Unraveling the biochemistry of spider silk

When the Greek maiden Arachne defeated Athena in a weaving contest, the jealous goddess turned the mortal weaver into a spider. Today, scientists envy silk-spinning arachnids for their molecular handiwork and the strong biological polymer they produce. Spiders use various types of silk for building webs, descending from heights, protecting their eggs or immobilizing their prey; scientists would like to create their own versions for uses such as artificial tendons, sutures and bulletproof vests.

Two molecular biologists unveil some biochemical secrets of spider silk in the September PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES (Vol.87, No.18). Randolph V. Lewis and Ming Xu at the University of Wyoming in Laramie have determined part of the amino acid sequence of the protein molecules that twine into dragline (major ampullate) silk of the orb-web spider *Nephila clavipes*. With its rubber-like springiness and its ability to suspend weights that would snap equivalent strands of steel, this silk has "nearly unmatched . . . strength and elasticity," the researchers note.

Uncovering the silk protein's structure stretches biochemists' skills. "It's an extremely difficult protein to work with," says Joseph Cappello of Protein Polymer Technologies, Inc., in San Diego.

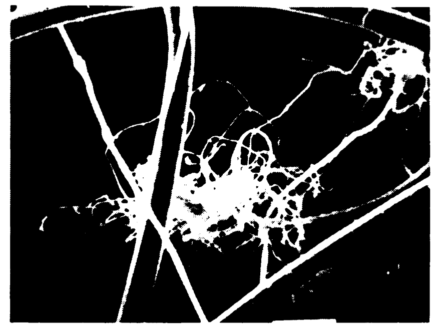
"Mother Nature has taken millions of years to design a superior product," adds Harvey W. Keene of the U.S. Army Research Development & Engineering Center in Natick, Mass., where scientists are sequencing the dragline protein in search of lighter and stronger materials for bulletproof vests.

All proteins are made of amino acids, variously linked into unique chains. But silk protein's toughness keeps it from dissolving readily and makes it resistant to the protein-slicing enzymes used in standard sequencing methods.

Lewis and Xu deployed heavy-duty solvents to untangle and dissolve the silk's meshed protein molecules and used hot, concentrated acid to chop them into fragments. Using genetic engineering techniques, they then reversed the normal cellular routine in which a gene made of DNA gets transcribed into messenger RNA (mRNA) molecules, which then get translated into protein molecules. Instead, they used silk protein fragments to make DNA probes, which served as homing molecules for locating mRNA molecules in the spider's silk-making glands. The mRNA molecules in turn served as templates for reconstructing roughly one-third of the gene for the silk protein.

The amino acid pattern corresponding to the partial gene might help explain silk's properties, Lewis says. It consists of repeating units up to 34 amino acids long, each divided into three segments. Each unit's longest segment contains a nearly identical sequence of 15 amino acids, which arrange into the so-called beta sheets that give the molecule its strength. Another segment includes a string made only of the amino acid alanine. Its ability to form a springy helix probably endows the protein with elasticity. The remaining segment has a more variable sequence, making its functional role more difficult to surmise, Lewis says. The silk protein of silkworms, in contrast, consists of rigidly repeated units.

The next steps awaiting silk researchers include sequencing the rest of the dragline protein and other fibrous arachnid proteins such as those making up the swathing silk that spiders use to keep their victims from leaving before dinner. — *I. Amato*



Lewis, Xu

Electron micrograph shows fibers of dragline silk with frayed strands.

Pouring water on the theory of hot spots

The term "wet spot" lacks the flair of "hot spot," but it may enter the geophysical lexicon if one oceanographer's argument proves correct.

According to the hot spot theory, many of Earth's volcanoes are fed by thin columns of unusually warm rock rising from deep within the mantle. But an analysis of seafloor rocks now suggests that volcanic activity at certain presumed hot spots arises from water, not warmth, says Enrico Bonatti of Columbia University's Lamont-Doherty Geological Observatory in Palisades, N.Y.

"This should cause at least some rethinking on the concept of hot spots, which has been so important in the last 20 years," Bonatti asserts.

He reached his controversial conclusion after examining rocks from the ocean bottom near the Azores in the North Atlantic. Geoscientists recognize these volcanic islands as the current location of a hot spot that once lay beneath Newfoundland. The hot spot's apparent southeastward migration is an illusion created by plate tectonics; the spot itself has remained stationary while Newfoundland and the Atlantic Ocean have migrated to the northwest over it.

Bonatti studied peridotite rocks collected by dredges, drill ships and deep submersibles. Peridotites originate in the mantle layer, offering scientists a window into the conditions beneath the tectonic plates. Using the chemistry of key peridotite minerals as geothermometers, Bonatti estimated the rocks' temperatures as they rose through the mantle to the surface. Chemical variations indicate how quickly the peridotite cooled.

Bonatti compared peridotites from the Azores with those from other volcanic sites in the Atlantic unassociated with hot spots. He surmised that the Azores samples would record a more rapid cooling rate because these hotter, more buoyant mantle rocks should rise faster. Instead, he found they recorded similar or slower cooling rates.

His research report in the Oct. 5 SCIENCE challenges the idea that a hot spot feeds volcanic activity in the Azores by melting mantle rock. Bonatti says his findings suggest that the mantle under the Azores is not hotter than normal, but instead contains unusually high concentrations of water and other volatile ingredients, such as carbon dioxide and chlorine. By lowering the melting temperature of rock, volatiles would encourage the uppermost mantle to melt, providing an alternative explanation for the area's volcanic activity.

Basaltic rocks previously collected from the ocean floor near the Azores support the wet spot theory, Bonatti says. These volcanic rocks hold two to three times as much water as normal basalts and also contain extra chlorine, bromine and fluorine.

Bonatti says his findings don't raise questions about most hot spots. But some areas, such as the Azores, may not fit the traditional interpretation, he says. In particular, he suggests that other so-called hot spots in the equatorial Atlantic may be wet spots.

Many geophysicists believe hot spots provide a pipeline for transporting heat from the planet's core to its surface. But Bonatti's work suggests that some hot spots may instead signify sites where volatile-rich material escapes upward.

Petrologist Henry J.B. Dick says he has also used peridotites as Atlantic geothermometers and has obtained results similar to Bonatti's. But he thinks the wet spot hypothesis doesn't hold water.

Dick, of the Woods Hole (Mass.) Oceanographic Institution, disputes Bonatti's assumption that peridotite at hot spots must rise quickly. In the Azores region, Dick says, hot mantle material might well rise slowly because volcanic activity there has created an extra-thick crust that could inhibit the upwelling rock. — *R. Monastersky*