APHIDS AND OTHER HEMIPTEROUS INSECTS | VOL. 15
5–16

General information on thorax morphology of selected species of psyllids /Hemiptera, Psylloidea/

JOWITA DROHOJOWSKA

Department of Zoology, University of Silesia
Bankowa 9, 40–007 Katowice, Poland
jowita.drohojowska@us.edu.pl

Abstract

The paper was concerned with general characteristics of morphological structure of a thorax of insects of the Psylloidea superfamily, referring to an analysis of nine species of Poland's fauna classified in three families. The structure of the following parts was studied: sternits, tergits and pleurites of all the parts of the thorax. Descriptions of particular elements building up thorax plates, their shape, size and links as well as a course of all the clefts and sulcus were provided. All the discussed elements building up particular sclerites were presented in pictures from a scanning microscope.

Introduction

Superfamily Psylloidea includes eight families (WHITE & HODKINSON, 1985): Psyllidae Burmeister, Triozidae Löw, Aphalaridae Löw, Homotomidae Heslop–Harrison, Calyophyidae Vondraček, Carsidaridae Crawford, Phacopteronidae Becker–Migdisova and Spondyliaspididae Schwarz. Until now over 2500 species spread all over the world have been described (BURCKHARDT & LAUTERER, 1997). So far the research concerning this group of insects and their morphology concentrated mainly on the construction of the head, forewings and hindwings as well as genitalia. The thorax of psyllids in comparison with complete body measurements is relatively large, however, in the references little information on its construction is provided mainly because most familiar morphological data relates to features of diagnostic importance and few such have been found as yet. So far there are publications concerning thorax part of selected accidentally few species (STOUGH, 1910; CRAWFORD, 1914; WEBER, 1929; VONDRAČEK, 1957; TREMBLAY, 1965; OUVRARD *et al*., 2002; OUVRARD *et al.,* 2008) and one study (KLIMASZEWSKI, 1964) in which the authors discuss homology within the Psylloidea superfamilia using the shape of thorax sclerits for the purpose apart from many other features (KLIMASZEWSKI, 1964).

Material and methods

The material was collected using an entomological sweep–net, it was then stored dry and after the preparation and cleansing with alcohol it was arranged for an analysis using low vacuum in the electron scanning microscope S–3400 N. The following species of the Aphalaridae family were analysed: *Livia juncorum* (Latreille, 1798) collected from *Juncus* sp.*, Craspedolepta nervosa* (Förster, 1848) collected from *Achillea millefolium,* from family Psyllidae: *Cacopsylla crataegi* (Schrank, 1801) collected from *Crataegus* sp., *Psylla fusca* Zetterstedt, 1828, collected from *Alnus* sp., *Psylla foersteri* Flor, 1861 collected from *Alnus glutinosa, Psyllopsis fraxinicola* (Förster, 1848) collected from *Fraxinus excelsior,* instead from family Triozidae: *Bactericera femoralis* (Förster, 1848) collected from *Alchemilla* sp. and *Heterotrioza pallida* (Haupt, 1935) collected from herbaceous plants.

Morphological terminology and the list of abbreviations used to describe the photographs is after OUVRARD *et al*. (2002, 2008): aas – anterior accessory sclerite, acl2 – anapleural cleft, apwp – anterior pleural wing processes, axc2 – axillary cord, cx1– procoxa, cx2 – mesocoxa, cx3 – metacoxa, epm1 – proepimeron, epm2 – mesoepimeron, epm3 – metaepimeron, eps1 – proepisternum, eps2 – mesoepisternum, eps3 – metaepisternum, ftna2 – fossa of the trochantinal apodeme, ftna3 – fossa of the trochantinal apodeme, hepm – heel of the epimeron, kes2 – katepisternum, mcs – meracanthus, nt1 – pronotum, pas – posterior accessory sclerite, pls1 – propleural sulcus, pls2 – mesopleural sulcus, pls3 – metapleural sulcus, pnt2 – mesopostnotum, pnt3 – metapostnotum, ppt – parapterum, psc2 – mesopraescutum, ptm2 – mesothorax peritreme, ptm3 – metathorax peritreme, s2 – mesosternum, sc2 – mesoscutum, sc3 – metascutum, scl2 – mesoscutellum, scl3 – metascutellum, stg – spiracle, tems – transepimeral sulcus, tg – tegula, trn2 – mesothorax trochantin, trn3 – metathorax trochantin.

Analysis of construction of thorax sclerits of selected species

Prothorax

Prothorax is the smallest thorax segment with a strongly modified structure which is the result of mouth apparatus being moved backwards which is related to a partial accretion of bottom labium with a ventral prothorax. Dorsal side of prothorax is formed by one sclerite – pronotum (nt 1), of varied shape and size in particular groups. In the Aphalaridae family a massive, wide and straight pronotum is observed as in the case of *Livia juncorum* (Latreille, 1798) (Fig. 1) or one that is narrower than the width of the head and slightly bended as in the case of *Craspedolepta nervosa* (Förster, 1848) (Fig. 2). Species of the Psyllidae family e.g. *Psylla fusca* Zetterstedt, 1828 have a greater narrowing and a stronger bending (Fig. 3). In the representatives of the Triozidae family one can observe a narrowing and bending of pronotum which modify it to become a thin, hardly visible batten, e.g. *Bactericera femoralis* (Förster, 1848) (Fig. 4). In the species of the remaining families the pronotum also has a diversified shape: wide, slightly bended – in the case of *Carsidaridae* and *Spondyliaspididae* species or much bended and narrowing to a different extent in the middle part as in the case of *Calyophyidae*.

The marginal part of pronotum is constituted by 2 pleurits, usually of the same size, easily visible in representatives of all the psyllid families, proepisternum (eps1) and proepimerum (epm1) (Figs. 5, 6). They are always clearly separated from each other by propleural sulcus, while their border with prothorax is not always visible. Propleural sulcus (pls1) runs from the basal coxa appendix up to pronotum with which it can be joined in different places e.g. its middle part (Fig. 5) or it can reach the hind corner of pronotum (Fig. 6). The shape of pleurits and location of stitch running between them, or in other words the exact spot where it joins pronotum are the only diagnostic features which have so far been described. Trochantin on prothorax is hardly visible.

Sternal part of prothorax is in the case of psyllids significantly reduced and almost invisible because it is covered by rostrum which is partly grown with it (Fig. 10).

Between pleurites of prothorax and mesothorax there are 3 tiny sclerites of arguable origin. These sclerites include the anterior accessory sclerite and posterior accessory sclerite (aas and pas) and perytrema (ptm2) surrounding stigma of mesothorax (Fig. 7). It is not always easy to mark them, as sometimes they are covered by mesoepisternum appendix which is pointed forward.

Mesothorax

Mesothorax is the biggest part of the abdomen which is related to a functional domination of forewings which is connected with the development of muscles which move them. The dorsal part of mesothorax is divided into a large mesonotum and battened mesopostnotum (Fig. 9). Mesonotum is divided into 3 sclerites mesopraescutum (psc2), mesoscutum (sc2) and mesoscutellum (scl2), which are separated from each other by clear sulcus. Mesopostnotum, which is situated behind mesonotum at the dorsal side, is not visible, it covers it as the mesoscutellum (scl2) which is totally at the front at the sides of mesopostnotum, has a form of a narrow batten running diagonally towards mesoepimeral sclerite.

Pleural side of mesothorax (Fig. 8) consist of two large sclerites, Bigger mesoepisternum (eps2) and smaller – mesoepimerum (epm2), often incompletely separated from each other (that is why mesopleural sulcus may have a different length). Mesoepisternum (eps2) takes different shapes depending on the position and run of pleural sulcus (pls2) and anapleural cleft (acl2). Anapleural cleft divides mesoepisternum into dorsal anaepisternum and ventral preepisternum and/or katepisternum. Anapleural cleft may exist as a deep ditch or membraneous area or it may not exist at all. Also the run of the anapleural cleft may be different ranging from diagonal to almost horizontal. Mesoepimeron is more complex than mesoepisternum because of a vertical groove which Ouvrard *et al.* (2002) referred to as transepimeral sulcus (tems, Fig. 8). The widest part of mesoepimeron is situated at the front towards the transepimeral sulcus. Dorsal, posterior ridge of this sclerite (at the front of third peritrema and the back of transepimeral sulcus) supports the basis of anterior pleural wing processes (apwp, Fig. 8). The anterior pleural wing processes is thin and pliable and may be distal deep seated towards dorsal ridge of mesopleuron. It is separated from this ridge by something which has a shape of a narrow, membraneous area. The orientation of a further or supporting part of anterior pleural wing processes may be different both towards the front and to the dorsum. Often pleural sulcus on mesothorax follows a round way from condyle of coxa joint and approaches a point in the middle of pleuron but never meets the basis of the wing (Ouvrard *et al.*, 2002). In the case of psyllids the position of the pleural sulcus is much changeable ranging from relatively straight and vertical (as in many specimens of Pterygota) to winding and/or almost horizontal. When it is horizontal the sulcus sometimes joins the anapleural cleft. Katepisternal complex is formed by katepisternum (kes2) and trochantin (trn2) and separated from anaepisternum by the anapleural cleft (Fig. 8). Katepisternal complex is cylindrical and striped. On the frontal–ventral edge or in the middle of katepisternal complex of the mesothorax (kes2) there appears fossa of the trochantinal apodeme (ftna2, Fig. 8). The ventral side of mesothorax is constituted by a well developed sclerite–mesosternum (s2), grown with forecoxa of the second pair of legs (Fig. 10).

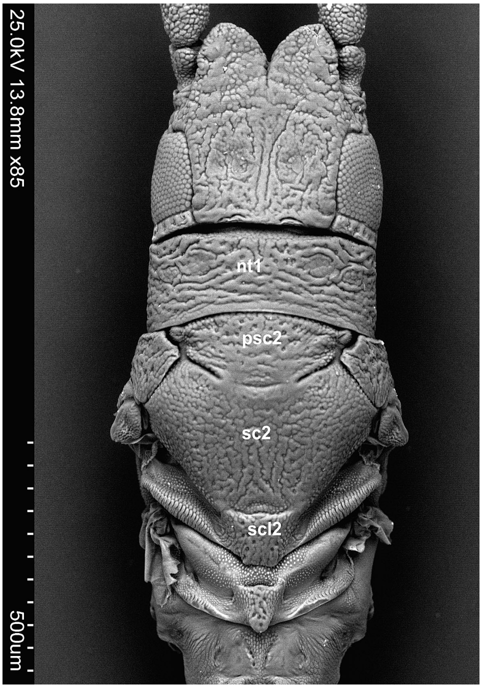

Figure 1. *Livia juncorum*, dorsal view

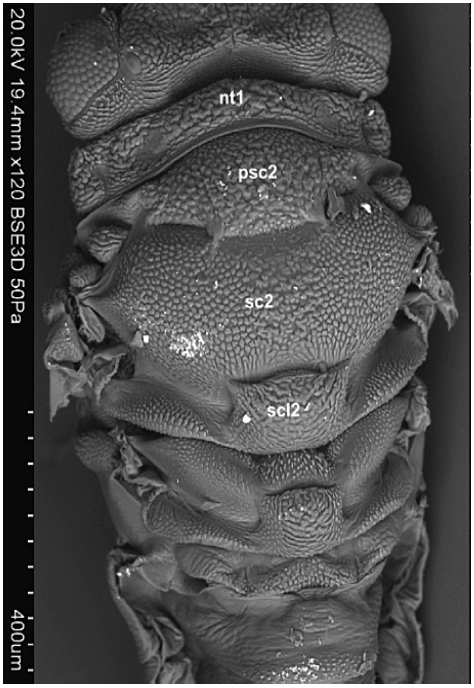

Figure 2. *Craspedolepta nervosa*, dorsal view

Metathorax

Metathorax of psyllids is unevenly developed in its dorsal and ventral part. The dorsal part is relatively small because muscles which are situated in it move the hindwings which are much less developed than the muscles of mesothorax. However, the ventral part, in which huge muscles of saltatorial legs of the third pair (characteristic of psyllids) are located grows out significantly and additionally reinforces by inclusion of large forecoxae of the legs of the third pair (Klimaszewski, 1964). The dorsal side of metathorax is joined with metanotum and metapostnotum (Fig. 9). In the metanotum one can distinguish two pleurites, metascutum (sc3) and metascutellum (scl3) (sometimes they are covered by metascutum which is in the front and by metapostnotum which is behind them). The metapostnotum (pnt3) has a nearly trapezial shape and it includes apart from the proper metapostnotum also a tergit of the first segment of the abdomen, which is completely joined with it (Fig. 9). Lateral pleurites of the metathorax (metapleurites) are quite well developed but a metapleural sulcus which runs between them is hardly visible and never separates them entirely (Fig. 8). Metapleuron is strongly modified by a vertical prolonging of coxa meron which enforces on metaepimeron and metaepisternum a development into a long, thickened arch stretching above the metacoxa. One can observe a reverse rotation of the metaepimeron with metaepisternum (Ouvard *et al.*, 2002). On metaepisternum one can find metathorax stigma (stg3) whose plate become entirely embraced within the pleurite (ptm3, Fig. 8). One cannot determine the border between metaepimeron and metapostnotum. Trochantin on metathorax (trn3, Fig. 8) is well developed. It is prolonged along the posterior edge of metapleuron in the front of thigh. External fossa of the trochantinal apodeme is well visible (ftna3, Fig. 8). Sternal part of metathorax has a shape of a narrow plate which is strongly thickened in the front and which surrounds thighs of legs of the third pair with lengthened processes.

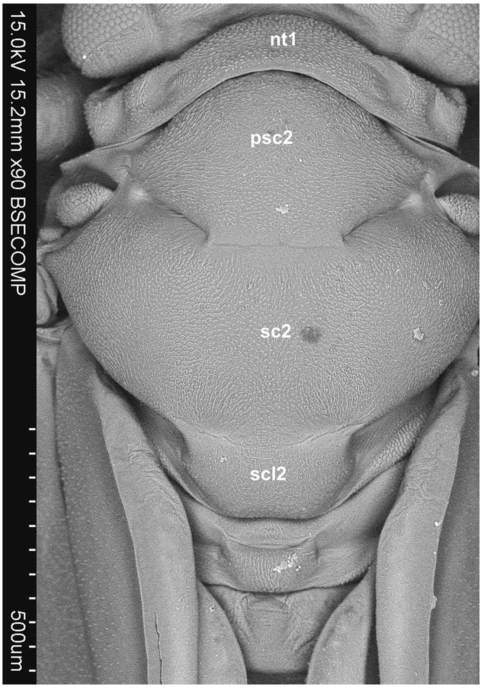

Figure 3. *Psylla fusca*, dorsal view

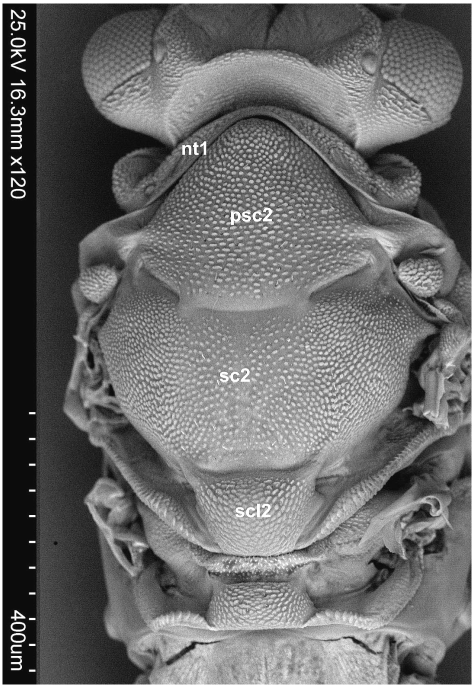

Figure 4. *Bactericera femoralis*, dorsal view

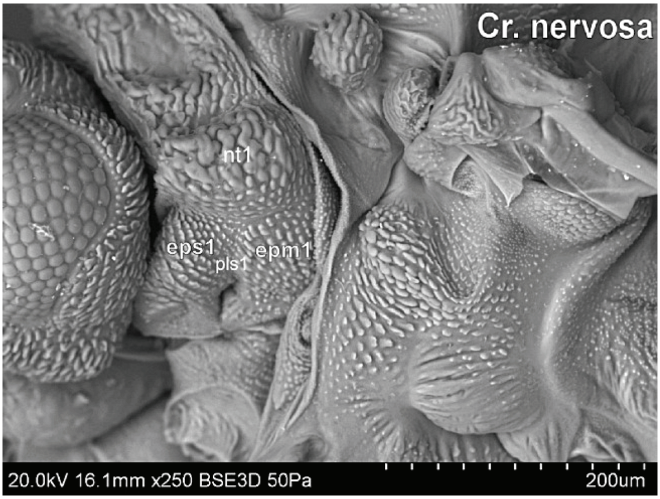

Figure 5. *Craspedolepta nervosa*, lateral view

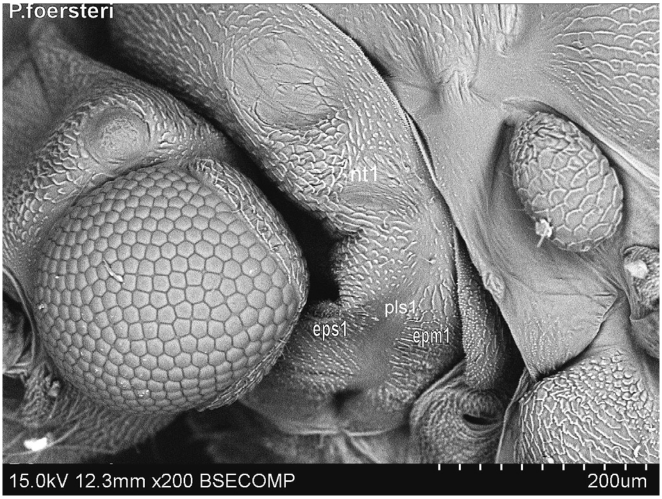

Figure 6. *Psylla foersteri*, lateral view

Discussion

The structure of thorax in psyllids is within the schema of winged insect thorax but it reveals also individual features characteristic only for this group. One of them is an uneven development of particular thorax parts which is connected with a functional domination of forewings over the hindwings and legs of the third pair over the remaining ones. The extension of muscles moving the forewings and the ability to jump which is connected with the growth of the muscles of the third pair of legs causes that particular elements in the thorax are moved. In connection with the unique ability of psyllids to jump it is difficult to interpret homology of many components which build the metathorax in psyllids with the same part in other insects (OUVRARD *et al.*, 2002). A typical feature of psyllids includes additional sclerites situated between prothorax and mesothorax which are not always well visible and their origin is disputable. Most researchers claim that sclerites belong to mesothorax but were moved to the front by the mesothorax due to a strong development of major pleurites. This is supported by the fact that one of the mentioned sclerites is constituted by stigma plate (peritrema) with stigma situated on it. According to HESLOP-HARRISON (1952) this plate does not belong to mesothorax but to prothorax whereas mesothorax stigma was reduced and its plate was included into a lateral wall of the segment. This conclusion seems to be false because in other hemipterous insects, though not only hemipterous insects, the prothorax stigma is always reduced and that is why it would be different in the case of psyllids. CRAWFORD suggested (1914) that the anterior accessory sclerite was a fragment separated from the dorsal part of peritrema. A thesis put forth by OUVRARD *et al.* (2002) seems to be right as he claims that it requires further research on muscle fastening in order to explain the origin of these sclerites.

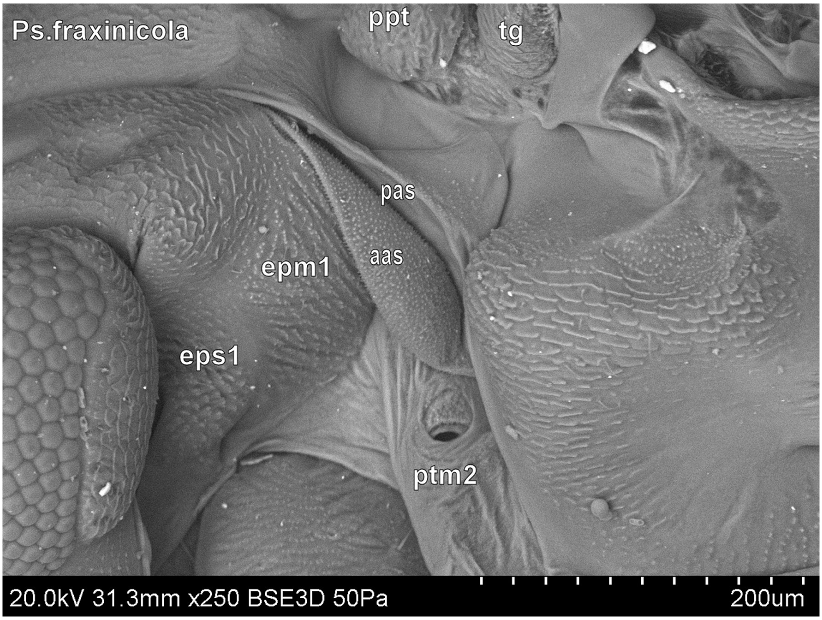

Figure 7. *Psyllopsis fraxinicola*, lateral view

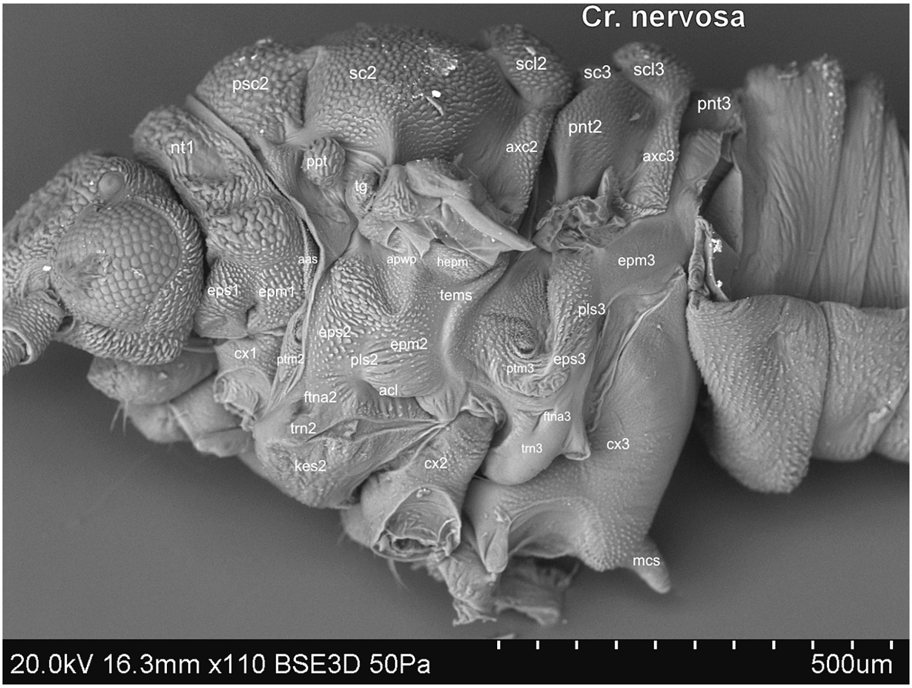

Figure 8. *Craspedolepta nervosa*, lateral view

An incomplete formation of pleural cleft separating mesoepimeron and mesoepisternum is a typical feature encountered in all the species of psyllids. It always runs from joint coxa condyle of the thing towards the wing base and finishes in different places of pleuron not reaching the wing basis. Crawford claimed (1914) that the pleural cleft may reach the anterior pleural wing processes but the analysis of the internal side of pleuron as carried out by Ouvrard *et al.* (2002) showed that cleft never touches the wing's processer. In all the species that the author analysed the pleural cleft also did not link with the anterior pleural wing processes. This cleft has a changeable shape and course in particular species. Clark suggested (1962) that this incomplete pleural cleft was observed in adult psyllids and it may explain their relative weakness at flying. It seems to be indisputable that psyllids do not belong to insects that fly well. They fly only short distances from one plant to another, always the one that is closest, and when disturbed they never fly away but jump away. When observing their flight one may consider it chaotic while its trajectory reminds one of big circles. Clark's (1962) viewpoint seems to be correct due to the fact that adult winged insects have a full pleural cleft on mesothorax even when in the larval stage it is not entirely formed as it was showed by Snodgrass (1909).

Studies of the internal side of pleuron by OUVRARD *et al.* (2002) apart from evoking uncertainty as to an uneven development of the pleural cleft also explained a false interpretation of transepimeral cleft running through mesoepimeron. Some authors (JOURNET & VICKERY, 1978) interpreted this cleft as a pleural cleft but OUVRARD *et al.* (2002) showed that the transepimeral cleft in its internal side does not have pleural apophysis and hence should be considered as a second cleft. Thanks to the analysis of the internal part of abdomen in psyllids some authors (OUVRARD *et al.*, 2002) also explained among others, the structure of katepisternal complex, trochanin as well as the position and course of the anapleural cleft enabling, thus, to correctly interpret these structures in other species. Also the delineation of borders between particular parts of the thorax has so far caused difficulties but after their analysis it is easier.

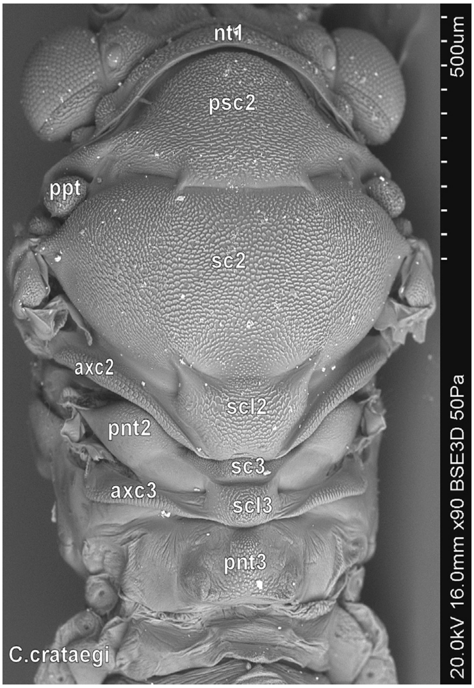

Figure 9. *Cacopsylla crataegi*, dorsal view

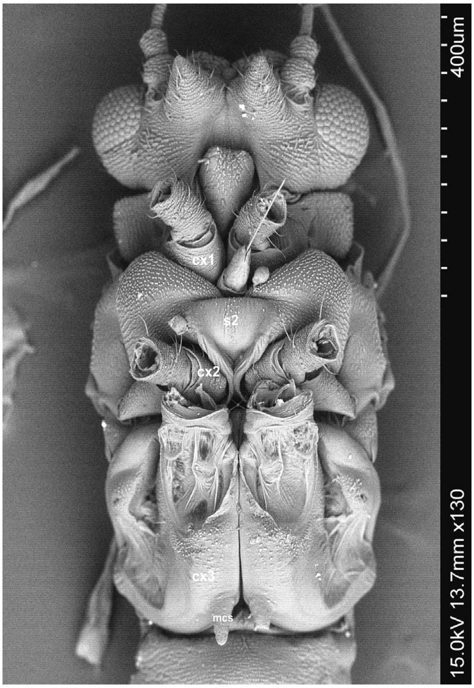

Figure 10. *Heterotrioza palliada*, ventral view

KLIMASZEWSKI (1964) also pointed out to relations between basic sclerites of the thorax and to developmental tendencies of these relations. He showed certain features in the thorax structure which he claimed to be characteristic to families. These were mainly the relations between pronotum, mesopraescutum and mesoscutum. This led him to discover a similarity among species classified to belong to particular families. He also considered wide pronotum as a plesiomorphic feature and confirmed a more or less equal development of mesopraescutum and mesoscutum. When analyzing the structure of the thorax part it is worth noting not only the characteristic features of the taxons of the upper order such as a family, but also for taxons of a lower order such as subfamilies, tribes or genera. Research conducted by the author of this paper on many species considered to belong to the same genus show that within one genus the structure of the thorax part is almost the same.

It appears that getting to know the structure of the thorax in psyllids and finding out features that have not been described and used before may let one to verify the existing hypotheses concerning the related connections within the superfamily of Psylloidea and also within the entire Sternorrhyncha. A systematic check–list of hemipterous insects which is being formed on the basis of numerous taxonomic studies is constantly updated. Views on classification are changed because of new morphological, anatomical, embryological, molecular and other data. So, an analysis of a larger number of features for a given taxon lets one choose the most optimal features and the most optimal classification. Such type of research on related connection using the morphology of the thorax part were already conducted successfully on aphids (*Aphidinea*) (WĘGIEREK, 2002), a group that is close to psyllids within the suborder of Sternorrhyncha.

References

BURCKHARDT D., LAUTERER P. 1997. A taxonomic reassessment of the triozid genus *Bactericer*a (Hemiptera: Psylloidea). Journal of Natural History, 31: 99–153.

CLARK L. R. 1962. The general biology of *Cardiaspina albitextura* (Psyllidae) and its abundance in relation to weather and parasitism. Australian Journal of Zoology, 10: 537–586.

CRAWFORD D. L. 1914. A monograph of the jumping plant–lice or Psyllidae of the new world. Smithsonian Institution United States National Museum Bulletin, 85: 1–186.

HESLOP-HARRISON G. 1952. Preliminary Notes on the Ancestry. Family Relations. Evolution and Speciation of the Homopterous Psyllidae–II. Annals and Magazine of Natural History, Londyn, (12) 5: 679–696.

JOURNET A. R., VICKERY V. R. 1978. Studies on nearctic *Craspedolepta* Enderlein, 1921 (Homoptera, Psylloidea): external morphology. Canadian Entomologist, 110: 13–36.

KLIMASZEWSKI S. M. 1964. Studies on systematic of the suborder Psyllodea. Annales Zoologici, 22, 5: 81–138.

OUVRARD D., BOURGOIN T., CAMPBELL B. C. 2002. Comparative morphological assessment of the psyllid pleuron (Insecta, Hemiptera, Sternorrhyncha). Journal of morphology, 252: 276–290.

OUVRARD D, BURCKHARDT D, SOULIER–PERKINS A, BOURGOIN T. 2008. Comparative morphological assessment and phylogenetic significance of the wing base articulation in Psylloidea (Insecta, Hemiptera, Sternorrhyncha). Zoomorphology, 127: 37–47.

SNODGRASS R. E. 1909. The thorax of insects and the articulation of the wings. Proceedings of the U.S. National Museum, 36: 511–595

STOUGH H. B. 1910. The hackberry Psylla, *Pachypsylla celtidismammae* Riley. A study in comparative morphology. Kansas University Science Bulletin, 5: 121–165.

TREMBLAY E. 1965. Studio morfo–biologico sulla Trioza tremblay Wagner (Hemiptera–Homoptera, Psyllidae). Bolletino del Laboratorio di Entomological Agraria Filippo Silvestri. 23: 37–138.

VONDRAČEK K. 1957. Mery– Psylloidea. Fauna .S.R., 9, Praha, 431p.

WEBER H. 1929. Kopf und Thorax von *Psylla mali* Schmidb. (Hemiptera–Homoptera). Eine morphogenetische Studie. Zeitschrift für Morphologie und Ökologie der Tiere, 14: 59–165.

WĘGIEREK P. 2002. Relationships within Aphidomorpha on the basis of thorax morphology. Prace Naukowe Uniwersytetu Śląskiego w Katowicach nr 2101. Wydawnictwo Uniwersytetu Śląskiego.

WHITE I. M., HODKINSON I. D. 1985. Nymphal taxonomy and systematics of the Psylloidea (Homoptera). Bulletin of the British Museum, 50 (2): 153–301.

Acknowledgements

Special thanks go to Ms Malwina Roszkowska and Magdalena Kowalewska-Groszkowska from the Department of Scanning Microscopy at the Polish Academy of Sciences for taking microscopic pictures.

Ogólne informacje o morfologii tułowia wybranych gatunków koliszków /Hemiptera, Psylloidea/

Streszczenie

W pracy podano ogólną charakterystykę budowy morfologicznej odcinka tułowiowego owadów należących do nadrodziny Psylloidea opierając się na analizie dziewięciu gatunków fauny Polski klasyfikowanych w trzech rodzinach. Porównano budowę sternitów, tergitów oraz pleurytów wszystkich odcinków tułowia. Zamieszczono opisy poszczególnych elementów budujących płytki tułowiowe, ich kształt, wielkość, połączenia, a także przebieg wszystkich bruzd oraz szwów. Wszystkie omawiane elementy budujące poszczególne skleryty zostały przedstawione na zamieszczonych zdjęciach z mikroskopu skaningowego.