

Evolution & Behavior

Secrets of legless leapers revealed

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ABSTRACT

Jumping insects are a familiar sight: Jumping by legless, wormlike larvae is altogether unexpected. We used high-speed imaging and scanning electron microscopy to reveal the physical mechanisms that enable the larvae of a secretive gall midge to propel themselves into the air and travel many body lengths in less than a second.

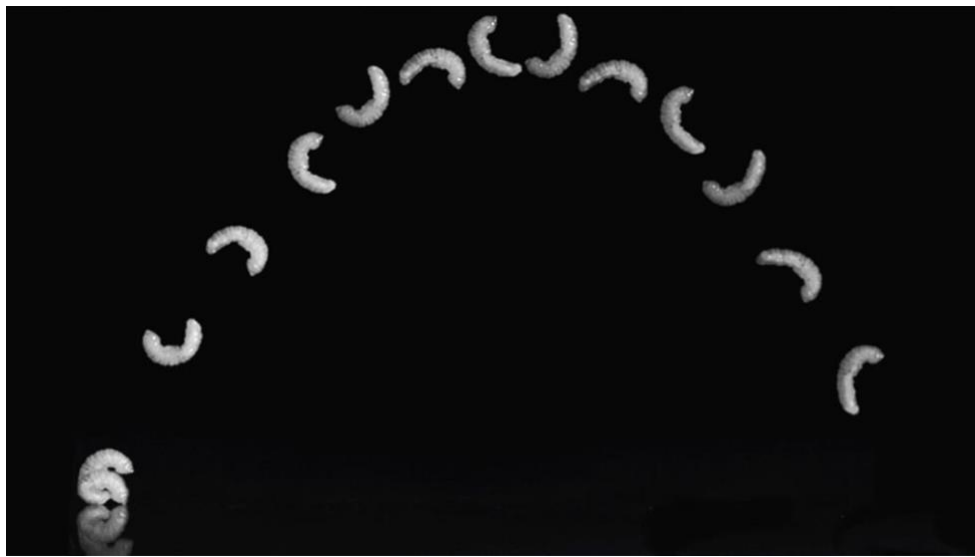


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While we marvel at falcons, cheetahs, and dolphins for their remarkable skills at flying, running, and swimming, we tend to belittle more humble creatures. Among the most lowly are worms, with their unsophisticated crawling and wriggling. However, the biological world holds an endless array of surprises—including soft-bodied, legless insects with leaping abilities that rival renowned jumping insects like fleas, grasshoppers, springtails, and click beetles.

One such legless jumper is the larva of a gall midge (a tiny type of fly) that feeds on goldenrod plants. An adult gall midge lays eggs on the stem tip of a young plant, which stunts the growth of the plant and induces it to form a leafy rosette gall at the top of the stem. This gall serves as both dormitory and cafeteria

for up to a few dozen gall midge larvae. Each of them lives in a tiny, tear-shaped chamber nestled amid the small leaves, where they stay until pupation and emergence as adult flies.

One could hardly imagine a more sedentary existence than that of these gall-inhabiting larvae. Nevertheless, when a gall chamber is breached, the exposed larva immediately begins jumping and continues to jump until it finds a suitable spot of soil in which to bury itself. We undertook this study to figure out the details of how legless, soft-bodied larvae are able to launch themselves and to quantify the forces, flight paths, and distances of their leaps.

Our leaping species (*Contarinia*) turned out not to be the species that induces the galls

(*Asphondylia*), but an uninvited guest, or "inquiline." The inquilines' mothers lay eggs inside the gall chambers, and the larvae usurp the chambers from the original inhabitants. The gall-inducing species is not able to leap but only wriggles fruitlessly if removed from its chamber.

In late summer, we collected stems of silverrod (a white-flowered species of goldenrod) with rosette galls containing gall-midge larvae. We dissected individual gall chambers to remove healthy, full-grown *Contarinia* larvae. We used high-speed imaging to record the jumps and scanning electron microscopy to reveal the physical details of the latching mechanism that enables the storage of hydrostatic pressure required to power the jumps.

We found that the jumping process consisted of four phases. First, a larva positions its tail-end on the ground and deforms its body into a loop by latching thousands of finger-like microstructures on the ventral ("belly") surface of its third segment (near the head-end) to similar structures on the eleventh segment (the tail-end). Second, the larva contracts its body to form a distinct hinge near the middle of the body, as well as pressurized "transient leg" out of the segments posterior to the hinge. Third, the buildup of hydrostatic pressure stretches the body to store elastic energy and eventually causes the microscopic latches to release (like legions of tiny Tiddlywinks), which thrusts the anterior part of the body upward and presses the lower part against the substrate. Fourth, the stored elastic energy in the body pushes the transient leg against the substrate and causes the larva to launch itself ballistically into the air.

The distance these gall midge larvae travel varies greatly from jump to jump. In our laboratory study, the mean horizontal distance per jump was 77 mm, with a maximum distance of 121 mm. Jumps of twice this distance have been observed by these larvae under more benign conditions. At only 3 mm long, an average jump enables a larva to travel about 25 times its body length in less than one second. Such a feat is obviously much quicker and more energy-efficient than crawling, and it would certainly help a larva to escape predators and find a safe place to hide and pupate. Moreover, the acceleration, launch angle, and relative distance covered place these soft-bodied, legless larvae firmly into the pantheon of champion jumpers that possess legs and hardened body parts.

Many technological innovations were evolved by plants and animals long before humans "invented" them. The mechanisms used by these jumping gall-midge larvae may end up informing a variety of technological endeavors. For instance, their microscopic pads and finger-like extensions may serve as models of biological adhesion. Along with their novel latching mechanism, the larvae's production and release of elastic energy storage through hydrostatic pressure are paragons of small, high-acceleration systems. More intriguingly, all of these mechanisms for jumping may provide useful information in the growing discipline of soft robotics. Truly, there are high hopes for these formerly lowly, leaping larvae.