section 4

Using Mirrors and Lenses

Microscopes

For almost 500 years, lenses have been used to observe objects that are too small to be seen with the unaided eye. The first microscopes were simple and magnified less than 100 times. Today, a compound microscope like the one in **Figure 22** uses a combination of lenses to magnify objects by as much as 2,500 times.

Figure 22 also shows how a microscope forms an image. An object, such as an insect or a drop of water from a pond, is placed close to a convex lens called the objective lens. This lens produces an enlarged image inside the microscope tube. The light rays from that image then pass through a second convex lens called the eyepiece lens. This lens further magnifies the image formed by the objective lens. By using two lenses, a much larger image is formed than a single lens can produce.

as you read

What **You'll Learn**

- **Explain** how microscopes magnify objects.
- **Explain** how telescopes make distant objects visible.
- **Describe** how a camera works.

Why **It's Important**

Microscopes and telescopes are used to view parts of the universe that can't be seen with the unaided eye.

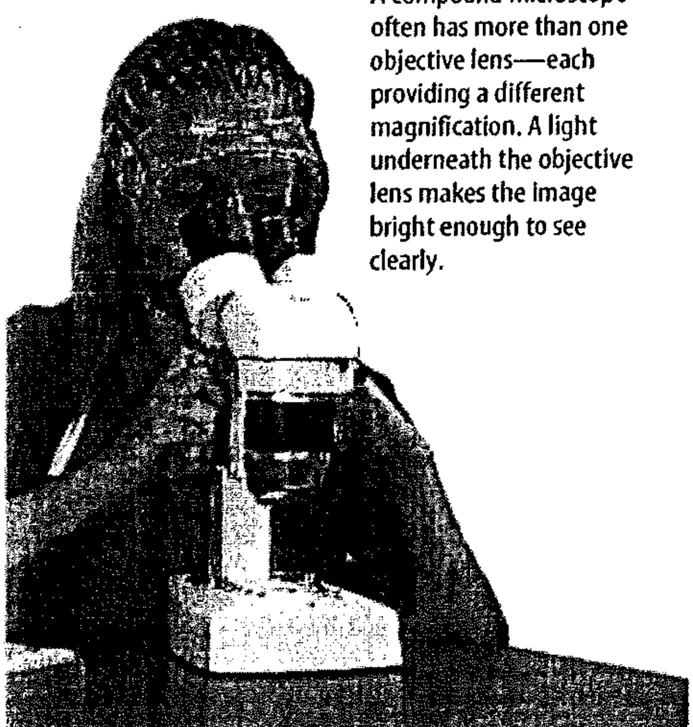
Review Vocabulary

retina: region on the inner surface of the back of the eye that contains light-sensitive cells

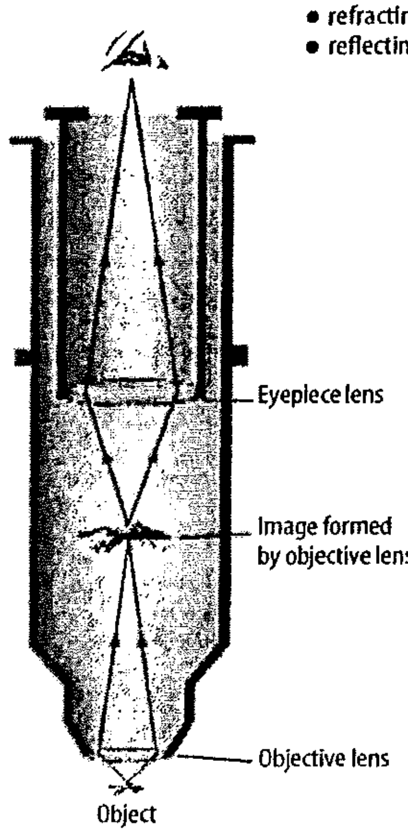
New Vocabulary

- refracting telescope
- reflecting telescope

Figure 22 A compound microscope uses lenses to magnify objects.



A compound microscope often has more than one objective lens—each providing a different magnification. A light underneath the objective lens makes the image bright enough to see clearly.



The objective lens in a compound microscope forms an enlarged image, which is then magnified by the eyepiece lens.

MiniLAB

Forming an Image with a Lens

Procedure

1. Fill a glass test tube with water and seal it with a stopper.
2. Write your name on a 10-cm × 10-cm card. Lay the test tube on the card and observe the appearance of your name.
3. Hold the test tube about 1 cm above the card and observe the appearance of your name through it again.
4. Observe what happens to your name as you slowly move the test tube away from the card.

Analysis

1. Is the water-filled test tube a concave or a convex lens?
2. Compare the images formed when the test tube was close to the card and far from the card.

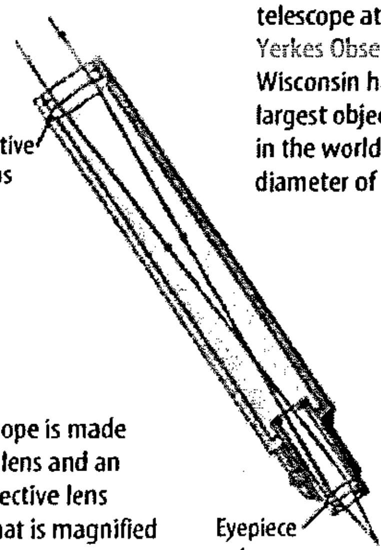
Telescopes

Just as microscopes are used to magnify very small objects, telescopes are used to examine objects that are very far away. The first telescopes were made at about the same time as the first microscopes. Much of what is known about the Moon, the solar system, and the distant universe has come from images and other information gathered by telescopes.

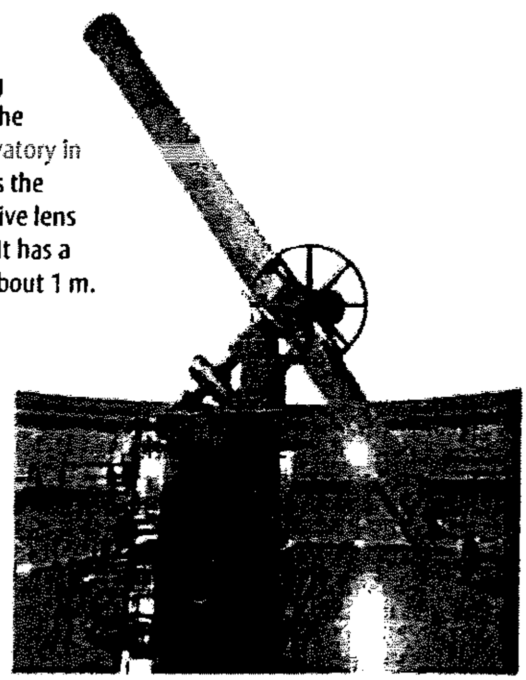
Refracting Telescopes The simplest **refracting telescopes** use two convex lenses to form an image of a distant object. Just as in a compound microscope, light passes through an objective lens that forms an image. That image is then magnified by an eyepiece, as shown in **Figure 23.**

An important difference between a telescope and a microscope is the size of the objective lens. The main purpose of a telescope is not to magnify an image. A telescope's main purpose is to gather as much light as possible from distant objects. The larger an objective lens is, the more light can enter it. This makes images of faraway objects look brighter and more detailed when they are magnified by the eyepiece. With a large enough objective lens, it's possible to see stars and galaxies that are many trillions of kilometers away. **Figure 23** also shows the largest refracting telescope ever made.

Reading Check *How does a telescope's objective lens enable distant objects to be seen?*



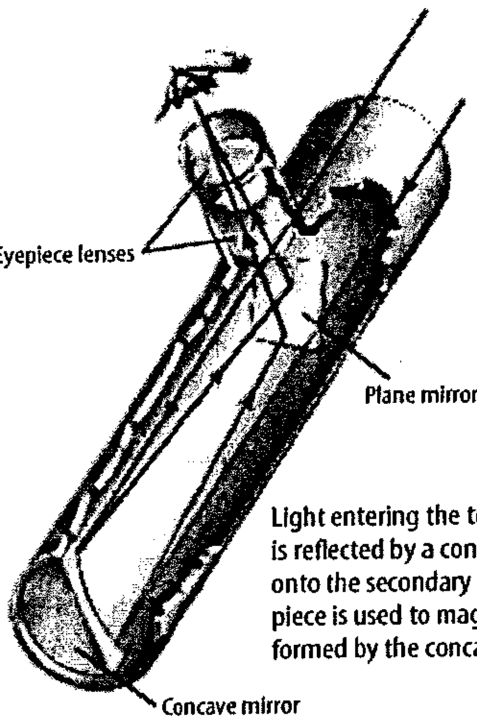
A refracting telescope is made from an objective lens and an eyepiece. The objective lens forms an image that is magnified by the eyepiece.



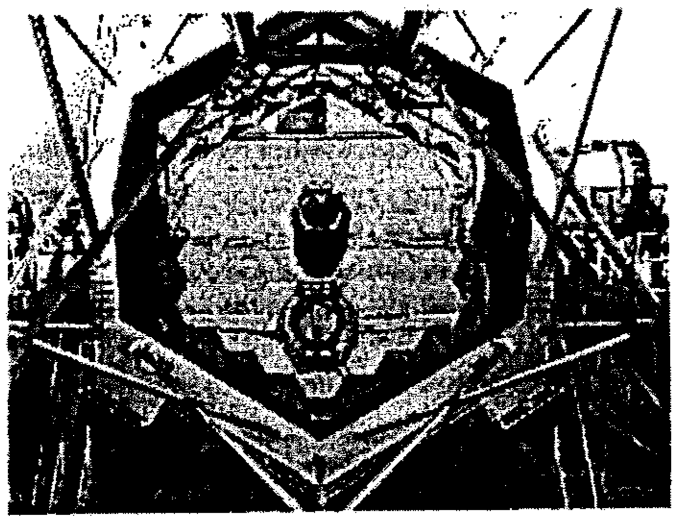
The refracting telescope at the Yerkes Observatory in Wisconsin has the largest objective lens in the world. It has a diameter of about 1 m.

Figure 23 Refracting telescopes use a large objective lens to gather light from distant objects.

Figure 24 Reflecting telescopes gather light by using a concave mirror.



Light entering the telescope tube is reflected by a concave mirror onto the secondary mirror. An eyepiece is used to magnify the image formed by the concave mirror.



The Keck telescope in Mauna Kea, Hawaii, is the largest reflecting telescope in the world.

Reflecting Telescopes Refracting telescopes have size limitations. One problem is that the objective lens can be supported only around its edges. If the lens is extremely large, it cannot be supported enough to keep the glass from sagging slightly under its own weight. This causes the image that the lens forms to become distorted.

Reflecting telescopes can be made much larger than refracting telescopes. **Reflecting telescopes** have a concave mirror instead of a concave objective lens to gather the light from distant objects. As shown in **Figure 24,** the large concave mirror focuses light onto a secondary mirror that directs it to the eyepiece, which magnifies the image.

Because only the one reflecting surface on the mirror needs to be made carefully and kept clean, telescope mirrors are less expensive to make and maintain than lenses of a similar size. Also, mirrors can be supported not only at their edges but also on their backsides. They can be made much larger without sagging under their own weight. The Keck telescope in Hawaii, shown in **Figure 24,** is the largest reflecting telescope in the world. Its large concave mirror is 10 m in diameter, and is made of 36 six-sided segments. Each segment is 1.8 m in size and the segments are pieced together to form the mirror.

INTEGRATE History

The First Telescopes
A Dutch eyeglass maker, Hans Lippershey, constructed a refracting telescope in 1608 that had a magnification of 3. In 1609 Galileo built a refracting telescope with a magnification of 20. By 1668, the first reflecting telescope was built by Isaac Newton that had a metal concave mirror with a diameter of about 5 cm. More than a century later, William Herschel built the first large reflecting telescopes with mirrors as large as 50 cm. Research the history of the telescope and make a timeline showing important events.

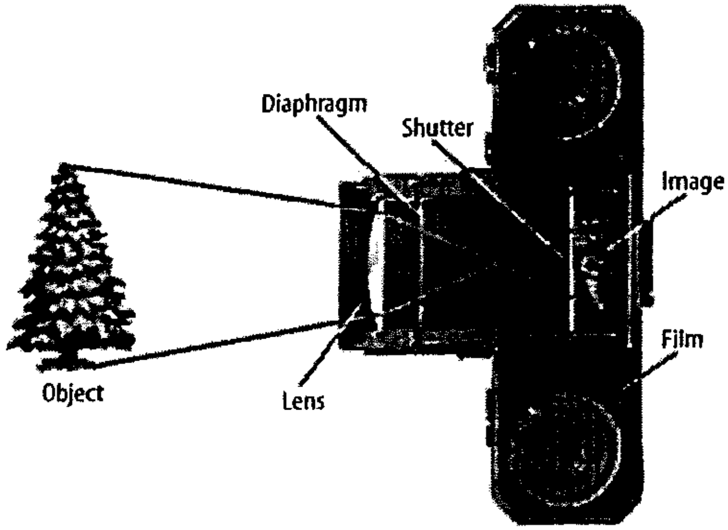


Figure 25 A camera uses a convex lens to form an image on a piece of light-sensitive film. The image formed by a camera lens is smaller than the object and is inverted.

Cameras

You probably see photographs taken by cameras almost every day. A typical camera uses a convex lens to form an image on a section of film, just as your eye's lens focuses an image on your retina. The convex lens has a short focal length, so it forms an image that is smaller than the object and inverted on the film. Look at the camera shown in **Figure 25.** When the shutter is open, the convex lens focuses an image on a piece of film that is sensitive to light. Light-sensitive film contains chemicals that undergo chemical reactions when light hits it. The brighter parts of the image affect the film more than the darker parts do.

Reading Check *What type of lens does a camera use?*

If too much light strikes the film, the image formed on the film is overexposed and looks washed out. On the other hand, if too little light reaches the film, the photograph might be too dark. To control how much light reaches the film, many cameras have a device called a diaphragm. The diaphragm is opened to let more light onto the film and closed to reduce the amount of light that strikes the film.

Science Online

Topic: Lasers

Visit ips.msscience.com for Web links to information about uses for lasers.

Activity Make a table listing different types of lasers and how they are used.

Lasers

Perhaps you've seen the narrow, intense beams of laser light used in a laser light show. Intense laser beams are also used for different kinds of surgery. Why can laser beams be so intense? One reason is that a laser beam doesn't spread out as much as ordinary light as it travels.

Spreading Light Beams Suppose you shine a flashlight on a wall in a darkened room. The size of the spot of light on the wall depends on the distance between the flashlight and the wall. As the flashlight moves farther from the wall, the spot of light gets larger. This is because the beam of light produced by the flashlight spreads out as it travels. As a result, the energy carried by the light beam is spread over an increasingly larger area as the distance from the flashlight gets larger. As the energy is spread over a larger area, the energy becomes less concentrated and the intensity of the beam decreases.