Can spider genes be genetically engineered to make eco-friendly cars?

Spider silk has a unique combination of properties that make it a highly desirable material. But since spiders can’t be farmed, it’s not suitable for mass production. The Department of Energy has awarded a grant to a laboratory at Utah State University that is researching transgenic bacteria that produce spider silk. Their hope is that spider silk will make safer, more energy-efficient cars.

Dr. Randy Lewis, whose lab at Utah State University studies spider silk, compares the molecular properties of spider silk to Legos and to Slinkys. Spider silk is strong because it has a pin-and-hole locking mechanism, akin to the way Legos stick together. It’s elastic because it is long and spiral-shaped, like a Slinky.

If you’ve ever accidentally walked through a spider web, you have some idea of the amazing properties of spider silk. Pound for pound, it’s stronger than steel, but it’s also extremely light, stretchy, and resistant to damage.

Reportedly, ancient Greeks used spider silk to dress wounds. Australian Aborigines used it as fishing line. In World War II, black widow silk was used for crosshairs in firearm sights. In 2012, Japanese researcher Shigeyoshi Osaki made spider-silk violin strings. The same year, the Victoria and Albert Museum in England proudly displayed the largest garment ever made of spider silk. But it took one million spiders and four years to make.

Unfortunately, we can’t farm spiders very well. They’re predatory, territorial, and cannibalistic. But we can grow bacteria. Enter transgenic bacteria with spider genes.

So why bacteria? Lewis’s team has investigated quite a few organisms that might be able to produce spider silk. They have inserted spider silk into alfalfa and into silkworms. Both of those organisms have their benefits, because they can be scaled up well. We already know how to farm alfalfa and silkworms. Unfortunately, the strains of alfalfa and silkworms we have don’t produce enough spider silk to make them efficient yet. Utah State University also has a herd of over 30 transgenic goats expressing spider silk proteins in their milk, first bred by Nexia Biotechnologies in 2000. A regulatory element was included with the introduction of the spider silk gene, so that the goats express the spider silk gene only in their milk. The goats’ milk must be filtered and dried to extract the protein, which is then made into a fiber and pulled through a syringe to make a thread of the silk. But the purification process is difficult, and the amount of protein we can get from a goat this way makes it impractical. Lewis is still researching goats, silkworms, and alfalfa to see if he can get more silk out of them.

Lewis’s lab has also engineered E. coli bacteria that produce spider silk. Bacteria are also a good bet, because transgenic bacteria are already used to produce proteins such as human insulin. While goats can take a year or two to begin producing milk, one of Dr. Lewis’s vats of bacteria can churn out half a kilogram of spider silk in about 18 hours. But there’s a major problem with using bacteria: they are very good at making small proteins like insulin (molecular weight: 6 kDa) but not so good at making larger proteins like spider silk (molecular weight: 80 kDa and up). Thus, his team has had to engineer the expression plasmid.
that produces the protein in the bacteria to be able to produce larger proteins.

The startup costs for bacteria-based spider silk production include giant, specialized vats to hold the bacteria. In the past, this has proved prohibitive. However, Lewis reports that their facility has dramatically increased its production of transgenic bacteria with the addition of two custom-built 500-liter fermenting vats.

Lewis recently received a grant from DOE Energy Efficient Transportation to research spider silk’s applications as a material for safe, eco-friendly materials in the automotive industry. He plans to investigate spider silk as an alternative to carbon fibers in cars.

Carbon fiber is used in some high-end vehicles because it is lighter than traditional steel. This makes cars more energy-efficient, because less weight means lower fuel consumption and greenhouse gas emissions in gas-powered cars. Decreasing weight could also make battery-powered cars more practical.

But spider silk is even lighter than carbon fiber, which could make it even more energy-efficient. Unlike carbon fiber, spider silk is not a petroleum product. Also unlike carbon fiber, spider silk can be sourced in the U.S. Since spider silk is biodegradable, silk could reduce the problem of waste as well. By contrast, one of the major environmental problems with carbon fiber is that it’s more difficult to recycle than traditional steel car bodies. Carbon fiber is also very expensive. So is spider silk- for now. But scaled mass production of spider silk is a hope Lewis has for the future.

Data on how spider silk would respond in a car crash are not yet available, but we have reason to believe that spider silk may be safer than carbon fiber. Carbon fiber holds up pretty well in car crashes, but it’s brittle. Spider silk is highly elastic- and the faster you pull it, the tougher it gets. Spider silk also has some degree of ability to pop back into shape after traumatic force has been applied, like ‘smart’ shape-memory alloys.

In addition, spider silk could make a highly effective airbag. Airbags right now are a problem because they’re explosive- note the warnings in cars not to let small children sit in the front seat. Lewis envisions airbags that envelop you rather than using explosive force to protect you from your windshield and dashboard. Because spider silk is very good at absorbing force, you would need less explosive force in a spider-silk airbag than a traditional airbag to keep you from hitting your dashboard in a wreck.

Even if you’re not in the market for a new car, spider silk technology has something for you. Because of spider silk’s unique physical properties, the other uses for it are boundless. In the future, spider silk may be used for medical applications like sutures or artificial tendons or ligaments. There’s even been some talk of lightweight, stretchy, tough spider-silk athletic wear, and I for one can’t wait to try that.

Steph Gorski is currently completing her PhD in entomology at NC State University. She is a contributor to Genetic Literacy Project, Biology Fortified, and SkeptiForum. You can email her at slgorski@ncsu.edu.
Additional resources:

- Bacteria with spider genes spin out silk, Wired
- The global transgenic menagerie, Genetic Literacy Project
- Bizarre yet beneficial uses of modern biotech, redOrbit
- What the F@$! is synthetic biology?, Genetic Literacy Project