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SENSORY ORGANS OF MESOSTIGMATIC MITES (ACARINA, MESOSTIGMATA) DWELLING IN BODY CAVITIES OF MAMMALS AND BIRDS

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ABSTRACT

Receptors on palps and fore tarsi of *Pneumonyssus simicola* Banks, 1901, *Raillietia auris* and *Raillietia* sp. (Trouessart, 1902) (Mesostigmata: Halarachnidae), dwelling in lungs and ears of mammals, and of *Sternostomoides turdi* (Zumpt et Till, 1905) and *Tinaminyssus sp.* (Mesostigmata: Rhinonyssidae), dwelling in nasal cavities of birds, were examined in a scanning electron microscope. Morphological changes of sense organs, associated with adaptation to parasitizing in body cavities, are discussed.

Key words: mites, sensory organs, *Pneumonyssus, Raillietia, Sternostomoides, Tinaminyssus, Uropoda*, scanning electron microscopy

ОРГАНЫ ЧУВСТВ МЕЗОСТИГМАТИЧЕСКИХ КЛЕЩЕЙ (ACARINA, MESOSTIGMATA), ПОЛОСТНЫХ ПАРАЗИТОВ МЛЕКОПИТАЮЩИХ И ПТИЦ

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РЕЗЮМЕ

Рецепторные органы, расположенные на пальпах и передних тарзальных члениках ног были исследованы методами растровой электронной микроскопии у клещей *Pneumonyssus simicola* Banks, 1901, *Raillietia auris* (Trouessart, 1902) и *Raillietia* sp. (Mesostigmata: Halarachnidae), обитателей легких и носовой полости млекопитающих, а также у *Sternostomoides turdi* (Zumpt et Till, 1905) и *Tinaminyssus* sp. (Mesostigmata: Rhinonyssidae), обитателей носовой полости птиц. Обсуждаются обнаруженные морфологические преобразования органов чувств, связанные с адаптацией к обитанию в полостях тела млекопитающих и птиц.

Ключевые слова: клещи, органы чувств, *Pneumonyssus, Raillietia, Sternostomoides Tinaminyssus, Uropoda*, сканирующая электронная микроскопия

INTRODUCTION

Sensory organs form the interface between the environment and the behavior of an organism. All the information on the state of the environment and on its changes, necessary for the survival, reproduction, etc. reaches central nervous system via this interface. Many parasitic arthropods spend a part of their active life outside the host; in these animals, sensory system plays the crucial role in host finding; in parasites constantly dwelling on hosts or inside them, sensory system helps them to find the sexual partner and also provides the survival of parasites (Leonovich 2005). Thus, sensory organs play an important role in mite

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evolution; besides, any data on the structure and functioning of these organs can help us to elaborate new methods of mite control by breaking the important interface between the parasitic organism and its environment.

Mesostigmatic mites, the largest group of mites in the order Parasitiformes, comprise mites with different mode of feeding, including free-living predators, scavengers, and facultative and obligatory parasites. Many parasitic species are economically important, e.g., the chicken mite *Dermanyssus gallinae* (De Geer, 1778) (Mesostigmata: Dermanyssidae), a dangerous pest breeding in poultry farms (Chauve 1998). Many mesostigmatic mites transmit dangerous human and animal diseases. Some mites (representatives of the families Laelapidae, Halarachnidae, and Rhinonyssidae), are endoparasites dwelling in body cavities of mammals and birds (external auditory canal, nasal cavities, lungs, bird air sacks, etc.). Ecological specialization of mesostigmatic mites, including facultative and obligatory parasites, is to a significant degree determined by the structure and function of their sensory organs (Leonovich 1989, 2008; Alberti and Coons 1999).

Sensory organs of mesostigmatic mites were examined in some representatives of parasitic and free-living species (Leonovich and Troitsky 1981; Jaggers op Akkerhius et al. 1985; Leonovich 1989, 1998, 2006, 2007; Alberti and Coons 1999; Leonovich and Stanyukovich 2002; Cruz et al. 2005, etc.).

At the same time, the data on sense organs of endoparasitic mites remain fragmentary, being limited to a single representative of the genus *Halarachna* (Mesostigmata: Halarachnidae), dwelling in nasal cavities of *Halichoerus grypus* (Carnivora: Phocidae) (Pugh 1996) and some representatives of the family Rhinonyssidae (Mesostigmata), dwelling in nasal cavities of birds, including *Ptilonyssus motacillae* Fain, 1956*, Rhinonyssus rhinoletrum* (Trouessart, 1895)*, Rh. subrhinolethrium* Butenko, 1970 (Leonovich and Stanyukovich 2002) and *Sternostoma tracheocolum* Lawrence, 1948 (Leonovich 2008).

In the present work, the authors had examined sense organs in mesostigmatan mites of three species dwelling in ears and lungs of mammals, and also in two species from nasal cavities of birds with a scanning electron microscope and tried to analyze the data obtained in the present study together with the literary data.

MATERIAL AND METHODS

The following endoparasitic species of mesostigmatan mites were examined: *Pneumonyssus simicola* Banks, 1901, *Raillietia auris* (Trouessart, 1902), and *Raillietia* sp. (Halarachnidae), *Sternostomoides turdi* (Zumpt et Till, 1905) and *Tinaminyssus* sp. (Rhinonyssidae).

Pieces of lungs of the rhesus monkey *Macaca mulatta* (Primates: Cercopithecidae) that died in the St. Petersburg Zoo (the cause of death is unknown) were fixed in 70% alcohol and then carefully dissected in laboratory with a razor blade. Mites were removed from lungs and used for determination and morphological studies of sense organs. One of photographs of this species, given in the present publication (Fig. 5), was published in the work of Leonovich (2010), concerning to attachment places of the mite in monkey lungs, but the structure of sense organs was not even mentioned in the cited work. A total of 11 adult mites were examined.

Specimens of *Raillietia auris* from *Bos primigenius* (Artiodactyla: Bovidae) were taken from the collection of the Zoological Institute, Russian Academy of Sciences (ZIN RAS) and were available only as samples mounted in Foure-Berlese medium on glass slides. The medium was dissolved in a warm (40 °C) distilled water for two days; after that, specimens were placed into a 70% alcohol solution and treated as all the other material fixed in alcohol. We examined three females. A single specimen in a separate slide possessed different structure of its tarsal organ in comparison with other *R. auris* specimens examined; as far as any designation of the host was absent in the label, and the specimen was dissected (so its determination became impossible) we designate it as *Raillietia* sp. Probably, this specimen belongs to the closely related species *Raillietia caprae* Quintero, Bassols et Acevedo, 1980 described from nasal cavities of *Capra aegagrus* (Artiodactyla: Bovidae) (Quintero et al. 1980).

Rhinonyssid mites were collected from nasal cavities of birds crushed by cars during seasonal migrations. *Sternostomoides turdi* were collected from *Turdus philomelos* (Passeriformes: Turdidae). A total of 4 specimens were examined. Mites *Tinaminyssus sp.* were collected from *Fringilla coelebs* (Passeriformes: Fringillidae) and were determined only as the genus (2 specimens).

For the study of mites in a scanning electron microscope (SEM), they were fixed in 70% alcohol, dehydrated in a series of alcohols, cleaned in an ultrasonic cleaner D-300 (Russia), placed into acetone, and dried in a Hitachi HSP-2 critical point dryer with liquid nitrogen as the drying agent. Dry specimens were mounted on alumina or brass stubs, coated with platinum in an Eiko-5 ion coater (Japan), and examined in a Hitachi S570 scanning electron microscope. Images were recorded in digital form.

For the comparison, similar sensory structures were also examined in several free-living and exoparasitic species. For this purpose, we selected the following species: the predatory (scavenger?) mite *Euryparasitus emarginatus* (Koch, 1839) (Mesostigmata: Ologamasidae), common in litter, bird nests, and occasionally found on birds (7 specimens) and the mite *Uropoda repleta* (Berlese, 1904) (Mesostigmata: Uropodidae) (5 specimens). Mites of the family Uropodidae have been found in large numbers in poultry litter. Adult and premature stages may attach themselves to bird feathers or skin as means of transportation. They are known to be strictly fungus feeders and therefore pose no threat to birds (Rives and Barnes 1988). The free-living mite *Parasitus kempersi* Oudemans, 1902 (Mesostigmata: Parasitidae) was examined by one of the authors in an earlier publication (Leonovich 2008). In the present work, we give an unpublished scanning micrograph of mouthparts and palps of this species.

As far as no traces of sexual dimorphism were ever found in the structure of palpal and tarsal sense organs of mesostigmatic mites (Leonovich 2005), we give descriptions of these organs in adult mites without mentioning their sexual belonging.

The material is illustrated by electron micrographs obtained in SEM (Figs 1–17) and by schematic drawings (Figs 18, 19).

RESULTS

Sensory system of mesostigmatic mites comprises sensory organs informing mites on the state of their inner medium, on the state of the environment, and on the presence and location of food and sexual partner; the latter receptors are concentrated in palps and fore tarsi (Leonovich 2005) (Figs 1, 2).

The palpal organ is situated on the tip of each palp tarsus (Figs 1, 3, 4, 18). In *Uropoda repleta*, it comprises 15 sensilla of 3 structural and functional types (Figs 4, 5); this set is typical of the majority of mesostigmatic mites, excluding endoparasitic species (Leonovich 1998). The first type (designated by Arabic numbers in Fig. 4) is represented by 5 SW-UP (single-wall upper-pore) sensilla. The detailed morphological and physiological classification of tick and mite sensilla is given in the monograph by Leonovich (2005). According to our data, obtained during the study of the palpal organ in *D. gallinae*, each sensillum of this type is innervated by 6–7 bipolar sensory neurons; 4–5 of them form sensory cilia, penetrating into the cavity of the hollow basiconic hair and running to its tip, bearing a single apical pore. Two sensory neurons of each sensillum do not penetrate into the cavity, but terminate at the socket, forming tubular bodies. So, SW-UP palpal sensilla are combined chemo-mechanosensitive organs (Leonovich 2007).

The second type (designated by Roman numbers in Fig. 4) distinctly differs from the first one in the shape and in the inner morphology (these sensilla are double-walled, possessing two inner longitudinal cavities in the cuticular hair. One cavity contains non-branched sensory cilia and the second one, processes of enveloping cells) (Leonovich 1998). In ticks (Ixodoidea), this difference reflects their different functional and behavioral role – perception of sex pheromones or detection of a feeding site; in ticks, the latter function is performed by double-walled upper-pore sensilla (Leonovich and Dusbabek 1991). In a scanning electron microscope, differences between the inner structure of two types of sensilla can be easily revealed in broken hairs (Figs 12, 13). All other palpal sensilla (Fig. 3) are pure mechanoreceptors, similar to those forming the chaetom of mesostigmatic mites. Two long mechanoreceptive sensilla (shown opposite to the claw in Fig. 18a) are situated outside the palpal organ itself (comprising only 9 chemoreceptor sensilla). However, in all the parasitic species examined by us, they are shifted toward the top of the ultimate palpal segment and form a kind of a common sensory field with chemoreceptors of the organ itself.

Such structure of the palpal organ (the presence of 5 + 4 chemo-mechano-sensitive sensilla is typical of the majority of mesostigmatic mites examined so far (Jaggers op Akkerhius 1985; Leonovich 1998).

In previously examined species of mesostigmatic mites, the tarsal sensory organ comprised 20–30 sensilla, forming a compact group on the foreleg tarsus (Fig. 2) (Leonovich and Troitskii 1981; Jaggers op Akkerhius 1985; Moraza 2005; Leonovich
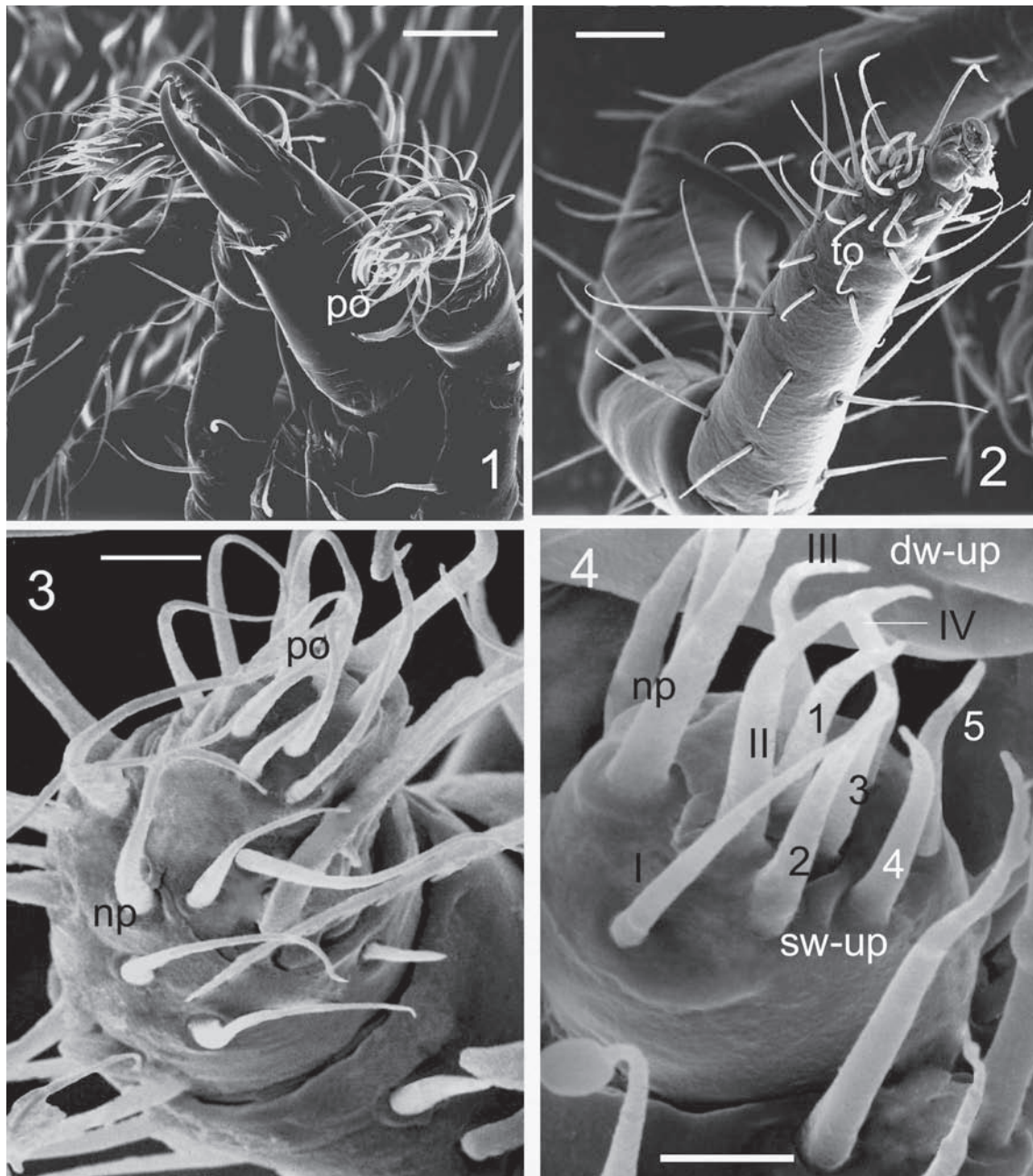
Figs 1–4. Main organs of distant perception in some free-living mesostigmatic mites. 1 – mouthparts and palps of *Parasitus kempersi* (Parasitidae); 2 – tarsal sensory complex of *Euryparasitus emarginatus* (Laelapidae); 3–4 – palpal organ of *Uropoda repleta* (Uropodidae).

Abbreviations: po – palpal organ; to – tarsal organ; sensilla: dw-up – double-wall upper-pore sensilla (sensilla are numbered in Roman numerals); np – no-pore sensilla; sw-up – single-wall wall-pore sensilla (numbered in Arabic numerals). *Scales* (all measurements are given in µm): 1 – 20; 2 – 10; 3 – 8; 4 – 4.
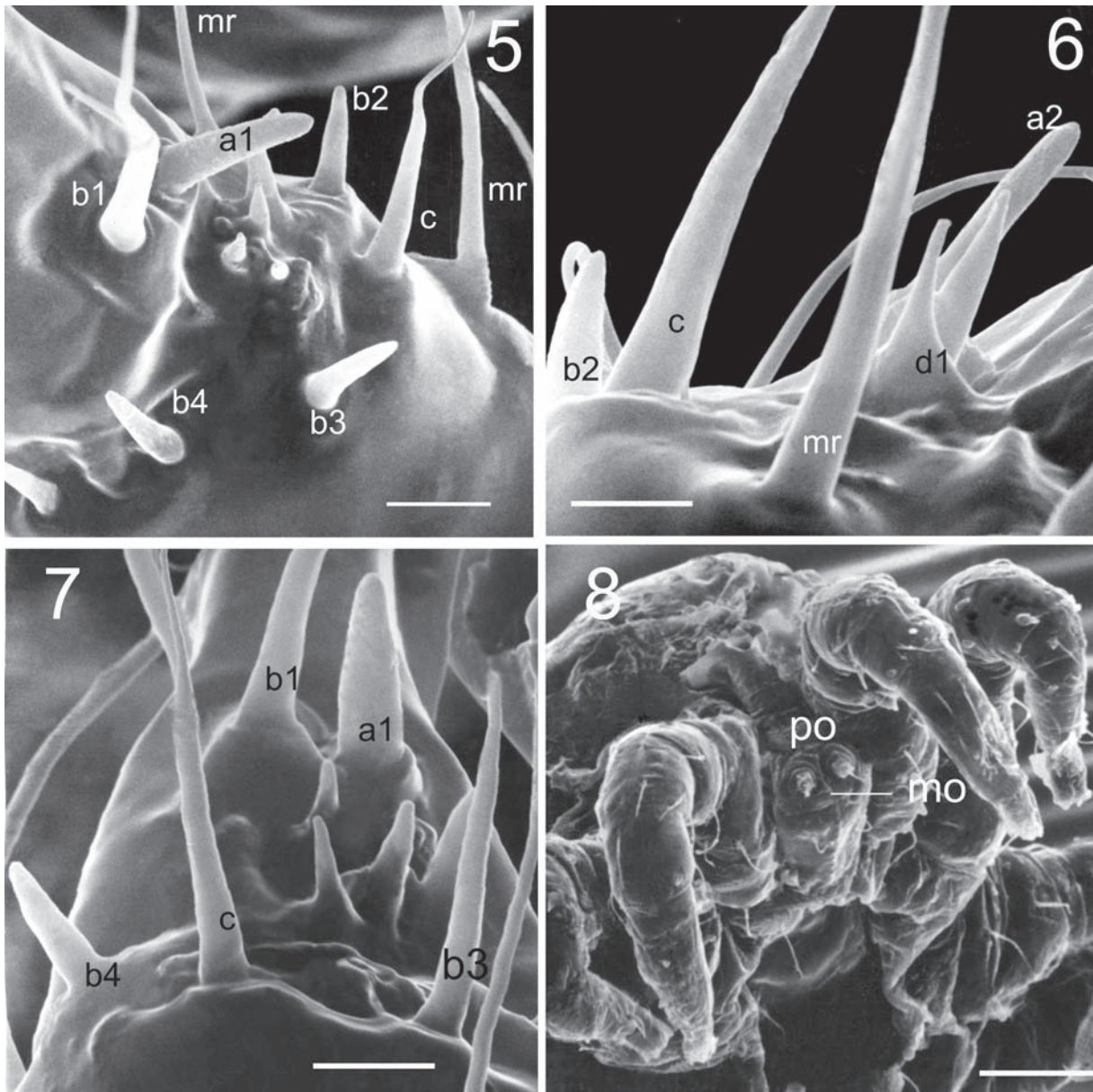
Figs 5–8. *Pneumonyssus simicola* (Halarachnidae). 5 – general view of the tarsal organ demonstrating the arrangement of sensilla; 6–7 – sensillar types; 8 – anterior part of the body with mouth orifice (mo) and very small palps with palpal organs (po).

Abbreviations: a – sw-wp olfactory sensilla; b – dw-wp sensilla of type 1; c – dw-wp sensillum of type 2; d – np-sw sensillum; mr – sw-up contact chemo-mechanoreceptive sensilla. *Scales* (all measurements are given in μm): 5 – 5; 6 – 2.5; 7 – 3; 8 – 40.
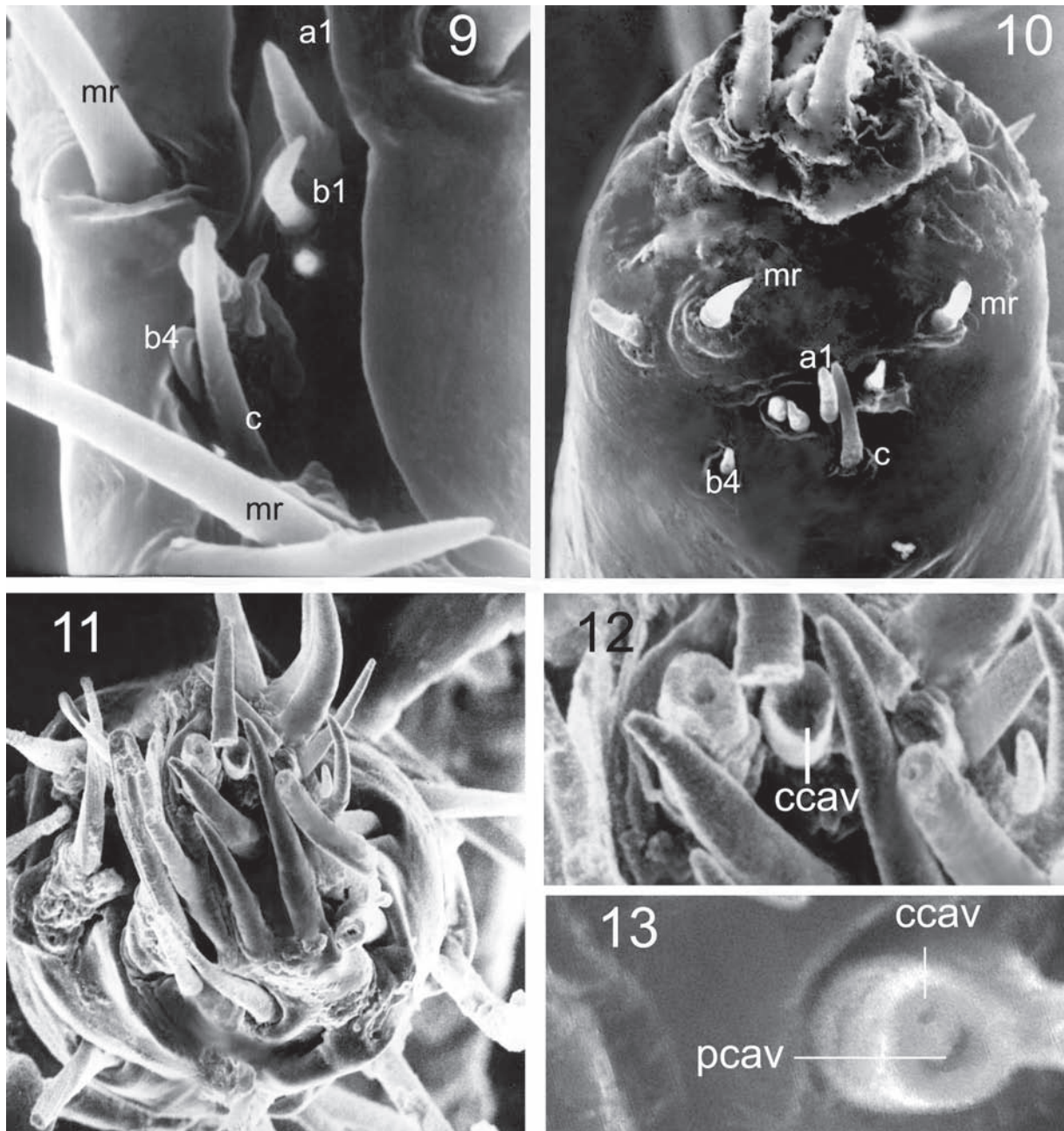
Figs 9–13. *Raillietia* (Dermanyssidae). 5 – sensilla in the central part of the tarsal organ in *R. auris*; 6 – tarsal organ of *Raillietia sp*.; 7 – palpal organ of *R. auris*; 8–9 – types of contact chemosensory sensilla.

Abbreviations: ccav – central cavity; pcav – peripheral cavity; other abbreviations as in Figs 1–8.
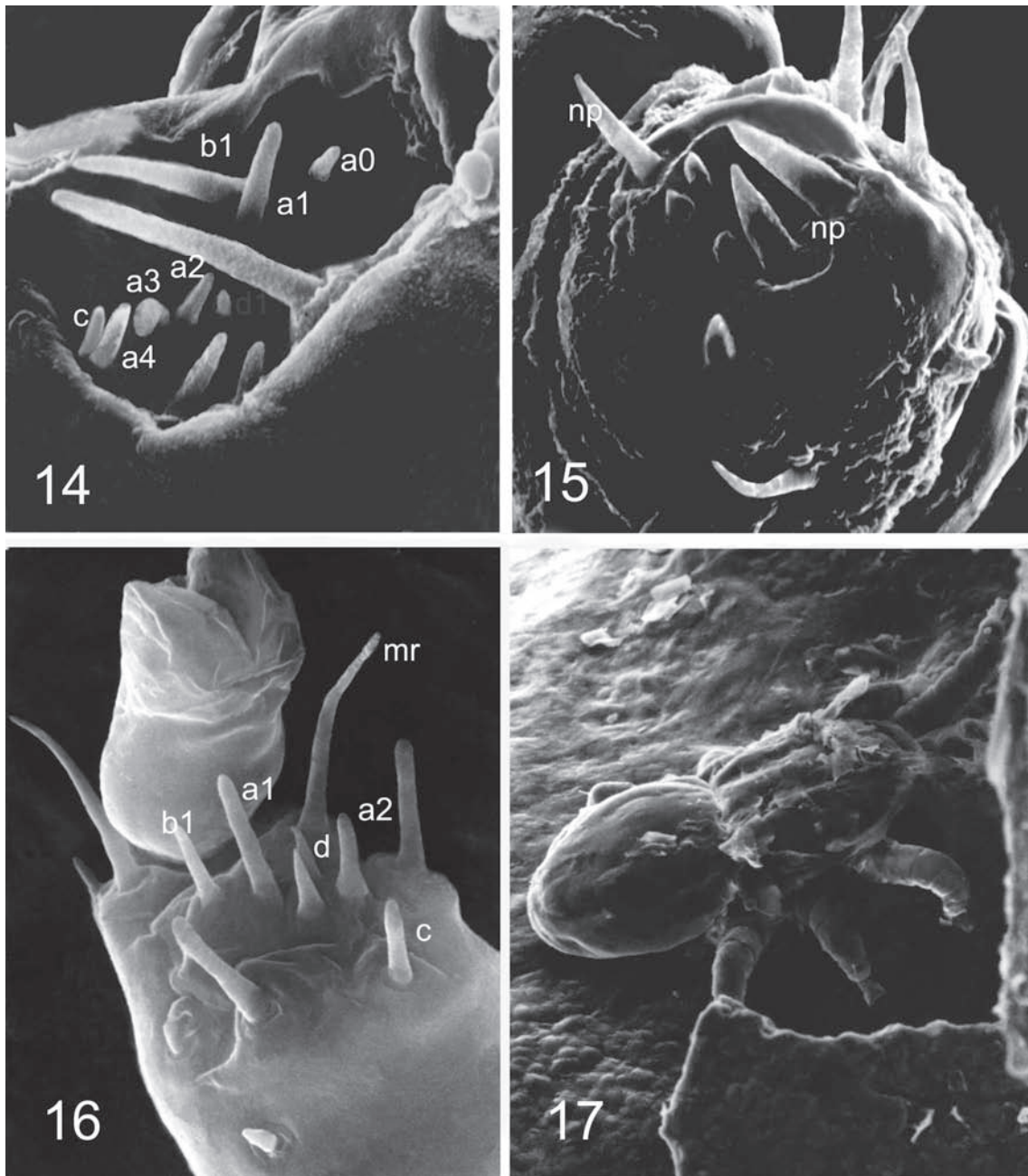
Figs 14–17. Sense organs in representatives of the family Rhinonyssidae. *Sternostomoides turdi*: 14 – central part of the tarsal complex; 15 – palpal organ; *Neonyssus* sp.: 16 – tarsal complex; 17 – mite attached to nasal epidermis.
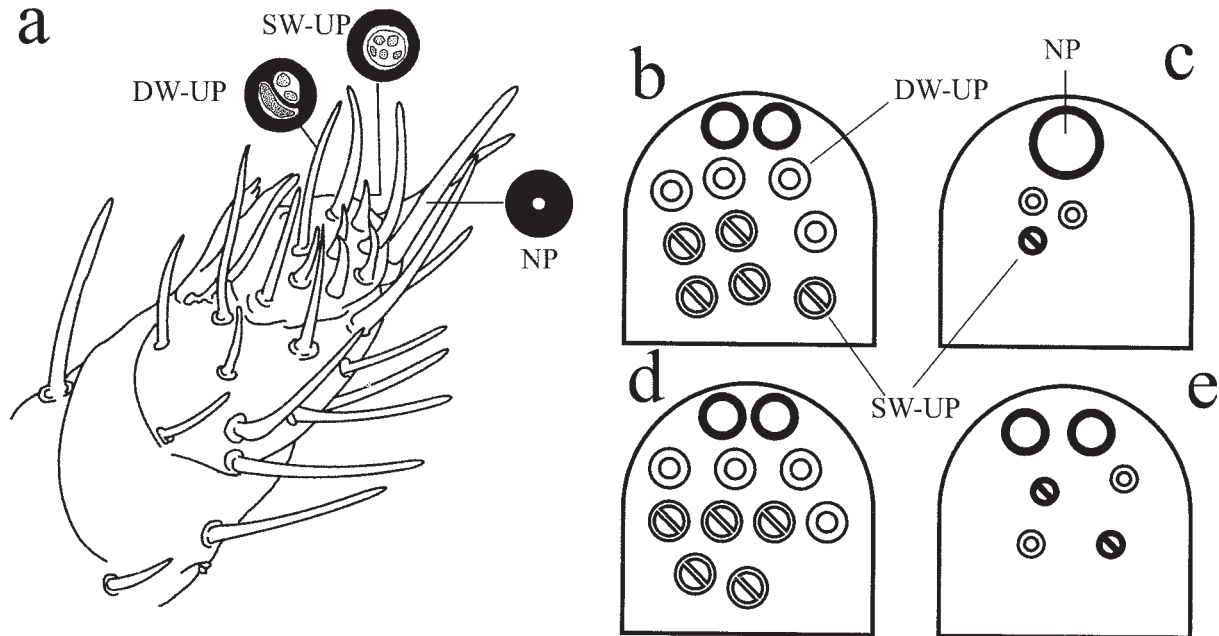
Abbreviations: as in Figs 1–13.

Fig. 18 (a–e). Scheme showing the number and arrangement of the main sensillar types on palps of some mesostigmatic mites. a – *Dermanyssus gallinae* (figure from Leonovich 2005). Four longer hairs with blunt tips belong to DW-UP (double-wall upper pore) type of chemo-mechanosensitive sensilla; five smaller hairs with pointed tips, to SW-UP (single-wall upper-pore) type; two long solid hairs, to NP (no pore) tactile mechanoreceptive sensilla. All the other sensilla situated lower to the tip of the palp (the palpal organ), separated by a groove, also belong to the NP type; b–e: the number and arrangement of sensilla in the palpal organ: b – *Uropoda repleta*; c – *Pneumonyssus simicola*; d – *Raillietia auris*; e – *Sternostomides turdi*.

2006, etc). This complex was examined in detail in *Hirstionyssus criceti* (Sulzer, 1774) (Mesostigmata: Hirstionyssidae) and *Dermanyssus gallinae* (Leonovich 2006). It included sensilla of six morphological types: basiconic sensilla with hollow thin-walled hairs and numerous wall pores (olfactory receptors); single-walled wall-pore thick-walled sensilla with pores situated in longitudinal grooves (olfactory receptors of another type); dw-up (double-walled wall-pore sensilla with well-developed sockets and upper pores (contact chemo-mechanoreceptors); two types of double-walled wall-pore sensilla, possessing a "spinning-wheel" structure in crosscuts (probable chemo-thermo-receptors), and sensilla without pores, looking like cones with fine apical processes (probable cold and humidity receptors) (Figs 19a, 19b) (Leonovich 2005, 2006).

In the present study, it was impossible to examine the internal morphology of sensilla by means of transmitting electron microscopy. This method needs obtaining of alive mites for fixation; we had in our possession only mites fixed in alcohol or even

mites embedded in slides. Unfortunately, it is hardly possible to provide perfect quality of such material. Nevertheless, in many cases it was possible to determine the type of certain sensilla on the basis of their external morphology; on the basis of examination of broken hairs; and, occasionally, on the basis of the location of sensilla. Determination of the type of each hair included its examination in SEM from different angles and revealing of its shape, presence of pores (e.g., visible in hairs a1 in Fig. 5 and a2 in Fig. 6) or grooves (e.g., visible in hair c in Fig. 6); in some preparations, some hairs are distinctly identified, and others are not; in other preparations, it could be other hairs. So, our identification of hair types is based on the study of as many samples as possible and on the application of a principle of combination of characters: if any certain combination better corresponds to some type that to all the others, we attribute the given sensillum as belonging just to this type.

The tarsal sensory organ of the monkey lung mite is characterized by a smaller number of sensilla in comparison with free-living and ectoparasitic mites
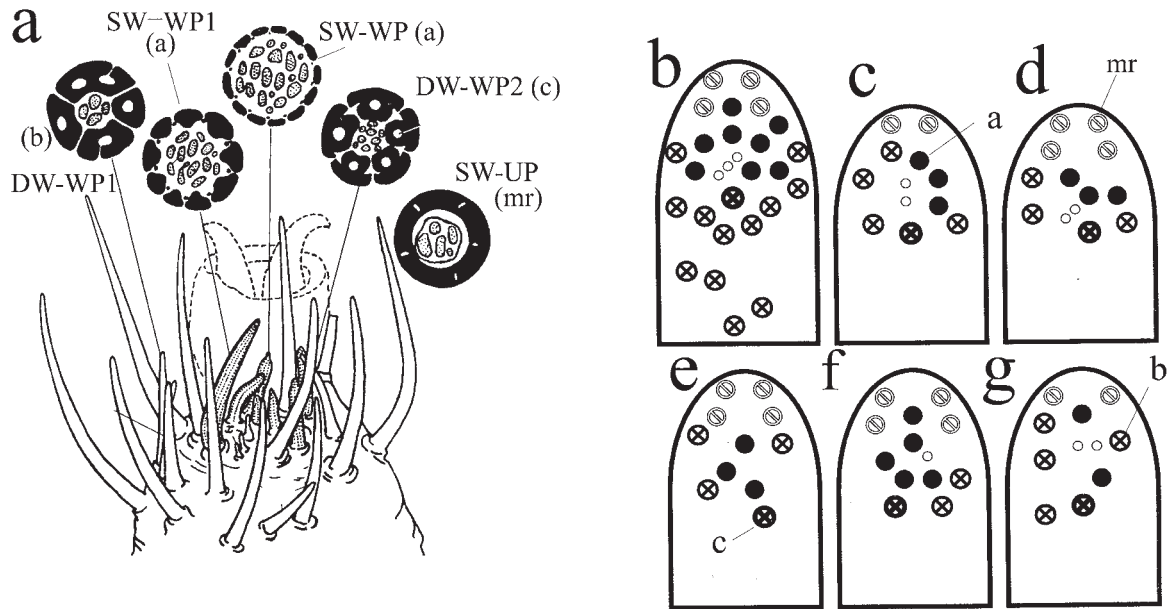
Fig. 19 (a–g). Scheme showing the number and arrangement of the main sesillar types in the tarsal organ of some mesostigmatic mites. a, b – *Histionyssus criceti* (figures from Leonovich 2005, simplified). Single-walled wall-pore olfactory sensilla (thin-walled and thick-walled) can hardly be distinguished among reduced sensilla of the tarsal organ in mites dwelling in body cavities; therefore, they are designated as one type (type a in Figs 5–7, 9, 10, 14, 16). Comparison of Figs 19a and 19b demonstrates the how bases of sensilla are shown in schematic form); c – *Pneumonyssus simicola*; d – *Raillietia auris*; e – *Rh.* sp.; f – *Sternostomides turdi*; g – *Tinaminyssus* sp. Different types of circles demonstrate only the arrangement of sensilla, but not their size.

(Figs 2, 5–7, 19c). Two basiconic single-walled wall-pore sensilla are developed very strongly (especially the most distant sensillum designated as a1 in Fig. 5). Double-walled wall-pore sensilla (type b in Figs 5–7) are less developed, except for the sensillum situated closely to a1 (b1 in Figs 5, 7). Sensillum c (Figs 5–7) is also strongly developed. In examined mite species (Leonovich 2005, 2006), the sensillum of this appearance located in the same place belonged to the dw-wp type with the specific spinning-wheel channel system. All the other sensilla of the central group are typical of free-living mites examined (Figs 5–7). The arrangement of sensilla is shown in Fig. 19c).

Pneumonyssus simicola possesses very small palps (Fig. 8). Its palpal organ is strongly reduced, whereas a single mechanosensory sensillum, in other mites located proximally to the sensory field in the palp apex, is overdeveloped. The structure of this organ was described in our previous publication (Leonovich 1998). It is shown schematically in Fig. 18b.

In *Raillietia auris*, the central part of the tarsal sensory complex contains all the sensillar types mentioned above (Fig. 9). The arrangement of sensilla and their set is shown in Fig. 19d. A single specimen in a separate slide, designated by us as *Raillietia* sp., differed in the arrangement of sensilla and absence of short hairs of the central group (Figs 10, 19e).

At the same time, the palpal organ in these mites is developed very strongly (Figs 11, 19d). All the sensilla of the organ are long and solid, and look rather similar, in spite of the fact that they are represented by two main types, mentioned above. Both types can be clearly distinguished by the inner structure of their cuticular parts, visible in broken hairs (Figs 11–13). Even in specimens with broken external parts of sensilla (Fig. 11) it is clearly seen that the set of palpal sensilla corresponds to the general scheme typical of the majority of mesostigmatic mites (Figs 3, 4, 18d).

In *Sternostomoides turdi*, olfactory sensilla of both types are easily distinguished by the presence of large pores (the latter can be easily seen even in sensilla, where in other mite species pores are hidden in longitudinal grooves) (Fig. 14). The arrangement

of sensillar types can be seen in Fig. 19f). The presence of a relatively large number of all the types of sensilla, typical of the tarsal complex, possessing, however, shortened cuticular parts attracts attention (Figs 14, 19 f).

The palpal organ in these mites is characterized by strongly reduced sensilla of all the types; among these reduced sensilla, thickened mechanosensitive hairs are developed best of all (Figs 15, 18e).

In *Tinaminyssus* sp., olfactory sensilla in the tarsal complex are reduced in number (Fig. 16). Shorter length is typical even of tactile sensilla near the claw and around the complex. It is interesting, that these mites are strongly attached to the nasal epithelium with their mouthparts, being, probably, immobile during the majority of their adult life (Fig. 17). Their most distal olfactory sensillum (a1 in Fig. 16) is developed nearly to the same extent as tactile hairs. The arrangement of sensilla in the complex is shown in Fig. 19g).

DISCUSSION

In comparison with free-living and ectoparasitic species, mites dwelling in body cavities of mammals and birds possess rather strongly modified main distant sensory organs.

In the species examined, palpal and tarsal sensory organs are rather strongly reduced in relation to the number of sensilla and the size of the latter (Figs 6, 13, 14). In some mite species, these processes are characteristic of both main distal sensory organs (palpal and tarsal complexes); in other species, only of one of these organs. These changes, in our opinion, can be explained by differences in mite behavior.

The monkey lung mite *Pneumonyssus simicola* is a lung dweller of *Macaca mulatta*. All the life stages of *P. simicola* dwell in lungs of a single animal, and infestation of other animals is performed during close contacts, mainly between a female and a baby monkey (Fremming et al. 1957). Noteworthy, palps of these mites are very small. According to our assumption, these mites feed on the mucus, but not on the host blood (Leonovich 2010). At the same time, some basiconic olfactory sensilla in the tarsal complex of the monkey lung mite (especially sensillum a1) (Figs 5–7) are strongly developed.

The life cycle of ear mites of the genus *Raillietia* consists of the egg, larva, proto- and deutonymph and adult. The proto- and deutonymph are free living,

non-feeding instars. The teneral adult is the transfer stage, and adults never leave their host (da Costa et al. 1992). Thus, adult females of *R. auris* need to find their hosts, or, at least, places of possible contact with the latter, and, at the same time, after finding the host, they need to stay in its ear channels for the rest of their life. It is interesting that the structure of the tarsal complex differs in both species of *Raillietia* examined, concerning mainly protective structures (solid tactile hairs surrounding the central part of the complex) whereas the structure of the palpal organ is rather similar.

Among all the mites examined, the structure of the palpal sensory complex in *R. auris,* parasites of the meatus (ear channel) of ungulates (Artiodactyla), is most closely related to that typical of free-living and ectoparasitic mites (Figs 3, 7) (Leonovich 2006, 2007, 2008). Probably, well-developed sense palpal organs are necessary for host-finding by adult females that emerged in pastures. Sensilla in the tarsal complex are reduced in size; at the same time, the most distal porous olfactory sensillum in this species (a1 in Fig. 9) is well-developed. The same situation is observed in *Halarachne halichoeri* Allman, 1847 (Pugh 1996).

Reduction of the palpal organ occurs mainly in species spending all their life cycle in body cavities of the host. This observation, made earlier by the authors in nasal mites of the genus *Ptilonyssus* (Leonovich and Stanyukovich 2002), is confirmed in the present work.

It is commonly accepted that the reduction in the number of sensilla of the same type (oligomerization) and total reduction processes are typical events accompanying adaptation to endoparasitism. These processes were also revealed by us in the present study. At the same time, we demonstrated that adaptation to endoparasitism frequently leads to retaining and even to the stronger development of certain sensilla (e.g., olfactory porous sensillum designated as a1); in many cases, they are developed to a greater extent than in free-living mites (compare Figs 2 and 5, 9, 14). We can assume that these sensilla play an important role not in host-finding, but rather in the sexual behavior of mites. Unfortunately, our knowledge on this behavior in endoparasitic mesostigmatic mites is extremely insufficient. We can only mention that in the sister group of ixodid ticks, where sexual behavior and physiology of sensilla are studied rather completely, strong development of the most distal olfactory porous sensilla within the Haller's organ

is determined by their crucial role in the sexual behavior (Leonovich 2004). Our assumption is supported by ethological experiments that had evidently demonstrated that males of the predatory gamasid mite *Macrocheles muscadomesticae* (Scopoli, 1772) (Mesostigmata: Macrochelidae) lost their ability to respond to female pheromone and to find females after amputation of their fore tarsi (Yasui 1992).

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