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Ballooning spiders hitch a ride on electric fields

At first glance, spiders might not seem like the most likely of aeronauts, but there are in fact many species that take to the skies through the art of ‘ballooning’. By pointing their spinnerets in the air and releasing silken strands in a fan-like fashion, these spiders are able to ascend skywards up to altitudes of over 4000 metres! The mechanics of this ballooning phenomenon were first examined over 200 years ago when the prevailing ideas were that these spiders were relying on either aerodynamic or electrostatic forces in the environment to stay airborne. Even Charles Darwin shared his thoughts on the subject after witnessing scores of such spiders taking off from the Beagle, suggesting that thermal currents may have a role to play. Although the aerodynamic and thermal gradient theories have previously been investigated experimentally, their results do not appear to explain observations of the spiders ballooning in unfavourable weather conditions, suggesting that an important piece of this puzzle has been overlooked.

In a recently published study, Erica Morley and Daniel Robert from the University of Bristol, UK, set out to investigate the previously unexplored relationship between spider ballooning and naturally occurring electric fields (e-fields) known as the atmospheric potential gradient (APG). In order to recreate these e-fields in a controlled environment, the team constructed a chamber with electrically stimulated aluminium plates at the top and bottom to generate either neutral-, low- or high-strength e-fields. This chamber contained ballooning take-off sites for the spider that replicated natural ballooning launch pads such as tree branches and was constructed inside a Faraday cage to block any unwanted electrical interference. Once the tiny money spiders (members of the family Linyphidae) had been introduced to the chamber, the electrically charged plates were switched on to generate the e-fields and the spiders were filmed performing their amazing aerial acrobatics.

Through analysis of the video footage, the team found that ballooning was always initiated by two specific behaviours: first, the spider would stretch its abdomen upwards into a position fabulously referred to as ‘tiptoeing’, and second, the spider would drop a silk ‘dragline’ to keep them anchored before releasing the ballooning silk fibres and taking flight. Once the spiders were airborne, the researchers were able to demonstrate a strong relationship between e-fields and ballooning by repeatedly switching the e-field on and off, which reliably resulted in the spider rising and falling in the air. Interestingly, the spiders initiated significantly more of these tiptoe and dragline drop events when exposed to higher strength e-fields, suggesting that the spiders were somehow able to detect these atmospheric changes and alter their behaviour to capitalize on them.

Not satisfied with simply watching levitating spiders, the researchers then wished to determine how the spiders were detecting these e-field changes. By narrowing their focus to the hair-like ‘trichobothria’ on the spider’s legs, known primarily for their detection of minute air vibrations, the researchers were able to examine the physical responses of the trichobothria to e-fields using laser Doppler vibrometry. These micro-measurements revealed that the hairs do indeed become stimulated and move in response to the activation of these fields and are quite likely acting as electro-mechanical receptors that can detect subtle changes in the APG. Finally, the authors discuss the ecological significance of these findings, emphasising the important role of spiders as natural pest controllers throughout the world and how this research may help us to better understand their dispersal mechanisms in the wild.

One last question posed by the researchers is, I think, a crucial one: once the spiders get up there, are they able to steer their balloons or navigate their flight paths at all? Perhaps it’s simply a case of holding on and crossing their trichobothria for good luck.

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Great, now the dogs are lying

Lately, usually after reading the news, I find myself looking at my dog and saying, ‘Now *here* is an honest mammal’. Like all dogs, Mister Garçon lacks the ability to understand how lying may get him ahead

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in life. He may put on a show when treats are on offer, sure; but he doesn't *lie*. 'I commend you on your honesty, Mister Garçon', I say, and then I rough him up a little bit to remind him who's boss.

The thing is, it's not true. Dogs do lie. And small male dogs like Mister Garçon are the worst of the bunch. Perhaps out of academic interest or perhaps from being burned by a dog one too many times, Betty McGuire and her team at Cornell University endeavoured to get to the bottom of this dishonesty once and for all.

The dishonesty in question has to do with scent marking. Scent can convey all sorts of information, including sex, age, health, kinship, individual identity, and social and reproductive status. As such, scent marking is a common way for animals to transmit information about themselves into the future for other individuals to receive. We've all seen this before, usually in the form of dogs peeing on (i.e. transmitting) or sniffing (i.e. receiving) neighbourhood infrastructure. Interestingly, when dogs do this, the information they transmit or receive is conveyed not only in the scent signal itself, but also in the space it occupies: a scent located high up the lamppost signifies that a large dog walks these streets. For male dogs, this potentially wards off rival males while simultaneously attracting curious females.

Knowing this, the Cornell team hypothesized that adult male dogs embellish their height when urine marking, predicting that small male dogs aimed higher up the lamppost than large male dogs. To test this, the team first investigated whether raised-leg angle is indeed a proxy for urine mark height. Turns out it is. The researchers found that the angle between a dog's raised leg and the axis perpendicular to the ground was positively correlated with the height of the urine mark in similarly sized dogs. In fact, raised-leg angle was the best predictor of any proxy they investigated.

With this confirmed, McGuire and her team got to the meat of it: do small dogs raise their legs higher than large dogs? Yes! The findings revealed that the smaller the dog, the higher the raised-leg angle. This implies not only that urine marking can be dishonest, but also that small male dogs do what they can to appear more intimidating and/or alluring than they actually are. In other words, they lie.

My relationship with Mister Garçon has been affected by these findings. A goal of any guardian is to foster honesty in those they care for, and how this has manifested for the two of us is through my awkward attempts to physically push Mister Garçon's leg down while simultaneously trying to avoid looking weird in front of the neighbours. 'He's being dishonest', I say in response to their baffled looks from the porch; 'I'll send you the paper'. Fostering honesty while keeping up appearances has been a delicate dance, and it's not been an easy one. Perhaps I'll just relent and heed that age-old advice to let a peeing dog lie.

10.1242/jeb.170167

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Why cortisol soars in flying squirrels

It's hard to ride a seesaw alone. As sad as this mental image is, it's a great way to conceptualize the delicate balance of cortisol regulation. Cortisol is a hormone that travels through the body at high concentrations during stress to induce a number of metabolic and behavioural responses that bring the body back to a resting state. Regulating cortisol levels is critical because it has such a substantial effect on physiology, so cortisol brings friends to the playground to help it balance, including: Negative Feedback, who rides the opposite side of the seesaw and drives cortisol back down when it reaches the top; and Corticosteroid Binding Globulin (CBG), who rides in the middle and buffers cortisol on this wild ride. For most animals, this up-and-down runs smoothly and tissues are protected from excess cortisol. But the southern flying squirrel seems to do things differently. This nocturnal trapeze artist boasts some of the highest non-stress cortisol levels of any vertebrate, yet, unlike other animals with high resting cortisol, its CBG has a poor capacity for buffering this heavy load. How, then, do non-stressed squirrels prevent their tissue from being overloaded with cortisol? This is what researchers from the Burness lab at Trent University, Canada, wanted to find out. They reasoned that the squirrel's negative feedback must have a higher set point, meaning their tissues are less sensitive to cortisol, in order for the animals to maintain continually high cortisol levels in their blood.

The research crew, led by PhD student Lanna Desantis, headed to the deep, dark woods to live-trap flying squirrels and test their cortisol regulating strategy. First, Desantis injected each squirrel with different concentrations of dexamethasone, a synthetic cortisol, and quantified plasma cortisol levels 3 h later to determine how much dexamethasone is needed to engage the negative feedback mechanism. She found that flying squirrels needed 16 times more dexamethasone than that required in related species to drop plasma cortisol below resting levels. This means that the negative feedback set-point is much higher in flying squirrels than in other mammals. The scientists reason that the squirrels likely have low-affinity cortisol receptors, so more cortisol is needed to saturate these receptors and engage negative feedback; or put another way, the squirrels' tissue sensitivity to cortisol is much lower than in other mammals.

Knowing that cortisol also plays a role in seasonal transitions, such as helping to shift energetic usage between reproduction and growth, Desantis and her colleagues were curious as to whether male and female flying squirrels had different basal cortisol or negative feedback regulation during the breeding and non-breeding seasons. When she compared resting cortisol levels, she found that female squirrels had higher cortisol compared with males, and that non-breeding squirrels had higher cortisol than breeding squirrels. When Desantis gave the squirrels dexamethasone, she found that non-breeding squirrels still had higher plasma cortisol than breeding animals, even if she gave them twice as much dexamethasone as she gave the squirrels in the breeding season. This means that there is both sex-specific and seasonal variation in cortisol negative feedback in flying squirrels, with non-breeding females having the lowest tissue sensitivity to cortisol. This differential sensitivity is likely key to helping these night-time fliers navigate the seasonal trade-offs between survival and reproduction.

10.1242/jeb.170225

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Sea bass (can't) smell trouble under elevated CO_2

Elevated levels of dissolved carbon dioxide (CO_2), such as those expected by the end of this century, have been shown to harm marine fish by affecting how they sense and interact with their environment, ultimately increasing their mortality. The sensory and behavioural changes caused by CO_2 have largely been attributed to chemical changes in fish brains, with little investigation into other mechanisms. However, sensory information is first gathered outside the brain through systems such as the olfactory system, with which fish sense food, find potential mates, detect predators and locate suitable habitats. Cosima Porteus and colleagues from the University of Exeter, UK, in collaboration with scientists from Portugal and other UK institutions, hypothesized that fish olfactory tissue – which is in direct physical contact with water – is also likely affected by elevated CO_2 and that changes in this tissue may thus be responsible for some of the effects of high CO_2 on fish behaviour.

To test their hypothesis, the team first confirmed that the behaviour of their study animal, the European sea bass, was affected by exposure to water with high dissolved CO_2. Indeed, they found that the fish swam less and were more likely to 'freeze' in the presence of a predator when exposed to high CO_2. Next, the researchers exposed only the odour-sensing tissues of the fish to water with normal CO_2 or high CO_2 levels that also contained chemicals that the fish should be able to smell. They then measured how strongly the nerves in the scent-sensing tissue responded to the different chemicals. High CO_2 levels reduced the sensitivity of the nerves to most of the odour chemicals, and the sensitivity was more impaired for some chemicals than for others. In fact, the scientists estimated that by the end of the century, fish might have to be almost twice as close to the source of an odour to smell it.

Porteus and colleagues also wanted to find out how exposure to elevated CO_2 might affect the sea bass on a molecular level, so they measured the expression of genes in both the odour-sensing tissue and the odour-processing area of the brain after they exposed fish to current or end-of-century levels of CO_2 for 2 or 7 days. In both the water-contacting tissues and brain, they found that the expression of genes involved in neuron development and function was reduced after high CO_2 exposure, suggesting an impairment of smelling ability even at the molecular level.

Overall, Porteus and her fellow scientists showed that the effects of high CO_2 levels on fish behaviour are not simply due to changes in brain chemicals; rather, they are likely due to a combination of alterations in the odour-sensing tissue itself and in the odour-processing centre in the brain. Unfortunately, the scientists' findings suggest that by the end of this century, fish may have a harder time noticing when something smells, well, fishy.

10.1242/jeb.170217

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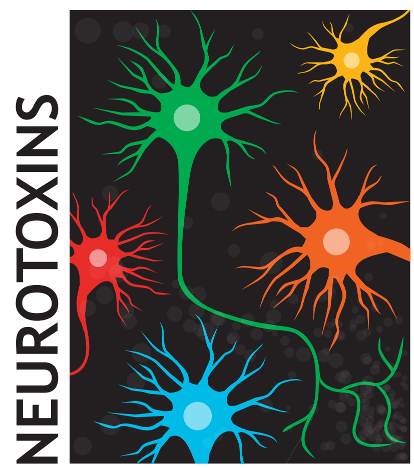
Risking the land of milk and honey



Bees are one of those species: you either love them or hate them. On the one hand, most of us are rather partial to the occasional honey-covered slice of bread made possible by the industrious insects, while on the other hand, others become rather scared when faced with their stripy appearance. Yet, the stinging insects are fundamental for much of agriculture: a third of all our food depends on bee pollination. However, bees are in danger. In recent years, beekeepers around the world have noticed that the valuable insects are vanishing at an alarming rate. One potential cause of this decline is the use of neurotoxin insecticides to protect crops. Bees ingest the toxin when consuming contaminated pollen and nectar, which damages their central nervous system and disrupts their ability to learn and form memories. And the insects' memories are key to their frenetic lifestyle, allowing them to recall which plant species are currently blooming, where they are located, which blooms they have visited already and how to find their way home.

In order to investigate the connection between neurotoxin insecticides and memory and learning in bees, a team of researchers led by Harry Siviter from the Royal Holloway University of London, UK, began scouring the internet for any information about the impact of these toxins on bee memories. Compiling the knowledge from 23 publications, Siviter and his colleagues found that fewer bees were able to learn to associate a scent with the presence of food and retain the memory for up to 48 h after ingesting neurotoxins. This provided strong evidence that pesticide exposure has a negative effect on the insects' learning ability and memory. And when the team addressed previous criticisms – that the doses of toxin that the bees were exposed to in the lab did not reflect the amount of toxin that they experience in the wild – the new analysis showed that even the smallest doses, which are similar to those in the wild, impaired the insects' abilities to learn. The team also noted with concern that the bees' abilities to learn and form new memories were severely affected by even the shortest exposures to the toxic insecticides. And it was also apparent that all groups of neurotoxic insecticide had similar impacts: they all impaired bee memory and learning.

Thanks to the wealth of previous research in this area, the European Union is instituting a near-total ban of one group of neurotoxins – known as the neonicotinoids – by the end of the year, but the others will still be in use in other parts of the world. This 'meta' study highlights that it is essential that we continue to monitor the environmental impact of plant protection products if we do not want to risk our land of milk and honey.

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