A SEM study of the reindeer sinus worm (*Linguatula arctica*)

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Abstract: Pentastomids are a group of peculiar parasitic arthropods, often referred to as tongue worms due to the resemblance of some species to a tongue. *Linguatula arctica* is the sinus worm of the reindeer (*Rangifer tarandus*), being the only pentastomid to have a direct life cycle and an ungulate as a definite host. Here, the surface structures and internal anatomy of adult *L. arctica* are described as seen by scanning electron microscope (SEM). Sinus worms were collected in the winter 1991-92 in Finnish Lapland. Paranasal cavities of about 80 reindeer were examined and 30 sinus worms were found. The sinus worms had typical *Linguatula* sp. morphology, being paddle-shaped, transparent, pale yellow, dorsoventrally flattened and pseudosegmented with a long tapering end. Present at the anteroventral part of the cephalothorax was an oral opening with a large, conspicuous, head-like papillar structure. Bilaterally, on both sides of this opening, was a pair of strong curved hooks. The cephalothorax and abdomen had a segmented appearance, as they showed distinct annulation. There was a small cup-shaped sensory organ present at the lateral margin on each annula. The posterior edge of each annula was roughened by tiny spines projecting backwards. Throughout the cuticular surface, small, circular depressions that represented the apical portion of chloride cells. The genital opening of the male was located medioventrally between the tips of the posterior pair of hooks, and that of the female posteroventrally and subterminally. In both sexes, the genital opening was bilaterally flanked by papillar (in males) or leaf-like (in females) structures. One copulating couple was present, with the male attached to the posteroventral part of the female with its anteroventral hooks and papillae.

Several structures typical of arthropods and other pentastomids were identified. Because SEM allows only surfaces to be studied, the morphology and especially the sense organs of *L. arctica* remain obscure. Transmission electron microscopy should be employed to gain more information about this fascinating creature and its origin.

Key words: Arthropoda, Crustacea, morphology, Pentastomida, tongue worm.

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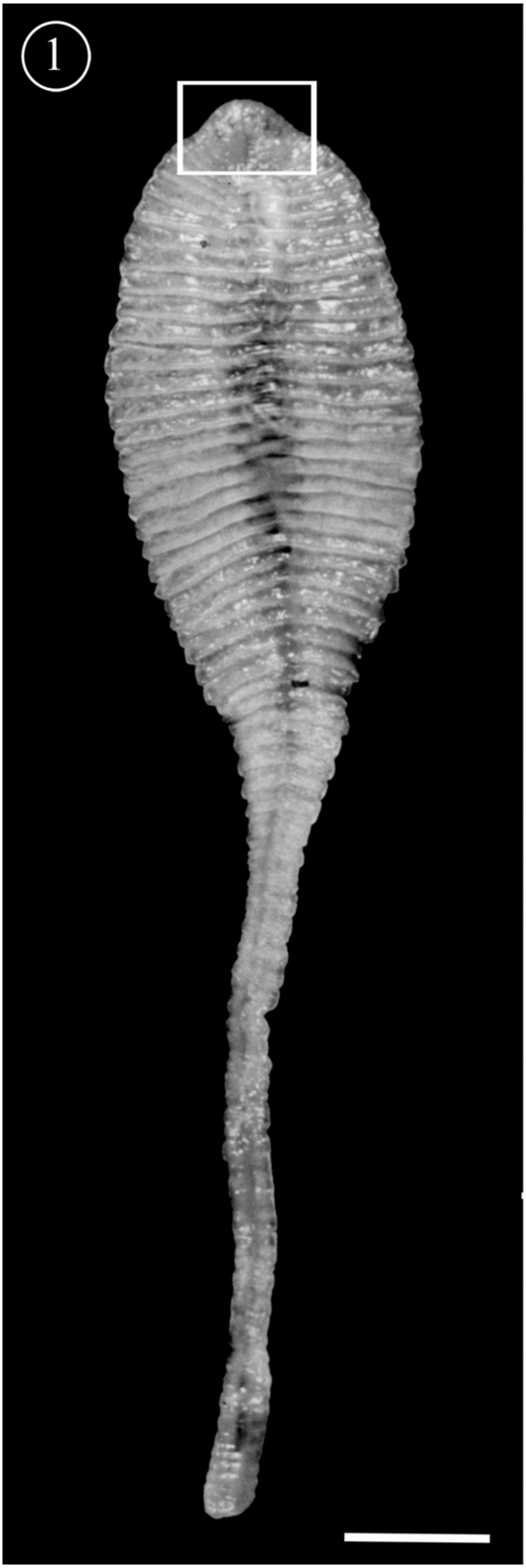
Introduction

Pentastomids are a group of peculiar parasitic invertebrates, often referred to as tongue worms due to the resemblance of some species to a tongue. There are about 130 species of pentastomids. The majority are obligatory parasites of the respiratory passages of reptiles in tropical regions. However, the subclass also includes some parasites of the upper respiratory tract of birds and mammals (Riley, 1986). Despite their flat and worm-like appearance, pentastomids belong to the phylum Arthropoda, finding their current placement in the phylum quite recently. The fossils from the Upper Cambrian and Lower Ordovicium identified as pentastomids suggest that they had branched very early from other arthropods, and their parasitic lifestyle was established long before the terrestrialization of the ancestors of their present hosts (Walossek & Muller, 1994). It is perhaps because of this early branching that pentastomids still have morphological similarities to other groups of invertebrates, thus resulting in their phylogeny being controversial. The first attempt to classify pentastomids as crustaceans was by Wingstrand (1972), who showed that the structure of the spermatozoa of pentastomids is iden-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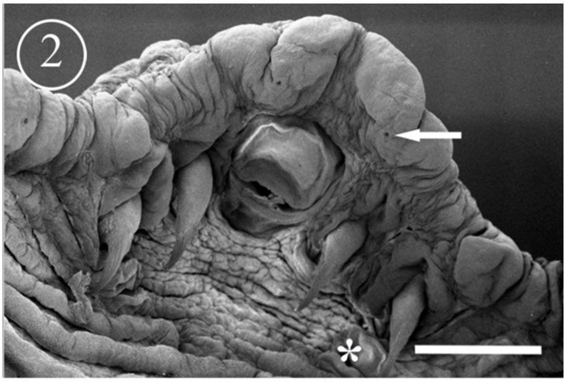
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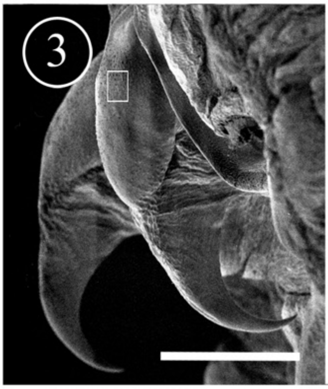
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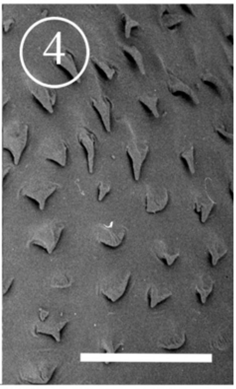
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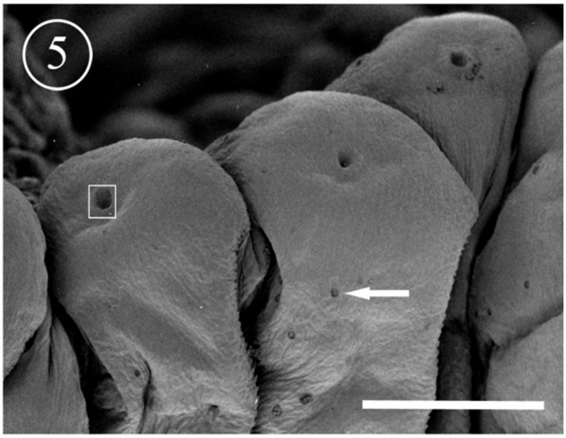
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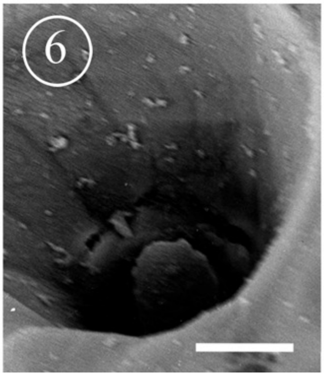
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Fig. 1. Female *Linguatula arctica,* the sinus worm of the reindeer. An enlargement of the area in the rectangle is depicted in Fig. 2. The elongated mass of eggs in uterus is seen as the dark median region. Scale bar = 1 cm.

Fig. 2. Anteroventral view of a female *L. arctica* showing the hooks and oral opening with distinct papillae. One pair of papillae (asterisks) is present in the vicinity of the posterior pair of hooks. Note the opening of the frontal gland (arrow). Scale bar = 500 µm.

Fig. 3. Close-up of the curved, sharp, retractable hooks of the female *L. arctica.* An enlargement of the area in the rectangle is depicted in Fig. 4. Scale bar = 200 µm.

Fig. 4. Magnification of the calotte-like structure covering the proximal part of the hook with fine triangular cuticular spines. Scale bar = 20 µm.

Fig. 5. Lateral view of the cephalothoracic annuli of the female *L. arctica*, showing cup-shaped lateral sense organs (one in rectangle) and the apical parts of chloride cells seen as round, scattered hollows (arrow). An enlargement of the area in the rectangle is depicted in Fig. 6. Scale bar = 200 µm.

Fig. 6. Close-up of the cup-shaped lateral sense organ. Scale bar = 5 µm.

Fig. 7. High magnification of the apical part of the chloride cell. Scale bar = 5 µm.

tical to the corresponding structures of another group of living organisms, namely the branchiuran fish lice, belonging to parasitic crustaceans. There are also similarities to the reproductive behaviour of the fish louse, as sperm are usually transferred to and stored in the spermatheca of the female (Fryer, 1982). Recently, techniques based on molecular biology have been employed to elucidate the taxonomic position of pentastomids. Lavrov *et al.* (2004) determined the complete sequence of the mitochondrial DNA of a pentastomid (*Armillifer armillatus*) and compared it with complete or nearly complete mitochondrial DNA sequences of four different groups of Crustacea. Their findings indicated "unambiquously that pentastomids are a group of modified crustaceans." To summarize, pentastomids are currently classified as arthropods, more precisely to the class Maxillopoda within the subphylum Crustacea (see e.g. Fauna Europaea at www.faunaeur.org). However, the dissimilar morphology of pentastomids to other maxillopods raises some doubts about the justification for the current classification, and many textbooks continue to regard pentastomids as a phylum of its own.

Pentastomids are divided into two orders: Cephalobaenida and Porocephalida. In the order Porocephalida, the genus *Linguatula* (Frölich 1789) presently includes six species, five of which as adults parasitize the respiratory tract of carnivorous mammals, with mammals serving as intermediate hosts (Swetman, 1971), and the sixth, *Linguatula arctica*, being the sinus worm of the reindeer (*Rangifer tarandus*) (Haugerud & Nilssen, 1986). Reindeer sinus worm differs from other linguatulids not only by having an ungulate as a definite host but also by possessing a direct life cycle (Haugerud & Nilssen, 1985; 1990), although the possibility of an invertebrate intermediated host cannot be totally excluded (Riley *et al.*, 1987). The best known member of the *Linguatula* family is *L. serrata,* a cosmopolitan parasite living in the sinuses of canids. Thus, unsurprisingly, all of the early reports of the sinus worm (*L. arctica*) in reindeer were recorded as *L. serrata*. Murie (1926) described *L. serrata* in caribou in Alaska in 1926, and Voblikova (1961) reported a high prevalence (31%, *n*=130) of *L. serrata* in reindeer in Taimyr, Russia. According to Skjenneberg (1965), *L. serrata* was common in Norwegian reindeer, confirmed by extensive population studies *of L. arctica* in semi-domesticated and wild reindeer in Norway (Haugerud, 1986; 1988). In Swedish reindeer, *L. serrata* was first reported by Christensson *et al.* (1974) and later by Rehbinder and Nordkvist (1982), who autopsied 33 reindeer, 24% of which were positive for *L. serrata*. In Finland the earliest record of *L. serrata* in reindeer is from 1963 (Collections of University of Oulu, Itämies, pers. comm. 2006). Nikander & Rahko (1989), who studied sinusitis in reindeer in Finnish Lapland, found 5 out of 25 randomly sampled animals to be infected by *L. arctica*.

The morphology and life cycle of the reindeer sinus worm were described by Riley *et al.* (1987), and their morphological description was based on findings with light microscopy (LM). Scanning electron microscopy (SEM) is a valuable tool when supplementary information to morphological observations with LM is needed. In the present study, the surface structures and internal anatomy of adult *L. arctica* are described as seen by SEM. The functional morphology of these structures is also discussed.

Material and methods

Sinus worms were collected in a three months period from December 1991 to February 1992 during the slaughter in Savukoski in the eastern part of Finnish Lapland. The muzzles of reindeer were opened by sawing them transversally behind the back teeth, and the paranasal cavities were carefully examined. About 80 reindeer, mainly calves, were inspected and 30 sinus worms were found. Worms were immediately fixed in a mixture of formaldehyde (10%), paraformaldehyde (2%) and glutaraldehyde (0.1%). The dehydration of the samples was carried out through a series of increasing concentrations of ethanol (50%, 60%, 70%, 80%, 90%, 96% and 100%). The alcohol series was followed by drying using a critical point dryer, mounting on brass stubs and coating with gold (JOEL JFC-sputter). The internal organs were brought out by breaking some dried worms before mounting and coating with gold. The specimens were examined under a scanning electron microscope (JEOL JMS-820) operating at 3-6 kV at the Electron Microscopy Unit of the Institute of Biotechnology, University of Helsinki.

Results

In infected reindeer, one or two sinus worms were usually present unilaterally in the palatinal sinuses. The sinus worms had typical *Linguatula* sp. morphology, being paddle-shaped, transparent, pale yellow, dorsoventrally flattened and pseudosegmented with a long tapering end.

The biggest females were about 10 cm long. Their body consisted of a 2-cm-wide cephalothorax and a thin abdomen which occupied over half of the length of the worm. The uterus could be seen as an orange coloured elongated mass of eggs (shown dark in the figure) in the middle of the cephalothorax (Fig. 1). Present at the anteroventral part of the cephalothorax was an oral opening with large, conspicuous, head-like papillar structure (Fig. 2). Around this opening, the cuticle formed a well-defined circular ridge. Bilaterally, on both sides of the oral opening, was a pair of strong curved hooks with sharp tips (Figs. 2, 3, 8). The proximal third of the dorsal side of the hooks was covered by a calotte-like chitinous layer with fine triangular spines (Figs. 3, 4). The cephalothorax and abdomen had a segmented appearance, as they showed distinct annulation. There was a small cup-shaped cavity present at the lateral margin on each annula (Fig. 5). Furthermore, at the bottom of the cavity, a globular projection was observed (Fig. 6). Throughout the cuticular surface were scattered, small, circular depressions with a porous, grooved or granular surface (Figs. 5, 7, 14). Subterminally, bilaterally and ventrolaterally, both the males (Fig. 8) and the females had a cluster of receptors and glands consisting of an opening, a row of 3 or 4 setae and conical papillar projections (Fig. 9). The genital opening of the male was located medioventrally between the tips of the posterior pair of hooks (Fig. 10). The genital opening was bilaterally flanked by broad-based papillary structures (Figs. 10, 12). The posterior margin of the oral opening was bumpy, consisting of multiple, papillar elevations that created a surface resembling cobble-stones (Fig. 13). Clot of blood cells were occasionally observed in the oral opening (Fig. 11). Each thoracic annula overlapped slightly with the adjacent annula, and the posterior edge was roughened by tiny spines projecting backwards (Fig. 14).

Fig. 8. Anteroventral view of the hooks and oral papillae of the male *L. arctica*. Scale bar = 500 µm.

Fig. 9. Magnification of the structures located subterminally and anteroventrally (the area is indicated with an arrow in Fig. 2). The conspicuous hole is seemingly an opening of the frontal gland. The three delicate setae and conical papillae were considered as sensory organs. Scale bar = 300 µm.

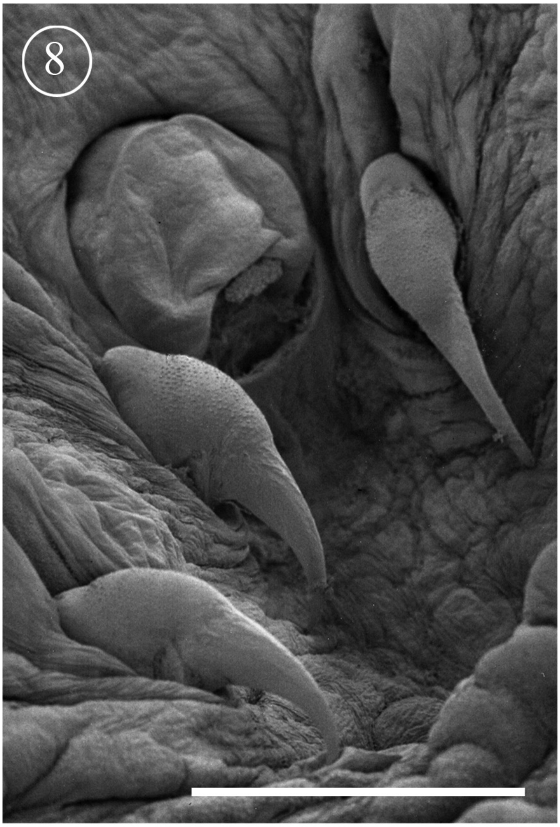
Fig. 10. The genital opening (arrow) of the male *L. arctica* is located between the posterior pair of hooks. This opening is bilaterally flanked with papillar structures (rectangle). An enlargement of the area in the rectangle is depicted in Fig. 12. Scale bar = 500 µm.

Fig. 11. A clot consisting of blood cells and fibrin is seen in the oral opening of the sinus worm. Scale bar = 500 µm.

Fig. 12. Magnification of the lateral papilla situated in the vicinity of the genital opening of the male sinus worm. Scale bar = 50 µm.

Fig. 13. Posterior margin of the oral opening of *L. arctica* showing cobble-stone-like cuticular ornamentation. Scale bar = 10 µm.

Fig. 14. Posterior edge of one cephalothoracic annula showing cuticular spines projecting backwards. Two chloride cells can also be seen. Scale bar = 100 µm.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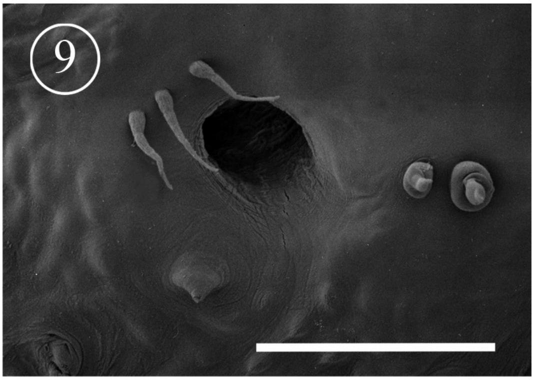
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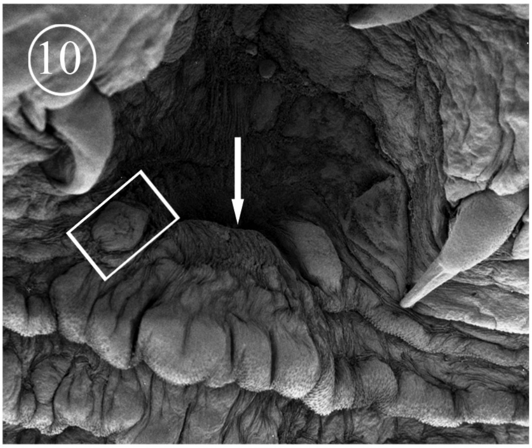
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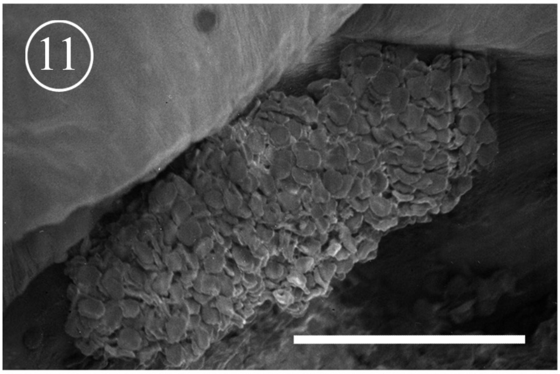
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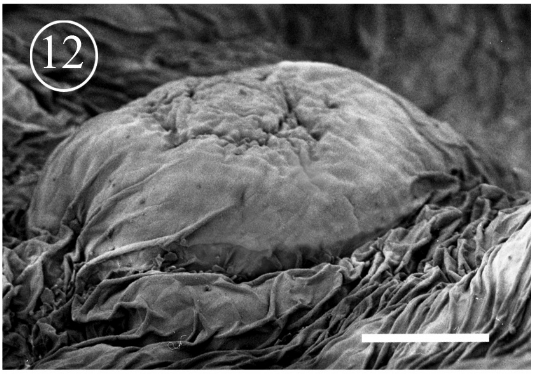
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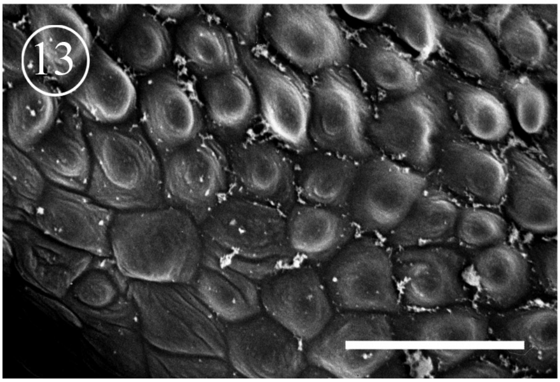
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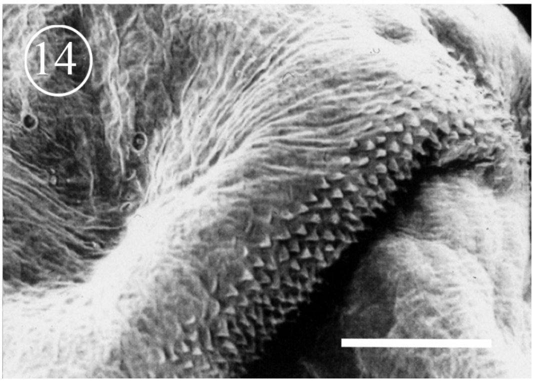
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The reproductive and digestive systems were the dominant structures seen in SEM from dissected females. The ovary resembled a cluster of grapes (Fig. 15), and the paired seminal receptacles were packed with long slender spermatozoa (Fig. 16). The uterus in the adult female was a long, winding tube filled with spherical eggs (Fig. 17) and ending in a posteriorly, subterminally located gonopore. The genital opening was bilaterally flanked by leaf-like extensions (vaginal lips) protruding from the gonopore (Fig. 20). The intestine was a straight tube (Fig. 18) extending from the mouth to the anus (Figs. 19, 20). Among the sinus worms studied, one copulating couple was present, with the male attached to the posteroventral end of a small-sized female with its anteroventral hooks and papillae.

Discussion

Since the SEM technique is performed on dried specimens, shrinkage should always be taken into account when these findings are interpreted. The measurements and scale bars presented in this paper should therefore be considered merely indicative.

The difficulties in classifying pentastomids as arthropods are obvious, as they lack the most characteristic morphological feature of arthropods, namely, jointed appendages. Nevertheless, they possess several morphological structures and biological features that are typical of arthropods. These features have been reviewed by, for instance, Riley (1986) and Haugerud (1989). The most important features are chitinous cuticle, muscle striation and its attachment to cuticle, sensory sensillae, lack of free cilia, shape and structure of spermatozoa, dorsal organ and blastoderm cuticle of the egg, paired embryonic appendages, certain parts of the reproductive system and the developmental ecdysis.

The scanning electron microscope is an excellent tool for investigating surface structures. The entire body surface of *L. arctica* is covered by a chitinous sheath with annuli and spines, resembling insect maggots. Present at the anterior end of sinus worms are five distinct protuberances, inspiring the Latin name Pentastomida ("five mouths"). In reality, only one of the protuberances is connected to the mouth, the remaining four being heavily sclerotized holdfast hooks. The size and shape of the hooks have been used to identify pentastomids (Riley 1986). However, these measurements must be interpreted cautiously, as hooks increase in size at each molt (Fain, 1964). The hooks have been shown to be of the arthropodal type. They are considered as remnants of limbs that have during evolution been reduced to hooks more useful to the current niche (Riley, 1986; Walossek & Muller, 1994). As evidence for such an evolution, in the Cephalobaenida pentastomids, the hooks are located at the tip of leg-like protuberances (Bush *et al.*, 2001). The hooks seen in Porocephala pentastomids arise from the socket provided by the body. What is left of the ancient limbs is two podomeres and a joint membrane between them (Walossek & Muller, 1994). In *L. arctica,* a calotte-like structure dorsally covers the proximal part of all hooks. The surface of this thickened portion has cuticle-like configuration with spines and is regarded as a remnant of the joint membrane.

Fig. 15. The ovary resembles a cluster of grapes. Scale bar = 500 µm.

Fig. 16. Tightly packed bundles of spermatozoa stored in the seminal receptacle of the female sinus worm. Scale bar = 10 µm.

Fig. 17. Dissected uterus showing the spherical eggs of the female *L. arctica*. Scale bar = 100 µm.

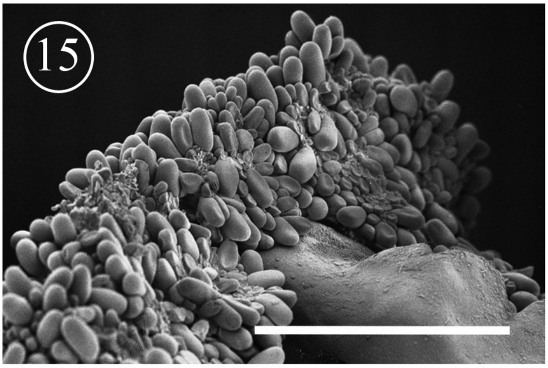
Fig. 18. Cross-section of the intestine of the female *L. arctica*. Scale bar = 50 µm.

Fig. 19. Posterior end of the male *L. arctica* with a vertical anal opening. Scale bar = 500 µm.

Fig. 20. Posterior end of the female *L. arctica* with a subterminal, slightly dorsally located anus (arrow) and a ventrally located gonopore (asterisk). Note the leaf-like protrusions of the genital opening. Scale bar = 500 µm.

Fig. 21. Copulating couple of *Linguatula arctica*. Note that at the time of mating the female sinus worm is about the same size as the male, being 3–4 cm in length, while the adult female typically exceeds 10 cm. Scale bar = 1 mm.

The mouth was situated between the proximal parts of the inner hooks on the anteroventral side of the sinus worm. The posterior margin of the oral opening was one of the sites where the generally smooth cuticle of *L. arctica* was uneven. The lumpy, cobble-stone-like cuticular surface probably forms a functional counterpart for oral papilla during feeding. Relatively little is known about the feeding habits of *L. arctica*, but pentastomids typi-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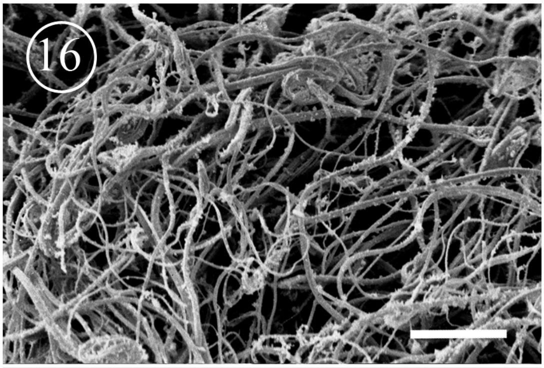
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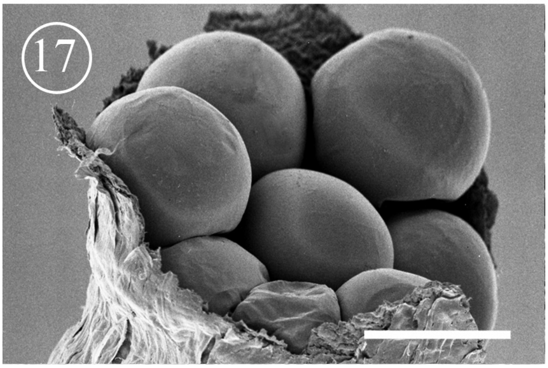
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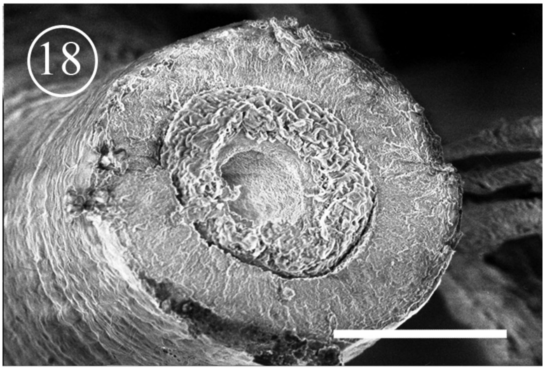
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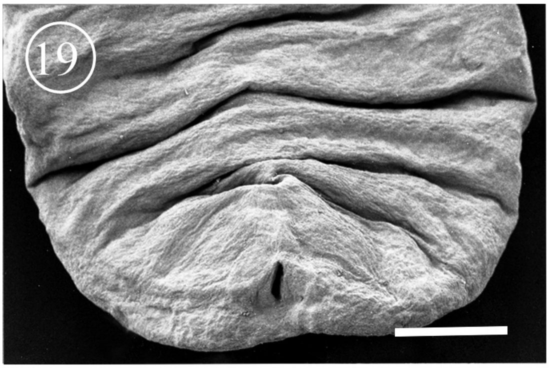
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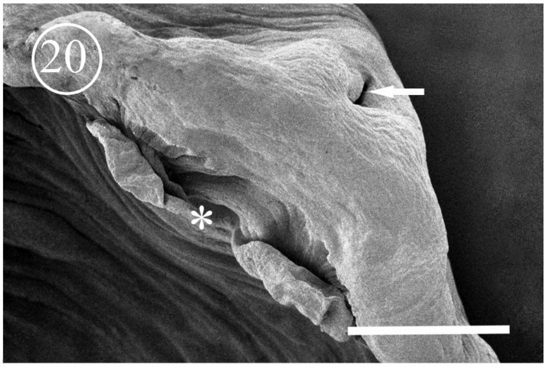
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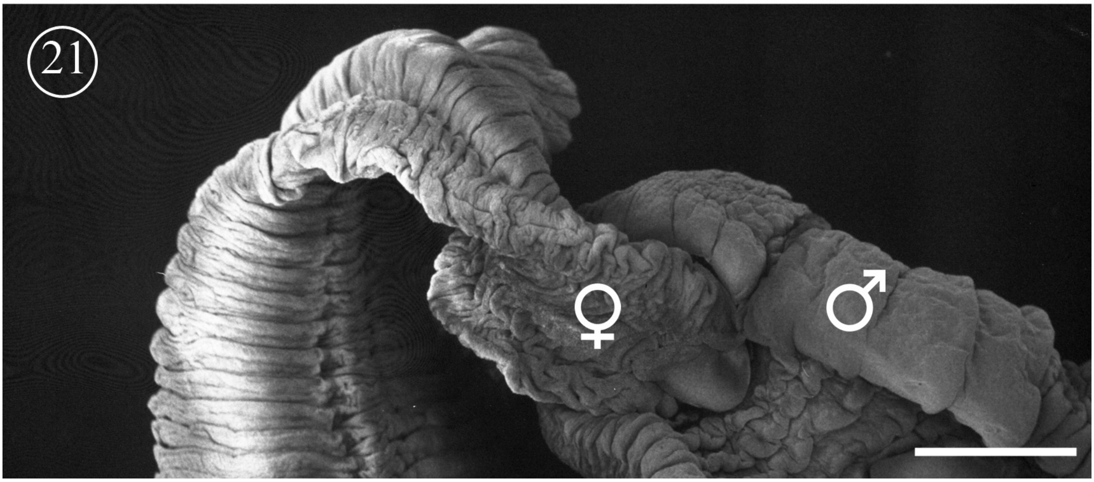
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cally feed on blood (Riley, 1986). With the help of an oral papilla, the sinus worm produces an ulcer on the epithelium and feeds on the blood pooling on the ulcer. A conspicuous ulcerative lesion was a constant finding at the attachment site in the sinusoid mucosa of reindeer. Occasionally, clotted red blood cells could be seen in the oral opening of sinus worms in SEM. The digestive physiology seems to be a unifying feature of all pentastomids. They have a pharyngeal pump, which by rhythmic expansion and contraction enables ingestion (Riley, 1973).

Bilaterally, in the direction of ten and two o'clock from the head papilla there was a conspicuous hole present. SEM revealed several other structures in the vicinity of these openings. Near the anterior edge of the opening was a row consisting of 3 or 4 delicate setae, and on the opposite side of the opening, were two groups of setae with two stout conical papillae. These structures are apparently sensory organs. The hole is probably an opening of the frontal gland, which, in many pentastomids, has been shown to secrete a lamellate material resembling the pulmonary surfactant produced by type II alveolar epithelial cells of the host (Riley, 1992). The substance produced by the glands covers the entire pentastomid, likely to help the parasite to evade its host's immune system (Riley, 1992).

Small cup-shaped cavities seen as a chain running through the lateral margin of annuli were considered to be sensory structures (lateral sense organs) (Riley, 1986). Storch & Böckeler (1979) described the ultrastructure of sensory cells of *Reighardia sternae* and showed that they consist of one apical cilium, which is surrounded by two sheat cells, forming a complex with a close resemblance to the sensillae of other arthropods. Because SEM allows only surface structures to be investigated, the sense organs of *L. arctica* have been poorly studied, and at least transmission electron microscopy should be employed to gain more information about these structures.

The strainer-like, round, abundant, cuticular depressions scattered throughout the body are in fact the visible, apical part of cells, earlier referred to as epidermal glands (Hett, 1924) and currently as chloride cells, class I cells or ionocytes (Riley, 1986; Bush *et al.*, 2001). They were described in detail by Banaja *et al.* (1977) and, according to their description, they consist of one or more pyriform cells. These cells are probably responsible for maintaining the hydromineral balance for the haemolymph of the sinus worm. Since pentastomids feed on host blood or lymph, both of which are rich in sodium and chloride, chloride cells have been proposed to secrete excess ions (Banaja *et al.*, 1977). One of the typical features of pentastomids is their lack of excretory systems. Interestingly, a group of Aphasmida nematodes, such as *Trichuris* (Sheffield, 1963; Wright, 1968) and *Trichinella* (Bruce, 1970), shares this feature. As a substitute for the excretory system, they possess bacillary cells comparable to chloride cells. A question awaiting an answer is whether this is an example of convergent evolution taking place independently in two groups of parasites or whether these groups share related ancestor.

Copulation in Porocephala pentastomids is a complex process. Although being long-lived, females evidently copulate only once in their lifetime, but males are probably able to copulate several times (Riley, 1983). As mating occurs only once, it has seldom been observed in sinus worms (R. Haugerud, 2006, pers. comm.). The male grasps the tip of the female's abdomen with its hooks such that the genital pores are in juxtaposition. Possibly the calotte-like extension of the hook with its spines, functions as a stopper during the attachment to prevent infliction of injuries to the female. Once the initial attachment has taken place, the male can insert its spicules into the vagina. The papillar structures flanking the genital pore of the male correspond in dimension to similar structures in the female, thus these structures are evidently morphological counterparts involved in copulation. The copulation is temporally determined since only in young (small) females are the vagina and the receptacula seminis close enough together for a sperm injection by the cirri into the spermatheca. Thus, the mating happens before oocytes are fully developed, and the spermatozoa are retained by the female in the spermatheca, remaining inactive during the storage period (Riley, 1986). This kind of reproductive behaviour is common in pentastomids and in the forementioned fish lice (Fryer, 1982). This peculiarity of pentastomids explains the small size of the female engaged in copulation in our material. In adult females, stored sperm could be seen in tightly packed bundles and whorls. The infective eggs of *L. arctica* are spread out on the pasture (Haugerud & Nilssen,1986). We have twice observed in August the narrow tail of the female sinus worm is protruding through the sphenopalatinal foramen of the reindeer into its nasal cavity, suggesting that fertilized eggs are expelled from the palatinal sinus with the aid of the long tail of the female.

In conclusion, pentastomids can be considered aberrant parasites, and *L. arctica* stands out from the rest as being the only pentastomid to have a direct life cycle and an ungulate (reindeer) as a definite host. These prehistoric freaks of nature continue to elude scientists, probably because they were separated from other arthropods during primeval stages, and thus, they also have features common to other contemporary phyla. The lack of free-living species reflects their complete adaptation to a parasitic existence (Riley, 1983). Pentastomids, including *L. arctica*, are fascinating examples of the richness and biodiversity of nature.

References

Banaja, A. A., James, J. L. & Riley, J. 1977. Observations on the osmoregulatory system of Pentastomids: The tegumental chloride cells. – *International Journal for Parasitology* 7: 27-40.

Bruce, R. G. 1970. *Trichinella spiralis*: fine structure of body wall with special reference to formation and moulting of cuticle. – *Experimental Parasitology* 28: 499-511.

Bush, A. O., Fernanéz, J. C., Esch, G.W. & Seed, J. R. 2001**.** Pentastomida: the tongue worms. – *In: Parasitism – The diversity and ecology of animal parasites*. Cambride University Press, Cambridge, UK, pp. 214-224.

Christensson, D., von Geijer, I. & Nordkvist, M. 1974. Tungmask påvisad hos ren i Sverige. – *Svensk Veterinärtidning* 26: 717-719.

Fain, A. 1964. Observations sur le cycle e´volutif du genre Raillietiella (Pentastomida). – *Bulletin de la Classe des Sciences de l´ Acade´mie Royale de Belgique 50: 1036-1060.*

Fryer, G. 1982. *The Parasitic Copepoda and Branchiura of British Freshwater Fishes. A Handbook and Key.* Freshwater Biological Association, Ambleside, *Scientific Publication* No 46.

Haugerud, R. E. & Nilssen, A. C. 1985. *Linguatula* sp. (pentastomida) in reindeer. A new species with a direct life-cycle? In: Proceedings of the 12th Scandinavian Symposium of Parasitology, Tromsø, Norway, June, 1985. – *Information* 18: 51. Institute of Parasitology, Åbo Akademi, Åbo, Finland.

Haugerud, R. E. 1986. Om *Linguatula arctica*, reinens bihulemark (About *Linguatula arctica*, the sinus worm of the reindeer). In: Proceedings of the Third Nordic Workshop on Reindeer Research, Rovaniemi, Finland, 15-17 October 1986. – *Rangifer* 6 (1-Appendix): 80-87. (In Norwegian with summary in English).

Haugerud, R. E. & Nilssen, A. C. 1986. Reinens bihulemark. In: Parasitter hos rein. – *Ottar* 161 (4/86): 22-29. Tromsø Museum, Universitetet i Tromsø. (In Norwegian).

Haugerud R. E. 1988. *A life history appoach to the parasite-host interaction* Linguatula arctica *(Riley, Haugerud and Nilssen, 1987)* – Rangifer tarandus *(Linnaeus, 1758)*. Thesis in ecology, zoology, University of Tromsø, Norway.

Haugerud, R. E. 1989. Evolution in the Pentastomids. – *Parasitology Today* 5(4): 126-132.

Haugerud, R. E. & Nilssen, A. C. 1990. Life history of the reindeer sinus worm, *Linguatula arctica* (Pentastomida), a prevalent parasite in reindeer calves. In: Proceedings of the Fifth International Reindeer/Caribou Symposium, Arvidsjaur, Sweden, 18-22 August, 1988. – *Rangifer* Special Issue No. 3: 333-334.

Hett, M. L. 1924. On the family Linguatulidae. – *Proc. Zool. Soc. London* 1: 107-159.

Lavrov, D. V., Brown, W. M, & Boore, J. L. 2004 Phylogenetic position of the pentastomida and (pan)crustacean relationships. – Proc. *Biol. Sci.* 271: 537-544.

Murie, E. A. 1926. On the presence of *Linguatula serrata* Froel. in the caribou. – *Journal of Parasitology* 12: 180.

Nikander, S. & Rahko, T. 1989. Sinusitis in reindeer caused by *Linguatula arctica. In: Poster Abstract of 13th WAAVP conference* (P 3-15), Berlin 1989.

Rehbinder, C. & Nordkvist, M. 1982. ***Linguatula serrata*** in Swedish reindeer. –*Rangifer* 2: 45-46.

Riley, J. 1973. **The structure of the buccal cavity and phar**ynx in relation to the method of feeding of *Reighardia sternae* Diesing 1864 (Pentastomida). – *International Journal for Parasitology* 3: 149-156.

Riley, J. 1983. Recent advances in our understanding of pentastomid reproductive biology. – *Parasitology* 86: 59-83.

Riley, J. 1986. The biology of pentastomids. In: Baker, J. & Muller, R. (eds.). – *Advances in Parasitology* 25: 45-128.

Riley, J., Haugerud, R. E. & Nilssen, A. C. 1987. A new species of pentastomid from the nasal passage of the reindeer (*Rangifer tarandus*) in northern Norway, with speculation about its life-cycle. – *Journal of Natural History* 21: 707-716.

Riley, J. 1992. Pentastomids and the immune system. – *Parasitology Today* 8: 133-137.

Sheffield, H. G. 1963. Electron microscopy of the bacillary band and stichosome of *Trichuris muris* and *T. vulpis*. – *Journal of Parasitology* 49: 998-1009

Skjenneberg, S. 1965. *Rein og reindrift*. As Fjell-Nytt, Lesjaskog, Norway, p. 96.

Storch, V. & Böckeler, W. 1979. Electron Microscopic Observations on Sensilla of Pentastomid *Reighardia sternae* (Diesing, 1864). – *Zeitschrift fur Parasitenkunde* 60: 77-86.

Sweatman, G. K. 1971. Mites and Pentastomes. – *In*: Da . & Anderson, R. C. (eds.). *Parasitic disease of wild mammals*. The Iowa State University Press Ames, Iowa, pp. 3-64.

Walossek, D. & Muller, K. J. 1994. Pentastomid parasites from the Lower Palaezoic of Sweden. – *Transactions of the Royal Society of Edinburgh: Earth Sciences* 85: 1-37.

Wright, K. A. 1968. Structure of the bacillary band of *Trichuris mycocastoris*. – *Journal of Parasitology* 54: 1106-1110.

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Elektronimikroskooppinen tutkimus poron kielimadosta (*Linguatula arctica*)

Abstract in Finnish / Yhteenveto: Pentastomida (matoäyriäiset) ovat ryhmä erikoisia parasiitteihin kuuluvia niveljalkaisia. Niitä kutsutaan usein kielimadoiksi, sillä monet ryhmään kuuluvista lajeista ovat muodoltaan kielimäisiä. *Linguatula arctica*, poron kielimato, on poron nenäonteloon liittyvissä sivuonteloissa elävä loinen. Se on ainoa tunnettu matoäyriäinen, jolla on sorkkaeläin pääisäntänä ja suora (ilman väli-isäntää tapahtuva) elämänkierto. Tässä tutkimuksessa tarkasteltiin *L. arctica* -loisen pinta- ja sisärakenteita pyyhkäisyelektronimikroskoopin avulla. Loiset kerättiin Suomen lapista talvella 1991–92. Nenän sivuontelot tutkittiin loisten varalta noin 80 porosta, ja niistä löydettiin yhteensä 30 kielimatoa. Kielimatojen ulkonäkö oli tyypillinen *Linguatula*-suvun loisille. Ne olivat melanmuotoisia, läpikuultavia, vaalean kellertäviä, litteitä, ne vaikuttivat jaokkeisilta ja niillä oli pitkä loppua kohden kapeneva häntä. Suu sijaitsi vatsapuolella lähellä etupäätä, ja suuhun liittyneenä oli selvästi erottuva päämäinen uloke. Suuaukon tuntumassa, suuaukon molemmilla puolilla oli pari voimakkaasti kehittyneitä kynsimäisiä koukkurakenteita. Kielimadon ulkopinta koostui annulaarisista rakenteista, mistä johtuen se vaikutti jaokkeiselta. Loisen sivuissa, kunkin jaokkeen reunassa, oli tuntoelin, joka näkyi pyyhkäisyelektronimikroskoopilla kuppimaisena syvennyksenä. Jaokerenkaiden takareuna oli pienten, taaksepäin suuntautuneiden kitiinipiikkien karhentama. Koko ulkopinnan alueella nähtiin pieniä, pyöreitä painautumia, joiden todettiin olevan loisen pintaan avautuva kärkiosa niin kutsutuista kloridisoluista. Koiraskielimadon sukuaukko sijaitsi vatsapuolella takimmaisen koukkuparin kärkien tasolla, naaraan vastaavasti vatsapuolella lähellä takapäätä. Sekä koiraalla että naaraalla nähtiin sukuaukon molemmissa reunoissa ulokkeet, jotka koiraalla olivat nystymäiset ja naaraalla lehtimäiset. Tutkitussa materiaalissa todettiin yksi paritteleva kielimatopari. Tutkimuksessa voitiin tunnistaa useita niveljalkaisille ja matoäyriäisille tyypillisiä rakenteita. Koska pyyhkäisyelektronimikroskoopin avulla voidaan tutkia ainoastaan pintarakenteita, erityisesti tuntoelimien rakenteista saatu informaatio jäi pinnalliseksi. Läpivalaisu- eli transmissioelektronimikroskoopin avulla tästä kiehtovasta eliöstä ja sen alkuperästä olisi mahdollista saada lisää tietoa.

En elekronmikroskopisk studie av renens bihålemask (*Linguatula arctica*)

Abstract in Swedish / Sammandrag: Pentastomiderna är en grupp egendomliga, parasitiska ledfotingar ofta beskrivna som tungmaskar beroende på att några arter är tunglika. *Linguatula arctica* är renens (*Rangifer tarandus*) bihålemask, den enda pentastomid som har en direkt livscykel och ett klövdjur som slutvärd. Nedan beskrivs ytstrukturer och inre morfologi av könsmogna *L. arctica* sedda med skanningelektronmikroskop (SEM). Bihålemaskarna insamlades vintrarna 1991 och 1992 i Finlands Lappland. De paranasala håligheterna på ca. 80 slaktade renar undersöktes och 30 bihålemaskar upptäcktes. Bihålemaskarna hade för *Linguatula* arterna typisk morfologi. De var paddelformade, delvis genomskinliga, svagt gulaktiga, tillplattade och skenbart segmenterade med en lång smal bakkropp. På framkroppens undre sida fanns en munöppning med ett stort tydligt huvudliknande utskott. På båda sidor om denna öppning fanns ett par starka krökta hakar. Framkroppen och bakkroppen hade ett segmenterat utseende, emedan ytan hade tydlig annulation. Det fanns små koppformade känselorgan på sidan av varje annula. Bakkanten av varje annula var försedd med små bakåt riktade taggar. Hela ytan (kutikulan) var full av små, runda fördjupningar, som var den synliga delen av kloridcellerna. Hanens genitalöppning var på undre sidan mellan det bakre paret av hakarna och honans i spetsen på bakkroppen. Genitalöppningen hos hanen hade lateralt papiller och honans bladlika strukturer. Ett kopulerande par där hanen hade fäst sig med hakar och papiller vid honans bakkropp observerades. Flera strukturer karakteristiska för ledfotingar och pentastomider identifierades. Emedan endast ytor kan studeras med SEM förblir morfologin, speciellt känselorganens, okänd. Undersökningar med transmissionselektronmikroskop borde göras för att få mer information om denna fascinerande varelse och dess ursprung.