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Battling bugs help solve mysteries of weapon evolution

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To study the damage inflicted during wrestling matches between male giant mesquite bugs (Thasus neocalifornicus), the researchers outfitted some of them with body armor consisting of patches of faux leather glued onto their backs. Each bug also was given a number to keep track of the outcomes. Here, contestants "140" and "115" are about to duke it out. Credit: Zachary Emberts/University of Arizona

Remember "the first rule of Fight Club?" That's right: "You don't talk about Fight Club." Luckily, the rules of Hollywood don't apply to science. In new published research, University of Arizona researchers report what they learned when they started their own "fight club"—an exclusive version where only insects qualify as members, with a mission to shed light on the evolution of weapons in the animal kingdom.

In many animal species, fighting is a common occurrence. Individuals may fight over food, shelter or territory, but especially common are fights between males over access to females for mating. Many of the most striking and unusual features of animals are associated with these mating-related fights, including the horns of beetles and the antlers of deer. What is less clear is which individuals win these fights, and why they have the particular weapon shapes that they do.

"Biologists have generally assumed that the individual who inflicts more damage on their opponent will be more likely to win a given fight," said John J. Wiens, a professor in the University of Arizona Department of Ecology and Evolutionary Biology, who co-authored two recent studies on bug battles. "Surprisingly, this fundamental assumption had yet to be tested in an experimental study."

To find out who wins fights and why, Zachary Emberts, a postdoctoral fellow in Wiens's lab and lead author of both studies, collected 300 male insects known as leaf-footed bugs from the desert near Tucson, Arizona, and staged one-on-one fights.

In the summer, these bugs can be found occupying mesquite trees in great numbers, where they crowd the branches and jostle each other over access to females. The males fight using enlarged spikes on their hind legs.

So, what does a fight between leaf-footed bugs look like? The best analogy, according to Emberts, is a college wrestling match.

Configure

"They come up on each other, and they lock each other in, and they will try to squeeze themselves toward one another with their weaponized legs, and that is how they inflict the damage," he said.

"Think of it as a wrestling match where the opponents sneak knives in," Wiens added.

Male and female giant mesquite bug (Thasus neocalifornicus) on a branch in a mesquite tree in Southern Arizona, their natural habitat. Credit: Zachary Emberts/University of Arizona

Emberts and Wiens were specifically interested in investigating whether damage influences who wins these fights. For this experiment, published in the journal *Functional Ecology*, they chose a particular species of leaf-footed bugs: giant mesquite bugs, a common species of the desert Southwest.

In addition to the spikes on their legs, the males also have increased thickness in the part of their wings where the spikes usually strike, suggesting that this thickening acts as natural armor during fights. The researchers attached pieces of faux leather to the wings of 50 of their test insects, to provide extra armor against punctures from the spikes of rivals.

The researchers found that individuals with this extra armor were 1.6 times more likely to win fights than individuals without extra armor or with the same amount of armor placed in a different location.

"This tells us that damage is important in who wins the fights," Emberts said. "This had previously been hypothesized, and it makes intuitive sense, but it had not been experimentally shown before."

The other major question the researchers wanted to investigate: Why do weapons differ among species? Different species of leaf-footed bugs have different arrangements of spikes on their legs. For example, some sport a lone, big spike, while others have a row of several small ones.

"Evolution has produced an incredible diversity of weapons in animals, but we don't fully understand why," Emberts said. "And if selection favors weapons that inflict the most damage, then why don't all weapons look the same?"

Emberts and Wiens said they chose to look at leaf-footed bugs because the damage from their spikes can easily be measured, as the weapons leave distinct holes in their opponents' wings. The holes don't close up, so once a bug suffers this kind of damage, it has to live with it for the rest of its life.

"We can directly count and measure the holes they make in their opponents' wings," Wiens said, "and we find that certain weapon morphologies cause more and bigger holes."

In their second study, published in the journal *Proceedings of the Royal Society B*, Emberts and Wiens tested the idea that the evolution of different weapon shapes is related to how much damage these weapons can cause.

They measured the shape and size of hindlimb spikes in 17 species of leaf-footed bugs from around the world. They also measured the average amount of damage on the forewing of each species, including the size and number of punctures from the spikes. The work was done in collaboration with Wei Song Hwang, curator of entomology at the National University of Singapore.

The results revealed that some weapons are more effective than others at causing damage to opponents.

"This tells us that much of the weapon diversity seen in animals that fight over resources and mates can be explained by how well different weapons perform at inflicting damage," Wiens said. "How well the weaponry is performing—how much damage it inflicts in fights—is driving its diversification."

In other words, certain blade designs provide an evolutionary edge (pun intended). But these results came with a surprise, too.

"Very different looking weapons can also inflict the same average amount of damage," Emberts said. "This tells us there could be multiple solutions to inflicting damage."

For example, two distantly related species of leaf-footed bugs were found to cause almost identical amounts of damage: In one species, the males carry several spines on their femur, while the other species bears a single spine on the tibia.

"This finding helps answer the question, why don't all weapons evolve to look the same?" Wiens explained. "Rather than evolving towards one optimal weapon shape, there are very different shapes that perform almost as well, solving the mystery of why weapons look so different among species."

The authors suggest that the basic principles that explain weapon diversity in leaf-footed bugs might also apply to other groups of animals in which different species have different weapon shapes, such as horned mammals.

Emberts and Wiens have begun experiments to tease apart the physiological reasons underlying the evolutionary cost of suffering damage from fights. They say we should stay tuned for more news from UArizona's very own "Bug Fight Club."

More information: Zachary Emberts et al. Defensive structures influence fighting outcomes, *Functional Ecology* (2020). DOI: 10.1111/1365-2435.13730

Zachary Emberts et al. Weapon performance drives weapon evolution, *Proceedings of the Royal Society B: Biological Sciences* (2021). DOI: 10.1098/rspb.2020.2898

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