Vestnik zoologii, **50**(6): 511–516, 2016
DOI 10.1515/vzoo-2016-0058

Morphology

DE GRUYTER OPEN

UDC 595.792(477)

REVIEW OF METANOTAL SCULPTURE OF APHIDIINE WASPS (HYMENOPTERA, BRACONIDAE, APHIDIINAE)

M. O. Kaliuzhna

Schmalhausen Institute of Zoology, NAS of Ukraine,
vul. B. Khmelnytskogo, 15, Kyiv, 01030 Ukraine
E-mail: kaliuzhna.maryna@gmail.com

Review of Metanotal Sculpture of Aphidiine Wasps (Hymenoptera, Braconidae, Aphidiinae). Kaliuzhna, M. O. — Morphological data on metanotal sculpture of aphidiine wasps (Hymenoptera, Braconidae, Aphidiinae), are reviewed based on the specimens collected in Ukraine. Specimens of 20 species of 13 genera were studied using light and scanning electron microscopy. Differences in menatonal morphology appear diagnostic for some genera or generic groups, such as tribes and subtribes. Seven general types of metanotal sculpture were distinguished. The proposed diagnostic characters are: the relative proportions of the metanotum and its parts (metascutellum, metascutellar arms), the shape and setation of the metascutellum, the number and form of the carinae arising from the base of metascutellum toward the mesoscutellum. To facilitate describing the structure of the metanotum in Aphidiinae, following measurements were established: the length and width of the metanotum and the metascutellum, the length of the metascutellar arms. The discovered characters could be used as additional diagnostic tools for aphidiine identification, and perhaps also in studies on their evolution and phylogeny.
Key words: metanotum, Aphidiinae, Braconidae, morphology, sculpture.

Introduction

Aphidiinae is a subfamily of Braconidae (Hymenoptera) specialized solitary aphid endoparasitoids. They play an important role in regulation of aphid population growth in natural ecosystems and agricultural landscapes. Some species are widely used as agents for aphid biocontrol (Davidian, 2007; Krasavina et al., 2008; Starý, 1970; Tobias, Kiriyak, 1986).

Identification of aphidiine wasps by morphological characters is occasionally problematic, due to variability of established diagnostic characters. However, their proper taxonomy is critical for solving problems of aphidiine biology, ecology and distribution of certain species as well as for practical purposes: e. g., mass production and effective releases of parasitoids in agroecosystems. Main taxonomic characters used in the aphidiine identification keys are forewing venation pattern, morphology and chaetotaxy of antennae, shape of petiole, shape of ovipositor sheaths, proportion and sculpture of propodeum, proportion and chaetotaxy of head, mesoscutum and rarely, legs (Davidian, 2007; Starý, 1970; Tobias, Kiriyak; 1986). Despite the number of established diagnostic characters, there is still a demand for new informative morphological characters for the species identification. In addition, new morphological characters may shed light on evolutionary and phylogenetic relationships within Aphidiinae (Quicke, 2015).

The aim of this study was a comparative review of aphidiine morphology, especially the body parts being traditionally neglected and rarely used in aphidiine taxonomy. The metanotum (the dorsal sclerite of metathorax, a part of mesosoma) was found to be one of such neglected body parts.

No studies had been conducted so far on the sculpture of aphidiine metanotum. Some illustrations of the metanotum were shown in the images of the propodeum (Kiriyak, 1977; Tobias, Kiriyak, 1986; Tomić et al., 2005; Tomanović et al., 2009), but not discussed. So, our study aimed, first of all, to constitute a preliminary background for further studies of metanotal variability among various genera and in less extent between species.

Material and methods

Specimens of 20 species of 13 genera were studied: *Adialytus ambiguus* (Haliday, 1834), *Adialytus salicaphis* (Fitch, 1855), *Aphidius ervi* Haliday, 1834, *Areopraon silvestre* (Starý, 1971), *Binodoxys acalephae* (Marshall, 1896), *Binodoxys angelicae* (Haliday, 1833), *Diaeretiella rapae* (M'Intosh, 1855), *Ephedrus persicae* Froggatt, 1904, *Ephedrus plagiator* (Nees, 1811), *Ephedrus validus* (Haliday, 1833), *Lipolexis gracilis* Förster, 1862, *Lysiphlebus confusus* Tremblay & Eady, 1978, *Lysiphlebus fabarum* (Marshall, 1896), *Pauesia abietis* (Marshall, 1896), *Praon volucre* (Marshall, 1896), *Protaphidius wissmannii* (Ratzeburg, 1848), *Toxares deltiger*

(Haliday, 1833), *Trioxys cirsii* (Curtis, 1831), *Trioxys curvicaudus* Mackauer, 1967, *Trioxys pallidus* (Haliday, 1833). The specimens were collected by sweeping in various regions of Ukraine or reared in laboratory from infested aphids collected in a field. Material was collected by author and colleagues from I. I. Schmalhausen Institute of Zoology, NAS of Ukraine (SIZK).

Morphological characters of the metanotum were examined on permanent Canada balsam microscopic slides under upright Olympus CX41 microscope with mounted camera Olympus C3040 (in SIZK), and also using the Scanning Electron JEOL JSM-6480LV Microscope (in the Royal Museum for Central Africa, Tervuren, Belgium), totally for 34 specimens. Some images were obtained at different focal distances and then stalked in CombineZP programme. All photos were processed in GIMP 2.8.8. The phylogeny follows Belshaw and Quicke (1997).

The morphological terminology follows the Hymenoptera Anatomy Ontology (HAO, Yoder et al., 2010). According to HAO, the metanotum comprises three main elements (fig. 1, *1*): 1) the metascutellum (MtSc), the more or less noticeable tubercle located posteromedially on the metanotum; 2) the metanotal troughs (MtT), slightly concave lateral parts of metanotum, usually smooth or slightly sculptured; 3) the metascutellar arms (MtA), transverse protuberances on posterior margin of metanotum, which are delimited medially by the metascutellum, and laterally by the supraalar area. Also, we distinguish the carinae (C), arising from the anterior border of the metascutellum, and areolae (A), the areas delimited by these carinae. To facilitate describing the structure of the metanotum in Aphidiinae, we propose the following measurements: the length of the metanotum (a), the length of the metascutellum (b), the width of the metascutellum (c), the length of the metascutellar arms (d) and the width of the metanotum (e) (fig. 1, *2*).

Results

Our study on the sculpture of the metanotum of aphidiines has revealed some remarkable differences between the studied taxa. These differences appear diagnostic for some genera or generic groups, such as tribes and subtribes (fig. 2). According to the level of the metanotum development, we recognize seven general types of metanotal sculpture: 1) one for Ephedrini (*Ephedrus, Toxares*) (fig. 2, *1, 2*); 2) one for Praini (*Praon, Areopraon*) (fig. 2. *3, 4*); four for Aphidiini: 3) for *Aphidius*, *Diaeretiella* (fig. 2, *5, 6*), 4) for *Adialytus, Lysiphlebus* (fig. 2, *7–10*), 5) for *Protaphidius* (fig. 2, *11*), 6) for *Pauesia* (fig. 2, *12*); 7) one for Trioxini (*Trioxys, Binodoxys, Lipolexis*) (fig. 2, *14–18*). The differences include: shape and proportions of the metanotum and its parts; presence, number and form of the carinae arising from the metascutellum; chaetotaxy of the metanotum.

Shape and proportions of the metanotum and its parts

The metanotum is generally uniform across the subfamily: more or less transverse, being much wider than long (fig. 2). Long enough metanotum of *P. abietis* is near 3 times as wide as long medially (fig. 1, *2*, e/a; fig. 2, *12*), while the same measurement in much shorter metanotum of *Binodoxys* spp. is 4.4–4.5 (fig. 2, *16, 17*).

In the center of metanotum, the metascutellum can occupy almost the entire length of the metanotum (*Adialytus, Diaeretiella, Lysiphlebus*) (fig. 2, *6–10*) or more often only a part of it (*Aphidius, Areopraon, Binodoxys, Ephedrus, Praon* etc.) (fig. 2, *1–5, 11–18*). The metascutellum more often has transverse shape (fig. 2, *1, 3, 4, 6–11, 13–18*). Among studied species, the metascutellum is longer then wide only in *T. deltiger, A. ervi, P. abietis* (fig. 2, *2, 5, 12*).

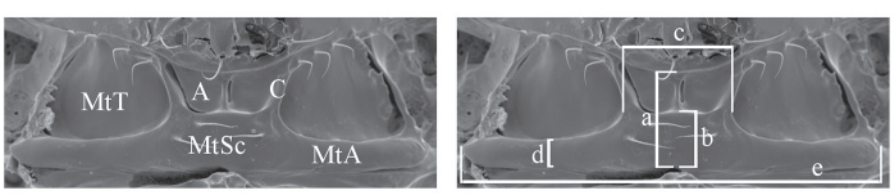

Fig. 1. Metanotum morphology and measurements (basing on Hymenoptera Anatomy Ontology project (Yoder et al., 2010): *1* — the main structures of the metanotum: MtSc — metascutellum, MtT — metanotal troughs, MtA — metascutellar arms, A — areola, C — carina; *2* — measurements of the metanotum: a — length of metanotum, b — length of metascutellum, c — width of metascutellum, d — length of metascutellar arms, e — width of metanotum.

The metascutellum is generally relatively longer than metascutellar arms if compared. The MtSc/MtA medium length (fig. 1, *2*, b/d) varies from 1.8 in *E. plagiator* (fig. 2, *1*) or *P. wissmannii* (fig. 2, *11*) up to 3.5–3.6 times in *T. deltiger* (fig. 2, *2*) and *L. gracilis (*fig. 2, *18*), to 4.5 times in *P. abietis* (fig. 2, *12*) and even nearly 5 or more times in *T. curvicaudus* (fig. 2, *14*). If the metascutellum occupies not an entire length of the metanotum, then some carinae usually arise from its anterior border.

Presence, number and form of the carinae arising from the metascutellum

The metanotum of the representatives of the genera *Ephedrus* and *Toxares* (Ephedrini) (fig. 2, *1, 2*) is characterized mainly by three carinae arising radially from the base of the metascutellum and delimiting two areolae in the proximal area. In *E. validus* and *E. persicae* we registered only two carinae, which is also confirmed by images of other authors (Kiriyak, 1977, Tomanović et al., 2009).

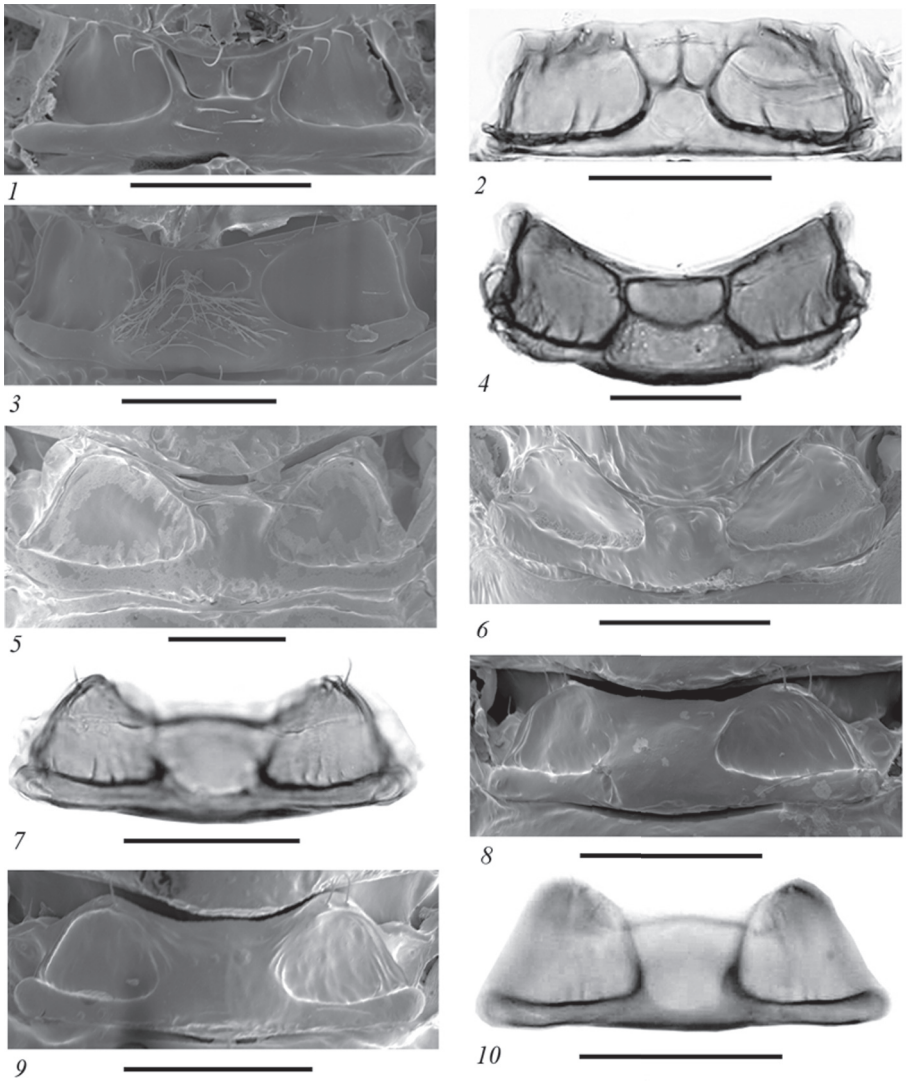

Fig. 2. Metanotum: *1 — Ephedrus plagiator, 2 — Toxares deltiger, 3 — Praon volucre, 4 — Areopraon silvestre, 5 — Aphidius ervi, 6 — Diaeretiella rapae, 7 — Lysiphlebus confusus, 8 — Lysiphlebus fabarum, 9 — Adialytus ambiguus, 10 — Adialytus salicaphis.* Scale bar 0.1 mm.

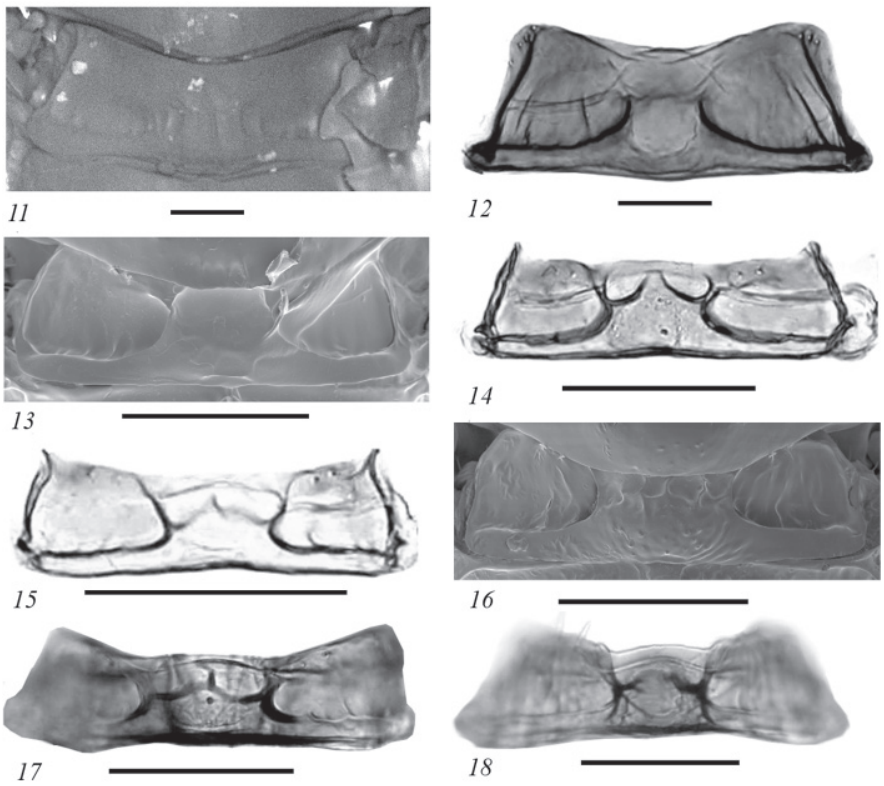

Fig. 2. Metanotum (continued): *11 — Protaphidius wissmannii, 12 — Pauesia abietis, 13 — Trioxys cirsii, 14 — Trioxys curvicaudus, 15 — Trioxys pallidus, 16 — Binodoxys acalephae, 17 — Binodoxys angelicae, 18 — Lipolexis gracilis*. Scale bar 0.1 mm.

In the genera *Praon* and *Areopraon* (Praini) (fig. 2, *3, 4*) the metanotum bears two carinae, running almost parallel from anteriolateral sides of metascutellum to the base of metanotum and delimiting one areola proximately to the metascutellum.

There are a few types of metanotum sculpture within Aphidiini. The representatives of *Aphidius* and *Diaeretiella* have no distinct areolae situated proximately to the metascutellum. The area above the metascutellum is slightly elevated upon the metanotal troughs (fig. 2, *5, 6*), and one or two tiny depressions are noticeable there. These depressions may happen to be the remains of the reduced areolae.

The metascutellum occupies almost the entire length of the metanotum and bears no carinae in the representatives of the genera *Adialytus* and *Lysiphlebus* (fig. 2, *7–10*). However, the metascutellum of *P. wissmannii* (fig. 2, *11*) is almost as long (fig.1, *2*, b) as the metascutellar arms (fig.1, *2*, d), and its proximal side is bearing 6–7 tiny carinae. The metascutellum of *P. abietis* occupies nearly a half of the metanotal length, although it is not bearing any clearly visible carinae (fig. 2, *12*).

The metascutellum of Trioxini, for instance, the species of *Trioxys* (fig. 2, *13–15*), is nearly rounded and is bearing three carinae arising radially from its anterior border. Sometimes, the median carina is somewhat reduced (fig. 2, *15*). In *Lipolexis* (fig. 2, *18*), the metascutellum is also somewhat rounded, and is bearing two short carinae. In the *Binodoxys*, the metascutellum is transversely elongated, and is bearing three or more carinae (fig. 2, *16–17*).

Chaetotaxy of the metanotum

There are also some differences in the chaetotaxy of the metanotum of Aphidiinae. The metascutellum of Ephedrini is bearing a few setae (fig. 2, *1*), or is nearly bare in Aphidiini

and Trioxini (fig. 2, *5–10*). Otherwise, in Praini it is generally densely pubescent (fig. 2, *3*). Also, there are a few setae mostly on anterior (Ephedrini, Praini, Trioxyni) (fig. 2, *1–4, 14–15, 17–18*) or anterolateral (Aphidiini) (fig. 2, *7–9, 12*) margins of metanotum.

Discussion

As it was stated above, the metanotum attracted far less attention by the aphidiine experts, if compared with other body parts of these insects. The lack of such attention to this sclerite can be explained by some difficulties in its observation: small body size of aphidiine wasps and their metanotum as well; partial coverage by mesonotum; traditional point-mounting of these insects on the side of their thorax that can reduce metanotum visibility (hiding by hind wing or entomological glue). We tried to constitute a background for further studies of metanotal morphology. Herein, we proposed some preliminary types of the menatonal structure of aphidiine wasps and measurements to facilitate its describing.

On our opinion, found differences in metanotal structure in most cases reflect established phylogenetic relationships among aphidiines on tribes and subtribes level. Ephedrini (*Ephedrus, Toxares*) as the basal tribe has most complete sculpture of the metanotum including usually three carinae and two areolae. The most noticeable difference between *Ephedrus* and *Toxares* is proportion of the metanotum parts, especially the metascutellum (fig. 1, *2,* a/b, b/c, b/d, a/e, fig. 2, *1, 2*). Praini (*Praon, Areopraon*) has also unified sculpture with two carinae and one areola, and very similar proportions of metanotum parts (fig. 2, *3, 4*). Densely pubescent metascutellum seems to be diagnostic for Praini as well. Among tribe Aphidiini we recognize four types of metanotum sculpture, which mostly correlate with subtribe division (fig. 2, *5–12*). Similar characters are clearly visible within subtribes Aphidiina (*Aphidius, Diaeretiella*) (fig. 2, *5, 6*) and Lysiphlebina (*Lysiphlebus, Adialytus*) (fig. 2, *7–10*). However, studied specimens of Protaphidina (*Protaphidius, Pauesia*) (fig. 2, *11–12*) show significant difference in metanotal sculpture that can support the idea of more independent evolutionary position of *Protaphidius* (Starý, 1970, Sanchis et al., 2000) or its connections with Trioxini (Davidian, 2010). Representatives of Trioxini (*Trioxys, Binodoxys, Lipolexis*) (fig. 2, *13–18*) have clearly visible common characters: rounded more or less transverse metascutellum, distinctly longer than metascutellar arms, with three (rarely two) or usually more carinae, arising radially from anterior border of the metascutellum. Thereafter some subtypes of metanotal sculpture may be distinguished within proposed types, on the basis of more detailed study of proportions of metanotal parts and chaetotaxy of this sclerite.

This first preliminary analysis of the morphological variability of the metanotum in Aphidiinae, is expected to be expanded further when more taxa from different regions are studied. There is a need for further development of proposed measurements system for the aphidiine metanotum. Among difficulties, we can mention measurement of the length of the metanotum (fig. 1, *2,* a), because this sclerite is often covered by mesoscutellum, and measurement of the length of the metascutellum (fig.1, *2,* b), because in some genera it has no distinct margin. We think that chaetotaxy of the metanotum may be useful as an additional diagnostic character, particularly setation of the metascutellum. Study of setae localization on anterior and anterolateral margin of metanotum may reveal some results in future. Research that is more detailed is needed to check variability of newly observed morphological characters among genera and within aphidiine genera at species level, as a next important step of this research.

My sincere thanks are due to A. G. Kotenko and A. V. Gumovsky (SIZK) for consultations, and to all colleagues, who collected and granted the material for this study. Special thanks are due to A. V. Gumovsky for SEM imaging and to E. S. Kobzev for extensive support of this research. The author is very grateful to the two reviewers for their evaluation of this work and for proposed corrections to improve the paper.

References

Belshaw, R., Quicke, D. L. J. 1997. A molecular phylogeny of the Aphidiinae (Hymenoptera: Braconidae). *Molecular phylogenetics and evolution*, **7** (3), 281–293. http://www.sciencedirect.com/science/article/pii/S1055790396904005

Davidian, E. M. 2007. Fam. Aphidiidae. *In*: Leley, A. S., ed. *Keys to the insects of Russian Far East,* **IV** (5). Dal'nauka, Vladivostok, 192–254 [In Russian], http://www.zin.ru/labs/insects/hymenopt/projects/key-fe/pdf-4-5/0192-0254.pdf

Davidian, E. M. 2010. On the system of parasitoids of the family Aphidiidae (Hymenoptera). *Proceedings of the Russian Entomological Society.* St. Petersburg, **81** (2), 16–20 [In Russian], https://www.zin.ru/societies/res/rus/periodicals/horae/80-4.pdf

Gärdenfors, U. 1986. Taxonomic and biological revision of Palearctic Ephedrus Haliday (Hymenoptera: Braconidae, Aphidiinae). *Entomologica Scandinavica*. Supplement, **7**, 13–21.

Kiriyak, I. G. 1977. Species of genus *Ephedrus* (Hymenoptera, Aphidiidae) in USSR. *Izvestiya AN Moldavskoy SSR.* Seria biol. i chim. nauk, **5**, 48–64 [In Russian].

Krasavina, L. P., Grigorieva, E. E., Anisimov, A. I. 2008. Parasitic aphidiines in orangery and green-houses with complex composition of crops. *Zashchita i karantin rasteniy,* **1**, 28–29 [In Russian].

Quicke, D. L. J., 2015. Phylogeny and systematics of the Braconidae. *In*: Quicke, D. L. J., *The Braconid and Ichneumonid Parasitoid Wasps: Biology, Systematics, Evolution and Ecology*. John Wiley & Sons, Ltd, 212–224.

Tobias, V. I., Kiriyak, I. G. 1986. Fam. Aphidiidae. *In* Medvedev, G. S., ed. *Keys to the insects of the European part of the USSR*, **3** (5). Nauka, Leningrad, 232–283 [In Russian].

Tomanović, Ž., Petrović, A., Starý, P., Kavallieratos, N. G., Žikić, V., Rakhshani, E. 2009. Ephedrus Haliday (Hymenoptera: Braconidae: Aphidiinae) in Serbia and Montenegro: tritrophic associations and key. *Acta entomologica serbica*, **14** (1), 39–53.

Tomić, M., Tomanović, Ž., Kavallieratos, N. G., Starý, P., Athanassiou, C. G., Tomić, V., Lučić, L. 2005. Morphological variability of several biotypes of *Ephedrus plagiator* (Nees, 1811) (Hymenoptera: Braconidae: Aphidiinae) and description of a new species. *Zoologischer Anzeiger,* **244**, 153–162.

Sanchis, A., Latorre, A., Gonzalez-Candelas, F., Michelena, J. M. 2000. An 18S rDNA-based molecular phylogeny of Aphidiinae (Hymenoptera: Braconidae). *Mol. Phylogenet. Evol.,* **2**, 180–194

Starý, P., 1970. *Biology of aphid parasites (Hymenoptera: Aphidiidae) with respect to integrated control.* Schimitschek, E. ed., W. Junk, The Hague, 1–643 (Ser. entomologica; Vol. 6).

Yoder, M. J., Mikó, I., Seltmann, K. C., Bertone, M. A., Deans, A. R. 2010. A Gross Anatomy Ontology for Hymenoptera. *PLoS ONE,* **5 (**12). e15991. doi:10.1371/journal.pone.0015991.

Received 11 November 2016
Accepted 5 December 2016