METASOMA OF Orthochirus (Scorpiones: Buthidae): ARE SCORPIONS EVOLVING A NEW SENSORY ORGAN?

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Abstract:
A peculiar array of over 1000 cuticular pits is found ventrally and laterally on the posterior segments of metasoma and telson of a few taxa of Buthidae (Scorpiones), including all species of the widespread Old World desert genus Orthochirus Karsch. SEM investigation shows those pits adorned with variable size setae, which exhibit microanatomical features characteristic for chemoreceptors (curved shape, end pore). Observations in nature (Central Asia) show an unusual in scorpions rest/defense posture in Orthochirus, with metasoma pressed flat to the mesosoma, its small telson folded dorsally in a groove, and the ventral surface of the metasomal segment V forming a "face shield". We suggest that the up-and-forward facing ventral/lateral surfaces of the posterior metasomal segments in Orthochirus and related genera could be used as a chemo-sensory array, analogous to insect antennae.

Key words: Scorpiones, Buthidae, Orthochirus, metasoma, sensory setae.

Introduction
As soon as the first species of the genus Orthochirus Karsch, 1880 (Scorpiones: Buthidae) have been described, the unusual among scorpions structure of their metasoma ("tail") has been noticed: pitted ventral and lateral surfaces of metasomal posterior segments, especially IV and V, and the telson. The name scrobiculatus given by Grube (1873) to the most widespread species of Orthochirus, means "pitted" (from Latin scrobiculus, "a little trench"); the word "scrobiculated" in fact exists in English.

These metasomal pits have been used as a taxonomic character in Buthidae (Leyvi & Amitai, 1980), but were never analyzed at the microscopic level. Several small (below 50 mm), dark-colored species of Orthochirus are common in the Palearctic deserts from North Africa to Central Asia (Leyvi & Amitai, 1980; Fet & Lowe, 2000). Leyvi & Amitai (1980: 101) observed that its “metasoma is held curled, pressed to the back with the stinger completely hidden”, which is not a common feature in scorpions. Also, a peculiar side-to-side motion of metasoma in “pitted” species of buthids during prey search was reported (Shulov & Amitai, 2001).

Pitted metasomal surface has been found in several scorpion genera, all from the Old World deserts, and presumably of African origin (Fet et al., 2003). Birula (1917) even established a special subfamily Orthochirinae, to accommodate this genus and its kin. Recently, Lourenço (2001) was the first to publish SEM images of similar pits in the South African genus Karasbergia, which appeared to carry specialized chemoreceptory setae.
Material and Methods

Material. Adult females and males of Orthochirus scrobiculosus (Grube, 1873) were collected by Victor Fet on April 18, 2002 at Repetek, Turkmenistan (East Karakum Desert) at night using UV “black light”. Scorpions were preserved in 96% ethanol and brought to Marshall University, West Virginia, USA.

Microscopy. Metasomas were removed from the animals and treated as follows. Specimens were fixed for 12 hours in 0.1 M sodium cacodylate with 2.5% gluteraldehyde (freshly prepared). After rinse/soak for 12 hours in plain 0.1 M sodium cacodylate, specimens were post-fixed for 2 hours in freshly prepared 1% osmium tetroxide again in sodium cacodylate. Specimens were rinsed three times with distilled water and dehydrated in an ethanol series (50, 75, 95, and two changes of 100%) before being dried and coated with gold/palladium (ca. 10 nm thickness) in a Hummer sputter coater. SEM images were acquired with a JEOL JSM-5310LV. Acceleration voltage (10-20 kV), spot size, and working distance were adjusted as necessary to optimize resolution, adjust depth of field, and to minimize charging.

Results

SEM images. Orthochirus metasoma at magnifications from 15x to 5,000x is illustrated (Figs. 1-5). On the ventral and lateral surface of metasomal segments, especially segments IV-V and the telson, we observed arrays of multiple cuticular pits, with a single socketed seta emanating from each. Pits varied in diameter and length, their mutual position was irregular. Number of pits counted on adult females (n=4) was: on metasomal segment V, 15.9 ± 2.30 per mm² (n=4); on segment IV, 12.2 ± 1.08 per mm² (n=12); on segment III, 735 ± 74; on segment II, 112 ± 11. On the lateral and ventral surfaces, 735 ± 74; on metasomal depth, their mutual position was irregular. Number of setae emanating from each. Pits varied in diameter and shape, with a single socketed seta. The socketed setae were especially segments IV-V and the telson, we observed patterns with hexagonal cells of ca. 10 µm across; these are well observable within pits, forming a honeycomb pattern with hexagonal cells of ca. 10 µm across; these are believed to demarcate the cuticular contribution of single epithelial cells. The socketed setae emanating from the pits varied considerably in length and shape, from longer and straighter ones to short and curved ones (Figs. 2-3). Setae ranged in size between 50 and 100 µm. All observed pit setae had an apical pore (Figs. 3-5), characteristic for chemosensory setae in scorpions (Grube, 1873) has a principally different physiological role compared to the “non-pitted” metasoma of most buthid species. The observed side-to-side metasomal motion

Discussion

Cuticular sensory organs are common in all arachnids. In scorpions, short, curved chemosensory setae are scattered all over the animal’s body (Foelix & Mueller-Vorholt, 1983; Farley, 2000; Gaffin & Brownell, 2001). However, the observations of these setae were sporadic, concentrating largely on leg tarsi which bear contact chemosensory setae. No SEM study so far addressed the possible concentration of chemosensory setae on metasoma of Orthochirus.

Brownell (2001) wrote: “...terrrestrial arachnids can claim some of the most elaborate chemosensory organs among the Arthropoda. ...Taken together, the Arachnida reveal an evolutionary trend toward specialization of chemosensory appendages in arthropods, one that begins with gustation by leg-like appendages contacting the substrate [in scorpions and solpugids] and ends with olfaction by antenna directed into the air [in amblypygids, uropygids, and solpugids].” Surprisingly, we see in the case of Orthochirus that the “antennalization” (Brownell, 2001) could possibly take place in scorpions as well, in addition to their remarkable contact chemoreception by pectinal organs, with their thousands of peg sensilla (up to 120,000 per male; Gaffin & Brownell, 2001).

The setate pits themselves are, of course, a common structural feature of arthropod cuticle, e.g. in beetles’ elytra. It remains to be seen if the metasomal pitted array of setae in Orthochirus and other “pitted” scorpions (genera Microbuthus, Buthoeus, Karasbergia) has a principally different physiological role compared to the “non-pitted” metasoma of most buthid species. The observed side-to-side metasomal motion

Fig. 1-5: Orthochirus scrobiculosus; 1. Metasoma, segments I-V and telson, ventral surface (15x). 2, pitted ventral surface of the metasomal segment V (A. 35x; B. 200x). 3. metasoma V, a short pit seta (A. 500x; B. 2,000x). 4. metasoma V, tip of pit seta (5,000x). 5. metasoma I, tip of pit seta (5,000x).
during prey search seems to agree with a possible special functional role.

Scorpion metasoma ends with a venomous gland in its telson, and is naturally thrust forward due to its role in defense and attack. In many non-buthid scorpions (e.g. family Scorpionidae) metasoma is shortened, and the role of venom is decreased as well as its potency. In Buthidae, on the contrary, potency and specificity of venom toxins reaches the known scorpion maximum. The Old World desert Buthidae, including Orthochirus, are a monophyletic group (Fet et al., 2003), with a number of derived features. Orthochirus has a potent venom (Kozlov et al., 2000), and routinely uses its metasoma for both attack and defense – with the ventral surface of its posterior metasomal segments “directed into the air” when in rest posture. It is not too farfetched to envision evolution of a concentrated chemosensory array on this surface, given that chemosensory setae are readily available on scorpion’s body.

Or, quoting Brownell (2001) on arachnid chemoreception, “God has a plan after all!”

Conclusions

Are scorpions evolving a new organ? It is tempting to think of the Orthochirus “face shield” as a budding equivalent of insect antennae. We know that the chelate pedipalps in scorpions combine functions of predation and antenna-like mechanoreception (with their arrays of trichobothria). Could the scorpion “antennalize” its “tail”, strategically positioned for a strike in front of the cephalothorax, to double as an antenna-like chemoreceptory device?

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Bibliography


BROWNELL, P. H. 2001. A comparison of major chemosensory organs in arachnids (God has a plan after all!). Abstracts of the XV International Congress of Arachnology, Badplaas, South Africa.


