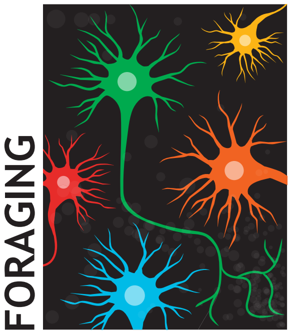
OUTSIDE JEB

Making a bee-line for food with octopamine



How do you find the newest, trendiest restaurants with the best food in your neighborhood (that is, of course, during non-pandemic times when restaurants are all open)? Well, one way that you may notice the new hip spot is to follow the crowds. If you wander by a spot filled with folks enjoying mouth-wateringly delicious food, you will likely be drawn to visit that restaurant yourself. But, how does your brain process these signals about food resources and quality? Tianfei Peng and two of his colleagues from the University of Mainz in Germany dug into this question by looking at the inner-workings of a slightly simpler brain – that of the stingless bee – to uncover the brain's role in social animal foraging.

The trio suspected that the compound octopamine could play a role in how both individuals and social groups find food and perceive its value. Octopamine is a major player in the brain function of invertebrate animals, including many insects, equivalent to the fight-or-flight hormone noradrenaline in vertebrates, including humans. Past research highlighted the key role of octopamine in the ability of individual honey bees to learn about food resources and to communicate that information to their buddies. Like honey bees, stingless bees live in colonies that are characterized by strict division of labor and unwavering cooperation, yet the stingless bees' ancestors diverged from their honey bee cousins over 80 million years ago. Could octopamine also stimulate individual and social foraging behaviors in stingless bees?

Peng and colleagues tested this idea in wild colonies of the Brazilian stingless bee (*Plebeia droryana*). To get the bees foraging, they set up feeders close to each colony filled with tasty sugar syrup. Once the bees had learned to snack at the feeders, the researchers dosed the syrup with octopamine, to test their theory that bees would feed more and in bigger groups when they experimentally boosted this important brain compound.

And they were right. Individual foraging increased almost 75% following an octopamine-laced treat. Although past studies show that octopamine has lightning-fast impacts on social foraging in honey bees (detectable in a matter of minutes), the stingless bees took a bit longer to follow their friends to the feeders and it took more than 2 h for the team to detect larger groups at the feeder after the insects had consumed octopamine. So, although stingless bees are a bit slower to jump on the octopamine wagon, the effects of the hormone on their behavior are undeniably similar to those of their honey bee cousins, despite millions of years of diverging evolution.

The researchers suggest that these octopamine-induced changes in the response to food may be driven by the brain's perception of food value and the potential rewards at different food patches. If the brain perceives a food resource as rewarding, insects are more likely to return to it again and again, bringing their friends along on subsequent visits. There is a still a huge amount to learn about how the brain shapes stingless bee behaviors and particularly how octopamine interacts with other brain hormones to regulate important daily tasks like sleeping, learning, aggression and social interactions. But when it comes to feeding, octopamine seems right for increasing a bee's appetite.

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Peng, T., Schroeder, M. and Gruter C. (2020). Octopamine increases individual and collective foraging in a neotropical stingless bee. *Biol. Lett.* **16**, 20200238. https://doi.org/10.1098/rsbl.2020.0238

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Birds keep their balance underfoot

Every day is a balancing act for two-legged, land-dwelling animals traversing tree roots, rocks or any other obstacles they may encounter. The balance system of one nimble two-legged animal, the guinea fowl, is remarkably robust, allowing them to remain stable even when encountering the most extreme trips and slips: their leg muscles rapidly counteract a bad step in response to signals sent from nerve sensors embedded in the muscles. A team of researchers led by Monica Daley, now at the University of California, Irvine, USA, had previously conducted a series of experiments to learn how the guinea fowls' muscles pull off this feat, but the role of the nerve sensors had eluded them. So, they decided to study how guinea fowl take obstacles in their stride when a critical sensory nerve is knocked out.

They first trained the animals to run on a laboratory treadmill set to speeds ranging from 1.3 to 2.0 m s^{-1} – the equivalent to a brisk walk in humans. Then, to challenge the birds' stability, they introduced 5 cm high hurdles on the treadmill at every 10th step taken by the animal. Once the birds were used to hurdling, the team severed the sensory nerve in the ankle muscle that, under normal circumstances, corrects the muscle length back to normal and maintains balance during running. In addition, the team implanted mechanical and electrical sensors in the ankle muscle to measure its force production and to gauge when nerve and brain signals activated the muscle. Finally, to find out how the birds fared when their nerve signals were cut, the team compared the birds' responses with those of another group of birds with intact nerves.

When the researchers looked at how the birds cleared the hurdles, they found that those with a severed nerve were still able to retain their stability, which underscores their remarkable agility. However, the birds that lacked sensory signals from the ankle muscle relied on generating a large burst of muscle force when stepping over the hurdle. This suggests that the birds compensated for the loss of the sensory feedback from the ankle nerve by using an alternative strategy to activate their muscles and maintain stability.

To learn more about this substitute strategy, the team turned their attention to the muscle activations and found that the birds that lacked sensory nerve signals from the ankle activated their ankle muscles about 23 ms sooner and over a longer duration than the birds with an intact nerve. The shift in muscle activation timing suggests that the brain compensated for the loss of nerve signals by ramping up its signal to the ankle muscle. The compensation shows that the signal from the ankle muscle sensory nerve plays a role in maintaining balance – without the nerve signal, the brain must step in to compensate for the loss.

Daley and her colleagues have shown that nerve sensors that monitor ankle muscle length contribute to maintaining balance in guinea fowl. The current results add to the understanding of how balance is maintained across two- and four-legged vertebrates and may even have implications for understanding how human balance problems arise from nerve injury or neurodegenerative disorders – because we, like guinea fowls, are only as stable as our next foothold.

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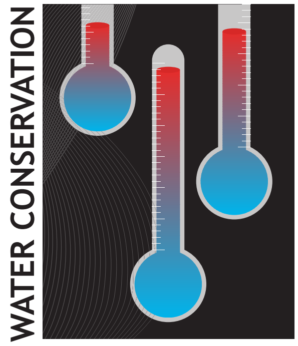
Drinking desert birds keep cool



As is often the case for animals living in extreme environments, desert birds face a choice between two competing physiological needs: in their case it's staying cool (which uses up a lot of body water) versus staying hydrated. Birds deal with this trade-off in different ways: some species make daily visits to reliable watering holes, sometimes flying considerable distances to quench their thirst, while other species hardly drink at all and conserve every drop they can get from meals of juicy insects. Zenon Czenze, a postdoctoral fellow at the University of Pretoria, South Africa, and colleagues investigated the implications of these different drinking habits for the thermal physiology of desert birds.

The team hypothesized that the heat tolerance of desert birds co-evolved with their dependence on surface water sources and, correspondingly, how much water they could commit to fending off the desert heat. Animals naturally lose water across their skin and when they breathe, a process known as evaporative water loss. Some animals, including sweating humans and panting dogs, turn this loss into their gain by getting rid of a little bit of body heat as the water turns into vapour, a process termed evaporative cooling. Czenze and colleagues predicted that birds that regularly imbibed fluids would take greater advantage of evaporative cooling to dump excess heat. With this additional cooling capacity, the team also expected that drinking species would tolerate hotter temperatures than species that rarely frequent watering holes.

To test these ideas, the researchers rounded up 12 species of songbirds with either drinking or non-drinking lifestyles from the Nama Karoo shrubland in South Africa. They implanted the animals with temperature sensors and measured their body temperature, metabolic rate and evaporative water loss rate at progressively higher temperatures.

As the temperature climbed, every species of bird examined increased their rate of evaporative water loss by panting. The species that refrained from drinking increased their rate of evaporative water loss 8-fold, whereas drinking species increased it 12-fold, showing that drinking species had more scope for evaporative cooling than species that drink little. Drinking species also had greater heat tolerance than non-drinking species and could withstand air temperatures of 52°C or higher, while the non-drinking species maxed out at 'only' 50°C. In addition, the species that tolerated the hottest temperatures were also those that showed the greatest increase in water loss, cementing the link between filling up on surface water and heat tolerance.

Almost everything comes down to conserving water or staying cool in the desert and arid-zone birds approach this trade-off in different ways. Regularly drinking species capitalize on predictable water sources to supercharge their body's air-conditioning compared with their non-drinking relatives, highlighting the close interrelationships between diet, movement ecology and thermal physiology in desert birds.

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Czenze, Z. J., Kemp, R., van Jaarsveld, B., Freeman, M. T., Smit, B., Wolf, B. O. and McKechnie, A. E. (2020). Regularly drinking desert birds have greater evaporative cooling capacity and higher heat tolerance limits than non-drinking species. *Funct. Ecol.* doi:10.1111/1365-2435.13573

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Flying snakes undulate for longer air times

Many animals from fish to snakes move using undulations, or rhythmic back-and-forth motions of their bodies, for propulsion. As snakes have no limbs for additional propulsion, they rely entirely on the undulations of their bodies to get around. Some snakes in Southeast Asia have even taken to the skies, flattening their bodies to resemble an airplane wing to create lift as they glide from trees. All these snakes undulate when gliding, but it was not known whether serpentining helps them fly or whether it is just a leftover behavior from their ground-dwelling ways. Do undulations give flying snakes more air time?

Isaac Yeaton and colleagues at Virginia Tech, USA, sought to answer this question by recording high-speed 3D videos of paradise flying snakes (*Chrysopelea paradisi*) making gliding descents between an oak branch on an artificial tree and the ground in a theatre on the Virginia Tech campus. The team then captured the motion of small reflective markers placed along the length of the snake's body with 23 cameras arranged around the test area to accurately measure how the snakes moved and changed their body shape during the descent. Then they used the measurements to reconstruct the snake's movements and create simulations of snake glides without using undulations. Finally, they compared the gliding performance of these simulations with simulations of regular undulating snakes to determine whether the maneuver helps the reptiles fly.

While ground-dwelling snakes oscillate their bodies from side to side when moving on land, Yeaton and colleagues' new measurements showed that flying snakes use not only lateral undulations but also vertical undulations. However, these up and down body ripples are smaller and twice the frequency of the side to side waves, and the peaks of the vertical bends coincide with the locations that are bent sideways least at that instant. In simulations, the snakes that used horizontal undulations when descending from a height of 75 m were able to glide an average of 7 m farther than snakes with no undulations by improving their ability to stabilize rotations of the body. In contrast, vertical waves had a smaller effect on performance.

Another behavior that the snakes used to improve their flight stability was elevating their tail slightly above their head during glides. The team found that simulated snakes with the tail well below their head began pitching downward and fell, while snakes with tails high above their head pitched upward and glided over shorter distances than snakes that held their tail either level with, or slightly above, their heads. Simulated snakes that held their tails slightly higher than their head flew the furthest. Overall, the snakes used undulations and the slope of their bodies from head to tail relative to the ground to achieve longer air times by preventing falls out of the sky due to rotational instability.

It turns out that flying snakes' undulations are not just a vestigial leftover from their grounded ancestors, but actually help them to glide farther and with better stability. These reptiles have co-opted a movement pattern already in their repertoire to take to the skies. Understanding how the undulations of flying snakes help them to remain airborne will hopefully enable the development of robotic models to test how the nervous system and muscles of these animals control their flights and may also inspire novel mechanisms to stabilize flying robots.

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