THE ULTRASTRUCTURE OF THE TRACHEAE OF TRACHEAL LUNGS IN *SCUTIGERA COLEOPTRATA* (NOTOSTIGMOPHORA, CHILOPODA)

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The ultrastructure of the tracheae of tracheal lungs in *Scutigera coleoptrata* is presented. The tracheal wall is constituted of flat epithelial cells which secrete towards the lumen a resistant network of thin fascicles.

Gases exchange is realised between the air passed through the branched, blind-ended tracheae of tracheal lungs and the haemolymph which bathes the tracheae.

The discussions about the oneness of the tracheal lungs in the class Chilopoda and in the whole Arthropoda, the apomorphic state of the median spiracles and the presence of haemocyanin in the haemolymph of *S. coleoptrata* have occasioned the phylogenetic considerations.

Key words: tracheal lungs, ultrastructure, *Scutigera coleoptrata.*

The respiratory system formed by a series of seven pairs of tracheal lungs in the species of the order Scutigeromorpha represents an original respiratory solution, unique in the whole Arthropoda. This exceptional morphologic trait belongs to an order of Chilopoda, highly related to Pleurostigmomorpha chilopods.

The aims of the present paper are to describe the ultrastructure of the tracheae of tracheal lungs in *S. coleoptrata* and to debate some problems related to the origin and diversity of the respiratory system in Chilopoda.

MATERIAL AND METHODS

Male and female individuals of *Scutigera coleoptrata* were captured alive during the spring of 1992, in Casavet Cave (Enisala, Dobruja, Romania).

After ether anaesthesia, the tracheal lungs were isolated and immersed in 2.5% glutaraldehyde solution in 0.2 M cacodylate buffer, pH 7.2, for 24 h, at 4°C. The material was postfixed in 1.33% OsO_4 solution in cacodylate buffer for 2 h, in darkness, at room temperature. After repeated washings, there followed dehydrations of the samples using graded ethanol solutions. The samples were embedded in Epon 812. Semithin sections through the tracheal

lungs were stained with toluidine blue. The ultrathin sections double-contrasted with uranyl acetate and lead citrate were studied in TEM.

For histologic observations, the material fixed in Bouin solution was processed for inclusion in paraffin by routine techniques. Histologic sections of 5 µm were stained with Hemalum-Eosin.

RESULTS

The tracheal lungs of *Scutigera coleoptrata* are symmetrical structures formed of the expansions of the pericardium in which a closed tracheal system is branched.

The tracheal lungs are situated only on the segments with large tergites, respecting the dorsal heteronomy specific to the orders Chilopoda anamorpha and to the order Scolopendromorpha.

The tracheal system of each tracheal lungs pair is constituted of an aerial chamber (atrium), which communicates with the surrounding medium by a mid-dorsal spiracle in the form of slit, and of numerous tracheae which branch towards the right and left sides and then end blindly (L e w i s, 1981).

The tracheae of tracheal lungs are tubular invaginations of the epithelium which lines the aerial chamber (Fig. 1). The tracheal tubules start from the median zone of tracheal lungs, branch here and there towards the lateral extremities (Fig. 2), where they end in the form of finger glove. The haemolymph which bathes the outer part of tracheal walls contains numerous blood cells (Fig. 3). The epithelial cells lining the tracheal walls are flat cells with a scanty cytoplasm (Fig. 4). The tracheal wall is reinforced by the fascicles of fine electron-dense filaments (Fig. 4, 5 and 6). These filaments are arranged in a network (Fig. 7) to prevent the flattening of the tracheae. The tangential or oblique sections through the tracheal walls demonstrate the presence of long electron-dense filaments which have a predominantly circular orientation and a network texture confirming the resistance role of these structures (Fig. 6 and 7).

The epithelial cells present few cytoplasms (Fig. 4 and 5). This feature may be considered an adaptation for their role in gases exchange. Also, the junctions between epithelial cells of the trachea are realised without the thickening of the cells (Fig. 5).

The epithelial cells cytoplasm contains many ribosomes, free or associated with endoplasmic reticulum (Fig. 4 and 6), suggesting an intense synthesis activity.

The tracheae of tracheal lungs lack taenidial thickenings.

Fig. 1. – Transversal semithin section through the tracheal lungs. Toluidine blue. 170 x.

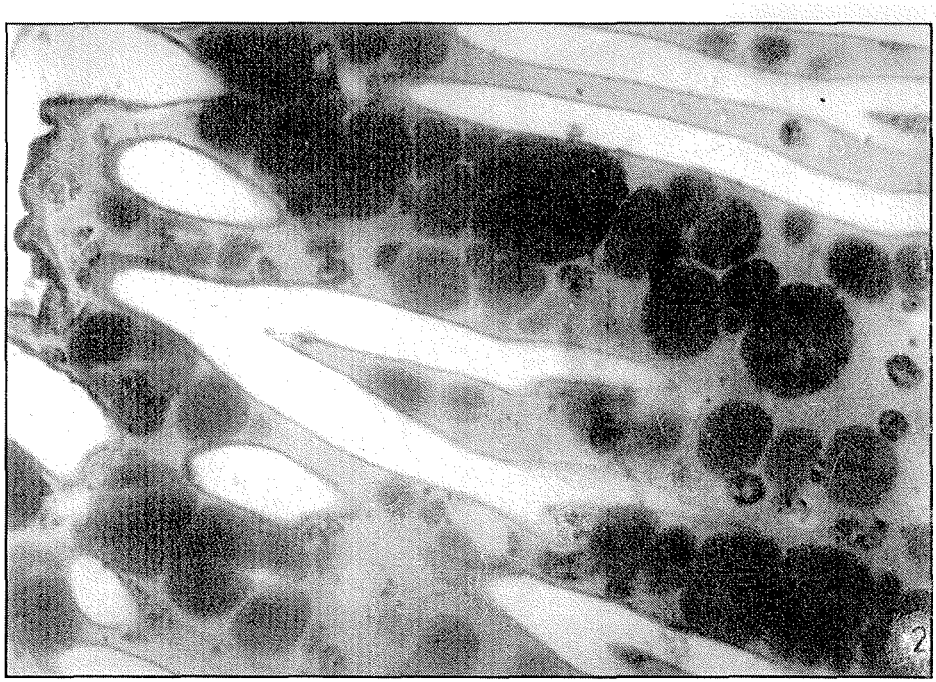

Fig. 2. – The branching of the tracheal tubules. Detail of Fig. 1. 640 x.

Fig. 3. – The tracheal tubules in a transversal-oblique thin section. The granulocytic-type blood cells are observed among the tubules, in haemolymph. 2,250 x.

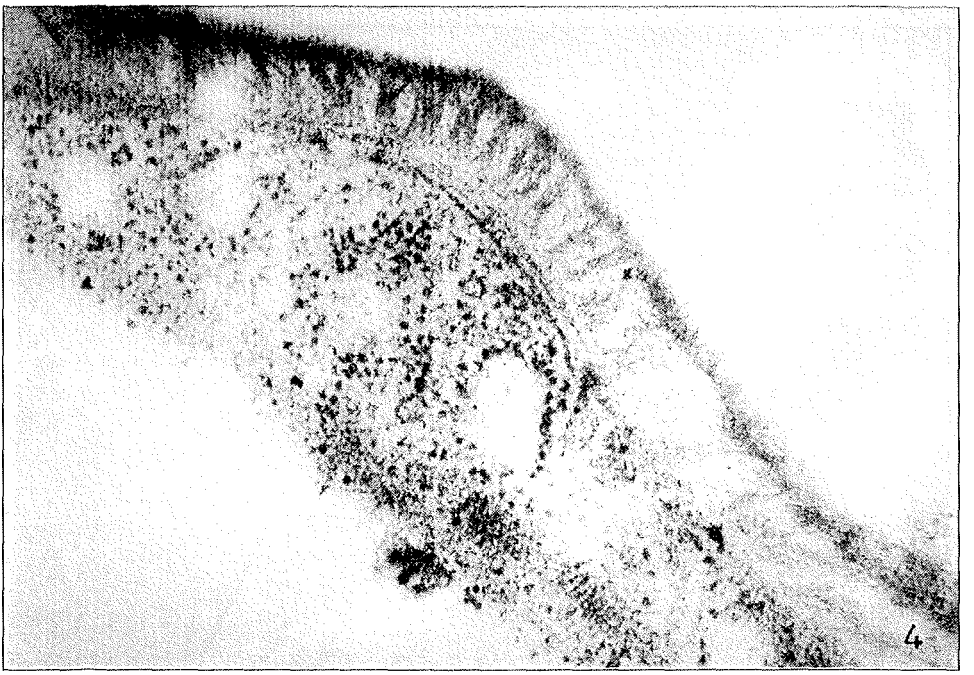

Fig. 4. – Epithelial cell with ribosomes, rough endoplasmic reticulum and electron-dense filaments forming the rigid skeleton of the tracheal tubule. 46,000 x.

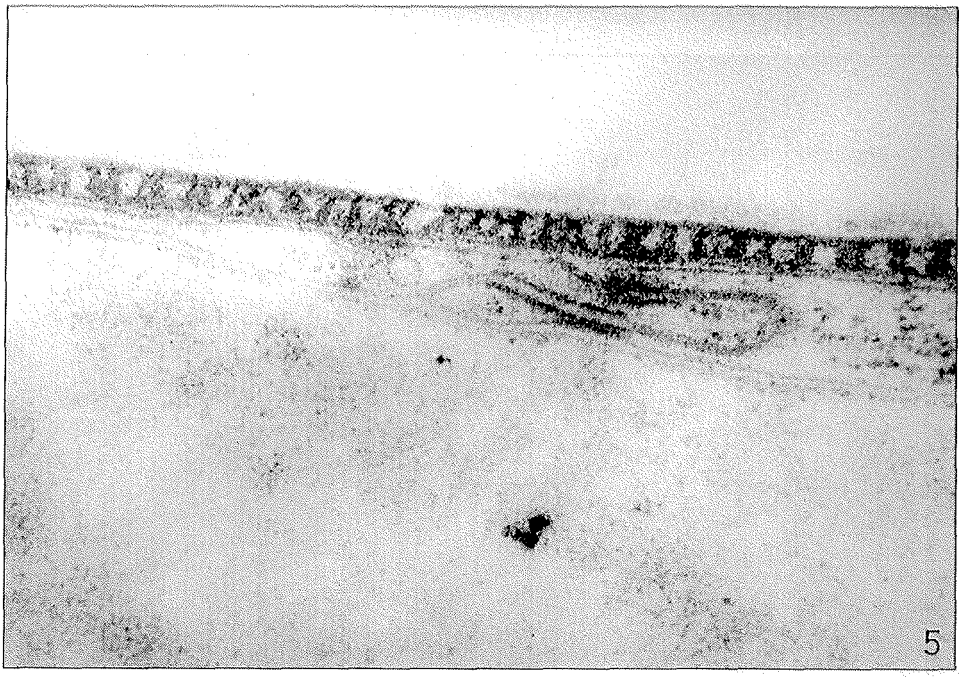

Fig. 5. – Longitudinal section through the tracheal wall. Note the junctional relation between two epithelial cells. 30,000 x.

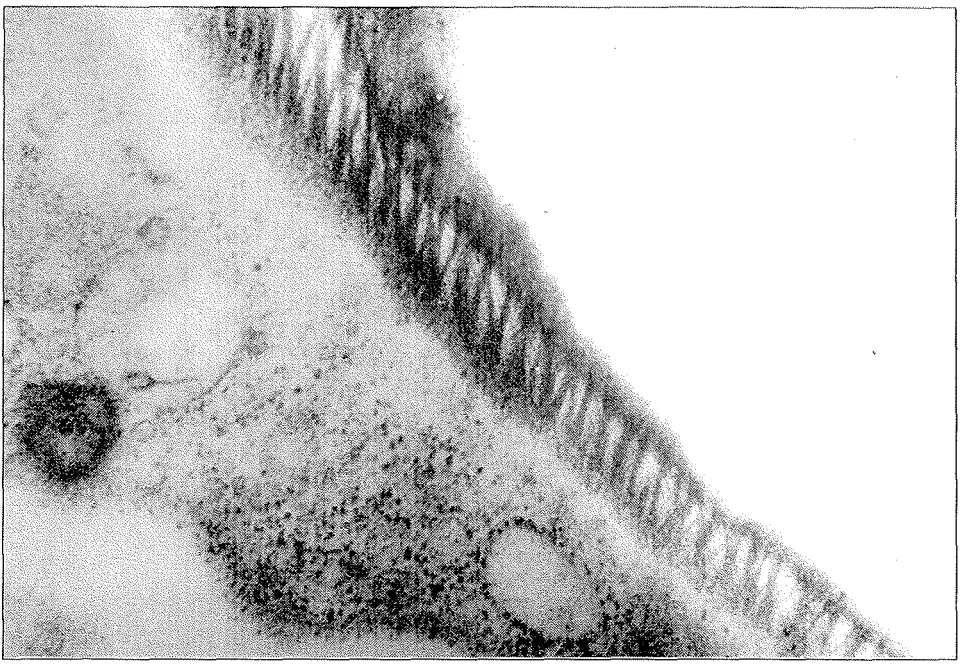

Fig. 6. – Oblique section through the tracheal wall. Note the network texture of the fascicles of thin filaments. 30,000 x.

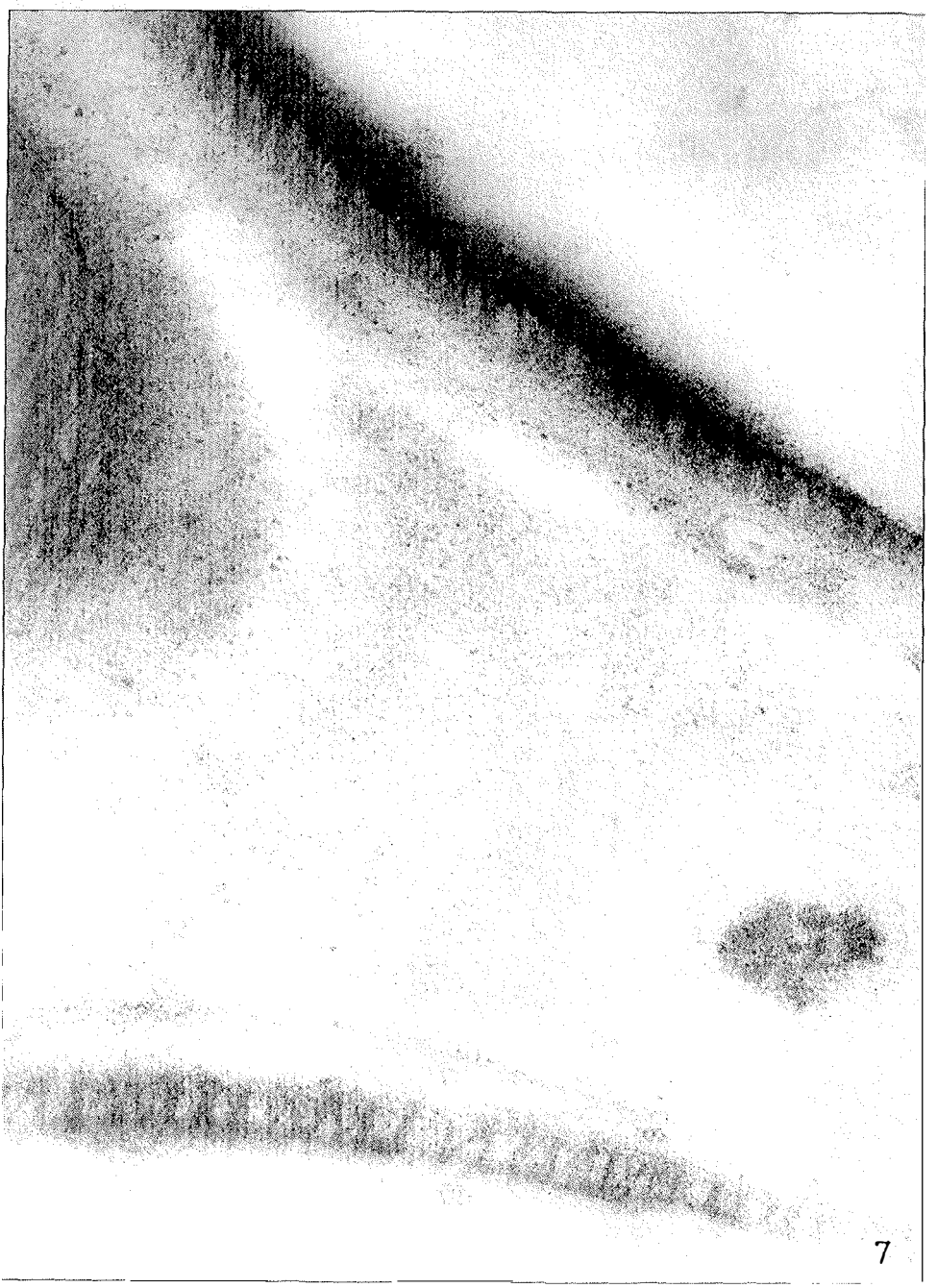

Fig. 7. – Transversal-oblique section through three tracheae. Note the predominantly circular orientation of the thin filaments which reinforce the skeleton of the tracheal tubules. 46,000 x.

DISCUSSION

The respiratory system originality of the order Scutigeromorpha consists in the presence of the tracheal lungs and in the use of the respiratory pigment haemocyanin dissolved in haemolymph, as an oxygen carrier (Rajulu, 1971; Ellerton et al., 1983; Magnum and Godette, 1986).

The representatives of the order Scutigeromorpha are the unique Tracheata in which the respiratory orifices (spiracles) are disposed in the mid-dorsal zones of the tergites. The presence of spiracles on the segments with large tergites certifies the common origin of the respiratory system in all chilopods with a heteronomous dorsal segmentation. From this point of view, the respiratory system of modern Chilopoda is monophyletic and may be inferred from a metameric respiratory system with spiracles situated on the segments with large tergites already existent in the common ancestor of Chilopoda (Prunescu, 1965; 1996).

The existence of a left lobe, respectively of a right lobe, of the tracheal lungs in Scutigeromorpha suggests the migration of bilateral tracheal lungs towards the median zone of the large tergite (Haase, 1885).

In a recent paper (Prunescu, 1996), it is discussed the concordance between the tracheal-pulmonary system in the order Scutigeromorpha and the life conditions of these chilopods (open air and a low-humidity atmosphere).

We consider that the respiratory system existent in the unique ancestor of the modern chilopods presented pleural spiracles respecting the bilateral symmetry, specific to all Tracheata.

As in the case of the median position of spiracles in the order Scutigeromorpha, we consider this an apomorphic character which coexists with a great accumulation of plesiomorphic features of external and anatomic morphology.

The recent work realised by Hilken (1996) has established that the tracheae of *S. coleoptrata* are strengthened by a network of chitin fibres. Thus, Rajulu's interpretation (1971) regarding the collagen composition of the tracheae in Scutigeromorpha has been corrected.

The chitinous resistance structure of the tracheae remains valid for the whole class Chilopoda. This fact may be a supplementary argument for the monophyletic origin of the tracheae.

The lack of taenidia in the tracheae of tracheal lungs must be connected with the fact that in Scutigeromorpha the tracheae are the organs through which it is realised the gases exchange, while in Pleurostigmophora chilopods the main function of tracheae is the air transport to the body tissues. Hence, in Pleurostigmophora chilopods the tracheae are elastic aerial canals resistant to the pressure exerted by organs (muscles or surrounding tissues), while in Scutigeromorpha the tracheae show a simplified resistance structure, as they are situated in the tracheal lungs in direct connection with the haemolymph.

During the ontogeny of the Insecta, the inner part of the tracheal wall is smooth, the taenidia occurring later (Blum, 1985).

It is evident that in the tracheal lungs of Scutigeromorpha it was not a real necessity of increasing the resistance of the tracheal skeleton by taenidial thickenings.

The existence of haemocyanin dissolved in haemolymph in Scutigeromorpha (Rajulu, 1971; Ellerton et al., 1983; Magnum and Godette, 1986) seems to plead for the chilopods origin directly from one group of ancient Mandibulata, which used as a respiratory pigment the haemocyanin.

The biochemical comparative studies on different haemocyanins and the chemical structure of these oxygen carriers point out their implication in gases exchange in some species of the orders Decapoda, Isopoda and Amphipoda of subclass Malacostraca (Crustacea), a species of the order Rhizocephala of subclass Cirripedia (Crustacea), in the representatives of the order Scutigeromorpha (Chilopoda) and in many orders of Chelicerata and Mollusca (Ellerton et al., 1983).

The paper of Magnum and Godette (1986) concludes on the high similarity between the quaternary structure of the haemocyanin of *S. coleoptrata* and the haemocyanin from other arthropods. The authors consider that the presence of the haemocyanin in different taxonomic groups of arthropods is a positive argument for the hypothesis of the monophyletic origin of Arthropoda.

Kraus O. and Kraus M. (1994), using among other arguments some anatomic and external morphologic characters, plead for a simultaneous origin of the Tracheata and Crustacea from an ancient line of the Mandibulata. Within the frame of Tracheata, the authors consider Chilopoda to be the line which is related the most to the mandibulate ancestors of the Tracheata.

By continuing other anatomic comparative studies, it should be possible to obtain new data and to identify the arthropodan type which could be a candidate for the role of the modern representative of the aquarian arthropod ancestor from which the Chilopoda evolved.

In our opinion, the hypothetic ancestor of the modern Chilopoda might have proceeded from a group of aquarian arthropods sufficiently evolved in comparison with the Mandibulata ancestor.

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