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INSIDE JEB

Hover flies lack gravity sensors

A hover fly prior to release. Photo credit: R. Goulard and S. Viollet.

The screaming on most rollercoasters begins almost as soon as anticipation of the stomach-churning descent begins. Even in the dark we know that we are plummeting from the instant we tip over the summit, and the secret of the thrill lies deep in gravity sensors in our inner ears and intestines. As soon as the descent is launched and we begin free falling, the effect of gravity on the sensors is eliminated, producing the familiar stomach-churning sensation. However, Stéphane Viollet, from the CNRS and Aix-Marseille University, France, explains that the feedback from gravity sensors can sometimes be misleading and in some circumstances they may even fail if a manoeuvre is particularly extreme, saturating the receptors so that they no longer respond. Knowing that hover flies are extraordinarily agile and routinely perform aggressive high acceleration manoeuvres, Viollet and colleagues Roman Goulard and Jean-Louis Vercher wondered whether the insects rely on gravity-sensing organs to detect when the world has fallen away from beneath their feet.

Designing a gravity-defying joy-ride in which the unsuspecting flies were dropped instantaneously from an electromagnet, Viollet and Goulard were then able to simulate free-fall conditions to find out how swiftly the insects responded to the loss of the sensation of gravity and attempted to fly. However, knowing that flies also rely on vision and the sensation of air flowing over mechanosensory hairs on their bodies to determine their orientation, Viollet and Goulard also messed with their view of the world by releasing the flies in three different surroundings: pitch dark, a uniform white box illuminated from above and a box lined with horizontal stripes that should intensify the visual sensation as they fell.

Having filmed the plummeting flies and noted when the insects initiated a last-ditch effort to pull out of the dive, Viollet and Goulard realised that the flies that fell in the dark rarely, if ever, began beating their wings in time to rescue themselves from a crash. ‘After 200 ms in every condition it is impossible for the fly to stop the fall’, says Viollet; so the free-falling flies seemed to be unaware that they were falling until they had passed the point of no return, and even then they had no sense of which direction they were moving and often flew into the floor or wall, instead of soaring to safety. They clearly had no gravity sensors – accelerometers – and must be relying on the sensation of air flow to rectify their fall.

However, as Viollet and Goulard gradually reintroduced visual cues, the flies seemed to do better: they triggered wing beats earlier as they fell in the white box, and when the duo installed the stripy wallpaper the majority of the flies triggered flight and avoided a crash within 150 ms of release. The flies were using vision in addition to sensing airflow to determine their orientation. The two scientists are now eager to understand how the tiny aviators integrate all of this information in their brains, as they hope to use the information to design better autopilots. ‘Every airplane or drone is equipped with accelerometers because they are vital for the vehicles to measure their orientation… but it seems that flies do not need that… so it means that there are tricks that flying insects are using that don’t use accelerometers to stabilise their flight’, says Viollet, adding, ‘For us it is a complete breakthrough in the design of autopilot systems’.

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Goulard, R., Vercher, J.-L. and Viollet, S. (2016). To crash or not to crash: how do hoverflies cope with free-fall situations and weightlessness? *J. Exp. Biol.* **219**, 2497-2503.

Kathryn Knight

Bull ants’ eyes don’t lock temporal schedule

A nocturnal bull ant, *Myrmecia pyriformis*, worker. Photo credit: Ajay Narendra.

Bull ants have a fearsome reputation, delivering vicious stings to anything that stumbles into their path. However, when it comes to living in harmony with other members of the bull ant family, the aggressive insects have evolved the ultimate timeshare solution: they take it in turns to come out. Some species specialise in daytime activity, while others roam at dusk and dawn, and others have opted for a nocturnal take on the day. However, it was not clear what locks each of these closely related species into their own unique schedule. ‘Competition and temperature tolerance did not explain this’, says Ajay Narendra, from Macquarie University, Australia. Puzzled by the ability of the close relatives to partition the day and knowing that some ant species have a pupil structure in the eye that can expand to admit more light in dim conditions, Narendra and colleagues from The Australian National University, Willi Ribi and Jochen Zeil, wondered whether bull ants with different activity patterns might have specially adapted eye designs that could account for their temporal segregation.

Narendra selected four species that live in close proximity – daytime active *Myrmecia croslandi*, dawn active *M. tarsata*, dusk active *M. nigriceps* and nocturnal *M. pyriformis* – and recalls that it was simply a matter of arriving at the nest just as the ants became active in order to collect them; ‘The activity schedule of these ants is so predictable’, he says. However, no one risked approaching the nests without protective gum boots, and Narendra adds that collecting the nocturnal species was particularly

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hazardous: ‘we armed ourselves with infrared cameras to spot the ants before they found us,’ he chuckles.

Back in the lab, Narendra, Ribi and Birgit Greiner exposed all four species to bright light and total darkness. Scrutinising how the eye structures responded, the team clearly saw a pupil structure that constricted when the light was bright in the eyes of the three species that are active in the darker conditions. The pupil was composed of pigment cells that encircled the crystalline cone, reducing the aperture through which light passes to 0.8 µm in the twilight and dawn active ants and 1.6 µm in nocturnal *M. pyriformis*. However, when all three species experienced 24 h of darkness, the pigment cells migrated away from the crystalline cone, expanding the aperture to over 5 µm in *M. pyriformis*. In contrast, there was no difference in the pupil diameter of the day active *M. croslandi ants*, which remained stable at 1.2 µm regardless of the light conditions. All three species that restricted their activity periods to times when light was low were capable of adapting their vision to bright light conditions, and Narendra says, ‘The properties of the compound eye do not restrict nocturnal ants to be active exclusively at night’.

Having confirmed that the ants’ vision was not responsible for their time-shifted lifestyles, the team investigated how the nocturnal ants control their sensitivity to bright light to find out whether the movement of the pupil pigment cells is triggered by the presence of light or the ants’ internal body clock. After exposing nocturnal *M. pyriformis* ants to light during the night and taking ants that had been kept in the dark during the day and exposing them to light, the team found that the ants can contract the pupil at any time of day, suggesting that pupil formation is controlled by light exposure. However, when the team exposed the ants to dark conditions during the day, the ants were unable to fully open the pupil, suggesting that the insect’s body clock controls when the pupil aperture opens to some extent.

10.1242/jeb.146886

Narendra, A., Greiner, B., Ribi, W. A. and Zeil, J. (2016). Light and dark adaptation mechanisms in the compound eyes of *Myrmecia* ants that occupy discrete temporal niches. *J. Exp. Biol.* **219**, 2435-2442.

Kathryn Knight

How migrating lake sturgeon cope in fishways

A lake sturgeon fitted with an accelerometer. Photo credit: Jason Thiem.

Migrations have always been gruelling, from the Herculean flights of bar-headed geese to the epic odysseys of salmon returning upriver to their spawning grounds. However, when humans began altering river systems, taming them with dams, the channels of many migrating fish became utterly impassable. To mitigate the disruption, fish ladders – or fishways – are often installed to expedite the passage of migrating species. However, many of the current fishway designs are based on our understanding of a few poster-child species, such as the salmon, and few have considered the impact on other, less athletic species. ‘Sturgeons are one of the most threatened groups of fish in the world’, says Jason Thiem, from Carleton University, Canada, adding, ‘Little research has been conducted on fishway use by sturgeon, despite the recognition that barriers to migration represented a threat to the process’. With the future of these species in jeopardy, Thiem, Jeff Dawson and Steven Cooke decided to track the progress of lake sturgeon (*Acipenser fulvescens*) through a fishway to find out how much exertion the ungainly swimmers require to negotiate these obstacles.

After selecting the Vianney-Legendre Fishway on Quebec’s Richelieu River for their study with the help of sturgeon and fishway experts Pierre Dumont and Daniel Hatin, Thiem and colleagues had only a brief 2-week period to capture sturgeon as they congregated below the fishway, ready to negotiate the obstacle in a bid to swim upstream to spawn. ‘It took 3 years to get the right field conditions for us to be able to undertake this field study’, says Thiem, who recalls battling adverse conditions. Having previously drained the 85 m long channel and fitted 15 antennae at intervals along its course to track the fish’s progress, the team then fitted electronic tags and accelerometers to 44 sturgeon to monitor their movements, before releasing the animals and recording their progress as they ascended the fishway.

Retrieving the tags from the fish and releasing them at a spawning site, Thiem realised that although seven of the fish had successfully negotiated the 85 m channel – after as many as 16 attempts – 23 failed to reach the end and 14 never even attempted the climb. Calculating the fish’s swimming speeds, the team discovered that most of the fish swam at relatively leisurely rates ($\leq$1.25 m s^{-1}); ‘We rarely observed high speed swimming and hyperactivity’, recalls Thiem. And when Thiem, Andy Danylchuk, Adrian Gleiss and Rory Wilson analysed the fish’s energy consumption, there was little difference between the fish that succeeded in reaching the top and those that did not. However, the successful fish used more energy per meter (42.75 J kg^{-1} m^{-1}) than the unsuccessful sturgeon (25.85 J kg^{-1} m^{-1}). And when the team calculated the fishes’ energy consumption as they negotiated the two turns in the channel, they saw that the sturgeons’ cost of transport increased significantly. The team also compared the plucky sturgeons’ energy consumption as they tackled the ascent with the energy consumption of sturgeon swimming at similar speeds through a tranquil lake – their usual environment – and realised that as they repeatedly attempted to ascend the channel, the sturgeon consumed as much energy as sturgeon swimming 5.8–28.2 km in peaceful lakes.

‘Swimming uphill is energetically demanding’, says Thiem, adding, ‘We expected sturgeon to be poor swimmers… [however,] this is not the case and swimming performance is unlikely to be a limiting factor in fishway passage success’. Thiem also adds that sturgeon would benefit enormously if fishways were redesigned and the turn structures removed. ‘We identified that the absence of turning basins in the current fishway design would reduce passage time and correspondingly reduce energy expenditure’, he says.

10.1242/jeb.146910

Thiem, J. D., Dawson, J. W., Hatin, D., Danylchuk, A. J., Dumont, P., Gleiss, A. C., Wilson, R. P. and Cooke, S. J. (2016). Swimming activity and energetic costs of adult lake sturgeon during fishway passage. *J. Exp. Biol.* **219**, 2534-2544.

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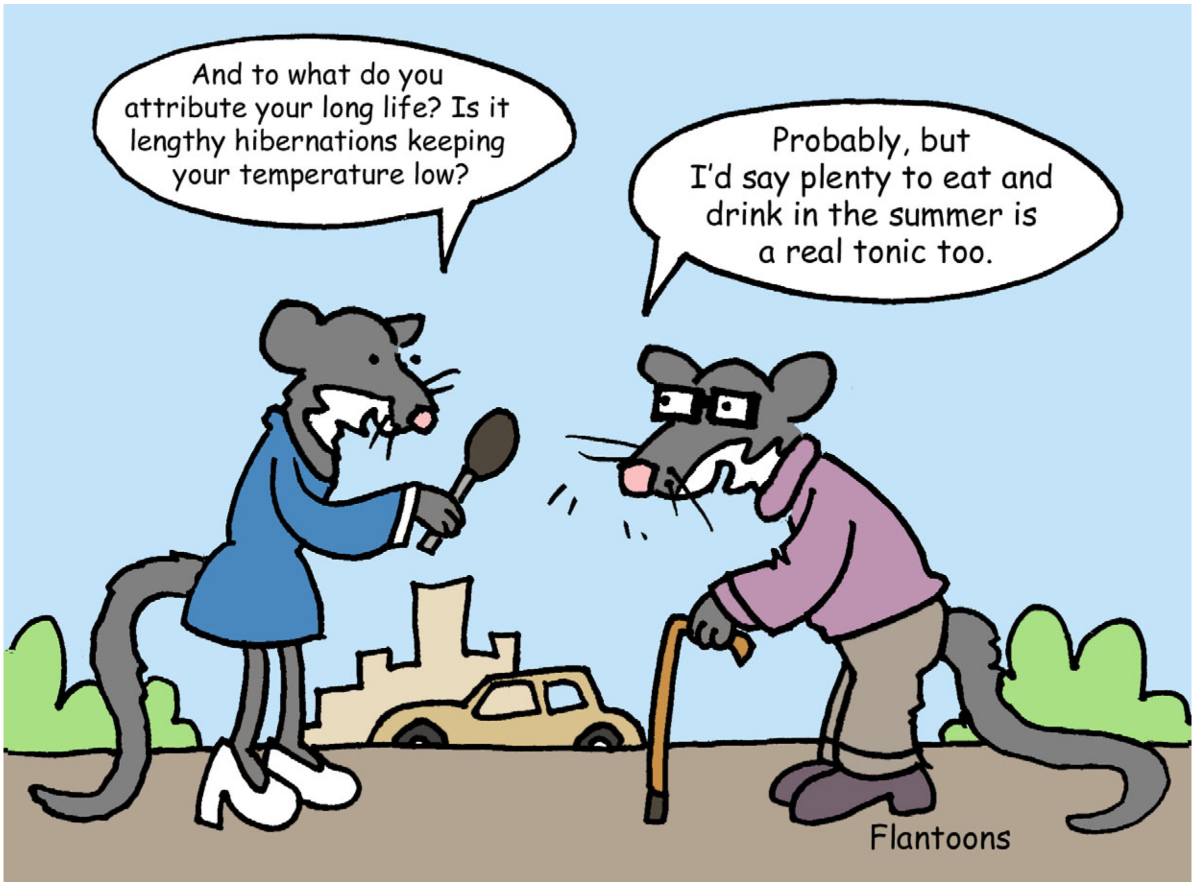
Up-and-about dormice reset telomere clock



Within almost every animal there is a ticking clock that contributes to determining their lifespan. Each time that a cell divides, the capping structures that protect the ends of chromosomes – known as telomeres – become shorter, and the length of these structures is correlated with life expectancy. However, it was unclear how this alarm clock performs in one small mammal, the edible dormouse, which has a life expectancy that is 50% greater than that of other similarly sized mammals. Knowing that hibernation slows cellular damage and that the small rodents can spend as much as 11.4 months out of every year hibernating, Franz Hoelzl and colleagues from the University of Veterinary Medicine, Austria, wondered what effect the dormouse's lethargic lifestyle might have on their telomere length.

After monitoring the body temperature (which is a good indicator of when an animal is active or hibernating) of wild dormice in the Vienna woods over 12 months and gently collecting cells from the animals' mouths at the beginning and end of the period to measure their telomere length, Hoelzl and colleagues compared the length of the animals' telomeres with their activity pattern. However, the team was surprised to discover that the drop in body temperature that occurs during hibernation was not correlated with reductions in the length of the animals' telomeres. Instead, the rate at which the animals emerged from hibernation – which they do periodically over a hibernation season – was the best indicator of the rate of telomere loss. However, the animals appeared to compensate for the loss and were able to elongate their telomeres during the active season, but only if food was plentiful.

10.1242/jeb.146894

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