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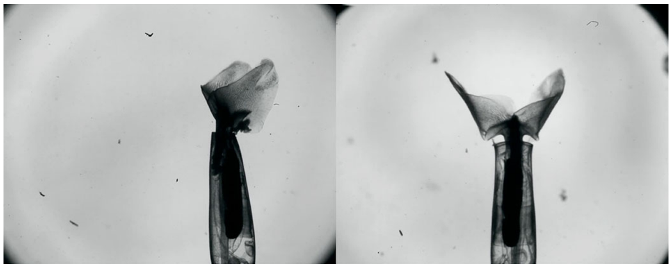
INSIDE JEB

Flexible sea butterflies embrace to thrust



Perpendicular views of a swimming *Cuvierina atlantica* sea butterfly opening its wings out of an embrace behind the body. Photo credit: Ferhat Karakas and David Murphy.

Remarkable as it may seem, some snails – sea butterflies – have more in common with the insects buzzing in your garden than the molluscs munching on your brassicas. *Limacina helicina*, a species of sea butterfly, waft through the Pacific Ocean much like flying insects, flapping their pseudopod wings in the same figure-of-eight wingbeat pattern. But David Murphy from the University of South Florida, USA, explains that sea butterfly wings are far more flexible than the rigid wings of insects. To find out whether this flexibility affects how some sea butterflies swim, Leocadio Blanco-Bercial, from the Bermuda Institute for Ocean Sciences (BIOS) and Ferhat Karakas, from the University of South Florida, set sail in the tropical ocean off Bermuda in search of members of the sea butterfly family to discover more about their unconventional swimming styles.

'We have a lobster pot hauler that we use to deploy and retrieve the net', says zooplankton ecologist Amy Maas, also at BIOS, describing how the net sinks down 100 m before they haul it back to the surface. Back on shore, Maas identified each of the 30 or so sea butterflies retrieved from the depths, before rushing the molluscs to Murphy and Karakas in the lab to film the animals' manoeuvres in 3D. Placing several of the 0.05–1 cm long animals in a tiny tank, Murphy trained two high-speed cameras on the centre of the tank and hoped that some of the molluscs would swim into view. 'There were high fives all around', says Murphy, recalling the moment when their patience was rewarded and the first *Cuvierina atlantica* wobbled into shot, swinging back and forth like a pendulum, swimming at 3.5 cm s^{-1}.

Slowing the movies and reconstructing the flapping motion of the wings in 3D, Murphy and Karakas realised that *C. atlantica* have evolved a completely unique flapping style. Instead of pulling their wings back and clapping them together before peeling them apart to generate lift and propel themselves forward – like *L. helicina* – *C. atlantica* sweep their wings widely from front to back, overlapping the tips in an embrace as they meet, forming a cylinder. *Cuvierina atlantica* then angle the wings upward while peeling them apart and sweeping them wide around to the other side of the body where they meet again in another embrace during the second half of the wingbeat cycle.

'We also put a lot of algae in the water – much higher than would occur in nature – so that we could track the water motion', says Murphy, describing how they filmed the water's movement with a high-speed camera through a microscope lens to track the trajectory of the algae and hence the water flow, with the added advantage that the molluscs could also dine on the morsels. And when the team analysed the swirling motion of the water, they realised that the sea butterflies generated lift when they tilted the wings back when opening out of the first embrace, before forcing a propulsive jet of water down as the wings came together to form the second embrace on the other side of the body.

By flexing their wings and bringing them together on both sides of their elongated shell and body, *C. atlantica* are able to generate thrust on two occasions during each wingbeat cycle, in comparison with sea butterflies that swim like flapping insects, which only generate thrust once. And Murphy is excited about *C. atlantica*'s flexible approach, which has inspired him to build a pneumatically operated soft-bodied robot to learn more about their exotic propulsion mechanism.

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