Orb weaver spider glue properties evolve faster than their glue genes, scientists find

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Spiders that don't weave good silk don't get to eat. The silk spiders produce to create their webs is key to their survival—but spiders live in many different places that require webs fine-tuned for local success.

Scientists have now studied the glue that makes orb weaver spiders' webs sticky to understand how its material properties vary in different conditions.

"Discovering the sticky protein components of biological glues opens the doors to determining how material properties evolve," said Dr. Nadia Ayoub of Washington and Lee University, co-corresponding author of the study published in *Frontiers in Ecology and Evolution*. "Spider silk fibers and glues represent a fantastic model for answering such questions since they are primarily made of proteins and proteins are encoded by genes."

"Spider silks and glues have huge biomimetic potential," added Dr. Brent Opell of Virginia Tech, co-corresponding author. "Spiders make glues with impressive properties that would have applications in industry, medicine, and beyond."

Tangled up in spider webs

Each strand of an orb weaver spider's web contributes to the capture of food. The web has a stiff frame that absorbs the impact of prey, which is then trapped by sticky lines until the spider can tackle it. These lines are made sticky by an aqueous glue synthesized in aggregate glands. The glue absorbs water from the atmosphere and must be optimized to achieve the best stickiness results for the local humidity. But there are many species of orb weaver spider living in different environments, which means their glue must adapt to different levels of humidity.

To understand how spider glue stickiness adapts, Ayoub and her colleagues focused on two species, Argiope argentata, which lives in dry environments; and Argiope trifasciata, which lives in humid environments. The team collected webs from A. trifasciata in the wild and had A. argentata spiders build webs in the lab. To ensure that these

webs were equivalent to webs in the wild, the scientists fed the spiders a diet comparable to their usual prey and compared glue droplet volume to wild controls to make sure that the humidity in the lab wasn't affecting the droplets' properties. They then analyzed the proteins in the glue and the droplets' material properties.

A sticky situation

The team found that droplets from A. argentata spiders are smaller than those from A. trifasciata and absorb less water as local humidity increases. They also had smaller protein cores, occupying a smaller proportion of the droplet's volume, and absorbed less water from the atmosphere. The toughness of glue droplets for both species of spider is based on the stiffness of the protein core of the droplets, and A. argentata protein core toughness decreased as the humidity went up. A. argentata thread glue droplets were generally more closely spaced and stickier.

The scientists also analyzed the proteins found in the glue droplets to understand how these differences in material properties arise from the proteins. Although the proteins they found were similar, they appeared in different proportions, and A. argentata glue contained the protein products of four genes that didn't appear in A. trifasciata glue. These extra proteins and a more balanced ratio of AgSp1 and AgSp2 proteins may explain both the greater toughness of this glue and its lower capacity for water absorption.

"Despite the dramatic differences in material properties, the two species share most of their protein components," said Opell. "The sequences of these proteins are also similar between species, but the relative abundance of individual proteins differs. Modifying the ratios of proteins is likely a rapid mechanism to adjust material properties of biological glues."

"This study only examined two species, so our proposed relationships between proteins and material properties are limited," cautioned Ayoub. "However, we are in the process of documenting protein components and material properties of a diverse set of species, which will allow more power to detect the mechanisms of how proteins give rise to material properties."

More information: Orb weaver aggregate glue protein composition as a mechanism for rapid evolution of material properties, *Frontiers in Ecology and Evolution* (2023). DOI: 10.3389/fevo.2023.1099481

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