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Internal structures of the mouthparts of Coccinea (Hemiptera: Sternorrhyncha)

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Abstract. Internal structures of the mouthparts of Coccinea were examined on the basis of cross-section across the third segment of rostrum. The research was conducted on representatives of 7 families. It has been observed that the general model of the internal structures of the mouthparts is closely similar in various Coccinea families. In the studied groups of scale insect, there is one model of the inner structure of the mouthparts. Three locks connect the maxillae: dorsal, middle and ventral. The locks consist of various processes. Small differences in the shape of the processes in the middle lock have been observed. The mandibles are not mirror images of each other. In phylogenetic studies the character of interlocking apparatus and other internal and external structures of the mouthparts in scale insects can be utilised in the identification of higher categories for all the Hemiptera.

Key words: Coccinea, Ortheziidae, Monophlebidae, Kermesidae, Eriococcidae, Cerococcidae, Pseudococcidae, Coccidae: mouthparts, internal connecting systems, maxillary locks, food and salivary canals, phylogenetic relationships.

INTRODUCTION

In Coccinea the internal structures of the mouthparts have been poorly studied, especially the interlocking mechanism between both maxillae and mandibles. PESSON (1944) made reference to a cross-section across the mouthparts in a few species: *Aulacaspis rose* BAUCHÉ, 1933, *Pseudococcus adonidum* (LINNAEUS, 1766), *Pulvinaria mesembryanthemi* (VALLOT, 1830) and *Icerya purchasi* (MASKELL, 1878).

KOTEJA (1974, 1976) drew attention to the external and partially to the internal structures of the mouthparts in Coccinea. Of the three examined structures of the mouthparts, the labium was found to have the largest number of characters useful in systematics, followed by clypeolabral shield and the salivary pump (KOTEJA 1974a, 1976). Moreover, KOTEJA

(1976) suggested that research into other structures of the mouthparts, e.g., the sucking stylets, tentorium, mandibles and maxillae, might produce some findings, which could be utilised in the taxonomy, particularly at higher levels. Hence, the first aim of this paper is to study the connecting apparatus between both maxillae and mandibles, the shape of maxillae and mandibles, and the size and location of the food and salivary canals in particular families of Coccinea. The second aim is to determine the usefulness of these characters in the analysis of the relationships between various groups of Coccinea.

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MATERIAL AND METHOD

The structure of the mouthparts was analysed in cross-section across the subapical (third) rostral segment of adult specimens. For comparison, in three species cross-sections were made across the second and first (basal) rostral segments as well.

Material for analysis was obtained from Professor KOTEJA's collection (Agricultural University of Cracow, Poland). The mouthparts (labium with maxillae and mandibles) were fixed in glutaraldehyde, post-fixed in osmium tetroxide, dehydrated in an ethanol series and embedded in an epon. The sections (transversely through half the rostrum) were cut on Ultratome using glass knives and were stained with uranyl acetate and lead citrate. Sections were examined in transmission electron microscopy (TEM). Thus obtained documentation helped to reconstruct the rostrum from the point of cross-section.

The general model of the internal structure of the mouthparts was established for representatives of Coccinea. Figures and photographs are presented in apical view from the base to the apex of rostrum.

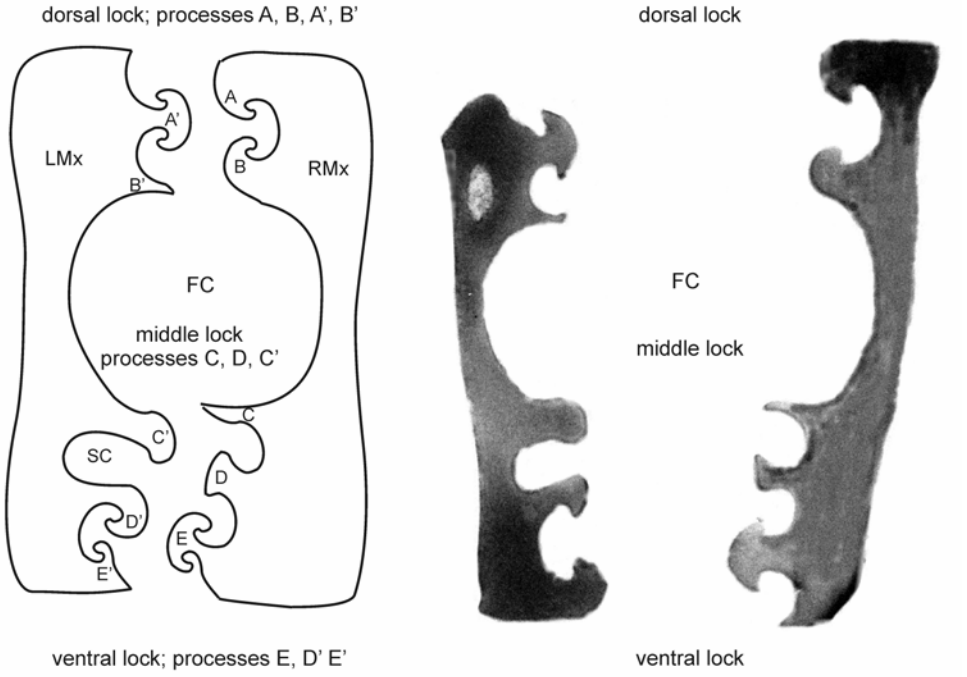
The following species were examined:

Orthezia urticae (LINNAEUS, 1758) – Ortheziidae;
Icerya purchasi (MASKELL, 1878) – Monophlebidae;
Kermes quercus (LINNAEUS, 1758) – Kermesidae;
Greenisca brachypodii (BORCHSENIUS et DANZING, 1966) – Eriococcidae;
Pollinia pollini (COSTA, 1857) – Cerococcidae;
Trionymus newsteadi (GREEN, 1917) – Pseudococcidae;
Saissetia hemisphaerica TARGIONI-TOZZETTI, 1867 – Coccidae.

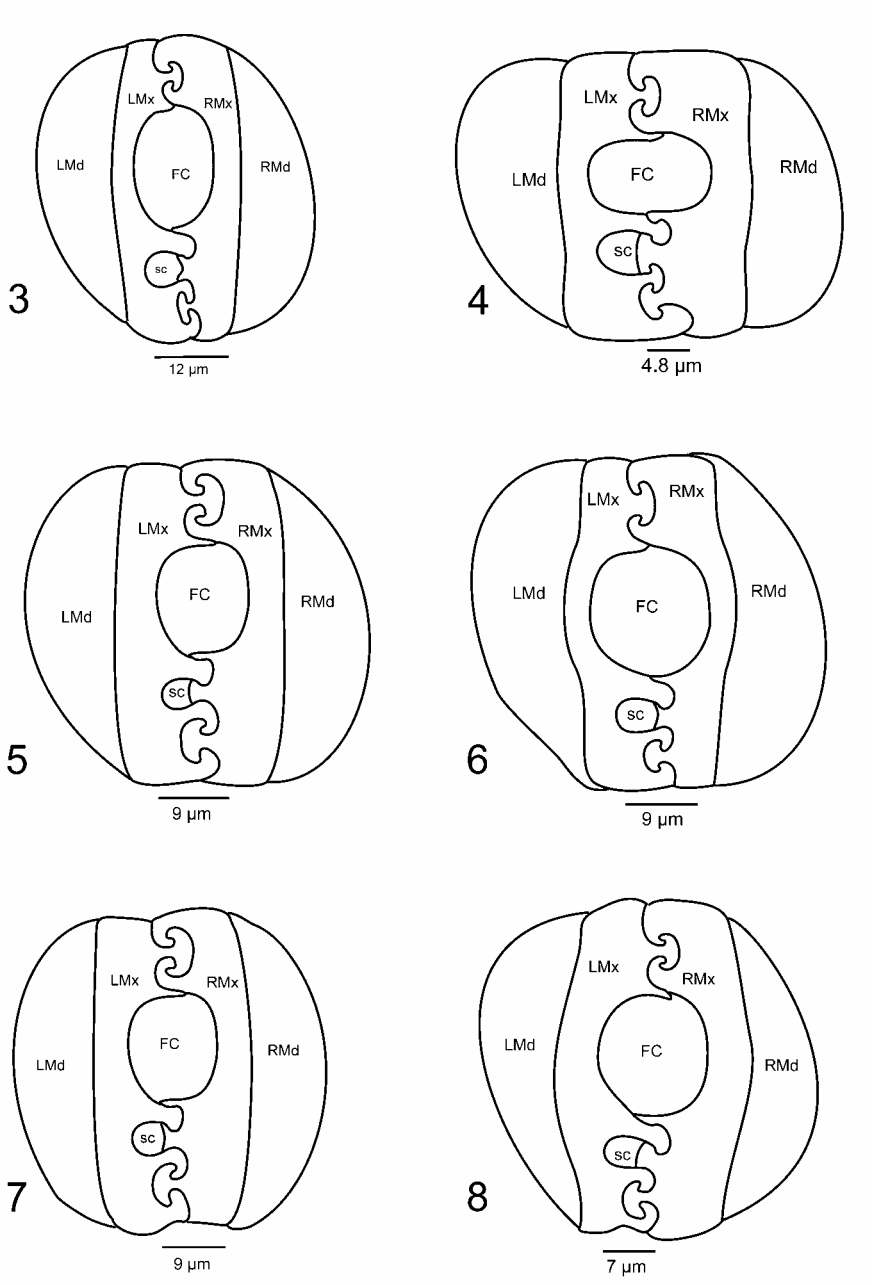
RESULTS

General characteristics

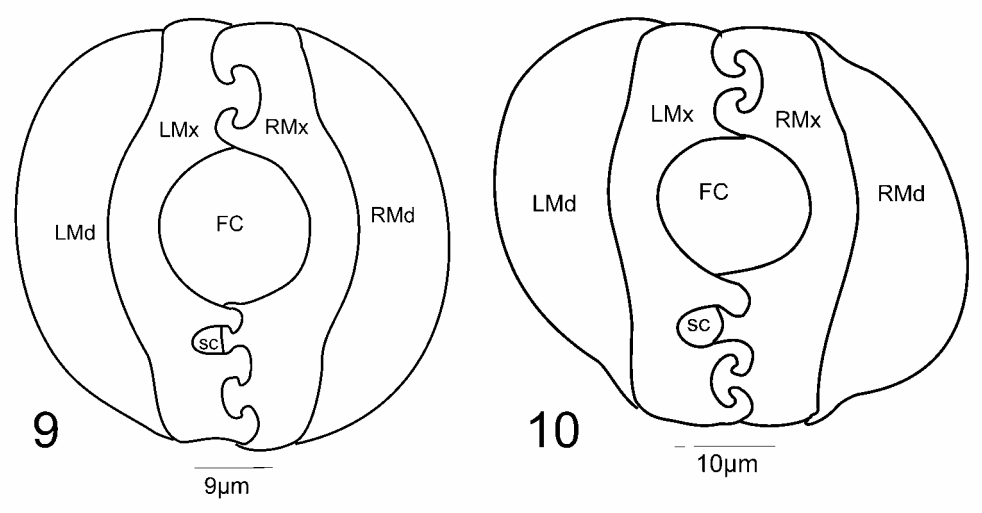
In a cross section across the mouthparts of the studied representatives of Coccinea, there are three processes of various shape on the inner surface of the right and left maxilla. The relative placement of processes on the right (RMx) and left (LMx) maxillae forms an interlocking system: dorsal, middle and ventral locks (Figs 1, 2). If in the locks of the maxilla there are two processes, one above the other, these structures are called the upper and the lower process. Unlike a T-shaped process, a hooked process is bent to one side; clavate is wider at the top, and a straight process not deflected. The number of processes on the right and left maxilla is the same.



Figs 1–2. Cross-sections of the third rostral segment of Coccinea; maxillae with three locks. FC - food canal; SC - salivary canal, RMx - right maxilla, LMx - left maxilla, LMd - left mandibula, RMd - right mandibula, A - upper, hooked right process of the dorsal lock. A' - T-shaped upper left process of the dorsal lock. B - hooked lower right process of the dorsal lock. B' - straight lower left process of the dorsal lock. C - straight upper right process of the middle lock. C' - clavate left process of the middle lock. D - T-shaped or clavate lower right process of the middle lock. D' - hooked lower left process of the middle lock. E - right, T-shaped process of the ventral lock. E' - lower, hooked left process of the ventral lock.



Figs 3–8. Cross sections by maxillae and mandibulae in scale insects: 3 - *Orthezia urticae* (Orthezii-dae), 4 - *Icerya purchasi* (Monophlebidae), 5 - *Kermes quercus* (Kermesidae), 6 - *Greenisca brachy-podii* (Eriococcidae), 7 - *Pollinia pollini* (Cerococcidae), 8 - *Trionymus newsteadi* (Pseudococcidae).



Figs 9–10. 9 - *Trionymus newstead* (Pseudococcidae), cross-sections across of basal part of the rostrum, 10 - *Saissetia hemisphaerica* (Coccidae).

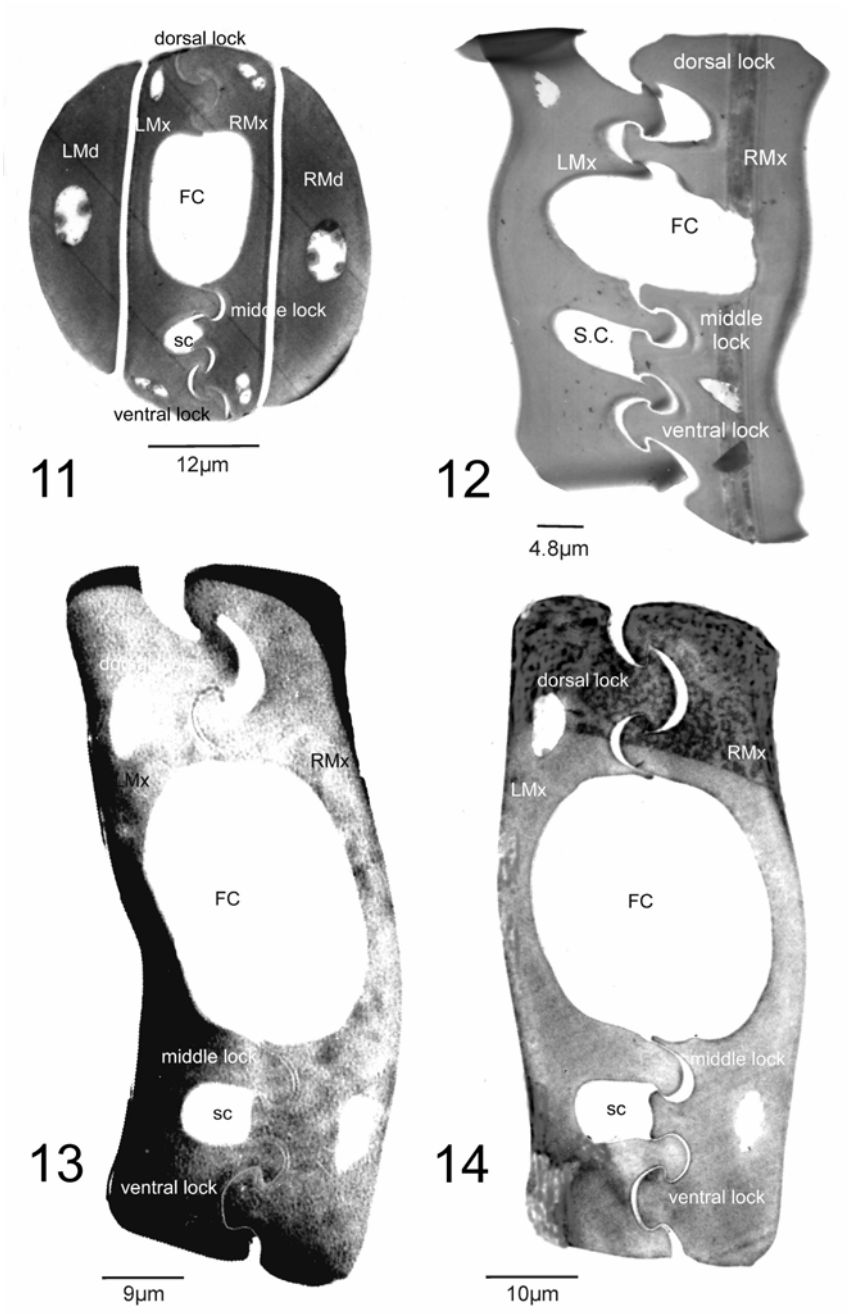
Four processes form the dorsal lock. On the right maxilla there are two hooked processes – the upper (A) and the lower (B) (Fig. 1). On the left maxilla also two processes are present: the upper T-shaped (A') and the lower straight (B').

Three processes form the middle lock: one clavate – straight and wider at the top (C') – on the left maxilla and two (C, D) on the right maxilla. The upper process (C) on the right maxilla is straight, while the lower process (D) is straight and wider at the top (Fig. 2). The lower process closes the salivary canal.

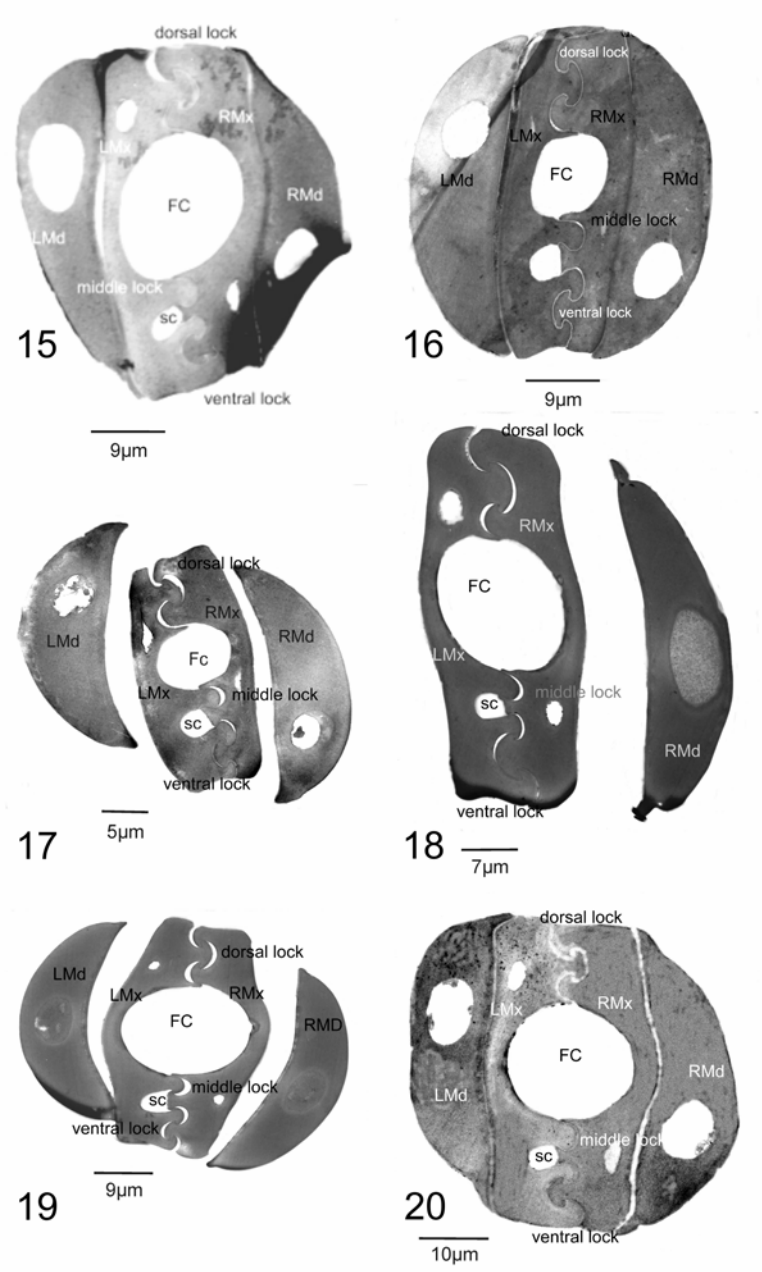
Three processes form the ventral lock. On the right maxilla there is a T-shaped process E (Fig. 1). On the left maxilla there are two hooked processes (D' and E'), which interlock with process E on the right maxilla (Fig. 1).

The food canal is formed by both maxillae, between the dorsal and the middle locks. It is usually oval in cross-section due to concave inner walls of the maxillae. The salivary canal is placed entirely in the left maxilla and closed by process D (Fig. 1), which can be clavate (not strongly deflected) or T- shaped, as in *Icerycha purchasi* (Figs 4 & 11). The salivary canal is always semicircular and much smaller than the food canal.

In cross section across the rostrum in scale insects, the maxillae always seem more or less flattened laterally (Figs 4, 6, 8, 10, 12, 15, 17, 18 & 20); however, in some species the maxillae are almost rectangular (Figs 3 & 11, *Orthezia urticae*; Figs 5 & 13: *Kermes quercus*; Figs 7 & 16: *Pollinia pollini*). Generally, in all examined species the left maxilla is narrow in the dorsal portion and wide in the ventral part, quite the opposite of the right maxilla. The maxillae are the widest on the level of the food canal in the basal portion of rostrum (Figs 9, 14 & 19).



Figs 11–14. 11 - *Orthezia urticae* (Ortheziidae), 12 - *Icerya purchasi* (Monophlebidae), 13 - *Kermes quercus* (Kermesidae), 14 - *Kermes quercus* (Kermesidae), cross-section across basal part of the rostrum.



Figs 15–20. 15 - *Greenisca brachypodii* (Eriococcidae), 16 - *Pollinia pollini* (Cerococcidae), 17 - *Pollinia pollini* (Cerococcidae), cross-section across basal part of the rostum, 18 - *Trionymus newsteadi* (Pseudococcidae), 19 - *Trionymus newsteadi* (Pseudococcidae), cross-section across basal part of the rostum, 20 - *Saissetia hemisphaerica* (Coccidae).

The mandibles (Md) are placed laterally in relation to the maxillae (Mx) and are not connected with them.

In some species of scale insects, the mandibles are not symmetrical (they are not mirror images of each other). The left mandible is often widest in the dorsal portion and tapered ventrally, as in *Saissetia hemisphaerica* (Coccidae) and *Greenisca brachypodii* (Eriococcidae). The shape of the right mandible is the reverse of the left (Figs 6, 10, 15 & 20). The mandibles can be the same length as maxillae, as in *Orthezia urticae, Pollinia pollini*, and *Trionymus newsteadi* (Figs 3, 7, 8, 11, 16, 17 & 18), or longer, as in *Greenisca brachypodii* and *Saissetia hemisphaerica* (Figs 6, 10, 15 & 20). If the mandibles are longer than the maxillae (Figs 10 & 20), then the dorsal tip of the left mandible touches the dorsal tip of the left maxilla (on the right the situation is reversed). If the mandibles are the same length as the maxillae, then the upper and lower tips of the mandibles touch the lateral walls of the maxillae (Figs 3, 7, 11 & 16).

A comparison of cross-sections across various points of the rostrum shows that the maxillae tend to be markedly enlarged near the head, on the level of food canal, where their diameter is bigger (Figs 14 & 19).

DISCUSSION AND CONCLUSION

In contrast with other structures of the mouthparts (KOTEJA 1976), the type of the connection between maxillary stylets in Coccinea has never been presented. On the basis of the cross-section analysis of the rostrum, it seems that the general internal structure of the mouthparts is highly similar in various families of scale insects. In the studied groups there is one model of the inner structure of the mouthparts (Figs 1 & 2). Three locks connect the maxillae: dorsal, middle and ventral. In cross section across the rostrum, the locks are formed with various processes. Only small differences have been observed in the shape of the processes forming the middle lock (Figs 3, 4, 5, 6, 12 & 13).

An interesting aspect of the internal structure of the mouthparts in the discussed scale insect groups is the presence of a T-shaped process in the dorsal and ventral locks. This contrasts with the other groups of Steronrrhyncha (Aphidomorpha, Psyllomorpha and Aleyrodomorpha), where a T-shaped process does not occur. The information about the absence of a T-shaped process is based on photographs (POLLARD 1970, PARRIS 1967, FORBES 1966, 1972). In place of a T-shaped process in Aphidomorpha, Psyllomorpha and Aleyrodomorpha there is a hooked process. However, T-shaped processes have been observed in a few groups of Heteroptera (BROŻEK & HERCZEK 2004). Locking constructions with T-shaped processes are probably stable and provide for disjunction from the maxillae. It is necessary while injecting the stylet bundle into plants and sucking the fluid from vascular systems of plants because the maxillae are flexible in Coccinea. From a different perspective, the presence of T-shaped processes in Coccinea and in the majority of representatives of Heteroptera can indicate parallel evolution of connecting systems of the maxillae.

The fact that various families of scale insects represent different feeding types (KOTEJA 1985) is probably of no significance for the internal structure of the mouthparts. Representatives of the family Ortheziidae exemplify the most primitive type of feeding; they suck fluid from the surface of plants. The other families represent a feeding type which is regarded as highly specialised; they suck fluid from the vascular system or particular cells of the epidermis or mesophyll (KOTEJA 1985). In the examined representatives of scale insects, the internal structures of the mouthparts are similar in spite of the existing differences in the type of feeding. The diameter of the food canal is large, in contrast to the salivary canal. The food canal is placed centrally, formed by both maxillae, whose walls are symmetrically concave. This feature has been observed in all analysed Coccinea and in the remaining Hemiptera, except Enicocephalomorpha - Heteroptera (COBBEN 1978, BROŻEK & HERCZEK 2004). The size of the salivary canal in many specialised families of scale insects is always small and stable all along the maxillae. The small size of the salivary canal in these insects may show the primitive character of this group. The small size of this canal in comparison with the food canal has been observed in Fulgoromorpha and Cicadomorpha (TAVELLA & ARZONE 1993, BROŻEK & HERCZEK 2001). In Coccinea the salivary canal is located only in the left maxillae, a position specific for Sterorrhyncha (PESSON 1944, FORBES 1969, HOOF 1958, PARRISH 1967, POLLARD 1971, SAXENA & CHADA 1971).

The position of the salivary canal in Steronrrhyncha has been interpreted as a plesiomorphic feature, which marks off this insect group from other Hemiptera (COBBEN 1978). In Heteroptera, Fulgoromorpha and Cicadomorpha the salivary canal is located in the right maxillae or centrally (COBBEN 1978, EMELJANOV 1985, BROŻEK & HERCZEK 2001, 2004).

In researches on the mouthparts other structures have been considered too, e.g., the salivary pump. The relative size of the salivary pump and salivary ducts has been analysed in particular groups of scale insects (KOTEJA 1976). A large salivary pump has been identified in the members of the families Diaspididae, Asterolecaniidae, Conchaspididae, Kermesideae and Porphyrophoridae, while a small salivary pump in Ortheziidae, Pseudococcidae and Coccidae. An analysis of the relative size of the salivary pump in various families (KOTEJA 1976) has shown that the size of the organ is not indicative of the relationship on the family level. However, KOTEJA (1976) has suggested that the size of the salivary pump can be used for distinction of higher taxa in all Hemiptera. It seems that the small diameter of the salivary canal in scale insects could also be considered in the phylogeny of all Hemiptera because this character is present only in all Steronorrhyncha.

A comparative analysis of the mouthparts shows that the shape of the maxillae is stable and that the presence of a small salivary canal and a large food canal is also constant in the examined taxa of scale insects. Small differences have been observed only in the length and shape of the mandibles (Figs 11, 15, 16 & 20). Thus, the analysed features of the internal structures of the coccid mouthparts prove highly similar on the family level.

On the basis of selected morphological characters, KOTEJA (1974, 1976, 1989, 1996) and other researchers have identified two major branches in the phylogeny of Coccinea: the superfamilies Orthezioidea and Coccoidea, which evolved probably from a common stock.

In early classification systems proposed by SILVESTRI (1939), BORCHSENIUS (1950), and BODENHEIMER (1952), scale insects were divided into two major groups: the Paleococcoidea = Archaeococcoidea and Neococcoidea. The former group was considered as more primitive, while the latter as more specialized (SILVESTRI 1939, BODENHEIMER 1952, BORCHSENIUS 1950). The superfamily Orthezioidea corresponds to Paleococcoidea, and Coccoidea, to Neococcoidea (KOTEJA 1976). Although the analysed internal structure of the connection system and other characters, such as the shape of the mandibles and maxillae, the size and location of the salivary canal, and the size of the salivary pump (KOTEJA 1976), are not distinctive on the family level, they are features of all Coccinea. The present investigations into the internal characters of the mouthparts do not introduce a new phylogenetic conception of Coccinea but they could be considered in the discussion on the monophyly of this insect group. The scale insects are widely accepted as a monophyletic group (KOTEJA 1976) and the present investigations support this view. In phylogenetic studies the interlocking apparatus and other internal and external structures of the mouthparts in scale insects can be utilised as indicative of higher categories of the Hemiptera.

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