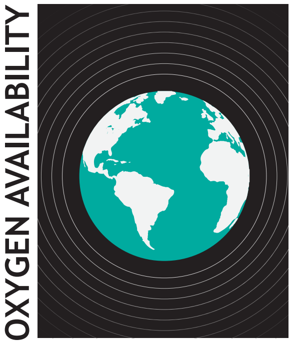
OUTSIDE JEB

Warm fish eggs gasp for oxygen



Breathing underwater is tough. Fish get by thanks to their elaborate gills, which have a large surface area to efficiently extract oxygen from the water. However, eggs don't have this luxury and must rely entirely on whatever oxygen seeps in through their jelly-like shells. The situation worsens the larger the egg, where the influx of oxygen must supply a greater volume. Benjamin Martin at the University of Amsterdam in The Netherlands wondered whether the largest aquatic eggs, like those of Chinook salmon, may struggle at times to get the oxygen they need.

With an international team of collaborators, Martin set about investigating how developing salmon eggs respond to an increase in oxygen demand due to higher temperatures, or a limited supply when oxygen in the water is depleted; both of these scenarios afflict the river beds where wild salmon spawn and are becoming increasingly frequent as our planet warms. In a super-sized experiment, the team reared thousands of salmon eggs in the lab at nine different combinations of temperature and oxygen levels and monitored how much oxygen the embryos consumed throughout development.

It turns out that for an embryo encased in jelly, everything depends on oxygen: the rate at which they develop, their tolerance of higher temperatures, the size of the hatchlings and, importantly, survival. A decrease in the amount of oxygen in the water has dire consequences, increasing mortality of the brood, but it was especially devastating when it occurred late in development, when the embryos' need for oxygen was highest. An increase in temperature generally led to faster embryo growth, but also a greater need for oxygen, making them even more vulnerable to a depletion of oxygen in the water. The team then fed these results into a mathematical model that illuminated the egg's inner oxygen supply. Salmon embryos were surprisingly tough and tolerated an 80% cut in oxygen within the egg. However, in late development, the embryos were always oxygen starved, which constrained their growth, and even a small decrease in the oxygen level in the water or an increase in temperature could push them over the edge and decrease survival.

But nature is messy in ways that lab experiments and mathematical models cannot capture. Therefore, the team reared additional eggs in artificial gravel beds that naturally mimicked the salmons' spawning grounds. The slow water flow through the pebbles meant that the oxygen consumed by the eggs wasn't replenished as quickly as in the lab, making them even more vulnerable to higher temperatures. In addition, the hapless eggs sitting downstream of the bunch suffered most, as their greedy siblings upstream had already gobbled up all the oxygen in the water, resulting in smaller hatchlings and lower survival. Even eggs sitting right next to one another would experience vastly different levels of oxygen, because the water flow through the egg–gravel mix was random. As if braving low oxygen and high temperatures wasn't enough, in the wild, the survival of a salmon egg is also a lottery.

While some adult fish seem to handle the whims of climate change quite well, their embryos typically do not. In the long term, a species is only as resilient as its most sensitive life stage. The high vulnerability of fish embryos is rooted in their precarious oxygen supply within the egg. Even under optimal conditions, growing fish embryos become starved of oxygen, which leaves only razor-thin margins to tolerate any increase in temperature or decrease in oxygen level. The life of a fish embryo is like a reckless tightrope act where survival depends on walking a delicate balance between oxygen supply and demand.

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Gusty winds, flappy wings

Birds must fly in all manner of windy weather. At first glance, this may not seem like such an impressive feat; after all, flying is what birds are born to do. But if you consider that they remain suspended in the air while being continually buffeted by sudden gusts of wind, which do not send them tumbling, the trick appears more remarkable. Humans caught on a ship in inclement weather have a hard time remaining upright even with handrails to grab onto, so it is quite striking how birds deal with wind in such a graceful style. Stability also ensures safe landings and successful prey capture, and provides flying animals with a steady view of the world. Spurred on to learn more, a team of researchers from the Royal Veterinary College and the University of Bristol, UK, set out to study how birds remain stable when flying through unexpected gusts of wind.

The team trained a barn owl to glide through a 17 m laboratory corridor equipped with high-speed cameras that tracked the bird's movement. To deliver a

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perturbing gust to the flying bird, they put a fan at the end of the corridor placed beneath the flight path to deliver an unexpected blast to the underside of the bird. The owl experienced three increasing gusts of 3.1, 4.5 and 5.2 m s^{-1} – comparable to gentle, yet destabilizing, breezes – as it flew through the corridor. Then they measured how the owl coped with the gusts by tracking its wing movements, in addition to comparing the movement of the flying bird's torso with the movement predicted from computer simulations, to calculate how well the gusts were tackled.

Employing a near-immediate response when gliding into the unexpected gust, the bird pivoted its wings around its shoulders, forming a V-shape when viewed from the front, with its head and torso located at the bottom, while its wings formed each ascending limb of the V. This initial manoeuvre deflected 32% of the lift generated by the gust within 80 ms of its impact, ensuring that the bird's torso and head remained on an unperturbed course. The team found that the bird's quick response was aided by the build and shape of the wing: the mass distribution along its length ensures that the wing's pivoting motion imparts no secondary upward or downward movement to the torso, keeping the head firmly in place during the unexpected impact. Then, after the initial wing rotation, the bird tipped the front edge of the wing downward, which decreased the lift force generated by the gust, reducing the impact of the gust by an additional 48%, thereby allowing the bird to continue smoothly on its way.

Analysing the manoeuvre, the team found that the speed of the response was the key to maintaining stability, suggesting that the bird's central nervous system may not be important for tackling the initial impact of a gust. This means that passive mechanisms, such as the shape and weight of the bird wing, absorb wind gusts, much like a suspension system in a car ensures a smooth ride through rough terrain. This novel discovery is also exciting news for engineers trying to build small aircraft. Understanding how shape and form endow flying stability may greatly simplify the task of flying through unpredictable weather conditions without needing to depend on complex sensors to gauge stability. Taking a hint from the barn owl: flapping wings can make for unflappably steady flight.

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Mole-rats play evolution by ear

Scuttling around their burrows, mole-rats can kick up a bit of a racket, calling out in the dark to their extensive family. Surprisingly, naked mole-rats and their close relatives Damaraland mole-rats have terrible hearing, especially compared with other rodents. Mole-rats have no outer ears and the vibration-sensing hair cells in their inner ear are weirdly connected to their nerves, but neither feature totally explains why they are nearly deaf. Why they evolved bad hearing is a mystery too. They might have lost hearing over time like other subterranean animals lost sight. Alternatively, poor hearing could be an advantage, dampening echoes in noisy burrows. Sonja Pyott from the University of Groningen, The Netherlands, and colleagues investigated the physiological and evolutionary causes of mole-rats' poor hearing.

First, the authors did a mole-rat hearing test to see what sounds got their inner ear – the cochlea – talking to their brain and found that naked and Damaraland mole-rat ears respond to tones between 0.5 and 4 kHz or 2 kHz, respectively, a narrower and lower range than for other rodents. Next, the authors did a full auditory system workup, seeking a physiological mechanism to explain why mole-rats are hard of hearing. As hair cells vibrate in response to incoming sounds, they make noises called otoacoustic emissions. Typically, otoacoustic emissions increase with louder noises and they track how well the cochlea amplifies sounds. Yet, unlike all mammals studied to date, mole-rat otoacoustic emissions were similar across the range of sounds tested (~70 dB, comparable to an alarm clock), meaning their cochleas didn't make quiet sounds louder.

The researchers wondered why mole-rat inner ears didn't amplify sounds, focusing on the outer hair cells that convert soundwaves into brainwaves. As mutations in the hair cell protein prestin, which helps hair cells vibrate, cause hearing loss in humans, the team hypothesized that mole-rat prestin might be dysfunctional. But, when they checked, the mole-rats didn't have any problems with their prestin; they had the right amount in the right places and none of the usual mutations previously associated with hearing loss. Moreover, when they isolated hair cells from mole-rats, the sensors sent electrical signals just as well mouse hair cells, meaning that the lack of cochlear amplification in mole-rats wasn't caused by loss or dysfunction of prestin.

Undeterred, the team turned their attention to stereocilia bundles, the 'tufts' attached to the hair cells that sway in response to sound. Scanning electron microscopy revealed that mole-rat stereocilia are a mess, jutting out at sharp angles and even missing in some places – a situation that probably makes they them less sensitive to sounds. The disorganization seemed to be caused by several mutations in the linker proteins that connect the tips of individual stereocilia like wires, causing all of the stereocilia to sway in unison, co-ordinating their auditory signals.

Confident they had identified one mechanism for poor mole-rat hearing, the team tackled the ultimate question: why? Comparing mole-rat linker proteins with those of other rodents, they found far more amino acid sequence-altering mutations than expected in the mole-rat proteins; the probability of accumulating all those mutations randomly was infinitesimal, making it unlikely they had occurred by chance. The authors concluded that several of the linker protein mutations, and the poor hearing they caused, are likely advantageous for mole-rats.

As you'd expect a noisy, sociable, subterranean rodent to have excellent hearing, hard of hearing mole-rats have long been a mystery. But now part of that mystery has been resolved and a key piece of the puzzle is a few mutations in proteins that connect a small, but mighty, part of their ears.

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Synthetic sunflower scent trains bees for better pollination

When honeybees go foraging in gardens or forests, the world is their bouquet. But sometimes we need them to forage and pollinate vast fields of a single commercial crop such as sunflowers, so how can we entice them to selectively pollinate a single crop? Researchers Walter Farina, Andrés Arenas and colleagues from Universidad de Buenos Aires, Argentina, wanted to find out whether they could train honeybees to pollinate a crop of sunflowers.

The scent of a sunflower is a cocktail of about 200 compounds. However, bees may only respond to a few of the compounds to locate a particular flower. Knowing this, the team developed two synthetic blends including just three compounds, each mimicking the natural scent of sunflowers, and tested whether bees respond to them as they do to natural sunflowers. For this, they trained young forager bees to associate the synthetic sunflower scents with sugar solution reward – a bit like Pavlov's dogs learned to associate a ringing bell with the arrival of food – and tested whether the bees could distinguish the fake scent from genuine sunflower scent and that of another natural flower, jasmine. Interestingly, the trained bees could not discriminate the synthetic sunflower scents from natural sunflower scent: three scent components were as good as the real thing. However, they could discriminate the synthetic scents from jasmine scent, as expected. This helped the team to choose a sunflower-mimic scent that could help the bees to establish a long-term memory (lasting at least 4 days), which could help them to learn to visit sunflowers. But were these sunflower-like sweet memories sufficient to entice the bees to prefer sunflowers over other flowers?

When honeybee foragers find food, they convey the distance and direction of the food source to their nestmates by performing elaborate waggle dances when they return to the hive. To test whether the bees that were fed synthetic sunflower scent-infused sugar solution would bias their foraging toward a sunflower crop, the team decoded the bees' waggle dances by filming inside the hive. The team found that those colonies that had been fed with sugar solution laced with sunflower-mimic scent advertised more and earlier for the sunflower plot than colonies that had been fed sugar solution with the scent of jasmine. Also, the former colonies collected more sunflower pollen and increased their foraging activity, with more hive residents visiting nearby sunflower patches and larger numbers of well-laden foragers returning home. The bees that were fed sugar solution with synthetic sunflower scent found the sunflower plots more alluring.

The team then used an additional test involving colour powder scattered on cotton at the hive entrance to mark the outgoing bees to reveal the foraging preferences of colonies raised on sunflower- or jasmine-mimicking sugar solutions. Collecting over 300 bees at the sunflower plots and on other nearby wild blooms, the team found that the bees trained with the sunflower-mimic scent visited sunflowers more often than other flowers near the hives. And when the team checked to find out whether the trained bees' fascination with sunflowers translated into improved sunflower seed yields, they were delighted to see that the flowers visited by the trained bees produced up to 57% more seed.

Floral scents learned inside bee hives can thus help increase pollination efficiency and crop yield. Notably, this method works without compromising the environment, unlike the alternatives that involve spraying pheromones on the flowers to attract honeybee foragers. Just by training the bees with relevant information about your crop, you can help them offer precise pollination services.

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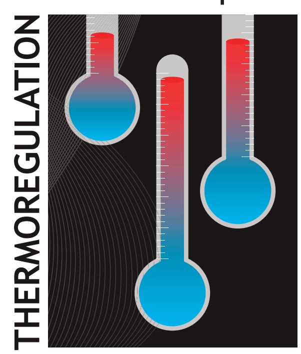
Panting zebra finches twitter to keep cool



To survive searing heat, desert birds have developed adaptations to stay cool; they sweat, vibrate their throat muscles to flutter air over the moist surface of their throat, or pant like a dog, although panting is the least efficient mechanism for remaining cool. Yet, songbirds, which make up over half of all bird species, are only able to resort to panting to keep their temperatures down, so how have they managed to colonise even the hottest regions on Earth when keeping cool is quite costly for then? One group of researchers from Australia and South Africa had noticed that zebra finches that live in arid Australian deserts also switch to singing when panting to prevent themselves from overheating. In addition, the scientists discovered that parents that twittered while panting when sitting on their eggs gave their young a better start in the hot environment. Anaïs Pessato from Deakin University, Australia, and her colleagues sought to understand whether singing while panting helped the birds cool off more quickly while also saving water in their dry habitat.

To solve this mystery, the team recorded when wild zebra finches began silent panting or singing while panting, and how long they continued, across temperatures ranging from 35°C up to 44°C. To investigate how quickly singing while panting had an effect on the birds' ability to regulate their temperature, the team compared the animals' water loss, energy use and body temperature during the run up to, and after, normal panting and the same period before and after the birds took up tweeting while panting. In addition, they investigated how the birds coped over longer periods by measuring the proportion of time spent panting, or singing while panting, at 35, 40, 42 and 44°C.

As soon as the birds began normal silent panting, the team noticed that they were using more water to cool down, although they were also, unexpectedly, using a lot less energy. However, when the birds began singing while panting, their water loss rates increased even more, going up by 4%. Because vocal panting increases the amount of water being evaporated, it allows the birds to cool faster, which allows them to survive at hotter temperatures, albeit at the cost of increased water loss. In fact, the birds that vocally panted for over half of the 14 min experiment had an almost 60% greater chance of enduring the hottest temperature, 44°C. Although water is a scarce resource in the desert, using it to avoid overheating in hot temperatures is worth it for these desert birds.

In addition, the team noticed that individuals always began panting silently at around the same body temperature and they also spent the same proportion of time panting silently and vocally. Each bird also tended to switch to singing after an initial period of regular panting that was specific to themselves, suggesting that zebra finches may be able to adjust when they implement this alternative form of panting in order to combat the rising temperatures they will likely encounter as a consequence of climate change.

Pessato and her team have found that singing while panting helps songbirds keep cool in the Australian desert, which allows them to survive sizzling temperatures up to 44°C. However, melodic panting comes at a cost: the birds have to consume more water, which is an expensive commodity for desert species. This newly discovered adaptation to cope with hot temperatures, and how it is different in birds within a population, will help us to understand how species may survive as climate change continues.

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