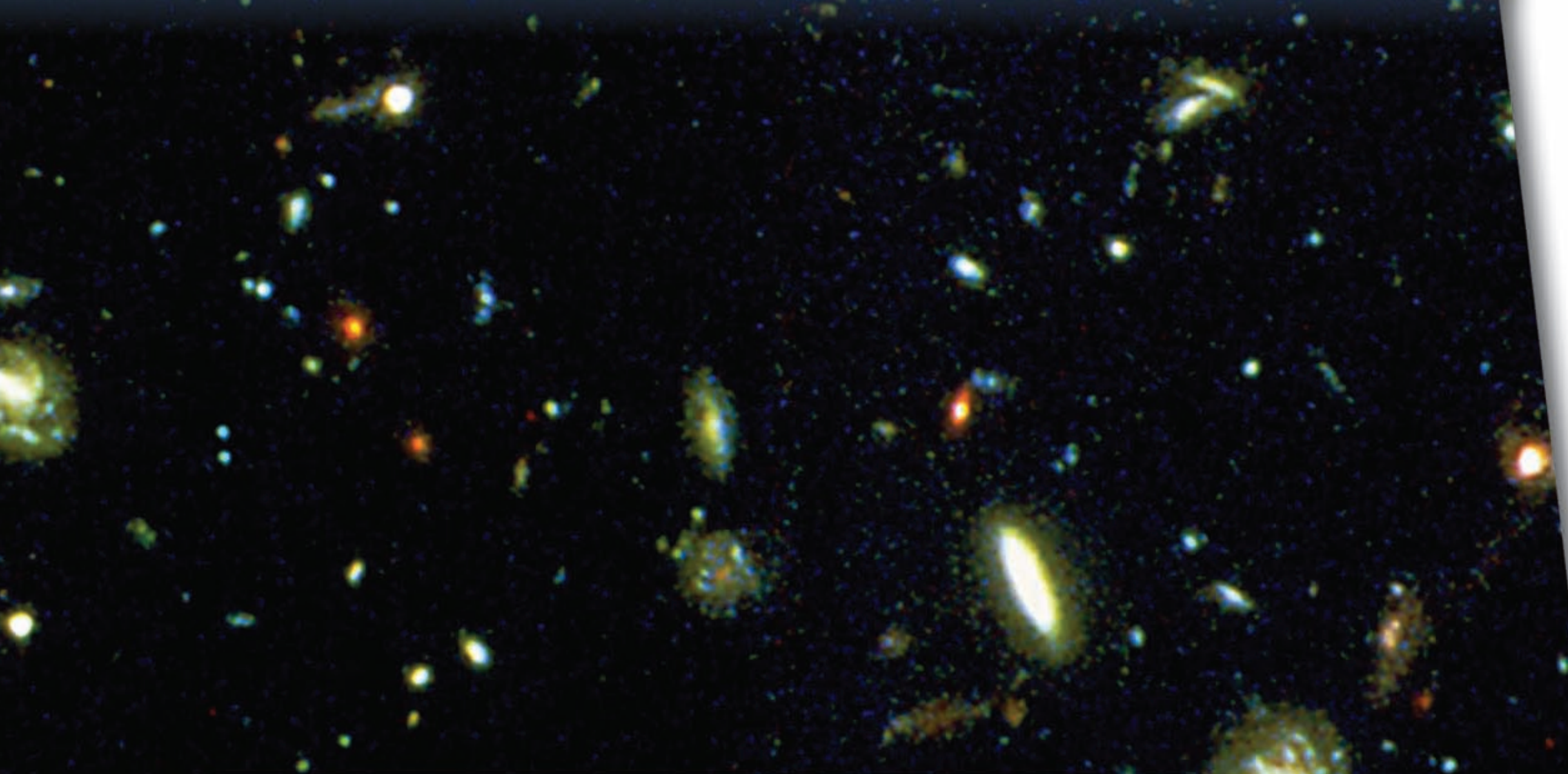
Chapter 6

Human vision can be corrected and extended using optical systems.



This remarkable photograph is definitely one for the record books. These are the most distant objects ever observed by humans using visible light. Why is this photograph so amazing? Consider that it is a photograph, not a drawing or a painting or an artist's imagination of what might be in space. Every swirl and every point of light is a real object. However, none of the points of light are individual stars. Every dot and swirl is a complete galaxy, which means that each and every dot is made up of billions of stars. Human sight and the development of optical systems such as the Hubble Space Telescope have made it possible for us to see more objects in more detail than ever before. We can peer into distant galaxies, view the inside of a beating heart, and examine our home planet from both close up and far away.

What You Will Learn

In this chapter, you will
- **explain** how human vision works
- **investigate** ways to correct and enhance human vision
- **compare** a sheep eye with a human eye
- **explain** how optical devices magnify objects
- **build** an optical device

Why It Is Important

Understanding how we see helps us to understand how to correct vision problems. Optical instruments, such as microscopes and telescopes, enable us to see objects that are otherwise too small or too far away to see.

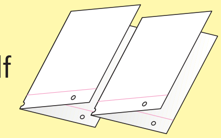
Skills You Will Use

In this chapter, you will
- **explain** how optical systems work
- **work** co-operatively to research and communicate information
- **demonstrate** scientific literacy
- **demonstrate** ethical, responsible, co-operative behaviour

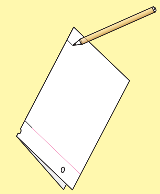
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 6.

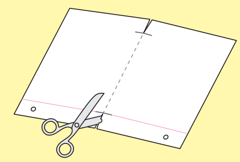
STEP 1 **Fold** two sheets of notebook paper in half along the short axis.



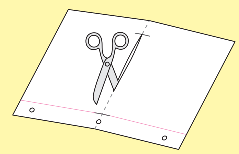
STEP 2 **Mark** both folds 2.5 cm from the outer edges. (On notebook paper, the margins are marked 2.5 cm from the outer edges.)



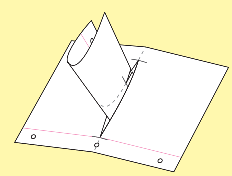
STEP 3 On one of the folded sheets, **cut** from the top and bottom edge to the marked spot on both sides.



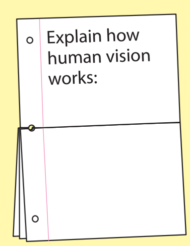
STEP 4 On the second folded sheet, start at one of the marked spots and **cut** the fold between the marks.



STEP 5 **Roll** the first sheet of paper into a long tube, place it through the large opening cut in the second sheet, and **open** the tube so that the folds of the first and second sheet align.



STEP 6 **Fold** the connected sheets in half along the original fold line to form an 8 page book. Give your book the title "Human Vision Can Be Corrected and Extended Using Optical Systems." Inside your book, **label** each page with one of the bullet points from the "What You Will Learn" list on this page of your textbook.



Read and Write As you read this chapter, fill your journal with notes and diagrams on the appropriate page.

6.1 Human Vision

The cornea-lens-retina system focusses light at the back of the eye. Special cells in the retina called rod cells and cone cells convert light into electrical signals that are sent to the brain. Light does not always fall on the retina in perfect focus. Near-sightedness results when the eye cannot form a sharp image of distant objects. Near-sightedness can be corrected by placing a concave lens in front of the eye. Far-sightedness results when the lens of the eye cannot form a sharp image of nearby objects. Far-sightedness can be corrected by placing a convex lens in front of the eye.

Key Terms

astigmatism
blind spot
cornea
iris
optic nerve
pupil
retina
sclera

Think about the different kinds of objects you see every day. With one glance you might see the words on this page, the colour illustrations, and a classmate sitting next to you. Human eyes can focus on objects both near and far and adapt to both blazing sunlight and the dimmest of moonlight. We have one vision system to see in colour and another to see only in shades of grey. How is all of this possible? Much of it can be understood by taking a close look at the structure of the human eye.

6-1 Changing Colours

Find Out ACTIVITY

In this activity, you can observe how your colour vision adapts to changing lighting conditions.

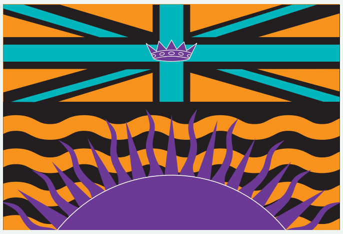
What to Do

1. Look at the image of the flag of Canada, which is printed in a greenish tint. Stare at the image of the flag for 25 s, making sure not to move your eyes around.
2. Immediately switch your gaze to a white space on the page, and wait a few seconds. What do you see? Achieving this effect may take a few tries.
3. Try the same test with the flag of British Columbia.

What Did You Find Out?

1. (a) What did you see when you stared at the white page?
   (b) Why do you think you saw this?
2. How might this adaptability of your colour vision help you as you walk through a forest in bright sunlight and at twilight?

Flag of Canada



Flag of British Columbia

How Light Enters the Eye

Light enters your eye through the pupil (see Figure 6.1). The **pupil** is an opening that appears dark because light passes through it without reflecting back. The **iris** is the coloured circle of muscle surrounding the pupil. The iris is the structure we refer to when we speak about the colour of someone's eyes being grey, brown, blue, or hazel. The iris controls the amount of light entering the eye. In dim light, the iris dilates, or expands, the pupil to allow more light to enter (see Figure 6.2A). In bright light, the iris contracts the pupil to reduce the amount of light entering the eye (see Figure 6.2B).

Covering the iris and pupil is a transparent tissue called the **cornea**. The cornea is made of cells that are transparent enough to let light pass through, yet tough enough to hold the eye together. Surrounding the cornea is an opaque tissue called the **sclera**. We see the sclera as the white region surrounding the iris.

Behind the pupil is a flexible convex lens. The light rays pass through the lens and are focussed on a screen at the back of the eye called the **retina**, where an image is formed. Special light-sensitive cells in the retina detect the image. Other cells in the retina convert the light rays into electrical signals that are sent to the brain through a thick nerve called the **optic nerve**.

Did You Know?

The human eye is more sensitive to green light than to any other colour. If you look at a green light and a red light of the same intensity, the green light appears to be brighter.

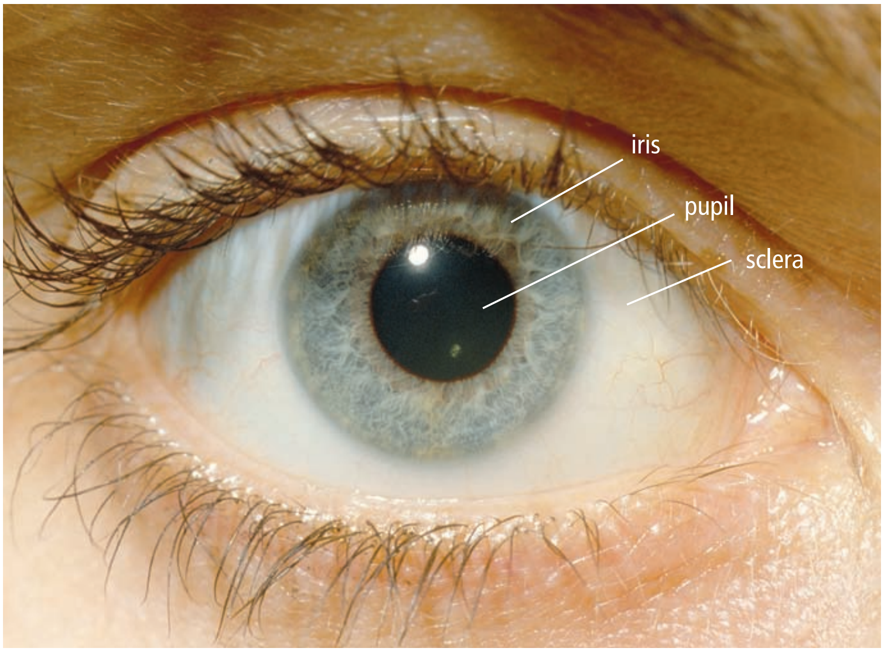


Figure 6.1 Light enters the eye through a transparent opening called the pupil.

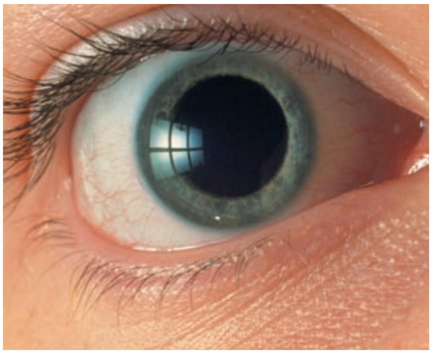


Figure 6.2A A dilated pupil

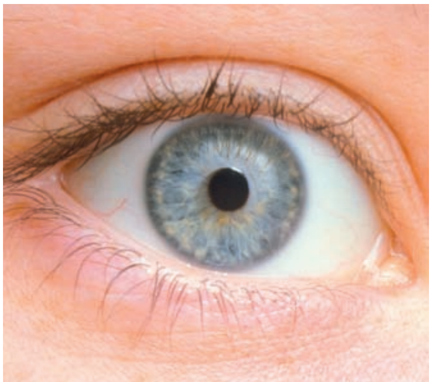


Figure 6.2B A contracted pupil

The Cornea-Lens-Retina System

Light rays pass through a focussing system involving the cornea, the lens, and spaces in the eye filled with a watery fluid (see Figure 6.3). The fluid between the lens and the cornea supports both the cornea and the lens, and provides nutrients to the cornea, which does not have any blood vessels. The fluid behind the lens gives shape to the eye and supports the lens.

Word Connect

The term "cornea" comes from the Latin word for horn, the front part of an animal's head. The cornea is the most forward part of the eye.

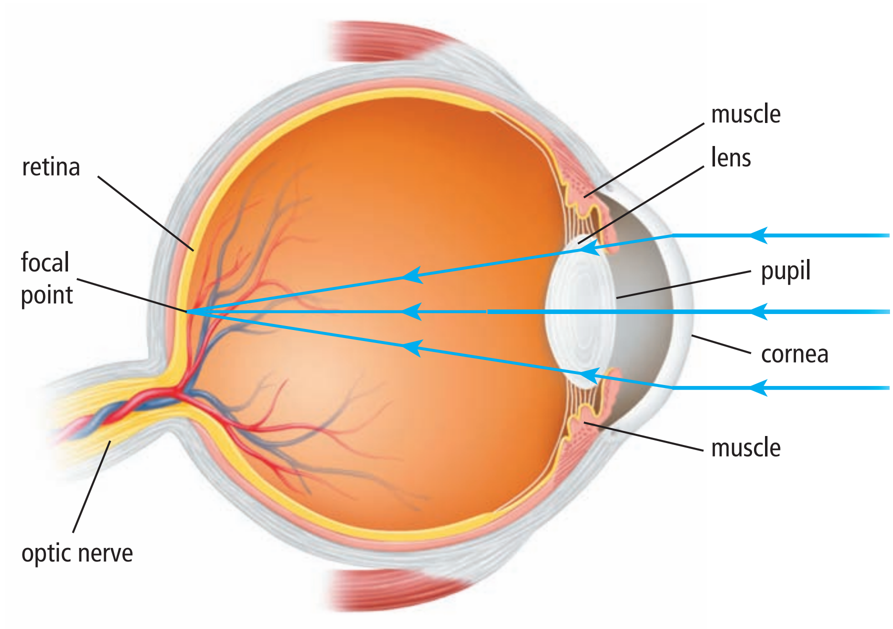


Figure 6.3 The eye in cross section

Light rays begin to be focussed as soon as they pass into the cornea. The cornea refracts incoming light rays so that they converge toward the retina. The cornea provides most of the focussing done by our eyes. The lens does the remaining focussing. This may be a surprise to you because we usually think of the lens as doing the focussing. Perhaps it is because we do not notice the amount of focussing done by the cornea that we tend not to think about its function in forming the image.

The lens has the ability to fine-tune our focus by automatically changing its shape. When certain muscles in the eye contract, there is less tension on the lens, allowing the lens to become thicker. A thicker lens can focus on near objects. When you look at distant objects, these same muscles relax, increasing tension on the lens and making it thinner. You can feel your eyes working hard to focus if you hold a finger up very close and try to see it clearly.

Did You Know?

In some species of animals, such as the octopus, the lens and the retina can move closer together.

Forming an image

All the light rays that enter the eye from one spot on the base of an object come together again in one place at the top of the retina. Similarly, all the light rays that enter the eye from a spot at the top of an object come together at one place at the bottom of the retina. As shown in Figure 6.4 the image formed by the lens is inverted. However, you do not have to stand on your head to see upright. Your brain interprets the image as being upright.

Suggested Activity

Conduct an Investigation 6-4, on page 212

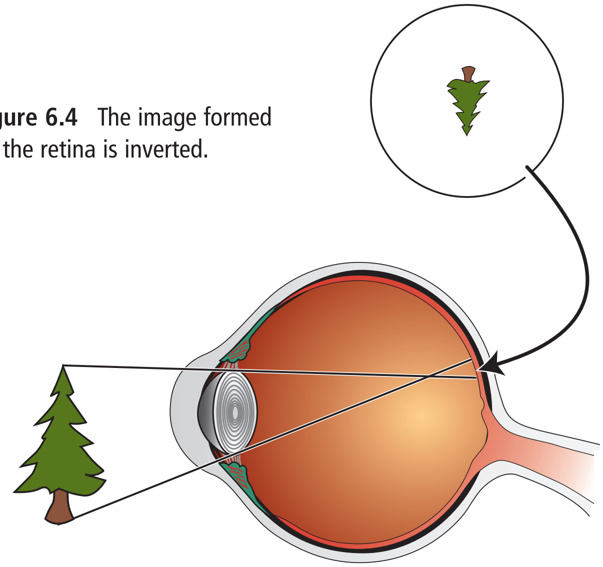


Figure 6.4 The image formed on the retina is inverted.

Blind Spot

The area where the optic nerve enters the retina does not have any light-sensing cells. This area is known as the **blind spot**. You can easily demonstrate the presence of your blind spot by following the steps outlined in Figure 6.5. Note that each eye sees what the other misses because the blind spots are not in the same place.

●   **X**

Figure 6.5 To locate your blind spot, hold this book at arm's length. Cover your right eye with your hand. Stare at the X while you move the book slowly toward yourself. The dot should disappear and then reappear as its image moves onto your blind spot and then off again.

internet connect

An optical or visual illusion tricks the eye and brain into perceiving something unlike what actually exists. Check out examples of optical illusions and find out what they reveal about the way we see. Start your search at **www.bcscience8.ca.**

Reading Check

1. What happens to light rays after they enter the eye through the pupil?
2. Where does most of the focussing in the eye occur?
3. How does the lens change to focus on objects that are close?
4. How does the lens change to focus on objects that are distant?
5. Why is the image of an object inverted when it strikes the retina?

Black-and-White Vision and Colour Vision

Once the light rays are focussed correctly on the retina, the cells that absorb the light begin their job. Some cells in your retina specialize in detecting low levels of light. Other cells detect bright light. The cells in your retina that absorb light come in two basic shapes: longer cylindrical ones called rod cells and rounder ones called cone cells (see Figure 6.6).

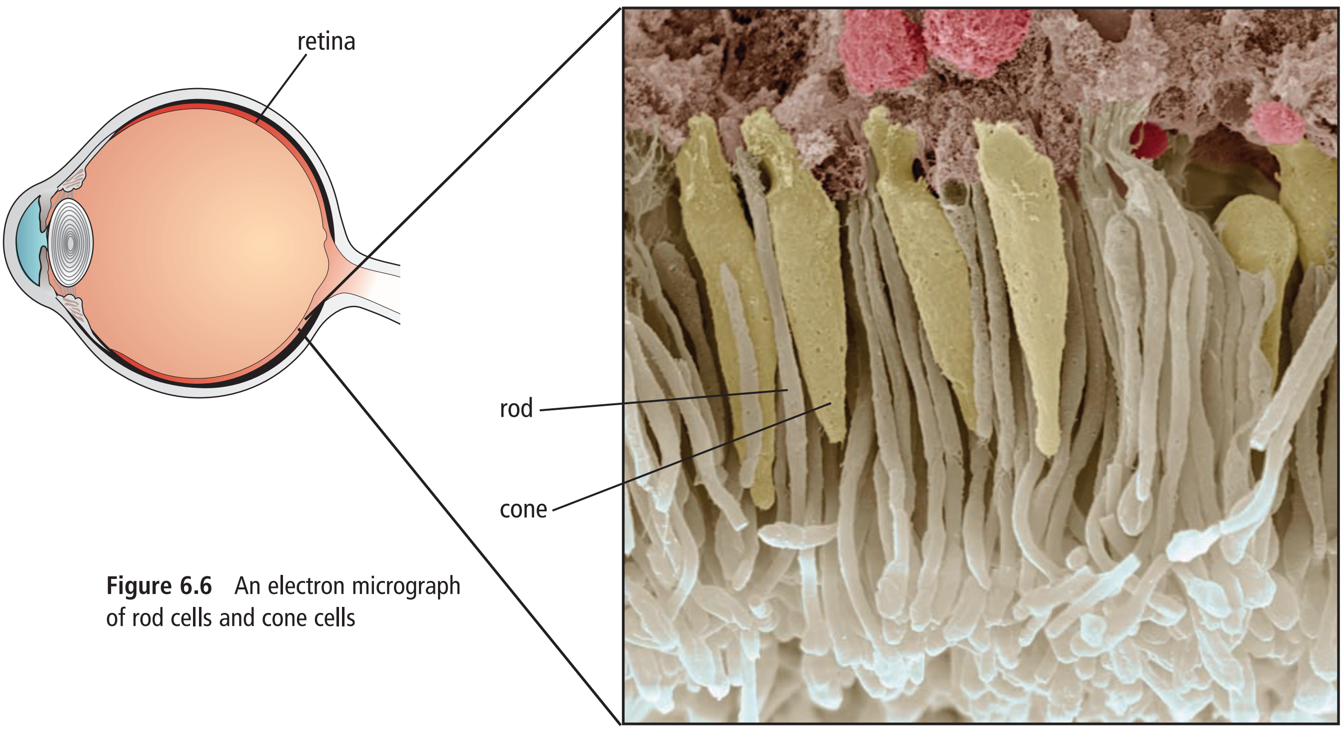


Figure 6.6 An electron micrograph of rod cells and cone cells

Rod cells—shapes, movement, and shades of grey

Rod cells can absorb almost any colour of light, but they absorb green light particularly well. Even so, our brain does not use any of the signals from rod cells to determine colour—just shades of light and dark. This is called our black-and-white vision system, and in low-light conditions it helps us see shapes and movement.

Did You Know?

We sometimes forget we see in black and white at night because we know what the colours should be.

Cone cells—seeing the rainbow

Cone cells allow us to detect colour. We have three kinds of cone cells, each possessing a slightly different kind of pigment. Recall that by using only red, green, and blue it is possible to see all the colours of the rainbow. If our brain receives an equal amount of all three colours, then we see the object as white. The human brain can combine and balance the different colour signals that it receives. This is why the white page of a book can appear white to us under varying amounts of daylight.

What Colours Do Rod and Cone Cells Detect?

In Part 1 of this activity, you will use the information in a table to answer questions about rod cells and cone cells. In Part 2 of this activity, you will use the information in a graph to determine which colours rod cells and cone cells detect.

What to Do

Part 1

1. Use the table below to help you answer the questions that follow. Pigment is the colouring matter in a cellular tissue.

Functions of Rod Cells and Cone Cells

Rod Cells	Cone Cells
Used for night vision	Used for bright illumination vision
Very light sensitive	Not very light sensitive
One type of light-sensitive pigment	Three types of light-sensitive pigment
Have more pigment than cones, so can detect less light	Have less pigment than rods, so require more light to detect images
Slow response to light	Fast response to light
Smaller than cone cells	Larger than rod cells
About 100 million in the human eye	About 6 million in the human eye
Mostly found on the outer edges of the retina	Mostly found in the centre of the retina

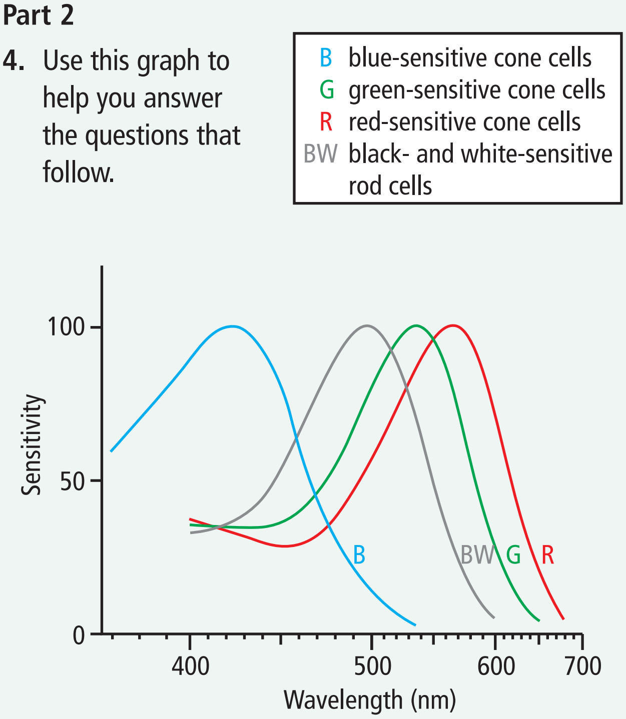
2. Why are rod cells more useful for night vision?
3. Why are cone cells more useful for colour vision?

Science Skills

Go to Science Skill 5 for help with reading a graph.

Part 2

4. Use this graph to help you answer the questions that follow.



A graph of the ability of cone cells and rod cells to absorb light of differing wavelengths

5. Consider the line labelled "R," for red-sensitive cone cells.
   (a) At what wavelength, in nanometres, are these cells most effective at detecting light?
   (b) What colour does the wavelength in (a) correspond to?
   (c) Which colour are the red-sensitive cells able to detect more easily—green or red?
   (d) Suggest a reason why these cells are called red-sensitive cells even though they can detect many other colours as well.
6. (a) At what wavelength do the black- and white-sensitive rod cells absorb light most efficiently?
   (b) What colour does the wavelength (a) correspond to?
7. Examine the graph and explain why humans are able to detect faint amounts of green light.

Correcting Focus Problems

Most people have trouble focussing clearly at some time in their lives. As children grow, especially in their teen years, the shape of their eye changes. The change of shape can affect their ability to focus and may require the temporary use of eyeglasses. As adults age, the flexibility of the eyes' lenses often decreases, making it harder to focus on nearby objects.

Normal vision

When light rays from a distant object enter the eye, the rays are nearly parallel (see Figure 6.7). The lens, which is convex, causes the rays to converge at the retina, producing a sharp image. Light rays from a nearby object are diverging when they enter the eye, so muscles in the eye cause the lens to change shape, making the lens thicker. This gives the lens a greater ability to converge the light rays to form a clear image.

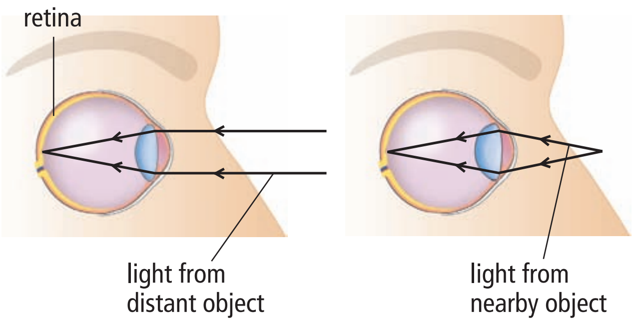
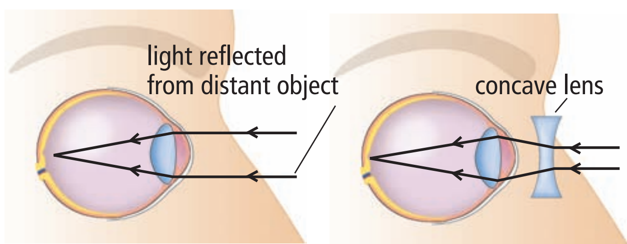


Figure 6.7 How the lens in a normal human eye focusses light rays onto the retina

Correcting near-sighted vision

People who can see nearby objects clearly but who cannot bring distant objects into focus are **near-sighted** (see Figure 6.8). This condition occurs because the lens converges the light rays to form an image in front of the retina. By the time the light rays actually strike the retina they have begun to spread out again, causing the person to see a fuzzy image. A concave lens is used to diverge the parallel rays slightly so that the image forms farther back, on the retina.



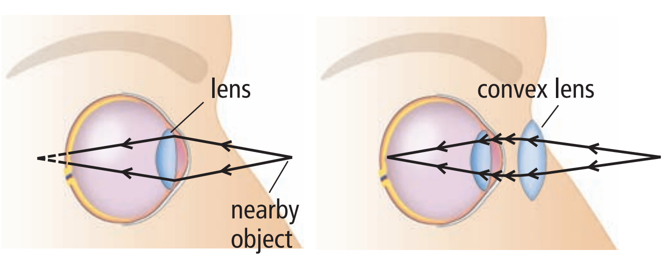
Near-sighted vision: image falls short of retina (eye has longer shape than normal eye)

Vision corrected with concave lens: lens allows image to fall on retina

Figure 6.8 How a concave lens in eyeglasses corrects near-sightedness

Correcting far-sighted vision

Some people can see distant objects clearly but find that nearby objects remain fuzzy no matter how hard they try to focus on them, a condition known as **far-sighted** vision (see Figure 6.9). Light rays from distant objects are nearly parallel, and require less refraction to converge them than light from nearby objects. However, light rays from nearby objects are diverging as they enter the eye. A convex lens is needed for the light rays to come into focus exactly on the retina.



Far-sighted vision: image falls behind retina (eye has shorter shape than normal eye)

Vision corrected with convex lens: lens allows image to fall on retina

Figure 6.9 How a convex lens in eyeglasses corrects far-sightedness

Correcting astigmatism

Some people need vision correction because their cornea has a distorted shape, a condition known as **astigmatism**. A normal cornea is shaped spherically, like a soccer ball, while an astigmatic eye has an irregularly-shaped cornea. This condition causes an image to focus on more than one point on the retina, resulting in blurred vision (see Figure 6.10). Astigmatism can be corrected using eyeglasses or contact lenses (see Figure 6.11) or with laser surgery to reshape the cornea.

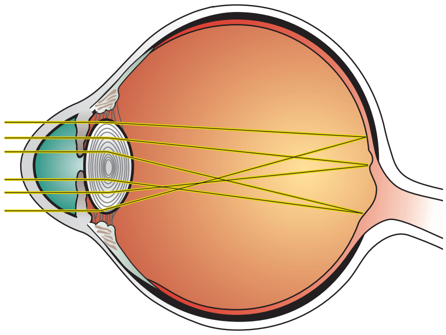


Figure 6.10 In astigmatism, the shape of the cornea causes the image to focus on more than one point of the retina.

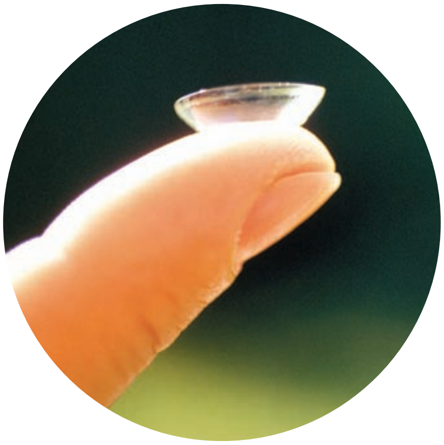


Figure 6.11 Contact lenses are small plastic lenses that float on the cornea. Almost any correction that can be made using prescription eyeglasses can also be made using contact lenses.

Blindness

Blindness can be any vision impairment that keeps people from doing important life activities such as riding a bike, reading, or recognizing their friends through sight. In very rare cases, a blind person may not be able to detect any light whatsoever. Most people who are legally blind can perceive some light or even have a limited amount of vision.

In some types of blindness a person can see only a tiny part of the middle of a whole scene. Other people who are blind have the opposite situation: they can see on the edges of their vision, but not directly ahead. Others can detect light and darkness, but no amount of visual aids can help them to see clearly.

In developing countries, blindness is most often a result of disease or malnutrition. Children in poorer communities are more likely to be affected by blindness caused by disease than are children in more affluent communities. Of the approximately 40 million people who are blind in the world today, about 80 percent could have some or all of their sight restored through treatment. However, many people in developing countries cannot afford even basic vision aids such as eyeglasses.

Suggested Activity

Think About It 6-3 on page 211

Figure 6.11 Inuit snow goggles of caribou antler.

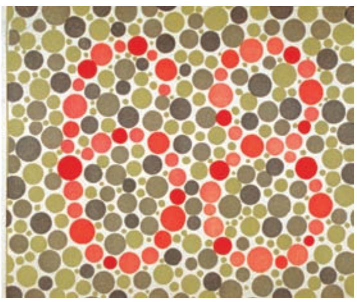


Figure 6.12 Those who do not have red-green colour vision deficiency should see the number 68 here.

Other Types of Blindness

Snow blindness is a painful condition of temporary partial or complete blindness caused by overexposure to the glare of sunlight, such as on snow fields at high altitudes. Treatment includes resting the eyes in a dark room for several days to allow the inflammation to decrease. The Inuit traditionally wore goggles with thin slits to help prevent snow blindness (see Figure 6.11).

Night blindness is a condition in which it is difficult or impossible to see in dim light. The most common cause is the rod cells losing their ability to respond to light. A person might be born with night blindness, or it could develop due to injury or malnutrition.

Colour blindness is the ability to see only in shades of grey, and occurs in about one person in every 40 000. Colour blindness is usually considered a disability, but there are situations in which a person who is colour-blind has an advantage over a person who sees colour. For example, a person who is colour-blind may find it easier to pick out an object from a confusing background.

Although colour blindness is rare, colour vision deficiency is quite common, occurring in about 8 percent of males and 1 percent of females. Colour vision deficiency is an inability to distinguish certain colours. There are many kinds of colour vision deficiency because one, two, or all three kinds of cone cells may be involved. The most common kind of colour vision deficiency involves the inability to tell red and green apart. For many affected people, both colours appear to be shades of yellow. A simple test for colour vision deficiency is shown in Figure 6.12.

Explore More

There are many kinds of vision problems related to focussing, colour perception, and size of field. Other vision problems involve high pressure in the eye, degeneration of parts of the eye or optic nerve, detachment of the retina, or hardening of the lens. Find out more about vision problems. Start your search at **www.bcscience8.ca.**

Reading Check

1. What can cause focussing problems as children grow? As adults age?
2. Explain why a person who is near-sighted can see a close object clearly, but not a distant one.
3. Explain why a person who is far-sighted can see a distant object clearly, but not a close one.
4. How does an irregularly-shaped cornea cause astigmatism?
5. What are three examples of what a person who is blind might be able to see?
6. Why are children in developing countries at a greater risk of becoming blind?
7. How can snow blindness be prevented?

6-3 Being Blind

Think About It

In this activity, you will learn about the life of a blind student.

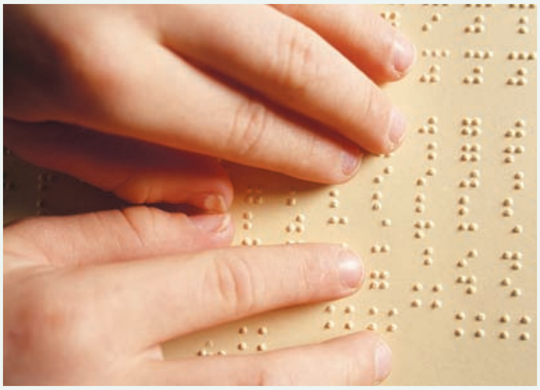
What to Do

1. Read the letter and answer the questions that follow.

Hello, my name is Sean, and I am blind. Although I was born blind, I have learned how to understand the world around me. I can read braille and I really love reading books in the same way sighted kids learn how to enjoy reading print. The only difference is that I read with my fingers instead of my eyes.

I also enjoy listening to "talking books" on my iPod®. You might think it strange, but I talk about "reading" books, even though I read through my fingers or listen through my ears. I like to do all the things people with sight like to do, like playing with my dog, going swimming, listening to music, or just hanging out with my friends.

I go to school with kids who can see. My favourite subjects are math and English. I use a computer with a braille keyboard and voice output, so I can check what I have done. The best part of school is the friends I have made. They help me "see" things I cannot see, and I help them with things that are not so visible.



The braille alphabet allows a blind person to read by touch.

A braille keyboard

What Did You Find Out?

1. (a) Based on Sean's writing, or on friendships you have with people who are blind or visually impaired, do you think you should use expressions when you talk to them like, "See you later" or "Did you watch the TV show last night?" Explain your answer.
   (b) What about expressions like "The book is over there" or "Come here"? Explain your answer.
2. How could you help a student who is visually impaired who was new to your classroom?
3. How could your classroom be improved to make it easier for a student who is visually impaired to learn?

6-4 Dissecting a Sheep Eye

Skill Check
- Observing
- Classifying
- Communicating
- Explaining systems

A sheep eye and a human eye have many things in common—as well as a few important differences. Examining a sheep eye will help you better understand how your own eyes function.

Question

How does a sheep eye function?

Safety

- The sheep eye is raw meat. Make sure you wash your hands with soap after completing the dissection to ensure that all bacteria have been washed off.
- Keep your hands away from your eyes and mouth when handling the sheep eye.
- Ensure that all of the animal parts are cleaned up and discarded according to your teacher's instructions.
- Sharp edges can cut. Be careful with scissors and prods.

Materials

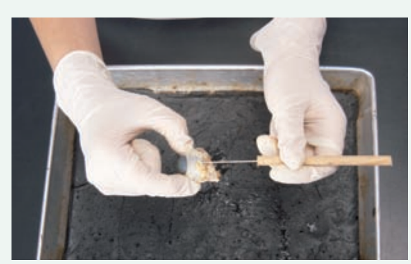
- preserved sheep eye
- scissors
- prod
- dissection tray
- protective gloves
- paper towel
- plastic disposal bag
- 10 percent bleach solution
- Wear protective gloves. Follow your teacher's instructions for removing and disposing of them.

Procedure

Exterior view of a sheep eye

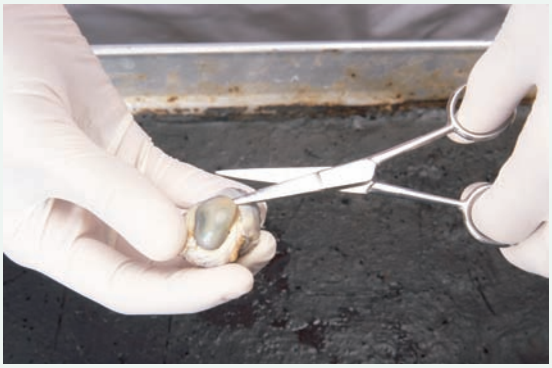
Trim away fat and muscle.

1. Put on your gloves. Examine the outside of the sheep eye. Notice that it is covered in a layer of fat and muscle. The fat is yellow tissue, and the muscle may appear grey.
   - The fat protects the eye, while the muscle helps the eye to move in its socket. A sheep eye has four large muscles to move the eye up, down, left, and right.
   - Humans have six muscles, which allow us to roll our eyes.
2. Use scissors to trim away the excess fat and muscle.
3. Look at the front of the eye and note the outer layer, called the cornea. The cornea is clear in the living eye, but may have become cloudy in the preserved eye. The cornea is curved, which means light passing through it is focussed.
4. Examine the rest of the outside of the eye. Note that an opaque layer, the sclera, covers the eye.
   - The sclera has a dark layer that prevents the passage of light into the eye from the side. This keeps out stray light.
   - The optic nerve enters the eye at the back.
5. Use the prod to poke a hole in the eye halfway between the cornea and the optic nerve. Some liquid will come out when you do this. Use scissors to cut all the way around the eye, separating it into front and back halves. Try not to disturb the internal parts of the eye as you cut.



Poke a hole into the sclera so that scissors can be used to cut the eye in half.

6. Separate the eye into two halves. Taking the front half of the eye, try to look through it. It may be possible to see right through the lens and cornea. See if you can read text through the eye. If you can see an image through the eye, note whether it appears upright or upside down.
7. Use the prod again to poke a hole at the junction of the cornea and the sclera. Use the scissors to cut a circle around the cornea in order to remove it.
   - Under the cornea is more jelly-like substance that is liquid in the living eye. The jelly-like substance supports the cornea and helps to give it shape.
   - Under the cornea is the iris, which is a ring of tissue. In a sheep, the iris is oval shape. In humans it is circular. The pupil is seen to be simply a hole in the iris.



Cut a circle around the cornea in order to remove it.

8. Remove the lens from the eye and, using a paper towel, wipe all the jelly from it. The lens will probably be yellow, but it is colourless and clear in the living eye. See if you can see an image through the lens. The lens will be hard, but in the living eye it is soft and can change shape in order to focus.
9. Examine the inside of the back half of the eye. Note where the optic nerve comes into the eye. There are no rod or cone cells here, and this is the sheep's blind spot. Humans have a similar blind spot.
   - The retina is a network of nerves that flow into the optic nerve. The retina may be found against the inside back of the eye. If the retina has come off it will likely be attached to the eye at a single spot (the blind spot).
   - The back of the eye may appear black or blue. In sheep, there is also a shiny or iridescent layer that helps the sheep to see in low-light conditions.
   - Humans do not have this layer, and the layer under the retina in our eyes is black, to absorb stray light.
10. Place all of the eye parts in a plastic disposal bag. Clean up all equipment and work areas with a 10 percent bleach solution. Remove and dispose of your gloves as your teacher instructs.
11. Wash your hands thoroughtly with warm soapy water.

Analyze

1. List four differences between the anatomy of a sheep eye and a human eye.
2. Is the image that is cast on the retina at the back of the eye upright or inverted? Draw a ray diagram to explain your observations.
3. Describe the appearance, colour, shape, and feel of the lens from the sheep eye.

Conclude and Apply

1. Make a labelled diagram of a cross section of the sheep eye that includes all of the structures you studied.
2. You may have observed that the retina seemed to be continuous with the optic nerve. Do you think the retina is part of the brain? Explain.

Wild, Weird, Wonderful

www Science

Can You See What I Hear?

Bats, dolphins, and whales all use natural sonar systems to perceive the world around them. Do you? You may be surprised. If you have normal hearing, then you might want to try this experiment. Have 10 people stand in a line. Face away from them and then have one person make a sound. You are likely to be able to turn and face the exact person who made the sound.

There are some interesting reasons for this. The sound reaches each ear at different times, and your brain can detect the difference in the arrival times of the sound signals. Another reason is that you have an awareness of the space around you, and when you hear your friend make the sound, you locate him or her in this space. You can even keep track of this as you turn around to face your friend. In other words, you can "see" what you just heard.

Echolocation involves producing sounds and then interpreting the environment based on the echo. Bats emit high-pitched chirps. They can use the echoes of the chirps to avoid wires and find insects to eat. Some people who are blind make their own clicking sounds when walking. Then they interpret the echoes to find out about objects close by.

This ability has inspired a number of researchers to construct devices that produce sounds that people who are blind can use to find out about the location, size, shape, and even texture of objects around them. For example, a loud, clear echo might represent a close, hard object. We all have an inborn ability to interpret sounds in a visual way, and those who practise it get much better at it .

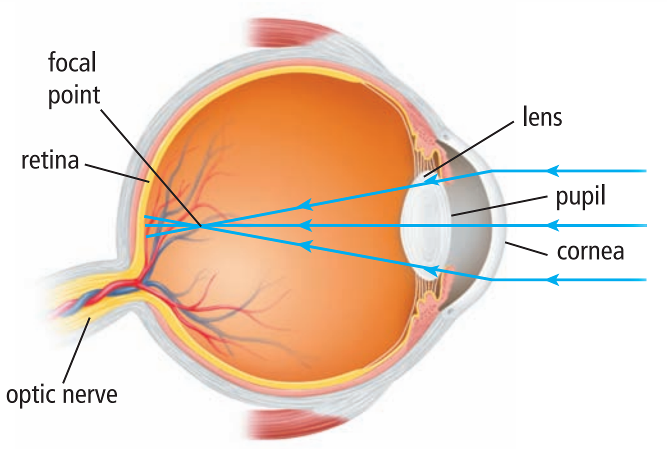
The woman above is wearing a video camera. The camera is mounted in her sunglasses, as is the digital equipment that creates an audio signal of every object she faces. The woman listens to the sounds and converts the "sound scape" into a mental image of her environment.

The use of these devices is very experimental. With the current technology, bright objects are made to produce a loud sound. Black objects are silent. As objects get closer to you they look bigger. This translates as a higher pitch. A car driving away from you sounds like a falling tone. Although we are still a long way from getting to "I can see what you see," we may be only a big step away from "I can hear what you see."

Check Your Understanding

Checking Concepts

1. Make a table that lists the parts of the eye in one column and the function of each part in the other.
2. (a) Which parts of your eye are involved in focussing an image?
   (b) What is the role of each part?
3. (a) Describe the vision problem shown by the illustration below.
   (b) Why does this vision problem become more common as people age?



4. Why can the human eye see colours better in bright light than in dim light?
5. Write a definition of blindness in your own words.

Understanding Key Ideas

6. What would happen to a person's vision if the eye's lens was unable to change shape?
7. Why is it necessary to have three kinds of cone cells operating in order to have full colour vision?
8. Describe how the eye adapts to the following changes in conditions:
   (a) sudden increase in brightness
   (b) gradual dimming of light until it is almost dark
   (c) looking at a kite, then down at your hand to let out string
9. Most mammals, including dogs and cats, cannot see colours. Infer how the retina of a cat's eye might be different from the retina of a human eye.

Pause and Reflect

After years of work in the field of vision and community service, you have been selected to become the high commissioner for the Elimination of Preventable Vision Disabilities. You have a budget of $1 billion. Your commission is responsible for defining four goals that will improve vision in the developing world. Reflect on this problem and then list your four goals along with the portion of the budget that each should receive. Briefly explain your choices.