Chapter 5

Sensation and Perception

Figure 5.1 If you were standing in the midst of this street scene, you would be absorbing and processing numerous pieces of sensory input. (credit: modification of work by Cory Zanker)

Chapter Outline

Introduction

Imagine standing on a city street corner. You might be struck by movement everywhere as cars and people go about their business, by the sound of a street musician's melody or a horn honking in the distance, by the smell of exhaust fumes or of food being sold by a nearby vendor, and by the sensation of hard pavement under your feet.

We rely on our sensory systems to provide important information about our surroundings. We use this information to successfully navigate and interact with our environment so that we can find nourishment, seek shelter, maintain social relationships, and avoid potentially dangerous situations.

This chapter will provide an overview of how sensory information is received and processed by the nervous system and how that affects our conscious experience of the world. We begin by learning the distinction between sensation and perception. Then we consider the physical properties of light and sound stimuli, along with an overview of the basic structure and function of the major sensory systems. The chapter will close with a discussion of a historically important theory of perception called Gestalt.

5.1 Sensation versus Perception

Learning Objectives

By the end of this section, you will be able to:

- Distinguish between sensation and perception
- Describe the concepts of absolute threshold and difference threshold
- Discuss the roles attention, motivation, and sensory adaptation play in perception

SENSATION

What does it mean to sense something? Sensory receptors are specialized neurons that respond to specific types of stimuli. When sensory information is detected by a sensory receptor, **sensation** has occurred. For example, light that enters the eye causes chemical changes in cells that line the back of the eye. These cells relay messages, in the form of action potentials (as you learned when studying biopsychology), to the central nervous system. The conversion from sensory stimulus energy to action potential is known as **transduction**.

You have probably known since elementary school that we have five senses: vision, hearing (audition), smell (olfaction), taste (gustation), and touch (somatosensation). It turns out that this notion of five senses is oversimplified. We also have sensory systems that provide information about balance (the vestibular sense), body position and movement (proprioception and kinesthesia), pain (nociception), and temperature (thermoception).

The sensitivity of a given sensory system to the relevant stimuli can be expressed as an absolute threshold. **Absolute threshold** refers to the minimum amount of stimulus energy that must be present for the stimulus to be detected 50% of the time. Another way to think about this is by asking how dim can a light be or how soft can a sound be and still be detected half of the time. The sensitivity of our sensory receptors can be quite amazing. It has been estimated that on a clear night, the most sensitive sensory cells in the back of the eye can detect a candle flame 30 miles away (Okawa & Sampath, 2007). Under quiet conditions, the hair cells (the receptor cells of the inner ear) can detect the tick of a clock 20 feet away (Galanter, 1962).

It is also possible for us to get messages that are presented below the threshold for conscious awareness—these are called **subliminal messages**. A stimulus reaches a physiological threshold when it is strong enough to excite sensory receptors and send nerve impulses to the brain: This is an absolute threshold. A message below that threshold is said to be subliminal: We receive it, but we are not consciously aware of it. Over the years there has been a great deal of speculation about the use of subliminal messages in advertising, rock music, and self-help audio programs. Research evidence shows that in laboratory settings, people can process and respond to information outside of awareness. But this does not mean that we obey these messages like zombies; in fact, hidden messages have little effect on behavior outside the laboratory (Kunst-Wilson & Zajonc, 1980; Rensink, 2004; Nelson, 2008; Radel, Sarrazin, Legrain, & Gobancé, 2009; Loersch, Durso, & Petty, 2013).

Absolute thresholds are generally measured under incredibly controlled conditions in situations that are optimal for sensitivity. Sometimes, we are more interested in how much difference in stimuli is required to detect a difference between them. This is known as the **just noticeable difference (jnd)** or **difference threshold**. Unlike the absolute threshold, the difference threshold changes depending on the stimulus intensity. As an example, imagine yourself in a very dark movie theater. If an audience member were to receive a text message on her cell phone which caused her screen to light up, chances are that many people would notice the change in illumination in the theater. However, if the same thing happened in a brightly lit arena during a basketball game, very few people would notice. The cell phone brightness does not change, but its ability to be detected as a change in illumination varies dramatically between the two contexts. Ernst Weber proposed this theory of change in difference threshold in the 1830s, and it has become known as Weber's law: The difference threshold is a constant fraction of the original stimulus, as the example illustrates.

PERCEPTION

While our sensory receptors are constantly collecting information from the environment, it is ultimately how we interpret that information that affects how we interact with the world. **Perception** refers to the way sensory information is organized, interpreted, and consciously experienced. Perception involves both bottom-up and top-down processing. **Bottom-up processing** refers to the fact that perceptions are built from sensory input. On the other hand, how we interpret those sensations is influenced by our available knowledge, our experiences, and our thoughts. This is called **top-down processing**.

One way to think of this concept is that sensation is a physical process, whereas perception is psychological. For example, upon walking into a kitchen and smelling the scent of baking cinnamon rolls, the *sensation* is the scent receptors detecting the odor of cinnamon, but the *perception* may be "Mmm, this smells like the bread Grandma used to bake when the family gathered for holidays."

Although our perceptions are built from sensations, not all sensations result in perception. In fact, we often don't perceive stimuli that remain relatively constant over prolonged periods of time. This is known as **sensory adaptation**. Imagine entering a classroom with an old analog clock. Upon first entering the room, you can hear the ticking of the clock; as you begin to engage in conversation with classmates or listen to your professor greet the class, you are no longer aware of the ticking. The clock is still ticking, and that information is still affecting sensory receptors of the auditory system. The fact that you no longer perceive the sound demonstrates sensory adaptation and shows that while closely associated, sensation and perception are different.

There is another factor that affects sensation and perception: attention. Attention plays a significant role in determining what is sensed versus what is perceived. Imagine you are at a party full of music, chatter, and laughter. You get involved in an interesting conversation with a friend, and you tune out all the background noise. If someone interrupted you to ask what song had just finished playing, you would probably be unable to answer that question.

LINK TO LEARNING

openstax

See for yourself how inattentional blindness works by checking out this **selective attention test (http://openstaxcollege.org/l/blindness)** from Simons and Chabris (1999).

One of the most interesting demonstrations of how important attention is in determining our perception of the environment occurred in a famous study conducted by Daniel Simons and Christopher Chabris (1999). In this study, participants watched a video of people dressed in black and white passing basketballs. Participants were asked to count the number of times the team in white passed the ball. During the video, a person dressed in a black gorilla costume walks among the two teams. You would think that someone would notice the gorilla, right? Nearly half of the people who watched the video didn't notice the gorilla at all, despite the fact that he was clearly visible for nine seconds. Because participants were so focused on the number of times the white team was passing the ball, they completely tuned out other visual information. Failure to notice something that is completely visible because of a lack of attention is called **inattentional blindness**.

In a similar experiment, researchers tested inattentional blindness by asking participants to observe images moving across a computer screen. They were instructed to focus on either white or black objects, disregarding the other color. When a red cross passed across the screen, about one third of subjects did not notice it (**Figure 5.2**) (Most, Simons, Scholl, & Chabris, 2000).

Figure 5.2 Nearly one third of participants in a study did not notice that a red cross passed on the screen because their attention was focused on the black or white figures. (credit: Cory Zanker)

Motivation can also affect perception. Have you ever been expecting a really important phone call and, while taking a shower, you think you hear the phone ringing, only to discover that it is not? If so, then you have experienced how motivation to detect a meaningful stimulus can shift our ability to discriminate between a true sensory stimulus and background noise. The ability to identify a stimulus when it is embedded in a distracting background is called **signal detection theory**. This might also explain why a mother is awakened by a quiet murmur from her baby but not by other sounds that occur while she is asleep. Signal detection theory has practical applications, such as increasing air traffic controller accuracy. Controllers need to be able to detect planes among many signals (blips) that appear on the radar screen and follow those planes as they move through the sky. In fact, the original work of the researcher who developed signal detection theory was focused on improving the sensitivity of air traffic controllers to plane blips (Swets, 1964).

Our perceptions can also be affected by our beliefs, values, prejudices, expectations, and life experiences. As you will see later in this chapter, individuals who are deprived of the experience of binocular vision during critical periods of development have trouble perceiving depth (Fawcett, Wang, & Birch, 2005). The shared experiences of people within a given cultural context can have pronounced effects on perception. For example, Marshall Segall, Donald Campbell, and Melville Herskovits (1963) published the results of a multinational study in which they demonstrated that individuals from Western cultures were more prone to experience certain types of visual illusions than individuals from non-Western cultures, and vice versa. One such illusion that Westerners were more likely to experience was the Müller-Lyer illusion (**Figure 5.3**): The lines appear to be different lengths, but they are actually the same length.

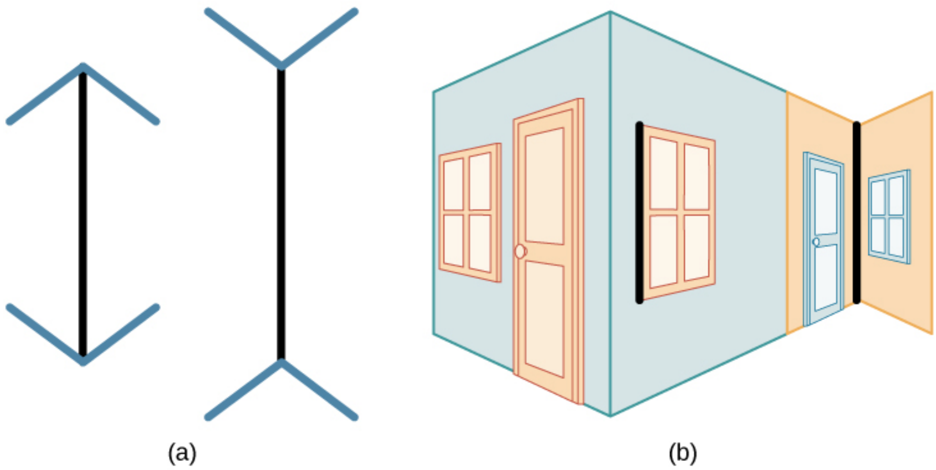

Figure 5.3 In the Müller-Lyer illusion, lines appear to be different lengths although they are identical. (a) Arrows at the ends of lines may make the line on the right appear longer, although the lines are the same length. (b) When applied to a three-dimensional image, the line on the right again may appear longer although both black lines are the same length.

These perceptual differences were consistent with differences in the types of environmental features experienced on a regular basis by people in a given cultural context. People in Western cultures, for example, have a perceptual context of buildings with straight lines, what Segall's study called a carpentered world (Segall et al., 1966). In contrast, people from certain non-Western cultures with an uncarpentered view, such as the Zulu of South Africa, whose villages are made up of round huts arranged in circles, are less susceptible to this illusion (Segall et al., 1999). It is not just vision that is affected by cultural factors. Indeed, research has demonstrated that the ability to identify an odor, and rate its pleasantness and its intensity, varies cross-culturally (Ayabe-Kanamura, Saito, Distel, Martínez-Gómez, & Hudson, 1998).

Children described as thrill seekers are more likely to show taste preferences for intense sour flavors (Liem, Westerbeek, Wolterink, Kok, & de Graaf, 2004), which suggests that basic aspects of personality might affect perception. Furthermore, individuals who hold positive attitudes toward reduced-fat foods are more likely to rate foods labeled as reduced fat as tasting better than people who have less positive attitudes about these products (Aaron, Mela, & Evans, 1994).

5.2 Waves and Wavelengths

Learning Objectives

By the end of this section, you will be able to:

- Describe important physical features of wave forms
- Show how physical properties of light waves are associated with perceptual experience
- Show how physical properties of sound waves are associated with perceptual experience

Visual and auditory stimuli both occur in the form of waves. Although the two stimuli are very different in terms of composition, wave forms share similar characteristics that are especially important to our visual and auditory perceptions. In this section, we describe the physical properties of the waves as well as the perceptual experiences associated with them.

AMPLITUDE AND WAVELENGTH

Two physical characteristics of a wave are amplitude and wavelength (Figure 5.4). The **amplitude** of a wave is the height of a wave as measured from the highest point on the wave (**peak** or **crest**) to the lowest point on the wave (**trough**). **Wavelength** refers to the length of a wave from one peak to the next.

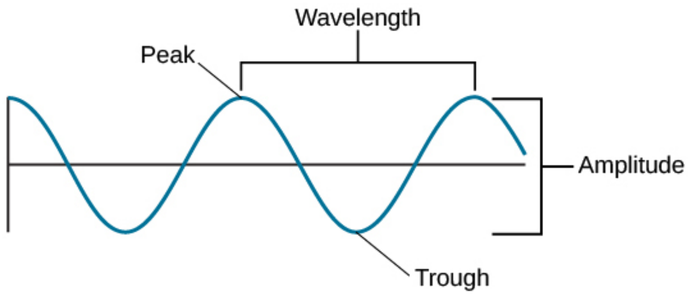

Figure 5.4 The amplitude or height of a wave is measured from the peak to the trough. The wavelength is measured from peak to peak.

Wavelength is directly related to the frequency of a given wave form. **Frequency** refers to the number of waves that pass a given point in a given time period and is often expressed in terms of **hertz (Hz)**, or cycles per second. Longer wavelengths will have lower frequencies, and shorter wavelengths will have higher frequencies (Figure 5.5).

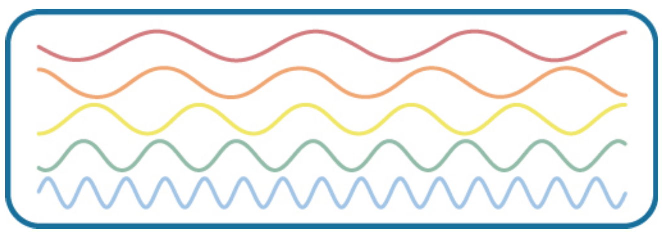

Figure 5.5 This figure illustrates waves of differing wavelengths/frequencies. At the top of the figure, the red wave has a long wavelength/short frequency. Moving from top to bottom, the wavelengths decrease and frequencies increase.

LIGHT WAVES

The **visible spectrum** is the portion of the larger **electromagnetic spectrum** that we can see. As Figure 5.6 shows, the electromagnetic spectrum encompasses all of the electromagnetic radiation that occurs in our environment and includes gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves, and radio waves. The visible spectrum in humans is associated with wavelengths that range from 380 to 740 nm—a very small distance, since a nanometer (nm) is one billionth of a meter. Other species can detect other portions of the electromagnetic spectrum. For instance, honeybees can see light in the ultraviolet range (Wakakuwa, Stavenga, & Arikawa, 2007), and some snakes can detect infrared radiation in addition to more traditional visual light cues (Chen, Deng, Brauth, Ding, & Tang, 2012; Hartline, Kass, & Loop, 1978).

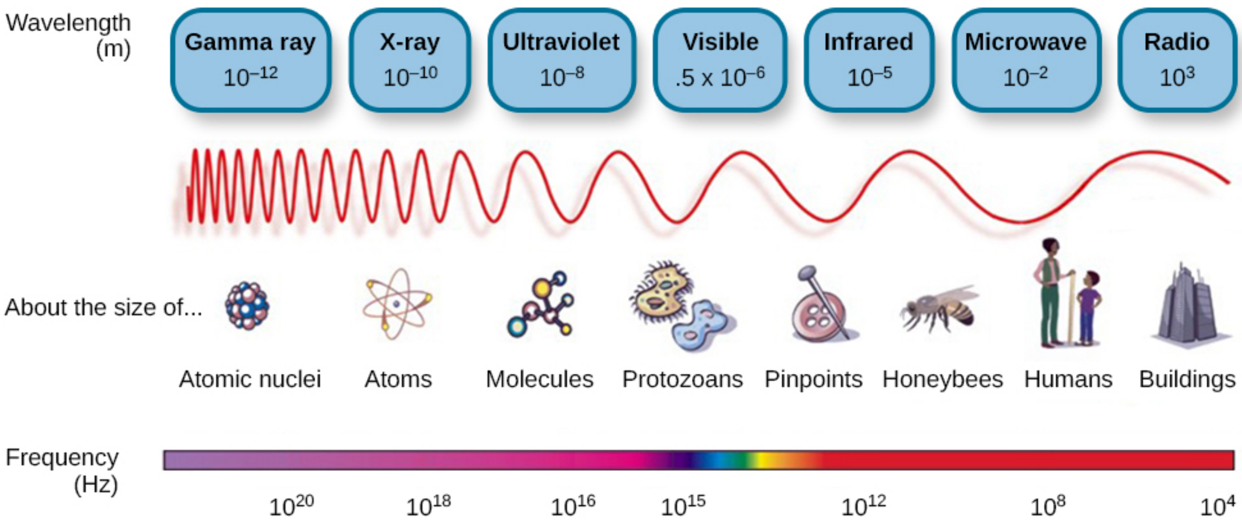

Figure 5.6 Light that is visible to humans makes up only a small portion of the electromagnetic spectrum.

In humans, light wavelength is associated with perception of color (**Figure 5.7**). Within the visible spectrum, our experience of red is associated with longer wavelengths, greens are intermediate, and blues and violets are shorter in wavelength. (An easy way to remember this is the mnemonic ROYGBIV: **r**ed, **o**range, **y**ellow, **g**reen, **b**lue, **i**ndigo, **v**iolet.) The amplitude of light waves is associated with our experience of brightness or intensity of color, with larger amplitudes appearing brighter.

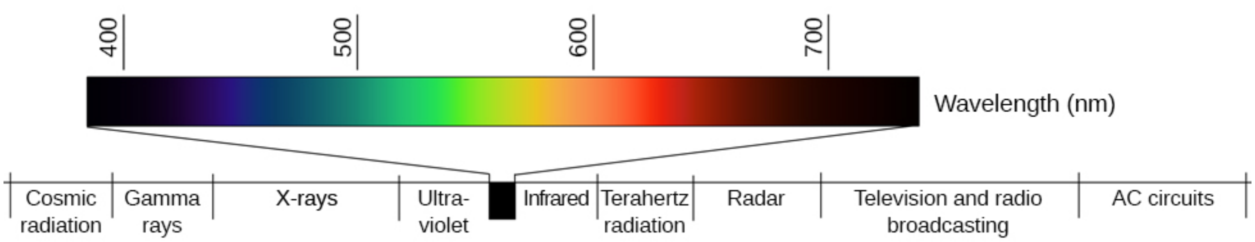

Figure 5.7 Different wavelengths of light are associated with our perception of different colors. (credit: modification of work by Johannes Ahlmann)

SOUND WAVES

Like light waves, the physical properties of sound waves are associated with various aspects of our perception of sound. The frequency of a sound wave is associated with our perception of that sound's **pitch**. High-frequency sound waves are perceived as high-pitched sounds, while low-frequency sound waves are perceived as low-pitched sounds. The audible range of sound frequencies is between 20 and 20000 Hz, with greatest sensitivity to those frequencies that fall in the middle of this range.

As was the case with the visible spectrum, other species show differences in their audible ranges. For instance, chickens have a very limited audible range, from 125 to 2000 Hz. Mice have an audible range from 1000 to 91000 Hz, and the beluga whale's audible range is from 1000 to 123000 Hz. Our pet dogs and cats have audible ranges of about 70–45000 Hz and 45–64000 Hz, respectively (Strain, 2003).

The loudness of a given sound is closely associated with the amplitude of the sound wave. Higher amplitudes are associated with louder sounds. Loudness is measured in terms of **decibels (dB)**, a logarithmic unit of sound intensity. A typical conversation would correlate with 60 dB; a rock concert might check in at 120 dB (**Figure 5.8**). A whisper 5 feet away or rustling leaves are at the low end of our hearing range; sounds like a window air conditioner, a normal conversation, and even heavy traffic or a vacuum cleaner are within a tolerable range. However, there is the potential for hearing damage from about 80 dB to 130 dB: These are sounds of a food processor, power lawnmower, heavy truck (25 feet away), subway train (20 feet away), live rock music, and a jackhammer. The threshold for pain is about 130 dB, a jet plane taking off or a revolver firing at close range (Dunkle, 1982).

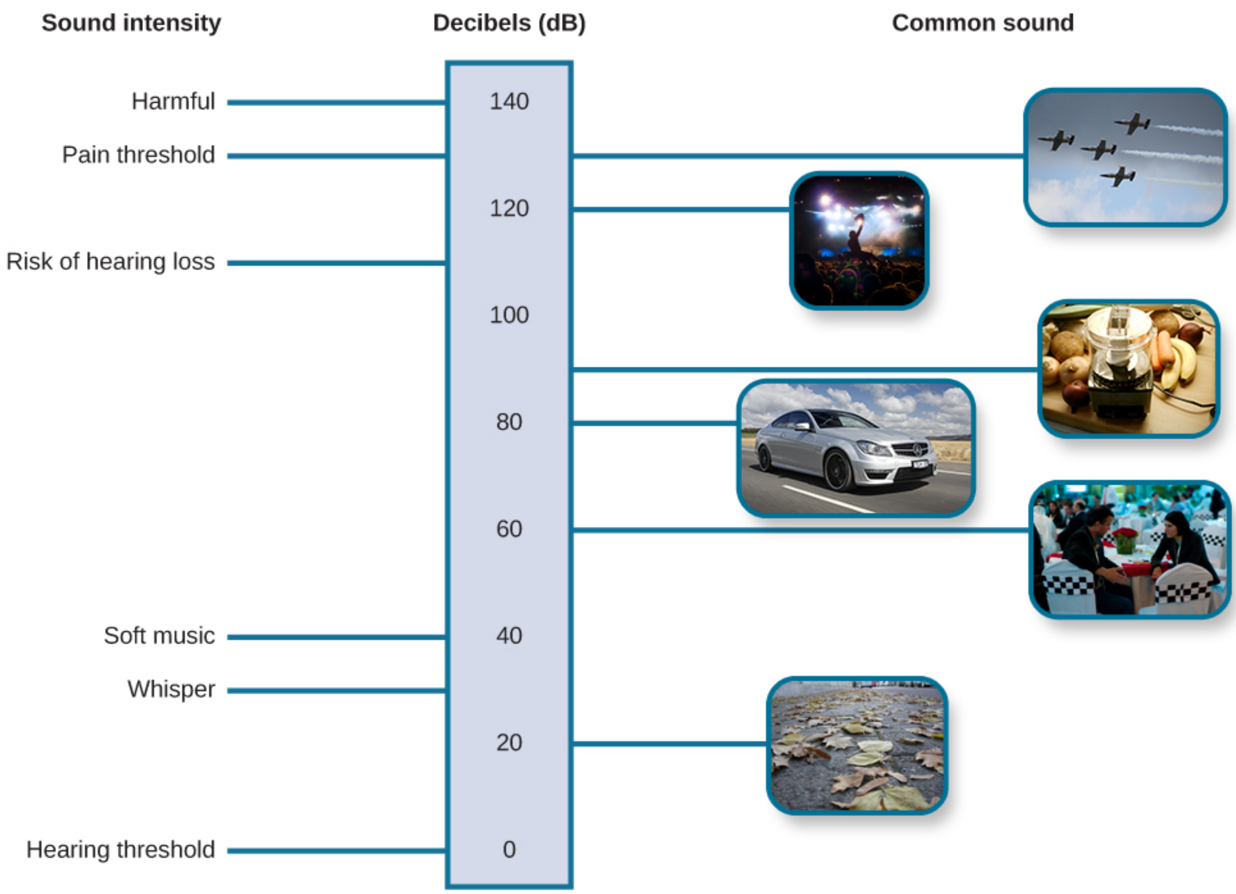

Figure 5.8 This figure illustrates the loudness of common sounds. (credit "planes": modification of work by Max Pfandl; credit "crowd": modification of work by Christian Holmér; credit "blender": modification of work by Jo Brodie; credit "car": modification of work by NRMA New Cars/Flickr; credit "talking": modification of work by Joi Ito; credit "leaves": modification of work by Aurelijus Valeiša)

Although wave amplitude is generally associated with loudness, there is some interaction between frequency and amplitude in our perception of loudness within the audible range. For example, a 10 Hz sound wave is inaudible no matter the amplitude of the wave. A 1000 Hz sound wave, on the other hand, would vary dramatically in terms of perceived loudness as the amplitude of the wave increased.

LINK TO LEARNING

Watch this **brief video (http://openstaxcollege.org/l/frequency)** demonstrating how frequency and amplitude interact in our perception of loudness.

Of course, different musical instruments can play the same musical note at the same level of loudness, yet they still sound quite different. This is known as the timbre of a sound. **Timbre** refers to a sound's purity, and it is affected by the complex interplay of frequency, amplitude, and timing of sound waves.

5.3 Vision

Learning Objectives

By the end of this section, you will be able to:

- Describe the basic anatomy of the visual system
- Discuss how rods and cones contribute to different aspects of vision
- Describe how monocular and binocular cues are used in the perception of depth

The visual system constructs a mental representation of the world around us (**Figure 5.9**). This contributes to our ability to successfully navigate through physical space and interact with important individuals and objects in our environments. This section will provide an overview of the basic anatomy and function of the visual system. In addition, we will explore our ability to perceive color and depth.

Figure 5.9 Our eyes take in sensory information that helps us understand the world around us. (credit "top left": modification of work by "rajkumar1220"/Flickr"; credit "top right": modification of work by Thomas Leuthard; credit "middle left": modification of work by Demietrich Baker; credit "middle right": modification of work by "kaybee07"/Flickr; credit "bottom left": modification of work by "Isengardt"/Flickr; credit "bottom right": modification of work by Willem Heerbaart)

ANATOMY OF THE VISUAL SYSTEM

The eye is the major sensory organ involved in vision (**Figure 5.10**). Light waves are transmitted across the cornea and enter the eye through the pupil. The **cornea** is the transparent covering over the eye. It serves as a barrier between the inner eye and the outside world, and it is involved in focusing light waves that enter the eye. The **pupil** is the small opening in the eye through which light passes, and the size of the pupil can change as a function of light levels as well as emotional arousal. When light levels are low, the pupil will become dilated, or expanded, to allow more light to enter the eye. When light levels are high, the pupil will constrict, or become smaller, to reduce the amount of light that enters the eye. The pupil's size is controlled by muscles that are connected to the **iris**, which is the colored portion of the eye.

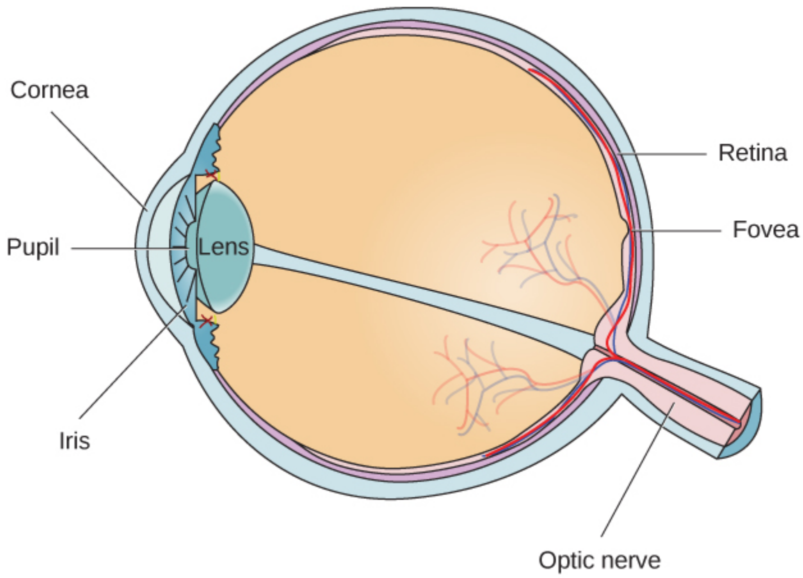

Figure 5.10 The anatomy of the eye is illustrated in this diagram.

After passing through the pupil, light crosses the **lens**, a curved, transparent structure that serves to provide additional focus. The lens is attached to muscles that can change its shape to aid in focusing light that is reflected from near or far objects. In a normal-sighted individual, the lens will focus images perfectly on a small indentation in the back of the eye known as the **fovea**, which is part of the **retina**, the light-sensitive lining of the eye. The fovea contains densely packed specialized photoreceptor cells (**Figure 5.11**). These **photoreceptor** cells, known as cones, are light-detecting cells. The **cones** are specialized types of photoreceptors that work best in bright light conditions. Cones are very sensitive to acute detail and provide tremendous spatial resolution. They also are directly involved in our ability to perceive color.

While cones are concentrated in the fovea, where images tend to be focused, rods, another type of photoreceptor, are located throughout the remainder of the retina. **Rods** are specialized photoreceptors that work well in low light conditions, and while they lack the spatial resolution and color function of the cones, they are involved in our vision in dimly lit environments as well as in our perception of movement on the periphery of our visual field.

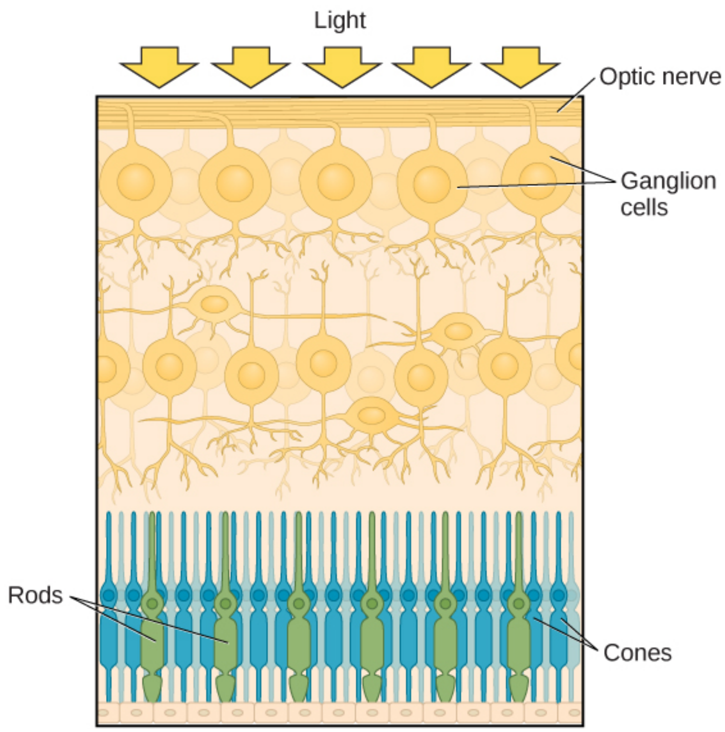

Figure 5.11 The two types of photoreceptors are shown in this image. Rods are colored green and cones are blue.

We have all experienced the different sensitivities of rods and cones when making the transition from a brightly lit environment to a dimly lit environment. Imagine going to see a blockbuster movie on a clear summer day. As you walk from the brightly lit lobby into the dark theater, you notice that you immediately have difficulty seeing much of anything. After a few minutes, you begin to adjust to the darkness and can see the interior of the theater. In the bright environment, your vision was dominated primarily by cone activity. As you move to the dark environment, rod activity dominates, but there is a delay in transitioning between the phases. If your rods do not transform light into nerve impulses as easily and efficiently as they should, you will have difficulty seeing in dim light, a condition known as night blindness.

Rods and cones are connected (via several interneurons) to retinal ganglion cells. Axons from the retinal ganglion cells converge and exit through the back of the eye to form the **optic nerve**. The optic nerve carries visual information from the retina to the brain. There is a point in the visual field called the **blind spot**: Even when light from a small object is focused on the blind spot, we do not see it. We are not consciously aware of our blind spots for two reasons: First, each eye gets a slightly different view of the visual field; therefore, the blind spots do not overlap. Second, our visual system fills in the blind spot so that although we cannot respond to visual information that occurs in that portion of the visual field, we are also not aware that information is missing.

The optic nerve from each eye merges just below the brain at a point called the **optic chiasm**. As **Figure 5.12** shows, the optic chiasm is an X-shaped structure that sits just below the cerebral cortex at the front of the brain. At the point of the optic chiasm, information from the right visual field (which comes from both eyes) is sent to the left side of the brain, and information from the left visual field is sent to the right side of the brain.

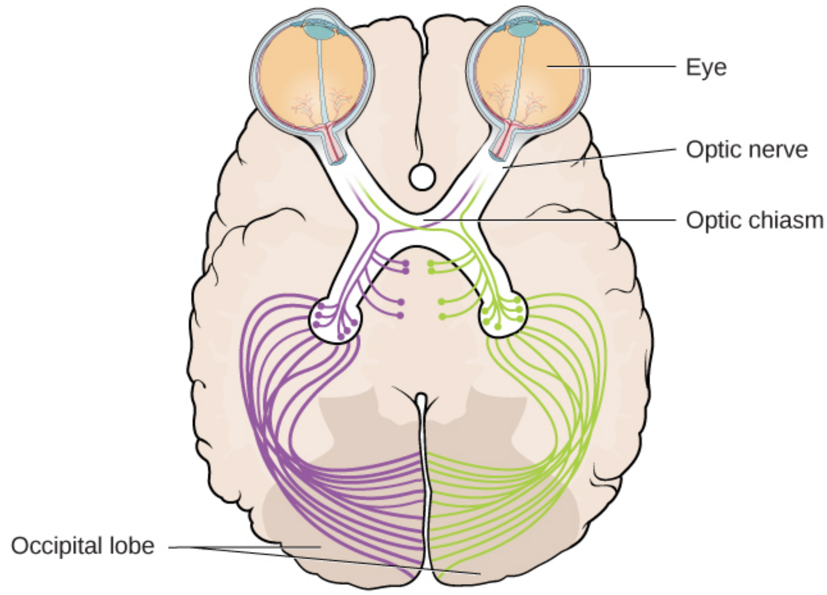

Figure 5.12 This illustration shows the optic chiasm at the front of the brain and the pathways to the occipital lobe at the back of the brain, where visual sensations are processed into meaningful perceptions.

Once inside the brain, visual information is sent via a number of structures to the occipital lobe at the back of the brain for processing. Visual information might be processed in parallel pathways which can generally be described as the “what pathway” and the “where/how” pathway. The “what pathway” is involved in object recognition and identification, while the “where/how pathway” is involved with location in space and how one might interact with a particular visual stimulus (Milner & Goodale, 2008; Ungerleider & Haxby, 1994). For example, when you see a ball rolling down the street, the “what pathway” identifies what the object is, and the “where/how pathway” identifies its location or movement in space.

COLOR AND DEPTH PERCEPTION

We do not see the world in black and white; neither do we see it as two-dimensional (2-D) or flat (just height and width, no depth). Let’s look at how color vision works and how we perceive three dimensions (height, width, and depth).

Color Vision

Normal-sighted individuals have three different types of cones that mediate color vision. Each of these cone types is maximally sensitive to a slightly different wavelength of light. According to the **trichromatic theory of color vision**, shown in **Figure 5.13**, all colors in the spectrum can be produced by combining red, green, and blue. The three types of cones are each receptive to one of the colors.

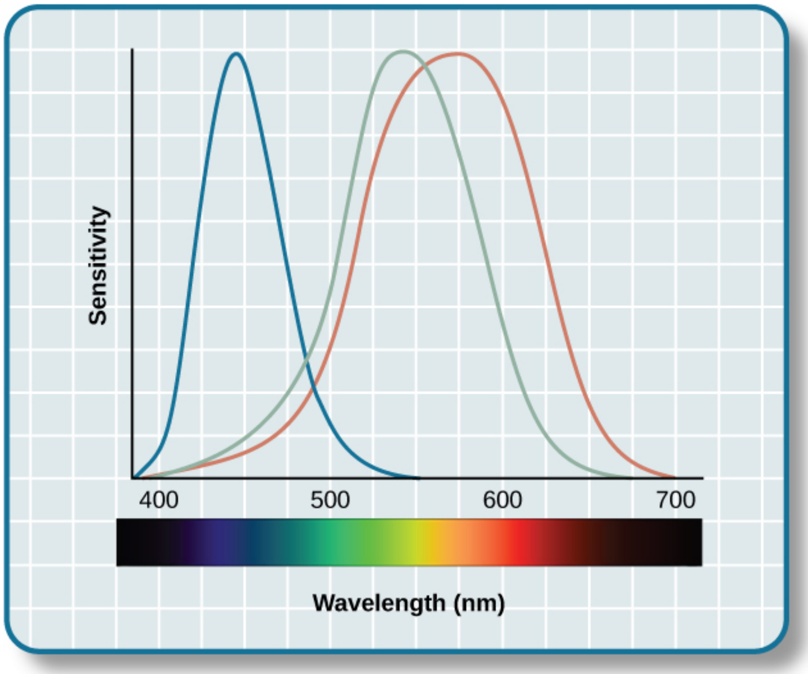

Figure 5.13 This figure illustrates the different sensitivities for the three cone types found in a normal-sighted individual. (credit: modification of work by Vanessa Ezekowitz)

The trichromatic theory of color vision is not the only theory—another major theory of color vision is known as the **opponent-process theory**. According to this theory, color is coded in opponent pairs: black-white, yellow-blue, and green-red. The basic idea is that some cells of the visual system are excited by one of the opponent colors and inhibited by the other. So, a cell that was excited by wavelengths associated with green would be inhibited by wavelengths associated with red, and vice versa. One of the implications of opponent processing is that we do not experience greenish-reds or yellowish-blues as colors. Another implication is that this leads to the experience of negative afterimages. An **afterimage** describes the continuation of a visual sensation after removal of the stimulus. For example, when you stare briefly at the sun and then look away from it, you may still perceive a spot of light although the stimulus (the sun) has been removed. When color is involved in the stimulus, the color pairings identified in the opponent-process theory lead to a negative afterimage. You can test this concept using the flag in **Figure 5.14**.

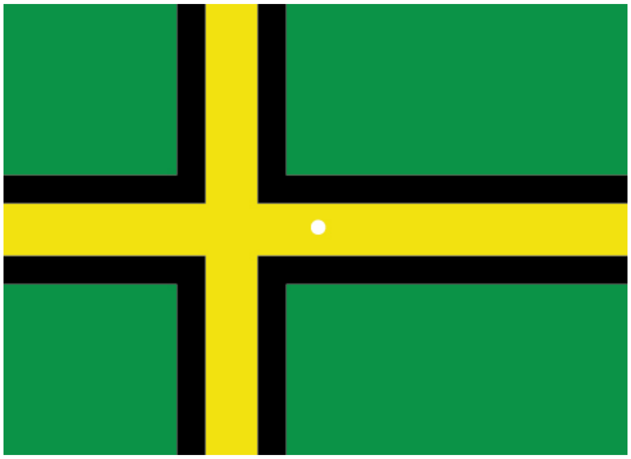

Figure 5.14 Stare at the white dot for 30–60 seconds and then move your eyes to a blank piece of white paper. What do you see? This is known as a negative afterimage, and it provides empirical support for the opponent-process theory of color vision.

But these two theories—the trichromatic theory of color vision and the opponent-process theory—are not mutually exclusive. Research has shown that they just apply to different levels of the nervous system. For visual processing on the retina, trichromatic theory applies: the cones are responsive to three different wavelengths that represent red, blue, and green. But once the signal moves past the retina on its way to the brain, the cells respond in a way consistent with opponent-process theory (Land, 1959; Kaiser, 1997).

LINK TO LEARNING

Watch this **video (http://openstaxcollege.org/l/colorvision)** to see the first part of a documentary explaining color vision in more detail.

Depth Perception

Our ability to perceive spatial relationships in three-dimensional (3-D) space is known as **depth perception**. With depth perception, we can describe things as being in front, behind, above, below, or to the side of other things.

Our world is three-dimensional, so it makes sense that our mental representation of the world has three-dimensional properties. We use a variety of cues in a visual scene to establish our sense of depth. Some of these are **binocular cues**, which means that they rely on the use of both eyes. One example of a binocular depth cue is **binocular disparity**, the slightly different view of the world that each of our eyes receives. To experience this slightly different view, do this simple exercise: extend your arm fully and extend one of your fingers and focus on that finger. Now, close your left eye without moving your head, then open your left eye and close your right eye without moving your head. You will notice that your finger seems to shift as you alternate between the two eyes because of the slightly different view each eye has of your finger.

A 3-D movie works on the same principle: the special glasses you wear allow the two slightly different images projected onto the screen to be seen separately by your left and your right eye. As your brain processes these images, you have the illusion that the leaping animal or running person is coming right toward you.

Although we rely on binocular cues to experience depth in our 3-D world, we can also perceive depth in 2-D arrays. Think about all the paintings and photographs you have seen. Generally, you pick up on depth in these images even though the visual stimulus is 2-D. When we do this, we are relying on a number of **monocular cues**, or cues that require only one eye. If you think you can't see depth with one eye, note that you don't bump into things when using only one eye while walking—and, in fact, we have more monocular cues than binocular cues.

An example of a monocular cue would be what is known as linear perspective. **Linear perspective** refers to the fact that we perceive depth when we see two parallel lines that seem to converge in an image (**Figure 5.15**). Some other monocular depth cues are interposition, the partial overlap of objects, and the relative size and closeness of images to the horizon.

Figure 5.15 We perceive depth in a two-dimensional figure like this one through the use of monocular cues like linear perspective, like the parallel lines converging as the road narrows in the distance. (credit: Marc Dalmulder)

DIG DEEPER

Stereoblindness

Bruce Bridgeman was born with an extreme case of lazy eye that resulted in him being stereoblind, or unable to respond to binocular cues of depth. He relied heavily on monocular depth cues, but he never had a true appreciation of the 3-D nature of the world around him. This all changed one night in 2012 while Bruce was seeing a movie with his wife.

The movie the couple was going to see was shot in 3-D, and even though he thought it was a waste of money, Bruce paid for the 3-D glasses when he purchased his ticket. As soon as the film began, Bruce put on the glasses and experienced something completely new. For the first time in his life he appreciated the true depth of the world around him. Remarkably, his ability to perceive depth persisted outside of the movie theater.

There are cells in the nervous system that respond to binocular depth cues. Normally, these cells require activation during early development in order to persist, so experts familiar with Bruce's case (and others like his) assume that at some point in his development, Bruce must have experienced at least a fleeting moment of binocular vision. It was enough to ensure the survival of the cells in the visual system tuned to binocular cues. The mystery now is why it took Bruce nearly 70 years to have these cells activated (Peck, 2012).

Key Terms

absolute threshold minimum amount of stimulus energy that must be present for the stimulus to be detected 50% of the time

afterimage continuation of a visual sensation after removal of the stimulus

amplitude height of a wave

basilar membrane thin strip of tissue within the cochlea that contains the hair cells which serve as the sensory receptors for the auditory system

binaural cue two-eared cue to localize sound

binocular cue cue that relies on the use of both eyes

binocular disparity slightly different view of the world that each eye receives

blind spot point where we cannot respond to visual information in that portion of the visual field

bottom-up processing system in which perceptions are built from sensory input

closure organizing our perceptions into complete objects rather than as a series of parts

cochlea fluid-filled, snail-shaped structure that contains the sensory receptor cells of the auditory system

cochlear implant electronic device that consists of a microphone, a speech processor, and an electrode array to directly stimulate the auditory nerve to transmit information to the brain

conductive hearing loss failure in the vibration of the eardrum and/or movement of the ossicles

cone specialized photoreceptor that works best in bright light conditions and detects color

congenital deafness deafness from birth

congenital insensitivity to pain (congenital analgesia) genetic disorder that results in the inability to experience pain

cornea transparent covering over the eye

deafness partial or complete inability to hear

decibel (dB) logarithmic unit of sound intensity

depth perception ability to perceive depth

electromagnetic spectrum all the electromagnetic radiation that occurs in our environment

figure-ground relationship segmenting our visual world into figure and ground

fovea small indentation in the retina that contains cones

frequency number of waves that pass a given point in a given time period

Gestalt psychology field of psychology based on the idea that the whole is different from the sum of its parts

good continuation (also, continuity) we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines

hair cell auditory receptor cell of the inner ear

hertz (Hz) cycles per second; measure of frequency

inattentional blindness failure to notice something that is completely visible because of a lack of attention

incus middle ear ossicle; also known as the anvil

inflammatory pain signal that some type of tissue damage has occurred

interaural level difference sound coming from one side of the body is more intense at the closest ear because of the attenuation of the sound wave as it passes through the head

interaural timing difference small difference in the time at which a given sound wave arrives at each ear

iris colored portion of the eye

just noticeable difference difference in stimuli required to detect a difference between the stimuli

kinesthesia perception of the body's movement through space

lens curved, transparent structure that provides additional focus for light entering the eye

linear perspective perceive depth in an image when two parallel lines seem to converge

malleus middle ear ossicle; also known as the hammer

Meissner's corpuscle touch receptor that responds to pressure and lower frequency vibrations

Merkel's disk touch receptor that responds to light touch

monaural cue one-eared cue to localize sound

monocular cue cue that requires only one eye

Ménière's disease results in a degeneration of inner ear structures that can lead to hearing loss, tinnitus, vertigo, and an increase in pressure within the inner ear

neuropathic pain pain from damage to neurons of either the peripheral or central nervous system

nociception sensory signal indicating potential harm and maybe pain

olfactory bulb bulb-like structure at the tip of the frontal lobe, where the olfactory nerves begin

olfactory receptor sensory cell for the olfactory system

opponent-process theory of color perception color is coded in opponent pairs: black-white, yellow-blue, and red-green

optic chiasm X-shaped structure that sits just below the brain's ventral surface; represents the merging of the optic nerves from the two eyes and the separation of information from the two sides of the visual field to the opposite side of the brain

optic nerve carries visual information from the retina to the brain

Pacinian corpuscle touch receptor that detects transient pressure and higher frequency vibrations

pattern perception ability to discriminate among different figures and shapes

peak (also, crest) highest point of a wave

perception way that sensory information is interpreted and consciously experienced

perceptual hypothesis educated guess used to interpret sensory information

pheromone chemical message sent by another individual

photoreceptor light-detecting cell

pinna visible part of the ear that protrudes from the head

pitch perception of a sound’s frequency

place theory of pitch perception different portions of the basilar membrane are sensitive to sounds of different frequencies

principle of closure organize perceptions into complete objects rather than as a series of parts

proprioception perception of body position

proximity things that are close to one another tend to be grouped together

pupil small opening in the eye through which light passes

retina light-sensitive lining of the eye

rod specialized photoreceptor that works well in low light conditions

Ruffini corpuscle touch receptor that detects stretch

sensation what happens when sensory information is detected by a sensory receptor

sensorineural hearing loss failure to transmit neural signals from the cochlea to the brain

sensory adaptation not perceiving stimuli that remain relatively constant over prolonged periods of time

signal detection theory change in stimulus detection as a function of current mental state

similarity things that are alike tend to be grouped together

stapes middle ear ossicle; also known as the stirrup

subliminal message message presented below the threshold of conscious awareness

taste bud grouping of taste receptor cells with hair-like extensions that protrude into the central pore of the taste bud

temporal theory of pitch perception sound’s frequency is coded by the activity level of a sensory neuron

thermoception temperature perception

timbre sound’s purity

top-down processing interpretation of sensations is influenced by available knowledge, experiences, and thoughts

transduction conversion from sensory stimulus energy to action potential

trichromatic theory of color perception color vision is mediated by the activity across the three groups of cones

trough lowest point of a wave

tympanic membrane eardrum

umami taste for monosodium glutamate

vertigo spinning sensation

vestibular sense contributes to our ability to maintain balance and body posture

visible spectrum portion of the electromagnetic spectrum that we can see

wavelength length of a wave from one peak to the next peak

Summary

5.1 Sensation versus Perception

Sensation occurs when sensory receptors detect sensory stimuli. Perception involves the organization, interpretation, and conscious experience of those sensations. All sensory systems have both absolute and difference thresholds, which refer to the minimum amount of stimulus energy or the minimum amount of difference in stimulus energy required to be detected about 50% of the time, respectively. Sensory adaptation, selective attention, and signal detection theory can help explain what is perceived and what is not. In addition, our perceptions are affected by a number of factors, including beliefs, values, prejudices, culture, and life experiences.

5.2 Waves and Wavelengths

Both light and sound can be described in terms of wave forms with physical characteristics like amplitude, wavelength, and timbre. Wavelength and frequency are inversely related so that longer waves have lower frequencies, and shorter waves have higher frequencies. In the visual system, a light wave's wavelength is generally associated with color, and its amplitude is associated with brightness. In the auditory system, a sound's frequency is associated with pitch, and its amplitude is associated with loudness.

5.3 Vision

Light waves cross the cornea and enter the eye at the pupil. The eye's lens focuses this light so that the image is focused on a region of the retina known as the fovea. The fovea contains cones that possess high levels of visual acuity and operate best in bright light conditions. Rods are located throughout the retina and operate best under dim light conditions. Visual information leaves the eye via the optic nerve. Information from each visual field is sent to the opposite side of the brain at the optic chiasm. Visual information then moves through a number of brain sites before reaching the occipital lobe, where it is processed.

Two theories explain color perception. The trichromatic theory asserts that three distinct cone groups are tuned to slightly different wavelengths of light, and it is the combination of activity across these cone types that results in our perception of all the colors we see. The opponent-process theory of color vision asserts that color is processed in opponent pairs and accounts for the interesting phenomenon of a negative afterimage. We perceive depth through a combination of monocular and binocular depth cues.

5.4 Hearing

Sound waves are funneled into the auditory canal and cause vibrations of the eardrum; these vibrations move the ossicles. As the ossicles move, the stapes presses against the oval window of the cochlea, which causes fluid inside the cochlea to move. As a result, hair cells embedded in the basilar membrane become enlarged, which sends neural impulses to the brain via the auditory nerve.

Pitch perception and sound localization are important aspects of hearing. Our ability to perceive pitch relies on both the firing rate of the hair cells in the basilar membrane as well as their location within the membrane. In terms of sound localization, both monaural and binaural cues are used to locate where sounds originate in our environment.

Individuals can be born deaf, or they can develop deafness as a result of age, genetic predisposition, and/or environmental causes. Hearing loss that results from a failure of the vibration of the eardrum or the resultant movement of the ossicles is called conductive hearing loss. Hearing loss that involves a failure of the transmission of auditory nerve impulses to the brain is called sensorineural hearing loss.

5.5 The Other Senses

Taste (gustation) and smell (olfaction) are chemical senses that employ receptors on the tongue and in the nose that bind directly with taste and odor molecules in order to transmit information to the brain for processing. Our ability to perceive touch, temperature, and pain is mediated by a number of receptors and free nerve endings that are distributed throughout the skin and various tissues of the body. The vestibular sense helps us maintain a sense of balance through the response of hair cells in the utricle, saccule, and semi-circular canals that respond to changes in head position and gravity. Our proprioceptive and kinesthetic systems provide information about body position and body movement through receptors that detect stretch and tension in the muscles, joints, tendons, and skin of the body.

5.6 Gestalt Principles of Perception

Gestalt theorists have been incredibly influential in the areas of sensation and perception. Gestalt principles such as figure-ground relationship, grouping by proximity or similarity, the law of good continuation, and closure are all used to help explain how we organize sensory information. Our perceptions are not infallible, and they can be influenced by bias, prejudice, and other factors.

Review Questions

1. ________ refers to the minimum amount of stimulus energy required to be detected 50% of the time.
a. absolute threshold
b. difference threshold
c. just noticeable difference
d. transduction

2. Decreased sensitivity to an unchanging stimulus is known as ________.
a. transduction
b. difference threshold
c. sensory adaptation
d. inattentional blindness

3. ________ involves the conversion of sensory stimulus energy into neural impulses.
a. sensory adaptation
b. inattentional blindness
c. difference threshold
d. transduction

4. ________ occurs when sensory information is organized, interpreted, and consciously experienced.
a. sensation
b. perception
c. transduction
d. sensory adaptation

5. Which of the following correctly matches the pattern in our perception of color as we move from short wavelengths to long wavelengths?
a. red to orange to yellow
b. yellow to orange to red
c. yellow to red to orange
d. orange to yellow to red

6. The visible spectrum includes light that ranges from about ________.
a. 400–700 nm
b. 200–900 nm
c. 20–20000 Hz
d. 10–20 dB

7. The electromagnetic spectrum includes ________.
a. radio waves
b. x-rays
c. infrared light
d. all of the above

8. The audible range for humans is ________.
a. 380–740 nm
b. 10–20 dB
c. 20–20,000 dB
d. less than 300 nm

9. The quality of a sound that is affected by frequency, amplitude, and timing of the sound wave is known as ________.
a. pitch
b. tone
c. electromagnetic
d. timbre

10. The ________ is a small indentation of the retina that contains cones.
a. optic chiasm
b. optic nerve
c. fovea
d. iris

11. ________ operate best under bright light conditions.
a. cones
b. rods
c. retinal ganglion cells
d. striate cortex

12. ________ depth cues require the use of both eyes.
a. monocular
b. binocular
c. linear perspective
d. accommodating

13. If you were to stare at a green dot for a relatively long period of time and then shift your gaze to a blank white screen, you would see a ________ negative afterimage.
a. blue
b. yellow
c. black
d. red

14. Hair cells located near the base of the basilar membrane respond best to ________ sounds.
a. low-frequency
b. high-frequency
c. low-amplitude
d. high-amplitude

15. The three ossicles of the middle ear are known as ________.
a. malleus, incus, and stapes
b. hammer, anvil, and stirrup
c. pinna, cochlea, and urticle
d. both a and b

16. Hearing aids might be effective for treating ________.
a. Ménière's disease
b. sensorineural hearing loss
c. conductive hearing loss
d. interaural time differences

17. Cues that require two ears are referred to as ________ cues.
a. monocular
b. monaural
c. binocular
d. binaural

18. Chemical messages often sent between two members of a species to communicate something about reproductive status are called ________.
a. hormones
b. pheromones
c. Merkel’s disks
d. Meissner’s corpuscles

19. Which taste is associated with monosodium glutamate?
a. sweet
b. bitter
c. umami
d. sour

20. ________ serve as sensory receptors for temperature and pain stimuli.

a. free nerve endings
b. Pacinian corpuscles
c. Ruffini corpuscles
d. Meissner's corpuscles

21. Which of the following is involved in maintaining balance and body posture?

a. auditory nerve
b. nociceptors
c. olfactory bulb
d. vestibular system

22. According to the principle of ________, objects that occur close to one another tend to be grouped together.

a. similarity
b. good continuation
c. proximity
d. closure

23. Our tendency to perceive things as complete objects rather than as a series of parts is known as the principle of ________.

a. closure
b. good continuation
c. proximity
d. similarity

24. According to the law of ________, we are more likely to perceive smoothly flowing lines rather than choppy or jagged lines.

a. closure
b. good continuation
c. proximity
d. similarity

25. The main point of focus in a visual display is known as the ________.

a. closure
b. perceptual set
c. ground
d. figure

Critical Thinking Questions

26. Not everything that is sensed is perceived. Do you think there could ever be a case where something could be perceived without being sensed?

27. Please generate a novel example of how just noticeable difference can change as a function of stimulus intensity.

28. Why do you think other species have such different ranges of sensitivity for both visual and auditory stimuli compared to humans?

29. Why do you think humans are especially sensitive to sounds with frequencies that fall in the middle portion of the audible range?

30. Compare the two theories of color perception. Are they completely different?

31. Color is not a physical property of our environment. What function (if any) do you think color vision serves?

32. Given what you've read about sound localization, from an evolutionary perspective, how does sound localization facilitate survival?

33. How can temporal and place theories both be used to explain our ability to perceive the pitch of sound waves with frequencies up to 4000 Hz?

34. Many people experience nausea while traveling in a car, plane, or boat. How might you explain this as a function of sensory interaction?

35. If you heard someone say that they would do anything not to feel the pain associated with significant injury, how would you respond given what you've just read?

36. Do you think women experience pain differently than men? Why do you think this is?

37. The central tenet of Gestalt psychology is that the whole is different from the sum of its parts. What does this mean in the context of perception?

38. Take a look at the following figure. How might you influence whether people see a duck or a rabbit?

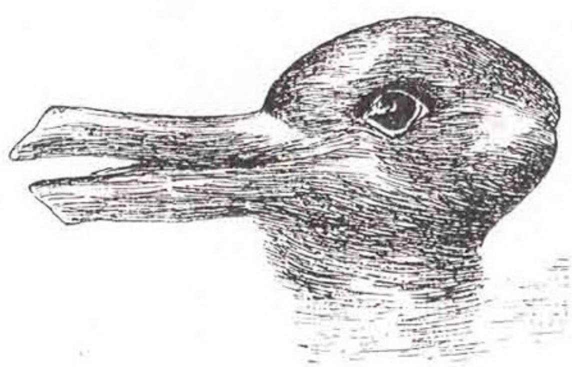

Figure 5.28

Personal Application Questions

39. Think about a time when you failed to notice something around you because your attention was focused elsewhere. If someone pointed it out, were you surprised that you hadn't noticed it right away?

40. If you grew up with a family pet, then you have surely noticed that they often seem to hear things that you don't hear. Now that you've read this section, you probably have some insight as to why this may be. How would you explain this to a friend who never had the opportunity to take a class like this?

41. Take a look at a few of your photos or personal works of art. Can you find examples of linear perspective as a potential depth cue?

42. If you had to choose to lose either your vision or your hearing, which would you choose and why?

43. As mentioned earlier, a food's flavor represents an interaction of both gustatory and olfactory information. Think about the last time you were seriously congested due to a cold or the flu. What changes did you notice in the flavors of the foods that you ate during this time?

44. Have you ever listened to a song on the radio and sung along only to find out later that you have been singing the wrong lyrics? Once you found the correct lyrics, did your perception of the song change?