

# MASTERING THE WORLD OF PSYCHOLOGY

## SECOND EDITION

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0-205-45795-9 Exam Copy ISBN  
(Please use above number to order your exam copy.)

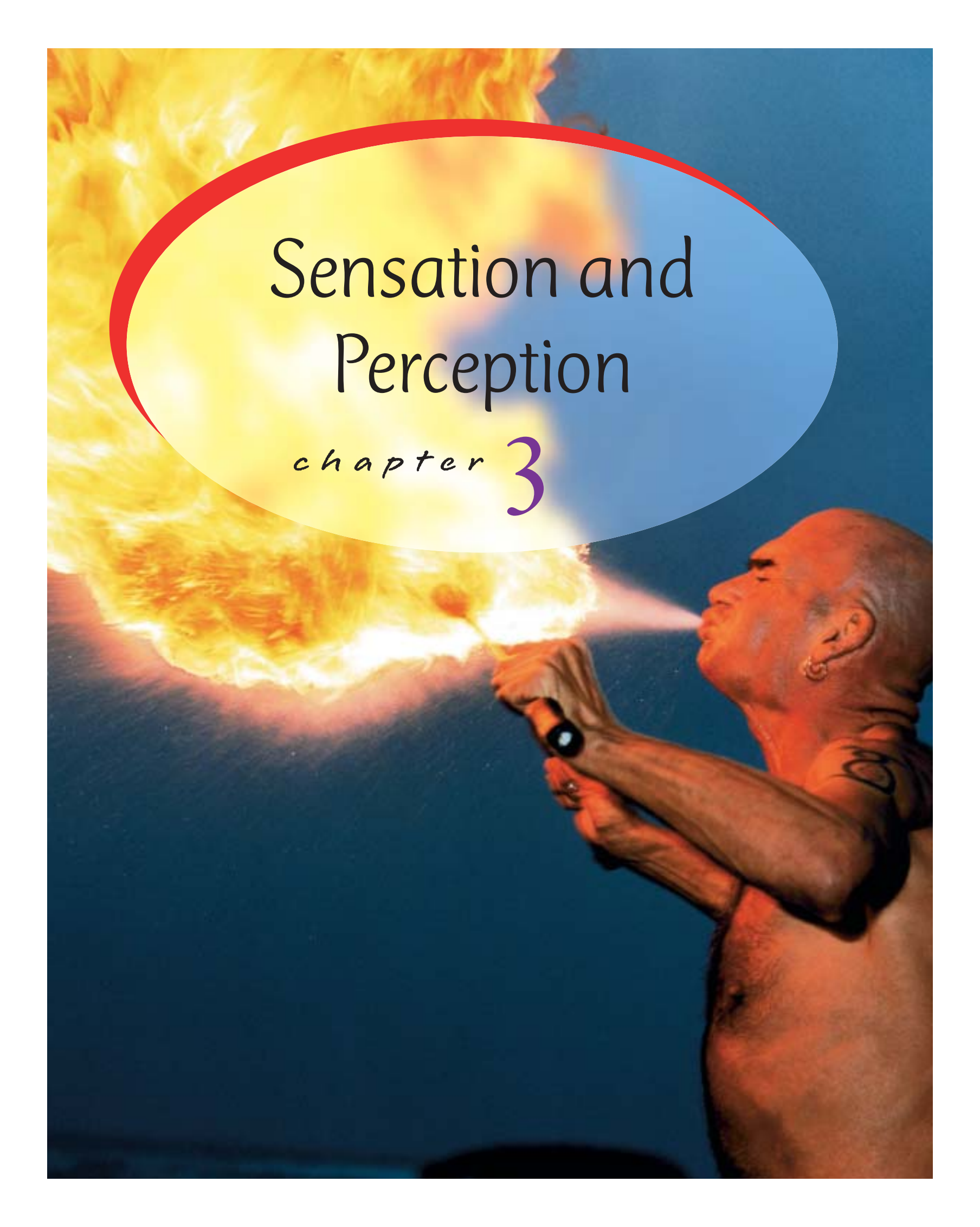
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## Sample Chapter

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A photograph of a man breathing fire into a large, bright flame. The man is shown in profile, looking upwards and to the left. He has a tattoo on his left shoulder and is wearing a black watch on his left wrist. The background is a clear blue sky. A large, glowing yellow and orange flame is being blown from the man's mouth, filling the upper left portion of the frame. A large, light blue oval with a red border is overlaid on the image, containing the title and chapter information.

# Sensation and Perception

*chapter* 3

## The Process of Sensation

- ◆ How is sensory information transmitted to the brain?

## Vision

- ◆ How does each part of the eye function in vision?
- ◆ What path does visual information take from the retina to the primary visual cortex?
- ◆ How do we detect the difference between one color and another?
- ◆ What two major theories attempt to explain color vision?

## Hearing

- ◆ What determines the pitch and loudness of a sound, and how is each quality measured?
- ◆ How do the outer ear, middle ear, and inner ear function in hearing?

- ◆ What two major theories attempt to explain hearing?

## Smell and Taste

- ◆ What path does a smell message take from the nose to the brain?
- ◆ What are the primary taste sensations, and how are they detected?

## The Skin Senses

- ◆ How does the skin provide sensory information?
- ◆ What is the function of pain, and how is pain influenced by psychological factors, culture, and endorphins?

## The Spatial Orientation Senses

- ◆ What kinds of information do the kinesthetic and vestibular senses provide?

## Influences on Perception

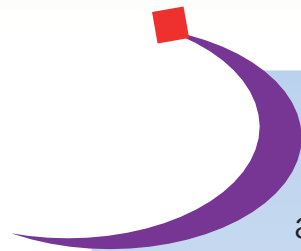
- ◆ What is gained and what is lost in the process of attention?
- ◆ How does prior knowledge influence perception?
- ◆ How does information from multiple sources aid perception?

## Principles of Perception

- ◆ What are the principles that govern perceptual organization?
- ◆ What are some of the binocular and monocular depth cues?
- ◆ How does the brain perceive motion?
- ◆ What are three types of puzzling perceptions?

## Unusual Perceptual Experiences

- ◆ In what ways does subliminal perception influence behavior?
- ◆ What have studies of ESP shown?



# W

hat would it be like to hear a color or see a song?

If you have the condition known as *synesthesia*, the capacity for experiencing unusual sensations along with ordinary ones, you may know. For instance, Sean Day sees the color blue simultaneously with the taste of beef, and an orange blob appears in his field of vision when he consumes foods that have been seasoned with ginger (Carpenter, 2001). Day's unusual sensations do not take the place of those that are experienced by most people in response to these stimuli. Instead, the atypical sensory experiences of synesthetes such as Day supplement the more typical responses.

In the past, many psychologists regarded synesthesia as the result of an overactive imagination or some kind of learned association. In 1993, however, neurologist Richard Cytowic published a popular book called *The Man Who Tasted Shapes*, which sparked interest in the use of modern brain-imaging techniques to study the phenomenon. In the years that followed, many such studies were carried out. The majority suggested that synesthesia has a neurological basis (Cytowic, 2002). In other words, when Sean Day bites into a juicy piece of pot roast, his brain quite literally "sees" blue, just as it would if a blue object were placed in front of his eyes.

Research also indicates that the most common type of synesthesia is one in which individuals sense colors in response to spoken words, known as "colored hearing" (Carpenter, 2001). Neuroimaging studies suggest that colored hearing is not the result of learned associations. Rather, different brain areas are active in synesthetes who

associate words with colors than in research participants who have been trained to consciously engage in such associations (Nunn et al., 2004).

A number of hypotheses have been proposed to explain synesthesia. Some psychologists speculate that all newborn brains are synesthetic and that the capacity for synesthesia is lost in most people as the various brain areas become more specialized over the years of childhood and adolescence (Mondloch & Maurer, 2004). However, some drugs produce temporary synesthesia, leading a few scientists to hypothesize that the neural connections that underlie synesthetic experiences are present in the brains of both synesthetes and nonsynesthetes alike (Grossenbacher & Lovelace, 2001). Nevertheless, the jury is still out with regard to both the origin and the neurological basis of synesthesia (Carpenter,

2001). A great deal more research needs to be done on this phenomenon.

Studies of synesthesia illustrate the fact that sensing and perceiving stimuli are separate processes. **Sensation** is the process through which the senses pick up visual, auditory, and other sensory stimuli and transmit them to the brain. **Perception** is the process by which the brain actively organizes and interprets sensory information. Sensation furnishes the raw material of sensory experience, whereas perception provides the finished product. Synesthesia is of interest to neuroscientists because it is one of several phenomena that involve perception without sensation. We will return to the topic of unusual sensory and perceptual experiences at the end of the chapter. First, however, we will examine how sensation and perception work in most people most of the time.

#### ◆ sensation

The process through which the senses pick up visual, auditory, and other sensory stimuli and transmit them to the brain.

#### ◆ perception

The process by which the brain actively organizes and interprets sensory information.

#### ◆ absolute threshold

The minimum amount of sensory stimulation that can be detected 50% of the time.

#### ◆ difference threshold

A measure of the smallest increase or decrease in a physical stimulus that is required to produce a difference in sensation that is noticeable 50% of the time.

#### ◆ just noticeable difference (JND)

The smallest change in sensation that a person is able to detect 50% of the time.

#### ◆ Weber's law

The law stating that the just noticeable difference (JND) for all the senses depends on a proportion or percentage of change in a stimulus rather than on a fixed amount of change.



## The Process of Sensation

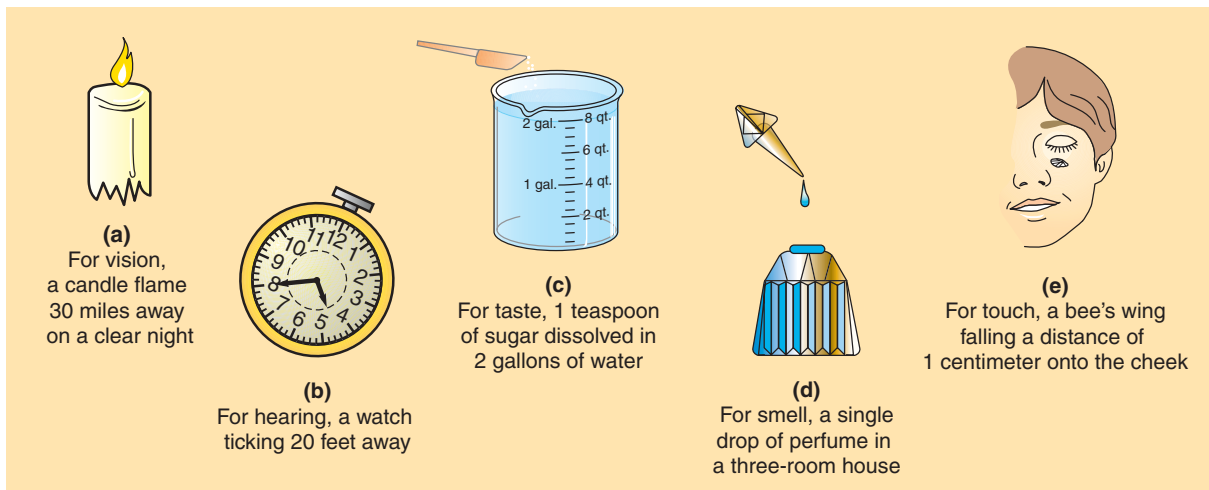
What is the softest sound you can hear, the dimmest light you can see, the most diluted substance you can taste? Researchers in sensory psychology have performed many experiments over the years to answer these questions. Their research has established measures for the senses known as absolute thresholds. Just as the threshold of a doorway is the dividing point between being outside a room and inside, the **absolute threshold** of a sense marks the difference between not being able to perceive a stimulus and being just barely able to perceive it. Psychologists have arbitrarily defined this absolute threshold as the minimum amount of sensory stimulation that can be detected 50% of the time. The absolute thresholds for vision, hearing, taste, smell, and touch are illustrated in Figure 3.1.

If you are listening to music, the very fact that you can hear it means that the absolute threshold has been crossed. But how much must the volume be turned up or down for you to notice a difference? Or, if you are carrying some bags of groceries, how much weight must be added or taken away for you to be able to sense that your load is heavier or lighter? The **difference threshold** is a measure of the smallest increase or decrease in a physical stimulus that is required to produce the **just noticeable difference (JND)**. The JND is the smallest change in sensation that a person is able to detect 50% of the time. If you were holding a 5-pound weight and 1 pound was added, you could easily notice the difference. But if you were holding 100 pounds and 1 additional pound was added, you could not sense the difference. Why not?

More than 150 years ago, researcher Ernst Weber (1795–1878) observed that the JND for all the senses depends on a proportion or percentage of change in a stimulus rather than on a fixed amount of change. This observation became known as **Weber's law**. A weight you are holding must increase or decrease by  $\frac{1}{50}$ , or 2%, for you to notice the difference; thus, adding 1 pound to 100 pounds should not be noticed

### FIGURE 3.1 Absolute Thresholds

Absolute thresholds have been established for humans for vision, hearing, taste, smell, and touch.



because the additional weight does not add the required 2% change. In contrast, if you were listening to music, you would notice a difference if a tone became slightly higher or lower in pitch by about only 0.33%. According to Weber's law, the greater the original stimulus, the more it must be increased or decreased for the difference to be noticeable.

Weber's law best applies to people with average sensitivities and to sensory stimuli that are neither very strong (loud thunder) nor very weak (a faint whisper). For instance, expert wine tasters would know if a particular vintage was a little too sweet, even if its sweetness varied by only a fraction of the 20% necessary for changes in taste. Furthermore, people who have lost one sensory ability often gain greater sensitivity in others. For example, one study found that children with early-onset blindness were more capable of correctly labeling 25 common odors than were sighted children, while another found that congenitally deaf students possessed motion-perception abilities superior to those of hearing students (Bavelier et al., 2000; Rosenbluth et al., 2000).

The sense organs provide only the beginning of sensation, which must be completed by the brain. The body's sense organs are equipped with highly specialized cells called **sensory receptors**, which detect and respond to one type of sensory stimuli—light, sound waves, odors, and so on. The form of each type of sensory receptor is unique.

◆ How is sensory information transmitted to the brain?

#### ◆ sensory receptors

Highly specialized cells in the sense organs that detect and respond to one type of sensory stimuli—light, sound, or odor, for example—and transduce (convert) the stimuli into neural impulses.



What is the dimmest light this lifeguard could perceive in the darkness? Researchers in sensory psychology have performed many experiments over the years to answer such questions. Their research has established measures known as absolute thresholds. Just as the threshold of a doorway is the dividing point between being outside a room and being inside it, the absolute threshold of a sense marks the difference between not being able to perceive a stimulus and being just barely able to perceive it.

### ◆ transduction

The process through which sensory receptors convert the sensory stimulation into neural impulses.

### ◆ sensory adaptation

The process in which sensory receptors grow accustomed to constant, unchanging levels of stimuli over time.

### ◆ visible spectrum

The narrow band of electromagnetic waves that are visible to the human eye.

### ◆ wavelength

A measure of the distance from the peak of a light wave to the peak of the next.

### ◆ cornea

(KOR-nee-uh) The tough, transparent, protective layer that covers the front of the eye and bends light rays inward through the pupil.

### ◆ lens

The transparent disk-shaped structure behind the iris and the pupil that changes shape as it focuses on objects at varying distances.

### ◆ accommodation

The flattening and bulging action of the lens as it focuses images of objects on the retina.

Through a process known as **transduction**, the sensory receptors convert the sensory stimulation into neural impulses, the electrochemical language of the brain. The neural impulses are then transmitted to precise locations in the brain, such as the primary visual cortex for vision or the primary auditory cortex for hearing. We experience a sensation only when the appropriate part of the brain is stimulated. The sense receptors provide the essential link between the physical sensory world and the brain.

After a time, the sensory receptors grow accustomed to constant, unchanging levels of stimuli—sights, sounds, or smells—so we notice them less and less, or not at all. For example, smokers become accustomed to the smell of cigarette smoke in their homes and on their clothing. This process is known as **sensory adaptation**. Even though it reduces our sensory awareness, sensory adaptation enables us to shift our attention to what is most important at any given moment. However, sensory adaptation is not likely to occur in the presence of a very strong stimulus, such as the smell of ammonia, an ear-splitting sound, or the taste of rancid food.

## Vision

Vision is the most studied of all the senses. One thing vision researchers have known for a long time is that there is a great deal more information in the sensory environment than our eyes can take in. Our eyes can respond only to visible light waves, which form a small subgroup of *electromagnetic waves*, a band called the **visible spectrum** (see Figure 3.2). These waves are measured in **wavelengths**, the distance from the peak of one wave to the peak of the next. The shortest light waves we can see appear violet, while the longest visible waves appear red. But sight is much more than just response to light.

### The Eye

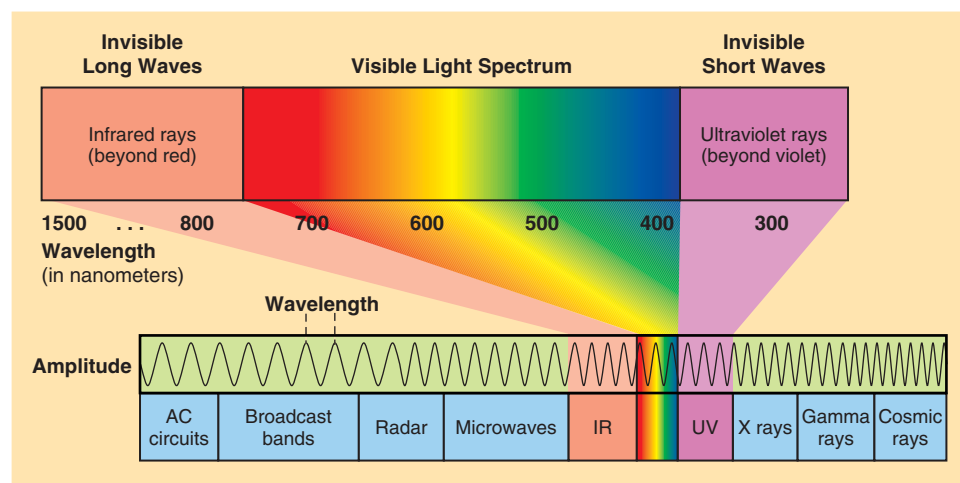
The globe-shaped human eyeball, shown in Figure 3.3, measures about 1 inch in diameter. Bulging from the eye's surface is the **cornea**—the tough, transparent, protective layer covering the front of the eye. The cornea performs the first step in vision by bending the light rays inward. It directs the light rays through the *pupil*, the small, dark opening in the center of the *iris*, or colored part of the eye. The iris dilates and contracts the pupil to regulate the amount of light entering the eye.

Suspended just behind the iris and the pupil, the **lens** is composed of many thin layers and looks like a transparent disk. The lens performs the task of focusing on viewed objects. It flattens as it focuses on objects at a distance and becomes more spherical, bulging in the center, as it focuses on close objects. This flattening and bulging action of the lens is known as **accommodation**. With age, the lens loses the ability to change

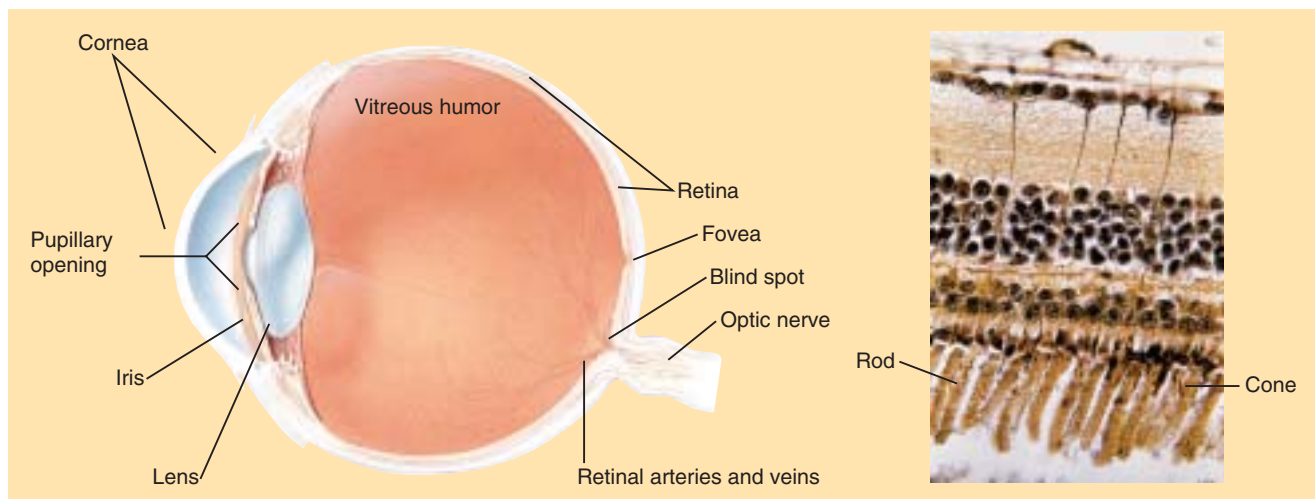
FIGURE 3.2

### The Electromagnetic Spectrum

Human eyes can perceive only a very thin band of electromagnetic waves, known as the visible spectrum.



**FIGURE 3.3** The Major Parts of the Human Eye



its shape to accommodate for near vision, a condition called *presbyopia* (“old eyes”). This is why many people over age 40 must hold a book or newspaper at arm’s length or use reading glasses to magnify the print.

The lens focuses the incoming image onto the **retina**—a layer of tissue about the size of a small postage stamp and as thin as onion skin, located on the inner surface of the eyeball and containing the sensory receptors for vision. The image that is projected onto the retina is upside down and reversed from left to right, as illustrated in Figure 3.4 on page 84.

In some people, the distance through the eyeball (from the lens to the retina) is either too short or too long for proper focusing. Nearsightedness (*myopia*) occurs when the lens focuses images of distant objects in front of, rather than on, the retina. A person with this condition will be able to see near objects clearly, but distant images will be blurred. Farsightedness (*hyperopia*) occurs when the lens focuses images of close objects behind, rather than on, the retina. The individual is able to see far objects clearly, but close objects are blurred. Both conditions are correctable with eyeglasses or contact lenses or by surgical procedures.

At the back of the retina is a layer of light-sensitive receptor cells—the **rods** and the **cones**. Named for their shapes, the rods look like slender cylinders, and the cones appear shorter and more rounded. There are about 120 million rods and 6 million cones in each retina. The cones are the receptor cells that enable us to see color and fine detail in adequate light, but they do not function in very dim light. By contrast, the rods in the human eye are extremely sensitive, allowing the eye to respond to as few as five photons of light (Hecht et al., 1942).

A substance called *rhodopsin* present in the rods enables us to adapt to variations in light. Rhodopsin has two components: *opsin* and *retinal* (a chemical similar to Vitamin A). In bright light, opsin and retinal break apart, as the process of *light adaptation* takes place. During *dark adaptation*, opsin and retinal bond to one another, re-forming rhodopsin. As you’ve no doubt experienced, when you move from bright light to total darkness, as when you enter a darkened movie theater, you are momentarily blind until the opsin and retinal recombine. Similarly, when you leave the theater again, you become temporarily blind until the two substances break apart once again.

At the center of the retina is the **fovea**, a small area about the size of the period at the end of this sentence. When you look directly at an object, the image of the object is focused on the center of your fovea. The fovea contains no rods but has about 30,000 cones tightly packed together, providing the clearest and sharpest area of vision in the whole retina. The cones are most densely packed at the center of the fovea; their density decreases sharply just a few degrees beyond the fovea’s center and then levels off more gradually to the periphery of the retina.

◆ How does each part of the eye function in vision?

◆ **retina**

The layer of tissue that is located on the inner surface of the eyeball and contains the sensory receptors for vision.

◆ **rods**

The light-sensitive receptor cells in the retina that look like slender cylinders and allow the eye to respond to as few as five photons of light.

◆ **cones**

The light-sensitive receptor cells in the retina that enable humans to see color and fine detail in adequate light but do not function in very dim light.

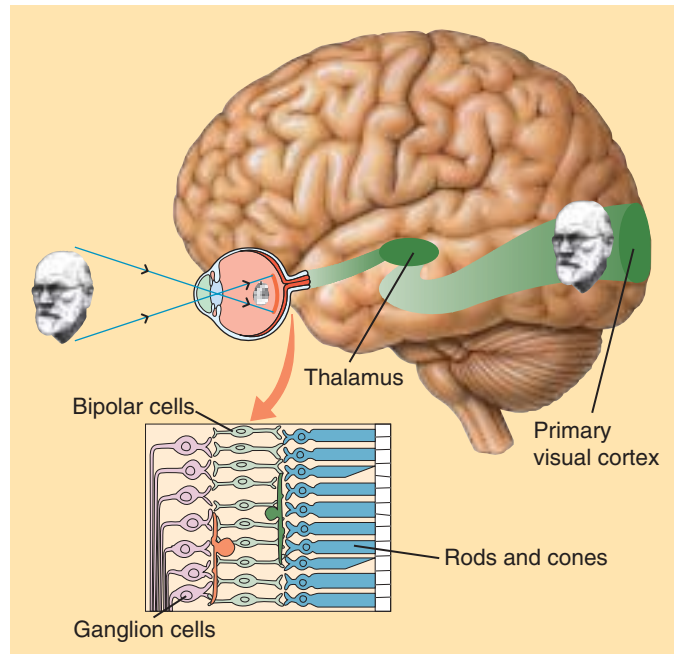
◆ **fovea**

(FO-vee-uh) A small area at the center of the retina that provides the clearest and sharpest vision because it has the largest concentration of cones.

**FIGURE 3.4**

### From Retinal Image to Meaningful Information

Because of the way the lens alters light rays to produce a clear image, images are upside down on the retina. The brain's visual processing system takes the upside-down retinal image and flips it so it is properly orientated.



## Vision and the Brain

As you can see in Figure 3.4, the brain is responsible for converting the upside-down retinal images into meaningful visual information. But the first stages of neural processing actually take place in the retina itself. The rods and cones transduce, or change, light waves into neural impulses that are fed to the bipolar cells, which, in turn, pass the impulses along to the ganglion cells. The approximately 1 million axonlike extensions of the ganglion cells are bundled together in a pencil-sized cable that extends through the wall of the retina, leaving the eye and leading to the brain. There are no rods or cones where the cable runs through the retinal wall, so this point is a **blind spot** in each eye.

Beyond the retinal wall of each eye, the cable becomes the **optic nerve** (refer to Figure 3.3). The two optic nerves come together at the *optic chiasm*, a point where some of their nerve fibers cross to the opposite side of the brain. The nerve fibers from the right half of each retina go to the right hemisphere, and those from the left half of each retina go to the left hemisphere. This crossing over is important because it allows visual information from a single eye to be represented in the primary visual cortex of both hemispheres of the brain. Moreover, it plays an important part in depth perception.

From the optic chiasm, the optic nerve fibers extend to the thalamus, where they form synapses with neurons that transmit the impulses to the **primary**

**visual cortex**, the part of the brain that is devoted to visual processing. Thanks to researchers David Hubel and Torsten Wiesel (1959, 1979; Hubel, 1963, 1995), who won a Nobel Prize for their work in 1981, we know a great deal about how specialized the neurons of the primary visual cortex are. By inserting tiny microelectrodes into single cells in the visual cortexes of cats, Hubel and Wiesel (1959) were able to determine what was happening in individual cells when the cats were exposed to different kinds of visual stimuli. They discovered that each neuron responded only to specific patterns. Some neurons responded only to lines and angles, while others fired only when the cat saw a vertical or horizontal line. Still others were responsive to nothing but right angles or lines of specific lengths. Neurons of this type are known as **feature detectors**, and they are already coded at birth to make their unique responses. Yet we see whole images, not collections of isolated features, because visual perceptions are complete only when the primary visual cortex transmits the millions of pieces of visual information it receives to other areas in the brain, where they are combined and assembled into whole visual images (Perry & Zeki, 2000).

The major structures of the visual system are summarized in *Review and Reflect 3.1*.

◆ *What path does visual information take from the retina to the primary visual cortex?*

#### ◆ **blind spot**

The point in each retina where there are no rods or cones because the cable of ganglion cells is extending through the retinal wall.

#### ◆ **optic nerve**

The nerve that carries visual information from each retina to both sides of the brain.

#### ◆ **primary visual cortex**

The part of the brain in which visual information is processed.

#### ◆ **feature detectors**

Neurons in the brain that respond only to specific visual patterns (for example, to lines or angles).

## Color Vision

Why does the skin of an apple appear to be red, while its flesh is perceived as an off-white color? Remember, what we actually see is reflected light. Some light waves striking an object are absorbed by it; others are reflected from it. So, why does an apple's skin look red? If you hold a red apple in bright light, light waves of all the different wavelengths strike the apple, but more of the longer red wavelengths of light are reflected from the apple's skin. The shorter wavelengths are absorbed, so you see only the reflected red. Bite into the apple, and it looks off-white. Why? You see the near-white



## REVIEW and REFLECT 3.1

### Major Structures of the Visual System

STRUCTURE	FUNCTION
Cornea	Translucent covering on the front of the eyeball that bends light rays entering the eye inward through the pupil
Iris	Colored part of the eye that adjusts to maintain a constant amount of light entering the eye through the pupil
Pupil	Opening in the center of the iris through which light rays enter the eye
Lens	Transparent disk-shaped structure behind the pupil that adjusts its shape to allow focusing on objects at varying distances
Retina	Layer of tissue on the inner surface of the eye that contains sensory receptors for vision
Rods	Specialized receptor cells in the retina that are sensitive to light changes
Cones	Specialized receptor cells in the retina that enable humans to see fine detail and color in adequate light
Fovea	Small area at the center of the retina, packed with cones, on which objects viewed directly are clearly and sharply focused
Optic nerve	Nerve that carries visual information from the retina to the brain
Blind spot	Area in each eye where the optic nerve joins the retinal wall and no vision is possible

color because, rather than being absorbed, almost all of the wavelengths of the visible spectrum are reflected from the inside part of the apple. The presence of all visible wavelengths gives the sensation of a near-white color. If an object does indeed reflect 100% of visible wavelengths, it appears to be pure white.

Our everyday visual experience goes far beyond the colors in the rainbow. We can detect thousands of subtle color shadings. What produces these fine color distinctions? Researchers have identified three dimensions of light that combine to provide the rich world of color we experience: The chief dimension is **hue**, which refers to the specific color perceived—red, blue, or yellow, for example. **Saturation** refers to the purity of a color; a color becomes less saturated, or less pure, as other wavelengths of light are mixed with it. **Brightness** refers to the intensity of the light energy that is perceived as a color and corresponds to the amplitude (height) of the color's light wave.

### Theories of Color Vision

Scientists know that the cones are responsible for color vision, but exactly how do they work to produce color sensations? Two major theories have been offered to explain color vision, and both were formulated before the development of laboratory technology capable of testing them. The **trichromatic theory**, first proposed by Thomas Young in 1802, was modified by Hermann von Helmholtz about 50 years later. This theory states that there are three kinds of cones in the retina and that each kind makes a maximal chemical response to one of three colors—blue, green, or red. Research conducted in the 1950s and the 1960s by Nobel Prize winner George Wald (1964; Wald et al., 1954) supports the trichromatic theory. Wald discovered that even though all cones have basically the same structure, the retina does indeed contain three kinds of cones. Subsequent research demonstrated that each kind of cone is particularly sensitive to one of three colors—blue, green, or red (Roorda & Williams, 1999).

◆ How do we detect the difference between one color and another?

#### ◆ hue

The dimension of light that refers to the specific color perceived.

#### ◆ saturation

The purity of a color, or the degree to which the light waves producing it are of the same wavelength.

#### ◆ brightness

The dimension of visual sensation that is dependent on the intensity of light reflected from a surface and that corresponds to the amplitude (height) of the light wave.

#### ◆ trichromatic theory

The theory of color vision suggesting that three types of cones in the retina each make a maximal chemical response to one of three colors—blue, green, or red.

◆ *What two major theories attempt to explain color vision?*

The other major attempt to explain color vision is the **opponent-process theory**, which was first proposed by physiologist Ewald Hering in 1878 and revised in 1957 by researchers Leon Hurvich and Dortha Jamison. According to the opponent-process theory, three kinds of cells respond by increasing or decreasing their rate of firing when different colors are present. The red/green cells increase their firing rate when red is present and decrease it when green is present. The yellow/blue cells have an increased response to yellow and a decreased response to blue. A third kind of cells increase their response rate for white light and decrease it in the absence of light.

If you look long enough at one color in the opponent-process pair and then look at a white surface, your brain will give you the sensation of the opposite color—a negative **afterimage**, a visual sensation that remains after the stimulus is withdrawn. After you have stared at one color in an opponent-process pair (red/green, yellow/blue, white/black), the cell responding to that color tires and the opponent cell begins to fire, producing the afterimage. Demonstrate this for yourself in *Try It 3.1*.

But which theory of color vision is correct? It turns out that each theory explains a different phase of color processing. It is now generally accepted that the cones perform color processing in a way that is best explained by the trichromatic theory. The cones pass on information about wavelengths of light to the ganglion cells, the site of opponent processes. And color perception appears to involve more than just these two phases. Researchers think that color processing starts at the level of the retina, continues through the bipolar and ganglion cells, and is completed in the color detectors in the visual cortex (Masland, 1996; Sokolov, 2000).

You may have wondered what it means if someone is “color blind.” Does that person see the world in black and white? No—the term **color blindness** refers to an inability to distinguish certain colors from one another. About 7% of males experience some kind of difficulty in distinguishing colors, most commonly red from green (Montgomery, 2003). By contrast, fewer than 1% of females suffer from color blindness. (Recall from Chapter 2 that this sex difference is explained by the fact that genes for color vision are carried on the X chromosome.)

Research has shown that color blindness can have degrees; it isn’t simply a matter of either-you-have-it-or-you-don’t. Why are some of us better able to make fine distinctions between colors, as we must do when sorting black and navy blue socks, for instance? These differences appear to be related to the number of color vision genes individuals have. Researchers have found that, in people with normal color vision, the X chromosome may contain as few as two or as many as nine genes for color perception (Neitz & Neitz, 1995). Those who have more of such genes appear to be better able to make very fine distinctions between colors.

◆ **opponent-process theory**

The theory of color vision suggesting that three kinds of cells respond by increasing or decreasing their rate of firing when different colors are present.

◆ **afterimage**

A visual sensation that remains after a stimulus is withdrawn.

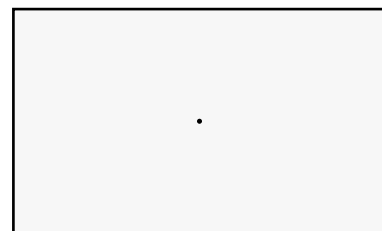
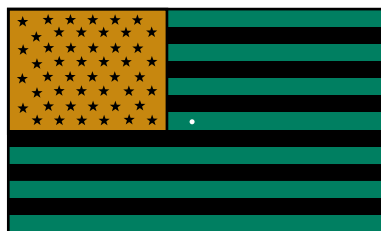
◆ **color blindness**

The inability to distinguish certain colors from one another.

## Try It 3.1

### A Negative Afterimage

Stare at the dot in the green, black, and yellow flag for approximately 1 minute. Then shift your gaze to the dot in the blank rectangle. You will see the American flag in its true colors—red, white, and blue, which are the opponent-process opposites of green, black, and yellow.





On the left a hot air balloon is shown as it would appear to a person with normal color vision; on the right is the same balloon as it would appear to a person with red-green color blindness.

## Hearing

“In space, no one can hear you scream!” Years ago, the frightening science fiction movie *Alien* was advertised this way. Although the movie was fiction, the statement is true. Light can travel through the vast nothingness of space, a vacuum, but sound cannot.

### Sound

Sound requires a medium, such as air, water, or a solid object, through which to move. This fact was first demonstrated by Robert Boyle in 1660 when he suspended a ringing pocket watch by a thread inside a specially designed jar. When Boyle pumped all the air out of the jar, he could no longer hear the watch ring. But when he pumped the air back into the jar, he could again hear the watch ringing.

**Frequency** is determined by the number of cycles completed by a sound wave in one second. The unit used to measure a wave’s frequency, or cycles per second, is known as the hertz (Hz). The *pitch*—how high or low the sound is—is chiefly determined by frequency—the higher the frequency (the more cycles per second), the higher the sound. The human ear can hear sound frequencies from low bass tones of around 20 Hz up to high-pitched sounds of about 20,000 Hz. The lowest tone on a piano sounds at a frequency of about 28 Hz, and the highest tone at about 4,214 Hz. Many mammals, such as dogs, cats, bats, and rats, can hear tones much higher in frequency than 20,000 Hz. Amazingly, dolphins can respond to frequencies up to 100,000 Hz.

The loudness of a sound is determined by a measure called **amplitude**. The force or pressure with which air molecules move chiefly determines loudness, which is measured using a unit called the *bel*, named for Alexander Graham Bell. Because the bel is a rather large unit, sound levels are expressed in tenths of a bel, or **decibels (dB)**. The threshold of human hearing is set at 0 dB, which does not mean the absence of sound but rather the softest sound that can be heard in a very quiet setting. Each increase of 10 decibels makes a sound 10 times louder. Figure 3.5 on page 88 shows comparative decibel levels for a variety of sounds.

Another characteristic of sound is **timbre**, the distinctive quality of a sound that distinguishes it from other sounds of the same pitch and loudness. Have you ever thought about why a given musical note sounds different when played on a piano, a guitar, and a violin, even though all three instruments use vibrating strings to produce sounds? The characteristics of the strings, the technique used to initiate the vibrations,

◆ *What determines the pitch and loudness of a sound, and how is each quality measured?*

#### ◆ frequency

The number of cycles completed by a sound wave in one second, determining the pitch of the sound; expressed in the unit called the hertz.

#### ◆ amplitude

The measure of the loudness of a sound; expressed in the unit called the decibel.

#### ◆ decibel (dB)

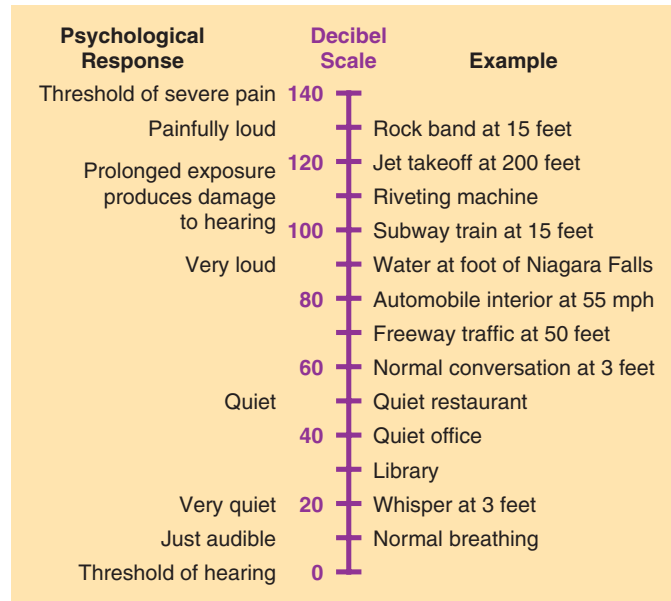
(DES-ih-bel) A unit of measurement for the loudness of sounds.

#### ◆ timbre

(TAM-burr) The distinctive quality of a sound that distinguishes it from other sounds of the same pitch and loudness.

**FIGURE 3.5****Decibel Levels of Various Sounds**

The loudness of a sound (its amplitude) is measured in decibels. Each increase of 10 decibels makes a sound 10 times louder. A normal conversation at 3 feet measures about 60 decibels, which is 10,000 times louder than a soft whisper of 20 decibels. Any exposure to sounds of 130 decibels or higher puts a person at immediate risk for hearing damage.

**◆ audition**

The sensation and process of hearing.

**◆ outer ear**

The visible part of the ear, consisting of the pinna and the auditory canal.

and the way the body of the instrument amplifies the vibrations work together to produce a unique “voice,” or timbre, for each instrument. Human voices vary in timbre as well, providing us with a way of recognizing individuals when we can’t see their faces. Timbres vary from one instrument to another, and from one voice to another, because most sounds consist of several different frequencies rather than a single pitch. The range of those frequencies gives each musical instrument, and each human voice, its unique sound.

◆ *How do the outer ear, middle ear, and inner ear function in hearing?*

**◆ middle ear**

The portion of the ear containing the ossicles, which connect the eardrum to the oval window and amplify sound waves.

**◆ inner ear**

The innermost portion of the ear, containing the cochlea, the vestibular sacs, and the semicircular canals.

**◆ cochlea**

(KOK-lee-uh) The fluid-filled, snail-shaped, bony chamber in the inner ear that contains the basilar membrane and its hair cells (the sound receptors).

**◆ hair cells**

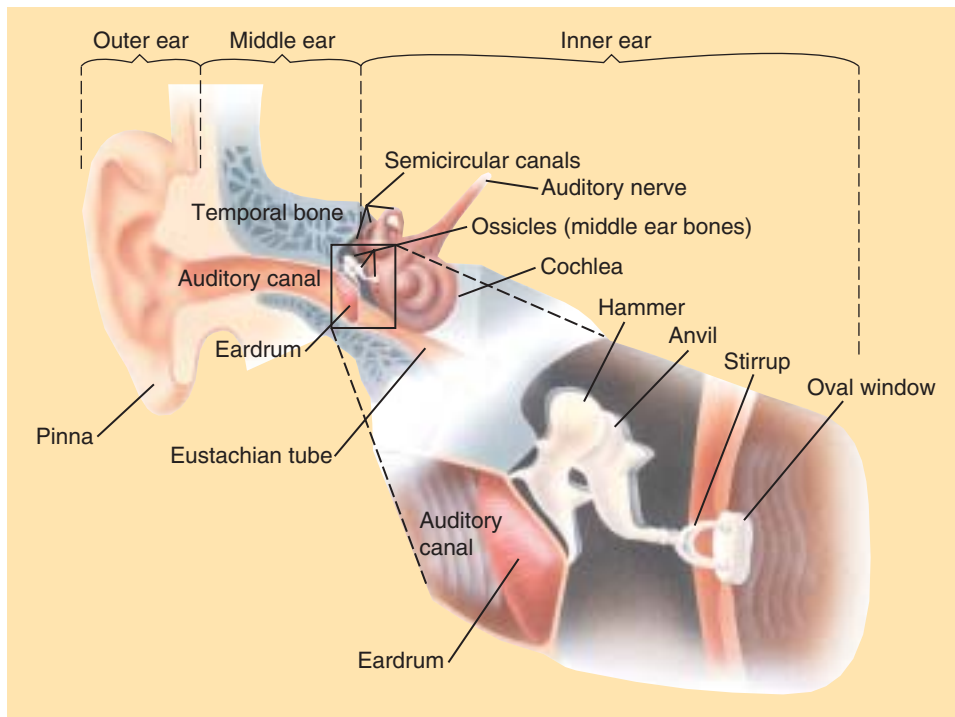
Sensory receptors for hearing that are attached to the basilar membrane in the cochlea.

**The Ear**

**Audition** is the sensation and process of hearing. The oddly shaped, curved flap of cartilage and skin called the *pinna* is the visible part of the **outer ear** (see Figure 3.6). Inside the ear, the *auditory canal* is about 1 inch long, and its entrance is lined with hairs. At the end of the auditory canal is the *eardrum* (or *tympanic membrane*), a thin, flexible membrane about  $\frac{1}{3}$  inch in diameter. The eardrum moves in response to the sound waves that travel through the auditory canal and strike it.

The **middle ear** is no larger than an aspirin tablet. Inside its chamber are the *ossicles*, the three smallest bones in the human body. Named for their shapes, the ossicles—the hammer, the anvil, and the stirrup—are connected in that order, linking the eardrum to the oval window (see Figure 3.6). The ossicles amplify sound waves some 22 times (Békésy, 1957). The **inner ear** begins at the inner side of the oval window, at the **cochlea**—a fluid-filled, snail-shaped, bony chamber. When the stirrup pushes against the oval window, it sets up vibrations that move the fluid in the cochlea back and forth in waves. Inside the cochlea, attached to its thin basilar membrane are about 15,000 sensory receptors called **hair cells**, each with a bundle of tiny hairs protruding from it. The tiny hair bundles are pushed and pulled by the motion of the fluid inside the cochlea. If the tip of a hair bundle is moved only as much as the width of an atom, an electrical impulse is generated, which is transmitted to the brain by way of the auditory nerve.

We can hear some sounds through *bone conduction*, the vibrations of the bones in the face and skull. When you click your teeth or eat crunchy food, you hear these sounds mainly through bone conduction. And, if you have heard a recording of your voice, you may have thought it sounded odd. This is because recordings do not reproduce the sounds you hear through bone conduction when you speak, so you are hearing your voice as it sounds to others.



**FIGURE 3.6**

### The Anatomy of the Human Ear

Sound waves pass through the auditory canal to the eardrum, causing it to vibrate and set in motion the ossicles in the middle ear. When the stirrup pushes against the oval window, it sets up vibrations in the inner ear. This moves the fluid in the cochlea back and forth and sets in motion the hair cells, causing a message to be sent to the brain via the auditory nerve.

Having two ears, one on each side of the head, enables you to determine the direction from which sounds are coming (Konishi, 1993). Unless a sound is directly above, below, in front of, or behind you, it reaches one ear very shortly before it reaches the other (Spitzer & Semple, 1991). The brain can detect differences as small as 0.0001 second and interpret them, revealing the direction of the sound (Rosenzweig, 1961). The source of a sound may also be determined by the difference in the intensity of the sound reaching each ear, as well as the position of the head when the sound is detected (Kopin-ska & Harris, 2003; Middlebrooks & Green, 1991).

## Theories of Hearing

How do the parts of the ear work together to produce auditory sensations? Scientists have proposed two theories to explain hearing.

In the 1860s, Hermann von Helmholtz helped develop **place theory**. This theory of hearing holds that each individual pitch a person hears is determined by the particular spot or place along the basilar membrane that vibrates the most. Observing the living basilar membrane, researchers verified that different locations do, indeed, vibrate in response to differently pitched sounds (Ruggero, 1992). Even so, place theory seems to apply only to frequencies higher than 150 Hz.

Another attempt to explain hearing is **frequency theory**. According to this theory, the hair cells vibrate the same number of times per second as the sounds that reach them. Thus, a tone of 500 Hz would stimulate the hair cells to vibrate 500 times per second. However, frequency theory cannot account for frequencies higher than 1,000 Hz because individual neurons linked to the hair cells cannot fire more than about 1,000 times per second. So, even if a receptor vibrated as rapidly as the sound wave associated with a higher tone, the information necessary to perceive the pitch wouldn't be faithfully transmitted to the brain. Consequently, frequency theory seems to be a good explanation of how we hear low-frequency tones (lower than 500 Hz), but place theory better describes the way in which tones with frequencies higher than 1,000 Hz are heard (Matlin & Foley, 1997). Both frequency and location are involved when we hear sounds whose frequencies are between 500 and 1,000 Hz.

◆ *What two major theories attempt to explain hearing?*

#### ◆ **place theory**

The theory of hearing that holds that each individual pitch a person hears is determined by the particular location along the basilar membrane of the cochlea that vibrates the most.

#### ◆ **frequency theory**

The theory of hearing that holds that hair cell receptors vibrate the same number of times per second as the sounds that reach them.

# Smell and Taste

Clearly, our sensory experiences would be extremely limited without vision and hearing, but what about the chemical senses—smell and taste?

◆ *What path does a smell message take from the nose to the brain?*

◆ **olfaction**  
(ol-FAK-shun) The sense of smell.

◆ **olfactory epithelium**  
Two 1-square-inch patches of tissue, one at the top of each nasal cavity, which together contain about 10 million olfactory neurons, the receptors for smell.

◆ **olfactory bulbs**  
Two matchstick-sized structures above the nasal cavities, where smell sensations first register in the brain.

## Smell

If you suddenly lost your capacity for **olfaction** (sense of smell), you might think, “This isn’t so bad. I can’t smell flowers or food, but, on the other hand, I no longer have to endure the foul odors of life.” But your *olfactory system*—the technical name for the organs and brain structures involved in the sense of smell—aids your survival. You smell smoke and can escape before the flames of a fire envelop you. Your nose broadcasts an odor alarm to the brain when certain poisonous gases or noxious fumes are present. Smell, aided by taste, provides your line of defense against putting spoiled food or drink into your body. And, believe it or not, every single individual gives off a unique scent, which is genetically determined (Axel, 1995).

You cannot smell a substance unless some of its molecules vaporize—pass from a solid or liquid into a gaseous state. Heat speeds up the vaporization of molecules, which is why food that is cooking has a stronger and more distinct odor than uncooked food. When odor molecules vaporize, they become airborne and make their way up each nostril to the **olfactory epithelium**. The olfactory epithelium consists of two 1-square-inch patches of tissue, one at the top of each nasal cavity; together these patches contain about 10 million olfactory neurons, which are the receptor cells for smell. Each of these neurons contains only one of the 1,000 different types of odor receptors (Bargmann, 1996). Because humans are able to detect some 10,000 odors, each of the 1,000 types of odor receptors must be able to respond to more than one kind of odor molecule. Moreover, some odor molecules trigger more than one type of odor receptor (Axel, 1995). The intensity of a smell stimulus—how strong or weak it is—is apparently determined by the number of olfactory neurons firing at the same time (Freeman, 1991). Figure 3.7 shows a diagram of the human olfactory system.

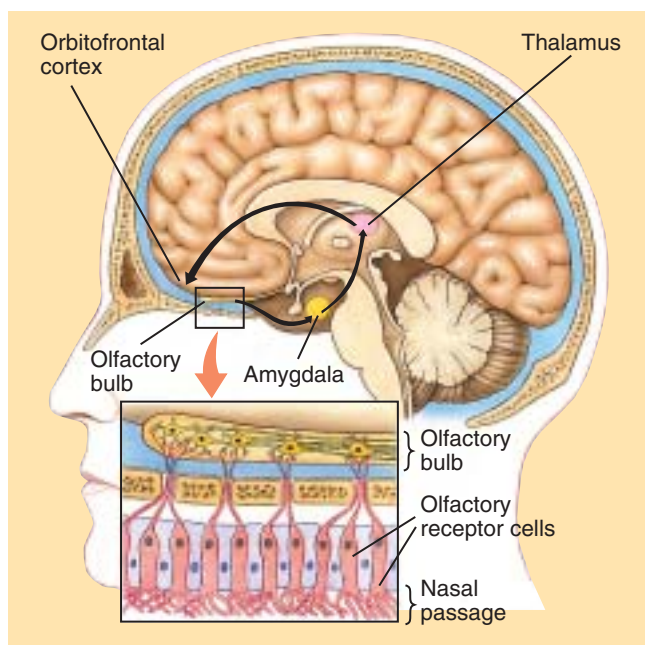
Have you ever wondered why dogs have a keener sense of smell than humans? Not only do many dogs have a long snout, but, in some breeds, the olfactory epithelium can be as large as the area of a handkerchief and can contain 20 times as many olfactory neurons as in humans (Engen, 1982). It is well known that dogs use scent to recognize not only other members of their species, but also the humans with whom they live. Humans have this ability, too. The mothers of newborns can recognize their own babies by smell within hours after birth. But can humans recognize the scents of other species—their own pets, for example? Yes, to a remarkable degree. When presented with blankets permeated with the scents of dogs, some 89% of the dog owners easily identified their own dog by smell (Wells & Hepper, 2000).

Olfactory neurons are different from all other sensory receptors: They both come into direct contact with sensory stimuli and reach directly into the brain. These neurons have a short lifespan; after functioning for only about 60 days, they die and are replaced by new cells (Buck, 1996).

The axons of the olfactory neurons relay a smell message directly to the **olfactory bulbs**—two brain structures the size of matchsticks that rest above the nasal cavities (refer to Figure 3.7). From the olfactory bulbs, the mes-

**FIGURE 3.7** The Olfactory System

Odor molecules travel up the nostrils to the olfactory epithelium, which contains the receptor cells for smell. Olfactory receptors are special neurons whose axons form the olfactory nerve. The olfactory nerve relays smell messages to the olfactory bulbs, which pass them on to the thalamus, the orbitofrontal cortex, and other parts of the brain.



sage is relayed to the thalamus and the orbitofrontal cortex, which distinguish the odor and relay that information to other parts of the brain.

The process of sensing odors is the same in every individual, but there are large differences in sensitivity to smells. For example, perfumers and whiskey blenders can distinguish subtle variations in odors that are indistinguishable to the average person. Young people are more sensitive to odors than older people, and nonsmokers are more sensitive than smokers (Matlin & Foley, 1997).

## Taste

You might be surprised to learn that much of the pleasure you attribute to the sense of taste actually arises from smells, when odor molecules are forced up the nasal cavity by the action of the tongue, cheeks, and throat when you chew and swallow. Even without a sense of taste, your sense of smell would provide you with some taste sensations. Still, life without the ability to fully experience the tastes of the foods we love would, no doubt, be less enjoyable.

Psychology textbooks have long maintained that **gustation**, the sense of taste, produces four distinct kinds of taste sensations: sweet, sour, salty, and bitter. This is true. But recent research suggests that there is a fifth taste sensation in humans (Herness, 2000). This fifth taste sensation, called *umami*, is triggered by the substance glutamate, which, in the form of monosodium glutamate (MSG), is widely used as a flavoring in Asian foods (Matsunami et al., 2000). Many protein-rich foods, such as meat, milk, aged cheese, and seafood, also contain glutamate.

All five taste sensations can be detected on all locations of the tongue. Indeed, even a person with no tongue could still taste to some extent, thanks to the taste receptors found in the palate, in the mucus lining of the cheeks and lips, and in parts of the throat, including the tonsils. When tastes are mixed, the specialized receptors for each type of flavor are activated and send separate messages to the brain (Frank et al., 2003). In other words, your brain perceives the two distinctive flavors present in sweet and sour sauce quite separately. This analytical quality of the sense of taste prevents your being fooled into eating spoiled or poisoned food when the characteristic taste of either is combined with some kind of pleasant flavor.

If you look at your tongue in a mirror, you will see many small bumps called *papillae*. **Taste buds** lie alongside some of these papillae (see Figure 3.8). Each taste bud is composed of 60 to 100 receptor cells. The lifespan of the taste receptors is very short—only about 10 days—and they are continually being replaced.

◆ *What are the primary taste sensations, and how are they detected?*

### ◆ **gustation**

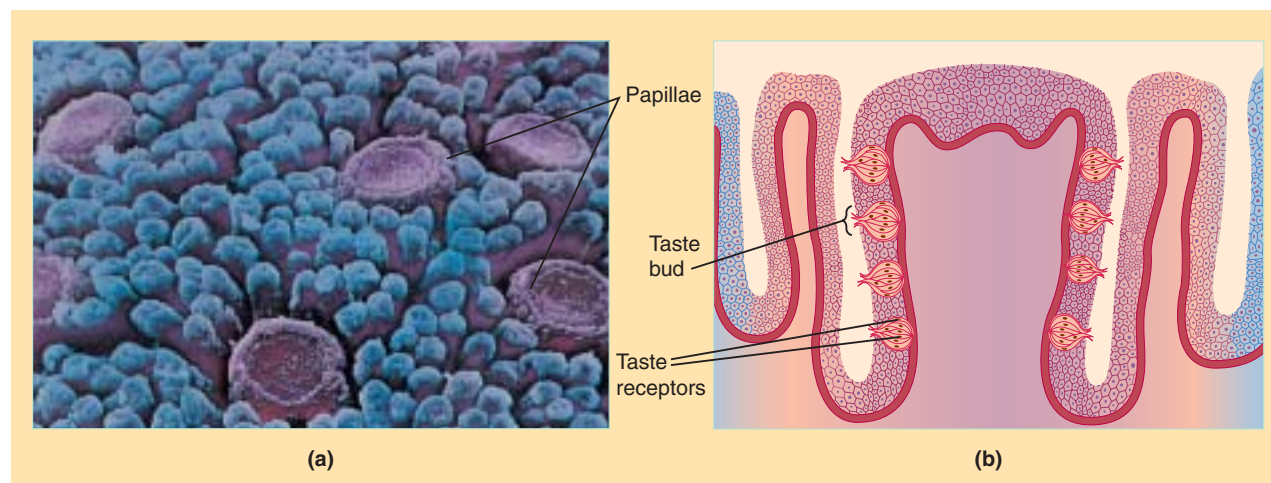
The sense of taste.

### ◆ **taste buds**

Structures in many of the tongue's papillae that are composed of 60 to 100 receptor cells for taste.

## FIGURE 3.8 The Tongue's Papillae and Taste Buds

(a) A photomicrograph of the surface of the tongue shows several papillae. (b) This vertical cross-section through a papilla reveals the location of the taste buds and taste receptors.



Research indicates that individuals vary widely in their capacity for experiencing taste sensations (Yackinous & Guinard, 2002). Nontasters are unable to taste certain sweet and bitter compounds, but they do taste most other substances, albeit with less sensitivity. Supertasters taste these sweet and bitter compounds with far stronger intensity than other people. Researchers are currently investigating links between taste sensitivity, eating behaviors, and health status variables, such as obesity. For example, supertasters who are particularly sensitive to the chemical that gives fruits and vegetables a bitter taste eat less salad than medium tasters and nontasters (Yackinous & Guinard, 2002). Still, supertasters appear no more likely to be overweight than medium tasters or nontasters. In fact, among individuals who report that they never deliberately restrict their diets to try to lose weight, supertasters of the bitter chemical have less body fat than medium tasters or nontasters (Tepper & Ullrich, 2002). So, researchers know that taste sensitivity is linked to food preferences, but not how these preferences may be connected to nutritional status.

## The Skin Senses

How important is the sense of touch? Classic research in the mid-1980s demonstrated that premature infants who were massaged for 15 minutes three times a day gained weight 47% faster than other premature infants who received only regular intensive care treatment (Field et al., 1986). The massaged infants were more responsive and were able to leave the hospital about 6 days earlier on average than those who were not massaged. Thus, the sense of touch is not only one of the more pleasant aspects of life, but is also critical to our survival. And it may be just as important to adult as to infant survival. For instance, you may feel a poisonous spider crawling up your arm and flick it away before it can inflict a deadly bite. The other skin sense—pain—is also vital because it serves as an early warning system for many potentially deadly conditions, as you’ll learn in this section.

### Touch

Your natural clothing, the skin, is the largest organ of your body. It performs many important biological functions, while also providing much of what is known as sensual pleasure. **Tactile** information is conveyed to the brain when an object touches and depresses the skin, stimulating one or more of the several distinct types of receptors found in the nerve endings. These sensitive nerve endings in the skin send the touch message through nerve connections to the spinal cord. The message travels up the spinal cord and through the brainstem and the midbrain, finally reaching the somatosensory cortex. (Recall from Chapter 2 that the somatosensory cortex is the strip of tissue at the front of the parietal lobes where touch, pressure, temperature, and pain register.) Once the somatosensory cortex has been activated, you become aware of where and how hard you have been touched. In the 1890s, one of the most prominent researchers of the tactile sense, Max von Frey, discovered the *two-point threshold*—the measure of how far apart two touch points on the skin must be before they are felt as two separate touches.

If you could examine the skin from the outermost to the deepest layer, you would find a variety of nerve endings that differ markedly in appearance. Most or all of these nerve endings appear to respond in some degree to all types of tactile stimulation. The more densely packed with these sensory receptors a part of the body’s surface is, the more sensitive it is to tactile stimulation.

### Pain

Although the tactile sense delivers a great deal of pleasure, it brings us pain as well. Scientists are not certain how pain works, but one major theory that attempts to answer

◆ How does the skin provide sensory information?

◆ **tactile**

Pertaining to the sense of touch.



this question is the *gate-control theory* of Ronald Melzack and Patrick Wall (1965, 1983). These researchers contend that an area in the spinal cord can act like a “gate” and either block pain messages or transmit them to the brain. Only so many messages can go through the gate at any one time. You feel pain when pain messages carried by small, slow-conducting nerve fibers reach the gate and cause it to open. Large, fast-conducting nerve fibers carry other sensory messages from the body; these can effectively tie up traffic at the gate so that it will close and keep many of the pain messages from getting through. What is the first thing you do when you stub your toe or pound your finger with a hammer? If you rub or apply gentle pressure to the injury, you are stimulating the large, fast-conducting nerve fibers, which get their message to the spinal gate first and block some of the pain messages from the slower-conducting nerve fibers. Applying ice, heat, or electrical stimulation to the painful area also stimulates the large nerve fibers and closes the spinal gate.

The gate-control theory also accounts for the fact that psychological factors, both cognitive and emotional, can influence the perception of pain. Melzack and Wall (1965, 1983) contend that messages from the brain to the spinal cord can inhibit the transmission of pain messages at the spinal gate, thereby affecting the perception of pain. This phenomenon explains why soldiers injured in battle or athletes injured during games can be so distracted that they do not experience pain until some time after the injury.

As you learned in Chapter 2, the body produces its own natural painkillers, the **endorphins**, which block pain and produce a feeling of well-being. Endorphins are released when you are injured, when you experience stress or extreme pain, and when you laugh, cry, or exercise. Some people release endorphins even when they merely *think* they are receiving pain medication but are being given, instead, a placebo in the form of a sugar pill or an injection of saline solution. Asthma, high blood pressure, and even heart disease can respond to placebo “treatment” (Brown, 1998). Why? Apparently, when patients believe that they have received a drug for pain, that belief stimulates the release of their own natural pain relievers, the endorphins.

Finally, the proportion of people who suffer from chronic pain, or pain that lasts for three months or longer, varies across cultures. Why? Researchers don’t have a definitive answer. However, they do know that the experience of pain has both physical and emotional components, both of which vary from person to person. Pain experts distinguish between pain and suffering—suffering being the affective, or emotional, response to pain. Sullivan and others (1995) found that people suffered most from pain when they harbored negative thoughts about it, feared its potential threat to their well-being, and expressed feelings of helplessness. Thus, cross-cultural variations in chronic pain may be linked to differences in people’s emotional states.

◆ *What is the function of pain, and how is pain influenced by psychological factors, culture, and endorphins?*

◆ **endorphins**

(en-DOR-fins) The body’s own natural painkillers, which block pain and produce a feeling of well-being.

## The Spatial Orientation Senses

The senses you’ve learned about so far provide you with valuable information about your environment. But how would you keep from falling if you couldn’t sense whether you were standing up straight or leaning to one side? Fortunately, the kinesthetic and vestibular senses keep you apprised of exactly where all parts of your body are and how the location of your body is related to your physical environment.

The **kinesthetic sense** provides information about (1) the position of body parts in relation to each other and (2) the movement of the entire body or its parts. This information is detected by receptors in the joints, ligaments, and muscles. The other senses, especially vision, provide additional information about body position and movement, but the kinesthetic sense works well on its own. Thanks to the kinesthetic sense, we are able to perform smooth and skilled body movements without visual feedback or a studied, conscious effort. (But why do we perceive ourselves as stationary in a moving car? More on this later in the chapter.)

◆ *What kinds of information do the kinesthetic and vestibular senses provide?*

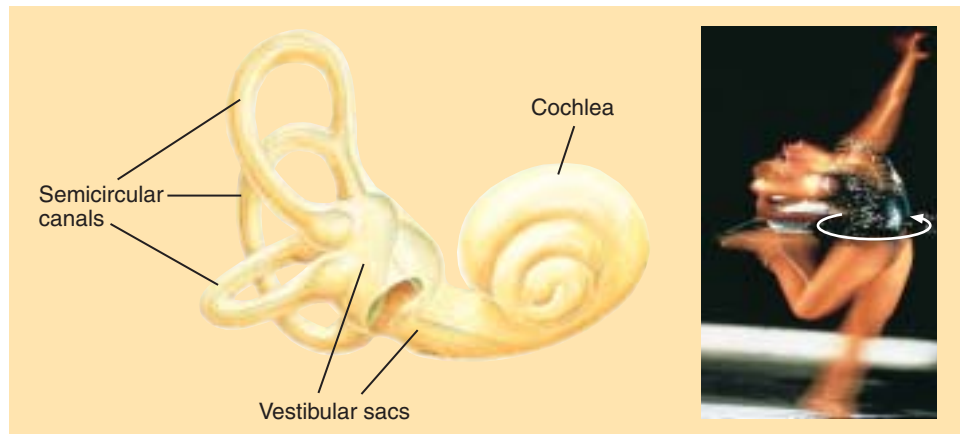
◆ **kinesthetic sense**

The sense providing information about the position of body parts in relation to each other and the movement of the entire body or its parts.

**FIGURE 3.9**

### Sensing Balance and Movement

You sense the rotation of your head in any direction because the movement sends fluid coursing through the tubelike semicircular canals in the inner ear. The moving fluid bends the hair cell receptors, which, in turn, send neural impulses to the brain.



The **vestibular sense** detects movement and provides information about the body's orientation in space. The vestibular sense organs are located in the semicircular canals and the *vestibular sacs* in the inner ear. The **semicircular canals** sense the rotation of your head, such as when you are turning your head from side to side or when you are spinning around (see Figure 3.9). Because the canals are filled with fluid, rotating movements of the head in any direction send the fluid coursing through the tubelike semicircular canals. In the canals, the moving fluid bends the hair cells, which act as receptors and send neural impulses to the brain. Because there are three canals, each positioned on a different plane, rotation in a given direction will cause the hair cells in one canal to bend more than the hair cells in the other canals.

The semicircular canals and the vestibular sacs signal only changes in motion or orientation. If you were blindfolded and had no visual or other external cues, you would not be able to sense motion once your speed reached a constant rate. For example, in an airplane, you would feel the takeoff and the landing, as well as any sudden changes in speed. But once the plane leveled off and maintained a fairly constant cruising speed, your vestibular organs would not signal the brain that you are moving, even if you were traveling at a rate of hundreds of miles per hour.

## Influences on Perception

So far, you have been reading about *sensation*, the process of taking in information from the outside world through the senses. We've discussed vision, hearing, smell, taste, touch, and the spatial orientation senses. However, we have yet to discuss *perception*, the process through which the brain assigns meaning to sensations. Sensation tells you that an apple is red on the outside and white on the inside. It tells you that the apple has a distinctive odor, taste, and texture. Sensation even provides you with the kinesthetic sense needed to toss an apple to your roommate. By contrast, perception enables you to link these sensations to the knowledge that apples are food, that you either like or dislike them, and that they have a variety of symbolic associations (e.g., "an apple for the teacher").

Perception is influenced by a number of factors. Before we discuss some of the principles that govern perception in all human beings, we will consider three factors that contribute to perceptual processes: attention, prior knowledge, and cross-modal perception.

### Attention

In some cases, linking sensations to meanings—the essence of the process of perception—requires very little mental effort. For instance, when reading familiar words, the sensation of seeing the word and the perception of its meaning occur almost simultaneously (Heil et al., 2004). Likewise, while we are driving, perceiving that the other objects on the road with us are cars takes very little mental effort because we are so

◆ **vestibular sense**

(ves-TIB-yu-ler) The sense that detects movement and provides information about the body's orientation in space.

◆ **semicircular canals**

Three fluid-filled tubular canals in the inner ear that sense the rotation of the head.



Daniel J. Simons

## How Did You Find Psychology?

Have you had trouble settling on a major? So did psychologist Daniel J. Simons, one of the leading researchers in the study of attention. In fact, Simons considered English, French, physics, and computer science as majors when he

was an undergraduate. However, when he took an introductory psychology course, Simons was “hooked” and finally settled on psychology as his field of study. A summer spent doing research with graduate students at the University of Minnesota convinced him that he wanted a career in teaching and research, and he moved on to graduate school as soon as he finished his bachelor’s degree.

At the beginning of his graduate career, Simons reports, he was interested in learning how infants acquire concepts (D. Simons, personal communication, November 23, 2004). This interest inspired him to examine perceptual processes in infants more closely. Along the way, he discovered that his greatest interest was in researching the basic processes of perception and attention in adults. When Simons determined that his interests would be bet-

ter served by transferring to Cornell University, he didn’t hesitate to make the change.

The theme that ties together Simons’s eclectic academic background and his current research is the joy of discovery. He points out that researchers, although they may have hypotheses in mind, never really know what new kinds of questions may arise out of a study. It is this element of the unexpected, he says, that continues to motivate him. Now, as a professor, he enjoys watching students develop the same kind of passion for discovery that motivates him.

One lesson that you might learn from Simons’s experience is that academic and career paths that may appear to outsiders to be somewhat disorganized can reflect some very positive personal characteristics. In other words, his love of the unexpected may be what shaped the paths Simons followed as an undergraduate and graduate student and ultimately guided him to the career that was right for him. Moreover, the same trait has been the impetus for his highly creative research on attention, research that has earned Simons numerous awards. Thus, if you are still stammering and equivocating when people ask “What’s your major?”, an answer of “I haven’t decided” may portend great things for your future.

familiar with them. In other words, connecting the sensation of seeing a car with the perception that the object is a car is an *automatic* (noneffortful) mental process. However, more mental effort is required to determine which cars we should watch most closely. When we engage in this kind of mental effort, the process of *attention* is at work. **Attention** is defined as the process of sorting through sensations and selecting some of them for further processing. Without attention, perception of all but the most familiar sensations would be impossible.

Of course, we cannot pay attention to everything at once. Thus, in a complex perceptual task, such as the everyday experience of driving in traffic, it’s important to realize that attention carries certain perceptual costs. Research examining the phenomenon of **inattention blindness** has helped to illustrate these costs (Mack, 2003; Mack & Rock, 1998; Most et al., 2001). Inattention blindness occurs when we shift our attention from one object to another and, in the process, fail to notice changes in objects to which we are not directly paying attention (Woodman & Luck, 2003). In many studies of inattention blindness, experimenters have presented participants with a scene and ask them to attend to a particular element in it. For example, Daniel Simons and colleagues (e.g., Simons & Chabris, 1999) showed participants a videotape of a basketball game in which one team wore white uniforms and the other team wore black uniforms. Participants were instructed to count how many times the ball was passed from one player to another, either on the white team or on the black team. Under such conditions, about one-third of participants typically failed to later recall the appearance on the screen of even extremely incongruent stimuli (for example, a man dressed in a gorilla costume). The inattention blindness happens even when the incongruous stimulus is present on the screen for a long period of time. Simons’s research helps us understand why we sometimes exclaim, “Where did that car come from?” when a car we had been ignoring suddenly swerves into our path.

◆ *What is gained and what is lost in the process of attention?*

### ◆ attention

The process of sorting through sensations and selecting some of them for further processing.

### ◆ inattention blindness

The phenomenon in which we shift our focus from one object to another and, in the process, fail to notice changes in objects to which we are not directly paying attention.

Similar costs arise when we attend to auditory sensations. Suppose you are standing in a crowded room in which a large number of conversations are going on simultaneously. What would happen if someone mentioned your name? Research shows that you would zero in on the conversation that included your name and ignore others. This *cocktail party phenomenon* was documented in classic research by E. C. Cherry (1953). Remember, perception is the process of attaching meaning to sensations—and what is more meaningful to a person than his or her own name? Thus, when you hear your name, you assume that whatever is to follow will be personally meaningful to you. The process of attending to the conversation that included your name, however, would prevent you from adequately perceiving other conversations. Thus, you might fail to pick up on other conversations that might have more meaning for you.

Attentional demands involving more than one sense can also lead to attention failures. Research by David Strayer and his colleagues (2003) showed that drivers (using a simulator, not actually driving a car) often failed to perceive vehicles braking directly in front of them while they were engaged in hands-free cellphone conversations. Moreover, participants engaged in cellphone conversations were less able than control participants to recognize other visual stimuli, such as billboards. Consequently, experts advise that you pull off the road when you want to talk on the phone. Furthermore, many communities are banning cellphone use by drivers for these reasons.

Although attending to a stimulus is clearly associated with deficits in the ability to attend to other stimuli, it is clearly not an all-or-nothing process. We can, and often do, process more than one stimulus at a time. Indeed, research shows that we are capable of accurately perceiving some sensations to which we do not pay direct attention. For example, in the same series of classic studies that led to the discovery of the cocktail party phenomenon, E. C. Cherry (1953) discovered that listeners who were presented with different verbal messages in either ear could remember the content of only the message to which the experimenter directed their attention (e.g., “Pay attention to the message in your left ear”). Nevertheless, they were able to remember many things about the unattended message, such as whether it had been delivered by a male or a female.

## Prior Knowledge

Think back to the example of attending to cars on the road while driving. How do we make judgments about which cars require most of our attention? To a great extent, our past driving experiences, or prior knowledge, help us make such decisions. Prior knowledge is helpful when interpreting the meanings of sensations, but it can lead to perceptual errors as well.

Suppose you were presented with the coded message XBDID FXI XIL. How would you go about deciphering the words? You might conclude that each word uses X to represent a letter, so X must stand for one of the more common letters in English, such as R. You might then insert R in the position of X to see if you could come up with something that makes sense. Such a strategy would involve **bottom-up processing**. This approach begins with the individual components of a stimulus that are detected by the sensory receptors. The information is then transmitted to areas in the brain where it is combined and assembled into patterns. The brain then uses prior knowledge to make inferences about these patterns. For instance, what is the next number in the sequence 2, 7, 12, 17? Your brain infers the pattern  $y = x + 5$  (where  $x$  is the number that immediately precedes  $y$ ) from the sequence and proposes that the next number is 22.

What if you noticed that the second and third words in XBDID FXI XIL have two letters in common and are both three letters long and then compared them to real three-letter words in English that share two letters? You would then be using **top-down processing**. In top-down processing, previous experience and conceptual knowledge are applied to recognize the nature of a “whole” and then logically deduce the individual components of that whole. Of course, we use both bottom-up and top-down processing to form perceptions. Either approach, or a combination of the two, eventually leads to the conclusion that the words in the coded message are ROSES ARE RED.

◆ How does prior knowledge influence perception?

### ◆ bottom-up processing

Information processing in which individual components of a stimulus are combined in the brain and prior knowledge is used to make inferences about these patterns.

### ◆ top-down processing

Information processing in which previous experience and conceptual knowledge are applied to recognize the nature of a “whole” and then logically deduce the individual components of that whole.

Prior knowledge also contributes to perception by leading us to expect certain perceptions. For example, if you ordered raspberry sherbet and it was colored green, would it still taste like raspberry, or might it taste more like lime? The **perceptual set**—what we expect to perceive—determines, to a large extent, what we actually see, hear, feel, taste, and smell. Such expectations are, of course, based on prior knowledge (that lime sherbet is usually green and green meat is usually spoiled). Such expectations do seem to influence perception. So, green raspberry sherbet might, indeed, taste a bit like lime.

In a classic study of perceptual set, psychologist David Rosenhan (1973) and some of his colleagues were admitted as patients to various mental hospitals with “diagnoses” of schizophrenia. Once admitted, they acted normal in every way. The purpose? They wondered how long it would take the doctors and the hospital staff to realize that they were not mentally ill. But the doctors and the staff members saw what they expected to see and not what actually occurred. They perceived everything the pseudo-patients said and did, such as note taking, to be symptoms of their illness. But the real patients were not fooled; they were the first to realize that the psychologists were not really mentally ill.

## Cross-Modal Perception

Earlier in the chapter, you learned that motion perception involves both the visual and the kinesthetic senses. In fact, many complex perceptual tasks require the brain to integrate information from more than one sense, a process called **cross-modal perception**. Experiments in which participants are exposed to conflicting visual and auditory information have shown that cross-modal perception is strongly dependent on the availability of accurate sensory information.

You have participated in a cross-modal perception “experiment” if you have ever seen a movie in which the actors’ lip movements didn’t match their spoken language. Research shows that it is very difficult to understand speech under such conditions (Thomas & Jordan, 2004). In effect, we must block out the visual information to understand what the speakers are saying. The opposite happens when facial expressions and vocal characteristics seem to be conveying different emotional messages. When a person looks angry but speaks in a happy voice, the visual information is typically judged to be more reliable than the auditory input (Vroomen et al., 2001).

◆ *How does information from multiple sources aid perception?*

### ◆ perceptual set

An expectation of what will be perceived, which can affect what actually is perceived.

### ◆ cross-modal perception

A process whereby the brain integrates information from more than one sense.

## Principles of Perception

Some influences on perception—particularly the application of prior knowledge to perceptual tasks—can lead to wide variations in how a stimulus is perceived. However, researchers have found a few principles that appear to govern perceptions in all human beings.

## Perceptual Organization and Constancy

**Gestalt Principles of Perceptual Organization** The Gestalt psychologists maintained that people cannot understand the perceptual world by breaking down experiences into tiny parts and analyzing them separately. When sensory elements are brought together, something new is formed. That is, the whole is more than just the sum of its parts. The German word **Gestalt** has no exact English equivalent, but it roughly refers to the whole form, pattern, or configuration that a person perceives. The Gestalt psychologists claimed that sensory experience is organized according to certain basic principles of perceptual organization:

◆ *What are the principles that govern perceptual organization?*

- **Figure-ground.** As we view the world, some object (the figure) often seems to stand out from the background (the ground) (see Figure 3.10 on page 98).
- **Similarity.** Objects that have similar characteristics are perceived as a unit. In Figure 3.11(a), dots of a similar color are perceived as belonging together to form horizontal rows on the left and vertical columns on the right.

### ◆ Gestalt

(geh-SHTALT) A German word that roughly refers to the whole form, pattern, or configuration that a person perceives.

**FIGURE 3.10**

### Reversing Figure and Ground

In this illustration, you can see a white vase as a figure against a black background, or two black faces in profile on a white background. Exactly the same visual stimulus produces two opposite figure-ground perceptions.



**FIGURE 3.11** Gestalt Principles of Grouping

Gestalt psychologists proposed several principles of perceptual grouping, including similarity, proximity, continuity, and closure.



#### ◆ perceptual constancy

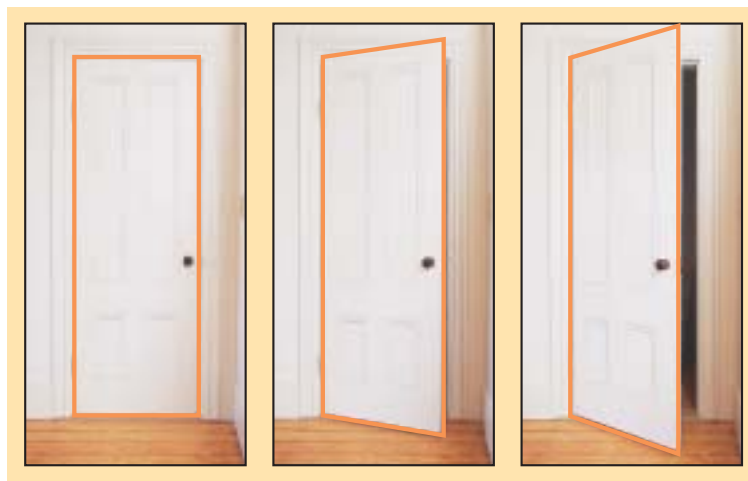
The phenomenon that allows us to perceive objects as maintaining stable properties, such as size, shape, and brightness, despite differences in distance, viewing angle, and lighting.

- *Proximity*. Objects that are close together in space or time are usually perceived as belonging together. Because of their spacing, the lines in Figure 3.11(b) are perceived as four pairs of lines rather than as eight separate lines.
- *Continuity*. We tend to perceive figures or objects as belonging together if they appear to form a continuous pattern, as in Figure 3.11(c).
- *Closure*. We perceive figures with gaps in them to be complete. Even though parts of the figure in Figure 3.11(d) are missing, we use closure and perceive it as a triangle.

**FIGURE 3.12**

### Shape Constancy

The door projects very different images on the retina when viewed from different angles. But because of shape constancy, you continue to perceive the door as rectangular.



**Perceptual Constancy** When you say good-bye to friends and watch them walk away, the image they cast on your retina grows smaller and smaller until they finally disappear in the distance. So how does your brain know that they are still the same size? Scientists call this phenomenon **perceptual constancy**. Thanks to perceptual constancy, when you watch someone walk away, the information that the retina sends to the brain (the sensation that that person is shrinking in size) does not fool the perceptual system. As objects or people move farther away, you continue to perceive them as being about the same size. This perceptual phenomenon is known as *size constancy*.

You do not make a literal interpretation about the size of an object from its retinal image—the image of the object projected onto the retina. If you did, you would believe that objects become larger as they approach and smaller as they move away.

The shape or image of an object projected onto the retina changes according to the angle from which it is viewed. But your perceptual ability includes *shape constancy*—the tendency to perceive objects as having a stable or unchanging shape, regardless of changes in the retinal image resulting from differences in viewing angle. In other words, you perceive a door as rectangular and a plate as round from whatever angle you view them (see Figure 3.12).

We normally see objects as maintaining a constant level of brightness, regardless of differences in lighting conditions—a perceptual phenomenon known as *brightness constancy*. Nearly all objects reflect some part of the light that falls on them, and white objects reflect more light than black objects. However, a black asphalt driveway at noon in bright sunlight actually reflects more light than a white shirt does indoors at night in dim lighting. Nevertheless, the driveway still looks black, and the shirt still looks white. Why? We learn to infer the brightness of objects by comparing it with the brightness of all other objects viewed at the same time.

## Depth Perception

**Depth perception** is the ability to perceive the visual world in three dimensions and to judge distances accurately. We judge how far away objects and other people are. We climb and descend stairs without stumbling and perform numerous other actions requiring depth perception. Depth perception is three-dimensional. Yet each eye is able to provide only a two-dimensional view. The images cast on the retina do not contain depth; they are flat, just like a photograph. How, then, do we perceive depth so vividly?

**Binocular Depth Cues** Some cues to depth perception depend on both eyes working together. These **binocular depth cues** include convergence and binocular disparity. *Convergence* occurs when the eyes turn inward to focus on nearby objects—the closer the object, the more the two objects appear to come together. Hold the tip of your finger about 12 inches in front of your nose, and focus on it. Now, slowly begin moving your finger toward your nose. Your eyes will turn inward so much that they virtually cross when the tip of your finger meets the tip of your nose. Many psychologists believe that the tension of the eye muscles as they converge conveys to the brain information that serves as a cue for depth perception. Fortunately, the eyes are just far enough apart, about 2½ inches or so, to give each eye a slightly different view of the objects being focused on and, consequently, a slightly different retinal image. The difference between the two retinal images, known as *binocular disparity* (or *retinal disparity*), provides an important cue for depth perception (see Figure 3.13). The farther away from the eyes (up to 20 feet or so) the objects being viewed, the less the disparity, or difference, between the two retinal images. The brain integrates the two slightly different retinal images and creates the perception of three dimensions.

**Monocular Depth Cues** Close one eye, and you will see that you can still perceive depth. The visual depth cues perceived with one eye alone are called **monocular depth cues**. The following is a description of seven monocular depth cues, many of which have been used by artists in Western cultures to give the illusion of depth to their paintings.

- *Interposition*. When one object partly blocks your view of another, you perceive the partially blocked object as being farther away.
- *Linear perspective*. Parallel lines that are known to be the same distance apart appear to grow closer together, or converge, as they recede into the distance.
- *Relative size*. Larger objects are perceived as being closer to the viewer, and smaller objects as being farther away.

### ◆ depth perception

The ability to perceive the visual world in three dimensions and to judge distances accurately.

### ◆ binocular depth cues

Depth cues that depend on both eyes working together.

### ◆ monocular depth cues

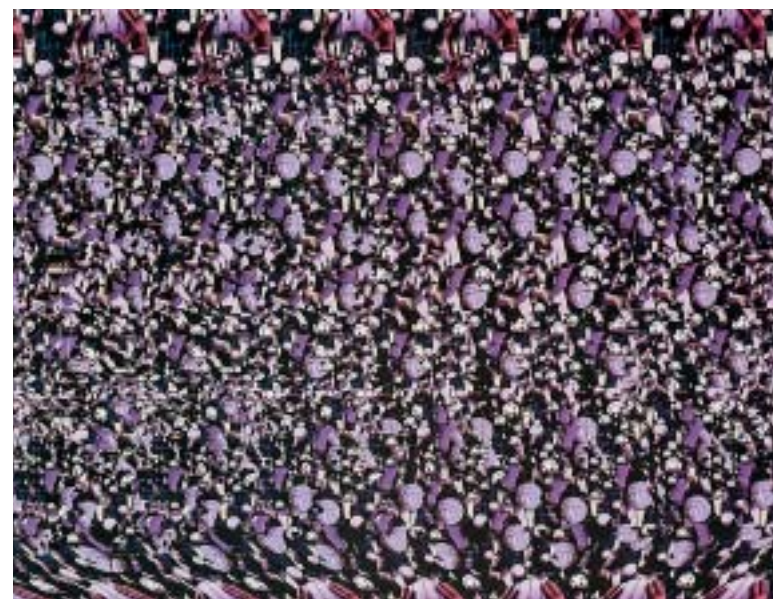
(mah-NOK-yu-ler) Depth cues that can be perceived by one eye alone.

◆ What are some of the binocular and monocular depth cues?

FIGURE 3.13

### Retinal Disparity and Viewing a Stereogram

Retinal disparity enables most of us to perceive 3-D images in stereograms. Place this picture against the tip of your nose and then very, very slowly move the book straight back from your face. Look at the image without blinking. A 3-D picture of soccer players and their fans will suddenly appear.



- *Texture gradient.* Objects close to you appear to have sharply defined features, and similar objects that are farther away appear progressively less well defined or fuzzier in texture.
- *Atmospheric perspective* (sometimes called *aerial perspective*). Objects in the distance have a bluish tint and appear more blurred than objects close at hand.
- *Shadow or shading.* When light falls on objects, they cast shadows, which add to the perception of depth.
- *Motion parallax.* When you ride in a moving vehicle and look out the side window, the objects you see outside appear to be moving in the opposite direction and at different speeds; those closest to you appear to be moving faster than those in the distance. Objects very far away, such as the moon and the sun, appear to move in the same direction as the viewer. Photos illustrating each of these cues are shown in Figure 3.14.

## Perception of Motion

Imagine you're sitting in a bus looking through the window at another bus parked parallel to the one in which you are sitting. Suddenly, you sense your bus moving; then, you realize that it is not your bus that moved but the one next to it. In other words, your ability to perceive the motion of objects has been fooled in some way. This example illustrates the complexity of motion perception.

◆ How does the brain perceive motion?

One of the most important contributors to our understanding of motion perception is psychologist James Gibson. Gibson points out that our perceptions of motion appear to be based on fundamental, but frequently changing, assumptions about stability (Gibson, 1994). Our brains seem to search for some stimulus in the environment to serve as the assumed reference point for stability. Once the stable reference point is chosen, all objects that move relative to that reference point are judged to be in motion. For example, in the bus situation, your brain assumes that the other bus is stable, and when the motion sensors linked to your retina detect movement, it concludes that your bus is moving. And when you're driving a car, you sense the car to be in motion relative to the outside environment. But your brain uses the inside of the car as the stable point of reference for your own movements. Only your movements in relation to the seat, steering wheel, and so on are sensed as motion by your brain.

The fact that the eyes are never really completely still also contributes to perceptions of motion. For instance, if you stare at a single unmoving light in a dark room for a few seconds, the light will appear to begin moving, a phenomenon called the *autokinetic illusion*. If you look away from the light and then return to watching it, it will again appear to be stable. (Could this phenomenon account for some sightings of “unidentified flying objects”?) Two lights placed close to each other will appear to move together, as if they are linked by an invisible string. What is really happening is that your eyes, not the lights, are moving. Because of the darkness of the room, the brain has no stable visual reference point to use in deciding whether the lights are actually moving (Gibson, 1994). But when the room is lit up, the brain immediately “fixes” the error because it has a stable visible background for the lights.

In one kind of study of false-motion perceptions, several stationary lights in a dark room are flashed on and off in sequence, causing participants to perceive a single light moving from one spot to the next. This type of illusion, called the *phi phenomenon* (sometimes called *stroboscopic motion*), was first discussed by Max Wertheimer (1912), one of the founders of Gestalt psychology. You encounter one of the most common examples of the phi phenomenon whenever you go to the movies. As you probably know, movies are simply a series of still photographs shown in rapid succession.

## Puzzling Perceptions

Not only can we perceive motion that doesn't exist, but we can also perceive objects that aren't present in a stimulus and misinterpret those that are.

**Ambiguous and Impossible Figures** When you are faced for the first time with an *ambiguous figure*, you have no experience to call on. Your perceptual system is puzzled



**FIGURE 3.14** Monocular Depth Cues



and tries resolve the uncertainty by seeing the ambiguous figure first one way and then another, but not both ways at once. You never get a lasting impression of ambiguous figures because they seem to jump back and forth beyond your control. In some ambiguous figures, two different objects or figures are seen alternately. The best known of these, “Old Woman/Young Woman,” by E. G. Boring, is shown in Figure 3.15(a) on page 102. If you direct your gaze to the left of the drawing, you are likely to see an attractive young woman, her face turned away. But the young woman disappears when you suddenly perceive the image of the old woman. Such examples of object ambiguity offer striking evidence that perceptions are more than the mere sum of sensory parts. It is hard to believe that the same drawing (the same sum of sensory parts) can convey such dramatically different perceptions.

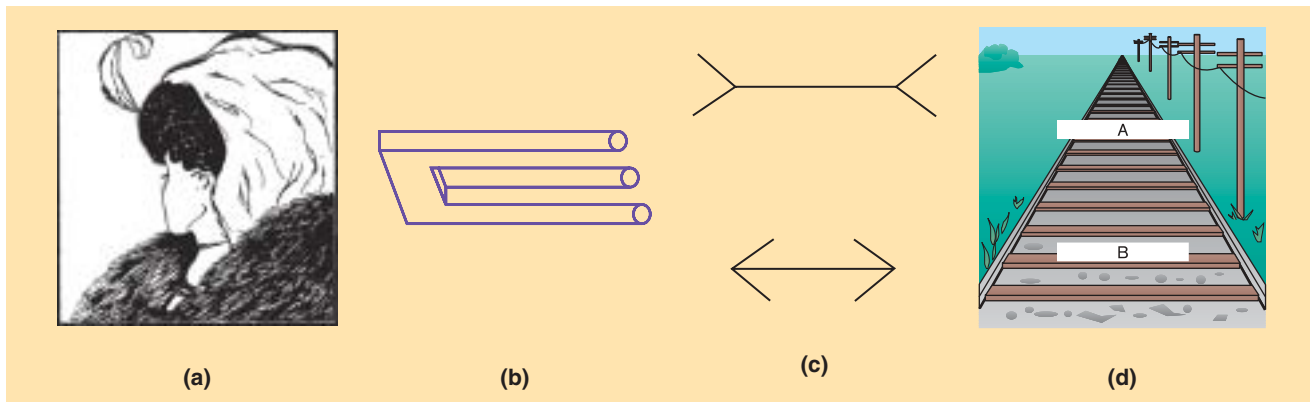
At first glance, many impossible figures do not seem particularly unusual—at least not until you examine them more closely. Would you invest your money in a company that manufactured the three-pronged device shown in Figure 3.15(b)? Such an object could not be made as pictured because the middle prong appears to be in two different places at the same time. However, this type of impossible figure is more likely to confuse people from Western cultures. Classic research in the 1970s showed that people in some African cultures do not represent three-dimensional visual space in their art, and they do not perceive depth in drawings that contain pictorial depth cues. These people see no ambiguity in drawings similar to the three-pronged trident, and they can

◆ What are three types of puzzling perceptions?

### FIGURE 3.15 Some Puzzling Perceptions

(a) Do you see an old woman or a young woman? (b) Why couldn't you build a replica of this three-pronged device? (c) Which horizontal line appears to be longer? (d) Which bar, A or B, is longer?

Source: "Old Woman/Young Woman" by E. G. Boring.



draw the figure accurately from memory much more easily than people from Western cultures can (Bloomer, 1976).

**Illusions** An **illusion** is a false perception or a misperception of an actual stimulus in the environment. We can misperceive size, shape, or the relationship of one element to another. We need not pay to see illusions performed by magicians. Illusions occur naturally, and we see them all the time. An oar in the water appears to be bent where it meets the water. The moon looks much larger at the horizon than it does overhead. Why? One explanation of the *moon illusion* involves relative size. This idea suggests that the moon looks very large on the horizon because it is viewed in comparison to trees, buildings, and other objects. When viewed overhead, the moon cannot be directly compared with other objects, and it appears smaller.

In Figure 3.15(c), the two lines are the same length, but the diagonals extending outward from both ends of the upper line make it look longer than the lower line, which has diagonals pointing inward, a phenomenon known as the *Müller-Lyer illusion*. The *Ponzo illusion* also plays an interesting trick on our estimation of size. Look at Figure 3.15(d) Contrary to your perceptions, bars A and B are the same length. Again, perceptions of size and distance, which we trust and which are normally accurate in informing us about the real world, can be wrong. If you saw two obstructions like the ones in the illusion on real railroad tracks, the one that looks larger would indeed be larger. So the Ponzo illusion is not a natural illusion but a contrived one. In fact, all these illusions are really misapplications of principles that nearly always work properly in normal everyday experience.

#### ◆ illusion

A false perception or a misperception of an actual stimulus in the environment.



Some visual illusions seem to be culture-dependent. For example, Zulus and people from other cultures in which the houses lack straight sides and corners do not perceive the Müller-Lyer illusion.

#### Cultural Differences in the Perception of Visual Illusions

Because responses to a number of illusions are universal, many psychologists believe they are inborn. However, British psychologist R. L. Gregory believed that susceptibility to the Müller-Lyer and other such illusions is not innate. Rather, the culture in which people live is responsible to some extent for the illusions they perceive. To test whether susceptibility to the Müller-Lyer and similar illusions is due to experience, Segall and others (1966) tested 1,848 adults and children from 15 different cultures in Africa, the Philippines, and the United States. Included were a group of Zulus from South Africa and a group of Illinois residents. The study revealed that “there were marked differences in illusion susceptibility across the cultural groups included in this study” (Segall, 1994, p. 137). People from all the cultures showed some tendency to perceive the

Müller-Lyer illusion, indicating a biological component, but experience was clearly a factor. Zulus, who have round houses and see few corners of any kind, are not fooled by this illusion. Illinois residents saw the illusion readily, while the Zulu tribespeople tended not to see it.

In another classic cross-cultural study of illusions, Pedersen and Wheeler (1983) studied perceptions of the Müller-Lyer illusion among two groups of Navajos. The group who lived in rectangular houses and had experienced corners, angles, and edges tended to see the illusion. The members of the other group, like the Zulus, tended not to see it because their cultural experience consisted of round houses.

## Unusual Perceptual Experiences

At the beginning of the chapter, you read about **synesthesia**, the capacity for responding to stimuli with both unusual perceptions and typical ones. As noted earlier, brain-imaging studies have demonstrated that synesthesia is a very real phenomenon, but what about other kinds of unusual perceptual experiences?

### Subliminal Perception

Recall that synesthesia involves perception without sensation. For decades, psychologists have studied a similar phenomenon known as **subliminal perception**, the capacity to perceive and respond to stimuli that are presented below the threshold of awareness. Neuroimaging studies show that the brain does, indeed, respond physiologically to subliminally presented stimuli (Brown, 2004; Bernat et al., 2001). Moreover, subliminal information can influence behavior to some degree. For example, when people are subliminally exposed to a picture of one person hitting another, they are more likely to judge a consciously perceived neutral scene, such as two people talking in a restaurant, as involving some kind of aggression (Todorov & Bargh, 2002).

But how strongly does subliminal perception affect behavior? You might remember the infamous “rats” commercial that the Republican party ran during the 2000 presidential campaign, in which the word *bureaucrats* was reduced to *rats* for about  $\frac{1}{30}$  of a second. Democrats accused Republicans of attempting to subliminally influence voters against Albert Gore, the Democratic party candidate. The use of messages presented below the threshold of awareness in advertising, often called *subliminal persuasion*, has been around for decades. However, most research on subliminal perception suggests that, although the phenomenon does exist, it probably cannot produce the kinds of behavior changes claimed by the proponents of its use for advertising purposes (Greenwald, 1992).

Similarly, people who want to lose weight may purchase audiotapes containing subliminal messages such as “I will eat less” embedded in recordings of music or ocean waves in the hopes that listening to the tapes will help them control their appetite. Recordings of this kind are also marketed to people who want to quit smoking. However, experimental, placebo-controlled studies have found that such subliminal messages have no effect on behavior (Greenwald, 1992; Greenwald et al., 1991; Russell et al., 1991).

### Extrasensory Perception

**Extrasensory perception (ESP)** is defined as gaining information about objects, events, or another person’s thoughts through some means other than the known sensory channels. Several different kinds of ESP have been proposed to exist. *Telepathy* means gaining awareness of the thoughts, feelings, or activities of another person without the use of the senses—in other words, reading a person’s mind. *Clairvoyance* means gaining information about objects or events without use of the senses, such as knowing the contents of a letter before opening it. *Precognition* refers to an awareness of an event before it occurs. Most of the reported cases of precognition in everyday life have occurred while people were dreaming.

◆ In what ways does subliminal perception influence behavior?

#### ◆ **synesthesia**

The capacity for responding to stimuli simultaneously with normal and unusual perceptions

#### ◆ **subliminal perception**

The capacity to perceive and respond to stimuli that are presented below the threshold of awareness.

#### ◆ **extrasensory perception (ESP)**

Gaining information about objects, events, or another person’s thoughts through some means other than the known sensory channels.

◆ *What have studies of ESP shown?*

Many studies of ESP employ the *Ganzfeld procedure*, a study design in which two individuals, a “sender” and a “receiver,” are placed in separate rooms. The rooms are specially designed to minimize distractions and to facilitate deep concentration. Experimenters provide senders with messages that they are supposed to attempt to transmit to receivers. Some studies using the Ganzfeld technique have suggested that ESP exists and that some people are more capable of sending and receiving extrasensory messages than others (Bem & Honorton, 1994). However, in almost all cases, attempts at replication of these studies have failed (Milton & Wiseman, 2001). Thus, most psychologists remain skeptical about the existence of ESP.

**Looking Back** We began and ended this chapter with an examination of some unusual kinds of perceptual experiences. In synesthesia, one kind of perception (e.g., visual) occurs in response to stimuli that normally elicit another kind of perception (e.g., auditory). Subliminal perception occurs in response to stimuli that we are unaware of having sensed. ESP, if it exists, involves perception in the absence of any sensory stimulus. While such phenomena are intriguing, navigating through our everyday sensory environments would be much more difficult without reliable connections among sensory stimuli, the process of sensation, and the process of perception that mark our more typical sensory and perceptual experiences.

## Apply It 3.1 Noise and Hearing Loss

Did you know that every individual has a fairly high risk of suffering from some kind of hearing loss? About one in every 1,000 infants in the United States is born with a hearing loss caused by birth injury or genetic defects (CDC, 2003). In addition, diseases and injuries can cause hearing loss in individuals of any age. *Conduction deafness* occurs when the eardrum or the bones of the middle ear are affected. Most such defects can be repaired medically or surgically. Likewise, there are effective treatments for *sensorineural hearing loss* in which the cochlea suffers damage (i.e., cochlear implant surgery). Congenital hearing losses and those that are caused by disease or injury are preventable only to the extent that the underlying causes are preventable. By contrast, hearing loss due to excessive noise is clearly preventable.

According to experts more than 75% of the cases of hearing loss in older adults are caused by exposure to loud noises (Kalb, 1997). Moreover, cross-cultural research comparing elders in noisy and non-noisy cultural environments supports this conclusion. In one such study, 80-year-old individuals from a rural tribe in the Sudan in Africa scored as well on a hearing test as 20-year-old individuals from industrialized countries (Bennett, 1990).

How much noise does it take to damage hearing? According to the Environmental Protection Agency, just 3 minutes of exposure to sounds above 100 decibels can cause permanent hearing loss (Noise Pollution Council, 2003). Moreover, there are many sources



**Members of some Sudanese tribes play stinged instruments rather quietly during celebrations. Perhaps because they are not exposed to much noise, these people generally have very sharp hearing.**

of excessive noise in our everyday environments.

### Noisy Toys

Experts warn that children who play with toy weapons may be at risk for temporary or permanent hearing loss. In an eye-opening classic

## Apply It 3.1 *(continued)*

study, researchers Axelsson and Jerison (1985) tested seven squeaking toys that, at a distance of 10 centimeters, emitted sound levels loud enough to put toddlers at risk for hearing loss at only 2 minutes of daily exposure. These researchers' tests of various toy weapons also found that all exceeded the 130-decibel peak level that is considered the upper limit for exposure to brief explosive sounds if hearing loss is to be avoided.

### Fireworks

Firecrackers and other popular fireworks items pose a significant hearing hazard if they explode close enough to the ear. In one study, a number of firecrackers were tested at 3 meters, and sound levels were found to range from 130 decibels to a highly dangerous 190 decibels (Gupta & Vishwakarma, 1989).

### Amplified Music

Individuals who routinely crank up the volume on their CD players to full blast expose themselves to potentially damaging sounds every day, often with little or no awareness of the threat posed to hearing. Moreover, this blast of high-decibel sound is often delivered to the inner ear at very close range through headphones or "earbuds."

And the decibel levels common at rock concerts can damage hearing very rapidly. For example, rock musician Kathy Peck lost 40% of her hearing in a single evening after her band opened a stadium concert. In 1986, the rock group The Who entered the *Guinness Book of World Records* as the loudest rock band on record, blasting out deafening sound intensities that measured 120 decibels at a distance of 164 feet from the speakers. Unless their ears were protected, audience members within that 164-foot radius probably suffered some irreversible hearing loss. And the band members? Pete Townsend of The Who has severely damaged hearing and, in addition, is plagued by *tinnitus*, an annoying condition that causes him to experience continuous ringing in the ears.

### Power Tools

Many types of power tools emit sufficient noise to damage hearing. Experts claim that exposure to a lawn mower, for example (a noise level of about 90 decibels), for more than 8 hours in a 24-hour period can damage hearing. For every increase of 5 decibels, maximum exposure time to the tool should be cut in half: 4 hours for 95 deci-

bels, 2 hours for 100 decibels, and 1 hour for 105 decibels.

### Protect Yourself from Hearing Loss

How can you protect yourself from the effects of noise?

- If you must be exposed to loud noise, use earplugs (not the kind used for swimming) or earmuffs to reduce noise, or put your fingers in your ears. Leave the scene as soon as possible.
- If you must engage in an extremely noisy activity, such as cutting wood with a chain saw, limit periods of exposure so that stunned hair cells can recover.
- Keep the volume down on your portable radio or CD player. If the volume control is numbered 1 to 10, a volume above 4 probably exceeds the federal standards for noise. If you have ringing or a tickling sensation in your ears after you remove your headset, or if sounds seem muffled, you could have sustained some hearing loss.

## Chapter 3 Summary

### ◆ The Process of Sensation p. 80

#### ◆ How is sensory information transmitted to the brain?

p. 81

Stimuli that cross the sensory thresholds are picked up by sensory receptors in the sense organs. Through the process of transduction, these receptors change sensory stimuli into neural impulses.

### ◆ Vision p. 82

#### ◆ How does each part of the eye function in vision? p. 82

The cornea bends light rays inward through the pupil—the small, dark opening in the eye. The iris dilates and contracts the pupil to regulate the amount of light entering the eye. The lens changes its shape as it focuses images of objects at varying distances on the retina, a thin layer of tissue

that contains the sensory receptors for vision. The cones detect color and fine detail; they function best in adequate light. The rods are extremely sensitive and enable vision in dim light.

#### ◆ What path does visual information take from the retina to the primary visual cortex? p. 84

The rods and the cones transduce light waves into neural impulses that pass from the bipolar cells to the ganglion

cells, whose axons form the optic nerve beyond the retinal wall of each eye. At the optic chiasm, the two optic nerves come together, and some of the nerve fibers from each eye cross to the opposite side of the brain. They synapse with neurons in the thalamus, which transmit the neural impulses to the primary visual cortex.

◆ **How do we detect the difference between one color and another?**  
p. 84

The perception of color results from the reflection of particular wavelengths of the visual spectrum from the surfaces of objects.

◆ **What two major theories attempt to explain color vision?**  
p. 85

Two major theories that attempt to explain color vision are the trichromatic theory and the opponent-process theory.

◆ **Hearing** p. 87

◆ **What determines the pitch and loudness of a sound, and how is each quality measured?** p. 87

The pitch of a sound is determined by the frequency of the sound waves. The loudness of a sound is determined largely by the amplitude of the sound waves.

◆ **How do the outer ear, middle ear, and inner ear function in hearing?** p. 88

Sound waves enter the pinna and travel to the end of the auditory canal, causing the eardrum to vibrate. This sets in motion the ossicles in the middle ear, which amplify the sound waves. The vibration of the oval window causes activity in the inner ear, setting in motion the fluid in the cochlea. The moving fluid pushes and pulls the hair cells attached to the thin basilar membrane, which transduce the vibrations into neural impulses. The auditory nerve then carries the neural impulses to the brain.

◆ **What two major theories attempt to explain hearing?**  
p. 89

Two major theories that attempt to explain hearing are place theory and frequency theory.

◆ **Smell and Taste** p. 90

◆ **What path does a smell message take from the nose to the brain?**  
p. 90

The act of smelling begins when odor molecules reach the smell receptors in the olfactory epithelium, at the top of the nasal cavity. The axons of these receptors relay the smell message to the olfactory bulbs. From there, the smell message travels to the thalamus and the orbitofrontal cortex, which distinguish the odor and relay that information to other parts of the brain.

◆ **What are the primary taste sensations, and how are they detected?** p. 91

The primary taste sensations are sweet, salty, sour, and bitter, along with a newly discovered one for glutamate, called umami. The receptor cells for taste are found in the taste buds on the tongue and in other parts of the mouth and throat.

◆ **The Skin Senses** p. 92

◆ **How does the skin provide sensory information?** p. 92

Sensitive nerve endings in the skin convey tactile information to the brain when an object touches and depresses the skin. The neural impulses for touch sensations ultimately register in the brain's somatosensory cortex.

◆ **What is the function of pain, and how is pain influenced by psychological factors, culture, and endorphins?** p. 93

Pain can be a valuable warning and a protective mechanism, motivating people to tend to an injury, to restrict activity, and to seek medical help. Negative thinking can influence the perception of pain. Some cultures encourage individuals to suppress

(or exaggerate) emotional reactions to pain. Endorphins are natural painkillers produced by the body, which block pain and produce a feeling of well-being.

◆ **The Spatial Orientation Senses** p. 93

◆ **What kinds of information do the kinesthetic and vestibular senses provide?** p. 93

The kinesthetic sense provides information about the position of body parts in relation to one another and movement of the entire body or its parts. This information is detected by sensory receptors in the joints, ligaments, and muscles. The vestibular sense detects movement and provides information about the body's orientation in space. Sensory receptors in the semicircular canals and the vestibular sacs sense changes in motion and the orientation of the head.

◆ **Influences on Perception** p. 94

◆ **What is gained and what is lost in the process of attention?**  
p. 95

Attention enables the brain to focus on some sensations while screening others out. Unattended stimuli may be missed altogether or incorrectly perceived.

◆ **How does prior knowledge influence perception?** p. 96

Individuals use bottom-up and top-down processing to apply prior knowledge to perceptual processes. Expectations based on prior knowledge may predispose people to perceive sensations in a particular way.

◆ **How does information from multiple sources aid perception?**  
p. 97

The brain integrates information from different senses to process complex stimuli such as speech and the movement of objects.

## ◆ Principles of Perception p. 97

### ◆ What are the principles that govern perceptual organization? p. 97

The Gestalt principles of perceptual organization include figure-ground, similarity, proximity, continuity, and closure. Perceptual constancy is the tendency to perceive objects as maintaining the same size, shape, and brightness, despite changes in lighting conditions or changes in the retinal image that result when an object is viewed from different angles and distances.

### ◆ What are some of the binocular and monocular depth cues? p. 99

Binocular depth cues include convergence and binocular disparity, which depend on both eyes working together for depth perception. Monocular depth cues, those that can be perceived by one eye, include interposition, linear perspective, relative size, texture gradient, atmospheric perspective, shadow or shading, and motion parallax.

### ◆ How does the brain perceive motion? p. 100

The brain perceives real motion by comparing the movement of images across the retina to information derived from the spatial orientation senses and to reference points it assumes to be stable.

### ◆ What are three types of puzzling perceptions? p. 100

Three types of puzzling perceptions are ambiguous figures, impossible figures, and illusions.

## ◆ Unusual Perceptual Experiences p. 103

### ◆ In what ways does subliminal perception influence behavior? p. 103

Subliminal perception has subtle influences on behavior but appears to be ineffective at persuading people to buy products or to vote in certain ways.

### ◆ What have studies of ESP shown? p. 104

Some studies of ESP have suggested that this type of perception exists, but researchers have not been able to replicate their results.

## ◆ KEY TERMS

absolute threshold, p. 80  
accommodation, p. 82  
afterimage, p. 86  
amplitude, p. 87  
attention, p. 95  
audition, p. 88  
binocular depth cues, p. 99  
blind spot, p. 84  
bottom-up processing, p. 96  
brightness, p. 85  
cochlea, p. 88  
color blindness, p. 86  
cones, p. 83  
cornea, p. 82  
cross-modal perception, 97  
decibel (dB), p. 87  
depth perception, p. 99  
difference threshold, p. 80  
endorphins, p. 93  
extrasensory perception, 103  
feature detectors, p. 84  
fovea, p. 83  
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frequency theory, p. 89  
Gestalt, p. 97  
gustation, p. 91  
hair cells, p. 88  
hue, p. 85  
illusion, p. 102  
inattentional blindness, p. 95  
inner ear, p. 88  
just noticeable difference (JND), p. 80  
kinesthetic sense, p. 93  
lens, p. 82  
middle ear, p. 88  
monocular depth cues, p. 99  
olfaction, p. 90  
olfactory bulbs, p. 90  
olfactory epithelium, p. 90  
opponent-process theory, p. 86  
optic nerve, p. 84  
outer ear, p. 88  
perception, p. 80  
perceptual constancy, p. 98

perceptual set, p. 97  
place theory, p. 89  
primary visual cortex, p. 84  
retina, p. 83  
rods, p. 83  
saturation, p. 85  
semicircular canals, p. 94  
sensation, p. 80  
sensory adaptation, p. 82  
sensory receptors, p. 81  
subliminal perception, p. 103  
synesthesia, p. 103  
tactile, p. 92  
taste buds, p. 91  
timbre, p. 87  
top-down processing, p. 96  
transduction, p. 82  
trichromatic theory, p. 85  
vestibular sense, p. 94  
visible spectrum, p. 82  
wavelength, p. 82  
Weber's law, p. 80

# Study Guide 3

Answers to all the Study Guide questions are provided at the end of the book.

## SECTION ONE: Chapter Review

- The process through which the senses detect sensory information and transmit it to the brain is called (sensation, perception).
- The point at which you can barely sense a stimulus 50% of the time is called the (absolute, difference) threshold.
- The difference threshold is the same for all individuals. (true/false)
- Which of the following is not true of sensory receptors?
  - They are specialized to detect certain sensory stimuli.
  - They transduce sensory stimuli into neural impulses.
  - They are located in the brain.
  - They provide the link between the physical sensory world and the brain.
- The process by which a sensory stimulus is converted into a neural impulse is called \_\_\_\_\_.
- Each morning when Jackie goes to work at a dry cleaner, she smells a strong odor of cleaning fluid. After she is there for a few minutes, she is no longer aware of it. What accounts for this?
  - signal detection theory
  - sensory adaptation
  - transduction
  - the just noticeable difference
- Match each part of the eye with its description.  
\_\_\_\_ (1) the colored part of the eye  
\_\_\_\_ (2) the opening in the iris that dilates and constricts  
\_\_\_\_ (3) the transparent covering of the iris  
\_\_\_\_ (4) the transparent structure that focuses an inverted image on the retina  
\_\_\_\_ (5) the thin, photosensitive membrane at the back of the eye on which the lens focuses an inverted image
  - retina
  - cornea
  - pupil
  - iris
  - lens
- The receptor cells in the retina that enable you to see in dim light are the (cones, rods); the cells that enable you to see color and sharp images are (cones, rods).
- Neural impulses are carried from the retina to the thalamus by the \_\_\_\_\_ and then relayed to their final destination, the \_\_\_\_\_.
  - optic chiasm; primary visual cortex
  - rods and cones; optic nerve
  - optic nerve; primary visual cortex
  - optic nerve; optic chiasm
- Pitch is chiefly determined by \_\_\_\_\_; loudness is chiefly determined by \_\_\_\_\_.
  - amplitude; frequency
  - wavelength; frequency
  - intensity; amplitude
  - frequency; amplitude
- Pitch is measured in (decibels, hertz); loudness is measured in (decibels, hertz).
- Match the part of the ear with the structures it contains.  
\_\_\_\_ (1) ossicles                      **a.** outer ear  
\_\_\_\_ (2) pinna, auditory canal      **b.** middle ear  
\_\_\_\_ (3) cochlea, hair cells        **c.** inner ear
- The receptors for hearing are found in the
  - ossicles.
  - auditory canal.
  - auditory membrane.
  - cochlea.
- The two major theories that attempt to explain hearing are
  - conduction theory and place theory.
  - hair cell theory and frequency theory.
  - place theory and frequency theory.
  - conduction theory and hair cell theory.
- The technical name for the process or sensation of smell is (gustation, olfaction).
- The olfactory, or smell, receptors are located in the
  - olfactory tract.
  - olfactory nerve.
  - olfactory epithelium.
  - olfactory bulbs.
- The five taste sensations are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.



18. Each (papilla, taste bud) contains from 60 to 100 receptor cells.
19. Each skin receptor responds only to touch, pressure, warmth, or cold. (true/false)
20. The (kinesthetic, vestibular) sense provides information about the position of body parts in relation to each other and about movement in those body parts.
21. The receptors for the (kinesthetic, vestibular) sense are located in the semicircular canals and vestibular sacs in the (middle ear, inner ear).
22. When people try to keep track of several moving objects at once, they often exhibit \_\_\_\_\_.
23. When people look for a perceptual pattern in individual bits of sensory information, they are using \_\_\_\_\_.
24. When a speaker's lips don't match what she is saying, it is difficult to understand what she is saying because speech perception requires \_\_\_\_\_.
25. Match each Gestalt principle with its example:  
 \_\_\_\_ (1) \*\*\*\* \*\* perceived as three groups of four  
 \_\_\_\_ (2) - - - - -> perceived as an arrow  
 \_\_\_\_ (3) \*\*\*&&&###@@@ perceived as four groups of three  
 a. closure  
 b. similarity  
 c. proximity
26. Retinal disparity and convergence are two (monocular, binocular) depth cues.
27. Match the appropriate monocular depth cue with each example.  
 \_\_\_\_ (1) one building partly blocking another  
 \_\_\_\_ (2) railroad tracks converging in the distance  
 \_\_\_\_ (3) closer objects appearing to move faster than objects farther away  
 \_\_\_\_ (4) objects farther away looking smaller than near objects  
 a. motion parallax  
 b. linear perspective  
 c. interposition  
 d. relative size
28. Rob had been staring at a point of light in the night sky when it suddenly appeared to start moving. Rob's experience is an example of the phi phenomenon. (true/false)
29. An illusion is  
 a. an imaginary sensation.  
 b. an impossible figure.  
 c. a misperception of a real stimulus.  
 d. a figure-ground reversal.
30. In situations where you have some prior knowledge and experience, you are likely to rely more on (bottom-up, top-down) processing.
31. Perceptual set is most directly related to a person's  
 a. needs.  
 b. interests.  
 c. expectations.  
 d. emotions.
32. Images that are presented below the level of conscious awareness have no effect on subsequent behavior. (true/false)
33. ESP is often studied using the \_\_\_\_\_.

## ◆ SECTION TWO: Multiple Choice

1. Perception is the process we use to  
 a. organize and interpret stimuli.  
 b. detect stimuli.  
 c. gather information from the environment.  
 d. retrieve information from memory.
2. Which part of the nose serves the same function as the retina in the eye and the basilar membrane in the ear?  
 a. olfactory bulbs  
 b. olfactory lining  
 c. olfactory neurons  
 d. olfactory epithelium
3. The vestibular system is most closely related to  
 a. audition.  
 b. olfaction.  
 c. gustation.  
 d. kinesthetics.
4. As you look down a sandy beach, the sand seems to become more fine as it goes into the distance. This depth cue is called  
 a. elevation.  
 b. convergence.  
 c. texture gradient.  
 d. linear perspective.
5. The minimum amount of physical stimulation necessary for a person to experience a sensation 50% of the time is called the  
 a. figure-to-ground ratio.  
 b. blind spot.  
 c. difference threshold.  
 d. absolute threshold.
6. Which of the following is the correct sequence of structures encountered by light moving toward the retina?  
 a. lens, cornea, pupil  
 b. pupil, lens, cornea  
 c. pupil, cornea, lens  
 d. cornea, pupil, lens
7. Which theory suggests that color vision can be explained by the existence of three types of cones, which are maximally sensitive to blue, green, or red?  
 a. opponent-process theory  
 b. trichromatic theory  
 c. signal detection theory  
 d. gate-control theory

8. Ms. Scarpaci complains that the street noise in her apartment is much louder than the noise in her upstairs neighbor's apartment. To test her claim, you use a sound meter to check the noise in each apartment. Your meter registers 50 dB in Ms. Scarpaci's apartment and only 30 dB in her neighbor's. From these readings, how much louder is Ms. Scarpaci's apartment than her neighbor's?
  - a. 20% louder
  - b. 10 times louder
  - c. 100 times louder
  - d. not enough to be noticeable
9. When you hear a tone of 400 Hz, some of the hair cells in your ear are stimulated, but most others are not. This is the basic idea behind the
  - a. place theory of hearing.
  - b. volley principle of hearing.
  - c. frequency theory of hearing.
  - d. bone conduction theory of hearing.
10. The receptors for odors are located in the
  - a. olfactory epithelium.
  - b. projecting septum.
  - c. turbinate mucosa.
  - d. vestibular membrane.
11. Nerve endings in the skin send signals to the somatosensory cortex for processing. This area of the brain is found in the
  - a. frontal lobe.
  - b. temporal lobe.
  - c. parietal lobe.
  - d. occipital lobe.
12. Which of the following sensations would best be explained by the gate-control theory?
  - a. the pain of a pin prick
  - b. the smell of dinner cooking
  - c. the taste of your favorite cookie
  - d. the sound of paper rustling
13. The receptors for the kinesthetic sense are located in the
  - a. middle ear.
  - b. inner ear.
  - c. joints, ligaments, and muscles.
  - d. cortex.
14. The depth cue that occurs when your eyes "cross" to see an object that is very near your face is called
  - a. convergence.
  - b. elevation.
  - c. aerial perspective.
  - d. binocular disparity.
15. Weber's law applies to
  - a. difference thresholds.
  - b. absolute thresholds.
  - c. transduction thresholds.
  - d. retinal thresholds.
16. Gustation is also known as the sense of
  - a. taste.
  - b. hearing.
  - c. smell.
  - d. vision.
17. In the Ponzo illusion, two bars of equal length are superimposed over a picture of railroad tracks that recede into the distance and eventually converge at a single point. One reason the bars appear to be of unequal lengths is because the illusion takes advantage of
  - a. binocular disparity cues.
  - b. linear perspective cues.
  - c. apparent motion cues.
  - d. depth disparity cues.
18. Perceptual set reflects
  - a. bottom-up processing.
  - b. top-down processing.
  - c. subliminal processing.
  - d. extrasensory processing.
19. The process through which the senses detect sensory stimuli and transmit them to the brain is called
  - a. consciousness.
  - b. perception.
  - c. sensation.
  - d. reception.
20. If you were listening to music and your friend wanted to know how far he could turn the volume down without your noticing, he would need to know your
  - a. sensory threshold for sound.
  - b. absolute threshold for sound.
  - c. transduction threshold for sound.
  - d. difference threshold for sound.
21. Margaret is reaching middle age and is having trouble reading fine print. She did not have this problem when she was younger. Her optometrist has concluded that she has presbyopia, or "old eyes." Given this diagnosis, you know that Margaret's difficulty is due to the aging of her
  - a. corneas.
  - b. lenses.
  - c. retinas.
  - d. rods and cones.
22. The trichromatic theory of color is based on the idea that the retina contains three types of
  - a. rods.
  - b. cones.
  - c. bipolar cells.
  - d. ganglion cells.
23. Megan watches from the car as her parents drive away from her grandfather's house. Because of \_\_\_\_\_, Megan knows her grandfather's house remains the same size, even though the image gets smaller as they drive farther away.
  - a. the law of good continuation
  - b. the law of proximity
  - c. size constancy
  - d. the Müller-Lyer illusion

24. If you are sitting in a restaurant and hear someone at a nearby table mention your name, research examining the \_\_\_\_\_ suggests that you are likely to focus your attention on the table where that conversation is occurring.
- autokinetic illusion
  - principle of closure
  - cocktail party phenomenon
  - Ponzo illusion
25. \_\_\_\_\_ is a type of ESP in which people know what is going to happen in the future.
- telepathy
  - clairvoyance
  - precognition

### ◆ SECTION THREE: Fill In the Blank

- Sensation is to \_\_\_\_\_ as perception is to \_\_\_\_\_.
- The \_\_\_\_\_ threshold is a measure of the smallest change in a physical stimulus required to produce a noticeable difference in sensation 50% of the time.
- Researchers in sensory psychology and \_\_\_\_\_ study phenomena related to sensation, such as the least amount of a stimulus required for detection.
- \_\_\_\_\_ refers to the process by which a sensory stimulus is changed by the sensory receptors into neural impulses.
- As part of his training in personnel relations, Ted had to spend a whole day in a very noisy factory. Although the sound seemed almost painful at first, he noticed by the end of the day that it didn't seem so loud anymore. This is an example of \_\_\_\_\_.
- One of the major parts of the eye, the \_\_\_\_\_, performs the first step in vision by bending the light rays inward through the pupil.
- According to the \_\_\_\_\_ theory of color vision, certain cells in the visual system increase their rate of firing to signal one color and decrease their firing rate to signal the opposing color.
- An important characteristic of sound, \_\_\_\_\_ is determined by the number of cycles completed by a sound wave in 1 second.
- The taste sensation called \_\_\_\_\_ results from such protein-rich foods as meat, milk, cheese, and seafood.
- \_\_\_\_\_ psychologists studied perception and were guided by the principle that "the whole is more than the sum of its parts."
- That humans seem to perceive the environment in terms of an object standing out against a background is known as the \_\_\_\_\_ principle.
- Ted, an artist, creates pictures that force viewers to fill in gaps in the lines, thereby forming a whole pattern. Ted's art takes advantage of the principle of \_\_\_\_\_.
- One important contribution to three-dimensional perception is \_\_\_\_\_, which results when each eye receives a slightly different view of the objects being viewed.
- When a person's facial expression and tone of voice don't match, we usually rely on her \_\_\_\_\_ to make a determination about her actual emotional state.
- Studies examining \_\_\_\_\_ show that the brain responds to stimuli that are presented below the threshold of awareness.

### ◆ SECTION FOUR: Comprehensive Practice Test

- The process by which humans detect visual, auditory, and other stimuli is known as
  - perception.
  - transduction.
  - sensation.
  - threshold.
- The process of organizing and interpreting the information gathered through vision, hearing, and the other senses is known as
  - perception.
  - the absolute threshold.
  - transduction.
  - sensory induction.

3. The \_\_\_\_\_ is the minimum amount of stimulus that can be detected 50% of the time.
  - a. difference reaction
  - b. absolute reaction
  - c. difference threshold
  - d. absolute threshold
4. The \_\_\_\_\_ is a measure of the smallest change in a stimulus required for a person to detect a change in the stimulus 50% of the time.
  - a. difference reaction
  - b. absolute difference
  - c. difference threshold
  - d. sensory threshold
5. Sense organs have specialized cells called \_\_\_\_\_ that detect and respond to particular stimuli.
  - a. sensory detectors
  - b. sensory receptors
  - c. perceptual responders
  - d. perceptual receptors
6. When you see, hear, taste, smell, or feel a sensory stimulus, the physical energy that caused the stimulus is changed to neural impulses that are processed in your brain. This process is known as
  - a. sensory adaptation.
  - b. the absolute threshold.
  - c. perceptual organization.
  - d. transduction.
7. Joe installed an in-ground pool last spring, although his wife thought he was crazy to do so when it was still cool outside. The first day it seemed a little warm Joe jumped in the new pool, but soon he realized just how cold the water really was. As he continued to “enjoy” the water, it seemed to become less cold and even comfortable. This was probably due to a process called
  - a. sensory adaptation.
  - b. difference threshold.
  - c. sensory threshold.
  - d. perceptual adaptation.
8. If someone tells you she loves the color of your eyes, she is actually talking about your
  - a. pupils.
  - b. corneas.
  - c. irises.
  - d. retinas.
9. Rods are to cones as \_\_\_\_\_ is to \_\_\_\_\_.
  - a. dim light; color
  - b. color; dim light
  - c. bright light; color
  - d. color; bright light
10. The blind spot in the back of the eye is where
  - a. the rods and cones come together.
  - b. the retina converges on the fovea.
  - c. the optic nerve leaves the eye.
  - d. the blood supply enters the eye.
11. When you read a book, the lenses in your eyes are probably a little more spherical, and when you gaze up at the stars at night, your lenses become flatter. These differences are due to a process known as
  - a. retinal disparity.
  - b. lens reactivity.
  - c. accommodation.
  - d. adaptation.
12. LaShonda tells her roommate that we see color because three kinds of cones react to one of three colors—blue, green, or red. LaShonda has been reading about the \_\_\_\_\_ theory of color vision.
  - a. opponent-process
  - b. trichromatic
  - c. relative disparity
  - d. complementary color
13. The number of cycles completed by a sound wave in 1 second is the wave’s
  - a. decibel level.
  - b. timbre.
  - c. amplitude.
  - d. frequency.
14. The job of the \_\_\_\_\_, also known as the hammer, the anvil, and the stirrup, is to amplify sound as it moves from the eardrum to the oval window.
  - a. ossicles
  - b. cochlear bones
  - c. hair cells
  - d. timbre bones
15. Tomas says that we hear different pitches depending on which spot along the basilar membrane vibrates the most. He is talking about the \_\_\_\_\_ theory of hearing.
  - a. frequency
  - b. position
  - c. cochlea
  - d. place
16. Olfaction refers to
  - a. the sense of taste.
  - b. the sense of smell.
  - c. the ability to detect skin temperature.
  - d. the ability to differentiate sounds.
17. All parts of the tongue can detect sweet, sour, salty, and bitter. (true/false)
18. Tactile is used in reference to the sense of
  - a. smell.
  - b. balance.
  - c. taste.
  - d. touch.
19. The gate-control theory of pain suggests that slow-conducting nerve fibers carry pain messages and that these messages can be blocked by messages from fast-conducting nerve fibers. (true/false)
20. An athlete’s ability to move gracefully on the parallel bars is due to the \_\_\_\_\_ sense.
  - a. tactile
  - b. olfactory
  - c. kinesthetic
  - d. eustachian
21. The vestibular sense provides information that allows you to know that a red door is still red even in a dark room. (true/false)

22. The half-time show at a football game involved a hundred people marching on the field—all in different colored uniforms. Then they took on a formation and suddenly all the red uniforms spelled out the initials of the home team. Gestalt psychologists would suggest that the principle of \_\_\_\_\_ explains why fans could read the initials.
- a. similarity                      c. closure  
b. continuity                      d. constancy
23. Which of the following is not a Gestalt principle of grouping?
- a. closure                          c. constancy  
b. similarity                      d. proximity
24. If you move your finger closer and closer to your nose and focus on perceiving only one image of the finger even when it is almost touching the nose, your eyes begin to turn inward. This eye movement is known as
- a. disparity.                      c. congruity.  
b. monocular adjustment.      d. convergence.
25. Cues such as interposition, linear perspective, and relative size are known as \_\_\_\_\_ depth cues.
- a. binocular                      c. monocular  
b. divergent                      d. bimodal
26. Lines of the same length with diagonals at their ends pointing in or out appear to be of different lengths because of the \_\_\_\_\_ illusion.
- a. Ponzo                          c. trident  
b. Müller-Lyer                      d. ambiguous
27. Bottom-up processing is to \_\_\_\_\_ stimuli as top-down processing is to \_\_\_\_\_ stimuli.
- a. unfamiliar; familiar      c. familiar; unfamiliar  
b. visual; auditory              d. perceptual; subliminal
28. In the game “Name That Tune,” players try to guess the name of a song after hearing only its first few notes. Succeeding at this game requires
- a. top-down processing.  
b. bottom-up processing.  
c. cross-modal perception.
29. Most psychologists think that
- a. subliminal advertising is very effective.  
b. some people have a special talent for ESP.  
c. synesthesia is the result of an overactive imagination.  
d. the brain is capable of perceiving stimuli presented below the threshold of awareness.

## ◆ SECTION FIVE: Critical Thinking

- Vision and hearing are generally believed to be the two most highly prized senses. How would your life change if you lost your sight? How would your life change if you lost your hearing? Which sense would you find more traumatic to lose? Why?
- Explain how perceptual set can lead to errors in witnesses' courtroom testimony.
- Using what you have learned about how noise contributes to hearing loss, prepare a statement indicating what you think the government should do to control noise pollution, even to the extent of banning certain noise hazards. Consider the workplace, the home, automobiles and other vehicles, toys, machinery, rock concerts, and so on.

### Answers:

**SECTION ONE:** 1. sensation 2. absolute 3. false 4. c 5. transduction 6. b 7. (1) d (2) c (3) b (4) e (5) a 8. rods; cones 9. c 10. d 11. hertz; decibels 12. (1) b (2) a (3) c 13. d 14. c 15. olfaction 16. c 17. sweet, sour, salty, bitter, umami 18. taste bud 19. false 20. kinesthetic 21. vestibular; inner ear 22. attentional blindness 23. bottom-up processing 24. cross-modal perception 25. (1) c (2) a (3) b 26. binocular 27. (1) c (2) b (3) a (4) d 28. false 29. c 30. top-down 31. c 32. false 33. Ganzfeld procedure **SECTION TWO:** 1. a 2. d 3. d 4. c 5. d 6. d 7. b 8. c 9. a 10. a 11. c 12. a 13. c 14. a 15. a 16. a 17. b 18. b 19. c 20. d 21. b 22. b 23. c 24. c 25. c **SECTION THREE:** 1. a 2. difference 3. psychophysics 4. transduction 5. sensory adaptation 6. cornea 7. opponent-process 8. frequency 9. umami 10. Gestalt 11. figure-ground 12. closure 13. binocular disparity 14. facial expression 15. facial expression **SECTION FOUR:** 1. c 2. a 3. d 4. c 5. b 6. d 7. a 8. c 9. a 10. c 11. c 12. b 13. d 14. a 15. d 16. b 17. true 18. d 19. true 20. c 21. false 22. a 23. c 24. d 25. c 26. b 27. a 28. b 29. d