Nature Watch Series

Animal vision

TONY SEDDON

Animal vision

This book contains just about everything you might want to know about animal eyes. It leads you from simple explanations of light and color to descriptions of how the eyes work and the many different kinds of eyes found in the animal kingdom as well as their significance. You will discover the many types of vision used in different environments and for different purposes. There are vivid descriptions of eyes that squirt blood and eyes that light up, four-eyed fish and crying turtles, as well as entertaining sections on optical illusions and a quiz. By the time you have read this book you will no longer be sure that seeing is believing.

The Nature Watch Series provides readers with a suberbly crafted introduction to the natural world in all its aspects. Within the covers of these books, readers will discover the excitement of learning about the wonders of animal behavior and anatomy and unlocking the intricate mysteries behind the way animals adapt to various environments and climates, whether hundreds of feet deep in the ocean or high above rugged mountain peaks.

Each book in contains more than 100 illustrations, many of which are full color photographs. Specially commissioned line art is used to explicate difficult concepts not readily explained by text alone. As well as providing a wealth of accessible information on fascinating natural history topics, the books seek to involve the reader in a lifelong process of exploring the natural world.

Features that enhance the reference value of each book include a glossary, an index and fact boxes.

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Note to the reader
On page 59 of this book you will find the glossary. This gives brief explanations of words which may be new to you. Answers to questions are given on page 58.

Contents

All about light

Seeing colors

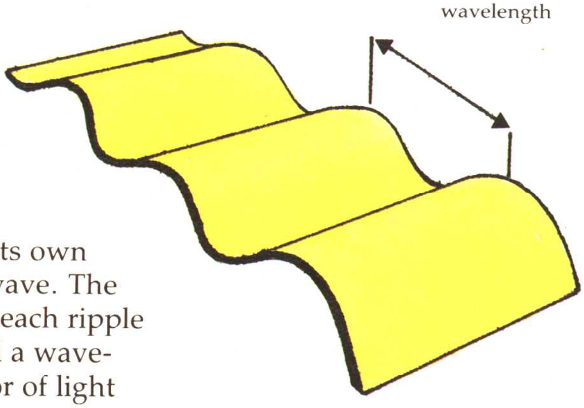
Sunlight is made up of the different colored wavelengths of light. When you look at a rainbow, you can see all these colors. We call these colors the spectrum. Light reflects or bounces off objects in its path. When we see an object we see the light that it reflects. A leaf appears green to us because it reflects green light. It absorbs or takes in all other colors. A white dress reflects all the colors of the spectrum. This is why it appears white. Why does a piece of coal look black?

▲ The Earth receives all its light and heat from the Sun, 90 million miles out in space. Light waves travel at 180 thousand miles a second. Can you work out how long it takes for light to reach the surface of the Earth from the Sun?

Wave after wave

Light consists of tiny packets of energy called photons. Bright light contains lots of photons. Moonlight contains only a few. There are no photons if it is completely dark. Light travels in waves like the ripples on the surface of a pond.

Each color has its own special shape of wave. The distance between each ripple of a wave is called a wavelength. Every color of light has a different wavelength.



Me and my shadow

Light travels in straight lines. This explains why you cannot see around a corner. It also explains why light causes shadows. If light cannot pass through an object, a shadow will be formed.

Animal shadows are telltale signs. They point to where an animal is resting. Because of this, many animals try to avoid making shadows with their bodies. Many animals lie low against the ground. They sometimes press themselves flat against a tree trunk. Some lizards even have flaps of skin along their sides. These act as shadow "disguises."

A glaring problem

Light is reflected from the surface of calm water. This makes it difficult for birds like pelicans to see clearly, or does it?

Diving birds seem to be able to cope easily with the bright glare. For example, the brown pelican swims with its wings held open. The wings block out the Sun and stop glare from the surface of the water so that it can see the fish swimming below.

▲ A pelican's eyes may work like a pair of sunglasses, with some kind of filter inside to cut out surface glare.

The umbrella bird

The black heron is even more skillful when it is fishing. It stands with its wings arched over its head, just like an umbrella. This forms a shadow and stops reflection from the water. The heron can now clearly see its prey swimming just below the surface.

▼ The heron's wings make a circular shadow on the water surface. It always hunts for fish inside this circle.

Refraction and its problems

When light passes from air into another substance, it bends. This is called refraction. Have you noticed how the lines on the bottom of a swimming pool seem to bend in a strange way? It is very easy to see at the shallow end. This is another example of refraction. Imagine the problem that diving birds like sea gulls might have with refraction. It could easily cause the bird to miss its target when it is hunting. Sea gulls solve this problem by diving vertically onto their prey. Other diving birds do the same. In this way they make sure of a tasty meal.

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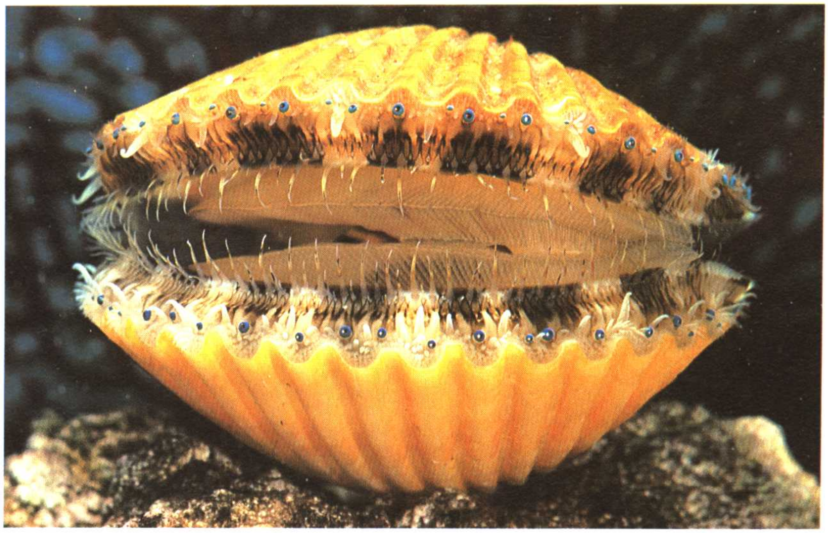
Many different eyes

Animals without backbones (invertebrates) form about 95% of all animal species. They include creatures such as insects, mollusks, worms, and crabs, as well as starfish, corals, lobsters, and squids. The simple and compound eyes of insects will be looked at later. Here we will look at the tremendous variety of shapes and sizes of eyes of other invertebrates.



▲ Each of the small brilliant eyes along the edge of the mantle of a scallop is only about 0.04 inches across. With these the scallop can detect the difference between light and shade, as well as movement.

Simple eyes

The most simple "eyes" are merely cells that are only able to detect light and dark. Some invertebrates, such as mussels, no longer have eyes because the ability to "see" is of no use to them. Incredibly, the young have tiny eyespots which they lose as they grow older.

An animal usually has eyes which suit its needs and way of life. Spiders have simple eyes around the head. These help them to spot approaching prey extremely quickly. The jumping spider has eight simple eyes of various sizes. When it sees an insect, it judges how far away it is with the outer pair of front eyes. Then it stalks its prey using the huge center pair of eyes which give clearer vision.

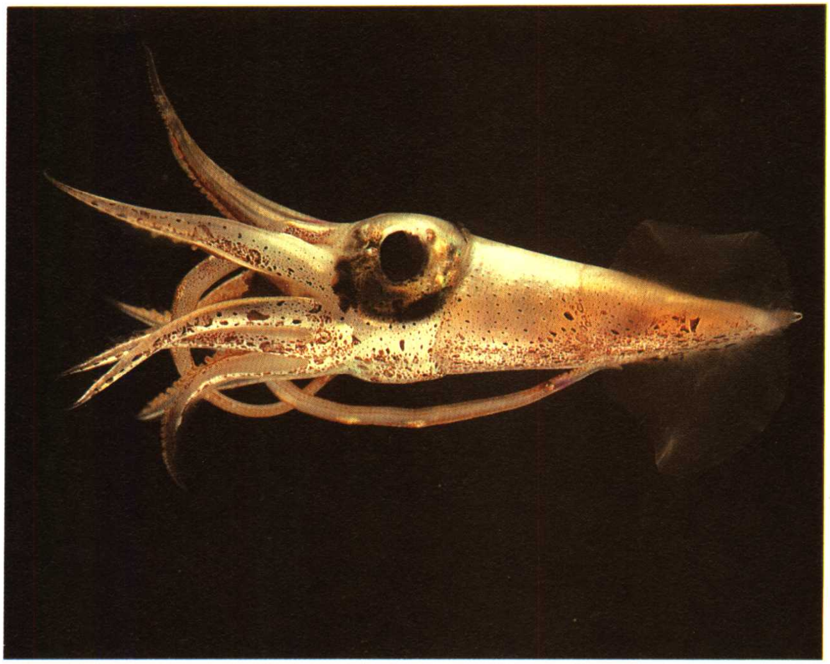
The biggest eyes in the world

Some of the most efficient eyes must be those of the squids. They have two eyes, similar to our own, at the base of their tentacles. One of the largest squids ever recorded was washed up on the shore in New Zealand in 1933. It measured almost 69 and a half feet long and its eyes were about 4 inches

◄ The jumping spider has simple eyes all around its head which it uses to detect the approach of a flying insect. Imagine how useful it is to be able to see in all directions at once.

across, the largest known eyes in the whole animal kingdom. It is possible that this was not the largest squid, and there may be even larger ones in the depths of the ocean. A squid's eyes are not only large, they are also very good at seeing fine details.

A squid may hold the record for the largest eyes, but the scallops hold the record for the greatest number of eyes. A scallop may have between 50 and 200 metallic-blue eyes studded like jewels around the edge of its mantle. The scallop does not depend only on its eyes. It has many fine filaments around its mantle. These can detect movement in the water, and can warn of an approaching predator long before it could ever be seen.



▼ Rather than lying buried in the sand like ghost crabs, this purple shore crab hides among mangrove roots. So, it only needs eyes on short stalks, not long ones.

▲ The eyes of a squid are large and very efficient. They are very like human eyes, though the squid probably cannot see as much detail as we can.

Eyes on stalks

Some animals have eyes in unusual places. Crabs and snails may have eyes on the end of long stalks. For example,the ghost crab spends much of its time buried in sand ready to ambush any passing animals. Only its eyes protrude like a pair of periscopes to scan the beach for the next meal.

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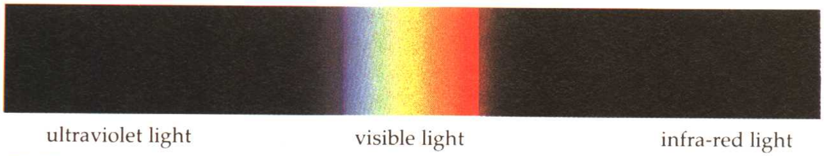
Color vision in animals

Different wavelengths of light produce different colors. Everyone knows the red, orange, yellow, green, blue, indigo, and violet colors of a rainbow. We call this band of colors the visible spectrum because we can see it. Most humans have good color vision, but they cannot see beyond the ends of the visible spectrum. Some other animals react to non-visible light. Many insects and birds see ultraviolet light. Even more remarkable are certain types of snakes which explore the world in infra-red light. They detect this light as heat.

"Seeing" ultraviolet

Although butterflies and bees have a fuzzy view of the world, their eyes are extra sensitive to ultraviolet light. This is very important to them. The colors that we see will look very different when seen in ultraviolet light. When a drab-looking butterfly with white spots opens and closes its wings, it doesn't look very spectacular to us. But to other butterflies, which are seeing ultraviolet light, the white appears as flashes of vivid blue. This is a much better signal for gaining attention.

Some flower heads also give off ultraviolet signals which are picked up by passing insects. Dull yellow flower heads form bright beacons to an insect's eyes. They work like the lights on an airport runway, helping the insects to make a safe landing on the flower head.



◄ A spectrum showing the visible part, which we see, and the ultraviolet and infra-red parts, which insects and some snakes see.

▼ This is how a flower appears to our eyes. It is rather dull and not very exciting.

▼ This is a similar type of flower reflecting ultraviolet light. This is how an insect would see it.

◀ This rattlesnake uses its normal eyes during the day. At night it changes over to its other pair of "eyes." It has two pit organs which it uses to find its prey in the dark.

Red rag to a bull

Most mammals, such as cats, dogs, horses, and cows, are "color-blind." They see only shades of gray or perhaps very pale shades of color. Their eyes are made to detect movement around them. It is not important for such animals to see their surroundings in bright color.

You have probably been warned never to walk through a field with a bull in it if you are wearing a piece of red clothing. The color red is supposed to make the bull angry so that it will want to charge you. But bulls are almost certainly "color-blind." It will not make any difference to the bull what you wear. His eyes are tuned in to pick up movement. Rather than worrying about your red scarf, you should take more care not to stop and start suddenly, or make jerky actions!

"Seeing" infra-red

Infra-red rays are found beyond the red end of the spectrum. We cannot see them because their wavelength is too long, but we can feel them as heat. The rattlesnake in the picture can find a warm-blooded animal in complete darkness by means of the heat-seeking pits on the front of its face. It "sees" the heat image of a mouse just as easily as we see the animal in bright daylight.

Colored filters

Daytime birds not only display very bright plumage, they also see a greater range of colors than humans, including ultraviolet light. Their eyes also use another interesting method to detect different shades and colors. Each cone of a bird's eye contains a tiny oil droplet. The oil acts like a filter. It reacts to each color of light as it falls on the retina. These filters are especially sensitive to orange, yellow, and red. This is probably why flowers pollinated by birds usually have these same colors.

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Insect eyes

The eyes of an insect are very different from human eyes. They cannot produce sharp pictures of the world around them. Many insects can see in color. Some see far more colors than us, while others see far fewer. Their world looks very different from our own.

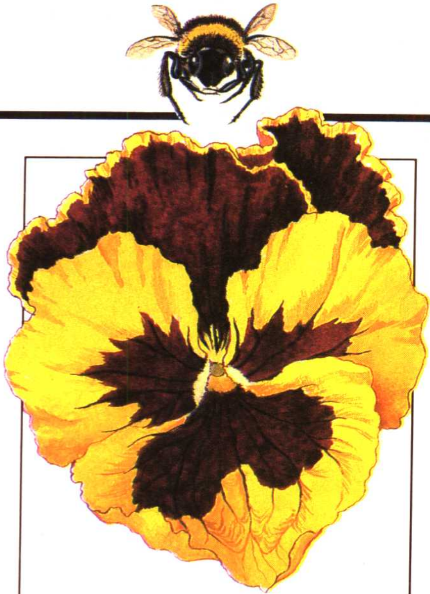
Insects can have two types of eye, compound and simple. Sometimes both types are found on the same insect. The most basic type is called a simple eye. This is a small, rounded, clear lens which can only tell light from dark, and sometimes sees colors. It is found on caterpillars or on the forehead of adult insects.

Compound eyes

The second type of eye is much more complicated. It is much larger and is called a compound eye. It is made up of hundreds of tiny pieces placed together in a honeycomb pattern.

Each part of a compound eye is shaped like a long, pointed tube. The broad end of the tube reaches the outside of the eye and contains a clear lens. The thin end of the tube is joined to a special type of cell that turns light into electrical signals. Each color of light produces a different signal. A compound eye sees the world as a jigsaw of tiny images. Each tube within the eye produces a tiny part of the overall picture.

▼ One compound eye of an insect can have from 10 to 30,000 sections, depending on the kind of insect. This picture shows the rainbow-colored eyes of a horse fly.



Flower power

Insects that visit flowers for food need to tell one color from another. Over millions of years, these insects have learned which colors lead to food. At the same time, flowers have developed patterns to attract certain types of insect. It is useless for a bee with a short tongue to visit a flower with deep petals. The bee would be unable to reach the nectar. To avoid wasting time, the bee only visits flowers whose color pattern it recognizes, and which it knows will provide food.

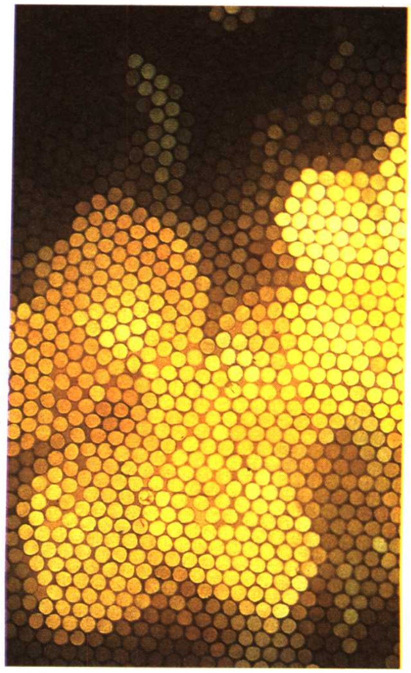
▲ A dragonfly has enormous eyes compared to the size of its body. On the same scale, a human would have eyes more than three feet in diameter.

The lenses in the insect's compound eye cannot move, and so it cannot produce sharp pictures. The most that an insect can see is a fuzzy pattern of light, dark, and color. Many insects can only see an object if it moves, or if it is very close to them. A few insects, such as dragonflies or praying mantises, are very good at seeing movement and shape. Their eyes have up to 30,000 tubes, each seeing a tiny part of the complete picture. They depend upon their eyes to help them catch other insects as food.

Most adult insects have two compound eyes, one on each side of their head. Insects with simple eyes may have many placed in a ring or clumped together. The outside of all these eyes is made from a very hard substance. They do not need to be protected like human eyes.

If you look carefully at a magnified part of a compound eye you will see lots of tiny hairs, knobs, or pits. These are special sense organs which the insect uses to smell, taste, and feel. No other animals can do this with their eyes!

▼ Hold the book away from you to see flowers as an insect with compound eyes might see them.



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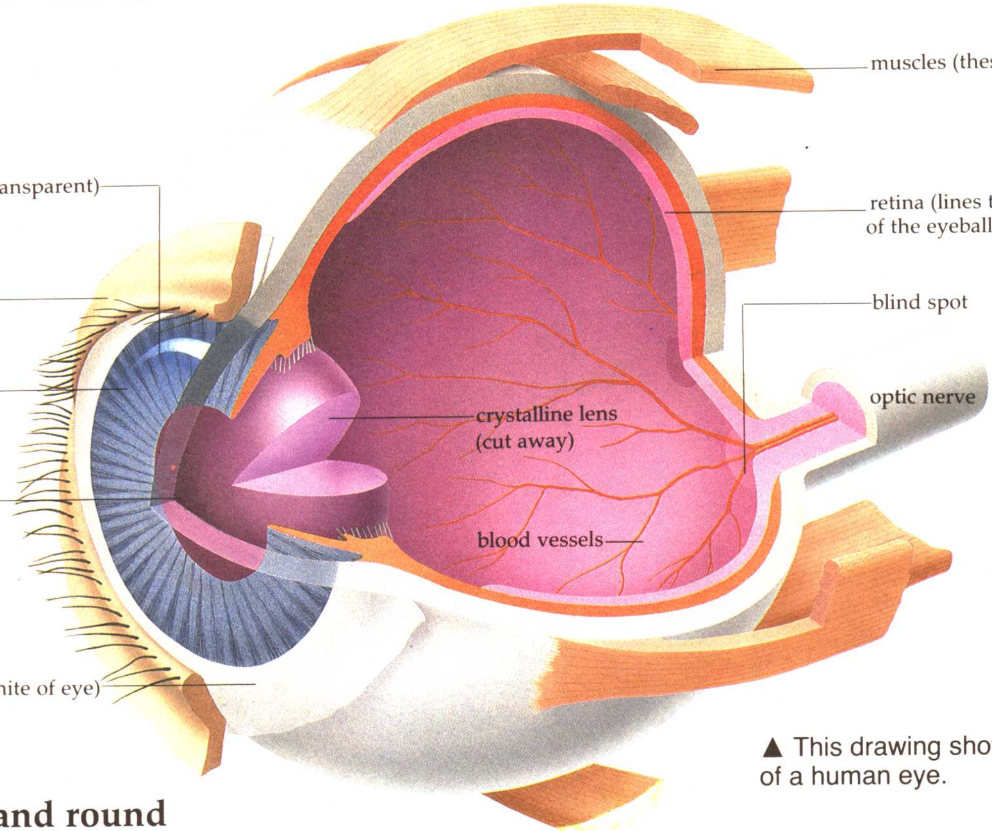
Our eyes



▲ This drawing shows the inside of a human eye.

Soft and round

The eyes are one of the most sensitive parts of the human body. By gently rubbing them, you can feel that they are soft and round. These features help the eye to work in the way it does.

Look carefully at your eyes in a mirror. Around the outside is a white layer, the sclera. This contains many blood vessels which bring food and blood to the eye.

Eyelids and irises

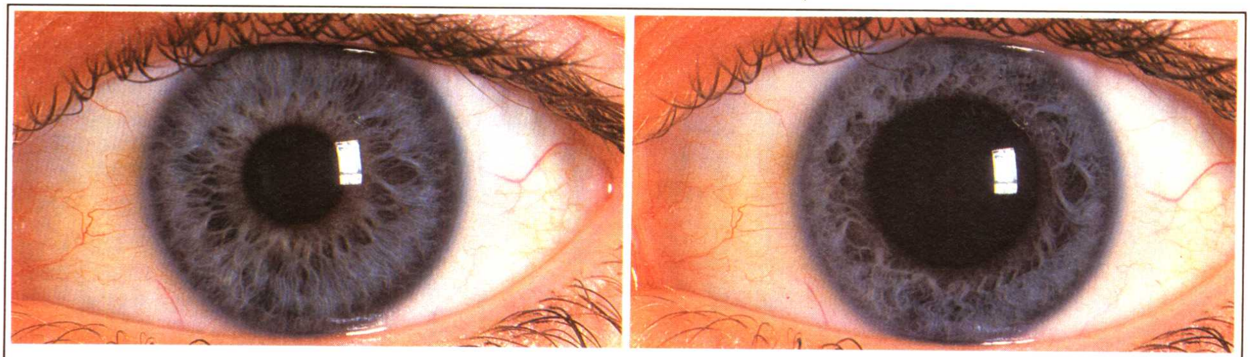
There are two eyelids at the front of each eye. Each has a fringe of hairs called the eyelashes which protect the eyes from dust. The colored circle is called the iris. When you say someone has blue eyes you are describing their iris. In the center of the iris is a dark hole called the pupil. The iris controls how much light enters the eye through the pupil.

Eye make-up

Your eye works like a small camera. There is a film at the back of the camera on which the picture is made. Your eye has a kind of film at the back called the retina. This is where the light makes an image of what you see. Your eye also has a lens, like a camera, and this focuses the light entering the eye on to the retina.

What's on the retina

The retina is made up of millions of tiny nerve cells called rods and cones. The rods respond to dim light for seeing at night. The cones react to bright light and to colors. They are used for daylight vision. The retina collects the light signals and sends messages to the brain. The brain builds these signals up into a picture of the world you see.



In bright light, the iris closes the pupil. Less light is now able to enter the eye. In dim light the opposite happens. Now the pupil opens wider and more light can enter. The iris is changing the size of the pupil all the time as the strength of the light changes. What do you think would happen to your pupils if you went out of a dark room into bright sunlight?

Sharp sight

Everyone likes to think that they have a "sharp" pair of eyes. But how good is human vision? It varies from person to person. Some people have better eyesight than others. There is an average which the optician calls normal eyesight. But did you know there is a record of a young woman living in West Germany whose eyesight is twenty times better than average!

An upside down world

Did you know that you see the world upside down? Well you don't but your eyes do. The lens in the eye turns light upside down as it passes through. This means that the image which is formed on the retina is also upside down. Your brain learns to change it back again. So you do see the world the right way up after all.

Taking care of the eyes

Our eyes need looking after very carefully. The eyes do have their own natural "care-takers." The eyelids and eye-lashes protect them from damage caused by small bits of dust blowing into them. They also receive a good "eyewash" every minute of the day. When we blink we wash the surface of each eye with tears. These keep the eye moist. They also help to kill any germs which get into the eyes.

▼ It is an upside down world on your retina (right), but you still see things the right way up (left). Your brain takes care of this.

More about

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How we see color

Not all animals see colors as we do. For many, the world is a place of shades of gray, similar to what we see in a black and white photograph. Other animals see their natural surroundings in very pale colors. They probably get a "washed-out" view of the world which we find so bright and beautiful and full of color.

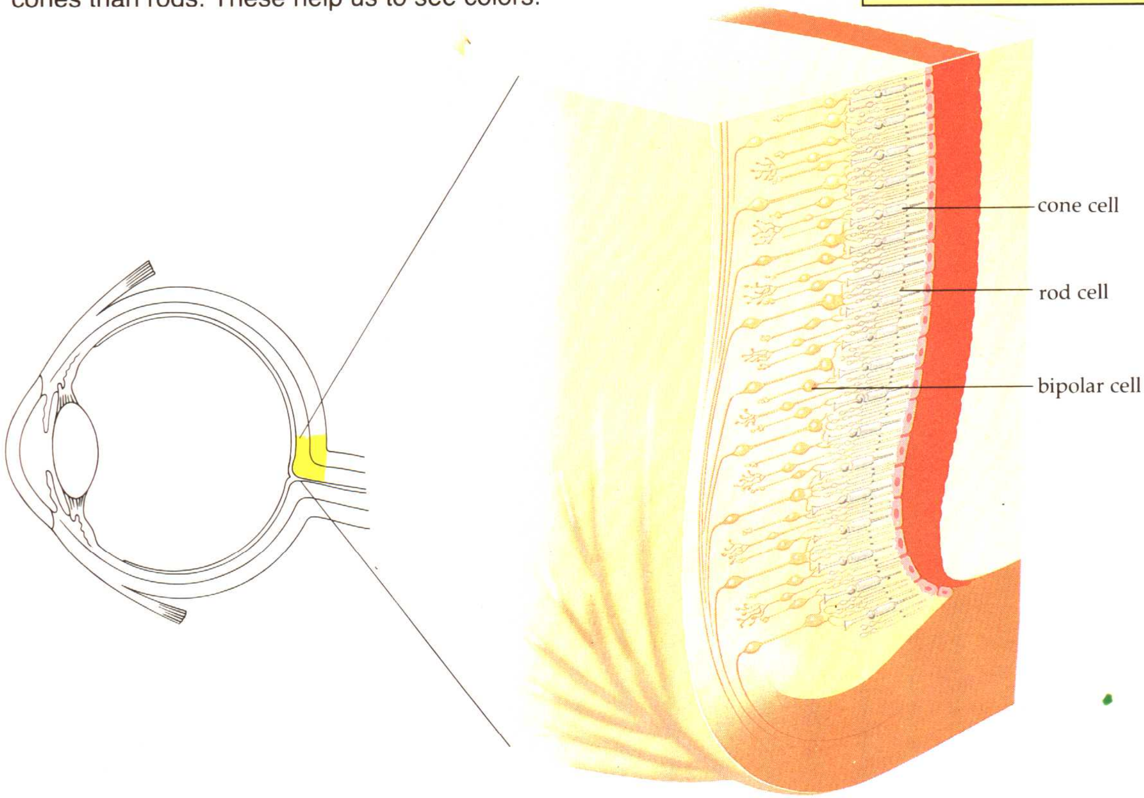
Humans have very good color vision, as do our nearest relatives, the monkeys and apes. And the showiest animals of all, the fish and birds, probably see a range of colors beyond our imagination!

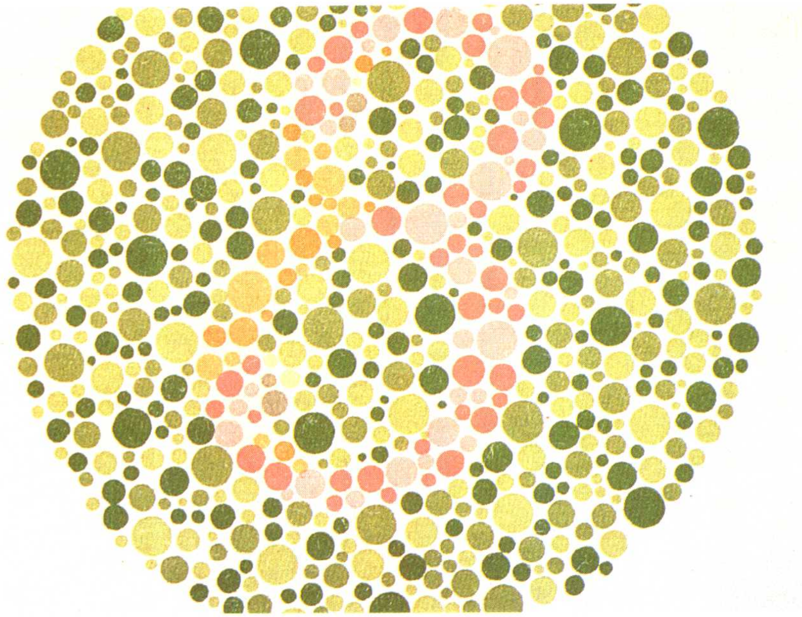
Rods and cones

In order to find out how color vision works, we need to have a good look at the structure of the sensitive retina which lies at the back of the eye. This layer is made up of millions of tiny cells, or light receptors, called rods and cones. You can see from the drawing that each cell gets its name from its shape.

Light falling on the retina passes through the outer layer of nerve cells to reach the rods and cones. Only about a quarter of the light entering the eye stimulates the receptor cells. Many light rays pass between the rods and cones and are wasted. Receptor cells which react to light are "fired" to send signals, or impulses, to the brain. The rods and cones respond to different strengths of light. Rods react to low levels of light and are used for seeing in dim light. Cones are for daylight vision and for seeing color.

▼ The retina at the back of the eye is lined with rods and cones. In the center of the retina at the back of the human eye there are more cones than rods. These help us to see colors.

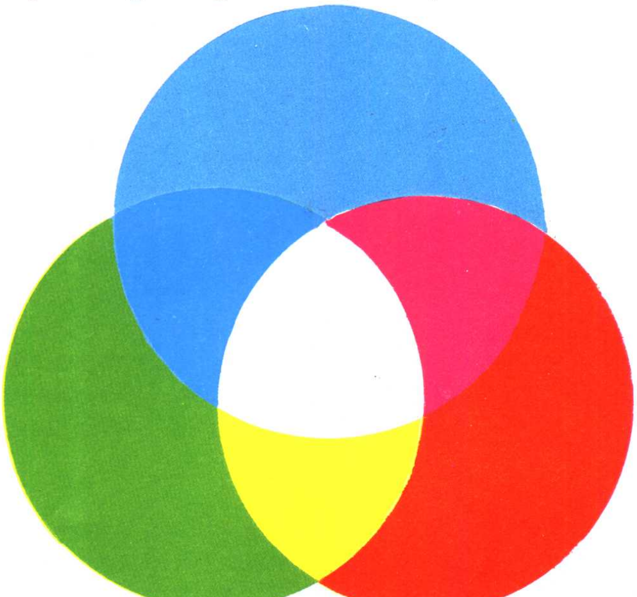




◄ Some people cannot tell the difference between red and green. They are red/green color-blind. Are you one of them? Look at the circle on the left. Can you see a figure 8? If so, you have normal color vision. Do you think being color-blind affects a car driver waiting at traffic lights?

How do we see different colors?

There are three types of cone cells in the retina. Each type is sensitive to only one color, either red, green or blue. These are the three primary colors. By mixing red, green, and blue light in different ways we can make any other color. When a colored ray of light reaches the retina and "fires" the nerve cells, the three types of cone break up the ray of light into the three primary colors.



Making pictures

We are still not sure how the brain "sees" a colored picture. Each cone may deal with one small part of the view the eye sees. Small groups of cones send their messages to a special cell, called a bipolar cell. The signals from these cones are then transmitted as a "collected" message to the brain along the optic nerve. The brain translates the signals from the bipolar cells and uses them to build up a colored picture of the original view.

It all works just like a jig-saw puzzle, where each piece of the jig-saw is represented by a group of cones on the retina. Each bipolar cell unit will receive signals from only one piece of the retina. The brain then takes these pieces and puts them all together again to build up a colored picture of the view.

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