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Why are North American velvet ants more colorful?

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Abstract

What is your reaction when you see a brightly colored insect? Probably "danger, stay away!" And in fact, female *Mutillidae*, commonly known as velvet ants (but actually wasps, not ants) use their bright colors to deter predators. They also have a nasty sting. Many velvet ant species that live in the same location and environment look a lot like each other. When a predator learns that a particular species is harmful, it typically avoids all species that look similar. North American velvet ants can be placed into eight different color pattern groups. How about in Africa, where there are even more velvet ant species? Do they also mimic each other? We found four color pattern groups for African velvet ants. So it's interesting that North America has far fewer velvet ant species than Africa, but more color pattern groups. Why? We think some possible reasons include fewer *ecoregions* and lower predator *diversity* in Africa.

Introduction

If you have ever been stung by a wasp, you might think they are just mean. Actually, their *venomous* sting is a form of self-defense. One specific type of wasp has so many defense mechanisms that it is almost unbeatable: the female velvet ant (Figure 1). Unlike the males, female velvet ants have no wings, but a very painful sting. They are brightly colored and covered with velvety hair that makes them look like large, fuzzy ants.

But how do they hide with those bright colors? They don't. Instead, they use them as a warning signal to keep predators away. It works so well that they took it to the next level: many species in the same *ecoregion* have *evolved* to mimic each other's colors. Potential predators quickly learn to avoid all species displaying the same local color pattern. We call this *Müllerian mimicry*: two or more harmful, neighboring species evolve to look alike and benefit from a shared signal. In a previous study, more than 300 North American velvet ant species were grouped in eight distinctive color patterns (so-called *mimicry rings*). Velvet ants represent one of the most widespread and diverse mimicry systems known to scientists.

Figure 1: A Red velvet ant *(Dasymutilla occidentalis)* from the Eastern United States. The bright colors of female velvets ant send warning signals to their potential predators. The males don't sting, but they have wings and fly away when facing a predator.

Africa is home to one third of all of the world's velvet ant species (around 1600 species), yet we didn't know whether or not they also had a mimicry system. Africa definitely has a more diverse and species-rich velvet ant population than North America. However, two factors that affect the diversity of color patterns - the diversity of ecological regions and predators - are significantly lower. Therefore, we hypothesized that African velvet ants would likely have fewer mimicry rings (color patterns) than those in North America.

Methods

To test our hypothesis, we investigated the color patterns and distributions of female velvet ants, as well as the diversity of ecoregions and predators in Africa.

- We collected data from 304 African velvet ant species; 261 of those were *specimens* from *entomology* departments of various universities, museums, and nature centers. 43 of them were described and illustrated in other publications.
- We took many pictures of the specimens and studied their color patterns in detail. We specifically looked at the colors and patterns present on each of their body segments. Then, we grouped the velvet ant species based on visual similarities.
- We analyzed the distribution of these species across Africa. Using the WWF's (World Wildlife Foundation) *terrestrial* ecoregions system, we determined each species' location and ecoregion.
- We studied the diversity of predators (particularly Iguanian lizards, examples include agamas, ground agamas, horned lizards, and spiny lizards – likely potential predators of velvet ants) in Africa and North America from lizard databases and publications.
- We counted the number of ecoregions in North America and Africa. Since no velvet ant or lizard species live in the tundra, we excluded ecoregions from that *biome* (Figure 2).

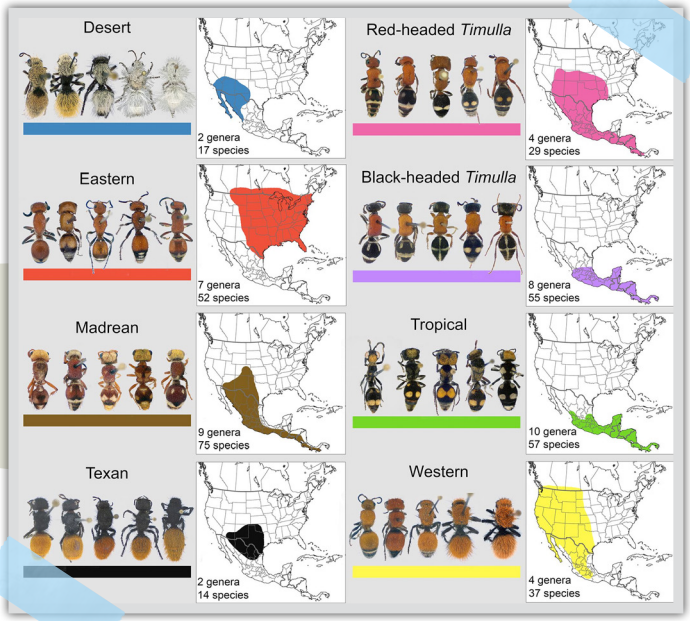

Figure 2: In 2015, we studied over 300 North American species of velvet ants and grouped them in 8 distinct mimicry rings by their color patterns. This is one of the most widespread and diverse mimicry systems in the world. Here, each ring is represented by 5 species. Look at their colors and markings. Can you describe the color patterns for each ring?

Results

Mimicry rings: We were able to place a total of 304 African velvet ant species into 4 mimicry rings based on shared color, pattern, and geographic location (Figure 3). We named these mimicry rings based on their geographic location: the Mediterranean-Steppe (along the Mediterranean coast and areas of North Africa that are not fully desert), the Equatorial (near the equator), the Arid (dry, including the desert biome), and the Pan-African (including all parts of Africa).

Predator diversity comparison: Iguanian lizard diversity is higher in North America (> 500 species) compared to Africa (> 175 species). Overall lizard species richness (all of the lizard species found on a continent like iguanian lizards, geckos, skinks, legless lizards, and wall lizards) is very similar: ~940 species in Africa, and ~980 species in North America.

Ecoregion diversity comparison:

	Number of Ecoregions	Surface Area
Africa	108 ecoregions in 9 biomes	29,200,000 km2
North America	168 ecoregions in 13 biomes	17,521,000 km2

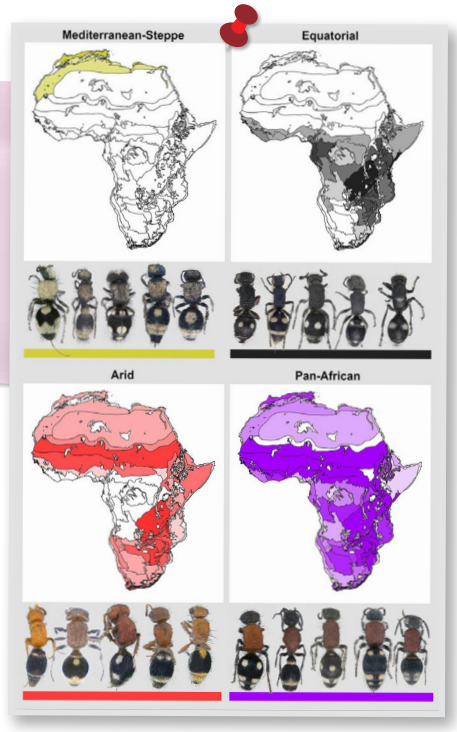

Figure 3: Here, we grouped over 300 species of African velvet ants into 4 distinct color patterns. Again, each mimicry ring is represented by 5 species. The Pan-African ring has by far the largest number of species (187).

Can you tell the difference between North American and African mimicry systems?
Hint: Look at the number and size of ecoregions.

Discussion

Africa has a large velvet ant mimicry system, composed of 4 distinct mimicry rings. However, this is only half the number of North America's mimicry rings, even though Africa has many more velvet ant species. So why are they less diverse in terms of color patterns? Let's think about what forced female velvet ants to evolve in the first place: predators and environment.

1. **Predators:** North America and Africa both have roughly the same number of lizard species, but much of North America is not habitable for lizards (or velvet ants), for instance on glaciers and in tundra and taiga biomes found in Canada and Alaska. This packs North American lizard and velvet ant species more densely into smaller habitable regions on the continent. Because they share a smaller space, velvet ants and lizards likely interact more with each other. And because many lizards eat ants, velvet ants might have evolved distinct colorful patterns to make them look different from ants and to warn potential predators of their painful sting.
2. **Ecoregion diversity:** Even though Africa is much larger than North America, the continent does not have as many distinctive ecoregions. Also, Africa does not have some important velvet ant- containing biomes that North America has, like tropical coniferous forests, temperate broadleaf forests, and temperate grasslands. The higher ecoregion and biome diversity in North America could have led velvet ants to evolve more distinct color patterns there.

Conclusion

Color, odor, a hard *exoskeleton*, a painful sting… Velvet ants are masters of self-defense and virtually untouchable. Insects, in general, are some of the most numerous and successful creatures on Earth. Studying their interactions and responses to changes in the environment could help us better understand and protect our world. Are you interested in insects? Then you can help entomologists by participating in *citizen science projects*.

Check out the Citizen science project website in the references below to find many entomology projects and participate from your own backyard. You can also check out the entomology departments of your local universities, museums, and science centers. Happy bug hunting!

Glossary of Key Terms

Biomes - distinct biological communities of plants and animals that have formed in response to the environment they inhabit (coniferous forests, rainforests, deserts, tunda, etc.)

Citizen Science Projects - projects in which volunteers and scientists work together to answer real world questions and gather data.

Diversity - the variety of organisms that live in any given ecosystem. We say that there is high diversity when there are lots of different types of plants and animals in an ecosystem.

Ecoregion - an ecologically and geographically defined area that is smaller than a biome. Ecology is the relation of living organisms to one another and to their physical surroundings.

Entomology - the scientific study of insects, a branch of zoology (the study of all animals).

Exoskeleton - a rigid external covering for the body in some invertebrate animals, especially arthropods, providing both support and protection.

Evolution - the process by which different kinds of living organisms developed and diversified from earlier forms.

Mimicry - an adaptation in which one living thing resembles a different kind of living thing. Mimicry helps animals and plants in various ways. It can keep them from being eaten, or to get food. Example: a leaf insect can blend into the background of a tree because it looks so much like a leaf.

Mimicry rings - a group of species all mimicking the same pattern. Example: Velvet ants species who have similar color patterns are in the same mimicry ring. North America has 8 velvet ant mimicry rings.

Müllerian mimicry - a form of mimicry in which two or more harmful (painful sting, venomous, or poisonous) animals develop similar appearances for protection. So if a predator learns to avoid one of the harmful species, it will avoid the mimic species as well.

Specimen - an individual animal, plant, piece of a mineral, etc., used as an example of its species or type for scientific study or display

Terrestrial - on or related to land.

Tundra - ecosystems of treeless regions found in the Arctic and on the tops of mountains, where the climate is cold, windy and without much rainfall.

Venomous - an organism that injects a toxin into its prey/victim.

REFERENCES

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The Guardian: Velvet ants share warning signals with their neighbours
https://www.theguardian.com/science/grrlscientist/2015/aug/17/velvet-ants-share-warning-signals-with-their-neighbours

Biologywise: Batesian Mimicry vs. Müllerian Mimicry
https://biologywise.com/batesian-mimicry-vs-mullerian-mimicry

List of Citizen Science Projects:
http://pbskids.org/scigirls/citizen-science
https://scistarter.com/finder

Check your understanding

1 What is mimicry? How does Müllerian mimicry help organisms to survive?

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2 Aposematism describes coloration and other markings that send a signal to predators to keep away. How does it benefit the organism and its predators? Can you name some animals or plants with aposematic colors?

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3 The velvet ant is a sexually dimorphic insect, which means males and females are quite different from each other. Females have bright colors, fuzzy hair, and a painful sting. Males can be colorful or rather plain, but they have wings. What could be the reason that female and male velvet ants evolved to have different characteristics?

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4 Africa has a diverse population of velvet ants. However, there are only 4 mimicry rings (color patterns) in African velvet ants, and 8 in their North American cousins. Why do you think African velvet ants have fewer mimicry rings?