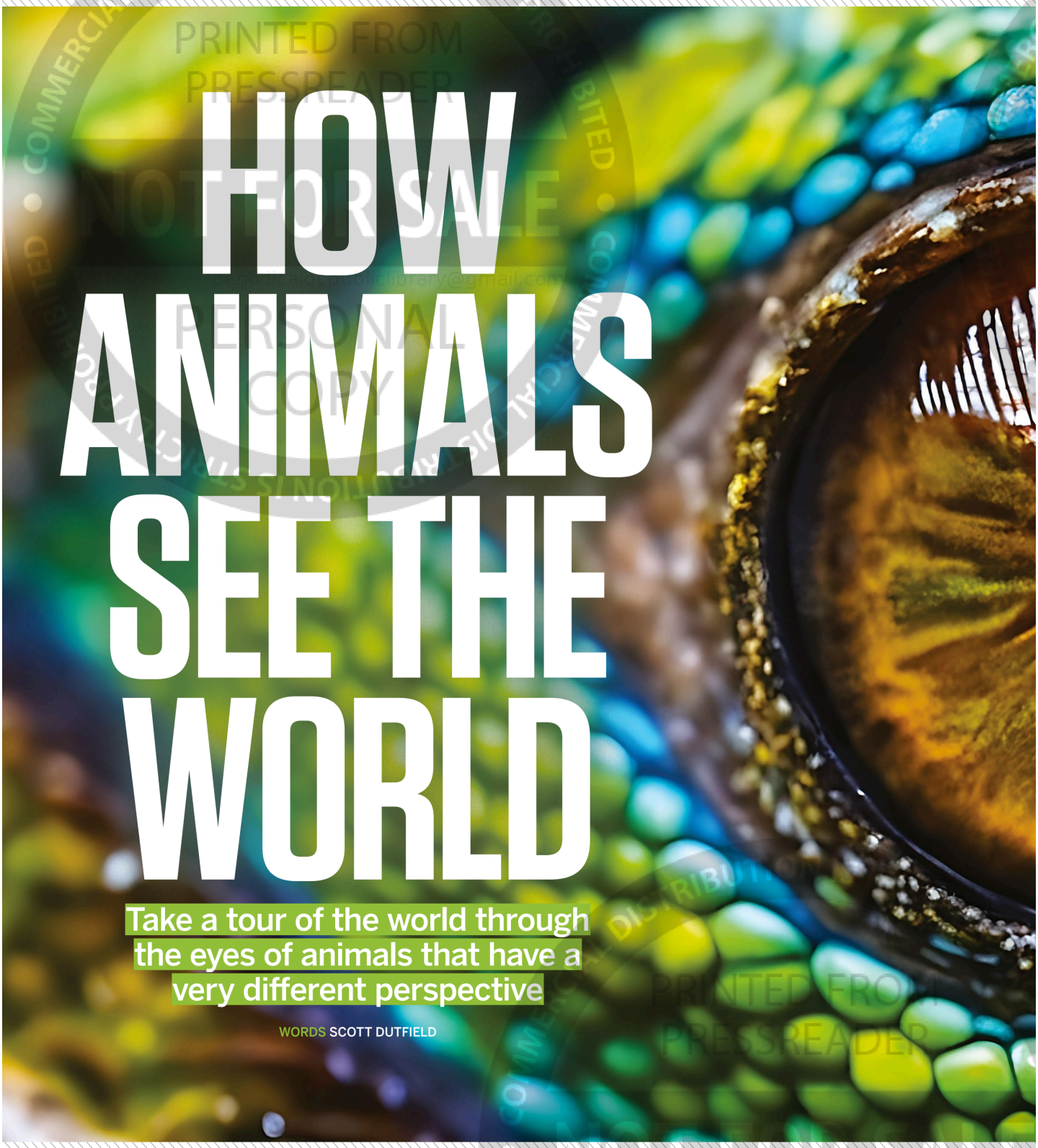
- Animals—anatomy

ENVIRONMENT



HOW ANIMALS SEE THE WORLD

Take a tour of the world through the eyes of animals that have a very different perspective

WORDS SCOTT DUTFIELD

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DID YOU KNOW? Mantis shrimp can see ten times as many colours than the human eye



Just like humans, in animals the ability to see comes from cells called photoreceptors, which are found in a light-sensitive layer at the back of the eye called the retina. When excited by light, these cells generate an electrical signal that travels along nerve cells to the brain to create an image. Among these are two types of photoreceptors, called rod and cone cells. Rod cells are responsible for communicating brightness and the contrast between light and dark. Cone cells, on the other hand, perceive a wide array of colours. Within the human eye, there are around 6 million cone cells, of which there are three types: blue, green and red. Rod cells, however, dominate the retina, with around 120 million cells in each eye.

When the photoreceptor cells are excited by photons of light, it triggers the cells to release a neurotransmitter molecule called glutamate. These molecules then travel across a short junction to reach an adjacent bipolar cell, generating an electrical impulse that is sent to the brain for the translation and formation of an image.

Did you know?
Ostrich eyes are bigger than their brains

Not all animals have eyes, but many can still 'see' the world around them. For example, sea urchins use light-sensitive cells on the tubular feet covering their bodies. The photoreceptors across the sea urchin's body provide a 360-degree 'view' of changes in light levels around it.

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THE ANATOMY OF SIGHT

How rod and cone cells perceive colour and brightness

1 DISCS
Flat discs that are densely packed with light-sensing molecules to absorb light.

6 LIGHT
A pigment called rhodopsin in the rod cell discs is responsible for perceiving light and dark.

5 COLOUR
A pigment called photopsin in the cone cell discs is responsible for detecting different wavelengths of light.

2 MITOCHONDRIA
As they do in any cell in the body, mitochondria supply the rod and cone cells with chemical energy to function.

3 NUCLEUS
This organelle houses all the genetic information needed for cone and rod cells to grow and regenerate when damaged.

4 SYNAPTIC ENDING
When the cell is stimulated by light, a series of chemical reactions within the cell cause it to release a neurotransmitter called glutamate from the synaptic ending, to bind with adjacent nerve cells.

ROD

CONE

Did you know?
A dragonfly's eye has 28,000 lenses

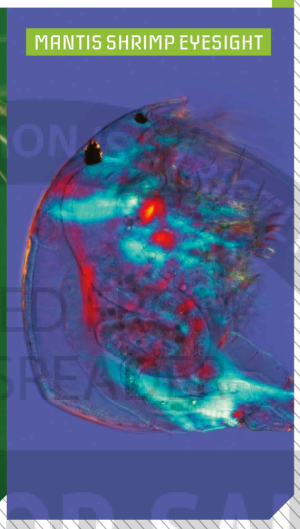


SEEING THE POLAR OPPOSITE

Ordinarily, ambient light travels in wavelengths that move in every possible direction and orientation. However, light is 'polarised' when its wavelengths all travel in the same direction. The polarisation of light can be caused by a lot of things – sometimes when it's scattered by the atmosphere or reflected by a surface – but only certain groups of animals are able to see it. Among those are mantis shrimp, bug-eyed crustaceans living in coral reefs. Unlike our single-lensed eyes, mantis shrimp have 'compound eyes' with thousands of individual lenses and photoreceptors.

Within each photoreceptor are tiny projections called microvilli. Some of the microvilli can align in such a way that they can act as a polarising filter for light. They work similarly to how sunglasses can filter polarised light. Mantis shrimp are thought to have evolved this ability to spot prey at greater distances. Scientists have also found that certain parts of the shrimp's bodies can reflect polarised light as a way to communicate with one another.





DID YOU KNOW? A moth's eyes are covered in a water-repellent and anti-glare coating

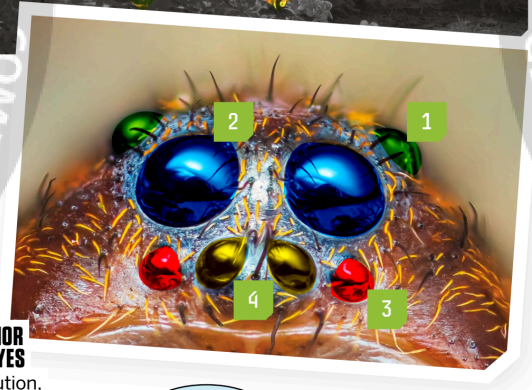
X MARKS THE SPOT

With the same number of eyes as legs, spiders have an array of sight organs in their head to spot potential prey and any incoming predators. There are two types of spiders in the animal kingdom: those with two rows of eyes, such as wolf spiders, or a single row like jumping spiders. Of their eight eyes, the two largest are set in the front of the head and are used for focusing on an image, but each only has a narrow boomerang-shaped view. The remaining eyes gather information from their peripheral vision. The front principal pair of eyes can observe the full range of colours humans can and more, including ultraviolet light. However, the secondary adjacent eyes lack colour-sensitive cells. They can only see in black and white and don't have the same high acuity the two primary eyes have. All eight eyes work together to create an almost-360-degree view of the world.



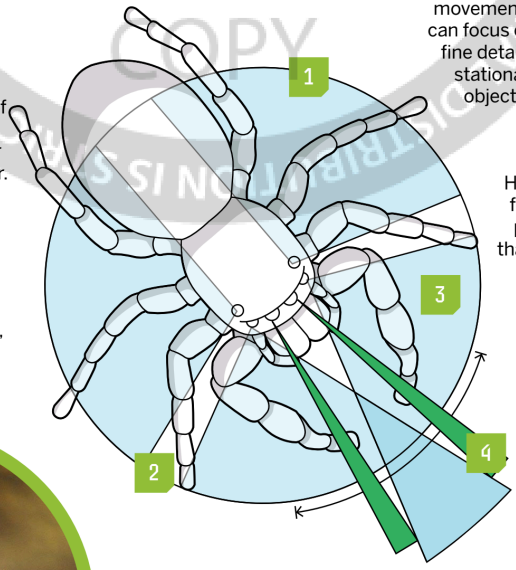
EIGHT-EYED

Having more than two eyes gives these animals an advantage when it comes to hunting



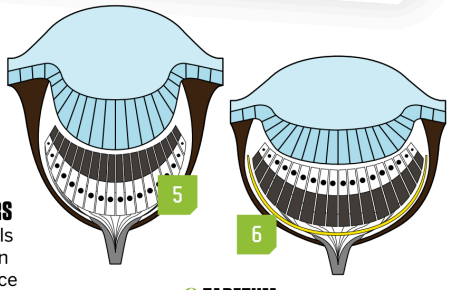
1 POSTERIOR LATERAL EYES
Sat at the back of the head, these monitor the rear view of the spider.

2 POSTERIOR MEDIAL EYES
Found on the sides of the head, these are highly sensitive to low light.



3 ANTERIOR LATERAL EYES
These are highly sensitive to movement and can focus on the fine details of stationary objects.

4 ANTERIOR MEDIAL EYES
High-resolution, forward-facing principle eyes that see in colour.



5 PHOTORECEPTORS
Photoreceptor cells in the retina within the primary eye face towards the light, but are inverted within the secondary eyes in some species of jumping spiders.

6 TAPETUM
A reflective tissue found at the back of the eyes used to increase the amount of light detected by the inverted photoreceptor cells in the secondary eyes.



A GREEN WORLD

Unlike humans, horses only have two of the three colour cone cells in their eyes. Without any red-light cone cells, our equine pals can only see blue and yellow wavelengths, with all the variety of shades associated with those colours – mostly greens. But what they lack in their ability to see colour, they make up for in night vision. Horses have a ratio of around 20:1 rod to cone cells. For comparison, a human eye has a ratio of about 9:1 rod to cone cells. As rod cells are responsible for detecting light at low levels, having so many rod cells gives horses excellent night vision. Horses also have a layer of reflective tissue called the tapetum lucidum at the back of the eye, something our eyes aren't equipped with. It reflects light through the retina to enhance the horse's night vision, but it can blur images whenever the eye is overloaded with light.



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INFRARED VISION

A snake's vision is dichromatic, meaning they have just two types of cone cells in their retinae that allow them to see blue and green. However, snakes have evolved another organ that assists their eyes and creates a thermal image in their heads. Between a snake's eyes and nostrils are heat-sensitive depressions called the pit organ. Scientists still aren't completely sure how, but this organ can pick up on the infrared waves emitted from the snake's environment and nerve impulses to create a thermal image of the world around it in the snake's brain.

As fearsome predators, this gives these animals an advantage over their prey during the dark of night. The warm bodies of prey such as small rodents or birds emit a lot of infrared, which the snake is sensitive to, allowing them to detect their prey's movements in the darkness to ambush them.





ULTRAVIOLET SIGHT

Many insects, including the humble bumblebee, have a talent for seeing in a range of light wavelengths much narrower than we do. Our vision allows us to see light in wavelengths of around 380 to 700 nanometers. However, insects like bees can observe light wavelengths of around 300 to 650 nanometres. While bees miss out on longer wavelengths of light, such as red light, they can see shorter wavelengths of ultraviolet light. As an important pollinator, bees rely on their ultraviolet vision to locate flowering feeding sites. Many flowering plants have evolved ultraviolet patterns on their petals to grasp the attention of passing pollinators. Bees use these patterns as landing sites to locate delicious nectar within the flower, gathering pollen along the way.



SEEING EVERY ANGLE

The ability to see the whole world around you without needing to move a muscle is an ability few animals have. Chameleons, however, have evolved a pair of eyes that can do just that. The cone-shaped eyes of these reptiles have adapted to move individually and can pan around their surroundings to create a 360-degree view of their environment. They can also switch between binocular and monocular vision so that they can see an object with both eyes or using just one.

Chameleons see the full spectrum of light that humans do, as well as viewing extras, including ultraviolet and infrared. Ultraviolet light in particular is a handy way to spot pollinator prey at nighttime. Chameleons have no rod cells in their retinae, which means they are almost completely blind at night. Their ability to see ultraviolet light is the only way they can see in the dark. Studies have also shown that chameleons have ultraviolet patterns on their bodies, which might be used for attracting a mate.





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DID YOU KNOW? Colossal squid have the largest eyes in the animal kingdom, measuring up to 27 centimetres wide

THE SHARPEST SIGHT IN NATURE

If you find yourself scoring 20/20 vision at your next opticians appointment, don't be too smug, because there's a group of animals that are sure to have you beat. Eagles have 20/4 or 20/5 vision, meaning these birds can see things at around six metres that a person with normal vision could only see at around 1.5 metres. This talent comes in handy when soaring high in the sky looking down to spot unsuspecting prey.

What separates human and eagle eyes are the many 'foveae' within them. Within the retinae are depressions of these tightly packed photoreceptor cells, responsible for creating the sharpness, or 'high acuity', of an image. The human eye has a single fovea in each eye, whereas an eagle has two. The number of photoreceptors within each fovea is also worlds apart for humans and eagles, with just 200,000 cone cells per millimetre in a human fovea and around a million cone cells in an eagle's fovea. Their collection of cones also allows them to see a wider range of colours than humans can, including ultraviolet light.



Did you know?

Butterflies have 15 different types of cone cells

5 FACTS COLOUR-BLIND CREATURES

1 WHALES
Living in oceans and waterways made up of different shades of grey, all species of whale swim without the ability to see colour, but they can distinguish between light and dark.

2 SEALS
Like most other marine mammals, seals can also only see in black, white and grey. Their vision is well suited to life underwater, but less so on land.

3 SNAILS
Known to have poor eyesight, snails have a very blurry image of the world that is completely black and white.

4 PRIMATES
Many primates have trichromic vision similar to our own. However, some nocturnal monkeys, such as the owl monkey, have monochromatic vision. With more rod cells than cone cells, these monkeys have excellent night vision.

5 SHARKS
With only one type of cone cell and one type of rod cell in their retinae, it's thought that sharks are monochromatic seers. Scientists have found that at least ten species of sharks have no cone cells at all.

HOW DO WE KNOW WHAT ANIMALS SEE?

When it comes to estimating what colours animals might be able to see, peering into the anatomy of their eyes is crucial. While examining the cellular composition of the animal's retina, scientists can locate and count the number of colour-sensitive cone cells. If the retina is missing these cells, then scientists know that the animal is most likely colour blind. The same conclusion can be drawn by scanning the brain activity of animals to see how the activity changes when the animal is exposed to different colours. When it comes to identifying the perception of different light wavelengths, such as ultraviolet or polarised light, scientists often set up experiments for animals to interact with objects that are known to reflect or emit those wavelengths of light. For example, one of the first experiments to prove mantis shrimp could see polarised light used food containers that reflected polarised light and others that didn't. The shrimp were more likely to interact with the containers that reflected polarised light.


Scientists use a combination of anatomical and behavioural studies to determine an animal's sight

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