Inside JEB 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

SLEEP-DEPRIVED BEES HAVE DIFFICULTY RELEARNING

Everyone feels refreshed after a good night's sleep, but sleep does more than just rejuvenate, it can also consolidate memories. 'The rapid eye movement form of sleep and slow wave sleep are involved in cognitive forms of memory such as learning motor skills and consciously accessible memory', explains Randolf Mezel from the Freie Universtät Berlin, Germany. According to Menzel, the concept that something during sleep reactivates a memory for consolidation is a basic theory in sleep research. However, the human brain is far too complex to begin dissecting the intricate neurocircuits that underpin our memories, which is why Menzel has spent the last four decades working with honey bees: they are easy to train, well motivated and it is possible to identify the miniaturised circuits that control specific behaviours in their tiny brains. Intrigued by the role of sleep in memory consolidation and knowing that a bee is sleeping well when its antennae are relaxed and collapsed down, Menzel decided to focus on the role of sleep in one key memory characteristic: relearning (p. 3981). The challenge that Menzel set the bees was to learn a new route home after being displaced from a familiar path.

Menzel and his colleague Lisa Beyaert provided a hive with a well-stocked feeder and trained the bees to visit the feeder and return home fully laden. Then, when the duo were convinced that the bees had memorized the routine, they cunningly intercepted the bees at the feeder and transported them to a new location before releasing the insects to find their way home. According to Menzel, foragers learn the general lay of the land as novices before specialising in a few well-travelled routes later in their careers. He explains that the displaced bees had to rely on their earlier experiences to learn their new way home. How would loss of sleep affect the bee's ability to learn the new route? To determine this, Menzel and Beyeart first had to check that the bees could learn the new route and that sleep deprivation hadn't made them too tired or altered their motivation to forage.

Teaming up with electrical engineer Uwe Greggers, Menzel kitted the bees out with tiny RADAR transponders; the RADAR technology was particularly demanding to operate. Tracking the insects' progress as they tried to learn the alternative route home, Menzel and his colleagues saw that by the second run home, the displaced bees had learned the new route. And when the trio disturbed the insects' sleep during the night before the initial displacement by shaking them awake every 5 min, they found that the bees were unfazed. In fact they didn't seem to need sleep to maintain their foraging energy levels and the foragers that were deprived of sleep before the first displacement run had no problems learning the new route home.

However, when the team disrupted the bees' sleep after they had allowed the bees a single run along the new displaced route, the lack of sleep played havoc with their memories on the following day. Fewer than half of the sleep-deprived foragers made it home successfully, and those that did took more than twice as long as bees that had enjoyed an uninterrupted night's sleep.

Sleep deprivation had dramatically affected the bees' ability to alter a well-established memory and the team is now keen to see whether they can identify characteristic activity patterns in the slumbering insects' brains that could represent memory formation.

10.1242/jeb.081307

Beyaert, L., Greggers, U. and Menzel, R. (2012). Honeybees consolidate navigation memory during sleep. *J. Exp. Biol.* **215**, 3981-3988.

Kathryn Knight

TREE FROGS CLEAN STICKY FEET BY WALKING

Developing a self-cleaning adhesive is one of the adhesive industry's Holy Grails. 'If you think about a piece of sticky tape or some sort of glue, you can't reuse it and if you get a bit of dirt on it, it doesn't work anymore', says Niall Crawford from the University of Glasgow, UK. But nature invented self-cleaning adhesives aeons before humans began bonding objects together. Explaining that animals have evolved two different attachment systems – wet and dry – Crawford points out that sticky tape is most analogous to the smooth wet attachment systems employed by some insects and tree frogs. Yet tree frogs' sticky toe pads remain clean after thousands of


Thomas Endlein

uses while sticky tape is useless after one. Explaining that grooming isn't an option for tree frogs clinging to precarious surfaces with their sticky toes, Crawford and his colleagues Thomas Endlein and Jon Barnes decided to find out whether the simple act of walking is sufficient to clean their toe pads (p. 3965).

First the team tested how well contaminated and uncontaminated White's tree frogs clung to a glass plate as they rotated it from horizontal, through vertical to upside down. Explaining that the frogs tended to want to jump off when they began to feel insecure, Crawford and Endlein gently encouraged the frogs to hold tight by shielding them with their hands and caught them when the plate became too steep and the frog's hold failed. Monitoring the plate's angle, the team found that the frogs with uncontaminated feet only began to slip as the plate tipped over (106 deg) and finally lost their grip at 142 deg. However, when they dusted the frog's feet with microscopic glass beads, the animals began slipping soon after the glass plate began to tilt. They had lost adhesion, so how could they recover?

Knowing that dry-footed geckos and wet-footed insects shuck dirt from their feet while walking, the team set out to determine whether tree frogs use the same approach. Holding a tree frog on a computer-controlled stage and carefully applying a single layer of glass beads to one of its toe pads, Crawford and Endlein carefully pressed the contaminated toe onto a glass coverslip and then pulled it free. Measuring the adhesion force as they pulled the frog away, they found that it had fallen to zero: the frog was completely incapable of clinging on to the smooth surface with its contaminated feet. The situation hardly improved after the duo repeated the manoeuvre multiple times and when they checked the coverslip surface they saw that barely any of the beads had been shed from the amphibian's foot. Simply dabbing the toe onto a surface was not sufficient to clean it.

However, when they simulated real tree frog footsteps, by gently dragging the toe pad sideways after contact with the coverslip, the situation was completely different. Over the course of eight simulated footsteps the toe pad gradually recovered adhesion, slowly at first (only recovering 20% of adhesion after the first five steps) but returning to normal by the final contact. In addition, when the team checked the cover slip at the end of each toe pad step, they found large numbers of beads deposited on the surface.

So the keys to the tree frog's self-cleaning success are the sliding motion – which shears particles away from the toe pad and increases the contact area with the surface – and the sticky mucous secretions – which help flush away contaminants – although Crawford suspects that it will be a while before the adhesive industry successfully produces tree-frog-inspired sticky tape.

10.1242/jeb.081281

Crawford, N., Endlein, T. and Barnes, W. J. P. (2012). Self-cleaning in tree frog toe pads; a mechanism for recovering from contamination without the need for grooming. *J. Exp. Biol.* **215**, 3965-3972.

Kathryn Knight

CLIMBING GOBIES HAVE SMALL BUT POWERFUL SUCKERS


Takashi Maie

Scaling waterfalls through torrents of water would be an impressive feat for any creature, but for tiny juvenile gobies returning to their homes in the upper reaches of island streams, it's an inevitable rite of passage. Many goby larvae are washed out to sea soon after hatching, so species that reside in the upper reaches of streams have no choice but to scale obstacles in their path on the return journey. However, the youngsters are well prepared for this trial. They have a sucker formed from fused pelvic fins on their undersides that they use for climbing. Adult fish also face the risk of being washed downstream. However, they seem to climb less than youngsters. According to Takashi Maie from Clemson University, USA, the adults' suckers may not adhere strongly enough to support the larger fish's mass, as their suckers only increase in size in proportion to their body length, whereas their mass increases much more. Intrigued by this possibility, Maie realised that he would have to measure the adhesive pressure and sucker suction force from fish with different lifestyles and of different sizes to find out how their adhesion varies as they grow. Teaming up with Heiko Schoenfuss from St Cloud State University, USA, and Richard Blob from Clemson, Maie travelled to the Hilo field station of the Division of Aquatic Resources, Hawai‘i, to measure how tightly goby suckers fasten to surfaces (p. 3925).

Scrambling up waterfalls to the gobies' homes and donning wetsuits to snorkel and catch the fish, the trio successfully collected five species of climbing fish ranging in size from 0.1 to 15 g, in addition to one non-climbing species collected at low altitude. Back at the field station, the team gently anaesthetised the fish and lightly touched their suckers to a simulated climbing surface. The suckers immediately formed a seal and stuck on. Measuring the pressure in the cavity between the sucker and surface at inclinations ranging from 45 deg to over 90 deg and comparing the sucker sizes and adhesive forces between the two lifestyles (climbing and non-climbing), Maie and his colleagues noticed that the non-climbers' suckers increased in size much more rapidly than if they were growing in proportion to the rest of the body, whereas the climbers' suckers only grew in proportion of the rest of their bodies. The non-climbers' suckers were relatively large for their size.

Next the team measured the sucker's adhesion as the fish ascended waterfalls. After building a gently cascading simulated miniwaterfall, Maie drilled a hole in the surface, inserted a pressure transducer to measure the fish's adhesion and waited for the animals to pass over the pressure transducer as they ascended the slope. Comparing the climbers' suction force with the passive force that they had measured when the fish were anaesthetised, Maie realised that the active suction forces were more than twice as great as the passive, and were sufficient to bear more than twice the fish's mass. In contrast, the non-climbers' adhesion forces were much weaker than those of their climbing cousins, despite the relatively large size of their suckers. The team suspects that the non-climbers enlarged suckers may compensate for their weaker adhesion.

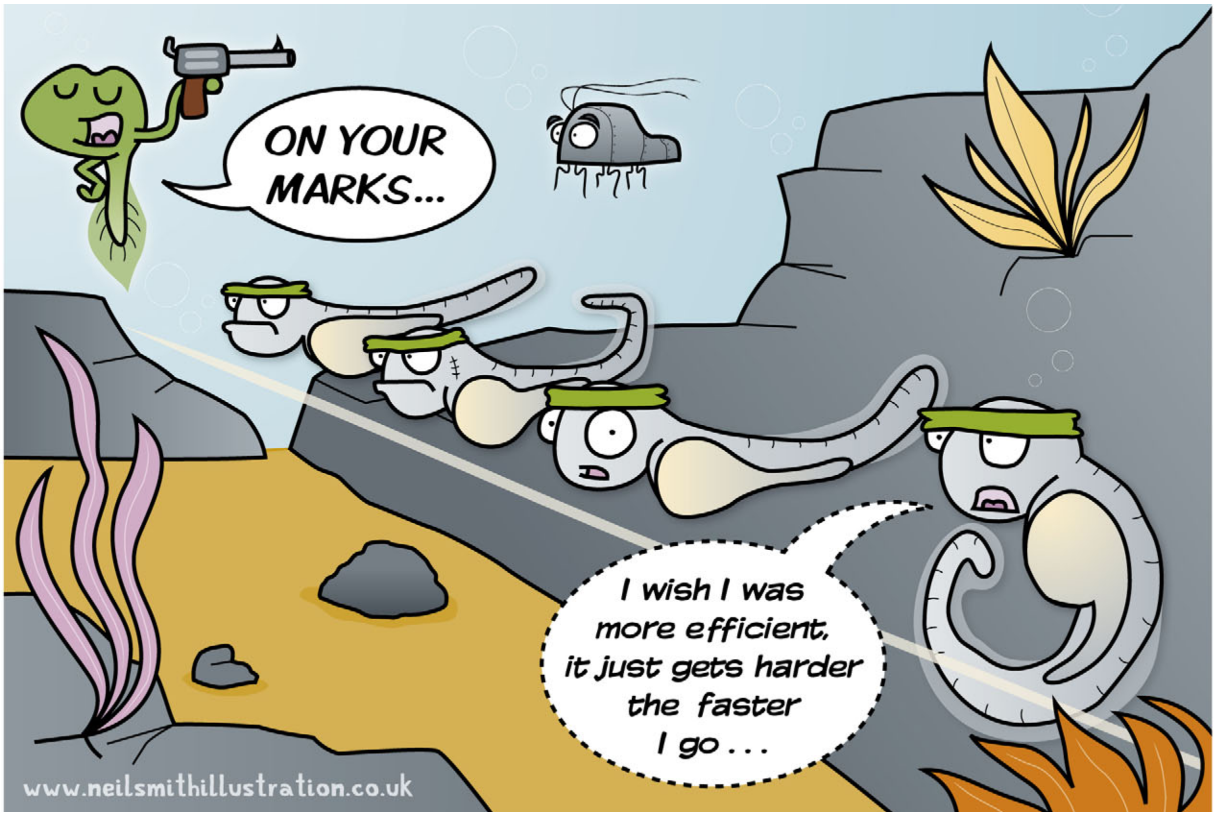
Having shown that climbing gobies have smaller suckers than their non-climbing cousins but that the climbers' suction is much stronger, Maie explains that the climbers actively expand their suckers while in contact with the surface to increase their suction, and he and his colleagues are keen to find out how the muscles and ray structures that support the sucker alter with age to help growing gobies get a grip.

10.1242/jeb.081273

Maie, T., Schoenfuss, H. L. and Blob, R. W. (2012). Performance and scaling of a novel locomotor structure: adhesive capacity of climbing gobiid fishes. *J. Exp. Biol.* **215**, 3925-3936.

Kathryn Knight

ZEBRAFISH LARVAE HAVE TO WORK HARDER TO SWIM FASTER



Sauntering along the road, it's hard to appreciate the complex interplay of forces that propel us along. And the situation becomes even more complex when trying to understand how fish swim. It is impossible to directly measure the forces that they exert on their surrounding fluid, which is why scientists have turned to vast and complex computational models to calculate how adult fish interact with their environment. However, no one had tried to tackle how tiny fish larvae propel themselves through water, which is relatively sticky on their diminutive scale. Working with collaborators from the Netherlands and the USA, Hao Liu from Chiba University, Japan, built a computational model that predicts the forces that propel the fish through water based on accurate measurements of the larvae's movements provided by Ulrike Müller (p. 4015). Simulating regular undulatory swimming and a specialised escape response, known as the C-start, the team were able to accurately reproduce the complex fluid flows produced by the fish in real life in their computational simulation and show that the larvae produce thrust with their rear ends. The team was also able to exaggerate the larvae's swimming style, simulating unnaturally large and small undulations, successfully reproducing how the tiny fish's speed increased. In addition, the team found that as the larvae's speed increased, the animals had to put in proportionately more effort – the mechanical power quadrupled – although their efficiency hardly improved, increasing their cost of transport dramatically.

10.1242/jeb.081299

Li, G., Müller, U. K., van Leeuwen, J. L. and Liu, H. (2012). Body dynamics and hydrodynamics of swimming fish larvae: a computational study. *J. Exp. Biol.* **215**, 4015-4033.

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