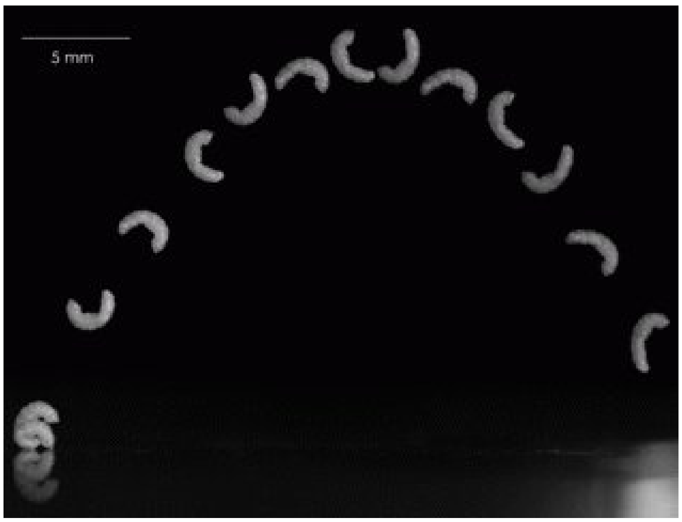
Developing flies jump without legs

January 8 2018



Overlaid image illustrates a full jump trajectory of a midge. Credit: Grace Farley

Imagine jumping 25 times your body length in only 2.5 seconds. Impossible, right? Now imagine making that jump with no running start, having just gotten out of bed…and with no legs. Though utterly impossible for humans to conceive, some larval insects across many orders, including Hymenoptera, Lepidoptera, and Diptera–the true flies, can do this by using their entire body to propel themselves.

Grace Farley, lab manager in the Patek lab at Duke University and presenting author at the annual meeting of the Society of Integrative and Comparative Biology (SICB), explains. "The midge larvae (Cecidomyiidae: Asphondylia sp.) is a little soft bodied cylinder that looks like a little puff Cheeto that usually crawls around like an inch worm." However, the midge larvae can also curl up into a loop shape, latching their anterior end into a protuberance just under their head segment. Once circular, the midge larvae will begin to compress due to swelling in the posterior third of the midge. Once here, the midge likely pumps fluid into that posterior body region, causing hydrostatic pressure to build. Then whoosh! "When the latch releases, the hydrostatically pressurized posterior third of the midge's body acts like a leg, pushing into the substrate and launching the midge into the air."

During this jump, a midge larvae can reach a velocity of 0.9 meters/second, accelerate at ~18,000 meters/second^2, and jump 20-30 times its body length. Compared to other legless jumpers, such as the click-beetle which accelerate at only ~400 meters/second^2, the midge larvae accelerate much more quickly than other jumpers. Also, the power output of these jumps (~9,000 Watts/kilogram as a conservative calculation), demonstrate that this is a power-amplified mechanism. This means that the force produced by these jumps cannot be generated by muscle power alone, as it far exceeds the known limits of insect muscle (100 Watts/kilogram)! The latch is a key mechanism in producing that extra power that we see, as it allows for hydrostatic pressure to build and release at timescales much shorter than produced by muscle.

But why do they do this? We typically think about organisms developing in confined spaces, with little room to behave or locomote; so why would this phenomenal ability to jump have evolved? Some answers can be found by examining the life history of closely related gall midge species. Gall midges reproduce by laying their eggs on the leaves of plants. The host plant builds up a gall around the developing larvae, providing a relatively safe home. Larvae are restrained inside the gall until they emerge from the gall, fall to the ground, and jump to find a more suitable habitat for pupation and maturation.

The particular midge larvae that Farley et al. are studying, however, add another layer of complexity. The species they are using for understanding jumping behavior does not emerge from the gall until it is a full grown adult, a stage at which the organism has an entirely different body plan and can no longer jump. This raises interesting questions about why this particular species has the ability to jump if it typically spends its entire larval development confined in the gall. "This behavior might be an evolutionary hold-over" says Farley. "[Midge larvae] may not need this behavior anymore but still have the capability of doing it." However, the mechanism for this behavior is very robust, and it is very likely that it still serves the larvae somehow. It may be important due to the high rate of gall predation, as the ability to jump may be a means of predator avoidance.

Shockingly, this hydrostatic mechanism works really well for soft bodied jumping and seems to be used by many Diptera, Hymenoptera and Lepidoptera larvae, as well as in adult organisms such as nematode worms. Farley is excited to broaden our understanding of larval locomotory capabilities, and hopes to continue exploring the evolution of this behavior and mechanism across many species.

Provided by Society for Integrative & Comparative Biology