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## More Than a Rudder (p. 2943)

Take a look at a fish's back, and you'll be looking at an evolutionary snap shot. As fish have evolved, their dorsal fins have become more complex. Salmon have the simplest fins, with one soft structure on their backs. But as you look further up the evolutionary tree, fish have added a second spiny fore-fin, until you arrive at perch-like fishes, where the two fins are fused. Knowing that the soft part of the fin was the evolutionarily conserved section, Eliot Drucker and George Lauder wondered whether sunfish used the ancient portion of the fin while swimming, and if they did, how much the was fin contributing to the fishes overall manoeuvrability.

According to Drucker, 'vortices are the hallmark of fluid force production', so he watched the eddy patterns the fish left behind as they swam upstream. Using a digital imaging technique, he was able to map the way that vortices swirled away from the dorsal fin, and the way these wake structures interacted with the fish's other fins.

At slower speeds, the fish didn't use the dorsal fin at all, but as the fish accelerated up to 23 cm $s^{-1}$ the dorsal fin began to wave back and forth, behaving like a two-stroke engine. Each sweep of the fin generates a vortex that is sent from the tip of the fin. The vortices that spiral away from the fin at the top and bottom of each stroke interact behind the fish to produce a propulsive jet of water that pushes the fish along. On closer inspection, Drucker and Lauder realised that the dorsal fin may also contribute to the force produced by the fish's caudal fin. The vortex produced by the dorsal fin swirls down the tail fin, and joins up with the tail fin's vortex. Drucker believes that this composite tail-vortex could contribute significantly to the fish's forward thrust.

When they investigated the way the fish uses the fin when turning, they found that it plays an even more significant role. First they had to startle the fish into turning. Watching from above, they saw the dorsal fin flip out. It did half of the two-stroke action it used when going forwards, so the net force turned the fish, rather than pushing it forward. This single flip contributed almost 35 % of the fish's turning force.

Drucker is pleased that he's shown that the dorsal fin is more than just a rudder, but now he wants to look at fish with different fin arrangements. The next challenge for Drucker is to paint the larger picture, looking at the ways that other fish use the soft fin. He says 'we haven't got the full evolutionary picture yet, but we are beginning to find out what it means to have different dorsal fin designs'.

## Adjusting to the Light (p. 2921)

Filmgoers really appreciate how sensitive their vision can be. It usually only takes a few moments after walking into the dark of the cinema for your eyes to adjust and the darkness to recede, 'but hopefully not long enough for you to have dropped your popcorn', says Richard Kramer. Our eyes are capable of adapting to almost any light level, even though the background intensity can have changed a million-fold. The mechanisms that adjust our vision over this enormous dynamic range involve changes in the biochemical machinery of the retina's light-sensitive cells.

The molecule at the heart of phototransduction is a cyclic-nucleotide-gated (CNG) channel that converts changes in cyclic nucleotide concentration into an electrical event. In the dark cGMP levels in the cell are high, which keeps the CNG channel open. But when rhodopsin molecules in the cell membrane pick up photons, they trigger a cascade that drops the cellular levels of cGMP and closes the CNG channel so that the receptor cell becomes hyperpolarized and triggers a neural signal. Kramer's interest has focused on the structure and function of CNG channels in several sensory systems. In the review that he has co-written with his colleague, Elena Molokanova, they summarise the current understanding of CNG channel regulation in the visual system.

Calcium was identified early on as a CNG channel modulator. Light itself causes changes in calcium, so it was natural to guess that this would be important for adaptation. However, as the field matured, it became clear that it modulated many other steps in the phototransduction cascade, and that its effect on the CNG channels wasn't very significant. So, other signals must also be fine-tuning vision through the CNG channel.

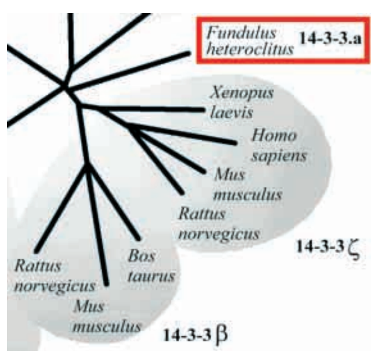
The list of ion channel regulators that have been identified includes transition metals such as zinc and nickel. These ions bind the channels and modulate their activity. Because zinc interacts with other molecules in the phototransduction cascade, light can cause a dramatic redistribution of zinc within the cell, which could be one way that light modulates the channel activity.

Not surprisingly, CNG channels are also regulated by phosphorylation. The first kinases shown to interact with the channels were serine/threonine kinases. More recently, work in Kramer's own lab has shown that tyrosine phosphorylation is another regulator of these ion channels.

Other membrane bound proteins also interact with CNG channels. Some of these proteins are kinases and phosphatases, which also have an allosteric regulatory function.

Kramer discusses other regulatory systems where the biochemistry is less well characterised. Lipid metabolites, such as diacylglycerol, have been known to modulate CNG channels since the 1990s, but the mechanism remains unclear. It also seems that visual sensitivity fluctuates on the diurnal scale, but again the biochemistry isn't known.

Having described the nuts and bolts of CNG channel regulation, the next question is 'when' does the visual system use these regulatory mechanisms? Now that Kramer knows how they work, he wants to know what they're for.




## Switching the Pump (p. 2975)

Living in water makes life a constant battle against the forces of osmosis. Anchovy fans know what salt does to fish, which is fine if you're destined for the dinner plate, but not so great if you're free in the ocean. Fish that live in either fresh or brackish water have well developed ion-pumping systems. Seawater dwellers secrete salt, while those who make their home in freshwater absorb salt. But what about the fish who divide their lives between the two worlds? They have to be able to switch the pumps, whatever water they're in.

Dietmar Kültz noticed that many cellular changes that happen in osmotic adjustment also occur in other forms of adaptation. He reasoned that the switches that regulate the other adaptive processes might also regulate the cellular adaptations of osmotic regulation.

14-3-3 is a key protein in some physiological adaptations, so he reasoned that if euryhaline fish carried a homologous gene, it might be an osmotic switch candidate.

The euryhaline fish, *Fundulus heteroclitus* lives in mudflats and estuaries along the east coast of the United States. It moves freely between saline and freshwater environments, so Kültz chose it to search for 14-3-3 homologues in euryhaline fish.

After he cloned a homologue of 14-3-3 from this species he tested how the gene reacts to osmotic changes. First he acclimatised the fish to running seawater. Then he transferred them to three separate environments: freshwater, seawater at the same concentration and seawater with twice the amount of salt. After allowing the fish 24 h to adapt to the new environments he searched for the fish 14-3-3 gene in different tissue.

Not surprisingly, 14-3-3 levels hadn't changed much in most of the fish's organs, but both 14-3-3 mRNA and protein levels were altered in the gills. Kültz points out that there is no linear correlation between salinity and the levels of 14-3-3 gene expression. However, the surprise was that protein expression was also modified under different osmotic conditions, and the protein existed as two isoforms.

14-3-3 proteins are involved in phosphoprotein recognition, so Kültz built a molecular model of the fish homologue to confirm that crucial amino acids involved in phosphotyrosine recognition were structurally conserved in the homolgue. Kültz also constructed a phylogenetic tree, to see which 14-3-3 proteins were most closely related to the fish proteins. He hoped that this may give a clue to the signalling cascades that this protein regulates. But the fish 14-3-3 failed to cluster convincingly with any of the known mammalian or amphibian isoforms, so no clues there.

For Kültz, the search is now on to find which pathways 14-3-3 controls. As usual, identifying the gene has turned out to be the start of a story that has many more chapters to write before it is complete.

## Sniffing for a Living (p. 3085)

According to Kevin Daly, you can train a sphinx moth to respond to almost any scent under the sun. They can even be trained to respond to smells they'd never encounter naturally, which would seem to be a contradiction. Why would an insect evolve a sense of smell that can detect and discriminate more odours than it will encounter in its day-to-day wanderings? Intrigued by this question, Daly set out to discover how an insect that has an estimated 60 scent receptors can recognise and discriminate among so many scents.

*Picture provided by W. P. Armstrong.*

The way to a moth's brain seems to be via its stomach. Moths associate floral scents with food. Once the moth recognises that a certain smell represents a meal, it usually tries to feed the next time that it picks up the scent. Daly uses the feeding response to tell him when a moth has recognised a familiar smell.

Daly trained moths to respond to three volatile compounds (alcohols and ketones) with specific chain lengths, by associating the odours with food (sugar water). Then he tested how well they responded to related alcohols and ketones that they hadn't experienced before. The aim was to see how well the moths discriminated between other volatile compounds that differed slightly in length.

He found that when the moths had been trained with a short alcohol or ketone, the intensity of the feeding response to the novel scents weakened systematically when the moths were tested with compounds with longer chains. The moths could even distinguish chains that differed by as little as a single carbon unit! So, carbon chain length is a key aspect of the moth's sensory system: it is a 'perceptual dimension' of odour space.

The fact that moths can respond to scents that they have not been trained to recognise suggests that some odour receptors have evolved to respond to a broad array of scents. In many respects this is similar to the way that mammals use a few broadly-tuned light-sensitive cells to see the entire rainbow. An individual scent is probably signalled by a volatile molecule binding to more than one class of scent receptors, resulting in a scent-specific combination of sensory signals in the antennal lobe that the moth brain recognises.

But why has the sphinx moth evolved such a sophisticated sense of smell? Daly believes that this incredible adaptability is because food-related odours aren't constant for sphinx moths. Flowers come and go with the seasons, and a moth born at the beginning of spring won't be around to enjoy the flowers of late summer. So the moth must learn which scents are associated with food for its 'here and now'. Instead of hard-wiring receptors to only recognise a few floral scents for a selected location and time of year, the moth has developed a sense of smell that it can fine tune to the time and the place, no matter where it emerges.

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