Psychology in the News

Lindsey Vonn Defeats Pain to Win Olympic Gold

WHISTLER, BRITISH COLUMBIA, February 18, 2010. Lindsey Vonn today became the first U.S. woman to win the gold medal in the Olympic downhill race. "I was completely overwhelmed," Vonn said. "It was one of the best feelings I've ever had in my life. Everyone expected me to do it, but it's not as easy as just saying you can do it."

That's a huge understatement, since Vonn had seriously injured her shin during training a week earlier and had to have fluid drained from the deep bruise, which was bleeding internally. "When I tried my boot on, I was just standing there in the hotel room barely flexing forward, and it was excruciatingly painful. And I've got to try to ski downhill at 75, 80 miles an hour with a lot of forces pushed up against my shin," Vonn said at the time of the injury. "I don't know honestly if I'll be able to do it."

Vonn said she fought through pain the whole way down the bumpy, challenging course, on which several other skiers had crashed. When Vonn took off, she shaved every millisecond she could off her time by skiing tightly around the turns. "It wasn't an option to ski passively," Vonn said. "I had to really take it."

UFO Sighting Over St. Louis

CLEVELAND, OH, March 15, 2010. Thousands of Cleveland residents have been flocking to the Lake Erie riverfront to take pictures of mysterious lights in the night sky. For almost two weeks, the lights have been appearing at about 7:30 p.m., moving back and forth for a while and then disappearing.

"At first, I figured it was just a star," said medical technician Eugene Erlikh, 20. "But the way it would move, I've never seen anything like it." The local NASA facility said the lights have nothing to do with their work, and air-traffic controllers could not explain them either. UFO sightings are common in Ohio. More than 20 reports of mysterious lights or objects have been made in the past two years.

One of the earliest UFO accounts occurred in the late 1940s, when a rancher noticed some strange objects strewn about his property near Roswell, New Mexico. When the Air Force quickly blocked off and cleared the site, stories circulated that a spacecraft had crashed and that alien corpses had been recovered. Thousands of believers in UFOs still flock to the International UFO Museum in Roswell.

Are these alien spacecraft? Many people who viewed these odd objects in the skies above Santos, Brazil, were convinced they were seeing UFOs.

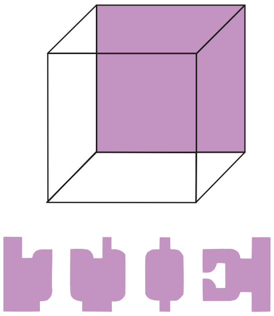
CHAPTER 6

Sensation and Perception

How in the world does anyone win an Olympic gold medal while skiing in pain after an injury, and why do some people think they have seen UFOs that others dismiss as planes and planets in the night sky? And what in the world do these two stories have in common? The answer is that our sensations often deceive us. We think of pain, sights, tastes, and sounds as being obvious, "real," right there. "I saw it with my own eyes!" people exclaim, meaning "Don't argue with me," as they report seeing an image of Jesus on a garage door, Osama bin Laden's face in smoke billowing from the doomed World Trade Center, or Mother Theresa's face in a cinnamon bun. These illusions seem very real to the people who see them, and the reverse is also true: A real sensation, as of intense pain, can disappear under the stress of battle or the thrill of competition.

In this chapter, we will explore how our senses take in information from the environment and how our brains use this information to construct a model of the world. We will focus on two closely connected sets of processes that enable us to know what is happening both inside our bodies and in the world beyond our own skins. The first, **sensation**, is the detection of physical energy emitted or reflected by physical objects. The cells that do the detecting are located in the *sense organs*—the eyes, ears, tongue, nose, skin, and internal body tissues. Sensory processes produce an immediate awareness of sound, color, form, and other building blocks of consciousness. Without sensation, we would lose touch—literally—with reality.

But to make sense of the world impinging on our senses, we also need **perception**, a set of mental operations that organizes sensory impulses into meaningful patterns. Our sense of vision produces a two-dimensional image on the back of the eye, but we perceive the world in three dimensions. Our sense of hearing brings us the sound of a C, an E, and a G played simultaneously on the piano, but we perceive a C-major chord. Sometimes, a single sensory image produces two alternating perceptions, and the result is an image that keeps changing, as illustrated by the two examples on the next page.



If you stare at the cube, the colored panel will alternate from being at the back to being at the front. The second drawing can also be perceived in two ways. Can you see the word?

Sensation and perception are the foundation for learning, thinking, and acting. Findings on these processes can also be put to practical use, as in the design of industrial robots and in the training of astronauts, who must make crucial decisions based on what they sense and perceive. An understanding of sensation and perception also helps us think more critically about our own experiences, and encourages humility: Usually we are sure that what we sense and perceive must be true, yet sometimes we are just plain wrong. As you read this chapter, you will learn why people sometimes perceive things that are not there and, conversely, why they sometimes miss things that *are* there—why we can look without seeing, listen without hearing.

YOU are about to learn...

- why we experience separate sensations even though they all rely on similar neural signals.
- what kind of code in the nervous system helps explain why a pinprick and a kiss feel different.
- how psychologists measure the sensitivity of our senses.
- the bias that influences whether or not you think you hear the phone ringing when you are in the shower.
- what happens when people are deprived of all external sensory stimulation.
- why we sometimes fail to see an object that we're looking straight at.

sensation The detection of physical energy emitted or reflected by physical objects; it occurs when energy in the external environment or the body stimulates receptors in the sense organs.

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

sense receptors Specialized cells that convert physical energy in the environment or the body to electrical energy that can be transmitted as nerve impulses to the brain.

doctrine of specific nerve energies The principle that different sensory modalities exist because signals received by the sense organs stimulate different nerve pathways leading to different areas of the brain.

Our Sensational Senses

At some point, you probably learned that there are five senses: vision, hearing, taste, touch, and smell. Actually, there are more than five senses, though scientists disagree about the exact number. The skin, which is the organ of touch or pressure, also senses heat, cold, and pain, not to mention itching and tickling. The ear, which is the organ of hearing, also contains receptors that account for a sense of balance. The skeletal muscles contain receptors responsible for a sense of bodily movement.

All of our senses evolved to help us survive. Even pain, which causes so much human misery, is an indispensable part of our evolutionary heritage, for it alerts us to illness and injury. Some people are born with a rare condition that prevents them from feeling the usual hurts and aches of life, but you shouldn't envy them: They are susceptible to burns, bruises, and broken bones, and they often die at an early age because they can't take advantage of pain's warning signals.

The Riddle of Separate Sensations

Sensation begins with the **sense receptors**, cells located in the sense organs. The receptors for smell, pressure, pain, and temperature are extensions (dendrites) of sensory neurons (see Chapter 4). The receptors for vision, hearing, and taste are specialized cells separated from sensory neurons by synapses.

When the sense receptors detect an appropriate stimulus—light, mechanical pressure, or chemical molecules—they convert the energy of the stimulus into electrical impulses that travel along nerves to the brain. Sense receptors are like military scouts who scan the terrain for signs of activity. These scouts cannot make many decisions on their own; they must transmit what they learn to "field officers," sensory neurons in the nerves of the peripheral nervous system. The field officers in turn must report to generals at a command center, the cells of the brain. The generals are responsible for analyzing the reports, combining information brought in by different scouts, and deciding what it all means.

The sensory-neuron "field officers" all use the same form of communication, a neural impulse. It is as if they must all send their messages on a bongo drum and can only go "boom." How, then, are we able to experience so many different kinds of sensations? The answer is that the nervous system *encodes* the messages. One kind of code, which is *anatomical*, was first described in 1826 by the German physiologist Johannes Müller in his **doctrine of specific nerve energies**. According to this doctrine, different sensory modalities (such as vision and hearing) exist because signals received by the sense organs stimulate different nerve pathways leading to different areas of the brain. Signals from the eye cause impulses to travel along the optic nerve to the visual cortex. Signals from the ear cause impulses to travel along the auditory nerve to the auditory cortex. Light and sound waves produce different sensations because of these anatomical differences.

The doctrine of specific nerve energies implies that what we know about the world ultimately reduces to what we know about the state of our own nervous system: We see with the brain, not the eyes, and we hear with the brain, not the ears. It follows that if sound waves could stimulate nerves that end in the visual part of the brain, we would "see" sound. In fact, a similar sort of crossover does occur if you close your right eye and press lightly on the right side of the lid: You will see a flash of light seemingly coming from the left. The pressure produces an impulse that travels up the optic nerve to the visual area in the right side of the brain, where it is interpreted as coming from the left side of the visual field. By taking advantage of such crossover from one sense to another, researchers hope to enable blind people to see by teaching them to interpret impulses from other senses that are then routed to the visual areas of the brain. Canadian neuroscientists are developing a device that translates images from a camera into a pattern of electronic pulses that is sent to electrodes on the tongue, which in turn sends information about the pattern to visual areas of the brain that process images (Chabat et al., 2007; Ptito et al., 2005). Using this device, congenitally blind people have been able to make out shapes, and their visual areas, long quiet, have suddenly become active.

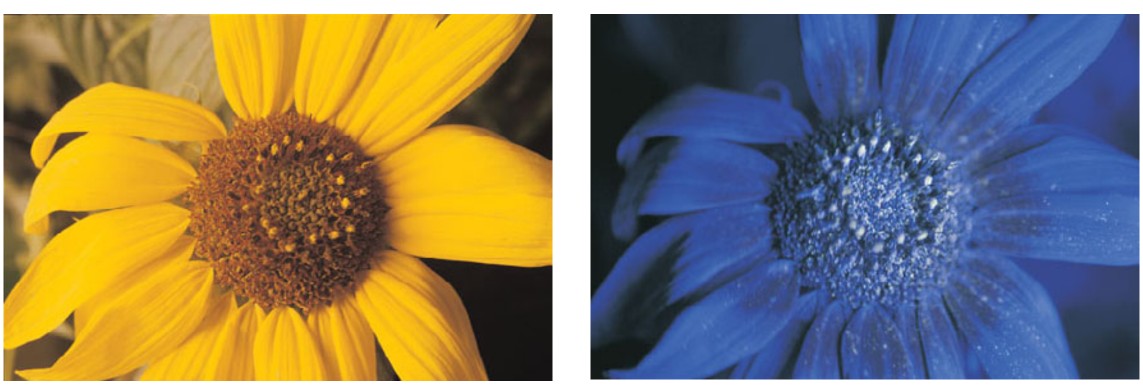
Sensory crossover also occurs in a rare condition called **synesthesia**, in which the stimulation of one sense also consistently evokes a sensation in another. A person with synesthesia may say that the color purple smells like a rose, the aroma of cinnamon feels like velvet, or the sound of a note on a clarinet tastes like cherries. Most synesthetes are born with the condition, but it can also result from damage to the brain. In one interesting case, a woman who had recovered from a stroke experienced sounds as a tingling sensation on the left side of her body (Ro et al., 2007). No one is sure yet about the neurological basis of synesthesia, but there are two leading theories. One attributes the condition to a lack of normal disinhibition in signals between different sensory areas of the brain (e.g., Cohen Kadosh et al., 2009). The other attributes it to a greater number of neural connections between different sensory brain areas (e.g., Bargary & Mitchell, 2008; Rouw & Scholte, 2007).

synesthesia A condition in which stimulation of one sense also evokes another.

Synesthesia, however, is an anomaly; for most of us, the senses remain separate. Anatomical encoding does not completely solve the riddle of why this is so, nor does it explain variations of experience *within* a particular sense—the sight of pink versus red, the sound of a piccolo versus the sound of a tuba, or the feel of a pinprick versus the feel of a kiss. An additional kind of code is therefore necessary. This second kind of code has been called *functional*. Functional codes rely on the fact that sensory receptors and neurons fire, or are inhibited from firing, only in the presence of specific sorts of stimuli. At any particular time, then, some cells in the nervous system are firing and some are not. Information about *which* cells are firing, *how many* cells are firing, the *rate* at which cells are firing, and the *patterning* of each cell's firing forms a functional code. You might think of such a code as the neurological equivalent of Morse code but much more complicated. Functional encoding may occur all along a sensory route, starting in the sense organs and ending in the brain.

Measuring the Senses

Just how sensitive are our senses? The answer comes from the field of *psychophysics*, which is concerned with how the physical properties of stimuli are related to our psychological experience of them. Drawing on principles from both physics and psychology, psychophysicists have studied how



Different species sense the world differently. The flower on the left was photographed under normal light. The one on the right, photographed under ultraviolet light, is what a butterfly might see, because butterflies have ultraviolet receptors. The hundreds of tiny bright spots are sources of nectar.

absolute threshold The smallest quantity of physical energy that can be reliably detected by an observer.

difference threshold The smallest difference in stimulation that can be reliably detected by an observer when two stimuli are compared; also called *just noticeable difference* (*jnd*).

the strength or intensity of a stimulus affects the strength of sensation in an observer.

Absolute Thresholds One way to find out how sensitive the senses are is to show people a series of signals that vary in intensity and ask them to say which signals they can detect. The smallest amount of energy that a person can detect reliably is known as the **absolute threshold**. The word *absolute* is a bit misleading because people detect borderline signals on some occasions and miss them on others. Reliable detection is said to occur when a person can detect a signal 50 percent of the time.

If your absolute threshold for brightness were being measured, you might be asked to sit in a dark room and look at a wall or screen. You would then be shown flashes of light varying in brightness, one flash at a time. Your task would be to say whether you noticed a flash. Some flashes you would never see. Some you would always see. And sometimes you would miss seeing a flash, even though you had noticed one of equal brightness on other trials. Such errors seem to occur in part because of random firing of cells in the nervous system, which produces fluctuating background noise, something like the static in a radio transmission that is slightly out of range.

By studying absolute thresholds, psychologists have found that our senses are very sharp indeed. If you have normal sensory abilities, you can see a candle flame on a clear, dark night from 30 miles away. You can taste a teaspoon of sugar diluted in two gallons of water, smell a drop of perfume diffused through a three-room apartment, and feel the wing of a bee falling on your cheek from a height of only one centimeter (Galanter, 1962).

Despite these impressive skills, our senses are tuned in to only a narrow band of physical energies. We are visually sensitive to only a tiny fraction of the electromagnetic energy that surrounds us; we do not see radio waves, infrared waves, or microwaves (see Figure 6.1). Many other species can pick up signals that we cannot. Dogs can detect high-frequency sound waves that are beyond our range, as you know if you have ever called your pooch with a “silent” doggie whistle. Bees can see ultraviolet light, which merely gives human beings a sunburn.

Difference Thresholds Psychologists also study sensory sensitivity by having people compare two stimuli—such as the weight of two blocks, the brightness of two lights, or the saltiness of two liquids—and judge whether they are the same or different. The smallest difference in stimulation that a person can detect reliably (again, half of the time) is called the **difference threshold** or *just noticeable difference (jnd)*. When you compare two stimuli, A and B, the difference threshold will depend on the intensity or size of A. The larger or more intense A is, the greater the change must be before you can detect a difference. If you are comparing the weights of two pebbles, you might be able to detect a difference of only a fraction of an ounce, but you would not be able to detect such a subtle difference if you were comparing two massive boulders.

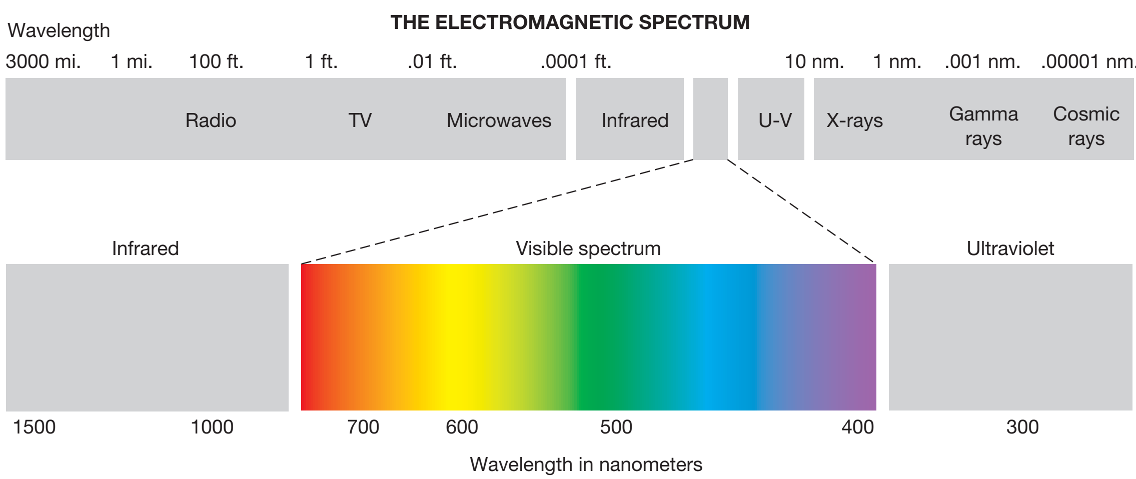


FIGURE 6.1
The Visible Spectrum of Electromagnetic Energy
Our visual system detects only a small fraction of the electromagnetic energy around us.

Signal-Detection Theory Despite their usefulness, the procedures we have described have a serious limitation. Measurements for any given individual may be affected by the person's general tendency, when uncertain, to respond, "Yes, I noticed a signal (or a difference)" or "No, I didn't notice anything." Some people are habitual yea-sayers, willing to gamble that the signal was there. Others are habitual naysayers, cautious and conservative. In addition, alertness, motives, and expectations can influence how a person responds on any given occasion. If you are in the shower and you are expecting an important call, you may think you heard the telephone ring when it did not. In laboratory studies, when observers want to impress the experimenter, they may lean toward a positive response.

Fortunately, these problems of *response bias* are not insurmountable. According to **signal-detection theory**, an observer's response in a detection task can be divided into a *sensory process*, which depends on the intensity of the stimulus, and a *decision process*, which is influenced by the observer's response bias. To separate these two components, a researcher may include some trials in which no stimulus is present and others in which a weak stimulus is present. Under these conditions, four kinds of responses are possible: The person (1) detects a signal that was present (a "hit"), (2) says the signal was there when it wasn't (a "false alarm"), (3) fails to detect the signal when it was present (a "miss"), or (4) correctly says that the signal was absent when it was absent (a "correct rejection").

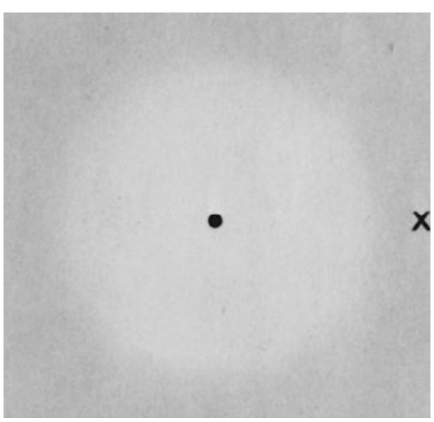
Yea-sayers will have more hits than naysayers, but they will also have more false alarms because they are too quick to say, "Yup, it was there." Naysayers will have more correct rejections than yea-sayers, but they will also have more misses because they are too quick to say, "Nope, nothing was there." This information can be fed into a mathematical formula that yields separate estimates of a person's response bias and sensory capacity. The individual's true sensitivity to a signal of any particular intensity can then be predicted.

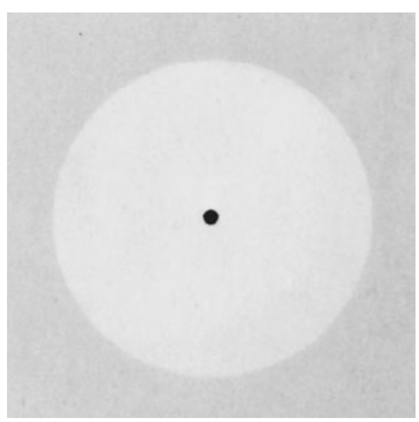
The original method of measuring thresholds assumed that a person's ability to detect a stimulus depended solely on the stimulus. Signal-detection theory assumes that there is no single threshold because at any given moment a person's sensitivity to a stimulus depends on a decision that he or she actively makes. Signal-detection methods have many real-world applications, from screening applicants for jobs that require keen hearing to training air-traffic controllers, whose decisions about the presence or absence of a blip on a radar screen may mean the difference between life and death.

signal-detection theory A psychophysical theory that divides the detection of a sensory signal into a sensory process and a decision process.

Get Involved! Now You See It, Now You Don't

Sensation depends on change and contrast in the environment. Hold your hand over one eye and stare at the dot in the middle of the circle on the right. You should have no trouble maintaining an image of the circle. However, if you do the same with the circle on the left, the image will fade. The gradual change from light to dark does not provide enough contrast to keep your visual receptors firing at a steady rate. The circle reappears only if you close and reopen your eye or shift your gaze to the *X*.





sensory adaptation The reduction or disappearance of sensory responsiveness when stimulation is unchanging or repetitious.

sensory deprivation The absence of normal levels of sensory stimulation.

Simulate Methods of Constant Stimuli on mypsychlab.com

Sensory Adaptation

Variety, they say, is the spice of life. It is also the essence of sensation, for our senses are designed to respond to change and contrast in the environment. When a stimulus is unchanging or repetitious, sensation often fades or disappears. Receptors or nerve cells higher up in the sensory system get "tired" and fire less frequently. The resulting decline in sensory responsiveness is called **sensory adaptation**. Usually, such adaptation spares us from having to respond to unimportant information; most of the time you have no need to feel your watch sitting on your wrist. Sometimes, however, adaptation can be hazardous, as when you no longer smell a gas leak that you thought you noticed when you first entered the kitchen. **Simulate**

We never completely adapt to extremely intense stimuli—a terrible toothache, the odor of ammonia, the heat of the desert sun. And we rarely adapt completely to visual stimuli, whether they are weak or intense. Eye movements, voluntary and involuntary, cause the location of an object's image on the back of the eye to keep changing, so visual receptors do not have a chance to "fatigue."

What would happen if our senses adapted to *most* incoming stimuli? Would we sense nothing, or would the brain substitute its own images for the sensory experiences no longer available by way of the sense organs? In early studies of **sensory deprivation**, researchers studied this question by isolating male volunteers from all patterned sight and sound. Vision was restricted by a translucent visor, hearing by a U-shaped pillow and noise from an air conditioner and fan, and touch by cotton gloves and cardboard cuffs. The volunteers took brief breaks to eat and use the bathroom, but otherwise they lay in bed, doing nothing. The results were dramatic. Within a few hours, many of the men felt edgy. Some were so disoriented that they quit the study the first day. Those who stayed longer became confused, restless, and grouchy. Many reported bizarre visions, such as a squadron of squirrels or a procession of marching eyeglasses. It was as though they were having the kind of waking dreams described in Chapter 5. Few people were willing to remain in the study for more than two or three days (Heron, 1957).

But the notion that sensory deprivation is unpleasant or even dangerous turned out to be an oversimplification (Suedfeld, 1975). Later research, using better methods, showed that hallucinations are less frequent and less disorienting than had first been thought. Many people enjoy limited periods of deprivation, and some perceptual and intellectual abilities actually improve. Your response to sensory deprivation depends on your expectations and interpretations of what is happening. Reduced sensation can be scary if you are locked in a room for an indefinite period, but relaxing if you have retreated to that room voluntarily for a little time-out, perhaps at a luxury spa or a monastery.

Thinking Critically about Sensory Deprivation

Still, the human brain does require a minimum amount of sensory stimulation to function normally. This need may help explain why people who live alone often keep the radio or television on continuously, and why prolonged solitary confinement is used as a form of punishment or even torture.

Is sensory deprivation pleasant or unpleasant? The answer isn't "either–or"; it depends on the circumstances and how you interpret your situation. Being isolated against your will can be terrifying. But many people have found meditating alone, away from all sights and sounds—as this woman is doing in a "flotation tank"—to be calming and pleasant.

Sensing without Perceiving

If too little stimulation can be bad for you, so can too much, because it can lead to fatigue and mental confusion. If you have ever felt exhausted, nervous, and headachy after a day crammed with activities, you know firsthand about sensory overload. When people find themselves in a state of overload, they often cope by blocking out unimportant sights and sounds and focusing only on those they find interesting or useful. When you become engrossed in a great conversation at a noisy party, you are likely to ignore other voices, the clink of ice cubes, and bursts of laughter across the room.

Hard though it is to believe, even a person in a gorilla suit may go unnoticed if people's attention is elsewhere.

Even when overload is not a problem, our capacity for **selective attention**—the ability to focus on some parts of the environment and block out others—protects us from being overwhelmed by the countless sensory signals that are constantly impinging on our sense receptors. Competing sensory messages all enter the nervous system, however, and get processed at varying levels of awareness; this is the reason that we are able to pick up anything important, such as our own name spoken by someone several yards away.

That's the good news. The bad news is that selective attention, by its very nature, causes us to miss much that is going on around us. As a result, our conscious awareness of the environment is much less complete than most people think. We may even fail to consciously register objects that we are looking straight at, a phenomenon known as **inattentional blindness**: We look, but we do not see (Mack, 2003). When people are shown a video of a ball-passing game and are asked to count up the passes, they may even miss something as seemingly obvious as a man in a gorilla suit walking slowly through the ball court, thumping his chest (Simons & Chabris, 1999).

Selective attention, then, is a mixed blessing. It protects us from overload and allows us to focus on what's important, but it also deprives us of sensory information that we may need. That could be disastrous if you are so focused on texting a friend that you walk right into a pothole or a street full of traffic.

selective attention The focusing of attention on selected aspects of the environment and the blocking out of others.

inattentional blindness Failure to consciously perceive something you are looking at because you are not attending to it.

Quick Quiz

If you are not on overload, try answering these questions.

1. Even on the clearest night, some stars cannot be seen by the naked eye because they are below the viewer's __________ threshold.
2. If you jump into a cold lake but moments later the water no longer seems so cold, sensory __________ has occurred.
3. You are immobilized in a hospital bed, with no roommate, TV, or cell phone. If you feel edgy and disoriented, you may be suffering the effects of __________.
4. During a break from your job in a restaurant, you are so caught up in a book that you fail to notice the clattering of dishes or orders being called out to the cook. This is an example of __________.
5. In real-life detection tasks, is it better to be a "naysayer" or a "yea-sayer"?

Answers:

1. absolute **2.** adaptation **3.** sensory deprivation **4.** selective attention **5.** Neither; it depends on the consequences of a "miss" or a "false alarm." Suppose that you are in the shower and you're not sure whether your phone is ringing in the other room. You might want to be a yea-sayer if you are expecting a call about a job interview, but a naysayer if you are not expecting any calls and don't want to get out dripping wet for nothing.

Study and **Review** on **mypsychlab.com**

YOU are about to learn...

- how the physical characteristics of light waves correspond to the psychological dimensions of vision.
- the basics of how the eye works, and why the eye is not a camera.
- how we see colors, and why we can describe a color as bluish green but not as reddish green.
- how we know how far away things are.
- why we see objects as stable even though sensory stimulation from the object is constantly changing.
- why perceptual illusions are valuable to psychologists.

Vision

Vision is the most frequently studied of all the senses, and with good reason. More information about the external world comes to us through our eyes than through any other sense organ. Because we evolved to be most active in the daytime, we are equipped to take advantage of the sun's illumination. Animals that are active at night tend to rely more heavily on hearing.

What We See

The stimulus for vision is light; even cats, raccoons, and other creatures famous for their ability to get around in the dark need some light to see. Visible light comes from the sun and other stars and from lightbulbs, and it is also reflected off objects. Light travels in the form of waves, and the *physical* characteristics of these waves affect three *psychological* dimensions of our visual world: hue, brightness, and saturation.

hue The dimension of visual experience specified by color names and related to the wavelength of light.

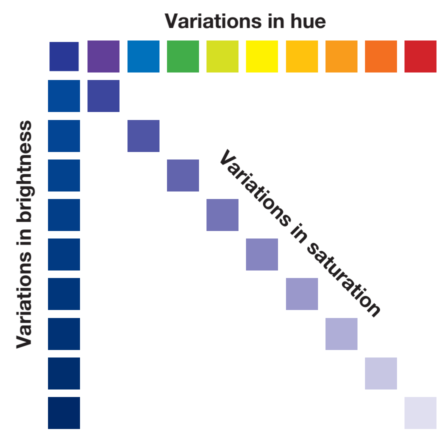
brightness Lightness or luminance; the dimension of visual experience related to the amount (intensity) of light emitted from or reflected by an object.

saturation Vividness or purity of color; the dimension of visual experience related to the complexity of light waves.

1 **Hue**, the dimension of visual experience specified by color names, is related to the *wavelength* of light—that is, to the distance between the crests of a light wave. Shorter waves tend to be seen as violet and blue, longer ones as orange and red. The sun produces white light, which is a mixture of all the visible wavelengths. Sometimes, drops of moisture in the air act like a prism: They separate the sun's white light into the colors of the visible spectrum, and we are treated to a rainbow.

2 **Brightness** is the dimension of visual experience related to the amount, or *intensity*, of the light an object emits or reflects. Intensity corresponds to the amplitude (maximum height) of the wave. Generally speaking, the more light an object reflects, the brighter it appears. However, brightness is also affected by wavelength: Yellows appear brighter than reds and blues even when their physical intensities are equal.

3 **Saturation** (colorfulness) is the dimension of visual experience related to the *complexity* of light—that is, to how wide or narrow the range of wavelengths is. When light contains only a single wavelength, it is said to be pure, and the resulting color is completely saturated. At the other extreme is white light, which lacks any color and is completely unsaturated. In nature, pure light is extremely rare. We usually sense a mixture of wavelengths, and we see colors that are duller and paler than completely saturated ones.



An Eye on the World

Light enters the visual system through the eye, a wonderfully complex and delicate structure. As you read this section, examine Figure 6.2. Notice that

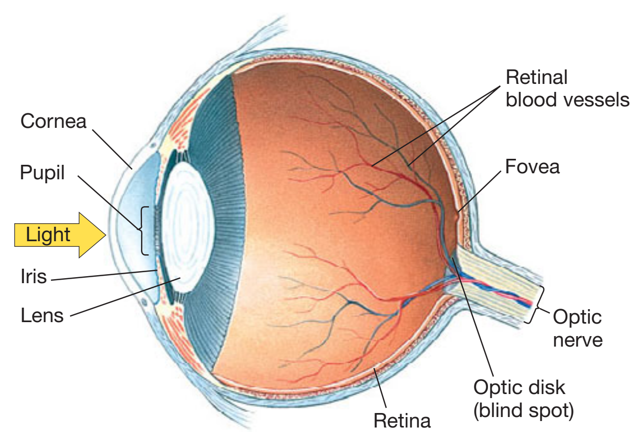


FIGURE 6.2
Major Structures of the Eye
Light passes through the pupil and lens and is focused on the retina at the back of the eye. The point of sharpest vision is at the fovea.

the front part of the eye is covered by the transparent *cornea*. The cornea protects the eye and bends incoming light rays toward a *lens* located behind it. A camera lens focuses incoming light by moving closer to or farther from the shutter opening. However, the lens of the eye works by subtly changing its shape, becoming more or less curved to focus light from objects that are close by or far away. The amount of light that gets into the eye is controlled by muscles in the *iris*, the part of the eye that gives it color. The iris surrounds the round opening, or *pupil*, of the eye. When you enter a dim room, the pupil widens, or dilates, to let more light in. When you emerge into bright sunlight, the pupil gets smaller, contracting to allow in less light.

The visual receptors are located in the back of the eye, or **retina**. (The retina also contains special cells that communicate information about light and dark to the brain area that regulates biological rhythms, as discussed in Chapter 5.) In a developing embryo, the retina forms from tissue that projects out from the brain, not from tissue destined to form other parts of the eye; thus, the retina is actually an extension of the brain. As Figure 6.3 shows, when the lens of the eye focuses light on the retina, the result is an upside-down image. Light from the top of the visual field stimulates light-sensitive receptor cells in the bottom part of the retina, and vice versa. The brain interprets this upside-down pattern of stimulation as something that is right side up.

About 120 to 125 million receptors in the retina are long and narrow, and are called **rods**. Another 7 or 8 million receptors are cone-shaped, and are called, appropriately, **cones**. The center of the retina, or *fovea*, where vision is sharpest, contains only cones, clustered densely together. From the center to the periphery, the ratio of rods to cones increases, and the outer edges contain virtually no cones.

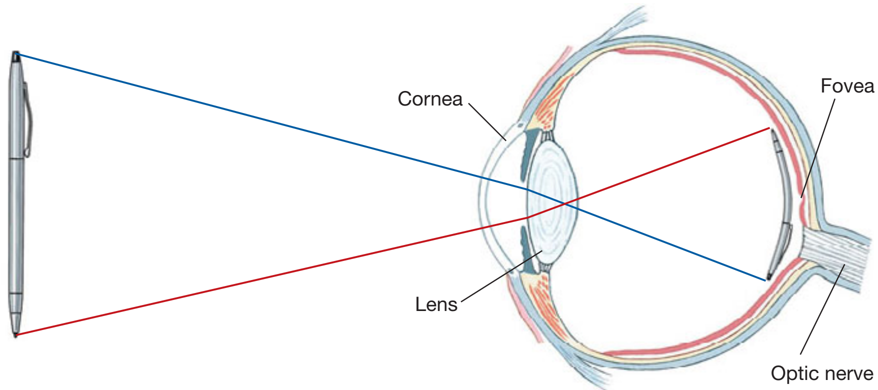
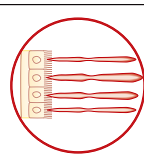
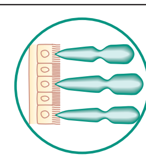


FIGURE 6.3 **The Retinal Image**
When we look at an object, the light pattern on the retina is upside down. René Descartes (1596–1650) was probably the first person to demonstrate this fact. He cut a piece from the back of an ox's eye and replaced the piece with paper. When he held the eye up to the light, he saw an upside-down image of the room on the paper!

Rods are more sensitive to light than cones are. They enable us to see in dim light and at night. (Cats see well in dim light in part because they have a high proportion of rods.) Because rods occupy the outer edges of the retina, they also handle peripheral (side) vision. But rods cannot distinguish different wavelengths of light so they are not sensitive to color, which is why it is often hard to distinguish colors clearly in dim light. The cones, on the other hand, are differentially sensitive to specific wavelengths of light and allow us to see colors. But they need much more light than rods do to respond, so they don't help us much when we are trying to find a seat in a darkened movie theater. (These differences are summarized in Table 6.1.) Explore

Explore Light and the Optic Nerve on **mypsychlab.com**

TABLE 6.1
Differences Between Rods and Cones

	 Rods	 Cones
How many?	120–125 million	7–8 million
Where most concentrated?	Periphery of retina	Center (fovea) of retina
How sensitive?	High sensitivity	Low sensitivity
Sensitive to color?	No	Yes

retina Neural tissue lining the back of the eyeball's interior, which contains the receptors for vision.

rods Visual receptors that respond to dim light.

cones Visual receptors involved in color vision.

dark adaptation A process by which visual receptors become maximally sensitive to dim light.

ganglion cells Neurons in the retina of the eye, which gather information from receptor cells (by way of intermediate bipolar cells); their axons make up the optic nerve.

feature-detector cells Cells in the visual cortex that are sensitive to specific features of the environment.

We have all noticed that it takes some time for our eyes to adjust fully to dim illumination. This process of **dark adaptation** involves chemical changes in the rods and cones. The cones adapt quickly, within 10 minutes or so, but they never become very sensitive to the dim illumination. The rods adapt more slowly, taking 20 minutes or longer, but are ultimately much more sensitive. After the first phase of adaptation, you can see better but not well; after the second phase, your vision is as good as it ever will get.

Rods and cones are connected by synapses to *bipolar cells*, which in turn communicate with neurons called **ganglion cells** (see Figure 6.4). The axons of the ganglion cells converge to form the *optic nerve*, which carries information out through the back of the eye and on to the brain. Where the optic nerve leaves the eye, at the *optic disk*, there are no rods or cones. The absence of receptors produces a blind spot in the field of vision. Normally, we are unaware of the blind spot because (1) the image projected on the spot is hitting a different, "nonblind" spot in the other eye; (2) our eyes move so fast that we can pick up the complete image; and (3) the brain fills in the gap. You can find your blind spot by doing the Get Involved exercise on the facing page.

Why the Visual System Is Not a Camera

Although the eye is often compared with a camera, the visual system, unlike a camera, is not a passive recorder of the external world. Neurons in the visual system actively build up a picture of the world by detecting its meaningful features.

Ganglion cells and neurons in the thalamus of the brain respond to simple features in the environment, such as spots of light and dark. But in mammals, special **feature-detector cells** in the visual cortex respond to more complex features. This fact was first demonstrated by David Hubel and Torsten

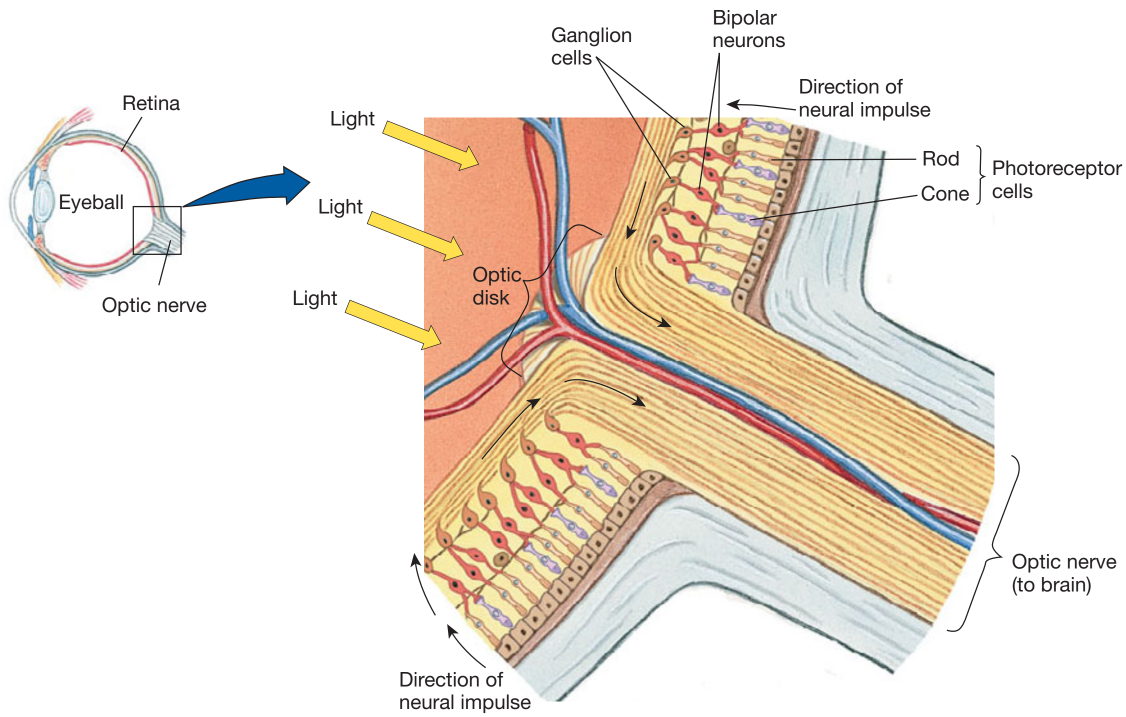


FIGURE 6.4
The Structures of the Retina
For clarity, all cells in this drawing are greatly exaggerated in size. To reach the receptors for vision (the rods and cones), light must pass through the ganglion and bipolar cells as well as the blood vessels that nourish them (not shown). Normally, we do not see the shadow cast by this network of cells and blood vessels because the shadow always falls on the same place on the retina, and such stabilized images are not sensed. But when an eye doctor shines a moving light into your eye, the treelike shadow of the blood vessels falls on different regions of the retina and you may see it—a rather eerie experience.

Get Involved! Find Your Blind Spot

A blind spot exists where the optic nerve leaves the back of your eye. Find the blind spot in your left eye by closing your right eye and looking at the magician. Then slowly move the book toward and away from yourself. The rabbit should disappear when the book is between 9 and 12 inches from your eye.

Wiesel (1962, 1968), who painstakingly recorded impulses from individual cells in the brains of cats and monkeys. In 1981, they were awarded a Nobel Prize for their work. Hubel and Wiesel found that different neurons were sensitive to different patterns projected on a screen in front of an animal's eyes. Most cells responded maximally to moving or stationary lines that were oriented in a particular direction and located in a particular part of the visual field. One type of cell might fire most rapidly in response to a horizontal line in the lower right part of the visual field, another to a diagonal line at a specific angle in the upper left part of the visual field. In the real world, such features make up the boundaries and edges of objects.

Since this pioneering work was done, scientists have found that other cells in the visual system have more complex specialties, such as bull's eyes and spirals. Some cells in the right temporal lobe even appear to respond maximally to *faces* (Kanwisher, 2000; Ó Scalaidhe, Wilson, & Goldman-Rakic, 1997; Young & Yamane, 1992). Some scientists have concluded that evolution has equipped us with an innate *face module* in the brain. The existence of such a module could help explain why infants prefer looking at faces instead of images that scramble the features of a face, and why a person with brain damage may continue to recognize faces even after losing the ability to recognize other objects.

A facility for deciphering faces makes evolutionary sense because it would have ensured our ancestors' ability to quickly distinguish friend from foe, or, in the case of infants, mothers from strangers. However, some psychologists and neuroscientists think that infants' apparent preference for faces is really a preference for curved lines, eye contact, or patterns that have more elements in the upper part (e.g., two eyes) than in the lower part (e.g., just a mouth) (Turati, 2004). Moreover, some of the brain cells that supposedly make up the face module respond to other things as well, depending on a person's experiences and interests. In one study, cells in the presumed face module fired when car buffs examined pictures of classic cars but not when they

Cases of brain damage support the idea that particular systems of brain cells are highly specialized for identifying important objects or visual patterns, such as faces. One man's injury left him unable to identify ordinary objects, which, he said, often looked like "blobs." Yet he had no trouble with faces, even when they were upside down or incomplete. When shown this painting, he could easily see the face but he could not see the vegetables comprising it (Moscovitch, Winocur, & Behrmann, 1997).

trichromatic theory A theory of color perception that proposes three mechanisms in the visual system, each sensitive to a certain range of wavelengths; their interaction is assumed to produce all the different experiences of hue.

opponent-process theory A theory of color perception that assumes that the visual system treats pairs of colors as opposing or antagonistic.

looked at pictures of exotic birds; the exact opposite was true for bird watchers (Gauthier et al., 2000). Cars, of course, do not have faces! In another study by the same researchers, cells in the "face module" fired after people were trained to distinguish among cute—but faceless—imaginary creatures called greebles (Gauthier et al., 1999).

Even if face and other specialized modules do exist, the brain cannot possibly contain a special area for every conceivable object. In general, the brain's job is to take fragmentary information about edges, angles, shapes, motion, brightness, texture, and patterns and figure out that a chair is a chair and the thing next to it is a dining room table. The perception of any given object probably depends on the activation of many cells in far-flung parts of the brain and on the overall pattern and rhythm of their activity

How We See Colors

For over 300 years, scientists have been trying to figure out why we see the world in living color. We now know that different processes explain different stages of color vision.

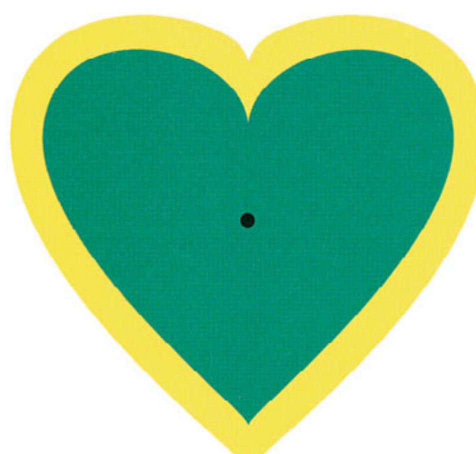
The Trichromatic Theory The **trichromatic theory** (also known as the *Young-Helmholtz theory*) applies to the first level of processing, which occurs in the retina of the eye. The retina contains three basic types of cones. One type responds maximally to blue, another to green, and a third to red. The thousands of colors we see result from the combined activity of these three types of cones.

Total color blindness is usually due to a genetic variation that causes cones of the retina to be absent or malfunctional. The visual world then consists of black, white, and shades of gray. Many species of animals are totally color-blind, but the condition is extremely rare in human beings. Most "color-blind" people are actually *color deficient*. Usually, the person is unable to distinguish red and green; the world is painted in shades of blue, yellow, brown, and gray. In rarer instances, a person may be blind to blue and yellow and may see only reds, greens, and grays. Color deficiency is found in about 8 percent of white men, 5 percent of Asian men, and 3 percent of black men and Native American men (Sekuler & Blake, 1994). Because of the way the condition is inherited, it is rare in women.

The Opponent-Process Theory The **opponent-process theory** applies to the second stage of color processing, which occurs in ganglion cells in the retina and in neurons in the thalamus and visual cortex of the brain. These cells, known as *opponent-process cells*, either respond to short wavelengths but are inhibited from firing by long wavelengths, or vice versa (DeValois & DeValois, 1975). Some opponent-process cells respond in opposite fashion to red and green, or to blue and yellow; that is, they fire in response to one and turn off in response to the other. (A third system responds in opposite fashion to white and black and thus yields information about brightness.) The net result is a color code that is passed along to the higher visual centers. Because this code treats red and green, and also blue and yellow, as antagonistic, we can describe a color as bluish green or yellowish green but not as reddish green or yellowish blue.

Get Involved! A Change of Heart

Opponent-process cells that switch on or off in response to green send an opposite message—"red"—when the green is removed, producing a negative afterimage. Stare at the black dot in the middle of this heart for at least 20 seconds. Then shift your gaze to a white piece of paper or a white wall. Do you get a "change of heart"? You should see an image of a red or pinkish heart with a blue border.



Opponent-process cells that are *inhibited* by a particular color produce a burst of firing when the color is removed, just as they would if the opposing color were present. Similarly, cells that *fire* in response to a color stop firing when the color is removed, just as they would if the opposing color were present. These facts explain why we are susceptible to *negative afterimages* when we stare at a particular hue—why we see, for instance, red after staring at green (do the Get Involved exercise to see for yourself). A sort of neural rebound effect occurs: The cells that switch on or off to signal the presence of "green" send the opposite signal ("red") when the green is removed and vice versa.

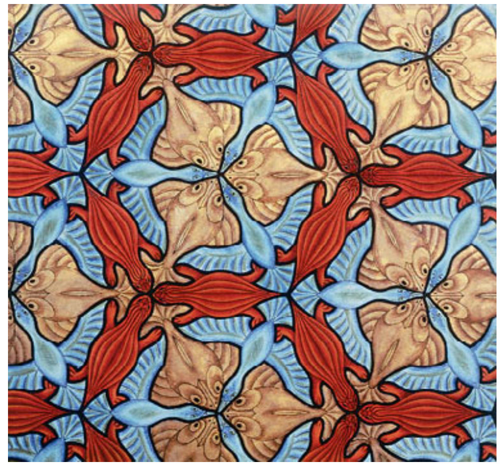


FIGURE 6.5
Figure and Ground
Which do you notice first in this drawing by M. C. Escher—the fish, geese, or salamanders? It will depend on whether you see the blue, red, or gold sections as figure or ground.

Constructing the Visual World

We do not actually see a retinal image; the mind must actively interpret the image and construct the world from the often-fragmentary data of the senses. In the brain, sensory signals that give rise to vision, hearing, taste, smell, and touch are combined from moment to moment to produce a unified model of the world. This is the process of *perception*.

Form Perception To make sense of the world, we must know where one thing ends and another begins. In vision, we must separate the teacher from the lectern; in hearing, we must separate the piano solo from the orchestral accompaniment; in taste, we must separate the marshmallow from the hot chocolate. This process of dividing up the world occurs so rapidly and effortlessly that we take it completely for granted, until we must make out objects in a heavy fog or words in the rapid-fire conversation of someone speaking a language we don't know.

The *Gestalt psychologists*, who belonged to a movement that began in Germany and was influential in the 1920s and 1930s, were among the first to study how people organize the world visually into meaningful units and patterns. In German, *Gestalt* means "form" or "configuration." The Gestalt psychologists' motto was "The whole is more than the sum of its parts." They observed that when we perceive something, properties emerge from the configuration as a whole that are not found in any particular component.

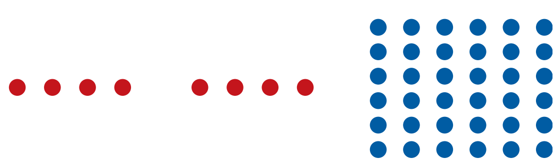
The Gestalt psychologists also noted that people always organize the visual field into *figure* and *ground*. The figure stands out from the rest of the environment (see Figure 6.5). Some things stand out as figure by virtue of their intensity or size; it is hard to ignore the bright glare of a flashlight at night or a tidal wave approaching your piece of beach. The lower part of a scene tends to be seen as figure, the upper part as background (Vecera, Vogel, & Woodman, 2002). Unique objects also stand out, such as a banana in a bowl of oranges, and so do moving objects in an otherwise still environment, such as a shooting star. Indeed, it is hard to ignore a sudden change of any kind in the environment because our brains are geared to respond to change and contrast. However, selective attention—the ability to concentrate on some stimuli and to filter out others—gives us some control over what we perceive as figure and ground, and sometimes it blinds us to things we would otherwise interpret as figure, as we saw earlier. **Simulate**

Simulate Gestalt Laws of Perception on mypsychlab.com

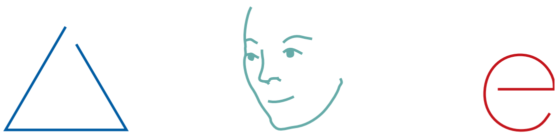
Other **Gestalt principles** describe strategies used by the visual system to group sensory building blocks into perceptual units (Köhler, 1929; Wertheimer, 1923/1958). The Gestalt psychologists believed that these strategies were present from birth or emerged early in infancy as a result of maturation. Modern research, however, suggests that at least some of them depend on experience (Quinn & Bhatt, 2005). Here are a few well-known Gestalt principles:

Gestalt principles Principles that describe the brain's organization of sensory information into meaningful units and patterns.

1 **Proximity.** Things that are near each other tend to be grouped together. Thus you perceive the dots on the left as three groups of dots, not as twelve separate, unrelated ones. Similarly, you perceive the pattern on the right as vertical columns of dots, not as horizontal rows:



2 Closure. The brain tends to fill in gaps and thereby perceive complete forms. This is fortunate because we often need to decipher less-than-perfect images. The following figures are easily perceived as a triangle, a face, and the letter *e*, even though none of the figures is complete:



3 Similarity. Things that are alike in some way (as in color, shape, or size) tend to be perceived as belonging together. In the figure on the left, you see the circles as forming an *X*. In the one on the right, you see horizontal bars rather than vertical columns because the horizontally aligned stars are either all red or all outlined in red:

4 Continuity. Lines and patterns tend to be perceived as continuing in time or space. You perceive the figure on the left as a single line partially covered by an oval rather than as two separate lines touching an oval. In the figure on the right, you see two lines, one curved and one straight, instead of two curved and two straight lines, touching at one focal point:

Unfortunately, many consumer products are designed with little thought for Gestalt principles,

Monocular Cues to Depth

Most cues to depth do not depend on having two eyes. Some monocular (one-eyed) cues are shown here.

LIGHT AND SHADOW

Both of these attributes give objects the appearance of three dimensions.

INTERPOSITION

An object that partly blocks or obscures another one must be in front of the other one, and is therefore seen as closer.

MOTION PARALLAX

When an observer is moving, objects appear to move at different speeds and in different directions. The closer an object, the faster it seems to move; and close objects appear to move backward, whereas distant ones seem to move forward.

which is why it can be a major challenge to find the pause button on your DVD player's remote control or to change from AM to FM on your car radio (Bjork, 2000; Norman, 1988). Good design requires, among other things, that crucial distinctions be visually obvious.

Depth and Distance Perception Ordinarily we need to know not only *what* something is but also *where* it is. Touch gives us this information directly, but vision does not, so we must infer an object's location by estimating its distance or depth.

To perform this remarkable feat, we rely in part on **binocular cues**, cues that require the use of two eyes. One such cue is **convergence**, the turning of the eyes inward, which occurs when they focus on a nearby object. The closer the object, the greater the convergence, as you know if you have ever tried to cross your eyes by looking at your own nose. As the angle of convergence changes, the corresponding muscular changes provide information to the brain about distance.

The two eyes also receive slightly different retinal images of the same object. You can prove this by holding a finger about 12 inches in front of your face and looking at it with only one eye at a time. Its position will appear to shift when you change eyes. Now hold up two fingers, one closer to your nose than the other. Notice that the amount of space between the two fingers appears to change when you switch eyes. The slight difference in lateral (sideways) separation between two objects as seen by the left eye and the right eye is called **retinal disparity**. Because retinal disparity increases as the distance between two objects increases, the brain can use it to infer depth and calculate distance.

Binocular cues help us estimate distances up to about 50 feet. For objects farther away, we use only **monocular cues**, cues that do not depend on using both eyes. One such cue is *interposition*: When an

binocular cues Visual cues to depth or distance requiring two eyes.

convergence The turning inward of the eyes, which occurs when they focus on a nearby object.

retinal disparity The slight difference in lateral separation between two objects as seen by the left eye and the right eye.

monocular cues Visual cues to depth or distance, which can be used by one eye alone.

RELATIVE SIZE

The smaller an object's image on the retina, the farther away the object appears.

TEXTURE GRADIENTS

Distant parts of a uniform surface appear denser; that is, its elements seem spaced more closely together.

RELATIVE CLARITY

Because of particles in the air from dust, fog, or smog, distant objects tend to look hazier, duller, or less detailed.

LINEAR PERSPECTIVE

Parallel lines will appear to be converging in the distance; the greater the apparent convergence, the greater the perceived distance. Artists often exaggerate this cue to convey an impression of depth.

object is interposed between the viewer and a second object, partly blocking the view of the second object, the first object is perceived as being closer. Another monocular cue is *linear perspective*: When two lines known to be parallel appear to be coming together or converging (say, railroad tracks or a highway stretching for miles ahead of you), they imply the existence of depth. These and other monocular cues are illustrated on the previous pages.

The perception of distance is also influenced by some factors that have nothing to do with vision, such as your emotional state, a goal you are trying to reach, and the effort necessary to reach that goal (Proffitt, 2006). Suppose you are out walking and, tired and cranky, you see an appealing coffee shop up ahead. You are likely to think it is farther away if you are wearing a heavy backpack than if you are wearing a light one, because of the increased energy it would take you to get there.

Likewise, if you are asked to throw a ball into a basket, you will probably estimate the distance of that basket as farther when the ball is heavy than when it is light. If an object is just out of reach, you may think it is nearer when you can touch it with a baton than when you can't touch it, because touching it makes it seem closer to your "personal space." And if you are looking down from a balcony, you will probably overestimate the distance to the ground if you are afraid of heights but not if heights don't worry you.

Visual Constancies: When Seeing Is Believing

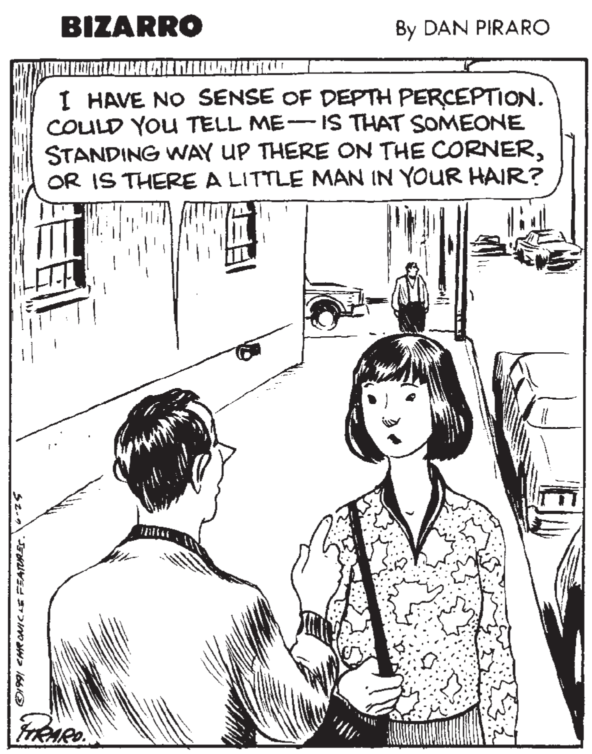
Your perceptual world would be a confusing place without still another important perceptual skill. Lighting conditions, viewing angles, and the distances of stationary objects are all continually changing as we move about, yet we rarely confuse these changes with changes in the objects themselves. This ability to perceive objects as stable, or unchanging, even though the sensory patterns they produce are constantly shifting, is called **perceptual constancy**. The five kinds of constancies that have been most thoroughly studied are visual, and they are:

perceptual constancy The accurate perception of objects as stable or unchanged despite changes in the sensory patterns they produce.

1 Size constancy. We see an object as having a constant size even when its retinal image becomes smaller or larger. A friend approaching on the street does not seem to be growing; a car pulling away from the curb does not seem to be shrinking. Size constancy depends in part on familiarity with objects; you know that people and cars and your dog Ruby do not change size from moment to moment. It also depends on the apparent distance of an object. An object that is close produces a larger retinal image than the same object farther away, and the brain takes this into account. When you move your hand toward your face, your brain registers the fact that the hand is getting closer, and you correctly perceive its unchanging size despite the growing size of its retinal image. There is, then, an intimate relationship between perceived size and perceived distance.

2 Shape constancy. We continue to perceive an object as having a constant shape even though the shape of the retinal image produced by the object changes when our point of view changes. If you hold a Frisbee directly in front of your face, its image on the retina will be round. When you set the Frisbee on a table, its image becomes elliptical, yet you continue to see it as round.

3 Location constancy. We perceive stationary objects as remaining in the same place even though the retinal image moves about as we move our eyes, heads, and bodies. As you drive along the highway, telephone poles and trees fly by on your retina. But you know that these objects do not move on their own, and you also know that your



When size constancy fails.

body is moving, so you perceive the poles and trees as staying put.

4 Brightness constancy. We see objects as having a relatively constant brightness even though the amount of light they reflect changes as the overall level of illumination changes. Snow remains white even on a cloudy day and a black car remains black even on a sunny day. We are not fooled because the brain registers the total illumination in the scene and automatically adjusts for it.

5 Color constancy. We see an object as maintaining its hue despite the fact that the wavelength of light reaching our eyes from the object may change as the illumination changes. For example, outdoor light is "bluer" than indoor light, and objects outdoors therefore reflect more "blue" light than those indoors. Conversely, indoor light from incandescent lamps is rich in long wavelengths and is therefore "yellower." Yet an apple looks red whether you look at it in your kitchen or outside on the patio.

Part of the explanation involves sensory adaptation, which we discussed earlier. Outdoors, we quickly adapt to short-wavelength (bluish) light, and indoors, we adapt to long-wavelength light. As a result, our visual responses are similar in the two situations. Also, when computing the color of a particular object, the brain takes into account *all* the wavelengths in the visual field immediately around the object. If an apple is bathed in bluish light, so, usually, is everything else around it. The increase in blue light reflected by the apple is canceled in the visual cortex by the increase in blue light reflected by the apple's surroundings, and so the apple continues to look red. Color constancy is further aided by our knowledge of the world. We know that apples are usually red and bananas are usually yellow, and the brain uses that knowledge to recalibrate the colors in those objects when the lighting changes (Mitterer & de Ruiter, 2008).

Visual Illusions: When Seeing Is Misleading Perceptual constancies allow us to make sense of the world. Occasionally, however, we can be fooled, and the result is a *perceptual illusion*. For psychologists, illusions are valuable because they are systematic errors that provide us with hints about the perceptual strategies of the mind.

Although illusions can occur in any sensory modality, visual illusions have been the best studied. Visual illusions sometimes occur when the strategies that normally lead to accurate perception are overextended to situations where they do not apply. Compare the lengths of the two vertical lines in Figure 6.6. You will probably perceive the line on the right as slightly longer than the one on the left, yet they are exactly the same. (Go ahead, measure them; everyone does.) This is the Müller-Lyer illusion, named after the German sociologist who first described it in 1889.

One explanation for the Müller-Lyer illusion is that the branches on the lines serve as perspective cues that normally suggest depth (Gregory, 1963). The line on the left is like the near edge of a

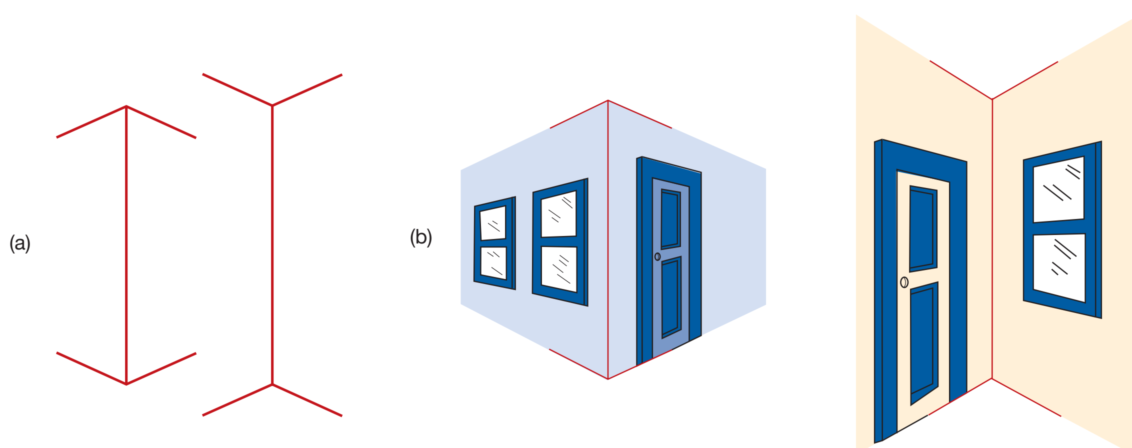
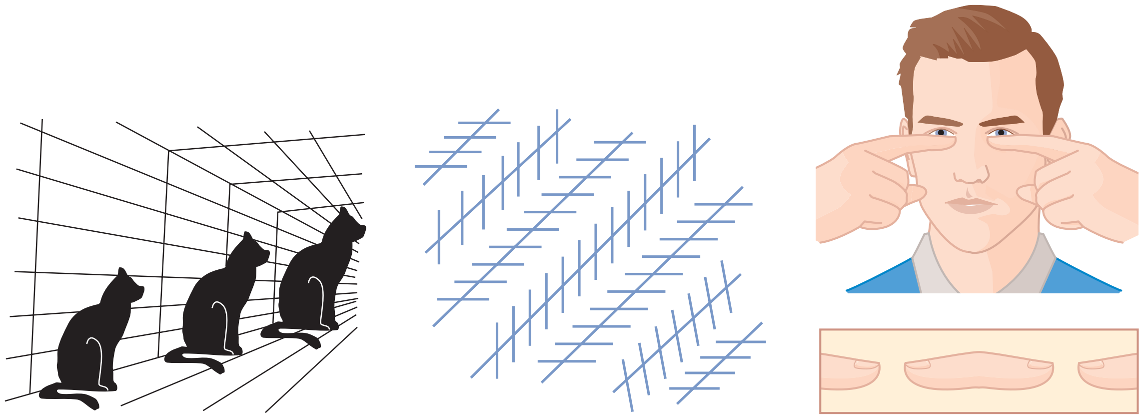


FIGURE 6.6
The Müller-Lyer Illusion
The two lines in (a) are exactly the same length. We are probably fooled into perceiving them as different because the brain interprets the one with the outward-facing branches as farther away, as if it were the far corner of a room, and the one with the inward-facing branches as closer, as if it were the near edge of a building (b).



(a) (b) (c)

FIGURE 6.7
Fooling the Eye
Although perception is usually accurate, we can be fooled. In (a), the cats as drawn are exactly the same size; in (b), the diagonal lines are all parallel. To see the illusion depicted in (c), hold your index fingers 5 to 10 inches in front of your eyes as shown and then focus straight ahead. Do you see a floating "fingertip frankfurter"? Can you make it shrink or expand?

building; the one on the right is like the far corner of a room (see part b of the figure). Although the two lines produce retinal images of the same size, the one with the outward-facing branches suggests greater distance. We are fooled into perceiving it as longer because we automatically apply a rule about the relationship between size and distance that is normally useful: When two objects produce the same-sized retinal image and one is farther away, the farther one is larger. The problem, in this case, is that there is no actual difference in the distance of the two lines, so the rule is inappropriate.

Just as there are size, shape, location, brightness, and color constancies, so there are size, shape, location, brightness, and color *in*constancies, resulting in illusions. The perceived color of an object depends on the wavelengths reflected by its immediate surroundings, a fact well known to artists and interior designers. That is why you never see a good, strong red unless other objects in the surroundings reflect the blue and green part of the spectrum. When two objects that are the same color have different surroundings, you may mistakenly perceive them as different.

Some illusions are simply a matter of physics. Thus, a chopstick in a half-filled glass of water looks bent because water and air refract light differently. Other illusions occur due to misleading messages from the sense organs, as in sensory adaptation. Still others occur because the brain misinterprets sensory information, as in the Müller-Lyer illusion. Figure 6.7 shows some other startling illusions.

Perhaps the ultimate perceptual illusion occurred when Swedish researchers tricked people into feeling that they were swapping bodies with another person or even a mannequin (Petkova & Ehrsson, 2008). The participants wore virtual-reality goggles connected to a camera on the other person's (or mannequin's) head. This allowed them to see the world from the other body's point of view as an experimenter simultaneously stroked both bodies with a rod. Most people soon had the weird sensation that the other body was actually their own; they even cringed when the other body was poked or threatened. The researchers speculate that some day the body-swapping illusion could be helpful in marital counseling, allowing each partner to *literally* see things from the other's point of view, or in therapy with people who have distorted body images.

In everyday life, most illusions are harmless and entertaining. Occasionally, however, an illusion interferes with the performance of some task or skill, or may even cause an accident. For example, because large objects often appear to move more slowly than small ones, drivers sometimes underestimate the speed of onrushing trains at railroad crossings. They think they can beat the train, with tragic results.

Quick Quiz

This quiz is no illusion.

1. How can two Gestalt principles help explain why you can make out the Big Dipper on a starry night?
2. *True or false*: Binocular cues help us locate objects that are very far away.
3. Hold one hand about 12 inches from your face and the other one about 6 inches away. (a) Which hand will cast the smaller retinal image? (b) Why don't you perceive that hand as smaller?
4. From an evolutionary point of view, people are most likely to have a mental module for recognition of (a) flowers, (b) bugs, (c) faces, (d) chocolate, (e) cars.

Answers:

1. *Proximity* of certain stars encourages you to see them as clustered together to form a pattern; *closure* allows you to "fill in the gaps" and see the contours of a "dipper." **2.** false **3. a.** The hand that is 12 inches away will cast a smaller retinal image. **b.** Your brain takes the difference in distance into account in estimating size; also, you know how large your hands are. The result is size constancy. **4.** c

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YOU are about to learn...

- the basics of how we hear.
- why a note played on a flute sounds different from the same note played on an oboe.
- how we locate the source of a sound.

Hearing

Like vision, the sense of hearing, or *audition*, provides a vital link with the world around us. Because social relationships rely so heavily on conversations, people who lose their hearing sometimes come to feel socially isolated. That is why many people with hearing impairment feel strongly about teaching deaf children American Sign Language (ASL) or other gestural systems, which allow them to communicate with other signers.

What We Hear

The stimulus for sound is a wave of pressure created when an object vibrates (or, sometimes, when compressed air is released, as in a pipe organ). The vibration (or release of air) causes molecules in a transmitting substance to move together and apart. This movement produces variations in pressure that radiate in all directions. The transmitting substance is usually air, but sound waves can also travel through water and solids, as you know if you have ever put your ear to the wall to hear voices in the next room.

As with vision, *physical* characteristics of the stimulus—in this case, a sound wave—are related in a predictable way to *psychological* aspects of our experience:

1 **Loudness** is the psychological dimension of auditory experience related to the *intensity* of a wave's pressure. Intensity corresponds to the amplitude, or maximum height, of the wave. The more energy contained in the wave, the higher it is at its peak. Perceived loudness is also affected by how high or low a sound is. If low and high sounds produce waves with equal amplitudes, the low sound may seem quieter.

Sound intensity is measured in units called *decibels* (dB). A decibel is one-tenth of a *bel*, a unit named for Alexander Graham Bell, the inventor of the telephone. The average absolute threshold of hearing in human beings is zero decibels. Unlike inches on a rule, decibels are not equally distant; each 10 decibels denotes a tenfold increase in sound intensity. On the Internet, decibel estimates for various sounds vary a lot from site to site; this is because the intensity of a sound depends on things like how far away it is and the particular person or object producing the sound. The important thing to know is that a 60-decibel conversation is not twice as loud as a 30-decibel whisper; it is 1,000 times louder.

2 **Pitch** is the dimension of auditory experience related to the frequency of the sound wave and, to some extent, its intensity. *Frequency* refers to how rapidly the air (or other medium) vibrates—the number of times per second the wave cycles through a peak and a low point. One cycle per second is known as 1 *hertz* (Hz). The healthy ear of a young person normally detects frequencies in the

loudness The dimension of auditory experience related to the intensity of a pressure wave.

pitch The dimension of auditory experience related to the frequency of a pressure wave; the height or depth of a tone.

timbre The distinguishing quality of a sound; the dimension of auditory experience related to the complexity of the pressure wave.

organ of Corti [core-tee] A structure in the cochlea containing hair cells that serve as the receptors for hearing.

cochlea [KOCK-lee-uh] A snail-shaped, fluid-filled organ in the inner ear, containing the organ of Corti, where the receptors for hearing are located.

range of 16 Hz (the lowest note on a pipe organ) to 20,000 Hz (the scraping of a grasshopper's legs).

3 **Timbre** is the distinguishing quality of a sound. It is the dimension of auditory experience related to the *complexity* of the sound wave, the relative breadth of the range of frequencies that make up the wave. A pure tone consists of only one frequency, but pure tones in nature are extremely rare. Usually what we hear is a complex wave consisting of several subwaves with different frequencies. Timbre is what makes a note played on a flute, which produces relatively pure tones, sound different from the same note played on an oboe, which produces complex sounds.

When many sound-wave frequencies are present but are not in harmony, we hear noise. When all the frequencies of the sound spectrum occur, they produce a hissing sound called *white noise*. Just as white light includes all wavelengths of the visible light spectrum, so white noise includes all frequencies of the audible sound spectrum.

An Ear on the World

As Figure 6.8 shows, the ear has an outer, a middle, and an inner section. The soft, funnel-shaped outer ear is well designed to collect sound waves, but hearing would still be pretty good without it. The essential parts of the ear are hidden from view, inside the head.

A sound wave passes into the outer ear and through an inch-long canal to strike an oval-shaped membrane called the *eardrum*. The eardrum is so sensitive that it can respond to the movement of a single molecule! A sound wave causes it to vibrate with the same frequency and amplitude as the wave itself. This vibration is passed along to three tiny bones in the middle ear, the smallest bones in the human body. These bones, known informally as the hammer, the anvil, and the stirrup, move one after the other, which has the effect of intensifying the force of the vibration. The innermost bone, the stirrup, pushes on a membrane that opens into the inner ear.

The actual organ of hearing, the **organ of Corti**, is a chamber inside the **cochlea**, a snail-shaped

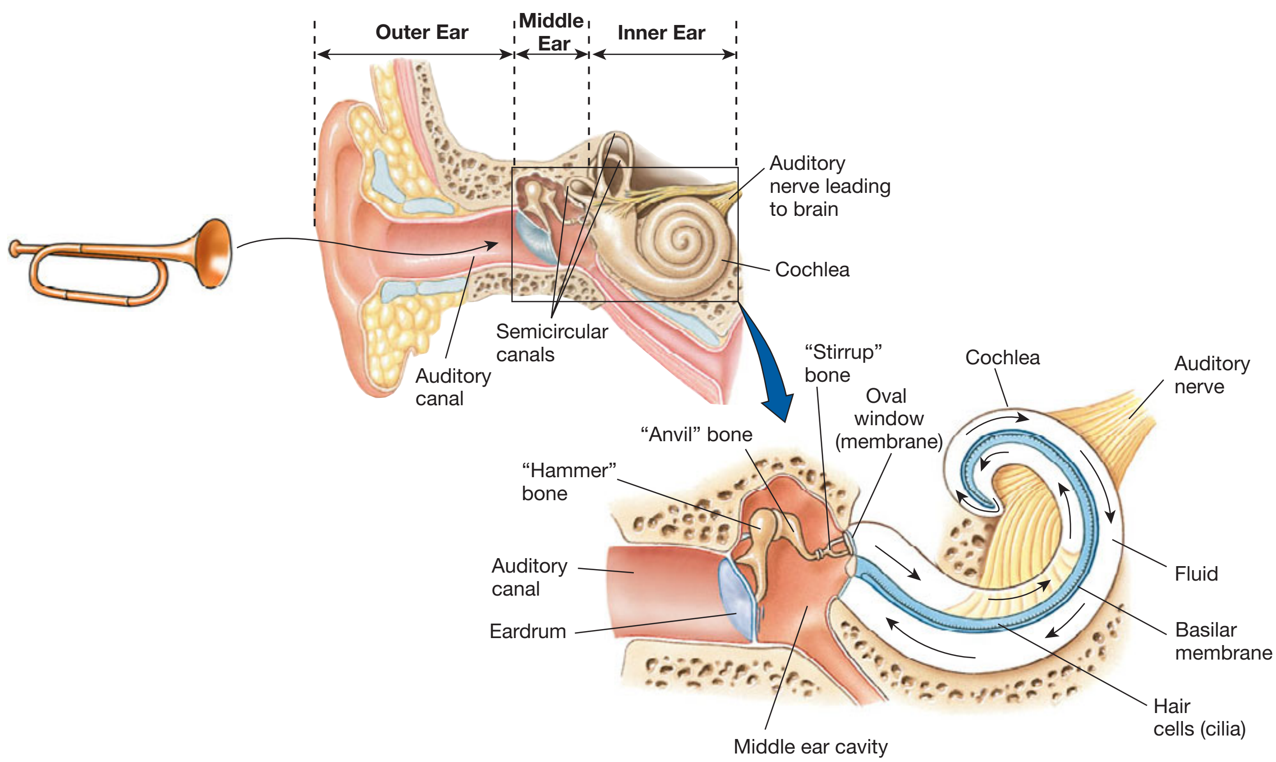
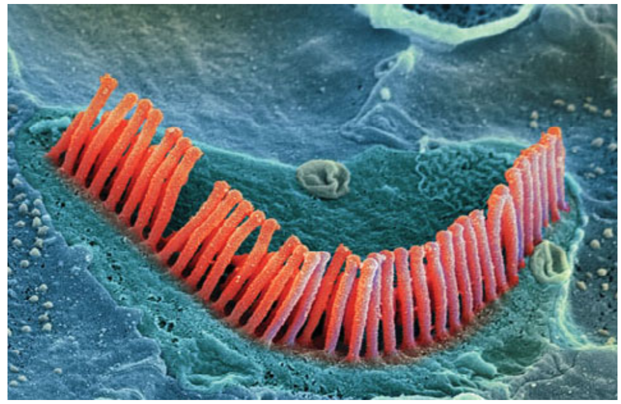


FIGURE 6.8
Major Structures of the Ear
Sound waves collected by the outer ear are channeled down the auditory canal, causing the eardrum to vibrate. These vibrations are then passed along to the tiny bones of the middle ear. Movement of these bones intensifies the force of the vibrations separating the middle and inner ear. The receptor cells for hearing (hair cells), located in the organ of Corti (not shown) within the snail-shaped cochlea, initiate nerve impulses that travel along the auditory nerve to the brain.



If prolonged, the 120-decibel music at a rock concert can damage or destroy the delicate hair cells of the inner ear and impair the hearing of fans standing close to the speakers. The microphotograph on the right shows minuscule bristles (cilia) projecting from a single hair cell.

structure within the inner ear. The organ of Corti plays the same role in hearing that the retina plays in vision. It contains the all-important receptor cells, which in this case look like bristles and are called *hair cells* and are topped by tiny bristles, or *cilia*. Brief exposure to extremely loud noises, like those from a gunshot or a jet airplane (140 dB), or sustained exposure to more moderate noises, like those from shop tools or truck traffic (90 dB), can damage these fragile cells. The cilia flop over like broken blades of grass, and if the damage affects a critical number, hearing loss occurs. In modern societies, with their rock concerts, deafening bars, leaf blowers, jackhammers, and MP3 players turned up to full blast, such damage is increasingly common, even among teenagers and young adults (Agrawal, Platz, & Niparko, 2008). Scientists are looking for ways to grow new, normally functioning hair cells (Izumikawa et al., 2005; Sage et al., 2005). But hair-cell damage is currently irreversible.

The hair cells of the cochlea are embedded in the rubbery *basilar membrane*, which stretches across the interior of the cochlea. When pressure reaches the cochlea, it causes wavelike motions in fluid within the cochlea's interior. These waves of fluid push on the basilar membrane, causing it to move in a wavelike fashion, too. Just above the hair cells is yet another membrane. As the hair cells rise and fall, their tips brush against it, and they bend. This causes the hair cells to initiate a signal that is passed along to the *auditory nerve*, which then carries the message to the brain. The particular pattern of hair-cell movement is affected by the manner in which the basilar membrane moves. This pattern determines which neurons fire and how rapidly they fire, and the resulting code in turn helps determine the sort of sound we hear. We discriminate high-pitched sounds largely on the basis of where activity occurs along the basilar membrane; activity at different sites leads to different neural codes. We discriminate low-pitched sounds largely on the basis of the frequency of the basilar membrane's vibration; again, different frequencies lead to different neural codes.

Could anyone ever imagine such a complex and odd arrangement of bristles, fluids, and snail shells if it did not already exist? **Explore**

Explore Structures of the Ear on mypsychlab.com

Constructing the Auditory World

Just as we do not see a retinal image, so we do not hear a chorus of brushlike tufts bending and swaying in the dark recesses of the cochlea. Instead, we use our perceptual powers to organize patterns of sound and to construct a meaningful auditory world.

In class, your psychology instructor hopes you will perceive his or her voice as *figure* and distant cheers from the athletic field as *ground*. Whether these hopes are realized will depend, of course, on where you choose to direct your attention. Other Gestalt principles also seem to apply to hearing. The *proximity* of notes in a melody tells you which notes go together to form phrases; *continuity* helps you follow a melody on one violin when another violin is playing a different melody; *similarity* in timbre and pitch helps you pick out the soprano voices in a chorus and hear them as a unit; *closure* helps you understand a cell phone caller's words even when interference makes some of the individual sounds unintelligible.

Besides needing to organize sounds, we also need to know where they are coming from. We can estimate the *distance* of a sound's source by using loudness as a cue; we know that a train sounds louder when it is 20 yards away than when it is a mile off. To locate the *direction* a sound is coming from, we depend in part on the fact that we have two ears. A sound arriving from the right reaches the right ear a fraction of a second sooner than it reaches the left ear, and vice versa. The sound may also provide a bit more energy to the right ear (depending on its frequency) because it has to get around the head to reach the left ear. It is hard to localize sounds that are coming from directly in back of you or from directly above your head because such sounds reach both ears at the same time. When you turn or cock your head, you are actively trying to overcome this problem. Horses, dogs, rabbits, deer, and many other animals do not need to do this because, lucky creatures that they are, they can move their ears independently of their heads.

Study and **Review** on **mypsychlab.com**

Quick Quiz

How well can you localize the answers to these questions?

1. Which psychological dimensions of hearing correspond to the intensity, frequency, and complexity of the sound wave?
2. Fred's voice is nasal and Ted's is gravelly. Which psychological dimension of hearing describes the difference?
3. An extremely loud or sustained noise can permanently damage the _______ of the ear.
4. During a lecture, a classmate draws your attention to a buzzing fluorescent light that you had not previously noticed. What will happen to your perception of figure and ground?

Answers:

1. loudness, pitch, timbre **2.** timbre **3.** hair cells (cilia) **4.** The buzzing sound will become figure and the lecturer's voice will become ground, at least momentarily.

YOU are about to learn...

- the basics of how we taste, smell, and feel.
- why saccharin and caffeine taste bitter to some people but not to others.
- why you have trouble tasting your food when you have a cold.
- why pain is complicated to understand and treat.
- how two senses inform us of the movement of our own bodies.

Other Senses

Psychologists have been particularly interested in vision and audition because of the importance of these senses to human survival. However, research on other senses is growing rapidly, as awareness of how they contribute to our lives increases and new ways are found to study them.

papillae [pa-PILL-ee] Knoblike elevations on the tongue, containing the taste buds. (Singular: *papilla.*)

taste buds Nests of taste-receptor cells.

Taste: Savory Sensations

Taste, or *gustation*, occurs because chemicals stimulate thousands of receptors in the mouth. These receptors are located primarily on the tongue, but some are also found in the throat, inside the cheeks, and on the roof of the mouth. If you look at your tongue in a mirror, you will notice many tiny bumps; they are called **papillae** (from the Latin for "pimples"), and they come in several forms. In all but one of these forms, the sides of each papilla are lined with **taste buds**, which up close look a little like segmented oranges (see Figure 6.9). Because of genetic differences, human tongues can have as few as 500 or as many as 10,000 taste buds (Miller & Reedy, 1990).

The taste buds are commonly referred to, mistakenly, as the receptors for taste. The actual receptor cells are *inside* the buds, 15 to 50 to a bud. These cells send tiny fibers out through an opening in the bud; the receptor sites are on these fibers. New receptor cells replace old ones about every ten days. However, after age 40 or so, the total number of taste buds (and therefore receptors) declines. Interestingly, the center of the tongue contains no taste buds. However, as in the case of the eye's blind spot, you will not usually notice the lack of sensation because the brain fills in the gap.

There are four basic tastes that are part of our evolutionary heritage: *salty*, *sour*, *bitter*, and *sweet*, each produced by a different type of chemical.

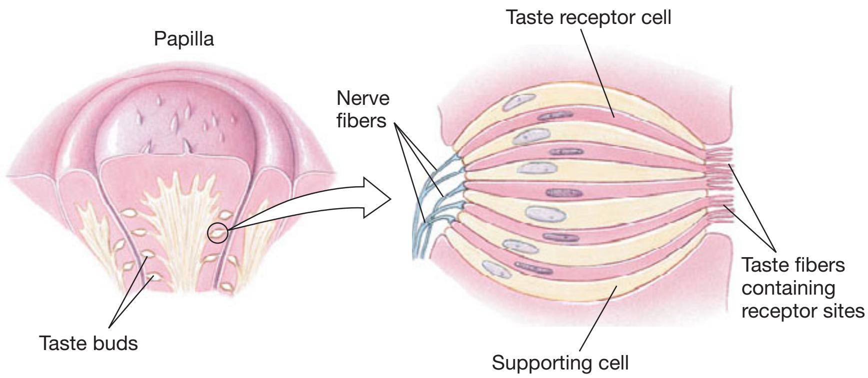


FIGURE 6.9
Taste Receptors
The illustration on the left shows taste buds lining the sides of a papilla on the tongue's surface. The illustration on the right shows an enlarged view of a single taste bud.

These hardwired taste receptors are tuned to molecules that alert us to good or dangerous tastes: Bitter tastes detect poison; sweet tastes attract us to eat biologically useful sugars; salty tastes enable us to identify sodium, a mineral crucial to survival; and sour tastes permit us to avoid acids in concentrations that might injure tissue (Bartoshuk, 2009). All of the basic tastes can be perceived at any spot on the tongue that has receptors, and differences among the areas are small. When you bite into an egg or a piece of bread or an orange, its unique flavor is composed of some combination of these tastes.

Some researchers believe that there is a fifth basic taste, *umami*, the taste of monosodium glutamate (MSG), which is supposed to detect protein. (Umami, which means "delicious" in Japanese, was identified by Japanese chemists in the early 1900s as a flavor enhancer.) However, findings from research on umami, which has largely been funded by the MSG industry, are debatable for two reasons: First, the umami taste is not perceptible in many foods containing protein. Second, umami lacks one of the most important properties of a basic taste: a hardwired response causing most people everywhere to react to it the same way. On the contrary, some individuals like umami, but others do not (Bartoshuk, 2009).

The evidence that umami is probably not a hardwired fifth taste has led to another fascinating discovery: Taste receptors are found throughout the gastrointestinal tract and may have different functions in different locations. Protein molecules are too large to be sensed by taste or smell; but when they are eaten, they are broken into their constituent amino acids, stimulating glutamate receptors in the gut, which in turn signal the brain that protein has been consumed, and creating a conditioned preference for the sensory properties of protein-rich foods such as bacon, roast beef, and cheese. Response to umami therefore occurs in the gut, not the mouth, and is a learned preference rather than a universal one (Bartoshuk, 2009).

Everyone knows that people live in different "taste worlds" (Bartoshuk, 1998). Some people love broccoli and others hate it. Some people can eat chili peppers that are burning hot and others cannot tolerate the mildest jalepeño. One reason for these differences is genetic. In the United States, about 25 percent of people are *supertasters* who find saccharin, caffeine, broccoli, and many other substances to be unpleasantly bitter. (Women, especially Asian women, are overrepresented in this group.) In contrast, "tasters" detect less bitterness in these foods, and "nontasters" detect none at all. Supertasters also perceive sweet tastes as sweeter and salty tastes as saltier than other people do, and they feel more "burn" from substances such as ginger, pepper, and hot chilies (Bartoshuk et al., 1998;

Get Involved! The Smell of Taste

Demonstrate for yourself that smell enhances the sense of taste. While holding your nose, take a bite of a slice of apple, and then do the same with a slice of raw potato. You may find that you can't taste much difference. If you think you do taste a difference, perhaps your expectations are influencing your response. Try the same thing, but close your eyes this time and have someone else feed you the slices. Can you still tell them apart? It's also fun to do this little test with flavored jelly beans. They are still apt to taste sweet, but you may be unable to identify the separate flavors.

Lucchina et al., 1998). Supertasters have more taste buds than other people. In addition, the papillae on their tongues are smaller, are more densely packed, and look different from those of nontasters (Reedy et al., 1993).

Other taste preferences are a matter of culture and learning. Many North Americans who enjoy raw food such as oysters, smoked salmon, and herring are nevertheless put off by other forms of raw seafood that are popular in Japan, such as sea urchin and octopus. And within a given culture, some people will greedily gobble up a dish that makes others turn green. Some of these learned taste preferences may begin in the womb or during breastfeeding. A baby whose mother drank carrot juice while pregnant or nursing is likely to be more enthusiastic about eating porridge mixed with carrot juice than porridge mixed with water, whereas babies without this exposure show no such preference (Mennella, Jagnow, & Beauchamp, 2001). The same findings turn up for many other flavors transmitted to an infant in breast milk, such as vanilla, cheese, mint, hot spices, and garlic.

The attractiveness of a food can also be affected by its color, temperature, and texture. As Goldilocks found out, a bowl of cold porridge is not nearly as delicious as one that is properly heated. And any peanut butter fan will tell you that chunky and smooth peanut butters just don't taste the same. Even more important for taste is a food's odor. Much of what we call "flavor" is really the smell of gases released by the foods we put in our mouths. Indeed, subtle flavors such as chocolate and vanilla would have little taste if we could not smell them (see Figure 6.10). Smell's influence on flavor explains why you have trouble tasting your food when you have a stuffy nose. Most people who have chronic trouble detecting tastes have a problem with smell, not taste.

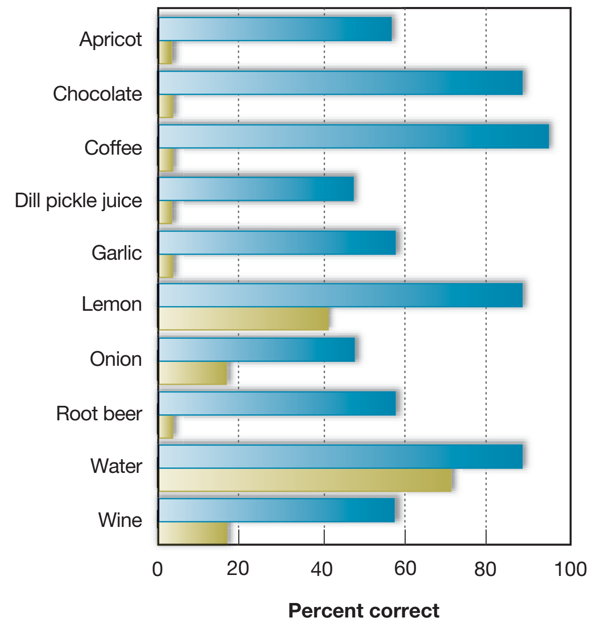


FIGURE 6.10
Taste Test
The turquoise bars show the percentages of people who could identify a substance dropped on the tongue when they were able to smell it. The green bars show the percentage that could identify the substance when they were prevented from smelling it (Mozell et al., 1969).

Smell: The Sense of Scents

The great author and educator Helen Keller, who became blind and deaf as a toddler, once called smell "the fallen angel of the senses." Yet our sense of smell, or *olfaction*, although seemingly crude when compared to a bloodhound's, is actually quite good; the human nose can detect aromas that sophisticated machines fail to detect.

The receptors for smell are specialized neurons embedded in a tiny patch of mucous membrane in the upper part of the nasal passage, just beneath the eyes (see Figure 6.11). Millions of receptors in each nasal cavity respond to chemical molecules in the air. When you inhale, you pull these molecules into the nasal cavity, but they can also enter from the mouth, wafting up the throat like smoke up a chimney. These molecules trigger responses in the receptors that combine to yield the yeasty smell of freshly baked bread or the spicy smell of a curry. Signals from the receptors are carried to the brain's olfactory bulb by the *olfactory nerve*, which is made up of the receptors' axons. From the olfactory bulb, they travel to a higher region of the brain.

Figuring out the neural code for smell has been a real challenge. Of the 10,000 or so smells we detect (rotten, burned, musky, fruity, fishy, spicy, and so on), none seems to be more basic than any other. Moreover, roughly 1,000 kinds of receptors exist, each kind responding to a part of an odor molecule's structure (Axel, 1995; Buck & Axel, 1991). Distinct odors activate unique combinations of receptors, and signals from different types of receptors are combined in individual neurons in the brain.

Although smell is less vital for human survival than for the survival of other animals, it is still important. We sniff out danger by smelling smoke, rotten food, and gas leaks, so a deficit in the sense of smell is nothing to turn up your nose at. Such a loss can result from infection, disease, injury to the olfactory nerve, or smoking. A person who has

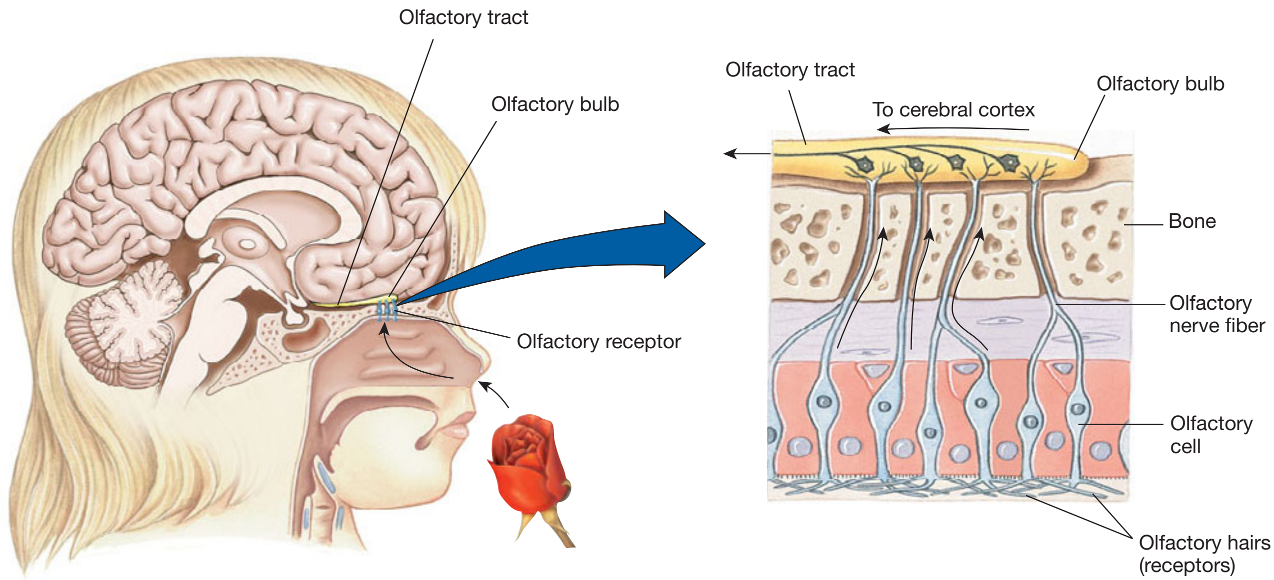


FIGURE 6.11
Receptors for Smell
Airborne chemical molecules (vapors) enter the nose and circulate through the nasal cavity, where the smell receptors are located. The receptors' axons make up the olfactory nerve, which carries signals to the brain. When you sniff, you draw more vapors into the nose and speed their circulation. Vapors can also reach the nasal cavity through the mouth by way of a passageway from the throat.

smoked two packs a day for ten years must abstain from cigarettes for ten more years before the sense of smell returns to normal (Frye, Schwartz, & Doty, 1990).

Odors, of course, have psychological effects on us, which is why we buy perfumes and sniff flowers. Perhaps because olfactory centers in the brain are linked to areas that process memories and emotions, specific smells often evoke vivid, emotionally colored memories (Herz & Cupchik, 1995; Vroon, 1997). The smell of hot chocolate may trigger fond memories of cozy winter mornings from your childhood; the smell of rubbing alcohol may remind you of an unpleasant trip to the hospital. Odors can also influence people's everyday behavior, which is why shopping malls and hotels often install aroma diffusers in hopes of putting you in a good mood.

Many dubious, unsupported claims have been made for the powers of particular aromas, but now some serious research is being done. For example, Dutch researchers have found that the citrus scent of an all-purpose cleaner, unobtrusively left in a hidden bucket, can activate the mental concept *cleaning* and can even affect people's "cleaning behavior" (Holland, Hendriks, & Aarts, 2005). In one of their studies, participants wrote down five activities they were planning to do during the rest of the day. Those who had been exposed to the scent listed a cleaning activity more often than those who had not been exposed to it. In another study, participants did a task and then moved to another room, where they were invited to

Smell has not only evolutionary but also cultural significance. These pilgrims in Japan are purifying themselves with holy incense for good luck and health.

sit at a table and eat a crumbly biscuit as a hidden video camera recorded their hand movements. People who had been exposed to the cleaning scent while working on the initial task were much more likely to wipe away crumbs from the table than those who had not been exposed! Apparently, activation of the concept *cleaning* made them more likely to clean up after themselves. Later experiments found that clean scents even prime people to be more generous and trusting (Liljenquist, Zhong, & Galinsky, 2010).

After each of these studies, the researchers questioned the participants and found that none had been aware of the scent's influence. In fact, most were not even aware of having smelled the scent at all. Clearly, scent can have a nonconscious influence on what we think and do. This information should be helpful for anyone who has (or is!) a selfish or sloppy roommate. **Watch**

Watch the **Video Aromatherapy** on **mypsychlab.com**

Senses of the Skin

The skin's usefulness is more than just skin deep. Besides protecting our innards, our two square yards of skin help us identify objects and establish intimacy with others. By providing a boundary between ourselves and everything else, the skin also gives us a sense of ourselves as distinct from the environment.

The basic skin senses include *touch* (or pressure), *warmth*, *cold*, and *pain*. Within these four types are variations such as itch, tickle, and painful burning. Although some spots on the skin are especially sensitive to the four basic skin sensations, scientists had difficulty finding distinct receptors and nerve fibers for these sensations, except in the case of pressure. But then Swedish researchers discovered a nerve fiber that seems responsible for the kind of itching caused by histamines (Schmelz et al., 1997). Another team has found that the same fibers that detect pain from a punch in the nose or a burn also seem to detect the kind of pathological itch that is unrelated to histamines and that can't be relieved by antihistamine medications (Johanek et al., 2008). Scientists have also identified a possible cold receptor (McKemy, Neuhausser, & Julius, 2002; Peier et al., 2002).

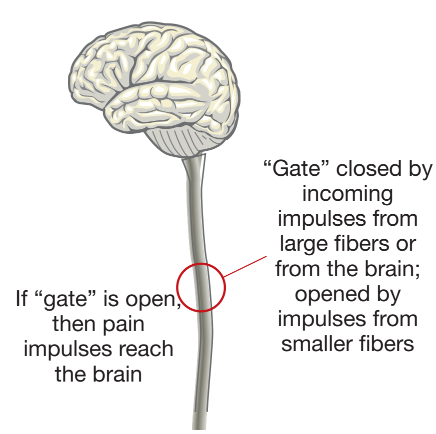
Perhaps specialized fibers will be discovered for other skin sensations as well. In the meantime, many aspects of touch remain baffling. Scientists still do not know why gently touching adjacent pressure spots in rapid succession produces tickle and why scratching relieves (or sometimes worsens) an itch. Decoding the messages of the skin senses will eventually tell us how we are able to distinguish sandpaper from velvet and glue from grease.

gate-control theory The theory that the experience of pain depends in part on whether pain impulses get past a neurological "gate" in the spinal cord and thus reach the brain.

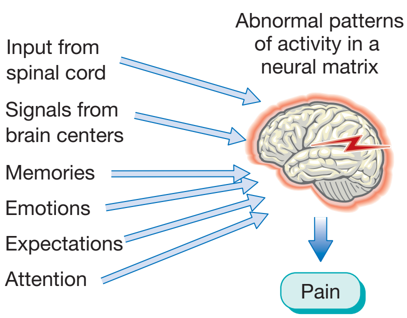
The Mystery of Pain

Pain, which is both a skin sense and an internal sense, has come under special scrutiny. Pain differs from other senses in an important way: Even when the stimulus producing it is removed, the sensation may continue, sometimes for years. Understanding the physiology of pain has been an enormous challenge, because different types of pain (from, say, a thorn, a bruise, or a hot iron) involve different chemical changes and different changes in nerve-cell activity at the site of injury or disease, as well as in the spinal cord and brain. Several chemical substances are involved and so are glial cells, the cells that support nerve cells (see Chapter 4); they release inflammatory substances that can worsen the pain (Watkins & Maier, 2003).

The Physiology of Pain For many years, a leading explanation of pain has been the **gate-control theory**, which was first proposed by Canadian psychologist Ronald Melzack and British physiologist Patrick Wall (1965). According to this theory, pain impulses must get past a "gate" in the spinal cord. The gate is not an actual structure, but rather a pattern of neural activity that either blocks pain messages from the skin, muscles, and internal organs or lets those signals through. Normally, the gate is kept shut, either by impulses coming into the spinal cord from large fibers that respond to pressure and other kinds of stimulation or by signals coming down from the brain itself. But when body tissue is injured, the large fibers are damaged and smaller fibers open the gate, allowing pain messages to reach the brain unchecked. The gate-control theory correctly predicts that mild pressure, or other kinds of stimulation, can interfere with severe or protracted pain by closing the spinal gate. When we vigorously rub a banged elbow or apply ice packs, heat, or stimulating ointments to injuries, we are applying this principle.



In the gate theory, the brain not only responds to incoming signals from sensory nerves but is also capable of generating pain entirely on its own (Melzack, 1992, 1993). An extensive *matrix* (network) of neurons in the brain gives us a sense of our own bodies and body parts. When this matrix produces abnormal patterns of activity, the result is pain. The brain's ability to generate pain can help explain the many instances of severe, chronic pain that occur without any sign of injury or disease whatsoever.



An extreme version of pain without injury occurs in **phantom pain**, in which a person continues to feel pain that seemingly comes from an arm or leg that has been amputated or a bodily organ that has been surgically removed. Phantom limb pain afflicts up to 90 percent of amputees. The person may feel the same aching, burning, or sharp pain from sores, calf cramps, throbbing toes, or even ingrown toenails that he or she endured before the surgery. Even when the spinal cord has been completely severed, amputees often continue to report phantom pain from areas below the break. There are no nerve impulses for the spinal-cord gate to block or let through, yet the pain can be constant and excruciating; some sufferers commit suicide.

A leading explanation of phantom pain is that the brain has reorganized itself: The area in the sensory cortex that formerly corresponded to the missing body part has been "invaded" by neurons from another area, often one corresponding to the face. Higher brain centers then interpret messages from those neurons as coming from the nonexistent body part (Cruz et al., 2005; Ramachandran & Blakeslee, 1998). Even though the missing limb can no longer send signals through touch and internal sensations, memories of these signals remain in the nervous system, including memories of pain, paralysis, and cramping that occurred prior to amputation. The result is an inaccurate "body map" in the brain and pain signals that cannot be shut off.

Vilayanur Ramachandran, the neurologist who first proposed this theory, has developed an extraordinarily simple but effective treatment for phantom limb pain. Ramachandran wondered whether he could devise an illusion to trick the brain of an amputee with phantom arm pain into perceiving the missing limb as moving and pain-free. He placed a simple mirror upright and perpendicular to the sufferer's body, such that the amputee's intact arm was reflected in the mirror. From the amputee's perspective, the result was an illusion of two functioning arms. The amputee was then instructed to move both arms in synchrony while looking into the mirror. With this technique, which has now been used with many people, the brain is fooled into thinking its owner has two healthy arms, resynchronizes the signals—and phantom pain vanishes (Ramachandran & Altschuler, 2009). Neurologists have been testing this method with Iraq veterans, and are finding it to be more successful than control therapies in which patients just mentally visualize having two intact limbs (Anderson-Barnes et al., 2009; Chan et al., 2007).

After his right leg was destroyed in an explosion while he was in Iraq, Army Sergeant Nicholas Paupore experienced excruciating phantom limb pain—as though the missing leg were constantly being shocked or stabbed. Even morphine didn't help. Then, as part of a clinical trial, he underwent a simple daily treatment. A mirror was placed at a strategic angle to reflect his intact leg, tricking his brain into registering two healthy legs that he could move freely. The pain subsided almost immediately. A year after therapy, he had only occasional, milder pain and needed no medication. In some patients, mirror therapy has eliminated phantom pain entirely.

The Psychology of Pain Whether pain arises normally or arises abnormally in the absence of tissue damage, psychological as well as physiological factors affect the severity of chronic pain and a person's reactions to it. When people dwell on their pain and talk about it constantly, or begin to define

phantom pain The experience of pain in a missing limb or other body part.

kinesthesis [KIN-es-THEE-sís] The sense of body position and movement of body parts; also called *kinesthesia*.

equilibrium The sense of balance.

themselves as a sick, suffering person, their pain typically intensifies (Pincus & Morley, 2001).

Expectations also exert a powerful influence. If you expect to feel pain, you may focus on it, producing a self-fulfilling prophecy. And if you expect *not* to feel pain, that expectation, too, can become self-fulfilling. In one study, ten healthy volunteers had heat applied to their lower legs (Koyama et al., 2005). The volunteers had been trained to expect jolts of heat of varying intensity depending on the delay between a tone and application of the heat; the longer the delay, the stronger the heat. Functional MRI showed that the stronger the pain the volunteers expected to feel, the greater the activity in certain brain regions prior to delivery of the pain, and most of these regions overlapped with those that responded to the actual pain. Moreover, when the researchers gave the signal for moderately painful heat and instead delivered the most painful heat, the subjects' self-reported pain fell by 28 percent, compared with when they expected the most painful heat and actually got it (see Figure 6.12). This decrease was equal to what they would have experienced had they received a shot of morphine!

Findings like these suggest a mechanism for how placebos reduce pain: When placebos affect expectations ("I'm going to get relief"), they also affect the brain mechanism's underlying pain. Indeed, when volunteers in another study had an "analgesic cream" (actually a placebo) rubbed on their skin before getting a painful shock to the wrist, MRI scans showed decreased activity in the pain matrix, the pain-sensitive areas of their brains (Wager et al., 2004).

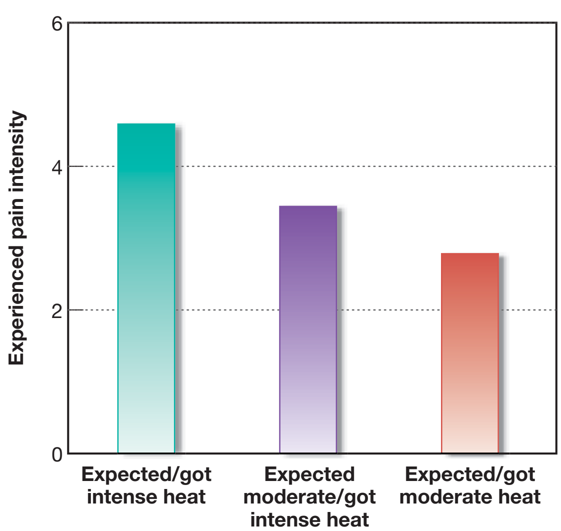


FIGURE 6.12
Expectations and Pain
When people expected moderate heat but got intense heat (purple bar), their self-reported pain was lower than it would have been had they expected the intense heat (green bar).

Placebos also promote the production of endorphins, the body's natural pain-relieving opiates. Researchers gave volunteers a slow, harmless injection of a pain-inducing solution in the jaw and had them rate their pain level (Zubieta et al., 2005). As the injection continued, the researchers told some of the participants (falsely) that a pain-relieving serum had been added and again asked all of the subjects to rank their discomfort. Throughout the procedure, PET scans tracked the activity of endorphins in the subjects' brains. Those who got the placebo produced endorphins in pain-control areas of the brain, which is just what would have happened had they taken a real pain killer.

As a result of such research, pain management programs now take psychological factors into account. Many are based on cognitive-behavior therapy, which teaches people living with chronic pain how to substitute adaptive thoughts for negative ones, and to use coping strategies such as distraction and imagery (see Chapter 12). These cognitive and behavioral strategies, in turn, affect pain-processing and pain-modifying circuits in the brain (Edwards et al., 2009). As scientists explore the puzzles of pain, they are beginning to see why it is that some people experience great pain when there is no apparent physiological reason for it, whereas others do not experience pain even when there is a physiological reason. Pain is not "just in people's heads," but it may be in their brains.

The Environment Within

We usually think of our senses as pipelines to the world around us, but two senses keep us informed about the movements of our own bodies. **Kinesthesis** tells us where our bodily parts are located and lets us know when they move. This information is provided by pain and pressure receptors located in the muscles, joints, and tendons. Without kinesthesis, you would have trouble with any voluntary movement. Think of how hard it is to walk when your leg has fallen asleep or how awkward it feels to chew when a dentist has numbed your jaw.

Equilibrium, or the sense of balance, gives us information about our bodies as a whole. Along with vision and touch, it lets us know whether we

This break-dancer obviously has exceptional kinesthetic talents and equilibrium.

are standing upright or on our heads and tells us when we are falling or rotating. Equilibrium relies primarily on three **semicircular canals** in the inner ear (refer back to Figure 6.8 on page 200). These thin tubes are filled with fluid that moves and presses on hairlike receptors whenever the head rotates. The receptors initiate messages that travel through a part of the auditory nerve that is not involved in hearing.

semicircular canals Sense organs in the inner ear that contribute to equilibrium by responding to rotation of the head.

Normally, kinesthesis and equilibrium work together to give us a sense of our own physical reality, something we take utterly for granted but should not. Oliver Sacks (1985) told the heartbreaking story of Christina, a young British woman who suffered irreversible damage to her kinesthetic nerve fibers because of a mysterious inflammation. At first, Christina was as floppy as a rag doll; she could not sit up, walk, or stand. Then, slowly, she learned to do these things, relying on visual cues and sheer willpower. But her movements remained unnatural; she had to grasp a fork with painful force or she would drop it. More important, despite her remaining sensitivity to light touch on the skin, she said she could no longer experience herself as physically embodied: "It's like something's been scooped right out of me," she told Sacks, "right at the center."

With equilibrium, we come, as it were, to the end of our senses. Every single second, millions of sensory signals reach the brain, which combines and integrates them to produce a model of reality. How does it know how to do this? Are our perceptual abilities inborn, or must we learn them? We turn next to this issue.

Quick Quiz

Study and Review on mypsychlab.com

See if you can make sense of the following quiz items.

A. What explanation of each problem is most likely?

1. April always has trouble tasting foods, especially those with subtle flavors.
2. May, a rock musician, does not hear as well as she used to.
3. June has chronic shoulder pain, though the injury that initially caused it seems to have healed. (Hint: Think about the gate-control theory.)

B. After reading about the research on how scent affects "cleaning behavior," what further questions might you want to ask?

C. After seeing a new pain-relief ointment advertised on TV, you try it and find that it seems to work. What other explanation is possible for the decrease in your pain?

Answers:

A. 1. April may have an impaired sense of smell, possibly due to disease, illness, or cigarette smoking. **2.** Hearing impairment has many causes, but in May's case, we might suspect that prolonged exposure to loud music has damaged the hair cells of her cochlea. **3.** Nerve fibers that normally close the pain "gate" may have been damaged, or a matrix of cells in the brain may be producing abnormal activity. **B.** Some questions to ask: Do other scents also affect behavior, and if so, which ones? (We do not want to oversimplify by assuming that similar results would occur for all scents.) Are pleasant and unpleasant scents equally likely to affect behavior? Would the effects be even stronger if the participants were aware of the scent? Most important, will other research replicate these initial findings? **C.** The relief you feel may be due at least in part to a placebo effect, which has reduced activity in the pain matrix of your brain or has led to increased production of endorphins.

YOU are about to learn...

- whether babies see the world in the way adults do.
- what happens when people who are born blind or deaf have their sight or hearing restored.
- how psychological and cultural factors affect perception.

Perceptual Powers: Origins and Influences

What happens when babies first open their eyes? Do they see the same sights, hear the same sounds, and smell the same smells as an adult does? Or is an infant's world, as William James once suggested, only a "blooming, buzzing confusion," waiting to be organized by experience and learning? The truth lies somewhere between these two extremes.

Inborn Abilities

In human beings, most basic sensory abilities and many perceptual skills are inborn or develop very early. Infants can distinguish salty from sweet and can discriminate among odors. They can distinguish a human voice from other sounds. They will startle to a loud noise and turn their heads toward its source, showing that they perceive sound as being localized in space. Many visual skills, too, are present at birth or develop shortly afterward. Human infants can discriminate sizes and colors very early, possibly even right away. They distinguish contrasts, shadows, and complex patterns after only a few weeks, and depth perception develops during the first few months.

Testing an infant's perception of depth requires considerable ingenuity. In a classic procedure, infants are placed on a device called a *visual cliff* (Gibson & Walk, 1960). The "cliff" is a pane of glass covering a shallow surface and a deep one (see Figure 6.13). Both surfaces are covered by a checkerboard pattern. The infant is placed on a board in the middle, and the child's mother tries to lure the baby across either the shallow side or the deep side. Babies only 6 months of age will crawl across the shallow side but will refuse to crawl out over the "cliff." Their hesitation shows that they have depth perception.

Even younger infants have been tested on the visual cliff, although they cannot yet crawl. At only 2 months of age, babies show a drop in heart rate when placed on the deep side but no change when they are placed on the shallow side. A slowed heart rate is usually a sign of increased attention. Thus, although these infants may not be frightened the way an older infant would be, it seems they can perceive the difference between the shallow and deep sides of the cliff (Banks & Salapatek, 1984).

Critical Periods

Although many perceptual abilities are inborn, experience also plays a vital role. If an infant misses

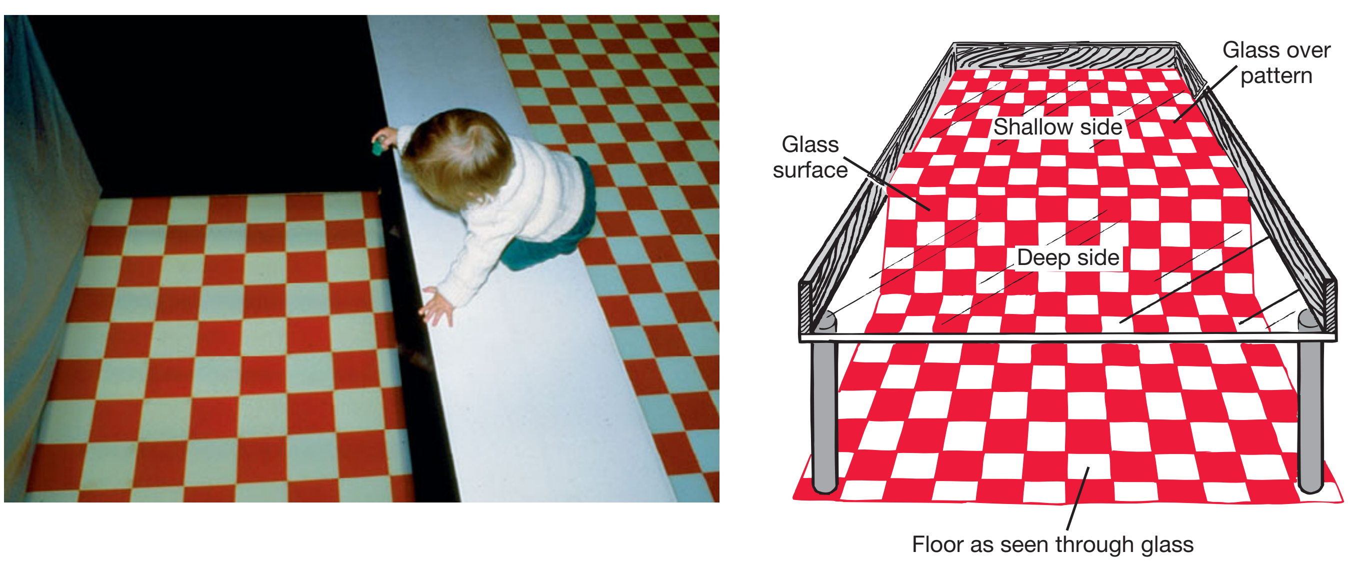


FIGURE 6.13
A Cliff-Hanger
Infants as young as 6 months usually hesitate to crawl past the apparent edge of a visual cliff, which suggests that they are able to perceive depth.

out on important experiences during a crucial window of time called a *critical period* (sometimes called a *sensitive period*), perception will be impaired. Innate abilities may not survive because cells in the nervous system deteriorate, change, or fail to form appropriate neural pathways.

One way to study critical periods is to see what happens when the usual perceptual experiences of early life fail to take place. To do this, researchers have studied kittens and other animals whose sensory and perceptual systems are similar to our own. Like human infants, kittens are born with the visual ability to detect horizontal and vertical lines and other spatial orientations; at birth, kittens' brains are equipped with the same kinds of feature-detector cells that adult cats have. But if they are deprived of normal visual experience, these cells deteriorate or change and perception suffers (Crair, Gillespie, & Stryker, 1998; Hirsch & Spinelli, 1970).

In one famous study, kittens were exposed to either vertical or horizontal black and white stripes. Special collars kept them from seeing anything else, even their own bodies. After several months, the kittens exposed only to vertical stripes seemed blind to all horizontal contours; they bumped into horizontal obstacles, and they ran to play with a bar that an experimenter held vertically but not to a bar held horizontally. In contrast, those exposed only to horizontal stripes bumped into vertical obstacles and ran to play with horizontal bars but not vertical ones (Blakemore & Cooper, 1970).

What about human beings? Because of the brain's impressive plasticity (see Chapter 4), some people who were unable to see until middle childhood or even adulthood can regain enough perceptual ability to get along fine in daily life (Ostrovsky, Andalman, & Sinha, 2006). However, their perception is unlikely to fully recover. When adults who have been blind from infancy have their vision restored, most of them do not see well. Areas in the brain normally devoted to vision may have taken on different functions when these individuals were blind. As a result, their depth perception may be poor, causing them to trip constantly. They cannot always make sense of what they see; to identify objects, they may have to touch or smell them. They may have trouble recognizing faces and emotional expressions. They may even lack size constancy and may need to remind themselves that people walking away from them are not shrinking in size (Fine et al., 2003). Generally, the best recoveries occur when an infant's congenital blindness is corrected early, probably because a critical period for visual development occurs in infancy or early childhood.

Similar findings apply to hearing. When adults who were born deaf, or who lost their hearing before learning to speak, receive cochlear implants (devices that stimulate the auditory nerve and allow auditory signals to travel to the brain), they tend to find sounds confusing. They are unable to learn to speak normally, and sometimes they ask to have the implants removed. But cochlear implants are more successful in children and in adults who became deaf late in life (Rauschecker, 1999). Young children presumably have not yet passed through the critical period for processing sounds, and older adults have already had years of auditory experience.

In sum, our perceptual powers are both inborn and dependent on experience. Because neurological connections in infants' brains and sensory systems are not completely formed, their senses are far less acute than an adult's. It takes time and experience for their sensory abilities to fully develop. But an infant's world is clearly not the blooming, buzzing confusion that William James took it to be.

Psychological and Cultural Influences

The fact that some perceptual processes appear to be innate does not mean that all people perceive the world in the same way. A camera doesn't care what it "sees." A digital recorder doesn't ponder what it "hears." But because we human beings care about what we see, hear, taste, smell, and feel, psychological factors can influence what we perceive and how we perceive it. Here are a few of these factors:

1. **Needs and motives.** When we need something, have an interest in it, or want it, we are especially likely to perceive it. For example, hungry individuals are faster than others at seeing words related to hunger when the words are flashed briefly on a screen (Wispé & Drambarean, 1953). People also tend to perceive objects that they want—a water bottle if they are thirsty, money they can win in a game, a personality test with favorable results—as being physically closer to them than objects they don't want or need. The researchers call these motivated misperceptions "wishful seeing" (Balcetis & Dunning, 2010).

2. **Beliefs.** What we hold to be true about the world can affect our interpretation of ambiguous sensory signals. If you believe that extraterrestrials occasionally visit the earth and one evening you see a round object in the sky, you may think you are seeing a spaceship. (Impartial investigations of UFO sightings show that they are actually weather balloons, rocket launchings, swamp

People often see what they want to see. Diana Duyser, a cook at a Florida casino, took a bite out of a grilled cheese sandwich and believed she saw the image of the Virgin Mary in what remained of it. She preserved the sandwich in plastic for ten years and then decided to sell it. An online casino bought it on eBay for $28,000, even with a bite of it missing!

gas, military aircraft, or ordinary celestial bodies, such as planets and meteors.) Images that remind people of Jesus or Mary have been reported on walls, dishes, tortillas, and plates of spaghetti; the Arabic script for "Allah" has been reported on fish scales, chicken eggs, and beans. Such images cause great excitement among those who believe that divine messages can be found on everyday objects. However, inevitably mundane explanations prove to be the right ones. A purported image of Jesus on a garage door in California turned out to be caused by two streetlights that merged the shadows of a bush and a "For Sale" sign in the yard.

3 Emotions. Emotions can also influence our interpretation of sensory information, as when a small child afraid of the dark sees a ghost instead of a robe hanging on the bedroom door. Pain is particularly intensified by negative emotions such as anxiety and sadness. Interestingly, when people perceive their pain as resulting from another person's malicious intent (e.g., they think the other person intentionally stepped on their toe), they feel the hurt more than they would if they thought it was simply due to a clumsy accident (Gray & Wegner, 2008).

4 Expectations. Previous experiences often affect how we perceive the world (Lachman, 1996). The tendency to perceive what you expect is called a **perceptual set.** Perceptual sets can come in handy; they help us fill in words in sentences when we haven't really heard every one. But perceptaul sets can also cause misperceptions. In Center Harbor, Maine, local legend has it that veteran newscaster Walter Cronkite was sailing into port one day when he heard a small crowd on shore shouting "Hello, Walter . . . Hello, Walter." Pleased, he waved and took a bow. Only when he ran aground did he realize what they had really been shouting: "Shallow water . . . shallow water!"

perceptual set A habitual way of perceiving, based on expectations.

By the way, the previous paragraph has a misspelled word. Did you notice it? If not, probably it was because you expected all the words in this book to be spelled correctly.

Culture and Context Our needs, beliefs, emotions, and expectations are all affected, in turn, by the culture we live in. Different cultures give people practice with different environments. In a classic study done in the 1960s, researchers found that members of some African tribes were much less likely to be fooled by the Müller-Lyer illusion and other geometric illusions than were Westerners. In the West, the researchers observed, people live in a "carpentered" world, full of rectangular structures. Westerners are also used to interpreting two-dimensional photographs and perspective drawings as representations of a three-dimensional world. Therefore, they interpret the kinds of angles used in the Müller-Lyer illusion as right angles extended in space, a habit that increases susceptibility to the illusion. The rural Africans in the study, living in a less carpentered environment and in round huts, seemed more likely to take the lines in the figures literally, as two-dimensional, which could explain why they were less susceptible to the illusion (Segall, Campbell, & Herskovits, 1966; Segall et al., 1999).

Culture also affects perception by shaping our stereotypes, directing our attention, and telling us what to notice or ignore. Westerners tend to focus mostly on the figure when viewing a scene and much less on the ground. East Asians, in contrast, tend to pay attention to the overall context and the relationship between figure and ground. When Japanese and Americans were shown underwater scenes containing brightly colored fish that were larger and moving faster than other objects in the scene, they reported the same numbers of details about the fish, but the Japanese reported more details about everything else in the background (Masuda & Nisbett, 2001). If it doesn't move, most Americans don't see it.

As you can see . . . well, what you see partly depends on the culture you live in! When travelers visit another culture and are surprised to find that its members "see things differently," they may be literally correct.

Quick Quiz

Direct your perceptual attention now to this quiz.

1. On the visual cliff, most 6-month-old babies (a) go right across because they cannot detect depth, (b) cross even though they are afraid, (c) will not cross because they can detect depth, (d) cry or get bored.
2. Newborns and infants (a) have few perceptual abilities, (b) need visual experiences during a critical period for vision to develop normally, (c) see as well as adults.
3. "Have a nice . . . " says Dewey, but then he gets distracted and doesn't finish the thought. Yet Clarence is sure he heard Dewey wish him a nice *day*. Why?

Answers:

1. c **2.** b **3.** perceptual set due to expectations

Study and **Review** on **mypsychlab.com**

YOU are about to learn...

- that perception is often unconscious.
- whether "subliminal perception" tapes will help you lose weight or reduce your stress.

Perception without Awareness

It would be impossible to be consciously aware of every single thing we see, hear, touch, or even smell in the course of a day; we rely on selective filters to focus our attention. Much of our perception occurs without our conscious awareness, yet may nonetheless influence our behavior.

Behavior can be affected even by stimuli that are so weak or brief that they are below a person's absolute threshold for detecting them—that is, *subliminal*. People sometimes correctly sense a change in a scene (say, in the color or location of an object) even though the change took place too quickly to be consciously recognized and identified (Rensink, 2004). And individuals who are subliminally exposed to a face will tend to prefer that face over one they did not "see" in this way (Bornstein, Leone, & Galley, 1987).

In many studies of nonconscious perception, researchers have used a method called **priming**, in which a person is exposed to information explicitly or subliminally and is later tested to see whether the information affects performance on another task. For example, when words flashed subliminally are

priming A method used to measure unconscious cognitive processes, in which a person is exposed to information and is later tested to see whether the information affects behavior or performance on another task or in another situation.

related to some personality trait, such as honesty, people are more likely later to judge someone they read about as having that trait. They have been "primed" to evaluate the person that way (Bargh, 1999).

Thus, people often know more than they know they know. In fact, nonconscious processing occurs not only in perception but also in memory, thinking, and decision making, as we discuss in Chapters 7 and 8. However, even in the laboratory, where researchers have considerable control, subliminal perception can be hard to demonstrate and replicate. The strongest evidence for its existence comes from studies using simple stimuli (faces or single words such as *bread*) rather than complex stimuli such as sentences ("Eat whole wheat bread, not white bread, if you know what's good for you!").

If subliminal priming can affect judgments and preferences in the laboratory, you may be wondering whether it can be used to manipulate people's attitudes and behavior in ordinary life. Subliminal persuasion techniques first became a hot topic back in the 1950s, when an advertising executive claimed to have increased popcorn and Coke sales at a theater by secretly flashing the words EAT POPCORN and DRINK COKE on the movie screen. The claim turned out to be a hoax, devised to save the man's struggling advertising company.

Listen to **Subliminal Messages** on **mypsychlab.com**

Ever since, scientists have been skeptical, but that has not deterred people who market subliminal tapes that promise to help you lose weight, stop smoking, relieve stress, boost your motivation, lower your cholesterol, or stop biting your nails, all without any effort on your part. Ah, if only those claims were true! But they are not. In study after study, placebo tapes—tapes that do not contain the messages that participants think they do—have been just as "effective" as subliminal tapes (Eich & Hyman, 1992; Merikle & Skanes, 1992; Moore, 1992, 1995). In one typical experiment, people listened to tapes labeled "memory" or "self-esteem," but some heard tapes that were incorrectly labeled. About half showed improvement in the area specified by the label *whether it was correct or not*. The improvement was due to expectations alone (Greenwald et al., 1991).

Thinking Critically about Subliminal Persuasion

However, previous efforts at subliminal persuasion may have left out an important ingredient: the person's motivation. A team of researchers used subliminal messages—the words *thirst* and *dry*—to make subjects feel thirsty and prime them to drink. Later, when given a chance to drink, the primed participants did in fact drink more than control subjects did, but only if they had been moderately thirsty to begin with (Strahan, Spencer, & Zanna, 2002). **Listen**

Does this mean that advertisers can seduce us into buying soft drinks or voting for political candidates by slipping subliminal slogans and images into television and magazine ads? The priming research has renewed the debate. Yet given the many studies that have found no evidence of subliminal persuasion in real life and the subtlety of the effects that occur in the laboratory (e.g., you have to be somewhat thirsty already to be primed to want to drink), we think there's little cause for worry about subliminal manipulation. And if you want to improve yourself or your life, you'll have to do it the old-fashioned way: by working at it consciously.

Study and **Review** on **mypsychlab.com**

Quick Quiz

Please remain conscious while you answer this question.

A study appears to find evidence of "sleep learning"—the ability to perceive and retain material played on an audio recording while a person sleeps. What would you want to know about this research before deciding to record this chapter and play it by your bedside all night instead of studying it in the usual way?

Answers:

Was there a control group that listened to, say, a musical selection or white noise? How complicated was the material that was allegedly learned: a few key words, whole sentences, a whole lecture by Professor Arbuckle? Were the results large enough to have any practical applications? How did the researchers determine that the participants really were asleep? When brain-wave measures are used to verify that volunteers are actually sleeping, no "sleep learning" takes place.

Psychology in the news REVISITED

Psychology in the News

Lindsey Vonn Defeats Pain to Win Olympic Gold

WHISTLER, BRITISH COLUMBIA, February 18, 2010. Lindsey Vonn today became the first U.S. woman to win the gold medal in the Olympic downhill race. "I was completely overwhelmed," Vonn said. "It was one of the best feelings I've ever had in my life. Everyone expected me to do it, but it's not as easy as just saying you can do it."

That's a huge understatement, since Vonn had seriously injured her shin during training a week earlier and had to have fluid drained from the deep bruise, which was bleeding internally. "When I tried my boot on, I was just standing there in the hotel room barely flexing forward, and it was excruciatingly painful. And I've got to try to ski downhill at 75, 80 miles an hour with a lot of forces pushed up against my shin," Vonn said at the time of the injury. "I don't know honestly if I'll be able to do it."

Vonn said she fought through pain the whole way down the bumpy, challenging course, on which several other skiers had crashed. When Vonn took off, she shaved every millisecond she could off her time by skiing tightly around the turns. "It wasn't an option to ski passively," Vonn said. "I had to really take it."

UFO Sighting Over St. Louis

CLEVELAND, OH, March 15, 2010. Thousands of Cleveland residents have been flocking to the Lake Erie riverfront to take pictures of mysterious lights in the night sky. For almost two weeks, the lights have been appearing at about 7:30 p.m., moving back and forth for a while and then disappearing.

"At first, I figured it was just a star," said medical technician Eugene Erlikh, 20. "But the way it would move, I've never seen anything like it." The local NASA facility said the lights have nothing to do with their work, and air-traffic controllers could not explain them either. UFO sightings are common in Ohio. More than 20 reports of mysterious lights or objects have been made in the past two years.

One of the earliest UFO accounts occurred in the late 1940s, when a rancher noticed some strange objects strewn about his property near Roswell, New Mexico. When the Air Force quickly blocked off and cleared the site, stories circulated that a spacecraft had crashed and that alien corpses had been recovered. Thousands of believers in UFOs still flock to the International UFO Museum in Roswell.

Are these alien spacecraft? Many people who viewed these odd objects in the skies above Santos, Brazil, were convinced they were seeing UFOs.

The great Greek philosopher Plato once said that "knowledge is nothing but perception." But simple perception is not always the best path to knowledge. As we have seen throughout this chapter, we do not passively register the world "out there"; we mentally construct it. If we are critical thinkers, therefore, we will be aware of how our beliefs, motivations, and assumptions shape our perceptions.

Sometimes those perceptions work to our advantage, as in the case of Lindsey Vonn, whose ability to ski in the Olympics trumped excruciating pain from an injury. The human capacity for selective attention, and our ability to focus on goals we are strongly motivated to achieve, can temporarily make people oblivious to pain they would otherwise feel, which is why we so often hear of athletes and dancers who are able to finish a performance despite sprained ankles, serious bruises, or even broken bones. Similarly, soldiers who are seriously wounded often deny being in much pain, even though they are alert and are not in shock. Their relief at being alive may offset the worry and fear that would otherwise make their pain worse, although the body's own pain-fighting mechanisms may also be involved.

At other times, our perceptions work to our disadvantage, as in the second story that opened this chapter, about people who report seeing spaceships. Some people, as we noted, are habitual yea-sayers who, because of their expectations, are quick to think they saw something that wasn't there. Others are fooled by the normal distortions of perception: When you are looking up at the sky, where there are few points of reference, it is difficult to judge how far away or how big an object is. And still others believe in UFOs and are longing to see one, and that wish can affect their perception of ambiguous objects.

Whenever impartial investigators have looked into UFO reports, they have found that what people actually saw were weather balloons, rocket launchings, swamp gas, military aircraft, or (in the vast majority of cases) ordinary celestial bodies, such as planets and meteors. The strange objects in the photo accompanying our news story, which look so much like flying saucers, are really lenticular (lens-shaped) clouds. And the "alien bodies" reported in Roswell were simply test dummies made of rubber, which the Air Force was dropping from high-altitude balloons before subjecting human beings to jumps from the same height. But even capable, intelligent people can be fooled. One astronomer who investigates UFO reports says, "I've been with Air Force pilots who thought they were seeing a UFO. But it was actually the moon. I've seen people look at Venus and say they could see port-holes on a spaceship" (quoted in Ratcliffe, 2000).

None of this means that the only real world is the mundane one we see in everyday life. Because our sense organs evolved for particular purposes, our sensory windows on the world are partly shuttered. But we can use reason, ingenuity, and science to pry those shutters open. Ordinary perception tells us that the sun circles the earth, but the great astronomer Copernicus was able to figure out nearly five centuries ago that the opposite is true. Ordinary perception will never let us see ultraviolet and infrared rays directly, but we know they are there, and we can measure them. If science can enable us to overturn the everyday evidence of our senses, who knows what surprises science has in store for us?

Remember this amazing photo from Chapter 1? After reading this chapter, you should have a better idea of why "seeing" should not always be "believing."

Taking Psychology with You

Can Perception Be "Extrasensory"?

Eyes, ears, mouth, nose, skin: We rely on these organs for our experience of the external world. Some people, however, claim they can send and receive messages about the world without relying on the usual sensory channels, by using *extrasensory perception (ESP).* Reported ESP experiences involve things like telepathy, the direct communication of messages from one mind to another without the usual sensory signals, and precognition, the perception of an event that has not yet happened. How should critical thinkers respond to such claims? What questions should they ask, and what kind of evidence should they look for?

Evidence or Coincidence? Much of the supposed evidence for extrasensory perception comes from anecdotal accounts. But people are not always reliable reporters of their own experiences. They often embellish and exaggerate, or they recall only part of what happened. They also tend to forget incidents that do not fit their beliefs, such as "premonitions" of events that fail to occur. Many ESP experiences could merely be unusual coincidences that are memorable because they are dramatic. What passes for telepathy or precognition could also be based on what a person knows or deduces through ordinary means. If Joanne's father has had two recent heart attacks, her premonition that her father will die shortly (followed, in fact, by her father's death) may not be so impressive.

The scientific way to establish a phenomenon is to produce it under controlled conditions. ESP has been studied extensively by researchers in the field of *parapsychology,* but studies have often been poorly designed, with inadequate precautions against fraud and improper statistical analysis. As a result, the history of research in this area has been one of initial enthusiasm because of apparently positive results (Bem & Honorton, 1994; Dalton et al., 1996), followed by disappointment when the results cannot be replicated (Milton & Wiseman, 1999, 2001). One researcher who tried for 30 years to establish the reality of psychic phenomena finally gave up in defeat. "I found no psychic phenomena," she wrote, "only wishful thinking, self-deception, experimental error, and even an occasional fraud. I became a skeptic" (Blackmore, 2001).

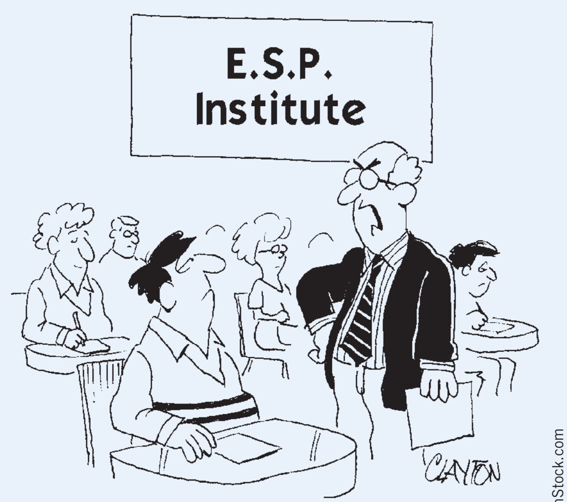
The issue has not gone away, however. Many people *really, really* want to believe that ESP exists. James Randi, a famous magician who is dedicated to educating the public about psychic deception, has for years offered a million dollars to anyone who can demonstrate ESP or other paranormal powers in the presence of independent observers and under controlled conditions. Many have taken up the challenge; no one has succeeded. We think Randi's money is safe.

Lessons from a Magician. Despite the lack of evidence for ESP, many people say they believe in it. Perhaps you yourself have had an experience that seemed to involve ESP, or perhaps you have seen a convincing demonstration by someone else. Surely you can trust the evidence of your own eyes. Or can you? We will answer this question with a true story, one that contains an important lesson about why it's a good idea to think critically regarding ESP.

During the 1970s, Andrew Weil (now known for his efforts to promote alternative medicine) set out to investigate the claims of a self-proclaimed psychic named Uri Geller (Weil, 1974a, 1974b). Weil, who believed in telepathy, felt that ESP might be explained by principles of modern physics, and he was receptive to Geller's claims. When he met Geller at a private gathering, he was not disappointed. Geller correctly identified a cross and a Star of David sealed inside separate envelopes. He made a stopped watch start running and made a ring sag into an oval shape, apparently without touching them. He made keys change shape. Weil came away a convert. What he had seen with his own eyes seemed impossible to deny . . . until he went to visit the Amazing Randi.

To Weil's astonishment, Randi was able to duplicate much of what Geller had done. He, too, could bend keys and guess the contents of sealed envelopes. But Randi's feats were tricks, and he was willing to show Weil exactly how they were done. Weil suddenly experienced "a sense of how strongly the mind can impose its own interpretations on perceptions; how it can see what it expects to see, but not see the unexpected."

Weil was dis-illusioned—literally. Even when he knew what to look for in a trick, he could not catch the Amazing Randi doing it. Weil learned that our sense impressions of reality are not the same as reality. Our eyes, our ears, and especially our brains can play tricks on us.



"What do you mean you didn't know that we were having a pop quiz today?"

Summary

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- *Sensation* is the detection and direct experience of physical energy as a result of environmental or internal events. *Perception* is the process by which sensory impulses are organized and interpreted.

Our Sensational Senses

- Sensation begins with the *sense receptors*, which convert the energy of a stimulus into electrical impulses that travel along nerves to the brain. Separate sensations can be accounted for by *anatomical codes* (as set forth by the *doctrine of specific nerve energies*) and *functional codes* in the nervous system. In *sensory substitution*, sensory crossover from one modality to another occurs, and in *synesthesia*, sensation in one modality consistently evokes a sensation in another, but these experiences are rare.
- Psychologists specializing in *psychophysics* have studied sensory sensitivity by measuring *absolute* and *difference thresholds*. *Signal-detection theory*, however, holds that responses in a detection task consist of both a sensory process and a decision process and will vary with the person's motivation, alertness, and expectations.
- Our senses are designed to respond to change and contrast in the environment. When stimulation is unchanging, *sensory adaptation* occurs. Too little stimulation can cause *sensory deprivation*. Too much stimulation can cause *sensory overload. Selective attention* prevents overload and allows us to focus on what is important, but it also deprives us of sensory information we may need, as in *inattentional blindness*.

Vision

- Vision is affected by the wavelength, intensity, and complexity of light, which produce the psychological dimensions of visual experience—*hue, brightness*, and *saturation*. The visual receptors, *rods* and *cones*, are located in the *retina* of the eye. They send signals (via other cells) to the *ganglion cells* and ultimately to the *optic nerve*, which carries visual information to the brain. Rods are responsible for vision in dim light; cones are responsible for color vision. *Dark adaptation* occurs in two stages.
- Specific aspects of the visual world, such as lines at various orientations, are detected by *feature-detector cells* in the visual areas of the brain. Some of these cells respond maximally to complex patterns. A debate is going on about the possible existence of specialized "face modules" in the brain. In general, however, the brain must take in fragmentary information about lines, angles, shapes, motion, brightness, texture, and other features of what we see and come up with a unified view of the world.
- The *trichromatic* and *opponent-process* theories of color vision apply to different stages of processing. In the first stage, three types of cones in the retina respond selectively to different wavelengths of light. In the second, *opponent-process cells* in the retina and the thalamus respond in opposite fashion to short and long wavelengths of light.
- Perception involves the active construction of a model of the world from moment to moment. The *Gestalt principles* (e.g., *figure and ground*, *proximity*, *closure*, *similarity*, and *continuity*) describe visual strategies used by the brain to perceive forms.
- We localize objects in visual space by using both *binocular* and *monocular* cues to depth. Binocular cues include *convergence* and *retinal disparity*. Monocular cues include, among others, *interposition* and *linear perspective*. *Perceptual constancies* allow us to perceive objects as stable despite changes in the sensory patterns they produce. *Perceptual illusions* occur when sensory cues are misleading or when we misinterpret cues.

Hearing

- Hearing (*audition*) is affected by the intensity, frequency, and complexity of pressure waves in the air or other transmitting substance, corresponding to the experience of *loudness, pitch,* and *timbre* of the sound. The receptors for hearing are *hair cells (cilia)* embedded in the *basilar membrane*, located in the *organ of Corti* in the interior of the *cochlea*. These receptors pass signals along to the *auditory nerve*. The sounds we hear are determined by patterns of hair-cell movement, which produce different neural codes. When we localize sounds, we use as cues subtle differences in how pressure waves reach each of our ears.

Other Senses

- Taste (*gustation*) is a chemical sense. Elevations on the tongue, called *papillae*, contain many *taste buds*, which in turn contain the taste receptors. The four hardwired basic tastes are salty, sour, bitter, and sweet, which evolved to ensure that humans would eat healthful, biochemically necessary food and avoid rancid or poisonous food. Some researchers believe that umami is a fifth basic taste, but the current evidence disputes this conclusion. Responses to a particular taste depend in part on genetic differences among individuals; some people are "supertasters." Taste preferences are also affected by culture and learning and by the texture, temperature, and smell of food.

- Smell (*olfaction*) is also a chemical sense. No basic odors have been identified, and up to a thousand different receptor types exist. But researchers have discovered that distinct odors activate unique combinations of receptor types, and they have identified some of those combinations. Odors also have psychological effects and can affect behavior even when people are unaware of their influence. Cultural and individual differences affect people's responses to particular odors.

- The skin senses include touch (pressure), warmth, cold, pain, and variations such as itch and tickle. Receptors for some types of itching and a possible receptor for cold have been discovered.

- Pain has proven to be physiologically complicated, involving the release of several different chemicals and changes in both neurons and *glial cells*. According to the *gate-control theory*, the experience of pain depends on whether neural impulses get past a "gate" in the spinal cord and reach the brain; in addition, a matrix of neurons in the brain can generate pain even in the absence of signals from sensory neurons. A leading theory of *phantom pain* holds that it occurs when the brain rewires itself after amputation of a limb or removal of a body organ. Expectations and placebos affect the subjective experience of pain through their effects on brain activity and endorphin production.

- *Kinesthesis* tells us where our body parts are located and *equilibrium* tells us the orientation of the body as a whole. Together, these two senses provide us with a feeling of physical embodiment.

Perceptual Powers: Origins and Influences

- Many fundamental perceptual skills are inborn or are acquired shortly after birth. By using the *visual cliff*, psychologists have learned that babies have depth perception by the age of 6 months and probably even earlier. However, without certain experiences during *critical periods* early in life, cells in the nervous system deteriorate, change, or fail to form appropriate neural pathways, and perception is impaired. This is why efforts to correct congenital blindness or deafness are most successful when they take place early in life.

- Psychological influences on perception include needs, beliefs, emotions, and expectations (which produce *perceptual sets*). Cultures give people practice with different kinds of experiences and influence what they attend to.

Perception without Awareness

- In the laboratory, studies using *priming* show that simple visual subliminal messages can influence behaviors and judgments, depending on a person's motivational state (e.g., thirst). However, there is no evidence that complex behaviors in everyday life can be altered by "subliminal-perception" tapes or similar products.

Psychology in the News, Revisited

- Human perception does not merely capture objective reality but also reflects our needs, biases, and beliefs. Our eyes and our ears (and especially our brains) can play tricks on us—causing us to "see" things that are not there and sometimes to overcome pain that is there.

Taking Psychology with You

- Years of research have failed to produce convincing evidence for extrasensory perception. What so-called psychics do is no different from what all good magicians do: capitalize on people's beliefs, expectations, wishful thinking, and, literally, mis-perceptions.

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perception **181**
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doctrine of specific nerve energies **182**
synesthesia **183**
functional codes **183**
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Sensation is the detection and direct experience of physical energy as a result of environmental or internal events.
Perception is the process by which sensory impulses are organized and interpreted.

The Senses

- Sensation begins with the **sense receptors,** which convert the energy of a stimulus into electrical impulses that travel along the nerves to the brain.
- Anatomical codes (as set forth by the **doctrine of specific nerve energies**) and functional codes in the nervous system account for separate sensations. In rare cases, however, sensory crossover results in **synesthesia**.

Measuring the Senses

- Psychologists specializing in psychophysics have studied sensory sensitivity by measuring **absolute** and **difference thresholds.**
- **Signal-detection theory** holds that responses in a detection task consist of both a sensory process and a decision process and vary with the person's motivation, alertness, and expectations.

Sensory Adaptation

- **Sensory adaptation** occurs when sensation is unchanging.
- **Sensory deprivation** occurs with too little stimulation.

Sensing without Perceiving

- We use **selective attention** to avoid sensory overload.
- **Inattentional blindness** is a failure to consciously perceive something you are looking at because you are not attending to it.

Hearing

The stimulus for hearing (*audition*) is a pressure wave or the release of compressed air.

What We Hear

- Intensity corresponds to the experience of **loudness.**
- Frequency corresponds to the experience of **pitch.**
- Complexity corresponds to the experience of **timbre.**

The receptors for hearing are hair cells (*cilia*) embedded in the basilar membrane of the **organ of Corti** in the interior of the **cochlea.**

Vision

The stimulus for vision is light, which travels in waves.

What We See

- Wavelength of light produces the experience of **hue.**
- Intensity of light produces the experience of **brightness.**
- Complexity of light produces the experience of **saturation.**

Visual Receptors

Visual receptors are located in the **retina** of the eye and send signals to the ganglion cells and ultimately to the *optic nerve.*

- **Rods** are responsible for vision in dim light.
- **Cones** are responsible for color vision.
- Rods and cones take time to adjust to dim illumination, a process known as **dark adaptation**.
- Information from rods and cones is processed and communicated by **ganglion cells**, the axons of which converge to form the *optic nerve.*
- **Feature-detector cells** in the visual areas of the brain detect specific aspects of the environment, such as line orientation.
- Some researchers believe that certain brain cells comprise a *face module.*

Color Vision

- The **trichromatic theory** accounts for the first level of color processing, which occurs in the retina, where three types of cones respond to different wavelengths of light.
- In the second level of color processing, **opponent-process** cells in the retina and thalamus respond in opposite fashion to short and long wavelengths of light.

Gestalt Principles

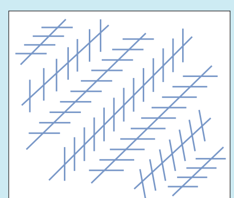
Gestalt principles—such as figure and ground, proximity, closure, similarity, and continuity—describe visual strategies used by the brain to perceive form, distance, and depth.

Depth and Distance Perception

- **Binocular cues** include **convergence** and **retinal disparity**.
- **Monocular cues** include light and shadow; interposition; motion parallax; relative size; texture gradients; relative clarity; and linear perspective.

Constancies and Illusions

- **Perceptual constancy** is the accurate perception of objects as stable despite changes in size, shape, location, brightness, and color.
- *Perceptual illusions* occur when sensory cues are misleading or we misinterpret them.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Other Senses

Taste

Taste (*gustation*) is a chemical sense.

- **Papillae** on the tongue contain **taste buds**, which contain taste receptors.
- The basic tastes are each produced by a different type of chemical: salty, sour, bitter, and sweet. A fifth taste, umami, is a conditioned preference that occurs in the gut, not the mouth, and is not hardwired.
- Genetic and cultural differences influence responses to a particular taste.

Smell

Smell (*olfaction*) is also a chemical sense.

- There are up to 1,000 different kinds of receptors.
- Distinct odors activate unique combinations of receptors.
- Cultural and individual differences affect people's responses to odors.

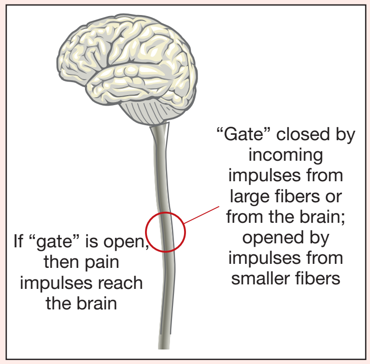
Senses of the Skin

Include *touch* (pressure), *warmth, cold,* and *pain* and variations such as itch and tickle.

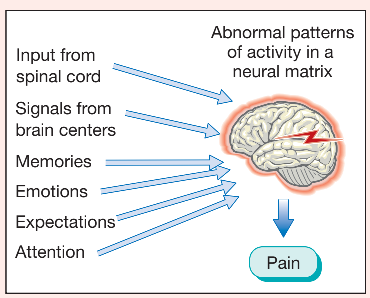
Pain

Pain is both a skin sense and an internal sense.

The **gate-control theory** holds that the experience of pain depends on whether neural impulses get past a "gate" in the spinal cord and reach the brain.



In the gate theory, the brain can generate pain even in the absence of signals from sensory neurons, because an extensive *matrix* of neurons in the brain gives us a sense of our own bodies. When the matrix produces abnormal activity, the result is pain.



A leading explanation of **phantom pain** is that the brain has reorganized itself, incorrectly interpreting messages from neurons as coming from a nonexistent body part.

The Environment Within

Kinesthesis tells us where our body parts are located. **Equilibrium** tells us the orientation of the body as a whole, and relies on three **semicircular canals** in the inner ear.

Perceptual Powers

Inborn Abilities

- *Visual cliff* experiments show that even at 6 months, babies have depth perception.
- Without certain experiences during *critical periods*, perception is impaired.

Psychological Influences on Perception

- Psychological influences on perception include needs, beliefs, emotions, and expectations (which produce **perceptual sets**).
- These influences are affected by culture.

Perception without Awareness

- In **priming**, a person is exposed to explicit or subliminal information and is later tested to see whether the information affects performance on another task. This method is often used to measure unconscious cognitive processes, including perception.
- When simple stimuli are used, subliminal priming can influence certain behaviors, judgments, and motivational states.
- However, no evidence of subliminal persuasion has been found with commercially marketed subliminal ads and tapes conveying complex messages.