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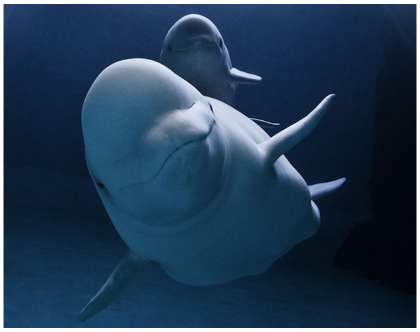
INSIDE JEB

Belugas' SCUBA tanks better primed at birth



Beluga mother and calf. Photo credit: Shedd Aquarium/Brenna Hernandez.

In the icy waters of the Arctic Ocean, a beluga mother gently noses her newborn to the surface for its first breath. These ocean-going mammals are as dependent on air as we are, and must visit the surface regularly throughout their lives. However, many young cetaceans lack the full range of physiological adaptations essential for long duration dives. Adult marine mammals usually have high levels of the oxygen-carrying protein myoglobin in their muscles, which act like a SCUBA tank carrying oxygen that can be released gradually during the course of a dive. In addition, they also have the capacity to neutralise lactic acid released into the muscle when they exhaust their oxygen supply and switch to anaerobic respiration. 'For bottlenose dolphins it takes up to 3 years for the muscle biochemistry for diving to be fully mature', says Shawn Noren, from the University of California, Santa Cruz, USA. Yet from an early age, baby belugas must follow their mothers under the sea ice, where air holes are transient and scarce. Could the youngsters develop the essential physical adaptations that would permit them to navigate for lengthy periods beneath the ice at an earlier age than other marine mammals?

Intrigued, Noren and Robert Suydam, from the Alaskan Department of Wildlife Management, collected muscle samples from belugas – from a full-term foetus to mature adults – that had died from natural causes and as part of the Point Lay community annual beluga subsistence hunt in the Chukchi Sea. 'This collaboration allowed us to obtain sufficient samples within one season', explains Noren.

Once all of the samples had been assembled, she measured their myoglobin concentrations. Interestingly, the myoglobin concentration in the muscle of newborn beluga calves [1.56 g (100 g wet muscle)$^{-1}$] was higher than that of other newborn cetaceans [0.13–1.3 g (100 g wet muscle)$^{-1}$], making belugas better prepared for diving at birth than other species. However, when Noren turned to the samples collected from older calves, she was astonished to see that their myoglobin levels had rocketed and were similar to those of fully grown adults. 'During the first year, the amount of myoglobin per 100 g of muscle increased by 452%, and mature levels are achieved by 14 months after birth', she exclaims. Noren also calculated the amount of oxygen that each animal could carry and then used the value to calculate the maximum dive length and depth that they could sustain. Impressively, both the dive length and depth increased dramatically over the first year of life, from 3.6 min and 216 m at birth to 8.54 min and 512 m – in contrast to fully grown adults (>10 years) that perform dives of up to 14 min and can reach depths of 812 m. However, the youngsters' ability to neutralise acid produced by anaerobic respiration wasn't much greater than that of other young cetaceans.

'Baby marine mammals are not just small versions of adult marine mammals', says Noren, who suspects that the rapid maturation of the calves' diving physiology is driven by the necessity that they accompany their mothers beneath sea ice from an early age. However, she is concerned that the retreat of the sea ice at the North Pole could place these animals under increasing stress. 'As sea-ice recedes further offshore, cod – which is an important prey of belugas – will follow, because cod prefer living near the ice edge and the belugas may follow. Indeed, there is evidence that when sea-ice cover is low, belugas are further offshore. This range shift may be problematic for immature belugas and females with calves that prefer nearshore habitats and are disadvantaged when competing for resources with larger animals that have greater dive capacities', Noren explains.

10.1242/jeb.149062

Noren, S. R. and Suydam, R. (2016). Navigating under sea ice promotes rapid maturation of diving physiology and performance in beluga whales. *J. Exp. Biol.* **219**, 2828-2836.

Kathryn Knight

Shoaling soothes damselfish

Chromis viridis on the Great Barrier Reef, Australia. Photo credit: Amy Cox.

Glinting beneath tropical balmy waters, the Great Barrier Reef is one of the brightest shows on earth. With shimmering shoals of iridescent fish ceaselessly darting between glimmering coral edifices, the spectacle is enchanting. 'The complexity of interactions between animals out on the reef is really amazing', says Lauren Nadler from James Cook University, Australia, who is intrigued by the factors that drive fish to form shoals. 'I had heard whispers and read some anecdotal evidence on this idea of a calming effect of living in a group. The rationale is that group-living may make individuals less fearful of threats, due to having "many eyes" to look for predators. This reduction in stress may allow fish to reduce their overall basic energetic needs', says Nadler. However, no one had succeeded in measuring the metabolic

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rates of individual fish in the midst of a shoal. 'There have been studies that looked at how the group as a whole is changing in terms of their overall energy demands, but they have not been able to get at that individual change', says Nadler.

After discussing the challenge of how to simulate the conditions experienced by individual damselfish without letting them directly interact with the other members of the shoal with Philip Munday, Mark McCormick and Shaun Killen, Nadler began developing a new respirometry approach. She started by placing a fish in a glass tube – which allowed her to measure their oxygen consumption – while immersing it in a tank surrounded by shoal-mates. The isolated fish remained calm so long as it could see and smell its chums; however, the fish's serenity vanished as soon the shoal-mates swam away. 'When the fish in the chamber couldn't follow, it would thrash around and make its metabolic rate increase', she recalls. The next time, she introduced a second chamber to ensure that the shoal remained in close proximity, allowing her to measure the oxygen consumption of an individual fish while surrounded by its shoal.

Having refined the details of the technique, Nadler tested the method on damselfish collected at the Lizard Island Research Station on the Barrier Reef. 'One of the things I wanted to do was make sure I was using fish that had already been living together in shoals, to ensure that I wasn't freaking them out by exposing them to strangers as opposed to friends', says Nadler. After using a barrier net to herd shoals together with Eva McClure and transporting the fish back to the lab, Nadler measured the metabolic rates of individuals in isolation and when surrounded by their shoal-mates, and saw an extraordinary 26% drop in metabolic rate, 'which is really quite a lot', she says understatedly. The fish were certainly soothed when surrounded by friends in a shoal. And when Nadler kept individuals in solitary confinement for several weeks, the strain was evident as they initially lost weight. However, after a fortnight, their condition stabilised, and when Nadler checked the metabolic rates of these isolated fish, she found the same impressive drop in metabolic rate when they were reintroduced to their shoal.

Converting the enormous energy savings gained from living in a shoal into practical benefits, Nadler explains, 'They have extra energy for all sorts of things; they can go out and find mates and reproduce and they have more energy to grow, and these are all processes that are going to help them to survive and do really well out on the reef and pass their genes on to the next generation of fish'.

10.1242/jeb.149070

Nadler, L. E., Killen, S. S., McClure, E. C., Munday, P. L. and McCormick, M. I. (2016). Shoaling reduces metabolic rate in a gregarious coral reef fish species. *J. Exp. Biol.* **219**, 2802-2805.

Kathryn Knight

Ants discover inner junkie

Campanotus floridanus. Photo credit: Marc Seid.

Viewed from a great height as we scurry about, it can be hard to tell the difference between human and ant societies. We both live in highly organised communities surrounded by architectural structures where each individual has a well-defined role. However, Brian Entler and colleagues, from The University of Scranton, USA, wondered whether we may also share a darker side to our characters. The team explains that some insects are capable of forming addictions if the drug is delivered simultaneously with food, teaching us essential lessons about the neurobiology of addiction. However, humans have the ability to become addicted to drugs that provide pleasure alone, and no other species seem to be able to develop such an addiction without the added temptation of food. Knowing that ants are keen to scurry around searching for titbits even if their escapades are unsuccessful, Entler, John Cannon and Marc Seid wondered whether the highly motivated insects could get hooked on a life of self-administered drug dependency.

Tempting Florida carpenter ants to visit a feeder full of tasty sugar solution, Entler gradually removed the sugar while simultaneously increasing the concentration of highly addictive morphine over a 6-day period in a bid to get them hooked. Initially, the ants lost interest in the feeders as the sugar concentration declined; however, once the insects were completely weaned off the sugar and only the morphine remained, the ants' interest in the feeder was rekindled. And when Entler offered the ants a choice of snacks – a feeder full of tasty sugar solution versus another containing the drug – their preferences were abundantly clear as they headed for the morphine-laced feeder to feed their habit despite the lack of nutrition. However, when Entler offered ants that had never touched the drug the same option, they clearly sought out the sweet treat. The ants were certainly attracted to morphine, but were they getting the reward-seeking 'high' of true junkies or did they just prefer the taste of morphine water?

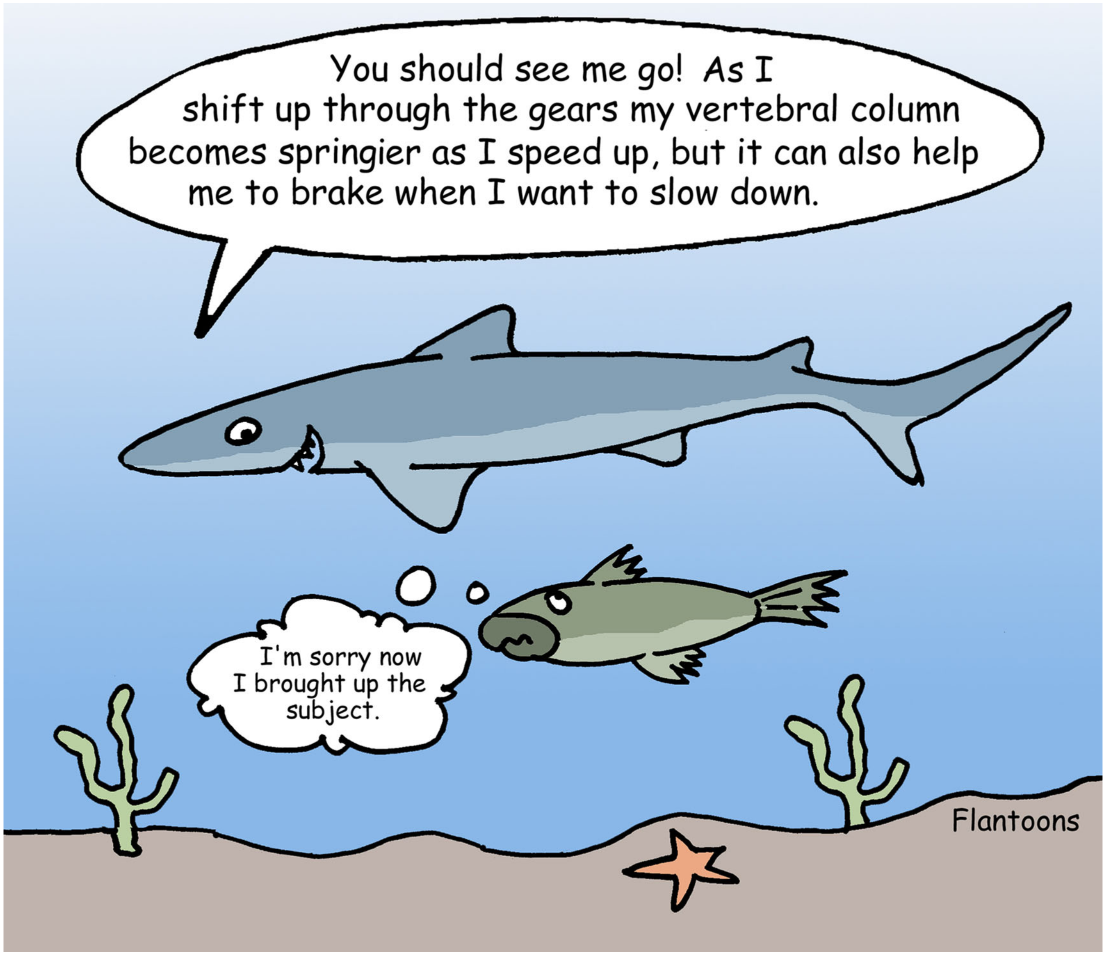
To answer the question, Entler analysed the ants' brains to find out whether they were producing any of the tell-tale neurotransmitters that indicate addiction, and found that the morphine-fed ants had higher levels of dopamine, which directs reward-seeking behaviour: the ants were true junkies. 'This study establishes ants as the first non-mammalian model of self-administration that is truly analogous to mammals', says the team, who are keen to begin untangling the basic neural circuits that drive drug addiction in ants and probably humans.

10.1242/jeb.149047

Entler, B. V., Cannon, J. T. and Seid, M. A. (2016). Morphine addiction in ants: a new model for self-administration and neurochemical analysis. *J. Exp. Biol.* **219**, 2865-2869.

Kathryn Knight

Shark's spring-loaded vertebral column provides continuous variable power transmission



At the core of the shark's hypnotic swimming motion, there is an elastic secret. Marianne Porter, from Florida Atlantic University, USA, explains that the fish's cartilaginous skeleton allows energy to be stored in the vertebrae as the vertebral column bends, compressing the bulky centra structures that stack together to build the spinal column. This energy is then released at the end of a tailbeat to power them on their way. According to Porter, the elastic vertebral column could store and release as much as 10% of the shark's energy, providing a substantial advantage over the rigid skeletons of bony fishes. However, Porter and colleagues Randy Ewoldt and John Long suspected that shark spinal columns were more than simple springs because of their complex material properties; '[the vertebral column] is a composite of different materials', they say. So they decided to investigate how sections of the vertebral column (comprising 9 or 10 vertebrae) from spiny dogfish (*Squalus acanthias*) exert force as the team systematically wiggled them to and fro over realistic swimming curvatures and tailbeat frequencies ranging from one tailbeat every 4 s to two tailbeats per second.

Measuring the displacement of the section of spinal column as it flexed and the force exerted at the end, the trio was then able to calculate how the stiffness of the vertebral column (energy storage) and energy dissipation (braking power) varied. 'Based on its mechanical behaviour, the vertebral column may serve as both a spring and a brake', say Porter and colleagues.

They suspect that the shark's remarkably elastic spinal column may become more springy to provide more propulsion as the animal increases speed, while increasing braking power as the shark continues beating the tail over a wide amplitude but at a slower rate when slowing down. And the team suggests that the vertebral column's unique combination of material properties provides 'continuous variable power transmission' to smoothly power sharks on their way.

10.1242/jeb.149039

Porter, M. E., Ewoldt, R. H. and Long, J. H., Jr (2016). Automatic control: the vertebral column of dogfish sharks behaves as a continuously variable transmission with smoothly shifting functions. *J. Exp. Biol.* **219**, 2908-2919.

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