

Bumblebees carry heavy loads in economy mode

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Bumblebees can fly while carrying up to their own bodyweight in nectar. A new study shows how bees can generate more lift by flapping their wings faster, or by using an energy-efficient economy mode. Credit: Andrew M. Mountcastle

Bumblebees are the big lifters of the insect world, able to fly back to the hive with almost their own bodyweight in nectar on board. A study published Feb. 5 in *Science Advances* shows how they do it—and that bees can show more flexibility in behavior than you might expect from a bumbling insect.

"They can carry 60, 70 or 80 percent of their [body weight](#) flying, which would be a huge load for us just walking around," said researcher Susan Gagliardi, a research associate in the College of Biological Sciences at the University of California, Davis. "We were curious to see how they do it and how much it costs them to carry food and supplies back to the hive."

Gagliardi and Stacey Combes, associate professor in the Department of Neurobiology, Physiology and Behavior, measured the energy expended by bumblebees flying in a specially designed chamber (an emptied snowglobe). They attached small pieces of solder wire to the bees to adjust their weight.

"We have the bees in a little chamber and we measure the carbon dioxide they produce. They are mostly burning sugar so you can tell directly how much sugar they are using as they are flying," Gagliardi said.

They also used high-speed video to examine [wing](#) beats and movements.

Bumblebees fly in a very different way to aircraft, Combes said. While air flows smoothly over an [aircraft wing](#) or rotor blade, bees move their wings at a high angle to the air generating vortices that curl round the wing. This produces much more lift than smooth airflow, but it is unstable as the vortices quickly break down. Bees are able to sustain flight by moving their wings very rapidly.

Two modes of flight

Because bumblebees fuel flight from the nectar they are carrying, they should get lighter as they fly and use less energy. To their surprise, Combes and Gagliardi found that the bees could actually use less energy per unit load when they were more heavily laden.

"They get more economical in flying the more heavily loaded they are, which doesn't make any sense in terms of energetics," Combes said.

Looking closely, the researchers found that bumblebees have two different ways to cope with increasing loads. They always increase stroke amplitude (how far the wings flap) when they are more heavily loaded, but this isn't enough to support the extra weight on its own. To make up the difference, bees can increase wingbeat frequency, which generates more lift and increases energetic cost.

But bees also have an alternative, subtly different flying mode that allows them to carry heavier loads while expending less energy than when they increase flapping frequency.

It's not yet clear exactly what this "economy mode" involves, Combes said, although it may involve a change in how the wing rotates to reverse direction between strokes. But it is something the bees can choose to do, or not.

"It turns out to be a behavioral choice they are making in terms of how they support the load," Combes said. When bees are lightly loaded or rested, they are more likely to increase wingbeat frequency. When they are more heavily loaded, they switch to the mysterious economy mode, producing enough force to support the load with only a small increase, or even a decrease, in flapping frequency.

Economy and stability

If the [bees](#) can save energy while flying, why don't they use this economy mode all the time? It's not clear, but it may be that high wingbeat frequency has performance advantages, for example in maintaining stability in turbulent air or avoiding obstacles, Combes said.

The work has prompted a shift in how Combes sees insects, she said.

"When I started in this field there was a tendency to see them as little machines, we thought they'll flap their wings one way when carrying zero load, another way when they're carrying 50 percent load and every bee will do it the same way every time," she said. "This has given us an appreciation that it's a behavior, they choose what to do. Even the same bee on a different day will pick a new way to flap its wings."

More information: S.A. Combes et al., "Kinematic flexibility allows bumblebees to increase energetic efficiency when carrying heavy loads," *Science Advances* (2020).

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Provided by UC Davis

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