Int. J. Insect Morphol. & Embryol. 2 (4): 299–303. 1973. Pergamon Press. Printed in Great Britain.

DEVELOPMENT OF FOREGUT OF SIX-SPOTTED LADYBIRD BEETLE, *CHILOMENES SEXMACULATA* FABR. (COLEOPTERA: COCCINELLIDAE)

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(*Accepted* 20 *February* 1973)

Abstract—A definite anterior imaginal ring is absent in the larva of the six-spotted ladybird beetle, *Chilomenes sexmaculata*. The oesophageal valve of the larva may be considered to function as an imaginal ring since it forms new cells. The larval cells of the oesophagus are passed into the adult after some cellular differentiation. Some of the cells in the posterior region of the oesophagus degenerate and form darkly staining globular bodies. In the region of the oesophageal valve new cells are formed by mitotic activity. These cells, together with the old larval cells, reconstitute the posterior region (proventriculus and oesophageal valve) of the adult foregut. The anterior region of the oesophagus passes into the adult without any apparent change.

Index descriptors (in addition to those in title): Anterior imaginal ring, alimentary canal, metamorphosis.

A NUMBER of publications have contributed to our knowledge of the metamorphosis of the alimentary canal in insects. Authors like Poyarkoff (1910), Patay (1939), Dobrovsky (1951) and Nitschmann (1959) have shown the formation of adult foregut epithelium by 'cellular redifferentiation'. These authors have further shown that the larval cells divide mitotically, change in shape and size, and finally take the adult form. However, Anglas (1901), Vaney (1902), Tiegs (1922), Gray (1931), and Robertson (1936) showed that the imaginal epithelium is formed from the proliferation of cells of the anterior imaginal ring, and the larval cells degenerate completely. In some insects, however, the foregut metamorphosis has been reported both by 'cellular redifferentiation' and by the cells of the anterior imaginal ring (Deegener, 1900; Hufnagel, 1918; Murray and Tiegs, 1935; Ameen, 1969; Bahadur and Kathuria, 1971 and Kathuria, 1972). In the present paper the changes in the foregut of *C. sexmaculata* during metamorphosis have been described and results have been analysed on the basis of existing literature.

MATERIALS AND METHODS

The larvae of different ages were collected from Madar (*Calotropis* sp.) plants and reared in small rectangular jars. They were supplied daily with the yellow aphids (*Brevicoryne brassicae* Linn.), upon which they usually feed. The mature larvae were separated and kept in separate jars for pupation. Larvae and pupae were taken from the rearing jars at various

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Trans. Roy. Entomol. Soc. Lond. **121**(6): 235–79.

times and dissected in normal saline. The gut was fixed in Bouin's solution for 6–8 hr and after usual dehydration and embedding, sections were cut at 6–8 μ. Heidenhain's iron haematoxylin with eosin as counter stain gave satisfactory results. Drawings have been made with the help of camera lucida.

OBSERVATIONS

Larval foregut

The epithelium in the anterior region of the foregut is flat and cell boundaries are not clear. Each cell contains a small nucleus and granular cytoplasm. The intima is smooth and folded. In the posterior region of the oesophagus the epithelium becomes thick and invaginates into the midgut to form the oesophageal valve. The oesophageal valve is a specially modified structure formed by the infolding of the posteroventral wall of the oesophagus (Fig. 1). It is composed of a doubly folded epithelium and does not form a complete ring.

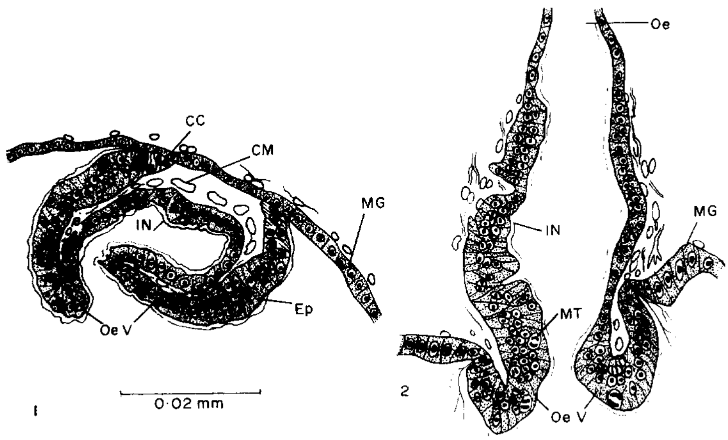


FIG. 1. C.S. of foregut through oesophageal valve of larva of *C. sexmaculata*.
FIG. 2. L.S. of foregut. 2–3 hr pupa;

Abbreviations used in figures

CC = cuboidal cells
CM = circular muscles
DC = degenerating cells
Ep = epithelium
IN = intima
MG = midgut
MT = mitosis
Oe Ep = oesophageal epithelium
Oe V = oesophageal valve
Pro = proventriculus
SP = spinous projections

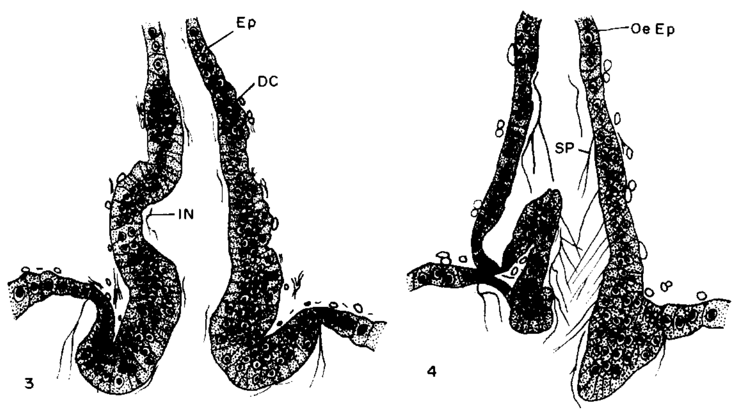
The 2 lateral folds lie separated from each other. The right fold slightly covers the left one, thereby enclosing a narrow lumen in between. The cells of the valve epithelium possess large nuclei. A group of low cuboidal cells is found near the junction of the foregut and midgut. A sclerotized intima arises from these cells to line the valve. Longitudinal and circular muscles are present between the 2 folds of the valve.

Metamorphic changes

During metamorphosis the foregut does not show much histological change except some growth and differentiation in the larval epithelial cells. During prepupal period, the cells of the foregut slightly increase in size and show a little mitotic activity in oesophageal valve region. The cells of the oesophagus appear slightly columnar with granular cytoplasm and distinct nuclei. The epithelium is 18 μ thick at this time. The lumen is narrow and the intima is not evident. The small cells present at the junction of fore- and midgut are retained from the larval period and do not show any visible change.

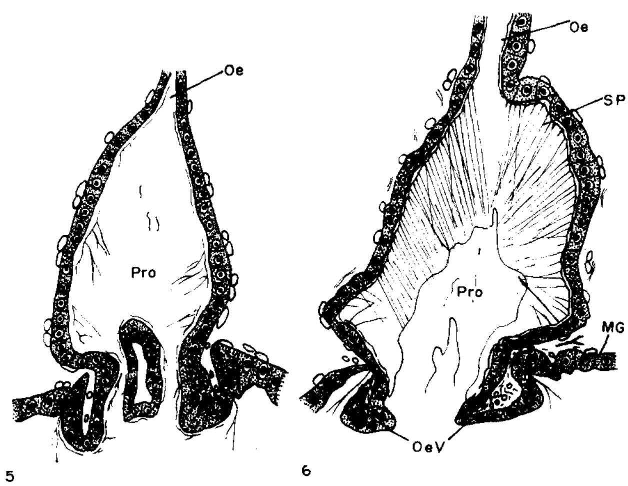
Since a number of new cells are formed, the foregut epithelium increases greatly in length and is thrown into longitudinal folds by the time the pupa is 3–5 hr old (Fig. 2). The intima makes its appearance by this time. The cells in the valve are now round or oval in shape and contain large nuclei. In the oesophagus, the cells are cuboidal with thick cytoplasm and large nuclei. Mitotic figures are still evident in the posterior region of the foregut.

After 9 hr of pupation, the foregut epithelium shows signs of partial degeneration. Large, darkly staining globular bodies appear in the epithelial cells (Fig. 3). In the posterior region the lumen slightly increases to give shape to the proventriculus.



FIGS. 3 and 4. L.S. of foregut 3. 9-hr pupa; 4. 40-hr pupa.

In the 40-hr pupa the posterior portion of the oesophagus is further dilated and its epithelium is lined by a thick sclerotized intima with small spinous projections (Fig. 4.)



FIGS. 5 and 6 L.S. of foregut. 5. 50-hr pupa; 6. 66-hr pupa.
The scale used in Figs. 2–6 is the same as in Fig. 1.

The epithelium consists of slightly columnar or spindle-shaped cells with dense cytoplasm and prominent nuclei. The epithelium of the oesophagus is thin and composed of flattened cells. But in the region of the oesophageal valve, the cells are still round or oval in shape.

By the time the pupa is 50 hr old, the epithelium of the entire foregut is reduced considerably in height. The cells in the oesophagus are still cuboidal while in the proventricular and oesophageal valve region, they are small columnar (Fig. 5). The cytoplasm is thick and granular with large prominent nuclei. The lumen in the proventriculus is wide and the intima is thick. Spinous projections are now very clearly visible and lie posteriorly directed. The epithelium is thrown into 4 longitudinal folds, covered externally by longitudinal and circular muscles.

In the 66-hr pupa, the oesophageal valve is well differentiated and is composed of a doubly folded epithelium, projecting into the midgut lumen (Fig. 6). No further changes are observed from the preceding stages so that the foregut now acquires an adult structure.

DISCUSSION

An anterior imaginal ring is absent in the larva of *C. sexmaculata.* The larval cells of the oesophageal valve divide mitotically during metamorphosis and rebuild the posterior region of the adult foregut. The larval cells do not degenerate but differentiate again during the formation of the adult foregut. Karawaiew (1898 and 1899), Lübben (1907), Oertel (1930) and Murray and Tiegs (1935) similarly showed the anterior imaginal ring to be absent in the insects they studied. They further showed the remodelling of the adult foregut by cellular redifferentiation. Although Anglas (1900) recognized a proliferating center near the foregut–midgut junction, he did not regard it as anterior imaginal ring. He called it "zone of growth". He further showed that a greater part of the imaginal epithelium is formed by the proliferation of cells of this growth zone. The old larval cells are absorbed by the newly formed advancing cells. The anterior part of the oesophagus becomes that of the adult. Similarly, in *C. sexmaculata* the old larval cells of the anterior part of the oesophagus are passed to the adult without apparent change. According to Dobrovsky (1951) the adult foregut of honey bee develops by the division of larval cells.

Deegener (1904 and 1908), Verson (1905) and Hufnagel (1918), however, recognized the presence of anterior imaginal ring in the foregut and stated that the larval cells redifferentiate into the adult epithelium; the proliferation of cells in the anterior imaginal ring makes only small additions to the larval cells. Deegener (1900), Gray (1931) and Nitschmann (1959) found that the larval cells of the entire foregut are destroyed and the imaginal epithelium is derived from the cells of the anterior imaginal ring. In *C. sexmaculata* some of the larval cells in the posterior region of the oesophagus give chromatin globules and degnenerate. Similarly Poyarkoff (1910) and Patay (1939) also observed chromatin globules given out from the developing foregut epithelium. Vaney (1902) and Perez (1910) found another imaginal disc situated posterior to the pharynx, and they called it hypodermal histoblastic disc. These authors further showed that the epithelium of the adult foregut is formed both by the anterior imaginal ring and the hypodermal histoblastic disc.

Although in *C. sexmaculata* a definite imaginal ring is lacking, the oesophageal valve of the larva may be considered to function as an imaginal ring since it forms new cells and rebuilds the adult structure during the course of metamorphosis. Lübben (1907) also regarded the whole oesophageal valve as imaginal ring in *Trichoptera,* following Deegener (1904).

Acknowledgements—I am grateful to Dr. J. Bahadur for suggesting the problem, criticism and encouragement. Thanks are also due to Dr. H. Swarup, Professor and Head, School of Studies in Zoology for providing necessary facilities.

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