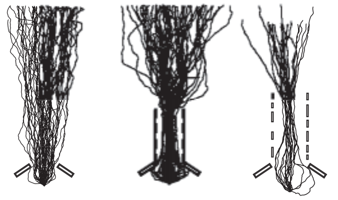

Right Down the Middle (p. 585)

A desert ant's short life is passed under constant threat from the cruel sun or hungry insects. Yet the foraging desert ants, *Cataglyphis fortis*, would rather risk the sun than end up on someone else's diner plate; they run right down the middle of any obstacles they encounter on a foraging sortie. Rudiger Wehner realised that these ants were behaving exactly like bees, who never deviate from the central path when they fly along a tube to their hive. When Mandyam Srinivasen originally noticed this behaviour, he called it 'centring'. Wehner wanted to know if his ants were using the same navigation system as the bees to navigate along an ant channel. After several months of baking in the Sahara desert with his ants, Wehner realised that they had come up with an entirely different strategy. The ants were judging the height of the channel's walls on either side and taking a path that made the walls appear to be the same height from the ant's perspective, even if they were different in reality.

Wehner and his student, Daniel Heusser, headed down to their desert research station to watch *Cataglyphis* scurrying along a channel. After training the ants to run back and forth between their nest and a well-stocked larder, they captured individuals just as they began their return journey, and transferred them to a parallel home run, to see how they reacted as they rushed home along the channel.

Wehner knew that bees balance visual information from both eyes as they fly along a tube to maintaining a central course. Srinivasen had made the bees think that one wall was moving faster by projected moving patterns onto the walls of the tube. The bees thought that they were closer to the 'faster' wall and diverted towards the 'slower' wall to balance the wall's speeds and hopefully keep an equal distance from both. Wehner and Heusser designed an ant channel with moving walls to see if they would make one wall seem closer than the other, and drive the ants away from their central path. But no matter how Heusser and Wehner tried to visually confuse the ants, they never deviated from the central path.

So the ants had developed a different strategy for navigating a channel. Wehner wondered if the ants were judging the height of the two walls, plotting a path that made both walls appear the same height from the ant's eye view. If he made one wall higher then the other, it should drive the ants towards the lower wall. Which it did.

After a season in the desert, Wehner and Heusser returned home. When they revisited the desert a year later, the channels left from the previous year's experiments had sprouted two lines of bushes, with one bush wall slightly taller than the other. Wehner and Heusser decided to see how freshly trained ants would react to this relatively natural setting. Sure enough, the ants always deviated towards the shorter bushes, because they believed that was the central path between the bush barriers.

Furious and Fast (p. 667)

Not many people would think of rattlesnakes as a 'simple system'. But when Kevin Conley looks at these animals, he doesn't just see a terrifying viper. To him they are the perfect simplified muscle system. Unlike complicated mammalian muscles, the rattlesnake shaker muscle is built from a single fibre type, which means that looking at the muscle that drives the rattlesnake's fearsome rattle 'is like looking at a single muscle cell' says Conley. These muscles also have a mysterious energy saving property: as the rattle frequency increases, the rattling force also increases, but the energetic cost of each muscular twitch stays constant. The result is that the snake uses the same energy for a fast contraction during high frequency rattling as it does for a slower contraction when rattling less vigorously. Conley had wondered how this could be, until he and Brad Moon analysed the reptile's furious rattling. They discovered the important mechanical tricks that the snakes use to improve performance without increasing energy use: by contracting more strongly for a shorter period of time, the muscle uses the same amount of energy as it would for a longer, weaker contraction.

Moon explains that the rattlesnakes were fantastically cooperative throughout the experiment 'because they are so irritable'. He secured each snake in a plastic box with its tail sticking out of a hole, ready to record the rattle. Moon needed to measure the rattle muscle's force as the rattle's pitch rose. Fortunately, as the snakes warm up, their rattling frequency increases too. With a snake resting safely in its box, he had plenty of time to gently warm it up while measuring the muscle's increasing force.

Measuring the twitch tension from individual muscle fibres was complicated. With the help of colleagues in the Zoology department, Moon built a force transducer to measure the net force generated as the muscle contracted. But before he could calculate the muscle's twitch tension he also measured the fibre's cross-sectional area by looking at the muscle's volume and the direction of the muscle's fibres.

He found that the muscle's twitch tension increased as the rattle's frequency rose. But as a stronger twitch lasted for a shorter length of time, the snake used the same energy per contraction, no matter how fast it rattled.

Moon was also surprised to see that the reptiles changed the way their rattles moved as they warmed up. At first they slowly waved the rattle from side to side, making a slow buzzing sound, but as he raised the temperature, the snakes waved the rattle less and began to twist it more to produce a faster buzzing sound. Moon says that the trade-off between the two buzzing styles helps the snake to conserve energy, allowing it to make a louder noise at little extra cost.

So while the rattlesnake's shaker muscle has helped Conley and Moon answer some fundamental questions about muscle physiology, it also gives a predator enough warning to help a threatened snake ward off its next unwanted encounter, even with an experimental biologist!

When it Can't Get Hotter! (p. 677)

If you've ever had a high temperature, you'll know how ill you felt, but shore dwelling snails often suffer temperatures that make a raging human fever seem like a mild cold. Yet they survive. Their well-developed cellular safety systems protect them even when the temperature goes critical. There are five protein components in the heat shock system: a transcription factor called hsf1, and four heat shock proteins (hsp): hsp40, hsp70 (comprising two isoforms, hsp72 and hsp74) and hsp90. Hsf1 activates transcription of the hsps. During heat shock, hsps have two roles: they protect the cell by stabilising threatened or denatured proteins, and they form a macromolecular complex with hsf1 to prevent it from activating an unprovoked heat shock response.

Over the last few years George Somero and Lars Tomanek have worked to understand how this molecular safety system protects threatened organisms and whether it could help to identify snails that find temperatures on their Monterey Bay beach stressful. In this issue of the *J. Exp. Biol.* they explain how two key components of the heat shock machinery could be the best warning signal for animals that can't stand the heat anymore.

Somero's lab at Hopkins Marine Station sits above a beautiful Californian beach, which is home to three members of the *Tugula* family of snails. *T. funebralis* lives above the low tide mark, and *T. montereyi* and *T. brunnea* both live beneath the low tide line, and are rarely exposed to the atmosphere.

T. funebralis experiences the greatest diurnal range of temperatures of the three species, and survives. But in 1999 Tomanek discovered that *T. funebralis*' couldn't adapt to warmer temperatures, no matter how hard it tried. The snail's thermostat had 'maxed out'. Meanwhile *T. montereyi* and *T. brunnea* easily adapted to warmer waters by raising the temperature that activated their heat shock response (called T_{on}). *T. funebralis*' inability to respond to increasing temperatures means that the snail would have to find cooler waters or face death if the beach's temperature rose. But it wasn't clear how the other two species reset the thermostat, and how *T. funebralis*' thermometer had reached its limit.

Tomanek and Somero looked at the molecular switch components to see how they varied between the three species in their different thermal worlds. Hsp70 levels had previously been believed to give the best indication of a thermally stressed animal, so they checked the snails' hsp70 levels. At 13°C and 18°C, all three snails had the same total levels of hsp70. However, when the snails were acclimated to 23°C, *T. montereyi* and *T. brunnea* sent their hsp70 levels rocketing, while *T. funebralis*' hsp70 levels didn't change at all as it acclimated to a higher temperature.

Although the total levels of hsp70 didn't differ between the three species, the ratio of the two isomers (hsp72/74) did; stressed *T. funebralis* always showed the biggest variation. Tomanek thinks that this ratio is probably the best indicator of how ecologically stressed a species is.

Tomanek was also surprised when he realised that *T. funbralis* also had unusually high levels of hsf1. No one had ever expected hsf1 levels to vary between closely related animals. It was also believed that high hsf1 levels would result in a reduced T_{on}, but *T. funebralis*' had stayed high, which probably means that controlling the heat shock response is even more complex than had been thought before.

The planet could well experience its own 'heat shock' in the not too distant future. Identifying species that are already living at their safety limits, before they vanish, is probably the only hope for species like *T. funebralis*.

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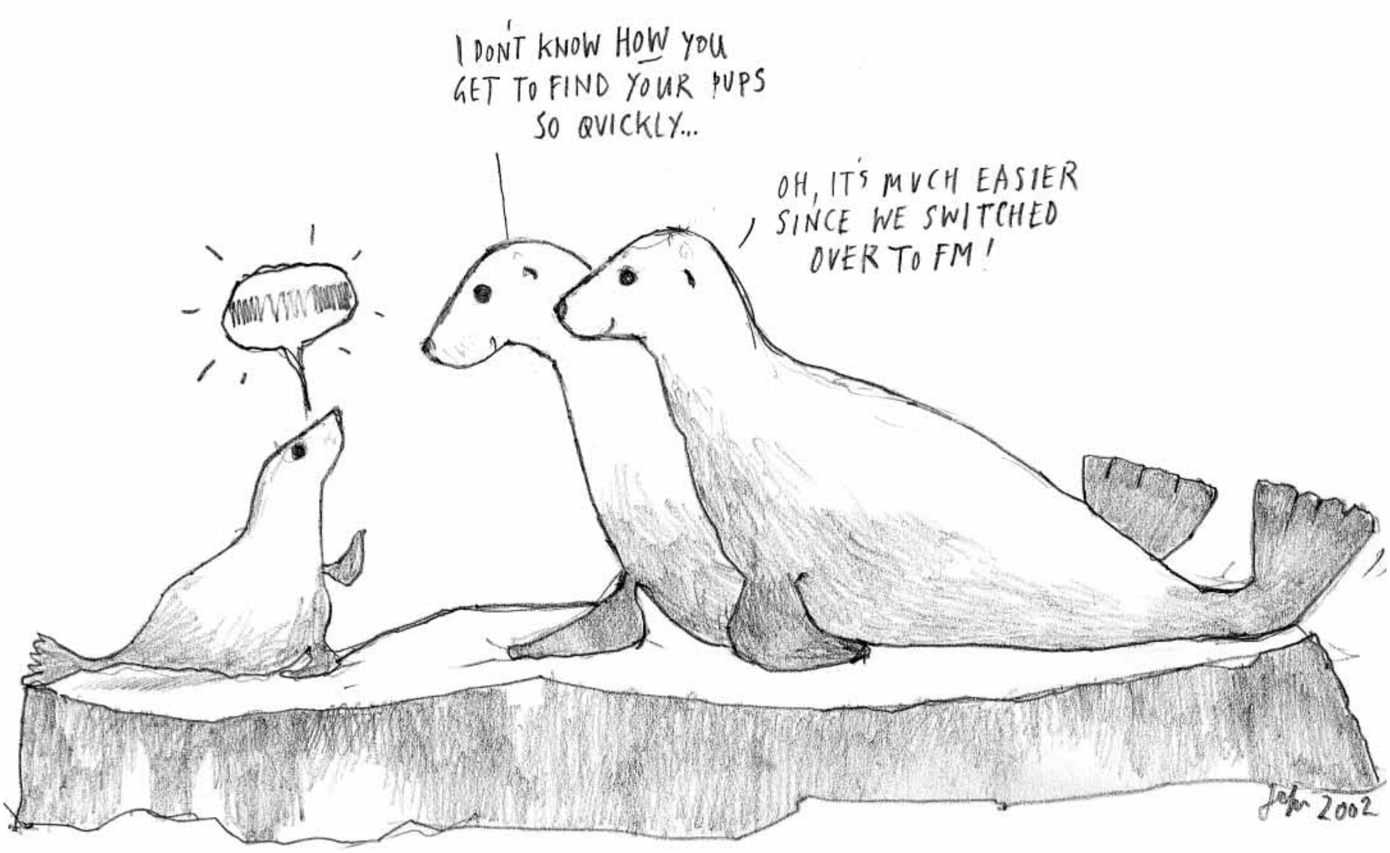

I Don't Know How You Get to Find Your Pups So Quickly (p. 603)

Charrier, I., Mathevon, N. and Jouventin, P. (2002). How does a fur seal mother recognize the voice of her pup? An experimental study of *Arctocephalus tropicalis. J. Exp. Biol.* **205,** 603–612.