OUTSIDE JEB

Temperature spikes snuff out Earth's biodiversity

Six out of the last 10 years hold records for being the hottest years measured on earth. We are racing to understand how a temperamental climate will ultimately affect the environment, humans and Earth's rich biodiversity as climate change breathes down our necks. But what part of a changing climate (floods? excess heat? drought?) is the most threatening for species? And can we harness this knowledge to predict the fate of species in the future? Cristian Román-Palacios and John Wiens from the University of Arizona, USA, brought together data from 538 species to take on these weighty questions in a two-part climate change study.

The duo first identified which component of climate change was causing species to disappear and go extinct. They combed through species surveys conducted around the world, taking data from any that measured whether a species (plants and animals) was recorded at a site over at least a 10 year time stretch, allowing them to see which species disappeared over time. They then asked what changes in climate best predicted whether species extinction happened or not. They found that places with the hottest temperatures had more species go extinct – not the hottest average temperature, but the highest temperature peaks. These temperature peaks were three times hotter in places with a species extinction than in places without an extinction. While other aspects of climate change were also related to species disappearances, temperature spikes were the most important driver.

Equipped with that knowledge, Román-Palacios and Wiens turned their gaze to the future. They used climate models to estimate whether a species would go extinct in its habitat over the next 50 years given the temperature peaks they would experience. They did this under two climate scenarios: one where we curb our greenhouse gas emissions (the 'best-case scenario') and one where greenhouse gas emissions continue to skyrocket unchecked (the 'worst-case scenario'). Depressingly, 78% (best case) to 86% (worst-case) of the 538 species will go extinct by 2070 if they stay in their present-day habitats. But plants and animals aren't fettered to one place. Species can persist by either moving and tracking their habitat across a changing landscape (yes, even plants can do this) or adapting to the new climate. The team used the historical survey data to estimate how far each species could move and their ability to adapt and survive in different future climates. When the researchers factored in species movement, 57–70% would still go extinct; however, when they considered their ability to adapt, the percentage extinctions fell to 35–42%.

Román-Palacios and Wiens' work truly advances our understanding of climate change in two important ways. First, they show that we should pay attention to heat peaks, not just rising temperature averages. Second, they show that a species' ability to adapt to climate change may be more important for their survival than their ability to move. The pair's findings promisingly show that if we stick to the Paris Agreement's effort to limit the temperature increase to 1.5°C, we should see the best-case scenario play out in real life over the next 50 years.

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Román-Palacios, C. and Wiens, J. (2020). Recent responses to climate change reveal the drivers of species extinction and survival. *Proc. Natl. Acad. Sci. USA* **117**, 4211–4217. doi:10.1073/pnas.1913007117

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Flying lizards plan ahead to avoid clutter

Packed with tall trees and vine-like lianas, the tropical forests of South and Southeast Asia present a maze for vertebrate flyers. In these forests, a wealth of species – frogs, lizards, snakes, squirrels and colugos – flit about on makeshift wings, trading potential energy of height for the benefit of gliding flight. But without the muscle-powered flapping ability of birds and bats, gliders possess far fewer means for control, making navigating a cluttered forest a potentially perilous endeavor. How do gliders avoid arboreal obstacles while gliding and landing safely? Pranav Khandelwal and Ty Hedrick of the University of North Carolina, USA, studied the flying lizard *Draco* in an Indian rainforest to see how visual information is integrated with mechanics in real-world gliding.

Most quantitative studies of gliding have been done in experimental conditions, but natural gliding may be different when an animal chooses to glide for its own reasons. Khandelwal and his field assistant traveled to the Agumbe Rainforest Research Station in the Western Ghats of India, where they arranged a rig of GoPro cameras to record a population of flying lizards going about the business of gliding in the wild. The lizards glided most often in the mornings, motivated by territoriality and mate pursuit, and the highly portable setup enabled the team to move swiftly to record the glides of multiple flying lizards.

To maneuver around obstacles in a cluttered natural environment, a flying

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animal must create directional forces, or it will plod along its forward path, subservient to Newton's third law. Birds, for example, turn by creating asymmetric forces on the wings by altering their flapping kinematics. It is unclear how flying lizards maneuver, but they must create forces with a different set of tools; mainly, a pair of non-flappable wings made of long ribs embedded in patagial skin and a fixed energy budget set by their initial takeoff height. Khandelwal and Hedrick hypothesized that lizards use these tools guided by their visual view of the world. For example, a lizard might plan its path from the start, choosing a route that requires minimal maneuvering when faced with a forest of obstacles. Alternatively, when gliding they could react immediately to an obstacle as it looms into view, although that could be energetically costly. Finally, the lizards might use some form of vision-based planning for braking when landing, lest they barrel headfirst into their landing site, receiving a deathly smack.

To test these ideas, the researchers used stereo recordings to extract the 3D paths, velocities and accelerations of the lizards and the exact locations of the trees in their visual environment. By mapping the locations of all trees in the area, they could calculate all possible combinations of takeoff and landing for comparison with the trees that the lizards actually chose. The lizards appeared to use their knowledge of the lay of the land prior to taking off as they navigated each flight. They chose to jump in directions with less surrounding clutter, producing glides with less maneuvering in the air and, in turn, they wasted less energy. Surprisingly, lizards did not take off directly toward their target tree, leaping instead 10–41 deg off the straight-line path. In the air, flying lizards minimized maneuvering with respect to both the obstacle and the target tree, evidence that they employ a vision-based steering model.

The data also provide insight into the lizard's flight biomechanics: modeling revealed that they maneuvered around trees by rolling a maximum of 21 deg, a side tilt that provides lateral force but reduces support for body weight by ∼7%. When landing, the lizards used a visual strategy known as 'tau-dot', where they gradually decelerate as they approach a target, a way to reduce impact forces as they land while maintaining enough lift to stay aloft. Overall, flying lizards appear to use visual input to guide all aspects of flight, from takeoff to landing, helping to avoid costly aerial collisions and surviving to climb another tree.

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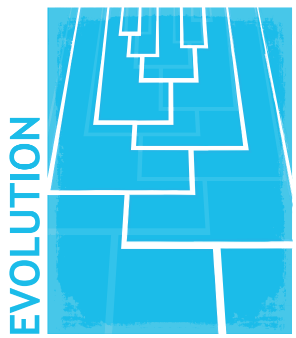
No oxygen? No mitochondria? No problem



Over two billion years ago, a single-celled organism engulfed a bacterium that could use oxygen to produce energy. The bacterium was protected by the bigger cell, while the bigger cell harnessed the bacterium's energy-producing superpower. Those oxygen-consuming bacteria are now called mitochondria and their DNA is so important that it is now encoded in the larger cell's nucleus. This mutually beneficial relationship is the hallmark of all eukaryotic, multicellular organisms. Or so we thought.

Recent work from Dayana Yahalomi from Tel Aviv University, Israel, and a group of international researchers from the USA, France and Canada, has revealed that a cnidarian (a relative of jellyfishes) called *Henneguya salminicola*, which also parasitizes salmon, has completely lost its mitochondrial genome. In other words, this organism is lacking the very machinery that scientists believed is part of what makes a eukaryote … well, a eukaryote: the ability to carry out aerobic cellular respiration.

The project began with Yahalomi and colleagues deciding to look for the genes that make mitochondria and mitochondrial proteins in *H. salminicola* spores. However, when they sequenced the cnidarian's genome, they couldn't find any of the essential genes that they had expected to find. So, to make sure that their experiments and analysis were working correctly, the researchers tested their techniques on a relative of *H. salminicola*, another parasite called *Myxobolus squamalis*, which is known to have mitochondria and was expected to have the mitochondria-coding genes in its DNA. Sure enough, after isolating and sequencing *M. squamalis* DNA, they found that the parasite had mitochondria-coding genes, which led them to the mind-boggling conclusion that the parasitic *H. salminicola* has done away with its mitochondria. However, when the authors used electron microscopy, they found that *H. salminicola* possess small cellular components that resemble mitochondria, called mitochondria-related organelles.

Intrigued by *H. salminicola*'s alternative to genuine mitochondria, the team took a closer look at the organelles using microscopes. They found that the cnidarian's mitochondria-related organelles did not resemble the organelles found in anaerobic, single-celled organisms. Instead, they looked a lot like genuine mitochondria, including having the hallmark internal folded membranes, called cristae. In addition, the team found that the organelles possess proteins that are usually lacking in these organelles in other organisms. By delving more deeply into the DNA of this cnidarian, the researchers also found incomplete mitochondria genes, called pseudogenes. Combining these observations, the authors concluded that *H. salminicola* lost their mitochondria relatively recently.

But why have *H. salminicola* lost their mitochondria and how are they able to 'make' energy without the essential structures? Yahalomi and her group suspect that the 'why' might have something to do with the cnidarian's lifestyle, which includes two periods when they reside within host organisms and are likely to experience extended periods without oxygen. The team suspects that instead of wasting energy-building mitochondria when no oxygen is available to fuel them, the parasite has simply done away with the structures.

Answering the question of how *H. salminicola* makes energy will take longer, because it is not possible to grow these animals in the laboratory. However, it is clear to Yahalomi and colleagues that losing their mitochondrial DNA and the ability to perform aerobic respiration has not hindered *H. salminicola* in any way, as they appear to thrive in marine, freshwater and terrestrial environments, which goes to show that, from the point of evolution, less can be more!

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Lizard athletes have a home-field advantage

Home-field advantage is a sports phenomenon where the home team tends to have an advantage over the visiting team. The causes of home-field advantage are debated, but range from physiological adaptions of players to the home-field climate, to psychological and behavioral effects of supportive fans, to greater familiarity with features of the home field. According to a recent study led by Nathalie Feiner, a postdoctoral fellow at Lund University in Sweden, lizard athletes also have a home-field advantage. The study investigated why lizards of the same species have different shapes in different environments and whether this affects their athletic performance in their environments. In a process known as phenotypic plasticity, individuals of the same animal species frequently develop different shapes and physiology when exposed to different environments or experiences, which includes why people who frequently lift weights get bigger muscles. Feiner sought to find out whether phenotypic plasticity is completely responsible for the lizards' home-field advantage.

Feiner and colleagues raised two species of anole lizard hatchlings (green and brown anoles), from the same sets of parents, in two different environments: one with narrow platforms that mimic thin branches and one with broad platforms that simulate the ground. After 5 months of growing up in their different homes, the lizards were tested to see how well they ran on narrow and wide platforms.

It turned out that the anoles that had been raised scampering along broad boards were better runners when tested on these than the anoles that had been raised in an environment where the boards were thin. The lizards that had a home-field advantage performed better in situations where they had significant prior experience. What caused this advantage, though?

After measuring the anoles' performance, Feiner and colleagues used CT scanners to create 3D X-ray images of the lizards to study their build and compare how they differed between the two environments. Both species had different shoulder and hip shapes depending on which environment they had grown up in, suggesting that they had adapted to their homes. The green anoles raised on the broad boards also had longer limbs, which may make running more efficient on wide surfaces. But, do these differences in the lizards' build explain the differences in their performance?

Not really. Using mathematical models, Feiner and colleagues found that the shape differences only helped a tiny bit. Something else was causing the anoles raised on wide platforms to perform better on their familiar surface, but what could that be? It turns out to be the same thing that allows trapeze artists to walk across tightropes, while the rest of us would fall after the first step; behavioral changes. By practicing for years, trapeze artists have learned the best methods for moving across tightropes, which most of us will never master. Similarly, Feiner suggests that the lizards that grew up on the wider platforms have developed better patterns of movement for confidently negotiating broad platforms through experience. Lizards that grew up on narrow platforms, however, have not learned the best methods, so they do not perform as well.

The home-field advantage is a real phenomenon. In lizards, Feiner and colleagues have shown that it is caused by changes in behavior rather than any physical changes. Anoles, like people, perform better when they feel comfortable and at home. So, next time you are at your favorite stadium, remember that when you cheer on the home team, you are actually helping them win!

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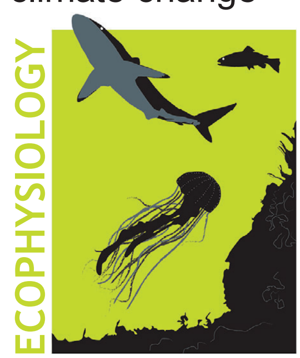
Full bellies stave off climate change



Climate change is bad, we know that much. But we've also learned that life can cope with change. Many fish can tweak their physiology to deal with warmer, less-oxygenated waters, or to combat the adverse effects of a more acidic ocean – but at what cost? A fish that must work harder to extract oxygen from the water, or to remove acid from its tissues, will have less energy available for the more important things in life, such as chasing prey, finding mates and having sex. Perhaps it's surprising then, that we often study the effects of climate change on well-fed fish in the lab, where energy limitations, such as those that occur in the wild, do not exist.

With this in mind, Louise Cominassi at the University of Hamburg, Germany, and her international team of collaborators, set out to test whether feeding changes how fish are affected by climate change. For a year, they held European seabass in different combinations of the two most dire outcomes of climate change: high temperatures (20°C) and elevated CO_2 to simulate ocean acidification. Then, they put half of the fish on a strict diet and let the other half feast to their stomach's content, observing the growth of both groups over several weeks.

Not surprisingly, the fish that feasted grew faster than those on a restricted diet. So far, so good. Also, seabass like warm water, which accelerated the growth of both groups. But, here's the kicker: when these fast-growing, warm-water-loving seabass were also exposed to ocean acidification, growth of the well-fed fish slowed dramatically and those on a restricted diet barely grew at all. This fits well with the idea that living in acidified water is costly and, when on a budget, energy spent on fighting acidity is not available for growth. In fact, increasing the seabass' energy budget with plenty of food improved their growth in acidic water over that of fish on a restricted diet, supporting the idea that a shortage of energy was limiting their growth.

So why was growth of the well-fed, warm-water seabass affected by ocean acidification? To answer this question, Cominassi had a closer look at how these animals used the food that they were provided with. When the fish in warm water were offered a feast, those in the acidified water chose to eat less, leading to slower growth. What had ruined their appetite? Cominassi found that the fish's digestion was slower in the acidic water and, generally, those with full stomachs are less peckish. The little food that they did eat, however, was also used less efficiently, meaning less growth per bite, perhaps as a result of the slowing of important digestive enzymes. In the end, when dealing with climate change, feeding changed everything.

A major effort is underway to get a grasp on how climate change will affect individual fish species and ultimately impact our ocean ecosystems. However, the waters are muddied by the interacting effects of rising temperature, CO_2 and acidity levels, in addition to the falling water oxygen levels due to the increase in temperature. Surely, some animals can cope with these changes, but whether they can afford to do so is a different question. Energy is a limited resource for any organism and future fish will face the challenge of how to spend that budget to cope with climate change and still have enough left in the tank to go on with their lives. Therefore, studying the effects of climate change on well-fed fish in the lab may underestimate the severity of the problem. As with many other problems in life, dealing with climate change is easiest on a full belly.

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