6.2 Extending Human Vision

Microscopes and some telescopes use lenses to capture and focus light. A telescope uses a lens or concave mirror to gather light. Camera design and human vision have a number of similarities and differences. Lasers produce light of only one wavelength and have special properties that make them useful in optical communication devices and in eye surgery. Laser light can be sent through fibre optic cables.

Key Terms

laser light
optical fibres
refracting telescope
reflecting telescope
total internal reflection

Human knowledge about our planet and the universe was very limited until we developed tools to extend our vision. We now have the ability to peer into the tiny world of micro-organisms and out into the vast reaches of outer space (see Figure 6.13). The tools we use for these inquiries may seem quite different from each other, but they are based on the same understanding of light, mirrors, and lenses.

Figure 6.13A A micro-organism

Figure 6.13B A nebula formed from an exploding star

6-5 Experimenting with a Simple Lens — Find Out ACTIVITY

In this activity, you will observe some properties of a test tube lens.

Materials

- glass test tube with stopper
- water
- paper or note card

What to Do

1. Fill a glass test tube with water and seal it with the stopper.
2. Print the name of your favourite scientist in capital letters on a piece of paper or a note card.
3. Lay the test tube flat on the note card, running left to right over the words you have written.
4. Observe whether the letters are magnified , whether the letters are in focus, and whether the image is upright or inverted. Record your observations.
5. Hold the tube about 1 cm above the card and observe the letters. Record your observations.
6. Repeat, holding the tube at several other heights above the words.

What Did You Find Out?

1. Describe what happens to the images of the letters as the lens is gradually moved away from the note card.
2. Draw and label a ray diagram showing the situation when the image appeared to be inverted and magnified.

How to Bring an Image into Focus

In order for the light rays passing through a lens to form a clear image, the screen that is receiving the image must be the correct distance from the lens. The screen must be at the place where all the light rays from a given point on the object converge. If the screen is placed too close to the lens, then the light rays do not fully converge by the time they strike the screen. There will be an image formed, but it will appear blurred. On the other hand, if the screen is too far away, then the light rays converge and then begin to diverge before they strike the screen, resulting in a blurred image. Adjusting the distance between the screen and the lens to make a clear image is called *focussing*. Focussing is an important step in using optical devices such as microscopes, telescopes, binoculars, and cameras.

Connection

Section 1.1 has more information on microscopes and how to use them.

Microscopes

A compound light microscope uses two convex lenses with relatively short focal lengths to magnify small, close objects. To *magnify* means to cause to look larger than the real size.

Figure 6.14 shows a microscope. The object to be viewed is placed on a transparent slide and illuminated from below. The light passes by or through the object on the slide and then travels through the objective lens.

The objective lens is a convex lens. Recall that if the distance from an object to a convex lens is between one and two focal lengths, it forms an enlarged image of the object. The eyepiece lens, which is another convex lens, then magnifies the image again. This final image can be hundreds of times larger than the actual object, depending on the focal lengths of the two lenses.

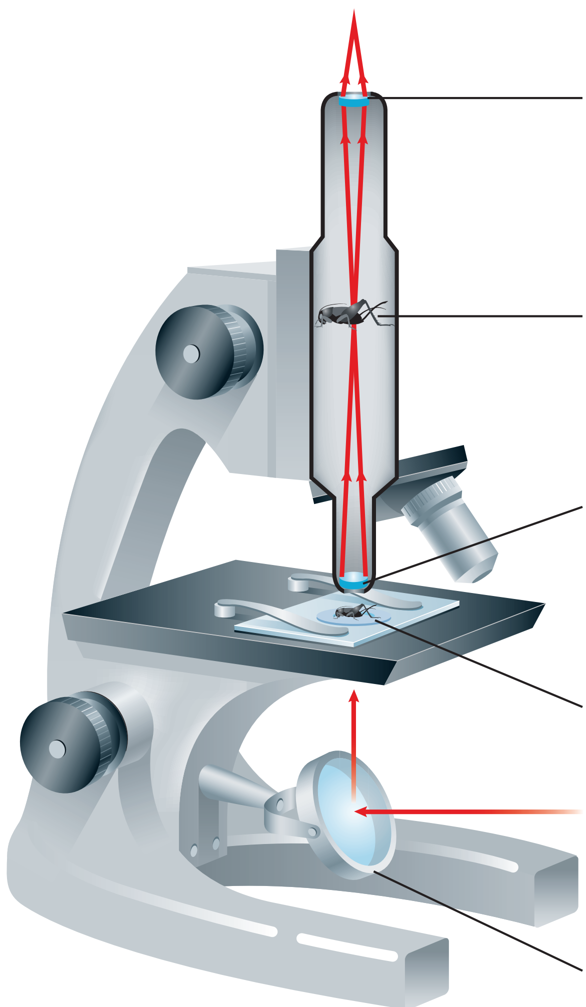


Figure 6.14 This microscope uses two convex lenses to magnify small objects. To focus the image, you have to move the object you are studying closer to or farther from the objective lens.

6-6 Microscopes on the Job

Think About It

In previous studies, you may have seen how biologists use microscopes. However, biologists are not the only people who need microscopes in their daily work. In this activity, you will find out how microscopes are used in other occupations. You will share your information in a brief presentation.

What to Do

1. Work in groups of two or three. In your group, select an occupation in which a microscope is used, for example:
   - medical laboratory technician
   - mineralogist (someone who studies minerals)
   - forensic laboratory technician (someone who studies evidence related to crimes)
   - gemologist (someone who studies precious stones)
   - metallurgist (someone who studies the properties of metals)
   - petrologist (a geologist who studies the origin and composition of rocks)
2. Research the type of work done by a person in the occupation you have selected. You can find information in the library or on the Internet, or by interviewing people in the occupation. Start your search at **www.bcscience8.ca**. Find answers to the following questions.
   (a) For what purpose does the person use the microscope?
   (b) What type of microscope does the person use?
   (c) What can be seen through the microscope? (In your presentation, include a typical view. Show this in a circle to represent the field of view of the microscope. Include the magnification, if possible.)
   (d) What does the person do with the information obtained by using the microscope?
   (e) How does using a microscope assist the person at work?
3. Create a presentation based on the occupation you have selected. Make sure you include information on all the questions that you researched. Use appropriate support materials, for example, a pamphlet, poster, overhead transparencies, video, computer, or web site. If possible, produce a multimedia presentation.

What Did You Find Out?

Based on the information in the presentations:

1. List those occupations that make similar uses of the microscope.
2. Identify which occupation uses the microscope in the greatest number of different ways.
3. (a) Which of these occupations is the most interesting to you?
   (b) What do you find interesting about the occupation?
4. Describe how your group's presentation could be improved.

A forensic scientist uses a microscope to examine a beetle found on a corpse.

An electron microscope image displayed on a computer screen

Telescopes

You know from experience that it is difficult to see faraway objects clearly. When you look at an object, only some of the light reflected from its surface enters your eye. As the object moves farther away, the amount of light entering your eye decreases, and so the object appears to be dimmer.

A telescope uses a lens or a concave mirror that is much larger than your eye to gather more of the light from distant objects. The largest telescopes can gather more than a million times more light than the human eye. As a result, objects such as distant galaxies appear much brighter. Because the image formed by a telescope is so much brighter, the image can be magnified to a greater extent to reveal more detail.

Refracting telescopes have similarities to microscopes

A telescope, like a microscope, has an objective lens and an eyepiece lens. However, the objective lens in a telescope has a longer focal length than in a microscope because the objects viewed are far from the lens. The simplest microscopes and telescopes use only two lenses. The lenses bend the light to focus it, which is why a telescope with this design is called a **refracting telescope** (see Figure 6.15).

In both the microscope and the refracting telescope an objective lens collects light and focusses it into an image (see Figure 6.16). This image is formed inside the microscope or telescope and is never seen directly. Instead, the image is magnified by the eyepiece lens, and directed into the eye of the operator or into a camera.

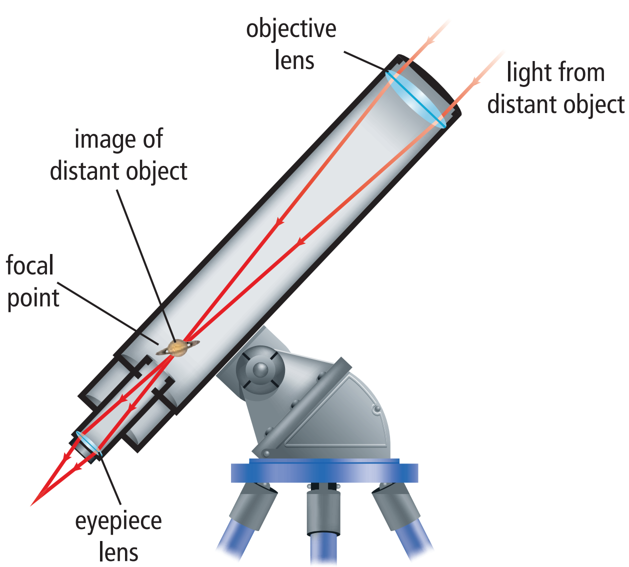


Figure 6.15 Light from a distant object passes though an objective lens and an eyepiece in a refracting telescope. The two lenses produce a large image.

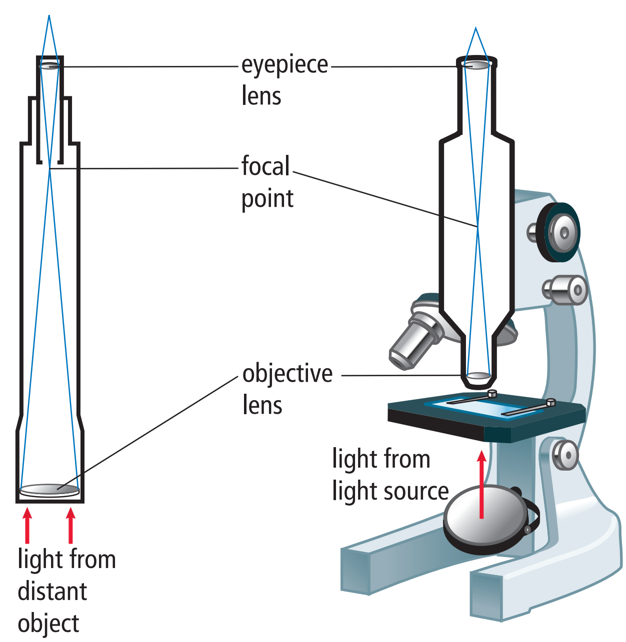


Figure 6.16 In order to focus with a microscope, the object being viewed is moved. In order to focus with a telescope, its eyepiece and the observer are moved.

Figure 6.17 The 102 cm refracting telescope at the Yerkes Observatory in Wisconsin is the largest refracting telescope ever used.

Problems with refracting telescopes

In order to form a detailed image of distant objects, such as planets or galaxies, the objective lens must be as large as possible (Figure 6.17). A large lens is heavy and can be supported in the telescope tube only around its edge. The lens can sag or flex due to its own weight, distorting the image it forms. Also, heavy glass lenses are costly and difficult to make, and even when the highest quality of glass is used, the lens absorbs some of the light.

Reflecting telescopes

Due to the problems with making large lenses, most large telescopes today are **reflecting telescopes**. A reflecting telescope uses a concave mirror, a plane mirror, and a convex lens to collect and focus light from distant objects. Figure 6.18 shows a reflecting telescope. Light from a distant object enters one end of the telescope and strikes a concave mirror at the opposite end. The light reflects off this mirror and converges. Before it converges at a focal point, the light strikes a plane mirror that is placed at an angle within the telescope tube. The light is reflected from the plane mirror toward the telescope's eyepiece. The light rays converge at the focal point, creating an image of the distant object. Just as in a refracting telescope, a convex lens in the eyepiece then magnifies this image.

Some telescopes used to study distant galaxies collect the light rays from several mirrors and then combine the rays into a single image. One such telescope is the Keck telescope located in Hawaii (see Figure 6.19).

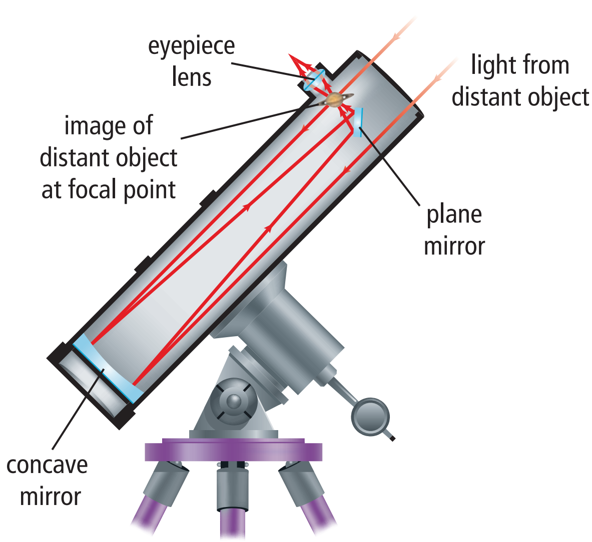


Figure 6.18 Reflecting telescopes use two mirrors to create an image, which is then magnified by a convex lens. In order to focus an image on a reflecting telescope, the eyepiece (convex lens) is moved.

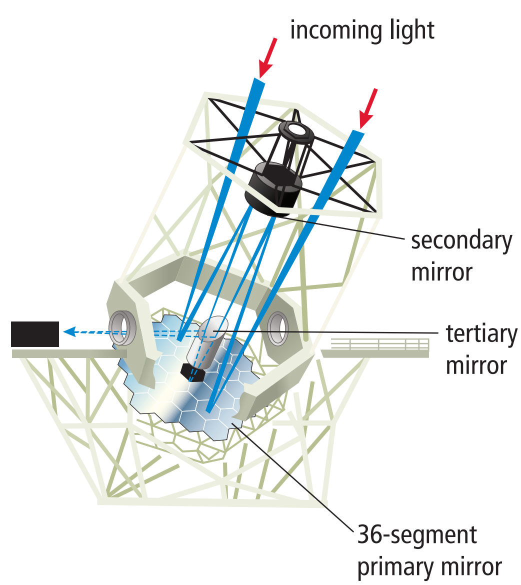


Figure 6.19 The Keck telescope combines light from two mirror systems like the one in the diagram to make a single image that is many times clearer than an image produced by one mirror.

The Hubble Space Telescope

Imagine being at the bottom of a swimming pool and trying to read a sign by the pool's edge. The water in the pool would distort your view of any object beyond the water's surface. In a similar way, Earth's atmosphere blurs the view of objects in space. To overcome the blurriness of our view into space, the Hubble Space Telescope was launched in 1990. The Hubble Space Telescope is a type of reflecting telescope that uses two mirrors to collect and focus light to form an image. The primary mirror in the telescope is 2.4 m across and can collect visible light—as well as other types of electromagnetic radiation—from planets, stars, and distant galaxies. Freed from the distortion caused by Earth's atmosphere, the Hubble Space Telescope has produced images much sharper and more detailed than the largest ground-based telescopes (see Figure 6.20).

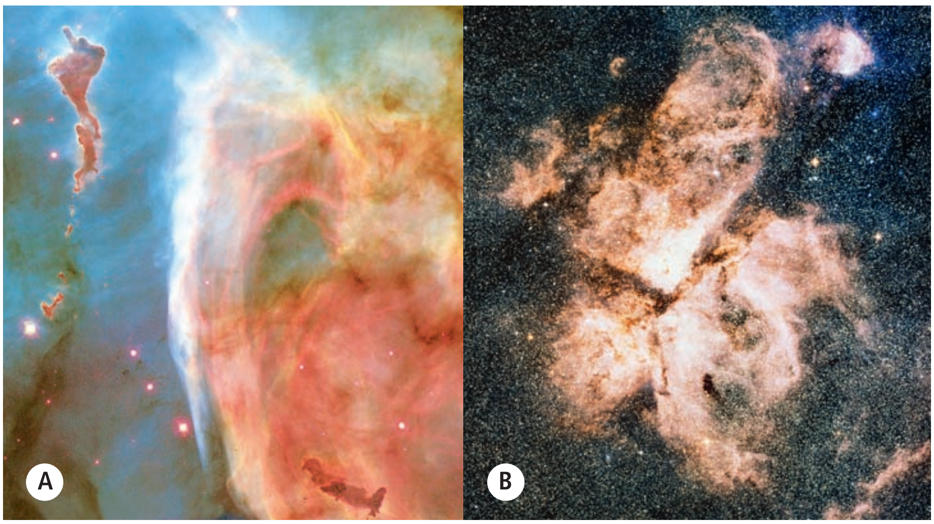


Figure 6.20 The image from the Hubble Space Telescope is clear (A), not blurred by Earth's atmosphere (B).

internet connect

Find out more about the Hubble Space Telescope, the images it has produced, and Canada's role in servicing the telescope. Start your search at **www.bcscience8.ca.**

Suggested Activity

Conduct an Investigation 6-8 on page 227

Binoculars

Binoculars are actually two refracting telescopes mounted side by side. You can imagine how difficult it would be to hold up two long telescopes. The telescopes in binoculars are shortened by placing prisms inside that serve as plane mirrors. Rather than travelling down the long tube of a telescope, the prisms reflect the light in binoculars back and forth inside a shorter tube (see Figure 6.21.

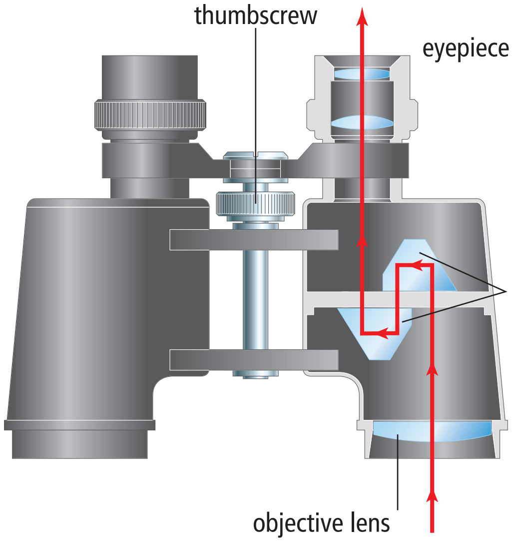


Figure 6.21
The thumbscrew on binoculars is used to change the focal length in order to focus on the objects being viewed.

Cameras

A digital camera works by gathering and bending light with a convex lens. The lens then projects an image onto a light detector to record a digital image of a scene. When you take a photograph, a shutter opens to allow light to enter the camera for a specific length of time. The light reflected off your subject enters the camera through an opening called the **aperture**. The light then passes through the lens, which focusses the image on the light detector. Because a convex lens is used, the image is inverted and smaller than the actual object.

Wide-angle lenses

Suppose you and a friend use two different cameras to photograph the same object at the same distance. If the cameras have different lenses, your pictures might look different. For example, some lenses have short focal lengths that produce a relatively small image of the object but have a wide field of view (see Figure 6.22). These lenses are called wide-angle lenses. Wide-angle lenses must be placed close to the light detector to form a sharp image with their short focal length.

Figure 6.22 A photograph taken with a wide-angle lens

Telephoto lenses

Telephoto lenses have longer focal lengths. The image through a telephoto lens seems enlarged and closer than it actually is (see Figure 6.23). Telephoto lenses are easy to recognize because they usually protrude from the camera to increase the distance between the lens and the light detector (see Figure 6.24).

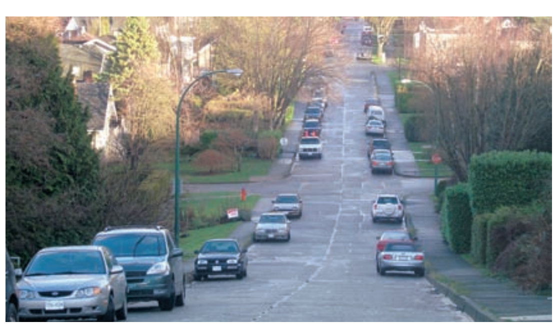


Figure 6.23 A photograph of the same scene as Figure 6.22 taken with a telephoto lens

Figure 6.24 A telephoto lens

Cameras Have Similarities to Human Eyes

There are many structural similarities between a camera and the human eye (see Figure 6.25). For example, compare the lens cap for a camera to the human eyelid. Both reduce the chance of accidental damage. An iris limits the amount of light entering the eye. In cameras, this function is accomplished using a device called a **diaphragm**. The diaphragm is made of a number of opaque circles that are arranged in a circle. The circles can be moved to make the central hole larger or smaller. Light passes through the lens and forms an inverted image in both the camera and the eye.

Not all structures in a camera work the same way as in the human eye. For example, changing the distance between the lens and the detector does the focussing in a camera. Recall that in humans, the lens changes shape, rather than moving closer to the retina.

At the back of the camera is a detector called a **charge-coupled device (CCD)**, which absorbs light and provides the electrical signals needed to produce a digital image. The CCD has many tiny regions, called pixels, each of which is capable of recording a tiny part of the whole image. The pixels correspond to the rods and cones that detect light in our eyes. Research is currently being done to try to connect the electrical signals from a digital camera directly to human optic nerves. This may one day provide a working vision system that will allow people who are blind to see.

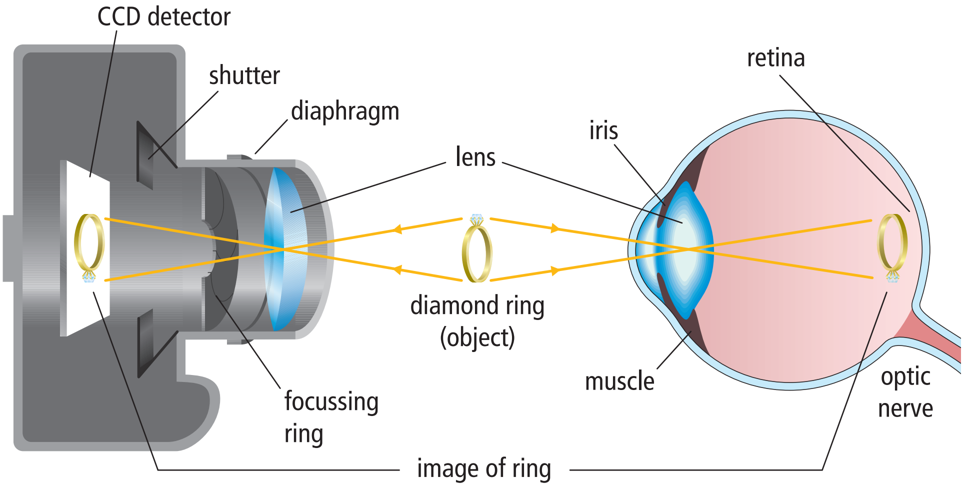


Figure 6.25 A comparison of the camera and the human eye

Suggested Activity

Think About It Activity 6-7 on page 226

Reading Check

1. How does a microscope magnify an image?
2. How is a reflecting telescope similar to a microscope?
3. How is a reflecting telescope different from a refracting telescope?
4. Why is the Hubble Space Telescope able to produce clearer images than telescopes on Earth?
5. What is the function of prisms in binoculars?
6. How does the focal length of a telephoto lens compare to the focal length of a wide-angle lens?
7. What are two ways in which a camera is similar to a human eye?
8. What are two ways in which a camera is different from a human eye?

Word Connect

"Laser" stands for **l**ight **a**mplification by **s**timulated **e**mission of **r**adiation.

Lasers

Recall that white sunlight contains all the colours of the rainbow. Sunlight and light from an incandescent light bulb contain a mixture of waves of different wavelengths (see Figure 6.26). In **laser light**, all of the light has the same wavelength, all the light rays are moving in the same direction, and all of the crests and troughs of the light are lined up (see Figure 6.26). Laser light travels great distances without spreading out, and can contain a lot of energy. Because lasers only contain one wavelength, the light does not refract into a rainbow, as would happen with normal light.

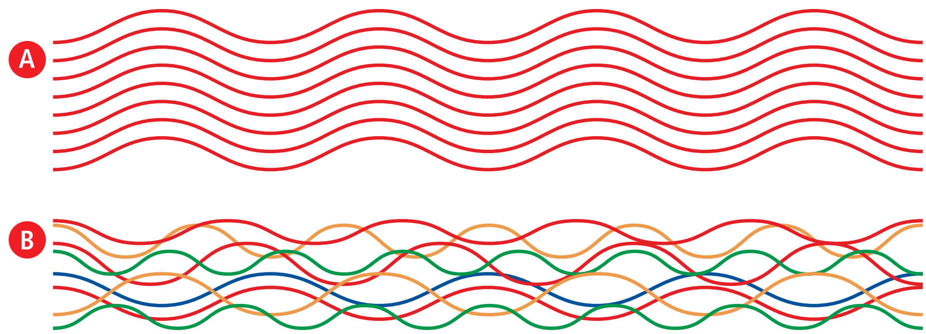
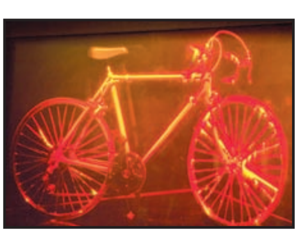


Figure 6.26A The light waves in laser light have the same wavelength and travel with their crests and troughs aligned.

Figure 6.26B The light from an ordinary light bulb contains more than one wavelength and does not travel with the crests and troughs aligned.

internet connect

A hologram is a photographic technology in which lasers are used to encode three-dimensional information about an object onto a flat surface. Find out where holograms are commonly used and why they work well for this purpose. Start your search at **www.bcscience8.ca.**



Laser Surgery

Lasers are routinely used to remove cataracts, re-attach retinas, stop bleeding, and reshape corneas. A cataract is a condition where the eye's lens has become cloudy. This condition can occur naturally with age. The laser is used to cut through the cornea so that the lens can be replaced with a synthetic one. If part of the retina has become detached from the inside of the eye, a laser can sometimes be used to weld the piece back in place and prevent further detachment from occurring. The energy from a laser beam is so intense that it can seal off blood vessels, which helps reduce bleeding during surgery.

Changing the shape of the cornea can also be accomplished with the use of laser surgery. It is possible to accurately map the surface of a person's cornea and then calculate the changes in shape that are needed to correct the person's vision. An eye surgeon can use a laser to weaken the surface of the cornea, allowing it to be folded back. The surgeon changes the shape of the inside of the cornea, and may use a laser to do this. The outer surface can then be returned to its original place. The procedures are not painful and in some cases the surgery is complete in only a few minutes. Like all types of medical procedures, there are some risks involved. Because laser eye surgery is only a few decades old, long-term risks and benefits are not yet known.

Figure 6.27 Surgeons can use lasers in place of scalpels to cut through body tissues. The energy from the laser seals off blood vessels in the incision and reduces bleeding.

Optical Fibres

Imagine using a flashlight to send a signal down a long hallway. If the hallway is straight, the light will pass down it with no problem. If the hallway has a bend in it, then a well-placed mirror will reflect the light beam around the bend. If the hallway has many bends, then many mirrors might be used to reflect the light to do the job. A simple way to transport light in this way is by using an **optical fibre** (see Figure 6.28). Optical fibres are transparent glass fibres that can transmit light from one place to another.

Light entering one end of an optical fibre is reflected continuously from the sides of the fibre until it emerges from the other end. Just as water moves through a sealed pipe without leaking away, almost no light is lost or absorbed in optical fibres. Every time a light ray strikes the wall of the fibre it is reflected back into it. This is called **total internal reflection** (see Figure 6.29).

Optical fibres are used in medicine to transmit images of the inside of a person's body from a tiny camera at one end of the fibre optics cable to a monitor at the other end. One bundle of fibres transmits light, while another carries the reflected light back to the monitor.

In telecommunications, laser light is sent through fibre optics cables to transmit telephone, video, and Internet signals. Just as different colours of two flashlights could be sent down the same hallway without becoming jumbled, laser beams of different wavelengths can be used to send different messages down the same cable without interfering with each other. This makes fibre optics technology useful for broadband transmissions, where thousands of different signals can be sent at the same time.

Figure 6.28 One optical fibre can carry thousands of phone conversations at the same time.

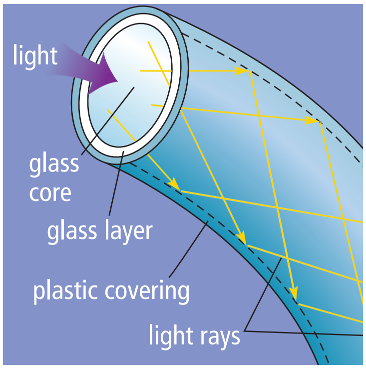


Figure 6.29 Optical fibres make use of total internal reflection.

Explore More

Heads-up displays (HUDs) are optical devices that can project information from an instrument panel onto a screen in front of a viewer. To find out more about HUDs visit **www.bcscience8.ca.**

Reading Check

1. What is the difference between laser light and ordinary light from a light bulb?
2. How can laser light be used to correct vision problems?
3. What is total internal reflection?
4. What are three uses for light sent through a fibre optics cable?

6-7 The Pros and Cons of Laser Eye Surgery

Think About It

In this activity, you will research the advantages and disadvantages associated with laser eye surgery.

What to Do

1. Research information about laser eye surgery by searching the Internet and other resources. Start your search at **www.bcscience8.ca**.

   With your teacher's permission, you might interview a laser surgeon or person who has undergone laser eye surgery.

   Keep in mind the following skills and attitudes associated with a scientifically literate person.

   - Identify the main points in what you find. Separate the useful information from unimportant information.
   - Be aware of preconceptions and assumptions (your own and the author's).
   - Use criteria for evaluating sources of information. (What is the bias? Is the information supported by research? Are you reading/hearing about a personal experience? Does the author have a vested interest in a certain outcome?)
   - Recognize that scientific knowledge is continually developing, and often builds on previous experience and theories.

2. Summarize your research by compiling three lists:
   (a) advantages or uses of laser eye surgery
   (b) pre-existing conditions that make it inadvisable to have laser eye surgery performed
   (c) risks of laser eye surgery
3. Compare your lists to other students' lists and generate a single list together.
4. Select one particular point of view, such as that of a surgeon, a person trying to decide whether to have laser eye surgery, a satisfied patient, a dissatisfied patient, the chair of a regulatory body such as the College of Physicians and Surgeons of BC, a representative of a support group for persons with poor outcomes of laser eye surgery, or an advocacy group promoting the use of laser eye surgery.
5. Research enough about your chosen role to participate in a panel discussion, where each person contributes to a conversation on the topic: "What an informed person needs to know about laser eye surgery."

What Did You Find Out?

1. (a) Did your opinion of laser eye surgery change as a result of your research? If so, why? If not, how was your opinion strengthened by what you found?
   (b) Did your opinion of laser eye surgery change as a result of the panel discussion? If so, why? If not, how was your opinion strengthened by what you heard?

6-8 Design a Device

Conduct an INVESTIGATION

Problem-Solving Focus

Skill Check

- Classifying
- Communicating
- Explaining systems
- Working co-operatively

When mirrors and lenses are combined in systems, we gain the ability to magnify small objects, see distant objects, and even see around corners. In this activity, you will construct an optical device.

Problem

Design a microscope, a refracting telescope, or a device that will allow you to see a magnified view of an object that is behind you.

Criteria

- The mirrors and lenses must be mounted safely and positioned on a flat surface, such as a bench.
- A microscope must magnify a close object, and a telescope must magnify a distant object.
- The device that magnifies an object behind you must involve sending the rays around two corners.

Safety

- Mirrors may have sharp edges.

Materials

You may use any of the following:

- convex lens (with a large curve)
- convex lens (with a small curve)
- cardboard
- 2 plane mirrors
- scissors
- tape
- ruler

Plan and Construct

1. In your group, choose which type of optical device you wish to make. If you have an idea for a device not mentioned above, get your teacher's permission first.
2. Together plan how to arrange the lenses and mirrors to achieve the results you are looking for. In particular, think about how to safely mount your lenses and mirrors, and how to decide which of the two mirrors should be closest to the object.
3. Prepare a sketch to show arrangement and distances. Have your teacher approve your plan.
4. Construct cardboard mounts for your lenses and mirrors. Create and test your device.

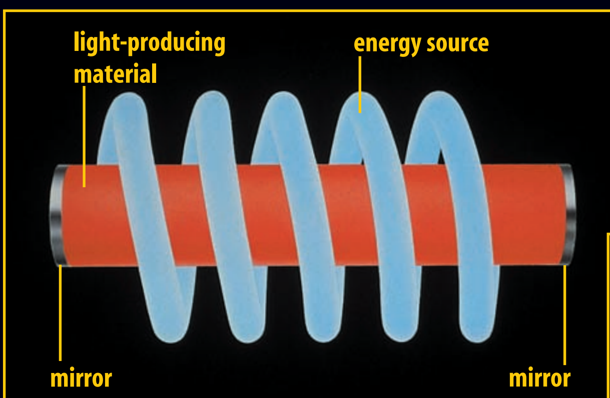
Evaluate

1. Did your arrangement work as you had planned? Explain.
2. Suggest a way to improve your design. This might include how to change the design to have an inverted image appear right side up, increase magnification, or make a similar device that has fewer or smaller parts.
3. How could you improve your contributions to your group the next time you work together?

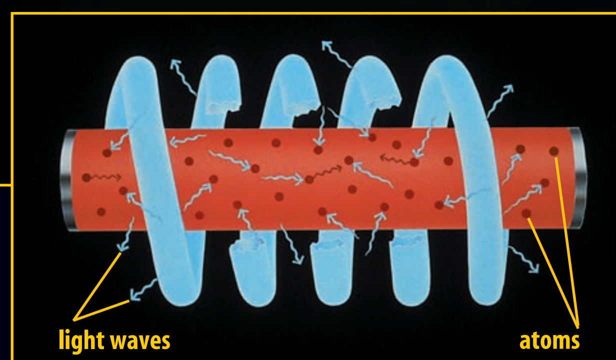
NATIONAL GEOGRAPHIC

VISUALIZING LASERS

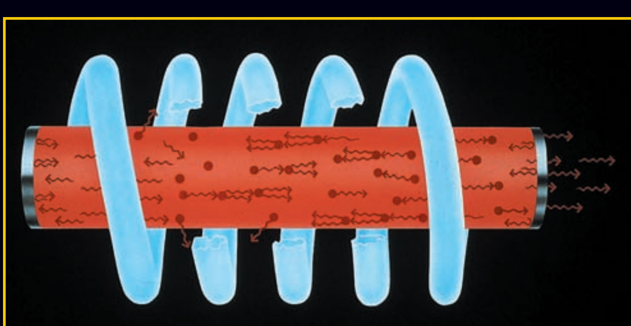
Lasers produce light waves that have the same wavelength. Almost all of these waves travel in the same direction. As a result, beams of laser light can be made more intense than ordinary light. In modern eye surgery, shown at the right, lasers are often used instead of a traditional scalpel.



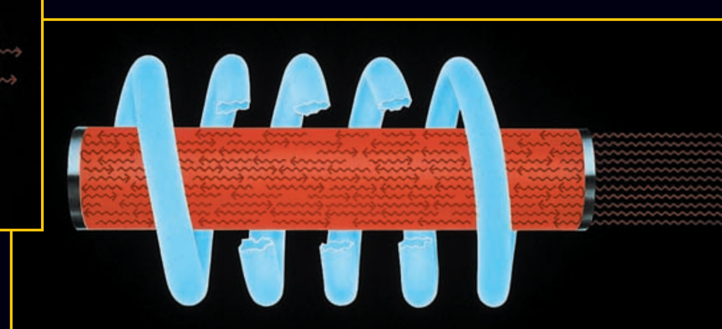
A The key parts of a laser include a material that can be stimulated to produce light, such as a ruby rod, and an energy source. In this example, the energy source is a light bulb that spirals around the ruby rod and emits an intense light.



B When the light bulb is turned on, energy is absorbed by the atoms in the rod. These atoms then re-emit that energy as light waves that are in phase and have the same wavelength.



C Most of these waves are reflected between the mirrors located at each end of the laser. One of the mirrors, however, is only partially reflective, allowing one percent of the light waves to pass through it and form a beam.



D As the waves travel back and forth between the mirrors, they stimulate other atoms in the ruby rod to emit light waves. In a fraction of a second, billions of identical waves are bouncing between the mirrors. The waves are emitted from the partially reflective mirror in a stream of laser light.

Will & Deni McIntyre/Photo Researchers

Check Your Understanding

Checking Concepts

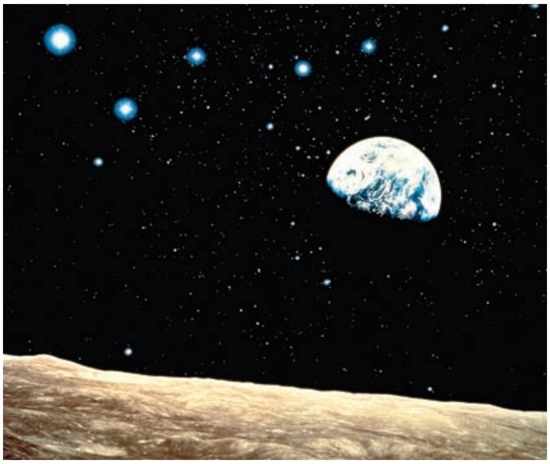
1. Make a table that lists the parts of a camera in one column and the function of each part in the other.
2. (a) Make a labelled diagram to show the arrangement of lenses in a refracting telescope.
   (b) Show how light rays pass from a distant object to the eye of a person looking through the eyepiece.
3. (a) Which lens in a microscope is responsible for producing a magnified image on the inside of the microscope that is not seen directly by the person using the microscope?
   (b) Why is this image produced?
4. List three features of laser light that make it special compared to light from a regular light bulb.
5. List three technological applications for lasers.

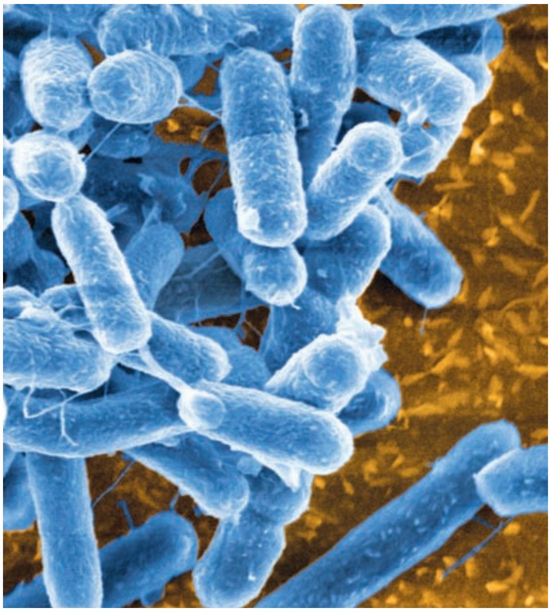
Understanding Key Ideas

6. (a) Explain why telescopes used to study distant galaxies need to have such large mirrors.
   (b) Give two reasons why a large lens is inferior to a large mirror in a telescope.
7. How is it possible for a fibre optics cable to carry many different signals at one time without the signals becoming scrambled?
8. How is the property of total internal reflection used in the operation of optical fibres?
9. How can a laser be used to perform surgery on the inside of an eye without having to cut open the eye first?

Pause and Reflect

Below are two photographs, one taken through a telescope and the other through a microscope. One is of Earth, taken from above the Moon. The other is of common bacteria called *E. coli*, which are found in the mouth of every healthy person on Earth. These two viewpoints were unknown to humans only three generations ago. Reflect on each, select one, and explain why being able to see this scene might be important to how humans see the world.





Chapter 6

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated how we see and how human vision can be extended using optical systems. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 10 for help with using graphic organizers.) Use the following headings to organize your notes:

1. The Structure of the Human Eye
2. How We See
3. Correcting Focus Problems
4. Using Optical Systems to Magnify Close Objects
5. Using Optical Systems to See Distant Objects

Checking Concepts

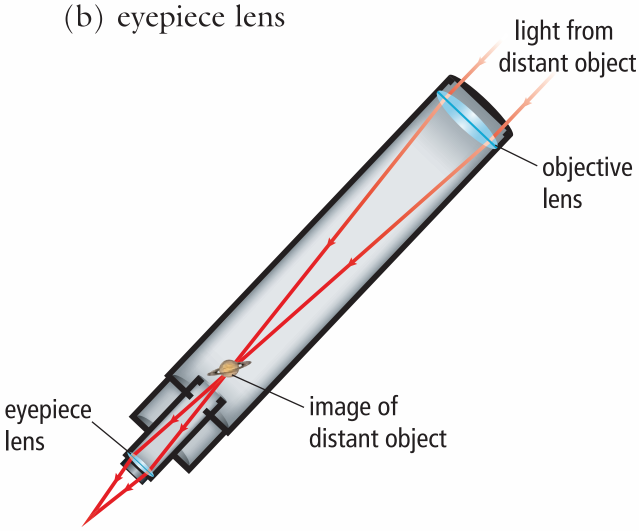
1. List the parts of the eye that are used to refract light.
2. Write a sentence that connects the given words in a meaningful way:
   (a) cornea/sclera
   (b) iris/pupil
   (c) rod cells/cone cells/retina
3. What does the diagram below reveal about your eye?

4. (a) Which type of lens, convex or concave, should a person who is near-sighted use? Explain.
   (b) Which type of lens, convex or concave, should a person who is far-sighted use? Explain.
5. What is astigmatism?
6. Draw a diagram showing the mirror and lens arrangement in a reflecting telescope.
7. (a) Explain how focussing occurs in a microscope.
   (b) Explain why this type of focussing would not work for a telescope.
8. Binoculars are similar to two telescopes mounted in parallel, except that they are not very long. How is this shortening accomplished?

Understanding Key Ideas

9. Explain how a white sheet of paper can continue to look white even though lighting conditions can gradually change throughout the day.
10. Explain why it takes a few minutes to be able to see when you walk from full daylight into a darkened room. List the adaptations that happen in the eye to adjust to low-light vision.
11. What does wearing glasses have in common with laser surgery as a method for correcting vision problems?

12. State the function in a telescope of:
   (a) objective lens or mirror
   (b) eyepiece lens



13. Why is the image that you observe in a refracting telescope inverted?
14. Suppose your camera is focussed on a person who is 2 m away. You now want to focus on a tree that is farther away. Should you move the lens closer to the CCD or farther away? Explain your answer.
15. When you use the highest magnification on a microscope, the image is much darker than it is at lower magnifications.
   (a) What are some possible reasons for the darker image?
   (b) What could you do to obtain a brighter image?

Pause and Reflect

Eyeglasses were first developed in Italy in the 13th century and were used mainly by nobles and the clergy. Then, in 1456, Johannes Gutenberg invented the printing press. What effect do you think the availability of eyeglasses had on the number of books printed? What effect do you think the number of books printed had on the production of eyeglasses? If eyeglasses were not available, would books have become an important source of information? Explain your ideas.

UNIT 2

Unit Summary

4 Many properties of light can be understood using a wave model of light.

- Waves are disturbances that transmit energy from one place to another. (4.1)
- Waves have amplitude, wavelength, and frequency. (4.1)
- As the wavelength decreases, the frequency increases. (4.1)
- Different colours of light have different wavelengths. (4.2)
- White light is a mixture of many wavelengths of light. (4.2)
- A prism can separate and recombine different colours of light. (4.2)
- The electromagnetic spectrum is made up of waves that are similar to light waves that have much longer or shorter wavelengths. (4.3)
- Radio waves, microwaves, and infrared waves have longer wavelengths than visible light. (4.3)
- Ultraviolet waves, X rays, and gamma rays have shorter wavelengths than visible light. (4.3)

5 Optical systems make use of mirrors and lenses.

- Ray diagrams help explain how beams of light travel in straight lines and how various materials can be opaque, translucent, or transparent. (5.1)
- Mirrors reflect light according to the law of reflection, which states that the angle of incidence equals the angle of reflection. (5.1)
- Light rays bend when they pass between two materials of different density. (5.1)
- Simple mirrors can be plane (flat), convex (curving out), or concave (curving in). (5.2)
- The image formed by a concave mirror depends on the distance of the object from the mirror. (5.2)
- Convex mirrors form images that are upright and smaller than the object. (5.2)
- Concave lenses are thinner in the middle than at the edge and diverge light rays. (5.3)
- Convex lenses are thicker in the middle than at the edge, and converge light rays. (5.3)

6 Human vision can be corrected and extended using optical systems.

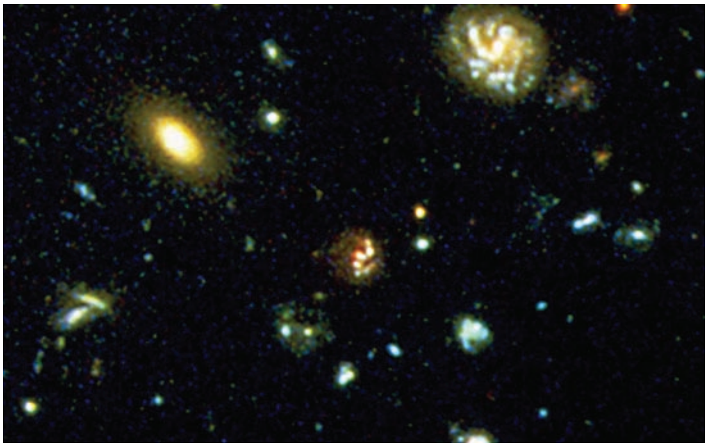
- Light is detected by the eye using the cornea-lens-retina system. (6.1)
- Rod cells detect dim light but are not sensitive to colour. (6.1)
- Cone cells dominate in bright light and distinguish between colours. (6.1)
- Vision deficiencies include near-sightedness, far-sightedness, astigmatism, and deficiencies in distinguishing between different colours. (6.2)
- Eyes, cameras, microscopes, and telescopes have some similarities in the way they operate. (6.3)
- Lasers and optical fibres are used to transmit data using light. (6.3)

Key Terms

- amplitude
- crest
- electromagnetic radiation
- energy
- frequency
- gamma rays
- infrared waves
- microwaves
- radio waves
- refraction
- spectrum
- trough
- ultraviolet waves
- visible light
- wave
- wavelength
- X rays

Key Terms

- angle of incidence
- angle of reflection
- angle of refraction
- concave
- converging
- convex
- diverging
- focal point
- lens
- normal
- opaque
- translucent
- transparent

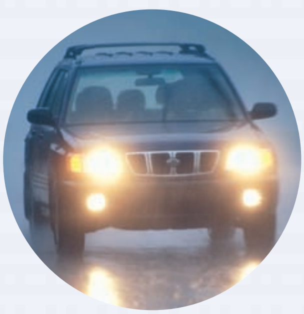


Key Terms

- astigmatism
- blind spot
- cornea
- iris
- optic nerve
- pupil
- retina
- sclera

Designing Fog Lights

Your company makes automobile lights and supplies them to a major auto firm. The company has divided its employees into teams to work on designing new fog lights. One team researches the design of the mirror behind the light, and another team examines the type of all-weather materials to be used in the outer part of the light. Your team must choose the best colour to make the lights.



Problem

Determine which colour of light you will recommend to your company.

Materials

- glass or plastic jar with no label
- milk
- water
- flashlight
- coloured film or cellophane wrap
- light meter

Criteria

- Collect experimental data indicating which colour penetrates best while reflecting least through fog.
- Determine which colours are prohibited from use on British Columbia highways.

Procedure

1. Create a data table to record your data. Give your table a title.
2. Learn how to use the light meter. Light meters vary in the units of light intensity they use, but this is not important as long as the same units are used in each test.
3. Fog can be simulated in a variety of ways. Research possible methods, or use "milk/water" fog. This kind of fog is made by placing about 10 mL of milk into about 100 mL of water. Experiment with different amounts of milk until you get a satisfactory amount of fogginess.
4. Shine the flashlight through the jar containing your fog mixture and detect the light coming through the back of the jar using the light meter. Also, detect the amount of reflection from the front of the jar. Record your results in your data table.
5. Place different colours of film on the flashlight to produce different colours of light. Record the amount of light transmitted and reflected for each colour.

Report Out

1. Present your experimental data in a clear and logical form.
2. Determine the three most penetrating colours of light. Eliminate any colours that are prohibited from use on British Columbia highways.
3. What colour of fog lights do you choose? Explain your choice.

Natural Vision Systems

In this investigation, you will choose an animal and compare its vision system to the human vision system.

Background

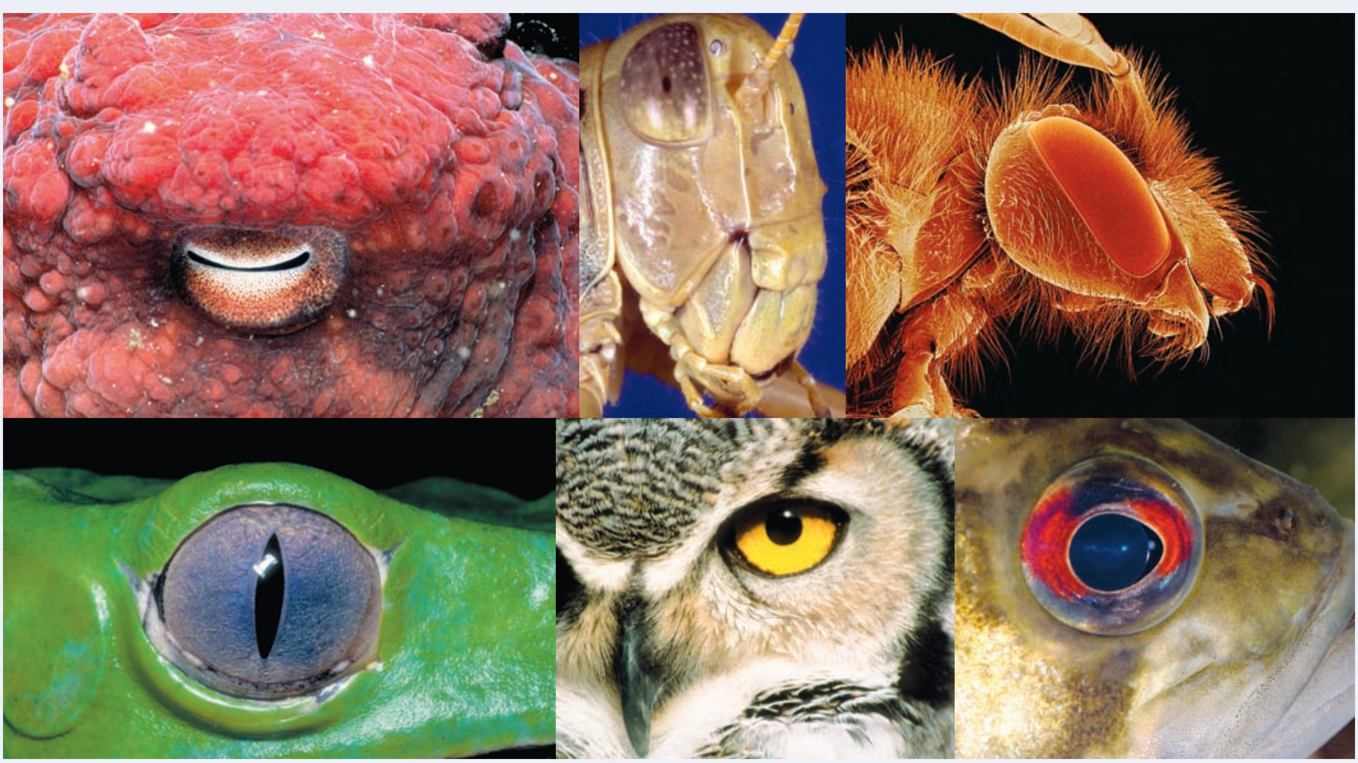
As with all characteristics of living creatures, eyes must meet the organism's needs. For example, humans once needed to be able to hunt and gather food. This required eyes that could focus on both close and distant objects. Hunting and gathering also required eyes positioned for three-dimensional viewing. It is not surprising that other mammals such as apes share these features.

Find Out More

Use the Internet, encyclopedias, or books to find more information about the vision system of the animal you have chosen to research. Identify how the vision system meets the animal's needs. Illustrate the structure of the animal's eye and the other parts of its vision system. Carefully record the information you discover. Be sure to cite the resources you used. You can start your search at **www.bcscience8.ca.**

Report Out

1. Compare the animal's vision system with the human vision system.
   (a) Use a Venn diagram to compare the systems. Include illustrations and photographs on your Venn diagram to show similarities and differences of the two systems.
   (b) Create a model of the animal's vision system and the human vision system. Use labels to show similar and different parts and abilities.

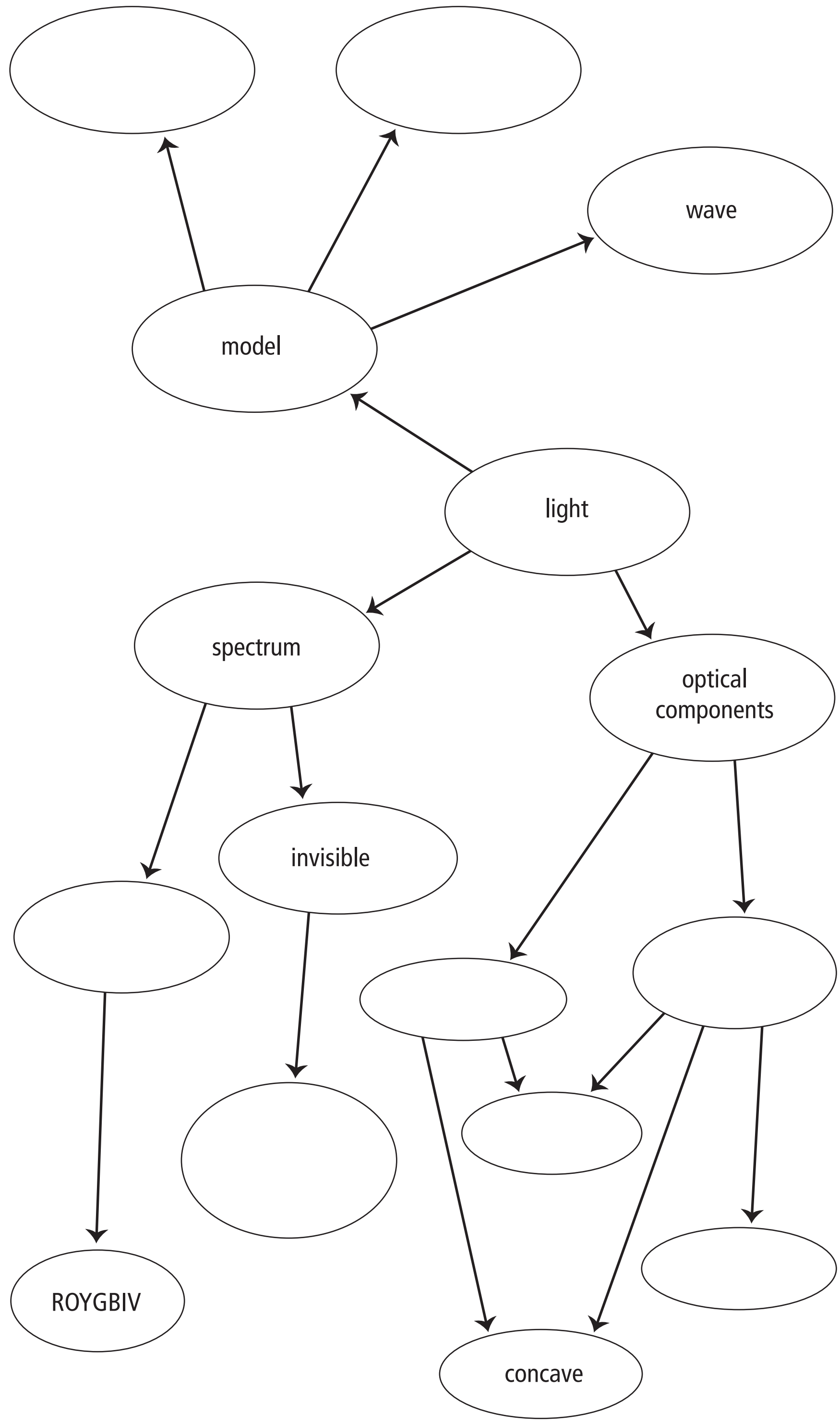


Insects need a type of eye that will allow them to detect nearby motion. The eyes of birds and aquatic creatures also have different structure and function from ours.

Unit Review

Visualizing Key Ideas

1. Copy the concept map about light into your notebook. Complete the map.



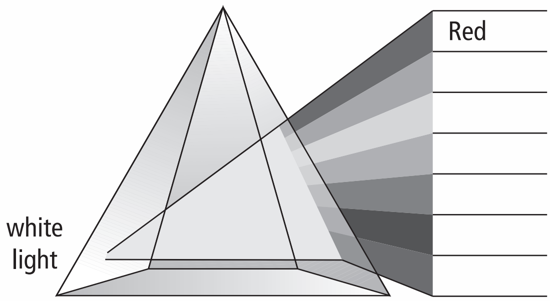
Using Key Terms

2. State whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) As the wavelength increases, the frequency decreases.
   (b) The amplitude of a wave is the distance between the wave crest and the wave trough.
   (c) A wave is a disturbance in a medium in which energy moves from one place to another.
   (d) An opaque material lets some light through, but no image is visible.
   (e) In a mirror, the angle of incidence equals the angle of refraction.
   (f) A convex mirror causes light rays to converge toward a focal point.
   (g) A convex lens causes light rays to converge toward a focal point.
   (h) Light passes through the eye in the following order: lens, cornea, pupil, retina.
   (i) The blind spot occurs where the optic nerve attaches to the sclera.
   (j) A refracting telescope is made of a combination of lenses and mirrors.

Checking Concepts

4

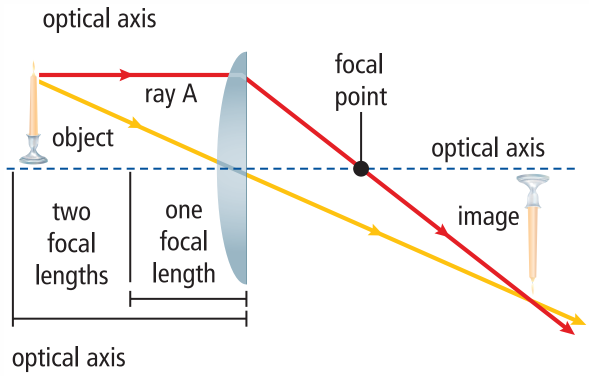
3. (a) Draw a light wave.
   (b) Label amplitude, wavelength, trough, and crest.
4. (a) Identify the object shown in the figure below.
   (b) Explain how the object affects white light that passes through it.
   (c) Identify the colours that would be seen on the right side of the object, in order of decreasing wavelength. Do not write in this book. List the colours in your notebook.



5. Describe the difference between an object that appears black and an object that appears white.
6. Order the following types of radiation according to decreasing wavelength: gamma rays, infrared waves, radio waves, X rays, ultraviolet waves, visible light.

5

7. (a) Draw a double concave lens. Show what happens to light rays passing through the lens.
   (b) Draw a double convex lens. Show what happens to light rays passing through the lens.
8. How does the wave model of light account for the bending of a light ray as it moves from air into glass?
9. (a) Which is denser, water or glass?
   (b) Would water or glass refract light more if light were to pass into it from the air?
10. (a) How are reflection and refraction different?
    (b) How are they similar?
11. Draw a labelled diagram to show what happens when light rays strike transparent, opaque, and translucent objects.
12. How is the angle of reflection of a mirror determined?
13. Explain the difference between focal point and focal length.
14. How does the thickness of a convex lens affect the focal length?
15. Explain whether light shining off a small metallic ball is an example of convergence or divergence.
16. The rear-facing mirror on the passenger side of a car often has the warning "Objects in the mirror are closer than they appear."
    (a) Draw and label the kind of mirror used for this application.
    (b) Why is this kind of mirror used?
17. Suppose the image of the candle moves away from the focal point in the following illustration. How did the position of the candle change?



Unit Review

6

18. (a) Draw a picture of a human eye from the front and the side view.
    (b) Label the following in your diagrams: retina, sclera, lens, optic nerve, blind spot, iris, pupil, and cornea.
19. Why does a scene that is brightly coloured in full daylight look grey at twilight?
20. (a) What are the parts of the eye involved in focussing light?
    (b) Which part of the eye does the most focussing?
21. Describe how the shape of the lens in your eye changes when you look at a nearby object, and then at a distant object.
22. List and describe four common defects in human vision.
23. Compare and contrast a refracting telescope and a microscope.
24. Draw a labelled diagram showing how binoculars work.
25. Explain why a beam of laser light can deliver more energy to a smaller area than light from a light bulb can.
26. Use a labelled diagram to help you explain how optical fibres transmit light.

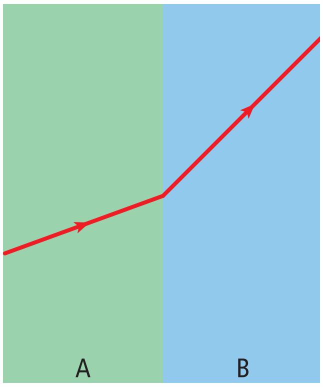
Understanding Key Ideas

27. Compare and contrast the reflection of light from a white wall with a rough surface, with the reflection of light from a mirror.
28. Distinguish between ultraviolet light and infrared light using the wave model.
29. Illustrate how the term "disturbance" could be used to describe the motion of light through space.
30. Summarize two uses of the invisible spectrum in producing medical images of the human body.
31. Give examples of optical components that are able to cause light rays to converge.
32. Summarize how the term "normal" is used to determine the way light reflects off mirrors and refracts through lenses.
33. Show the relationship of how curved a convex lens is to its ability to converge light rays.
34. Defend this statement: A concave mirror could be used to form an image on a screen, but a convex mirror could not.
35. Relate the density of a transparent material to its ability to refract light.
36. Give examples to show why the inability of cone cells to detect the colour red could be considered a vision problem.
37. Explain why a telescope uses a large mirror instead of a large lens to collect dim light from distant stars.
38. Compare how colour vision works with how black-and-white vision works.

Thinking Critically

39. A lens made of plastic is placed in liquid. Light rays travelling in the liquid are not refracted when they pass through the lens. Compare the speed of light in the plastic and the liquid.
40. If you place the tips of two fingers and a thumb together to make a tiny hole, and then look through the hole at a distant object, the object becomes clearer. Use a ray diagram to explain how this happens.

41. Examine the ray diagram below in which the green (A) and the blue (B) regions are different materials.
(a) Which material is denser? Explain.
(b) If both materials were used to make lenses, which would be able to make the more powerful lens? Explain.



42. What would happen to an image made by projecting light through a lens onto a screen if you cover the left half of the lens with your hand?

43. Why can a person not focus clearly underwater without wearing goggles or a facemask?

44. (a) Why must telescope mirrors be very smooth?
(b) What would happen to the image if the mirror were not smooth?

45. How has the use of telescopes contributed to scientific research?

46. A person takes a photograph of an image in a plane mirror. If the camera is 2 m in front of the mirror, at what distance should the camera lens be focussed?
Draw a labelled diagram to help you answer this question.

47. A camper has forgotten to bring matches on a camping trip, and is using a magnifying glass to start a campfire. Draw a ray diagram to show how the Sun's light is brought into focus by the magnifying glass.

Developing Skills

48. A student plucks a pair of strings on a guitar.
(a) In order to play middle C, the string vibrates 524 times in 2 s. What is the frequency of middle C in hertz?
(b) In order to play the A below middle C, the string vibrates 660 times in 3 s. What is the frequency of A below middle C in hertz?

Pause and Reflect

By studying other planets and galaxies with telescopes we can better understand our own planet. This is an example of how an optical technology has improved our lives. Explain how another optical system has contributed to scientific research.