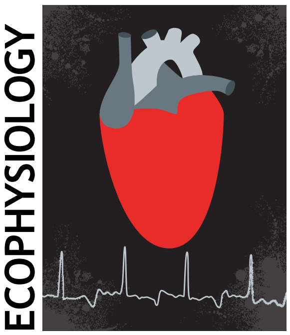
OUTSIDE JEB

Arctic fish aren't cool about hotter water



In the Canadian North Pole, there exists but one freshwater fish species: the Arctic char (*Salvelinus alpinus*). This keystone species is an indicator of ecosystem health, because it is highly sensitive to environmental changes. And, because many northerners depend on char for their survival, it also has great cultural importance. Arctic char are anadromous fish, meaning they migrate every year from the sea, up freshwater rivers, to spawn. Their epic journey is treacherous for several reasons, including the large temperature fluctuations – ranging from 0 to 21°C – that they face. Unfortunately, the future of the Arctic char is uncertain, as climate change is warming the Canadian Arctic three times faster than global averages. If the rivers the char encounter heat any further, it could doom the fish. Yet, little was known about the exact effects climate change might have on char battling to reach their spawning grounds. Given the scarcity of field stations and immense costs of research in the North Pole, a group of scientists has come up with an ingenious solution to overcome the challenges of working in such an inhospitable environment. Matthew Gilbert, from the University of British Columbia, Canada, along with biologists from three other Canadian institutions, decided to take the lab to the north and study how rapid warming could affect the char.

If it takes a village to raise a child, then it takes a community to build a lab in the middle of the Artic. With the help of the Ekaluktutiak Hunters and Trappers Organization and the Arctic Research Foundation, the team hauled a mobile shipping container to Cambridge Bay, Nunavut, and converted it into a self-sustaining laboratory, complete with state-of-the-art equipment, solar panels, wind turbines and a built-in toilet. They also brought along temperature-regulated tanks in which to test the fish. To see how climate change might impact the char, the team measured the fish's oxygen consumption and heart rate as they swam at different temperatures, by slowly heating the water in the tanks (2–5°C h^{-1}), from 4 to 25°C. In one set of tests, the team determined the fish's 'critical thermal maximum' (CT_{max}), the temperature at which they toppled over and could no longer swim or their heart beats became erratic (a sign of cardiac failure), because there was not enough oxygen for them to survive the heat. For the second set of tests, the team investigated whether hotter temperatures would reduce the fish's athletic performance, by measuring the amount of oxygen they consume when swimming full speed, known as the aerobic scope; the harder the fish can swim, the more physiologically fit they are.

The team found that the char's heart was working at its hardest at 16°C, whereas fitness – aerobic scope – was impaired to the point that the fish were incapable of fast swimming. This indicates that Arctic char are already performing at their peak levels during their annual migrations. However, when the temperature was raised past 21°C, the char began to tip over and their hearts began skipping beats. This was a very worrying finding, as it showed that any further increases in river temperature could cause debilitating respiratory and cardiac problems and prevent the wayfaring fish from reaching their spawning grounds.

Once again, a scientific study has pointed out the damaging effects of climate change on an ecologically important species. It reveals that the lopsided rate of heating skewed to the Canadian north could have devastating consequences for Arctic char in the not-too-distant future. Without any effective environmental policies by governments or fast adaptation by the char, the physiological impairments imposed by warming will probably harm the long-term survival of these fish.

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One bug on-the-go, please

If you saw your lunch step off your plate, you might lose your appetite completely. If you happen to be a neotropical bat, though, a walking meal might just be a good way to find your next meal. Some bats use echolocation to detect their food, and movement might signal to a bat where they can find a tasty insect instead of a leaf. One katydid species – a grasshopper relative found in Central America – often finds itself next on bat menus and walking is not the only form of movement that could give these potential victims away. Grasshoppers produce loud chirrups to attract mates with lavish movements that echolocating bat predators could tune into. But, some insects produce mating calls with remarkably little movement by quietly vibrating their abdomens. These whispers may have developed as a channel that eavesdropping bats are less

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likely to spy on. Nevertheless, the diet of one particular type of bat, *Micronycteris microtis*, is largely made up of these quiet katydids. A team of researchers at the Smithsonian Tropical Research Institute in Panama, with researchers from Dartmouth College and The Ohio State University, USA, set out to assess whether or not *M. microtis* are tuning in to the insects' movements or their discrete chirrups in order to locate the quiet prey.

The team designed a flight cage, which they allowed wild-caught bats to explore until they found dead katydids in specific locations around the cage. Next, they assessed the bats' attraction to different types of movement by presenting them with a choice between two toy crickets, which resembled the quiet katydids, that were still, 'walking' or 'whispering' for a mate. To mimic walking, the experimenters attached the toy to a fishing line and gently slid it 15 cm. To mimic the katydid's mating call, they recorded the wild insects and replayed the calls through a mini vibrating machine attached to the toy, so that it would buzz at the same frequencies. The experimenters then recorded which toy the bat approached with its sonar beam from multiple angles.

Every bat chose a walking toy over a still toy, suggesting that although the bats can identify prey that is not moving – like the dead bugs they initially retrieved – they are more attracted to movement. To verify that their results were not due to random chance, the experimenters then simulated how 5000 arbitrary bat choices would play out to compare against their observations and found that the bats' preference for moving toys, either walking or buzzing, was unlikely to be due to chance alone. The team also observed that the bats spent more time approaching moving prey, whether it was walking or buzzing. The longer time spent scanning with their sonar beam allows the bats to gather more information and build a better idea of where the prey is and where it is headed.

Although the bats might not be eavesdropping on the insects' private communication channel to locate a tasty snack, movement alone is sufficient to betray the softly spoken creatures, potentially sending the females unwittingly right into a searching bat's belly as they approach a whispered romantic serenade.

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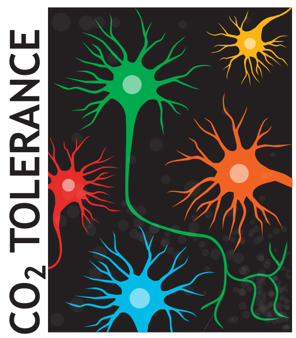
Fresh air is foul for naked mole-rats



Cancer-resistant, pain-tolerant and long-lived naked mole-rats (*Heterocephalus glaber*) are one of nature's most remarkably resilient creatures, earning them superhero status among animal researchers. Of course, all superheroes need a secret lair and for naked mole-rats, this lair is an underground burrow bustling with up to 300 other mole-rats. These crowded conditions often contain elevated levels of CO_2 (up to 2.3% versus 0.04% in the atmosphere), which would be difficult for many mammal species to endure. It was previously thought that naked mole-rats had forcibly adapted a tolerance to these high CO_2, or hypercapnic, conditions, but a recent study by a team of neuroscientists from the New York campus of The City University of New York, USA, has revealed that naked mole-rats don't just tolerate these harsh hypercapnic conditions – they are key to their survival.

In mammals, brain activity is partly regulated by gamma-aminobutyric acid (GABA) neurotransmitters, which stop the brain from becoming overstimulated and causing debilitating seizures. However, after analysing the naked mole-rat genome, the team of researchers was fascinated to find that this supposed super-species had a significant weakness in their ability to use GABA neurotransmitters to prevent seizures, thanks to a single mutation. Given mole-rats lack this important cog in the neurological machine, do their uniquely hypercapnic living arrangements help in shielding them from convulsions?

The researchers placed naked mole-rats in semi-natural laboratory colonies and watched their behaviour in response to different CO_2 concentrations. They also implanted the mole-rats with small radio transmitters, allowing them to track where the mole-rats spent their time within the colony. They quickly realised that the mole-rats preferred to spend time in chambers with the highest levels of CO_2, and when the CO_2 was reduced in one burrow chamber and increased in another, the mole-rats relocated their main huddling burrows to the new hypercapnic hot-spot.

This curious result spurred the team on to investigate the naked mole-rats' susceptibility to seizures outside of their burrow, so they constructed a test chamber that could recreate the environmental conditions of both underground and surface environments of the rodents' East African habitat. They also implanted some of these mole-rats with electroencephalogram electrodes, allowing them to measure the animals' brain activity and look for signs of seizures. When exposed to fresh outside air and a temperature of 42°C, mimicking above-ground conditions, 90% of the mole-rats showed signs of seizures, but none of these signs appeared when the fresh air was replaced with the higher-CO_2 burrow air. Instead of causing drowsiness and confusion, as would normally be expected in mammals, the high CO_2 conditions of the burrows actually helped to prevent neurological overstimulation and maintain a balanced brain.

It appears that on the surface (literally), the naked mole-rats' impaired neurotransmitters are a serious handicap to survival, but underground, they serve as an important energy-saving mechanism that allows the rodents to rely less on the costly chemical processes that regulate their brains and more on the freely available CO_2 in their burrows. The researchers propose that this niche adaptation is probably why naked mole-rats tend to avoid leaving and starting new burrows. Intriguingly, the same genetic mutation has also been identified in humans and is associated with febrile seizures, epilepsy and schizophrenia, leading the authors to consider the applications of this research for human healthcare. With these new insights into the role of this mutation in seizure-related conditions, perhaps hypercapnia holds potential for anticonvulsant treatment, because – as naked mole-rats can attest – a breath of fresh air can sometimes do more harm than good.

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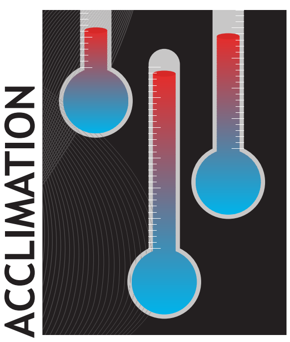
A radical cost to thermal flexibility



Understanding how animals cope with environmental change is a central goal of eco-physiology. One common strategy, known as acclimation, is the adjustment of an animal's physiological systems to suit the prevailing conditions. The benefits of acclimation are obvious, as this process allows an animal to maintain performance under a range of environmental conditions. The capacity for acclimation is not universal among animals, however, suggesting that this process may be costly and not always advantageous. However, these theoretical costs have been hard to identify in practice.

To understand these costs, Isabella Loughland and Frank Seebacher, at the University of Sydney, Australia, turned to the mosquitofish *Gambusia holbrooki*. These tiny tropical fish live in habitats that can change dramatically in temperature, sometimes subjecting the fish to stressfully cold conditions. First, the authors simply asked how well mosquitofish could acclimate to a 10°C temperature change. They raised more than 400 fish under either warm or cold conditions, then put each one in a swim flume (a 'fish treadmill') and measured how fast they could swim. Each fish was then exposed to the opposite (warm or cold) temperature, allowed to acclimate for a few weeks, and then their swimming performance was retested at the new temperature.

The capacity to acclimate varied dramatically among individuals. Some fish perfectly acclimated to the temperature change – the maximum swimming speed was the same at the two temperatures – while others could hardly adjust and thus performed much better at one temperature than the other. To understand why this variation exists, the authors first examined the possibility that acclimation ability negatively impacts maximum performance – the idea that a jack-of-all-trades is a master of none. For fish raised in warm water, the fastest swimmers were indeed those that had the lowest capacity to acclimate to cold conditions. Thus, the ability to adjust swimming physiology to changes in temperature comes at the expense of peak performance.

Next, the authors wanted to understand the mechanistic basis of this trade-off. They were particularly intrigued by the role of oxidative stress, which occurs when potentially damaging reactive oxygen species (sometimes called free radicals) form in the mitochondria as a by-product of energy production. Successful thermal acclimation depends on mitochondrial adjustments that often increase oxidative stress, and building cellular defence mechanisms to mitigate this stress is energetically costly. It is also well known that there are huge innate differences in the amount of oxidative stress experienced by individuals within a population. The authors thus reasoned that innately oxidatively stressed individuals might have less energy available for acclimation to changing temperatures. Consistent with this idea, mosquitofish with the smallest capacity for swim-performance acclimation also faced the highest levels of oxidative stress. Furthermore, this relationship between acclimation capacity and oxidative stress disappeared in mosquitofish that were experimentally administered the anti-oxidant drug *N*-acetylcysteine, suggesting a causal relationship between these variables.

Conventional wisdom states that the best way to cope with environmental change is to physiologically adjust in response. However, we now know that this is an energetically expensive solution that can limit maximum performance. To avoid this problem, mosquitofish seem to have evolved another solution to thrive in variable environments. These fish produce offspring that vary in the temperature at which they excel, ensuring that at least some individuals in the next generation will have the physiological tools required to do well in whatever the environment throws their way. And while this bet-hedging strategy may work well for mosquitofish, I'm sure glad my own parents took a different approach.

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