spotlight

Jumping spiders

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Figure 1 **A male of *Aelurillus v-insignitus* illustrating the forward-pointing principal eyes flanked by the first pair of lateral secondary eyes.**

Jumping spiders are predators. They can jump higher and see better than other spiders and can outwit their prey. They are truly kings of the undergrowth. Jumping spiders are easy to recognise. One pair of their eight eyes is large and directed forward, giving them a distinctive, big-eyed look (see Figure 1). They have an easily recognisable, jerky way of moving. Like other spiders, they have eight legs, two body parts (**carapace** and abdomen), no antennae and use venom to kill their prey. But the prey capture strategy of jumping spiders differs from that of other spiders. They don't build a web but rely on stalking and hunting, finally jumping on their prey like cats.

The intention of this column is to throw a *spotlight* on individual organisms — not to blind you with science but to reveal important and fascinating aspects of specific plants, animals and microorganisms.

There are over 5000 species of jumping spiders. They constitute the largest spider family, yet they have a surprisingly short evolutionary history. The oldest described fossils of jumping spiders are preserved in amber and are less than 50 million years old. Today, jumping spiders flourish in most terrestrial ecosystems, especially in the tropics. Two biological traits are probably responsible for their evolutionary success — their jumping mechanism and their superb vision.

The hydraulic jumping mechanism

Jumping spiders are able to leap on or after their prey. They can also jump backwards and sideways to avoid capture. They can leap as much as 25–30 times their body length, but they lack the obvious specialisation of their legs of most jumping insects. Locusts jump by the sudden extension of their long hind legs using strong extensor muscles. The flea's take-off depends on an elastic click mechanism associated with short hind legs (see pp. 25–28). Jumping spiders don't have such structures. Indeed, as with other spiders, some joints of their legs don't even have extensor muscles. So, how exactly do jumping spiders jump?

All locomotion, including jumping, depends on a pressure-operated hydraulic mechanism of the carapace (see Figure 2). How this pressure is produced and what muscles are involved is a matter of debate, but a spider is capable of suddenly increasing the pressure of its body fluid (**haemolymph**) to execute a jump. At rest, the normal pressure of most spiders is maintained at approximately 5000–8000 Pa. During walking it rises to 13 000 Pa and a jump requires a maximum pressure of up to 66 000 Pa. Thus, the jump is due to hydraulic forces generated in the carapace. The sudden and high haemolymph pressure causes a rapid straightening of the third or fourth pair of legs, which initiates the leap.

Control of the jump

In order to control the jump, a spider fastens a silk dragline to the ground before take-off. Tension of this

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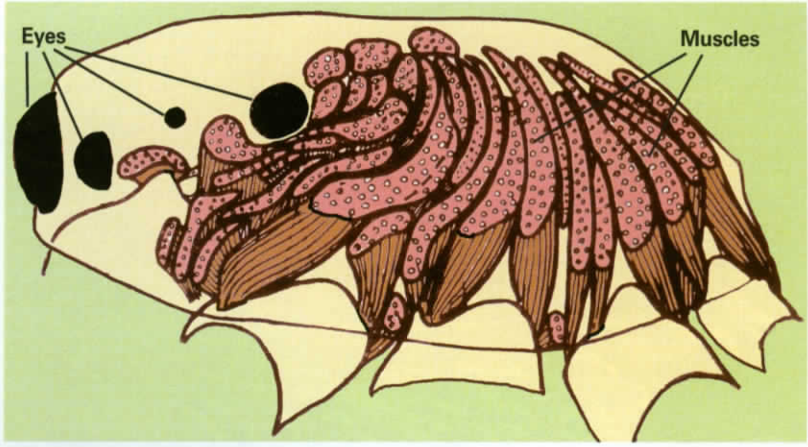

Figure 2 **A male of *Marpissa muscosa* (left) has a massive carapace (above). Strong muscles (pink) situated inside it and shown in the diagram are responsible for the operation of the hydraulic jumping mechanism. (Modified from Palmgren, 1978)**

thread probably accounts for braking and proper landing of the spider at the end of its jump (see Figure 3). Without such a thread, or if it is broken, the spider makes a complete somersault.

Two claws and two foot pads on each leg (see Figure 4 on p. 8) are also used to control the jump. The claws are probably involved in handling the dragline, especially during climbing over vertical surfaces. The foot pads consist of adhesive hair-like **setae** (some 40 per leg, see Figure 4) and help the spider's locomotion. How adhesion is achieved is not yet fully understood, but the grip of the jumping spider is so strong that it could hold 170 times its body weight, or even hang upside down on a Teflon sheet with ease. This indicates that **molecular adhesion** is operating, and in this respect the jumping spider's clinging ability resembles that of a gecko (a lizard) more than that of an insect (see Biological Sciences Review, Vol. 17, No. 4, pp. 21–23).

The foot pads of jumping spiders, particularly those on the first two pairs of legs, are also useful for prey capture. Non-jumping hunting spiders can capture prey equal to approximately 70% or less of their own body length. Many jumping spiders regularly catch prey larger and heavier than themselves, sometimes twice their own body size. The adhesion provided by the foot pads plays a crucial role in holding such large prey items.

Because jumping spiders are excellent climbers and jumpers, they can search for prey in many different locations, from the ground to tree trunks and in the canopy. When capturing prey they pounce on flies, grasshoppers and even other spiders with amazing accuracy. This ability is due largely to their superb vision, which far exceeds the capabilities of other spiders.

Visual system

Jumping spiders can see and recognise their prey, or potential mates, from a distance of up to 30 cm. This ability is due to the pair of large, forwardly pointing principal eyes, which perceive size, colour and form. These eyes resemble a pair of binoculars, and each is a miniature telephoto system (see Figure 5 on p. 8). There is a single corneal lens at the front of a long eye tube with a small **retina** at the end. Just before the retina, there is a second lens that augments the magnification of the corneal lens. These eyes are specialised in two ways. First, they have a narrow field of view (2–5° horizontally). Second, the retina is arranged in four layers, each sensitive to a certain wavelength (colour) of light. As a result, these animals have good colour vision.

The sharpness of a jumping spider's vision can easily compete with our own and relies on the rearmost layer of the retina. Its central part, the fovea (see Figure 5), contains the highest concentration of light-sensitive cells

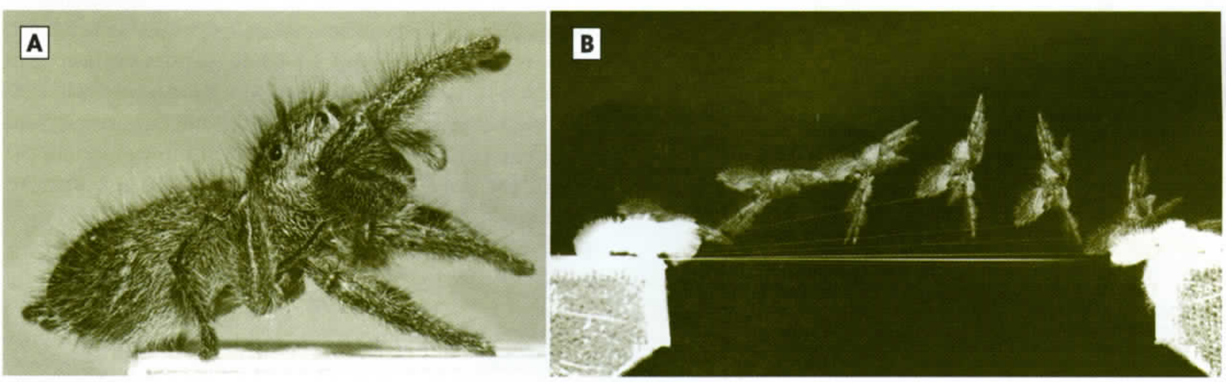

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Figure 3 **(A) A female of *Phidippus princeps* ready to jump, and (B) a multiple-image photograph of its jump.**

Figure 4 **Scanning electron micrograph of the claws and foot pad of adhesive setae on the tip of the first leg of a male jumping spider *Yllenus arenarius*. ×250**

and is used for resolving fine detail. To centre an object on the fovea, muscles around each eye tube move the retina horizontally and vertically, and even rotate it to some degree. This scanning process ensures that each eye surveys a much larger area than is provided for by the retinal structure alone, and is essential for perceiving and processing the shape and form of an object.

Besides the principal eyes, jumping spiders also have three pairs of secondary eyes situated along the sides of the carapace (see Figure 5). These have wide-angle lenses and primarily detect movement, whereupon the spider turns to face the object. It can then be scanned and properly identified by means of the principal eyes.

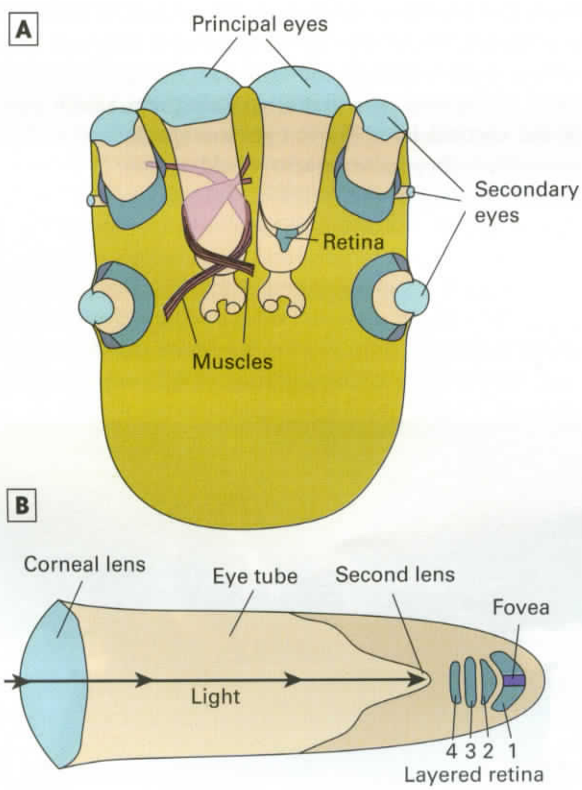

Figure 5
(A) Horizontal section of a jumping spider carapace.
(B) Internal structure of the principal eye as viewed from above. (Modified from Foelix, 1996 and Harland and Jackson, 2000)

TERMS explained

Carapace The hard outside covering of a spider's forebody (= cephalothorax).

Haemolymph The fluid circulated in the body cavity of insects, spiders and crustaceans. It is similar to blood in many ways.

Molecular adhesion The intermolecular contact between two surfaces.

Retina The layer of light-sensitive cells at the back of the eye.

Setae Bristles or stiff, hair-like structures.

Stridulatory organs The sound-producing structures, which make a rasping sound when rubbed together.

As clever as cats

The sophisticated but compact visual system of jumping spiders has allowed them to develop elaborate vision-mediated behaviour. Orientation, accuracy of jumps, prey capture and mating strategies are all controlled by visual stimuli. It seems likely that the resolving power of the eyes and colour vision have been major factors in the evolution of their colourful markings, which are especially evident during courtship.

Visual signals are the primary trigger for courtship, although tactile and chemical stimuli are also involved. All male jumping spiders display their species-specific courtship movements in front of the female. An individual display is often elaborate and consists of many postures and movements (see Figure 6), such as raising and then lowering of extremities, sideways runs, creeping and even 'singing', as in locusts, using specialised **stridulatory organs**. Even within the same species, different courting strategies are used depending on the female's maturity, location and other factors. The primary function of a male's courtship display is to stimulate a receptive female of his own species to mate.

Predation strategy is another complex behaviour. Jumping spiders creep up on their prey until they are a few centimetres away, then they pause, fasten a dragline to the substrate and jump, grabbing their prey with their forelegs. While stalking, a jumping spider does not have to take a straight line to reach its prey. It can take a circuitous route, sometimes temporarily losing sight of the prey. This behaviour alone suggests remarkable problem-solving abilities.

Owing to the versatility of their predatory strategies, the jumping spiders were once called 'eight-legged cats'. This term relates both to their good eyesight and problem-solving abilities. However, a small brain means few neurones, and this is an engineering constraint working against spiders. Therefore jumping spiders are relatively slow compared to a cat when it comes to seeing, with their slow scanning process, and solving a problem.

Although slower than large predators, jumping spiders are sophisticated jacks-of-all-trades, being capable of many unique and unexpectedly complex things. Many of these skills and habits are not properly

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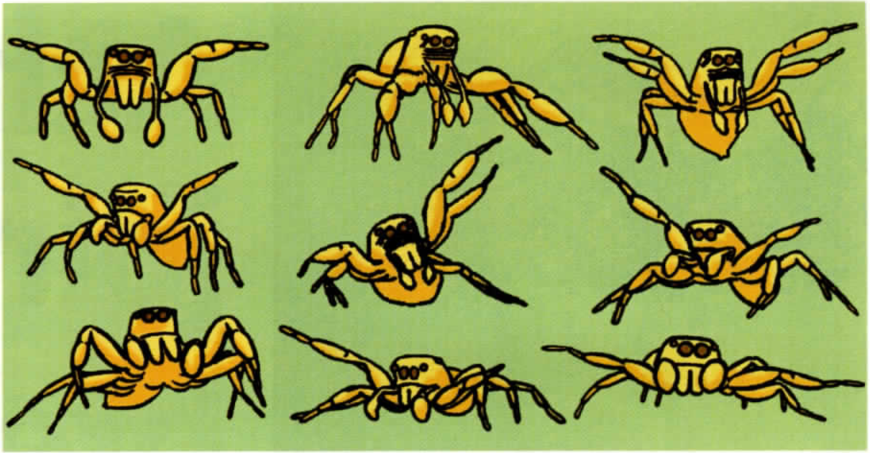

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Figure 6 **A male of *Evarcha falcata* (left) and diagram showing some elements of its complex courtship repertoire (right).**

understood, and many more presumably await discovery. For example, the detouring behaviour of a jumping spider (i.e. its circuitous predatory pursuit) requires an exceptional three-dimensional visual orientation. Yet, we don't know how its 'navigational system' actually works. Nor do we fully understand what visual cues are used by jumping spiders for distinguishing between their insect prey and other objects such as mates, rivals and others. And finally, can we ever fully fathom the mind of a spider? Hardly, but we definitely should try, for it will help us to better understand ourselves and the world we live in. All these and many other problems present a serious challenge for anyone who is ready to pick it up. It could be you!

Further reading

Foelix, R. F. (1996) *Biology of Spiders*, Oxford University Press.

Hillyard, P. (1994) *The Book of the Spider*, Avon Books, New York.

Jackson, R. R. and Wilcox, R. S. (1998) 'Spider-eating spider', *American Scientist*, Vol. 86, pp. 350–57.

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