5.4 Hearing

Learning Objectives

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

- Describe the basic anatomy and function of the auditory system
- Explain how we encode and perceive pitch
- Discuss how we localize sound

Our auditory system converts pressure waves into meaningful sounds. This translates into our ability to hear the sounds of nature, to appreciate the beauty of music, and to communicate with one another through spoken language. This section will provide an overview of the basic anatomy and function of the auditory system. It will include a discussion of how the sensory stimulus is translated into neural impulses, where in the brain that information is processed, how we perceive pitch, and how we know where sound is coming from.

ANATOMY OF THE AUDITORY SYSTEM

The ear can be separated into multiple sections. The outer ear includes the **pinna**, which is the visible part of the ear that protrudes from our heads, the auditory canal, and the **tympanic membrane**, or eardrum. The middle ear contains three tiny bones known as the **ossicles**, which are named the **malleus** (or hammer), **incus** (or anvil), and the **stapes** (or stirrup). The inner ear contains the semi-circular canals, which are involved in balance and movement (the vestibular sense), and the cochlea. The **cochlea** is a fluid-filled, snail-shaped structure that contains the sensory receptor cells (hair cells) of the auditory system (**Figure 5.16**).

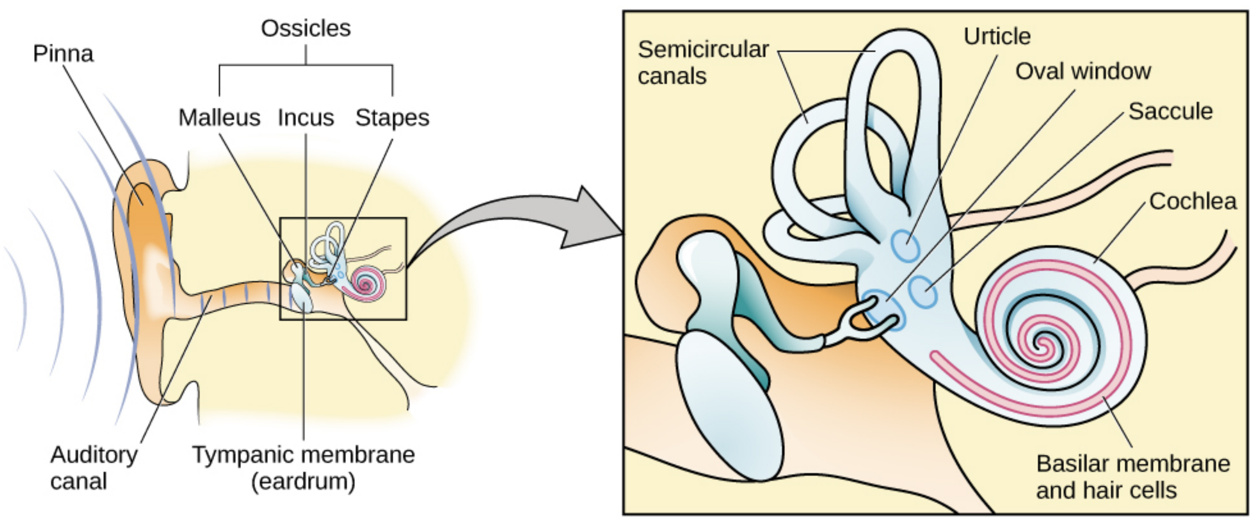

Figure 5.16 The ear is divided into outer (pinna and tympanic membrane), middle (the three ossicles: malleus, incus, and stapes), and inner (cochlea and basilar membrane) divisions.

Sound waves travel along the auditory canal and strike the tympanic membrane, causing it to vibrate. This vibration results in movement of the three ossicles. As the ossicles move, the stapes presses into a thin membrane of the cochlea known as the oval window. As the stapes presses into the oval window, the fluid inside the cochlea begins to move, which in turn stimulates **hair cells**, which are auditory receptor cells of the inner ear embedded in the basilar membrane. The **basilar membrane** is a thin strip of tissue within the cochlea.

The activation of hair cells is a mechanical process: the stimulation of the hair cell ultimately leads to activation of the cell. As hair cells become activated, they generate neural impulses that travel along the auditory nerve to the brain. Auditory information is shuttled to the inferior colliculus, the medial geniculate nucleus of the thalamus, and finally to the auditory cortex in the temporal lobe of the brain for processing. Like the visual system, there is also evidence suggesting that information about auditory recognition and localization is processed in parallel streams (Rauschecker & Tian, 2000; Renier et al., 2009).

PITCH PERCEPTION

Different frequencies of sound waves are associated with differences in our perception of the pitch of those sounds. Low-frequency sounds are lower pitched, and high-frequency sounds are higher pitched. How does the auditory system differentiate among various pitches?

Several theories have been proposed to account for pitch perception. We'll discuss two of them here: temporal theory and place theory. The **temporal theory** of pitch perception asserts that frequency is coded by the activity level of a sensory neuron. This would mean that a given hair cell would fire action potentials related to the frequency of the sound wave. While this is a very intuitive explanation, we detect such a broad range of frequencies (20–20,000 Hz) that the frequency of action potentials fired by hair cells cannot account for the entire range. Because of properties related to sodium channels on the neuronal membrane that are involved in action potentials, there is a point at which a cell cannot fire any faster (Shamma, 2001).

The **place theory** of pitch perception suggests that different portions of the basilar membrane are sensitive to sounds of different frequencies. More specifically, the base of the basilar membrane responds best to high frequencies and the tip of the basilar membrane responds best to low frequencies. Therefore, hair cells that are in the base portion would be labeled as high-pitch receptors, while those in the tip of basilar membrane would be labeled as low-pitch receptors (Shamma, 2001).

In reality, both theories explain different aspects of pitch perception. At frequencies up to about 4000 Hz, it is clear that both the rate of action potentials and place contribute to our perception of pitch. However, much higher frequency sounds can only be encoded using place cues (Shamma, 2001).

SOUND LOCALIZATION

The ability to locate sound in our environments is an important part of hearing. Localizing sound could be considered similar to the way that we perceive depth in our visual fields. Like the monocular and binocular cues that provided information about depth, the auditory system uses both **monaural** (one-eared) and **binaural** (two-eared) cues to localize sound.

Each pinna interacts with incoming sound waves differently, depending on the sound's source relative to our bodies. This interaction provides a monaural cue that is helpful in locating sounds that occur above or below and in front or behind us. The sound waves received by your two ears from sounds that come from directly above, below, in front, or behind you would be identical; therefore, monaural cues are essential (Grothe, Pecka, & McAlpine, 2010).

Binaural cues, on the other hand, provide information on the location of a sound along a horizontal axis by relying on differences in patterns of vibration of the eardrum between our two ears. If a sound comes from an off-center location, it creates two types of binaural cues: interaural level differences and interaural timing differences. **Interaural level difference** refers to the fact that a sound coming from the right side of your body is more intense at your right ear than at your left ear because of the attenuation of the sound wave as it passes through your head. **Interaural timing difference** refers to the small difference in the time at which a given sound wave arrives at each ear (**Figure 5.17**). Certain brain areas monitor these differences to construct where along a horizontal axis a sound originates (Grothe et al., 2010).

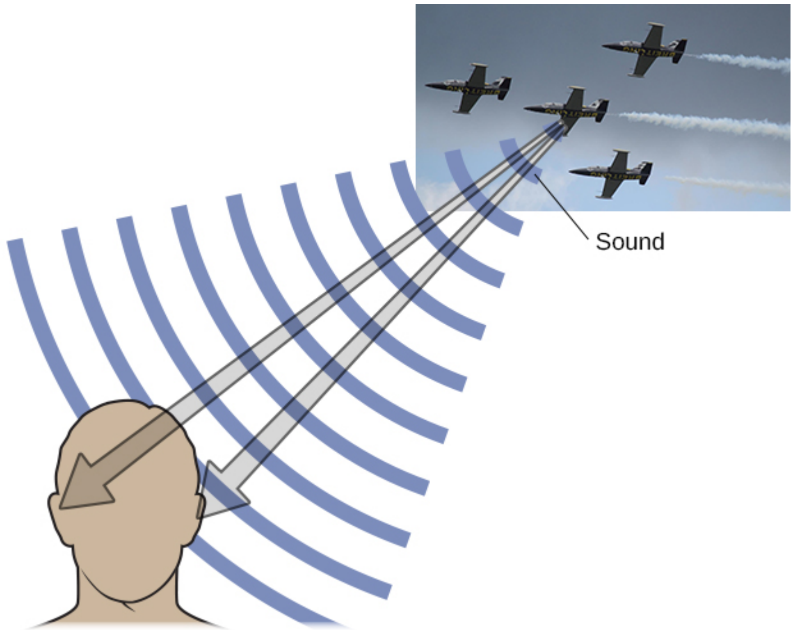

Figure 5.17 Localizing sound involves the use of both monaural and binaural cues. (credit "plane": modification of work by Max Pfandl)

HEARING LOSS

Deafness is the partial or complete inability to hear. Some people are born deaf, which is known as **congenital deafness**. Many others begin to suffer from **conductive hearing loss** because of age, genetic predisposition, or environmental effects, including exposure to extreme noise (noise-induced hearing loss, as shown in **Figure 5.18**), certain illnesses (such as measles or mumps), or damage due to toxins (such as those found in certain solvents and metals).

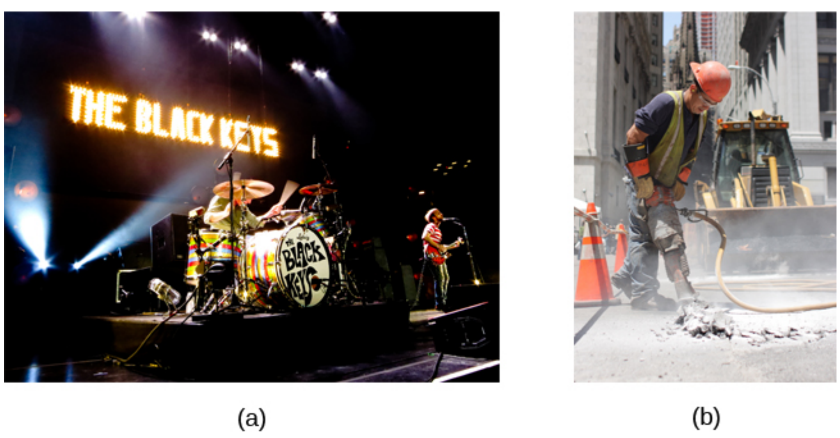

Figure 5.18 Environmental factors that can lead to conductive hearing loss include regular exposure to loud music or construction equipment. (a) Rock musicians and (b) construction workers are at risk for this type of hearing loss. (credit a: modification of work by Kenny Sun; credit b: modification of work by Nick Allen)

Given the mechanical nature by which the sound wave stimulus is transmitted from the eardrum through the ossicles to the oval window of the cochlea, some degree of hearing loss is inevitable. With conductive hearing loss, hearing problems are associated with a failure in the vibration of the eardrum and/or movement of the ossicles. These problems are often dealt with through devices like hearing aids that amplify incoming sound waves to make vibration of the eardrum and movement of the ossicles more likely to occur.

When the hearing problem is associated with a failure to transmit neural signals from the cochlea to the brain, it is called **sensorineural hearing loss**. One disease that results in sensorineural hearing loss is **Ménière's disease**. Although not well understood, Ménière's disease results in a degeneration of inner ear structures that can lead to hearing loss, tinnitus (constant ringing or buzzing), **vertigo** (a sense of spinning), and an increase in pressure within the inner ear (Semaan & Megerian, 2011). This kind of loss cannot be treated with hearing aids, but some individuals might be candidates for a cochlear implant as a treatment option. **Cochlear implants** are electronic devices that consist of a microphone, a speech processor, and an electrode array. The device receives incoming sound information and directly stimulates the auditory nerve to transmit information to the brain.

LINK TO LEARNING

Watch this **video (http://www.youtube.com/watch?v=AqXBrKwB96E)** describe cochlear implant surgeries and how they work.

WHAT DO YOU THINK?

Deaf Culture

In the United States and other places around the world, deaf people have their own language, schools, and customs. This is called deaf culture. In the United States, deaf individuals often communicate using American Sign Language (ASL); ASL has no verbal component and is based entirely on visual signs and gestures. The primary mode of communication is signing. One of the values of deaf culture is to continue traditions like using sign language rather than teaching deaf children to try to speak, read lips, or have cochlear implant surgery.

When a child is diagnosed as deaf, parents have difficult decisions to make. Should the child be enrolled in mainstream schools and taught to verbalize and read lips? Or should the child be sent to a school for deaf children to learn ASL and have significant exposure to deaf culture? Do you think there might be differences in the way that parents approach these decisions depending on whether or not they are also deaf?

5.5 The Other Senses

Learning Objectives

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

- Describe the basic functions of the chemical senses
- Explain the basic functions of the somatosensory, nociceptive, and thermoceptive sensory systems
- Describe the basic functions of the vestibular, proprioceptive, and kinesthetic sensory systems

Vision and hearing have received an incredible amount of attention from researchers over the years. While there is still much to be learned about how these sensory systems work, we have a much better understanding of them than of our other sensory modalities. In this section, we will explore our chemical senses (taste and smell) and our body senses (touch, temperature, pain, balance, and body position).

THE CHEMICAL SENSES

Taste (gustation) and smell (olfaction) are called chemical senses because both have sensory receptors that respond to molecules in the food we eat or in the air we breathe. There is a pronounced interaction between our chemical senses. For example, when we describe the flavor of a given food, we are really referring to both gustatory and olfactory properties of the food working in combination.

Taste (Gustation)

You have learned since elementary school that there are four basic groupings of taste: sweet, salty, sour, and bitter. Research demonstrates, however, that we have at least six taste groupings. Umami is our fifth taste. **Umami** is actually a Japanese word that roughly translates to yummy, and it is associated with a taste for monosodium glutamate (Kinnamon & Vandenbeuch, 2009). There is also a growing body of experimental evidence suggesting that we possess a taste for the fatty content of a given food (Mizushige, Inoue, & Fushiki, 2007).

Molecules from the food and beverages we consume dissolve in our saliva and interact with taste receptors on our tongue and in our mouth and throat. **Taste buds** are formed by groupings of taste receptor cells with hair-like extensions that protrude into the central pore of the taste bud (**Figure 5.19**). Taste buds have a life cycle of ten days to two weeks, so even destroying some by burning your tongue won't have any long-term effect; they just grow right back. Taste molecules bind to receptors on this extension and cause chemical changes within the sensory cell that result in neural impulses being transmitted to the brain via different nerves, depending on where the receptor is located. Taste information is transmitted to the medulla, thalamus, and limbic system, and to the gustatory cortex, which is tucked underneath the overlap between the frontal and temporal lobes (Maffei, Haley, & Fontanini, 2012; Roper, 2013).

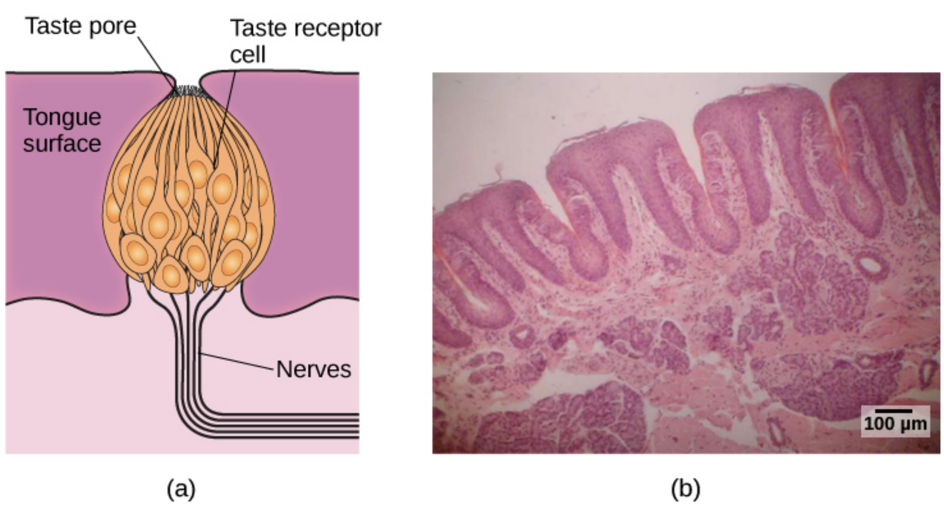

Figure 5.19 (a) Taste buds are composed of a number of individual taste receptors cells that transmit information to nerves. (b) This micrograph shows a close-up view of the tongue's surface. (credit a: modification of work by Jonas Töle; credit b: scale-bar data from Matt Russell)

Smell (Olfaction)

Olfactory receptor cells are located in a mucous membrane at the top of the nose. Small hair-like extensions from these receptors serve as the sites for odor molecules dissolved in the mucus to interact with chemical receptors located on these extensions (**Figure 5.20**). Once an odor molecule has bound a given receptor, chemical changes within the cell result in signals being sent to the **olfactory bulb**: a bulb-like structure at the tip of the frontal lobe where the olfactory nerves begin. From the olfactory bulb, information is sent to regions of the limbic system and to the primary olfactory cortex, which is located very near the gustatory cortex (Lodovichi & Belluscio, 2012; Spors et al., 2013).

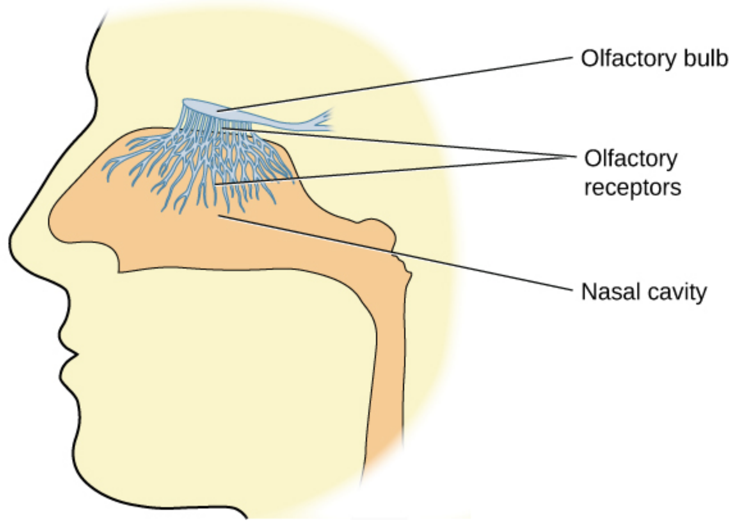

Figure 5.20 Olfactory receptors are the hair-like parts that extend from the olfactory bulb into the mucous membrane of the nasal cavity.

There is tremendous variation in the sensitivity of the olfactory systems of different species. We often think of dogs as having far superior olfactory systems than our own, and indeed, dogs can do some remarkable things with their noses. There is some evidence to suggest that dogs can "smell" dangerous drops in blood glucose levels as well as cancerous tumors (Wells, 2010). Dogs' extraordinary olfactory abilities may be due to the increased number of functional genes for olfactory receptors (between 800 and 1200), compared to the fewer than 400 observed in humans and other primates (Niimura & Nei, 2007).

Many species respond to chemical messages, known as **pheromones**, sent by another individual (Wysocki & Preti, 2004). Pheromonal communication often involves providing information about the reproductive status of a potential mate. So, for example, when a female rat is ready to mate, she secretes pheromonal signals that draw attention from nearby male rats. Pheromonal activation is actually an important component in eliciting sexual behavior in the male rat (Furlow, 1996, 2012; Purvis & Haynes, 1972; Sachs, 1997). There has also been a good deal of research (and controversy) about pheromones in humans (Comfort, 1971; Russell, 1976; Wolfgang-Kimball, 1992; Weller, 1998).

TOUCH, THERMOCEPTION, AND NOCICEPTION

A number of receptors are distributed throughout the skin to respond to various touch-related stimuli (**Figure 5.21**). These receptors include Meissner's corpuscles, Pacinian corpuscles, Merkel's disks, and Ruffini corpuscles.**Meissner's corpuscles** respond to pressure and lower frequency vibrations, and **Pacinian corpuscles** detect transient pressure and higher frequency vibrations. **Merkel's disks** respond to light pressure, while **Ruffini corpuscles** detect stretch (Abraira & Ginty, 2013).

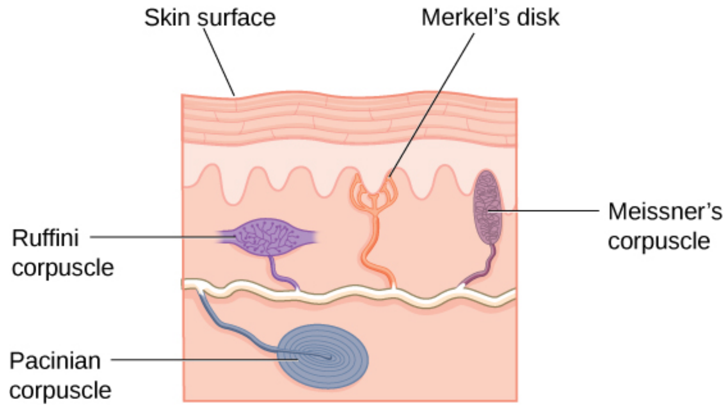

Figure 5.21 There are many types of sensory receptors located in the skin, each attuned to specific touch-related stimuli.

In addition to the receptors located in the skin, there are also a number of free nerve endings that serve sensory functions. These nerve endings respond to a variety of different types of touch-related stimuli and serve as sensory receptors for both **thermoception** (temperature perception) and **nociception** (a signal indicating potential harm and maybe pain) (Garland, 2012; Petho & Reeh, 2012; Spray, 1986). Sensory information collected from the receptors and free nerve endings travels up the spinal cord and is transmitted to regions of the medulla, thalamus, and ultimately to somatosensory cortex, which is located in the postcentral gyrus of the parietal lobe.

Pain Perception

Pain is an unpleasant experience that involves both physical and psychological components. Feeling pain is quite adaptive because it makes us aware of an injury, and it motivates us to remove ourselves from the cause of that injury. In addition, pain also makes us less likely to suffer additional injury because we will be gentler with our injured body parts.

Generally speaking, pain can be considered to be neuropathic or inflammatory in nature. Pain that signals some type of tissue damage is known as **inflammatory pain**. In some situations, pain results from damage to neurons of either the peripheral or central nervous system. As a result, pain signals that are sent to the brain get exaggerated. This type of pain is known as **neuropathic pain**. Multiple treatment options for pain relief range from relaxation therapy to the use of analgesic medications to deep brain stimulation. The most effective treatment option for a given individual will depend on a number of considerations, including the severity and persistence of the pain and any medical/psychological conditions.

Some individuals are born without the ability to feel pain. This very rare genetic disorder is known as **congenital insensitivity to pain** (or **congenital analgesia**). While those with congenital analgesia can detect differences in temperature and pressure, they cannot experience pain. As a result, they often suffer significant injuries. Young children have serious mouth and tongue injuries because they have bitten themselves repeatedly. Not surprisingly, individuals suffering from this disorder have much shorter life expectancies due to their injuries and secondary infections of injured sites (U.S. National Library of Medicine, 2013).

LINK TO LEARNING

Watch this **video (http://openstaxcollege.org/l/congenital)** to learn more about congenital insensitivity to pain.

THE VESTIBULAR SENSE, PROPRIOCEPTION, AND KINESTHESIA

The **vestibular sense** contributes to our ability to maintain balance and body posture. As **Figure 5.22** shows, the major sensory organs (utricle, saccule, and the three semicircular canals) of this system are located next to the cochlea in the inner ear. The vestibular organs are fluid-filled and have hair cells, similar to the ones found in the auditory system, which respond to movement of the head and gravitational forces. When these hair cells are stimulated, they send signals to the brain via the vestibular nerve. Although we may not be consciously aware of our vestibular system's sensory information under normal circumstances, its importance is apparent when we experience motion sickness and/or dizziness related to infections of the inner ear (Khan & Chang, 2013).

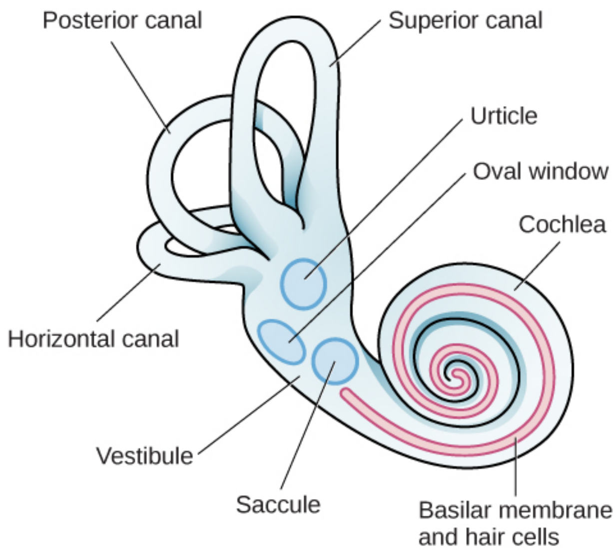

Figure 5.22 The major sensory organs of the vestibular system are located next to the cochlea in the inner ear. These include the utricle, saccule, and the three semicircular canals (posterior, superior, and horizontal).

In addition to maintaining balance, the vestibular system collects information critical for controlling movement and the reflexes that move various parts of our bodies to compensate for changes in body position. Therefore, both **proprioception** (perception of body position) and **kinesthesia** (perception of the body's movement through space) interact with information provided by the vestibular system.

These sensory systems also gather information from receptors that respond to stretch and tension in muscles, joints, skin, and tendons (Lackner & DiZio, 2005; Proske, 2006; Proske & Gandevia, 2012). Proprioceptive and kinesthetic information travels to the brain via the spinal column. Several cortical regions in addition to the cerebellum receive information from and send information to the sensory organs of the proprioceptive and kinesthetic systems.

5.6 Gestalt Principles of Perception

Learning Objectives

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

- Explain the figure-ground relationship
- Define Gestalt principles of grouping
- Describe how perceptual set is influenced by an individual's characteristics and mental state

In the early part of the 20th century, Max Wertheimer published a paper demonstrating that individuals perceived motion in rapidly flickering static images—an insight that came to him as he used a child's toy tachistoscope. Wertheimer, and his assistants Wolfgang Köhler and Kurt Koffka, who later became his partners, believed that perception involved more than simply combining sensory stimuli. This belief led to a new movement within the field of psychology known as **Gestalt psychology**. The word *gestalt* literally means form or pattern, but its use reflects the idea that the whole is different from the sum of its parts. In other words, the brain creates a perception that is more than simply the sum of available sensory inputs, and it does so in predictable ways. Gestalt psychologists translated these predictable ways into principles by which we organize sensory information. As a result, Gestalt psychology has been extremely influential in the area of sensation and perception (Rock & Palmer, 1990).

One Gestalt principle is the **figure-ground relationship**. According to this principle, we tend to segment our visual world into figure and ground. Figure is the object or person that is the focus of the visual field, while the ground is the background. As **Figure 5.23** shows, our perception can vary tremendously, depending on what is perceived as figure and what is perceived as ground. Presumably, our ability to interpret sensory information depends on what we label as figure and what we label as ground in any particular case, although this assumption has been called into question (Peterson & Gibson, 1994; Vecera & O'Reilly, 1998).

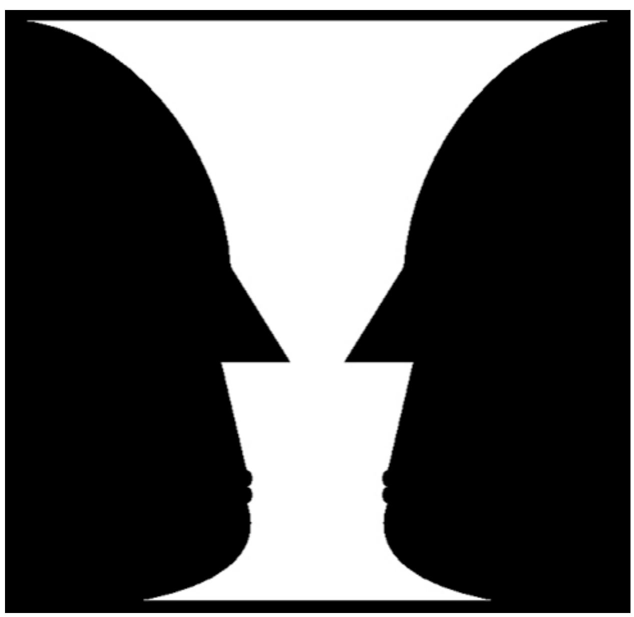

Figure 5.23 The concept of figure-ground relationship explains why this image can be perceived either as a vase or as a pair of faces.

Another Gestalt principle for organizing sensory stimuli into meaningful perception is **proximity**. This principle asserts that things that are close to one another tend to be grouped together, as **Figure 5.24** illustrates.

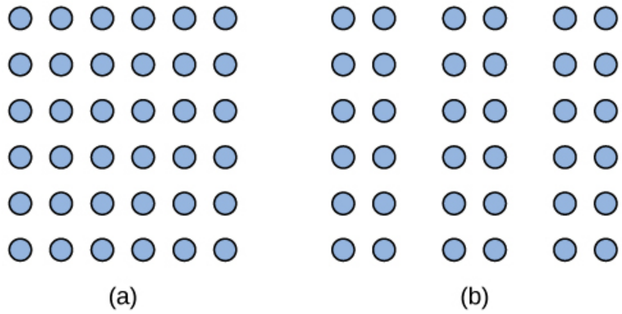

Figure 5.24 The Gestalt principle of proximity suggests that you see (a) one block of dots on the left side and (b) three columns on the right side.

How we read something provides another illustration of the proximity concept. For example, we read this sentence like this, notl iket hiso rt hat. We group the letters of a given word together because there are no spaces between the letters, and we perceive words because there are spaces between each word. Here are some more examples: Cany oum akes enseo ft hiss entence? What doth es e wor dsmea n?

We might also use the principle of **similarity** to group things in our visual fields. According to this principle, things that are alike tend to be grouped together (**Figure 5.25**). For example, when watching a football game, we tend to group individuals based on the colors of their uniforms. When watching an offensive drive, we can get a sense of the two teams simply by grouping along this dimension.

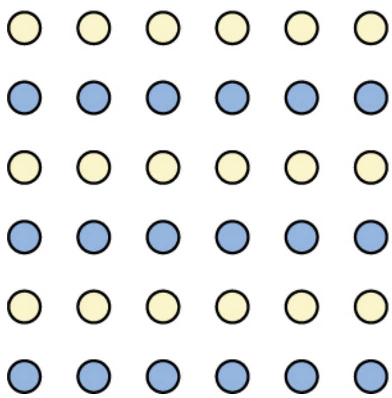

Figure 5.25 When looking at this array of dots, we likely perceive alternating rows of colors. We are grouping these dots according to the principle of similarity.

Two additional Gestalt principles are the law of **continuity** (or **good continuation**) and **closure**. The law of continuity suggests that we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines (**Figure 5.26**). The **principle of closure** states that we organize our perceptions into complete objects rather than as a series of parts (**Figure 5.27**).

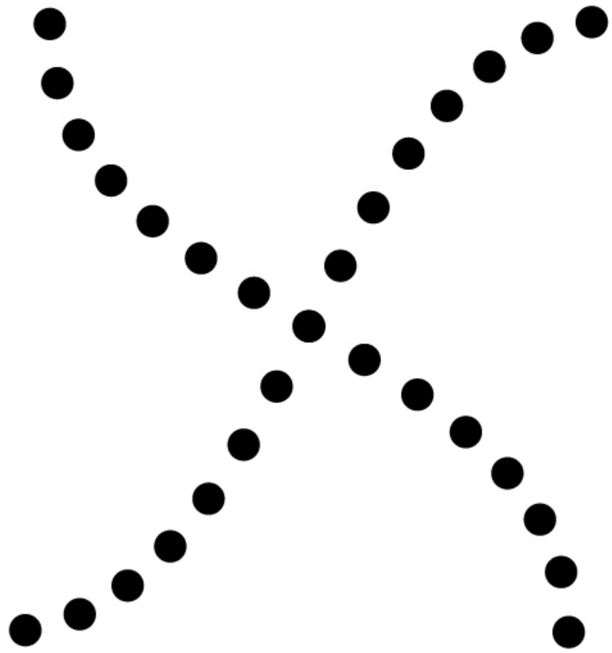

Figure 5.26 Good continuation would suggest that we are more likely to perceive this as two overlapping lines, rather than four lines meeting in the center.

Figure 5.27 Closure suggests that we will perceive a complete circle and rectangle rather than a series of segments.

LINK TO LEARNING

Watch this video (http://openstaxcollege.org/l/gestalt) showing real world illustrations of Gestalt principles.

According to Gestalt theorists, **pattern perception**, or our ability to discriminate among different figures and shapes, occurs by following the principles described above. You probably feel fairly certain that your perception accurately matches the real world, but this is not always the case. Our perceptions are based on **perceptual hypotheses**: educated guesses that we make while interpreting sensory information. These hypotheses are informed by a number of factors, including our personalities, experiences, and expectations. We use these hypotheses to generate our perceptual set. For instance, research has demonstrated that those who are given verbal priming produce a biased interpretation of complex ambiguous figures (Goolkasian & Woodbury, 2010).

DIG DEEPER

The Depths of Perception: Bias, Prejudice, and Cultural Factors

In this chapter, you have learned that perception is a complex process. Built from sensations, but influenced by our own experiences, biases, prejudices, and cultures, perceptions can be very different from person to person. Research suggests that implicit racial prejudice and stereotypes affect perception. For instance, several studies have demonstrated that non-Black participants identify weapons faster and are more likely to identify non-weapons as weapons when the image of the weapon is paired with the image of a Black person (Payne, 2001; Payne, Shimizu, & Jacoby, 2005). Furthermore, White individuals' decisions to shoot an armed target in a video game is made more quickly when the target is Black (Correll, Park, Judd, & Wittenbrink, 2002; Correll, Urland, & Ito, 2006). This research is important, considering the number of very high-profile cases in the last few decades in which young Blacks were killed by people who claimed to believe that the unarmed individuals were armed and/or represented some threat to their personal safety.

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?

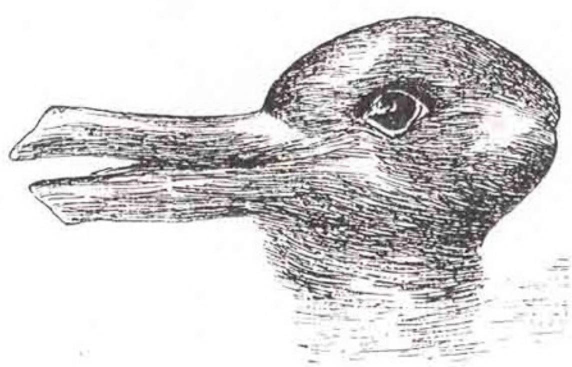

Figure 5.28

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?