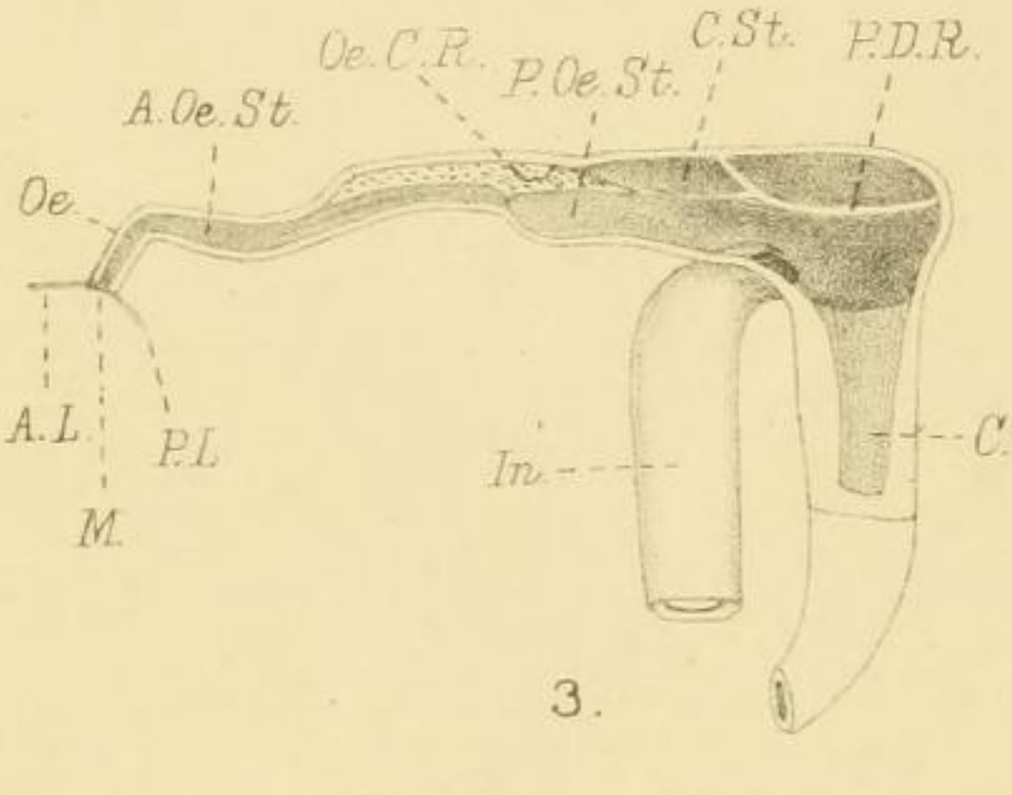

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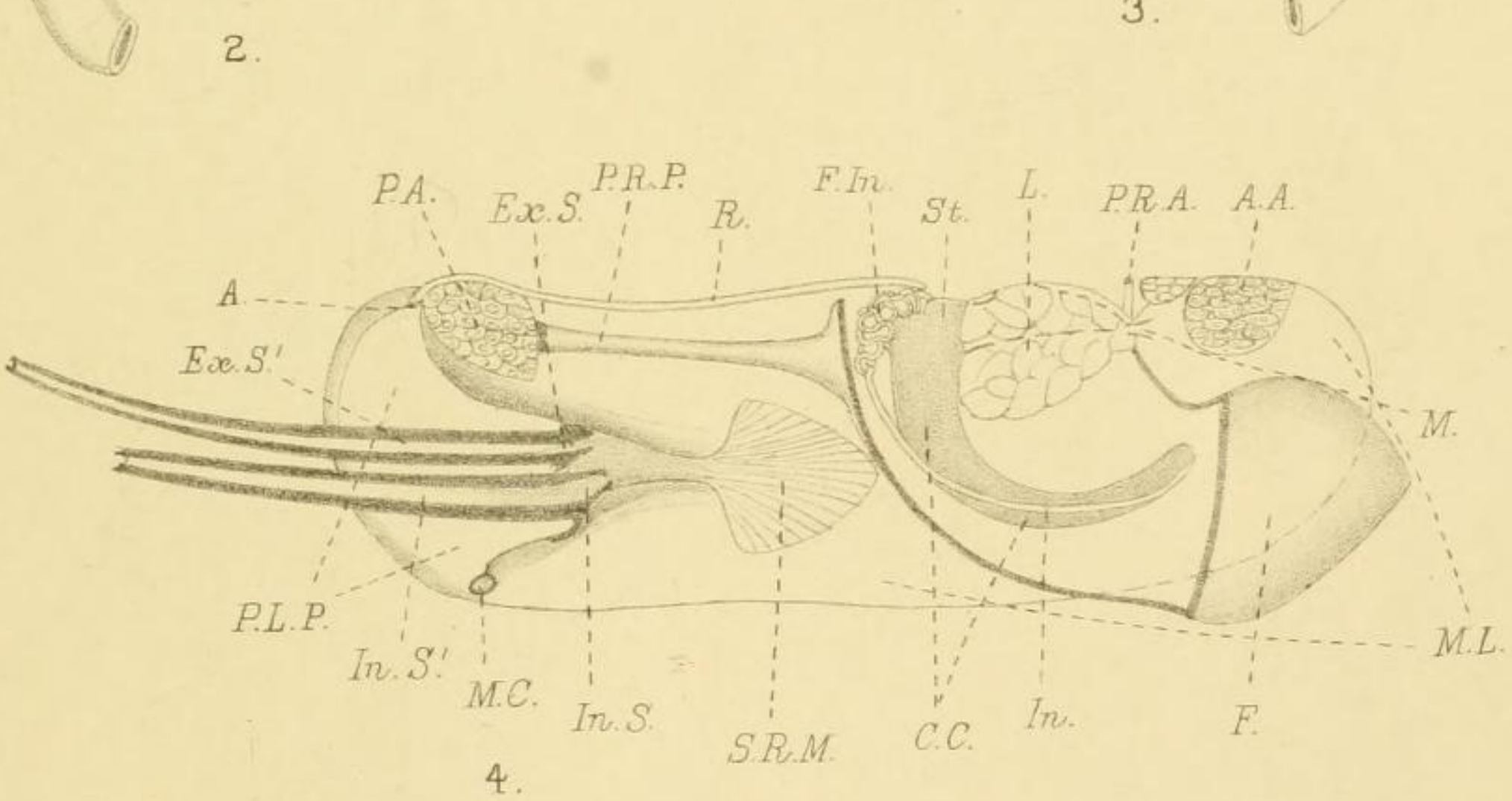

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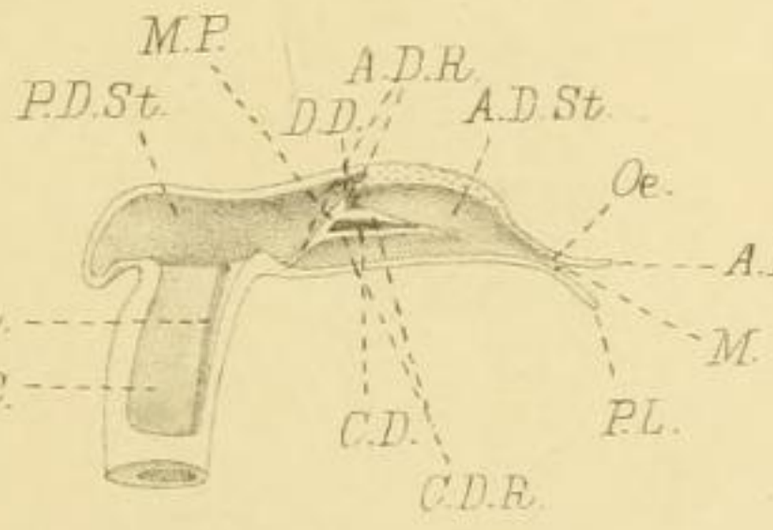

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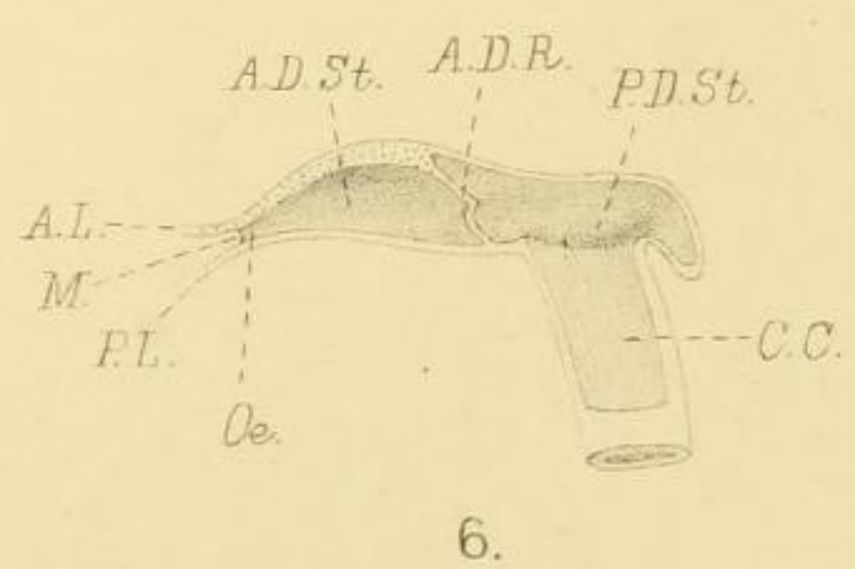

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ANATOMY OF PHARELLA & TAGELUS.