Geared Up for Jumping!

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Gears are rarely found in animals, and when they are, they have never been reported to intermesh and rotate functionally as mechanical gears. Until now, that is. Malcolm Burrows and Gregory Sutton used microscopes to locate gears in the planthopper *Issus coleoptratus* and made high-speed videos to record the gears in action [1]. This flightless insect goes through about five nymphal stages before becoming an adult. The nymphs, but not adults, have gears to synchronize jumping movements in their hind legs. The oldest nymphs are about 5 mm long, but they can jump about one meter! Apparently this is essential for avoiding predators and other natural behaviors.

Planthoppers are among the best jumping insects. The hind legs move counter-rotationally in approximately the same near-horizontal plane beneath the body. With this arrangement, it is essential that the two legs be synchronized to avoid veering off to the left or right (referred to as spinning in the yaw plane). Using high-speed video microscopy (up to 30,000 frames per second), Burrows and Sutton found that take-off could occur within 2 milliseconds. The two propulsive hind legs started moving within 30 microseconds of each other. Such precise synchrony would be difficult to achieve with neural control that operates on a millisecond time scale. However, the left and right power-producing muscles are innervated by independent sets of two motor neurons each, and all four neurons are synchronized. Apparently the neural connection assists the synchronization of leg movements, but the gears ensure that the hind legs move together within microseconds of each other.

The proximal segment of each hind leg had a curved strip of gear teeth (Figure 1). The gear on one segment enmesh with a corresponding gear of the same size and

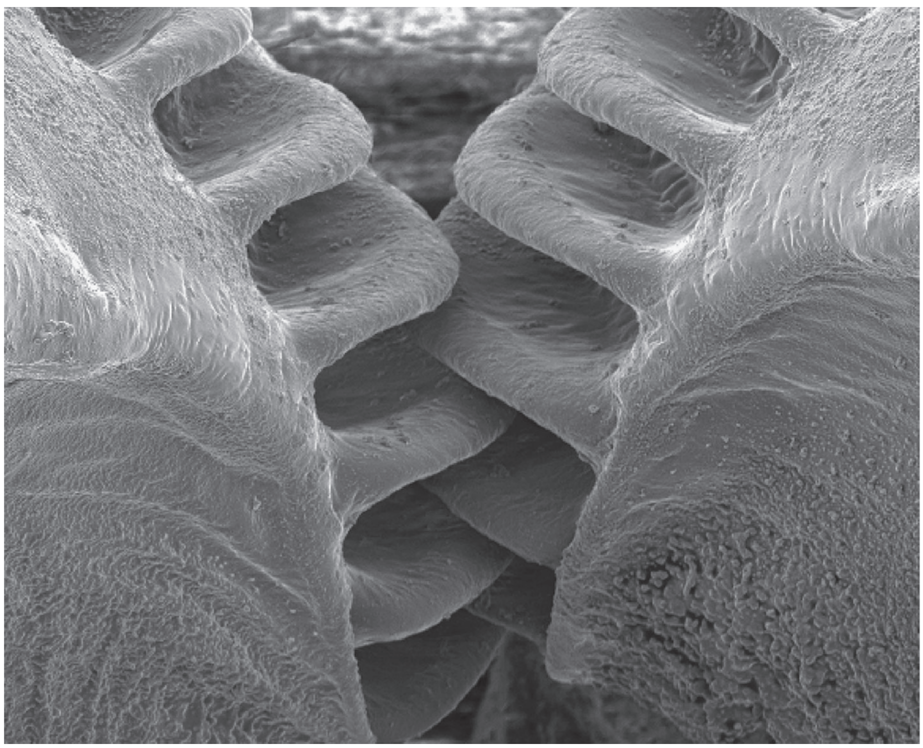

Figure 1: A scanning electron micrograph of gear teeth in the hind leg a planthopper nymph. Full width = 140 µm.

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shape on the other hind leg. Gears were not present on the front or middle legs.

Each gear strip was about 400 µm long, contained 10 to 12 teeth, and had a radius of curvature of about 200 µm. Each gear tooth was about 9 µm thick, 20 µm tall, and separated from adjacent teeth by about 30 µm. The dark color of the teeth suggested that they are heavily sclerotized, which might be expected in a rugged mechanical gear. The shape of the teeth was asymmetrical, which would be appropriate if it only transmitted power while turning in one direction, as would be the case in jumping forward.

The gear teeth are lost during the final molt into adulthood. However, adults are better jumpers than nymphs. The gears are replaced by a high-performance system based on friction to achieve synchronization. If a gear tooth breaks in a nymph, it can be replaced at the next molt, but this is not possible after the final molt.

Burrows and Sutton have demonstrated that a mechanical arrangement, previously thought to be only in man-made machines, is present in nature to make it possible for planthoppers to jump straight!

References

[1] M Burrows and G Sutton, *Science* 341 (2013) 1254–56.

[2] The author gratefully acknowledges Dr. Malcolm Burrows for reviewing this article.

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