The Eye and Light

The BIG Idea

Light is a wave that interacts with everything you see.

LESSON 1 6.a, 6.e
What is light?

(Main Idea) Visible light is an electromagnetic wave.

LESSON 2 6.b, 6.c, 6.f, 6.g
Light and Matter

(Main Idea) Light interacts with matter in different ways.

LESSON 3 6.d
Using Lenses

(Main Idea) Lenses form images by causing light rays to bend.

LESSON 4 5.g, 6.b, 6.d, 6.e
The Eye and Vision

(Main Idea) The eye is a complex organ made up of different parts.

Seeing the Light

The Sun looks like a glowing yellow ball as it sets behind the Golden Gate Bridge in San Francisco, California. You see the light waves emitted by the Sun and other light sources when these light waves enter your eyes. Your eyes are made of structures that function together to enable you to see the world around you.

Science Journal

List five things that emit light.
Can you make a rainbow?

What colors are produced when white light passes through a prism?

**Procedure**

1. Complete a lab safety form.
2. Place a **prism** between a **flashlight** and a sheet of clean **white paper**.
3. Aim the flashlight beam through the prism; move the prism until a band of colors spreads across the white paper.
4. In your Science Journal, draw the colors you observe in order and identify each.
5. Determine if you can change the order of the colors.

**Think About This**

- **Describe** how the order of colors changed as the direction of the flashlight beam changed.
- **Infer** which color light waves have changed direction the most and the least after passing through the prism.

**Foldables™ Study Organizer**

**The Eye** Make the following Foldable to record the structure and function of the different parts of the eye.

**STEP 1** Fold a sheet of paper in half lengthwise.

**STEP 2** Cut along the first line and then every fifth or sixth line of the top flap to form seven tabs.

**Visualizing**

As you read this chapter, list the names of the parts of the eye on the tabs. Beneath each tab, describe the structure and function of that part.

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Learn It! Good readers compare and contrast information as they read. This means they look for similarities and differences to help them to remember important ideas. Look for signal words in the text to let you know when the author is comparing or contrasting.

**Compare and Contrast Signal Words**

<table>
<thead>
<tr>
<th>Compare</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>as</td>
<td>but</td>
</tr>
<tr>
<td>like</td>
<td>or</td>
</tr>
<tr>
<td>likewise</td>
<td>unlike</td>
</tr>
<tr>
<td>similarly</td>
<td>however</td>
</tr>
<tr>
<td>at the same time</td>
<td>although</td>
</tr>
<tr>
<td>in a similar way</td>
<td>on the other hand</td>
</tr>
</tbody>
</table>

Practice It! Read the excerpt below and notice how the author uses contrast signal words to describe the differences between the refraction of different wavelengths by a prism.

When white light passes through the prism, light waves with different wavelengths are refracted by different amounts. Violet light waves have the shortest wavelengths and are bent the most. Red light waves are bent the least.

Apply It! Compare and contrast the concave lens and the convex lens on page 443.
**Target Your Reading**

Use this to focus on the main ideas as you read the chapter.

1. **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   - Write an A if you **agree** with the statement.
   - Write a D if you **disagree** with the statement.

2. **After you read** the chapter, look back to this page to see if you’ve changed your mind about any of the statements.
   - If any of your answers changed, explain why.
   - Change any false statements into true statements.
   - Use your revised statements as a study guide.

### Before You Read A or D | Statement | After You Read A or D
--- | --- | ---
1 | Light always travels at the same speed. |   
2 | Light can travel through empty space. |   
3 | Light rays always travel in straight lines from one point to another. |   
4 | Only shiny objects, such as mirrors, reflect light. |   
5 | The color of an object depends on the light the object reflects. |   
6 | The human eye sends light out to objects and detects the light that is reflected back to the eye. |   
7 | Three colors of light can be mixed together to make almost all the colors that you see. |   
8 | Eyeglasses magnify objects so the eyes can see them. |   
9 | The lens in the human eye does not change shape. |   
10 | Not eating enough leafy, green vegetables is the most common cause of the inability to see colors. |   

Print a worksheet of this page at [ca7.msscience.com](ca7.msscience.com).
What is light?

(Main Idea) Visible light is an electromagnetic wave.

Real-World Reading Connection Imagine you are standing on a beach watching giant waves rolling toward you. As they reach the beach, you hear them crashing down and feel them pound the sand. The energy that shakes the ground and creates the noise is energy transferred by the waves. Light is also a type of wave that transfers energy from one place to another.

Light Transfers Energy

Think about what happens when you throw a rock into a still pool of water, as in Figure 1. The rock hits the water and changes, or disturbs, the flat surface of the pool. This disturbance is caused by the energy transferred to the water from the moving rock. As you watch, waves move outward from the place where the rock entered the water. These waves carry energy to other parts of the pool.

Similar to water waves, light waves also carry energy from place to place. A source of light, such as the candle shown in Figure 1, or the Sun, emits light waves. These waves spread out in all directions. Sometimes, however, it is easier to think of light in a different way. A light ray is a narrow beam of light that travels in a straight line. In Figure 1, the light rays emitted by the candle are represented by arrows. You can think of a source of light as emitting light rays that travel away from the source in all directions.

The candle emits light rays that travel in straight lines in all directions.
Parts of a Wave

1. Imagine that you are holding one end of a rope that is attached to a wall, as shown in Figure 2. The rope is in its resting position when it is held so that it is perpendicular to the wall.

2. Now, think about what happens when you move your end of the rope in a steady, up-and-down motion. You create a wave in the rope. The wave has a shape that looks like a sideways letter S repeating many times.

   The highest points of the wave are called crests. The lowest points are called troughs. The distance between any two crests or any two troughs is called the wavelength. The amplitude of the wave is the distance from a crest or trough of the wave to the resting position.

Frequency and Wavelength

As you move the rope up and down, you make crests and troughs that travel along the rope. The number of crests or troughs that pass a given point in one second is related to the frequency of the wave. The frequency (FREE kwun see) of a wave is the number of wavelengths that pass a given point in one second. The frequency of the wave on the rope is also equal to the number of times each second that your hand moves up, down, and up again.

3. If you move your end of the rope more quickly, the frequency of the wave increases. Then the crests and troughs of the wave become closer together on the rope. This means that as the frequency of a wave increases, the wavelength decreases. The same is true for all waves, including light waves.

4. If you move the end of the rope more slowly, the crests and troughs become more spread out. This means that the wavelength increases as the frequency decreases. This is true for all waves, including light waves. The lower a light wave’s frequency, the greater its wavelength will be.

Reading Check

How does the wavelength change as the frequency decreases?
To reach the boy's eye, a light ray reflected from the fish travels through a liquid, a solid, and a gas.

**Electromagnetic Waves**

When you think of waves, you might think of ocean waves or waves transferred along a rope. In these examples, the substance through which the wave moves is called the **medium**. The medium through which ocean waves move is water. The medium through which the rope wave moves is the material that makes up the rope.

Light can travel through different mediums. As shown in Figure 3, light can travel through solids, liquids, and gases. Unlike water waves or waves on a rope, however, light can travel through empty space where there is no matter. Light is an electromagnetic wave, which is a type of wave that can travel in empty space as well as in matter.

**The Electromagnetic Spectrum**

Like waves on a rope, electromagnetic waves have a range of wavelengths and frequencies. The entire range of electromagnetic waves of different wavelengths and frequencies is called the **electromagnetic spectrum** (ih lek troh mag NEH tik • SPEK trum).

**A Range of Wavelengths**

As shown in Figure 4, the electromagnetic spectrum includes all electromagnetic waves arranged from those with the longest wavelengths to those with the shortest wavelengths. Because frequency increases as wavelength decreases, the electromagnetic spectrum is also arranged in order of increasing frequency.
Visible Light

The light that you can see is only a very small part of the electromagnetic spectrum. Figure 4 shows the visible light spectrum, which is the range of electromagnetic waves human eyes can detect. Visible light has wavelengths that are so short they are usually measured in units of nanometers (nm). One nanometer equals one billionth of a meter. The wavelengths of visible light waves range from about 700 nm to about 400 nm, which is about 100 times smaller than the width of a human hair. Colors that you can see depend on the wavelengths of the light waves that enter the eye.

Figure 4 What wavelength of light is red? What wavelength of light is blue?

**Figure 4** Visible light waves are part of the electromagnetic spectrum.

**Academic Vocabulary**

range (RAYNJ) (verb) to change or differ within limits
From sunrise to sunset, the temperature ranged from 10°C to 25°C.
Visible Light and the Electromagnetic Spectrum

The light that human eyes can see is only a small part of an electromagnetic spectrum. The entire electromagnetic spectrum ranges from waves with wavelengths of thousands of meters to waves whose wavelength is less than the width of an atom. In fact, the electromagnetic spectrum has no upper or lower limits. All electromagnetic waves, whether part of the visible spectrum or some other part of the electromagnetic spectrum, transfer energy as they travel from one place to another.

Using Vocabulary

1. Define electromagnetic spectrum in your own words.
2. The ______ is the material through which a wave travels.

Understanding Main Ideas

3. State two different kinds of electromagnetic waves.
4. Describe the relationship between wavelength and frequency.
5. Organize Copy and fill in the graphic organizer below. In each oval, list a different part of the electromagnetic spectrum.

Electromagnetic Spectrum

6. In which does light travel the fastest?
   A. air
   B. empty space
   C. diamonds
   D. light always travels at the same speed

7. Give an example of an electromagnetic wave that has a wavelength longer than visible light.

Applying Science

8. Predict how the speed of a light wave changes as it travels from the Sun, through Earth’s atmosphere, to a fish in the ocean.

Scientific Notation

Scientific notation is a way to write large and small numbers. A number written in scientific notation has the form \( M \times 10^N \).

To convert a large number to scientific notation, move the decimal point to the left until there is only one nonzero digit to the left of the decimal point. Then \( N \) is the number of places you moved the decimal point and is a positive number.

To convert a small number to scientific notation, move the decimal point to the right until there is only one nonzero digit to the left of the decimal point. Then \( N \) is the number of places you moved the decimal point and is a negative number.

Examples

To write the number 92,700 in scientific notation, follow these steps:

1. Write the number in scientific notation form with a decimal point at the end: \( 92,700. \times 10^N \)
2. Count the number of places you move the decimal point until there is only one nonzero digit to the left of the decimal point. Here, the decimal point moves four places to the left: \( 9.2700 \times 10^N \)
3. The decimal point moved four places to the left, so \( N = 4 \): \( 9.2700 \times 10^4 \)
4. Delete the zeros at the end of the number: \( 9.27 \times 10^4 \)

To write the number 0.0013 in scientific notation, follow these steps:

1. Write the number in scientific notation form: \( 0.0013 \times 10^N \)
2. Count the number of places you move the decimal point until there is only one nonzero digit to the left of the decimal point. Here, the decimal point moves three places to the right: \( 0001.3 \times 10^N \)
3. The decimal point three places to the right, so \( N = -3 \): \( 0001.3 \times 10^{-3} \)
4. Delete the zeros at the beginning of the number: \( 1.3 \times 10^{-3} \)

Practice Problems

1. The wavelength of an electromagnetic wave is 100,000 m. Express this wavelength in scientific notation.
2. The wavelength of an X ray is 0.0000000001 m. Express this wavelength in scientific notation.
Can you identify waves in the electromagnetic spectrum?

The wavelengths of waves in the electromagnetic spectrum range from large numbers to small numbers. One way to write large or small numbers is to use scientific notation. For more help in using scientific notation, see the Applying Math feature on the previous page.

**Data**

Copy the data table below and complete the second column.

<table>
<thead>
<tr>
<th>Wavelengths of Different Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave Number</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

**Data Analysis**

1. **Use Figure 4** on page 429 to determine the type of electromagnetic wave represented in each row. If the wave is in the visible spectrum, identify its color.

2. **Determine** the wavelength, in scientific notation, of a wave whose wavelength is 10 times longer than wave #3.

**Science Content Standards**

6.a Students know visible light is a small band within a very broad electromagnetic spectrum.
**Light and Matter**

(Main Idea) Light interacts with matter in different ways.

Real-World Reading Connection When you look around the room, light that enters your eyes comes from different objects. You might see sunlight passing through the glass in a window or your reflection in a mirror. How does the light from these objects reach your eyes?

The Interaction of Light and Matter

Have you ever seen a pinball machine? When the ball is launched, it enters a field of obstacles. It then rolls in straight lines until it hits a bumper. Then it bounces in a different direction. Sometimes the ball goes into a hole and then is shot out a short time later. Light rays behave in some similar ways. When light rays hit matter, they can be absorbed by the matter, be reflected, or pass right through the material.

All electromagnetic waves, including light, transfer energy from one place to another. Figure 5 shows an industrial laser that uses the energy carried by infrared waves to cut through steel. When light waves hit a material, some of the energy carried by the light waves is transferred to the atoms or molecules in the material. Atoms can absorb some of this energy so that the material becomes warmer. Atoms can also absorb some of the light energy and then emit new light waves.

**Figure 5** The energy carried by infrared waves from this laser causes the steel to melt.
Absorption of Light

On a sunny day, an asphalt parking lot can be very hot. The asphalt is hot because some of the energy carried by sunlight is absorbed by the asphalt. As shown in Figure 6, when light rays hit a material, some of the light ray’s energy is transferred to the atoms in the material. This transfer of energy can cause the temperature of the material to increase. The process of transferring light energy to the atoms or molecules in a material is called absorption (ub SORP shun).

The amount of energy absorbed when light rays strike a material depends on the types of atoms in the material. The amount of energy absorbed also depends on the wavelengths of light. The atoms in asphalt absorb more energy from sunlight than the atoms in grass. As a result, the asphalt becomes hotter than grass.

Transmission of Light

When you look through a window, you see objects on the other side of the glass. Light waves from these objects pass through the glass and enter your eyes. Instead of being absorbed by the glass, these light waves are transmitted through the glass. Transmission occurs when light waves strike a material and pass through it. Whether light waves are transmitted or absorbed by a material depends on the wavelength of the light waves that strike the material. Some materials, like glass, transmit only certain wavelengths. Other materials do not transmit any light waves.

Scattering of Light

Have you ever noticed dust particles in a beam of sunlight? When the light waves in a sunbeam strike a dust particle, two things happen. First, they are absorbed by the dust particle, and then they are emitted. The light rays that are emitted travel in all directions. Scattering occurs when a material causes light waves traveling in one direction to travel in all directions. When the light waves in a sunbeam strike a dust particle, they are scattered in all directions. You see the dust particle as a bright speck of light when some of these scattered light waves enter your eye.
Opaque, Transparent, and Translucent Materials

The three candleholders in Figure 7 are made of different materials. These materials absorb, transmit, and scatter light in different ways. The candleholder on the left is made from an opaque material. An opaque material only absorbs and reflects light—no light is transmitted through it. The middle candleholder is translucent. A translucent material allows some light to pass through, but scatters light so you cannot see clearly through it. The candleholder on the right is transparent—it transmits nearly all the light that strikes it.

The Speed of Light in Different Materials

Light waves and all electromagnetic waves travel through empty space at a speed of about 300,000 km/s. This speed is called the speed of light. No object or wave can move faster than the speed of light in empty space.

However, when light waves travel in matter, they move more slowly. Figure 8 compares the speed of light in different materials. Light waves slow down in a material because they interact with the atoms and molecules in the material.

Under what conditions does light travel fastest?
Refraction

When light rays move from one medium to another, such as from air to water as shown in Figure 9, they can change direction. Refraction (rih FRAK shun) occurs when a light ray changes direction when it moves from one material into another.

Refraction and Speed Changes

Why does the light beam in Figure 9 change direction? Light waves change direction, or refract, whenever they change speed in moving from one medium into another. The light beam bends because light waves slow down as they move from air into water. The greater the difference in speed between the two materials, the greater the amount of refraction. However, refraction does not occur for waves that are traveling perpendicular to the boundary between the materials. Figure 10 shows how the refraction of light waves causes a straw in water to look like it is broken.
**Refraction and the Visible Spectrum**

A prism, like the one in Figure 11, is a piece of transparent glass or plastic that is usually shaped like a wedge. When light rays pass through the prism, they change direction. Light waves slow down as they move from air into the glass prism. This causes light waves to refract when they enter the prism. Light waves speed up and refract when they move from the prism back into the air.

Refraction produces the rainbow of colors shown in Figure 11. White light is a combination of all light waves in the visible light spectrum. When white light passes through the prism, light waves with different wavelengths are refracted by different amounts. Violet light waves have the shortest wavelengths and are bent the most. Red light waves are bent the least.

**White Light**

You know that passing white light through a prism separates the white light into the visible light spectrum. But does the process work in reverse? Can you combine different colors of light to make white light? Figure 12 shows that it is possible to make white light by mixing colored lights. You can also mix colors together to make other colors. For example, where the green and red light overlap, there is yellow light. Red, green, and blue light are called the primary colors of light. Almost any color of light can be made by mixing these three colors in different amounts.

**Academic Vocabulary**

**primary** (adjective) of first rank, importance, or value

*A firefighter’s primary goal is to save people who are trapped in burning buildings.*

**Figure 11** Prisms separate white light into the various colors of the visible spectrum.

**Figure 12** White light can be made by combining the three primary colors of light.
Reflection

Light waves usually travel in straight lines in a material or through space. However, light waves can change direction when they speed up or slow down. Light waves also change direction when they are reflected from a surface. When light rays are reflected, the direction of the reflected ray depends on the direction of the incoming light ray that strikes the surface.

What are the two ways light waves can change direction?

The Law of Reflection

The direction of a reflected light ray is determined by the law of reflection, as shown in Figure 13. The incoming ray and the reflected ray make an angle with a line perpendicular to the surface. The line perpendicular to the surface is called the normal to the surface. The angle of incidence is the angle between the incoming light ray and the normal. The angle of reflection is the angle between the reflected ray and the normal. According to the law of reflection (rih FLEK shun), when a light ray is reflected from a surface, the angle of incidence equals the angle of reflection. Light rays reflected from all surfaces always obey the law of reflection.

Figure 13  All light waves obey the law of reflection.

State the relationship between the angle of incidence and the angle of reflection.
Regular and Diffuse Reflection

Although the surface of a sheet of paper might seem smooth, it’s not as smooth as the surface of a mirror. Figure 14 shows how the rough paper surface reflects light rays in many directions. Each light ray reflected from the uneven surface of the paper obeys the law of reflection. But each one hits a surface that is at a slightly different angle. This means the light rays that are parallel before they hit the surface end up going many different directions after they strike the surface. This reflection from a rough surface is called diffuse reflection.

However, the smooth surface of a mirror reflects parallel light rays so that they remain parallel. Reflection from a mirror is called regular reflection. Whether a surface is rough or smooth, all light rays that strike the surface obey the law of reflection.

Explain how diffuse reflection is different from regular reflection.

Reflection and Color

Look around the room. Notice the colors of different objects. Why do some things look red while others appear green? Figure 15 illustrates why different objects have different colors. As white light strikes an object, some of the light is absorbed and some is reflected. The reflected light is what enters your eyes and causes you to see the object. For example, what makes the flower look red? The flower looks red because the materials in the flower absorb all wavelengths of light except red. The red light is reflected to your eyes, and you see the flower as red.

Figure 15  The color of an object depends on the wavelengths of light that are reflected by the object.
What have you learned?

In this lesson, you read about the different ways light can interact with matter. All objects that you see either reflect light or are sources of light. The energy carried by light waves can be absorbed by the atoms in a material. Some of this energy also can be emitted by atoms as new light waves. The interaction of light and matter causes light waves to be reflected and refracted. Light passes through a transparent material, is partially scattered by a translucent object, and does not pass through an opaque object.

**LESSON 2 Review**

Create your own lesson summary as you write a script for a television news report.

1. **Review** the text after the **red** main headings and write one sentence about each. These are the headings of your broadcast.
2. **Review** the text and write 2–3 sentences about each **blue** subheading. These sentences should tell who, what, when, where, and why information about each **red** heading.
3. **Include** descriptive details in your report, such as names of reporters and local places and events.
4. **Present** your news report to other classmates alone or with a team.

**Using Vocabulary**

1. _______ is the bending of light when it travels from one medium to another.
2. State the law of reflection in your own words.

**Understanding Main Ideas**

3. **Label** a drawing of white light being split into the visible spectrum by a prism. Which color is bent the most? Which is bent the least?
4. **Describe** how a light ray travels as it moves through empty space.
5. **Identify** Copy and fill in the graphic organizer below to identify three ways light interacts with matter.

**Standards Check**

6. **What is the process of absorbing light and then reemitting it in a different direction?**
   A. opaque
   B. scattering
   C. translucent
   D. transmission

7. **Give an example** not discussed in the text of a transparent, a translucent, and an opaque object.

8. **Compare and contrast** absorption, scattering, and transmission.

**Applying Science**

9. **Critique** the statement, “The color of an object depends on the wavelengths of light it absorbs.” Why is the statement inaccurate? How could you change the statement so it is correct?
Using Lenses

**Main Idea** Lenses form images by causing light rays to bend.

**Real-World Reading Connection** Have you ever used a camera to take a picture of a friend? All cameras record the light that is emitted or reflected by objects. Cameras, microscopes, and telescopes use lenses to form images that you can see.

**What is a convex lens?**

You are probably familiar with different devices that change how you see things. Eyeglasses change the way light is focused on a person’s eye. Magnifying lenses and microscopes make very small objects appear to be large. Telescopes and binoculars make objects that are far away appear to be closer. All of these devices use at least one lens to form images. A **lens** is a transparent object with at least one curved side that causes light waves to bend. **Figure 16** shows two different types of lenses.

A lens that bulges outward, such as the one shown in the left photo in **Figure 16**, is called a **convex** (kahn VEKS) **lens**. Parallel light rays passing through a convex lens are bent so they come together, or converge. As shown on the right of **Figure 16**, a concave lens is thinner in the middle than at the edges. Parallel light rays passing through a concave lens spread apart, or diverge.
Figure 17  Light rays passing through convex lenses converge.

Light’s Path Through a Convex Lens
Convex lenses are usually made out of glass or plastic. Light travels more slowly in both glass and plastic than it does in air. This means that a light ray bends when it slows down as it moves from air into the lens. The light ray bends again when it speeds up as it moves from the lens back into the air.

Focal Point and Focal Length
Figure 17 shows several beams of light shining parallel to the optical axis of a convex lens. These beams of light all bend toward the optical axis. The point where all of the beams of light converge is called the focal (FOH kuhl) point. In a convex lens, all light rays traveling parallel to the optical axis are bent so that they pass through the focal point. The distance from the center of the lens to the focal point is called the focal length.

Image Formation by a Convex Lens
Figure 18 shows that the image formed by a convex lens depends on the position of an object in relation to the focal point. Notice that the images in the first two panels appear where the light rays converge. The light rays never converge in the third panel. Instead, they diverge from the lens, forming an image that is right-side up, on the same side of the lens as the flower and bigger than the flower.

MiniLab
How does the image change?
A magnifying lens is a convex lens. How does moving the lens change the image you see?

Procedure
1. Read and complete a lab safety form.
2. Slowly raise up a hand lens from a table until a sharp image of a ceiling light appears on the table. The distance from the lens to the table is the focal length. Record this length.
3. Place a book or magazine with a large title on the floor.
4. Hold the lens less than one focal length above the title. Look through the hand lens and describe what you see.
5. Have a partner hold the lens more than one focal length above the title. Move your head until you see a clear image. Describe what you see.

Analysis
Describe how the image changed as you changed the location of the lens.

Visual Check
Figure 18 How is the candle’s image different in the bottom panel from the images in the other two panels?
Visualizing Images Formed by a Convex Lens

**Figure 18**

A convex lens can form images of an object that are bigger or smaller than the object. The image can also appear upright or upside down, compared to the object. The type of image formed by a convex lens depends on the location of the object relative to the focal point of the lens.

If the object is more than two focal lengths from the lens, the image formed is upside down and smaller than the object. As the object moves farther from the lens, the image becomes smaller.

If the object is between one and two focal lengths from the lens, the image is upside down and larger than the object. As the object moves closer to the focal point, the image becomes larger.

If the object is less than one focal length from the lens, the image is upright and larger than the object. The image becomes smaller as the object moves closer to the lens.
Optical Instruments

Have you ever thought about why it’s so hard to see objects that are far away? An optical instrument uses lenses to focus light and create useful images. Often, an optical instrument acts as a bigger eye by collecting more light than your eyes can collect. It gathers the light and then forms an image that your eyes can see. Different optical instruments do this by combining lenses in various ways.

Cameras

A typical camera, like the one shown in Figure 19, uses several lenses to form an image. The camera is focused by moving the lenses back and forth until a sharp image is formed. The image is smaller than the object and is upside down. In some types of cameras, the image is formed on a section of film. In digital cameras, the image is formed on an electronic light sensor. When you take a picture, the camera shutter opens so that light enters the camera, and the film or the electronic sensor is exposed.

If too much light strikes the film or the light sensor, the image formed is overexposed and looks washed out. If too little light enters the camera, the photograph can be too dark. To control the amount of light that reaches the film or the light sensor, cameras have a device called a diaphragm or an aperture. The opening in the aperture becomes larger to let more light into the camera. The aperture opening becomes smaller to reduce the amount of light that enters the camera.

Figure 19 The convex lens in a camera forms an image on the film.
Refracting Telescopes

Why is it hard to see far-away objects clearly? As an object gets farther away, less of the light from the object enters the openings in your eyes. As a result, the object appears dimmer and less detailed.

A telescope is an optical instrument that makes far-away objects seem closer. There are two basic types of telescopes. A simple refracting telescope is a combination of two convex lenses in a tube, as shown in Figure 20. The larger lens is the objective lens. The objective lens forms an image, which is enlarged by the smaller eyepiece lens.

The objective lens in a refracting telescope is much larger than the opening in a human eye. This means that much more light from a distant object enters the objective lens than would enter an eye. This causes the image formed by the objective lens to be brighter than the image your eye would form. Because the image is brighter, more detail can be seen when the image is magnified. Making the objective lens larger lets more light pass through the lens. Then even clearer images can be formed.

Reflecting Telescopes

The second type of telescope is a reflecting telescope. In a reflecting telescope, the objective lens is replaced with a mirror that has a curved reflecting surface. An image of a distant object is formed inside the telescope tube when light rays are reflected from the curved surface. A simple reflecting telescope is shown in Figure 21. Light from a distant object enters one end of the tube and strikes the curved mirror at the other end. The light is reflected from the curved mirror to a flat mirror inside the tube. The flat mirror then reflects the light to an eyepiece lens, which magnifies the image.

Which mirror in a reflecting telescope is like the convex lens in a refracting telescope?
Large Telescopes

In order to form detailed images of very distant objects, such as planets and galaxies, the objective lens or curved mirror of a telescope must be as large as possible. Because a lens can be supported only around its edges, very large lenses tend to sag due to their weight. However, a large mirror can be supported rigidly on its back side so that it doesn’t sag. As a result, the largest telescopes are reflecting telescopes instead of refracting telescopes. Figure 22 shows one of the largest telescopes in the world, the Hale telescope at Mount Palomar Observatory in southern California.

Microscopes

A refracting telescope uses convex lenses to enable distant objects to be seen. A microscope uses convex lenses to make a small object appear larger. Figure 23 shows a simple microscope. Light from the object passes through the objective lens. The objective lens is positioned so that it forms an enlarged image of the object. The light rays from that image then pass through the eyepiece lens. This lens is positioned so it is closer to the image than one focal length. As a result, the image is made even larger. By using more than one lens, a microscope forms a much larger image than a single lens can produce.
What have you learned?
A convex lens can form an image by causing light rays to refract. Lenses are used to form images in optical instruments such as cameras, telescopes, and microscopes. Telescopes use lenses and mirrors to collect light from objects that are too distant to be seen. Microscopes use lenses to magnify objects that are too small to see with your eyes alone. In the next lesson, you will read about how lenses can be used to correct some common vision problems.

LEsson 3  Review

**Summarize**
Create your own lesson summary as you organize an outline.

1. **Scan** the lesson. Find and list the first red main heading.
2. **Review** the text after the heading and list 2–3 details about the heading.
3. **Find** and list each blue subheading that follows the red main heading.
4. **List** 2–3 details, key terms, and definitions under each blue subheading.
5. **Review** additional red main headings and their supporting blue subheadings. List 2–3 details about each.

**Using Vocabulary**

1. Define lens in your own words.
2. Distinguish between focal point and focal length.

**Understanding Main Ideas**

3. Explain how the focal length changes as a convex lens becomes flatter.
4. Describe what happens to light rays that travel parallel to the optical axis as they pass through a convex lens.
5. Compare and Contrast Copy and fill in the graphic organizer below to compare and contrast details about telescopes.

<table>
<thead>
<tr>
<th>Telescope</th>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflecting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refracting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. What is the purpose of the aperture in a camera? 
   A. to invert images
   B. to magnify images
   C. to control the amount of light
   D. to control the image color

7. Demonstrate how you could use a convex lens to create an image of an object that is smaller than the original.

8. Compare and contrast a refracting telescope and a microscope.

**Applying Science**

9. Imagine you are a scientist studying distant stars. Write a short paragraph describing how your telescope works to a friend who understands light and lenses but doesn’t know how telescopes work. Include a drawing of the telescope.

**ScienceOnline**
For more practice, visit Standards Check at ca7.msscience.com.
The Eye and Vision

Main Idea The eye is a complex organ made up of different parts.

Real-World Reading Connection Cameras, telescopes, and microscopes all use lenses to form images. Did you know that your eyes also contain lenses? Like other optical instruments, the human eye uses refraction to form images.

How the Eye Forms an Image

Your eye detects light that is emitted by or reflected from objects. In some ways an eye is similar to a camera, as shown in Figure 24. In a camera, light from an object enters the lens. The lens forms an image on the film or light sensor at the back of the camera. The film or light sensor then records the image.

As light enters your eye, lenses in your eye focus light to produce an image on the back of your eye. Special cells at the back of the eye convert the image into electrical signals. These signals then travel to your brain, where they are interpreted as the object you are looking at.

Reading Guide

What You’ll Learn

► Describe the parts of the human eye.
► Explain how the parts of the eye form an image.
► Explain how the eye sees colors.

Why It’s Important

Seeing is an important way people learn about the world around them.

Vocabulary
cornea
pupil
iris
retina
pigment

Review Vocabulary
organ: groups of tissues that work together and perform one or more functions (p. 104)
Figure 25 shows the different parts of the human eye. The eye is roughly spherical and is about 2.5 cm in diameter. The outer layer of the eye is called the sclera. The front part of the sclera is clear.

Light enters your eye through the cornea (KOR nee uh), which is a clear area of the sclera. The cornea is a convex lens that causes light rays to converge as they enter the eye. Although the eye contains another convex lens that helps focus light rays, most of the refraction of light rays occurs when they enter the cornea.

Iris
After passing through the cornea, light rays then pass through the pupil. The pupil (PYEW pul) is the dark opening into the interior of your eye. The pupil is surrounded by the iris (I rus), which is the colored part of your eye behind the cornea. The pupil and the iris are shown in Figure 26.

The amount of light that enters the inside of your eye is controlled by the iris. When the light is dim, your iris is small and the pupil is large. This allows more light to enter the interior of your eye. When the light is bright, your iris is larger and your pupil is smaller, so that less light enters your eye.

Why does the pupil get smaller when the eye is exposed to bright light?
**Figure 27** The lens in an eye changes shape so that sharp images of nearby and faraway objects can be formed on the retina.

**Figure 28** Rod cells and cone cells line the retina and send signals to the brain when they are hit by light.

**Academic Vocabulary**

**flexible** (FLEK suh buhl) *(adjective)* capable of being bent

*The flexible fishing pole bent as the fisherman pulled in the heavy fish.*

---

**Lens**

After passing through the pupil, light rays pass through the lens. The lens in your eye is convex, like the lens in a magnifying glass. However, instead of being made of rigid glass or plastic, the lens in your eye is **flexible**. The ciliary (SIH lee air ee) muscles attached to the lens change its shape, as shown in **Figure 27**. When you look at objects that are farther away, the muscles contract. This flattens the lens. When you look at objects that are closer, the muscles relax. This makes the lens rounder. By changing its shape, the lens enables sharp images of both nearby and distant objects to be formed on the retina.

**Retina**

The light rays that pass through the lens form an image on the retina of the eye. The **retina** is a sheet of light-sensitive cells in the back of the eye. As shown in **Figure 28**, the retina contains two types of cells, called rods and cones. When these cells absorb light energy, chemical reactions occur. These chemical reactions produce nerve impulses that are transmitted to the brain by the optic nerve. Rod cells respond to dim light. Cone cells enable you to see colors but need brighter light to function than rod cells. **Table 1** summarizes the structures in the eye and their functions.
### Table 1 Parts of the Eye

<table>
<thead>
<tr>
<th>Function</th>
<th>Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>To control the amount of light entering the eye</td>
<td>The iris controls the amount of light entering the eye. The opening in the eye is the pupil. The iris contracts in dim light, making the pupil larger, and allowing more light to enter the eye. The iris expands in bright light, making the pupil smaller, and reducing the amount of light that enters the eye.</td>
</tr>
<tr>
<td>To form a sharp image on the retina in the back of the eye</td>
<td>The cornea, the lens, and the ciliary muscles produce a sharp image on the retina. The cornea is a convex lens that causes light rays to converge as they enter the eye and reach the lens. The ciliary muscles make the flexible lens flatter or rounder. This enables a sharp image of nearby and far-away objects to be formed on the retina.</td>
</tr>
<tr>
<td>To convert the light energy that strikes the retina to nerve signals</td>
<td>The retina contains rod cells and cone cells that convert the light energy that strikes them into nerve signals. Rod cells function in dim light and enable objects to be seen at night. Cone cells function in bright light and enable colors to be seen.</td>
</tr>
</tbody>
</table>
Seeing Color

How do cone cells enable you to see color? You have about seven million cone cells in each retina. Light waves reflected from objects enter the pupil and strike the retina. The response of the cone cells to different wavelengths of light causes you to see objects as having color.

Three Types of Cone Cells in the Retina

There are three types of cone cells. Each type responds to different wavelengths of light. One type of cone cells responds to the wavelengths of red and yellow light. These cells cause you to see the color red. The second type responds to yellow and green light and causes you to see the color green. The third type responds to blue and violet light and causes you to see the color blue.

How are the three types of cone cells different?

Light waves that strike the retina cause the three types of cone cells to send signals to the brain. The brain interprets the combination of the signals from the cone cells as the various colors you see.

Pigment Colors

Some colors of the objects you see are caused by pigments. A pigment is a material used to change the color of other materials or objects. The color of a pigment, such as paint, depends on the wavelengths of the light it reflects. Blue paint reflects blue light and absorbs all other wavelengths. As shown in Figure 29, there are three primary pigment colors—magenta, cyan, and yellow. Figure 29 also shows that each primary pigment color absorbs one of the primary light colors—red, green, or blue—and reflects the other primary colors. Most colors can be made by mixing different amounts of the primary pigment colors.

How do you see colors in the dark?

Procedure
1. Complete a lab safety form.
2. Get six pieces of paper that are different colors and about 10 cm x 10 cm.
3. Darken a room and wait 10 min for your eyes to adjust to the darkness.
4. Write on each sheet of paper the color you think the paper is.
5. Turn on the light and compare the color you wrote with the actual color.

Analysis
1. Identify Which colors were your eyes able to identify correctly?
2. Describe Which colors can rod cells detect?
3. Explain If the room were perfectly dark, what would you see? Explain.
Lesson 4 • The Eye and Vision 455

**Color Printing**

Look at a color picture in a magazine with a magnifying lens. As shown in Figure 30, the picture is formed by many tiny dots of color. Only four colors of dots are used to make all the different colors in the picture. These four colors are usually the primary colors of pigments—magenta, cyan, and yellow—as well as black. The four colors are combined in dots that are too small for the human eye to see clearly. As a result, the light reflected by the dots combines to make all the colors you see in magazines. This book was printed using four-color printing.

**Common Vision Problems**

If you have normal vision, you should be able to see objects clearly when they are 25 cm or farther from your eyes. Also, you should be able to detect all colors of visible light. However, some people cannot detect certain colors. Also, many people have problems seeing nearby objects or distant objects.

**Color Deficiency**

Take a look at Figure 31. Do you see a number? If not, you might have a red-green color deficiency. About 8 percent of males and 0.4 percent of females have a difficult time telling the difference between red and green. People with this deficiency either lack green or red cones or they have green or red cones that do not function correctly.
Nearsightedness

You probably know someone who wears glasses or contacts, or maybe you wear them yourself. Two common vision problems that glasses correct are nearsightedness and farsightedness.

A nearsighted person cannot see faraway objects clearly. As Figure 32 shows, in a nearsighted eye a sharp image is formed in front of the retina. The image on the retina is blurry. A concave lens causes light rays to diverge before they enter the eye. Then the cornea and the lens can form a sharp image on the retina.

Farsightedness

A person who is farsighted cannot see nearby objects clearly. As shown in Figure 33, a sharp image of a nearby object would be formed behind the retina. Glasses with convex lenses make light rays converge more before they enter the eye. Then a sharp image is formed on the retina.

How does the convex lens placed in front of the eye correct farsightedness?
What have you learned?

The eye is a complex light-detecting organ. The iris regulates the amount of light entering the eye, while the cornea and lens focus incoming light to form images. The images fall on the retina, which contains cells whose specialized function is to respond to light of specific wavelengths. These cells then send electrical signals to the brain, where they are processed and perceived as the objects around you.

LESSON 4 Review

Summarize

Create your own lesson summary as you write a newsletter.

1. Write this lesson title, number, and page numbers at the top of a sheet of paper.

2. Review the text after the red main headings and write one sentence about each. These will be the headlines of your newsletter.

3. Review the text and write 2–3 sentences about each blue subheading. These sentences should tell who, what, when, where, and why information about each headline.

4. Illustrate your newsletter with diagrams of important structures and processes next to each headline.

Using Vocabulary

1. Distinguish between iris and pupil.

2. The _____ is the sheet of light-sensitive cells at the back of the eye.

Understanding Main Ideas

3. List, in order, the structures that light passes through before it reaches the retina.

4. Describe how the lens in a human eye changes shape as the eye looks at a distant object and then at a closer object.

5. Take Notes Copy the graphic organizer below and list the function of each part of the eye.

<table>
<thead>
<tr>
<th>Part</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornea</td>
<td></td>
</tr>
<tr>
<td>Iris</td>
<td></td>
</tr>
<tr>
<td>Lens</td>
<td></td>
</tr>
<tr>
<td>Retina</td>
<td></td>
</tr>
</tbody>
</table>

6. Explain the type of eye problem shown below. How does the lens placed in front of the eye help correct the problem?

7. Determine which cones are involved in seeing the color white.

8. Compare a camera and the human eye.

Applying Science

9. Suggest why glasses are more common among older people. Use the fact that the lens in the eye becomes less flexible as people age.

10. Justify the following statement: “The eye is a complex organ made up of many parts.” Give specific examples that support the statement.

Science online

For more practice, visit Standards Check at ca7.msscience.com.
The different parts of the eye have different functions. Some parts move the eye and some parts control the amount of light that enters the eye. Some parts form a sharp image of the object that is being viewed and other parts detect the image and send signals to the brain. Can you sort and classify parts of the eye by function and then find them in the cow’s eye?

**Collect Data and Make Observations**

1. Read and complete a lab safety form.
2. Fill out the chart to classify parts of the eye according to function.
3. Get the following materials from your teacher: paper towels, a dissecting kit that includes a scalpel, scissors, and tweezers; a dissecting tray or surface, such as a polyurethane cutting board, a waste bucket, and a small bucket with soap and warm water for cleaning up afterward.
4. Get one cow’s eye for you and your partner from the supply your teacher has ready and set it on the paper towels in the dissecting pan.
5. Examine the eye to see and feel the following parts: sclera, cornea, muscles that move the eyeball, and optic nerve.
6. Use the dissecting scissors to cut the fat and muscle away from the eye.
7. Cut the eye around the middle with the scissors so you end up with a front half and a back half. Be careful; it is not easy to cut.
8. Look at the front half of the eye first. Try to locate and feel the lens, the back of the iris and the cornea.
9. Carefully make an incision in the cornea; cut until the clear liquid beneath the cornea is released.
10. Remove the cornea and lay it in the dissecting tray. Cut through the cornea; it is made of layers of clear tissue.

11. Pull out the iris, which is between the cornea and the lens. Look for the hole in the center of the iris. This is the pupil that lets light into the eye.

12. Look at the back half of the eyeball and try to find and feel these structures: the retina, the optic nerve, the blind spot where the optic nerve leaves the retina, the fovea, where light is focused (directly behind the pupil near the blind spot).

13. Remove the lens, which is round and looks somewhat clear. Try to look through the lens at some words on a paper.

14. On the inside of the back of the eyeball you should see some blood vessels that are part of a thin film. The film is the retina.

15. Find the spot where the retina is attached at the back of the eye. Find the bundle of nerves that go out of the back of the eye behind this spot. This is the optic nerve.

**Analyze and Conclude**

1. **Describe** the functions of the structures you observed in the cow’s eye.

2. **Sketch** the appearance of the eye you dissected as it appeared after steps 5, 8, and 12. Draw separate sketches of the cornea and lens.

3. **Explain** how light rays are affected by the structures in the eye as they enter the pupil and strike the retina.

4. **Describe** the appearance of the words on paper when you looked at them through the lens from the cow eye.

5. **Describe** the appearance of the retina in the cow eye.

**Communicate**

**Make a Poster** Create a poster that shows each part of the cow eye that you examined. Be sure to use realistic colors for each of the parts. Your poster should also show where these parts are found in a cow eye.
Behind the scenes of a dance company or a theater company, lighting technicians work to create interesting effects with light. Lighting technicians also help animate music, dance, theatrical, and art shows. The job requires an understanding of electronics, lights, and computers, a sense for artistry and design, and involves communication with actors, directors, and artists.

Imagine you’re a lighting technician working for a theater or a band. Write a journal entry about your experience lighting a show.

More than ten million people worldwide are blind due to retinal degenerative diseases. Scientists have been developing microchip devices that may restore some vision for these people. The picture shows an artificial retina device, consisting of a microchip that is surgically implanted in the retina. The microchip converts the light waves that strike it into electric signals that are carried by the optic nerve to the brain.

Visit Technology at ca7.msscience.com to find out more about these devices. Write a 500- to 700-word paper discussing microchip devices, including their components and how they work.
The Invention of Eyeglasses

More than 2,000 years ago, Seneca, the Roman philosopher, used a glass globe filled with water as a magnifier to read. Around the year A.D. 1000, glass blowers in Italy made reading stones made of solid glass that were similar to magnifying lenses. Most historians believe monks or craftsmen in Italy produced the first form of eyeglasses around 1285–1289. During the 1700s and 1800s eyeglasses advanced dramatically with the invention of the modern shape, monocles, bifocals, tinting, and more.

Visit History at ca7.msscience.com to find out more about these inventions. Create a graph that shows the timeline of these inventions. Make sure to label one axis for the invention and one for the appropriate date from A.D. 1700 to 1850.

The Impact of the Lightbulb on Society

Before the widespread use of lightbulbs, most lighting was done by gas or candles, both of which are fire hazards. Nights were dark as both candles and gas could only provide light in small areas. Gas lights also gave off fumes or leave sooty marks. With the development of the lightbulb and the subsequent electrical wiring of houses and businesses, lighting became both affordable and widespread. Thomas Edison and his company, General Electric, were instrumental in this change.

Visit Society at ca7.msscience.com to find out more about Thomas Edison, the lightbulb, and how it impacted society. Select one way in which the lightbulb positively impacted society and present a commercial about it. Make sure to give real-world examples of this impact.
**Lesson 1 What is light?**

*Main Idea* Visible light is an electromagnetic wave.
- Light is a wave that can travel through empty space.
- The spectrum of electromagnetic waves includes many types of waves.
- Visible light takes up a very small part of the electromagnetic spectrum.

**Lesson 2 Light and Matter**

*Main Idea* Light interacts with matter in different ways.
- Light rays can be absorbed, transmitted, or scattered by matter.
- Light rays bend when they change speed.
- The angle of reflection is the same as the angle of incidence.
- The color of an object is determined by the wavelengths of light it reflects.

**Lesson 3 Using Lenses**

*Main Idea* Lenses form images by causing light rays to bend.
- A lens is a transparent object with a curved surface that refracts light.
- Refracting telescopes use lenses to gather and focus light.
- Reflecting telescopes use mirrors to gather light.
- Microscopes use lenses to magnify small objects.

**Lesson 4 The Eye and Vision**

*Main Idea* The eye is a complex organ made up of different parts.
- The cornea and lens focus light in the eye.
- The iris controls the amount of light entering the eye.
- The image is projected onto the retina in the back of the eye.
- Rod cells in the retina detect light and work best in low light.
- Cone cells detect color and work in bright light.

**Additional Information**

- electromagnetic spectrum (p. 430)
- frequency (p. 429)
- medium (p. 430)
- wavelength (p. 429)
- absorption (p. 436)
- law of reflection (p. 440)
- refraction (p. 438)
- scattering (p. 436)
- transmission (p. 436)
- convex lens (p. 443)
- focal length (p. 444)
- focal point (p. 444)
- lens (p. 443)
- cornea (p. 451)
- iris (p. 451)
- pigment (p. 454)
- pupil (p. 451)
- retina (p. 452)

Download quizzes, key terms, and flash cards from ca7.mssscience.com.
Linking Vocabulary and Main Ideas

Use vocabulary terms from page 461 to complete this concept map.

Using Vocabulary

Fill in each blank with the correct vocabulary term.

8. _______ is the process of absorption and reemission as light passes through a transparent medium.

9. Rod cells and cone cells in the _______ detect light and send electrical signals to the brain.

10. The _______ does most of the focusing of light in the eye.

11. The _______ gets smaller in bright light and enlarges in dim light.

12. The distance between two troughs of a wave is a(n) _______.

13. The _______ includes X rays, ultraviolet waves, visible light, infrared light, microwaves, and radio waves.

14. The _______ is the spot where light rays converge after passing through a convex lens.
Checking Concepts

Choose the word or phrase that best answers the question.

1. Which property of a wave increases when its frequency decreases?
   A. amplitude
   B. crest
   C. speed
   D. wavelength

2. Which correctly shows a ray of light reflecting off a mirror?
   A. 
   B. 
   C. 
   D. 

3. What occurs when a light ray strikes the retina and is converted into an electrical signal sent?
   A. absorption
   B. reflectance
   C. scattering
   D. transmission

4. What is the order of parts light passes through on its path through the eye?
   A. cornea, lens, pupil
   B. lens, pupil, cornea
   C. lens, cornea, pupil
   D. cornea, pupil, lens

5. Which correctly describes the path of a light ray that passes through a convex lens parallel to the major axis?
   A. It will pass through the focal point.
   B. It will reflect off the vertical axis.
   C. It will hit the spot where the major axis and the vertical axis cross.
   D. It will pass through the lens and continue along its original path.

6. Which occurs when you see an object?
   A. The retina narrows to block out most of the light.
   B. The iris transmits electrical signals to your brain.
   C. The cornea and lens form an image on your retina.
   D. The eyeball moves so that the retina is more than two focal lengths from the lens.

7. Which correctly shows the way light rays are refracted by a convex lens?
   A. 
   B. 
   C. 
   D. 

8. Which light waves are refracted the most after passing through a prism?
   A. red waves
   B. yellow waves
   C. green waves
   D. blue waves
Applying Science

9. **Illustrate** why a rough surface, such as a road, becomes shiny in appearance and a better reflector when it is wet. Draw two diagrams to support your answer.

10. **Infer** If the speed of light were the same in all materials, would a lens cause light rays to bend?

11. **Suppose** a black plastic bowl and a white plastic bowl are placed in sunlight. After 15 minutes, the temperature of the black bowl is higher than the temperature of the white bowl. Which bowl absorbs more light waves and which bowl reflects more light waves?

12. **Compare** the mixing of three pigments to make different colors of paint to how the eye uses three types of cone cells to perceive different colors of light.

13. **Create a table** like the one below to classify devices that use different electromagnetic waves. Use examples you can find in your home, school, and community.

<table>
<thead>
<tr>
<th>Electromagnetic Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Wave</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Radio waves</td>
</tr>
<tr>
<td>Infrared waves</td>
</tr>
<tr>
<td>Visible light</td>
</tr>
<tr>
<td>X rays</td>
</tr>
</tbody>
</table>

14. **Write a paragraph** for a camping manual describing how to start a camp fire using a magnifying glass. Imagine you are writing for a friend your age who has not studied convex lenses. Be sure to explain how the lens works and the meanings of the terms *focal point* and *focal length*.

Cumulative Review

15. **Explain** the importance of blood pressure in the function of the heart. Be sure to define pressure in your explanation.

16. **Give an example** of a part in the human body that acts as a lever. Draw a diagram of the part and label the fulcrum. Write a few sentences describing how the body part acts as a lever.

Applying Math

17. The wavelength of a microwave is $1 \times 10^{-2}$ m. Express this number as a decimal.

18. The wavelength of a light waves is 0.0000006 m. Express this number in scientific notation.

19. The wavelength of an infrared wave is $1 \times 10^{-5}$ m. Express this number as a decimal.

20. The table below shows the wavelength of some electromagnetic waves.

<table>
<thead>
<tr>
<th>Electromagnetic Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wave</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Radio wave</td>
</tr>
<tr>
<td>Microwave</td>
</tr>
<tr>
<td>Visible light</td>
</tr>
</tbody>
</table>

How many times longer is the radio wave than the wave of visible light?
Use the figure below to answer questions 1 and 2.

1. What property of the wave is shown at F?
   A. amplitude
   B. wavelength
   C. crest
   D. trough

2. What property of the wave is shown at J?
   A. amplitude
   B. wavelength
   C. crest
   D. trough

3. What property of a light wave determines its color?
   A. wavelength
   B. amplitude
   C. speed
   D. interference

4. What happens when light travels from air into glass?
   A. It speeds up.
   B. It slows down.
   C. It travels at 300,000 km/s.
   D. It travels at the speed of sound.

5. What behavior of light waves lets you see a sharp, clear image of yourself in the water?
   A. refraction
   B. diffraction
   C. reflection
   D. interference

6. Why can’t you see a clear image of yourself if the water’s surface is rough?
   A. Regular reflection occurs.
   B. Diffuse reflection occurs.
   C. Light rays speed up.
   D. Light rays slow down.
7 Which is the function of the iris of the eye?
A It blends images to create a sense of distance.
B It controls the amount of light entering the eye.
C It receives information from the light that enters the eye.
D It transmits images to the brain.

8 The illustration below shows two waves.

How does the wavelength of wave A compare with the wavelength of wave B?
A The wavelength of A is half as long.
B The wavelength of A is the same.
C The wavelength of A is twice as long.
D The wavelength of A is three times as long.

9 Why does a leaf look green?
A It reflects green light.
B It absorbs green light.
C It reflects all colors of light.
D It reflects all colors except green.

Use the figure below to answer questions 10 and 11.

10 Which part of the eye gets smaller in bright light?
A cornea
B lens
C pupil
D retina

11 What is the function of the cornea and lens?
A focus light
B protect the center of the eye
C convert light to electrical signals
D control the amount of light entering the eye

12 A spoon rests inside a drinking glass that is half filled of water. Which wave behavior explains why the spoon looks like it is broken in the glass of water?
A absorption
B refraction
C scattering
D transmission