The Case of the Surfing Bees

by Robert Perkins

When stuck in water, bees create a wave and hydrofoil atop it, according to a recent study.

Walking on Caltech's campus, research engineer Chris Roh (MS '13, PhD '17) happened to notice a bee stuck in the water of Millikan Pond. Although it was a common-enough sight, it led Roh and his then-adviser Mory Gharib (PhD '83) to a discovery about the potentially unique way that bees navigate the interface between water and air.

Roh spied the bee during California's yearslong drought, when the pond's fountain was turned off and the water was still. The incident occurred around noon, so the overhead sun cast the shadows of the bee, and, more importantly, the waves churned by the flailing bee's efforts, directly onto the bottom of the pool.

As the bee struggled to make its way to the edge of the pond, Roh noticed that the shadows on the pool's bottom showed the amplitude of the waves generated by the bee's wings as well as the interference pattern created as the waves from each individual wing crashed into one another. "I was very excited to see this behavior, and so I brought a honeybee back to the lab to take a look at it more closely," Roh says.

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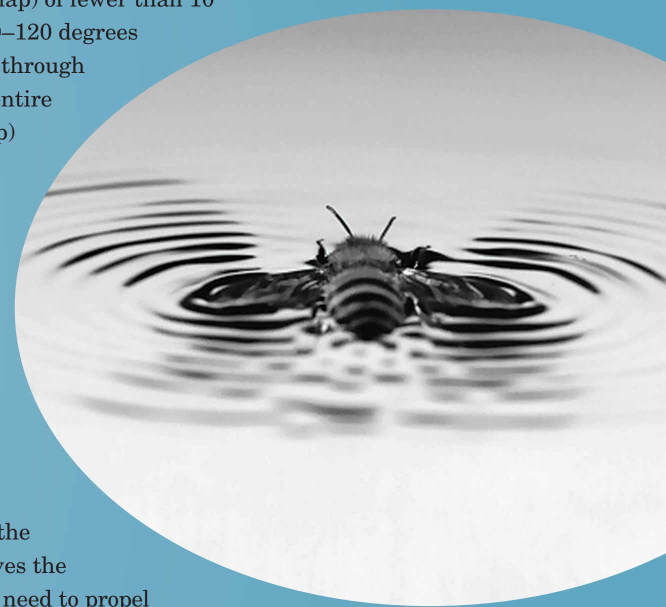
Roh worked with Gharib, Caltech's Hans W. Liepmann Professor of Aeronautics and Bioinspired Engineering, to recreate the conditions of Millikan Pond. He placed water in a pan, allowed it to become perfectly still, and then put bees, one at a time, into the water. As each bee flapped about in the water, filtered light was aimed directly down onto it, which created shadows on the bottom of the pan. Roh and Gharib studied 33 bees individually for a few minutes at a time, then carefully scooped them out to let them recover from their swimming efforts.

When a bee lands on water, the water sticks to its wings, which rob it of the ability to fly. However, that stickiness allows the bee to drag water and create waves that propel it forward. In the lab, Roh and Gharib noted that the generated wave pattern is symmetrical from left to right. A strong, large-amplitude wave with an interference pattern is generated in the water at the rear of the bee while the surface in front of the bee lacks the large wave and interference. This asymmetry propels the bees forward with the slightest of forces, about 20 millionths of a newton. (For reference, a medium-sized apple held in your hand exerts about 1 newton of force on your palm due to gravity.)

"The motion of the bee's wings creates a wave that its body is able to ride forward," Gharib says. "It hydrofoils, or surfs, toward safety."

Slow-motion video revealed the source of the potentially life-saving asymmetry: rather than just flap up and down in the water, the bee's wings pronate, or curve downward, when pushing down the water and supinate (curve upward) when pulling back up out of the water. The pulling motion provides thrust, while the pushing motion is a recovery stroke.

In addition, the wingbeats in water are slower, with a stroke amplitude (the measure of how far the bees' wings travel when they flap) of fewer than 10 degrees, as opposed to 90–120 degrees when the bees are flying through the air. Throughout the entire process, the dorsal (or top) side of the wing remains dry while the underside clings to the water. The water that sticks to the underside of the wing gives the bees the extra force they need to propel themselves forward. "Water is three orders of magnitude heavier than air, which is why it traps bees. But that weight is what also makes it useful for propulsion," Roh says.



The bees do not seem to be able to generate enough force to free themselves directly from the water, but their wing motion can propel them to the edge of a pool or pond, where they can pull themselves onto dry land and fly off. The motion has never been documented in other insects and may represent a unique adaptation by bees, Roh says.

Roh and Gharib, who work in Caltech's Center for Autonomous Systems and Technologies (CAST), have already started to apply their research to their robotics research, developing a small robot that uses a similar motion to navigate the surface of water. Though labor-intensive, the motion could one day be used to generate robots that can both fly and swim.

Watch a video of surfing bees at **magazine.caltech.edu/post/bees-surf**