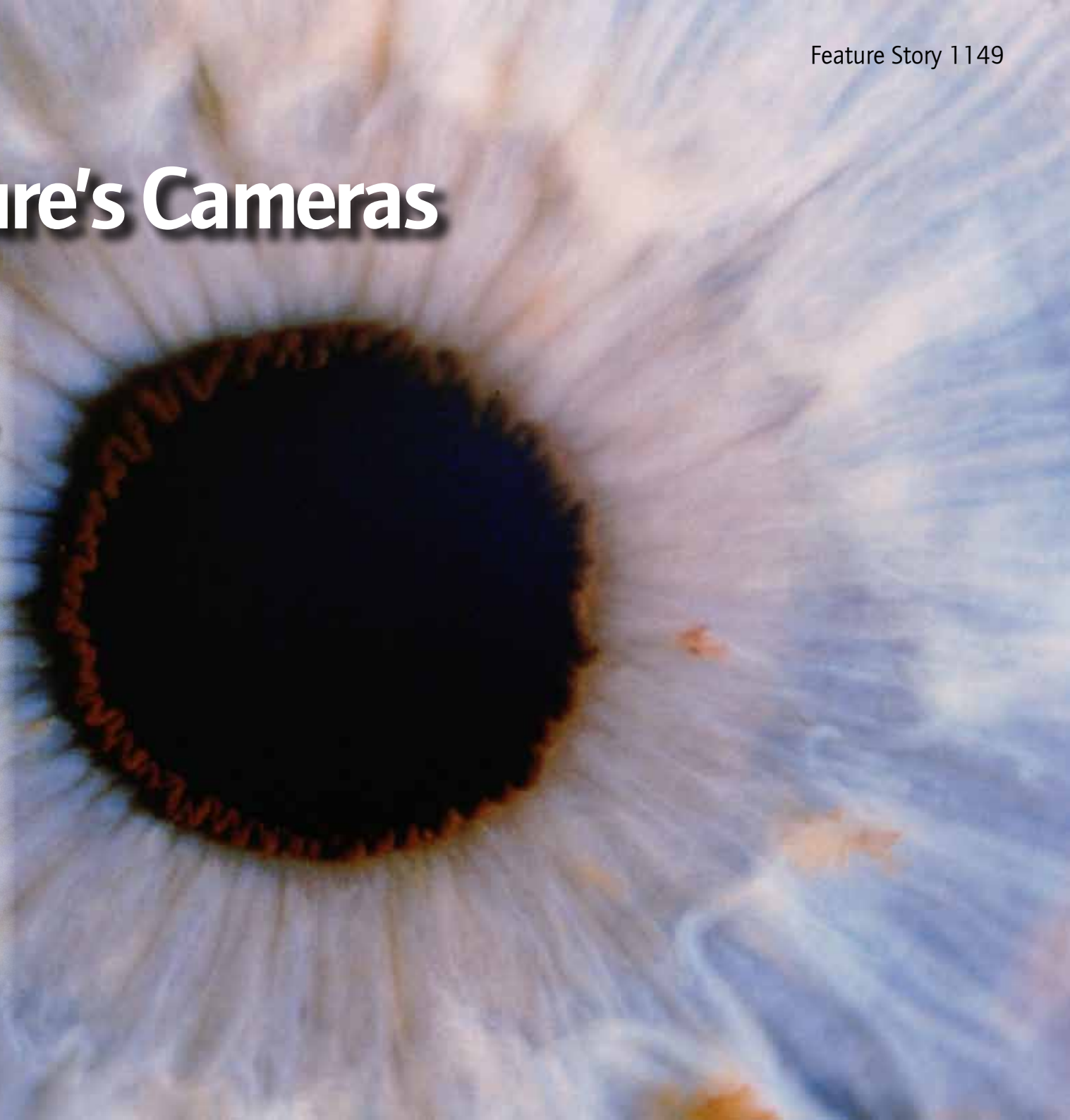


The Eye: Nature's Cameras

This portrait gallery of eyes from the animal kingdom shows their astonishing variety across the species that live on land, sea and air. From the water flea to the wasp, the pufferfish to the monkey, 9 out of 10 of all animals have eyes. Unlike the other senses, vision is the most prevalent method of gathering information about the environments that sea creatures, land animals and birds inhabit. The optical systems they have evolved to exploit these environments are some of the most complex organs we know of.



Eyes are nature's cameras. But why are eyes so popular? When and why did they appear, and how did they evolve into some of the most complex organs in nature? Creationists believe that eyes are impossible to explain by evolution alone, and that there is a hidden hand at work. Even Charles Darwin, author of 'On the Origin of Species', conceded that eyes would be difficult to explain by his theory of evolution because they are such 'organs of extreme perfection and complication ... To suppose that the eye could have been formed by natural selection seems, I freely confess, absurd ...'

But science has come a long way since Darwin's day, especially over the past thirty years. Technology like scanners and the great leap forward in our knowledge of genetics has given scientists more confidence that they can explain how eyes evolved - even though they concede that many puzzling questions remain.

Basically, evolution says eyes evolved because of the traits all organisms need to survive and multiply - avoid predators, find food, and locate mates. These are known as the 'big three'. Individuals who are better at avoiding predators, finding food and locating mates are more likely to survive and pass on those characteristics that helped them succeed to their offspring. And so it continues, down the generations.

Possibly the most important factor affecting life on Earth is light. Without sunlight, organic life as we know it would be impossible. But light, and the day/night cycle, is also the greatest source of information for most organisms. So, to be successful at the 'big three', an organism needs to exploit this world of light. And the eye has become the preferred mechanism for exploitation.

Eye origins

One of the most intriguing aspects of the eye - and which is still the subject of much speculation - is its sudden appearance on Earth. Before the period known as the Cambrian, some 542 to 530 million years ago, there were no creatures with eyes, just light-sensitive receptors. They could detect light, but couldn't process information like direction. Then came the Trilobite



bite with eyes.

The Trilobite was a curious creature, ancestor to today's crabs and spiders. It was a marine animal which fed on the seabed, and many of them were perfectly preserved in the fossil record. So they have been intensively studied. Sometime during the beginning of the Cambrian, Trilobites developed a collection of tiny, camera-like structures that were able to collect and focus light - a so-called 'compound eye'. The bodies of fossilised trilobites clearly show the tiny holes where the lenses once were.

Compound eyes still exist in today's insects: the hoverfly, for example. Each facet of the hoverfly's compound eye is a cone-shaped imaging device with a lens that focuses light onto an array of light-sensitive cells. Although the compound eye can't form a clearly-focused image, it allows the hoverfly to detect rapid movement and orient itself by the direction of light - the Sun - and its intensity.

The era which saw the development of the first primitive compound eye in the

Trilobite saw developments that would be crucial for the evolution of life on Earth. It is known as the 'Cambrian explosion' because, over a relatively small period in geological time, some 10 to 15 million years, an army of

new and diverse life-forms emerged which were far more complex than those before them. With this 'explosion' of life came shells, spines and other hard body parts.

During the Cambrian, the eye improved rapidly. The simple light receptors became more complex. As well as detecting light, they developed into optical systems that could produce images. These biological equivalents of the camera had lenses which formed images on a photosensitive layer at the back of the eye. This layer converted light into electrical energy which could be interpreted by the nervous system. These early eyes could detect motion and direction, evolutionary advances that were crucial to the attainment of the 'big three'.

Light switch theory

At the same time, the first carnivores and predators appeared on the scene of life. Although this has not been universally accepted, Prof. Andrew Parker, a research fellow at Oxford

University, has an interesting theory which directly links eyes with predators.

Called the 'Light Switch' theory, it suggests that the development of eyes in predators was a crucial evolutionary step during the Cambrian. Vision allowed them to detect and feast on the soft-bodied animals around them, who had no protection. Until, that is, nature evolved hard body parts like shells and spines in response.

According to the theory, the first predator to have developed true imaging, where it could actually see its prey, would have triggered off an 'arms race'. Both predators and prey would have to rapidly match - or better - their competitors in eye development if they were to survive. The eye had become the crucial organ in evolution.

Hunting eyes

Today's predators show how the eye has developed into a hunting device. The iguana has eyes on either side of its head. This gives it a wide field of view, but at the expense of binocular vision. Humans, by contrast, have eyes at the front of the head. This limits our field of view, yet gives us good binocular vision, which is needed for precise measurement of distance





for example, to the nearest prey.

To compensate for this, the iguana's eyes have evolved to become so mobile that both eyes can simultaneously zoom in on prey when needed: dual-mode eyesight.

Eagle owls, with their distinctive orange eyes, are another example of adaptation in predators. An old country myth gave owls the ability to turn their heads completely around through 360 degrees. In fact, they can't, but, like many country myths, the owl's ability to swivel based on observation: due to extra vertebrae in their neck, owls can rotate their heads through 270 degrees and literally look back over their own shoulders.

The reason for this is simple. Owls are night-time predators. To be effective at hunting at

night, you need large eyes for light-gathering. If the owl was as large as a human, its eyes would be as big as oranges. The owl's eyes are so well-developed for night vision that they have evolved into tubes, rather than eyeballs, that are actually locked into the skull. So, to move its eyes - natural night-vision scopes - the owl must move its entire head.

In complete contrast to the owl, the Jumping Spider has no fewer than 8 simple eyes - four on its face, four on the top of its head. But the reason for this curious arrangement is the same as that of the owl's night-vision scopes - it gives the Jumping spider excellent vision, allowing it to spot its prey from distance.

Not so different after all

As the images in this portrait gallery show,

there is a great deal of variety in the eyes of different species, especially between creatures with compound eyes, like the wasp, and those with paired eyes, like the argonaut.

But there is also a marked similarity in eye structure: most animals have camera-type eyes that are sensitive to a fairly small range of wavelengths in the visible light part of the spectrum. Why this should be is still a matter of debate, but one simple explanation may be the fact that eyes first evolved in creatures living in water, which filters out most electromagnetic radiation from the Sun. So the reason why eyes across species have similar structures may be due to the physical laws which govern the narrow band of visible

light they have evolved to detect.

In nature, only certain types of eye may be possible. Yet another unanswered question concerns the origin of eyes. Take marine animals. The cuttlefish has well-developed eyes which allow it to observe changes in its environment. Yet the Nautilus, a marine snail, has an eye like a simple pinhole camera, with low resolution and poor sensitivity to light. And the Right Whale, which can weigh over 100 tonnes, has eyes set so far back on its head that it literally has double vision: it sees two scenes, one to its left, the other to its right.

These three creatures have eyes adapted to their marine environment - the Nautilus doesn't need to see very much because it is a nocturnal bottom-feeding scavenger, whereas the

Right whale needs good eyesight to locate the swarms of plankton it feeds on.

But these creatures, which share a common environment, the sea, have very different kinds of eyes. The question is, did they evolve independently, or did they all follow a single evolutionary route?

For decades, it was believed that eyes evolved independently. After all, they do have an astonishing variety. We now know of at least eleven different and distinct optical systems in nature that produce images. The most recent discovery concerns the Chameleon, better known for its ability to camouflage itself to fit in with its surroundings - itself an evolutionary advantage in a predator-prey world of light. But the Chameleon also possesses a unique eye system similar to a telephoto lens. So common sense alone would suggest that different types of eye evolved differently.

However, researchers recently found evidence that eye development in many different species is triggered by a single 'master' gene called Pax-6. They have proposed that all eyes evolved only once, co-ordinated by this single gene. So the humble Trilobite may have been the ancestor of all eyes.

Not everyone agrees with this, and not only because it contradicts the accepted wisdom that eyes evolved along multiple lines. Pax-6 organises growth in organs other than the eye, for example. But researchers have also found similar sequences of genes that are responsible for the structure of eyes across a range of different species, so the debate continues.

This is the kind of research that, one day, will answer many of the questions still posed by the eye. That creatures as different as the pufferfish, the silverfish - a nocturnal insect, rather than a fish - and the lynx have evolved complex light-gathering optical systems that operate along similar lines is a marvel of nature. But the explanation for this doesn't have to invoke a higher power, only a better understanding of the principles that govern our world of light.

Evolution conundrum

One of the principal criticisms of evolution raised by creationists is that the 10-15 million



years of the Cambrian explosion wasn't long enough for the first eyes to evolve. They are just too precise and too complex - as Darwin himself admitted. But, in the 1990s, two scientists demonstrated that a primitive light receptor could evolve into something as complex as the human eye within a million years, simply through small mutations and natural selection. Other scientists who are more cautious believe this process actually took several million years, but the point had been proved.

And what of the most evolved species on the planet, humans? Our eyes don't have the telephoto capabilities of the chameleon, nor the night scope of the owl. But the human eye is a good example of nature's camera. We have binocular vision, which enables us to measure distance; we can see in colour, which is superior to monochrome in telling one object from another; we can move our head as well as our eyes, giving us a wide field of view; and we can focus swiftly, allowing us to view objects at a distance as well as right in front of us.

All these are traits which, over millions of years, have evolved via natural selection and small mutations. They have allowed us to become successful predators, avoid being prey, and select mates, partly based on their visual characteristics. The next time you see an attractive woman, or man, remember that you, too, live in a world of light.

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Written by Jon Trux
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FULL PICTURE SET

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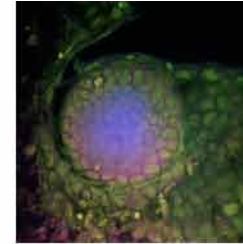
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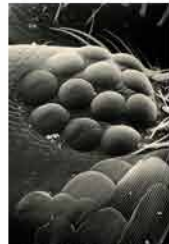
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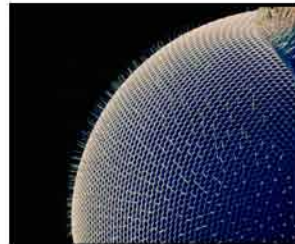
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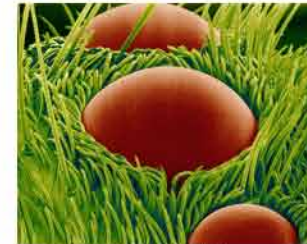
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