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The digestive system of *Anoecia* (Homoptera: Aphidoidea)

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Abstract

The digestive system of *Anoecia* has a short foregut which opens into a dilated stomach via a valve. The stomach is made up of triangular cells with a merocrine secretion. The transition from the stomach to the intestine is marked by a sharp loop. The first and second regions of the intestine form a compact structure. The second region contains groups of three small cells (triplets) among the strongly vacuolated intestinal cells. The descending intestine opens into the rectum, which terminates at the anal opening. These findings are in accordance with the conception of Heie (1980) that *Anoecia* must be placed outside the family Thelaxidae.

Introduction

The genus *Anoecia* belongs to Börner's family Thelaxidae (Börner, 1952). The digestive system of *Anoecia* sp. is illustrated by Börner (1938) and consists of a foregut, a dilated stomach, a short intestine, and a hindgut, but lacks a filter system (Börner, 1952; Börner & Heinze, 1957).

In the present study the anatomy of the digestive system of *Anoecia* is investigated in more detail.

Material and methods

Specimens of the species listed in Table 1, were collected randomly from the host plant and put in Duboscq-Brasil's fluid. Prior to embedding in paraplast the larvae were dehydrated in ethanol, methyl benzoate followed by methyl benzoate celluidin (2 %) for three days or longer. The sections (8 μm thick) were stained in 1 % methyl green aqueous solution (Calberla, 1887) for one hour. After staining the sections were rinsed in tap-water, dehydrated in methanol and in methyl benzoate, cleared in xylene, and finally mounted in xylene-dammar.

Table 1. List of species of *Anoecia* studied their host plant, and relevant locality data.

Aphid	Host plant	Locality, date
a *Anoecia corni* (F)	*Agrostis stolonifera*	Bennekom, 5.VIII.1982
b *Anoecia* sp.	*Cornus* sp.	Wageningen, 7.IX.1977
c *Anoecia* sp.	*Poa annua*	Wageningen, 14.VII.1982

Results

The alimentary tract starts as the food canal in the firmly interlocked maxillary stylets. The food canal passes into the pharyngeal duct which leads into the pharyngeal valve, pharyngeal pump, foregut, oesophageal valve, stomach, intestine, and rectum which terminates at the anal opening (Fig. 1). The total length of the gut is about twice that of the body.

The foregut (oesophagus) runs posteriad from the tentorium, between the two salivary glands and dorsal to the nervous system, to end into the oesophageal valve. The valve is an invagination of the foregut into the stomach and consists of two layers of cells. The inner layer is the continuation of the foregut consisting of squamous epithelium, whereas the outer layer is made up of cuboidal cells; both types of cell secrete a chitinous intima (Fig. 2A).

The midgut is the longest part of the alimentary tract and consists of a stomach, first and second regions of the intestine,and descending intestine. The three regions of the intestine are each about one and a half times as long as the stomach. In dissections the descending intestine is a transparent, sac-like structure that shows vigorous peristaltic movements generated by circular and longitudinal muscles. The stomach and intestine are opaque, show slow peristaltic movements, and have only circular muscles.

The stomach has a dilated structure and lies centrally in the dorsal region of the aphid and dorsal to the descending intestine. It starts in either the meso- or meta thorax and runs directly posteriad to the first, second, third, or fourth abdominal segment (Table 2). The transition from the stomach to the intestine is marked by a sharp loop (Fig. 1).

The maximum diameter of the stomach is at the end of the oesophageal valve. The epithelium is made up of a single layer of 19-26 triangular cells decreasing to 6-8 cells at the posterior end. Each cell contains basophilic cytoplasm with small vacuoles and a spherical nucleus that is usually situated in the basal region of the cell. The cells secrete continuously vacuoles (merocrine secretion) into the stomach lumen, where they dissolve (Fig. 2B). The lumen is completely filled with coagulated material, but does not occur in the intestinal lumen after the stomach passes into the intestine. The secretion of the stomach cells continues during larval life and proceeds into the adult stage without degeneration of cells.

The intestine is the tubular continuation of the stomach and can be divided histologically into two distinct regions. The first region of the intestine runs anteriorly from the stomach, loops back in the metathorax or first abdominal segment and subsequently passes into the second region of the intestine. This broader intestine

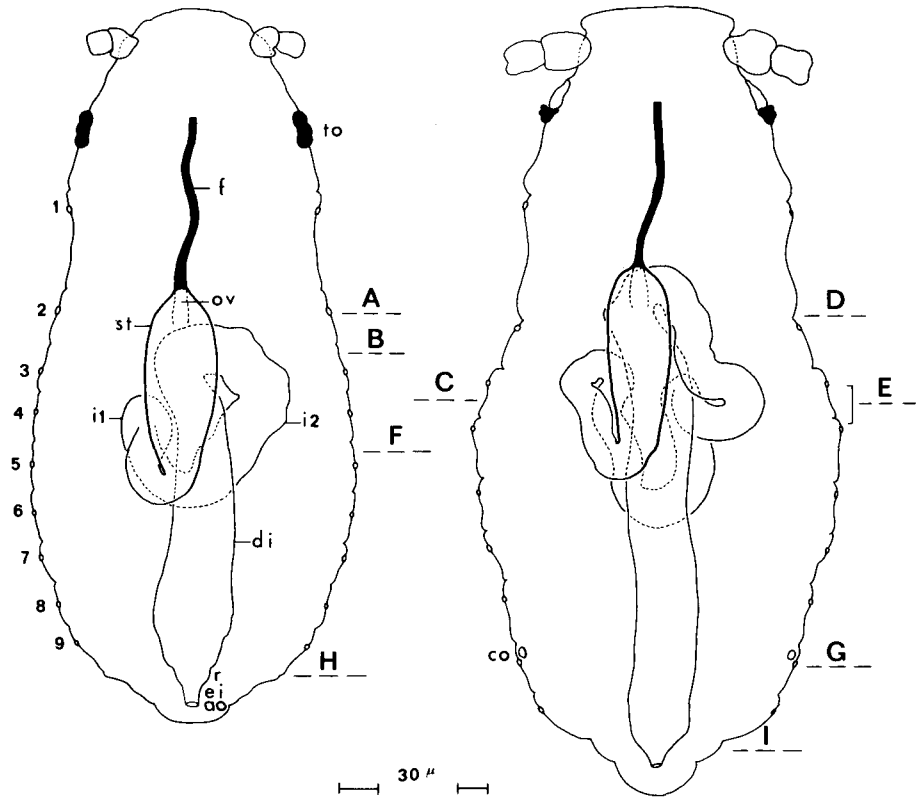

Fig. 1. Dorsal view of the digestive system of a wingless oviparous larva of *Anoecia* sp. from *Cornus* sp. (left) and a winged viviparous larva of *A. corni* (right) reconstructed from serial transverse sections. The siphunculi (pores, co) are situated on the sixth abdominal tergite.
1-2, meso- and metathoracic spiracles; 3-9, abdominal spiracles. ao, anal opening; di, descending intestine; ei, epidermal invagination; f, foregut; i1, first region of intestine; i2, second region of intestine; in, intima; ov, oesophageal valve; r, rectum; st, stomach; to, triommatidion.
The letters A-I correspond with transverse sections given in Fig. 2.

starts in the first, second, third, or fourth abdominal segment and runs either directly to the anterior part or the aphid to open into the descending intestine or as in *A. corni* it forms another coil before entering the descending intestine (Fig. 1). Within each species the first part of the intestine bends either to the right or to the left of the descending intestine. The absence of a long voluminous abdominal loop gives the digestive system of *Anoecia* a very compact structure. In transverse section, the intestine consists of 5-8 triangular cells; the cells of the first region of the intestine contain some vacuoles, wheras those of the second region are strongly vacuolated (Fig. 2C and D). The apical surfaces of both cell types have striated borders.

The second region of the intestine contains 6-9 groups of three small cells (Fig.

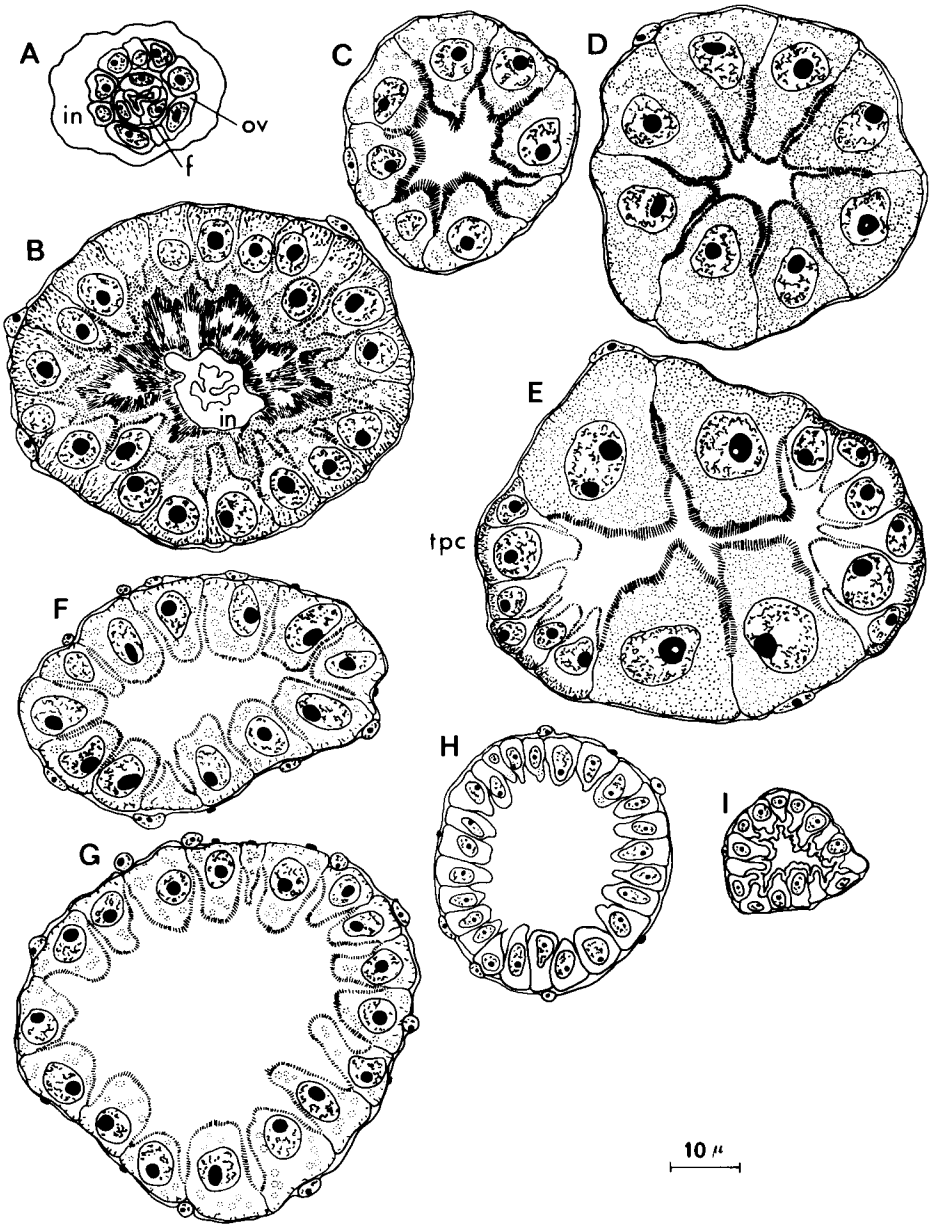

Fig. 2. Transverse sections of the digestive system of *Anoecia*. A, foregut and oesophageal valve; B, stomach; C, first region of the intestine; D, second region of the intestine; E, composition of five successive serial sections of the second region of the intestine showing triplet cells (tpc); F, descending intestine; G, descending intestine; H, rectum; I, epidermal invagination.
For explanation of abbreviations see Fig. 1. The position of the transverse sections A-I are given in Fig. 1.

Table 2. The position of the digestive system in the body cavity of the species of *Anoecia* studied. The letters a - c correspond with the host plant given in Table 1.

Aphid	Morph	Stomach starts in	Stomach ends in	Abdominal loop of intestine in	Thoracic loop of intestine in	Additional loop of intestine in
a *Anoecia corni*	wingless viviparous (2)	II	2	2	II	III-1
	winged viviparous (4)	II/III	1/2	2/3	II/III	III-1/2
b *Anoecia* sp.	wingless oviparous (4)	II/III	2/3	3	III/I	
	wingless males (4)	II	1/2	1/2	III	
c *Anoecia* sp.	winged viviparous (5)	II/III	2/4	3/4	II/III	II/III-III/2

I-III refer to thoracic segments; 1-9 refer to abdominal segments. In brackets number of aphids sectioned.

2E). Sometimes a triplet may occur singly, but the majority of them occur as two pairs of triplets among the epithelial cells. In each pair of triplets, the middle cell of one triplet has a relatively large spherical nucleus. The triplet cells contain numerous minute vacuoles, the microvilli of the apical cell membrane are shorter than those of the intestinal cells, and the basal cell membrane has abundant invaginations.

The fourth region of the midgut is the descending intestine. This runs from the thoracic loop directly caudally, to open into the rectum (Table 2). The triangular cells of the descending intestine are situated around a wide lumen (Fig. 2F and G). They contain small vacuoles, oval nuclei, and their luminal surfaces have small striated borders. Waxy droplets originating from fat cells and scattered throughout the body cavity do not occur in the lumen and inside the cells of the descending intestine. The transition from the second region of the intestine to the descending intestine is marked, in transverse sections, by a gradually increase in the number of strongly vacuolated intestinal cells then by an abrupt change to the typical cellular structure of the descending intestine. Histologically, the descending intestine of *Anoecia* is identical with that of the family Chaitophoridae (Ponsen, 1983).

The rectum begins in the eight abdominal segment and is made up of small columnar cells (Fig. 2H). It passes into an epidermal invagination of which the cuticular lining is thicker than that of the rectal epithelium (Fig. 2I). The anal opening is connected by muscles both laterally and dorsally to the ninth abdominal segment.

Discussion

The morphology of the digestive system of *Anoecia* described here agrees with Börner's (1938) illustration. The second region of the intestine of *Anoecia* living on the roots or basal parts of grass possesses one more coil than sexuales of *Anoecia* living on the leaves of *Cornus* sp. The transparent hindgut of *Anoecia* is of endodermal

origin, and therefore more correctly termed a descending intestine (Fig. 2F and G) like that of callaphidids, chaitophorids, *Glyphina*, and *Thelaxes* (Ponsen, 1983).

The genus *Anoecia* is placed by Börner (1952) in his family Thelaxidae. However, the digestive system of *Anoecia* differs from that of *Glyphina* and *Thelaxes* in the presence of a dilated stomach and a compactly coiled intestine, with the transition from the stomach to the intestine being marked by a sharp loop (Fig. 1). Consequently *Anoecia* does not belong in the same group as *Glyphina* and *Thelaxes*. This work supports Heie's (1980) placing the genus *Anoecia* in a separate family, the Anoeciidae.

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