WILLIAM & MARY
CHARTERED 1693

The brown recluse spider engineers extra-strong silk by spinning loops onto a flat strand

by Joseph McClain | **February 17, 2017**

It helps to know a little about the brown recluse to fully understand the discovery about what makes the silk of this particular spider so strong.

An international collaboration between William & Mary scientists and colleagues at the University of Oxford has discovered that the brown recluse makes extra-tough silk by spinning loops into each strand. The collaborators detailed their discovery in a paper in the journal *Materials Horizons*, a publication of the Royal Society of Chemistry.

Sean Koebley, a Ph.D. student in William & Mary's Department of Applied Science, is first author on the paper, "Toughness-enhancing metastructure in the recluse spider's looped ribbon silk." Koebley studies properties of various kinds of silk in the lab of Hannes Schniepp, the Adina Allen Term Distinguished Associate Professor.

Examination of natural silks continues to provide insight into new synthetic materials and the silk of the brown recluse is particularly promising because of its relative strength. Schniepp explained that all species of spiders produce strands of silk that are essentially protein cablets, more or less round in cross section. But the brown recluse's web is different in many respects – and is totally unique.

The brown recluse does not spin what most people think of as a typical spider web. Those concentric, spoked constructions that span sidewalks are different, the work of a class of spiders known as orb weavers, Schniepp said.

"Those spiders are targeting flying insects," Koebley said. "The recluse targets ground-dwelling insects, and the intent is to entangle the prey."

A recluse makes a web near the ground, a construction that looks chaotic in comparison to the traditional orb-weaver's snare. Several properties of the individual silk strands combine to make a recluse web deadly – if unsuitable for a more aerial spider species.

Orb weavers start their webs by rappelling down a single silk strand, but the ground-hugging recluse has no need of such support. In fact, a strand of recluse silk is so thin that a single strand won't support the spider itself. "But," Koebley noted, "that's only because it's so thin. A bar of steel that thin wouldn't support the spider either."

Hours of watching the spiders spinning and examining the silk itself allowed the researchers to figure out a large part of the reason that recluse silk is such an excellent material. They found that the spiders spin loops into each strand. Each spider has a spinneret that acts like a "high-speed sewing machine," turning out microloops at about 500 per inch.

Standard materials wisdom has held that loops giveth; loops taketh away: Schniepp said that engineers have long known that strings with loose knots can be tougher than unknotted strings. The loops add strength to filaments, but the very same loops cause premature failure of the fiber. His lab has figured out exactly how the recluse engineered a way to circumvent the drawbacks of looping.

"Unlike all other spiders, its silk is not round, but a thin, nano-scale flat ribbon, Schniepp explained. "The ribbon shape adds the flexibility needed to prevent premature failure, so that all the microloops can provide the additional toughness to the strand."

They even tested their flat-loop theory with common office adhesive tape: "Even a single loop significantly enhances the toughness," Koebley noted.

The individual loops themselves are quite strong, but will eventually open. The cumulative effect is that the loops make the fiber much more resistant to testing.

The next step is to begin the task of engineering a synthetic material inspired by the qualities and construction of recluse silk.

"It's one of the best silks among all the thousands of species of spiders," Schniepp said. "In talking about materials, we use terms like 'strength' and 'toughness.' And in both categories, recluse silk is an extremely good material. If you normalize strength by weight, it's better than steel. If you look at the toughness of the material, it's better than Kevlar."

Mathematical modeling bolstered the idea that recluse-looped artificial materials have great promise.

"Computer simulations demonstrate that fibers with many loops would be dozens of times tougher –and more," said collaborator Fritz Vollrath of the University of Oxford's Department of Zoology. "This right away suggests possible applications. For example, carbon filaments could thus be made less brittle, to allow them to serve in novel impact-absorbing structures, for example in spider-like webs of carbon-filaments to capture the floating space debris that endangers astronauts' lives and satellites' integrity."

Vollrath is a co-author, along with Koebley and Schniepp, on the paper. Schniepp, whose work at William & Mary was funded by the National Science Foundation, shares Vollrath's enthusiasm for the prospects of synthetic recluse fibers. He noted that there are a number of challenges to be met.

"First of all, no one has ever made a synthetic fiber with this ribbon kind of shape," he said. "And of course you would need to come up with a synthetic version of the protein. It's a multi-step process, but we want to work on all these things."

And no, they've never been bitten. Nor has any visitor to the lab.

Schniepp and Koebley work with a population of around 100 brown recluse spiders. The arachnids are venomous, but Schniepp said the reputation of the spiders is "really overhyped."

Home > News & Media > More Stories > 2017