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Evolution & Behavior

How Spiders Catch the Air for Their Flight

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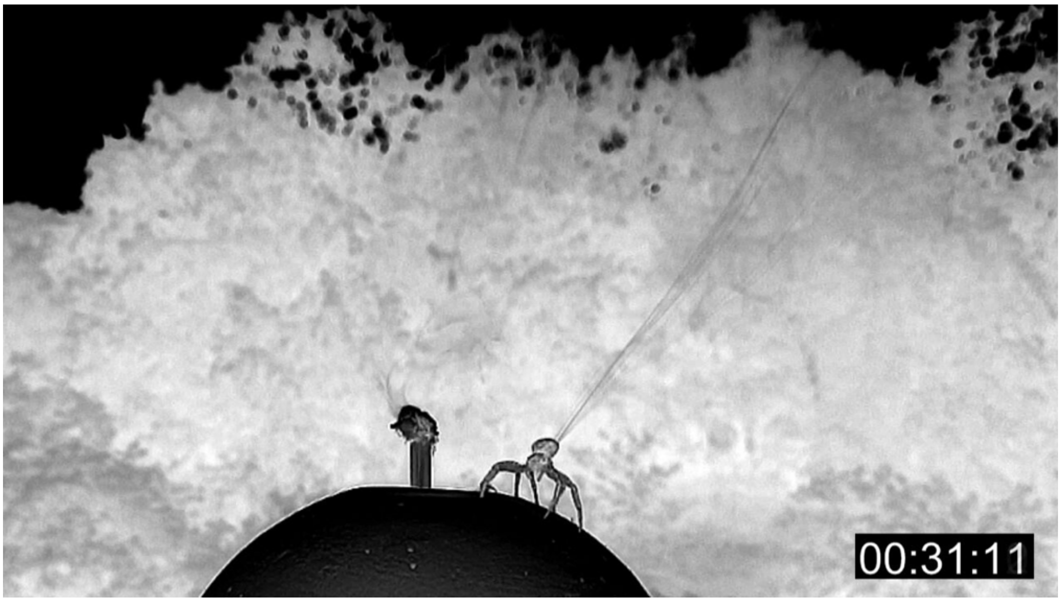
ABSTRACT

Though most spiders crawl from one location to another, some families of spiders travel through the air. This is known as ballooning. To better understand ballooning, we observed the flying spiders in nature and measured the properties of their ballooning silks in the laboratory.



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Bacteria or sperm cells can swim using a hair-like structure. Other organisms use similar structures to fly, like dandelion and thistle seeds with their parachute hairs. But this mode of flying is not limited to plant seeds. One weird aviator is the spider. Using their fine silks, spiders can travel through the air from over tens of meters to hundreds of kilometers. Some spiders were caught in the air at a height of a few kilometers above the ground! This flying behavior of spiders is called ballooning.

Most ballooning spiders are young or small adult spiders, less than 2 mm in length and 2 mg in weight, the size and mass of a millet seed. The young spiders take to the air to escape cannibalism just a few days after birth. Some adult spiders balloon to find a place for a new colony, food and mates. Small spiders become airborne even with light upward wind by producing a single or a few fine silks. These silks are however not enough for the larger ballooning spiders (10 to 150 mg, comparable with the size and mass of a small pill). To understand how spiders - especially the large ones - fly, we recorded and analyzed how spiders prepare and take to the air in nature. We also counted and measured the ballooning silks by inducing spiders to produce them and fly in a wind tunnel.

We selected crab spiders, which are among the relatively large spiders that balloon. We first observed their ballooning in the field, which revealed a couple of new facts. Spiders evaluated the wind conditions before taking off by raising their front leg for a few seconds. Spiders produce their silks in specialized glands. A single spider has many different silk glands and spins multiple types of silk. Previously, scientists thought that spiders fly using a thick silk named dragline. We found that crab spiders use the dragline to anchor themselves for safety in the case of failed takeoff. To fly, the spiders produce tens of fine wrapping silks.

After that, we placed spiders in front of a wind tunnel to get samples of the ballooning silks. Measuring the nanoscopically thin ballooning silks in the tunnel is not possible because they flutter in the wind. We had to collect the samples on a glass slide covered with a double-sided adhesive tape. Later, we observed the fibers with a scanning electron microscope, which allows the imaging of very small objects. Crab spiders spin 50 to 60 thin fibers for their flight. The thickness of these fibers is about 200 nm. This is smaller than the wavelength of visible light, 400 to 700 nm. This is why we could not use an optical microscope - visible light passes through this extremely thin silk. We also measured the length of the ballooning silks by winding them on a reel. The ballooning fibers measured 3 meters on average, with the longest reaching 6 meters.

Unlike other flying insects and birds which use their wings, spiders fly by spinning ballooning silks. Although the silks are nanoscopically thin, their length and their number are enough for the spiders to soar up even with a light upward wind. We may question how spiders catch the air with this extremely thin silk. In the macro-world, fluid force acting on an object is proportional to the projected area of that object (like bird wings). In the micro-world, this force is not proportional to the projected area of the object, but to the length of it. The thinness of spider silks keeps the fluid-dynamic character in the micro-world and the length enlarges the fluid force acting on this thin fiber. This is how spiders utilize micro-world dynamics to their advantage.

Similarly to dandelion and thistle seeds, we find hair-like structures in spiders' ballooning. In a microscopic world, this hair-like structure is an efficient structure to produce resistance force in the air. The interesting fact is that spiders are the heaviest organisms using this type of mechanics for their flight. This is possible because spiders produce uniquely thin and strong silks.