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OUTSIDE JEB

The early frog gets eaten

If a giant grizzly bear was to pop out from behind a bush and start approaching you, your first reaction would probably be to run immediately for your life in the hopes of reaching safety as quickly as possible. However, when a black-spotted pond frog sees an approaching predator, it actually waits for the attacker to move nearer before trying to flee. Why do some prey allow their predators to get closer, instead of getting the heck out of there? After all, the more distance between prey and a predator, the better for the prey, right? Not necessarily, according to recent research by Nozomi Nishiumi and Akira Mori. The two scientists from Kyoto University, Japan, studied the interactions between a predator (the Japanese striped snake) and its prey (black-spotted pond frog) to figure out what determines the victor in standoffs between the two.

Nishiumi and Mori went out into rice fields to watch snakes and frogs interact in the wild. In each of the encounters they saw, the frogs safely evaded the snakes. These snakes are known to regularly gobble up frogs, so there must have been a reason why these frogs kept gaining the upperhand. Nishiumi and Mori then brought some of the snakes and frogs into the lab, so that they could change the distance between the predator and its prey. They did this by putting the frogs on little leashes, which they used to nudge the animals in the 'right' direction. Once the snake and frog had noticed each other and were a certain distance apart, the scientists released the leash, allowing the snake and frog to duel unencumbered.

The researchers found that below a critical distance (which can be just 5 cm), whoever made the first move had the advantage. Beyond that distance, making the first move meant you were more likely to fail. In the snakes' case, that meant missing a meal, but in the frogs' case, that meant filling the snake's belly.

Below the critical distance, snakes can get the jump on frogs before they have a chance to react and frogs could hop out of danger before snakes could react, so the early bird gets the worm in these cases. However, jumping too early beyond the critical distance is risky for the frog for two reasons. The first is that if the frog moves first, it risks giving away its position to a snake that has not seen it yet. The second being that frogs cannot change direction midair, making them sitting (or jumping) ducks for a snake that can easily intercept them. On the other hand, if a snake strikes too early, it is also unable to change its direction mid-strike, so the frog is able to dodge the initial assault and escape before the snake has a chance to reload for the next attack.

People and perhaps other animals use this strategy too. Whether it is fencing, boxing or dueling, if you wait for your opponent to make the first move, you can gain the upper hand by reacting to the information they give you, informing your response. Like gunslingers in a wild west standoff, snakes and frogs wait motionless for their enemy to make the disadvantageous initial move. If this strategy did not work, our spaghetti western movies would be a lot less suspenseful…and much shorter.

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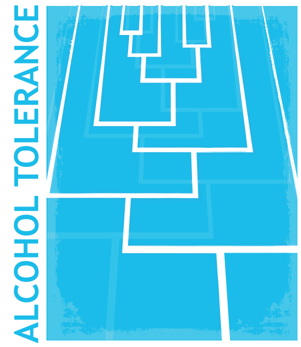
Natural alcohol intoxication demystified



Our intricate history with alcohol production and consumption dates to the Neolithic era. However, our evolutionary history with naturally produced alcohol, mainly ethanol, goes back even further, to our fruit- and nectar-eating ancestors, who used the odours of alcohols produced by natural fermentation to guide them during foraging. Approximately 10 million years ago, many humans developed a mutation that allowed alcohol-digesting enzymes, called alcohol dehydrogenases, to become 40 times more efficient at breaking down ethanol. This ability starts in our throats and continues in our stomachs. But have alcohol dehydrogenases evolved in the same manner and to the same degree in all fruit- and nectar-eating mammals? And do any of these animals get drunk?

To answer these questions, a team of researchers at University of Calgary in Canada, led by postdoctoral scholar, Mareike Janiak, looked at differences in the enzyme alcohol dehydrogenase IV – the main ethanol-digesting enzyme – across a variety of mammalian species. Using a public database of the genetic code (or genome) of different mammals, she found that the ability to break down ethanol varied among species and it is influenced by diet. Animals from the cetacean family, such as whales, porpoises and narwhals, along with carnivores, insectivores and herbivores appeared to have lost their alcohol dehydrogenase IV and the ability to break down ethanol entirely. The research team concluded that this loss was due to the animals' fruit- and nectar-free diets.

What struck the research group was that the ability to break down alcohol was also lost in herbivores, which was a surprise because plants produce their own alcohols, although they are very different from the ethanol produced by fruit. Through their analysis of the differences in mammal gut length and structure, Janiak and colleagues concluded that the smaller stomachs of herbivores allow food to pass into the intestine faster, where it is then digested by the gut bacteria. While the animals themselves may have lost the ability to break down alcohols, the authors suggest that perhaps gut bacteria compensate by digesting the alcohol on the animal's behalf. With this new discovery, the authors concluded that a combination of diet and gut size plays a role in the ability of mammals to break down alcohols.

But are there exceptions to the rule linking diet and gut length to the ability to digest alcohol? The authors found that koalas have set themselves apart, because they can digest ethanol, even though they do not eat fruit or nectar. In fact, they eat eucalyptus leaves, which are toxic to most mammals. Could their improved and efficient alcohol dehydrogenase IV serve other purposes and protect them from the poison in their diet? The team thinks so and urges researchers to explore the activity of this enzyme in koalas in the future.

Based on this research, though, how likely is it that mammals get drunk? Depending on the species, the authors think it is likely, but caution us not to attribute human characteristics, such as intoxication, to animal behaviour. If we want to have animal models for human diseases, such as alcoholism, Mareike Janiak and her group advise us to look at the physiology of individual species and how it connects to their evolution and ecology before labelling a certain behaviour as drunkenness. The authors suggest that we should not let our current understanding of our own physiology cloud how we see behaviour in other species without connecting it to its genetic history and habitat. There is no definitive manual of answers to every question of mammalian physiology; every species is, after all, unique.

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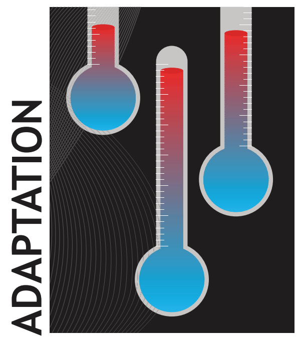
Shivering mice reveal their evolution



Living at high altitude pushes the physiology of the mammals that choose to live there to its limits, yet many species rise to the challenge. Some populations of deer mice can be found at 4300 m, where the extreme habitat requires them to cope with low levels of oxygen in the thin air, but keeping warm is an equal challenge for the small mammals. To overcome the cold, deer mice shiver to produce heat, which uses more of the scarce oxygen; and in highland natives, evolution has carefully tuned the cascade of steps that funnel oxygen to their muscles. Yet, their lowland relatives are not completely barred from these heights; given time, they can adjust their physiology to life in thin air, although highland natives are just better at coping with high altitudes. Whether generations of high-altitude evolution have shaped the highlander's oxygen transport cascade in unique ways, or whether they use the same old tricks as altitude-nurtured lowlanders, only better, is still unclear. Untangling the contribution of each – nature versus nurture – is not easy, but shivering mice are shedding some light on this old question.

Kevin Tate at McMaster University in Canada and his collaborators in the USA, set out to investigate exactly how low- and highland-native deer mice supply their bodies with oxygen when at high altitude. In the lab they kept groups of mice at different combinations of temperature (warm and cold) and oxygen (normal and low) allowing for an adjustment period in each condition, and then exposed the mice to frigid air (–5°C) with about half the normal oxygen content, simulating the harsh conditions at the peak. While the mice shivered to stay warm, the team measured their oxygen consumption to see whether highland natives (nature) had an edge over lowlanders that experienced an adjustment period at altitude (nurture).

When the mice were allowed to adjust to cold and low-oxygen conditions, both lowlanders and highlanders coped equally well in the simulated high altitude, using the same amount of oxygen. However, when the mice had adjusted to the warm low-oxygen conditions, the lowlanders struggled at altitude and were unable to match the high oxygen consumption of highlanders, whose high-altitude nature gave them an advantage not provided by the adjustment period alone. To answer why the deer mouse highlanders coped better, the team took a closer look at the different steps in the cascade that carries oxygen to their tissues.

The heartbeat of the lowlanders that had adjusted to the warm, low-oxygen condition slowed at altitude, which could hamper oxygen transport by the blood. However, the highlanders were unaffected by the heart-slowing effects of low oxygen and increased most steps in the oxygen transport cascade: their lungs extracted more oxygen from the air, their hearts beat stronger, their blood contained more oxygen and their muscles extracted more of it from the blood. While some of these steps in the oxygen transport cascade were naturally higher in the highlanders, others increased only after adjusting to the low-oxygen condition and in combination they boosted the highlander's performance.

Both low- and highland natives can benefit from a period of adjustment before ascending a peak. However, highlanders have evolved favourable traits along their oxygen transport cascade that provide an advantage at altitude and, more importantly, that can magnify the benefits of the adjustment period. As for the old question of nature versus nurture, it seems that highland-native deer mice cope with high altitude using a little of both, and

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perhaps a sprinkle of just toughing it out. However, a high-altitude lifestyle that relies on shivering for survival just doesn't sound that much fun and maybe when choosing their habitat the lowland mice had it right all along.

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Predators scare mountain goats kidless

Imagine you're home alone on a stormy night. This is usually fine, but you hear ominous footsteps outside, the window latch jiggles – your heart-rate quickens and your skin gets sweaty. Even though you know the windows are locked, you run to your car and speed off to safety (phew!). Just as you acted in this risky situation, a wild animal who senses a predator lurking nearby might also flee for the comfort of safety. But what happens if they can't easily escape? New research by Frédéric Dulude-de Broin and colleagues at the University of Laval, The Arctic University of Norway, and the Toronto Zoo wanted to address just this: what happens when animals live under constant threat of a predator attack?

Dulude-de Broin and colleagues focused their study on a species with little opportunity to run away from predators: mountain goats. Aptly named, mountain goats are often confined to mountain tops where their only option to evade predators, the likes of grizzly bears, cougars and wolves, is to scramble onto inaccessible cliffs and precarious ledges. This research group has been tracking a mountain goat population on Caw Ridge, Canada for 23 years. They have routinely trapped goats and marked them with colourful ear tags or collars so the researchers could identify the animals on daily visual scans with binoculars and spotting scopes during the spring and summer. Realising that they also observed predators while scrutinizing the goats, the team hypothesized that the goats would be more stressed in years when a large number of predators shared their slopes, just like you felt when responding to that potential home intruder. In this case, the physiological stress response can be a good thing, because it improves the likelihood of surviving a threat by increasing glucocorticoid hormones to free up stored energy and allow animals to mount the classic 'fight-or-flight' response. However, the stress response can also cause problems for animals in the long term, because it diverts energy away from routine body maintenance and reproduction.

Knowing this, Dulude-de Broin's team explored whether the goats were more stressed in years when there were high numbers of predators and whether chronic stress would be detrimental to mountain goat reproduction, potentially contributing to population decline. Reviewing their annual surveys, the team paid close attention to the females that had kids to measure how fertility varied each year. They also collected faeces from the goats that they trapped to measure the glucocorticoids in their systems in order to find out how stressed the animals were.

In years when the team observed large numbers of predators on Caw Ridge, the mountain goats were more stressed: for every 50 more predators spotted, the average glucocorticoid concentration increased by 53%. But what was the cost to the goats of living in a semi-permanent state of alarm? Well, normally, 50% of the female goat population produced a kid, but that percentage plummeted to 20% in the year following a period when a high number of predators prowled the peaks. The authors concluded that chronically high stress suppresses female fertility, likely delaying it to a less stressful season.

While mountain goats aren't at particular risk in Canada, these findings provide exciting insights into why the Caw Ridge herd has declined by 80% over the last decade. This team is the first to convincingly show that predator presence can suppress fertility in a wild, large-bodied mammal. Altogether, their work underscores that even just the risk of being eaten should not be underestimated when studying how predators shape prey populations.

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Voles light up when visiting their mate

Seeing a loved one, even virtually during this period of quarantine and social distancing, can make our faces light up with joy. But how does our brain light up when we see someone we care about? One area that may get excited is the nucleus accumbens, a pleasure-activated brain region critical for forming lifelong romantic relationships. However, finding monogamous mammals is challenging as it's the exception rather than the rule: only ∼10% of mammals commit to a single partner for life. Aside from humans, the prairie vole (*Microtus ochrogaster*) is another posterchild for committed relationships that can help us to explore how some brains are wired for devotion. As unattached prairie voles form lifelong pair bonds just as quickly in the lab as in the wild, Jennifer Scribner in the lab of Zoe Donaldson at the University of Colorado Boulder, USA, along with collaborators across the USA, recently explored how vole brains change as they're falling in love and have to choose between cuddling with their mate or a lurking Lothario.

First, Scribner's team needed a way to measure brain activity. To do so, they infused a virus into the nucleus accumbens region of the vole's brain that made cells shine brightly whenever calcium was released, which is a reliable proxy for neural activity. The researchers then introduced unattached voles into a chamber where they were free to mingle with two members of the opposite sex – but the date didn't provoke any changes in overall brain activity. Even after the team allowed two voles to bond for a week and then offered one a choice between an interloper and their new spouse, the nucleus accumbens did not light up differently in response to either their spouse or an interloper, even though the newlywed preferred to spend most of its time with its partner. While the nucleus accumbens is essential for forming a bond for life, the animals did not require a change in brain activity in that region to tie the knot.

Scribner then switched focus from the entire nucleus accumbens to single neurons in the structure to find out if any were tuned to their beloved. To do this, Scribner looked at where a vole was headed when choosing between its mate and a stranger and found two unique types of neuron: one that illuminated as a vole approached its partner and another that triggered as it neared a stranger. By counting individual cells, Scribner found increasing numbers of neurons active just before a vole approached its mate, far outnumbering the number of cells triggered en route to a stranger. Remarkably, the more time a vole spent mingling with its partner, the more partner-approach neurons appeared, suggesting that nucleus accumbens cells may become specialized for its mate to promote monogamous interactions.

Now, during the COVID-19 pandemic, more than ever, we appreciate how important social bonds and physical contact are. The findings by Scribner and colleagues in voles suggest that our brains and those of other monogamous mammals may be wired to adapt when falling in love.

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