The Complex Webs We Weave

Halloween is approaching and it's time to consider that ubiquitous symbol of the haunted house – the spider's web.

We often see spiders as scary or a nuisance, and their webs as something that must be brushed away, but in fact spiders and the webs they weave are one of the complex wonders of nature.

Dating back almost 400 million years ago, spiders are among the most diverse of terrestrial predators. At least 48,200 spider species, and 120 spider families have been recorded by taxonomists. While we typically associate spiders with webs, not all spiders spin webs (see Wolf Spiders) or use the silk they produce for webs (see Jumping Spiders). Species that produce silk but not webs, may use silk in several ways: as wrappers for sperm and for fertilized eggs; as a "safety rope"; for nest-building; and as "parachutes" by the young of some species.

But webs are what we notice, so let's learn a bit about web materials, web structure, web functions, and the evolution of webs.

Silk Production

First, let's take a look at the material used to construct webs. Spiders produce silk, a biopolymer, using movable spinnerets on their abdomen, each with several spigots connected to a silk gland. There are at least six types of silk gland, each producing a different type of silk.

Silk is made from a protein that hardens not by exposure to air but as a result of being drawn out, which changes the internal structure of the protein. Spider silk is incredibly strong, flexible, and elastic. Some varieties are five times as strong as an equal mass of steel and twice as strong as an equal mass of Kevlar. Spider silk is so superior to many synthetic materials in terms of lightness, strength and elasticity that scientists are inserting spider silk genes into mammals and plants to see if these can be used as silk factories.

Web Structure

A second fascinating feature of webs are their structure. Web structure varies a good deal from species to species. Some spiders build totally disorganized cobwebs, some form long funnels out of silk sheets, and some work as a colony to form huge masses of silk sheets around plant life. Some spiders, such as the net-casting spider, will form a small web between their legs and quickly wrap up any insect that gets caught.

The best-known web, however, is the orb web, the intricate concentric design spun by most garden spiders. This web is one of the most remarkable structures in nature, and its construction is among the most incredible activities you'll ever see in nature. Around our house this season are numerous examples, large and small, of orb webs. The largest known orb webs in the world are those produced by the Darwin's bark spider (Caerostris darwini), an orb weaver from Madagascar. Their webs range from 140 to 4,340 square inches (about 30 square feet) with bridge lines spanning up to 82 feet.

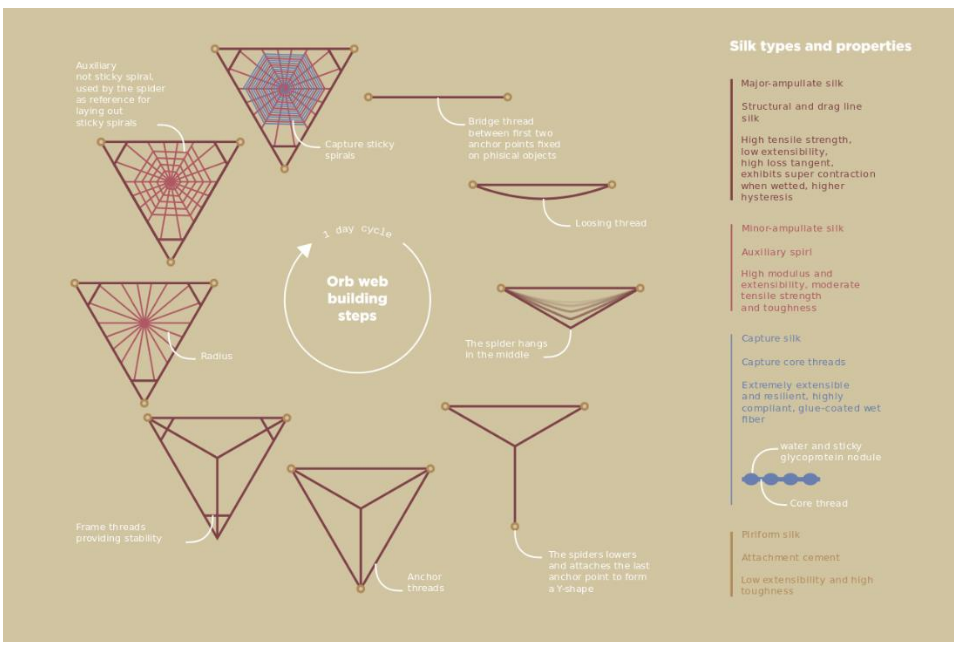
Figure 1 shows the typical construction plan for an orb web. Every web begins with a single "bridge" thread, which forms the basis of the rest of the structure. To establish this bridge, the spider climbs to a suitable starting point (up a tree branch, for example) and releases a length of thread into the wind.

With any luck, the free end of the thread will catch onto another branch. If the spider feels that the thread has caught onto something, it cinches up the silk and attaches the thread to the starting point.

It walks across the thread, releasing a looser thread below the first one. It attaches this thread on both ends and climbs to its center. The looser strand sags downward, forming a V-shape. The spider lowers itself from this point, to form a Y-shape. This forms the core support structure of the web. The spider easily grips the thin threads with special serrated claws, a smooth hook and a series of barbed hairs on the end of its legs. As it walks along the initial structural threads, it lays more frame threads between various anchor points. Then it starts laying out radius threads from the center of the web to the frames. The spider does not coat the frame and radius threads with sticky material, since it needs to walk across them to get around the web.

After building all the radius threads, the spider lays more nonstick silk to form an auxiliary spiral, extending from the center of the web to the outer edge of the web. The spider then spirals in on the web, laying out sticky thread and using the auxiliary spiral as a reference. The spider eats up the auxiliary spiral as it lays out the sticky spiral, resulting in a web with non-sticky radius threads, for getting around, and a sticky spiral for catching bugs.

Figure 1: Orb Web Building

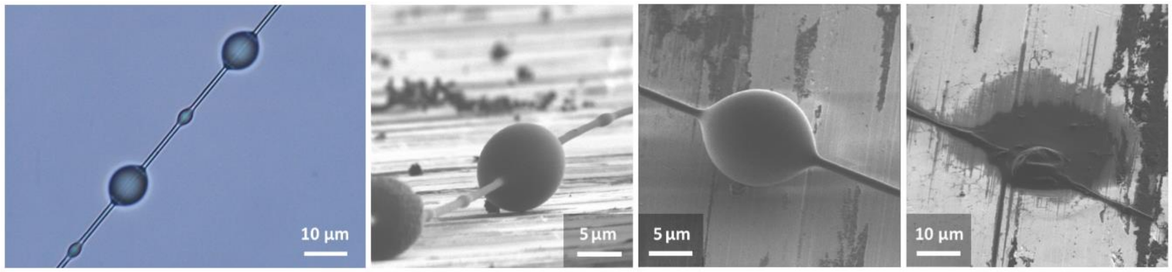


Source: [Davide Pedone, DensityDesign Research Lab]

Web Functions

We typically think of webs as means for spiders to trap prey. To do so, spiders use a bit of stickiness to help keep prey in place long enough for a spider to permanently subdue them (Figure 2). But not all webs get their stick the same way. Some webs snag insects with droplets of glue (ecribellate). Others are “wooly” (cribellate) —their silk is made of thin strands that cling to an insect’s hairs and legs, much like the threads of a sweater stick to a bur.

Figure 2: Microscopic Glue Drops on Spider Web Silk



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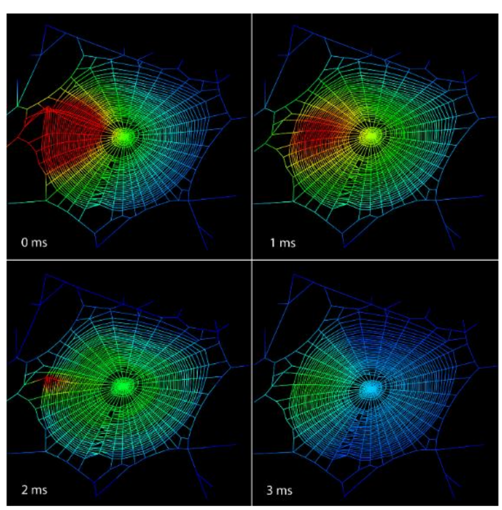
Source: https://commons.wikimedia.org/wiki/File:Glue_ball.png

Spiders also orient their webs in a manner that will increase prey capture. Varying placement of webs allows different species of spider to trap different insects in the same area, for example flat horizontal webs trap insects that fly up from vegetation underneath while flat vertical webs trap insects in horizontal flight.

While prey capture is a primary function of webs, it is not the only function. Web-building spiders have poor vision, but are extremely sensitive to vibrations. So, spiders use their webs as a sensory extension, monitoring the radius threads of the web for vibrations. Spiders have an innate ability to tell the difference between vibrations from insect prey and vibrations from other sources (a leaf falling into the web, for example). Many species can also distinguish the characteristic vibrations of dangerous insects, such as wasps, from their preferred prey.

A 2016 paper by British and Spanish researchers looked at how spider silk transmits vibrations (Figure 3). They found that web vibrations, across a wide range of frequencies, carry important information about prey, mates and even the structural integrity of a web. Spiders "manage" this vibrational information by changing web tension, silk stiffness and web architecture. Because web-dwelling spiders have poor vision, they use web vibrations to 'view' their world. In this way, the web extends the spider's sensory system over a much wider area.

Figure 3: Vibration Transmission Across A Web



Source: Mortimer, et al. (2016)

Web evolution

The ancestors of spiders emerged from a water environment around 400 million years ago. The shift to dry land spurred an evolutionary leap to silk production and use of webs. Scientists have a number of theories about how silk glands and webs evolved, but exact causes remain shrouded in the mists of time. One theory is that silk and webs evolved from the need of land spiders for shelter and a means to protect its eggs, moved into use as guide lines and finally morphed into interwoven traps. Key to this evolution has been spiders' extraordinary spatial orientation. Spiders employ a wide variety of sensory and orientation aids to build webs, including illumination, polarization patterns of the sky, gravity, and vibrations, as well as path integration using leg and body turns.

Now that you have immersed yourself in the 400 million years of cobweb of evolution and the extraordinary capabilities of spiders, go out and Make Your Own Spider Web for Halloween and remember the fascinating creatures that create these wonders of nature!

References and Further Reading

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