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STUDIES ON THE DIGESTIVE SYSTEM OF ODONTOPUS NIGRICORNIS STAL (HIMIPTERA, PYRRHOCORIDAE)

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INTRODUCTION

The feeding habits and the anatomy of the digestive organs of Hemiptera have attracted the attention of many workers in the past; notable among those are HAMILTON (1931); MALOUF (1933); BREAKY (1936); WOOLLEY (1949); SUTTON (1951); GOODCHILD (1952); PARSONS (1959) and RASTOGI (1960 & 1961a). These studies reveal that modifications in the digestive organs of the bugs are related with their feeding habits. SUTTON's studies are particularly important; he described bucco-pharyngeal teeth and peritrophic membrane in the Corixidae which are aquatic and feed on detritus matter. Such pharyngeal teeth have been described by RASTOGI (1961b) in *Coridius janus*, perhaps the only example of Geocorisae (PARSONS, 1962). Recently RASTOGI (1962) has questioned the status of ileum in phytophagous Hemiptera and showed that ileum in these bugs is an endodermal part and the Malpighian tubules which arise from it probably also are of endodermal nature.

The present paper deals with the histological studies of the digestive system of *Odontopus nigricornis* Stål. The study reveals noterworthy points hitherto unknown.

MATERIAL AND METHODS

Specimens for the present study were obtained from Saharanpur, United Provinces, India, from their host plants, *Bombax malabaricum* and Sterculiaceae.

The digestive organs have been studied with the help of dissections, serial sections and whole mounts. Sections were cut at 7—10 micra and the stain combinations used were DELAFIELD's haematoxylin and eosin, MANN's methylblue-eosin and MALLORY's triple. For sectioning the head MUKERJI's method (1937) was employed with considerable success.

HISTOLOGY OF THE ALIMENTARY CANAL AND ITS APPENDAGES

The gross morphology of the digestive organs of Odontopus nigricornis has been described by RASTOGI & DATTA GUPTA (1961).

The Foregut

The foregut consists of the pharynx and the oesophagus (Fig. 1).

P h a r y n x. The pharynx is histologically differentiated into a pharyngeal pump (cibarium) and the pharynx proper. The pharyngeal pump lies anterior to the brain overlying the cup of salivary syringe. The pump is a sclerotised V-shaped tube with a dorsal operculum (Fig. 2). The two flanks of the 'V' are lined with thick intima while the operculum is composed of relatively thin intima. The operculum bears a dorsal ligament on which dilator muscles are inserted arising from the clypeal area of the head. At the level of the circumoesophageal connectives the pharynx loses its V-shaped lumen and transforms into the pharynx proper (Fig. 3). The lumen of the pharynx proper becomes circular; it is lined by a thin folded epithelium consisting of cuboidal cells. The folds make the lumen considerably narrow. The epithelium secretes a thin layer of transparent intima and is surrounded by circular muscle bands which help the pharynx to perform sphincter function.

O e s o p h a g u s. The oesophagus is thin-walled and lined with a wavy and folded epithelium. The epithelium is composed of cuboidal cells which lack cell walls (Fig. 6). The epithelium secretes an irregularly folded intima; the cytoplasm is clear and mildly staining either with haematoxylin and eosin or with MALLORY's triple. The muscularis consists of an outer layer of longitudinal and an inner layer of circular muscles, forming discontinuous bands.

O e s o p h a g e a l v a l v e (Figs. 4 & 5). The junction between the foregut and the midgut is externally marked by a circular constriction bordered by thick musculature. The constriction represents the area of oesophageal invagination or the valve. The valve appears to be a circular fold in cross section composed of two lamellae of cells bound on both sides by chitinous intima secreted by oesophageal epithelum. The two lamellae are separated from each other by a thin core of connective tissue.

The valve can be well studied in a longitudinal section. The cells forming the inner lamella of the valve are cuboidal and seem to be derived from the oesophageal epithelium, secreting intima. These cells take less stain but the nuclei are clearly visible. The cells of the outer lamella of the fold gradually become tall and remain differentiated from the inner lamella, as well as the midgut. These cells take less stain but secrete intimal folds and are perhaps a group of cells which at one time were active in secreting a peritrophic membrane. These cells are designated here as P.

A peritrophic membrane is apparently lacking in Hemiptera, since they ingest liquid food only. Our study shows that the cells of the outer lamella designated as P secrete a membrane which is many-layered and trails caudad in the midgut. This membrane appears to be of a peritrophic nature (vide discussion).

The Midgut

The midgut of *Odontopus nigricornis* has four regions which differ from one another according to the degree to which the digestive processes have progressed. The midgut is characterised by the presence of columnar cells and weak musculature and by the absence of intima.



Fig. 1. Digestive organs of *Odontopus nigricornis*. Fig. 2. Cross section of the pharyngeal pump. Fig. 3. Cross section of the pharyngeal pump at the level of the brain. Fig. 4. Longitudinal section of the oesophageal valve. Fig. 5. Cross section through the oesophagus

The epithelium of the first midgut forms evaginations and folds consisting of columnar cells with clearly defined cell walls. In a fold the tips of the cells appear to be strongly pressed together, showing considerable elasticity. The cytoplasm is densely granular with deep staining and large circular and oval nuclei. A thick core of connective tissue projects in the interspace of each fold which becomes confluent with the peripheral connective tissue. Regenerative cells are few, mononucleate, and apparently of little activity. The muscularis is poorly developed and consists of a circular layer outside of which lie the fragmentary longitudinal muscles (Fig. 7). In actively secreting phase the cytoplasmic contents of the cells shift towards the cell-tips and produce bulgings due to cytoplasmic accumulation. When the bulgings are fully loaded the secretions are squeezed out in the lumen forming chains of non-nucleated buds (Fig. 7), suggesting merocrine method of secretion. After the discharge the cells become vacuolated and the nucleus occupies the basal half of such cells.

The second midgut region is paved with an unfolded epithelium consisting of regular columnar cells which are mostly mononucleate (Fig. 8). The circular layer of muscles is very thin and the longitudinal muscles are wanting. Regenerative cells are very few. Secretions are discharged by the usual merocrine method.

The third midgut region has a wider lumen and the epithelial cells, though of the columnar type, are smaller than those of the first midgut. The cells do not appear to be much pressed together and rest over a basement membrane. Regenerative cells are few and mononucleate. In this region a striated border in the epithelium is visible which is stained very lightly (Fig. 9). The mode of secretion is essentially the same as observed in the second midgut, but in addition to this several nuclei are also seen lying with the secretions. These nuclei have perhaps fallen out as a result of cell-bursting during sectioning. The muscle layers in this region are better developed and consist of an inner layer of circular and an outer coat of longitudinal muscles.

The fourth midgut has the usual tall and columnar cells with granular cytoplasm and circular nuclei (Fig. 10). At places the cell entads are seen in distorted condition while the nuclei occupy the basal half of the cells. Secretions are exclusively of a merocrine type and appear as chains of small globules. The two usual muscle layers are present.

The junction of the fourth midgut and the ileum shows a constriction externally where the midgut cells become very tall (Fig. 10). It is feasible that a valvular function is imparted by these cells in this region, though a distinct valvular mechanism is absent.

The Hindgut

The hindgut consists of an anterior bladder-like ileum and a posterior dilated rectum.

Ileum. The ileum is a three-lobed and thin-walled sac (Fig. 1). All the lobes are similar in their histological structure and from each lateral lobe arise a pair of Malpighian tubules. The muscles are poorly developed and consist of a thin layer of longitudinal muscles only. The lining of ileum is composed of a single layer of columnar cells with large, circular and deep staining nuclei. The



Fig. 6. Cross section through the oesophageal valve. Fig. 7. Portion of the cross section of the first midgut region. Fig. 8. Portion of the cross section of the second midgut region.Fig. 9. Portion of the cross section of the third midgut region. Fig. 10. Longidudinal section through the fourth midgut, ileum and rectum

cytoplasm is of a granular and secretory nature. Neither brush border nor regenerative cells are visible in this region. Small non-nucleated globules are seen here and there in the lumen suggesting merocrine mode of secretion. An intima so common with the hindgut is lacking here (Fig. 11). Thus the histology of this part resembles for a great deal that of the midgut, while typical proctodaeal structure is wanting.

Pyloric valve. Much behind the origin of the Malpighian tubules and at the junction of the ileum and the rectum a well-defined pyloric valve is situated (Fig. 11). The epithelium of ileum is unfolded but particularly at this junction it becomes folded and differentiated into a valvular arrangement. The cells forming the valve are extremely tall and narrow with lightly staining non-granular cytoplasm. The valvular folds appear pad-like and from this point a loose and thin intima is secreted which continues caudad as far as the rectum. Only longitudinal muscles are visible at the junction.

R e c t u m. The rectum is thin-walled and transparent with typical proctodaeal structure. The rectal epithelium is composed of large and flattened cells having large nuclei and non-granular cytoplasm (Fig. 11). The cell boundaries are invisible and the epithelium appears to be syncitial being drawn into several irregular folds. A thick and tough intima lines the epithelium throughout the rectum. Rectal pads or papillae are absent.

Malpighian tubules. Histologically the epithelium of the tubules resembles more that of the midgut. The cells are large, of a shape intermediate between cuboidal and columnar, and with large oval nuclei (Fig. 12). The cytoplasm is densely granulated and stains deeply. However, the cell entads do not show any striated or brushy border. In a cross section groups of four to five cells appear enclosed in a thin tunic of a peritoneal sheath.

The Salivary Gland system

There are two pairs of salivary glands which include a pair of four-lobed principal and a pair of tubular accessory glands (Fig. 13). From the principal gland arise two transparent ducts, one extending cephalad as the principal duct and the other running along with it as far as the head whence it turns caudad to run a sinuous course ending in a tubular accessory gland.

All the lobes of the principal gland are alike in their histology. The spaces between individual lobes are filled with connective tissue layer. The glandular epithelium consists of cuboidal cells (Fig. 14). All the cells are more or less uniform in size, with large nuclei and chromatin granules. The cells are highly secretory and have densely granular cytoplasm. The lumens of the lobes are packed with secretions in the form of fine droplets. This is essentially merocrine secretion. Regenerative cells are absent.

The accessory salivary glands are tubular and thin-walled; they are composed of a single layer of glandular cells surrounded externally by a thin sheath. There is a central duct lined by thick intima (Fig. 15). The cells contain spongy cytoplasm traversed by striations and vacuoles. The structure of the principal and accessory ducts is alike and differs slightly from the accessory gland. The cells of the ducts are cuboidal with striated cytoplasm and small but conspicuous deep staining



Fig. 11. Longitudinal section through the ileum and the rectum showing the proctodaeal valve. Fig. 12, Longitudinal section of the ileum showing attachment of the malpighian tubule. Fig. 13. Principal and accessory salivary glands with their ducts. Fig. 14. Cross section of the principal gland at the point where the salivary ducts make contact



Fig. 15. Cross section through the accessory gland. Fig. 16. Cross section through the salivary duct

nuclei (Fig. 16). Both the ducts fuse at the common junction in the main gland and form a ring of vacuolated cells. This is the common origin of both the ducts (Fig. 14).

DISCUSSION

Regional differentiation is at its maximum in the suborder Heteroptera. In the present case the midgut has four regions which are characteristic of many phytophagous families, although three divisions or even less may also be found (PAINTER, 1930; BREAKY, 1936; HOOD, 1937; and GOODCHILD, 1952). The gastric caeca are absent in Odontopus. It has been suggested that they have an important relationship with the feeding habits of the insect and are considered to be useful criteria for distinguishing the phytophagous group from the predatory or semi-predatory groups (ELSON, 1937). The gastric caeca are present in almost all strictly phytophagous families (GLASGOW, 1914), however there are several exceptions. The absence of gastric caeca in Odontopus nigricornis is an interesting point since two rows of caeca are present in Dysdercus koenigii (SAXENA, 1955a), a member of the same family. Further in a closely allied species, Dysdercus nigrifasciatus (GOODCHILD, 1952), the gastric caeca are absent. Thus the caeca may not form a sound basis for recognising plant feeding Heteroptera from other groups, but predaceous or semi-predaceous species are always devoid of them.

The oesophageal valve of *Odontopus* is a well-developed structure. The manylayered intima which hangs from the ring of peritrophic cells P at the junction of foregut and midgut is of a peritrophic nature. This intima projects much beyond the oesophageal valve into the midgut and is composed of chitinous material. It has been shown that the peritrophic membrane contains chitin with protein incorporated in it (WIGGLESWORTH, 1953). Sufficient evidence could be derived from literature in this connection. While studying the formation of peritrophic membrane in the larvae and adults of Diptera and the earwig, WIGGLESWORTH (1930) has shown that it is secreted in viscous form by a group of cells which are situated at the junction of the foregut and the midgut. VAN GEHUCHTEN (1890) was the first to suggest that the peritrophic membrane in sucking insects is produced by cells situated at the anterior end of the mesenteron. GAMBRELL (1933), who studied the development of the oesophageal valve and the origin of the peritrophic membrane in *Simulium*, states that the peritrophic membrane takes its origin from a group of cells at the tip of the reflected portion of the stomodaeum in the embryo and the group of cells that secrete the membrane is also ectodermal in origin. In the light of the above interpretations it is reasonably certain that the zone of cells at the junction of the oesophagus and the midgut in *Odontopus* represents the peritrophic cells and the intima secreted by them is the actual peritrophic membrane.

The midgut secretions are released mainly by merocrine method. In the first midgut it is more vigorous, while the process slows down gradually in the succeeding regions and ultimately shows little signs in the fourth midgut region, a conclusion which is supported by physiological studies (RASTOGI & DATTA GUPTA, 1961). This might suggest that the digestion is mostly completed in the first three regions and the fourth region has mainly the function of absorption.

The ileum of *Odontopus* has a close resemblance to the midgut. Earlier RASTOGI (1962) has pointed out that the ileum of phytophagous bugs is truly an endodermal part or a continuation of the midgut. Further evidence in favour of its endodermal nature may be derived from the position of the pyloric valve which is situated at the ileo-rectal junction. The position of pyloric valve appears to be very significant since it marks the posterior limits of the midgut and beginning of the hindgut. The valve also helps in establishing the relationship of the Malpighian tubules with the midgut.

The Malpighian tubules of Odontopus arise from the ileum having independent attachment much anterior to the pyloric valve. Since the ileum resembles the midgut in all essential details, the condition indicates that the tubules are also midgut evaginations. Histologically the wall of the tubules resembles the wall of the midgut. HARRIS (1938) and GOODCHILD (1952) also questioned the ectodermal origin of tubules in *Murgantia histrionica* and cacao capsid bugs respectively. SAXENA (1955b) observed in Typhlocybinae (Homoptera) that the tubules originated in front of the pyloric valve indicating their endodermal origin.

In the present work all the lobes of the principal salivary glands are alike in histology and their secretions are of one kind only. FAURE-FREMIET (1910) however postulated that different lobes of the principal glands secrete different chemical substances. The function of the principal gland appears to be mainly that of secretion. HARRIS (1938) held the opinion that the main glands had the function of storage. This opinion has not been supported by any other workers.

The tubular accessory gland possesses a glandular epithelium. The function of the accessory gland is little known. FAURE-FREMIET (1910), HARRIS (1938) and BAPTIST (1941) suggest that it is of a secretory nature, while POISSON (1924) attributes to it an excretory function. GOODCHILD (1952) suggests that the accessory gland might be partly secretory and partly serve for the absorption of water. Judging from present work its secretory function is confirmed by its structure.

SUMMARY

The histology of the digestive system of Odontopus nigricornis has been studied in detail. The oesophageal valve is well-developed; a zone of peritrophic cells has been located at the junction of the foregut and the midgut which secretes a peritrophic membrane trailing in the midgut. The midgut has four regions, a characteristic feature of phytophagous Hemiptera. The ileum appears to be a continuation of the midgut and the Malpighian tubules which arise from it may have an endodermal origin. The principal gland is four-lobed; both the principal and the accessory glands have the function of secretion as is revealed by their histology.

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ABBREVIATIONS USED IN THE FIGURES

AC D — accessory duct AC G — accessory gland AL — anterior lobe CM — circular muscles CON T — connective tissue C SD — common salivary duct CC — central canal DIL MS — dilator muscles E — eye IL — ileum INT — intima IL EPTH — epithelium of ileum LM — longitudinal muscles LUM — lumen LL — lateral lobe N — nucleus
OE — oesophagus
OE VLV — oesophageal valve
P — peritrophic cells
PMB — peritrophic membrane
PH — pharynx
PH PMP — pharyngeal pump
PL — posterior lobe
PR VLV — proctodaeal valve
M₁, M₂, M₃ and M₄ — first, second, third and fourth midgut regions
MT — Malpighian tubules
MS — muscles
M EPTH — midgut epithelium
REC — rectum

REFERENCES

BAPTIST, B. A., 1941, The morphology and physiology of the salivary glands of the Hemiptera. Quart. J. micr. Sci., vol. 83, p. 91-139.

BREAKY, E. P., 1936, Histological studies of the digestive system of the Squash Bug., Anasa tristis DeG. (Hemiptera, Coreidae). Ann. ent. Soc. Amer., vol. 29, p. 561-577.

ELSON, J. A., 1937, A comparative study of Hemiptera. Ann. ent. Soc. Amer., vol. 30, p. 579-597.

FAURE-FREMIET, E., 1910, Contribution a l'étude des glandes Hydrocorises. Ann. des. Sci. natur. (Zool), vol. 12, p. 217-240.

GAMBRELL, F. L., 1933, The embryology of the black fly, Simulium pictipes Hagen. Ann. ent. Soc. Amer., vol. 26, p. 641-672.

GLASGOW, H., 1914, The gastric caeca and caecal bacteria of Heteroptera. Biol. Bull., vol. 26, p. 101-170.

GOODCHILD, A. J. P., 1952, A study of the digestive system of the West African cacao capsid bugs (Hemiptera, Miridae). Proc. Zool. Soc. Lond., vol. 122, p. 543-572.

HAMILTON, M. A., 1931, The morphology of the water scorpion, Nepa cinerea Linn. (Rhynchota, Heteroptera). Proc. Zool. Soc. Lond., vol. 101, p. 1067-1136.

- HARRIS, C. S., 1938, The anatomy and histology of the alimentary system of the Harlequin cabbage bug, *Murgantia histrionica* Hahn. (Hemiptera, Pentatomidae). Ohio J. Sci., vol. 38, p. 316-331.
- HOOD, C. W., 1937, The anatomy of the digestive system of Oncopeltus fasciatus Dall. (Hemiptera, Lygaeidae). Ohio J. Sc., vol. 37, p. 151-160.
- MALOUF, N. S. R., 1933, Studies on the internal anatomy of the stink bug, Nezara viridula L. Bull. Soc. Roy. Entom. d'Egypte, p. 96-119.
- MUKERJI, D., 1937, A note on the section cutting of insects, Current Science, vol. 6, p. 16-17.
- PAINTER, R. H., 1930, A study of the cotton flea-hopper, *Psallus seriatus* Reut. with special reference to its effect on cotton plant tissues. J. Agric. Res., vol. 40, p. 485-516.
- PARSONS, M. C., 1959, The midgut of aquatic Hemiptera. J. Morph., vol. 104, 479-524.
- PARSONS, M. C., 1962, Skeleton and musculature of the head of Saldula pallipes (F). (Heteroptera : Saldidae). Trans. R. Ent. Soc. Lond., vol. 114, p. 97-130.
- POISSON, R., 1924, Contributions à l'étude des Hemiptères aquatiques. Bull. biol. Fr. Belg., vol. 58, p. 49-305.
- RASTOGI, S. C., 1960, The anatomy of the digestive system of Lygaeus pandurus Scop. (Heteroptera : Lygaeidae). Proc. Raj. Acad. Sci., vol. 7, p. 29-37.
- RASTOGI, S. C., 1961a, The anatomy of the digestive organs of *Sphaerodema rusticum* Fabr. (Heteroptera : Belostomatidae). Proc. Raj. Acad. Sci., vol. 8, p. 60-78.
- RASTOGI, S. C., 1961b, Studies on the digestive organs of some Hemiptera-Heteroptera. I. Morphology of the digestive organs of *Coridius janus* Fabr. (Pentatomidae, Dinidorinae). Proc. 48th Ind. Sci. Congr. vol. 3, (Abstracts), p. 424.
- RASTOGI, S. C., 1962, The status of Ileum in Heteroptera. Science & Culture, vol. 28, p. 31-33.
- RASTOGI, S. C. & DATTA GUPTA, A. K., 1961, Studies on the physiology of digestion in the alimentary canal and salivary glands of *Odontopus nigricornis* Stål. (Heteroptera : Pyrrhocoridae). Ind. J. Ent., vol. 23, p. 106-115.
- SAXENA, K. N., 1955a, Studies on the passage of food, hydrogenion concentration and enzymes in the gut and salivary glands of *Dysdercus koenigii* Fabr. (Pyrrhocoridae : Heteroptera). J. Zool. Soc. India, vol. 7, p. 145-154.
- SAXENA, K. N., 1955b, The anatomy and histology of the digestive organs and Malpighian tubulus of the Jassidae. (Homoptera). J. Zool. Soc. India, vol. 7, p. 41-52.
- SUTTON, M. F., 1951, On the food, feeding mechanism and alimentary canal of Corixidae (Hemiptera, Heteroptera). Proc. Zool. Soc. Lond., vol. 121, p. 465-499.
- GEHUCHTEN, A. VAN, 1890, Recherches histologiques sur l'appareil digestif de la larve de la *Psychoptera contaminata*. L'Étude du revêtement épithéliale et recherches sur la sécrétion. La cellule, vol. 6, p. 185–289.
- WIGGLESWORTH, V. B., 1930, The formation of the peritrophic membrane in insects, with special reference to the larvae of mosquitoes. Quart. j. micr. Sci., vol. 73, p. 593-616.
- WIGGLESWORTH, V. B., 1950, the Principles of insect physiology. 4th Edn. 544 p. Methuen, London.
- WOOLLEY, T. A., 1949, Studies on the internal anatomy of the Box-elder Bug., Leptocoris trivittatus (Say). (Hemiptera, Coreidae). Ann. ent. Soc. Amer. vol. 42, p. 203-226.



Rastogi, S C. 1964. "Studies on the digestive system of Odontopus nigricornis Stål (Hemiptera, Pyrrhocoridae)." *Tijdschrift voor entomologie* 107, 265–275.

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