

## THE STUDY OF THE ALIMENTARY TRACT OF SCHISTOCERCA GREGARIA (FORSKAL) (ORTHOPTERA : ACRIDIDAE)

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The average length of gut in normal position was 44.8 and 51.8 mm. in male and female Desert locust, respectively.

Histologically the alimentary tract was surrounded by peritoneum, muscular layers and epithelium through out its length. The development of muscular and chitinous layers was found to be maximum in the fore-gut. Longitudinal muscles in mid-gut were outside the circular muscles. The mid-gut and the hepatic caecae were the only part of the gut having columnar ciliated cells. The peritrophic membrane was non-cuticular ring.

Histologically hind-gut resembled the fore-gut except that the six longitudinal muscles were external to the circular muscles.

### Introduction

The vast damages done by the attacks of the Desert locust, *Schistocerca gregaria* (Forsk.) on different parts of the world do not need any introduction. They are voracious eaters and consume lot of green vegetation. In order to understand their nature of tremendous food consumption, research work on their feeding habits in relation to the physiology of the digestive system was undertaken. Before starting work on the physiological aspect of any organ it is important to have a complete understanding about its structure. Chauvin<sup>1</sup> did some work on the anatomy of the digestive system of Desert locust, in which he studied the pigmentation of cells in the crop, gizzard and rectum. He paid little attention to the structure of alimentary tract, except reporting that it consisted of a typical structure of an Acridine constituting epithelium, muscular layers and intima. Hence it was found necessary to investigate the external and internal structure of different parts of gut before undertaking the work on physiology.

### Material and Method

The locusts were kept in wooden cages of size 40" × 27" × 24", which were fitted with two electric bulbs of 200 watts each, at the top of the cage to maintain 35 ± 5°C. temperature. They were fed on cabbage leaves, but during nymphal stages they were also given artificial diet<sup>2</sup> consisting of glucose, yeast and brans in the ratio of 2:1:2. The preserved as well as fresh specimens of locust were employed to study the anatomy. For histological work fresh four-day old adult locusts were used. The locusts were starved before cutting the sections, as sand particles in the gut were a hinderence in getting good sections. Preservation was done in 70% alcohol. The alimentary canal

was fixed in Bouin's fixative after being freed from tracheae and Malpighian tubules. Tissues were embedded in paraffin of 59°C. melting point. The sections were cut at 3 to 4 microns; and were stained with haematoxylin and eosin.

### Results and Discussion

The external morphology of the alimentary canal was found to have all the characteristic features of Acridine, Fig. 1. It was a large cylindrical tube of epithelium surrounded by muscular coat. In normal position the average length of gut in male was about 44.8 mm., while in female it was about 51.8 mm. It was slightly longer than the body length. The diameter of the tract was variable depending upon the gut contents. Pharynx, oesophagus and colon were of minimum diameter. It was clearly divisible into fore-gut, mid-gut and hind-gut. The main salivary ducts united after entering the head. Similar findings were reported by Albrecht<sup>3</sup> in the grasshopper, *Nomadacris septemfasciata* (serville). Mid-gut was shorter than fore and hind-gut. The anterior lobes of caecae were larger than the posterior lobes. The combined length of both the lobes was a little smaller than that of the mid-gut (Table 1). Hodge<sup>4</sup> has described the caecae of the same length as that of the mid-gut of *Melanoplus differentialis*.

The diameter of the caecae was less than half the mid-gut. The data for the average measurement of the different regions of the alimentary canal are given in Table 1.

*Fore-gut.*—The fore-gut extending from the posterior end of the cibarium, approximately reached upto the first abdominal segment, Fig. 2. The cephalic region of the fore-gut was supported by

the anterior arms of the tentorium, pharyngeal muscles and foramen magnum. Fore-gut was clearly divisible into pharynx, oesophagus, crop and proventriculus. The mouth was situated at the proximal end of the cibarium and in between the two oral bars of the hypopharynx, Fig. 3. The wall of the fore-gut was marked by numerous closely arranged circular muscles, which were encircled externally by two very small dorso-lateral and two ventrolateral longitudinal muscles.

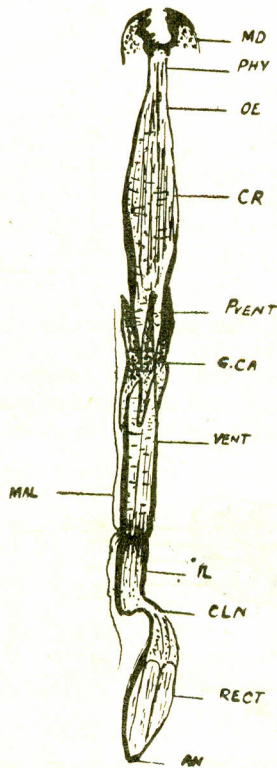


Fig. 1.—Showing general view of the alimentary canal (Semidiagrammatic 4x).

**Pharynx.**—White brownish tubular pharynx was joined with oesophagus at an obtuse angle, Fig. 3, and was divided into anterior and the posterior pharynx based on the origin of pharyngeal muscles. The muscles for anterior pharynx originated from frons, sub-antennal ridges and lamina-tentorium, while for posterior pharynx they originated from vertex and dorsal edge of the posterior tentorial arm. Similar findings in case of Desert locust have been reported by Misra,<sup>5</sup> while studying the musculature of head region.

The Pharynx had a thick intima which was provided with small posteriorly directed denticles. The circular muscles were well developed and the bundles of longitudinal muscle were present bet-

ween the longitudinal epithelial folds. The peritoneal membrane closely lined the outer border of the circular muscles. The epithelial cells were of two types, the columnar and the cuboid, provided with distinct nuclei having clear chromatin granules. Nuclei varied from round to ovoid in shape, Fig. 4 (a) and (b).

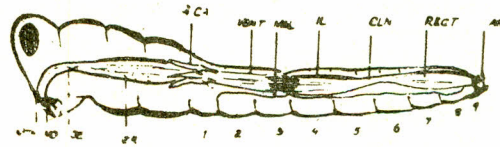


Fig. 2.—Showing right lateral view of the entire tract in situ (Semidiagrammatic 4x).

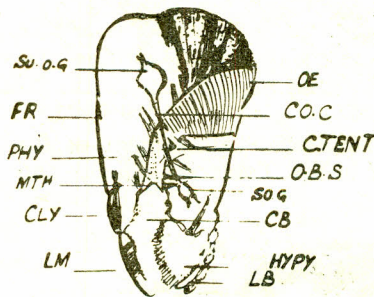


Fig. 3.—Showing the pre-oral cavity and the hypopharynx.

**Oesophagus.**—The oesophagus increased antero-posteriorly in diameter. The peritoneal membrane was present but not as distinct as found in pharynx, Fig. 5 (a) and (b). The circular muscles consisted of three to six fibres. Their nuclei were oval in shape. The inner longitudinal muscles were in the form of groups surrounded by epithelial folds. The musculature of oesophagus was weakly developed as compared to pharynx. The epithelium consisted of cuboid cells with round or oval nuclei. The deeply stained granules were present in the nuclei. The well developed intima was provided with posteriorly directed denticles on dorso-lateral sides only, Fig. 6 (a). These were not arranged in rows.

#### Abbreviations used in all the Figs:

AN, Anus; B. COR, Blood corpuscles; CB, Cibarium; CMCL, Circular muscles; CLN, Colon; CO. C, Circum oesophageal connective; C. TENT, Corpora tentorium; CR,; Crop, CLY, Clypeus, CT, Connective tissue; EPTH, Epithelium; FR, Frons; G. CAE, Gastric caecae; HYPY, Hypopharynx; IN, Intima; IL, Ileum, LB, Labium; LM, Labrum; MAL, Malpighian tubules; MD, Mandible MTH, Mouth; OE, Oesophagus; O.B.S, Oral bar of suspensorial sclerite; PVENT, Proventriculus; PR, Peritoneum; PVLV, Pyloric valve; RECT, Rectum; RG, Regenerative cells; RP, Rectal pad; SB, Striated border; SO.G, Sub. Oesophageal ganglion; SU.O.G, Supra oesophageal ganglion; SVLV, Stomodaeal valve; SP. CR, Spines of crop; VENT, Ventriculus; VAC, Cell vacuoles.

TABLE I.—SHOWING AVERAGE MEASUREMENT OF DIFFERENT PARTS OF THE GUT BASED ON FIFTY ADULT LOGUSTS OF EITHER SEX.

Alimentary canal	Length mm.		Breadth mm.	
	Male	Female	Male	Female
1. Fore-gut ..	20.5	21.8	1.0-3.5	1.0-4.0
a. Pharynx ..	1.8	1.8	1.4	1.5
b. Oesophagus ..	2.4	2.6	0.8	1.0
c. Crop ..	12.5	13.5	2.8	3.1
d. Proventriculus ..	3.1	3.7	1.4	1.5
2. Mid-gut ..	8.5	13.5	1.8	1.9
3. Hind-gut ..	15.2	16.5	0.7-2.0	0.7-2.0
a. Ileum ..	6.6	7.2	1.6	1.7
b. Colon ..	1.5	2.0	0.7	0.9
c. Rectum ..	6.0	6.5	1.7	2.0
4. Hepatic Caecae ..	6.5	9.0	1.6	1.8
a. Anterior lobe ..	3.9	5.8	0.9	1.0
b. Posterior lobe ..	2.6	3.2	0.7	0.8

*Crop*.—The crop was the enlargement of the oesophagus situated in the thoracic region, and

was clearly demarcated from proventriculus. Crop and proventriculus were more brownish as compared to the rest of the gut. Two conspicuous oval areas on the fore-gut wall in *Locusta migratoria* reported by Albrecht were found to be absent in



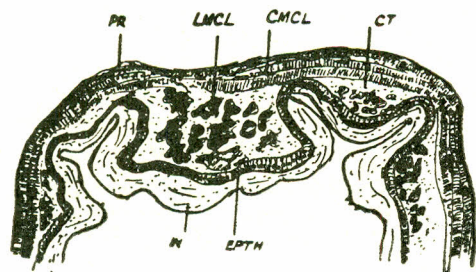
0.5MM

Fig. 4 (a).—Showing transverse section through pharynx x18.



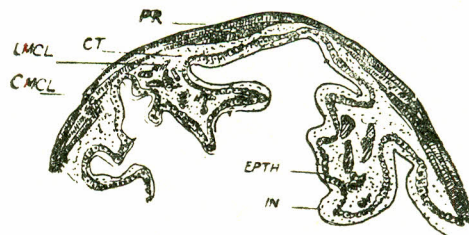
1MM

Fig. 5 (a).—Showing transverse section through oesophagus x18.



0.2MM

Fig. 4 (b).—Showing magnified transverse section through pharynx x120.



0.2 MM

Fig. 5 (b).—Showing magnified transverse section through oesophagus x120.

this species. The inner side of the crop was provided with a number of dorsolateral ridges arising from two ventro-longitudinal ridges, Fig. 6 (a). The dorsolateral ridges were found united mid-dorsally. The average number of ridges was 43 ranging from 35-50. Some of them were not complete, as they did not reach up to the dorsal side. The dark brownish posteriorly directed denticles were present on the ridges, Fig. 6(a) and (b) The number of denticles depended on the length of the ridge. Shorter or incomplete ridges had as low as 22 denticles on one side, while the complete ridges had an average number of 115 on each side. In the posterior region the ridges were broken and their number increased considerably. Histologically crop resembled the oesophagus, as epithelium consisted of cuboid cells only. The nuclei were clear with abundant chromatin granules, Fig. 7 (a) and (b) The connective tissue was better developed than that of oesophagus. The peritoneum was very thin and closely applied to the circular muscles as found in pharynx and oesophagus. The intima was comparatively thin as compared to pharynx and oesophagus and was provided with large number of posteriorly directed denticles.

*Proventriculus.*—The proventriculus was well developed like that of other Orthopterous insects

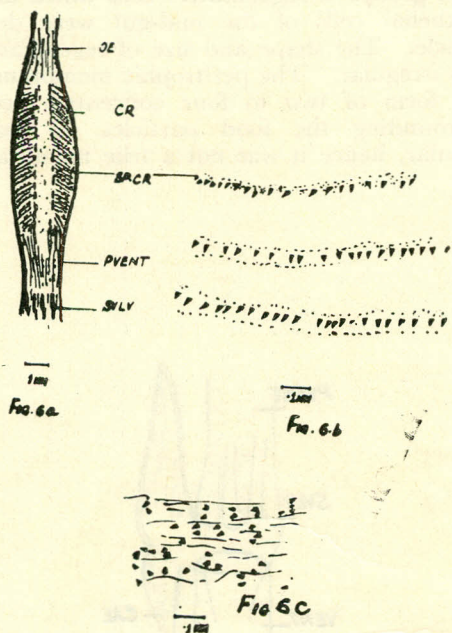


Fig. 6 (a).—Showing internal aspect of fore-gut x8.

Fig. 6 (b).—Showing three rows of spines of the crop.

Fig. 6 (c).—Showing spines on the wall of proventriculus.

as studied by Judd.<sup>6</sup> It was of the same size and colour as the crop, but not so elastic. A constriction at its anterior end marked it from crop. The dorsolateral ridges of the crop at the posterior end converged into many longitudinal folds which were heavily chitinized and covered with small denticles. At its posterior end these folds converged to form six large chitinized teeth of the proventricular valve, Fig. 8 (a) Histological studies revealed that the circular muscles of the proventriculus were thick as compared to the other parts of the fore-gut, Fig. 8 (b). The peritoneum was not clear and the epithelium consisted of cuboid cells. The intima was thick and provided with many denticles, which were smaller in size than crop, Fig. 6 (c) Connective tissue was well developed with ovoid nuclei containing the dense granules.

*Cardiac Valve.*—The cardiac valve separated the foregut from the mid-gut and consisted of six flaps, Fig. 8 (c) which projected proximally into the lumen of mid-gut. The inner longitudinal muscles gathered into six bundles inside the longitudinal flaps. The circular muscles were thick consisting of six to eight fibres.

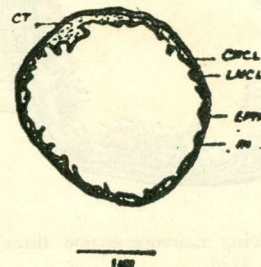


Fig. 7 (a).—Showing transverse section through crop x18.

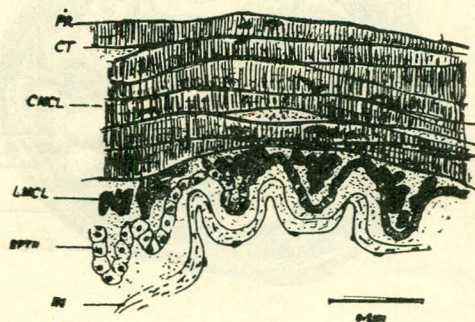


Fig. 7 (b).—Showing magnified portion of the transverse section through crop x120.

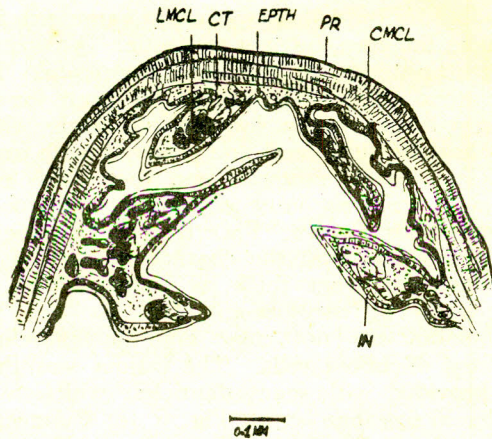


Fig. 8 (a).—Showing transverse section through the hinder end of proventriculus x120.

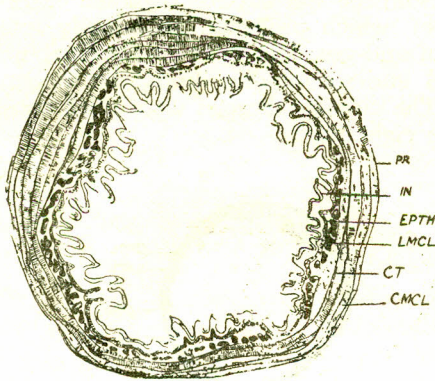


Fig. 8 (b).—Showing transverse section through proventriculus showing denticles x120.

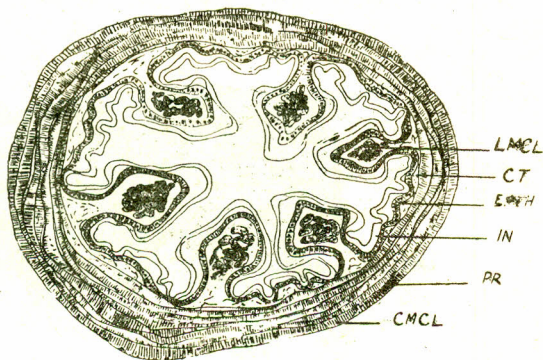


Fig. 8 (c).—Showing transverse section through the cardiac valve showing six flaps of longitudinal folds x120.

*Mid-Gut.*—The tubular mid-gut was shorter than the fore and hind-gut, and extended beyond the stomodaeal valve. Three pairs of hepatic caecae were opening into mid-gut at its anterior end, Fig. 9. Each light brown pair was a bilobed structure extending anteriorly and posteriorly and attached at the junction of mid-gut with fore-gut. They were surrounded by tracheae and Malpighian tubules. The mid-gut consisted of the same layers of longitudinal muscles, circular muscles and the epithelium as found in fore-gut, but musculature decreased much in this region, Fig. 10(a) and (b). The longitudinal muscles were on the out side of the circular muscles, extending along its full length reaching upto the pyloric valve. The circular muscle layer consisted of one to two muscle fibres. The connective tissue was distinct at the base of the epithelial cells, with big round or oval nuclei. The peritoneal membrane was weakly developed. The thickness of the mid-gut wall was mainly by the epithelial cells which began from the base of the anterior lamella of the stomodaeal valve. The epithelium consisted of columnar cells, with granular cytoplasm and round or ovoid nuclei. Many chromatin granules of irregular shape and size were present in the nuclei. The epithelium formed small folds around cup like depressions at the bottom of which there were groups of regenerative cells called nidi. The epithelial cells of the mid-gut were devoid of cuticle. The shape and size of regenerative cells was irregular. The peritrophic membrane was in the form of two to four concentric coverings surrounding the food particles. It was non-cellular, hence it was not a true membrane.<sup>7</sup>

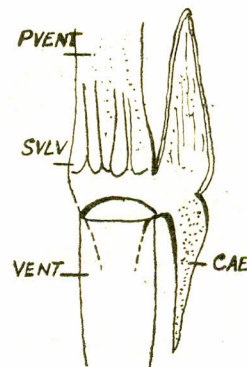


Fig. 9.—Showing cardiac valve (Semi-diagrammatic).

*Hepatic Caecae.*—Histologically the epithelial lining of the hepatic caecae resembled the mid-gut, except that cells were smaller than mid-gut cells, Fig. 11(a) and (b). Similar findings were also reported by Hodge,<sup>8,9</sup> in case of grasshopper, *Melanoplus differentialis* (Thomas) and *Locusta migratoria* (L). Internally epithelium was thrown into irregular longitudinal folds which ran along the entire length of the anterior lobes, while the posterior lobes were devoid of such longitudinal folds. The number of longitudinal folds in the anterior lobes varied between 14 to 18. The epithelial cells were columnar in shape having well developed nuclei abundant in chromatin granules. They were shorter on the tips than the sides and crypts of the longitudinal folds. Some of the cells had secretory vacuoles.

The secretion of cells seemed to be holocrine in nature as distal ciliated ends of the vacuolated cells were found to be broken. The regenerative cells became elongated in between the neighbouring cells and after undergoing proper development they became ciliated.

*Pyloric Valve.*—The pyloric valve, separated the mid-gut from the hind-gut and consisted of rounded flaps internally and marked by a circular ring of muscles externally. It was much weakly developed as compared to cardiac valve. The twelve openings of excretory ampullae formed by the union of Malpighian tubules were situated anterior to this valve, Fig. 12.

*Hind-gut.*—The hind-gut extending from the third abdominal segment upto the last segment of the body consisted of ileum, colon and rectum. It was not clearly demarcated from the mid-gut. It was relatively short as compared to fore-gut Table 1. The place of the origin of Malpighian tubules marked the junction of mid-gut with the hind-gut. In general morphology the hind-gut resembled the fore-gut more than the mid-gut. Ileum might extend upto the half length of fifth abdominal segment. Externally six longitudinal muscles ran along whole length of the hind-gut. The ileum consisted of the same layers like the rest of the hind-gut. It consisted of intima, epithelium and muscular lining, Fig. 13 (a) and (b). The intima was very thin. The epithelial cells varied from cuboid to columnar in shape and the connective tissue was extremely thin. The circular muscles were thin consisting of two to four fibres. The epithelium along with connective tissue and intima was thrown into villi like projections, Fig. 14. The maximum number of villi was found to be twelve at the anterior end and their number decreased posteriorly.

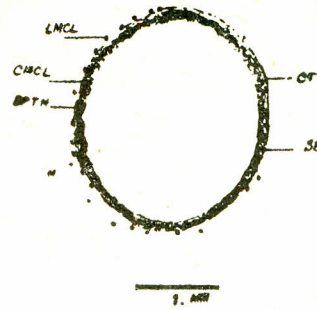


Fig. 10 (a).—Showing transverse section through mid-gut x18.

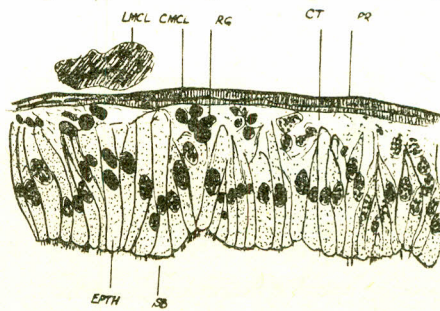


Fig. 10 (b).—Showing magnified transverse section through mid-gut x120.

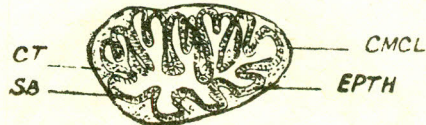


Fig. 11 (a).—Showing transverse section through hepatic caecum x1.8.

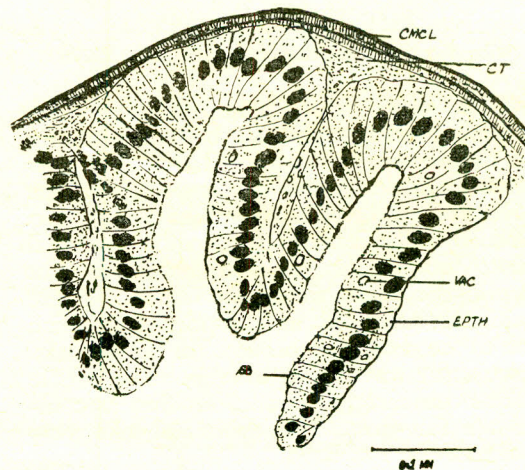


Fig. 11 (b).—Showing magnified transverse section through hepatic caecum x120.

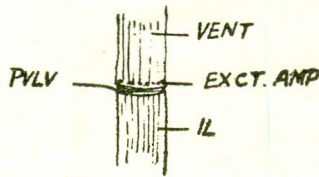


Fig. 12 (b).—Pyloric valve (Semi-diagrammatic).

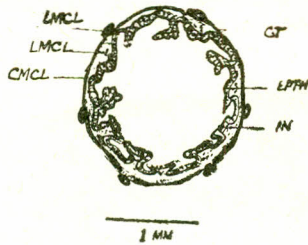


Fig. 13 (a).—Showing transverse section through ileum x18.

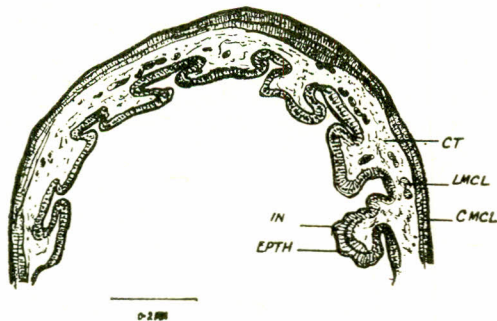


Fig. 13 (b).—Showing magnified transverse section through the ileum, showing thin intima and thin circular muscles x120.

*Colon.*—The colon was situated between fifth and sixth abdominal segments, with a diameter less than the ileum. It was noted that the outer longitudinal muscles were continued from the ileum. Histologically colon resembled ileum, Fig. 15 (a) and (b). The inner foldings of the epithelial lining were less as compared to the ileum, but they were bigger nearly filling the lumen. There were mainly six such folds at its hinder end, which passed on to the rectum to become the rectal pads. The musculature was similar to crop. The cuticle was thick as compared to ileum, but thin as compared to the fore-gut. The epithelial cells were small and more or less cuboid in shape.

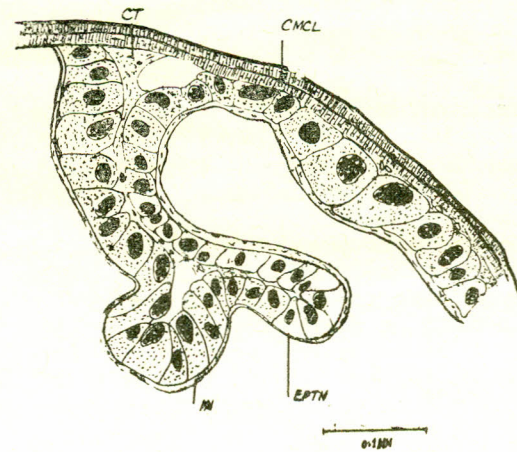


Fig. 14 (a).—Showing magnified transverse section through ileum x270.

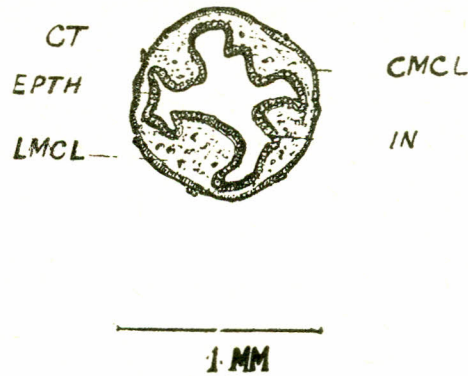


Fig. 15 (a).—Showing transverse section through colon x18.



Fig. 15 (b).—Showing magnified transverse section through colon x123.

*Rectal Valve.*—It consisted of enlarged folds at the proximal end of colon. This valve prevented the return of the faecal matter from the rectum back into the colon.

*Rectum.*—The rectum was the enlarged posterior end of the hind-gut, Fig. 2; and was clearly demarcated from the colon by its size and position, being a little above the long axis of the body. Six bundles of longitudinal muscles extended along its length in between the rectal pads, Fig. 16 (a) and (b). It narrowed posteriorly and ended into anus, which opened dorso-posteriorly.

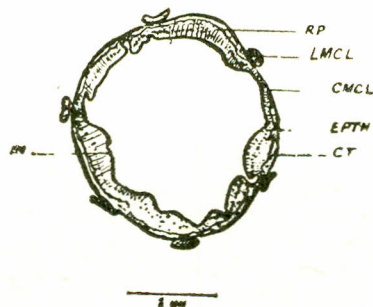


Fig. 16 (a).—Showing transverse section through rectum x18.

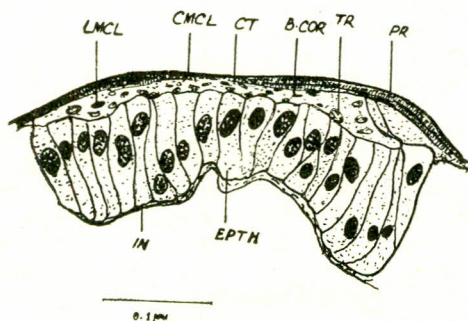


Fig. 16 (b).—Showing magnified transverse section through rectum x120.

Histologically the rectum was complicated and different from other portions of the hind-gut. The epithelium between the rectal pads was of cuboidal-columnar type with clear cell walls and nuclei. There was considerable variation in the size of the nuclei. Six ridges on its inner wall called rectal pads were longer than the other cells. These pads were present along the full length of the rectum, except the small posterior region of 1.5 to 2 mm. in length. Rectal pads consisted of a single layer of columnar epithelial cells as described by Phillips.<sup>10</sup> The connective tissue between the circular muscles and the epithelium was well developed with distinct nuclei. Cilia on the rectal gland cells was not distinguishable. Chauvin<sup>1</sup> also has not described their presence. The abundance of tracheae in the epithelium of the rectal glands, as described by Nenyukov and Parfentev<sup>11</sup> in *Locusta migratoria* has been confirmed from the present findings. The intima was extremely thin over the rectal pads, but comparatively thick between the pads. The peritoneal sheath was indistinguishable from the circular muscles, which consisted of 2-4 muscle fibres.

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