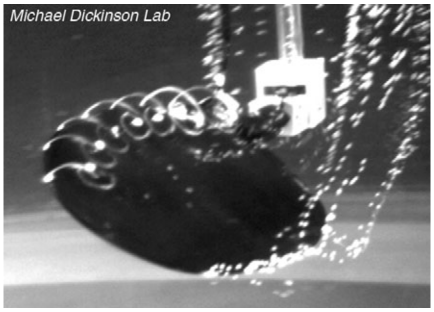
Inside JEB highlights the key developments in *The Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

CORIOLIS KEEPS LEADING EDGE VORTEX IN PLACE


Michael Dickinson Lab

Flies may not have the nicest of personal habits, but no one can fail to be amazed by their remarkable agility as they twist, turn and hover in the air. And their manoeuvrability has not escaped the notice of aeronautic engineers; they'd love to design a minute flying machine that hovers as well as a fly. But if engineers are to be successful, they must understand what keeps flies aloft. According to aeronautical engineer David Lentink, from Wageningen University in the Netherlands, the leading edge vortex keeps hovering flies in the air. Charlie Ellington found in 1996 that the leading edge vortex, a spinning mini-tornado, develops over the wing when small flies hover, reducing the air pressure above the wing to generate the lift necessary to keep the insect aloft. Amazingly, this vortex sticks to the wing and is not ripped off by the air flow, so when Lentink visited Michael Dickinson's California Institute of Technology lab, Dickinson suggested that Lentink looked into the air flows that keep the leading edge vortex in place to get a better understanding of what keeps hovering insects airborn (p. 2691, p. 2705).

Lentink realised that the only way to find out what goes on in the air flowing over a hovering fly's wings was to investigate an extremely complex suite of equations, known as the Navier–Stokes equations (p. 2691). These equations describe how fluid flows around flying insects and other flying animals and relates the animal's body shape and movements to the aerodynamic forces that keep the animal aloft. After a month of complex mathematical derivation Lentink came up with a series of equations that describe the fluid flows around flapping, translating and spinning wings.

Next Lentink began thinking about the ways that flapping wings move while an insect is hovering: they sweep back and forth horizontally as the wing revolves (swings) around the shoulder, so that the front edge of the wing points forward as it sweeps forward and backwards as it sweeps back. Calculating which motion provided the fluid flows that held the hovering insect's vortex in place, Lentink was surprised when he realised that the swinging motion about the shoulder joint must hold the vortex in place while the insect hovers.

Lentink explains that as the wing revolves about the shoulder joint, air sitting near the joint is forced to move outward under the influence of centrifugal acceleration. This forced airflow along the length of the wing experiences a Coriolis acceleration, which allows the air to keep up with the wing. Lentink realised that this accelerating air flow effectively pins the leading edge vortex in place, allowing the vortex to generate the lift required to keep a hoverer aloft. It was also clear that wings that spin around (like helicopter blades or falling spinning plant seeds) would be the most efficient way for a hovering machine to stay aloft.

However, there is a catch. Lentink explains that the leading edge vortex significantly increases the drag acting on the wing, but adds that this isn't really a problem for flies and other small insects. He explains that the drag forces that they experience while trying to move through viscous air are so huge that the extra drag incurred by the leading edge vortex hardly troubles them at all.

Having found that his calculations predicted that Coriolis acceleration was the key to holding the leading edge vortex in place, Lentink moved on to test how fluids flow over moving insect wings to see if his predictions held up in practice. But instead of measuring the fluid flows over tiny insect wings, Lentink turned to Dickinson's scaled up robotic fly, Robofly, which he could use to test out a wide range of flight conditions while watching to see whether leading edge vortices developed and stayed in place (p. 2705).

Simulating the viscosities that flies experience in air by filling Robofly's tank with liquids ranging from thick mineral oil to water, Lentink programmed a large scale Perspex® model of a fruit fly wing to flap in a variety of styles while he monitored the flow patterns across the wing with a stream of air bubbles. Lentink also monitored the lift and drag forces exerted on the flapping wing to find out which movements generated the most lift and drag.

Testing wing beats ranging from the wing spinning horizontally around its shoulder (like a helicopter blade), all the way through to a swinging hovering flap and an aeroplane-like translation, Lentink could see the vortex forming at the front of the wing in all of the flight modes. However, it only remained in place when the wing revolved like a helicopter or swung like a hovering fly's flapping wing.

Lentink also measured how effectively the wings generated aerodynamic lift and he found that the translating fly wing consumed up to 25% less energy than a hovering fly generating the same amount of lift, while the spinning fly wing did even better, generating the same amount of lift as a flapping hovering fly while consuming only half of the energy. 'Flapping wings waste a lot of energy accelerating the air back and forth,' explains Lentink.

So what does all this mean for engineers keen on designing microfliers? 'Engineers have been thinking that fly sized flying machines would have to fly like a fly,' says Lentink, but he now realises that this is not the case. Having shown that Coriolis acceleration along a stubby spinning wing holds the lift-generating leading edge vortex in place, Lentink explains that engineers could use the same trick to build a fly sized aeroplane. By copying the fly's stubby wings, which hold the leading edge vortex in place, and coupling them with the energy efficient helicopter-style 'spinning' motion, engineers could build a fly sized hovering microflier that only consumes half the energy of a flapping fly.

10.1242/jeb.034975

Lentink, D. and Dickinson, M. H. (2009). Biofluiddynamic scaling of flapping, spinning and translating fins and wings. *J. Exp. Biol.* **212**, 2691-2704.
Lentink, D. and Dickinson, M. H. (2009). Rotational accelerations stabilize leading edge vortices on revolving fly wings. *J. Exp. Biol.* **212**, 2705-2719.

CARNIVORE'S MASTICATORY MYOSIN IN SQUIRREL JAWS

Peter Reiser is intrigued by how muscles function. More specifically, how subtle differences in the proteins that comprise muscles influence their performance. Having frequently watched squirrels raiding the bird feeder in his garden and been struck by the speed at which they nibble sunflower seeds, Reiser was curious to find out more about the rodents' super speedy jaw muscles. So, when an undergraduate project student came to his office one day at a loose end, Reiser suggested that she took a look at the jaw muscles of a flying squirrel. Having separated the multiple forms of myosin (one of the main muscle proteins) from the flying squirrel's jaw on a gel, Reiser compared the protein gel with another of grey squirrel jaw myosin and quickly realised that something strange was going on. The mixture and sizes of myosin proteins from the two animals' jaws were completely different. The grey squirrel's jaw muscles were unlike those of other rodents. With his curiosity aroused, Reiser set about looking at the jaw muscles of more squirrels to see what else he might find (p. 2511).


Gwen Reiser

Fortunately, Reiser had access to a wide range of squirrel species, courtesy of a local animal control company dealing with problem rodents. Teaming up with Sabahattin Bicer, Reiser began separating the myosin proteins from the jaw muscles of rodents ranging from woodchucks, eastern chipmunks and southern flying squirrels to red and grey squirrels to find out which forms of myosin were found in the animals' jaw muscles. Looking at the myosin distribution in the grey squirrel's jaw muscles, the duo were in for a shock. It looked as if a protein that shouldn't be found in rodent jaw muscles had turned up in the grey squirrel: masticatory myosin.

Reiser explains that masticatory myosin is usually found in the jaw muscles of carnivores such as lions crocodiles and sharks, allowing them to bite down hard on prey. What is more, no one had ever found a masticatory myosin in rodent jaw muscles, so it had been assumed that rodents simply didn't have the protein.

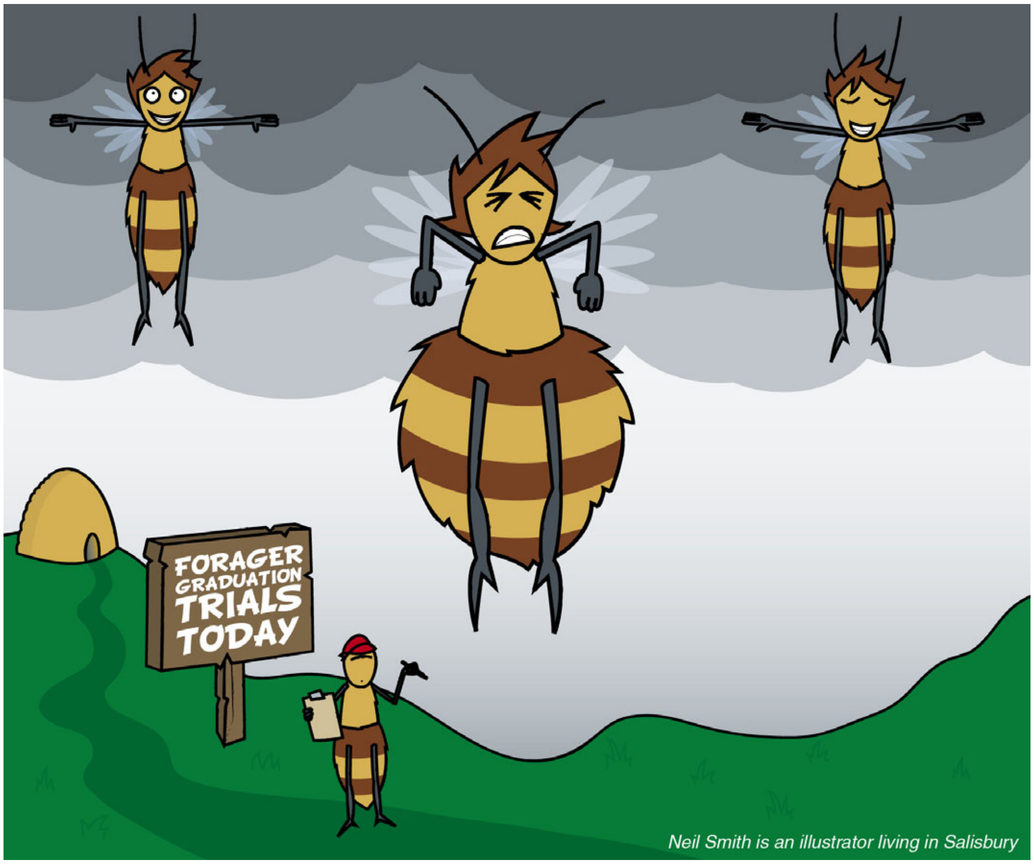
Needing more evidence that the unusual grey squirrel jaw muscle protein was a masticatory myosin, Reiser used an antibody that only sticks to masticatory myosin to pick it out of the gels, analysed the protein's sequence with mass spectrometry, and teamed up with Qun Chen, Ling Zhu and Ning Quan to look for the protein's mRNA in the grey squirrel's jaw muscles. Every test that he tried confirmed that the unusual protein was masticatory myosin. And when the team analysed the protein composition from five other species, the protein turned up in the jaws of eastern fox squirrels, woodchucks and eastern chipmunks. Only southern flying squirrels and red squirrels lacked the protein.

So why do omnivorous rodents use a jaw muscle protein that is usually associated with the life style of a hard-core carnivore? Reiser suspects that the answer lies in the ways that the animals approach their diet. He explains that southern flying squirrels and red squirrels, which lack the protein, make small incisions in shells to get to the nut within. However, grey and fox squirrels obliterate the shell. Reiser suspects that masticatory myosin may provide grey and fox squirrels with the additional contractile force necessary to shatter nutshells. He is also curious why some squirrels produce masticatory myosin while other squirrels do not, even though their teeth and skulls are almost indistinguishable.

10.1242/jeb.035873

Reiser, P. J., Bicer, S., Chen, Q., Zhu, L. and Quan, N. (2009). Masticatory ('superfast') myosin heavy chain and embryonic/atrial myosin light chain 1 in rodent jaw-closing muscles. *J. Exp. Biol.* **212**, 2511-2519.

LIGHT FORAGERS HOVER BETTER THAN HEAVY NURSES



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Changing role is a fact of life. As youngsters we are cared for, and as we age we become the carers. And it's similar in bee society. Recently matured young adults take on nursing roles while older bees forage for the nest. But it wasn't clear how a bee's role and age might affect its flight performance. Curious to find out how well nurse bees and foragers hover as they age, Stephen Roberts and his colleagues from the University of Nevada decided to investigate the flight capacity of hovering bees to see how their performances change as they switch from nursing to foraging (p. 2604).

Collecting nurse bees and foragers that hatched at the same time, the team weighed the insects, filmed them hovering in air and thin heliox, and found that the foragers were 42% lighter than nurse bees of the same age. But instead of losing muscle, the foragers had lost weight from their abdomens, effectively increasing their proportion of flight muscle. But would this make the foragers better fliers?

Analysing the insect's flight performances, the team found that the nurse bees were unable to hover in the thin heliox. Even in normal air, the heavier nurses were only just able to support their weight: they were already beating their wings as fast as possible just to stay aloft in normal air. And when the team compared old and young nurses, they all hovered equally 'well'.

However, the lighter foragers had no difficulty hovering in normal air, and could beat their wings 32% faster than in air in order to remain airborne in heliox. Comparing young and old foragers, it was clear that the youngest foragers could not beat their wings as fast as middle-aged foragers at the peak of their performance. So the foragers' hovering performance altered as they aged.

What does this mean for the occupants of a bees' nest? Roberts and his colleagues explain that bees are versatile creatures and can switch roles in response to environmental conditions. But young and old foragers, with lower flight capacities than middle-aged foragers, may not be able to keep the nest as well stocked as their middle-aged sisters, and nests that tend to produce very young foragers could be at a disadvantage compared with nests whose nurses graduate to foraging later in life.

10.1242/jeb.035881

Vance, J. T., Williams, J. B., Elekonich, M. M. and Roberts, S. P. (2009). The effects of age and behavioral development on honey bee (*Apis mellifera*) flight performance. *J. Exp. Biol.* **212**, 2604-2611.

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