Inside JEB is a twice monthly feature, which highlights the key developments in the *Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

Inside JEB

BIONIC ANKLES CUT WALKING COSTS


Picture by Catherine Kinnaird

Walking is a very economical way to get around. We continually recycle mechanical energy through the course of each stride. But no one had ever succeeded in measuring the metabolic energy used to move individual joints as we perambulate. Which is where Daniel Ferris's bionic boots step in. Initially designed to aid the rehabilitation of spinal injury patients, Ferris was curious to see if his neurally controlled robot boots could reduce the metabolic cost of walking by doing some of the ankle muscles' work. Teaming up with Gregory Sawicki, Ferris put a team of robot-boot clad students through their paces to see if their bionic walk was more economical (p. 1402).

Sawicki admits that wearing the boots is amazing, and adds 'I'd buy a pair if I could, but they're not going to be in the stores any time soon'. Powered by a pneumatic artificial muscle behind the leg which helps push the foot off the ground, the boot's movements are controlled directly by electrical activity from one of the wearer's calf muscles; the robots are directly controlled by the wearer's own central nervous system. According to Sawicki, it only took a few sessions before the wearers got used to using their ankle assistants and he could start collecting data.

Filming each walker, so that he could be sure that wearing the ankle robots hadn't changed their gait, Sawicki first measured their metabolic rate as they sauntered along wearing the unpowered boots. Then, he activated the boots and remeasured their metabolic rate while recording the mechanical work done by the robot's pneumatic muscle as it assisted the walker's calf muscles to push the foot off.

Initially, when the walkers put on the boots, their metabolic rate increased because they had to adjust to walking with the artificial muscles' assistance. However, as the students got used to their bionic footwear their metabolic rate dropped by 10%. The boots had made walking easier. 'You really notice when they're not there, your legs feel really heavy' says Sawicki.

Next, Sawicki used the robotic boots to measure the ankle's mechanical efficiency based on the work done by the pneumatic muscle, and realised it was almost 3 times greater than the team had expected. They suspect that instead of being powered by muscular contraction, the energy required to extend the ankle joint and push the foot off is supplied by the enormously springy Achilles' tendon, which stores energy from earlier in the stride cycle.

Having made the first measurements of mechanical efficiency in a human joint and found that we're even more efficient than they'd expected, Sawicki and Ferris are keen to learn more about individual muscles' contributions to walking by adapting the remarkable bionic boots to fit hips and knees.

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Sawicki, G. S. and Ferris, D. P. (2008). Mechanics and energetics of level walking with powered ankle exoskeletons. *J. Exp. Biol.* **211**, 1402-1413.

DIVISION OF LABOUR IN GOLDFISH METABOLIC REMODELLING

Mitochondria are the tiny cellular energy factories, fuelled by fats and sugars, which produce the ATP that powers most life on our planet. And when animals' metabolic demands increase, their mitochondrial levels rise to satisfy their increasing ATP demands. Chris Moyes, from Queen's University, Canada, explains that the key molecular components that control mitochondrial levels in mammals are well understood, but how mitochondrial proliferation is regulated in lower vertebrates was less clear. According to Moyes, the PPAR gamma coactivator (PGC-1) family of proteins are the 'master regulators' of mitochondrial synthesis in mammals. They work in conjunction with other transcription factors, such as NRF-1 to control mitochondrial gene expression, and PPAR to regulate the mitochondrion's fuel choice. Teaming up with Christophe LeMoine and Christine Genge, Moyes decided to find out whether PGC-1α and PGC1-β are also key players in the metabolic remodelling of a more 'comparative' model; the goldfish (p. 1448).

According to Moyes, fish respond to cold in the same way that animals respond to endurance training; their mitochondrial levels rise. So if he wanted to identify key cellular factors involved in mitochondrial proliferation during metabolic remodelling, all he'd have to do was maintain fish at different temperatures for several weeks as they adjusted their mitochondrial levels, and track the expression of remodelling related genes to identify the key transcriptional regulator. The goldfish was the obvious candidate, surviving temperatures that other model species can't tolerate.

Having kept the fish at 4, 20 and 35°C for 3 weeks, the team collected heart, muscle and liver samples and measured the mRNA levels of PGC-1α, PGC-1β, and the PPAR and NRF-1 transcription factors; key factors known to be involved in mammalian mitochondrial synthesis. LeMoine and Genge also measured the mRNA and enzyme activity levels of three major mitochondrial metabolic proteins (citrate synthase and two cytochrome oxidase subunits I and IV), to see if they correlated with PGC-1 expression levels.

But the team was in for a surprise. PGC-1α levels did not rise as mitochondrial gene expression increased in response to the cold; they plummeted. And when the team compared both PGC-1 transcript levels with the expression of mitochondrial genes and NRF-1 they found that PGC-1β was the protein regulating mitochondrial synthesis. So PGC-1β, and not PGC-1α, is the master regulator of mitochondrial synthesis in goldfish.

Knowing that animals also remodel mitochondria depending on which fuel they consume, the team fed fish on high fat, low fat and restricted diets to see how PGC1 regulated mitochondrial gene expression. This time PGC1α levels rose in line with the PPAR transcription factor, which regulates fat metabolism, suggesting that PGC1α has a role in setting the mitochondria's fuel preference.

So, unlike mammals, where metabolic remodelling is controlled by the PGC-1α master regulator, fish have opted for a division of labour scheme, with individual PGC-1 proteins responsible for different aspects of the remodelling response to altered metabolic demands.

10.1242/jeb.019174

LeMoine, C. M. R., Genge, C. E. and Moyes, C. D. (2008). Role of the PGC-1 family in the metabolic adaptation of goldfish to diet and temperature. *J. Exp. Biol.* **211**, 1448-1455.

RETINA PROCESSES UV POLARIZATION INFORMATION


Picture by Craig Hawryshyn

Humans tend to be a self-obsessed lot. We have problems imagining how other creatures see the world. So, when Craig Hawryshyn and Jim Bowmaker announced independently in the early 1980s that fish see ultraviolet (UV) wavelengths, 'the observation was met with some surprise' says Hawryshyn. However, 30 years on the tables have turned. Biologists have accepted that some vertebrates see not only UV but polarization too. But why have these creatures invested in visual systems that we lack? Hawryshyn explains that there is a strong selective pressure for UV and polarized light vision. While colour can be affected by environmental and atmospheric conditions, UV polarization remains stable beneath water or in shady conditions. Having established that UV and polarized light vision are standard for some fish, Hawryshyn is keen to understand the complex neural networks that deliver polarized light information from the retina to the central nervous system, starting with the retina (p. 1376).

Teaming up with Samuel Ramsden, Leslie Anderson and Martina Mussi, Hawryshyn began recording the electric signals generated in the retina and optic nerve as the researchers shone flashes of polarized light into a trout's eye. Changing the angle of the polarized light, Ramsden recorded the retina and optic nerve's electric activity, expecting to see similar activities in both tissues.

But when Ramsden appeared in Hawryshyn's office with both electric traces, Hawryshyn was in for a shock. They were different. The electric activity in the optic nerve showed two peaks of activity, one when the light was vertically polarized at 0°/180° and the second when the flash was horizontally polarized at 90°/270°, but two extra polarization sensitivity peaks had appeared at 45° and 135° in the retina's trace. Hawryshyn already knew that the fish's longwave cones responded to horizontal polarization and the UV cones responded to vertical polarization, but which cells were causing the 45° and 135° sensitivities, and how were they doing it?

Hawryshyn and Ramsden suspected that the extra peaks may be generated by feedback so they reduced the fish's sensitivity to horizontal polarization by exposing the retina to longwave light and checked to see how the fish responded to 45° and 135° polarized light. The 45° and 135° sensitivity peaks shifted. And when they reduced the retina's vertical polarization sensitivity with UV light, the peaks shifted again, but in the opposite direction. There was feedback between the cones, but which cells were generating the feedback?

Calling up his long time collaborator Maarten Kamermans in Amsterdam, Hawryshyn described his unexpected results. Kamermans suggested repeating the electrical recordings while varying the polarization, but this time switching off the negative feedback on cones with cobalt chloride to see if the horizontal cells were the source of the mysterious peaks. Ramsden and Hawryshyn were amazed when the 45° and 135° peaks vanished. The horizontal cells were responsible for the intermediate peaks.

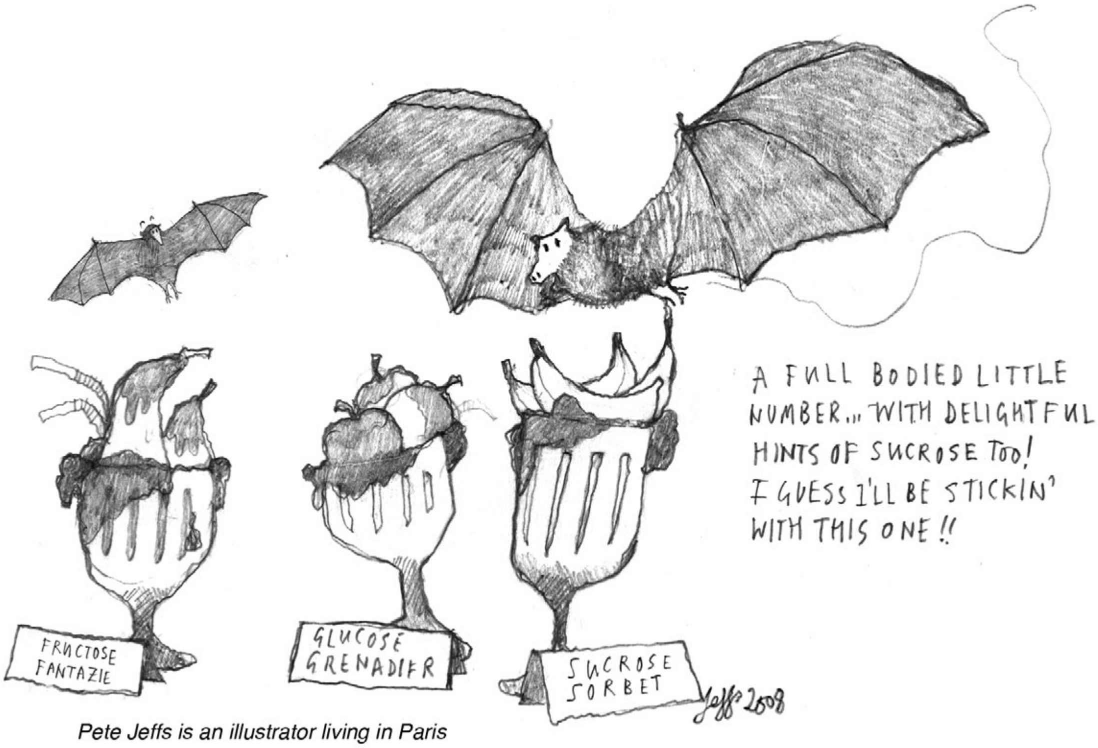
But why is horizontal cell feedback on cones activated so strongly when the polarization is 45°? Hawryshyn explains that at planes of polarization close to 45°, the cones that respond to horizontal and vertical polarization are stimulated almost equally, generating strong negative feedback and electric activity in the horizontal cells.

Having found that some of the earliest cells in the visual neural network are involved in processing polarized light sensory information, Hawryshyn is keen to find out more about the retina's role in polarized light vision.

10.1242/jeb.019158

Ramsden, S. D., Anderson, L., Mussi, M., Kamermans, M. and Hawryshyn, C. W. (2008). Retinal processing and opponent mechanisms mediating ultraviolet polarization sensitivity in rainbow trout (*Oncorhynchus mykiss*). *J. Exp. Biol.* **211**, 1376-1385.

ALCOHOL IS A NECESSARY EVIL FOR BATS



Pete Jeffs is an illustrator living in Paris

While some species may find the ingestion of alcohol relatively pleasant, ethanol is still a potent toxin. But for species that rely on fruit for sustenance, it is a necessary evil. According to Francisco Sánchez and colleagues from Ben-Gurion University of the Negev, the toxic effects of alcohol can be minimised if consumed with food containing natural sugars such as fructose, sucrose and glucose. As these sugars occur naturally in fruits, Sánchez and his colleagues decided to test how they affected the rate of alcohol elimination in the bat's breath. Giving Egyptian fruit bats food containing a shot of ethanol mixed with one of the three sugars, the team monitored the bat's breath alcohol content and found that the ethanol levels dropped fastest when it was ingested with fructose; the bats removed alcohol from their systems fastest when mixed with fructose (p. 1475).

The team also decided to investigate how the bats' perception of the foods' value changed when alcohol was added by measuring the amount of food left after a night's foraging. As the alcohol level was increased, the bats left less food containing sucrose than food containing the other two sugars; the value of sucrose consumed in the presence of alcohol increased more than the two other sugars' values, and the value of fructose increased more than that of glucose. So both fructose and sucrose are 'complementary' to ethanol, contributing more to the bat's fitness when consumed together than when consumed individually.

10.1242/jeb.019182

Sánchez, F., Kotler, B. P., Korine, C. and Pinshow, B. (2008). Sugars are complementary resources to ethanol in foods consumed by Egyptian fruit bats. *J. Exp. Biol.* **211**, 1475-1481.

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