Meet the toolmaking genius of the animal world

As night falls in my overgrown Australian garden a remarkable hunter stirs from her daytime hiding place, selects an ambush site, and begins to manufacture (in the truest sense of the word) a hand weapon that is elegant in design, precise in its craftsmanship and lethally efficient in operation. This remarkable tool maker is, of course, a spider. Its weapon, a small rectangular net fashioned from a knitted ribbon of specialised, multi-strand web-silk, is designed to be thrown over the spider's prey to immobilise it for the kill. It represents a strategy very like one that was used by a class of Roman gladiator known as a Retiarius, hence these spiders' common collective name, Retiarius spiders.

Deinopis subrufa (f), Sydney, NSW.

Retiarius Warriors

Wielding a trident and a large rope net with weights around its edges, a type of Roman gladiator known as *Retiarius* was customarily matched against an opponent armed with a sword, shield and helmet. Equipped with a strong elastic net and a pair of needle-sharp fangs, Retiarius spiders (Fam: Deinopidae) live up to their warrior name by regularly casting their hunting nets at almost anything that moves within their reach, a habit that occasionally pits them against such dangerous opponents as centipedes, scorpions and other spiders.

To capture such prey with least risk to themselves they select their ambush sites with great care. They walk around the potential hunting ground, tapping with their front feet to ensure that it has no loose debris that might entangle their net and spoil their attack. If it passes this inspection, they construct a minimal triangular scaffold of silk over the area and build into it an aerial 'platform' that sits directly above their chosen target zone.

It takes up to half an hour for a Net-casting spider to knit its highly specialised hand weapon, and they take great pains to ensure that it is well made and suspended at exactly the right height above the chosen target zone. They have no alternative: like the Retiarius gladiator, their lives absolutely depend on precision.

With their skull-like heads, boney palps, huge ruby hunting eyes and baleful glare the Deinopids are commonly referred to as the 'Ogre-faced spiders'. This a male Deinopis bicornis*.*

The original Retiarius

Net-casting spiders are well camouflaged for hiding in dry grass and dead foliage (*left*), so they are very rarely seen. In fact, few people even know they exist, and even fewer know their of their extraordinary talent for tool-making.

As the sun sets and the twilight begins, these hunters emerge from their hiding places and search for an appropriate site for an ambush. For this they need a small patch of fairly open flat ground fringed with tall grass or shrubs. It must also be free of loose litter that might snag their hunting nets. It should be said here that most of the hunters are female since males give up hunting after their final moult in order to concentrate on finding suitable mates.

Emerging from her daytime hiding places at twilight the Retiarius seeks out a potential ambush site and walks about the area, tapping the ground with her front feet, apparently to detect twigs and other debris that might snag her net and spoil the attack. Having selected the flattest, least-cluttered patch she then loops her primary silk threads—she has three kinds of silk—around two widely-spaced and carefully chosen 'bollards' on the ground, and erects a complex triangular 'scaffold', attaching its apex to the foliage at the edge of the clearing. She must ensure that this silken framework leans across the chosen target zone at an angle that allows her to site her aerial ambush 'platform' precisely over the target area, and at the optimum height for a successful attack. Too low and the net may touch the ground and become snagged on leaf-litter: too high and she may not be able to reach smaller prey at all. After adding some minor reinforcement to the structure she then hangs head-up at the apex of the triangle and begins to knit her hunting net …

Deinopis subrufa (f), Sydney, NSW.

The hunting net

Unlike the main scaffolding, the hunting net consists of three different kinds of silk from three different sets of silk glands, and she manufactures the final product 'manually,' knitting together these three kinds of silk with her hind feet to form a ribbon of enormous strength and elasticity. The two primary threads are like fine nylon fishing line: these provide the strength. The second pair of threads are multi-fibred, like wool, while the third type of silk, extruded by a battery of glands known as a cribellum, looks just like a thin ribbon of clear plastic. It consists, in fact, of a tight array of parallel fibres so fine they can be distinguished only under a microscope.

Although the three types of silk emerge as liquid amino acids, all of it hardens on contact with the air and none of the silk is equipped with the sticky coating that most garden spiders produce. The Retiarius hunting net snares its victims simply because its fibres are so fine they will catch on the slightest protuberance or irregularity—even those on the surface of plate glass.

As the three types of silk begin to extrude from the spider's silk glands she lays one of her rear feet across them, and with a quick pushing motion crimps both of the 'wool' strands and the ribbon of micro fibres into a continuous series of minute pleats. This act simultaneously lays these pleats on to the two heavy-duty silk lines extruded by her primary spinnerets. Her rear feet are equipped with specialised combs of stiff hair to help the pleating process, but it is so slow and tiresome that she swaps feet occasionally.

The composite ribbon of silk produced by this laborious process is the key to its effectiveness. Few victims escape the clutches of this complex hand weapon …

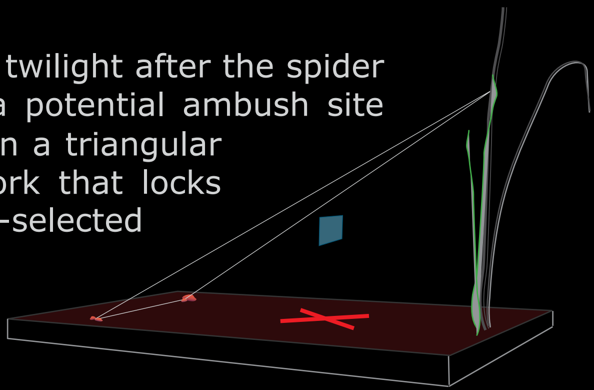
Deinopis subrufa (f), Sydney, NSW.

The Net-caster's mobile hand weapon

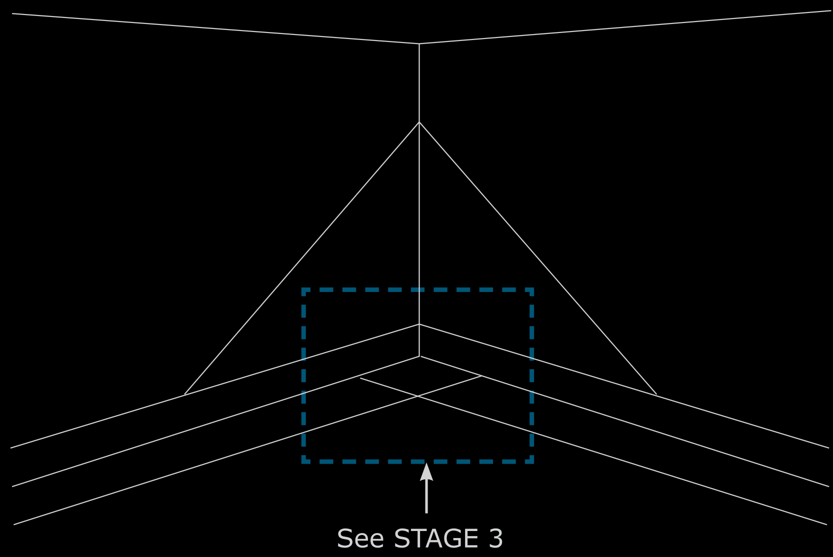
There are four major stages in its construction:

STAGE 1

This first stage begins at twilight after the spider has physically checked a potential ambush site for its suitability and spun a triangular three-line outer framework that locks the scaffolding to this pre-selected killing ground.



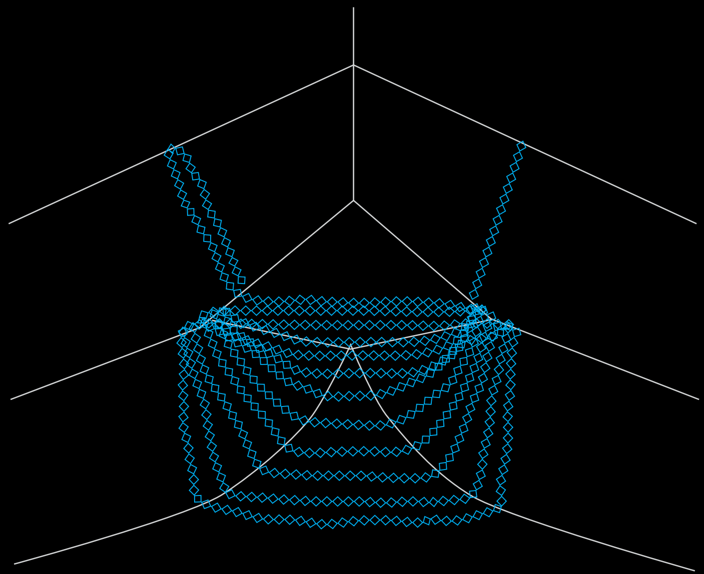
STAGE 2



This shows the spider's preliminary scaffold. The blue rectangle indicates the framework into which the hunting net will be set.

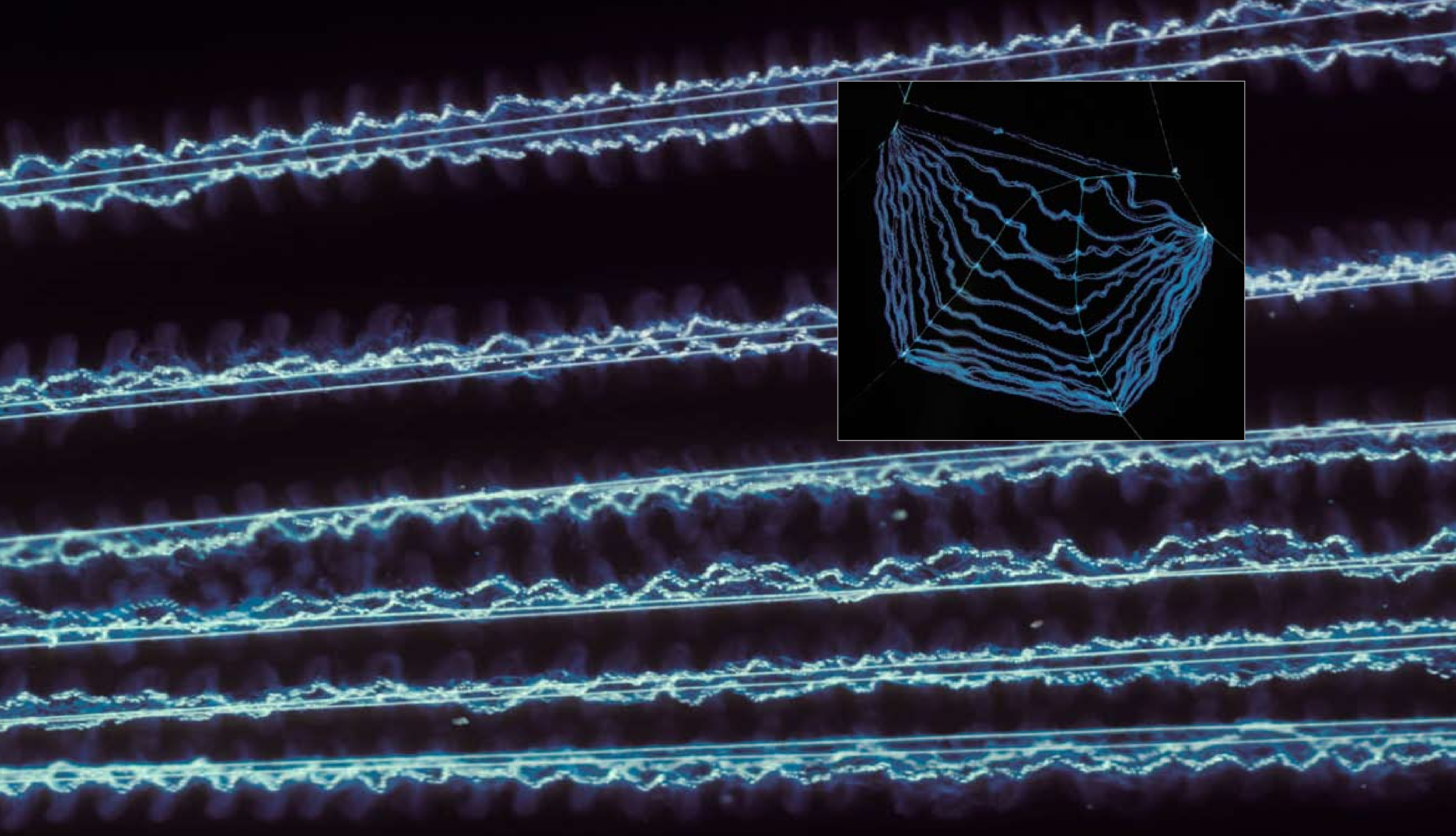
STAGE 3

Modified scaffold with the finished hunting net still under tension in its vertical position.

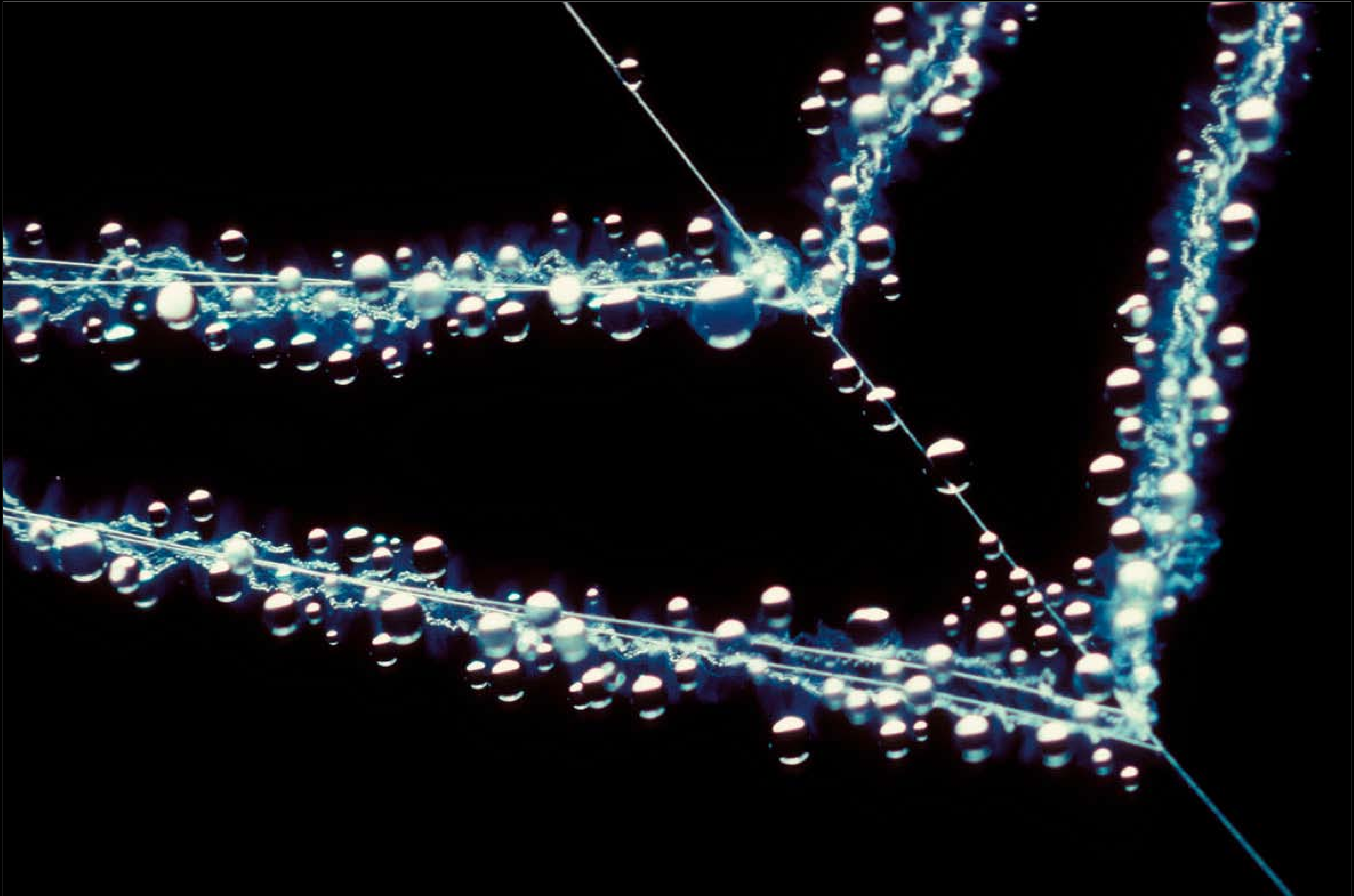


STAGE 4

The spider then bites through the vertical suspension line, which collapses the net downwards, leaving it suspended only by the three support lines on each side. This crucial act of deconstruction 'arms' the weapon, making it semi-mobile and able to be bounced downward when the spider lunges at its prey.



This is a portion of a net-caster's hunting net. The shadowy bluish loops that show on either side of the main threads reveal the even pleats in the broad array of micro-fibres that emerge from the spider's battery of specialised silk glands known as a cribellum. Each loop represents a push by the net-caster's 'knitting' foot. None of the silk is 'sticky', but its fibres are so fine that they will catch on the imperfections in the surface of plate glass. The bluish colour is characteristic of cribellate silk.



A sprinkling of dew transforms a Deinopid hunting net into an exquisite piece of fairy jewellery.

Testing the weapon

As soon as the small rectangular catching net is complete the spider switches off all but her main spinnerets and performs the final and most astonishing step of the whole manufacturing process. She climbs to the apex of the scaffolding immediately above the hunting net and bites through the crucial suspension point that has until now kept the net under tension in the vertical position. This allows the net to fall into loose horizontal folds, suspended only by the side stays. On the face of it, this crucial deconstructive act arms the weapon by making it semi-mobile. It also implies that the spider has maintained a thorough grasp of the overall design of the weapon she has built and is fully aware of the mechanics and limitations of the finished structure. But more on that subject in a moment.

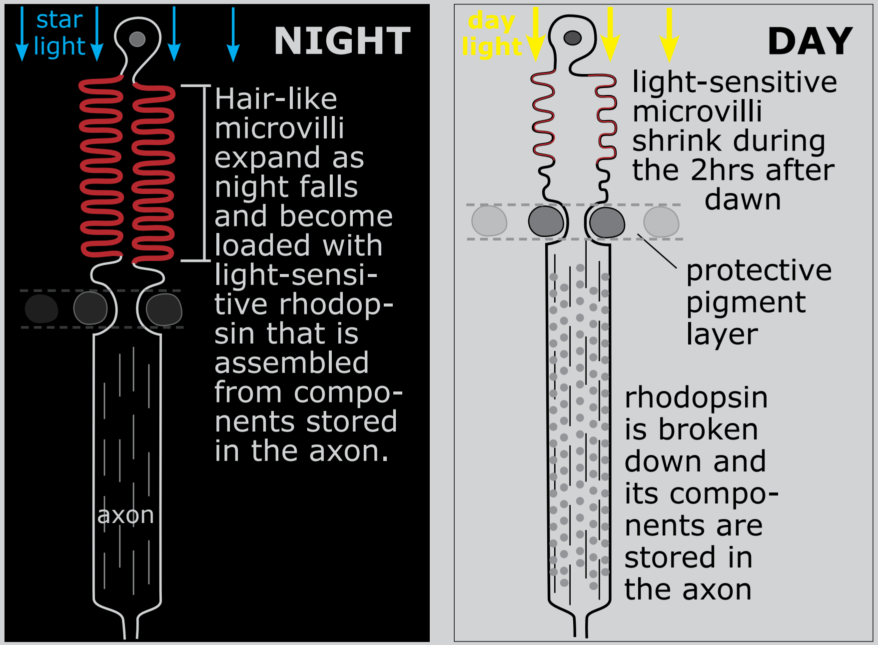
Rotating to a head-down position the spider then carefully picks up the four corners of the net with her claw-tipped front feet and begins a careful weapon-check. Still holding the corners of the net she extends each of her four front legs horizontally, one after the other, stretching the net diagonally in each direction to ensure that it is well-made and fully operational. If it passes this test, she delicately reaches down to touch the ground with one 'toe' (*right*) to ensure that the drop is perfect and that her prey will be within the range of her net-casting lunge. Then she settles down to wait.

Her livelihood now depends on her huge ruby hunting eyes. Their equivalent in photographic terms would be an f0.5 camera lens. They allow her to hunt by starlight alone, and the slightest movement in the target zone beneath her will trigger her attack reflex. The four front legs will flick downward and outward, spreading the net to more than four times its original size. …

Deinopis subrufa (f), Sydney, NSW.

Night and day vision

These are the photon receptors that form the retina of a net-caster's eye and give it unparalled night vision.



*Rhodopsin: See p.17

These eyes *really* have it!

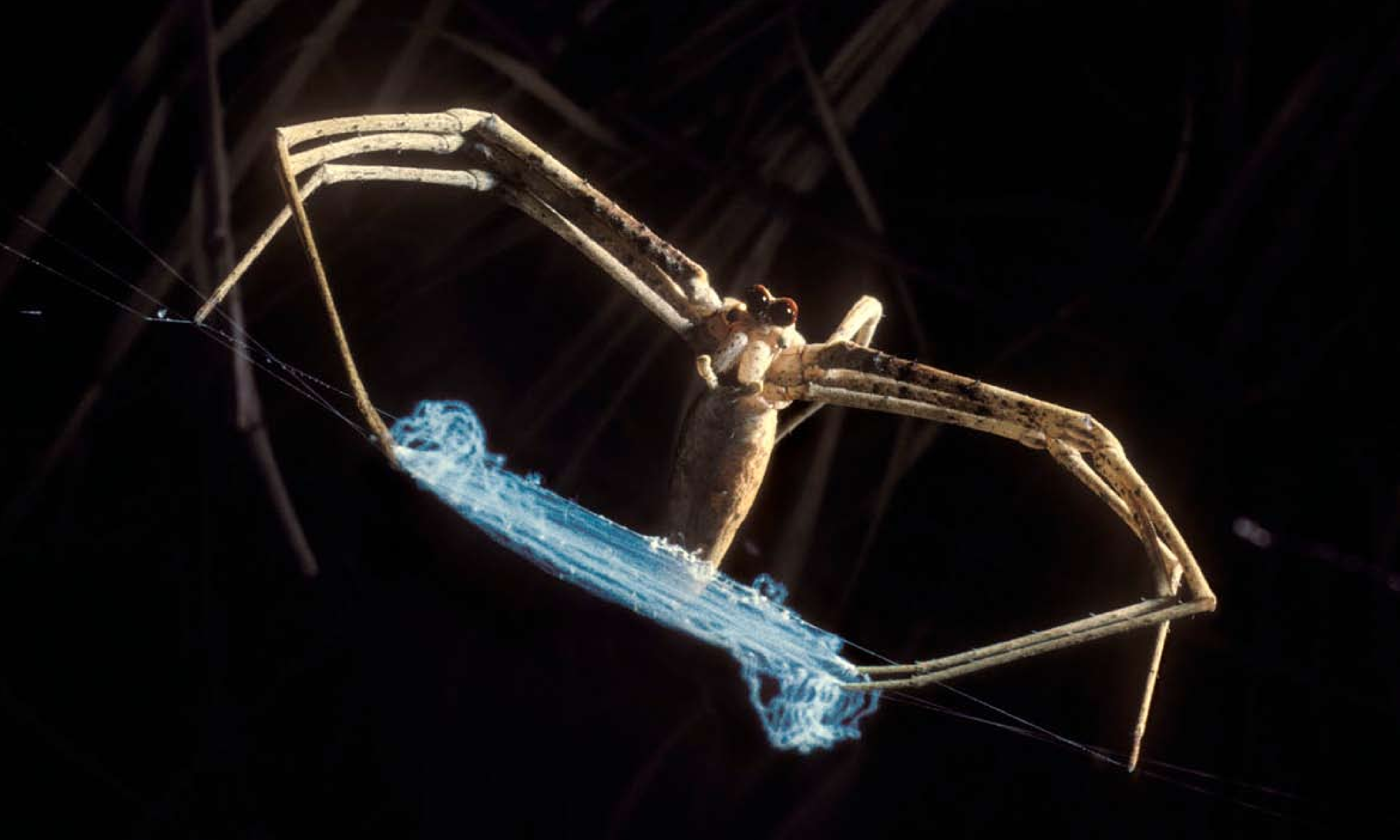
The second great weapon in the net-caster's armoury is just as complex and crucial as her hunting net. It is her hunting eyes.

All spiders have eight eyes arranged in four pairs, but none of them compare with the hunting eyes of *Deinopis*. In photographic terms each eye is like an f0.58 lens with a focal length of 40 mm mounted on a 35 mm camera. And their lenses are not simple. Each has two components that have different refractive indices, with the inner and outer elements combining to yield a sharper image.

To this impressive optical hardware evolution has added a retina lined with cells that are loaded with the highly light-sensitive orange-red pigment, rhodopsin. These cells are comparable to the rhodopsin-loaded rod cells that line the fringes of human retinas and enable us to see in dim light. Due to the peculiar construction of the 'microvilli' that display the spider's rhodopsin to the incoming photons of light, each of its light receptors receives almost 1500 times as many photons as a human rod cell. (Our rod cells are handicapped by being mounted 'in reverse' with their most sensitive rhodopsin reservoirs facing the back of the eye.)

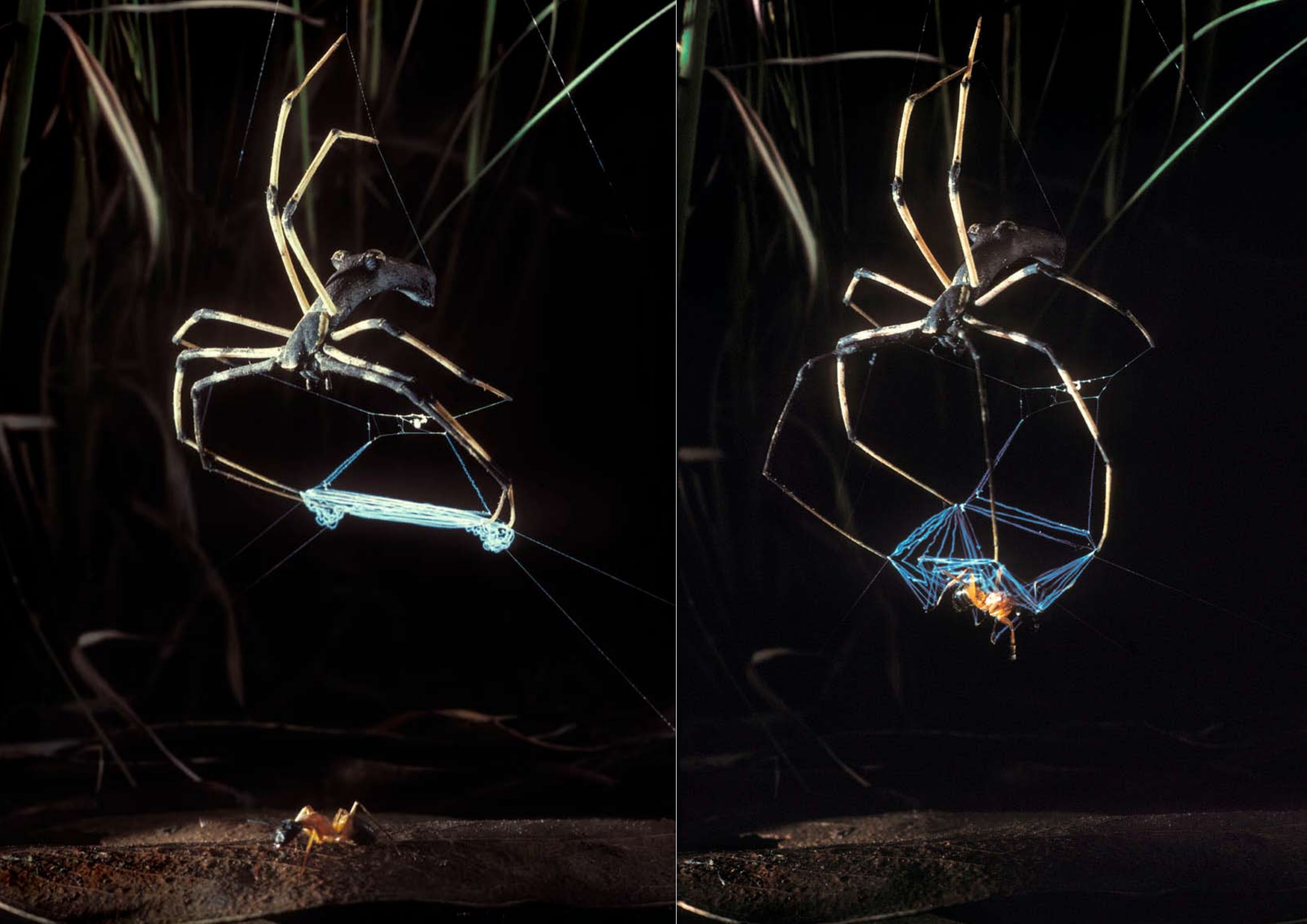
Nevertheless, the spider's superior eye design brings with it a very serious problem. She must shield her precious rhodopsin from automatic destruction by strong daylight. Consequently, the net-caster must spend the first two hours of each day dismantling her microvillar membrane and disassembling its rhodopsin below a light-proof pigmented layer. And as night falls, she must rebuild the rhodopsin microvilli before she can begin her nocturnal hunt for food. This too, is a very slow, energy-expensive sprocess that takes at least hour to complete.

(Diagrams modified from A.D. Blest 1977. See Acknowledgements page 16.)



A female Retiarius lies in wait in her aerial 'hide'. This is what her victims would see if they looked up just before her attack.

Deinopis subrufa (f), Sydney, NSW.



The net sticks to anything it touches, and the spider then withdraws, lifting her prey off the ground. This allows it to thrash about and become further entangled. When her victim is thoroughly, immobilised and beginning to weaken, she wraps some fresh cribellate silk around it, injects a lethal dose of poison through her long, curved fangs, and begins to feed.

Deinopis subrufa, Sydney, NSW.

Deinopis subrufa, Sydney, NSW.

Dangerous prey such as scorpions, centipedes and other spiders sometimes become victims, and in rare cases the net may entangle more than one victim in a single strike. Even moths that fly through the target zone of a Net-caster are at risk from her lightning-fast reflex-triggered attack.

Deinopis sp, MacDonnell Ra. NT.

There are two genera of net-casting spiders in Australia. *Avella* (*left*), tends to be much smaller and hunts in broad-leafed foliage. Members of this group usually prey upon ants, mites, beetles, spiderlings and small flower spiders. Members of the other genus, *Deinopis*, are larger and need larger prey, so they generally stake out their hunting territories on the ground. Although the family appears to have evolved from an ancient forest-dwelling ancestor, several species of Deinopis have now adapted to life in Australia's arid zones.

Avella sp (f), Sydney, NSW.

Despite the grim portent of their common name, 'Ogre-faced spiders, Deinopid females usually display a high level of maternal care for their eggs. During daylight hours the female *D. bicornis* (*left*) used her own well-camouflaged body to shield her snow-white egg sac from the gaze of potential predators. The *D.subrufa* female (*above*) spins an egg sac that is naturally camouflaged so she is content to attach it to some matching vegetation and keep watch nearby.

Deinopis bicornis (f), Sydney, NSW.

Passing on a knack for knitting

Since Net-caster spiderlings remain hidden near their birthplace for several days after they are born, and then disperse to hunt independently, they never see their mother build her aerial ambush platform or manufacture her complex hand weapon. We are therefore left with only one explanation for the similar behavior that all her babies display soon after hatching: it must be encoded in their genes. Particular behavior patterns are then switched in or out according to whether or not circumstances match the mental templates that are embedded in each spider's neuronal circuitry.

The net-making process represents an engineering achievement of astonishing sophistication for an animal of any kind, let alone a species with so small a brain. It therefore poses an intriguing question: where does the spider store the memory and the decision-making machinery for such complex technology? While no one would suggest that a spider 'thinks' as we do, the fact that the Net-caster nightly exhibits a level of technical and tactical proficiency that many humans would find hard to match—and then arms its complex weapon with one shrewd act of deconstruction—must at least make us pause and reconsider the sources of our own behavior. If this degree of behavioral complexity and the capacity for fast, flexible 'judgement' springs solely from spider DNA then perhaps we should not be too ready to dismiss the idea that DNA is the primary source of human behavior—even our tendency to manufacture tools.

Spiderlings: *Deinopis subrufa*, Sydney, NSW.

A footnote …

One of the traditional methods of defining humanity is to describe our species as the only tool-making animal in the world. Other animals may use tools, we say, but none manufacture them—except in the most marginal sense. It's comforting to believe that we are so 'special'.

Our clever evolutionary siblings the chimps, for example, are known to crack nuts by crushing them with a rock, and they occasionally strip leaves from saplings so that they can fish termites from their earthy homes or extract honey from bee hives. But selecting the rock or obtaining a twig and stripping the leaves from it does not really constitute manufacture as we commonly understand the term.

Similarly, a quick-witted bonobo, Kanzi, learned to fracture rocks and then use the sharp-edged stone chips to cut string tying down the lids of boxes that contained food. But Kanzi manufactured her cutting tools by holding one rock in her hands and throwing or striking it against the other rock on the ground. An orangutan learnt a similar trick, but neither animal was able to progress to the human method of holding both stones and striking one against the other. So their stone-chip tools remained the product of chance, and our honour as the world's only intelligent tool-makers remained intact. Yet the Net-casting spider's hunting technique and hand weapon is so sophisticated by human standards that it took members of our celebrated genus some 2.5 million years to devise anything that was remotely comparable.

Acknowledgements:

I am inordinately grateful to arachnologist Dr Mike Gray at the Australian Museum for introducing me to the astonishing world of the Net-casting spider and for his painstaking advice on this and related topics over the years.

My personal experience has also been informed by four excellent papers:

"***The rapid synthesis and destruction of photoreceptor membrane by a dinopid spider: a daily cycle***" (1977), by A.D. BLEST, Australian National University, Canberra ACT, Australia.

"***The physiological optics of Dinopis subrufus (L. Koch): a fish lens in a spider***" (1976), prepared by A.D. BLEST, University of Canterbury, Christchurch, New Zealand, and M.F. LAND, School of Bioloogical Sciences, University of Sussex, Brighton, England.

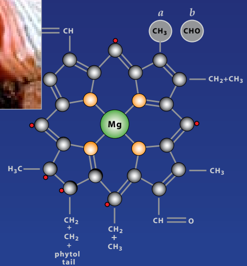
"**Notes on the construction of the net and sperm web of a cribellate spider *Dinopis subrufus***, by Densey CLYNE, 1967. *Australian Zoologist* vol.14 (2).

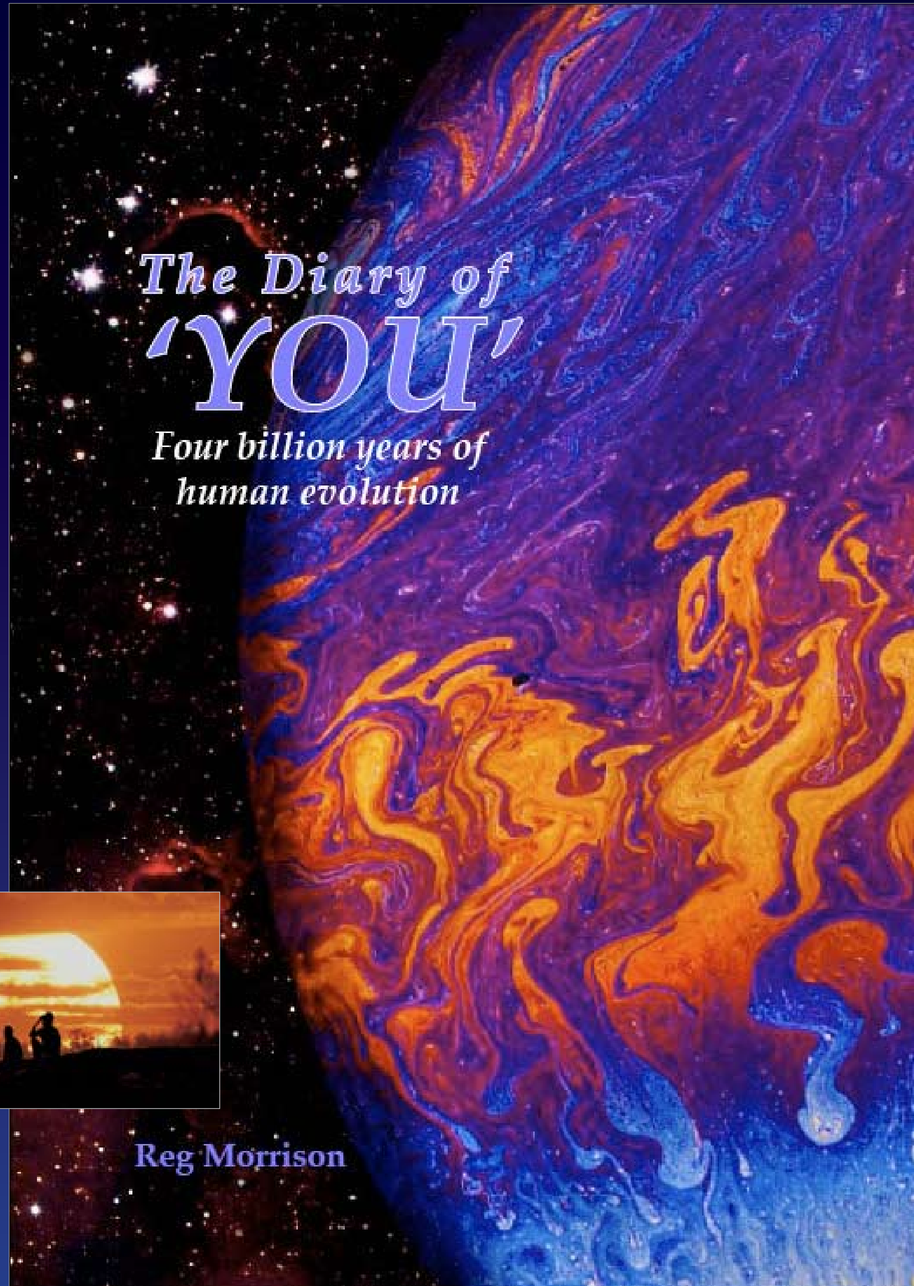
"**Silk, Spinnerets and Snares**," by Michael GRAY, 1978. *Australian Natural History*, vol.19 (7) pp.229–235.

THE DIARY of 'YOU'

The evolutionary origins of the rhodopsin-charged photo receptors that enliven the net-caster's eyes—and our eyes—is explained in greater detail in the author's forthcoming High School science resource entitled ***The Diary of 'You'*** (pp16-17).

The book outlines the four-billion-year evolution of our species by presenting, in chronological sequence, the evolutionary milestones that remain embedded in the cell structures and chemical pathways which define us today. The book is scheduled for release during 2008.*





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