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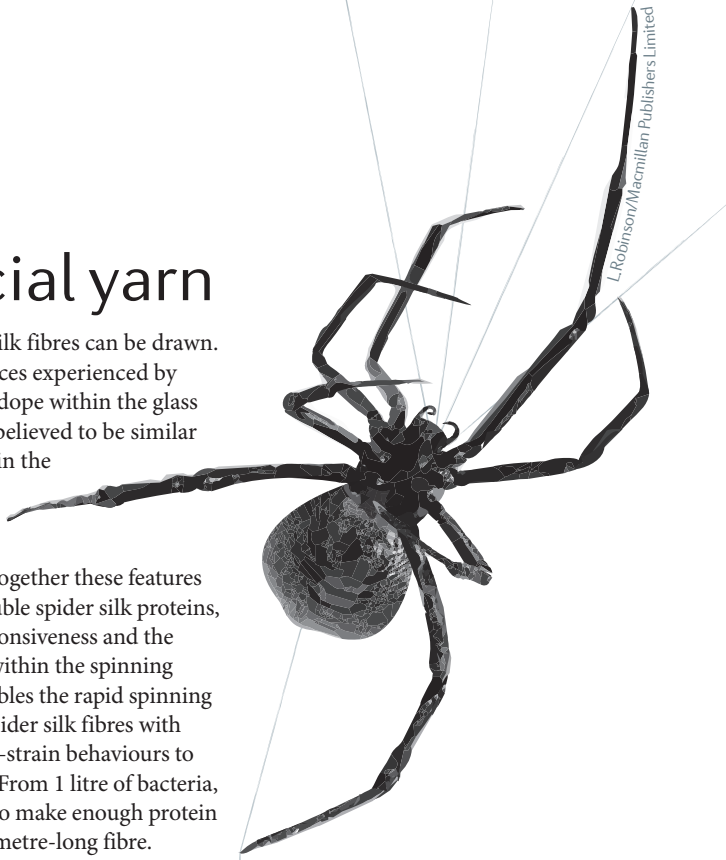
SPIDER SILK

Spinning an artificial yarn



Making a silk fibre takes a spider only a fraction of a second. However, this amazing process, and the high mechanical strength of native spider silk, is difficult to mimic in artificial systems. Now, Jan Johansson, Anna Rising and colleagues, writing in *Nature Chemical Biology*, have used their understanding of the mechanism of spider silk formation to make the toughest artificial spider silk fibres to date. "Our aim was to spin artificial spider silk in a biomimetic manner, that is, using the same proteins and conditions as the spider," explains Johansson.

The researchers designed a chimeric recombinant spider silk protein (spidroin) that combines soluble N- and C-terminal domains from two different species of spider. This extremely soluble spidroin is produced in a bacterial culture in high yields and at concentrations as high as 500 mg ml^{-1}. These transparent and viscous mixtures (often referred to as the spinning dope) are of similar concentrations to those that the spider stores proteins in inside its silk glands.

Johansson and Rising have also developed a spinning device that mimics the drop in pH (from around pH 7 to pH 5) and the shear forces that native spinning dope experiences in the spider's silk glands. More specifically, the concentrated spidroin spinning dope is pumped through a glass capillary into an aqueous buffer collection bath, from which silk fibres can be drawn. The shear forces experienced by the spinning dope within the glass capillary are believed to be similar to those within the narrow ducts of the silk gland.

Bringing together these features — highly soluble spider silk proteins, their pH responsiveness and the shear forces within the spinning device — enables the rapid spinning of artificial spider silk fibres with similar stress–strain behaviours to native fibres. From 1 litre of bacteria, it is possible to make enough protein to spin a kilometre-long fibre.

"Our process recapitulates the delicate molecular mechanisms that dictate native spider silk formation," says Rising. The pH decrease within the system causes the terminal domains of the spidroins to change their conformations in ways that mimic the mechanism of formation of native spider silk. The pH change causes the N-terminal domains to form dimers and lock the structures into larger networks. The C-terminal domains, however, unfold and form β-sheet fibrils, which, in turn, trigger the repetitive section of the protein to form β-sheets. It is this 'lock-and-trigger' mechanism that ensures that the silk proteins assemble into well-ordered structures in the silk fibre rather than form protein aggregates that usually result when denaturing conditions are used.

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"An advantage of this biomimetic method is that the small and defined nature of our designed spidroin and robustness of the spinning method allow precise control of the composition of the biomimetic fibres," explains Johansson. "We are now working on improving the mechanical properties of the fibres by using protein engineering and optimization of the spinning process," adds Rising. "Also, we aim to make defined 3D structures for tissue engineering applications, in particular, for nerve regeneration."

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