LESSON 24

Animal Optics


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The eyes of this fictional superhero are rather special. Do your eyes emit or absorb light?

INTRODUCTION

How do animals see? Eyes—the sense organ responsible for sight—come in a wide variety of forms. How do they work? How do they detect light or images and what happens to the information they gather? You will start this lesson by examining the eyes of the animal with which you are most familiar—you. You will investigate and look at a model of the human eye before reading about how your eye works. You will look at how the eye and brain receive and interpret the information and will discover that sometimes you can't always believe your eyes! You will discuss the eyes of other animals—how and why they differ from our own. You may find that eyes have some things in common with other optical devices you have investigated or read about.

OBJECTIVES FOR THIS LESSON

Examine the human eye.

Relate the structure of the eye to its function as an optical device.

Compare human optics to the optics of a camera.

Discuss how the eyes and brain work together as a visual system.

Experience and discuss optical illusions.

Look at and discuss the nature of the eyes of other animals.

Getting Started

1. Imagine you have to design a working eye for a robot. Discuss with your group what the eye would have to be able to do.

2. Now think about the design of your robot's eye. (You may find it useful to draw a sketch.) Look back to the camera in Lesson 23. This may give you a few ideas.

   What would it need to perform these functions?

3. In your notebook, jot down notes of your group's ideas. Be prepared to share them with the class.

MATERIALS FOR LESSON 24

For you

1 copy of Student Sheet 24.1: Investigating Human Eyes
1 copy of Student Sheet 24.2: Why Do You Have Two Eyes in the Front of Your Head?

For you and your lab partner

1 flashlight
2 D-cell batteries
1 large mirror
1 thick convex lens
1 thin convex lens
1 cardboard tube

Inquiry 24.1
Investigating Human Eyes

PROCEDURE

1. One member of your group should collect the plastic box of materials. Divide the materials between the pairs in your group.

2. Look at your eye in the mirror.

   A. Draw an accurate picture of your eye on Student Sheet 24.1: Investigating Human Eyes.

3. In dim light, look at your eye in the mirror. Shine a flashlight into your eye.

   B. Record what you observe when you shine the flashlight into your eye.

4. Now examine Figure 24.1 and the model of the eye your teacher has shown you.

   C. Use the figure and model to help you label the parts of the eye you have drawn on your picture.

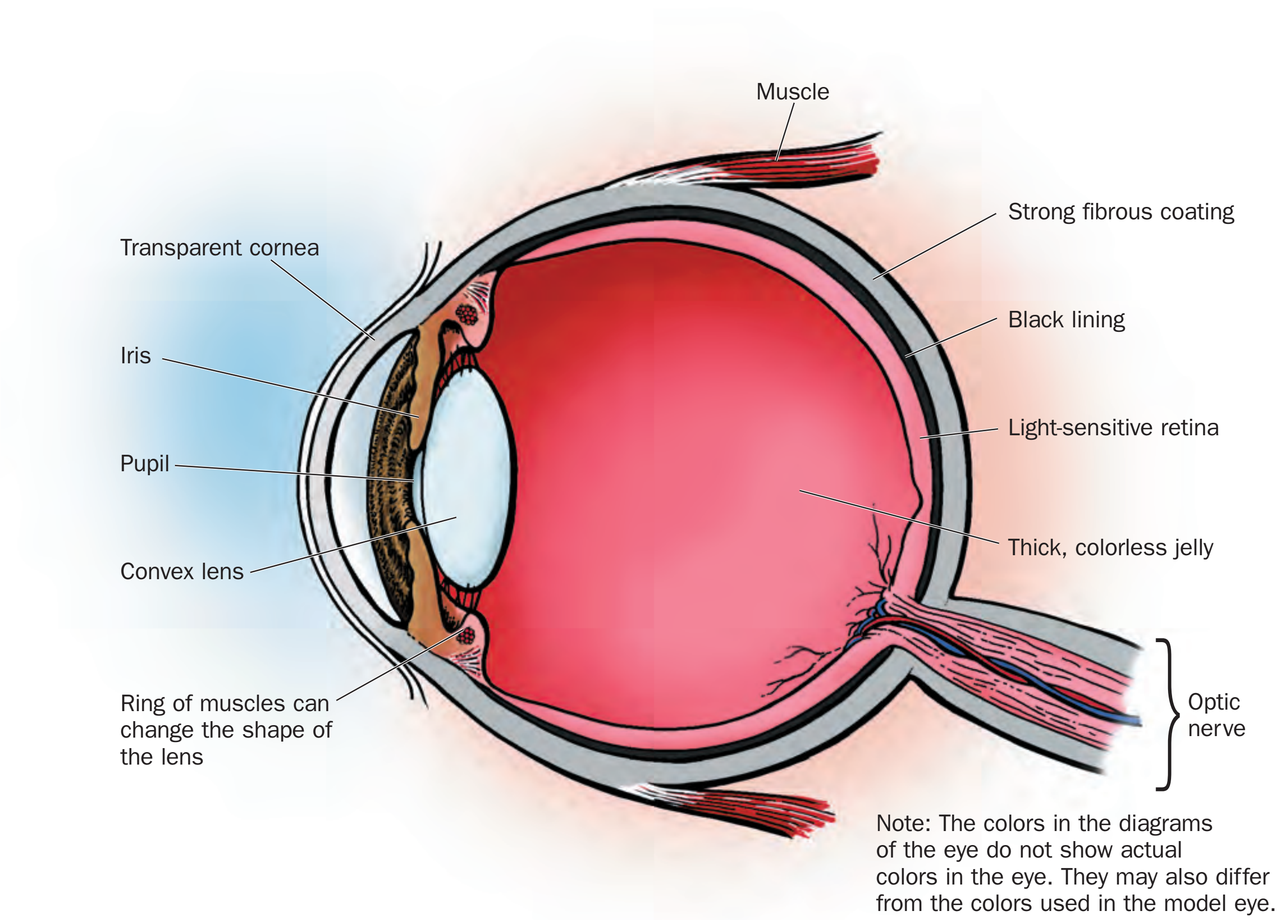


Figure 24.1 *Use this picture and the model of the eye to identify the parts of the eye.*

5. Discuss with your partner your observations of your own eyes, the model, and Figure 24.1.

D. Use the results of your discussion and your knowledge of light, lenses, and optical devices (particularly the camera) to predict which part(s) of the eye performs the following function(s). Record your predictions in Table 1 on Student Sheet 24.1.

- Allows light into the eye
- Controls the amount of light entering the eye
- Focuses light
- Detects light
- Prevents reflection inside the eye
- Transfers information from the eye to the brain

6. Discuss the following questions with your group. Be prepared to share your observations and ideas with the class.

How does the human eye compare with your ideas for a robot eye?

How does the human eye compare with the design of the camera you dissected in Lesson 23?

7. Look through the lenses you have been given.

E. Describe the lenses. How do the shapes of these lenses compare with the lens in the eye?

F. Each eye has one lens. What shape would the lens in the eye have to be if it could focus on distant objects? What shape would it have to be if it could focus on near objects? Draw the shapes.

G. Unlike these rigid plastic lenses, the lens in the eye is flexible. How could the flexible nature of the lens in the eye help the eye to focus on near and distant objects?

8. Read "How the Eye Produces a Clear Image."

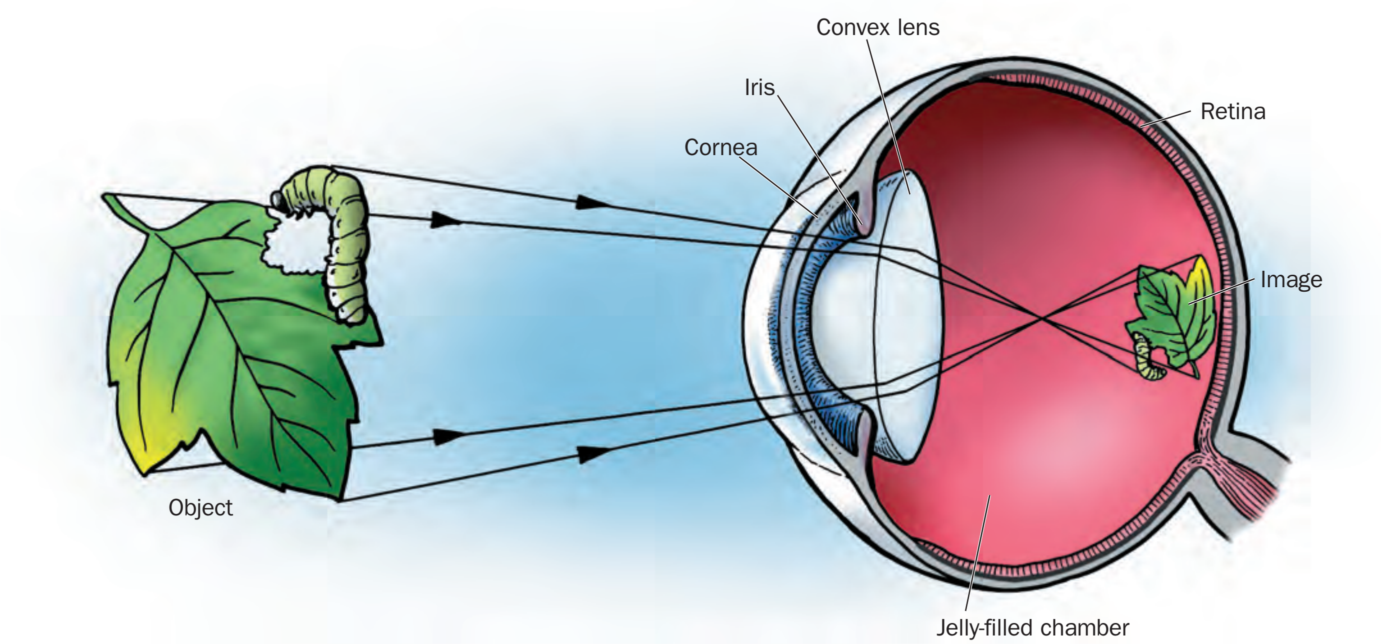
HOW THE EYE PRODUCES A CLEAR IMAGE

Light rays from objects we observe enter the eye. These rays are refracted at each place they travel from one transparent substance to another. Most of this refraction takes place as the light enters the eye at the cornea—the transparent outer covering of the eye. The light is also refracted as it goes from the jelly inside the eye into the lens and back into the jelly again. The lens adjusts its shape so that these refracted rays are brought into focus on the retina—a layer of light-sensitive cells at the back of the eye. As you can see from the illustration, the image is upside down. Tiny nerves connected to the light-sensitive cells of the retina carry signals along a larger optic nerve to the brain.

How the Lens Puts Things Into Focus

The lens of the eye is a flexible convex lens. The lens can change shape—it can become thicker or thinner. Ligaments (small fibers) are fixed to the rim of the lens. The other ends of the ligaments are attached to a ring of muscle that surrounds the lens. The eye uses this muscle to change the shape of the lens depending on whether it wants to look at near or far objects. When this ring of muscle is relaxed it becomes wider and the ligaments

The eye is a complex and delicate organ. You should have your eyes checked regularly.



Light is refracted at each surface—as it enters the cornea, the lens, and the jelly inside the eye. The lens adjusts its shape to focus the image on the retina. The image is inverted, but the brain interprets it as being right-side up.

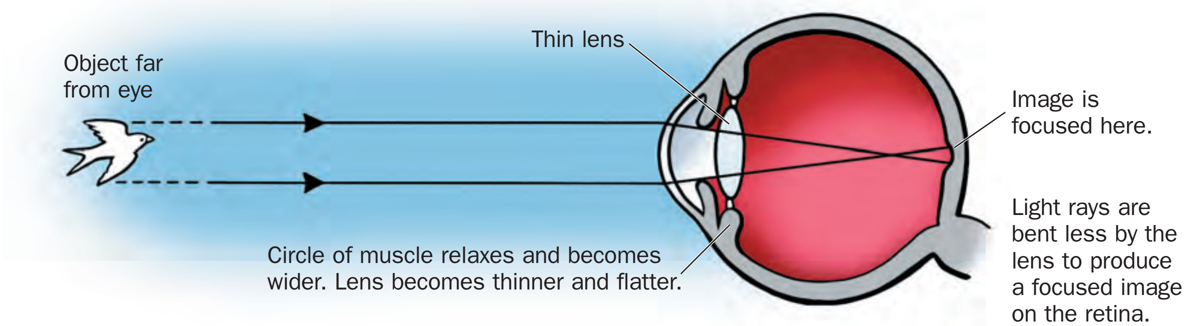
pull the lens into a flatter, thinner shape. In this shape the lens has a long focal length and focuses on distant objects.

When the eye looks at near objects, the ring of muscle contracts. The ligaments attached to the lens become loose, and the lens springs back to its thick, rounder shape. When the lens is this shape, it has a shorter focal length and focuses on near objects. The ability of the eye to adjust the focal length of the lens enables the eye to focus on distant, and then near, objects.

As people get older, the lenses in their eyes often become less flexible and do not spring back into shape. This makes close-up work—reading, for example—difficult. Many older people wear reading glasses or contact lenses to correct this change in their vision.

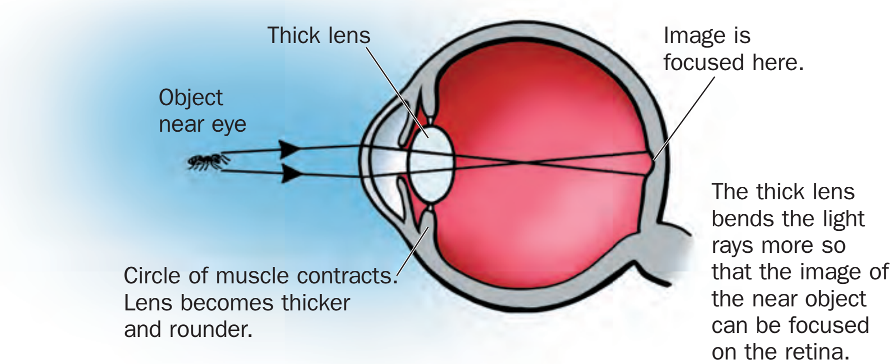

CORBIS/ROYALTY-FREE

Eyes that have problems focusing can usually be corrected by contact lenses or glasses.



When the ring of muscle that surrounds the lens is wide, ligaments fixed to the lens pull the lens into a flat shape. The lens has a longer focal length. This shape of lens focuses more distant objects onto the back of the eye.

When the muscles around the lens contract, the lens returns to its thick, rounder shape. Its focal length is shorter, and the eye can focus near objects onto the back of the eye.



Inquiry 24.2
Why Do You Have Two Eyes in the Front of Your Head?

PROCEDURE

1. What would it be like if you had only one eye? Try looking at things with one eye. What difference, if any, does it make? Discuss your ideas with your partner.

2. Hold a pen or pencil in a vertical position at arm's length. Look at it with both eyes. Then close one eye. Now open the other eye and close the one you had open. Do this a few times and then respond to A and B on Student Sheet 24.2: Why Do You Have Two Eyes in the Front of Your Head?

   A. What does the pen or pencil appear to do when you alternately open and close each of your eyes?

   B. What does this tell you about the image you get from each eye?

3. Get a pen or marker with a removable top. Hold the pen at arm's length in one hand and the top in the other. Starting each time with your hand holding the top near your body quickly put the top on and off the pen 10 times. Now close one eye and repeat the procedure again (see Figure 24.2).

   C. Record data comparing your attempts at replacing the top with two eyes open with your attempts with one eye open.

   D. What can you conclude from your data? Suggest one reason why you have two eyes. What role do you think the brain plays in this process?

Figure 24.2 *Hold the pen in a vertical position in one hand. Starting with your hand holding the top near your body, try to quickly put the top on and take it off the pen 10 times. First keep both eyes open and then try it again with one eye closed.*

4. Discuss E and F with your group before answering them on the student sheet.

   E. Would two eyes perform this function as well if they were in opposite sides of your head (like a chicken)? Give reasons for your answer.

   F. Why do you think some predators (like cats or owls) often have eyes facing forward, but prey species (like mice or pigeons) often have eyes in opposite sides of their heads?

5. Think back to Lesson 1, Inquiry 1.7. Do you remember when you looked down a tube? If not, use the tube to repeat the experiment.

   Can you now explain your observations?

6. Read "Optical Illusions."

OPTICAL ILLUSIONS

When you looked down the tube in Inquiry 1.7 you experienced an optical illusion. Optical illusions occur when your eyes and brain fail to gather visual information or misinterpret the visual information they do gather. Some optical illusions result from the way your eyes work. Other optical illusions result from your brain incorrectly interpreting the information that your eyes provide. Over millions of years, our eyes and brains have evolved mechanisms to provide us with accurate and useful information about our surroundings. But sometimes these mechanisms do not work as well as expected, and then you can't believe your eyes!

Inquiry 24.3
Experiencing Some Optical Illusions

PROCEDURE

1. Look at the cross and the dot in Figure 24.3.

2. Hold the page with the cross and dot at arm's length. Close your left eye and stare at the cross with your right eye. The cross should still be visible.

3. Bring the paper slowly toward your face.

   What do you observe?

   Was your sense of sight tricked? If so, how?

Figure 24.3 *Look at the cross and the dot and carefully follow the procedure in Steps 2 and 3.*

4. Look at Figure 24.4. On the diagram, you will see that the eye has a point where the optic nerve leaves the retina. At this spot, there are no light-sensitive cells.

Would you be able to detect light that entered the eye and fell on this spot?

How could this information be relevant to the observations you have just made?

5. Sometimes optical illusions are the result of how your eyes work. At other times, they are the result of your brain incorrectly interpreting the information supplied by the eyes.

Which of these two types of illusions is the one you have just experienced?

6. Look at the examples of optical illusions shown in Figures 24.5.

7. With your partner, carefully examine each illusion. In some cases, you may wish to use a ruler to check what you think you observe. Discuss how you think each illusion tricks your eyes or your brain.

8. Think about the following questions. Be prepared to share your observations and ideas with the class.

What do these illusions tell you about the way the brain interprets information from your eyes?

Why is it important to make measurements when conducting a scientific investigation?

How reliable is eyewitness testimony?

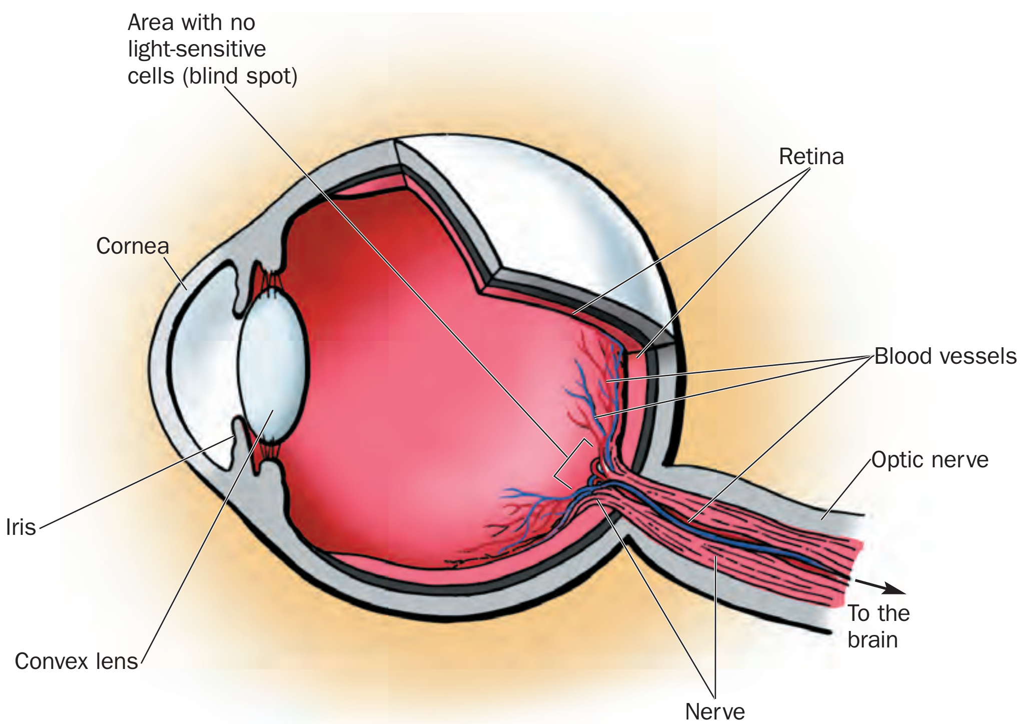


Figure 24.4 *What happens when light focused by the eye falls on an area where there are no light-sensitive cells?*

Start with illusion A. Stare at the flag for 10 seconds, then close your eyes. What do you see?

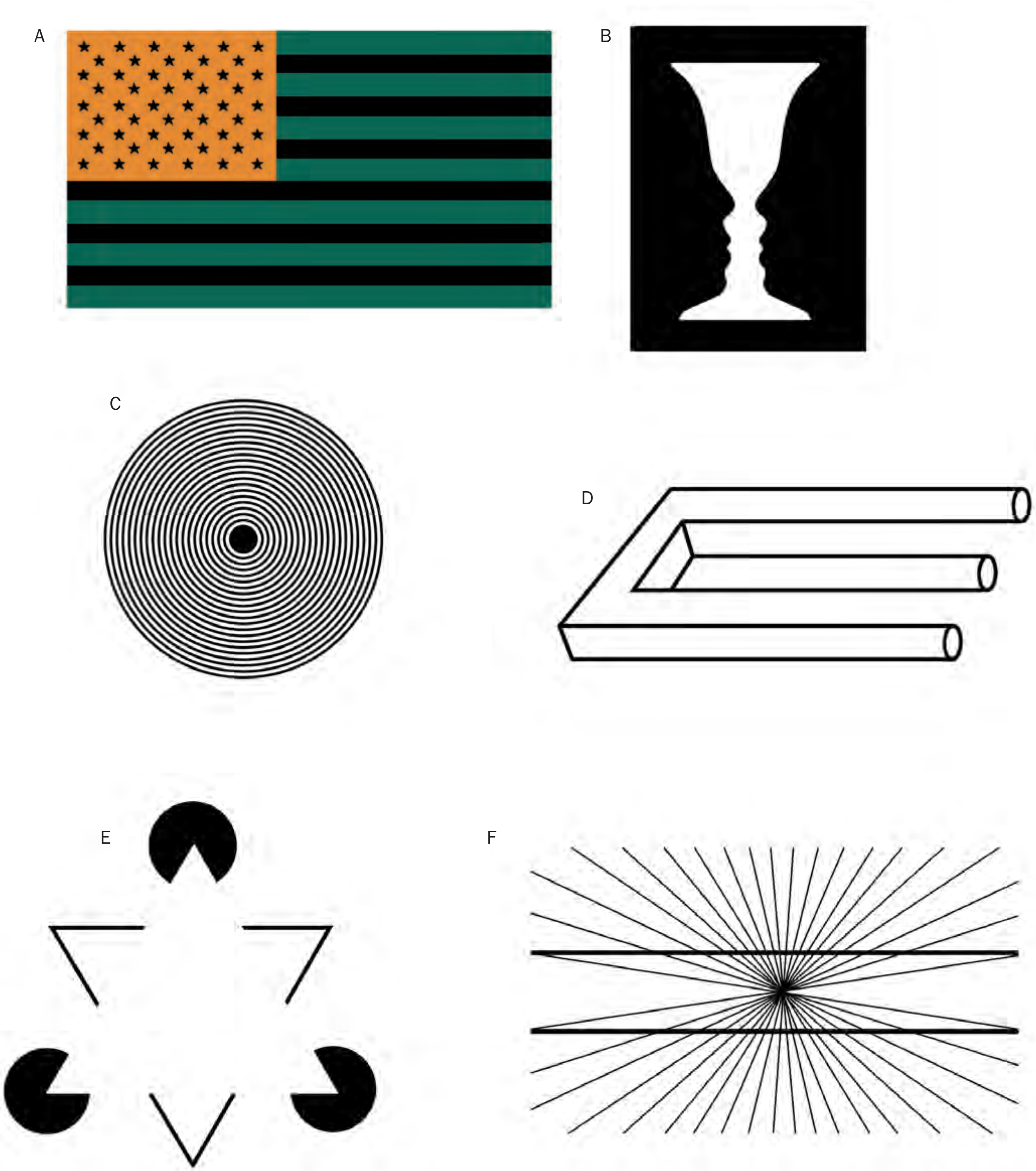


Figure 24.5 *Examine these optical illusions. How do they trick your eyes and brain?*

REFLECTING ON WHAT YOU'VE DONE

1. Read "How Do You Detect Light?" Be prepared to contribute to a class discussion about the reader.

2. Your teacher will show you a video about sight. After watching the video, try to imagine what it would be like to have different numbers of eyes, eyes on different parts of your body, or different types of eyes. Look at the photographs of different animal eyes. Speculate how the view these animals have of the world may differ from your own. Discuss with your group how the type, number, and the position of animal eyes (including human eyes) affects an animal's sense of sight.

Horses cannot see in full color. The position of their eyes tells you something about their field of vision.

No, this is not an alien. It's a tarsier. Why does it have big eyes that point forward?

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How many eyes does a spider have? Imagine what it sees.

E.R. DEGGINGER/COLOR-PIC, INC.

A cat has a reflective layer in its eye. Why is this adaptation important?

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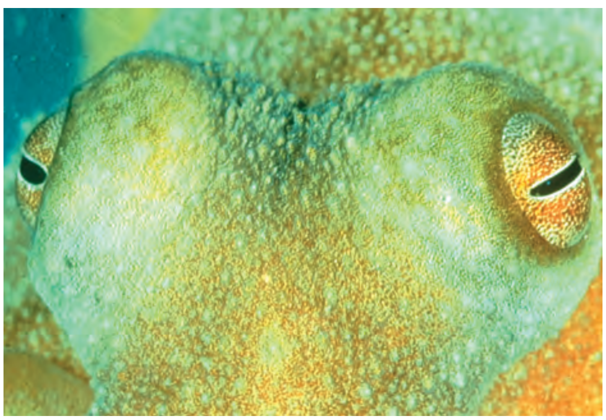

The octopus has excellent color vision. What is its field of vision like?

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Why do chameleons have such strange eyes? How can they change their field of vision?

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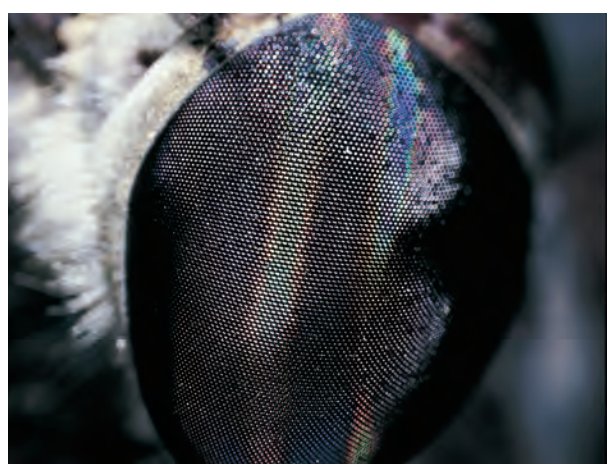
How do eyes on stalks allow this fiddler crab to increase its field of vision? Why would they be handy if you lived in a hole?

COURTESY OF CAROLINA BIOLOGICAL SUPPLY COMPANY

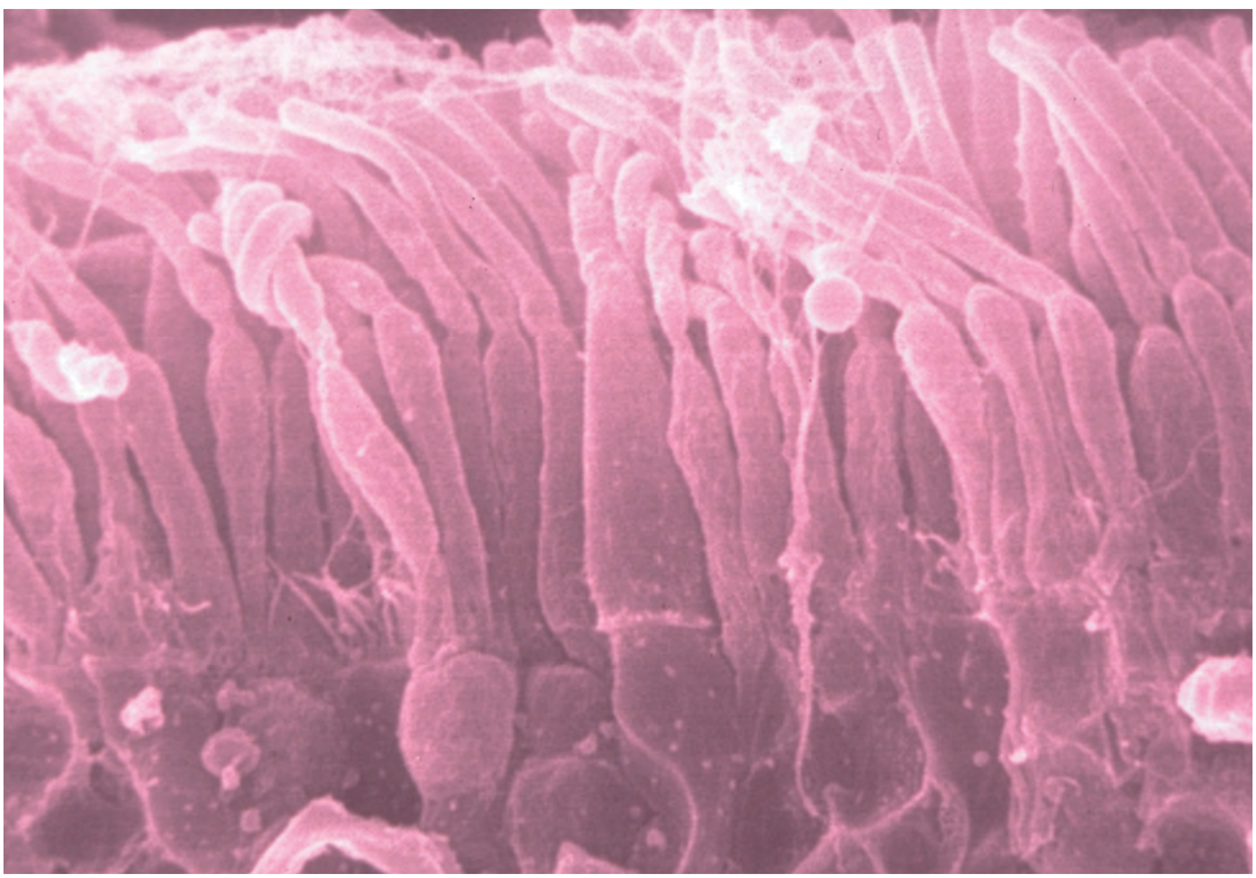


Insects have two big eyes (only one is shown here), each made up from lots of small simple eyes. Imagine what it would look like to peer through these compound eyes.

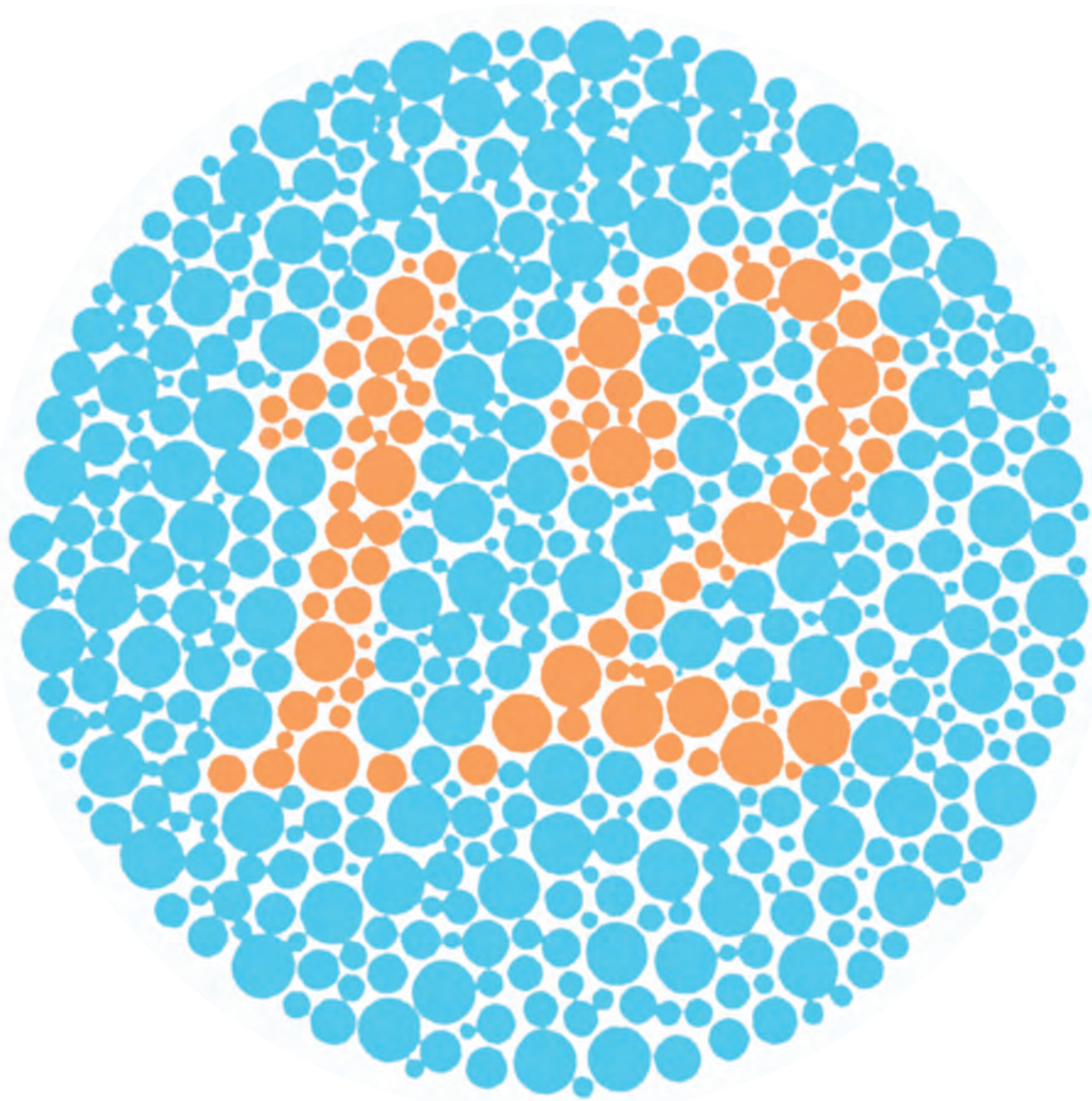
HOW DO YOU DETECT LIGHT?

How do your eyes detect light? You have seen how the cornea and the lens focus light on the retina. What happens next? The retina is made up of cells—about 130 million of them in each eye—that are sensitive to light. These cells contain pigments that change when light falls on them. These changes stimulate nerves that are attached to these cells. The stimulated nerves carry a signal to the brain. The brain interprets the signal—a process called visual perception.

There are two types of light-sensitive cells in the retina. One type of these cells, called rods, detects only light and dark—that is, shades of gray. These cells function in both bright and dim light. The other type, called cones, allow for color vision. They work only in quite bright light. Understanding the role of rods and cones explains why you may be able to see in a very dimly lit room but you can't see in color.



Light-sensitive cells in the retina are named according to their shape. The long thin cells are called rods and the cone-shaped cells are called cones. Only cones are involved in detecting color.

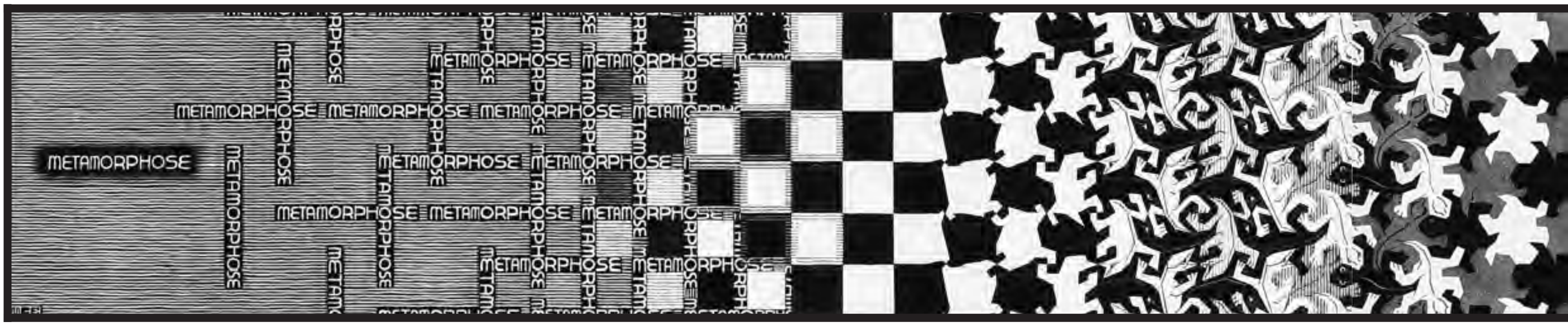


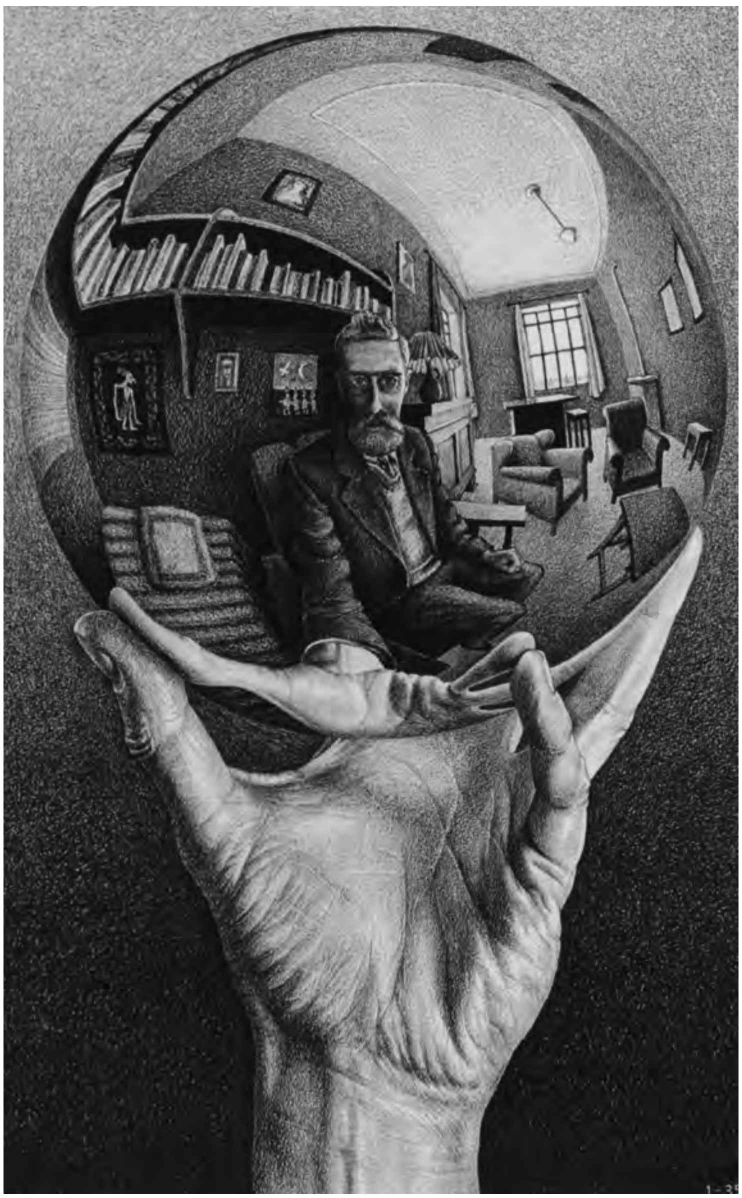
PHIL DEGGINGER/COLOR-PIC, INC.

Color-blind people have one or more types of cones missing from their retina. This image can be used to help diagnose red-green color blindness. What do you see when you look at this image? Can you read the number?

Three different types of cones respond to different wavelengths of light. The combination of these responses is interpreted by the brain as color. Remember that color is not a physical property of light. Rather, it is a sensation produced by the brain as it receives information from the cones in the retina. This is why you see, for example, a mixture of green and red light wavelengths as yellow. Your brain perceives this mixture of wavelengths as yellow—your eyes are not receiving any yellow wavelengths from the mixture.

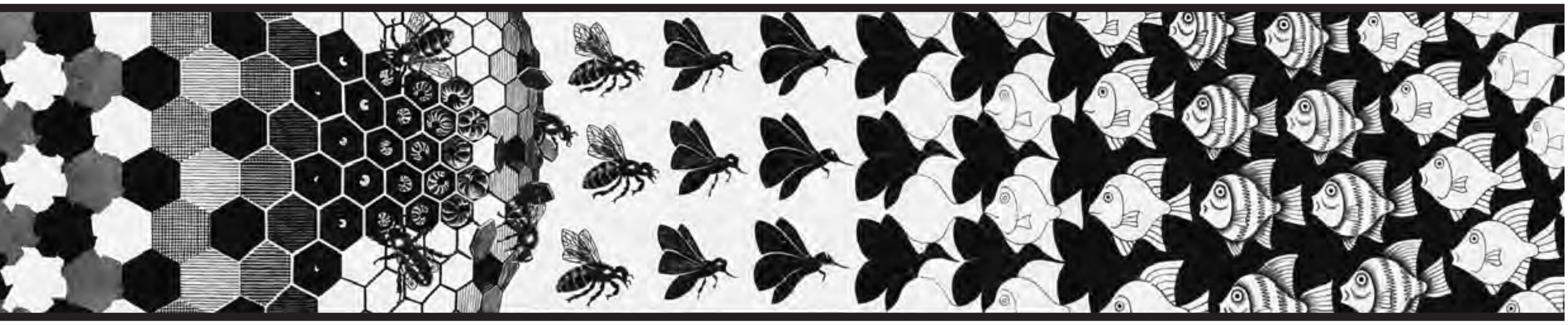
If one type of cone is missing from a person's eyes, the person perceives color differently. This is referred to as color blindness. There are different types of color blindness. The most common form makes it hard for people to see the difference between red and green. Red-green color blindness is genetic and is very common among men. Probably one or two boys in your class are red-green color blind. Different types and degrees of color blindness can be diagnosed using special test cards. ☐





The IMPOSSIBLE WORLDS of M.C. ESCHER

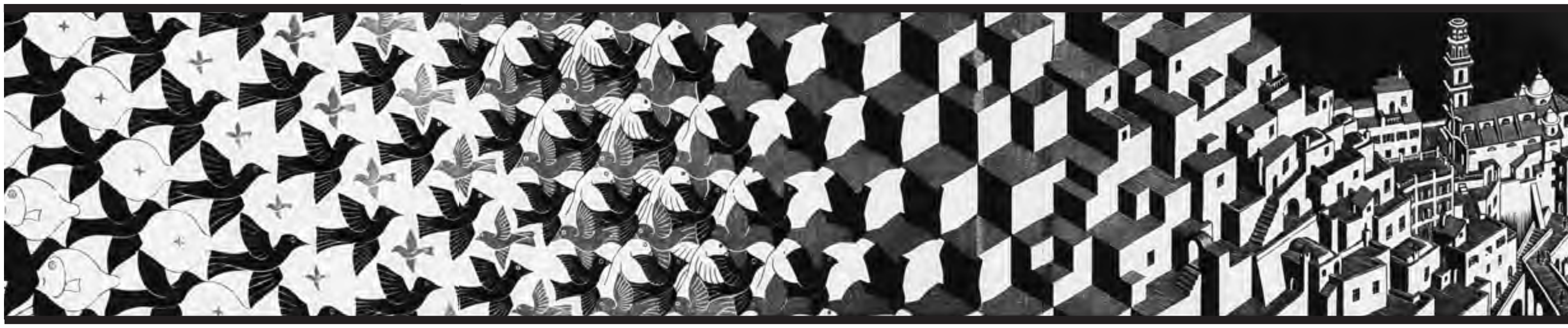
Hand With Reflecting Sphere *is a self-portrait by the graphic artist M.C. Escher (1898–1972). Escher used reflection, patterns, and "impossible figures" to create works of art that confuse the human visual system.*



In most subjects, Maurits Cornelis Escher was not a very successful student. But he did have a gift for art; he lived for his art lessons. Escher went to an art school in Haarlem, in the Netherlands, where he trained in the graphic arts—drawing, painting, and printing. He particularly enjoyed making prints, a technique he used often in his later work.

Like many young graduates, when Escher completed art school he decided to travel. He was attracted to the warmer climate of southern Europe around the Mediterranean. He spent some time in Italy and made money sketching landscapes. He also went to Spain where he visited the Alhambra palace. This maze of buildings—a wonder of Arab architecture—stands on a hill overlooking the ancient city of Granada. Arab artists had decorated the walls of the palace with tiles arranged in repeating patterns. The mathematical name for the type of pattern they had used is tessellation. These tessellated patterns captivated Escher. He found their geometry fascinating and began using similar patterns in his work. This was the beginning of Escher's life-long interest in the relationship between mathematics and art.

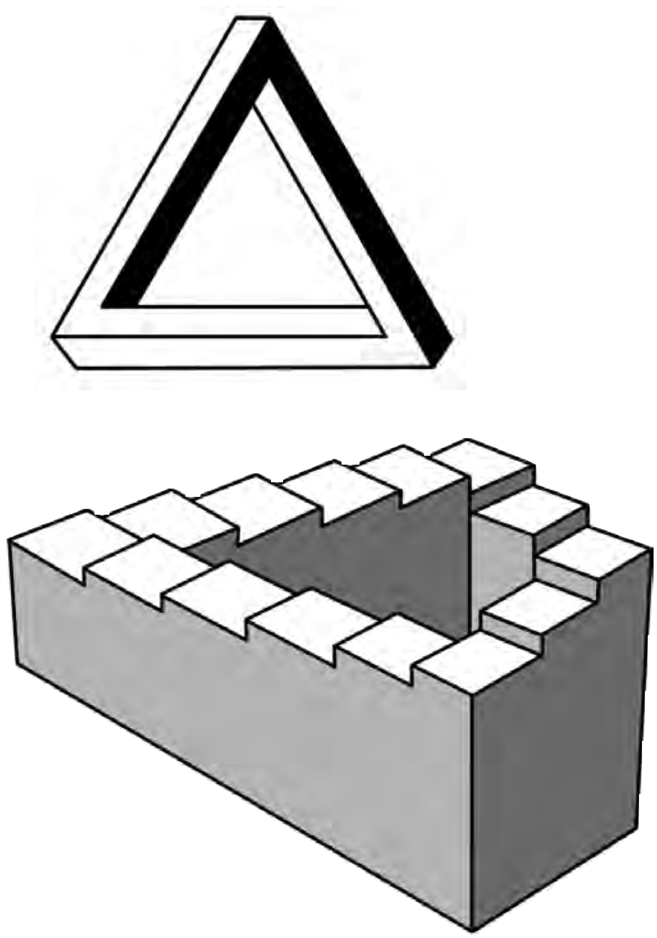
Escher produced many tessellation-like patterns in which repeated regular and irregular shapes interlock. One of his favorite approaches was to make prints, in which these patterns change, or metamorphose, slowly as they move across the print. For example, what starts out as a regular shape becomes distorted and changes into an insect; then perhaps a fish that may eventually evolve into a building. Look at the print spread across the top of this reader. Where do the shapes change to become different recognizable objects? Where do you first recognize the insect or the fish? Escher's art is playing tricks with how your visual system recognizes objects.



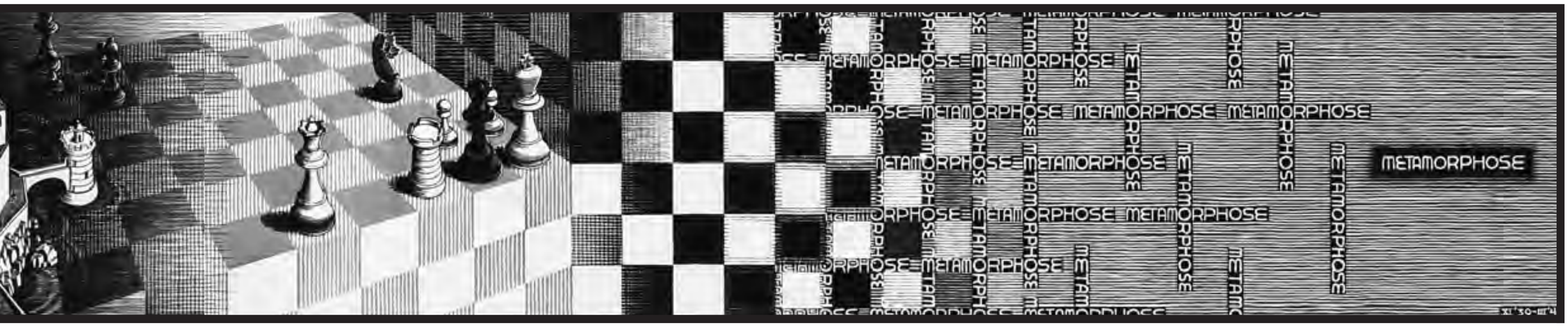
Escher began to experiment with other ways of confusing the eyes and brain. He became very interested in making impossible figures. These are drawings that trick the visual system into seeing impossible or changing images.

Most impossible figures rely on the brain's tendency to construct three-dimensional objects from flat, two-dimensional images—something we do all the time when we look at photographs or watch films. Look at his print *Convex and Concave*. Does the building change as you look at it? Do floors become ceilings or parts of the outside become inside? Escher's work confuses the viewer. It can make you think that water can flow uphill or that stairs can be linked in a continuous circular uphill stairway.

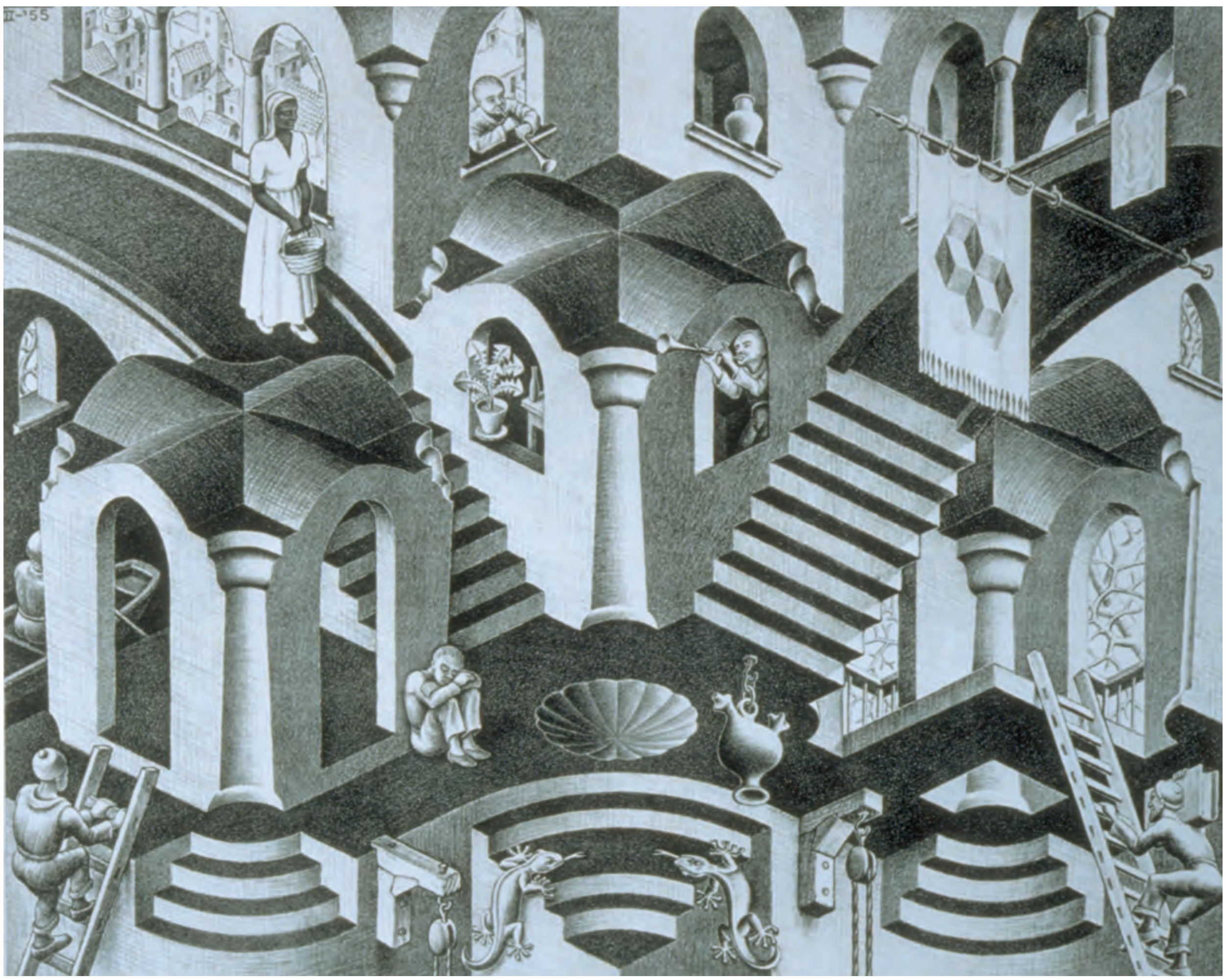
Escher developed his childhood gift for art, blended it with mathematics, and used both to create worlds of strange symmetry and illusion. He died in 1972 but left us impossible worlds of illusion—worlds that exploit the human visual system and will exist forever in his art. □



Two simple examples of impossible figures known as "strange loops": How do they trick the brain into observing the impossible? Escher used illusions like these in his art.



This is part of a 6-meter long print Escher produced called Metamorphosis III. *The tile-like objects and animals in the patterns transform effortlessly into each other. Is it difficult to decide where one object forms and another disappears?*



In his print Convex and Concave*, Escher uses optical illusions to confuse the viewer. The longer you look at this print, the more confusing it becomes.*