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

MULTIFOCAL LENSES COULD HELP SEALS SEE UNDERWATER

Frederike Hanke

We've all tried opening our eyes underwater, but for most of us the world becomes an unfocused blur without the benefit of goggles. However, this problem doesn't seem to affect seals and sea lions; they appear to see equally well whether diving beneath the waves or resting at the surface. Whether, or how, diving animals' eyesight has adjusted to both media has fascinated scientists for more than a century, but little progress had been made in understanding how seal vision works in both media. Intrigued by all aspects of harbour seal life, Guido Dehnhardt from the University of Rostock teamed up with Frederike Hanke from the University of Bochum to take a closer look at harbour seal eyes to find out how well the animals see above and beneath water (p. 3315).

Focusing on the seal's lens, Dehnhardt and Hanke decided to use a modern photorefractive technique to find out more about the animal's eyesight. Training two seals to climb onto a platform and plunge their heads into a tank of water, Hanke was able to collect infrared images produced by the lens on the retina, to see how it focuses light. Analysing the images, the duo were surprised to see that the lenses looked as if they might be multifocal. Hanke explains that Ronald Kröger at Lund University originally discovered multifocal lenses in the late 1990s in cichlid fish. The specialised lenses are usually found in creatures with colour vision, with each layer of the lens focusing a specific region of the optical spectrum to give animals sharp colour vision. However, the concentric rings in the infrared recordings from the seal eyes weren't clear-cut; Hanke needed more evidence to confirm that the lenses were multifocal.

Deciding to work directly with harbour seal lenses, Hanke travelled to Ursula Siebert's lab at the University of Kiel to be close to wild harbour seals. According to Hanke the German Seal Management Program closely monitors the health of newborn harbour seal pups on the Wadden Sea coast and attempts to rescue the weaker pups abandoned by their mothers. Unfortunately the intervention sometimes comes too late, so Hanke was on hand in Siebert's lab to collect the pups' lenses and test their refractive properties. Carefully extracting the lenses, Hanke used two methods to confirm that they were multifocal. In the first she shone a beam of white light through each lens and by filtering the light from the lens with a pinhole was able to produce an image of the lens with the telltale rainbow rings characteristic of a multifocal lens. In the second she scanned the lens with a laser while filming the position of the refracted beam of light as the laser moved across the lens, confirming that it was multifocal.

But why do harbour seals, which lack colour vision, have multifocal lenses? The team suspect that there could be two reasons. Either the lens could focus light in a way that provides the seals with some colour perception at low light levels, or the multifocal properties could improve the depth of focus in the animals' large eyes.

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Hanke, F. D., Kröger, R. H. H., Siebert, U. and Dehnhardt, G. (2008). Multifocal lenses in a monochromat: the harbour seal. *J. Exp. Bol.* **211**, 3315-3322.

STREAKER BEES STEER SWARM

It's one of the hallmarks of spring: a swarm of bees on the move. But how a swarm locates a new nest site when less than 5% of the community know the way remains a mystery. Curious to find out how swarms cooperate and are guided to their new homes, Tom Seeley, a neurobiologist from Cornell University, and engineers Kevin Schultz and Kevin Passino from The Ohio State University teamed up to find out how swarms are guided to their new nest site (p. 3287).

According to Schultz there are two theories on how swarms find the way. In the 'subtle guide' theory, a small number of scout bees, which had been involved in selecting the new nest site, guide the swarm by flying unobtrusively in its midst; near neighbours adjust their flight path to avoid colliding with the guides while more distant insects align themselves to the guides' general direction. In the 'streaker bee' hypothesis, bees follow a few conspicuous guides that fly through the top half of the swarm at high speed.

Schultz explains that Seeley already had still photographs of the streaks left by high-speed bees flying through a swarm's upper layers, but what Seeley needed was movie

footage of a swarm on the move to see if the swarm was following high-velocity streakers or being unobtrusively directed by guides. Passino and Seeley decided to film swarming bees with high-definition movie cameras to find out how they were directed to their final destination.

But filming diffuse swarms spread along a 12 m length with each individual on her own apparently random course is easier said than done. For a start you have to locate your camera somewhere along the swarm's flight path, which is impossible to predict in most environments. The team overcame this problem by relocating to Appledore Island, which has virtually no high vegetation for swarms to settle on. By transporting large colonies of bees, complete with queen, to the island, the team could get the insects to swarm from a stake to the only available nesting site; a comfortable nesting box. Situating the camera on the most direct route between the two sites, the team successfully filmed the chaotic progress of several swarms at high resolution.

Back in Passino's Ohio lab, Schultz began the painstaking task of analysing over 3500 frames from a swarm fly-by to build up a picture of the insects' flight directions and vertical position. After months of bee-clicking, Schultz was able to find patterns in the insects' progress. For example, bees in the top of the swarm tended to fly faster and generally aimed towards the nest, with bees concentrated in the middle third of the top layer showing the strongest preference to head towards the nest. Schultz also admits that he was surprised at how random the bees' trajectories were in the bottom half of the swarm, 'they were going in every direction,' he says, but the bees that were flying towards the new nest generally flew faster than bees that were heading in other directions; they appeared to latch onto the high-speed streakers. All of which suggests that the swarm was following high-speed streaker bees to their new location.

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Schultz, K. M., Passino, K. M. and Seeley, T. D. (2008). The mechanism of flight guidance in honeybee swarms: subtle guides or streaker bees? *J. Exp. Biol.* **211**, 3287-3295.

HOW SEALS MANAGE THEIR INTERNAL SCUBA TANK

The ocean depths are a mysterious realm. We must don SCUBA gear if we want to spend more than a few tens of seconds beneath the waves. But seals are perfectly capable of plumbing the depths for as much as 80 min on a single breath. How diving animals and birds manage their meagre oxygen supply fascinates chemical physicist Thomas Jue from U. C. Davis and marine biologist Paul Ponganis from U. C. San Diego. Jue explains that unlike human bodies, which only carry enough oxygen for a couple of minutes, diving seals' muscles are packed with 20 times more myoglobin (an oxygen-carrying protein) than human muscles, and their red blood cell levels are much higher than ours. This allows seals to carry up to an hour's supply of oxygen in their own personalised 'SCUBA tank'. Knowing that seals naturally hold their breath for up to 20 min while sleeping, Ponganis and Jue teamed up with Napapon Sailasuta and Ralph Hurd from GE Medical Systems to use groundbreaking NMR technology to track elephant seals' oxygen levels as they held their breath (p. 3323).

Jue admits that the project was an ambitious three-way collaboration that took several years of planning before the seals even saw the inside of the NMR magnet. Ponganis and Torre Stockard had to train two young elephant seals to climb unrestrained into a fibreglass tube that could be fitted inside the NMR magnet where the animals could slumber while the team made their measurements. Curious to know how the seals managed their blood flow while holding their breath, the duo also measured the animals' blood flow and found that it was reduced to just over 30% by the end of a breath-holding session. Meanwhile, Jue, Ulrike Kreutzer, Ping Chang Lin and Tuan-Khan Tran worked with Sailasuta and Hurd to tune the sensitive NMR magnets to pick up the incredibly weak signal generated by free myoglobin in the seal's muscle to monitor the animal's oxygen levels.

Eventually the team was ready to make its measurements on the sleeping animals. Driving from San Diego to the San Francisco Bay Area with the seals in a truck, Ponganis coaxed one of the seals into the NMR magnet, placed a smaller magnetic coil above the animal's longissimus dorsi muscle group and waited for it to fall asleep and stop breathing.

According to Jue it was a tense moment when the first seal stopped breathing; would the deoxymyoglobin signal increase as the storage protein began losing oxygen? Amazingly, it did. After all the years of preparation the team could clearly see the oxygen leaving the muscle's myoglobin stores for consumption by energy-generating mitochondria. 'It was one of those great moments,' says Jue, 'we were ecstatic'. The muscle's myoglobin-bound oxygen levels dropped by 20% during the first minute, before stabilising at a constant level until the seal began breathing again. Jue explains that by reducing oxygen levels in the muscle, the seal establishes an oxygen gradient between the muscle and blood, allowing the animal to extract more oxygen from its blood to replenish its muscle supplies while holding its breath.

The team also retuned the magnet to track phosphocreatine and ATP. Jue explains that seals consume oxygen to produce the two energy-rich molecules, so their levels can be tracked as an indicator of the amount of anaerobic energy the seals consume while holding their breath. The team found that the animals were not switching to anaerobic metabolism to supplement their energy demand. Instead they reduced their metabolism to conserve oxygen.

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Ponganis, P. J., Kreutzer, U., Stockard, T. K., Lin, P. C., Sailasuta, N., Tran, T.-K., Hurd, R. and Jue, T. (2008). Blood flow and metabolic regulation in seal muscle during apnea. *J. Exp. Biol.* **211** 3323-3332.

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