

Scorpions adapt their stinging, stingers and sting contents to minimize costs of venom use

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Figure 1. Morphological comparison of four Australian scorpions. (A) *Australobuthus xerolimnium* (Buthidae) (B) *Lychas buchari* (Buthidae) (C) *Hormurus waigiensis* (Hormuridae) (D) *Urodacus* sp. (Urodacidae). A. *xerolimnium* and *L. buchari* are more vagrant and active foragers, and have evolved relatively small chelicerae and thick powerful tails. *H. waigiensis* and *Urodacus* sp. are burrowing species, and have evolved larger chelicerae and smaller stinging apparatuses. Photographs by Edward Evans.

Replenishing venom takes time and energy—so it pays to be stingy with

stings.

According to researchers at the Australian National Institute of Tropical Health and Medicine, [scorpions](#) adapt their bodies, their behavior and even the [composition](#) of their [venom](#), for efficient control of prey and predators.

Writing in *Frontiers in Ecology and Evolution*, they say it's not just the size of the stinger, but also how it's used that matters.

Stingy stingers

"Scorpions can store only a limited volume of venom, that takes time and energy to replenish after use," says lead author Edward Evans.

"Meanwhile the scorpion has a reduced capacity to capture prey or defend against predators, so the costs of venom use are twofold."

As a result, over 400 million years of evolution scorpions have developed a variety of strategies to minimize venom use.

The most obvious of these is to avoid using venom at all.

"Research has shown the lighter, faster male specimens of one species are more likely to flee from danger compared to the heavier-bodied females, rather than expend energy using toxins," notes Evans.

"Others—particularly burrowing species—depend instead on their large claws or 'pedipalps,' and have a small, seldom-used stinging apparatus."

When immobility, threat or lively prey forces venom use, scorpions can adjust the volume they inject—both within each sting and through the application of multiple stings.

"Scorpions can hold prey in their pedipalps and judiciously apply stings,

just until it stops struggling."

At the other extreme, when the survival stakes are high some species abandon precision and spray their venom through the air.

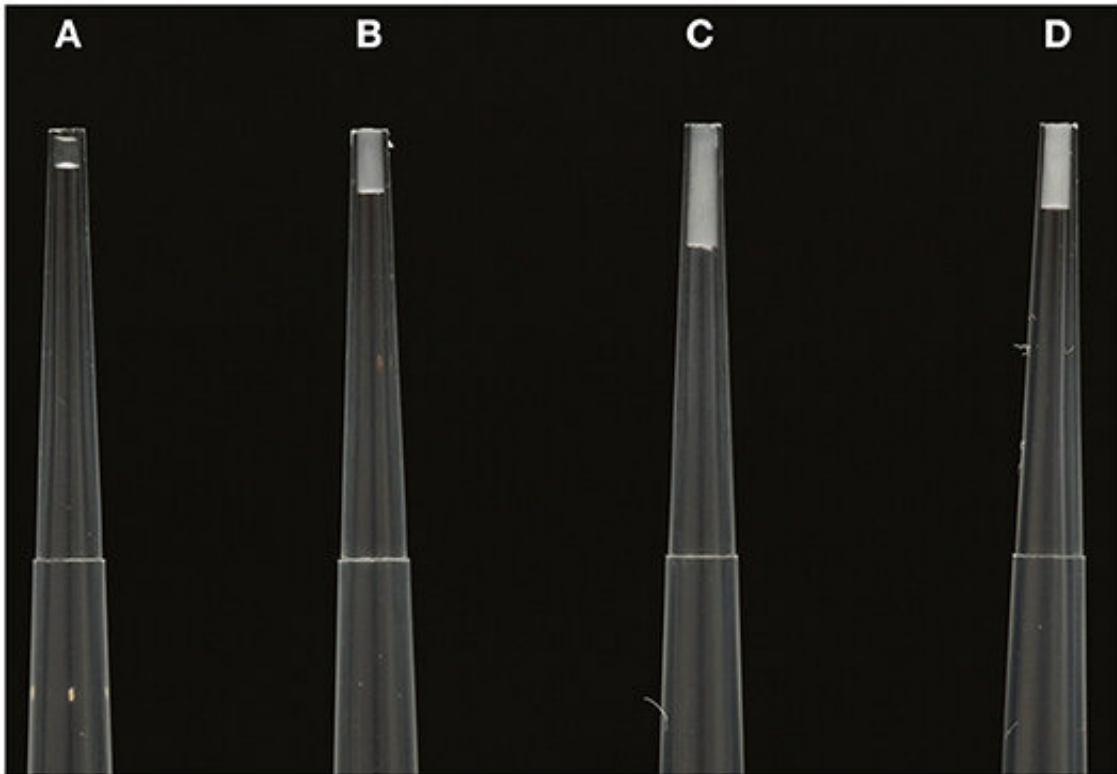


Figure 2. From (A–D)—consecutive venom secretions collected from *Hormurus waigiensis* during one milking event using electrostimulation of the venom gland. (A) The initial secretion is relatively clear, containing the compositionally simple pre venom. (B) The secretion changes from clear to milky (C,D). The later venom secretions are comparatively opaque and white, representing the peptide/protein rich mixture. Photograph by Edward Evans.

"Spraying venom defensively is potentially wasteful but can avoid dangerous close contact with predators such as grasshopper mice, which disarm scorpions by biting off their tails."

Venom versatility

Scorpions can also tailor the composition of their venom to a target—both on-the-fly, and more precisely over weeks of exposure.

For starters, any given sting has three levels: dry, prevenom or venom.

As a light deterrent, a scorpion may sting with no venom at all. A 'wet' [sting](#) begins with clear, salty prevenom—essentially a "stun" setting—and might go no further.

"Research on prevenom suggests it contains an extremely high potassium salt concentration, which may cause quick paralysis in insects and pain in vertebrates," says Evans. "It seems to regenerate quickly and presumably at a low metabolic cost."

If things get heavy, the scorpion can go on to inject or spray a thick, milky, protein-rich venom.

"Venom injection is reserved for more active, persistent or sizeable targets. It is more toxic, but once spent can take weeks to replenish—leaving the scorpion vulnerable and with limited prey options."

Recent work by the James Cook University group suggests that scorpions can make more personalized changes to venom composition, in response to extended periods of predator exposure.

"Repeated encounters with a surrogate vertebrate predator—a taxidermied mouse—over a six week period led the [scorpion](#) *Hormurus waigiensis* to produce a higher relative abundance of a particular group of toxins, including some with vertebrate predator-specific activity," explains senior author Dr. David Wilson.

How exactly the change occurs remains unknown, however.

"Future work is needed to investigate how far observed changes in venom composition and use are due to adaptive responses—and to identify the precise stimuli for change," Wilson and Evans conclude.

More information: Edward R. J. Evans et al. Venom Costs and Optimization in Scorpions, *Frontiers in Ecology and Evolution* (2019). DOI: [10.3389/fevo.2019.00196](https://doi.org/10.3389/fevo.2019.00196). www.frontiersin.org/articles/10.3389/fevo.2019.00196/full

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