Proc. Arthropod. Embryol. Soc. Jpn. 48, 43–45 (2017)

ISSN 1341–1527

[SHORT COMMUNICATION]

Tentorial Invaginations of the Collembolan *Tomocerus cuspidatus* Börner, 1909 (Hexapoda: Collembola, Tomoceridae)*

Shigekazu TOMIZUKA[1, 2] and Ryuichiro MACHIDA[1, 3]

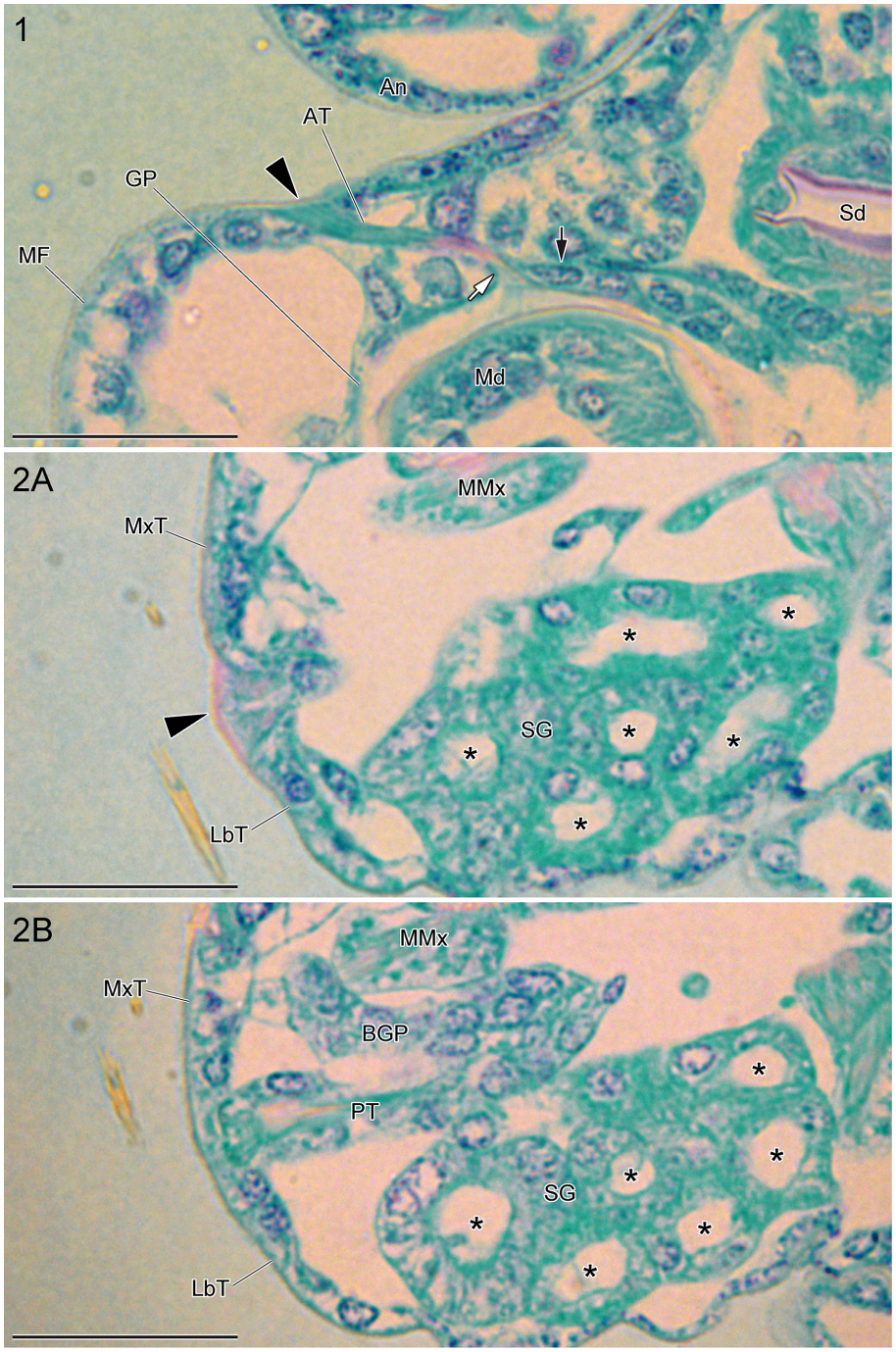
[1] *Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki 305–8572, Japan*
[2] *Current address: Echigo-Matsunoyama Museum of Natural Science, Matsunoyama Matsuguchi, Tokamachi, Niigata 942–1411, Japan*
[3] *Current address: Sugadaira Research Station, Mountain Science Center, University of Tsukuba, Sugadaira Kogen, Ueda, Nagano 386–2204, Japan*
E-mail: tomizuka@matsunoyama.com (ST)

Collembola, Protura, and Diplura belong to the Entognatha, on the basis of entognathy as the most reliable autapomorphy. Recent paleontological and morphological researches have provided evidence discounting the homology of entognathy among these three entognathan orders (Kukalová-Peck, 1987; Koch, 1997). Irrespective of whether they can be elucidated as homologous, undoubtedly entognathy and the mouth fold, which is a most staple constituent structure of entognathy, are novel structures. Although there is no doubt that entognathy is derived from ectognathy, which has been confirmed to be the groundplan of the mouth parts of hexapods, the evolutionary process, that is, evolutionary transformation from an ectognathous to entognathous conformation, has not been well examined and discussed so far, with only Folsom (1900) addressing the issue. In the embryological study of the collembolan *Annurida maritima*, he correlated the mouth fold of Entognatha with the subgena of Ectognatha, comparing the relative positions of the mouth fold and subgena with the gnathal appendages. A crucial weakness in Folsom's argument may be the lack of a landmark defining the extension of the mouth fold. The dorsal limit of subgena is defined by the subgenal suture, which is a lateral submarginal groove on the cranium of Ectognatha roughly connecting the anterior and posterior tentorial pits (cf. Snodgrass, 1935). However, the tentorial pits have not been identified in Entognatha, including Collembola (cf. Matsuda, 1965). As the result of our embryological study of *Tomocerus cuspidatus* Börner, 1909, we succeeded in identifying the posterior tentorial pits and designating the approximate position of the anterior tentorial pits for the first time in Entognatha. The details of the tentoria will be given in the full description of the entognathy formation of this species (Tomizuka and Machida, in prep.), and in the present paper we give a preliminary description.

Figures 1 and 2 are the cross sections of the head of a first instar larva of *Tomocerus cuspidatus*, in which the invaginations of tentoria are clearly demonstrated. Figures 1 and 2A are through the antennal base and posterior tentorial pit, respectively, and Figure 2B is through the maxillary base in the plane slightly anterior to Figure 2A. Figure 1 shows the anterior tentorial pit (arrowhead) in the region of the cranium ventrolateral to the antennal base. The anterior tentorium extends internally from its external pit and divides into two branches, one of which directs along the gnathal pouch enfolding the mandible (white arrow), and another of which extends in the direction toward the stomodeum (black arrow). Figure 2A and B show the posteior tentorium. The posterior tentorial pit is in the lateral region of the cranium, inside which the proximal end of the maxilla is located (arrowhead in Fig. 2A). The posterior tentorium extends internally along the blind end of the gnathal pouch, which enfolds the maxilla (Fig. 2B). In the later stage of embryonic development, in which the formation of entognathy is almost completed, the posterior tentorial pits are observed externally as a pair of invaginations (black arrowhead) between the maxillary and labial terga around the level of the proximal end of the labium (arrow) (Fig. 3). The anterior tentorial pit is located in the region of the cranium ventrolateral to the antennal base as in the first instar larva (shown by white arrowhead in Fig. 3), although the pit is concealed by the base of the antenna.

The mouth fold of *Tomocerus cuspidatus* is the ventral extension of the fused terga of the intercalary, mandibular and maxillary segments (Tomizuka and Machida, 2012; in prep.). The mouth fold can be defined as the structure extending ventrally, surpassing the appendicular bases and covering the mandibular and maxillary sides, and the dorsal limit of the mouth fold is should be designated by the appendicular bases. However, the mandibles and maxillae should be excluded

* This article, which was received in 2013 and should have been published in 2014, was printed in 2017 being much delayed due to various circumstances.



Figs. 1, 2 Cross sections of the head of a first instar larva of *Tomocerus cuspidatus*.

Fig. 1 A section through the antennal base, showing the anterior tentorium. The arrowhead and black and white arrows indicate the anterior tentorial pit and two branches of the anterior tentorium, respectively.

Fig. 2 Sections through the plane including the posterior tentorial pit (A) and that including the maxillary base, slightly anterior to A (B), showing the posterior tentorium. The arrowhead and asterisks indicate the posterior tentorial pit and ducts of the salivary gland, respectively.

An: antenna, AT: anterior tentorium, BGP: blind end of gnathal pouch, GP: gnathal pouch, LbT: labial tergum, Md: mandible, MF: mouth fold, MMx: musculature of maxilla, MxT: maxillary tergum, PT: posterior tentorium, Sd: stomodeum, SG: salivary gland. Scales = 20 μm.

from defining the dorsal limit of the mouth fould because, during entognathy formation, their bases are largely shifted dorsally from their original positions. Therefore, we use the line connecting the antennal and labial bases as the approximate dorsal limit of the mouth fold (broken line in Fig. 3). Figure 3 shows that the approximate dorsal limit of the mouth fold (broken line) can be approximated as the line connecting the anterior (white arrowhead) and posterior (black arrowhead) tentorial pits. As addressed above, the subgena in Ectognatha is the area below the subgenal suture, which is roughly the connection line between the anterior and posterior tentorial pits. Hence, the mouth fold in Collembola

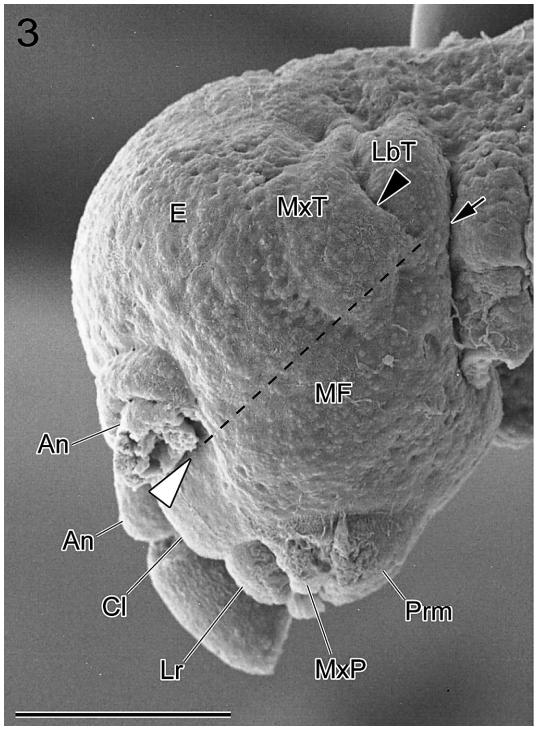


Fig. 3 An SEM of the cephalic region of an embryo of *Tomocerus cuspidatus*, lateral view. The left antenna was removed. Black and white arrowheads indicate the posterior tentorial pit and the approximate position of the anterior tentorial pit, respectively. Arrow indicates the labial base. Broken line indicates the dorsal limit of the mouth fold, approximated by the line connecting the antennal and labial bases. An: antenna, Cl: clypeus, E: eye, LbT: labial tergum, Lr: labrum, MF: mouth fold, MxP: maxillary palp, MxT: maxillary tergum, Prm: prementum. Scale = 50 μm.

and subgena in Ectognatha are approximately homologous, and Folsom's (1900) correlation of the mouth fold and subgena is supported.

Acknowledgments: We thank our friend Peter Rühr of Rheinische Friedrich-Wilhelms-Universität Bonn, Dr. Makiko Fukui of Ehime University, and Dr. Kaoru Sekiya of Sugadaira Montane Research Center, University of Tsukuba for their valuable suggestions. This study was supported by Grants-in-Aid from the JSPS (Scientific Research C: 21570089 & 2544020; Scientific Research B: JP16H04825) to RM. This is contribution by the Sugadaira Montane Research Center, University of Tsukuba.

References

Folsom, J. W. (1900) The development of the mouth-parts of *Anurida maritima* Guér. *Bulletin of Museum of Comparative Zoology*, **36**, 87–157, pls. I–VIII.

Koch, M. (1997) Monophyly and phylogenetic position of the Diplura (Hexapoda). *Pedobiologia*, **41**, 9–12.

Kukalová-Peck, J. (1987) New Carboniferous Diplura, Monura, and Thysanura, the hexapod ground plan, and the role of thoracic side lobes in the origin of wings (Insecta). *Canadian Journal of Zoology*, **65**, 2327–2345.

Matsuda, R. (1965) Morphology and evolution of the insect head. *Memoirs of the American Entomological Institute,* **4**, 1–334.

Snodgrass, R. E. (1935) *Principles of Insect Morphology*. McGraw-Hill, New York.

Tomizuka, S. and R. Machida (2012) Entognathy formation of Collembola, *Proceedings of the Arthropodan Embryological Society of Japan*, **47**, 29–31.