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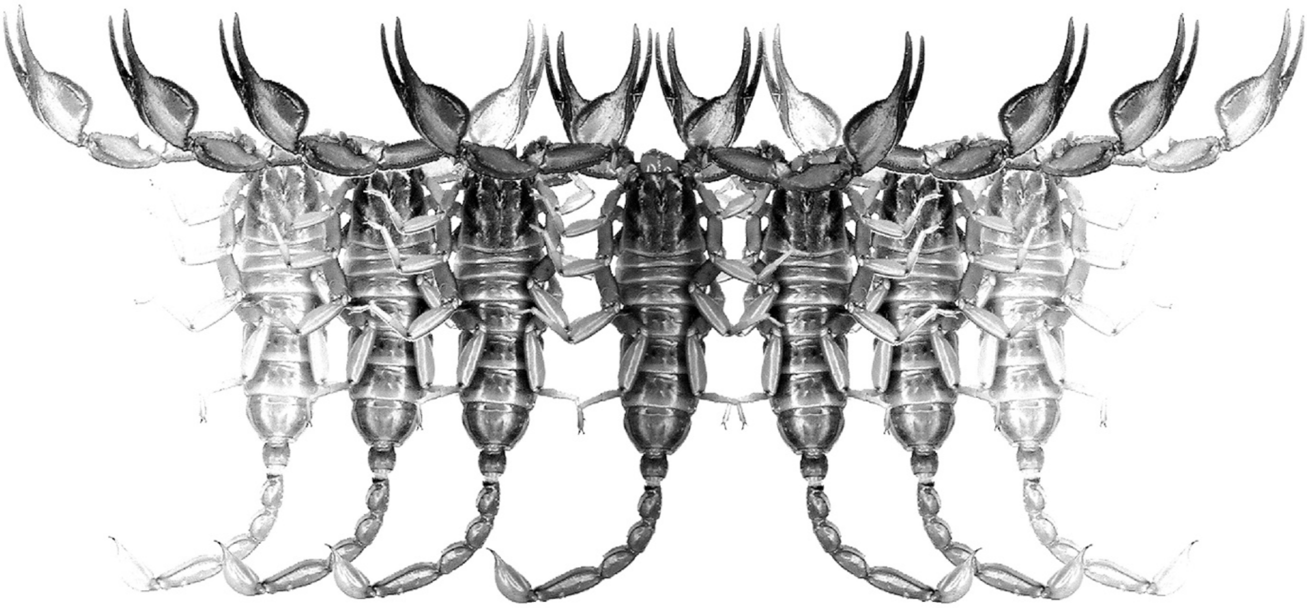

Methodologies for dry fixation and taxidermy of education-oriented scorpion specimens

Victoria Tang

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Methodologies for dry fixation and taxidermy of education-oriented scorpion specimens

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Summary

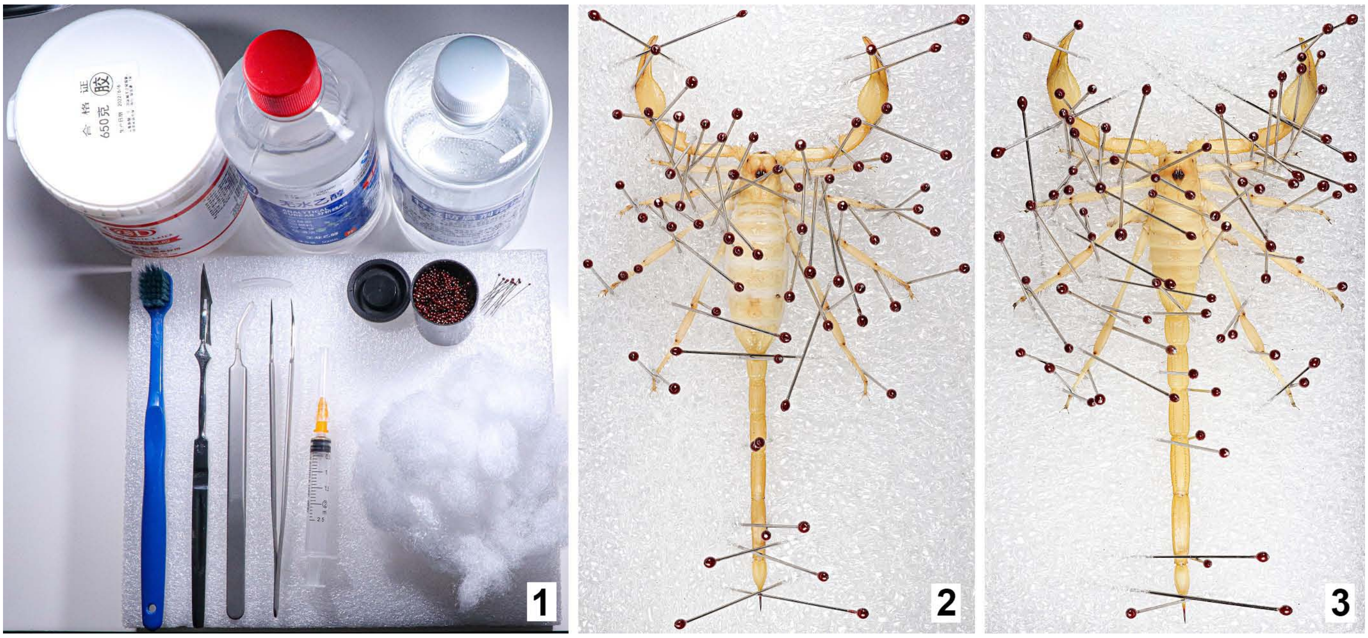
Scorpions hold a renowned status as iconic creatures across numerous cultures in the world. Traditionally preserved as desiccated specimens for educational purposes, they have been exhibited in museums and pedagogic collections, serving as concrete epistemological conduits for public education on biodiversity. However, these specimens frequently lack meticulous organization, potentially misrepresenting the animals' ethological characteristics. This brief article aims to offer paradigmatic guidance for taxidermy of scorpions, ensuring a more accurate depiction of their *in vivo* habitus, achievable through the use of readily obtainable tools and undemanding techniques.

Introduction

Biological specimens occupy a crucial position in humanity's quest to comprehend the natural world, symbolizing tangible anchors to reality. Among these specimens, name-bearing types hold particular significance, embodying the nexus between a term (a binomial name) and a concept (a species hypothesis, a category of individuals) (Miralles et al., 2024) and providing the bedrock upon which further scientific inquiry is built. According to the International Commission on Zoological Nomenclature (ICZN, Articles 16.4, 61, 72), modern zoological research mandates the designation of type specimens (an action known as "typification"), which underpins subsequent scientific investigations and taxonomic discussions. While type specimens serve as the core foundation for scientific research in academia, non-type material concurrently assumes a pivotal function as pedagogical instruments amidst an expanding societal cognizance regarding the significance of the natural sciences within contemporary milieu.

In the domain of zoology, scorpions, although constituting only a relatively minor fraction of the entire Animalia, garner significant notice owing to their global distribution and medical relevance to public health. They often feature prominently in exhibits within natural history museums, science and technology centers, and educational institutions. Preserved scorpion specimens, favored for their ease of storage and display, offer practical alternatives to their live counterparts, which demand constant care and may even pose safety hazards. Education-oriented scorpion specimens are typically desiccated due to the visual advantage they offer, as optical distortion of the animals' profile may occur if they are preserved in liquid during display. However, the fragility inherent in dried specimens poses challenges, as anatomical structures are susceptible to breakage during excess handling. Inconvenience also arises when attempting to examine dried specimens, where manipulation becomes impossible due to the unmalleable nature of these materials. Proposals have been put forth to restore the pliability of dried specimens, such as through the use of trisodium phosphate (Van Cleave & Ross, 1947). Nevertheless, dried specimens persist as the primary medium for public display as they do not necessitate the renewal of embalming fluid which may also pose health risks if certain volatile chemical compounds are involved, such as formalin, the aqueous solution of formaldehyde.

While taxidermy has received considerable attention for vertebrates and insects (e.g., Heraty et al., 2012), its development in scorpiology remains in its nascent stages. Upon observation, several issues, particularly in relation to their posture, are evident in the two prevalent forms of dried specimens: those fixed in wooden boxes and those intended to mimic live animals. The former often feature contorted appendages, occasionally concealing one another, hindering clear observation, while the latter frequently fail to accurately replicate the authentic dynamic postures of live scorpions, thereby misleading the public into the false belief that these static postures represent how a scorpion would actually behave. These shortcomings underscore the need for a rectified methodology of specimen fixation that reconciles scientific accuracy with educational value.



Figures 1–**3**: **Figure 1**. Basic tools used for the taxidermy methodology proposed in this paper (from above to below, left to right): PVA glue, 99.7% ethanol (can be diluted for lower concentration), purchased embalming fluid, brush, scalpel, tweezers, syringe, needles (3#), PP cotton and EPE board. **Figures 2**–**3**. Exemplar fixation of standard dry specimen, using adult female (2) and male (3) *Smeringurus mesaensis* (Stahnke, 1957). Both specimens have been preserved in 75% ethanol for over a week and filled with polypropylene cotton.

As a result, this paper endeavors to address the deficiencies observed in conventional scorpion specimens, categorizing them into two types: standard dry specimens and ecological (or ethological) specimens. Drawing on insights gleaned from a decade-long firsthand observation of live scorpions spanning approximately 160 species (of 51 genera and 11 families), the primary objective of this paper is to propose a paradigmatic guidance for the dry-fixation of scorpion specimens, which can be followed by educators and enthusiasts alike. This aims to ensure a more faithful representation of scorpion specimens in educational settings and foster a deeper public understanding of these arachnids. However, it is vitally important to underscore that the suggested methodologies are not intended for professional taxonomic studies.

Material, Methods & Abbreviations

Material. Freshly deceased specimens of adult scorpions are used for illustrative exemplification, all purchased as pets online: an adult pair of *Smeringurus mesaensis* (Stahnke, 1957) (Figs. 2–3) and an adult male *Androctonus australis* (Linnaeus, 1758) (Figs. 11–26). Visceral organs have been removed for all specimens and specimens of *S. mesaensis* have been preserved in 75% ethanol. Photographs of *A. australis* were taken 4 years ago, used for author's tutorial published online. Additional photographs serving as extra references were taken by mobile phone (Figs. 4–10).

Methods. Morphological structures follow conventional terminologies recognized for scorpions (Tang, 2024b). Specific methodologies proposed for each type of specimen are outlined in the following text. Terminologies for structural axes: (1) proximo-distal axis, is equate to the roll axis of a segment; (2) mediolateral axis, is equate to the pitch axis. When used jointly with abbreviations: "•" unites two adjacent segments, denoting the joint; "~" signifies the subordination (e.g., "A~B" indicates B is subordinate to A); "–" symbolizes the distance; "-" connects the two proximo-distal axes of two adjacent appendage segments; "∠" stands for the included angle formed by those proximo-distal axes.

Abbreviations. C, pedipalp chela; P, patella (applied to both pedipalps and legs); F, femur (applied to both pedipalps and legs); L, leg; T, tibia of leg; Bt, basitarsus; Tt, telotarsus; M, metasomal segment; Tl, telson; *d*, Euclidean distance. Subscript denotes the index of segment.

Standard dry specimen

I. **Basic tools**.

In the preparation of scorpion specimens for dry preservation, a selection of tools and materials proves indispensable. This paper aims to make use of items readily accessible (Fig. 1). Commencing externally, a brush, such as a toothbrush, aids in expunging dirt or other substances adhering to the scorpion's cuticle, when present. Next, a scalpel becomes requisite for dissecting the scorpion to remove internal tissues. Tweezers with a long, thin, curved tip are ideal for both extracting the viscera within the mesosoma and manipulating anatomical structures into desired orientations during the air-fixation stage. Furthermore, a syringe facilitates additional internal cleansing by expelling viscera and accumulated excrement with water. To forestall decay, embalming fluid, such as ethanol with a concentration ranging from 75% to 85%, or other commercially available alternatives, is essential. Cotton, contingent upon the specimen's condition, serves to fill the scorpion's coelom. Polypropylene (PP) cotton holds preference due to its flexibility and hydrophobic properties, naturally rendering a relatively uniform membrane surface post-filling. Securing the scorpion in place during the fixation stage entails a thick foam board. Expanded polyethylene (EPE) foam is recommended for its favorable tactile texture and easily penetrable surface. Nonetheless, it exhibits less rigidity compared to expanded polystyrene (EPS) foam, which may be more ideal for stable fixation. Needles or insect pins, selected based on appropriate size (typically #2 to #4) relative to the dimensions and rigidity of the scorpion (both body and appendages), are employed to stabilize the specimen at desired angles on the foam board. Finally, non-corrosive glue and iron wire are utilized for mending detached or broken structures when necessary. Polyvinyl acetate (PVA, white glue) assumes a translucent appearance upon drying in small quantities. Caution must be exercised with ethyl 2-cyanoacrylate (ECA, super glue), as it dries more rapidly. A basic workflow is illustrated in Fig. 81 (Appendix).

II. Basic steps.

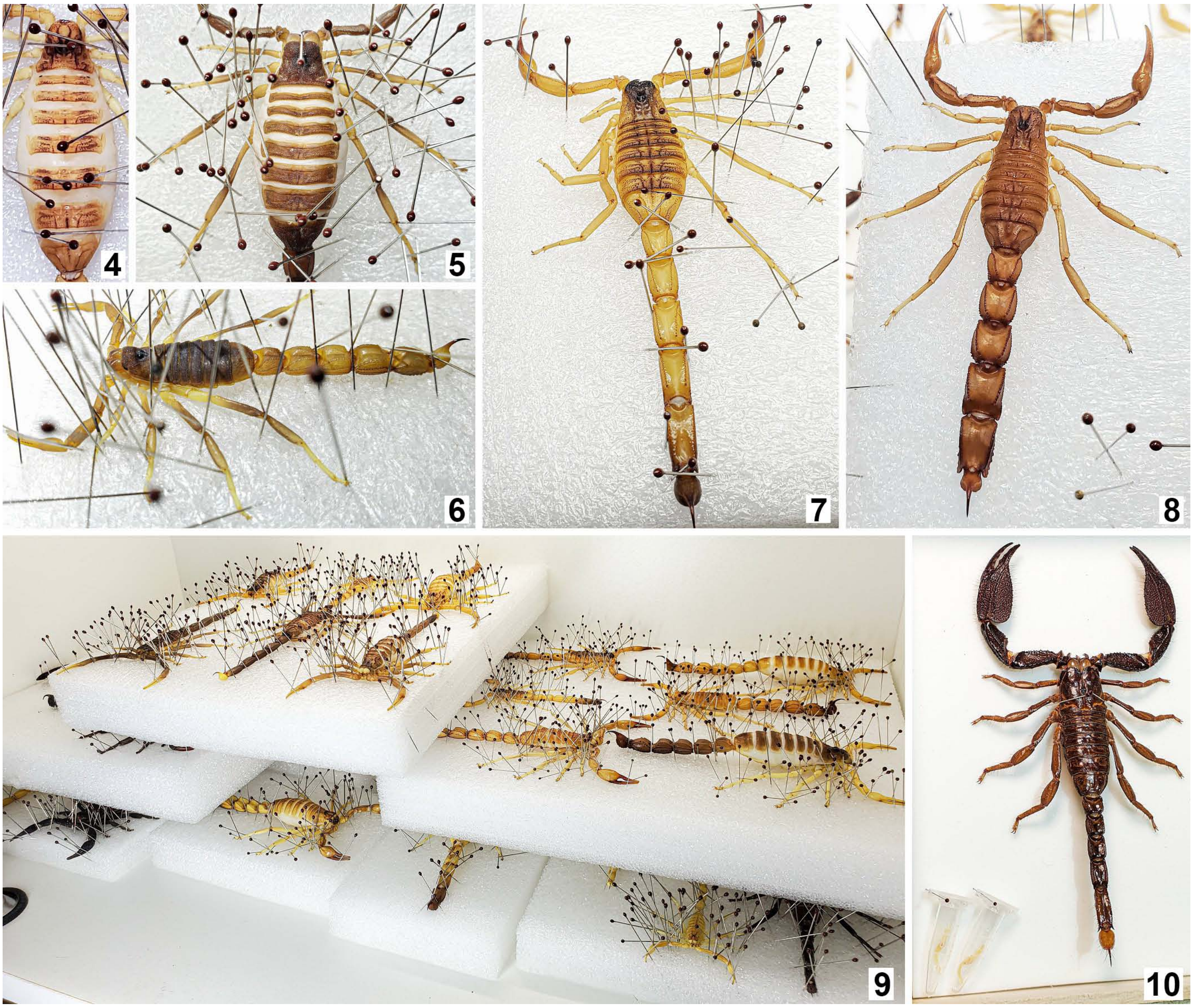
(1) Cleansing stage: A basic workflow illustrated with figures can be found in the Appendix. Firstly, use a soft-bristled brush to dislodge any extraneous matter adhering to the scorpion's exoskeleton, while simultaneously rinsing the scorpion under tap water. Next, use a scalpel to cut open the intersegmental membrane between adjacent sternites without reaching the pleural membrane so as to avoid undue rupture. The selection of the membrane between the 4th and 5th sternites (or the 2nd and 3rd visible sternites posterior to the pectinal plate) is considered optimal for its facilitation of a distance-balanced (relatively medial) internal cleansing in opposing directions. Subsequent to the dissection, apply a gentle pressure dorsoventrally to the specimen to expel the majority of internal tissues, followed by thorough extraction with tweezers. This procedure can be performed concurrently with flushing the scorpion under water, enabling the immediate removal of extracted tissues and providing a clear view into the coelom. Take caution with scorpions displaying color patterns within the epidermis beneath the cuticle, as these can be inadvertently removed. To circumvent this issue, refrain from scratching the ventral surface of tergites where pigmented epidermis is located. Similarly, when cleaning underneath the carapace, particularly around the median ocelli, disruption of the black epidermis should be prevented. However, joint removal of epidermis when extracting the viscera may be inevitable for moderately decomposed specimens due to the adhesion between tissues. Hemispermatophores in males are positioned near the first visible sternite (3rd sternite) and can be preserved independently (Fig. 10). Further purification of the pro- and mesosoma can be attained by the strategic insertion of a syringe via the oral cavity at variable depths, followed by flushing to ensure thorough cleanliness. Likewise, a similar technique can be employed via the anus for the metasoma, especially in instances of residual excrement. Extraction of the semi-transparent muscular tissues within the appendages is deemed unnecessary, as it may potentially incur the detachment of segments.

(2) Embalming stage: Upon completion of the cleansing process, air-dry the specimen and then immerse it in embalming fluid for a duration commensurate with its size (typically at least one week for median-sized (ca. 7 cm) species when employing 75% ethanol). The embalming fluid will stiffen the specimen, posing challenges for subsequent manipulation. Notably, certain genera such as *Hottentotta* Birula, 1908 and *Leiurus* Ehrenberg, 1828, characterized by a rigid cuticle, were observed with accelerated stiffening rates, necessitating preemptive measures such as pinning to a foam board to minimize distortion (e.g., Tang, 2023b: fig. 96). A simpler but less effective alternative involves stretching the appendages to mitigate curling. If embalming fluid is temporarily unavailable, store the specimens in the refrigerator (avoid freezing in water as ice formation could lead to breakage).

Cotton-filling, while its necessity is contingent upon various factors, can be done *a priori* or *a posteriori*. Scorpions with an inflated abdomen (typically fed juveniles or females) may require cotton-filling to prevent deformation, a recommendation also applicable to those with thin, soft cuticles (typically juveniles or certain small forest species, such as euscorpiids and *Liocheles* Sundevall, 1833). Specimens with contracted membrane or any taxa with hard cuticle (typically arid buthids, e.g., *Androctonus* Ehrenberg, 1828, *Parabuthus* Pocock, 1890, *Hottentotta*, *Leiurus*, *Olivierus* Farzanpay, 1987, etc.) may not require such intervention (Figs. 6–8). Preemptive cotton-filling is often deemed preferable for specimens with loosen membranes which will be rigidified by the embalming fluid, rendering *a posteriori* filling more challenging. *A priori* filling should be accompanied with infusing the scorpion's coelom with embalming fluid using a syringe to expel internal air and ensure complete immersion. This procedure can be conducted beneath the fluid surface to prevent leakage.

(3) Air-fixation stage: After embalming, retrieve the specimen and position it securely with needles at desired angles on a foam board dorsally. Any detached or damaged structures can often be repaired with glue. Iron wires may be used to reinforce narrow structures, such as appendages and metasoma, by connecting them to the body. In the presence of preemptively filled cotton, more surfaces are available for attaching the wired structures.

Allow the specimen to desiccate in a cool, dry environment (e.g., under an air-conditioner) for an extended period to minimize deformations (Fig. 9). Inadequate drying time may give rise to significant distortions due to incomplete desiccation of the intersegmental membrane, particularly in the angles secured for appendages and metasoma. However, even with months of drying, deformations may still occur, albeit to a lesser extent. An alternative method involves "baking" the scorpion under a reptile UVB light, which expedites desiccation but may result in more pronounced discoloration. If employing this method, it is important to ensure a safe distance between the specimen and the lamp.



Figures 4–10: Additional references depicting the fixation of standard dry specimen. **Figure 4**. *Buthus elmoutaouakili* Lourenço & Qi, 2006, adult female. **Figure 5**. *Parabuthus granulatus* (Ehrenberg, 1831), subadult female. **Figure 6**. *Parabuthus pallidus* Pocock, 1895, adult male. **Figure 7**. *Hottentotta minusalta* Vachon, 1959, adult female. **Figure 8**. *Androctonus turkiyensis* Yağmur, 2021, adult male. **Figure 9**. Stacks of fixed specimens during the open-air drying process. **Figure 10**. *Chersonesometrus tristis* (Henderson, 1919), adult male, with plasticized hemispermatophores stored in centrifuge tubes.

In the event that the ambient air humidity is unfavorable, one may also attempt to dehydrate the specimen by placing it in a box with silica gel desiccants covered upon. The author's trials revealed that this process can result in a more whitish appearance in the membrane, as opposed to the yellowish to brownish tones observed after "baking" the specimen.

On the other hand, if one opts to stabilize the specimen on the foam board prior to the embalming stage, using 99% ethanol can significantly facilitate the fixation of appendages, thus saving considerable time during the air-fixation stage. However, this method may require large quantities of pure ethanol, which may not be easily accessible for individuals in certain countries. The usage of pure ethanol can also be economically suboptimal due to their much higher volatilization rate.

III. Scenarios where specific steps are unnecessary or dry preservation is inadvisable

The suitability of dry preservation for many juvenile scorpions at early developmental stages (e.g., 2nd to 3rd instar) is cautioned against due to their inherent flexibility and fragility, rendering them susceptible to deformation during desiccation. Particularly, well-fed juveniles characterized by an inflated mesosoma often possess a soft, thin pleural membrane, further predisposing them to structural compromise. Certain species may exhibit conditions analogous to those observed in the juveniles of others, such as those with small body size, soft cuticle and loosen pleural membrane. Hence, preservation in embalming fluid is advocated as a preferable approach, a recommendation also applicable for the preservation of type specimens used in taxonomic studies. In addition, from an aesthetic perspective, scorpions that have been deceased for an extended period are deemed unsuitable candidates for dry preservation, given the propensity for discoloration and brittleness may manifest during the embalming process.

Specimens exhibiting a flattened mesosoma after an extended post-mortem period trivialize the removal of internal organs, as the rigidity of their membrane precludes facile dissection. Coercive dissection may result in the damage of specimen. Consequently, it necessitates prolonged immersion in embalming fluid to ensure sufficient antisepsis, which further reinforces the rigidity. Needles can be used to penetrate the specimen at the intersternite membrane to allow permeation. Despite the discoloration in those long-dead specimens, this defect is deemed inconsequential for dark-hued species. On the other hand, the excision of internal organs from those specimens may inadvertently remove adhered epidermis, resulting in regional translucency. To mitigate this effect, the application of brownish-black dye to cotton fillings offsets the resultant discoloration, particularly for darkly pigmented scorpions within taxa such as Pandininae and Heterometrinae, which are susceptible to analogous issues irrespective of post-mortem duration. However, it is important to note that dyeing only serves to enhance visual aesthetics and is not recommended for specimens intended for scientific purposes.

IV. Techniques for cotton-filling

The utilization of PP cotton is advocated over medical cotton owing to its greater flexibility, particularly conducive to the seamless expansion within the mesosoma, ensuring a relatively smooth resultant surface of the pleural membranes for specimens showcasing an inflated abdomen prior to dissection (Figs. 4–5). A methodical approach to cotton insertion is recommended to achieve a uniform final filling. Akin to the mathematical concept of integration, gradual incorporation in small, incremental amounts can prevent irregularities and maintain structural integrity. Careful consideration must be given to avoid excessive protrusions or overfilling, as such practices may yield an unnatural appearance or, worse still, precipitate the rupture of intersegmental membranes.

V. Techniques for pinning

The positioning of anatomical structures within a dry-preserved specimen is subjective, bereft of stringent rules. However, a configuration characterized by symmetry and even arrangement with a radial profile is hereby recommended for its aesthetic appeal (Figs. 2–3). A suggestive scheme for the general positioning, although not always strictly adhered to by myself, is outlined. This method has been applied in my preceding taxonomic papers before photographing the overall habitus of specimens (e.g., Tang, 2023b; Tang et al., 2024a; Tang et al., 2024b). Nevertheless, those specimens were not dried out but only temporarily fixed and frozen in such way in advance, thus the appendage displacement was inevitable. The following "axes" associated with the appendages (pedipalps and legs) as well as their segments, when undefined, pertain to the proximo-distal axes.

The rostrocaudal (= somatic) axis, aligning the prosoma, mesosoma, and metasoma, should be orthogonal to the femoral axis and parallel to the chelal axis. An obtuse angle between the patellar and femoral axes of the pedipalp is desirable. The Bt•Tt joints of the same order (e.g., left and right Bt•Tt joints of the 1st leg) should be on a common line orthogonal to the rostrocaudal axis to guarantee symmetry. The distance between adjacent ipsilateral legs (L_i–L_{i+1}, where $1 \leq i \leq 3$ is the index of leg) is standardized primarily by the distance between adjacent Bt•Tt joints (L_i~Bt•Tt–L_{i+1}~Bt•Tt, denoted as $d\{\text{Bt•Tt}\}$) and secondarily by that between adjacent F•P joints (L_i~F•P–L_{i+1}~F•P, denoted as $d\{\text{F•P}\}$). Equidistance is encouraged for contralateral (left and right) adjacent-leg pairs (e.g., left L_1–L_2 and right L_1–L_2 should be equal). Symbolically, to ensure left L_i–L_{i+1} = right L_i–L_{i+1}, the distance between adjacent joints must satisfy: left $d\{\text{Bt•Tt}\}$ = right $d\{\text{Bt•Tt}\}$ and left $d\{\text{F•P}\}$ = right $d\{\text{F•P}\}$. However, the overall distance can follow an increasing arithmetic progression; i.e., L_1–L_2 < L_2–L_3 < L_3–L_4, calibrated by the joints. That is, the distance between ipsilateral (left or right) adjacent-leg pairs need not to be equal.

Pinning methodology entails a combination of epi-cross-fixation (ECF) and hypo-cross-fixation (HCF), whereby needles secure structures without penetrating them. ECF stabilizes the scorpion on the foam board, suppressing the structure by crossing over. On the contrary, HCF finetunes the angle, supporting it by crossing beneath. Initial fixation involves ECF at the prosoma, followed by the junction of the mesosoma and the 1st metasomal segment, and finally the 5th metasomal segment and telson. These represent three backbone landmarks that can be, on a case-by-case basis, removed following the overall completion. Subsequent fixations can be applied to other parts of the metasoma, not necessarily confined to the junctions between adjacent segments. However, it is recommendable to ensure straight alignment of the metasoma, with the mediolateral axes of all dorsal surfaces approximately parallel to a common horizontal plane.

Stabilization of pedipalps involves securing key joints such as F•P and P•C. Ensure nearly horizontal dorsal surfaces of both patella and femur. Stabilization of legs initiates with extending the tarsus to an optimal position distally using tweezers, taking care not to dislodge the tarsus (gently clamping onto the basitarsus reduces the risk). Preference is given to first stabilizing the 1st and 4th legs to gauge the entire leg span, with a subsequent division of this interval into three quantiles by the remaining two legs. Fix the leg tarsus via ECF at or near Bt•Tt. Adjust the included angles formed by the proximo-distal axes of preceding segments, starting at the F•P joint. Pushing it forwardly with a needle would render a larger angle formed by the patellar and femoral axes. Additionally, inspect the left and right trochanteric axes of the same order (e.g., trochanters of left and right L_1) to yield a symmetric direction with respective to the rostrocaudal axis. Ensure that the leg gradually and smoothly descends to the horizontal foam surface from its connection with the prosoma

Figures 11–14: Freshly treated adult male *Androctonus australis* (Linnaeus, 1758); same for Figs. 15–27. **Figures 11–12**. Resting postures. **Figure 13**. Self-defending posture after being disturbed during its rest. **Figure 14**. Water-intaking posture.

(i.e., forming a large included angle between the leg axis and the sagittal plane of carapace), with needles providing support underneath to prevent the downward buckling at certain joints. Since the leg segment (e.g., femur) of scorpion is compressed at one direction, imagine it as a dorsoventrally flattened cuboid with the upper surface representing the prolateral surface. It is advisable to keep the majority of the prolateral surface visible to the observer when fixing the scorpion. That is, if the cuboid is tilted forwardly to the horizontal surface, the inclination angle formed by the horizontal surface and the upper surface should be acute (ca. ≤ 60°). However, those directional manipulations of legs may be impeded by the excessive rigidity caused by the embalming fluid if the immersion time is not well-controlled.

While not applied to all my dried specimens, readers may opt to open up the fingers of chelae and chelicerae so as to unveil the dentition on the opposing edges of those structures. The above elucidation may not be intuitive or exhaustively cover all nuances, and personal experimentation is encouraged for clear comprehension. The sequential order of pinning is deemed inconsequential and thus may be adjusted according to the discretion of practitioners as they see fit.

VI. Notes for fixation and desiccation

Upon extraction from the embalming fluid, scorpion specimens may exhibit considerable deviation from ideal anatomical orientations. The rigidity caused by weeks of immersion requires robust stabilization with the use of multiple needles. However, the extensive use of needles can obstruct visibility and potentially result in imperfect pinning. To address these challenges, a multi-phase approach to fixation and desiccation is proposed, comprising sequential adjustments tailored to the specimen's evolving physical state.

The initial phase serves as a rudimentary rectification step, aimed at ameliorating the specimen's distorted posture accrued during embalming. Coarse adjustments are performed by applying multiple needles to stabilize the specimen firmly. Upon transition to the second phase, characterized by partial desiccation, needles employed in the initial phase are removed, supplanted by a reduced complement strategically placed to re-stabilize the specimen. This judicious reduction optimizes visibility, precluding erroneous orientations while affording opportunities for corrective interventions prior to any inordinate desiccation. The third phase, optionally undertaken during the latter stages of desiccation, capitalizes on the specimen's near-fixed state for finer improvements. All needles are once again withdrawn, replaced by a minimal yet strategically positioned set to maintain contingent stabilization.

Ultimately, this incremental reduction in needle count, coupled with strategic placement, minimizes the risk of appendage breakage during the delicate final removal stage, wherein the specimen attains heightened fragility consequent to dehydration. By adhering to this progressive approach, practitioners can navigate the intricate equilibrium between stabilization and visibility, culminating in the meticulous preservation of scorpion specimens with diminished risk of structural compromise. However, evaluation of the specimen rigidity that indicates desiccation degree would require firsthand practice.

Ecological specimen

I. Overview

To clarify, the term "ecological specimen" as defined herein encompasses both an ethological specimen (one with designed postures emulating a live counterpart) and an artificial diorama. Absent the latter, it simply constitutes an ethological specimen. Despite the advanced techniques and supplementary tools involved in making an ecological specimen, it affords practitioners significant design flexibility. Orientating and stabilizing the scorpion in an approximately symmetrical configuration is uncalled for; rather, emphasis is placed on comprehending the biomechanics underlying each action and the precise postural geometry exhibited by live scorpions.

While extant scorpions display morphological diversity, their relatively conserved body plan allows for a general paradigm of ethology, albeit with exceptions due to specialized behaviors arising from various ecomorphological adaptations. Although extensive literature exists on scorpion ethology (e.g., Alexander, 1956, 1958; Eastwood, 1977; Foerster et al., 2021; Harington, 1978; Jiao & Zhu, 2009a, 2009b; Lira et al., 2019; Nime et al., 2016; Olguin-Perez et al., 2021; Olivero et al., 2019; Polis & Farley, 1979; Rein, 2003; Tang, 2023a; Triana et al., 2022), the veracity of a resultant ecological specimen does not necessarily mandate a perusal of those works. Direct observations on live scorpions are desirable, yet individuals may lack firsthand experience with scorpion ethology or access to live specimens. An ethological specimen symbolizes a fragment of time, an essence shared with photographs captured by a camera. This common nature parallels these two entities, thereby enabling practitioners to produce vivid ethological specimens by faithfully replicating postures with reference to online resources like the citizen science platform iNaturalist, which offer readily available photographs of wild scorpions.

A scorpion's behavioral repertoire is not confined to mere threatening postures with their metasoma raised aloft. Depending on the selected taxon, a plethora of different behavior exist for one to simulate, including: relaxation, burrowing, water-intake, resistance, self-defense, intraguild or intraspecific competition, venom-spraying, thanatosis, ambulation, gallop, prey-detection, prey-subjugation, prey-consumption, cannibalism, self-cleaning (daily, or post-predation) and courtship. Three main criteria are proposed for the quality of an ecological specimen, with a focal emphasis on the first: (1) fidelity (the degree to which the specimen resembles a living scorpion); (2) terrain setup; (3) color preservation.

II. Additional tools and basic steps

(1) Additional tools: Given that an ethological specimen may involve elevated positioning of anatomical structures, stronger supports are hence required. Toothpicks provide a cost-effective yet adequate option, while iron wires can also be employed for specific postures. Modeling clay may serve as the terrain foundation, with acrylic display boxes as containers. A variety of substrates and components are feasible for terrain setup, dependent on the microhabitat to be simulated. Ideally, utilizing materials directly sourced from the scorpion's original habitat is optimal. However, considering the variability in practitioners' proximity to natural environments, access to such materials may be constrained. In such cases, one may use alternative components to simulate the original microhabitat, referencing papers or platforms like iNaturalist for guidance. An exhaustive list of substitutes is omitted here; however, a few suggestions are provided below.

Tree powder, frequently used in the design of miniature scenery terrain, may function as "proxies" for true mosses, with appropriate dyeing enhancing realism. This obviates the need for sophisticated plant preservation techniques, such as through lyophilization and plasticization. Certain behaviors and dioramas may necessitate the use of white glue to replicate venom drops, while water texture gels can effectively mimic various transparent liquids, including environmental waterbodies or the saliva scorpions use for self-cleaning. A blend of different substrates recreates the wild microhabitat authentically, for instance, sand, gravel, peat, loam and clay (e.g., loess). Pure use of coconut soil (commonly used as the substrate for pet scorpions) is discouraged as no scorpions have been observed to reside in such substrates in nature. Similarly, pure sand should be used judiciously unless the selected species is psammophilic (e. g., *Apistobuthus* Finnegan, 1932, *Buthacus* Birula, 1908 and *Vachoniolus* Levy, Amitai & Shulov, 1973). Hardly do most scorpions inhabit entirely barren sand dunes lacking any other elements. It is advisable to include stones and debris from dead plants for decorative purposes.

(2) Basic steps: The process of creating an ecological specimen is more adaptable and personal, thus only some general tips are provided here. After embalming the scorpion, pin it onto a foam board in the desired posture (details below). Depending on the associated diorama, transferring it to the terrain setup before complete desiccation may be necessary, allowing adjustments to align with the terrain profile. White glue can be used to stabilize their tarsi on the surface. Use white glue or scenic spray glue (preferable for humid dioramas) to

Figures 15–18: **Figures 15–16**. Burrowing posture. **Figures 17–18**. Loitering (17) and striding (in a vigilant state; 18) postures.

adhere substrate or scene components to the clay base. Begin by sprinkling small grains as the base layer and then manually attach larger grains to add dimensions.

III. Color and texture preservation

The observed color of scorpions is primarily a combined optical effect of their amber-colored cuticle, pigmented epidermis, and internal viscera. Drawing from observations on scorpion exuviae, it is noticed that their cuticle maintains its pigmentation under normal conditions, particularly when preserved in a dry environment at room temperature. Viscera, typically light brownish, are removed during the dissection phase. Upon decomposition and dehydration, these organs infuscate over time post-mortem, contributing to a darkened hue in specimens devoid of their removal. On that account, the extraction of viscera becomes crucial, leading to an inevitable color discrepancy between live specimens and their dissected counterparts. While the use of dyed cotton in replacement of those tissues constitutes a viable option, replicating their intricate distribution within the coelom presents challenges. As such, the coloration of a treated specimen mainly hinges on the preservation of their epidermal pigments. Properly dissected and embalmed scorpion specimens derived from fresh materials typically avert significant epidermal discoloration, hence the abstention of specialized color preservation treatments. However, if other animals such as crickets, which scorpions prey upon, are included in the diorama, color preservation may become essential due to the delicate nature of these arthropods and their susceptibility to discoloration.

Mou et al. (2018) have proposed a preparation method for a preservative color retention agent (PCRA) targeted at green-colored insects in their patent application (in Chinese). Their PCRA requires the preparation for two solutions (termed A and B), and involves materials that may not be readily accessible (e.g., benzene solution). For the convenience of interested readers, a translated methodology is summarized below:

> Solution A is subdivided into solutions A-1 and A-2. For A-1 preparation, formalin (a 35-40 wt% saturated aqueous solution of formaldehyde) is mixed with water in a 1:1 volume ratio, followed by the addition and thorough mixing of 0.015 mol/L potassium sorbate and 0.01 mol/L DL-tartaric acid. Regarding A-2, 0.005 mol/L hindered amine light stabilizer-770, 0.03 mol/L sodium benzoate, and 0.01 mol/L phenylthiourea are added to anhydrous ethanol prepared in a 3:1 volume ratio to formalin. For preparation of solution A, A-1 and A-2 are mixed, and the pH is adjusted to 8.0-9.0 using a 0.01 mol/L sodium hydroxide solution. Solution B is a benzene solution of 0.02 mol/L UV-531.

Formaldehyde exhibits potent reducing and preservative bactericidal properties. Potassium sorbate and sodium benzoate are widely used preservatives in the food industry. DL-tartaric acid acts as an antioxidant synergist. Hindered amine light stabilizer-770 contributes to photostabilization and enhances the heat resistance of antioxidants. UV-531 in solution B also serves as a photostabilizer, primarily absorbing UV light within the range of 240–340 nm. For color preservation, immersion of the insect in solution A for 2–5 minutes, followed by drying and brushing with solution B, is recommended.

Given the unavailability of certain ingredients, I have veered to a more straightforward approach: plasticization. Polyethylene glycol (PEG) serves as a versatile polymer capable of penetrating tissues and displacing water, thus preventing shrinkage and distortion during processing. A juvenile *Acheta domesticus* (Linnaeus, 1758) was freshly euthanized in freezer, and immediately preserved for 7 days in a specialized embalming fluid purchased online (Tang, 2023b: 1). Early personal tests on fed juvenile scorpions demonstrated that although this fluid can maintain their rounded mesosoma with smooth membrane, significant shrinkage nonetheless occurred over a short time period upon air-desiccation. Gradient solutions of polyethylene glycol with a molecular weight of 600 (PEG-600) at four concentrations (25%, 50%, 75%, and 100%) were prepared using water. Submerging the cricket sequentially in each of these solutions for 24 hours yielded a satisfactory outcome (Figs. 53–54). Despite retaining its viscera, the cricket's abdomen did not undergo infuscation. Severe shrinkage was not observed even after desiccation for approximately 1000 days. Fortuitous tests employing the same method were also conducted on a pair of adult *Lychas mucronatus* (Fabricius, 1798). However, their pro- and mesosoma showcased significant darkening, hereby eclipsing the embedded color patterns. Still, compared with their counterparts subjected to conventional procedures which were rendered matte due to desiccation, the plasticized specimens retained a pronounced hydrated texture. This effect proved to be more authentic than the application of Tamiya gloss coating varnish utilized in the coloring of model figures. Albeit unexplored, it may be beneficial to consider a combination of techniques, such as incorporating photostabilizers into the embalming fluid and subjecting the dissected specimen to gradient solutions of PEG-600 for plasticization.

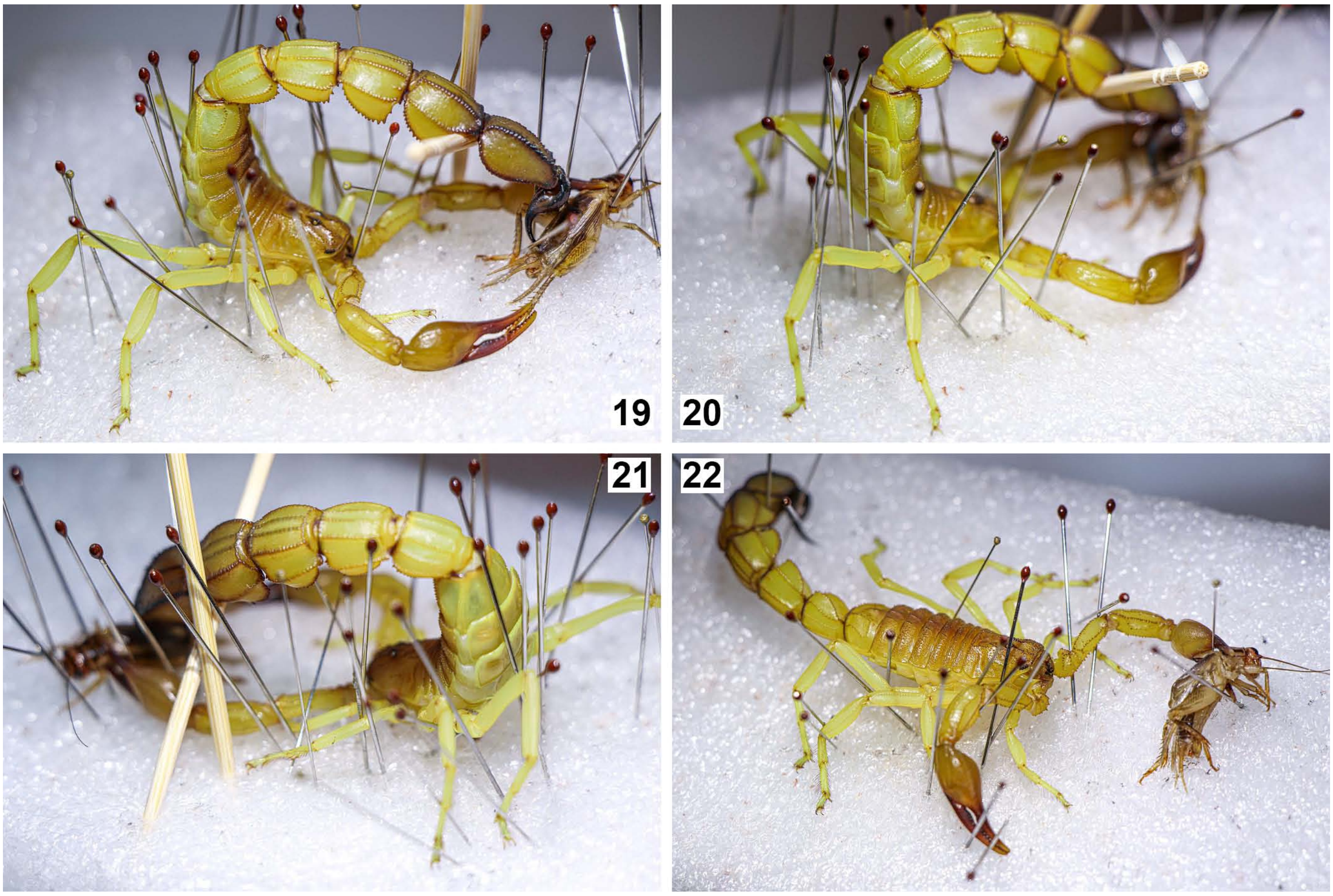
IV. Posture notes

As the main body of the ecological specimen aimed at replicating a live animal, the posture of the scorpion outweighs all other essential elements. A lifelike resemblance to a living scorpion can be achieved solely through accurate fixation, without the addition of scenic terrain. Unfortunately, many ecological (or ethological) scorpion specimens have fallen short in this aspect, often displaying exaggerated or twisted postures. These instances, where fidelity was not achieved, indicate that the crux lies in a dearth of episteme regarding scorpion behavior. A few authors have conducted studies on the locomotion of scorpions (e.g., Coelho et al., 2017; Root & Bowerman, 1978; Telheiro, 2019; Telheiro et al., 2021), which may prove informative for those unfamiliar with scorpion behavior. While those papers offer valuable and methodical insights, the same inductive understanding can be conveniently derived from direct observations. This paper aims to provide an intelligible interpretation of scorpion postures based on simple logic and empirical evidence.

The inherent flexibility of their articulated segments empowers scorpions to adopt miscellaneous postures, conditioned primarily on their instantaneous impetus, physiological state and environmental constraint. While it is easy to manipulate the corpse of a dead scorpion into various postures, not all of these are necessarily performed by live scorpions. In contrary, most scorpions adhere to a general paradigm regarding the orientation of their anatomical structures. Environmental constraints exert significant influence on a scorpion's locomotion, while abnormal physiological states may also contribute to static postures that appear unnatural. Unless the practitioner deliberately intends to replicate such scenarios, they may not be considered lifelike and those factors are therefore omitted from the following discussion.

(1) Curling angle of metasomal segments and telson: The curvature of metasomal segments varies depending on the posture of the scorpion. A resting scorpion typically adopts a more compact configuration of metasoma, progressively decreasing the included angle between adjacent segments towards the posterior end ($\angle M_5\text{-}M_4 < \angle M_4\text{-}M_3 < \angle M_3\text{-}M_2 < \angle M_2\text{-}M_1$), coiling it closer to the mesosoma. This pattern is mathematically intuitive. The progressively increasing length of metasomal segments, alongside the given fact that the intorsion begins at the distal segment, predetermine a decreasing rate of spiral and thus an increase in the included angle. In general, resting scorpions may curl up all segments or only M_4 and M_5 (e.g., Fig. 11). Occasionally, a curvature directed towards an opposite orientation may be observed at $M_2 \bullet M_1$, or the junction between M_1 and mesosoma, resulting in a S-shaped overall configuration (e.g., Fig. 12). The S-shaped metasomal configuration is more often observed in buthids dwelling narrow tree crevices (e.g., *Centruroides* Marx, 1890).

In cases where the metasoma is lifted (e.g., for intimidation or attacking, or during locomotion), the metasomal curvatures of most scorpions are very uniform, with similar included angles. However, some scorpions may often form a smaller included angle between M_4 and M_5 (e.g., Figs. 18, 72–73), occasionally with another relatively small angle between M_3 and M_4. These variations are predicated on interspecific differences in behavioral preference and the current physiological state of the individual. Be as it may, a rule of thumb can be generalized as: $\angle M_5\text{-}M_4 < \angle M_4\text{-}M_3 < \angle M_3\text{-}M_2 \leq \angle M_2\text{-}M_1$ (e.g., Fig. 13), unless extended forwardly, thereby concealing their mesosoma; otherwise, $\angle M_2\text{-}M_1 < \angle M_5\text{-}M_4 < M_4\text{-}M_3 \approx \angle M_3\text{-}M_2$ (e.g., Fig. 36). However, it must



Figures 19–22: **Figures 19–21**. Prey incapacitation posture. **Figure 22**. Post-predation cleaning (of aculeus and chelal fingers) posture.

be emphasized that this is only a proportional quantification of the included angle, and the exact angle values are dependent upon species. The pre-attack stance of metasoma can differ significantly across species; whereas some species may display a more straightened metasoma (e.g., Scorpionidae Latreille, 1802, *Leiurus*, etc.), others may prefer to keep it coiled to deliver a forceful strike (e.g., *Androctonus* and *Parabuthus*). Coelho et al. (2017) have demonstrated that the strike trajectory kinematics and shape vary interspecifically, conditioned upon factors such as the length and girth of metasoma, body size and preference for defensive strategy. For example, species with a robust metasoma may execute strikes with relatively greater velocity and acceleration. Nevertheless, exemplified by *Leiurus quinquestriatus* (Ehrenberg, 1828), slender metasoma can also produce a rapid strike for the less energy required to accelerate their lighter metasoma. Personal observations indicated that the pre-attack posture of metasoma largely dictates the ensuing strike. Scorpions that maintain their metasoma relatively straight tend to adopt motions akin to upward whipping, prioritizing attack distance (e.g., Tang, 2023a: figs. 1a), whereas those with a curled metasoma often demonstrate movements reminiscent of ejection, favoring the repulsion of the target (e.g., Tang, 2023a: fig. 7a).

Furthermore, in instances of evasive behavior, scorpions may adopt a trailing position of their metasoma to reduce mechanical loads on their feet and therefore maximizing their speed, particularly common in heavier adult females. Conversely, a contrasting behavior has been observed in scorpions urgently seeking shelter from intense sunlight, where their metasoma is raised aloft and extended forward, potentially aim to decrease their contact area with the scorching surface. The metasoma may also function to maintain balance during a scorpion's locomotion, similar to the role of the tail in felids. A change of metasoma position leads to a shift in the center of mass, especially when its mass constitutes a large fraction of the total body mass. The transition from a lowered to an elevated metasoma may also be prompted by an increase in the elevation angle of the surface upon which the scorpion resides. Scorpions with relatively strong metasoma have been observed to swing their metasoma during ascending, which may constitute an alternative for saltatory locomotion via legs. The forward extension of the metasoma may instantaneously generate a upward momentum conducive to meeting their slope-ascending needs. Redistributing their weight by aligning their metasoma with mesosoma will effectively shorten the length of the body (lever arm) and shift the center of mass to the anteriority. However, raising the metasoma over their mesosoma could also simultaneously increase the gravitational potential energy, in contrast to aligning it with the surface. As a result, scorpions with their metasoma lowered often exhibit higher speeds when ascending a slope (Figs. 55–56), whereas those with an arched metasoma tend to climb more slowly. Lowering the metasoma keeps the center of mass closer to the climbing surface, reducing the torque exerted by gravity that attempts to dislodge the animal from the substrate. This positioning makes it easier for the tarsal ungues to maintain a grip while the scorpion climbs, thereby facilitating an increased ascent speed. The adoption of either posture is not mutually exclusive and can be observed within the same individual at different phases. This variation in speed may lead to differences in leg movement magnitude, which subsequently affects leg positioning.

Scorpions usually do not exorbitantly extend their telson forward, aligning it with the curvature of their metasoma. However, such a posture may be observed during or just after the self-cleaning behavior when their telson is extended towards their chelicerae. Alternatively, a scorpion may keep its telson extended post-strike, especially after multiple stings that result in physical fatigue preventing retraction. This behavior may also occur when the scorpion perceives the target as relentless and requires timely attacks, thus keeping the telson close to it. Commonly, the included angle between the telsonic axis and M_5 is not obtuse ($\angle$Tl-$M_5 \leq 90°$) as it is otherwise physically demanding, unless the scorpion is making a desperate attempt to reach the target. The underlying logic is intuitive, as a sufficient trajectory interval is necessary to produce a powerful strike, and a partial retraction of the telson prevents unwanted breakage of aculeus due to accidental collision.

(2) Retraction and extension of pedipalps: The geometry of retracted pedipalps during a resting state is closely related to environmental constraints (e.g., in a burrow). Even in the absence of interference from surrounding debris, both pairs of pedipalps are often closely pressed against the prosoma (e.g., Fig. 53). Quantified by the included angles between adjacent pedipalp segmental axes, when viewed from the top, scorpions with their femur tightly adhered to their prosoma follow two paradigms: (1) ∠C-P < ∠P-F, when the chela is placed more posteriorly (e.g., Fig. 11); (2) ∠C-P > ∠P-F, when the chela is placed more anteriorly (e.g., Fig. 41). However, if the scorpion assumes a more relaxed posture where its femur deviates from the prosoma, then the relationship only complies to ∠C-P ≥ ∠P-F (e.g., Figs. 12, 30, 40); configurations where ∠C-P < ∠P-F, which are typically indicative of death, have been rarely observed in live scorpions. The rationale underlying such postural preference is unambiguous: pedipalps, being the primary sensory appendages, are structurally optimized for forward and inward movements, thus naturally aligned in a similar direction as the prosoma during their "idle mode".

In a threatening posture (e.g., Fig. 31) or when extending the pedipalps while walking (e.g., Figs. 17–18), the chela does not excessively tilt upwards relative to the patella. The laterally projected line segments of chelal and patella axes on a sagittal plane form a large included angle (typically, ∠C-P > ca. 150°). The reason behind this phenomenon is also explicit. In order to expand their sensory purview, scorpions naturally extend their pedipalps forward, while a downward bending at C•P shortens their radius. However, if the target is small (i.e., low vertical dimension) and close to the scorpion, causing their body to tilt forward to take aim, the alignment of their chelal axis with the horizon serves as a support to balance out their changed center of mass. This might lead to a smaller included angle between chelal and patellar axes if their patella is tilted upward as their body (e.g., Figs. 24–26).

(3) Position of legs: Erroneously placed legs represent the most ubiquitous problem observed in many existing ethological specimens, and rectifying this aspect could significantly improve the overall appearance. The posture of the legs is highly determined by the surrounding environment and the center of mass. The following discussion assumes that the center of mass is located at the centroid of the body or along the rostrocaudal axis, targeting a stationary scorpion without considering terrain design.

The sagittal positioning of legs (i.e., "spacing" between adjacent legs) can be quantified by the distance between adjacent Bt•Tt joints. Three main types of leg spacing can be recognized: (1) L_1–$L_2 \approx L_2$–$L_3 \approx L_3$–L_4, where the spacing is uniform between all leg pairs (e.g., Fig. 52); (2) L_1–$L_2 \approx L_2$–$L_3 < L_3$–L_4, where the 4th leg is further away from the preceding legs (e.g., Fig. 42); (3) L_1–$L_2 \approx L_3$–$L_4 < L_2$–L_3, where there is greater spacing between the 2nd and 3rd legs (e.g., Fig. 35). The reason scorpions rarely position their 2nd to 4th legs away from the 1st leg lies in the reduction of balance if such a posture is adopted. Excessive ground reaction forces would be exerted on the 1st pair of legs, which now solely supports the anterior end. Since the 1st pair of legs is the shortest in scorpions, it cannot effectively bear too much weight on its own.

The second error involves the extent of leg extension, i.e., the mediolateral positioning of legs. This also entails an understanding of balance. Define d_i as the distance between the i th Bt•Tt joint and the rostrocaudal axis, similarly, this can also be categorized into three general types. In the first type (e.g., Fig. 27), $d_3 > d_4 > d_2 > d_1$, the 3rd leg is extended to a farther location. The 3rd and 4th legs, being the longest and located near the middle part of the scorpion's body, bear the majority of the body weight. The 4th leg is less distal as it mainly serves to support the weight of the rear part, especially that of the metasoma. The more distal positioning of the 3rd leg is advantageous for embracing lateral momentum, as it increases the spanning area of the scorpion by approximating a circle such that the highest degree of balance is afforded. The more proximal positioning of the first two pairs of legs is ascribed to their more anterior location, where less mass is concentrated. In addition, the pedipalps may also cater for a robust support at the front end, particularly during a burrowing activity (e.g., Figs. 15–16). The second type (e.g., Fig. 39), $d_2 \approx d_4 > d_3 > d_1$, where the 3rd leg is retracted, the 2nd and 4th legs are extended. This positioning offers less balance and is often tailored for locomotion or other movements within specific environments. The third type is $d_1 \approx d_2 \approx d_3 \approx d_4$, a more rarely observed case where the legs are relatively evenly extended. Such positioning renders a straight line formed by Bt•Tt joints, nearly parallel to the rostrocaudal axis. It is less optimal for immediate movement, as the shorter 1st and 2nd

Figures 23–26: **Figure 23**. Prey consumption posture. **Figures 24–26**. Threatening posture.

legs mainly responsible for delicate anterior movements are extended, while the longer 3rd and 4th legs mainly responsible for violent movements are retracted. Consistent positioning of at least one 1st leg beneath the pedipalps is imperative, as it supports the front part of the body and must be positioned forward. A pervasive trend in which people tend to place all legs posterior to the pedipalps has been observed. Such posture would lead to a loss of balance and a forward tilting of the scorpion in reality, if the surface is not rough enough for them to cling onto.

The final issue pertains to the included angles between the femoral, patellar and tibial axes of legs. In most cases of forward movement or stationary standing, these angles follow ∠F-P ≤ ∠P-T, with the opposite occurring only when the scorpion is constrained by its surroundings or moving backward (or when a specific ambulatory phase is interrupted). A similar conclusion was derived by Root & Bowerman (1978: fig. 7). This pattern essentially emanates from the difference in the allowable retraction magnitude between the F•P and P•T joints. A greater range of motion is permitted at the F•P joint, facilitating robust movements, while the latter is specialized for finer, more delicate adjustments. Additionally, The F•P joint, being closer to the body, would have a shorter lever arm compared to the P•T joint. This shorter lever arm affords greater control over the leg's movement. The force exerted at this joint benefits from a greater mechanical advantage, potentially leading to more efficient propulsion or force generation. Such attributes prove advantageous in tasks demanding rapid movement or substantial force exertion, as well as in maintaining balance by counteracting momentum. As a result, a smaller included angle allows for more elastic potential energy to be stored in the system, preparing the scorpion to cope with unexpected situations. However, an exception is known within the genus *Brachistosternus* Pocock, 1893, where many species adopt an angular stance for their 4th leg characterized by ∠F-P > ∠P-T (cf. iNaturalist obs. IDs = 200507077, 142612487, 142605947, 141124448). This configuration appears advantageous for supporting their elongated body profile. Interestingly, during threatening situations, these species would occasionally adopt an S-shaped configuration (as opposed to a C-shaped observed in most taxa) for their metasoma (cf. iNaturalist obs. ID = 52872983), although that nonetheless varies contingently (cf. iNaturalist obs. IDs = 179477170, 87206550, 70994252, 16730961). This extension of metasoma might be intended for an upward whipping tactic that prioritizes increasing the attacking distance.

Alternative leg configurations are contingent upon the terrain layout and the phase of the scorpion's locomotion (gait). For instance, when simulating a walking stance, the superimposed strides should be vertically offset, thereby mitigating disruptive interference amid neighboring appendages (Root & Bowerman, 1978: fig. 1B). The designed length of each stride delineates the velocity of the scorpion's ambulation (positively correlated). As the foremost limb, the 1st leg serves to discern potential impediments along the trajectory during navigation. It may be elevated to a greater degree, succeeded by the 2nd leg, while the subsequent pairs are typically raised to a lesser extent (Root & Bowerman, 1978: fig. 1A). Consequently, in an ambulatory scorpion, the 1st pair of legs only bear limited loads (Telheiro et al., 2017: 123) and hence a low duty factor (duration of foot contact with the ground during the step cycle). Owing to the discrepancy in leg lengths, the path of the initial two legs significantly overlaps, necessitating more pronounced and frequent motions to cover equivalent distances as those achieved by the elongated 3rd and 4th legs. Shifting from an ambulatory stance to a defensive posture where their metasoma is raised and directed towards the anterior target may result in the change of center of mass, and correspondingly that of their leg positions to compensate undesirable rotational momentum.

V. Additional notes on details.

Aside from the abovementioned general geometric configurations that portray a scorpion's posture, attention to several details could enhance the authenticity of the specimen. For example, if the posture involves the movement of chelicerae, such as water intake, self-cleaning, and prey consumption, it may be necessary to extend or even open the cheliceral fingers (or one of them, to replicate an alternating action; e.g., Figs. 23, 35). Freshly molted scorpions also extrude their chelicerae to facilitate optimal sclerotization, avoiding structural deformations due to pressure (e.g., Fig. 34).

Furthermore, any interaction with the environment (the designed terrain) could potentially result in observable physical effects. In a burrowing diorama, it is conceivable that a scorpion would create a small pile of sand near its rear end, while excavating a slope anteriorly with its first two legs (e.g., Fig. 29). Similarly, an ambulatory scorpion would leave observable foot or even tail tracks on loosen, fine surfaces, such as sand dunes. Other noteworthy scenarios may include a depiction of a scorpion residing in its burrow or a shallow depression. Observations in captivity have shown that median to large ground debris are often removed from their resting area.

Discussion

Taxidermy specimens serve as invaluable educational tools in various institutions, ranging from museums and research facilities to pedagogic institutions and exhibitions. These meticulously preserved specimens afford unique opportunities for scientific inquiry, public engagement, and educational outreach. The utilization of taxidermy in showcasing vertebrate specimens is omnipresent, with their educational import transcending mere display. Typically, taxidermy specimens in museums are positioned to mirror the antemortem ethology of the animal within a designed terrain aimed to recreate their habitat, thereby offering direct insights into their morphological characteristics, behaviors and ecological roles, serving as a palpable avenue for the populace to learn about biodiversity. The raison d'être behind its application is unequivocal. Taxidermy specimens, with their merit in long-term display and study, provide direct encounters with life-sized animals. They function as a safer and more economic vehicle for representing diverse fauna, without requiring continual care demanded by live counterparts. Exhibitions featuring taxidermy specimens can enthrall audiences of all ages, sparking curiosity and fostering a deeper reverence for the natural world.

Scorpions, with their unique morphology, behavior, and ecological adaptations, present captivating subjects for exhibition. While some educational institutions have directly employed live scorpions for display due to their minimal space requirements and low metabolic rates, the nocturnal nature of these creatures is incongruent with the objective of constant display. In a misguided attempt to address this, taking advantage of their fluorescent properties, some premises illuminate live scorpions under UV light throughout business hours, which poses accumulated physiological harm to the animals. Additionally, certain facilities showcase a lack of knowledge in the proper maintenance of live scorpions, providing inadequate environments, occasionally devoid of shelters, to expose them to visitors. In light of these unethical practices, it is advisable to utilize ecological specimens for exhibition in lieu of their live counterparts. Through careful replication of lifelike postures and environmental settings, taxidermists can craft educational displays that delineate the diversity and complexity of scorpion biology. Regrettably, the existing ecological scorpion specimens often fall short in accurately portraying scorpion ethology. As a result, the present paper offers several key insights that may assist in enhancing the vividity of those specimens. A realistic ethological specimen can be simply achieved through replicating a photographed live animal. As a surrogate, ecological scorpion specimens hold promise as unparalleled exhibits in museums, but it is recommended to include a photo of the live animal near the display container to account for inevitable color distortion in preserved specimens.

The standard dry specimen fixation for scorpions introduced in this paper intends to proffer a suggestive paradigm which improves the overall geometric aesthetics. Well-organized dry specimens can captivate visitors' attention, making exhibitions more appealing and memorable. Traditionally, more emphasis has been placed on fixing insects. Many natural history museums even orchestrated the arrangement of those dry specimens, such as butterflies, into multifarious configurations that evoke an artistic ambiance. While opinions may vary regarding the exact arrangement of biological specimens, it is undeniably more desirable where those dry specimens retain their primary function of clearly displaying the animal's morphology.

In conclusion, this article serves as a referential paradigm for readers to freely exercise discretion in its pursuance. The prospect of taxidermy scorpions is auspicious, and aptitude is non-required for their execution. Thus, while the focus of this paper centers upon its practicability in educational settings (and not in taxonomy), individuals with an interest in the topic can also derive insights from it.

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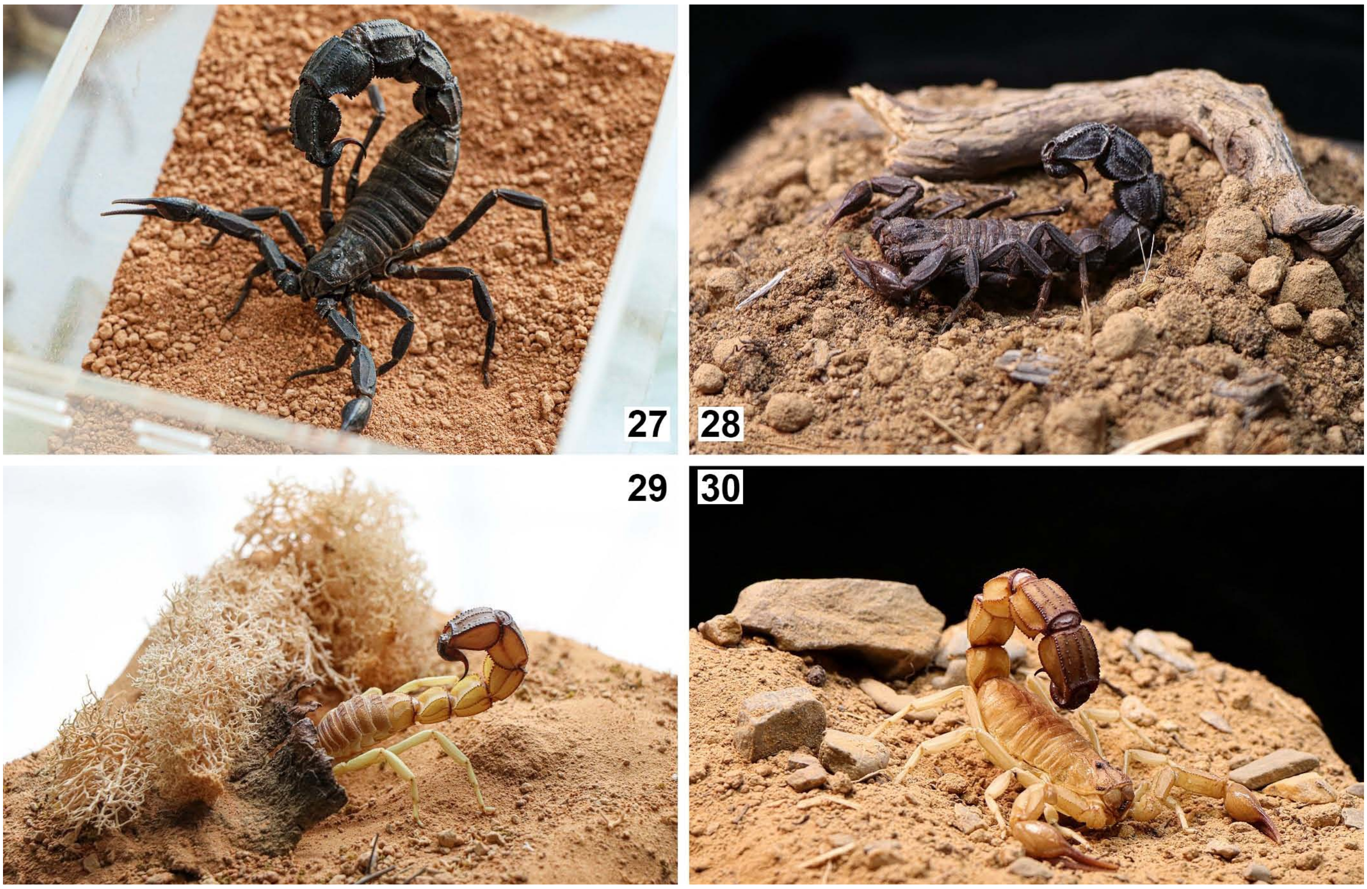
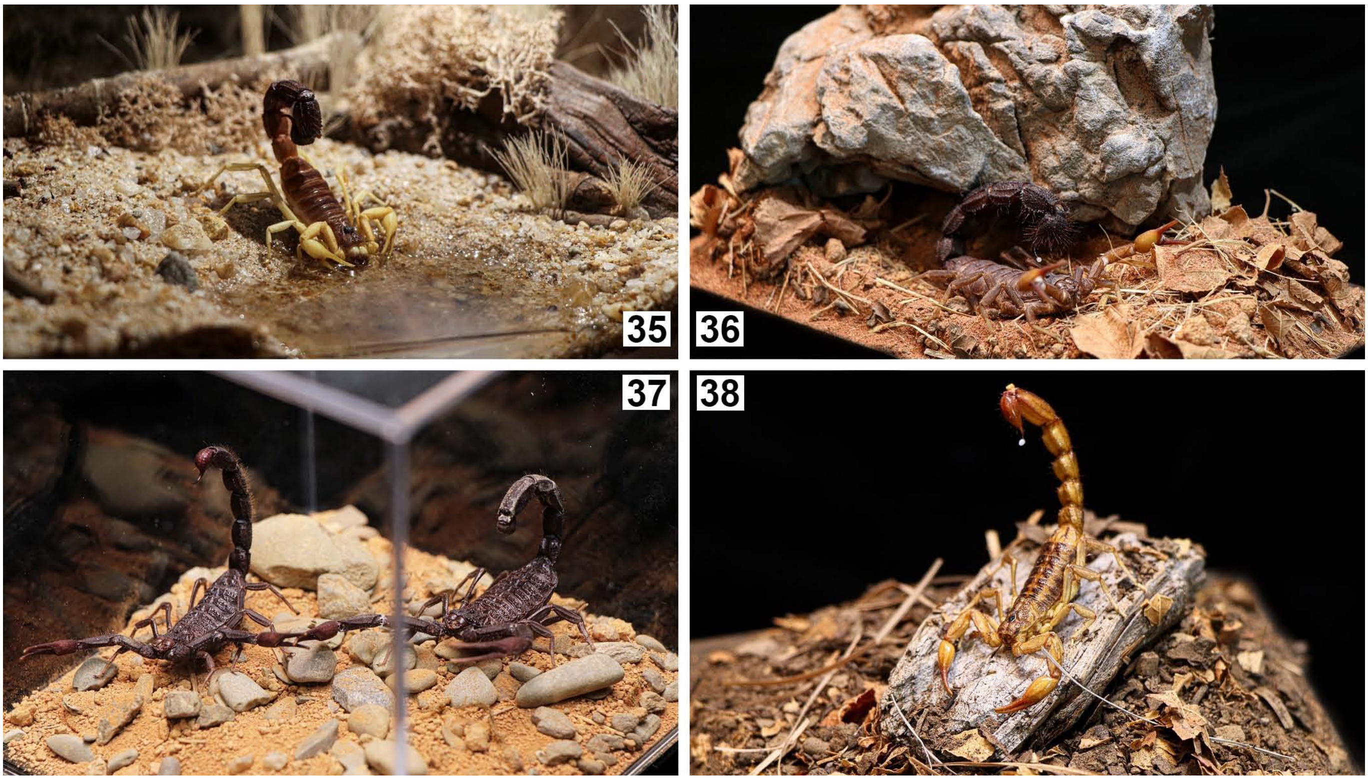
Appendix

A selection of the ecological/ethological scorpion specimens made by the author in the past few years. The author has also made similar specimens for Formicidae, Solifugae, Amblypygi, and Thelyphonida.



Figures 27–30: **Figures 27–28**. Ethological (27) and ecological (28) specimens of adult male *Androctonus mauritanicus* (Pocock, 1902). **Figures 29–30**. *Androctonus australis*, burrowing (29) and resting dioramas (30); a small pile of soil is mounted near the rear end.

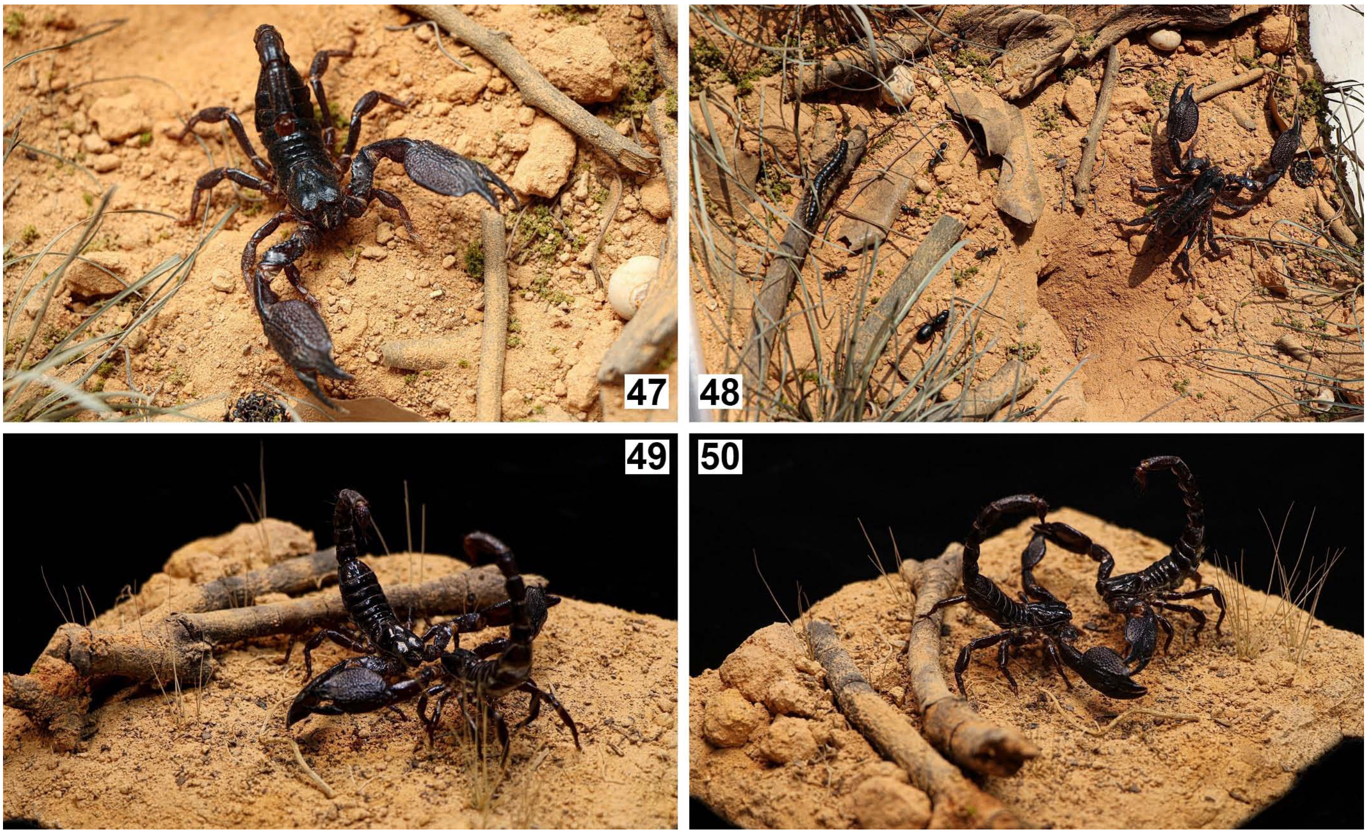
Figures 31–34: **Figure 31**. *Androctonus* aff. *crassicauda* (Olivier, 1807), threatening diorama of an adult male on dune slope; the metasoma is raised aloft and not excessively extended to prevent forward topple. **Figures 32–34**. *Teruelius grandidieri* (Kraepelin, 1900), post-ecdysis diorama of an adult male under tree bark; the chelicerae are pulled out and the exuvium is fixed in a typical stance.



Figures 35–38: **Figure 35**. *Parabuthus schlechteri* Purcell, 1899, water-intaking diorama of an adult male. **Figure 36**. *Parabuthus transvaalicus* Purcell, 1899, threatening diorama of an adult male, with venom drop on the tip of aculeus. **Figure 37**. *Hottentotta gentili* (Pallary, 1924), diorama replicating promenade á deux; the free pedipalp of the male is extended to replicate a forward detection and its metasoma is raised as typically observed in mating males (Tang, 2024a). **Figure 38**. *Mesomexovis punctatus* (Karsch, 1879), threatening diorama of an adult male, with venom drop on the tip of aculeus, inspired by the iNaturalist observation (obs. ID = 72967469).

Figure 39–42. Forest diorama depicting a resting *Heterometrus laevigatus* (Thorell, 1876) and several *Isometrus maculatus* (DeGeer, 1778).

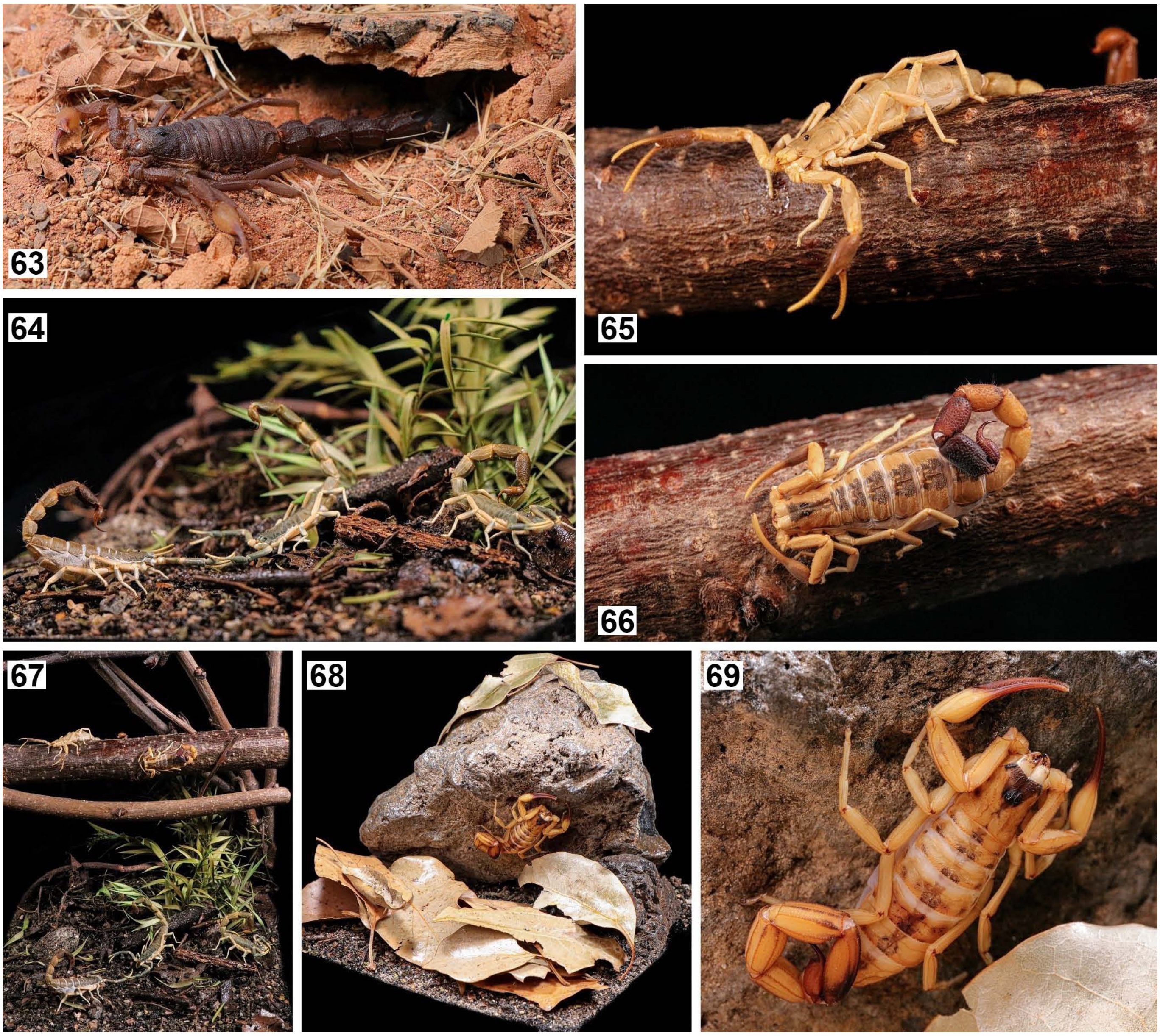
Figures 43–46: *Scorpiops validus* (Di et al., 2010). **Figures 43–44**. Adult female carrying newborns (plasticized prematurely deceased 1st instar scorplings). **Figures 45–46**. Promenade á deux.



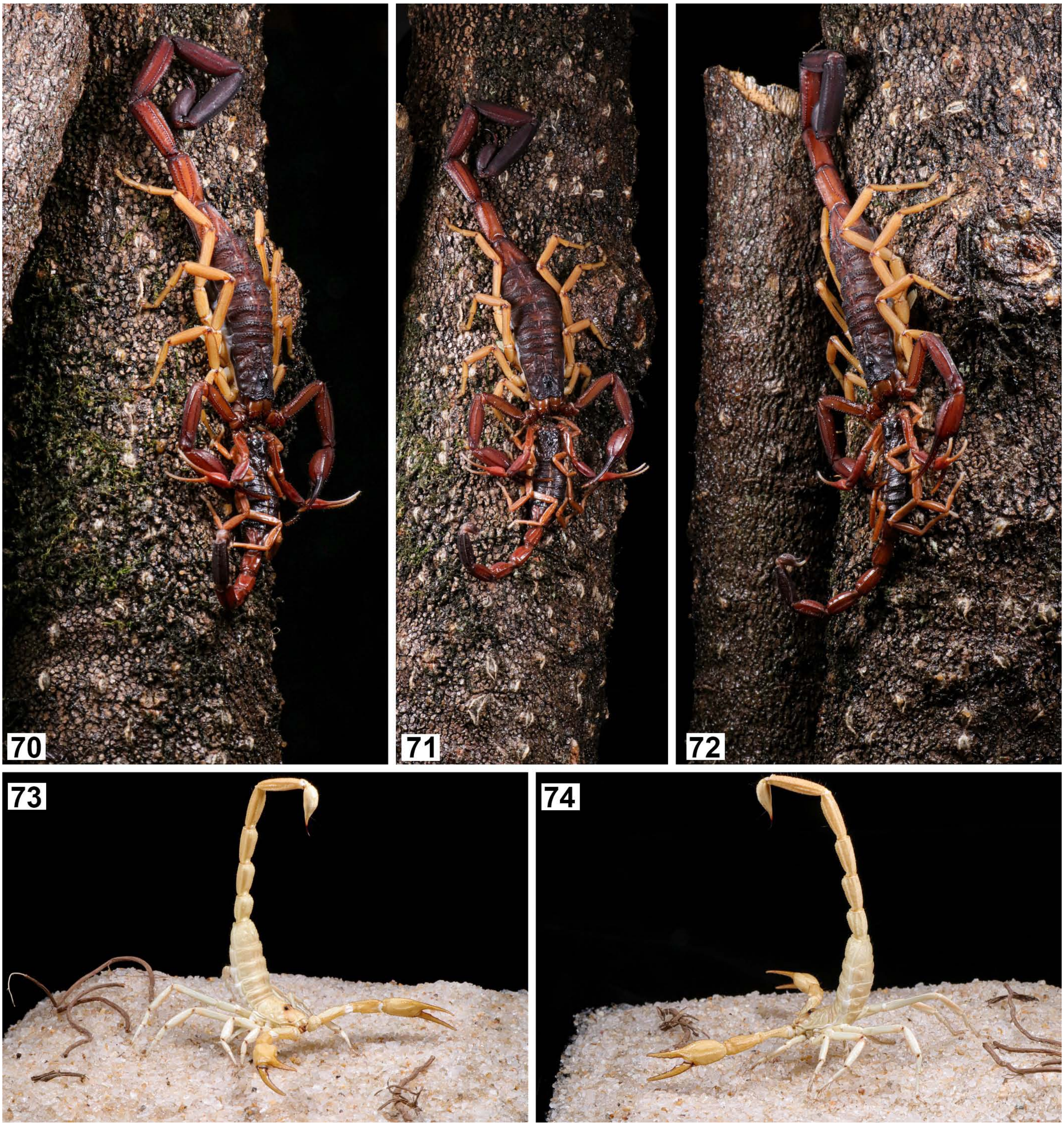
Figures 47–50: *Srilankametrus yaleensis* (Kovařík et al., 2019). **Figures 47–48**. The first scenic ecological specimen made by the author, delineating an adult male exiting its subterranean burrow. **Figures 49–50**. Arm-span competition (*sensu* Tang, 2023a) between two adult males.

Figure 51–**56**: **Figures 51**–**54**. *Heteroctenus junceus* (Herbst, 1800). **Figures 51**–**52**. An adult male with a captured cricket (51) and a resting adult female (52). **Figures 53**–**54**. Adult male in search of a soft spot to subdue a cricket; the cricket had been plasticized, and Fig. 54 was taken 945 days after the completion of plasticization, showing negligible deterioration in either texture or color. White objects are mothballs used for repelling borers. **Figure 55**–**56**. *Olivierus longichelus* (Sun & Zhu, 2010), adult male ascending a sand dune with replicated foot tracks; this species is psammophilous (cf. Tang et al., 2024b: fig. 154).

Figures 57–62. *Olivierus martensii* (Karsch, 1879), self-cleaning diorama of three adult males, with saliva recreated by water texture gels; note that the raw materials were ethanol-preserved specimens without removing the viscera. While *O. martensii* show considerable tolerance towards conspecifics, they may not cohabit in such density in their natural habitat. This diorama is aimed to collectively depict the various self-cleaning behaviors observed in this species.



Figures 63–69: **Figure 63**. *Parabuthus transvaalicus*, unilateral stretching/relaxation of appendages of an adult male; while this behavior has been constantly observed in captivity under dark condition, particularly post-ecdysis, which may facilitate their blood circulation, it is unclear as to how they would behave under natural environment. **Figures 64–67**. *Uroplectes olivaceus* Pocock, 1896, promenade á deux at the stage where the female shows resistance (64). *Uroplectes chubbi* Hirst, 1911, adult pair hanging on a twig (65–66). This diorama incorporates two sympatric species and depicts their different niche preferences (67). This diorama repositions two of the subjects above the base, creating the illusion of a section of a branch suspended in the air. Note also the loss of pigment in the mesosoma of male *Uroplectes*, as those were made from long preserved specimens. This is an imperfect diorama (and specimens were once broken) but serves to inspire readers. **Figures 68–69**. *Tityus stigmurus* (Thorell, 1876), adult female clinging under a rock.



Figures 70–74: **Figures 70–72**. *Centruroides gracilis* (Latreille, 1804), cannibalism between an adult male and a 5th instar juvenile. **Figures 73–74**. *Smeringurus mesaensis* (Stahnke, 1957), a subadult male displaying the iconic marching-threatening stance of this psammophilous species, with elevated metasoma and downward pedipalps.

Figures 75–80: **Figures 75–76**. *Scorpiops* sp. (Menglun, Yunnan; aff. *vachoni*), adult male displaying catalepsy in rigid posture (cf. Tang, 2023b: fig. 64). While this diorama seems mundane, personally, this is one of the most difficult postures to accurately replicate. **Figures 77–78**. *Pandinus imperator* (C. L. Koch, 1841), adult male displaying defensive posture (shielding response; Tang, 2023a) in a savannah diorama. **Figures 79–80**. *Teruelius flavopiceus* (Kraepelin, 1900), adult male descending to the leaf litter.

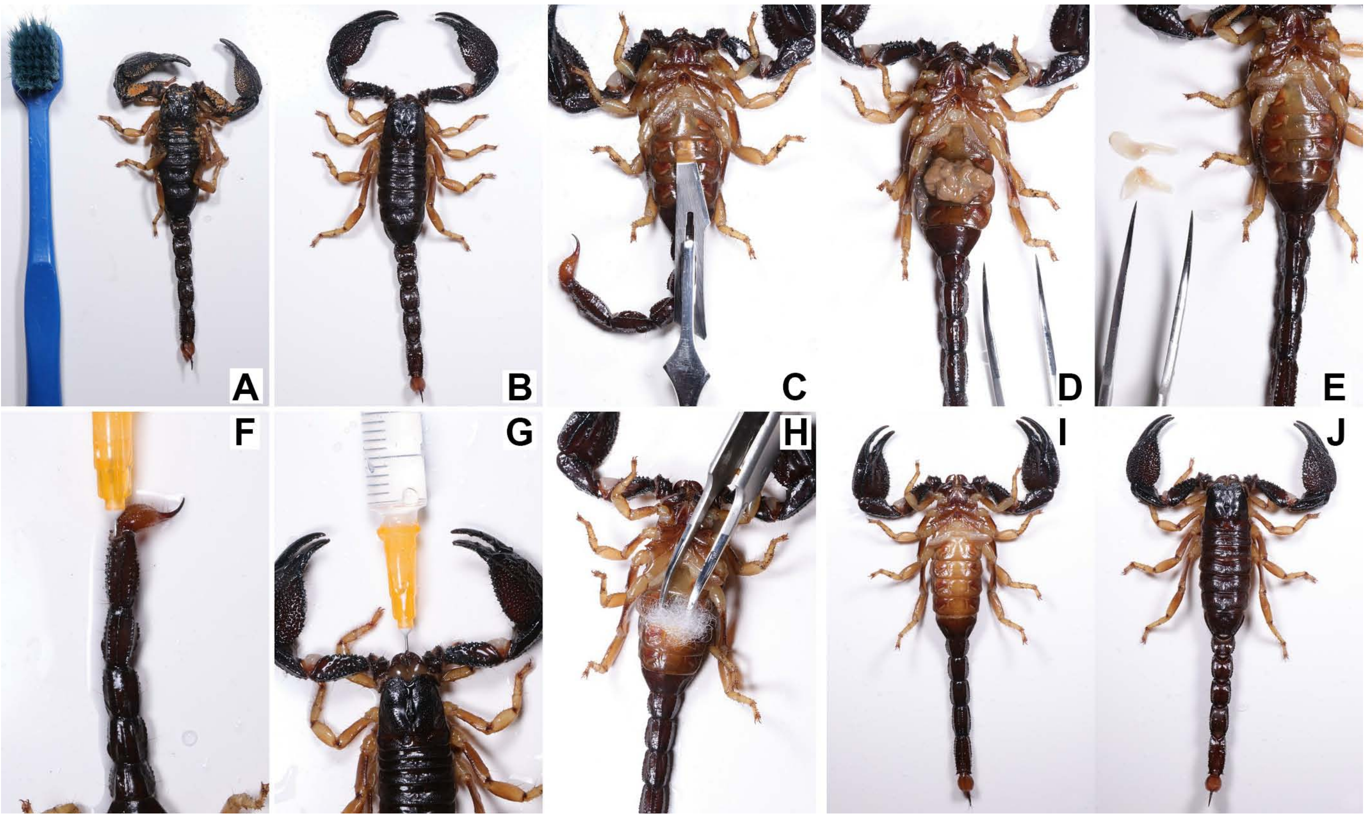


Figure 81. Montage of exemplary photographs illustrating the basic workflow for the preparation of specimen prior to the embalming and air-fixation stages, using an adult male *Chersonesometrus madraspatensis* (Pocock, 1900). **A**–**B**: external cleansing with brush. **C**–**D**: dissection at the membrane between the 4th and 5th sternites and repulsion of internal viscera. **E**: paired hemispermatophores. **F**–**G**: further cleansing with a syringe. **H**–**J**: filling of cotton. Note the change of perceived mesosoma color between B and J.