

Keeping track of the literature isn't easy, so Outside JEB is a monthly feature that reports the most exciting developments in experimental biology. Short articles that have been selected and written by a team of active research scientists highlight the papers that JEB readers can't afford to miss.

MAGNETOPERCEPTION



CATTLE AND DEER ALIGN NORTH (-NORTH-EAST)

Farmers, hunters, biologists and holiday-makers have invested much time and speculation on observations of cows and deer. Farmers identify that cattle face into the wind, whereas sheep face away. Hunters are very aware of wind direction while stalking, and will try to approach from down wind. Biologists have discussed body alignment strategies to make use of, or avoid, solar heating. And I remember my holidays being littered with sayings such as 'The cows are lying down – it must be about to rain ... now the cows are standing up – it must be about to rain ...'

It was therefore a bit of a surprise when Sabin Begall from the University of Duisberg-Essen, Germany, and her colleagues from the Czech Republic reported that Google Maps show a previously undescribed tendency in cattle: they align their bodies predominantly north-south (or, as the head is not easily distinguishable in the satellite images, perhaps south-north). It is such a surprise, in fact, that other explanations – confounding factors such as wind or sun direction – immediately spring to mind. But, when the best possible account is taken of these by considering prevalent wind directions across the world and measuring sun direction from shadows, they don't explain the observed north-south alignment bias.

Might sampling with Google Maps somehow provide a bias? It is difficult to see how, but more down to Earth measurements confirm this north-south alignment tendency. Both grazing deer and their 'beds' – body prints of resting deer in the snow – tended to have the head-end pointing north. But, presumably because of predation risks from lynx, approximately one-third of the deer faced south. Anecdotally, this preference for facing north sounds quite extreme: when looking

around, the deer kept their bodies pointing north, and changed their body direction for short periods when moving to the new grazing sites.

That the mechanism underlying this directional bias is magnetic is suggested from the Google Maps data: in regions where there is a big difference between magnetic north and true north (i.e. the axis of Earth rotation), cattle were much better aligned to magnetic north.

Interestingly, though, direct (magnetic) north/south is not the mean for cattle, falling outside the 99% confidence intervals in 3 of the 6 continents measured. In Africa and South America, cattle align more than 30 deg. east; worldwide, cattle actually orientate themselves NNNNE–SSSW.

So, Begall and colleagues have made a fascinating observation, and gone to some lengths to discount confounding factors, justifiably claiming that the 'most parsimonious' account for body axis direction is magnetic alignment.

And, with this, they 'challenge neuroscientists and biophysics to explain the proximate mechanism'. I would argue that perhaps a greater challenge is to behavioural and evolutionary biologists to determine the ultimate cause of this behaviour. Why on Earth should cattle and deer favour aligning with magnetic north-south? And why, in some regions, NNE/SSW?

10.1242/jeb.021378

Begall, S., Červený, J., Neef, J., Vojtěch, O. and Burda, H. (2008). Magnetic alignment in grazing and resting cattle and deer. *PNAS* **105**, 13453-13455.

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ESCAPE RESPONSE



FLIES PLAN SPEEDY GETAWAY

Biologists have long been fascinated by how animals escape certain death. Perhaps it's because escape behaviors are so strong and easy to reproduce, or perhaps it's just that we can't help cheering a little bit when an animal outsmarts something that is determined to kill it. One of the most well known of these behaviors is 'swatter escape' performed by flies in kitchens everywhere. How do flies jump away from an approaching swatter (or predator) so well? A recent paper in the journal *Current Biology* by Gwyneth Card and Michael Dickinson (Caltech University) addressed this question using high-speed videography of flies jumping for their lives.

First, the authors let single fruit flies (*Drosophila melanogaster*) climb onto a small platform; then they slid a large black disc toward the platform and filmed each fly's response. Every animal was oriented differently on the platform and so in each trial the disc approached from a different direction relative to the fly. Overall, the flies took no chances with the disc. They jumped directly away from the approaching stimulus no matter how it came at them. Furthermore, the visual component of the approaching disc alone was sufficient to evoke the response.

Next, the team wanted to know if flies angle their jumps away from approaching stimuli or whether they jump up without direction and steer away in flight. To address this, Card and Dickinson simply removed the insects' wings and retested them. Even while wingless, the animals jumped directly away from the approaching disc.

When the researchers examined each fly's fast footwork before takeoff, they found that before any wing movements the insects move their middle pair of legs and reposition their center of mass away from the looming stimulus. Furthermore, the

preflight routine does not just pile a new motor command on top of an existing stance or behavior; that is they don't just use a simple feed forward motor program. Instead, the flies take into account their own body position when the stimulus is detected and try to compensate.

These results suggest that fruit flies are doing a sophisticated sensory to motor transformation before they ever leave the ground. Each fly is turning a visual estimate of where a looming object is into a corresponding set of motor commands that reposition its center of mass for optimal takeoff. Furthermore, what the fly happens to be doing at the time is taken into account. Plus, they're doing all of this fast (~300ms). The ability to do this type of motor planning is usually associated with complex vertebrate cortices, not tiny fly brains.

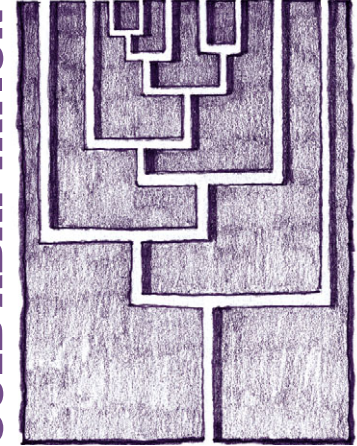
This work is an example of how if you look at a seemingly simple animal, doing a seemingly simple thing, they're often capable of a lot more than you'd think possible. This work is also a great example of how very close and very careful observation of escaping critters can answer important questions about how animals do what they do.

10.1242/jeb.21451

Card, G. and Dickinson, M. H. (2008). Visually mediated motor planning in the escape response of *Drosophila*. *Curr. Biol.* **18**, 1300-1307.

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COLD ADAPTATION



GENE DUPLICATION UNDERLIES COLD ADAPTATION IN ANTARCTIC FISH

For the past 10–15 million years, the Southern ocean has experienced sub-freezing temperatures. The fishes of the Southern ocean are dominated by a single suborder, the notothenioids, which evolved to survive at -1.86°C . The extreme cold that these fish endure has driven a number of unique adaptations such as the production of antifreeze proteins, the constitutive expression of inducible heat shock proteins, and the loss of hemoproteins in some cases. However, our current knowledge of the cold-adapted phenotype and the genomic alterations that support it has remained limited by a lack of genomic-scale information. In their recent paper in *PNAS*, Zuozhou Chen and colleagues from the Chinese Academy of Sciences and the University of Illinois explore, for the first time, the genomics of cold adaptation in this amazing group of fish.

The team generated a library of 33,560 DNA sequences based on genes that are expressed in brain, liver, ovary and head kidney of the Antarctic toothfish *Dissostichus mawsoni*. They eventually distilled the library down to 13,000 unique sequences, of which 6208 appear to encode known or predicted proteins that can be classified into 3114 non-redundant gene families. Many of the most abundant transcripts identified in these tissues are involved in mediating the cellular stress response or have previously been identified as important for surviving cold stress. These results suggest a shift in the transcriptome of Antarctic fish towards an elevated and sustained stress response under normal living conditions. By comparing the gene frequencies in the *D. mawsoni* DNA libraries with those available for five different species of tropical or temperate fish, the authors were able to identify 189 gene families that are

differentially expressed in *D. mawsoni* compared with the other species of fish including families involved in protein homeostasis and scavenging of reactive oxygen species, which are critical for cold adaptation.

The team also explored the genomes of three species of Antarctic fish (*D. mawsoni*, *Pagothenia borchgrevinki* and *Chaenocephalus aceratus*) for alterations that may explain the observed changes in the transcriptomes. The team compared the genomes of the three Antarctic species with those of two closely related fish from non-Antarctic waters (*Bovichtus variegatus* or *Eleginops maclovinus*). They discovered 118 duplicated or newly acquired genes and only 12 genes that appear to have contracted in the Antarctic species compared with the related temperate species. Most of the duplicated genes have a known function in other organisms, which suggests an augmentation of existing gene function as a major part of the process of adaptation to sub-freezing temperatures. Of particular interest are the 17 duplication events of the long interspersed nuclear element (LINE) genes, which facilitate the rearrangement of eukaryotic genomes through retrotransposition events. The authors speculate that this may help to explain the observed expansion of the genome in the notothenioid lineage.

This paper reveals the genomic changes that may underlie adaptation to sub-freezing temperatures in the Antarctic notothenioid fish. In general, an upregulation in gene expression and concomitant genome expansions of a rather modest number of gene families appear to be an important part of cold adaptation, and are consistent with known principles of metabolic compensation in response to cold acclimation. While this study certainly raises more questions than it answers, it does provide a framework for future investigations of cold adaptation in vertebrates.

10.1242/jeb.021493

Chen, Z., Cheng, C.-H. C., Zhang, J., Cao, L., Chen, L., Zhou, L., Jin, Y., Ye, H., Deng, C., Dai, Z., Xu, Q., Hu, P., Sun, S. and Shen, Y. (2008). Transcriptomic and genomic evolution under constant cold in Antarctic notothenioid fish. *PNAS* **105**, 12944-12949.

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HOW FLIES KEEP THEIR COOL

Unlike mammals, which regulate body temperature through metabolic heat production or sweating to cool off, insects must use behavioural adjustments to reach their desired body temperature. Behavioural thermoregulation, the ability to regulate body temperature to optimise growth and reproduction, is therefore a crucial facet of insect survival and evolutionary fitness. Much experimental work has shown that insects are capable of sensing and responding to environmental temperature variation on seasonal and daily timescales. Furthermore, some exciting progress has been made in unravelling the cellular basis of thermosensing with the recent discovery of temperature-gated ion channels. Generally, most scientists agree that behaviours maintaining optimal body temperatures of insects must have some genetic and cellular basis, but what these precise mechanisms are and where control centres are located are rather poorly understood. So how do behaviour and physiology interact to determine body temperature under a given set of conditions in insects?

Sung-Tae Hong and colleagues from the Korea Advanced Institute of Science and Technology explored the molecular and cellular components of behavioural thermoregulation using the model fly species *Drosophila melanogaster*. The team used a variety of methods to address this question. First, they undertook a large-scale screen of genetic mutants where the insects exhibited unusual thermoregulation behaviour to identify potential candidate genes. The results showed several genes involved in mushroom body formation and learning or memory formation, and also the cyclic AMP-dependent protein kinase A (cAMP-PKA) pathway, all of which are involved in the control of body temperature. From these results, the team hypothesized that mushroom bodies, a part of the fly's brain

involved in cognition, and cAMP-PKA signalling might be vital components of thermoregulation in these flies.

The team also mapped brain regions involved in thermoregulation by knocking out discrete parts of the fly brain and found that loss of the mushroom body led to a loss of body temperature control, suggesting that the mushroom body is a critical component of normal thermoregulatory behaviour. Other experiments, in which the mushroom body was completely deactivated, resulted in extreme cold preference. By contrast, deactivation of mushroom body neurons resulted in no distinct high or low temperature preference and, hence, poor thermoregulation.

Second, the team closely examined the role of cAMP-PKA signalling in the behavioural control of body temperature. Mutant flies with defects in cAMP-PKA pathways were generally widely distributed across a temperature gradient, indicating a lack of thermoregulation. However, mutants with low cAMP levels tended not to avoid low temperatures, while mutants with above average cAMP levels were unable to avoid high temperatures properly. This and subsequent experiments verified that the flies' preferred body temperatures were correlated with cAMP levels and PKA activity. Moreover, these experiments suggested that the cAMP-PKA pathway aids temperature recognition and facilitates preferred body temperature control.

Next, the team asked whether cAMP-PKA signalling influences thermoregulation through only the mushroom body or whether other parts of a fly's body are also involved. To tackle this, they generated flies in which normal cAMP-PKA signalling occurs only in the mushroom body but not elsewhere. The researchers also undertook experiments that manipulated the locations of normal cAMP-PKA function. The results showed that cAMP-PKA signalling in the mushroom body, but not in other parts of the insect's body, are critical for maintaining normal thermoregulatory behaviour. In conclusion, Hong and co-workers have made significant advances in revealing the molecular and neural basis of how flies keep their cool through behavioural thermoregulation.

10.1242/jeb.021410

Hong, S.-T., Bang, S., Hyun, S., Kang, J., Jeong, K., Paik, D., Chung, J. and Kim, J. (2008). cAMP signalling in mushroom bodies modulates temperature preference behaviour in *Drosophila*. *Nature* **454**, 771-776.

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