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The octopus: beauty in simplicity

The octopus: sentient and swift, with a bulbous mantle, tiny head fixed on a neckless body and eight nimble arms. These arms, symmetrically radiating outward from its body, would appear to allow the octopus to move in innumerable ways. But with so many possibilities, where and how does the octopus go? And what exactly does it do with so many arms? Although some studies of octopus arm movement had been conducted, how octopuses coordinate all those arms during movement was still unknown. In a recent study published in *Current Biology*, Guy Levy, at the The Hebrew University of Jerusalem, and his colleagues in Israel sought to understand the dance of the graceful octopus more deeply.

The authors placed nine common octopuses, *Octopus vulgaris*, in an aquarium with a transparent bottom and enough water for the octopuses to breathe and crawl, but not enough for them to swim. The team then filmed the movement of the octopuses as the animals readily crawled around obstacles and curiously inspected the tank and their observers. Then the scientists analysed the movements of the arms to determine how the octopuses used them and coordinated them to move.

Their study showed that the octopuses used their arms to move much like eight rubber bands with suction cups: scrunch, plant, extend. To the authors' surprise, they found that although the octopuses preferred to move at angles of about 45 deg relative to the direction that their body was facing they were capable of moving in any direction. So, the octopuses moved in all directions, though they preferred to move diagonally. The animals also preferred to use particular arms and arm pairs when crawling – specifically, those that would send them along their desired diagonal path. The body orientation and crawling direction were independent and the authors suggest that the octopuses coordinate crawling direction with body orientation in a way that maximizes sensory input and feeding.

Most surprisingly, unlike many other animals, octopuses lack rhythm; their arms do not move in a rhythmic way when crawling, they are irregular. Any arm can be used at any time to make an instantaneous movement in any direction.

The authors also found that when arms work in groups (of two to four arms) to move, each arm exerts virtually the same amount of force. For example, the octopuses don't push with twice as much force with one arm as the other arm. So, locomotor decisions are simplified; they don't have to decide how much force to use with each arm to move in a particular direction, they just have to decide which arms to use. This, the authors suggest, combined with the simple worm-like movement of the arms, makes the octopus truly unique. There is a beautiful simplicity in the rhythmless dance of the octopus. And the authors suggest that these specialized movements are the result of extraordinary adaptations of the soft-bodied octopus to its environment.

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Casey Gilman
University of Massachusetts Amherst
cgilman@bio.umass.edu

Life converges on solutions to swim optimally

Swimming is hard work: ask anyone donning a bathing cap and goggles during morning laps in their local pool. Yet, life underwater is a reality for millions of organisms on our blue planet. To overcome the physical challenges imposed by life in the depths, sea creatures have evolved a variety of body shapes and swimming styles to help them get around efficiently. But not all solutions to the problem of swimming optimally are equal, and some strategies are favoured over others. So what's the secret to an effortless swim? Researchers at Northwestern University in Illinois, USA, say that for some animals, it's all about undulation.

Rahul Bale and his colleagues wanted to understand how the laws of physics shape swimming in aquatic animals. They suspected that similar hydrodynamic challenges faced by all swimming creatures have led to convergence towards a few optimal strategies for enhanced speed and efficiency. However, instead of tackling the techniques of all swimmers, the team decided to test their idea on a smaller group of 22 animals that use pairs of elongated fins for propulsion – the so-called median-paired fin swimmers, which include cuttlefish and rays. Rather than beating a tail back and forth, these creatures move by rippling their fins length-wise across their bodies. These ripples, or undulations, can be described by two measures: the wavelength (distance between two peaks) and the amplitude (height of each peak). The team analysed video footage of median-paired fin swimmers such as flatworms and knifefish, and quantified the ratio of the wavelength to the mean amplitude of the fin undulation, which is known as the specific wavelength. They then used computer simulations and a large robotic fin to analyse the forces generated by a range of specific wavelengths to see whether nature has, indeed, come up with the best solution to the problem of underwater locomotion.

So what do flatworms, cuttlefish, rays and knifefish all have in common? Despite not looking alike and being only distantly related to one another, these median-paired fin swimmers generally swim with a specific wavelength of 20, which Bale and his team call the optimal specific wavelength. Amazingly, the team found that undulations at the optimal specific wavelength were ideal for maximizing force and speed during their simulations and in their robot fin. This consistency in the optimal specific wavelength across such a diverse group of animals suggests that necessity rather than chance led to convergent evolution towards a mechanically superior way of moving through water. The researchers estimate that there are over 1000 different aquatic creatures that probably swim with the optimal specific wavelength.

Of course, median-paired fin swimming isn't the only way to move underwater: lots of animals swim with their body and/or tails. In fact, some of the fastest underwater athletes like tuna and dolphins use this more common swimming style, which, on the whole, is more effective than rippling fins. Just how median-paired fin swimming has evolved multiple times from tail-fin swimming ancestors is still unclear. In any case, the optimal specific wavelength may not help you trim seconds off of your lap times, but it's definitely made life in the depths easier for some aquatic animals!

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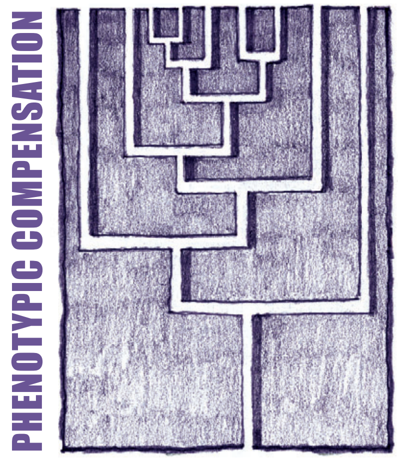
Sandra A. Binning
University of Neuchâtel
sandra.binning@unine.ch

Protective shells make for more risky behaviour



While some people enjoy throwing themselves out of aeroplanes or abseiling down cliffs, other folk are happier staying at home with a nice cup of tea. These differences in personality type have fascinated scientists for decades and, more recently, these interests have spread to the study of animal behavioural traits. Much of the emphasis on animal personality types has been centred on the bold–shy continuum and trying to understand why certain individuals are willing to take more risks than others. Being bold can confer many benefits and bold individuals have been found to have higher foraging rates and more mating opportunities. One of the downsides, however, to exhibiting more risk-taking behaviour is the higher chance of being preyed upon. A recent study, by Johan Ahlgren and colleagues at Lund University, Sweden, has demonstrated a strong link between bold risk-taking behaviour and shell morphology characteristics in the snail *Radix balthica*. It turns out that it is your ability to protect yourself against predation that dictates whether you are likely to indulge in risk taking or not.

The study, published in *Biology Letters*, focused on a small air-breathing aquatic snail species, commonly found in ponds and lakes. The authors had noticed that there was a large variation in the size and shape of the snail shells, even between individuals of the same age. Wondering how this might interact with personality traits and behaviour, they set out to collect snail eggs from a series of ponds close to the campus. Upon hatching, each snail was then individually tagged with a minute numbered tag to allow identification. An individual was then carefully transported to a personality assessment arena, where the time to emerge from the shell following a fright was used as a measure of boldness. To test the consistency of this personality trait, the trials were repeated again 1 week later. Then the team deployed a rather novel approach to measure each shell's shape – placing a snail onto a flatbed scanner, they scanned it to analyse the shells and their associated characteristics.

Each snail had a distinct shy or bold personality type and that trait was highly consistent and repeatable for each individual between trials. When the team linked their boldness scores to the shell morphological traits, they found that bolder snails have a more rounded shell shape with a wider shell aperture. These shell characteristics offer enhanced protection against predation as they have a higher crushing resistance, meaning the snails are safer from shell-crushing predators such as fish. So it seems that the safety provided by a rounder shell results in those individuals being more willing to take risks and display bold-type behaviour. What is of particular interest is that these bold individuals must be aware of the increased protection that such a shell type confers and have adjusted their behaviour accordingly.

This study implies that shell morphology influences the personality type of snails and suggests that these bolder individuals are able to offset the increased risk of being preyed upon that comes with being braver through having a tougher shell. The findings provide strong support for the 'phenotypic compensation' hypothesis, whereby individuals that demonstrate bolder personality traits are better equipped with anti-predator defences than more shy individuals. Such a finding suggests that morphology may be a strong contributing factor when it comes to maintaining personality type – and variation – among animals. For us, it's less likely that our morphology interacts quite so strongly with our propensity to display risky behaviour and it's far more likely that those who are risk averse just prefer being cosy in the warm.

10.1242/jeb.112581

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Steve Portugal
Royal Holloway
Steve.Portugal@rhul.ac.uk

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Don’t follow the leader, leader, leader

Living in a group has many perks: all the extra eyes and ears to look out for danger or prey, for instance. As it is inevitable that within a collective there will be disagreements on what to do, there must be a way for a group to resolve these conflicts in order to stay together. All this is straightforward enough in an egalitarian crowd: for instance, in shoals of fish, individuals simply follow the majority of their nearest neighbours. But what happens if a group is hierarchical, as is the case for animals such as hyenas, wolves and us? How are conflicts between the wishes of the majority and those of the leadership resolved?

A recent study published in *Science* by a team of researchers affiliated with institutions in the US, UK, Panama and Germany has addressed this question by looking at how a primate that lives in hierarchical groups, the olive baboon, moves about across the Kenyan savannah. These apes travel many miles per day in search of food, all the while staying very close to each other. How do they make sure that they stay together?

In order to track the behaviour of a troop at the Mpala Research Centre in which the social dynamics and hierarchy were fully characterised, the team fitted most of the individuals with a high-accuracy GPS collar that recorded their position once every second. They then developed computational tools to crunch the data in order to extract what decisions individuals made in relation to the behaviour of their neighbours. They reasoned that if the social hierarchy within the group influences collective decision making, a dominant individual’s movements should be more likely to be mirrored by its neighbours than the movements of a lower-ranking baboon.

However, strikingly, the team found that this was not the case: the dominant male in the troop did not have the highest chance of being followed by its neighbours, nor was there a correlation between the sex of the animal and the likelihood that it would be followed. If the baboons’ collective behaviour is not affected by social hierarchy, could it be shaped by similar mechanisms to those involved in non-hierarchical groups? In this case, previous work on collective movement predicts that an individual faced with two neighbours that go off in different directions makes its decision on where to go depending on how different its neighbours’ directions are: if the difference is small, the animal compromises between the two directions; if the difference is large, the animal chooses one or the other.

The team found that the baboons followed this principle exactly, showing that there is no difference in how hierarchical and egalitarian collectives make decisions. The social status of a baboon therefore has no bearing on whether it acts as a leader during the day-to-day business of wandering around in the search for food. Even though we don’t like to think of ourselves as herd animals, our behaviour is very likely to follow similar principles to that of the baboon. However, it is probably safest not to apply these findings to dealings with your superiors just yet.

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Maarten Zwart
HHMI Janelia Research Campus
zwartm@janelia.hhmi.org