THE ALIMENTARY CANAL OF THE MEXICAN BEAN BEETLE.

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INTRODUCTION.

The Mexican Bean Beetle, *Epilachna corrupta* Muls., is entirely a plant feeder, living usually on the leaves of garden and field beans. Its feeding habit differs in this respect from most other coccinellids, which (except for a few species), are predaceous on other insects.

Data concerning the economic importance, distribution, life history, habits, and control of the Mexican bean beetle have been published elsewhere by a number of writers, but no information concerning the internal anatomy was available. This work was undertaken because of the author's desire to become better acquainted with the internal structure.

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THE GROSS ANATOMY.

The alimentary canal is shown in Figure 1. It is a more or less simple tube running from the mouth to the anus. The canal has three, well-defined, primary divisions. These are the fore-intestine, mid-intestine and hind-intestine. The canal of the beetle is three times the length of the beetle, while the canal of the larva is nearly twice the length of the larva.

The fore-intestine is very short, extending back only as far as the first thoracic segment. It consists of a short pharynx, a short oesophagus, and a short, somewhat thin-walled crop. The oesophagus is slightly greater in diameter than the pharynx.

The mid-intestine or ventriculus is divided into what is known as the first and second divisions of the ventriculus. The first division runs from the first segment to the fifth segment in the form of a nearly straight tube of uniform diameter. At the fifth segment there is a slight constriction. From here the second division begins in the form of a tube one-third less in diameter than the first division, but twice the length of the first division. During its course it twice coils back on itself.

The hind-intestine, which is composed of three regions, starts at about the beginning of the eighth segment where it joins the mid-intestine slightly at an angle. The six malpighian vessels arise near

the point of union, and after a more or less lengthy course through the body cavity, they enter the large intestine at a point just behind where the ileum (first division) joins the colon (second division). The ileum is small, short and somewhat twisted.

The ileum attaches to the colon on the right side of the body at the beginning of the ninth segment. From this point the colon gradually enlarges as it bends back towards the meson, dorsad of the ileum. The diameter of the colon (including the peritoneal sheath that surrounds it) is nearly twice the diameter of the ileum and almost exactly twice the diameter of the rectum. The colon passes directly into the rectum (third division), which is only one short segment in length. The rectum is surrounded by well developed circular muscles, inside of which are eight epithelial folds bordered with intima which nearly fills the lumen. The excrement is always fluid-like and a large open passage would probably not be necessary.

Larva and Adult.

The histological nature of the digestive tract of the larva is very similar to that of the adult. The discussion given in this treatise is concerned with the adult. However, mention is made of the larva in places where the difference in the two is most noticeable.

The Histology of the Alimentary Canal.

THE FORE-INTESTINE.

Proportionately the pharynx is very short. The histological nature of the pharynx and oesophagus is almost identical in regards to the type of intima and epithelium. The epithelium is more simple and is not thrown into folds as is the case with the oesophagus. Epithelium cells of this region are slightly smaller and more irregular than in the oesophagus. The diameter of the oesophagus is only slightly greater than that of the pharynx while the diameter of the mid-gut is about three times as great as the diameter of the oesophagus. See Figure 5.

Intima of the oesophagus is only moderately well developed, and seems to be thrown into a series of longitudinal folds, usually four in number. The primary intima is very thin and stains slightly with eosin. The teeth are backward pointed and rather strong at the anterior end of this region, but disappear at the posterior end, and are here replaced by rather blunt projections and depressions in the folds of intima.

The epithelial cells of the oesophagus are small and irregular, and the cell divisions are not always clear. The nuclei stain rather dark. The cytoplasm is non-vascular, non-granular, and homogenous. A cross section through the oesophagus is shown in Figure 3.

The basement membrane is not clearly distinguishable in all the sections.

About fifteen longitudinal muscle fibers occur between the circular muscle layer and the basement membrane. They are inserted in the intima near the posterior end of the pharynx. From here they continue through the fore-intestine, the mid-intestine, and a part of the hind-intestine.

The longitudinal muscles of the fore-gut and circular muscles of the mid-gut lie snugly against the basement membrane, and are not very strongly developed except at the oesophageal valve.

The crop is not so well developed in *Epilachna corrupta*. See Figure 5, C.

The oesophageal valve, as in similar cases among insects, is a large fold of the fore-intestine, projecting into the mid-intestine, nearly closing the passage between them. Unlike the alder flea beetle (Woods, 1918) in this respect, the oesophageal valve of the bean beetle is rather large, with bulb-like folds, which are well developed. See Figures 4 and 5.

The intima is very thick towards the oesophagus, but becomes gradually thinner as one passes towards the mid-intestine, finally disappearing at a point immediately behind the top of the two folds which form the valve. The intima (chitin) on the folds has a somewhat bluntly-jagged or dull, toothed appearance.

The peritrophic membrane is secreted by the digestive epithelium on the posterior side of the oesophagael valve. This is a delicate structureless membrane, which is found in the lumen of the mid-intestine and the hind-intestine, lying between the food and the delicate epithelium. It protects the latter from injury from sharp food particles. Digestive juices secreted behind this membrane probably pass through it by osmosis.

A striated border in this region of the mid-intestine is seldom visible, and is never well developed.

The epithelial cells of the fore-gut in the anterior face of the oesophageal valve become cuboidal, then slightly more columnar, narrower, more elongate, and gradually change to the type more characteristic of the mid-gut.

On the posterior face of the oesophageal valve the cells are very long, narrow and crowded. They have small, oval nuclei which contain small, usually well separated chromatin granules. The layer of cells are arranged in such a way that they appear as being in more than one irregular layer, closely wedged together. The epithelium of the two oesophageal valve folds, particularly on the posterior side, stains rather dark. On the posterior face of the valve folds the cytoplasm granules are fine and dense.

The basement membrane is continuous from the fore-intestine to the mid-intestine.

The longitudinal muscle fibres are continuous from the fore-gut to the mid-gut. They are internal in the fore-gut and external in the mid-gut. The fibres evidently divide into two or three upon leaving the oesophageal valve since from a dozen to about fifteen medium-large fibres are found in the fore-gut, while from thirty-six to forty small fibres are observed in sections made through the mid-gut. All the fibres of the fore-intestine are larger than those of the mid-intestine.

THE MID-INTESTINE.

First Division of the Ventriculus.

A striated border is not clearly distinguishable in the anterior region of this division in *Epilachna corrupta*, but a rather thin striated

border is found towards the posterior end of this region. This condition is possibly due to the glandular nature of the cells in this vicinity and will be discussed later. The striæ are close together and not always clearly separated from the cytoplasm anteriorly.

The epithelium is of the columnar type and the cells are well defined. The cells of the anterior part of this region are long and medium wide, but may vary some in the same insect. In the anterior part of this same region, immediately behind the oesophageal valve, are found six to eight deep pits or annular folds, and it is from these pits that most of the secretion in this region comes. These annular pits or pouches may extend entirely around the intestine, and are found throughout the first one-third of the first division of the ventriculus, and can be seen in dissection. The epithelium of the posterior end of this division is not replaced by typical nests, but instead has embryonic cells scattered along the basement membrane at the base of the epithelium. The same conditions occurs in the larva. The nuclei are rather large, round, and usually medium in position except when the cell contents are being discharged. The cells are about four to five times as high as they are wide, depending upon their physiological condition. Cells at the anterior end of this division are much higher than those near the posterior end. In the resting state the cytoplasm becomes charged with vacuoles, which pass to the outer margin of the cells. A very thin basement membrane is present. See Figures 5 and 6.

Small, thin, striated circular muscle fibres surround the mid-intestine. The fibres are branched. They usually appear as one delicate muscular layer. This layer is outside the longitudinal muscles in the fore-gut and inside the longitudunal muscles in the mid-gut. Approximately thirty-six longitudinal branched muscle fibres lie outside the circular muscle layer. They become smaller towards the posterior end of the mid-gut.

The Second Division of the Ventriculus.

The striated border is not very well developed in this region. It shows more clearly at the posterior end of the first division of the ventriculus, but apparently it continues throughout the mid-gut with different degrees of development. The striæ do not seem to be clearly separated from the cytoplasm in this portion of the ventriculus. See Figures 9 and 10.

The epithelial cells are much longer and narrower than those of the first region. Often they nearly fill the lumen. They are not equal and straight as in the case with the posterior end of the first mid-gut division. The free ends of these cells are irregular to oval in shape. The secretions are more active here than in the preceding region. The cytoplasmic balls are very granular and stain a light pink with eosin. See Figure 8.

Discharged cells are replaced from nidi or nests of embryonic cells which lie on the basement membrane. The number of nests in a single section is from fifteen to twenty-five. Usually each nest contains from three to twelve nuclei. Usually these nidi are inside the circular muscles. However, some sections indicate that under certain conditions some of the nests lie outside the muscle layer.

Immediately preceding the transition to the hind intestine, the cells of the mid-intestine become smaller, more numerous and irregular. Small nests or nidi also become more prevalent. At the extreme end of the mid-intestine the cells lose their columnar structure, the cell divisions become very indistinct, and the replacement cells are close together and abundant. See Figures 12 and 13.

The basement membrane is of the same nature as in the former division.

Both circular muscle fibers and longitudinal fibers are of the same nature as in the preceding region.

THE HIND-INTESTINE.

No typical pyloric valve occurs in the gut of *Epilachna corrupta*. However, immediately behind the malpighian vessels the lumen of the ileum is very small, the intima smooth, and the epithelium nearly equal and straight, instead of being irregular or thrown into folds. Epithelial cells at this point are small and cubical with indistinct walls. The nuclei stain very distinctly. There are several compact, thick, interlacing circular muscle layers surrounding and fitting closely against the basement membrane, around the entire circumference of the intestine. Figures 11 and 14 show this condition.

The Proximal Portion of the Ileum.

The striated border of the mid-intestine stops entirely with the end of the mid-intestinal epithelium, and is here replaced by a layer of intima. Immediately behind the pyloric valve (Figure 15) there occurs a very thin primary layer of fine hair-like or cillia-like intima. The secondary intima is also thin but is solid and much thicker than the primary intima.

The epithelial cells of the hind-gut are at first narrow, but become wider and higher, and shortly merge into an epithelium typical of the middle portion of the ileum. The cytoplasm is slightly vascular, very fibrillar, non-vesicular, and homogenous. The epithelium is thrown into six large wavy folds, and is composed of slightly triangular to oblong cells, which are higher than they are wide. They are smaller than those of the distal ileum and do not have clearly distinguishable cell walls. The nuclei are round, chromatic, and full of densely packed granules.

The proximal portion of the ileum discussed here is very short and extends not more than a hundred micra caudad of the pyloric valve. See Figure 15.

The basement membrane is thin but is always present, it is continuous from one region to another, and clearly defined.

There are about fifteen to twenty longitudinal muscles fibers, which lie among connective tissue between the basement membrane and the circular muscles. Posteriorly they are probably inserted on the intima towards the distal portion of the ileum. There are usually three layers of circular muscle fibers which lie outside the longitudinal fibers. These fibers are well developed and about twice as thick as the mid-intestinal fibers.

The Distal Portion of the Ileum.

In the distal portion of the ileum all layers present are continuous with those of the proximal ileum.

A very narrow, irregular, tooth-like intima borders the epithelium. This intima is very thin and only appears as one (or primary intima). It becomes gradually thinner throughout this region.

The epithelium of this region is composed of medium-sized, irregularly cuboidal cells, whose cell walls are very distinct. The nuclei are medium large and may be round or oval in outline. They contain large, distinct, chromatic granules, especially in the center. The epithelium is often thrown into acute folds, but this varies in the different specimens. The folds are typically six in number. A very thin clearly distinguishable basement membrane is present. See Figure 16.

The longitudinal muscle fibers are continuous anteriorly with those of the distal-mid-intestine and end a little before reaching this region. They begin at the anterior end of the pharynx, are internal in the foregut, external in the mid-gut, and internal in the hind-gut (ileum). They are internal in the proximal region and end before reaching the distal end of the ileum. Circular muscle fibers are well developed, and as elsewhere, are striated. They are continuous anteriorly with those of the proximal section of the ileum, and posteriorly with those of the colon.

The Colon.

At the transition point or union the canal bends caudad but at this point there is practically no difference between the epithelium of the ileum as compared with that of the colon. The intima, basement membrane, and circualr muscles are continuous, while the longitudinal muscles of the ileum disappear entirely.

The intima is slightly thicker here than it was in the region just discussed, and a primary and secondary intima can be distinguished. In nearly all of the cases where the intima of the hind-gut is discussed by writers working on other Coleoptera, the intima is described by them as thicker than is in the case with the Mexican Bean Beetle. In this insect the primary intima appears only as a thin line. The secondary intima is clear and does not stain with eosin or with Delafield's haematoxylin.

In following the course of the colon towards the rectum the epithelial cells gradually become flatter and flatter. This change begins with the association of the malpighian vessels with the walls of the intestine. The epithelial cells of the distal portion of the colon are about one-third as high as those of the ileum. and are not quite as wide. The cytoplasm is of the same structure throughout, resembling very closely that of the preceding region. The nuclei are oval, and about the same size as those of the ileum, but the chromatic granules are slightly larger and fewer in number. Some of the cell divisions are clear, while some are not. Probably this is due to fixation. The epithelium is usually thrown into six acute folds which project into the lumen. See Figure 17. The basement membrane is always very thin and is not always distinct.

The circular layer of muscle fibers of the pyloric valve, ileum, and anterior part of the colon are well developed, but the fibers grow weaker and weaker as one traces them towards the rectum. They do not disappear, however, until the end of this region is reached. They are continuous with the circular muscles of the preceding region, where the most posterior muscle is inserted in the intima of the colon.

The Malpighian Vessels.

The malpighian vessels of the Mexican bean beetle are six in number, and constitute a single series, arising stysematically like six spokes on an axle. They begin at the junction of the mid-gut and the hind-gut and go anteriorly through the vicinity of the second division of the ventriculus (where they are very much coiled), and then closely appress the walls of the first division of the ventriculus as far as the crop (which is located in the prothorax). From this point they double back on themselves, and pass through the body cavity in close proximity to the intestine as far caudad as the rectum. At this point they again turn back on themselves until they reach the junction of the ileum and the colon, where three vessels enter the colon on each side very close together. They enter as six vessels, then divide, and re-divide, finally ramifying at the posterior end of the colon. A cross section made through the anterior end of the colon shows six small, circular vessels, while sections made through the posterior end of the colon may show as many as sixteen large irregularly shaped vessels.

The malpighian vessels are slightly larger along the vicinity of the ventriculus, but grow rather small a short distance before they enter the colon, and remain in this condition for a short distance after entering, then enlarge again towards the posterior end of this region. The vessels are of a thin, opaque-white color. See Figure 19.

The malpighian vessels in the body cavity are elliptical to circular in shape. They are covered interiorly by a lightly staining striated border. The striæ are pointed at the free ends, but wider at their bases. The cytoplasm stains a violet pink with eosin, is very granular, and presents a fibrillar aspect. The nucleus, which is proportionately large, varies in shape from elliptical to round, and is typically basal to central in position. The chromatic granules are large and usually well separated. There are four cells in a typical cross section. The malpighian cells of the free tubules have a distinct and well-developed basement membrane. There is no indication of a thin, delicate, irregular, lightly straining fibrillar area just inside the basement membrane as is the case with the cells of the distal portion of the tubules. A malpighian vessel, greatly enlarged, is shown in Figure 20.

The malpighian vessels are closely associated with the circular muscle layer of the colon. Their peritoneal sheaths grow out and join, so that a continuous nucleated peritoneal sheath is formed, which completely surrounds the colon enclosing the malpighian vessels. The vessels do not extend along the wall of the rectum, but instead they terminate blindly at the extreme posterior end of the large intestine. See Figure 17.

The Rectum.

The transition between the colon and the rectum is the most abrupt in the whole course of the alimentary canal. New circular muscles suddenly appear and the malpighian vessels and nucleated peritoneal sheath end abruptly. The epithelial cells of the colon become flatter and flatter, and the cell boundaries more and more distinct near the rectum; but this type changes very quickly to the glandular eosinophile cells, characteristic of the rectum. The rectum is very short and is only one-half the diameter of the colon.

There are at first more or less small, smooth, wavy folds in the intima and epithelium, but as one proceeds caudad these folds become more and more pronounced, and more tooth-like in shape, while the lumen becomes smaller. Probably the typical number of folds is six but as they are very irregular the number is often eight. The intima of this region is thicker, more jagged-like and more irregular than that of the colon. As expected, the primary and secondary intima are continuous with the primary and secondary cuticle of the body wall.

The cells of the epithelium are about one-half the size of those in the preceding region, but the cell divisions are not always clear. The epithelium cells are very thin, irregular in shape, and stretched out. At the bases of the folds, the cells are not clearly defined and often seem to be wanting. The cytoplasm is smooth and non-granular, while the nuclei are smaller than those of the ileum and colon, and are less chromatic. As one passes caudad, the epithelium becomes more and more glandular andcontinues out into the hypodermis of the body-wall. See Figure 18.

The basement membrane is continuous throughout the rectum as well as being continuous with the basement membrane of the body wall. In this region it is clear and well-defined.

There are several layers (usually three) of circular muscles that go around the rectum. They are striated and well-developed. These muscles are inserted on the cuticula around the proctodeal invagination. Each layer is attached independently of the other layers. There are no longitudinal muscles in the rectum of the Mexican bean beetle, neither internally nor externally.

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EXPLANATION OF THE PLATES.

All figures of adult except Fig. 7.

PLATE I.

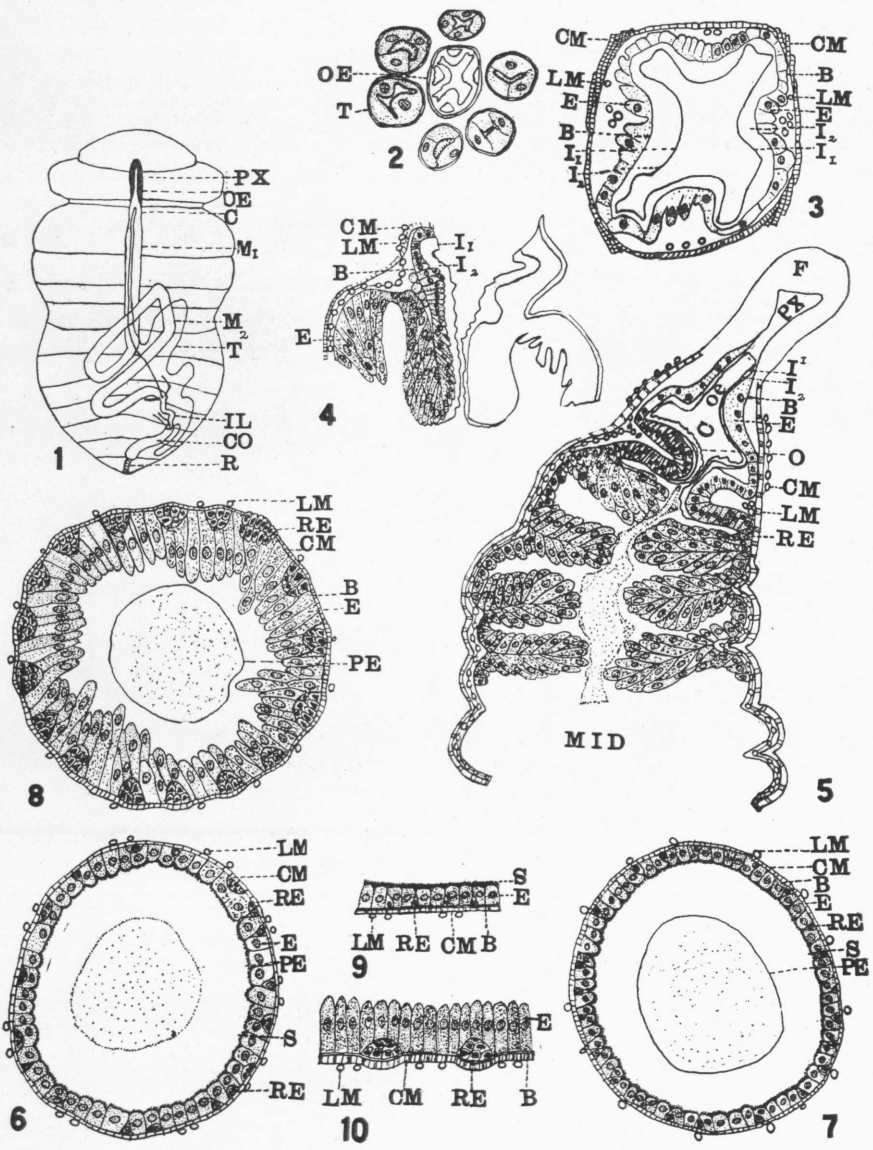
Fig. 1. The alimentary canal and malpighian tubules in the adult beetle.
Fig. 2. Cross section through the oesophagus to show its relation to the malpighian tubules.
Fig. 3. The oesophagus, cross section.
Fig. 4. The oesophageal valve, longitudinal section.
Fig. 5. The pharynx, oesophagus, crop, oesophageal valve, and the anterior portion of the first division of the mid-intestine (ventriculus), longitudinal section.
Fig. 6. The posterior portion of the first division of the ventriculus of the adult, cross section.
Fig. 7. The posterior portion of the first division of the ventriculus of the larva, cross section. Compare difference in replacement cells with Fig. 6.
Fig. 8. The second division of the ventriculus, cross section.
Fig. 9. The posterior portion of the first division of the ventriculus, cross section.

PLATE II.

Fig. 10. The second division of the ventriculus, cross section.
Fig. 11. The transition from the ventriculus to the ileum, longitudinal section.
Fig. 12. A cross section, made slightly at an angle, through the invagination of the malpighian tubules showing ventriculus epithelium on the left and the ileum epithelium on the right.
Fig. 13. The origin of the malpighian tubules, cross section made a few micra behind Fig. 12.
Fig. 14. Cross section through the ileum near the transition immediately behind Fig. 13.
Fig. 15. The posterior portion of the ileum taken a few micra behind Fig. 14. cross section.
Fig. 16. The central and posterior ileum, cross section.
Fig. 17. The colon; a cross section, showing the peritoneal sheath and malpighian tubules in their relation to the colon.
Fig. 18. The rectum, a cross section.
Fig. 19. Diagram showing the ramification of the malpighian vessels in the wall of the colon.
Fig. 20. A malpighian tubule greatly enlarged.

ABBREVIATIONS USED IN THE FIGURES.

B—Basement Membrane.
C—Crop.
CO—Colon.
E—Epithelium.
HI—Hind-Intestine.
LM—Longitudinal Muscle.
MID—Mid-Intestine.
M2—Mid-Intestine (second division).
OE—Oesophagus.
ORT—Origin Mal Tubules.
Pe—Peritrophic Membrane.
R—Rectum.
S—Striated Border.
CM—Circular Muscles.
CT—Connective Tissue.
F—Fore-Intestine.
IL—Ileum.
I—Primary Intima.
I2—Secondary Intima.
M—Muscle.
M1—Mid-Intestine (First division).
O—Oesophageal Valve.
P—Peritoneum.
PX—Pharynx.
RE—Replacement Cells.
T—Malpighian tubules.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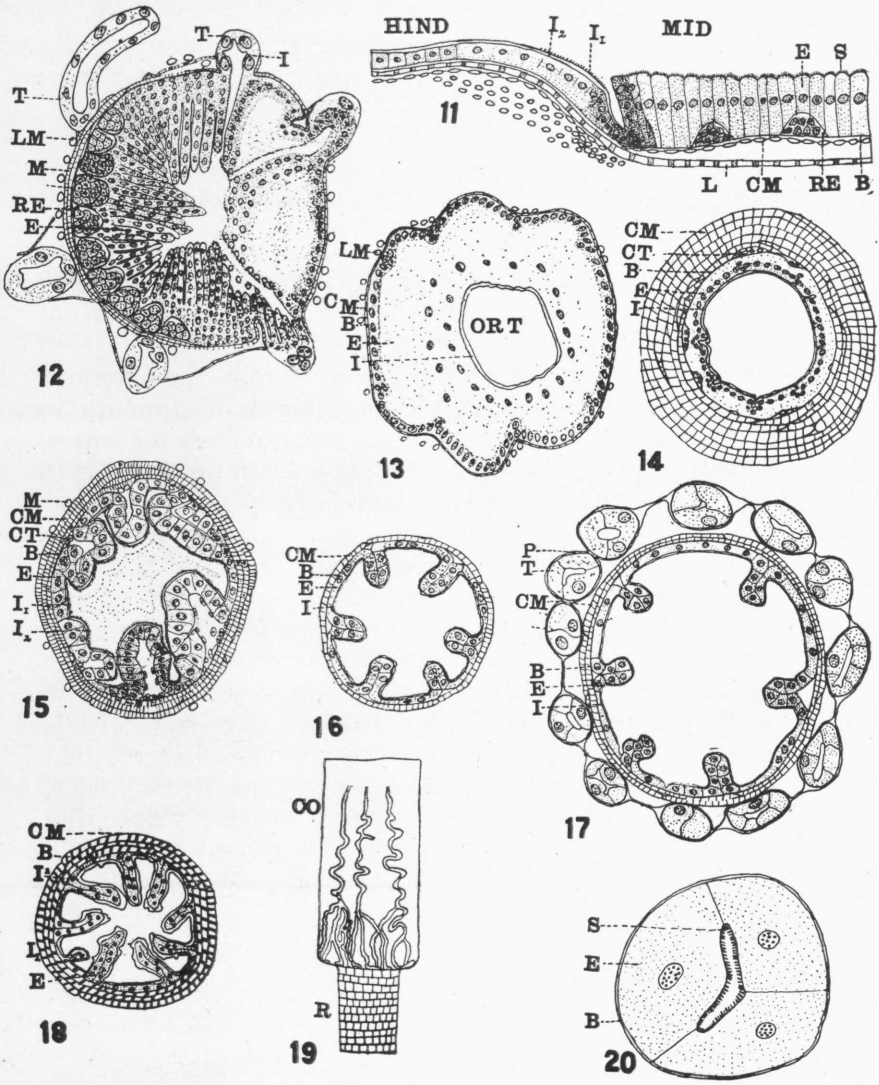
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