A COMPARISON OF THE ALIMENTARY CANALS OF THE ACTIVE AND HIBERNATING ADULTS OF THE MEXICAN BEAN BEETLE, EPILACHNA CORRUPTA MULS.

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INTRODUCTION.

The Mexican Bean Beetle (*Epilachna corrupta* Muls.) is a serious pest of beans, and unlike other members of the Coccinellidae is entirely phytophagous in habit. The beetle hibernates as an adult under leaves, pine-needles, grass, and the like.

The following results represent an attempt to describe the differences in histological structure that occur during the hibernating stage of the beetle.

THE GROSS ANATOMY.

Active adult.—The alimentary canal of the Mexican Bean Beetle is a much convoluted tube running from mouth to anus, and is approximately three times the length of the body. It is divided into three main divisions, the fore-intestine (stomodaeum), the mid-intestine (mesenteron or ventriculus), and the hind-intestine (proctodaeum). (Fig. 1).

The fore-intestine arises as an invagination of the ectoderm, the germ layer from which the hypodermis of the body wall is derived. It consists of pharynx, oesophagus, and crop, no gizzard being present. It is about 2 mm. in length.

The pharynx is a short tube, scarcely 0.15 mm. in diameter, and connects the mouth with the oesophagus.

The oesophagus extends from the pharynx to the crop, the posterior limit reaching the region of the mid-portion of the prothorax. It is but little larger in diameter than the pharynx, measuring on the average about 0.25 mm. The only essential difference between the pharynx and the oesophagus is size.

The crop appears as a small bulb which is slightly larger in diameter than the oesophagus. It is marked at the anterior end by the oesophagus and at the posterior end by the oesophageal valve.

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The oesophageal valve denotes the division between the fore-intestine and the mid-intestine and is indicated by a constriction of the stomodaeum. The valve lies in the region of the posterior sector of the prothorax.

The mid-intestine arises embryologically as an endodermal sac from the proliferation of rings of endodermal cells, one around the posterior end of the fore-intestine, the other around the anterior end of the hind-intestine. The mid-intestine is the longest of the three main divisions of the tract, measuring 9–10 mm. It is divided into two distinct portions, the anterior and the posterior portions of the ventriculus.

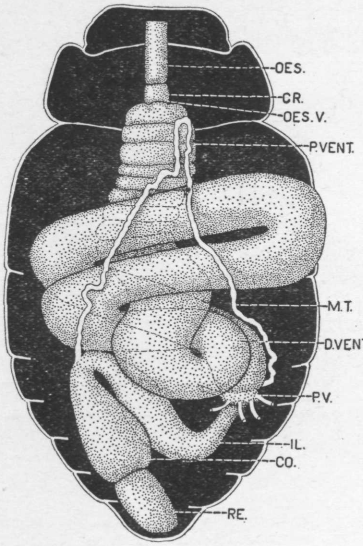

FIG. I.

Gross dissection of alimentary canal of the active adult of the Mexican Bean Beetle. OES., oesophagus; CR., crop; OES. V., oesophageal valve; P. VENT., anterior portion of ventriculus; M. T., Malpighian tubule; D. VENT., posterior portion of ventriculus; P. V., pyloric valve; IL., ileum; CO., colon; RE., rectum.

The anterior portion of the ventriculus measures 0.75–1.0 mm. in diameter and is characterized by a series of eight or more pseudo-segments. This area comprises about one-third of the mid-intestine.

The posterior portion of the ventriculus is marked by the gradual diminishing of these emarginations and caudad by the pyloric valve. It is in this section of the alimentary canal that the greatest convolution and doubling of the tract occurs. This part of the ventriculus is perhaps slightly smaller than the anterior portion and gradually diminishes in size to the valve.

The hind-intestine arises from the same germ layer as does the fore-intestine, and in the adult beetle is approximately 6 mm. in length. It is divided into four regions, the pyloric valve, the ileum, the colon, and the rectum.

The pyloric valve is distinguished in gross dissection as the point of origin of the six Malpighian tubules. These arise as spokes of a wheel, take a winding course up the mid-intestine as far as the crop, retrace themselves, and apparently return into the tract at the anterior part of the colon.

The ileum is bounded by the pyloric valve at the front and by the colon at the rear. It has a length of 2.5 mm. and a diameter scarcely over 0.25 mm.

The colon links the ileum and the rectum. Its anterior boundary may be recognized by the re-entrance of the Malpighian vessels into the tract. It is 2 mm. in length and slightly pear-shaped, its greatest diameter at the caudal portion being 0.75 mm. The six Malpighian tubules that enter may be seen to follow a winding course under the

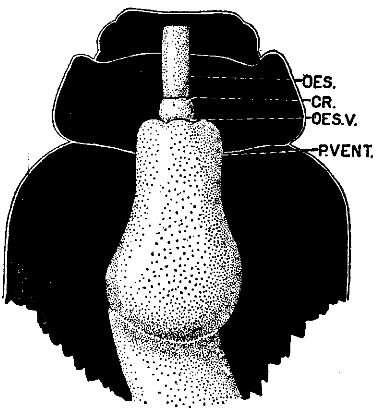

FIG. 2.

Gross dissection of the anterior portion of the ventriculus of the hibernating Mexican Bean Beetle. OES., oesophagus; CR., crop; OES. V., oesophageal valve; P. VENT., anterior portion of ventriculus.

peritoneal membrane down the entire length of the colon, the greatest meandering taking place near the rectum where they terminate.

The rectum is about half the width of the widest part of the colon, slightly barrel-shaped and only 1.0 mm. long.

Hibernating adult.—The fore-intestine is not different in gross structure from that of the active adult.

The anterior portion of the ventriculus, however, loses its segmented appearance, becoming greatly bulged and apparently very thin walled. This bulging effect varies in different specimens, the measurements ranging from 1.5–2.5 mm. at the widest point. This effect seems to be restricted to the first region of the mid-intestine in specimens taken from hibernation quarters in January, 1930, at Columbus, Ohio. Whether this would hold true in specimens taken later in the season of hibernation is not known. (Fig. 2).

Beginning at the posterior portion of the ventriculus, the size of the tube gradually decreases and becomes thread-like, continuing thus in miniature throughout its entire length, the different parts still holding their gross morphological structure.

This thread-like appearance is even found in the Malpighian vessels, which become very minute.

HISTOLOGY OF THE ALIMENTARY CANAL.

FORE-INTESTINE.

Active adult.—Throughout the fore-intestine there is a similarity of structures in its various parts. From the inside outward, the following structures appear:

1. Intima, or Cuticula of chitin, which is directly continuous with the cuticula of the body wall.
2. Epithelium of hypodermal cells.
3. Basement membrane.
4. Longitudinal muscles.
5. Circular muscles.

The intima is secreted by the hypodermal cells and is rather a thin, non-cellular, almost transparent layer which lines the whole fore-intestine. The layer of chitin in the pharynx, however, is thicker than in the other parts of the fore-intestine. (Plate I, Fig. 1).

Potts (1927) states that the intima of the oesophagus possesses teeth, but in this study, after examining many sections of this region, no teeth or spines were found. (Plate I, Fig. 7). In the crop, however, the intima is lined with rather long, stout spines, pointing, for the most part, caudad. These, in the absence of the gizzard, are probably used to grind up the food and help it on its way into the mesenteron.

The epithelium of the fore-intestine is continuous with the hypodermis. The cells are very small, the cell walls not always being clearly defined.

The basement membrane is not easily distinguished.

Outside the basement membrane are isolated bundles of longitudinal fibers.

Surrounding the longitudinal muscle fibers is a more conspicuous layer of circular muscle fibers.

The crop appears as a bulging of the fore-intestine into a pouch (Plate I, Figs. 1, 3). The wall makes a fold, forming a double pocket, the entire lining of the crop being stoutly spined. The epithelial layer is not as distinct as in the other parts of the stomodaeum, but the part is more heavily muscled. Many strands of longitudinal muscles are attached to the pockets and terminate in the lips of these oesophageal valves. These, with the aid of the circular muscles, motivate the expansion and contraction of the crop, driving the food materials through the valve and into the stomach.

The oesophageal valve is formed by the protruding of the fore-intestine into the lumen of the mid-intestine, the projection folding back on itself in such a way as to form lip-like structures. (Plate I, Fig. 1). This reflected surface joins the wall of the mesenteron. It is at this point that the chitin of the stomodaeum disappears. The epithelium layer of the fore-intestine once more comes into prominence at the cephalad portion of the valve, the cells becoming larger as the tip of the valve is reached. At the point most caudad in the lips of the valve, the longitudinal muscles are anchored, connecting this portion with the out-pocketings of the crop. Immediately outside this layer are numerous bundles of circular muscle fibers. This region is very heavily muscled, probably for the purpose of grinding and forcing the food into the stomach and preventing, by the contraction of the circular muscles in the valve, the regurgitation of predigested food.

At this junction of the fore- and mid-intestine the longitudinal muscles cross over the circular muscles.

Hibernating adult.—There are no differences in the histological structure of the fore-intestine in the active adult and in the hibernating form.

The Mid-Intestine.

THE ANTERIOR PORTION OF THE VENTRICULUS.

Active adult.—The anterior portion of the ventriculus consists of about one-third of the total mid-intestine, and is characterized by a series of folds, eight or ten in number. In gross dissection, they appear as segments of the intestine, but in section they show up as annular invaginations. (Plate II, Fig. 3).

The structure of the mid-intestine is markedly different than that of the fore-intestine. There is no chitinous intima, that structure being lost at the oesophageal valve. The layers of the mesenteron from the inside outward are as follows:

1. Intima, not chitinous.
2. Epithelium.
3. Basement membrane.
4. Circular muscles.
5. Longitudinal muscles.
6. Peritoneal membrane.

It will be noted that the circular muscle and the longitudinal muscle layers have changed position, the longitudinal muscle being on the outside.

The food of the stomach is always enclosed in a thin, elastic membrane known as the peritrophic membrane, which holds the food together in a compact cylindrical mass. This membrane is probably not chitinous but a secretion formed at the surface of the epithelial cells.

The epithelium layer is composed of elongate, columnar cells, closely following the folding of the tract and giving it its annular segmented appearance. (Plate II, Fig. 3). The inner surface of these cells possess a striated border.

Folsom and Welles (1906) in their paper on the mid-intestine of Collembola say in part, "The intima, or lining membrane, is a secretion of the stomach. It is striated transversely. . . . . They are due in all probability to minute pore-canals, through which fluid may be either secreted or absorbed. Frenzel, Oudemans, Somner, Gehuchten and others have described and figured the intima as a layer of fine filaments, to which they gave the name of 'Harchensaum.' In *Tomocerus*, however, the intima presents no such appearance, but it is clearly a membrane." So is it with the Bean Beetle, a membrane lining the epithelial cells that projects into the lumen of the gut. This layer is not always the same thickness throughout the mid-intestine, but becomes thinner in some parts.

Between the basement membrane and these epithelium cells are groups of replacement cells or nidi. In a cross section, as many as thirty of these replacement cell nests may be present. They are located on the basement membrane and extend up towards the lumen of the stomach, being surrounded by the epithelial cells. (Plate II, Fig. 1). These nidi do not fall beneath the muscle layers as is the case in many Coleoptera. They are specialized for the formation of new cells to take the place of those that are destroyed by secretion.

Surrounding the nidi, underneath the basement membrane is situated a rather prominent layer of circular muscles.

The longitudinal muscles lie in isolated strands outside the circular muscle layer.

Hibernating adult.—In the hibernating beetle an altogether different condition exists in the fore part of the mid-intestine. There appears a curious splitting of epithelial tissue that closely resembles the one found by Folsom and Welles (1906) in Collembola during the moulting periods.

In the extreme anterior portion of this region, the only evidence of this condition is the distended and structureless remains of the original epithelial layer. It is this part of the intestine that gives the swollen, thin-walled appearance in the gross anatomy. (Plate I, Figs. 5, 8).

In order to understand this condition, it is necessary to describe a section taken farther down the canal showing all the structures involved in this degeneration of epithelial tissue.

The food material in this part is surrounded with a peritrophic membrane, the food in this case being partly digested cells, distinguishable by the nuclei that are apparently the last part of the cell contents to become disintegrated. (Plate I, Fig. 2).

The fact that they are cells that are undergoing degeneration and not food particles from other sources is borne out by the absence of a striated border on the cells that now are around the lumen of the gut.

The cell walls of this inner layer of epithelium are not clearly defined, but the arrangement of the nuclei and the remains of cell walls clearly denote that this layer has been cut off from the layer just beneath it.

This inner layer of epithelium also has a thin peritrophic membrane surrounding it.

The remaining structure of the original or outer epithelium layer is very difficult to distinguish. It is a very thin layer, almost structureless, containing a few scattered nuclei. The cell walls are scarcely visible, the whole structure resembling a ring of almost homogenous cytoplasm, dotted here and there with a nucleus.

The remains of nidi may be seen in a few places. They have become very reduced in size and discernible only at scattered points in the sections.

Around the very thin basement membrane is a fine band of circular muscles, surrounded by scattered strands of longitudinal muscles.

It is this thin outside epithelial layer that remains in the extreme cephalad portion of the region. This part of the stomach contains no food materials of any sort, appearing in cross section as a thin, inflated ring. The absence of food in this region would suggest that after the disintegration of the cells at this point, they move down the tract, either becoming digested or stored, to be excreted when the beetle comes out of dormancy.

THE POSTERIOR PORTION OF THE VENTRICULUS.

Active adult.—The posterior portion of the ventriculus is characterized by the absence of the annular pseudosegments.

The layers of this portion of the ventriculus are similar to those of the anterior portion, the difference being in the shape of the epithelial cells.

The epithelial cells in this area are simple columnar and are much shorter than those of the preceding region.

At the caudal end of the posterior portion the epithelial cells again lengthen out until at the pyloric valve the cells almost entirely fill the lumen of the gut. (Plate I, Fig. 6).

In this region of the mid-gut it is possible to study the replacement of cells by nidi. (Plate II, Fig. 2). It appears as if each nidus replaced cells from a certain restricted area, making a line of demarcation between the replaced cells of one nidus from another. The nidi are small, rounded structures containing many nuclei, those on the border of the nidi towards the epithelial layer being somewhat flattened. The newly formed cells from these replacement nidi are small, flask-shaped structures. These cells are laid down alternately, each nucleus coming to the surface of the nidus and then becoming sloughed off, the axis being at the outer borders of the nidus. These new cells continually grow in size until they have reached the lumen of the gut. These cells contain many large vacuoles which, combined with the great rapidity in the replacement of cells, tend to show that a great deal of the secretion of the mid-intestine takes place in the region just anterior to the pyloric valve.

Hibernating adult.—This region of the mid-intestine of the hibernating adult also supports the marked change in structure from that of the active insect. It is very similar to that of the preceding hibernating region except that the outer epithelial layer is much thicker, and the cell walls are much more visible. (Plate I, Fig. 4).

Folsom and Welles (1906) consider this degeneration of epithelium tissue as an excretory function in Collembola. In the Mexican Bean Beetle that can hardly be the case, but it is possible that it is a mechanism to keep the animal nourished during its hibernation period by consuming its own cell body!

SECRETION.

Active adult.—In the insect world there are two distinct types of secretion, merocrine and holocrine. Merocrine is defined in *Stedman's Medical Dictionary* as, "Noting a gland, the product of which is secreted by the cells, the latter not being destroyed, such as a mucus gland."

This type of secretion is found in some Dipterous larvae where the digestive fluids are diffused through the cell wall, the cell itself not being destroyed. Holocrine is defined in *Stedman's Medical Dictionary* as, "Noting a gland (1) whose function is purely secretory, or (2) the secretion of which consists of altered cells of the gland, such as a sebaceous gland." *Webster* defines the term as, "Wholly used for secretion, applied to those cells whose entire substance is given up as a secretory product." In insects, the latter type seems to be the most common form of secretion in the mid-intestine.

Secretion in the Mexican Bean Beetle is a modified holocrine type, apparently taking place anywhere in the mesenteron, but more especially in the posterior portion of the ventriculus, and gaining its maximum just anterior to the pyloric valve. The cells at the time of secretion do not actually burst and let the contents flow out into the gut, but the ends of the secreting cells become constricted and form balls of digestive fluid, which finally pinch off and allow the globules to become free in the lumen of the stomach. During the process of secretion, the intima remains around the globule until it has been separated from the cell proper. (Plate II, Figs. 4, 7). The intima around the globule is greatly thinned, evidently due to the stretching of the intima. At the time of separation, the intima breaks, leaving but part of a border around the globule. The intima at the breaking points, however, apparently reunites and leaves the secreting cell intact except for its loss of cell contents through the process of secretion. In no case was the nucleus of the secreting cell found in the globule that was secreted.

These globules become less definite in outline as they reach the food body in the center of the lumen.

The secreting cells of the epithelium in the mid-gut are long and turgid with the secreting substance, becoming convex at their free surface. In the secreting cells large vacuoles occur, supposedly containing the digestive materials.

Replacement cells or nidi are very prevalent in the mid-intestine, suggesting that the secretory cells become functional, secrete, discharge, digest, and die, giving their places to new cells which arise from the nidi.

Hibernating adult.—There is no evidence of secretion of any type in the adult during hibernation. This is not to be expected, as during dormancy the adult does not feed.

THE HIND-INTESTINE.

Active adult.—The hind-intestine consists of four parts, the pyloric valve, the ileum, the colon, and the rectum. The tissue layers are the same in all parts, namely:

1. Intima of chitin.
2. Hypodermal epithelium.
3. Basement membrane.
4. Circular muscles.
5. Longitudinal muscles.
6. Peritoneal membrane.

The Malpighian vessels arise just caudad from the end of the mid-intestine and cephalad from the pyloric valve. There are six tubules arising as the spokes of a wheel around the intestine. The epithelial cells at the origin of the tubules are cuboidal in shape and are very small in comparison to the cells of the mid-intestine. (Plate I, Fig. 6).

The pyloric valve is very well developed. Grossly, it is a long structure placed in the tract in a manner similar to that of the "sections" in an orange. There are six of these "sections" and when viewed in cross section they appear as six lobes extending into the lumen of the hind-intestine. (Plate II, Fig. 5). These ridges occur in one form or another all along the proctodaeum.

The layer of chitin is well developed in the pyloric valve.

The epithelium layer consists of rather tall columnar cells closely following the invaginations of the basement membrane.

The most prominent layer in the pyloric region is the layer of circular muscles that is found outside the basement membrane. This layer of muscle is probably the most outstanding muscle layer in the whole alimentary canal, the only other region so greatly muscled is the rectum.

Outside the circular muscle layer are found isolated strands of longitudinal muscles.

The ileum still possesses the vestiges of the lobes of the pyloric valve. The epithelium cells, however, have lost their columnar type, becoming cuboidal. (Plate II, Fig. 8). The circular muscle has reduced in number of fibers, being only approximately half as many as in the pyloric region. This is bordered by isolated strands of longitudinal muscles.

The colon is marked by the entrance of the Malpighian tubules under the peritoneal membrane. (Plate II, Figs. 10, 11.)

The epithelium layer is similar to that of the ileum, though not quite as pronounced.

Outside the basement membrane is an insignificant layer of circular muscles. The longitudinal muscles are not easily distinguishable.

The most striking thing about the colon is the appearance of the Malpighian tubules under the peritoneal membrane. The Malpighian vessels usually consist of a tube, four-celled in cross section, and in the region of the hind-gut the inner border of the tubule is striated. (Plate II, Fig. 6). These vessels enter the small end of the colon as six separate tubules, and follow a fairly straight course down the colon to the point where it begins to bulge. Where the bulge begins, the vessels begin a series of folds or convolutions. At no point in their course do the tubules enter the hind-intestine, but wind their way under the outer layer down to the rectum where they come to an abrupt termination. (Plate II, Fig. 12). The winding of the Malpighian vessels under the peritoneal membrane explains the occurrence of more than six sections of tubules in some slides, some single tubules being sectioned more than once. (Plate II, Fig. 9). At no place do the Malpighian vessels branch.

The chitinous intima of the rectum is heavier and more jagged in appearance than in any other portion of the whole digestive tract. (Plate II, Figs. 10, 13).

The epithelium is indistinct, the cell outlines being very difficult to see. The epithelial layer is still thrown into six longitudinal folds.

The most outstanding layer in the rectum is the heavy layer of circular muscles that is found outside the basement membrane.

The longitudinal muscle layer is indistinct. Isolated strands are sometimes found intermingled with the circular muscles.

Hibernating adult.—There seems to be no difference in the structure of the hind-intestine of the hibernating adult. However, the diameter of this structure in the hibernating adult is much smaller. It usually becomes filled with structureless waste materials which are probably the indigestible remains of food that are held in this region until the beetle becomes active and once more can rid its system of waste substances.

CONCLUSION.

The purpose of this paper is not to solve for all time the changes in the morphology of the Mexican Bean Beetle during its dormant period, but merely to show and attempt to describe some of the histological differences that occur. A true and complete understanding of this phenomenon lies covered in the combined fields of morphology and physiology. Work along these lines would undoubtedly ferret out the causes and conditions under which this epithelial degeneration takes place, as well as describe more in detail the structures involved over the whole period of dormancy. It need not be said that a vast amount of work can be done along these lines, in other hibernating insects as well as in the Mexican Bean Beetle.

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Longitudinal section of pharynx, oesophagus, valve, and portion of mid-intestine. Active adult.
Fig. 2. Cross section of anterior portion of ventriculus, showing double splitting of the epithelium layer. Hibernating adult.
Fig. 3. Cross section of crop. Active adult.
Fig. 4. Cross section of posterior portion of ventriculus, showing single splitting epithelium. Hibernating adult.
Fig. 5. Longitudinal section of anterior portion of ventriculus. Hibernating adult.
Fig. 6. Longitudinal section of pyloric region, showing posterior portion of ventriculus, Malpighian tubule attachment, and section of pyloric valve. Active adult.
Fig. 7. Cross section of oesophagus. Active adult.
Fig. 8. Cross section of anterior portion of ventriculus. Hibernating adult.

PLATE II.

Fig. 1. Cross section of ventriculus. Active adult.
Fig. 2. Cross section of posterior portion of ventriculus, showing replacement of cells by nidi. Active adult.
Fig. 3. Longitudinal section of anterior portion of ventriculus. Active adult.
Fig. 4. Cross section of ventriculus, showing secretion. Active adult.
Fig. 5. Cross section of pyloric valve. Active adult.
Fig. 6. Cross section of Malpighian tubule. Active adult.
Fig. 7. Section showing cell in the process of secretion. Active adult.
Fig. 8. Cross section of ileum. Active adult.
Fig. 9. Cross section of colon, showing Malpighian tubules under the peritoneal membrane. Active adult.
Fig. 10. Longitudinal section of colon and rectum. Active adult.
Fig. 11. Enlargement of portion of longitudinal section of colon, showing Malpighian tubule under peritoneal membrane.
Fig. 12. Gross dissection showing arrangement of Malpighian tubules under the peritoneal membrane.
Fig. 13. Gross section of rectum. Active adult.

ABBREVIATIONS.

Anterior portion of Ventriculus—P. VENT.
Basement Membrane—B. M.
Circular Muscle—C. M.
Colon—CO.
Crop—CR.
Epithelium—EPI.
Food—FD.
Ileum—IL.
Intima—IN.
Inner Epithelium—I. EPI.
Longitudinal Muscle—L. M.
Malpighian Tubule—M. T.
Nidus—NI.
Oesophagus—OES.
Oesophageal Valve—OES. V.
Outer Epithelium—O. EPI.
Peritoneal Membrane—PTL. M.
Peritrophic Membrane—P. M.
Pharynx—PH.
Posterior Portion of Ventriculus—D. VENT.
Pyloric Valve—P. V.
Rectum—RE.
Secretion Globules—S. GL.
Spine—SP.

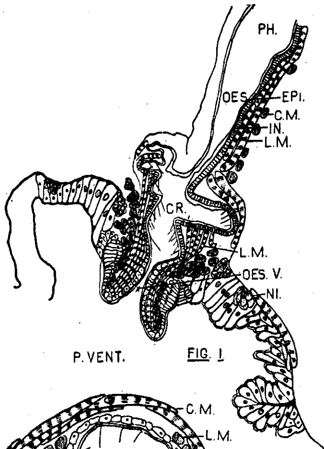


FIG. 1

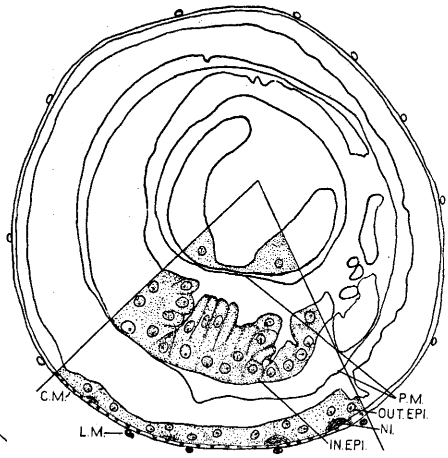


FIG. 2

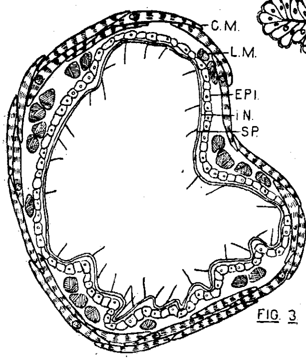


FIG. 3

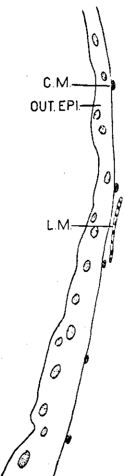


FIG. 5

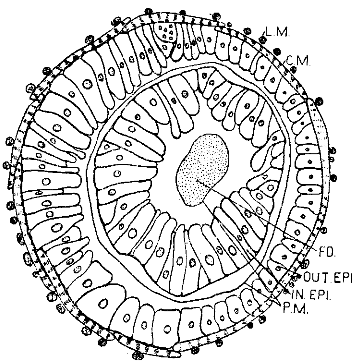


FIG. 4

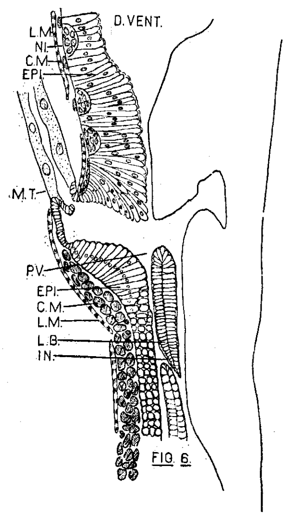


FIG. 6

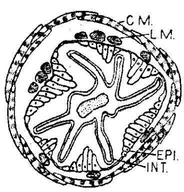


FIG. 7

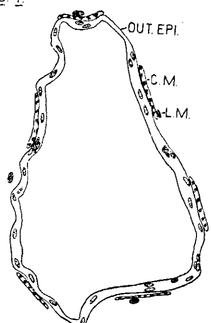
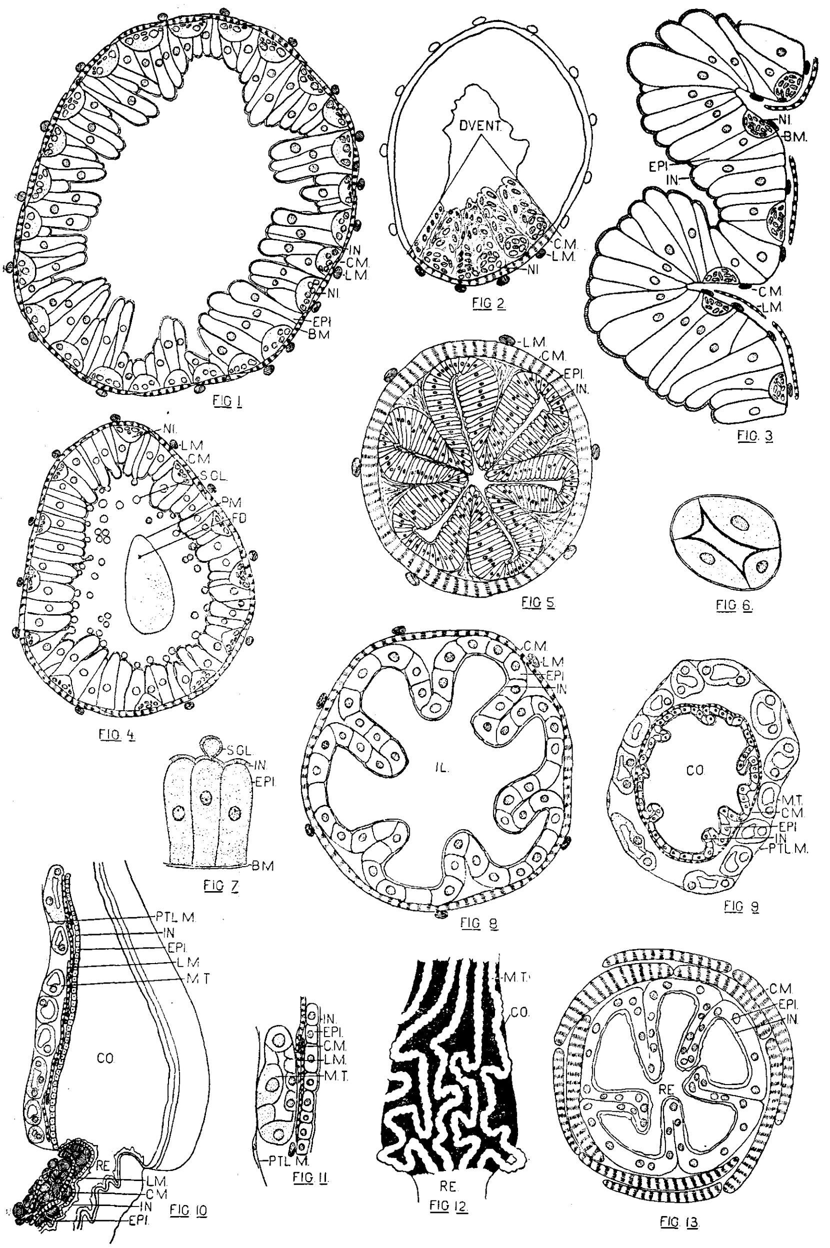


FIG. 8


IN
CM
LM
NI
EPI
BM
FIG 1
DVENT
CM
LM
NI
FIG 2
NI
BM
EPI
IN
CM
LM
FIG 3
NI
LM
CM
SCL
PM
FD
FIG 4
LM
CM
EPI
IN
FIG 5
FIG 6
SCL
IN
EPI
BM
FIG 7
CM
LM
EPI
IN
IL
FIG 8
CO
MT
CM
EPI
IN
PTL M
FIG 9
PTL M
IN
EPI
LM
MT
CO
RE
LM
CM
IN
EPI
FIG 10
IN
EPI
CM
LM
MT
PTL M
FIG 11
MT
CO
RE
FIG 12
CM
EPI
IN
RE
FIG 13

Qualitative Analysis.

This book was first published in 1909, the present revised edition differing from the first edition somewhat in the procedure for getting solid substances into solution, for accomplishing certain cation separations and making certain confirmatory tests using more recently developed methods.

The volume is intended as a brief but adequate treatment of the subject from the modern standpoint and includes sufficient precautionary directions for the student to secure a reasonable delicacy of reaction. So as to stimulate the initiative of the student, very few equations are given. The introductory material is limited to 16 pages, these dealing with: (a) reversible reactions; (b) reactions between ions; (c) dissociation in steps; (d) repression of ionization; (e) equilibrium in a saturated solution; (f) the solubility product; (g) solution; (h) hydrolysis; (i) amphoteric electrolytes; (j) electromotive series; and (k) oxidation and reduction. Students desiring more extensive information are referred to specified pages of Holmes Chemistry and the third edition of McPherson and Henderson's General Chemistry.

Presumably the author presents qualitative analysis as part of a first course in chemistry. It is doubtful as to whether qualitative analysis should in itself be the end in a first course or should merely be a stimulating means to an end—namely, that of a study of the metals and their ions with the non-metals and their ions included so as to give a more completed presentation of elementary qualitative analysis. The reviewer recognizes the fact that most departments of chemistry are service departments and as such are expected to give the students in certain of the professional courses a working familiarity with the procedures and techniques employed in establishing the qualitative composition of the more common inorganic substances.

The author's experience leads him to believe that skeleton outlines of procedure are apt to be followed rather blindly by the student, hence he has given sufficiently full directions and explanatory notes in procedures. This is a meritorius feature of the book. However, it cannot be denied that a much better picture of the relationships within a group of cations is available to the student if a composite procedure is all on one page (or a double page, if necessary).

In several instances a more careful choice or arrangement of words, would enhance the clarity of this Manual. A few examples are: (a) page 4, "NaCl being highly ionized," implies that $BaSO_4$ is not highly ionized; (b) page 11, "Salts of strong acids with strong bases," permits of two interpretations; (c) page 18, "This enables one to work on several parts of an analysis at the same time," (d) page 35, "If bismuth is present it becomes black due to separation in metallic form" (Na_2SnO_2 treatment); (e) "Make first preliminary tests 3;" (f) "Basic Analysis" (Cation Analysis), "Acid Analysis" (Anion Analysis), "Dry Substances" (Solid Substances).

The use of type of different point is generally employed for the purpose of emphasis. On pages 31 and 35, the notes are in smaller type than on page 33, yet all of these are of the same character and of equal importance. Apparently it was the author's desire to have all of the notes on a particular group or sub-group on one page—a feature which warrants some commendation. Frequently suggestions for the teacher and instructions for the student are contained in the same paragraph without even an aside.

Laboratory technique, particularly that involving apparatus, is not pronouncedly stressed, yet the author gives the impression that good technique is essential for rapid dependable work.

There is little evidence for the existence of $As^{\cdot\cdot\cdot\cdot}$, $Sb^{\cdot\cdot\cdot\cdot}$, $Sn^{\cdot\cdot\cdot\cdot}$, and perhaps $As^{\cdot\cdot\cdot}$ and $Sn^{\cdot\cdot\cdot}$. Ammonia and ammonium hydroxide are sometimes used synonomously—a usage which might be justified as our knowledge of a solution of ammonia in water is limited.

Barring these meticulosities of the reviewer the author has made a worthwhile contribution to the field of introductory qualitative analysis. Many of the books on the market are not only too extensive for students in first year chemistry, but are also too costly to these students—and of this sin the author of this volume cannot be accused.—J. E. Day.

Qualitative Chemical Analysis of Inorganic Substances. Olin Freeman Tower, Ph. D., Hurlbut Professor of Chemistry in Adelbert College of Western Reserve University. Sixth edition revised. P. Blakiston's Son and Co., Philadelphia. xv+92 pp., 1 Fig.+6 Tables, 23.7 × 16 cm. $1.50.