The Amazing Spider Silk

FROM CATCHING INSECTS TO INSPIRING REVOLUTIONARY MEDICAL DEVICES, THIS REMARKABLE MATERIAL IS WORTHY OF A SUPERHERO. BY ELLEN HOROWITZ

In the Spiderman comic books and movies, Peter Parker possesses a genius intellect, superhuman strength, and the ability to clamber up walls like, well, a spider. But his trademark skill is the ability to fire streams of "web fluid" from mechanical devices on his wrists. The strands allow him to swing through downtown skyscrapers, stop missiles, and bind up villains. Spiderman's "silk" is amazing.

The real thing is even more so.

Spider silk is the world's strongest known natural material. Ounce for ounce, it's up to five times stronger than steel or Kevlar. It can stretch as much as 40 percent beyond its original length and spring back to its former size and shape. It also withstands freezing temperatures without becoming brittle.

Once I began looking for it, spider silk seemed to be everywhere. Along forest trails and in tall grass beside creeks, I stopped to admire the wagon wheel–shaped webs adorned with dew drops and backlit by morning sun. Looking up, I saw streaks of gossamer sailing away on the gentlest breeze. Chickadees, nuthatches, and brown creepers probing their bills beneath scaly bark or furrowed tree trunks alerted me to the presence of the spiders' silken egg cases.

Unlike the Marvel Comics superhero, real spiders release silk from microscopic spigots on the spinneret organs on their abdomen. The silk begins as a liquid protein that hardens into a thread as it is stretched. The output from several spigots is interwoven to make a single silk thread.

Spiders' eight legs are tipped with tiny claws used to manipulate the threads to build webs for capturing prey and to weave protective blankets around their eggs. Spiders also use their silk to build shelters and to make sticky balls they fling to catch prey. Like tiny explorers, spiderlings release silk to hop a ride on the wind in a process called ballooning.

Spiders make different types of silk threads that vary in thickness, strength, and stickiness. Dragline silk—the strongest—is the classic

SILK SPIGOTS Near right: An electron micrograph shows a spider's front spinneret. The large spigot near the top produces the silk dragline. Smaller spigots produce short, sticky threads that make a strong attachment point for other silk lines. Far right: A young spiderling "balloons" in the breeze.

CLOCKWISE FROM TOP: PHOTO ILLUSTRATION BY LUKE DURAN; SHUTTERSTOCK; JUDY THOMPSON; AUSTRALIAN MUSEUM thread seen when a spider "drops in" out of thin air. Like a mountain climber, the spider uses the thread as a safety line so it can backtrack to safety if trouble appears. Over the years, old draglines become covered in dust and appear as cobwebs in corners and along ceilings. The word "cobweb" comes from the Old English word *coppe*, meaning "spider."

Nonsticky threads form the outer rim and spokes of an orb web, the type made by most garden spiders. In the spiraling portion of the web, where a fly or other insect might get caught, spiders employ their stickiest silk, which contains minute beadlike drops of glue. A freshly caught fly or other meal might then be sealed in another type of silk. A spider uses an entirely different type of thread to form a cocoon around its eggs. Some web-weaving spiders create ultraviolet-reflective silk adornments known as stabilimenta that serve as warning signs to prevent birds from flying through and destroying the carefully wrought webs.

Spiders aren't the only creatures that use their silk. Hummingbirds, kinglets, vireos, American redstarts, dusky flycatchers, goldfinches, and brown creepers are among the small Montana birds that combine silk with mosses, lichens, and other soft plant material to build nests.

Hummingbirds fasten their nests to the upper surfaces of branches, twigs, or pinecones with silk. Incorporated into the main body of the nest, silk gives the structure a spandexlike elasticity that stretches to accommodate growing chicks. Silk is also used to attach lichens and other items to the nest's exterior for camouflage.

You might think that sticky silk would work best for nest building. But like sticky tape, it is messy to work with and difficult to reposition. What's more, sticky silk quickly loses its adhesive properties as it gathers atmospheric dust. Mike Hansell, author of *Bird Nests and Construction Behavior*, found that birds instead use dry silk collected from sheet webs, cobwebs, funnel webs, and egg cocoons because it's abundant and easy to manipulate. Even though dry silk isn't

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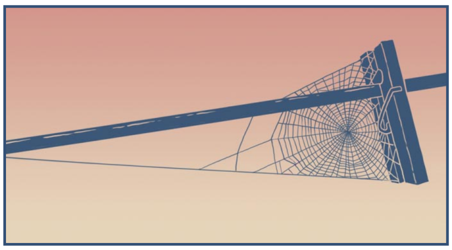
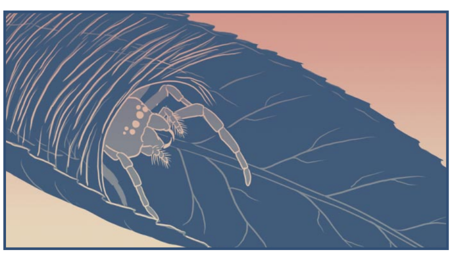
SPIDERS USE SILK TO:

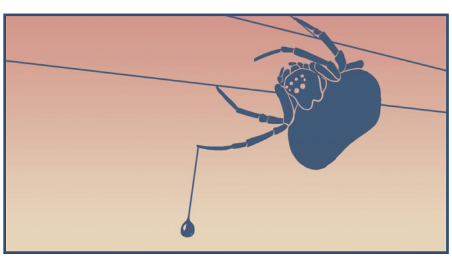


build webs to trap prey;

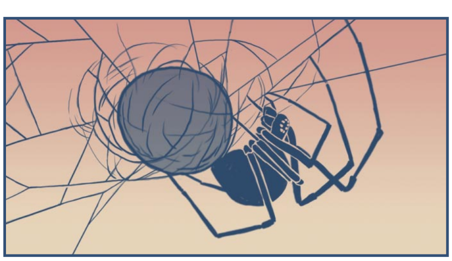
wrap up prey so it can't escape;



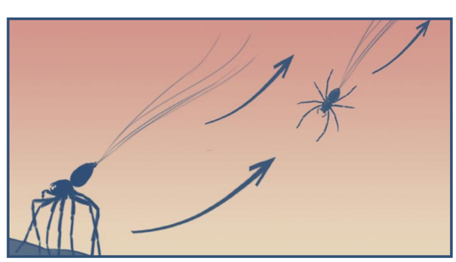
build shelters;



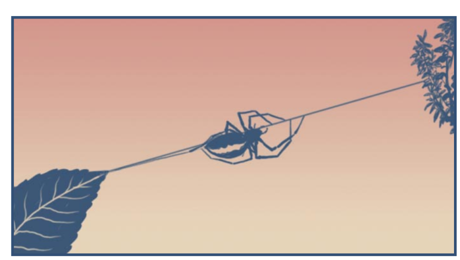
make sticky balls to catch prey;



construct containers for eggs;



send out balloon lines to float in the wind; and



make lines for anchoring and traveling.

LOVELY LATTICE In addition to being practical tools for capturing insects, spider webs are beautiful additions to the natural world.

SPIDER ILLUSTRATIONS BY TAINA LITWAK; SPIDER WEB PHOTO: SHUTTERSTOCK

MORE ROOM Hummingbirds combine silk with soft plant material such as mosses for nest building. The stretchy silk material expands to accommodate growing chicks.

coated with a sticky adhesive, microscopic loops within the fiber readily attach to minuscule, naturally occurring hooks found on mosses, lichens, leaves, and similar items used to build small nests. For birds, dry silk works like Velcro and can be repositioned with relative ease.

For thousands of years, humans have used spider silk. In ancient Greece, people applied cobwebs to wounds to stop bleeding. Australian Aborigines created fishing line from silk, and New Guinea natives wove fishing nets from the material. (The silk that for millennia has been spun into thread for fine cloth—and in the early 20th century as fly-fishing line—comes from cultivated silkworms, not spiders.)

Spider silk was also an important component in a variety of optical devices. In the early 1900s strands were built into levels, microscopes, surveyor transits, and telescopes as sighting marks. In the late 1930s, optics manufacturers began employing dragline silk from black widows and other orb-weaving spiders for the fine optical crosshairs of scopes later used on WWII rifles.

Recent uses of silk span a much broader range of applications, as scientists grow to better understand its molecular structure and how spiders make the material. In the emerging field of biomimicry, design and product engineers study natural processes and materials such as spider silk to create ecologically sustainable products and systems. Spiders have perfected their natural silk making over 380 million years, but production of nylon and other synthetic materials is one of the world's dirtiest industries. Scientists and engineers are finding ways to mimic the properties of spider silk and even create artificial versions that have the same molecular structure, using water, silica, and cellulose rather than toxic chemicals or petroleum products. Potential medical uses include artificial ligaments and tendons as well as sutures for microsurgery.

Some scientists have even genetically modified goats using genes from spiders, hoping to extract large amounts of silk material from the milk. Industrial applications might include wear-resistant shoes, bio-based glues, biodegradable fishing line, tear-resistant paper, lightweight parachute lines, and bulletproof vests.

Glass engineers who study spider silk stabilimenta (the UV-reflective adornments) have helped window manufacturers make insulated glass that reduces bird collisions. By some estimates, as many as 600 million birds die in window collisions in the United States and Canada every year. The new glass contains an ultraviolet-reflective surface visible to birds but imperceptible to humans.

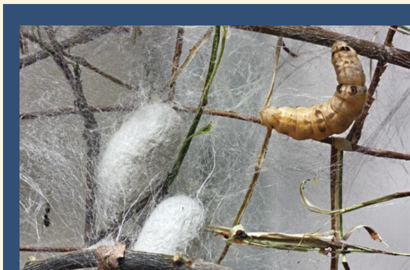
In the comic book world, synthetic spider silk helps a superhero fight evil-doers and protect the world from destruction. Turns out, real spider silk also has the potential to improve and even save lives. Amazing.

OTHER SILK SPINNERS

Spider silk begins as liquid protein in glands within a spider's abdomen and travels via narrow ductlike structures until it's squeezed through one of the spinnerets located at the spider's hind end. By the time the liquid exits the spider's body, it has morphed into a nearly waterproof thread. This process is completely different from that of insects such as silkworms, which make only one type of silk produced from their salivary glands.

The most common natural use of insect silk is pupation. Moth caterpillars are best known for their silk cocoons, but the quantity and quality of the silk varies. Giant silkworms used in commercial silk-making produce nearly 1,000 feet of silk from a single cocoon. Montana's two giant silk moths—the Columbia silkmoth and Polyphemus moth—are not used commercially.

The aquatic larvae of caddis flies produce silk for making shelters and obtaining food. Many of them build mobile homes by gluing tiny pebbles, grains of sand, or bits of vegetation together with silk. Other species of caddis forego a protective structure and instead spin silken nets for capturing prey or use silk as safety lines for swift currents. The aquatic larvae of black flies spin silk to anchor themselves to rocks in fast-moving water.



Above: A silkworm and cocoons. Below: A hydropsyche caddis fly "filter feeds" by building an underwater silk net.

TOP TO BOTTOM: MIKE'S BIRDS; SHUTTERSTOCK; STEVE ORMEROD