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

DISAPPEARING HOMING PIGEON MYSTERY SOLVED

Homing pigeons are usually remarkably efficient navigators; however, on rare occasions, things go drastically wrong. So, when Jon Hagstrum of the US Geological Survey (USGS) read in his local newspaper about two races during which pigeons had been lost in 1998, he was reminded of a lecture by Bill Keeton that he had heard years before as an undergraduate at Cornell University. Keeton had been studying how birds successfully navigated from distant and unfamiliar release sites. However, the birds almost always had problems selecting the correct bearing home when released from three local sites. According to Keeton, pigeons released at Castor Hill and the town of Weedsport consistently took the same wrong turn when they departed. Meanwhile, birds that were released from Jersey Hill tended to head off in random directions, but with one exception: all of the birds that departed from the hill on 13 August 1969 returned home successfully, having taken the correct bearing. Explaining that Keeton had already ruled out the possibility of a disturbance in the local magnetic field, Hagstrum recalls, 'Bill asked if we geologists had an idea what might be going on at these sites.'

Several years after Keeton's lecture, Hagstrum came up with a possible solution to the problem when he read that pigeons can hear incredibly low frequency 'infrasound'. Explaining that infrasound – which can be generated by minute vibrations of the planet surface caused by waves deep in the ocean – travels for thousands of kilometres, Hagstrum wondered whether homing pigeons are listening for the distinctive low-frequency rumble of their loft area to find their bearing home. In which case, birds that could not hear the infrasound signal, because the release site was shielded from it in some way, could not get their bearing and would get lost. Hagstrum decided to investigate the meteorological conditions on the days of unsuccessful releases to find out if there was something in the air that could explain the pigeons' disorientation (p. 687).

Fortunately, Hagstrum had access to accurate temperature, wind direction and speed measurements taken at local weather stations on the days of the releases so that he could reconstruct the atmospheric conditions. Having successfully installed a complex acoustics program – HARPA – with the help of USGS computer scientist Larry Baker to reconstruct the atmospheric conditions, Hagstrum then calculated how infrasound travelled from the loft through the atmosphere, refracting through layers in the air and bouncing off the ground, to find out if Jersey Hill was shaded from the loft's infrasound homing beacon and how the signal from the loft was channelled by the wind and local terrain to Castor Hill and Weedsport.

Amazingly, on all of the days when the birds vanished from Jersey Hill, Hagstrum could see that the loft's infrasonic signal was guided away from the ground and high into the atmosphere: the birds could not pick it up. However, on 13 August 1969, the atmospheric conditions were perfect and this time the infrasonic signal was guided directly to the Jersey Hill site. And when he calculated the paths that the loft's infrasonic signal travelled to Castor Hill and Weedsport they also explained why the birds consistently took the wrong bearing. The terrain and winds had diverted the infrasound so that it approached the release site from the wrong direction, sending the birds off on the wrong bearing.

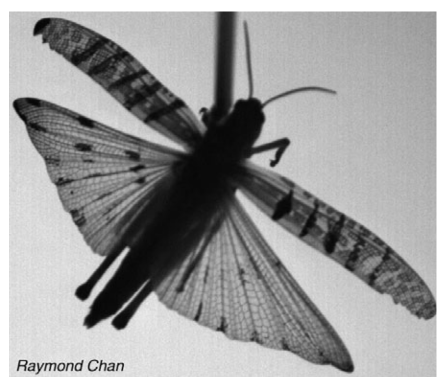
Explaining that the birds must use the loft's infrasonic homing beacon to get their bearing before setting the direction for their return flight according to their sun compass, Hagstrum says, 'I am a bit surprised that after 36 years I finally answered Bill Keeton's question to the Cornell Geology Department', adding that he is particularly pleased that he was able to use Keeton's own data to solve the mystery.

10.1242/jeb.085506

Hagstrum, J. T. (2013). Atmospheric propagation modeling indicates homing pigeons use loft-specific infrasonic 'map' cues. *J. Exp. Biol.* **216**, 687-699.

Kathryn Knight

UNPREDICTABILITY KEY TO COLLISION AVOIDANCE



Raymond Chan

Life is one big obstacle course for a locust. Living in swarms in dense tree canopies, they not only have to avoid bumping into branches and other members of the locust mob, but they also have to steer clear of collisions with peckish predators. Avoiding all of these hurdles is no mean feat, as Fabrizio Gabbiani from the Baylor College of Medicine, USA, explains: ‘Suddenly something approaches and then you have to combine what you’re already doing, which is flying, with avoiding an object, which is quite a complex behaviour. And on top of that you can have wind gusts, so there are also [other] disturbances that could affect what you do.’ Gabbiani knew that locusts react in a stereotypical way when threatened with a head-on collision – which is more likely to occur with stationary objects – but wondered how they would cope with a side impact when a predator swoops in for the kill (p. 641).

Suspecting that the locusts would also show stereotypical avoidance behaviour when presented with a side-on collision, Gabbiani and his post-doc Raymond Chan, headed out into the heat of the Texan sun to capture locusts in nearby shrublands to maintain their colony and begin their investigation.

The duo tethered the locusts with a thread in a wind tunnel to prevent them from crashing against the walls as they flew freely, and used high-speed cameras to record the locusts’ movements. They then simulated a predator-like threat by projecting an image of an expanding square onto the side of the wind tunnel, and filmed how the insects reacted to this perceived incoming object. However, the locusts did not simply fly away from the approaching threat using a tightly choreographed suite of moves as expected. Gabbiani remarks, ‘We found something that is much more complicated; they actually seem to be going in all possible directions, even sometimes towards the approaching object,’ adding that, ‘In retrospect that makes sense; if you really want to be able to avoid a predator you want to be as unpredictable as possible.’

To understand how the locusts were able to perform such an array of manoeuvres, the duo went back to the wind tunnel with their locusts to investigate the details of the insects’ evasive wing beats. This time a 2-cm-long thread restricted the locusts’ flight within a tiny sphere so that a camera could zoom in on their wings and film their movements at 500 frames s^{-1}. However, restricting their freedom changed their escape tactics slightly: the team noticed that the insects interrupted their wing beats more often, allowing them to dive in response to the sideways threat. Gabbiani suspects that the insects may have some understanding that they are tethered. Nonetheless, the duo was also able to detect changes in the wings that also explained the range of collision-avoidance movements undertaken by the free-flying locusts. They found that increased height in the forewings and slight deformations in the curvature or tilt of the wings led to changes in the locusts’ body orientation and flight direction that would allow the insects to evade predators.

Understanding how insects use their wings to fly is exciting and very useful as it may help us build better small flying robots, explains Gabbiani. These micro-fliers have great potential; for example, they could inspect burning buildings or aid rescue operations. However, to design appropriate robotic wings we need to better understand how minute deformations of the wing and split-second alterations in wing-beat patterns allow insects to duck and dive.

10.1242/jeb.084616

Chan, R. WM. and Gabbiani, F. (2013). Collision-avoidance behaviors of minimally restrained flying locusts to looming stimuli. *J. Exp. Biol.* **216**, 641-655.

Nicola Stead

CCAP SETS MOSQUITO HEARTS RACING

Like humans, mosquitoes are prone to picking up nasty infections, and like us, they also have a specialised immune system that fights off undesirable invaders. This defensive system, found in haemolymph, is propelled through the body by the heart. However, very little is known about how the mosquito heart controls haemolymph circulation and Julián Hillyer, an insect physiologist from Vanderbilt University, USA, wondered, ‘If haemocirculation is so important for how a mosquito fights infection, then how do we know so little about it?’ Intrigued, Hillyer decided to investigate what makes a mosquito’s heart tick and turned to CCAP, a neurohormone peptide, which he knew regulates cardiac function in a wide range of other arthropods, including crabs and fruit flies (p. 601).

Recruiting the help of his research assistant Tania Estévez-Lao and an undergraduate student, Dacia Boyce, Hillyer and his team carefully reared over 300 adult mosquitoes to begin their investigation into the role of the CCAP hormone in haemocirculation. Taking advantage of the mosquitoes’ see-through cuticle, the team was able to visualise and record the changes in the wave-like heart contractions following CCAP injection. They were also able to measure the haemolymph velocity after treating the mosquitoes with CCAP by injecting tiny fluorescent particles into the body and tracking their movement through the mosquitoes’ heart using a microscope.

These elegant experiments, whilst almost routine now, were far from trivial at first, remembers Hillyer. He recalls that it was very tricky to restrain the mosquitoes because they were prone to escaping. However, the hours spent delicately handling and recording the mosquitoes’ heart rate eventually paid off. After injection of CCAP into the mosquito’s body, the team saw an increase in heart rate of up to 28%, rising to over two beats per second. Exposure to the hormone also sped up haemolymph flow to a speedy 8.6 mm s^{-1}, with a maximum increase in the velocity of up to 33%. To confirm that CCAP was responsible for these racing hearts, the team then reduced expression of CCAP and saw that as they lowered production of the neurohormone they also slowed down heart contraction rates.

Having established the role of CCAP in speeding up heartbeats, the team next wanted to determine exactly where CCAP was being produced. By dissecting the mosquitoes’ head, thorax and abdomen, they were able to determine that CCAP was mostly produced in the head. With the expertise of colleague Hans-Willi Honegger, they were further able to pinpoint expression of the hormone to specific neurons in the brain that project onto the upper part of the circulatory system.

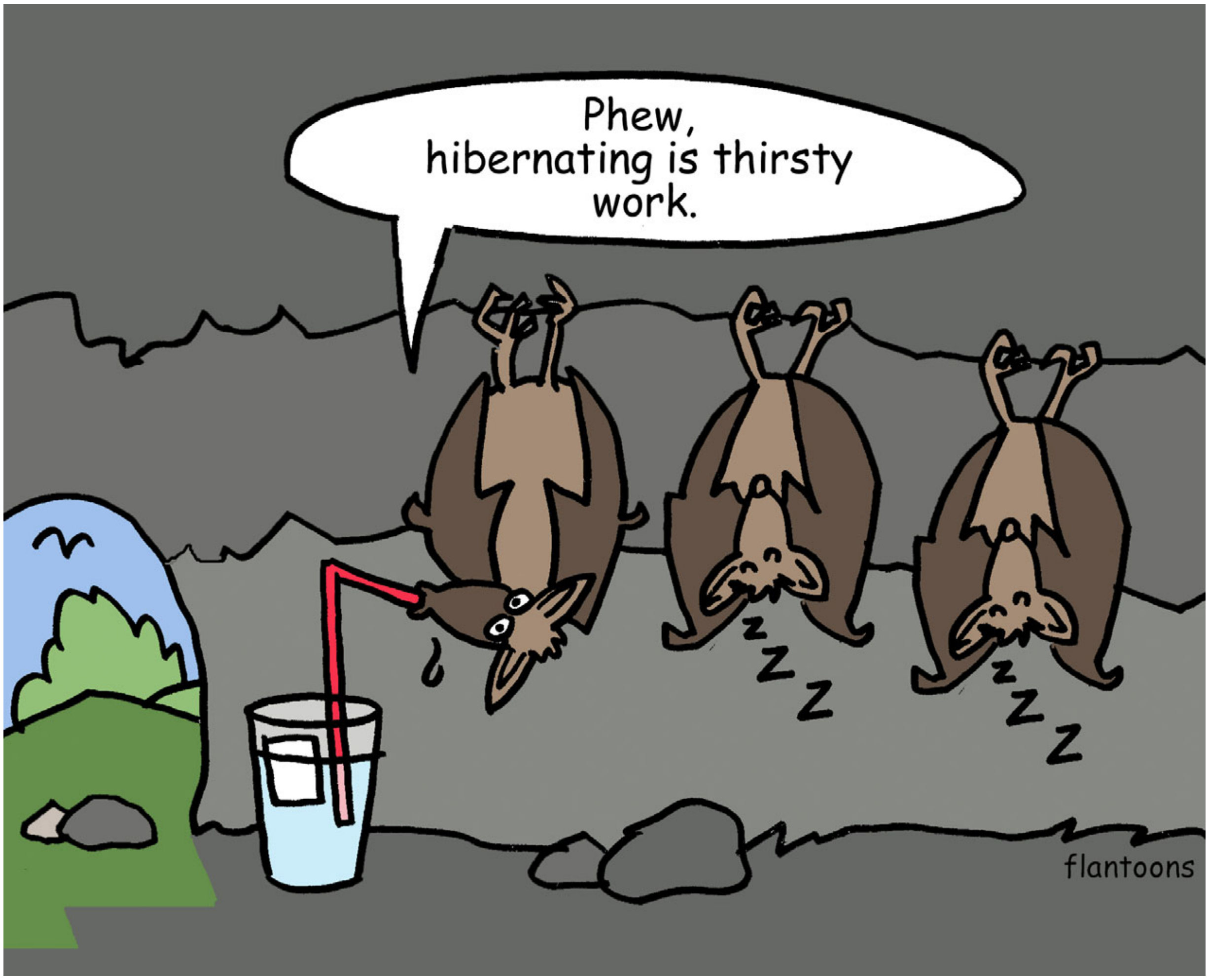
This is the first time that the adult mosquito heart has been shown to be under partial neuronal control, remarks Hillyer. However, perhaps the most exciting aspect for Hillyer is the new opportunity that CCAP offers to manipulate heart rates, allowing him to investigate how changes in haemolymph flow can affect a mosquito’s ability to fight off infections and hopefully avoid passing them onto us the next time they snack on our blood.

10.1242/jeb.084624

Estévez-Lao, T. Y., Boyce, D. S., Honegger, H.-W. and Hillyer, J. F. (2013). Cardioacceleratory function of the neurohormone CCAP in the mosquito *Anopheles gambiae.* **216**, 601-613.

Nicola Stead

HIBERNATION THIRSTY WORK FOR BATS



When winter approaches and the temperatures drop, curling up and hibernating seems like a blissful way to get through the dreary months. However, hibernation isn't all it's cracked up to be, with deep slumber being rudely punctuated by periods of arousal. These awakenings are energetically demanding, requiring the snoozing animals to raise their body temperatures and their metabolic rate to prepare for short bouts of activity. During the cold months, hibernating bats are only awake 5–10% of the time, but an incredible 85% of their winter energy expenditure goes towards powering these arousals. If these moments of alertness are so energetically draining, then what is the purpose of them? For *Pipistrellus kulii* bats it seems that these arousals are necessary for thirst-quenching drinks of water, according to a new study by Miriam Ben-Hamo and her colleagues from the Ben-Gurion University of the Negev, Israel (p. 573).

To determine what caused arousals in these bats, Ben-Hamo captured 25 bats in the surrounding Israeli desert before bringing them back to the university. Once there, the team slowly coaxed the bats into hibernation by mimicking wintery conditions, lowering the temperatures and decreasing daylight hours as well as providing enough food for them to fatten up before their hibernal sleep. Working quietly, the team of scientists then observed the bats, recording how long they hibernated before awakening and how frequently these arousals occurred. They also measured how much carbon dioxide they produced as an indicator of metabolic rate, and how much water they lost by evaporation under different humidity conditions.

The team found that changes in metabolic rate did not affect hibernation patterns. However, they did notice that the more water the bats lost through evaporation the less time they spent in deep slumber. These perspiring bats also awoke more frequently, and because waking up requires so much energy they also had lower body masses. Metabolic water production is not sufficient to replace evaporative water loss, so the team thinks that it is likely that the bats are waking up for a quick sip of water to rehydrate before drifting back to sleep.

10.1242/jeb.084608

Ben-Hamo, M., Muñoz-Garcia, A., Williams, J. B., Korine, C. and Pinshow, B. (2013). Waking to drink: rates of evaporative water loss determine arousal frequency in hibernating bats. *J. Exp. Biol.* **216**, 573-577.

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