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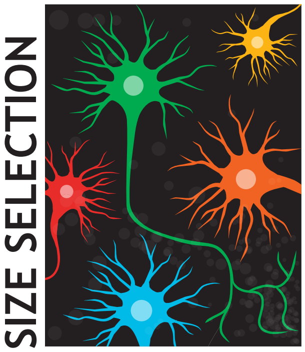
Bigger brains in trickier habitats



Size matters, especially when it comes to brains. Larger brains are often linked to increased mental performance, but not all animals are brainiacs. Even after considering differences in body size, some species have much larger brains than others. Different individuals within a single species can also vary tremendously in brain size. Scientists do not have a firm grasp of why this variation exists, despite centuries of interest, but some have suspected that brain size may depend on how difficult it is to find dinner. For animals that need to search complex habitats to find their prey, a big brain may equal a full stomach.

A new study, led by Caleb Axelrod at the University of Guelph, Canada, tested this 'habitat complexity' hypothesis of brain size by comparing pumpkinseed sunfish (*Lepomis gibbosus*) that lived in different parts of a large lake. Some sunfish always stick close to shore, where they search intensely amongst fallen branches and dense vegetation for tasty but well-hidden morsels like snails and crayfish. Other sunfish inhabit open water in the middle of the lake and simply snack on plankton as it drifts by. Axelrod and his team spent two summers catching sunfish from both habitats and then carefully collected and weighed their brains.

Exactly as predicted, the sunfish from complex, near-shore habitats had brains that were about 8% larger than those of open-water plankton eaters. This is the first evidence that brain size can be linked to differences in habitat within a single species and provides evidence for the hypothesis that living in complex environments may increase brain size. Even within each habitat, however, an individual fish may feed on different amounts of plankton versus hard-to-find prey. To test whether eating easy-to-catch plankton was linked to smaller brains, Axelrod also measured the size of the mouth; previous work had found that a small mouth is a good proxy for more plankton eating. Again, just as expected, small-mouthed fish that used the easier plankton-catching strategy tended to have smaller brains.

Next, Axelrod wanted to determine whether near-shore sunfish had larger brains overall, or whether a specialized region was bigger. Perhaps these fish had a particularly good sense of smell or vision? In other animals, these sorts of regional differences are common, but in the sunfish the proportional size of each brain region was the same in the two habitats. The implication is that the brainiac near-shore sunfish may have broadly improved cognitive abilities, but this remains to be studied in detail.

The process driving brain size differences in sunfish is not yet known. One possibility is that natural selection favours large-brained fish near the shore, or perhaps the simplicity of open-water living stunts brain growth. Regardless, it seems clear that the size of a sunfish brain is different depending on its habitat. So, should you complicate your life and fill your house with clutter to grow a bigger brain? It's probably too early to draw connections between fish and humans. But next time you're out fishing and trying to decide where to drop your hook, perhaps you should think about casting out far from shore to where the small-brained fish live.

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Crude awakening: larval mahi-mahi can't handle the heat

Cruising at top speeds of 93 km h^{-1} (move over, Usain Bolt!), there aren't many fish that swim faster than mahi-mahi. Like high-performing athletes, mahi-mahi have exceptionally conditioned hearts that allow them to swim so swiftly. Yet, these extraordinary ocean athletes are vulnerable during embryonic development and spend most of this time at the sea surface. Mahi-mahi spawn in the Gulf of Mexico, the site of the April 2010 Deepwater Horizon oil rig explosion, which occurred during the height of the mahi-mahi spawning season. David Attenborough doesn't need to explain what an ecological disaster this was, but to understand its impact, biologists from the RECOVER consortium have been researching the effect of Deepwater Horizon oil. In their recent publication, Prescilla Perrichon and colleagues from the Universities of Miami and North Texas, USA, demonstrate the combined, sinister effects of temperature and certain toxic hydrocarbon components of crude oil – polycyclic aromatic hydrocarbons – on larval mahi-mahi.

To accomplish this, the team artificially weathered Deepwater Horizon crude oil to mimic its naturally altered composition

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in the Gulf of Mexico (composed of a high proportion of polycyclic aromatic hydrocarbons). Next, the team separated 8 h old mahi-mahi embryos into two groups at different temperatures (26 and 30°C – the normal temperature range over which these embryos develop in the Gulf of Mexico) and subjected them to different concentrations of the artificially weathered oil, for 24 h. Typically, warmer temperatures accelerate embryonic development and increase their energy consumption, so the team wanted to see how the effects of the oil toxins would vary over the two temperatures. Finally, the researchers transferred the embryos to clean seawater and assessed the development of their hearts, at 56 h. They looked at the heart because hotter, faster-maturing embryos are more dependent on it – even as tiny embryos – because this vital organ is responsible for circulating oxygen, nutrients and other materials (including dangerous toxins) to the tissues.

The team found that the oil toxins caused the heart to pump less blood and beat more slowly. Also, the hotter embryos were affected more severely. In short, oil is toxic and even deadlier if you're a fast-growing larval fish.

Having discovered that the hydrocarbons impaired heart function, the researchers investigated whether this might be due to changes in heart structure. Microscopy images of specimens revealed that the oil toxins had caused unusually large amounts of fluid to accumulate around the heart, which places abnormal pressure on the tissue and distorts its shape. Unsurprisingly, as more fluid surrounded the heart, the worse it performed. The team also observed that the hotter embryos consumed their yolk faster than normal. This was an alarming observation, as hotter embryos rely more on their yolk to sustain their rapid growth. So, not only did the toxicity of the hydrocarbons impair heart shape and function but also it left hotter embryos with a perilously depleted energy supply, which they desperately need for their accelerated development and survival.

Although fish possess remarkable adaptations for adjusting to changes in their environment, this study shows that fish embryos might not be as resilient to human pollution when faced with higher temperatures. In the context of climate change, as sea-surface temperatures rise, aquatic organisms that are typically tolerant of higher temperatures might face dire outcomes. The combined effects of high temperature and pollution could impede the development of ecologically and economically important organisms, thereby imperilling their ability to successfully grow and reproduce in the near future.

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'Pacifishts' have nothing to fight for

Two years ago, pictures of bleached corals at the Great Barrier Reef in Australia shocked the world. A 9 month marine heat wave had caused global coral bleaching, leading to devastation of coral reefs across the planet. Bleaching occurs when corals are stressed by changes in temperature, light or nutrients. When faced with this challenge, the algae living inside the corals depart, causing the corals to turn completely white. Bleaching does not mean that all of the corals are dying, but as they feed on sugars produced by their algal lodgers, they often struggle without them. As the reefs are important underwater ecosystems providing breeding grounds and food sources for many fish species, Sally Keith from Lancaster University, UK, together with an international team of collaborators, wanted to know how coral mortality and fish behaviour are linked.

In recent years, the team has investigated reef fish behaviour on 17 reefs within the Indo-Pacific Ocean, including 10 that they studied before and after the 2016 bleaching event. On each occasion, they observed individual butterflyfish for 5 min periods, noting each encounter with other fish as well as how frequently the fish bit at corals. In addition, they compared the number of healthy corals before and after the heat wave and found that bleaching caused a loss of between 18% and 65% of corals across 13 reefs distributed across four regions in Indonesia, Japan and Christmas Island. However, the team also identified a fifth region in the Philippines where bleaching did not lead to the death of the corals. This allowed them to compare how the fish behaved in healthy and unhealthy reefs and revealed dramatic differences in the animals' behaviours.

Unexpectedly, the butterflyfish appeared to become less aggressive towards other fish in reefs that experienced coral death; the scientists observed up to 85% fewer bites at the fish's preferred corals and the fish did not compensate for this reduction by feeding more on the surviving coral species. Importantly, the bite rates on preferred corals in the reefs in which all corals survived declined by only 7% and the fish's aggression rates also changed only slightly, convincing the team that their findings were indeed related to the death of the coral. The researchers also ruled out that the changes they saw were caused by a reduction in the number of fish, as that did not differ before and after the bleaching event. Instead they think that the decrease in aggression is caused by a reduction in the availability of food. Aggressive encounters between fish species are linked to individuals defending the coral colonies in their territories, but hungry fish do not have a lot energy to fight and there might not be enough healthy corals left to justify the effort.

These behavioural changes are likely to be one factor explaining why fewer butterflyfish species are found in coral reefs in the 5 years following mass coral die offs. After losing their favourite staple, the fish will have to swim further to find food, which can eventually lead to them giving up their territories and abandoning ruined reefs.

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How wildebeest walk on the wilder side

Imagine, for a minute, that you're taking a stroll through the Kalahari desert under the unforgiving heat of a summer sun. Now imagine that stroll lasting for 5 days and covering an impressive 80 km. Finally, imagine undertaking this epic desert trek without a single break for food or water. For humans and many other mammals, this journey would be their final one, but for wildebeest, no imagination is required; this is their annual migration. Blue wildebeest (*Connochaetes taurinus*), also known as brindled gnus, are renowned for their ability to travel long distances in hot and dry environments, but it wasn't until recently that a research team from the University of London's Royal Veterinary College and the University of Botswana set out to investigate how they actually achieve this feat. This new study from lead authors Nancy Curtin and Alan Wilson not only explains how blue wildebeest are able to migrate without refuelling but also reveals that large mammal locomotor muscles are strikingly more efficient than was previously thought.

Much like their study species, the team's approach to the investigation was two-pronged. Firstly, they wanted to track the wildebeest using GPS collars to monitor their walking patterns and behaviours. Secondly, they wanted to examine the locomotor muscles of the wildebeest to see whether their physiological properties hold the key to their extreme endurance. From the GPS collar data, the team discovered that the wildebeest drank exclusively from a single river during the dry season and were capable of regularly going between 2 and 5 days without visiting the river for a drink, a feat that they were capable of repeating during their twice-yearly migrations through harsh waterless environments. The team were also able to extract locomotion speed data from the collars, which revealed that 97% of the distance covered by the wildebeest over a full year was completed at a slow walking pace close to the previously predicted optimum for reducing their energetic 'cost of transport'.

In addition, the team collected minute muscle samples from each animal, which they electrically stimulated to investigate how the tissue contracted, while also measuring the heat they produced during contraction to reveal a crucial piece of the puzzle: the efficiency of the muscle. While previous mammal muscle efficiencies from small rodent studies have fallen in the range 20–30%, the average efficiency of the wildebeest's muscle was a staggering 63%. The only locomotor muscles that are currently known to be more efficient are those of the notoriously slow and steady tortoise. These super-efficient muscles play a pivotal role in the wildebeest's endurance by generating very little heat during locomotion, allowing them to conserve energy and water instead of using it for thermoregulation. The team also collected muscle samples from farmyard cows to compare the extraordinary muscle properties of the blue wildebeest with those from large mammals that haven't adapted to the nomadic lifestyle. This revealed lower muscle efficiencies of around 42% for the cows, suggesting that the wildebeest's impressive muscle efficiency is not purely due to their body size.

The team conclude that maintaining a low cost of transport is essential for long-distance trekkers that may need to travel during the hottest and driest times of day in order to avoid predators. For blue wildebeest, the solution lies in the surprisingly high efficiency of their specialised locomotor muscles, allowing them to undertake journeys that are truly gnus-worthy.

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