OUTSIDE JEB

Featherwing beetles fly with style

The aerial athleticism of insects is impressive on any scale, but the airborne feats of the miniature beetle *Paratuposa placentis* are particularly impressive considering their ultra-compact size. At roughly the size of a small amoeba – just 400 µm – their bodies house tiny muscles. Nevertheless, they fly as fast as insects that are 3 times their size. Led by Alexey Polilov at Lomonosov Moscow State University, Russia, researchers at institutions across the globe – including in Russia, Japan, Germany and Vietnam – set out to investigate what strategies these petite insects employ to keep themselves upright and aloft.

Paratuposa placentis earned their nickname 'featherwing beetles' from their remarkable feathery wings. Instead of the membranous wings of their larger relatives, these beetles' wings are made up of one thick spine with bristles growing out of it like a fringe. Wispy wings are lighter than membranous wings, but they don't produce as much aerodynamic force.

To see how these distinctive wings allow the beetles to fly, the researchers captured high-speed videos of the insects in flight. The stunning videos provide a previously unseen glimpse into how flight is accomplished on such a small scale. They tracked the wing stroke paths by comparing wing positions across consecutive video frames. Like other insects, the beetles adjust the angle of their wings through each stroke so that the tips of their wings trace a figure-of-eight path. Unlike in larger insects, these beetles' wings often touch each other at both the highest and lowest part of each wing stroke. This maneuver, called 'clap-and-fling' gives each wing stroke an extra aerodynamic boost.

The team analyzed the wing paths and found that the unique wing stroke can be broken down into two half-strokes, each made up of a 'power' stroke that produces upward force and a 'recovery' stroke that stabilizes the animal. The power strokes create the aerodynamic force needed to keep the beetle in the air and the recovery strokes help the insect maintain balance. In addition to the wings, the beetles employ their hardened shell-like modified forewings, called elytra, to steady their flight. The elytra move in opposition to the wings, so that when the feathery wings are directed down, the elytra flap up and then down again as the wings swoop up. This antagonism stabilizes the beetle's body, so it doesn't somersault through the air.

Despite the beetles' miniscule size, they propel themselves through the air by employing unique wing stroke strategies. Their feathery wings and shell-like elytra flap in opposite directions to drive flight and steady the animal as it speeds through the air.

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Farisenkov, S., Kolomenskiy, D., Petrov, P., Engels, T., Lapina, N., Lehaman, F., Onishi, R., Liu, H. and Polilov, A. (2022). Novel flight style and light wings boost flight performance of tiny beetles. *Nature* **602**, 96-100. doi:10.1038/s41586-021-04303-7

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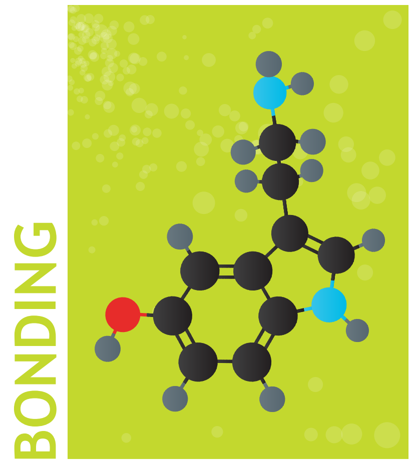
Long-term effects of the 'love potion' oxytocin



Throughout human history, pining lovers have sought so-called aphrodisiacs to win over affection. From oysters and dark chocolate to rhinoceros horns, these reported love potions sometimes have questionable ties to truth. However, scientists are beginning to unravel the genuine biology of 'love' by studying the neuroscience of monogamy and bonding. The monogamous love lives of titi monkeys (*Plecturocebus cupreus*) have been a fruitful focus. These non-human primates share an equal role in raising their young and mate for life, often romantically entwining their tails in their slumber. Only about 3% of mammals – including humans – exhibit this kind of social monogamy and we know that these strong attachments are cemented by powerful hormones, such as oxytocin and vasopressin. In fact, oxytocin is being explored as a potential treatment for disorders such as autism. Given the potential for the hormone to transform lives and the strong bonds that titi monkeys form, Rocío Arias-del Razo and colleagues from University of California Davis, USA, examined the long-term behavioural and neural effects of oxytocin treatment on the loyal animals.

Initially, the researchers dripped oxytocin dissolved in salt water into the nostrils of young titi monkeys daily for 6 months.

Each monkey lived with their parents and siblings for another full year after the oxytocin treatment ceased, before they were rehoused with a stranger who would become their mate. Of the original 15 treated, only one monkey did not take kindly to his arranged ‘marriage’, showing some initial signs of aggression, but even this ornery fellow quickly settled into his new role.

To examine how oxytocin treatment affects animal behaviour, the researchers observed the couples each day during their first 4 months together. They found that monkeys treated with oxytocin exhibited more tail twining (a more ‘intimate’ form of affection) at the expense of proximity and contact with their mate. The hormone seemed to affect how the monkeys interacted with their mates, rather than the total time spent interacting.

Besides these daily observations, the researchers also tested the behavioural responses of the monkey couples, 4 months after they were introduced. First, they presented each monkey with either their mate or a complete stranger in an adjacent cage. Both male and female monkeys spent more time touching their partner’s cage than that of the stranger, but the males that had been treated with oxytocin as youngsters showed a stronger preference for their partner. The second test examined the monkeys’ reactions to strangers. As titi monkeys lack self-recognition, they respond to their own reflection as if they were a stranger of the same sex, while they react to their partner’s reflection as a stranger of the opposite sex. Testing the monkeys’ responses to these reflections, the team found that the oxytocin-treated male monkeys were friendlier towards the strangers in the mirror, making more curious approaches, contacts, movements and lip smacks.

Finally, the researchers PET scanned the monkeys’ brains, both before and after forming a relationship with their partner, to examine the long-term effects of oxytocin in the brain. The scientists discovered brain activity patterns that confounded their expectations. Although they had anticipated that the long-term oxytocin treatment would increase activity in the regions of the youngsters’ brains that are associated with attachment and social skills, the activity levels remained unchanged. However, the team did find that the females that had been treated with oxytocin had higher brain activity than the males.

Oxytocin seems to sit at the epicenter of social monogamy, potentially regulating social engagement and the formation of long-term relationships as adults. Further research on the hormonal ties that bind could also have implications for how to treat autism and may even help us to be more successful in love.

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Razo, R. A.-d., Vazquez, M. L. V., Turcanu, P., Legrand, M., Floch, M., Weinstein, T. A. R., Freeman, S. M., Baxter, A., Witczak, L. R. et al. (2022). Long term effects of chronic intranasal oxytocin on adult pair bonding behavior and brain glucose uptake in titi monkeys (*Plecturocebus cupreus*). *Hormones Behav.* **140**, 105126. doi:10.1016/j.yhbeh.2022.105126

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Sensational shark skin and dazzling dermal denticles

Shark skin has a unique structure which has served as a source of inspiration for engineers interested in reducing drag in water or preventing parasites from becoming attached. The skin is covered in tooth-like structures called dermal denticles, made of an enamel-type tissue and dentine on the outermost portion and containing a central cavity filled with pulp. Their general shape is similar to a pointy canine tooth where the base is wider than the edge and is thought to reduce the amount of drag pulling on the animal when moving through water. Interestingly, previous work suggests a wide range of denticle shapes on the skin around the gills of dogfish, where the denticles closer to the head are rounded and smooth compared with the ridged and sharp denticles toward the tail. But does this diversity in denticle shape near the gills also occur in other shark species? And what purpose might these different shapes serve?

To study these questions, Molly Gabler-Smith and George Lauder from Harvard University, USA, Dylan Wainwright from Yale University, USA, and colleagues from Harvard University compared the shape and size of the denticles around the gills of 13 shark species with various lifestyles. They aimed to better understand whether the shape of these denticles differs between species and whether these differences might help water to flow over the gills.

The researchers collected the sharks from fishing surveys and museums, ranging from the thresher shark, known for its massive tail, enabling it to jump out of water like a dolphin, to the spiny dogfish, which are smaller and known to live in deep sea beds. They then took 3D measurements of denticle length and width and used electron and light microscopy to look at differences in denticle shape across the skin around the gills of individual sharks and between different species.

Comparing the structures, it turned out that the denticle shape varied across different areas of the skin surrounding the gills in all of the species, with the short broad denticles arranged toward the front of the shark and longer, pointier denticles occurring toward to the tail of the shark. In fact, the denticles found closer to the tail had pronounced ridges on their surfaces and three spiky spines, in contrast to the smoother almond-shaped denticles found towards the head. Some species, such as the chain catshark, had extreme changes in denticle shape over a distance of a few millimeters. They also found that the shark species that continuously swim to breathe had larger denticles toward the head compared with shark species that breathe by opening and closing their mouths to pump water over the gills.

The extreme differences in shape between the denticles found towards the head versus those toward the tail may serve to reduce friction and prevent damage to the skin when the gills flap against each other while breathing. The dramatic shape difference may also reduce drag from water moving through the gills, which could prevent water from flowing in the opposite direction, stopping the shark from getting enough oxygen from the water. This study gives us a foundation for future research on how denticle shape can help sharks to breathe and if there are differences in how water moves over the denticles surrounding the gills of active or passively breathing species. Understanding the great diversity and function of denticles in shark skin can help us to learn how they evolved and even allow us to better imitate their amazing ability to reduce drag in water.

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Gabler-Smith, M. K., Wainwright, D. K., Wong, G. A. and Lauder, G. V. (2021). Dermal denticle diversity in sharks: novel patterns on the interbranchial skin. *Integrative Organismal Biol.* **3**. doi:10.1093/iob/obab034

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Shipwrecks under the microscope: feeding the deep

The sediment of the deep sea is one of the largest ecosystems on the planet and also one of the least explored. The lack of light, high pressure and low temperature mean that only specialised organisms can inhabit these areas. These include microbes, often relying on any form of sustenance they can get, and what starts as just a cluster can form the base of biodiverse communities. Examples of deep-sea microbial hotspots include the areas around whale carcasses, which have been reasonably well studied, and wooden-hulled shipwrecks, both of which provide nutrition, a safe place to hide and surfaces to be colonised. However, the sites of shipwrecks have rarely been examined under the microscope. Justyna Hampel and colleagues from the University of Southern Mississippi, USA, and the US Bureau of Ocean Management examined two wooden-hulled deep-sea shipwrecks in the northern Gulf of Mexico: one relatively shallow (∼525 m) and one deep (∼1800 m), both from the late 19th century.

To describe the microbial ecosystems in the sediment surrounding the two historic sites, the authors used a remotely operated vehicle to take samples of the sediment at distances from 4 to 60 m along and out from each wreck. The team then extracted and sequenced DNA from any organisms that they collected in the sediment cores to find out what lifeforms were there. Finally, they analysed the differences between the microbial communities at the two shipwreck sites.

The team found the greatest microbiome diversity at the site of each shipwreck, decreasing the farther they moved away from it. They also discovered that the shipwrecks have a larger than expected influence on the local microbiology, with distinctive and unique core microbiomes at the two wreck sites. In addition, the presence of the shipwreck changed the availability of nearby tasty elements, such as nitrogen and carbon, that microbes can convert into food for larger organisms. However, the two wrecks affected the seabed in their respective areas in different ways, and the scientists think that this is largely due to differences in shipwreck depth, as well as their proximity to the mouth of the Mississippi river (∼30 km and ∼100 km), washing nutritious material from the land out to sea. Essentially, shipwrecks play a role in supplying deep-sea ecosystems with sustenance to an extent similar to that of other dead material from above, such as whale carcasses.

The authors conclude that wooden shipwrecks not only serve to provide refuge and surfaces for organisms to colonise but also are a significant and long-term source of the building blocks upon which diversity can flourish in a setting short of nutrients and far from the shore. Recent surveys of the seafloor in this area of the Gulf of Mexico have identified what appear to be many more nearby shipwrecks with depths in excess of 1000 m that have yet to be surveyed. These unexplored and unidentified sites can undoubtedly tell us more about the ecology of deep-sea microbes and how the arrival of structures made by humans changes the microbial diversity and composition of the seafloor.

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Hampel, J. J., Moseley, R. D., Mugge, R. L., Ray, A., Damour, M., Jones, D. and Hamdan, L. J. (2022). Deep-sea wooden shipwrecks influence sediment microbiome diversity. *Limnol. Oceanogr.* **9999**, 1-16. doi:10.1002/lno.12008

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