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OUTSIDE JEB

Light-exposed moths can't find the flame

It's a common literary trope, but moths really are attracted to the flame. And that usually goes poorly for the insect, with death a common outcome – either by burning or by predators that use the light source as a buffet table. As humans occupy an increasing share of the planet, we are lighting up ever more portions of the night sky, which may affect nocturnal species like moths that are attracted to light. Swiss researchers Florian Altermatt and Dieter Ebert, based in Zürich and Basel, thought that moths may be able to evolve changes in their behaviour to resist anthropological changes in light conditions. As artificial light can be so dangerous to moths, they hypothesized that moths from areas with bright lights at night might be less attracted to lethal light than moths from dark areas as a result of evolutionary changes in their behaviour.

To test this, the researchers set out collecting young caterpillars of the ermine moth *Yponomeuta cagnagella* from cities and towns in Switzerland and France that varied in their night-time light levels. They reared these caterpillars to adult moths in a laboratory where all the animals received the same light levels. They then set up an indoor flight cage with a light trap at one end, left the moths overnight to flutter to the light, and counted how many were collected by the trap in the morning to test how attracted to the light the moths were.

The duo found that female moths were much less likely to be trapped than male moths and that, in agreement with their hypothesis, moths from bright areas were much less likely to be trapped than moths from dark areas. This suggests that the moths from bright areas have undergone selection to avoid lethal bright city lights. As the researchers had collected the moths as young caterpillars, they think this response must be a genetic difference, rather than a difference in light exposure during development.

Altermatt and Ebert suggest this might be good news for moths and other nocturnal insects. If insects can evolve reduced attraction to light, perhaps light pollution won't be as dangerous for these species. But they caution that their results also show that as light pollution has caused systematic changes in animal behaviour to evolve, it may take several generations before moths see the benefits of efforts to reduce light pollution. In addition, it is unclear how the reduction in attraction of the moths to light might impact the insect's ecology. Our light pollution has taught the moth to avoid the flame, but perhaps at a cost.

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Monkeys alter tool use for different tasks

It is well documented that in the wild, some species of monkey use stones as tools to gain access to the tasty insides of nuts and fruits. It seems clever, but is there more to the movements that underpin this behaviour than meets the eye?

To investigate, a collaborative team of researchers, led by Madhur Mangalam from the University of Georgia, USA, studied the biomechanics of strikes made by capuchin monkeys when using stones to crack open nuts. They wanted to know exactly how the monkeys use these stone hammers. Do they alter their methods for different nut types? And what happens once the nut has cracked? Not only is this interesting in itself, but studying the way non-human primates use tools could help to inform scientists about how ancient humans may have used them.

The team studied seven wild bearded capuchin monkeys (*Sapajus libidinosus*) at a natural study site in north-east Brazil. They provided the monkeys with stones of known mass, and two types of locally available nut (tucum and piaçava), which differ significantly from each other. Tucum nuts are composed of two layers: a soft outer hull and a harder inner shell housing a single soft edible kernel. The tougher piaçava nuts have an outer hull and a very resistant inner shell, surrounding several kernels each within their own seed compartment. Knowing that grazing cattle often dislodge the outer hull of piaçava nuts before the monkeys get to them, the researchers first stripped off the hulls before giving them to the capuchins. By filming each of the monkeys as they used a stone to crack a nut, the team could measure how high the monkeys raised the stone before striking the nut and the speed of the stone at the moment of impact. They then compared these values between strikes, noting whether the nut had cracked.

When hitting the tucum nuts, the monkeys altered their technique based on the condition of the nut. They began by striking it with a moderate force and, if the nut failed to crack, they increased the height and velocity of the stone, hitting the nut harder. If the soft outer hull had

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partly cracked, they decreased the height and velocity of the stone for the next strike, probably because it requires less force to break a partially cracked nut. Once the hull had been breached completely, reaching the hard inner shell, the monkeys hit the nut harder by increasing the speed of the stone at impact. And once this shell had begun to crack, they again reduced the force of their strike, presumably to reduce damage to the nutritious kernel within. In contrast, when striking the piaçava nuts, the capuchins simply hit them repeatedly with the stone as hard as they could until the nut cracked.

Although hitting a nut more times with a smaller force is the safest way to extract the kernel without smashing it, the presence of seed compartment structures in the piaçava probably disrupts energy transferred during a strike. Maybe this is something each monkey has learnt by trial and error, discovering that the best way of cracking these nuts is to hit them with maximum force. With each crack in a nut, its material properties change and so the requirements of the next strike alter. These results show that capuchin monkeys can adjust the biomechanics of tool use in response to quickly changing tasks such as nut kernel extraction.

By comparing morphological features between today's primates and ancient humans, this type of research can help suggest how tool use by our ancestors may have evolved until we eventually began shaping stones to use as weapons and in construction. Perhaps the key to understanding how human civilisation began is locked within the nut-cracking abilities of our primate pals.

10.1242/jeb.130187

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Bold fish, shy fish: it's all in the metabolism

To flee, or not to flee? The answer to that question may lie in physiology. Whether an animal adopts an active or passive defense strategy when faced with danger is related to its behavioral phenotype, or 'personality'. For example, bold individuals typically behave actively and will fight off or flee from predators, whereas shy individuals try to avoid detection in the first place by remaining perfectly still. The fact that such divergent defense strategies persist within populations suggests that both confer a fitness advantage, but what are the physiological traits driving these personalities that selection acts upon? Given that active and passive defense strategies require markedly different energetic costs, Weiqun Lu and his student Emmanuel Rupia from Shanghai Ocean University, China, teamed up with visiting scientists Sandra Binning and Dominique Roche from University of Neuchâtel, Switzerland, to test whether different metabolic profiles underscore bold and shy behavioral phenotypes.

The team began by rigorously testing the behavior of olive flounders to figure out which individuals were bold (e.g. quickly investigated a novel food object and repeatedly tried to escape from a net), and which were shy (e.g. didn't swim away when touched and were slow to respond to food). Next, the team measured oxygen consumption rates during a series of tests to determine each fish's metabolic profile. First, they continuously chased and air-exposed a fish for several minutes and then measured the exhausted fish's oxygen consumption to determine its maximum metabolic rate (MR). The scientists then left the fish undisturbed for 24 h while measuring their oxygen consumption to find the animal's lowest metabolic rate while at rest (standard MR). The difference between maximum and standard MR is known as the aerobic scope (capacity for oxygen-fueled metabolism) and individuals with higher aerobic scopes can have more active lifestyles. At the end of the 24 h rest period, one member of the team startled the fish by waving their hand over the tank to determine the fish's MR during acute stress.

The team found that bold and shy flounders have very different metabolic profiles. Compared with bold fish, shy individuals had lower standard and maximum MRs as well as lower aerobic scopes, which is consistent with a passive and less energetically expensive behavioral phenotype. The fish's metabolic responses to an acute stress were also reversed; bold fish quickly increased their MR in response to the unexpected hand movement and this spike in oxygen consumption would help them to fight off or swim away from the supposed threat. Conversely, shy fish rapidly decreased their MR as the hand waved threateningly above them; this drop in oxygen consumption would enable them to remain perfectly still and undetected until the danger had passed. The strong correlations between metabolic profiles, stress-induced changes in MR, and behavioral phenotype are a clear indication that physiology can dictate personality.

10.1242/jeb.130195

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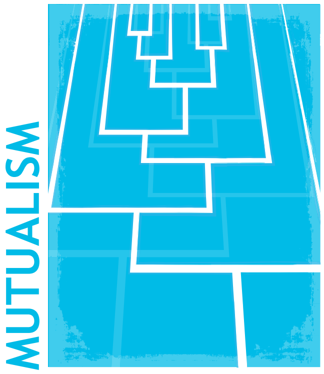
The bridge from naughty to nice



If we believe the popular press, animals are little more than glorified buses for the multitude of microbes that live on and within us. These microbes coordinate our diets, our immunity, our mate choice and much else. Given these claims, it is easy to believe that our microbial passengers are uniformly beneficial, that they toil for our betterment. But this is not quite the reality. Our bacteria instead run the gamut of utility, sometimes beneficial, sometimes harmful, but most often entirely indifferent to our welfare. And to make it more interesting, these functions can change through time and context. But how do these roles evolve? And can commensal bacteria, which neither hurt nor harm us, be pushed to become mutualists that help their hosts?

To address these questions, Kayla King from the University of Oxford, UK, and her colleagues from the Universities of York and Liverpool focused their experimental attention on the microbiota of the soil nematode, *Caenorhabditis elegans*. These nematodes eat bacteria, but not everything they eat is food. Instead, some bacterial species like *Enterococcus faecalis* take up residence in the nematode gut as mildly harmful commensals, while others like *Staphylococcus aureus* are highly pathogenic. On its own, *E. faecalis* kills less than 1% of worms, while *S. aureus* wipes out more than half of the worms that eat it. More interesting, when worms are colonized with *E. faecalis* before infection with *S. aureus*, mortality drops markedly. So far so good: by providing protection to the worms, the role of *E. faecalis* transitions from minor pest to major partner. But how does this protection arise and can it improve?

The team experimentally evolved *E. faecalis* within worms under two different regimes. In the first, *E. faecalis* was passaged serially through worms for 15 transfer cycles, while in the second *E. faecalis* was forced to share its space with *S. aureus*. This small change led to striking differences. Whereas *E. faecalis* in the first regime became marginally more aggressive towards the worms, *E. faecalis* in the second regime evolved into highly effective mutualists that fully suppressed *S. aureus* virulence. Instead of killing 20% of worms when grown with *E. faecalis* from the first regime, *S. aureus* grown with *E. faecalis* from the second regime killed almost none.

One possible conclusion from this study is that *E. faecalis* evolved to benefit worms because of some positive feedback between these two organisms. The bacteria helped the worms, and the worms helped the bacteria. However, the actual conclusion drawn by the authors is more interesting and, probably, more general. To suppress *S. aureus* virulence, *E. faecalis* simply evolved the ability to secrete toxins that killed its competitors. In other words, *E. faecalis* didn't evolve to become mutualistic because it cared about worms or gained something in return, but rather because it cared about its own welfare. By killing *S. aureus*, *E. faecalis* benefited directly, while any positive consequence of this for the worms was only a fortuitous by-product of inter-bacterial warfare. Fortunately for the worms, they were as indifferent to *E. faecalis* toxins as *E. faecalis* was to the worms.

What is particularly neat about this work is how rapidly the role of *E. faecalis* evolved. But do the bacteria in our guts have a similar capacity for change? At present, this isn't entirely clear. While the bacteria in our microbiome are extremely numerous, subject to huge mutational and ecological diversity, they are also rarely on their own. *Enterococcus faecalis* in the present work faced a static challenger. If *S. aureus* could co-evolve with *E. faecalis*, or if the competitive environment of the laboratory worm gut was more reflective of the wild-type gut, would the results have been the same? I certainly hope that the next step in this study is to find out.

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