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OUTSIDE JEB

The ants go marching one for all

When it comes to teamwork, there's a lot we can learn from ants. In Panama, a particular species of army ant displays inspiring acts of solidarity with a distinctly architectural flare: when the terrain gets dicey, they band together to form scaffolds with their bodies. These army ants usually march along at a quick pace, so it's remarkable that they stop completely to create a safer route for the colony as a whole. Researchers at the Max Planck Institute of Animal Behavior, Germany, led by Ian Couzin, decided to study these feats of camaraderie as a model for how the behavior of individuals can give rise to order in a complex system without explicit directions.

To characterize whether aspects of the environment influence the scaffolds that the ants form, the research team turned the ants' usual route into a perilous highway. They elevated a stretch of road a few centimeters above the ground and used sticks and leaves to create ramps on either end. In the middle of the elevated route, they positioned a platform which could be positioned at different angles to create a stretch of sloped terrain. The platform was covered in sandpaper to allow the ants to get a stable footing, so that any slipperiness would be due to the angle of the terrain. By watching this hazardous stretch of road, the researchers found that ants were more likely to form scaffolds on steeper terrain and that more ants joined scaffolds at steeper angles. They also observed that fewer ants tumbled off the platform once the scaffolds formed, which shows that scaffolds are an effective strategy for preserving the colony.

Next, the researchers wanted to test whether the ants start forming a collective structure as a result of their own experience of the terrain, possibly prompted by a loss of footing. They discovered that as the terrain becomes more inclined, an ant is more likely to slip, which would then trigger an instinct to stop marching. They built a computational model to test whether they could predict how many ants would join the scaffold and how quickly it would form based on the steepness of the incline and the density of traffic. If their model fell short of what they observed in the real ant colony, it would suggest that there are other factors governing the ants' collective behavior. Instead, they found that their models accurately predicted what they had observed in the real ant colony. The model predicted that steeper inclines would lead to scaffolds made up of more ants at a similar rate to what they had observed. The computational model also predicted the success of the structures: fewer ants would fall as time elapsed and the scaffold grew.

The algorithms didn't include an expressed objective to build a structure, so the accurate predictions validated their theory that the ants start to form scaffolds based on their own individual experiences of their environments, not as a result of a widely broadcasted signal to do so. For an army ant, taking a moment to stop in your busy trek to ensure your comrades' safety is a no-brainer.

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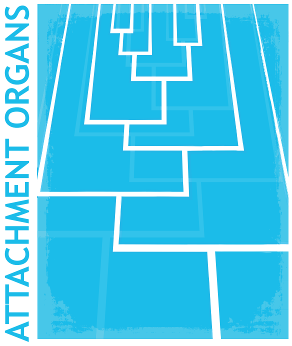
Baby fish with sticky heads



As animals grow and develop from birth to adulthood, many physical changes occur. In fishes, these changes can be especially dramatic as eggs hatch into tiny larvae that must quickly develop while avoiding predators. Larval fishes face some unique challenges because of their small size. They are unable to feed themselves, so they carry a yolk sac which provides nutrients. They also may have difficulties while swimming, which means that they could get swept up by the water or made into a quick meal by predators. Some larval fishes use a unique organ to stick to plants or rocks to stay safe and avoid being swept off into the current. This organ, called the larval attachment organ, is a temporary structure found on, or near, the head of the fish. While examples of larval attachment organs have been found in the largest group of ray-finned fishes, the teleosts, Amanda Pinion from Texas A&M University, USA, and colleagues from Germany, Mexico and the USA found a larval attachment organ in the tropical gar, *Atractosteus tropicus*, which is a type of primitive ray-finned fish. They wanted to better understand how the organ is shaped and how it works, so they studied images of the tissues in and around the snout throughout the fish's development.

Each day, the authors collected 20 tropical gar larvae over the course of their development from hatching to 6 days of age, measuring the larvae's length and the size of their larval attachment organs using both scanning electron microscopy and light microscopy.

They discovered that the larval attachment organ is a well-developed disc located on the snout when the gar larvae hatch. The gar larvae grow quickly, so while the larval attachment organ does not change much in size or shape, it appears to be proportionally smaller on the snout tip of the larvae. At 5 days old, the larvae resorb the larval attachment organ. This is also around the time at which they resorb their yolk sac and begin to swim freely in search of external food. After examining microscopic images of the cells in and around the larval attachment organ, the authors also found that the larval attachment organ is a complex super-organ composed of a circular clustering of about 35 individual attachment organs surrounded by a border of supporting cells. These individual attachment organs are made up of two different types of cells: support cells, with dense ridges for holding fluid, and attachment cells, which are filled with tiny sacs that may release a fluid from the attachment disk. These attachment cells probably secrete a sticky adhesive which helps to secure the fish to a plant or rock surface.

While the structure of cells in the larval attachment organs of gar is similar to that of previously studied fishes, the organ itself is unique in that it is composed of dozens of clustered individual attachment organs fused together. Future studies of larval attachment organs in fishes could shed light on the relatedness of these groups. Additionally, the underwater adhesive that helps to hold larval gar secure at the most vulnerable stage of their lives could inspire scientists to design a similar underwater adhesive, which has been challenging to develop so far. This work uncovers some of the mystery behind a unique adhesive organ in larval gar and, hopefully, will allow us to better understand some of the ways larval fish survive their first few vulnerable days of life.

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The bony tale of the bonytail's bony tail

When you picture a fish that spends its whole life constantly swimming at high speed, you probably see a tuna or marlin – something that cruises miles and miles each day through the open ocean. These fish generally have crescent-shaped tails with a narrow caudal peduncle – the part of the fish tail just before the tail fin – built for efficient swimming 24/7. However, fish living in fast-flowing rivers also need to swim fast constantly to be successful. The main difference from their deep-sea counterparts is that these riverine fish are swimming as hard as they can to go nowhere; they are essentially on a giant water treadmill. Living in torrential rapids, these fish need specialized traits to help them swim all day just to stay in the same spot, a behavior known as station-holding, to avoid getting washed downstream. Are the adaptations for swimming constantly in a flowing river to station-hold like those for roaming the relatively calm open ocean at speed?

To find out, a group of scientists from Northern Arizona University, USA, led by Daniel Kimball in Alice Gibb's lab, looked at the tail anatomy of three species of minnow from the southwestern USA to compare with that of tuna and other open ocean cruisers. These closely related minnows – bonytail, humpback chub and roundtail chub, listed in descending order of flow preference – are some of the species that traverse the world-famous rapids of the Colorado River as it passes through the Grand Canyon. Building on previous work, Kimball and colleagues found that not only does the bonytail have spines for muscle attachment on its vertebral column, which insert at sharper angles than for your typical fish, but the angle of these spines gets shallower from head to tail. This makes its caudal peduncle much thinner and more streamlined than those of most other fish, independently evolving the same shape as the tuna tail, despite being completely unrelated. Meanwhile, the slower-water preferring roundtail chub had more obtuse vertebral spines with a thicker, more typical tail shape.

Tails are more than just bones, though. How does the bonytail's tail muscles and connective tissues compare with those of tuna and other oceanic speedy species that prefer slower moving water? Kimball and colleagues tried stretching the muscles that move the minnows' tails to find out how much force they can withstand. They also measured how much collagen, a tough connective tissue, was found in these muscles by examining them under a microscope. The team found that the tail muscles of the bonytail resisted tearing better than those of the other species, with roundtail chub having the least tear-resistant muscles. This means that compared with its lazier, though still relatively active relatives, the bonytail can safely transmit a lot more force through its tail to propel itself through fast-flowing rapids. Additionally, the team found that the muscles powering the bonytail's tail had more collagen than its other muscles, which was not seen in the other species. This suggests their tail muscles may act like the springy tendons of tuna tails, storing elastic energy on each tail movement, allowing bonytails to swim efficiently at high speeds.

While there may not be any freshwater tuna, bonytails come as close as possible thanks to convergent evolution allowing both species to arrive at the same solution for high performance swimming. However, instead of swimming non-stop to cross entire oceans, bonytails swim non-stop just to stay still in fast-flowing rivers. Like a cross-country runner on a treadmill, the bonytail could cruise through the oceans with tunas if they wanted to, but prefer the scenic landscape of the Grand Canyon.

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Sea signals supper for flying foragers

Walking down a city street, we need only look to brightly lit restaurant signs to find our next meal, but animals searching for food in the wild must use cues from complex and changing environments. One of the most dynamic environments is found in coastal areas where seabirds must locate prey in the ever-changing flow of tidal waters. The foraging of various animals has been associated with large-scale features of the open ocean, like the swirling water of 100 km wide eddies, but it was not known what cues birds use to find prey at distances of 10–100 m where feeding actually occurs. In a recent study, Lilian Lieber of Queen's University Belfast, UK, and colleagues in Germany and the UK asked whether surface features such as the spinning and roiling of turbulent water could present visual cues to guide the searching seabirds. Specifically, they predicted that foraging behavior would be affected by turbulent features of the water's surface and the distance of these features from the birds.

The researchers focused on three species of terns foraging in the local flow generated by a decommissioned tidal energy structure in a tidal channel in Northern Ireland. Using an aerial drone, they recorded an overhead view of the water's surface simultaneously with the movements of terns flying over the channel. Lieber and her colleagues then used machine learning to track individual birds and calculate flight movements to determine whether birds were actively feeding by swooping and diving using slower speeds, or were transiting across the environment with faster and more direct flight. By tracking natural particles on the water's surface, they also reconstructed local surface water velocity through time and identified types of turbulent flow, including spinning vortices and upwelling, where deep water rises and spreads outward at the surface. Finally, they used statistical modeling to relate the flight path of individual birds to turbulent features below the bird, as well as those ahead of their flight path to test the prediction that terns modify their behavior based on visual information from the ocean surface.

The scientists found that terns were more likely to swoop, dive and feed at the surface when the water beneath them was swirling in strong vortices, consistent with their predictions. This turbulent feature could be important for finding food, because small fish can become trapped in the spinning water. Terns were also less likely to start actively catching prey when a strong upwelling was ahead of their flight path. As upwelling structures develop over time, new vortices begin to spin at the edges of the spreading water, which start to accumulate tasty prey. By sticking to their flight plan, instead of turning or diving when deep water upwells ahead, the birds could be anticipating rich pickings at the edges of the water structure when they arrive a few moments later.

Using drones is a powerful way to connect bird behavior to surface features of the ocean, which will be particularly important as man-made structures that disrupt the natural flow of water continue to change coastal environments. Although foraging animals likely use many cues to find food, this approach revealed the first evidence that seabirds may extract visual information from physical features of the water to guide foraging behavior at local scales. So, for these birds, it seems the sea itself says 'bon appétit'.

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