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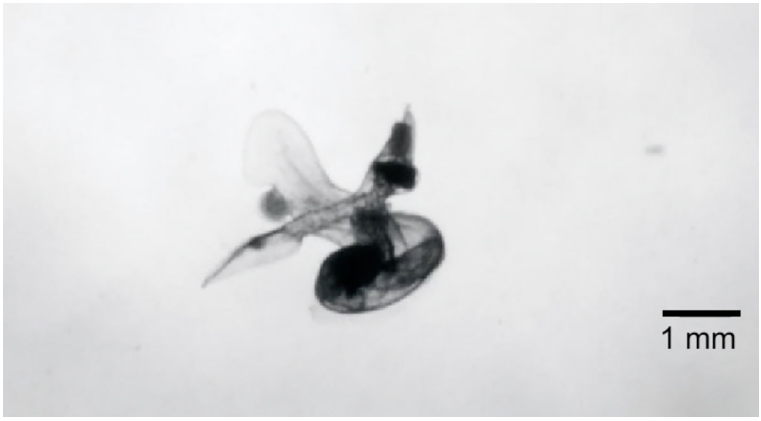
INSIDE JEB

Side-swimming plankton snail flaps shell like a fin



A still from an animation of a swimming heteropod snail. Image credit: Ferhat Karakas.

Amy Maas, Ferhat Karakas and David Murphy never know what they're going to turn up when they go trawling for zooplankton. 'We work on the swimming of various sea butterfly species', says Murphy, adding that unlike true butterflies, sea butterflies are miniscule snails that live at depth and swim to the surface at night, propelled by minute wings like flying insects. But one day in September 2017, the trio was in for a surprise. In addition to their usual haul of sea butterflies, Karakas and Maas turned up a pair of tiny heteropod snails, *Atlanta selvagensis*. 'I had never heard of heteropods before', admits Murphy. As virtually nothing was known about these rare aquatic molluscs, the trio rushed them back to Murphy's high-tech zooplankton movie set in the lab, in the hope of catching them in the act of swimming.

Describing the tank, Murphy says, 'Our filming system consists of three synchronized high-speed cameras pointed at a tiny aquarium from three different directions'. Liberating the plankton into the tank, Karakas kept his fingers crossed that the heteropods would swim precisely through the centre of the three cameras' field of view so that he could accurately reconstruct their movements in three dimensions. And, after staying up all night, his patience was rewarded when one of the minute snails flapped into view. But it wasn't waving its foot alone, like a miniature paddle; it was also moving its shell like an additional wing in time with the foot. 'My mind was completely blown when Ferhat showed me the video', says Murphy, as the shell had been thought to stabilise the mollusc like a ship's keel. 'We … realised that the existing (very cursory) description of its swimming behaviour was completely different from what we had captured'.

Painstakingly reconstructing their 3D trajectory, Murphy saw that the snails appeared to be swimming like birds that were flying on their sides, with the 'wing' structures meeting on the left and right of the animal. After closer inspection, he saw that the mollusc held the shell and foot fin together on one side of its body at the start of a wing beat and then peeled the front edges of the appendages apart before sweeping them above and below the body in an arc. Near the end of the first half of a wing beat (the power stroke), the snail curved the front edges of the foot fin and shell in toward each other, before snapping the rear edges of the structures together on the opposite side of its body. Then it repeated the whole process in reverse. In addition, the 2.2 mm long snails completed almost 10 wing beats per second and reached an impressive speed of 53.1 mm s^{-1} midway through the power-generating half of the wing beat. He also suspects that the swimming snails get two bangs for every wing-beat buck, generating a tiny region of spinning low-pressure above each flapping structure as they peel the wings apart at the beginning of both halves of the full wing beat to propel themselves through the water. However, the bulky shell is less manoeuvrable than the flexible foot fin, sweeping through 170 deg, in contrast to the fin, which sweeps over a colossal 220 deg. 'We think that this is the largest stroke amplitude ever measured in the animal kingdom', says Murphy.

Having revealed the heteropod's unconventional mode of transport, Murphy and his colleagues are keen to go on more voyages of plankton discovery to learn how fluid flowing around the minute aquanauts propels them to the surface.

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Karakas, F., D'Oliveira, D., Maas, A. E. and Murphy, D. W. (2018). Using a shell as a wing: pairing of dissimilar appendages in atlantiid heteropod swimming. *J. Exp. Biol.* **221**, jeb192062.

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