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Muscular Modulation (p. 2627)

Complicated vertebrates have networks of neurons that interact directly with groups of muscle fibres. Simpler invertebrates have fewer neurons yet manage to perform complex gymnastics by modulating the nerve signals that are sent to muscle tissue. They do this through a specialised type of neuron that releases modulator peptides. The peptides modulate the message by altering the release of neurotransmitter at the synapse and by making the muscle cell more or less responsive when it receives the message.

Proctolin is a modulator peptide that is released by a neuron that affects the dorsal muscles of *Idotea emarginata*. Proctolin was already known to modulate muscle contraction by triggering a phosphorylation cascade that opened calcium channels. But Sabine Kreissl and her colleagues in Konstanz suspected that proctolin might also mediate a response at the level of the contractile machinery. She set out to investigate.

Kreissl used muscular stimulation with caffeine to look for the effect of proctolin on muscle contraction. Sure enough, proctolin enhanced the contraction. Knowing that the proctolin receptor activated a kinase cascade, she looked for phosphorylated muscle proteins. She found that a 30 kDa protein from the muscle's thin filament became phosphorylated in response to proctolin stimulation. Although she hasn't sequenced the protein yet, it seems likely that it is Troponin I. Troponin I isn't just any old muscle protein, this is a key part of the contraction machinery's inhibitory mechanism.

For a muscle to contract, two muscle proteins – actin and myosin – must interact before myosin hydrolyses ATP and drives the contraction. Troponin I inhibits contraction by binding to actin and disrupting ATP hydrolysis. An increase in calcium levels in the cell releases the inhibiting Troponin I, and muscle contraction begins. Of course it's tempting to think that the proctolin-induced phosphorylation of Troponin I enhances invertebrate muscle contraction. However, that is pure speculation.

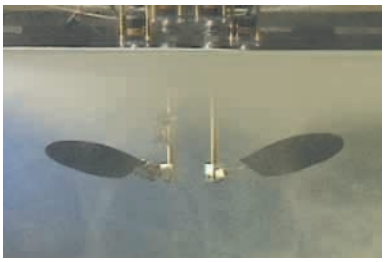
Toxic Lock-out (p. 2699)

Drosophila melanogaster is one of the most flexible organisms on the planet, setting up shop in pretty much every environment occupied by man, and a few more besides. The reason they are everywhere is that they have incredible powers of adaptation, which allows them to relieve population pressure by moving to new territory and exploiting new food resources. Of course, this puts them in a special place in the hearts of scientists, because faced with a challenge the flies rise to it. Take away their water, put them some where hot, or even stick them in a toxic swamp, and they'll patch together some bag of tricks so they can muddle along.

Urea is a toxin that humans deal with naturally every day of their lives, but to *Drosophila* it's a completely foreign compound. In the larval stage, *Drosophila* excrete ammonia, and after pupation the adults produce uric acid. Valerie Pierce wondered how *Drosophila* larvae would adapt if they were raised on lethal levels of urea. She realised that there are three alternative approaches that they could take. One could be to adapt their transport mechanisms so that they failed to absorb urea from the environment. Alternatively they could take one of their existing metabolic pathways and modify it to metabolise urea. The third scenario she imagined was that the larvae could have a dormant urea excretory mechanism, left over from a previous era, which they could reactivate when the need arose.

Fortunately for her, a colony of flies had been bred in the 1990s that thrived on 300 mmol l^{-1} urea. She cross-reared colonies and tested them for urea uptake, metabolism and excretion, searching for which of the three approaches the larvae had adopted. Her search for urea metabolic activity failed to find any enzymes that naturally detoxified urea, so they hadn't modified an existing pathway to their own needs. When she tested their urea excretion rates, she found that they were even lower than the wild-type larvae. That only left the third option, that they had closed the uptake channels and didn't absorb urea even when it was at high levels in the environment.

A side effect of living on urea is that these larvae seem to develop a little slower and are a touch on the small side, but they survive. The growth impairment seems to suggest that they are limited in uptake of some other nutrients. Urea isn't naturally soluble in membranes, so the most likely way the larvae could absorb it would be through other transporters such as those that allow uptake of sugars and other nourishment. Wild type *Drosophila* must be absorbing urea *via* a transporter, but when Pierce searched the *Drosophila* genome, she couldn't find a single urea-specific transporter homologue, so the urea is crossing the cell wall through a non-specific transporter. The urea-resistant larvae have sealed that route to exclude urea uptake, so the larvae are trading off poorer nutrition in favour of survival in a toxic environment. But which transporter and what mechanism… well, that's another story.



Is it a Bird? Is it a Plane? No, it's Robofly! (p. 2607)

Man has always been fascinated by the idea of flight but it is less than 100 years since the Wright brothers achieved this dream and took to the air. Some of the early flying machines designed in the 1900s tried to mimic the natural flight of birds, but they failed abysmally because the physics that gets birds off the ground was not understood. The aerodynamics of bird-flight has since been well studied, but the mechanics of insect flight has remained a mystery. 'Flapping insect flight is an open question because insects are small and flap their wings rapidly so it is difficult to directly measure the aerodynamic forces on their wings', says Sanjay Sane of U.C. Berkeley. This is now set to change, thanks to a dedicated band of biomechanists that include Sane and his colleague Michael Dickinson.

Early fly-aerodynamic studies focused on tethered flies, but they yielded the net force exerted on the body. It was almost impossible to untangle the individual force components, but Sane and Dickinson have overcome the problem by using a scaled up model of *Drosophila* that they use in complex flight simulations.

They programmed over 190 flight patterns into the fly-machine and measured the forces exerted at the hinge joint when the model simulates the wing beats of a hovering fly. The clever trick was to simulate the way the atmosphere feels to the tiny aeronaut. They found that immersing the mechanical wings in mineral oil reproduced the forces experienced by the real flies as they drag themselves through the atmosphere.

Work carried out in several 'flight' labs has identified three forces that are generated by insect flapping wings. They are called delayed stall, rotational circulation and wake capture. Delayed stall uses extra lift generated from a vortex on the leading edge of the wing just before it stalls. This is a game of brinkmanship, trading off the advantage of a lifting force briefly before it is lost. The second effect is found when the insect rotates its wing at the beginning or end of each stroke. When timed right, the effect gives good lift, but if the fly mistimes the rotation, the lift is lost. The third effect happens when the fly moves its wing back into the air that is trailing in its wake. Because the air is already moving, this increases the force acting on the wing. So the results are two types of force generation that rely on rotation and one that is due to the wing translating back and forth. The fly's incredible agility is based on juggling a mixture of these three effects.

Sane and Dickinson have developed a series of maps based on the mechanical simulations, where they have parameterised the forces exerted on the wing as it is swept through the oil. They intend to use these maps to predict the forces exerted on a wing as it moves on a particular trajectory. That will allow them to identify which type of lift the fly is generating when it mixes and matches different strokes, allowing Sane and Dickinson to integrate these data into a unified theory of *Drosophila* flight.

No Pain – No Gain! (p. 2683)

Anyone who's ever watched Marathon competitors limp away from the finish line will have some idea of the pain that they are in. Even the fittest and most seasoned athletes will feel the muscle damage for days after crossing the finishing line. But, our human efforts pale into insignificance against the annual trek that the Bar-tailed Godwit embarks on every year. These birds set out from their wintering grounds in West Africa, and migrate north, in a single leg, arriving in the Netherlands, almost 60 hours later. While in transit, they neither eat nor sleep and by the time they arrive, they have shrunk to half their body weight!

Birds extract much of their energy from fat stores, but unlike humans who satisfy sudden energy demands by metabolising carbohydrate, birds break down protein stores, including muscle tissue. So migrating birds face muscle loss from two sources, either through energy consumption or simple wear and tear due to exertion.

Picture provided by Jan van de Kam

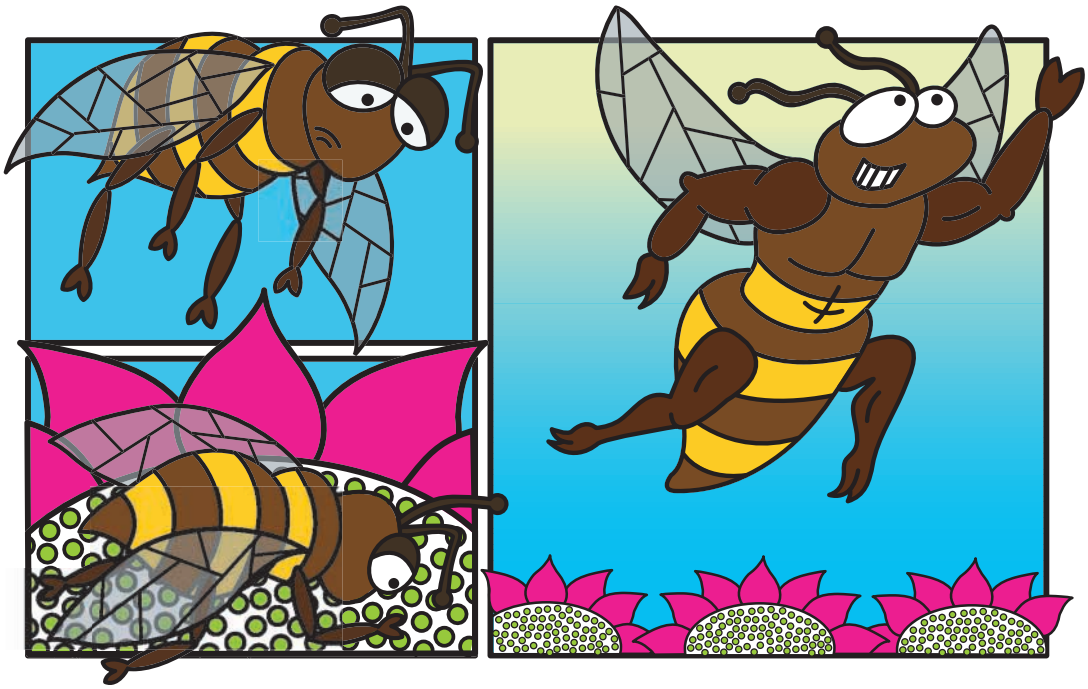
When Christopher Guglielmo set out to quantify the amount of muscle damage birds sustain on the marathon trek north, he thought 'their muscles would be all torn up'. He was hoping to index the amount of muscle damage so that he could use it as a way to estimate when a bird arrived from a long migration. But when he began to look at the physical state of two species that had recently arrived from their long haul flights, he was surprised by what he found.

The levels of muscle damage were unexpectedly low. When muscle becomes damaged by exercise, the membrane ruptures releasing cellular proteins into the blood. Guglielmo and colleagues measured the blood-levels of one of these proteins in godwits that had recently arrived from a long migration, and sandpipers that migrate in shorter hops. Sure enough, he was able to detect a muscle damage signature from the blood samples, and younger birds seemed to suffer more than hardier adults. He also found that the levels of muscle damage in birds decreased while they rested, suggesting that they repair the damaged tissue.

At first this would seem counterintuitive, but as Guglielmo says, 'when you think about it, maybe it's not so crazy, after all birds have been doing this for hundreds of thousands of years, and that's a lot of selection'. He also points out that the migration may be a form of natural selection too. After all, he was only able to measure muscle damage in the birds that survived their flight.

Although the amount of energy that an animal can supply will limit its endurance, there may be other factors, and the ability of muscle tissue to withstand wear and tear is probably one.

Kathryn Phillips



Sugar-charged Bees

Blatt, J. and Roces, F. (2001). Haemolymph sugar titers in foraging honey bees (*Apis mellifera carnica*): dependence on metabolic rate and *in vivo* measurement of maximal rates of trehalose synthesis. *J. Exp. Biol.* **204**, 2709–2716.