SECTION C
HISTOMORPHOLOGY AND ECOPHYSIOLOGY
SECTION-C: HISTOMORPHOLOGY AND ECOPHYSIOLOGY

CHAPTER IV

DIGESTIVE SYSTEM

As domestic pests, endowed with the unique capacity for cellulose digestion, the Lepismatids have evoked considerable interest among entomologists. The anatomy, histology and the microbial and parasitic associations have been intensively investigated by a number of investigators after Grassi (1888), Cornwall (1915) and Chang (1943), who contributed to the preliminary understanding of the morphology of the digestive system. Pohl (1957) worked out, on a comparative basis, the anatomy and histology of the digestive system of Lepisma saccharina and Atelura formicaria, a myrmecophilous species. A similar work was carried out by Barnhart (1961) on Lepisma saccharina and Ctenolepisma campbelli. Investigations of Modder (1967) on Acrotelsa collaris and of Larsson (1973) on Lepisma saccharina have shed further light on the histological aspects of the digestive system of these insects. Aspects of cellular digestion in C. lineata have been elaborately worked out by Lasker and Giese (1956). And yet, available informations on the digestive system of Indian species of Lepismatidae are preliminary (Cornwall, 1915 and Mukerji and Sengupta, 1955) and relate only to gross morphology.

The objective of the present investigation is to give a comparative account of the digestive system of a soil...
living species - *Acrotelsa collaris* and two domestic species *Thermobia domestica* and *Ctenolepisma longicaudata* and to bring out, as far as possible, the adaptive modifications in relation to their habitats. In this attempt, a brief report of the intestinal microflora and fauna was also found to be inevitable.

IV.1. MATERIALS AND METHODS:

*Acrotelsa collaris*, a free, soil living species, was collected from the scrub jungles of Maruthamalai and two domestic species namely *Thermobia domestica* and *Ctenolepisma longicaudata* were collected from houses, libraries and shops in and around Coimbatore. The specimens were anaesthetized in chloroform, partially embedded in wax and dissected in insect saline, as recommended by Yamasaki and Narahasi (1959). After disengaging the internal organs from the fat tissue, a few drops of 1% methylene blue was added for better differentiation and clarity of structures such as the salivary glands and malpighian tubules. Measurements of the digestive system were carried out with the help of oculometer under the binocular dissection microscope and drawings were made using Camera lucida.

In order to study the proventricular armature, the dissected materials were treated in 10% Potassium hydroxide for 24 hrs, washed in 5% acetic acid, dehydrated in cello-solve and mounted in polyvinyl - lactophenol.
For histological preparations, the anaesthetized entire insects as well as dissected materials of the digestive system were fixed in Bouin's fluid for 24 hours as well as in Carnoy's for 5-6 hrs. After several changes in 70% alcohol, the materials were processed following Peterfi's celloidin-paraffin embedding method. Longitudinal sections of the entire insects were cut at 8μ and both longitudinal and transverse sections of the digestive system were cut at 6μ. The sections were stained in Heidenhain's haematoxylin and eosin. Photomicrographs were taken using Ashahi Pentax photomicrographic equipments.

IV.2. GROSS MORPHOLOGY OF THE DIGESTIVE SYSTEM:

In general, the digestive tract of all Lepismatids is simple, tubular and distinctly divisible into the stomodaeum, the mesenteron and the proctodaeum, as reported in all other Lepismatids. The stomodaeum consists of a broad cibarium, a distinctly narrow pharynx, an equally narrow and elongated oesophagus, a bipartite thin walled crop and a thick walled muscular proventriculus. The mesenteron is anteriorly produced into several (10-12) diverticula or the gastric caeca that partially envelop the proventriculus. The mesenteron is further divisible into an anterior expanded region that gradually merges with a posterior narrow region. The proctodaeum is differentiated into an elongated ileum, a relatively shorter and wide colon and a more complicated
rectum with its rectal pads or rectal glands. The various components of the digestive tract present varying degrees of differentiation (specialization, as it may appear) in the 3 different species investigated here.

IV.2.1. Acrotelsa collaris:

The digestive tract in *A. collaris* (Plate XXVIII, 1 and Table 18) is a simple and straight tube.

The Stomodaeum: The pharynx is narrow and very short. The oesophagus is narrow and elongated, interrupted with minor sacculations. It is $2.067 \pm 0.176$ mm long and $0.493 \pm 0.048$ mm broad. The two posterior sacculations are prominently enlarged to form the thin walled, wide, bipartite sac designated here as the crop.

The crop or "ingluvies" of Larsson (1973) is $1.824 \pm 0.206$ mm long and $1.093 \pm 0.103$ mm broad. The anterior chamber of the crop is more elongated, $1.013 \pm 0.223$ mm long and $0.944 \pm 0.730$ mm broad and the posterior chamber is relatively shorter, $0.640 \pm 0.068$ mm long and $1.080 \pm 0.111$ mm broad.

The proventriculus or gizzard is a funnel shaped, thick walled muscular chamber, $1.347 \pm 0.084$ mm long and $1.20 \pm 0.103$ mm broad. It consists of an anterior bulbous muscular part that encloses the masticatory apparatus and a posterior,
PLATE XXVIII DIGESTIVE SYSTEM

A. COLLARIS

T. DOMESTICA

C. LONGICADA

OE

SP

CR₁

CR₂

PV

CO

MS

MT

IL

COL

RP

1 mm
TABLE 18  MORPHOMETRIC ANALYSIS OF THE DIGESTIVE SYSTEM (in mm, n = 6) MEAN ± S.E.

<table>
<thead>
<tr>
<th>Species</th>
<th>Oesophagus</th>
<th>Crop</th>
<th>Proventriculus</th>
<th>Mesenteron</th>
<th>Caecum</th>
<th>Ileum</th>
<th>Colon</th>
<th>Rectum</th>
<th>Salivary gland (up to the head)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrotelsa</td>
<td>L</td>
<td>2.067±</td>
<td>1.824±</td>
<td>1.347±</td>
<td>2.227±</td>
<td>0.267±</td>
<td>1.013±</td>
<td>0.653±</td>
<td>0.528±</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>0.176±</td>
<td>0.206±</td>
<td>0.084±</td>
<td>0.178±</td>
<td>0.034±</td>
<td>0.166±</td>
<td>0.063±</td>
<td>0.086±</td>
</tr>
<tr>
<td>Collaris</td>
<td>W</td>
<td>0.493±</td>
<td>1.093±</td>
<td>1.120±</td>
<td>0.707±</td>
<td>0.200±</td>
<td>0.387±</td>
<td>0.400±</td>
<td>0.688±</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>0.048±</td>
<td>0.103±</td>
<td>0.103±</td>
<td>0.086±</td>
<td>0.027±</td>
<td>0.025±</td>
<td>0.029±</td>
<td>0.067±</td>
</tr>
<tr>
<td>Thermobia</td>
<td>L</td>
<td>3.730±</td>
<td>1.427±</td>
<td>1.360±</td>
<td>2.400±</td>
<td>0.520±</td>
<td>1.760±</td>
<td>0.827±</td>
<td>0.640±</td>
</tr>
<tr>
<td>domestica</td>
<td>W</td>
<td>0.464±</td>
<td>1.133±</td>
<td>1.120±</td>
<td>0.992±</td>
<td>0.307±</td>
<td>0.347±</td>
<td>0.587±</td>
<td>1.427±</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>0.039±</td>
<td>0.056±</td>
<td>0.072±</td>
<td>0.078±</td>
<td>0.025±</td>
<td>0.034±</td>
<td>0.158±</td>
<td>0.068±</td>
</tr>
<tr>
<td>Ctenolepismia</td>
<td>L</td>
<td>3.107±</td>
<td>1.640±</td>
<td>1.240±</td>
<td>2.370±</td>
<td>0.507±</td>
<td>1.013±</td>
<td>0.613±</td>
<td>0.736±</td>
</tr>
<tr>
<td>longicaudata</td>
<td>W</td>
<td>0.587±</td>
<td>1.067±</td>
<td>0.853±</td>
<td>1.013±</td>
<td>0.253±</td>
<td>0.307±</td>
<td>0.373±</td>
<td>0.960±</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>0.057±</td>
<td>0.103±</td>
<td>0.040±</td>
<td>0.105±</td>
<td>0.025±</td>
<td>0.025±</td>
<td>0.027±</td>
<td>0.067±</td>
</tr>
</tbody>
</table>

L = Length        W = Width
short, relatively narrow passage (cardiac valve of Barnhart, 1961) leading to the mesenteron or the ventriculus of most authors.

The mesenteron (2.227±0.178mm long and 0.706±0.08 mm broad) or the stomach of Cornwall (1915) has two well defined regions, a short and wide anterior region 0.520±0.089 mm long and 0.707±0.086 mm broad and a narrow elongated posterior region, 1.707±0.218 mm long and 0.493±0.038 mm broad. The anterior region is evaginated all around to form 10 short peanut shaped gastric caeca. Each caecum is 0.267±0.034 mm long and 0.20±0.027 mm broad. The caecum and proventriculus are enveloped by a thick pad of fat tissue. The number of hepatic caecae appear to vary in Lepismatids. Cornwall (1915) had mentioned 8-10 large sacculi in his L. saccharina; 9 fingered rosette in C. campbelli (Barnhart, 1961). Whereas Barnhart (1961) reported them to be reduced in L. saccharina, Larson (1973) could not trace any.

The malpighian tubules are four in number and they originate distinctly from the posterior extremity of the mesenteron. In most of the earlier descriptions, the malpighian tubules are reported to open into the proctodaeum immediately anterior to the pyloric constriction (Barnhart, 1961 and Modder, 1967). Cornwall (1915) has described them to be marking the junction of stomach and small intestine. The number of malpighian tubules in Lepismatids appear to vary
considerably. Whereas most of them have been reported to have only 4, Cornwall (1914) has shown 5, Pohl (1957) 8, Handschin (1929) and Paclt (1956) 4 to 8 and Weber (1954) 4 to 20.

The **Proctodaeum** consists of a long and slightly bent ileum (1.013±0.166 mm long and 0.387±0.025 mm broad), histologically differentiated into anterior and posterior regions, followed by a short and wide colon (0.653±0.063 mm long and 0.4±0.029 mm broad) and the rectum whose wall is thrown into 4 rows of transversely oriented pouches or the rectal glands or the rectal pads. These pouches are arranged in four rows, a pair of dorsal median rows and a pair of lateral rows, each row having four pouches. The ileum has been described as "small intestine" by Cornwall (1915) and "anterior intestine" by Barnhart (1961) and Modder (1967). A distinct colon has not been recognised by earlier workers and the colon and rectum have been collectively designated as "large intestine" (Cornwall, 1915), posterior intestine (Modder, 1967) and rectum proper (Larsson, 1973).

The **salivary system** consists of a pair of elongated and transparent salivary glands (labial glands of Modder, 1967) lying on either side of the oesophagus and anteriorly entering the head as cephalic lobes (mandibular glands of Modder, 1967) with their less conspicuous lateral extensions into the head capsule. The cephalic lobe is referred here as the **anterior lobe** of the principal salivary gland and the
thoracic lobe as the posterior lobe of the principal salivary gland. The two posterior lobes unite posteriorly underneath the oesophagus. The two ducts of the salivary glands on each side are not distinctly visible in the dissected materials. But in sections, they originate at the junction of the anterior and posterior lobes of the principal salivary gland. The outer duct, here referred to as accessory salivary duct, deviates much from the inner duct on its course, enters the head capsule at its posterolateral angle, and enlarges into a transversely disposed vesicle at the vertex. The two vesicles then meet to form a spaceous common vesicle. The inner duct on each side, here referred to as the principal salivary duct, runs parallel to the oesophagus, enters the head capsule and at the occiput meets its fellow of the opposite side to form a short, common duct. This duct then meets the common vesicle of the accessory salivary duct and then both together enter ventrally into the anterior end of the pharynx.

IV.2.2. Thermobia domestica:

The digestive system of T. domestica (Plate XXVIII,2 & Table 18), resembles that of A. collaris in its basic pattern. The morphometric analysis of the digestive system is given in table 18. But it differs from that of A. collaris in the following points:

1. The Caeca that are 10 in number are prominently developed, especially the lateral caeca which are more
prominently elongated than the median caeca. Each lateral caecum is 0.520±0.027 mm long and 0.307±0.025 mm broad.

2. The junction of the proventriculus and the ventriculus is distinctly differentiated into a narrow short passage, whereas, in *A. collaris* the proventriculus apparently merges with the ventriculus to form a broad passage.

3. The ileum is coiled and it makes a complete loop before it joins the colon. It is comparatively longer (1.76±0.080 mm long).

4. The cephalic extension of the anterior lobe of the principal salivary gland is much more elaborately expanded within the head capsule, almost filling it entirely.

5. The accessory salivary vesicle on each side of the head capsule has more sacculations and a median anterior diverticulum.

IV.2.3. *Ctenolepisma longicaudata*:

The digestive system of *C. longicaudata* (Plate XXVIII, 3 & Table 18) too resembles that of *A. collaris* in its general morphology and approaches closer to that of *T. domestica* in its disposition. Ileum is not coiled as in *T. domestica* but more curved (1.013±0.064 mm long and 0.307±0.025 mm broad) than *A. collaris*. The caeca are large, 10-12 in number, 0.507±0.017 mm long and 0.253±0.025 mm broad. The salivary
glands are relatively shorter than those of *T. domestica* (1.296±0.064 mm long and 0.512±0.041 broad) and the ducts are similar in their disposition. However, the anterior diverticulum of the cephalic vesicle is not traced in the present investigation.

IV.3. **HISTOMORPHOLOGY:**

IV.3.1. **The Stomadaeum:**

The stomodaeum proper originates at the buccal cavity which is lined by fairly thick chitinous intima and bounded on its sides by the mouth parts (Plate XXIX, 1). The buccal cavity is divisible into two distinct regions by the hypopharynx, an anterior dorsal cibarium and a posterior more ventral salivarium which is the beginning of pharynx into which the common salivary duct opens midventrally.

A preoral cavity consisting of a cibarium and salivarium has been described by Modder (1967) in *A. collaris*. Such a distinction of a preoral cavity lying in front of the hypopharynx is not traced in the present investigation, though the common opening of chamber of the salivary ducts is clearly found opening behind the hypopharynx into the chitinized chamber, here referred to as pharynx. The lateral diverticula of the pharynx in *T. dimestica* (Plate XXIX, 4) is considered here as unique.
Pharynx: It is a short but wide tube that establishes an effective muscular connection with the fronto-clypeal (dorsal) region and the lateral and the posterior margins of the head capsule by three to four sets of pharyngeal dilator muscles which are more prominently developed in T. domestica (Plate XXIX, 2) than in A. collaris (Plate XXIX: 2). The wall of the pharynx consists of a layer of pavement epithelium surrounded by a layer of circular muscles. Longitudinal muscles are feebly developed. The lumen of the pharynx is incompletely partitioned by the longitudinal folds of its wall whose chitinous intima projects into the lumen. In T. domestica, the pharynx, at its origin, develops two very prominent lateral diverticula on each side, each surrounding the corresponding diverticulum of the accessory salivary vesicle (Plate XXIX, 4). The intimal lining of these pharyngeal diverticula is thick and spiny.

Barnhart (1961) and Larsson (1973) have observed sclerotised spines and hairs in the intima of the pharynx Oesphagus and crop in L. saccharina and C. campbelli. In the present investigation, the intima of the pharynx alone shows such intimal armature. Modder (1957) has reported occasional groupings of longitudinal muscle fibres between circular muscle and the epithelium in A. collaris. But in the present investigation, the longitudinal muscles have been found invariably outer to the circular muscles. Barnhart (1961) is of the view that emptying of solid food apparently occurs prior to ecdysis.
PLATE XLI

1. *A. collaris*: L.S. of the head passing through cibarium, hypopharynx and pharynx x75.

2. *A. collaris*: L.S. the head showing pharyngeal dilator muscles x100.

3. *T. domestica*: L.S. of the head showing pharyngeal dilator muscles x150.

4. *T. domestica*: L.S. of the head showing pharyngeal pouches and salivary duct x150.

5. *A. collaris*: L.S. of the oesophagus x150


7. *T. domestica*: L.S. of the oesophagus showing spore like hard materials in the food x150.

8. *T. domestica*: Enlargement of the wall of the oesophagus x400.

9. *A. collaris*: L.S. through crop showing a pouch with organic matter x100.

10. *A. collaris*: L.S. showing the junction of crop 1 and crop 2 x100.

11. *T. domestica*: L.S. showing the bipartite crop x50

12. *T. domestica*: L.S. showing the junction of oesophagus and crop showing regulatory valve x100.
**Oesophagus:** The oesophageal wall consists of an inner layer of chitinous intima showing varying degrees of development and projecting into the lumen. There is a single layer of cuboidal epithelium resting on a well defined basement membrane. The nuclei are round and less granular. The inner layer of circular muscles are more prominent than the outer longitudinal muscle layer at the proximal region of the oesophagus. But as it approaches the crop, the longitudinal muscles are found to be more prominent. At the proximal end of the oesophagus, the oesophageal-pharyngeal muscles establish contact with the powerful tentorium. A distinct oesophageal valve is lacking in *A. collaris*. But in *T. domestica* and in *C. longicaudata*, the epithelium is invaginated into the lumen to form prominent longitudinal folds (Plate XXIX, 8) that appear to serve as effective regulating mechanism. The chitinous intima in these two species is produced into simple minute convolutions, whereas, in *A. collaris* it is elaborately developed into several layers projecting into the lumen throughout the length of the oesophagus (Plate XXIX, 5 & 6). In *T. domestica*, at the junction of the oesophagus and the crop, the epithelial layer is produced into several prominent longitudinal folds which act as valves and regulate the flow of materials (Plate XXIX, 12). Such valvular arrangement is not seen in *C. longicaudata* and in *A. collaris*.

**Crop:** This is the largest part of the alimentary canal. In all the three species examined, the crop is found to be a
bipartite thin walled chamber (Plate XXIX, 10&11), with a long distended anterior part and a comparatively short posterior part, more dilated in *T. domestica*. The anterior crop is further differentiated into two chambers by a faint invagination of the wall. Histologically, there is no marked variation between oesophagus and crop. The crop wall is formed of an inner layer of chitinous intima, a flat cuboidal epithelium resting on a distinct basement membrane and a prominent layer of inner circular and outer longitudinal muscles. In *A. collaris* collected from the field, the crop shows prominent saccules, stuffed with food that consists of organic debris (Plate XXIX, 9). In the laboratory fed insects, however, such sacculations are not prominent. In the case of *T. domestica*, the crop as well as the oesophagus are stuffed with strongly chitinous spore like materials (Plate XXIX, 7).

**Proventriculus:** In all the three species, the proventriculus is a funnel form chamber with broad anterior and tapering posterior end and armed with definitive arrangement of chitinous plates that are provided with a variety of denticles and bristles. It is well differentiated from the crop by the thick muscular wall (Plate XXX, 4 & 5). The wall of the proventriculus in all the three species is composed of a single layer of flat epithelial cells resting on a basement membrane. This epithelial layer is lined by thick chitin that differentiates into a median dorsal, a median ventral
<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Description</th>
<th>Magnification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A. collaris</td>
<td>Proventricular armature</td>
<td>X50</td>
</tr>
<tr>
<td>2</td>
<td>T. donstagi</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>C. longicarin</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>A. collaris</td>
<td>L.S. through the crop and proventriculus showing the arrangement of proventricular armature</td>
<td>X50</td>
</tr>
<tr>
<td>5</td>
<td>C. longicarin</td>
<td>L.S. through the junction of crop and proventriculus notice the armature</td>
<td>X75</td>
</tr>
<tr>
<td>6</td>
<td>A. collaris</td>
<td>L.S. through the proventriculus showing the arrangement of proventricular armature</td>
<td>X75</td>
</tr>
<tr>
<td>7</td>
<td>A. collaris</td>
<td>Poster view showing the same</td>
<td>X150</td>
</tr>
<tr>
<td>8</td>
<td>T. donstagi</td>
<td>— through the proventriculus showing the six processes</td>
<td>X100</td>
</tr>
<tr>
<td>9</td>
<td>C. longicarin</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>C. longicarin</td>
<td>L.S. through the proventriculus in the caecum. Notice the bristle arrangement</td>
<td>X100</td>
</tr>
</tbody>
</table>
and 2 pairs of lateral processes (Plate XXX, 6 to 10) that vary considerably in their degrees of development and complexity in each species examined and provide an excellent material for biosystematic studies of Thysanura. The apices of all these six processes are opposed to each other and are heavily armed with denticles and bristles serving as effective mechanism for mastication (to be described below). The entire proventriculus at its proximal half is ensheathed by very powerful muscles arranged in six sectors. The fibres of each sector join the bases of each chitinous process. The longitudinal muscles are less prominent.

The Proventricular armature: In all the three species, the proventricular armature consists of six processes. The ventromedian process is elongated, club shaped and apically fringed with bristles. The paired elongated dorsolateral and ventrolateral processes are sword shaped and also fringed with denticles and bristles. In *C. longicaudata* the denticles are more prominently developed into a definite number of chitinous tubercles and in *T. domestica*, they are fringed with both tubercles as well as with more complicated elongated bristles (Plate XXX, 2 & 3). It is evident that duplication of these masticatory machinery is a specialization in *T. domestica*. In the case of *A. collaris* the tubercles are most prominent but less in number (Plate XXX, 1). The dorso-median process is an Y shaped armature, the two arms extending wide apart and connected to the dorsolateral processes by
Chitinous sheet. The inner surface of these arms is beset with fine bristles and the stem of the process faces the lumen of the crop serving as a partition wall, diverting the passage from the crop into the proventriculus through two distinct channels (Plate XXX, 4).

Thus, in *T. domestica*, the proventricular armature is more complicated and more elaborately developed than in the other two species. *A. collaris* has a more simple type and *C. longicaudata* has a more denticulate type.

Each component of this efficient masticatory apparatus is connected to each other and all of them move in a very co-ordinated fashion by the action of the sphincter type of circular muscles. By this arrangement, the lumen of the proventriculus is incompletely partitioned into six passages or channels. The lining of each passage is closely beset with chitinous armature that will not permit food particles to proceed further into the ventriculus without being finely masticated. In *A. collaris* and in *C. longicaudata*, the opening of the proventriculus into the mesenteron is wide and is guarded by a more prominent Cardiac valve (Plate XXXI, 1, 2 and 7). In *T. domestica*, the posterior part of the proventriculus is thickened to form a pad like muscular structure (Sphincter) with a narrow lumen that permits the passage of food intermittently in small quantities, thus serving as an efficient regulatory mechanism (Plate XXXI, 4).
In *C. longicaudata*, the passage is intermediate in size between that of *A. collaris* and *T. domestica*.

Though the proventriculus in Lepismatids has received considerable attention, the masticatory apparatus has not been adequately explained. Barnhart (1961) by comparing this armature with that of oriental cockroach, describes an anterior part with six sclerotized teeth and a posterior part with six cushions and a funnel like cardiac valve projecting into the mesenteron as six folds. Larsson (1973) describes 2 pairs of "valvula cordiaca" as intimal folds of flat epithelium of proventriculus. In the present investigation, it is clear that the complicity of the armature of the masticatory apparatus is directly related to the hardness of the food and the number of pieces of these processes is found to be almost double in *T. domestica*. The cardiac valve in all these three species examined appears to be circular invagination of the wall at the junction rather than as definite number of valvular folds.

The *Cardiac valve*: The entrance of the proventriculus into the ventriculus is guarded by a less prominent epithelial valve, commonly known as the cardiac valve or the stomodacal valve. The entrance is wide in *A. collaris* and *C. longicaudata*, whereas, it is too narrow in *T. domestica*. Though all three species have a well differentiated region of the proventriculus distal to the masticatory chamber, it is shortest,
5. **A. collaris**: H. V. through the junction of pre-ventricular and posterior (50).

6. **A. collaris**: Enlargement of the valve showing the cardiac valve. Notice the regenerative phenomenon (350).


8. **A. monstrosa**: H. V. through the junction of pre-ventricular and posterior (40). Notice the elongated ductus and the narrow elongated pre-ventricular valve.


10. **A. longicaudata**: H. V. through the junction of pre-ventricular and posterior (250).

11. **A. longicaudata**: Enlargement of the cardiac valve. Notice its similarity with that of **A. monstrosa** (250).

12. **A. collaris**: H. V. through the ductus (250).


14. **A. collaris**: Enlargement of the cardiac wall showing the secretory vesicles (50).

15. **A. collaris**: I. V. of ductus showing enlargement of cells under starvation (350).

16. **A. monstrosa**: H. V. through region of pre-ventricular showing fibrous muscular connection with the caecum (350).

17. **A. monstrosa**: Another view of the caeca (500).

18. **A. longicaudata**: I. V. of the caeca showing crypts (500).
1. **A. collaris**: L.S. through the junction of proventriculus and mesentron X50.

2. **A. collaris**: Enlargement of the same showing the cardiac valve. Notice the regurgitation phenomenon X150.


4. **C. domestica**: L.S. through the junction of proventriculus and mesentron. Notice the elongated caecum and the narrow posterior proventriculus X75.

5. **C. domestica**: Enlargement of the same showing cardiac valve X150.

6. **C. domestica**: Enlargement of the cardiac valve showing intravalvular space and muscles. Notice its chitinous nature and secretion of the peritrophic membrane X600.

7. **C. longicaudata**: L.S. through the junction of proventriculus and mesentron X150.

8. **C. longicaudata**: Enlargement of the cardiac valve. Notice its similarity with that of **T. domestica** X600.

9. **A. collaris**: L.S. through the caecum X150

10. **A. collaris**: Enlargement of the caecum. Notice the distribution of crypts X400.

11. **A. collaris**: Enlargement of the caecal wall showing the secretory vesicles X600.

12. **A. collaris**: L.S. of caecum showing enlargement of cells under starvation X150.

13. **T. domestica**: L.S. through region of proventriculus showing its muscular connection with the caeca X100.

14. **T. domestica**: Another view of the same X100.

15. **C. longicaudata**: T.S. of the caecum showing crypts X150.
widest and least muscular in \textit{C. longicaudata} and longest and narrowest and strongly contractile in \textit{T. domestica}. In \textit{A. collaris}, the epithelial valve (Plate XXXI, 3) is columnar and least differentiated and in marked contrast from the other two species, the epithelium is a continuation of the mesenteric columnar epithelium. In the case of \textit{T. domestica} and \textit{C. longicaudata}, the epithelium guarding the entrance is distinctly different from that of the proventriculus and that of mesenteron in being chitinous (Plate XXXI, 5, 6 & 8) and secretory and is considered here as the source of peritrophic membrane (discussed below). It is a single layer of epithelium that is thrown into convolutions. These serve as an effective regulatory mechanism, since they are lined by powerful longitudinal muscles as well as prominent intravalvular space that is filled with an interstitial tissue. The role of blood pressure in the regulatory effort cannot be ruled out.

IV.3.2. The mesenteron:

In all the 3 species investigated, the mesenteron is apparently similar histologically (Plate XXXII, 6, 7 & 8). The epithelium of anterior mesenteron and the posterior mesenteron appear to behave differently and for that reason they are not histologically same at any particular circumstance. The epithelium of both regions of the midgut consists of a single layer of columnar epithelial cells with striated border and an intermittent display of compactly packed short
PLATE XXXII

1. **A. collaris** : L.S. through the anterior and posterior mesontron. Notice the difference in the nature of the mid anterior secretory phase and posterior non-secretory phase X150.


4. **A. collaris** : L.S. through anterior and posterior mesontron under starvation. Notice the accumulation of secretory vacuoles at the posterior region X150.

5. **A. collaris** : Enlargement of the same showing degeneration of the anterior region and proliferation of posterior wall. X400.

6. **A. Collarig** : Enlargement of the mesontron showing food enclosed in peritrophic membrane X400.

7. **T. domesticus** : Enlargement of mesenteric wall X400.


9. **C. longicaudata**: Enlargement of the mesenteric wall showing peripthelial space X500.
regenerative cells or the nidi at the base. The basement membrane is distinctly seen, enveloped by a prominent inner layer of circular muscles and a less prominent outer layer of longitudinal muscles. The junction between the anterior and posterior regions is often marked by more elongated pillar like columnar cells (Plate XXXII, 1&5) that serve as columnar valve. The nidi of the epithelium in front of this valve shows stage of disengagement and distribution indicating active phase of secretion (Plate XXXII, 2), while the nidi of the epithelium behind this valve are compact, the cells appear to be in a quiescent stage or in a preparatory phase (Plate XXXII, 3). Under prolonged starvation, in A. collaris, when the epithelium of anterior mesenteron is completely depleted, the epithelium of posterior mesenteron shows profuse proliferation of cells (Plate XXXII, 4). Under normal conditions, when the food is present in the posterior mesenteron, the nidi have been found to be least defined. This suggests a phasic behaviour of the mesenteric epithelium.

In several samples of C. longicaudata, a distinct peri-epithelial space in between the epithelium and circular muscle, filled with loose tissue and nidi is noticed (Plate XXXII, 9). As will be described below, the malpighian tubules establish communication with this space, suggesting a functional significance of osmoregulatory nature.
In the active secretory phase, the nidi proliferate and replace the degenerating cells. Under such conditions, the nuclei are found either dispersed throughout the epithelium or arranged in a linear fashion, actively involved in secretion. The secretion, though one could expect it to be holocrine, appears to be merocrine. In *A. collaris* during prolonged starvation, the nidi are found to be less active and reduced and the midgut epithelium is found to be shrunken and thrown into distinct folds without any trace of secretions (Plate XXXII, 4).

**Gastric Caeca:**

The proximal limb of the mesenteron is wide and it evaginates anteriorly to develop into 10-12 diverticula, the gastric caeca. In all the three species, the gastric caeca histologically resemble the midgut in structure and arrangement of columnar epithelial cells, the nidi and the musculature. In *A. collaris*, the caeca are less developed (Plate XXXI, 9 & 10), whereas, in *T. domestica* and *C. longicaudata*, they are much elongated and almost envelop the proventriculus. The caecal epithelium is uniformly broad and the nidi are arranged at the base in *A. collaris* and *T. domestica*, whereas, in *C. longicaudata*, the caecal epithelium forms distinct crypts (Plate XXXI, 15). In *A. collaris*, under prolonged starvation, the gastric caeca enlarge considerably and their epithelial cells remain much elongated (Plate XXXI, 12) and do not appear to be actively secreting.
In the case of *T. domestica*, the posterior region of the proventriculus establishes muscular connection with the gastric caeca all around (Plate XXXI, 13 & 14), creating a muscular meshwork that serves as an ejaculatory mechanism. When the proventricular orifice contracts by means of the sphincter, the gastric caeca too contract synchronously, ejecting the secretory enzymes into the ventriculus. When the sphincter relaxes, the gastric caeca too expand. This may also serve as a stimulus for secretion. This regulatory mechanism is found to be a unique feature in *T. domestica*, not found in the other two species. Thus it appears that the flow of food from the proventriculus into the mesenteron and the corresponding ejection of digestive fluid from the caeca is synchronous and intermittent.

"Secretory spherules at the peritrophic membrane" and "cluster of clear vesicles" in the epithelium of caeca that are discharged into the lumen have been reported by Barnhart (1961) and Modder (1967) respectively. In the present investigation, such secretory spherules are found only in *A. collaris* and accumulation of such spherules at the posterior mesenteron (Plate XXXI, 11) of the insects under prolonged starvation is common. The occurrence of deeply staining granules in these spherules may tempt one to relate them to bacteriform bodies. But their association with the free ends of the epithelium clearly reveals the process of dissociation as secretory vesicles.
Peritrophic membrane:

The food present in the midgut as well as in the hind gut is found enveloped by peritrophic membrane that presents varying degrees of thickness. It is invariably present in all the three species investigated. The origin of this membrane appears to differ. In *A. collaris*, it is apparently secreted by the entire mesenteric epithelium by the process of delamination starting from the cardiac valve. In *T. domestica* and *C. longicaudata*, the chitinous tissue guarding the entrance of the proventriculus into the mesenteron secretes the peritrophic membrane and no delamination process is noticed in any part of the mesentric epithelium as seen in *A. collaris*. In all the three species, the ectoperitrophic space is fairly wide and the peritrophic membrane continues to persist in the hind gut too. In *A. collaris*, it is seen enveloping the food in the proventricular chamber (Plate XXXII, 6) also suggesting the possibility of a regurgitation phenomenon. In starved condition also, a distinct peritrophic membrane is recognizable in the midgut.

The occurrence of peritrophic membrane enveloping the food in the midgut is commonly reported in *Thysanira* (Snodgrass, 1935, Rockstein 1965, Barnhart 1961, Modder 1967 and Larsson 1973). But the origin of such chitinous, protective membrane in these insects is not so far reported. In the present investigation, in *T. domestica* and in *C. longicaudata*,...
it corresponds to the second type of peritrophic membrane of Waterhouse (1953), Richards and Richards (1971 and 1977) and Wigglesworth (1972) in which a band of chitinous cells of the cardiac valve facing the lumen is the source of peritrophic membrane. The occurrence of a spaceous ectoperitrophic membrane according to Richards and Richards (1977), is an evidence of such an origin of peritrophic membrane. Although a spaceous ectoperitrophic membrane is found in all the three species investigated, in *A. collaris*, the origin of this membrane is distinctly by delamination of midgut epithelium. Regurgitation of food into the proventriculus is found only in *A. collaris* and a similar phenomenon has been reported in coleoptera, Mallophaga and Orthoptera by Rockstein, (1965).

**Malpighian tubules:**

The malpighian tubules are four in number in all the three species and all arise independently of the other as evagination of the epithelium at the posterior extremity of the mesenteron (Plate XXXIII, 1, 4 & 7). In *C. longicaudata*, the wall of the malpighian tubule, as a continuation of the mesenteric epithelium, is found to make a convoluted course at the place of its origin (Plate XXXIII, 13) forming an "ampulla". In *A. collaris*, the lumen of the malpighian tubules are almost uniformly wide and with distinct brush border. In certain segments, the lumen contains excretory materials (Plate XXXIII, 6), whereas, in most part, the lumen is clear
1. **A. collaris**: L.S. through the junction of the aecessoron and filum showing opening of malpighian tubules X150.

2. **A. collaris**: L.S. of the same showing pyriform valve X150.

3. **A. collaris**: Enlargement of the pyriform valve, notice the entry of malpighian tubule into aecessoron X500.

4. **A. collaris**: Enlargement of the entry of malpighian tubule. Notice its aecessoric nature X1500.


6. **A. collaris**: L.S. of the malpighian tubule showing association X150.

7. **A. dentata**: L.S. through the junction of aecessoron tubules, notice the two regions of the filum and the opening of malpighian tubules into aecessoron X150.

8. **A. dentata**: Association of malpighian tubules with the aecessoron X150.

9. **A. dentata**: Enlargement of two limbs of malpighian tubules having common wall and the inner limb having common wall with aecessoron X500.

10. **A. dentata**: Intimate association of malpighian tubule with the aecessoron. Notice the muscular sheath around the tubule X1500.

11. **A. dentata**: Opening of a segment of the malpighian tubules into the aecessoron X500.

12. **C. longicaudata**: Junction of aecessoron of hind gut showing entry of malpighian tubules into aecessoron X150.

13. **C. longicaudata**: Enlargement of the aecessoronic wall where the malpighian tubules take origin as coiled tube X4000.

14. **C. longicaudata**: Enlargement of aecessoron showing the entry of malpighian tubule into the periglandular space X1500.

15. **C. longicaudata**: Vesicular nature of malpighian tubules X400.
In *C. longicaudata*, the malpighian tubules are dilated in certain segments and appear vesiculate (Plate XXXIII, 14). In *T. domestica* and in *C. longicaudata*, there is a distinct indication of development of crytonephric system. In *T. domestica*, it is more pronounced and throughout the length of the mesenteron, the malpighian tubules are found to be in close association with its wall (Plate XXXIII, 8). Often, two limbs of the malpighian tubules are bound by a common wall and the limb that lies attached to the mesenteric wall has no distinct wall of its own (Plate XXXIII, 9). In several places, the malpighian tubules establish openings into the hind part of the mesenteron, after having established intimate contact by being enveloped by a muscle layer or sheath (Plate XXXIII, 10 & 11). In the case of *C. longicaudata*, similar type of communication has been established between the malpighian tubules and the periepithelial space of the mesenteron (Plate XXXIII, 12 & 15). Absence of similar association in the case of *A. collaris* is significant. Water conservation in species living indoors is attributed to this association.

IV.3.3. **Proctodeaum:**

The proctodeaum in Lepismatids consists of three well defined regions, a tubular ileum, a wide colon and a rectum with rectal pads. The entrance of the mesenteron into the proctodeaum is guarded by epithelial valve or the
pyloric valve (Plate XXXIII, 2 & 3) which is apparently mesenteric in nature. The pyloric valve in all the three species is not so prominently developed as in many other insects.

The Ileum:

The Ileum is well marked from the mesenteron by the appearance of folds in the epithelium. It is referred to as anterior intestine in _A. collaris_ by Modder (1967). It is divisible into an anterior, more dilated region and a posterior narrow region (Plate XXXIV, 2). The ileac wall consists of chitinous intima that makes several convolutions, often found to be detached from the epithelium (Plate XXXIV, 1), a thick layer of columnar epithelium that makes numerous longitudinal and transverse folds (Plate XXXIV, 3) and an inner layer of circular and an outer layer longitudinal muscles. The chitinous intima is often found to be produced into short spinous projection into the lumen. The epithelium of the anterior ileum is less folded than that of the posterior ileum which gives more padded appearance. In _T. domestica_, as mentioned earlier, the ileum coils at its middle.

Colon:

Histologically, the colon (Plate XXXIV, 4), resembles the ileum to a certain extent. The epithelial folds are much more prominent and the circular muscles are
PLACE X:05 RV

1. *A. collaris*  
   L.S., through the junction of the mesenteron and ileum. Notice the nature of the anterior ileum. X150.

2. *A. collaris*  
   L.S., through the ileum and colon. Notice the longitudinal folds and their intestines. X 75.

3. *A. collaris*  
   T.S., through the posterior ileum (under starvation). Notice the longitudinal folds X 400.

4. *A. collaris*  
   L.S., through the colon and rectum. Notice the origin and insertion of the dilators. X 75.

5. *A. collaris*  
   Enlargement of the colon. Notice the packed nature of its epithelium. X400.

6. *A. collaris*  
   Rectal pad, lateral pouches X400.

7. *A. collaris*  
   Rectal pad, dorsal pouches X150.

8. *T. domesticus*  
   T.S., through colon. Notice the musculature and the chiasma of the lumen. X600.

9. *T. domesticus*  
   L.S., through colon showing anterior and posterior dilator muscles X250.

10. *T. domesticus*  
    L.S., through colon and rectum. Notice the natural passage into the rectum and the nature of the rectal pad. X 150.

11. *C. longirostris*  
    L.S., through the rectum. Notice the region of ilium and the ependymal lining of colon and its narrow passage into rectum. X 50.

12. *C. longirostris*  
    L.S., through the rectal pad. Notice the extremely narrow passage X 200.
more powerfully developed in the form of sphincter and the longitudinal muscles are less prominent. The epithelium that appears padded is less complicated in the case of *A. collaris* (Plate XXXIV, 5), whereas, in *T. domestica* it is found to be most complicated with numerous longitudinal folds and consequently the lumen is narrowed into several longitudinal canals (Plate XXXIV, 8). The epithelium consists of a layer of columnar epithelial cells with round nuclei and the cells secrete chitinous intima which is often found to remain detached in *A. collaris*. But it is not so in *T. domestica* and *C. longicaudata* (Plate XXXIV, 11). At its junction with the rectum, the colon is suspended from the body wall by means of two sets of dilator muscles, an anterior pair and posterior pair (Plate XXXIV, 9). These muscles appear to aid in the regulation of passage of food from the colon into the rectum.

**Rectum:**

Following the colon, the rectum is short and its wall evaginated to form prominent epithelial pouches, commonly known as the rectal pads. The rectal pads or the rectal pouches are arranged in 4 longitudinal rows, a pair of dorsomedian rows and a pair of ventro lateral rows. The dorsomedian rows as well as the lateral rows are connected by an anterior median dorsal and a posterior median dorsal pouches, the former communicating with the colon and the latter leading to the anus. Each row has four pouches and
each pouch has thick epithelium, with fairly weak circular muscles and the cell boundaries are not well defined. Throughout the wall, the epithelium of each pouch sends circular evaginations incompletely partitioning the lumen that increases the area of absorption. The rectal pads are more complicated and elaborately developed in A. collaris (Plate XXXIV, 6 & 7). In T. domestica and in C. longicaudata, the number of these pouches remains the same and they are less complicated. Their epithelium is less padded (Plate XXXIV, 10 & 12), and their surface area is reduced by the development of less number of transverse invaginations of the epithelium. Thus it is possible that A. collaris, by having a better developed rectal pad system, is able to conserve water better in the rectum, whereas, in T. domestica and C. longicaudata, by the development of a type of cryptonephric system, development of rectal pad in a more complicated fashion is eliminated. The water conservation mechanism in these three species, therefore, appears to be very efficient.

Modder (1967) described an anterior intestine (ileum) having indentations in six points and having a rectangular lumen, posteriorly turning stellate. The anterior rectangular lumen corresponds to the anterior ileum and the posterior stellate lumen corresponds to the colon in T. domestica as described here. Larsson (1973) reported an anterior rectum having six longitudinal ridges, each being separated by a furrow, corresponding to the 6 bands of
longitudinal muscles of Palm (1949) and Modder (1967). Larsson (1973) further reported glandular function to the rectal pouches of "vesicular circle" that are connected to the adjacent sclerites by strong muscle fibres corresponding to Modder's suspensory dilator muscles that are reported to be inserted on the hinder portion of the posterior intestine. Modder's (1967) description of these muscles relate to the anterior and posterior suspensory muscle fibres of the posterior extremity of the colon, as described here. Recognition of a prominent colon (correspond to anterior rectum of Larson) in the present investigation is on the basis of its histological distinctiveness from the ileum and the rectum. Since the epithelium of colon is conspicuously thick and non secretory, similar to the rectal pad of other insects (Wigglesworth, 1932), water absorbing function is attributed to this. The rectal pouches on the contrary are histologically different and not secretory too. The enormous increase in the surface area of this region by its epithelial invaginations suggests retention of faecal matter for longer period for the purpose of water absorption and subsequent pellet formation. Barnhart (1961) recognized inner longitudinal muscles and outer circular muscles on these rectal glands that perform rapid churning movement and both Barnhart (1961) and Modder (1967) have recognized a rectal valve. In the present investigation, it is found that the pouches have weakly developed circular muscles only, as reported by Modder (1967). Since the lumen of the colon is very narrow, and
its junction with the rectum is provided with circular sphincter type of muscles as well as with the suspensory muscle fibres, a regulatory mechanism is strongly evident, though a distinct rectal valve is not recognisable.

IV.3.4. The salivary system:

The salivary system has been analysed in detail. Only for two species; viz., A. collaris and T. domestica. Histological studies reveal that the two lobes of the salivary glands are distinctly different. In T. domestica, the lateral extensions of the anterior lobes are very prominent (Plate XXXV, 8), almost filling the entire head, beneath the brain, whereas, in A. collaris and in C. longicaudata they are less prominent. The anterior lobe (Mandibular gland of Modder, 1967) is distinguishable from the posterior lobe (Labial glands of Modder, 1967) by being packed with deeply staining, densely granulated cytoplasm (Plate XXXV, 1). The posterior lobes are more elongated extending posteriorly on either side of the oesophagus and meeting at their posterior extremities in the prothorax (Plate XXXV, 7). The salivary gland appears to be phasic in its secretory activity. Each lobe is further divided into a number of acini and during non secretory phase, the nuclei are compactly arranged in each acinus and the cells extensively vacuolated. During secretory phase (Plate XXXV, 2), the nuclei are spherical, granular and are disbursed uniformly and the secretory granules fill the entire gland.


3. *A. collaria*  Principal and accessory salivary ducts in the head capsule. Notice the accessory vesicle X400.

4. *A. collaria*  Anterior position of the same where the principal ducts meet X300.

5. *A. collaria*  A more anterior position of the same where both principal and accessory ducts meet to form a common salivary vesicle before entering the pharynx X150.

6. *A. collaria*  Entry of the common salivary vesicle into the pharynx midventrally X150.

7. *A. domestica*  Thoracic lobes of the salivary gland meeting beneath the esophagus. Notice the arrangement of nuclei-pod active phase X75.


9. *A. domestica*  Origin of the two salivary ducts at the junction of the anterior and posterior lobes X150.

10. *A. domestica*  Enlargement of the accessory salivary duct. Notice the secretory nature of its wall.

12. *T. domestica* : L.S. through the thorax showing the course of the two ducts. X100.


15. *T. domestica* : The enlargement of the accessory salivary vesicle showing valve at the entry into the diverticulum. X400.
Though both the ducts of the salivary system originate almost at the same place at the junction of the cephalic and thoracic lobes (Plate XXXV, 9), the histology of the principal salivary duct is different from that of accessory salivary duct (Plate XXXV, 3, 4 & 12). The former is so named because it runs straight into the head capsule just like the principal duct of any other insect, (Livingstone, 1967 & 1977), whereas, the latter deviates much from its main course and enters the head capsule (Plate XXXV, 9). Further, the wall of the principal duct consists of closely packed epithelium with its nuclei arranged apically (Plate XXXV, 10). The intima is very thick and the cells do not show any indication of secretory behaviour. The lumen is relatively very narrow. The wall of the accessory duct (Plate XXXV, 11), in marked contrast, has a syncytial epithelium with large, granulated, basally placed nuclei and with numerous vacuoles, indicating secretory behaviour. There is no trace of chitinous intima throughout the course of this duct till it enters the head and the lumen is fairly large. The accessory duct, therefore, appears to be a secreting system comparable to the accessory salivary system described in other insects (Goodchild, 1952; Livingstone, 1967 and 1977). This is further strengthened by the fact that the accessory duct enlarges considerably, especially in T. domestica, as it enters the head capsule, in the form of a prominent vesicle with its ramifications (Plate XXXV, 13 & 14). In A. collaris, such ramifications are not found (Plate XXXV, 5 & 6). This vesicle however has a
thin intimal lining and in *T. domestica* it is provided with an accessory diverticulum whose entrance is guarded by a valve (Plate XXXV, 15).

The principal duct does not develop such a vesicle and is uniformly wide throughout its course. The secretory nature of the wall of the accessory duct without an intimal lining, its termination into a distinct vesicle in the head capsule, and its subsequent union with the principal salivary duct before entering the pharynx through a common passage, tempt one to suggest that the accessory salivary duct functions as an independent salivary system in a similar fashion described in other higher orders of insects. The accessory salivary system has been considered to secrete watery saliva (Goodchild, 1963 & 1966, Miles, 1967 and Livingstone 1967 & 1977). Lepismatids too do not appear to be exempted from such a function. The functional significance of the occurrence of a special diverticulum with a valvular arrangement from the cephalic vesicle of the accessory duct is difficult to explain at this stage.

The term labial gland is employed by Barnhart (1961) and Modder (1967) for the posterior lobe of the salivary gland. The highly vacuolated condition (preparatory phase) and the compact granulated condition (active phase) have been described by Barnhart (1961) as large spherules and small
spherules respectively. He suggested a cyclic (mass discharge) function related to ecdysis. Modder (1967) has described dark staining granules in the mandibular glands (cephalic lobe) similar to the findings reported here.

IV.4. INTESTINAL MICROORGANISMS

IV.4.1. Gregarine Parasites:

The midgut of C. longicaudata, T. domestica and A. collaris has been found to harbour atleast two different species of gregarines. They are considered here as parasites because whenever they are present in large number in any part of the midgut, the epithelium appears much depleted (Plate XXXVI, 3). When these gregarines are present in large numbers, they are found to be of giant size in the second midgut filling the entire lumen as observed in C. longicaudata and T. domestica (XXXVI, 5 & 7). However, under starved conditions they are scarcely found. In C. longicaudata, two species are found and they resemble Lepismatophila Ctenolepismae and Gregarina Ctenolepismae described by Lindsay (1939) in the same species (Plate XXXVI, 6 & 8). Cornwall (1915) had earlier reported Lepismatophila cornwali (Bhatia) and Garnhamia aciculata (Bhatia) from a Ctenolepisma sp. However, Garnhamia aciculata has been synonymised later as Gregarina ctenolepismae. Tuzet et al., (1952) described Lepismatophila parva from C. lineata and Halder and Chakraborty (1977) have recorded Lepismatophila rhombocephala in C. nigra.
1. *A. collaris* : Gregarine parasite *X*400.

2. *A. collaris* : Another Gregarine parasite attached to mesenteric wall *X*400.

3. *T. domesticus* : T.S. of the mesenteron showing gregarine parasite *X*150.

4. *T. domesticus* : Enlargement of the same showing attachment of the parasite *X*400.

5. *T. domesticus* : L.S. of mesenteron showing the nature of infestation. Notice the relative size of the parasites *X*150.


7. *C. longicaudata* : The same under high infestation *X*150.


9. *C. longicaudata* : Lumen of mesenteron showing food and amoeboid structures (malanoevae?) *X*400.

10. *C. longicaudata* : Enlargement of ampullar tubules showing amoeboid structures (malanoevae?) *X*600.

11. *A. collaris* : T.S. of esophagus showing aggregation of bacteriform bodies *X*400.

12. *A. collaris* : Enlargement of the same *X*400.
Crusz (1960) recorded a new genus *Lepismatophila orientalis* from the same species. In the present investigation, the various stages of the gregarines have not been pursued.

In *Thermobia domestica* also, two species of gregarines (Plate XXXVI, 4 & 5) have been detected and one of them resembles *Lepismatophila thermobiae* Adams and Travis and the second one resembles *Gregarina ctenolepismae*, as described by Lindsay (1939). But specific confirmation is not possible at this stage. At least 3 species of gregarines have been reported by earlier workers from *T. domestica*, two by Adams (1935) (*Lepismatophila thermobiae, Colepismatophila watsonae*) and a third one from Australia by Lindsay (1939).

In *Acrotelsa collaris* also, two species (Plate XXXVI, 1 & 2) of gregarines have been observed. In the present investigation, the identification of which has not been confirmed. In *A. collaris*, earlier workers have recorded three species of gregarines viz., *Garnhamia aciculata crusz, Lepismatophila thermobiae* Adams and Travis and *Colepismatophila watsonae crusz*.

Thus, the occurrence of gregarine parasites in the gut of *Lepismatidae* appears to be an universal phenomenon and the maximum number of species (five) have been reported from *Lepisma saccharina* by several workers and the more common species has been reported by Paclt (1967) as *Gregarina*.
lagenoides Leger. *T. domestica* and *C. longicaudata*, though occur together in the same habitat, feeding on the same materials, offering similar chances of infection, though both of them heavily infested by the gregarines, appear to be different with respect to the host specificity of these parasites. A similar observation has been recorded by Lindsay (1939) too. The gregarine parasites found in *A. collaris* appear to be different from those found in the indoor species and the intensity of infestation in the former is relatively much less when compared with the latter. This may suggest the phenomenon of host resistance operating in the soil living species.

IV.4.2. *Amoebididae:*

In *C. longicaudata*, apart from the gregarine parasites, the midgut and the malpighian tubules contain amoeboid forms resembling the *Malamoeba locustae* King and Taylor, as described by Larsson (1976) in *Lepisma saccharina*. These are found in clusters around the food material in the midgut (Plate XXXVI, 9) as well as in the lumen of the malpighian tubules (Plate XXXVI, 10), suggesting their "Commensalistic" association. The amoebae found in the midgut content appear to be morphologically different from those found in the malpighian tubules. Several samples of the former are found to be larger in size, having 4 distinct nuclear bodies, with dense cytoplasm and the latter are relatively smaller having single distinctly vesicular nucleus. Lack of further
information does not permit the author to elaborate this finding. Larsson (1976) has reported very heavy infection in the midgut, the gastric caeca and the malpighian tubules of *Schistocerca gregaria*, whereas, in *L. saccharina* he could find no degeneration of epithelium. But the infection of malpighian tubules was found to be serious. Observations in *C. longicaudata* with regard to infection in the malpighian tubule may tempt one to corroborate Larsson's findings.

IV.4.3. **Bacteriform bodies:**

In the gastric caeca of a well fed *Acrotelsa collaris*, accumulation of spherical, deeply eosinophilic bacteriform bodies have been noticed (Plate XXXVI, 11 & 12) and such bodies have been found associated in large numbers at the free ends of the epithelial walls of the gastric caeca too. Occurrence of a bacterial layer (both Gram positive and Gram negative), whose symbiotic role is uncertain, has been reported in the stomodaeal epithelium of *L. saccharina* (Cowdry, 1923 and Larsson, 1973). Such bacterial layer is not found in the stomodaeum of any of the three species examined.

IV.5. **DISCUSSION:**

A straight intestine is considered to be a primitive feature among insects. Such a condition has been reported in *L. saccharina* (Cornwall, 1915 and Larsson, 1973) and in *C. campbelli* (Barnhart, 1961). A looped condition of ileum
(hind intestine) in a few other species of Lepismatids has been further reported by Lindsay (1940), Barnhart (1961) and Modder (1962 and 1964). In the present investigation, *A. collaris* has an almost straight ileum, whereas *T. domestica* has looped ileum. In *C. longicaudata*, it is intermediate. This suggests that *A. collaris* has a more primitive type of intestine and *T. domestica* has a more advanced type.

Earlier investigators on the digestive physiology and digestive enzymes in Lepismatididae (Swingle, 1925, Wall and Swift, 1954, Lasker, 1959 and Modder, 1962, 1964 and 1975) have established that these insects have enzymes not only for digesting starch, fat and proteins but also have their own cellulase and cellobiase for digesting cellulose (Lasker and Giese, 1956). Lindsay's (1940) conclusion that digestion of cellulose in silverfish is accomplished by symbiotic microorganism in the gut has since been stoutly opposed by Lasker and Giese (1956) and the symbiotic role of bacteria has been considered by Larsson (1973) as uncertain. Experiments of Lasker and Giese (1956) have further proved that these insects cannot live on cellulose alone since they seek a nitrogen source for sustenance. Modder (1962) has further demonstrated that an alkaline saliva neutralises organic matter at ingestion and an identical buffer mechanism operates in the stomodaeum and anterior mesenteron, suggesting that digestion takes place in stomodaeum too.
The present histomorphological investigations of the digestive systems in *A. collaris*, *T. domestica* and *C. longicaudata* have shown certain adaptive features which have eco-physiological significance. The crop, that is divided into 2 main chambers, serves as the main storage organ, capable of extensive expansion. The anterior chamber in all the three species is more extensive and provided with intermittent invaginations suggesting that peristalsis brings about intermittent release of food into the posterior chamber which is almost confluent with the proventriculus. Modder (1967) does not advocate for peristalsis in this region. There is no trace of bacteriform bodies or protozoan parasites in the stomodaeum. The chitinous intima is more elaborately developed in *A. collaris* and the crop content contains organic debris, suggesting the provision of a more efficient protective device in this soil living species than in the other two species. It is also found that both circular and longitudinal muscles are better developed in the crop of *A. collaris* correlating a direct functional relationship with the elaborate development of the intima. Though there is no evidence of secretion of any digestive fluid in the crop, the retention of food in it for longer duration may help salivary secretion to act, as suggested by Modder (1962) and Barnhart (1961). Under prolonged starvation too, the crop is never found free from food in all the three species. A similar observation has been reported in *L. saccharina* and *C. campbelli* by Barnhart (1961).
The more complicated masticatory apparatus, the relatively more narrow highly muscular posterior proventriculus, and the association of the proventricular wall with the gastric caeca by powerful muscle bands in *T. domestica*, not so far reported in any of the other Lepismatids, may lead one to conclude that this species is more advanced and ecophysiologically better adapted for feeding on more hard matter than the other two species. Presence of very hard core of spores (unknown nature) in the oesophagus and crop further confirms this conclusion. The armature is less complicated with least number of tubercles on the cutting plates in *A. collaris* whose food is humus and other organic debris of the soil and, therefore, apparently less specialized than *C. longicaudata* whose corresponding structures are found to be intermediate in nature.

The gastric caeca are least developed in *A. collaris* and very much elongated with more number of crypts in both *T. domestica* and *C. longicaudata*. Occurrence of bacteriform bodies in the gastric caeca and less number of gregarine parasites in the mesenteron are recorded only in *A. collaris*. The peritrophic membrane as product of delamination process of the mesenteric wall and the identification of the cardiac valve as the closely packed columnar epithelial cells of mesenteric nature are characteristic features of *A. collaris*, in marked contrast with the specialized chitinous epithelium of the cardiac valve of the other two species, secreting the
peritrophic membrane. While this aspect will strengthen the similarity of *T. domestica* and *C. longicaudata*, the argument that the development of such a tissue for the specific purpose of secreting the peritrophic membrane in these two synanthropic species could be considered as a specialization, may be too much of a generalization at this stage.

The development of a cryptonephric system in the two synanthropic species with their less complicated system of rectal pads for water absorption and a more complicated and elaborate development of rectal pads without any trace of association of malpighian tubules with the midgut in the case of soil living species will suggest that the cryptonephric system is a more advanced mechanism of water conservation.

The foregoing account throws some evidence of advancement and specialization of structures associated with nutrition and osmoregulation in synanthropic species over the soil living species.