SPIDER SILK RESEARCH LAB

SPINNING A NEW WEB

Using spider silk for clothing may not seem to be an attractive proposition for common people, but spider silk is the toughest natural fibre, which is also non-toxic and antibacterial. Therefore, scientists the world over want to tap into this resource. Spider silk-like materials can potentially be used in making military and sports clothing and equipment, smash-resistant films and casings, durable lightweight apparel and biomedical materials. What is more, **DR. SEAN BLAMIRES** from the Evolution and Ecology Research Centre, UNSW Science, Australia, believes dresses made of spider silk may be available for common people in future. Though the easiest way to get spider silk appears to be from the web itself, this is not feasible since spiders have a tendency to cannibalise each other. Therefore, any successful attempt to create spider silk would require use of cutting edge genetic and spinning technologies. And this is what Blamires, along with his team, aspires to achieve. He has undertaken an international study funded by the PLuS Alliance to examine whether spider silk can be replicated. In an email interview with **SAVITA VERMA**, Blamires elaborates on the project, success achieved so far, and the challenges ahead.

Why scientists are looking at creating spider silk in the laboratory? How important is making spider silk? What are its special features?

Spider silk is the toughest known material. Even tougher than Kevlar or other tough synthetic fibres, like nylon. It is tough because it has the unique combination of high strength—it is very hard to break it in two—and extensibility—it can stretch like rubber when pulled. Man-made fibres tend to have one or other of these properties, not both. Add to that, spider silk has a low density, so it has this amazing combination of strength, extensibility and light weight.

Accordingly, if we could make a material that performed like spider silk it would have thousands of potential applications. We cannot however set up spider farms and spool the silks straight from spiders as we do with silkworms. This is because spiders eat each other, need a lot of space for their large webs, and are difficult to handle for silking. Additionally, any one spider, such as a giant orb weaving spider or garden spider, gives us, if we are lucky, around 10 mg of silk which would take four hours plus to collect. This is not a viable option, so we are looking at ways to mass produce fibres using genetic engineering methods.

What are the potential applications of spider silk?

A synthetic spider silk would be of most benefit in applications where its performance can come to the fore. Anti-ballistic/anti-smash clothing, coatings or surfaces is an earmarked application. Other applications could take advantage of its anti-bacterial and biocompatibility properties. These might include medical devices like bandages, surgical (internal or external) sutures and connectors. Spider silk is also conductive and contractile when wet, so could serve as nerve or muscle transplants, or as lightweight and durable conductive materials in electronics.

Have there been any attempts to use natural spider silk, that is from the spider web?

The only applications of spider silks from webs I know of are historical (Roman, I think) and reported for some indigenous cultures. I have heard of Australian aboriginals using spider webs as nets and Pacific Islander people creating a thing called a "smothering hood" to suffocate widowed women within (for memory these are from the book *Gossamer Days* by Elaine Morgan).

If you are asking about silk that has been forcibly reeled straight from the spider, a golden coloured shroud and a gown was woven using over a million Madagascar golden orb weaving spiders. They took something like four years to put it together. The gown is on display in the Victoria and Albert Museum and the shroud is in the American Museum of Natural History.

Why is spider silk suitable for military and sports clothing?

It is the extreme toughness of spider silk that makes it (or perhaps a fibre mimicking its properties) attractive for such applications. A spider silk-like material would perform better than Kevlar or Twaron-based clothing and equipment at protecting terrestrial defence personnel in the field, as wearing and/or carrying the latter is extremely heavy, burdensome, and often uncomfortable. Spider silk has all the performance capabilities of Kevlar/Twaron but is light weight and, exceptionally smooth, and highly comfortable.

What improvements will spider silk make in the sector of medical devices and prosthetics, and why? What kind of medical devices and prosthetics are you talking about? What are the issues you hope to address with spider silk while making medical devices and prosthetics?

One of the goals of the Spider Silk Research Lab (SSRL) is to find, promote, and educate about all kinds of applications of spider silk and other natural materials. To this end, I promote the value and amazing properties of spider silk with the expectation that labs with previously unthought of applications might come forward. The next big application therefore might be one we cannot foresee.

What kind of efforts have been made in creating spider silk in other laboratories,

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and has there been any significant breakthroughs?
While I don't know what everyone is doing around the world, to the best of my knowledge there are just a few labs currently working on this, but the effort being put in by each of them is immense.

In my lab we research what is possible with spider silk, we describe the properties and potential applications and look for collaborators and/or customers that might work with us or purchase our products. We have a programme to develop recombinant (where the genes for the proteins are expressed by bacteria) spider silk, but it is in its infancy. We are trying to advance our programme at the moment. There are labs around the world that are more advanced in their genetic engineering programmes than we are. Some have also spun fibres, and some of these fibres are of high quality. A few companies, like Spiber (Japan) and Bolt Threads (US), have successfully incorporated threads into clothing. We think that success stories are positive and exciting, and the more we hear of them, the more this industry will grow. I do think it has enormous potential to become a boom industry.

When and how did the idea to research into spider silk strike you? What inspired you? What research have you carried out in creating spider silk in the lab, and how far have you succeeded?
I am, by background, an ecologist. I did my PhD on the ecology of the orb weaving spiders in the grounds of the University of Sydney. It struck me during this study that spiders use and entirely depend on a material that they manufacture from their food and water, and that this material is superior than anything that human engineering can come up with. Not to mention the structural engineering feat of its web (how it maximises materials yet is almost transparent to inset prey) and the reversibly adhesive water-based glue it uses to capture and hold on to insects in full flight. After my PhD, I decided I wanted to focus on spider silks and was fortunate enough to do a post-doctorate at Tunghai University in Taiwan, where I was given the freedom to explore cross-disciplinary methods, like mechanical and molecular characterisations using tensile machines and synchrotron radiation, to study spider silks in detail across hierarchical levels.

What is the estimated cost of this project?
The project for which we have a PLuS Alliance seed grant will be a collaboration between three of us (myself, Dr. Aditya Rawal and Associate Professor Chris Marquis) at the University of New South Wales, Jeffery Yarger, who heads the NMR Facility at Arizona State University, and Rivka Isaacson, a chemical biologist at King's College, London. The funding is around $50,000 for one year. It is modest, but it will help to rapidly advance our recombinant silk production programme and spin and test the fibres produced by it.

How do you plan to take this work forward? Which are the other institutes/ universities involved in this work and what will be their contributions.
The SSRL collaborates with many other teams from around the world and these have contributed, and will continue to contribute, to this and

other programmes. I would like to make mention of some significant ones:

Prof I-Min Tso and Dr. Dakota Piorkowski from my former lab at Tunghai University, Taiwan, are still actively associated with many of the SSRLs research and business activities, including the establishment of our silk supply chain.

I collaborate on a European Union funded project called the Biocombs4Nanofibres project, of which the most important direct collaborator is Dr. Anna-Christin Joel at RWTH University of Aachen in Aachen, Germany. I collaborate with Joel on research into adhesive silk fibres, and fibre manufacturing protocols.

I am working closely with UNSW Art and Design researcher Dr. Patricia Flanagan to find ways to incorporate natural and manufactured fibres into wearable designs.

The SSRL was involved in a long-term trans-continental study comparing the genetics and chemical and physical properties of silk from over 1,000 species of spider with researchers at Keio University and Riken in Japan, as well as a multitude of labs from other countries. We are preparing a major "silkomics" paper and will also make an open access silk property database.

I have a long-term research collaboration with the Institute for Frontier Materials at Deakin University and have initiated an exciting new applied materials collaboration with researchers at the Tech Lab at the University of Technology, Sydney.

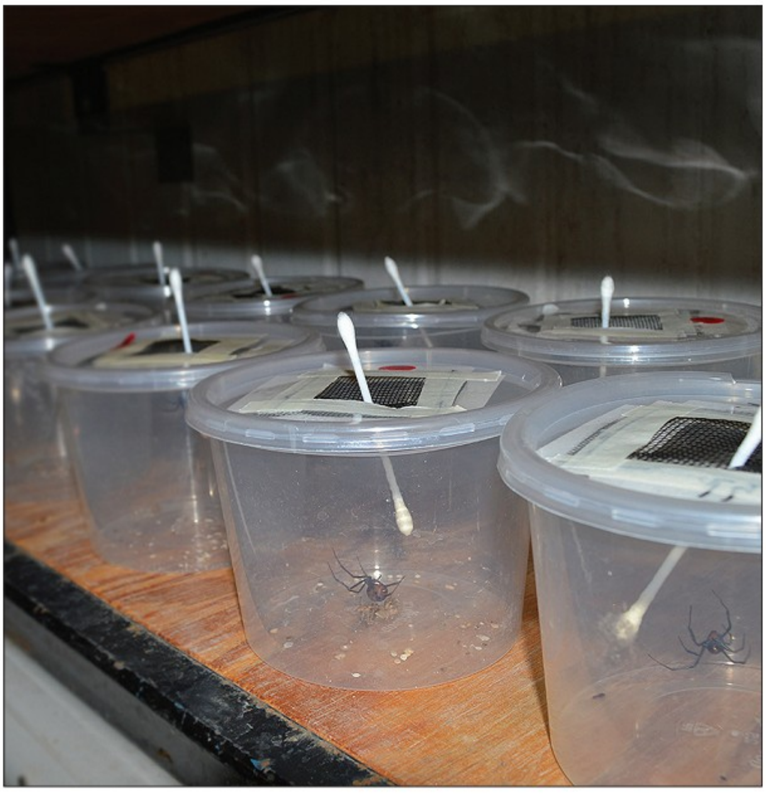
What will be the approach followed in the project? Does one need to identify all the proteins and replicate these in the lab or only some proteins? And how do you make these into fibres? Has some work already been done in this direction?

No, one does not need to know and replicate all of the proteins, just those directly involved in influencing the properties of the silk will do. Even then, we might only need partial amino acid sequences to accomplish the goal of making a tough silk. This is critical, as it is really difficult to get the bacteria used in the recombinant experiments to replicate full sequences as they are particularly long and repetitive.

The fibres can be spun from the proteins in many ways, but the principal is not much different to those used to spin fibres like rayon, that is, run a concentrated solution through a tube of decreasing width. Shear forces on the solution will force it to solidify as it is extruded from the column into a coagulating bath (usually ethanol or methanol). There are some extra things that might need to be done to replicate the chemical conditions found in the spider's silk gland as these might ensure the properties are adequately replicated. Sometimes a "focusing fluid" is involved to add extra shear.

Could you tell something about the Spider Silk Research Lab, founded by you. What was the idea behind setting up of this lab? What kind of work is being carried out in this lab?

The Spider Silk Research Lab was a name I gave my lab (it was more an unused bench space within what is called the "Sex Lab" at UNSW, run by Prof Rob Brookes) when I moved to UNSW from Tunghai University in 2014. I employed an IT designer to build me a website in 2015, within which she designed what I



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thought was a cool logo. When my post-doctorate at UNSW finished in 2018, I registered the lab as a business, with the intention of it becoming profitable enough to employ me full-time. It isn't there yet and I teach at a high school by day and run the lab in my spare time. I have kept however my lab and office space at UNSW where I have an honorary appointment. This has allowed the lab's activities to keep moving in the right direction. However, with a silk supply chain initiated, a good, solid team of new and long-term partners and collaborators, some amazingly great students, momentum building on the synthetic silk production and application, and now some seed funding, things are looking very positive.

Is the international study funded by the PLuS Alliance, part of the spider silk lab?
Yes. Promoting and collaborating on all kinds of spider silk research projects is a core activity of the lab including this one.

What is the time frame of this project?

How soon spider silk may be available for applications?
The grant is one year. It is to develop our technology to a level where we can approach industries for collaboration and/or funding. On building a new fibre, it is really difficult to put a timeframe. All going right, it could be a few years away. We don't really know and can't yet foresee the obstacles that may come at us. One thing that we do have is a plan for applying the fibres, as one of my collaborators, Patricia Flanagan at UNSW Art and Design, has identified some fascinating applications in wearable technology and is already experimenting with how they can be functionally incorporated into her designs.

What difference is this silk going to make for commoners? Can we see dresses, in the long run, made of spider silk?
My job is to promote all possibilities, so I am going to say, yes, we certainly could. At least a spider silk-wool/cotton hybrid or something like that. Indeed, this is the sort of thing Dr. Flanagan is keen to do.

What are the areas in which you have worked so far? In future, which directions you might take your research to?
Overall, I'd describe my research direction as: starting with big ecological questions (effects of seasonality, populations, diet,/nutrients predators on webs) as a PhD student back in the early/mid 2000s, I focused on the silks that comprise the webs soon after moving from University of Sydney to Tunghai (early 2010s). Having moved back to Australia, I narrowed my focus further to examining the genes making up, and proteins and molecules acting within, the silk. The idea to engineer and spin new fibres is new, however. My collaborator, Aditya Rawal at the Mark Wainwright Analytical Centre, and I floated it three or four years ago (he even asked his father, a molecular biologist in India, to help), but it only became an active project about two years ago, thanks to help from associate professor Chris Marquis at the Recombinants Facility at UNSW, and the incredible students he has managed to recruit.FF