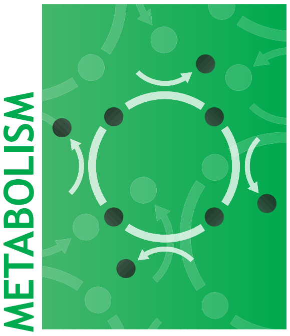
OUTSIDE JEB

Algal amalgamation alters anemone metabolism



Imagine every salad you ate gave your skin a grassy green color, allowing you to recharge in the sun. This is effectively what sea anemones and corals do. They host algae in their tentacles that pay rent by providing food. But this algae–anemone teamwork is fragile, as even small increases in temperature trigger anemones to expel the algae. Without their algal allies, the anemones become 'bleached', threatening their survival. This divorce is bad for the newly separated algae and anemones, but also for the fish and invertebrates that need anemones for food and shelter. As oceans warm, bleaching events are increasing, so it's urgent we study this marine mutualism. But it's hard to untangle such an intertwined connection. Scientists often study metabolism by sampling tissues, but in this case, the anemone tissues would be 'contaminated' with algae. How else can you distinguish what each species is doing? Madeleine van Oppen and her team from the University of Melbourne, Australia, tackled this question with a clever new technique, shedding light on just how algae and anemone unite metabolisms to thrive as a team.

The researchers first anesthetized the anemones (*Exaiptasia diaphana*) so they wouldn't sting during sampling – after all, anemones are related to stinging jellyfish. Then, the team took slices of the anemones, scanning each location for biological compounds. This created a sort of 'metabolic map', displaying the metabolism of each body part. Van Oppen and colleagues made maps for three groups of anemones: one with a species of algae commonly found in this anemone, one with an algal species not normally found in these anemones, and one without algae. Anemones were noticeably bigger when they hosted algae, but it mattered which algae they were hosting. Anemones with non-native algae had fewer fatty acids, which are important energy sources in animals. This matched results from a previous study showing that anemones had weaker immune systems and fewer fatty acids if they were cultured with the wrong algae. So algae altered anemone metabolism. But did all body parts undergo similar changes?

As it turns out, the metabolic maps really highlighted differences among body parts. To van Oppen and colleagues, two types of chemicals stood out: one in the tentacles, and another in the gut. The first, betaine, is made by algae and was in the tentacles of all anemones with algae. This was unsurprising – algal chemicals were in algae. But these betaines had different structures than what you'd normally find, suggesting that the anemones had changed the algal metabolism. Second, in the gut, there were high levels of ceramides. These waxy chemicals are used in hand creams because they stiffen connections between skin cells, like the cement in a brick wall. Neither anemone nor algae produce much of this compound alone, but production ramped up when they were partnered together. This means that algae coax their hosts into producing a pathway, like a waxy red carpet, to guide in more algal coworkers and keep the partnership strong.

But above all, the metabolic maps highlighted just how little we really know about marine invertebrates. Only a third of the chemicals the researchers found in the anemones could be identified. This means we only understand a fraction of how these animals digest their food, even though they form the foundation of one of Earth's most diverse ecosystems. Yet, this information is becoming increasingly urgent. Recently, global temperatures broke world records 4 days in a row, both on land and in the ocean. If we come to understand anemones better, we may save their algal tenants from eviction, and preserve the homes of countless marine animals as they cope with Earth's rapidly warming oceans.

doi:10.1242/jeb.245022

Chan, W., Rudd, D. and van Oppen, M. (2023). Spatial metabolomics for symbiotic marine invertebrates. *Life Science Alliance* **6**, 1-15. doi:10.26508/lsa.202301900

Michael William Country (0000-0001-5239-6607)
RIKEN Center for Developmental Biology
michael.william.country@gmail.com

A clashing colour combination with deadly consequences

Humans have a powerful ability to illuminate the night sky. We leave streetlights on from dusk until dawn, operate businesses through the night and light our homes well after sunset. In a world where natural light cycles govern the rhythm of life, we have created a major disruptor known as artificial light at night. In some cases, this light pollution we create is considered 'diffuse', such that there are many light sources originating from multiple directions and therefore weak shadows are cast in the environment (imagine an illuminated soccer pitch). In other cases, we create 'direct' sources of light that cast many dark shadows in the environment (imagine a lighthouse). In a fascinating new study, Kathryn Bullough and her team of researchers from the University of Exeter, UK, investigated the impacts of both diffuse and direct light pollution on the sea roach (*Ligia*

Outside JEB reports on the most exciting developments in experimental biology. The articles are written by a team of active research scientists highlighting the papers that JEB readers can't afford to miss.

oceanica), a marine crustacean that changes colour to blend in with its surroundings and avoid the prying eyes of predators. The researchers discovered that illuminated nights trigger an intriguing clash between sea roach behaviour and their colour-changing tactics at night.

Sea roaches live near the shore, where light from major coastal cities illuminates the underwater world. To understand how brighter nights impact these crustaceans, the team first collected dozens of sea roaches from the rocky shoreline of Swanpool Beach, UK. Afterwards, the team placed the animals into a pitch-black box to activate their colour-changing superpowers, encouraging them to turn as dark as possible. The researchers then transferred the sea roaches into buckets in which half of the bottom was lined with black gravel and half with white gravel. Some buckets were exposed to a direct source of light that projected strong shadows among the textured gravel floor, whereas others were exposed to diffuse light that obliterated any shadows. Over a 15-min observation period, the crustaceans chose to spend more time on black gravel. Moreover, when shadows were available, sea roaches actively chose to be in shadowy regions of the bucket, suggesting they had a clear preference for a dark background. This is where things got interesting. When the sea roaches experienced direct lighting, they generally stayed darker in colouration – sometimes becoming even darker than before to better match their coveted black and shadowy background. In contrast, sea roaches experiencing diffuse lighting became lighter in colour, even when on a dark background. Thus, the diffuse light pollution causes sea roaches to mix up which colour they should become – a mishap that leaves them especially visible and vulnerable to predators.

The team decided to take the study one step further and explore the movement of sea roaches in their buckets. The team predicted that sea roaches would move quickly but erratically when they clashed with their background to draw less attention to themselves. Bullough and colleagues hypothesized that if the crustaceans camouflage well with their environment, they would have no reason to move in such a stealthy manner. Indeed, when faced with diffuse lighting – where shadowy hideouts on both white and dark backgrounds were few and far between – the sea roaches were clever enough to make fast and irregular movements on white backgrounds, but if camouflaged, they hardly moved.

In the end, this study sheds light on the effects that our artificially brightened nights have on underwater animals. The team showed that artificially brightening our nights leads to colour-changing confusion in sea roaches, which can have major consequences on their ability to survive. Let's all turn down our lights at night and give sea roaches a chance to shine – just not too brightly.

doi:10.1242/jeb.245025

Bullough, K., Gaston, K. J. and Troscianko, J. (2023). Artificial light at night causes conflicting behavioural and morphological defence responses in a marine isopod. *Proc. R. Soc. B* **290**, 20230725. doi:10.1098/rspb.2023.0725

Giulia Rossi (0000-0002-4812-8869)
McMaster University
rossig1@mcmaster.ca

Guppies learn differently when their food is unpredictable

Scientists have long been fascinated by how learning varies among different taxa such as humans, monkeys and fish. Moreover, in humans, it is well known that some people learn differently from others. These learning differences between individuals can also be seen in other animals. For example, male and female guppies (*Poecilia reticulata*) differ in their ability to learn self-control. Tyrone Luccon-Xiccato, Giulia Montalbano and Cristiano Berlucci from the University of Ferrara, Italy, were interested in exploring what can cause these individual differences in learning. So, they set out to investigate if learning was different for guppies based on whether they were given food at predictable times and places or if this unpredictability helped them learn in other ways.

First, the team separated infant guppies into two different environments for 20 days: a predictable one where the guppies were fed once a day at the same time and in the same place, and an unpredictable one where the guppies were fed at a random time during the day in different places in the aquarium. Afterwards, the researchers tested how well the guppies learned by placing the fish in an aquarium with two chambers connected by a corridor. The fish chose between two different coloured discs, one of which was associated with an appetizing reward. The researchers counted every time the fish chose the right or wrong colour. The team repeated this every day until the fish made fewer than four mistakes for two consecutive days. All the guppies eventually learned to pick the correct colour, but the fish in the predictable environment learned to pick the right colour faster than the fish in the unpredictable environment. This suggested that knowing when your food is coming and where it's going to be enabled the guppies to learn fast, allowing them to make the most of their reliable resources.

The team then reversed the colour that gave the guppies a reward to test their flexibility in learning. The test was performed just like the previous one, by counting the number of right and wrong answers every day until the guppies made fewer mistakes. Again, all the guppies eventually learned the reverse colour, but fish from the unpredictable environments decreased the number of mistakes they made faster than the other fish. Interestingly, the guppies raised in an unpredictable environment learned slower at first, but when the researchers changed the colour that was rewarded, these guppies were faster at understanding the new colour now meant a reward.

Lastly, the team tested the self-control of the guppies by enticing them with a tube full of delicious, but inaccessible, brine shrimp snacks, and counting how many times the guppies tried to eat these tantalizing treats. Luccon-Xiccato and colleagues discovered that guppies raised in an unpredictable environment also attempted to eat the unattainable brine shrimp fewer times than guppies raised in a predictable environment. If the fish don't know where their food is coming from, self-control and being flexible in learning are advantageous, allowing them to change their behaviour.

The researchers stated that food predictability could be one of the many factors causing differences in learning. They also state the importance of more research being done to see whether this adaptability is constant throughout the guppies' life, or whether it can alter based on changes in the environment. This flexibility in learning based on when and where your food comes from could be one of the reasons why individuals have different learning abilities. For fish, knowing when your food is coming and where you're going to get it from can have major effects on your learning.

doi:10.1242/jeb.245024

Lucon-Xiccato, T., Montalbano, G. and Bertolucci, C. (2023). Adaptive phenotypic plasticity induces individual variability along a cognitive trade-off. *Proc. R. Soc. B* **290**, 20230350. doi:10.1098/rspb.2023.0350

Andrea Murillo (0000-0003-4793-708X)
McMaster University
murilloa@mcmaster.ca

Flight acro-bat-ics: the predatory pursuit of a stealthy bat

Many animals actively hunt their food on a daily basis, and insect-eating bats are no exception. However, these predators hunt in the dark hours of the night. While in flight, bats and insects alike employ complex manoeuvres to navigate their surroundings. Yet, insects need to evade being eaten and bats need to successively feed. To gain the upper hand, bats need to find, chase and capture their prey. Alberto Bortoni and colleagues from Brown University, USA, along with researchers from Lawrence Technological University, USA, and the University of Colorado, USA, set out to analyse the flight manoeuvres that Townsend's big-eared bats (*Corynorhinus townsendii*) use to successfully catch their meals. The stealthy Townsend's big-eared bat hunts at low speeds and, uniquely, performs aerobatic aerial manoeuvres while on the wing.

To analyse the flight behaviour of the bats, the team of researchers used mist nets to capture Townsend's big-eared bats at the American Museum of Natural History's Southwestern Research Station (SWRS) in Portal, AZ, USA. The researchers simultaneously collected moths and other insects with ultraviolet light live traps. The team released individual bats into an outdoor flight enclosure (6×4×2.3 m high cage), along with approximately one to five insects for them to catch. As each bat hunted its prey, their flights were video recorded, and the researchers recorded the bats' quiet echolocation calls while they were hunting. The team then used mathematical modelling and simulations to analyse the bats' flight behaviour from the videos. By doing this, the researchers were able to divide the hunting flights into distinct phases: the onset of pursuit; phase 1 – assessment; phase 2 – repositioning; and, if necessary, phase 3 – the chase.

At the start of pursuit, bats would initially detect their prey using their echolocation and slow down their flight speed. Then, during phase 1, the bats flight would pick up speed and the path was mostly straight, forward flight. Following this, the bats would enter phase 2, the repositioning phase, where bats completed an in-flight circular manoeuvre, bringing their body behind the flying insect. The researchers concluded that the first phases of the bats' flight path allowed this species to perform in-flight manoeuvres at low flying speeds, and importantly, respond to any changes in prey movements, all while maintaining their pursuit.

Catching insects quickly is important as it saves the bats energy. Approximately one-quarter of the successful hunts (12 cases out of 44) needed to proceed to a third phase: the chase. During this phase, a prolonged active chase occurred, which usually resulted from the prey increasing their own flight speed during the bats' repositioning phase. To eat the insect, bats would first catch the insect with their wings, but then move the insect to their membrane of skin between their legs and tail, which they use to flick the insect into their mouth all while remaining airborne.

Bortoni and colleagues discovered that all flight phases are incredibly important for the success of these bats in capturing their prey. Together, the stealthy flight, quiet echolocation calls and in-flight manoeuvres give the Townsend's big-eared bat the title of having the highest capture success rate out of any insect-eating bat species that hunts mid-air. These flying mammals really are acro-bats.

doi:10.1242/jeb.245021

Bortoni, A., Swartz, S., Vejdani, H. and Corcoran, A. (2023). Strategic predatory pursuit of the stealthy, highly manoeuvrable, slow flying bat. *Corynorhinus townsendii* **290**, 20230138. doi:10.1098/rspb.2023.0138

Kristina A. Muise (0000-0002-0497-4086)
Royal Veterinary College
kristinamuise@gmail.com