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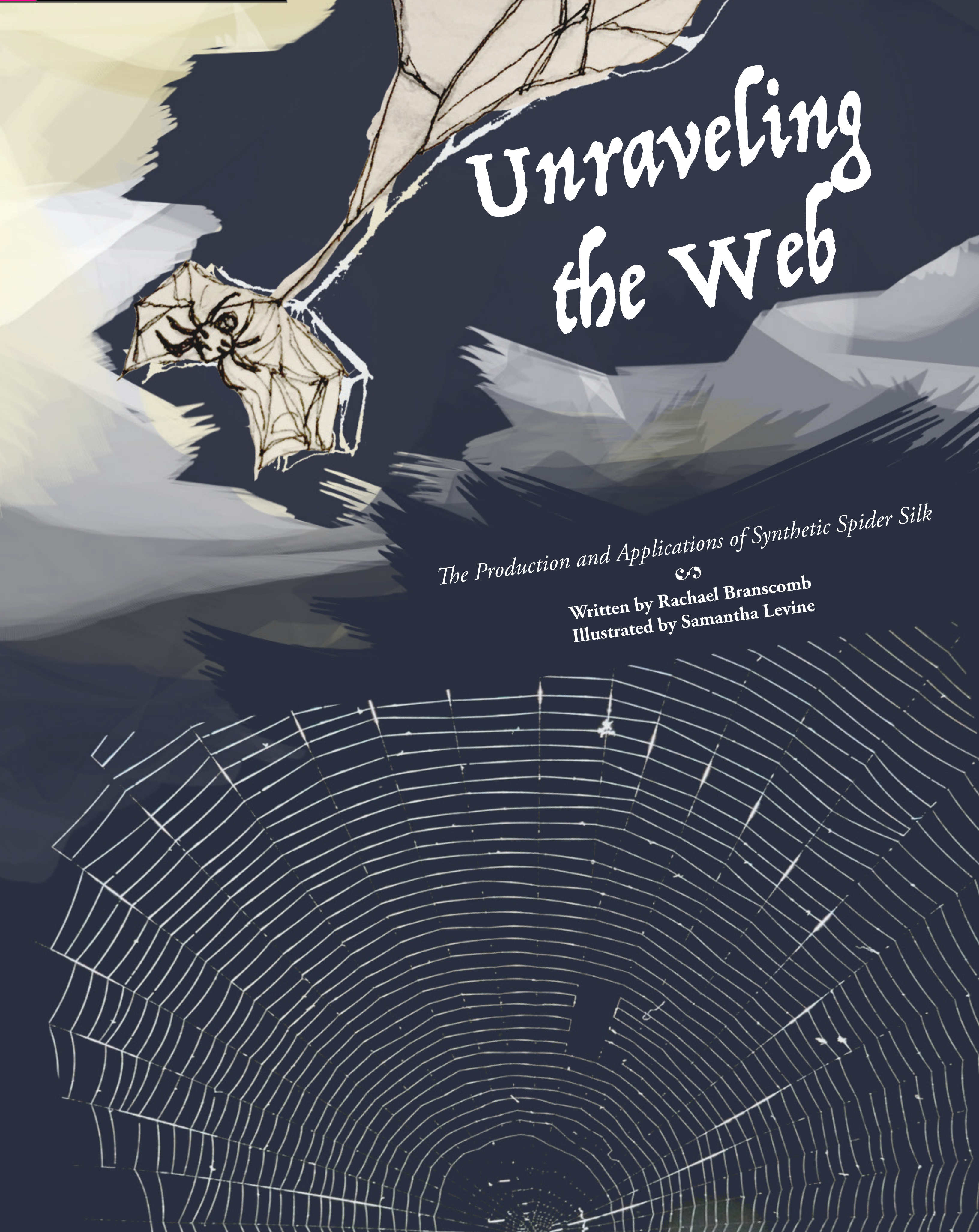
Unraveling The Web: The Production and Applications of Synthetic Spider Silk

Rachael Branscomb



Unraveling the Web

The Production and Applications of Synthetic Spider Silk

Written by Rachael Branscomb
Illustrated by Samantha Levine

Most people's interactions with spider silk are limited to an accidental panicked run-in with a web or the comic icon Spiderman. However, the incredible tensile strength and elasticity of spider silk could be a game changer in the production of everything from bulletproof clothing to synthetic skin. When size is taken into account, spider silk has greater tensile strength than high-density steel and is five times tougher than Kevlar. It is also biocompatible with the human body, biodegradable, antimicrobial, and hypoallergenic. Its usefulness in the medical world has already been widely recognized, but the synthetic silks generated up to this point have not been able to exhibit the same properties of natural silk. Scientists have also been unable to produce artificial silk proteins or spinning processes that would allow for the large-scale production of biomimetic silk.

Previous work in 2015 by Randy Lewis, a biochemist at Utah State University, led to the development of a method to generate synthetic fibers. Their artificial silk was much lower in protein level than the silk produced by a spider, resulting in weaker strength in the synthetic silk. Recently, a team of scientists led by Anna Rising from the Swedish University of Agricultural Sciences and the Karolinska Institute have developed a process to produce synthetic spider silk, nearly identical to a spider's own silk, by constructing recombinant DNA from two species of spiders. If the mass-production of silk from Rising's lab is possible, this discovery could revolutionize our industrial capabilities.

Spider silk is composed of a long chain of proteins, each with three main sections. The main body of the protein is made of repeating segments of amino acids called "repeats" that make up more than 90% of the whole protein. Lewis describes this repeating section as looking like towers of stacked Lego blocks connected by springs; the towers provide the strength, and the springs allow for elasticity. At each end of the main domain exists a non-repeating segment of amino acids that links to the next silk protein. This allows the proteins to attach to each other and produce fibers as the silk is spun.

Spiders store silk proteins as a water-based solution in their silk glands before it is shot out of spinnerets and spun into a continuous fiber. Thus, researches needed to find a similar starting protein that mimicked these watery proteins. Rising paired up with another biochemist, Jan Johansson, also from the Swedish University of Agricultural Sciences and the Karolinska Institute. Together, the two began to research how to artificially recreate the spider's silk proteins and the mechanisms by which silk is naturally produced.

Rising and Johansson's interdisciplinary team began the research process by collecting South African spiders and studying their genomes to determine which genes encoded the silk proteins. They then extracted these genes and used a polymerase chain reaction to make many copies of this particular sequence of DNA. These small segments of DNA were then inserted into E. coli bacteria, which implanted the silk genes into their own DNA and produced small amounts of natural silk proteins. However, the silk proteins that the bacteria were producing could not be dissolved in water, so the researchers were unable to make a protein solution like the one that spiders store in their silk glands.

Luckily, at the same time that Rising and Johansson were performing research with the African spiders, Chinese researchers were also tackling this project with Asian spiders. Working together, the two teams of researchers were able to select specific soluble parts of the two different spider species' genes and splice them together to create hybrid genes. These genes were then again inserted into bacteria, which produced a new chimeric protein. This new protein had a beginning section from the African spider's genes, a middle section composed of two repeats also from the African spider, and a terminating segment drawn from the genome of the Asian spider. The research put into splicing the spider's

genes to produce a new kind of protein paid off: the chimeric protein was found to be soluble in water! Rising's team had found a way to create a silk protein solution that was similar to that found in a spider's natural silk glands.

The next step was to figure out a mechanism to turn the newly formulated protein solution into actual fibers. Previous research by Rising and Johansson's team had determined that the pH of the silk gland solution decreased as it was drawn from the gland into strands. The lab developed a setup where the protein solution was pumped through a thin tube that narrowed at the tip and propelled the solution into a beaker of acidic solution via a jet stream of air. At the lower pH, the proteins linked up into chains to form spider silk threads. The lab was able to produce strands that were a kilometer long! These strands could then be pulled out of the solution and wound onto spools.

There is still room for improvement in this silk fiber production process. Further research is currently being done to determine how to increase the tensile strength of the artificial silk. Lewis and Johansson agree that the strength of spider silk likely stems from the number of repeats that the proteins have in their core domain. This makes this artificially created silk even more impressive because it is about a third the strength of naturally produced spider silk, but only has two percent of the number of repeats of the African spider's silk. Further research may need to be completed in this area to further test the possibilities of increasing the strength of artificial silk.

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Now that the basic ability to produce synthetic spider silk has been understood and developed, it is only a matter of time before we should be expecting to see its integration into many aspects of our lives. Rising and Johansson are now mainly focused on bringing the silk's unique abilities into the medical world. Their team is working on using spider silk for nerve regeneration associated with injuries to the spinal cord. With the incredible properties of artificial silk, it's possible that in the upcoming years we could see aircraft parts, tendons, protective gear, and possibly nerves all partly or completely comprised of spider silk. Though we may never be able to shoot web out of our wrists or swing around skyscrapers like the Amazing Spiderman, the applications for synthetic spider silk are still amazing in their own right!