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OUTSIDE JEB

Seahorse divorce? Of course, of course!

Long-distance, monogamous relationships are hard, regardless of how much you love your partner. Without seeing and interacting with them regularly, you may drift apart and fall for someone else. However, frequent and open communication can help keep the spark alive, even over a distance; I FaceTime my partner every night when I'm in the field. But other monogamous animals do not have cell phones or laptops; they cannot text or Zoom about their day or complain about their terrible co-workers. Without these tools, how robust are their relationships over periods of separation?

To figure this out, a team of scientists from the Chinese Ministry of Agriculture and the Chinese Academy of Fishery Sciences, led by Tingting Lin, looked at lined seahorse relationships. Seahorses form monogamous pairs and mate with their partners time after time, with the males tasked with carrying around the fertilized eggs. To strengthen their bonds, paired seahorses don their finest colors and participate in synchronized swimming every day in an act known as a daily greeting, which makes my day-to-day efforts of FaceTiming my partner seem rather poor. When seahorse pairs were kept together in the lab and were able to perform their daily ritual, Lin and the team found that females usually remained faithful to their partners, even in the presence of the most attractive male seahorses, illustrating their strong bonds. However, if their male partners were injured or sick, some females sought out new partners that were healthier and better able to care for their eggs, even while their current mate was pregnant. Apparently, 'in sickness and in health' means nothing to seahorses.

After they established that seahorse relationships tend to be strong, the team tested whether they are resilient enough to endure a break. First, Lin and the team allowed male and female seahorses to court each other, pair and mate. Then, they separated the partners for at least 12 days and introduced new males to the females, whereupon the females lost their faithfulness and mated with the new males. But it did not stop there. The scientists then separated the new male partners from the females for at least 4 days and then presented the female seahorses with the choice of either their former partner, the recent partner or a new mystery seahorse all at the same time, to see which male the females would select.

But instead of preferring one of her previous partners, the female seahorse selected her new partner at random. After only a few days of separation, females showed no preference for previous partners over a random male seahorse. Even a short period of separation seems to be long enough for female seahorses to either completely forget their previous partners and the offspring they shared, or drift apart, like, well, a seahorse without seagrass to hold onto.

While seahorse divorce may seem like a sad subject, it may have its benefits. If monogamous animals pair with poor quality mates, their bond, once formed, may be too strong for them to realize that their partner isn't appropriate, preventing them from seeking out better quality mates. Periods of separation may allow these animals to reassess their partners, giving them an opportunity to get out of bad relationships. So, if you do not want to end up like divorced seahorses, make sure to communicate well and/or dance in circles wearing your fanciest attire every morning.

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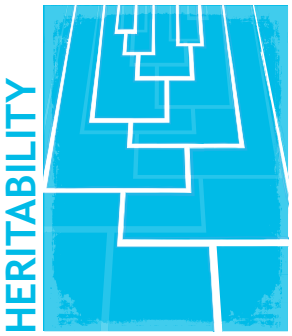
Gut bacteria are an 'outside' and an 'inside' job



The gut of virtually every creature is packed with an army of microscopic helpers, mostly bacteria but also viruses and fungi. These microscopic lifeforms – which together constitute the gut microbiome – help with food digestion and with training the immune system of the creatures they inhabit. Given the fundamental role of these microorganisms in life support, scientists have been curious to understand how much of the variability in the composition and abundance of gut microbes comes from genetic differences of their inhabitants as opposed to environmental factors. Although work in humans has suggested that variability in gut flora is mostly influenced by our diet and lifestyle rather than our genetic makeup, an international group of scientists led by Laura Grieneisen and Ran Blekhman from the University of Minnesota, USA, suspected that the story could be more complex, and wondered whether one of our close relatives, baboons, could help us to discover whether our bacterial lodgers are kept within the family.

Grieneisen and her colleagues collected over 16,000 fecal samples from 585 wild baboons over 14 years – which is a significant portion of the lifespans of most

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baboons – in Kenya's Amboseli National Park, to examine changes in their gut microbes. In addition, the team also knew the family relationships of each individual in each troop, their diet and their age when each fecal sample was collected, as well as how the local conditions were affecting them, so they could rule out similarities that were caused by the conditions that the animals were living in and identify true similarities owing to the baboons' shared genes.

The team's extensive work and dedication paid off: they found that the baboons inherited the majority of their gut microbiome communities (97%) from their predecessors. In addition, the researchers found that the similarity between family members' gut microbiomes were closer during the dry season than during the wet season. This was probably because baboons consume a greater range of foods in the wet season when fruits, flowers and greens become abundant. How old each individual was also had an impact on how similar their gut microbiomes were, as they became increasingly more alike as the baboons aged, possibly because of changes in their dietary tastes over the course of the animal's life.

Interestingly, the researchers found that the number of fecal samples available for each individual baboon – on average they collected 28 fecal samples per animal, rather than depending on one or two samples taken a single point during an animal's life – was an important factor that allowed them to reveal how heritable gut microbiomes are. When they collapsed their full dataset to only one fecal sample per individual baboon, to simulate the approach that scientists usually take, it incorrectly suggested that less than 5% of gut microbes were inherited. This goes to show how crucial it was to track the baboons over almost all of their entire lives, to bring out the true similarities between the individuals' gut microbiomes.

Grieneisen's study provides novel evidence about the role played by the genetics of the host animal in the regulation of their gut microbiome, challenging the concept that host genes are only bit players. These findings pave the way for novel and exciting research to try to identify the genetic code behind healthy human gut bacteria, which could help to improve the quality of our lives.

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Shark bellies flow like Tesla valves

Sharks, skates and rays are known for their unique intestines, which are spiral shaped and located behind the stomach. This unusual spiral intestine naturally slows digestion and expands the intestine's surface area to improve nutrient absorption. The inside of the spiral intestine can vary greatly in shape, but had previously only been studied through two-dimensional illustrations, losing the complexity of the structure's three-dimensional shape and preventing researchers from fully understanding the role that these designs may play in digestion. Samantha Leigh from California State University Dominguez Hills, USA, and colleagues from the University of Washington, Biomark Inc., and the University of California Irvine, USA, wanted to compare the three-dimensional (3D) shape and function of the spiral intestines from 22 shark families to better understand whether corkscrew shaped intestines could predict a shark's diet type and how food moves through these unconventional intestines.

After obtaining museum specimens of species ranging from the small and rare combtooth dogfish (*Centroscyllium nigrum*) to the large and charismatic smooth hammerhead (*Sphyrna zygaena*), the team removed the sharks' spiral intestines and CT scanned them at Friday Harbor Laboratories, USA, and the University of California Irvine. Analysing the structures of the intestines in 3D, the team realised that the digestive tracts came in four distinct forms: column-shaped, funnel-shaped toward the end, funnel-shaped toward the beginning and scroll-shaped. The team then selected four sharks, each representing one of the four intestine designs, and pushed three different solutions, ranging in viscosity from water to 25% glycerol, through the intestines to measure their flow rates. Lastly, the team injected a hormone that stimulates muscles to contract into the intestines of five dogfish sharks, to measure how long it takes for food to move through these spiral intestines as the animals digest dinner.

The researchers found that some shapes, such as the funnel-shaped spiral intestines, have a slower flow rate than others, suggesting that sharks with these shapes likely have slower digestion rates. This may also increase the water and nutrient absorption in the spiral intestine, so that sharks can harvest the most energy from their food. Though spiral intestines vary in shape, these shapes did not predict what the sharks chose to eat. In addition, when the team analysed how fluids flow through the pulsating tissue, they realised that spiral intestines work like a Tesla valve, which only allows fluid to move in one direction without the benefit of additional moving components, such as flap valves. In short, spiral intestines prevent food from moving backward, in the wrong direction. The team also realised that the pulsing contractions that propel food through these intestines can be concentrated in just a few locations and could help to mix and move food better as it progresses through the digestive system.

Most incredibly, this corkscrew intestine design evolved in a shark ancestor around 450 million years ago, so this structure is older than land animals! Yet, despite its success at sticking around for so long, it has only evolved in a few groups of fishes and occurs most in the cartilaginous fishes (such as the sharks, skates and rays). The main benefit of the curly design is that it naturally prevents blockages and food from accidentally flowing backward, maintaining a slow progress that is ideal for digestion. While the four different spiral intestine shapes may not be directly related to the diets that these animals

consume, they do affect how fast food moves through. Future studies might uncover why these different shapes evolved in the first place and what role the difference in food flow speed may have on a shark's digestion.

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Urban dung beetles forge fresh paths

Dung beetles know how to make the best of any situation: they can turn a pile of dung into a feast, a nursery and even a lookout post. One species of dung beetle in South Africa, *Scarabaeus satyrus*, caught the eye of Marie Dacke and her research team at Lund University in Sweden. The beetles are nocturnal, but somehow maintain relatively straight paths when rolling balls of dung – even on the darkest nights when there's no visible moon. Previously, the researchers found that when the moon isn't visible, dung beetles use light from stars as guides to roll away from the central dung pile in straight paths. In a follow-up study this year, the researchers sought to measure whether light pollution, which may obscure guiding light from stars, changes the paths of rolling dung beetles.

Usually, dung beetles obtain a lump of dung from a central dung pile and then roll it away to find their own place where they can consume it in peace and lay eggs on it. However, before they begin their journey away from the source of their lump of dung, they typically stand atop the ball and turn in a full circle, taking a mental snapshot of the view of the sky at the starting point of their journey. They then roll their dung trophy away along a straight path, comparing their course with their mental snapshot. The research team wanted to measure how the beetles navigate away from the central dung pile when starlight is shrouded by light pollution.

To investigate whether light pollution interferes with their mental snapshots, the researchers looked to see if beetles in a light-polluted city were more disoriented than beetles living in the surrounding countryside, where the stars are clearly visible. Travelling to Johannesburg, South Africa, Dacke and her colleagues found that the beetles in the city forged relatively straight paths. However, when she compared how well the city and rural beetles were dispersed around the dung piles, the city beetles weren't as evenly distributed, possibly leading to conflict over particularly imposing balls of dung. Instead, the urban beetles tended to drift toward the brightest light near the horizon. However, the beetles were still steering their balls of dung along straight paths, suggested that the beetles were not disoriented, and the shared directional preference suggested that the beetles were still using something to guide their way.

To test whether the urban beetles were guided to their shared destination by the city's artificial lights when starlight wasn't visible, they placed a flood light near the dung pile, and most of the beetles rolled their dung trophies toward the bright light. In other words, they were guided by the earthly light when it was brighter than celestial light. The researchers then observed the beetles as they encountered a dung pile surrounded by dark walls where no earthly lights were directly visible and the stars were masked by light pollution. This time the beetles rolled their balls of dung along curvier paths, as if they were disoriented when neither starlight nor building lights could be used to guide their way.

When dung beetles can't use the moon as a guide, they look to the stars. When they can't see the stars, they rely on earthly lights as landmarks to make their way away from the dung pile. Even when they can't tell where to go and where they've been, dung beetles keep on rolling their eponymous balls, even if their lack of direction sends them on a wobbly course that could send them into the path of another, with potentially disastrous consequences.

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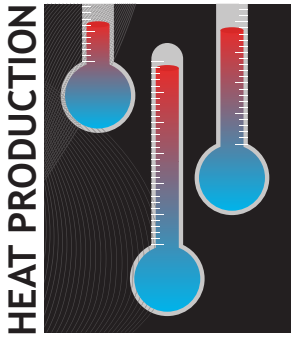
Leaky muscle, hotter otter



Just the thought of diving into 5°C water is enough to start many of us shivering, but many marine mammals spend their lives submerged in chilly ocean waters. While most of these aquatic animals have thick layers of insulating blubber, sea otters have only their dense fur to keep out the cold. But as the smallest of the sea-going mammals, sea otters lose body heat to cold water so rapidly that fur isn't enough to keep them warm. Instead, these animals must generate excess body heat to keep their temperatures up. Traver Wright of Texas A&M University, USA, and the University of Texas Medical Branch, USA, with colleagues from Texas, Alaska and California, investigated the source of this body heat to understand what allows sea otters and other mammals to thrive in such challenging environments.

Skeletal muscle is important for generating body heat through contractions like shivering, but in some cases it can also warm things up by 'leaking' energy from metabolism. Cellular metabolism involves converting food into chemical energy that can be used by the body for many different purposes. However, muscles can short circuit this energy-generating cycle to warm the body by diverting the proton gradient that usually drives the production of chemical energy to generate heat instead during the final

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steps of metabolism. Wright and his team hypothesized that because muscle is such a large and metabolically active tissue, muscle energy leak could be the key feature helping sea otters to keep warm. To test their prediction that sea otter muscle is leakier than that of other mammals, the team measured the metabolic activity from muscles of sea otters across a range of sizes and ages.

The researchers found that sea otter muscles produce amounts of stored chemical energy similar to that of the muscles of other mammals, but the amount of additional energy leaking out as heat was higher than seen in any other mammals of a similar size. This relatively high energy loss supports the hypothesis that muscle leak is important for maintaining body temperature in these sea otters. The team also found that sea otters had similar rates of muscle metabolic activity and leak regardless of size or age, including the youngest pups. This suggested that high metabolic heat production is important at all stages of life.

Wright and his colleagues then used published measures of sea otter muscle mass to calculate how much all the leaky muscles combined could contribute to whole-body heat production. They found that muscle leak could account for the energy demands of keeping sea otters warm at larger body sizes, but is not enough to explain the energy demands of the smallest sea otters. Instead, these pups may need to rely on heat generated from other tissues, actively shivering, or cuddling close to their mothers to stay warm.

Overall, leaky muscles can explain how high metabolic rates help to protect sea otters from the cold. The detection of this heat source in even the youngest sea otter pups suggests that it is an important adaptation for life in frigid waters. For these mammalian mariners, it's the leaks that keep them seaworthy.

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