12.1 Human Perception of Light

Here is a summary of what you will learn in this section:

- Focussing of light in your eye is accomplished by the cornea, the lens, and the fluids contained in your eye.
- Light is detected by the retina, which contains rod cells, used for low light vision, and cone cells, used for bright light colour vision.
- Far- and near-sightedness and astigmatism are conditions in which the eye is not able to converge light rays correctly in order to form a clear image on the retina.
- Many types of vision problems can be corrected.

Figure 12.1 Human vision can detect many aspects of an object including shape, colour, and movement.

Perceiving Light

How is your vision? If you have good vision, you can be reading this page, look away to see a distant object, and then continue reading, always in perfect focus. You can recognize shapes in Figure 12.1 and in the classroom. You can quickly detect when something moves, even at the edge of your visual field. If the light is bright enough, you can make out a vast range of colours. If the room becomes dark, you can no longer see colour, but you can still detect shapes among the shadows.

Perception of light is an amazing ability, but it is not an ability that everyone shares equally. Many people benefit at some point in their lives from technologies or procedures that improve perception of light. For example, on a bright day, polarized sunglasses can both reduce glare and block harmful ultraviolet rays. Anti-glare night vision glasses can help drivers filter out light rays that can be a problem at night when trying to see past the headlights of oncoming cars. Even the reflection of light bouncing off of the white page of a textbook can make it very difficult for some people to read the black letters of the text. In this case, eyeglasses with a blue or yellow tint can be helpful. Visual perception is a very complex process that involves both eyesight and using your brain to make sense of the images received by your eyes.

Vision testing is normally done by a trained professional called an **optometrist.** In some situations, the optometrist will refer you to a physician who specializes in eye care, called an **ophthalmologist** (Figure 12.2).

Eye exams normally take about half an hour. Your eye care provider will have you identify letters or shapes on an eye chart and may place different lenses in front of your eyes to find out whether this can help you see more clearly. Other tests include checking for double vision, depth perception problems, and colour vision deficiencies. There is even a test to measure the pressure inside your eye. By catching problems early, it is often possible to correct problems or to prevent problems from getting worse.

Figure 12.2 An ophthalmologist uses a device called an ophthalmoscope to determine whether contact lenses are a good choice for correcting a patient's vision.

D27 *Quick Lab*

What Do You See?

Purpose

To use different aspects of vision to make sense of images

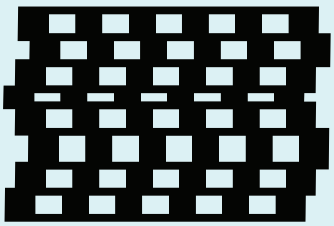


Figure 12.3 Step 1

Figure 12.4 Step 2

Figure 12.5 Step 3

Procedure

1. Are the horizontal lines in Figure 12.3 straight or curved? Make a prediction. Then use a ruler to check the result.
2. There are two different images in Figure 12.4. What do you see? Ask classmates what they see.
3. The Canadian flag in Figure 12.5 is coloured black and blue-green. Stare at the flag for about 20 s, and then immediately look at a white page. What do you see? You may need to try this several times.

Questions

4. For Figure 12.3, suggest whether the ability to detect edges and straightness occurs in the eye, the brain, or both.
5. For Figure 12.4, suggest whether the ability to give meaning to an image occurs in the eye, the brain, or both.
6. For Figure 12.5, suggest whether the ability to adapt to changes in colours occurs in the eye, the brain, or both.

Human Vision

In order to evaluate optical technologies related to the human perception of light, it can be helpful to understand how your own eyes work to focus light and detect images (Figure 12.6).

The outer surface of your eye where light enters is made of a transparent layer of tissue called the **cornea**. Light can pass right through the cornea because even though it is made of living cells, it is completely clear. Your cornea is made of strong tissue that is tough enough to protect your eye and hold it together, while remaining extremely sensitive to touch. The cornea is about as thick as a credit card and is sensitive enough to send you a strong pain signal if anything touches it. If it suffers from a small scratch, the cornea can heal itself. The light rays that arrive at your eye are refracted by the cornea. This helps direct the light correctly into your eye. Without the refractive properties of your cornea, you would not be able to focus.

WORDS MATTER

"Pupil" is derived from the Latin word *pupa*, meaning little doll, indicating the tiny reflections of people visible in pupils. The word "iris," the name of the structure that determines eye colour, is derived from the Greek word for rainbow.

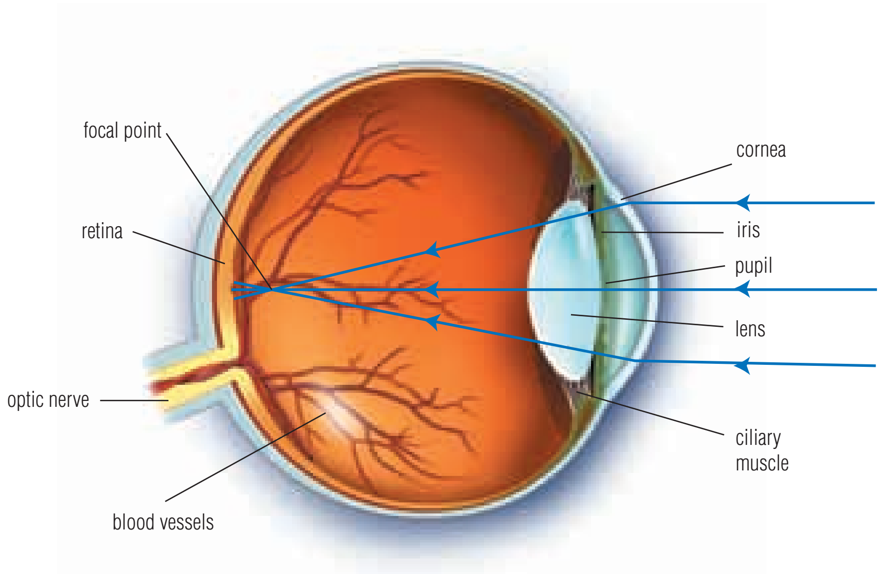
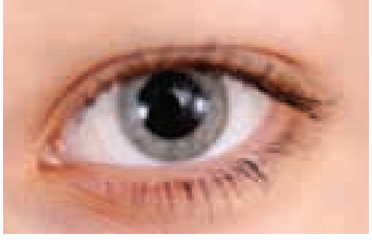


Figure 12.6 A cross-section of the human eye

(a)



(b)

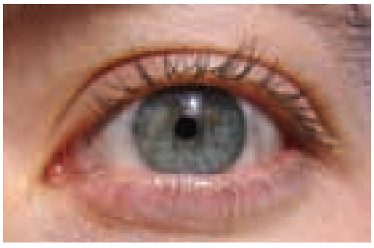


Figure 12.7 (a) Dilated pupil and (b) contracted pupil

After passing through the cornea, the light rays reach the pupil. The **pupil** is the dark circle that you see when you look at someone's eye. It is actually just a hole that allows light to pass into the eye. The pupil is black for exactly the same reason the entrance to a cave appears dark — light rays enter the cave but do not leave. The pupil is created by a circular band of muscle called the **iris**. When people refer to their eye colour, they are referring to the colour of the iris. The iris controls the size of the pupil, and so it controls the amount of light that enters the eye. In dim light, the iris opens and the pupil dilates (becomes wider) to let in more light. In bright light, the iris closes and the pupil contracts (becomes smaller) so that less light enters (Figure 12.7). Changes in pupil size happen automatically; you do not have to think about it.

Focussing the Light

Good eyesight requires precise focussing of light rays onto the retina. The **retina** is the inner lining at the back of the eye that acts as a projection screen for the light rays entering your eye (Figure 12.8). Most of the focussing of light in your eye is done by the cornea. However, the entire eye is a focussing system that involves the cornea, the lens, and even the spaces in front of and behind the lens that are filled with a watery fluid.

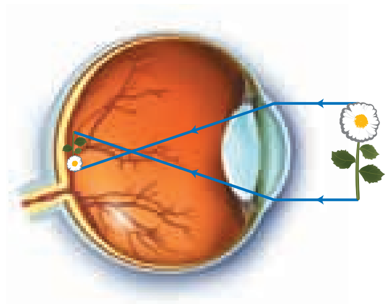


Figure 12.8 The image formed on the retina is inverted, but your brain interprets the image as being right side up.

Changing the Shape of the Lens

You may recall that a convex lens collects light and directs it to a focal point. Your eye includes a convex lens. Your lens allows you to change your focus so that you can see an object clearly regardless of whether it is right in front you or all the way out at the horizon. The lens is able to adjust its focal length because, unlike the cornea, it is attached to a tiny circle of muscles that can change its shape (Figure 12.9). When the muscles supporting your lens contract, the circle they form shrinks. This releases tension on your lens, allowing it to expand on its own into a more spherical or thicker shape. Your lens can now strongly refract light, which helps you focus on very near objects. Try focussing on this page when it is very close. You may be able to feel the muscles in your eye working.

When the circular muscle is relaxed, the circle they form expands, pulling your lens flatter and thinner. This is excellent for seeing distant objects. You may have noticed that if you allow your eyes to relax, nearby objects, such as this textbook, go out of focus, but distant objects are clear.

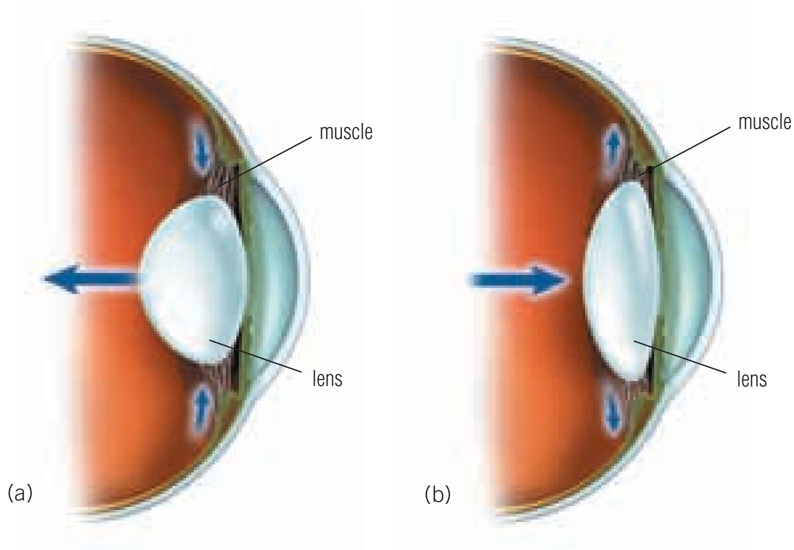


Figure 12.9 The muscles change the shape of the lens so you can focus on objects at various distances. (a) Position of muscles and shape of lens when focussing on nearby objects and (b) distant objects

Detecting Light

Suggested Activity •
D28 Inquiry Activity on page 478

Getting light into the eye and focussing it on the retina are only part of the task of seeing an image. In order for you to see, light rays must be absorbed by **photoreceptors**, which are cells in the retina that are sensitive to light. Photoreceptors include rod cells and cone cells (Figure 12.10). **Rod cells** help us detect shapes and movement in low light situations. Our brain does not recognize differences in colour from signals gathered by rod cells. Instead, we detect only shades of grey. Most of us are so used to our low light vision abilities that we do not even notice that we are not seeing in colour. **Cone cells** are photoreceptor cells used to detect colour. In humans, cone cells come in three types, each of which detects a different primary colour of red, green, or blue particularly well.

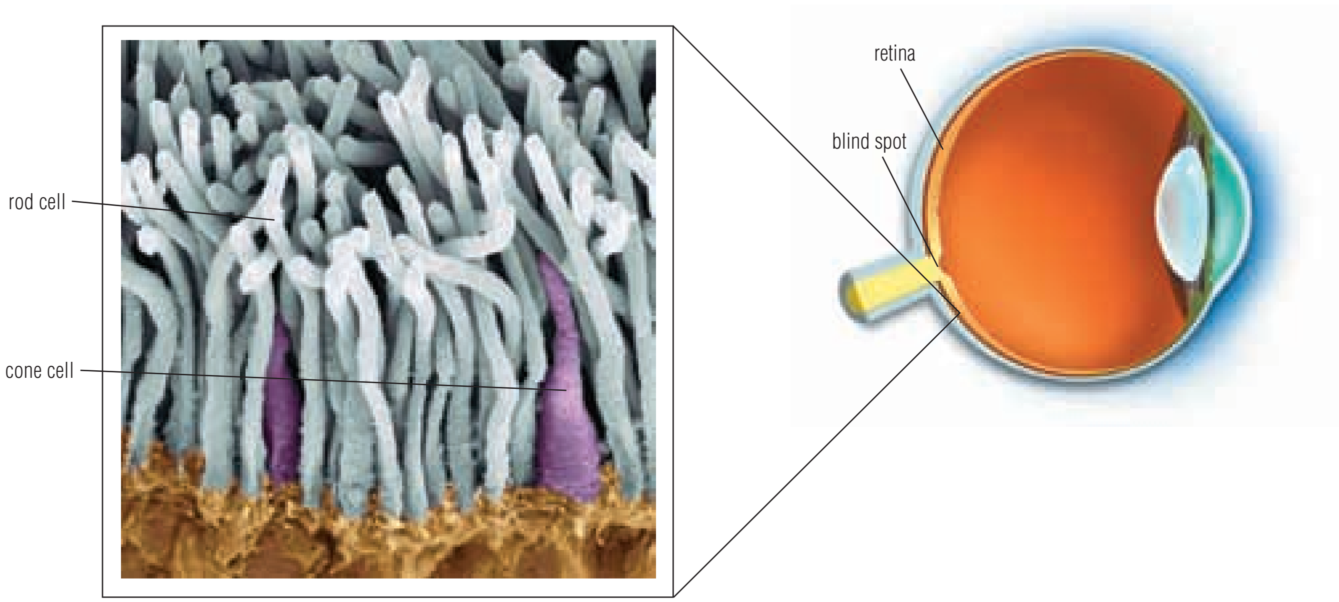


Figure 12.10 This is a false-colour electron micrograph image showing rod and cone photoreceptor cells in the retina at a magnification of 1800× at 10 cm. Cones are found in the central region of the retina. The more numerous rods are located outside the central region of the retina.

There is one place on the retina of every healthy eye called the blind spot, which has no photoreceptors and which cannot detect light. The **blind spot** is the place where the optic nerve attaches to the retina. The **optic nerve** connects your eye to your brain. You do not notice your blind spot because your brain "fills in" that spot with whatever colours are nearby in what you are looking at. You can use Figure 12.11 to help you detect your blind spot.

Figure 12.11 To find the blind spot in your right eye, close your left eye, and stare at the plus sign. Slowly move the book toward you and away from you. When the black spot disappears, you have found your blind spot.

Learning Checkpoint

1. What is the function of the cornea?
2. What structures control the amount of light that enters the eye?
3. What is the function of the retina?
4. What are two types of photoreceptors?
5. Where is the blind spot located?

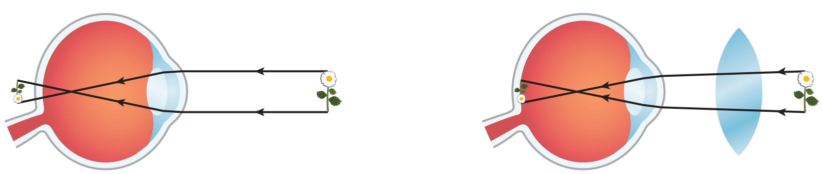
Correcting Vision Problems Using Lenses

The most important and widespread technological device related to human perception of light is the lens, whether it is a lens made of tempered glass or hardened plastic used in eyeglasses or a tiny plastic contact lens that floats on your cornea. Almost any focussing problem can be improved by placing a lens in front of your eyes.

Many people have trouble focussing clearly at some point during their life. Focussing problems sometimes occur in young children and teenagers, as their eyes grow along with the rest of their body. With aging, many adults become less able to see nearby objects clearly as the lenses in their eyes gradually harden and become less able to change shape. Most eye problems fall into one or more categories: far-sightedness, near-sightedness, and astigmatism.

Far-Sightedness

People who are **far-sighted** can see distant objects clearly, but they cannot see nearby objects clearly. The light rays from nearby objects diverge more strongly than rays from distant objects, which enter the eye nearly parallel. In far-sightedness, the eye cannot make the lens thick enough to refract diverging light rays from nearby objects correctly on the retina. Instead, the image falls into focus behind the eye, resulting in a blurry image on the retina. Adding a converging lens in front of the eye helps the light rays form the image correctly on the retina as shown in Figure 12.12.



(a) far-sightedness

(b) far-sightedness corrected by convex lens

Figure 12.12 (a) Far-sightedness and (b) far-sightedness corrected by a converging lens

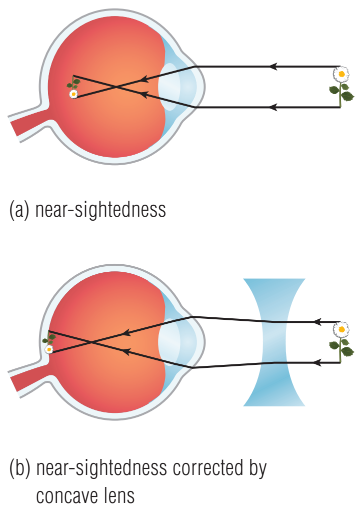


Figure 12.13 (a) Near-sightedness and (b) near-sightedness corrected by a diverging lens

Near-Sightedness

People who are **near-sighted** can see nearby objects clearly but cannot see distant objects clearly. In near-sightedness, the nearly parallel rays that arrive at the eye from distant objects are refracted so much that the image forms in front of the retina instead of on it. This happens because the eye cannot make the lens thin enough, resulting in a blurry image. To correct near-sightedness, a diverging lens is placed in front of the eye, causing light rays from distant objects to diverge as they approach the eye. The eye then causes the light rays to converge properly, just as with light rays coming from nearby objects, and the light rays fall correctly onto the retina in focus (Figure 12.13).

Astigmatism

A common condition is called **astigmatism**, in which the eye is unable to form a clear image because of an irregular shape of the cornea or lens. For example, the cornea may be shaped more like a football than the typical baseball shape. This irregular shape causes an image to be formed on more than one place on the retina, which results in blurry vision (Figure 12.14).

There are two general types of astigmatism. In one type, the eye refracts light better along the vertical axis. In this type, a person has difficulty seeing horizontal lines clearly, such as in the letters E or F. In the second type of astigmatism, the eye refracts light better along the horizontal axis and the person has difficulty focussing on vertical lines like I and J. Common symptoms of astigmatism include headaches and fatigue.

Almost all eyes have some irregularities in the shape of the cornea or lens. However, astigmatism needs to be corrected only if it interferes with normal vision. Like both far-sightedness and near-sightedness, astigmatism can be corrected with eyeglasses, contact lenses, or laser surgery (Figure 12.15).

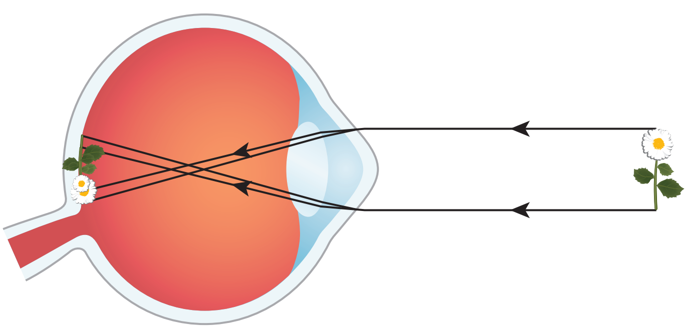


Figure 12.14 Astigmatism is a vision problem that results from a cornea that has an irregular shape.

Figure 12.15 Contact lenses sit directly on the cornea and can be used to correct far- and near-sightedness as well as astigmatism.

Reshaping the Cornea

Laser eye surgery is a general term for several different kinds of procedures that involve correcting vision by reshaping the cornea using energy from a laser (Figure 12.16). The procedures can be used to correct far- and near-sightedness as well as astigmatism. Millions of people worldwide have had successful laser surgery, eliminating their need for corrective lenses. However, as with any surgical procedure, it is not without risk. In some cases, laser surgery leads to poor night vision or problems caused by dry eyes.

Figure 12.16 Laser surgery, also called refractive eye surgery, reshapes the cornea in order to allow the eye to focus correctly.

Laser surgery is not suitable for everyone who might want it. This is due to differences in eyes from one person to another. The first task of every laser surgeon is to assess whether the procedure is appropriate for an individual patient and, if so, to give the patient enough information to make an informed decision. Some people delay having laser surgery because the procedure is only several decades old, and the long-term effects of laser surgery are not yet known.

During Writing

Thinking Literacy

Writing to Analyze

Scientists begin their writing with an important idea, question, or problem. They ask "What is important and why?" Then, they provide background information to help them draw a conclusion. When you analyze issues, start with a question, and then find the information you need to understand the answer.

Suggested STSE Activity

D29 Decision-Making Analysis Case Study on page 480

Learning Checkpoint

1. Where does the image form in persons who are far-sighted?
2. What type of lens is used to correct far-sightedness?
3. Where does the image form in persons who are near-sighted?
4. What type of lens is used to correct near-sightedness?
5. What causes astigmatism?

Optical Technologies for Persons with Blindness

You may have heard the term "blindness" applied to any type of vision impairment that prevents someone from being able to do important activities such as reading, driving a car, or seeing their friends clearly. Total blindness means that the person does not perceive any light at all. The term "legally blind" is often used to describe people with very low vision who, even with corrective lenses, would need to stand about 6 m from an object to see it as clearly as a normally sighted person could from about 60 m away. The term "legally blind" is also applied to people whose visual field is less than 20° instead of the 180° seen by those with normal vision.

Almost all people who are legally blind are able to detect some degree of light and form an image of some kind (Figure 12.17). For example, a legally blind person might be able to see using peripheral vision but not be able to form an image in the centre of the visual field. In another case, a legally blind person might see only a tiny spot at the centre of the visual field and not have any peripheral vision.

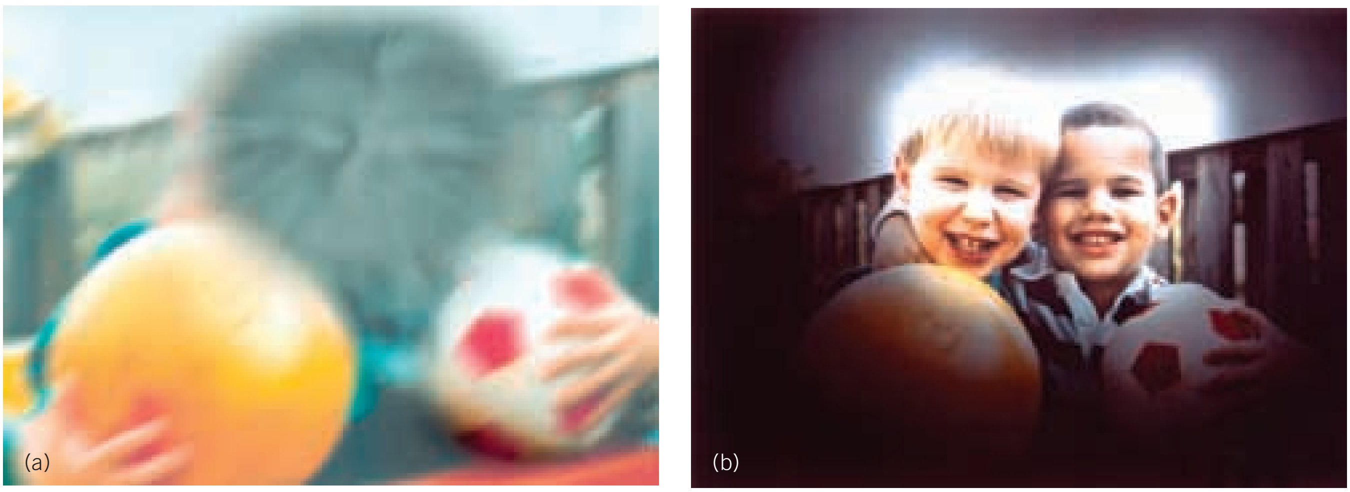


Figure 12.17 (a) Loss of the centre of vision field and (b) loss of peripheral vision

Many people who have very low vision can have most of their sight restored by wearing glasses or contact lenses or through surgery. For example, laser surgery can be used to help re-attach a retina that has become detached from the back of the eye. Laser surgery can also be used to remove cataracts, which are cloudy areas of the lens. Some treatments, such as retinal implants, are still very experimental. A retinal implant is an experimental procedure in which an electronic device is surgically implanted into the retina in order to replace natural photoreceptors that no longer function. The device can digitally detect light and transform it into electrical signals that can stimulate functioning parts of the retina to send signals to the brain.

Colour and Vision

True **colour blindness**, which is the ability to only see shades of grey, is very rare, occurring in about 1 person in 40 000. Colour-blind persons are able to see which traffic light in a stop light is on, but they cannot tell whether it is red or green. They must be careful to remember the position of the red and green relative to each other. Colour blindness is not always a disadvantage. In some cases, it allows a person to be able to more easily recognize an object set in a highly complicated colour background.

Colour vision deficiency is a more common condition, occurring in about 1 percent of females and 8 percent of males. **Colour vision deficiency** is the ability to distinguish some colours but not others (Figure 12.18). In one form of colour vision deficiency, often referred to as red-green colour deficiency, red and green appear to be the same colour. This is due to a lack of cone photoreceptors that detect red. Many people are not even aware that they have a colour vision deficiency until they are in their teens or later.

Some persons with a perceptual condition called dyslexia find it difficult to read text if it is written on a white background. In many cases, eyeglasses with coloured filters make reading much easier as they make the page appear to be coloured.

Take It Further

One of the roles of vision is to judge how far away objects are. Distance cues such as the size of familiar objects are called monocular cues, because only one eye is needed. The use of two eyes allows the brain to construct a 3D image and is called binocular vision. Find out more about depth perception using monocular and binocular vision. Begin your research at ***ScienceSource***.

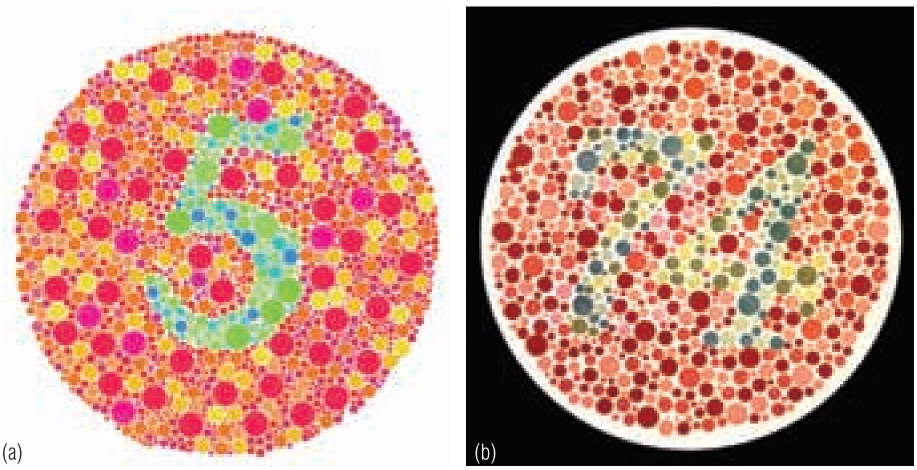


Figure 12.18 Persons who have full colour vision will see the number 5 in (a) and 74 in (b).

Learning Checkpoint

1. (a) How many degrees of visual field does a legally blind person have?
   (b) How many degrees of visual field does a person with normal vision have?
2. What are two technologies involving the use of a laser that can help people who are losing their sight?
3. Identify one advantage and one disadvantage of being colour blind.
4. What optical technology can help people with dyslexia?