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A Preliminary Note on Formation of the Digestive Tract during the Early Embryonic Stages in a Viviparous Scorpion *Liocheles australasiae* *

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Scorpion embryogenesis patterns are classified into two types based on the place where the embryo develops; 1) development within the lumens of the ovariuterine tubules, *i. e.*, "Apoikogenic development," and 2) development in the ovarian diverticula (special protuberances from the ovarian tubes), *i. e.*, "Katoikogenic development" (Laurie, 1896). Apoikogenic development is considered to be ovoviviparity, being identifiable based on the embryo having a large amount of yolk. In some cases, there is a combined development type between ovoviviparity and viviparity, where embryos are identifiable by a relatively small yolk and are partly nourished by their mother (Laurie, 1896). Katoikogenic development is considered to be full viviparity because the embryos are completely devoid of yolk and are totally dependent on their mother for nourishment. During the embryogenesis of the katoikogenic developmental type scorpions, a narrow cord-shaped special structure called the "appendix" is developed at the distal of each ovarian diverticulum, and it is considered that the embryo is nourished with maternal resources via this appendix.

Mathew (1956) reported on an interesting development process observed in the katoikogenic scorpion *Heterometrus scaber* (Scorpionidae). In the embryo of *H. scaber*, foregut and midgut formation begins at a remarkably early stage when the body segments and legs have still not differentiated, and the embryo absorbs the nourishment provided from its mother into its midgut. Compared to the formation of the digestive tract of apoikogenic scorpions and other arthropod groups, that of *H. scaber* occurs at an extremely early point. This early formation of the digestive tract and the unique mode of nourishment are considered to be an adaptation found only in viviparous (katoikogenic) species. However, in other katoikogenic species, the patterns and stages of digestive tract formation have not been studied in detail. One of the reasons may be in the fact that scorpion embryos develop in the maternal body (Anderson, 1973; Polis, 1990), and as a result it is difficult to recognize the starting point of their embryogenesis and to properly observe the timing of the distinct embryonic stages. These difficulties have been overcome by using the viviparous (katoikogenic) liochelid scorpion, *Liocheles australasiae* (Yamazaki *et al*., 1998). *L. australasiae* scorpions of Iriomote-jima Island are known to reproduce by means of thelytokous parthenogenesis (Makioka, 1993; Yamazaki and Makioka, 2005). Adult females reproduce parthenogenetically and cyclically repeat pregnancies and parturitions (Yamazaki and Makioka, 2005).

In the present study, we found that adult females of *L. australasiae* gave birth to 1st instars 362 ± 2.51 days (mean ± S.E., n = 42) after the last parturition, in the individually reared at 25℃. By using the easily identifiable date of parturition as the beginning of the next pregnancy cycle, the embryonic development process of scorpions can be described systematically, relating each stage and observation accurately to the start point of the cycle. In the present study, we focus on the embryogenesis of *L. australasiae*, with special reference to the digestive tract formation.

In the embryo of *Liocheles australasiae*, the invagination of its foregut (stomodaeum formation) commences about 70 days after the last parturition, while the foregut and midgut develop within further 10

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days. Around 80 days after the last parturition, the absorption and accumulation of nourishment from mother are already observed in digestive tract, prior to the complete differentiation of body regions, prosoma, mesosoma and metasoma, and leg rudiments (cf. Fig. 1A, B *vs*. Figs. 2, 3). The patterns and timing of digestive tract formation of *L. australasiae* are mostly similar to that of *H. scaber* described by Mathew (1956). Therefore, it is suggested that digestive tract formation in the very early stages is a common feature of katoikogenic scorpions, as they are fully viviparous and therefore need nutrition throughout their entire embryonic development.

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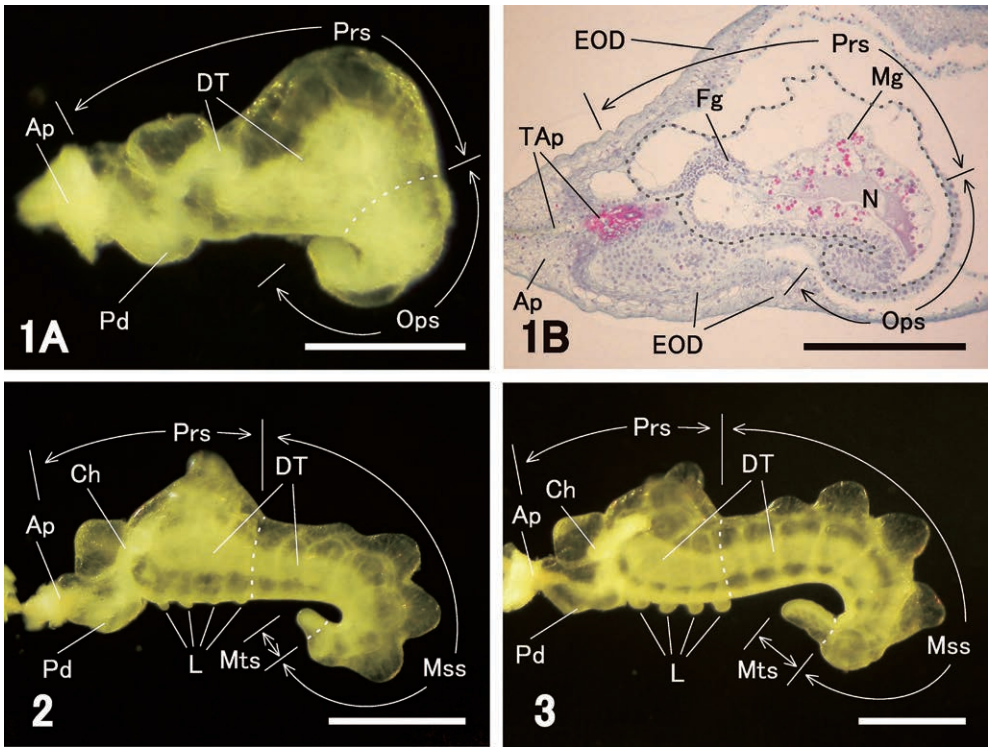

Figs. 1–3 *Liocheles australasiae* embryos (lateral views) and a sagittal section (hematoxylin-eosin staining) of an embryo. Anterior is to the left, and dorsal is at the top.

Fig. 1 An embryo about 80 days after the last parturition. A. A light micrograph of the embryo. Differentiation of prosoma (Prs) and opisthosoma (Ops; mesosoma + metasoma) are visible. Parts of the digestive tract (DT), especially the foregut and midgut of the embryo, have been developed. White dotted line shows the boundary of body regions, prosoma and opisthosoma. B. A sagittal section of an embryo at the same embryonic stage as shown in A. The proximal part of the tube of appendix (TAp) connects to the foregut (Fg) of the embryo, and nourishment (N) from the mother is absorbed and accumulated via the appendix and foregut into the midgut (Mg). Gray dotted line shows the embryonic area.

Fig. 2 An embryo about 120 days after the last parturition. A pair of chelicera (Ch) and four pairs of leg rudiments (L) are evident. Seven mesosomal segments are formed. White dotted lines show the boundary of body regions, prosoma (Prs), mesosoma (Mss) and metasoma (Mts).

Fig. 3 An embryo about 170 days after the last parturition. Five metasomal segments are differentiated. White dotted lines show the boundary of body regions, prosoma (Prs), mesosoma (Mss) and metasoma (Mts).

Ap: appendix, EOD: epithelium of ovarian diverticulum, Pd: pedipalp. Scales = 1: 250 μm; 2, 3: 500 μm.