# Spider Silk

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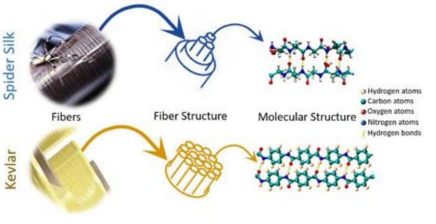
## What is it ?

Spider silk is a protein fibre spun by spiders. Spiders use their silk to make webs or other structures, which function as sticky nets to catch other animals, or as nests or cocoons to protect their offspring, or to wrap up prey. They can also use their silk to suspend themselves, to float through the air, or to glide away from predators. Most spiders vary the thickness and stickiness of their silk for different uses.

In some cases, spiders may even use silk as a source of food. While methods have been developed to collect silk from a spider by force, it is difficult to gather silk from many spiders compared to silk-spinning organisms such as silkworms.

All spiders produce silk, and even in non-web building spiders, silk is intimately tied to courtship and mating. Silk produced by females provides a transmission channel for male vibratory courtship signals, while webs and draglines provide a substrate for female sex pheromones. Observations of male spiders producing silk during sexual interactions are also common across phylogenetically widespread taxa. However, the function of male-produced silk in mating has received very little study.




## Properties

-<u>strength</u>

A dragline silk's tensile strength is comparable to that of high-grade alloy steel (450−2000 MPa), and about half as strong as aramid filaments, such as Twaron or Kevlar (3000 MPa).

-<u>density</u>

Consisting of mainly protein, silks are about a sixth of the density of steel (1.3 g/cm$^3$). As a result, a strand long enough to circle the Earth would weigh less than 500 grams (18 oz). (Spider dragline silk has a tensile strength of roughly 1.3 GPa. The tensile strength listed for steel might be slightly higher—e.g. 1.65 GPa, but spider silk is a much less dense material, so that a given weight of spider silk is five times as strong as the same weight of steel.)

-<u>extensibility</u>

Silks are also extremely ductile, with some able to stretch up to five times their relaxed length without breaking.

-<u>toughness</u>

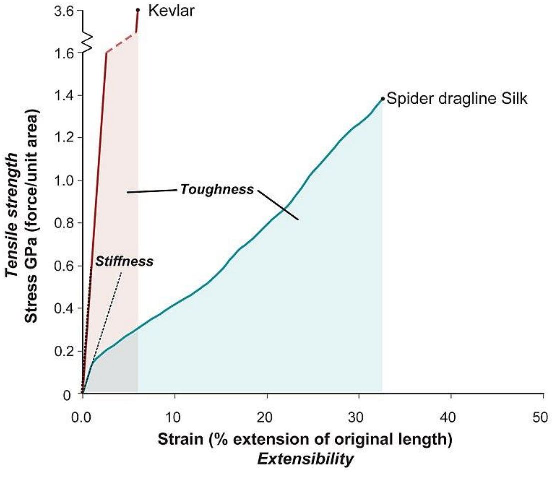
While unlikely to be relevant in nature, dragline silks can hold their strength below −40 °C (−40 °F) and up to 220 °C (428 °F). As occurs in many materials, spider silk fibres undergo a glass transition. The glass-transition temperature depends on the humidity, as water is a plasticiser for the silk.

-<u>super contraction</u>

When exposed to water, dragline silks undergo supercontraction, shrinking up to 50% in length and behaving like a weak rubber under tension. Many hypotheses have been suggested as to its use in nature, with the most popular being to automatically tension webs built in the night using the morning dew.

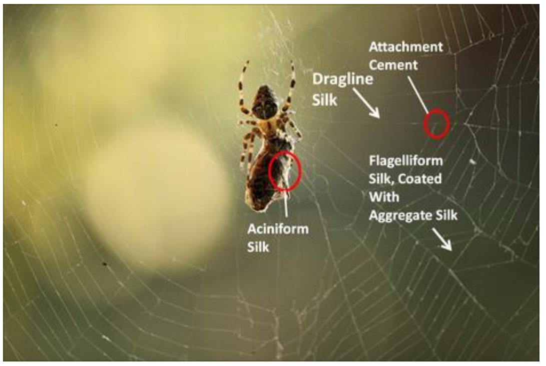
-highest performance

The toughest known spider silk is produced by the species Darwin's bark spider (*Caerostris darwini*): "The toughness of forcibly silked fibre's averages 350 MJ/m$^3$, with some samples reaching 520 MJ/m$^3$. Thus, *C. darwini* silk is more than twice as tough as any previously described silk, and over 10 times tougher than Kevlar".




Spider silk is incredibly tough and is stronger by weight than steel. Quantitatively, spider silk is five times stronger than steel of the same diameter. It has been suggested that a Boeing 747 could be stopped in flight by a single pencil-width strand and spider silk is almost as strong as Kevlar, the toughest man-made polymer. It is finer than the human hair (most threads are a few microns in diameter) and is able to keep its strength below -40°C. The toughest silk is the dragline silk from the Golden Orb-Weaving spider (Nephilia clavipes), so-called because it uses silk of a golden hue to make orb webs.

Spider silk is also very elastic and capture silk (sticky silk for catching prey) remains unbroken after being stretched 2-4 times its original length. Spider silk is tougher, more elastic and more waterproof than silkworm silk so it could have a much wider range of applications. It is simple to see why spider silk is of such interest to materials chemists since new ultra-strong fibres based on the silk could be developed.




To find out how most spider silk is five times stronger than steel, scientists analyzed the silk that venomous brown recluse spiders use to create their ground webs and hold their eggs, using an atomic force microscope. They found that each strand—which is 1000 times thinner than a human hair—is actually made up of thousands of nanostrands, only 20 millionths of a millimeter in diameter, they reported last month in ACS Macro Letters. Just like a tiny cable, each silk fiber is entirely composed of parallel nanostrands, which they measured to be at least 1 micron long. That may not sound very lengthy, but on a nanoscale, it's at least 50 times as long as these fibers are wide—and researchers believe they could stretch even further.

## Production

There are seven types of silk produced by seven silk glands. A single spider does not possess all seven glands but has at least three if it is male (dragline, attachment and swathing silk) or four if it is female. The additional one is for egg sac silk. The seven types of gland are:

-Achniform gland: swathing silk.
-Cylindriform gland: egg sac silk.
-Ampullate glands (major and minor): non-sticky dragline silk. Silk from the minor ampullate gland is only half as strong as that from the major gland.
-Pyriform gland: attaching threads - attachment discs are made which anchor a thread to a surface or another thread.
-Flagelliform gland: core fibres of sticky silk.
-Aggregate gland: outer part of sticky silk - droplets of an adhesive substance are deposited along the threads

## Applications of spider silk

Humans have been making use of spider silk for thousands of years. The ancient Greeks used cobwebs to stop wounds from bleeding and the Aborigines used silk as fishing lines for small fish. More recently, silk was used as the crosshairs in optical targeting devices such as guns and telescopes until World War II and people of the Solomon Islands still use silk as fish nets.

Current research in spider silk involves its potential use as an incredibly strong and versatile material. The interest in spider silk is mainly due to a combination of its mechanical properties and the non-polluting way in which it is made. The production of modern man-made super-fibres such as Kevlar involves petrochemical processing which contributes to pollution. Kevlar is also drawn from concentrated sulphuric acid. In contrast, the production of spider silk is completely environmentally friendly. It is made by spiders at ambient temperature and pressure and is drawn from water. In addition, silk is completely biodegradable. If the production of spider silk ever becomes industrially viable, it could replace Kevlar and be used to make a diverse range of items such as:

-Bullet-proof clothing
-Wear-resistant lightweight clothing
-Ropes, nets, seat belts, parachutesKevlar sail
-Rust-free panels on motor vehicles or boats
-Biodegradable bottles
-Bandages, surgical thread
-Artificial tendons or ligaments, supports for weak blood vessels.

However the production of spider silk is not simple and there are inherent problems. Firstly spiders cannot be farmed like silkworms since they are cannibals and will simply eat each other if in close proximity. The silk produced is very fine so 400 spiders would be needed to produce only one square yard of cloth. The silk also hardens when exposed to air which makes it difficult to work with.

https://www.sciencemag.org/news/2018/11/spider-silk-five-times-stronger-steel-now-scientists-know-why
https://en.wikipedia.org/wiki/Spider_silk
http://www.chm.bris.ac.uk/motm/spider/page2h.htm