in the left hemisphere, for example, often have difficulty speaking. The right hemisphere is more important for musical and artistic awareness; spatial and pattern perception; recognition of faces and emotional content of language; and for generating mental images of sight, sound, touch, taste, and smell.

Memory

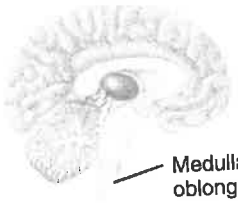
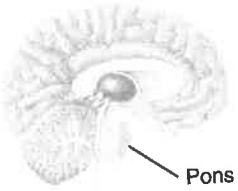
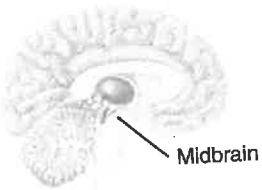
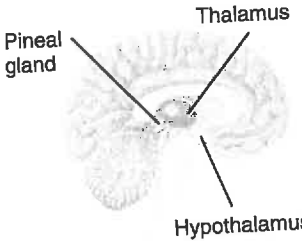
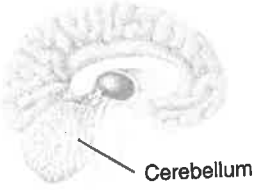
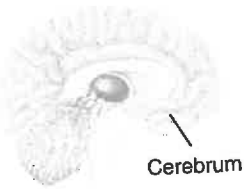
Without memory, we would repeat mistakes and be unable to learn. Similarly, we would not be able to repeat our successes or accomplishments, except by chance. ***Memory*** is the process by which information acquired through learning is stored and retrieved. For an experience to become part of memory, it must produce structural and functional changes in the brain. The parts of the brain known to be involved with memory include the association areas of the frontal, parietal, occipital, and temporal lobes; parts of the limbic system; and the diencephalon. Memories for motor skills, such as how to serve a tennis ball, are stored in the basal ganglia and cerebellum as well as in the cerebral cortex.

Electroencephalogram (EEG)

At any instant, brain neurons are generating millions of nerve impulses. Taken together, these electrical signals are called ***brain waves***. Brain waves generated by neurons close to the brain surface, mainly neurons in the cerebral cortex, can be detected by metal electrodes placed on the forehead and scalp. A record of such waves is called an ***electroencephalogram*** (e-lek′-trō-en-SEF-a-lō-gram) or ***EEG***. Electroencephalograms are useful for studying normal brain functions, such as changes that occur during sleep. Neurologists also use them to diagnose a variety of brain disorders, such as epilepsy, tumors, metabolic abnormalities, sites of trauma, and degenerative diseases.

Table 10.1 summarizes the principal parts of the brain and their functions.

Table 10.1 Summary of Functions of Principal Parts of the Brain

Part	Function
Brain Stem	
	***Medulla oblongata:*** Relays motor and sensory impulses between other parts of the brain and the spinal cord. Reticular formation (also in pons, midbrain, and diencephalon) functions in consciousness and arousal. Vital centers regulate heartbeat, breathing (together with pons), and blood vessel diameter. Other centers coordinate swallowing, vomiting, coughing, sneezing, and hiccupping. Contains nuclei of origin for cranial nerves VIII, IX, X, XI, and XII.
	***Pons:*** Relays impulses from one side of the cerebellum to the other and between the medulla and midbrain. Contains nuclei of origin for cranial nerves V, VI, VII, and VIII. Together with the medulla, helps control breathing.
	***Midbrain:*** Relays motor impulses from the cerebral cortex to the pons and sensory impulses from the spinal cord to the thalamus. Most of substantia nigra and red nucleus contribute to control of movement. Contains nuclei of origin for cranial nerves III and IV.
Diencephalon	
	***Thalamus:*** Relays almost all sensory impulses to the cerebral cortex. Provides crude perception of touch, pressure, pain, and temperature. Also functions in cognition and awareness. ***Hypothalamus:*** Controls and integrates activities of the autonomic nervous system and pituitary gland. Regulates emotional and behavioral patterns and circadian rhythms. Controls body temperature and regulates eating and drinking behavior. Helps maintain waking state and establishes patterns of sleep. ***Pineal gland:*** Secretes the hormone melatonin.
Cerebellum	
	Compares intended movements with what is actually happening to coordinate complex, skilled movements. Regulates posture and balance.
Cerebrum	
	Sensory areas are involved in the perception of sensory information, motor areas control muscular movement, and association areas deal with more complex integrative functions such as memory, personality traits, and intelligence. Basal ganglia coordinate automatic muscle movements and help regulate muscle tone. Limbic system functions in emotional aspects of behavior related to survival.

CHECKPOINT

13. Why is the hypothalamus considered part of both the nervous system and the endocrine system?
14. What are the functions of the cerebellum and basal ganglia?
15. Where are the primary somatosensory area and primary motor area located in the brain? What are their functions?
16. What areas of the cerebral cortex are needed for normal language abilities?
17. Compare and contrast the posterior column–medial lemniscus pathway and the spinothalamic pathways.

CRANIAL NERVES

OBJECTIVE • Identify the 12 pairs of cranial nerves by name and number and give the functions of each.

The 12 pairs of ***cranial nerves***, like spinal nerves, are part of the peripheral nervous system. The cranial nerves are designated with roman numerals and with names (see Figure 10.8). The roman numerals indicate the order (anterior to posterior) in which the nerves emerge from the brain. The names indicate the distribution or function.

Cranial nerves emerge from the nose (cranial nerve I), the eyes (cranial nerve II), the inner ear (cranial nerve VIII), the brain stem (cranial nerves III–XII), and the spinal cord (part of cranial nerve XI). Two cranial nerves (cranial nerves I and II) contain only sensory axons and thus are *sensory nerves*. The rest are *mixed nerves* because they contain axons of both sensory and motor neurons. Cranial nerves III, IV, VI, XI, and XII are mainly motor. A few of their axons are sensory axons from muscle proprioceptors, but most of their axons are motor neurons that innervate skeletal muscles. Cranial nerves III, VII, IX, and X include both somatic and autonomic motor axons. The somatic axons stimulate skeletal muscles; the autonomic axons, which are part of the parasympathetic division, go to glands, smooth muscle, and cardiac muscle.

Table 10.2 lists the cranial nerves, along with their components (sensory or mixed) and functions.

CHECKPOINT

18. What is the difference between a mixed cranial nerve and a sensory cranial nerve?

Table 10.2 Summary of Cranial Nerves (see Figure 10.8)

Number	Name*	Components	Function
I	**Olfactory nerve** (ol-FAK-tō-rē; *olfact-* = to smell)	***Sensory:*** Axons in the lining of the nose.	Smell.
II	**Optic nerve** (OP-tik; *opti-* = the eye, vision)	***Sensory:*** Axons from the retina of the eye.	Vision.
III	**Oculomotor nerve** (ok′-ū-lō-MŌ-tor; *oculo-* = eye; *-motor* = mover)	***Sensory part:*** Axons from proprioceptors in the eyeball muscles.	Muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate muscles of upper eyelid and four muscles that move the eyeballs plus axons of parasympathetic neurons that pass to two smooth muscles—the ciliary muscle of the eyeball and the sphincter muscle of the iris.	Movement of eyelid and eyeball; alters lens for near vision and constricts pupil.
IV	**Trochlear nerve** (TRŌK-lē-ar; *trochle-* = a pulley)	***Sensory part:*** Axons from proprioceptors in the superior oblique muscles (muscles that move the eyeballs).	Muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate the superior oblique muscles.	Movement of the eyeball.
V	**Trigeminal nerve** (trī-JEM-i-nal = triple, for its three branches)	***Sensory part:*** Consists of three branches: the *ophthalmic nerve* contains axons from the scalp and forehead skin; the *maxillary nerve* contains axons from the lower eyelid, nose, upper teeth, upper lip, and pharynx; and the *mandibular nerve* contains axons from the tongue, lower teeth, and the lower side of the face.	Touch, pain, and temperature sensations and muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate muscles used in chewing.	Chewing.

(Continues

Table 10.2 Summary of Cranial Nerves (Continued)

Number	Name*	Components	Function
VI	**Abducens nerve** (ab-DOO-senz; *ab-* = away; *-ducens* = to lead)	***Sensory part:*** Axons from proprioceptors in lateral rectus muscles (muscles that move the eyeballs).	Muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate the lateral rectus muscles.	Movement of eyeball.
VII	**Facial nerve** (FĀ-shal = face)	***Sensory part:*** Axons from taste buds on tongue and axons from proprioceptors in muscles of face and scalp.	Taste and muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate facial, scalp, and neck muscles plus parasympathetic axons that stimulate lacrimal (tear) glands and salivary glands.	Facial expressions; secretion of tears and saliva.
VIII	**Vestibulocochlear nerve** (vest-tib-ū-lō-KOK-lē-ar; *vestibulo-* = small cavity; *-cochlear* = a spiral, snail-like)	***Vestibular branch, sensory part:*** Axons from semicircular canals, saccule, and utricle (organs of equilibrium).	Equilibrium.
		Vestibular branch, motor part: Axons that synapse with sensory receptors (hair cells) for equilibrium.	Adjusts sensitivity of hair cells.
		Cochlear branch, sensory part: Axons from spiral organ (organ of hearing).	Hearing.
		Cochlear branch, motor part: Axons that synapse with sensory receptors (hair cells) for hearing.	Modifies responses of hair cells.
IX	**Glossopharyngeal nerve** (glos′-ō-fa-RIN-jē-al; *glosso-* = tongue; *-pharyngeal* = throat)	***Sensory portion:*** Axons from taste buds and somatic sensory receptors on part of tongue, from proprioceptors in some swallowing muscles, and from stretch receptors in carotid sinus and chemoreceptors in carotid body.	Taste and somatic sensations (touch, pain, and temperature) from tongue; muscle sense (proprioception); monitoring blood pressure; monitoring oxygen and carbon dioxide in blood for regulation of breathing.
		Motor portion: Axons of somatic motor neurons that stimulate swallowing muscles of throat plus parasympathetic axons that stimulate a salivary gland.	Swallowing; secretion of saliva.
X	**Vagus nerve** (VĀ-gus; *vagus* = vagrant or wandering)	***Sensory portion:*** Axons from proprioceptors in muscles of neck and throat, from stretch receptors and chemoreceptors in carotid sinus and carotid body, from chemoreceptors in aortic body, and from visceral sensory receptors in most organs of the thoracic and abdominal cavities.	Somatic sensations (touch, pain, temperature) from throat and pharynx; monitoring of blood pressure; monitoring of oxygen and carbon dioxide in blood for regulation of breathing; sensations from visceral organs in thorax and abdomen.
		Motor portion: Axons of somatic motor neurons that stimulate skeletal muscles of the throat and neck plus parasympathetic axons that supply smooth muscle in the airways, esophagus, stomach, small intestine, most of the large intestine, and gallbladder; cardiac muscle in the heart; and glands of the gastrointestinal tract.	Swallowing, coughing, and voice production; smooth muscle contraction and relaxation in organs of the gastrointestinal tract; slowing of the heart rate; secretion of digestive fluids.

Number	Name*	Components	Function
XI	**Accessory nerve** (ak-SES-ō-re = assisting)	***Sensory part:*** Axons from proprioceptors in muscles of throat and voice box.	Muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate muscles of the throat and neck.	Swallowing and movements of head and shoulders.
XII	**Hypoglossal nerve** (hi′-pō-GLOS-al; *hypo-* = below; *-glossal* = tongue)	***Sensory part:*** Axons from proprioceptors in tongue muscles.	Muscle sense (proprioception).
		Motor part: Axons of somatic motor neurons that stimulate muscles of tongue.	Movement of tongue during speech and swallowing.

*A mnemonic device that can be used to remember the names of the nerves is: "**O**h, **o**h, **o**h, **t**o **t**ouch **a**nd **f**eel **v**ery **g**reen **v**egetables—**AH**!" Each boldfaced letter corresponds to the first letter of a pair of cranial nerves.

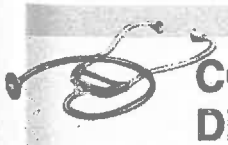
AGING AND THE NERVOUS SYSTEM

OBJECTIVE • Describe the effects of aging on the nervous system.

The brain grows rapidly during the first few years of life. Growth is due mainly to an increase in the size of neurons already present, the proliferation and growth of neuroglia, the development of dendritic branches and synaptic contacts, and continuing myelination of axons. From early adulthood onward, brain mass declines. By the time a person reaches age 80, the brain weighs about 7% less than it did in young adulthood. Although the number of neurons present does not decrease very much, the number of synaptic contacts declines. Associated with the decrease in brain mass is a decreased capacity for sending nerve impulses to and from the brain. As a result, processing of information diminishes. Conduction velocity decreases, voluntary motor movements slow down, and reflex times increase.

■ CHECKPOINT

19. How is brain mass related to age?



COMMON DISORDERS

Spinal Cord Injury

Most spinal cord injuries are due to trauma as a result of factors such as automobile accidents, falls, contact sports, diving, or acts of violence. The effects of the injury depend on the extent of direct trauma to the spinal cord or compression of the cord by fractured or displaced vertebrae or blood clots. Although any segment of the spinal cord may be involved, most common sites of injury are in the cervical, lower thoracic, and upper lumbar regions. Depending on the location and extent of spinal cord damage, paralysis may occur. ***Monoplegia*** (*mono-* = one; *-plegia* = blow or strike) is paralysis of one limb only. ***Diplegia*** (*di-* = two) is paralysis of both upper limbs or both lower limbs. ***Paraplegia*** (*para-* = beyond) is paralysis of both lower limbs. ***Hemiplegia*** (*hemi-* = half) is paralysis of the upper limb, trunk, and lower limb on one side of the body, and ***quadriplegia*** (*quad-* = four) is paralysis of all four limbs.

Shingles

Shingles is an acute infection of the peripheral nervous system caused by *herpes zoster* (HER-pēz ZOS-ter), the virus that also causes chickenpox. After a person recovers from chickenpox, the virus retreats to a posterior root ganglion. If the virus is reactivated, it may leave the ganglion and travel down sensory axons to the skin. The result is pain, discoloration of the skin, and a characteristic line of skin blisters. The line of blisters marks the distribution of the particular sensory nerve belonging to the infected posterior root ganglion.

Amyotrophic Lateral Sclerosis

Amyotrophic lateral sclerosis (ALS) (ā′-mī-ō′-TROF-ik; *a-* = without; *myo-* = muscle; *trophic* = nourishment) is a progressive degenerative disease that attacks motor areas of the cerebral cortex, axons of upper motor neurons, and lower motor neuron cell bodies. ALS is commonly known as *Lou Gehrig's disease* after the New York Yankees baseball player who died of it at age 37 in 1941. ALS causes progressive muscle weakness and atrophy. ALS often begins in sections of the

spinal cord that serve the hands and arms but rapidly spreads to involve the whole body and face, without affecting intellect or sensations. Death typically occurs in 2 to 5 years. ALS may be caused by the buildup in the synaptic cleft of the neurotransmitter glutamate released by motor neurons. The excess glutamate causes motor neurons to malfunction and eventually die. The drug riluzole, which is used to treat ALS, reduces damage to motor neurons by decreasing the release of glutamate. Other factors implicated in the development of ALS include damage to motor neurons by free radicals, autoimmune responses, viral infection, deficiency of nerve growth factor, apoptosis (programmed cell death), environmental toxins, and trauma.

Cerebrovascular Accident

The most common brain disorder is a ***cerebrovascular accident (CVA)***, also called a ***stroke*** or ***brain attack***. CVAs affect 500,000 people a year in the United States and represent the third leading cause of death, behind heart attacks and cancer. A CVA is characterized by abrupt onset of persisting symptoms, such as paralysis or loss of sensation, that arise from destruction of brain tissue. Common causes of CVAs are hemorrhage from a blood vessel in the pia mater or brain, blood clots, and formation of cholesterol-containing atherosclerotic plaques that block brain blood flow. The risk factors implicated in CVAs are high blood pressure, high blood cholesterol, heart disease, narrowed carotid arteries, transient ischemic attacks (discussed next), diabetes, smoking, obesity, and excessive alcohol intake.

Transient Ischemic Attack

A ***transient ischemic attack (TIA)*** is an episode of temporary cerebral dysfunction caused by impaired blood flow to part of the brain. Symptoms include dizziness, weakness, numbness, or paralysis in a limb or in one side of the body; drooping of one side of the face; headache; slurred speech or difficulty understanding speech; and a partial loss of vision or double vision. Sometimes nausea or vomiting also occurs. The onset of symptoms is sudden and reaches maximum intensity almost immediately. A TIA usually persists for 5 to 10 minutes and only rarely lasts as long as 24 hours. It leaves no persistent neurological deficits. The causes of TIAs include blood clots, atherosclerosis, and certain blood disorders.

Poliomyelitis

Poliomyelitis, or simply ***polio***, is caused by a virus called poliovirus. The onset of the disease is marked by fever, severe headache, a stiff neck and back, deep muscle pain and weakness, and loss of certain somatic reflexes. In its most serious form, the virus produces paralysis by destroying cell bodies of motor neurons, specifically those in the anterior horns of the spinal cord and in the nuclei of the cranial nerves. Polio can cause death from respiratory or heart failure if the virus invades neurons in vital centers that control breathing and heart functions in the brain stem. Even though polio vaccines have virtually eradicated polio in the United States, outbreaks of polio continue throughout the world. Due to international travel, polio could easily be reintroduced into North America if individuals are not vaccinated appropriately.

Several decades after suffering a severe attack of polio and following their recovery from it, some individuals develop a condition called ***post-polio syndrome***. This neurological disorder is characterized by progressive muscle weakness, extreme fatigue, loss of function, and pain, especially in muscles and joints. Post-polio syndrome seems to involve a slow degeneration of motor neurons that innervate muscle fibers. Triggering factors appear to be a fall, a minor accident, surgery, or prolonged bed rest. Possible causes include overuse of surviving motor neurons over time, smaller motor neurons because of the initial infection by the virus, reactivation of dormant polio viruses, immune-mediated responses, hormone deficiencies, and environmental toxins. Treatment consists of muscle-strengthening exercises, administration of drugs to enhance the action of acetylcholine in stimulating muscle contraction, and administration of nerve growth factors to stimulate both nerve and muscle growth.

Parkinson Disease

Parkinson disease (PD) is a progressive disorder of the CNS that typically affects its victims around age 60. Neurons that extend from the substantia nigra to the putamen and caudate nucleus, where they release the neurotransmitter dopamine (DA), degenerate in PD. The cause of PD is unknown, but toxic environmental chemicals, such as pesticides, herbicides, and carbon monoxide, are suspected contributing agents. Only 5% of PD patients have a family history of the disease.

In PD patients, involuntary skeletal muscle contractions often interfere with voluntary movement. For instance, the muscles of the upper limb may alternately contract and relax, causing the hand to shake. This shaking, called ***tremor***, is the most common symptom of PD. Also, muscle tone may increase greatly, causing rigidity of the involved body part. Rigidity of the facial muscles gives the face a mask-like appearance. The expression is characterized by a wide-eyed, unblinking stare and a slightly open mouth with uncontrolled drooling.

Motor performance is also impaired by ***bradykinesia*** (*brad-* = slow), slowness of movements. Activities such as shaving, cutting food, and buttoning a shirt take longer and become increasingly more difficult as the disease progresses. Muscular movements also exhibit ***hypokinesia*** (*hypo-* = under), decreasing range of motion. For example, words are written smaller, letters are poorly formed, and eventually handwriting becomes illegible. Often, walking is impaired; steps become shorter and shuffling, and arm swing diminishes. Even speech may be affected.

Alzheimer Disease

Alzheimer disease (ALTZ-hī-mer) or ***AD*** is a disabling senile dementia, the loss of reasoning and ability to care for oneself, that afflicts about 11% of the population over age 65. In the United States, AD afflicts about 4 million people and claims over 100,000 lives a year. The cause of most AD cases is still unknown, but evidence suggests it is due to a combination of genetic factors, environmental or lifestyle factors, and the aging process. Mutations in three different genes (coding for presenilin-1, presenilin-2, and amyloid precursor protein) lead to early-onset forms of AD in afflicted families but account for less than 1% of all cases. An environmental risk factor for developing AD is a history of head injury. A similar dementia occurs in boxers, probably caused by repeated blows to the head.

Individuals with AD initially have trouble remembering recent events. They then become confused and forgetful, often repeating questions or getting lost while traveling to previously familiar places. Disorientation increases; memories of past events disappear; and episodes of paranoia, hallucination, or violent changes in mood may occur. As their minds continue to deteriorate, AD patients lose their ability to read, write, talk, eat, or walk. At autopsy, brains of AD victims show three distinct structural abnormalities: (1) loss of neurons that liberate acetylcholine from a brain region called the nucleus basalis, located below the globus pallidus; (2) beta-amyloid plaques, clusters of abnormal proteins deposited outside neurons; and (3) neurofibrillary tangles, abnormal bundles of protein filaments inside neurons in affected brain regions. A person with AD usually dies of some complication that afflicts bedridden patients, such as pneumonia.

MEDICAL TERMINOLOGY AND CONDITIONS

Analgesia (an′-al-JĒ-zē-a; *an-* = without; *-algesia* = painful condition) Pain relief.

Anesthesia (an′-es-THĒ-zē-a; *-esthesia* = feeling) Loss of sensation.

Consciousness (KON-shus-nes) A state of wakefulness in which an individual is fully alert, aware, and oriented, partly as a result of feedback between the cerebral cortex and reticular activating system.

Dementia (de-MEN-shē-a; *de-* = away from; *-mentia* = mind) Permanent or progressive general loss of intellectual abilities, including impairment of memory, judgment, and abstract thinking, and changes in personality.

Encephalitis (en′-sef-a-LĪ-tis) An acute inflammation of the brain caused by either a direct attack by any of several viruses or an allergic reaction to any of the many viruses that are normally harmless to the central nervous system. If the virus affects the spinal cord as well, the condition is called ***encephalomyelitis***.

Epidural block Injection of an anesthetic drug into the epidural space, the space between the dura mater and the vertebral column, to cause a temporary loss of sensation. Such injections in the lower lumbar region are used to control pain during childbirth.

Meningitis (men-in-JĪ-tis) Inflammation of the meninges.

Nerve block Loss of sensation due to injection of a local anesthetic; an example is local dental anesthesia.

Neuralgia (noo-RAL-jē-a; *neur-* = nerve; *-algia* = pain) Attacks of pain along the entire length or a branch of a peripheral sensory nerve.

Neuritis (*neur-* = nerve; *-itis* = inflammation) Inflammation of one or several nerves, resulting from irritation caused by bone fractures, contusions, or penetrating injuries. Additional causes include infections; vitamin deficiency (usually thiamine); and poisons such as carbon monoxide, carbon tetrachloride, heavy metals, and some drugs.

Reye (RĪ) ***syndrome*** Occurs after a viral infection, particularly chickenpox or influenza, most often in children or teens who have taken aspirin; characterized by vomiting and brain dysfunction (disorientation, lethargy, and personality changes) that may progress to coma and death.

Sciatica (sī-AT-i-ka) A type of neuritis characterized by severe pain along the path of the sciatic nerve or its branches; may be caused by a slipped disc, pelvic injury, osteoarthritis of the backbone, or pressure from an expanding uterus during pregnancy.

STUDY OUTLINE

Spinal Cord Structure (p. 243)

1. The spinal cord is protected by the vertebral column, meninges, and cerebrospinal fluid.
2. The meninges are three connective tissue coverings of the spinal cord and brain: dura mater, arachnoid mater, and pia mater.
3. Removal of cerebrospinal fluid from the subarachnoid space is called a spinal tap. The procedure is used to remove CSF and to introduce antibiotics, anesthetics, and chemotherapy.
4. The spinal cord extends from the lowest part of the brain, the medulla oblongata, to the upper border of the second lumbar vertebra in the vertebral column.
5. The spinal cord contains cervical and lumbar enlargements that serve as points of origin for nerves to the limbs.
6. The roots of the nerves arising from the lumbar, sacral, and coccygeal regions of the cord are called the cauda equina.
7. The gray matter in the spinal cord is divided into horns and the white matter into columns. Parts of the spinal cord observed in cross section are the central canal; anterior, posterior, and lateral gray horns; anterior, posterior, and lateral white columns; and sensory (ascending) and motor (descending) tracts.

Spinal Nerves (p. 246)

1. The 31 pairs of spinal nerves are named and numbered according to the region and level of the spinal cord from which they emerge.
2. There are 8 pairs of cervical, 12 pairs of thoracic, 5 pairs of lumbar, 5 pairs of sacral, and 1 pair of coccygeal nerves.
3. Spinal nerves are attached to the spinal cord by means of a posterior root and an anterior root.
4. All spinal nerves are mixed nerves containing sensory and motor axons.
5. Branches of spinal nerves, except for T2 to T11, form networks of nerves called plexuses. Nerves T2 to T11 do not form plexuses and are called intercostal nerves.

6. The major plexuses are the cervical, brachial, lumbar, and sacral plexuses.

Spinal Cord Functions (p. 247)

1. The spinal cord white matter and gray matter have two major functions in maintaining homeostasis. The white matter serves as highways for nerve impulse conduction. The gray matter receives and integrates incoming and outgoing information and is a site for integration of reflexes.
2. A reflex is a fast, involuntary sequence of actions that occurs in response to a particular stimulus. The basic components of a reflex arc are a receptor, a sensory neuron, an integrating center, a motor neuron, and an effector.

Brain (p. 248)

1. The major parts of the brain are the brain stem, diencephalon, cerebellum, and cerebrum (see Table 10.1 on page 262). The brain stem consists of the medulla oblongata, pons, and midbrain. The diencephalon consists of the thalamus, hypothalamus, and pineal gland.
2. The brain is well supplied with oxygen and nutrients. Any interruption of the oxygen supply to the brain can weaken, permanently damage, or kill brain cells. Glucose deficiency may produce dizziness, convulsions, and unconsciousness.
3. The blood–brain barrier (BBB) limits the passage of certain material from the blood into the brain.
4. The brain is protected by cranial bones, meninges, and cerebrospinal fluid.
5. The cranial meninges are continuous with the spinal meninges and are named dura mater, arachnoid mater, and pia mater.
6. Cerebrospinal fluid is formed in the choroid plexuses and circulates continually through the subarachnoid space, ventricles, and central canal.
7. Cerebrospinal fluid protects by serving as a shock absorber. It also delivers nutritive substances from the blood and removes wastes.
8. The medulla oblongata, or medulla, is continuous with the upper part of the spinal cord. It contains regions for regulating heart rate, diameter of blood vessels, breathing, swallowing, coughing, vomiting, sneezing, and hiccupping. Cranial nerves VIII–XII originate at the medulla.
9. The pons links parts of the brain with one another; it relays impulses for voluntary skeletal movements from the cerebral cortex to the cerebellum, and it contains two regions that control breathing. Cranial nerves V–VII and part of VIII originate at the pons.
10. The midbrain is between the pons and diencephalon. It conveys motor impulses from the cerebrum to the cerebellum and spinal cord, sends sensory impulses from the spinal cord to the thalamus, and mediates auditory and visual reflexes. It also contains nuclei associated with cranial nerves III and IV.
11. The reticular formation is a netlike arrangement of gray and white matter extending throughout the brain stem that alerts the cerebral cortex to incoming sensory signals and helps regulate muscle tone.
12. The thalamus contains nuclei that serve as relay stations for sensory impulses to the cerebral cortex. It also contributes to motor functions by transmitting information from the cerebellum and basal ganglia to motor areas of the cerebral cortex.
13. The hypothalamus is inferior to the thalamus. It controls the autonomic nervous system, secretes hormones, functions in rage and aggression, governs body temperature, regulates food and fluid intake, and establishes circadian rhythms.
14. The cerebellum occupies the inferior and posterior aspects of the cranial cavity. It attaches to the brain stem by cerebellar peduncles. It coordinates movements and helps maintain normal muscle tone, posture, and balance.
15. The cerebrum is the largest part of the brain. Its cortex contains gyri (convolutions), fissures, and sulci. The cerebral lobes are frontal, parietal, temporal, and occipital.
16. The white matter is deep to the cortex and consists of myelinated and unmyelinated axons extending to other CNS regions.
17. The basal ganglia are several groups of nuclei in each cerebral hemisphere. They help control automatic movements of skeletal muscles and help regulate muscle tone.
18. The limbic system encircles the upper part of the brain stem and the corpus callosum. It functions in emotional aspects of behavior and memory.
19. The sensory areas of the cerebral cortex receive and perceive sensory information. The motor areas govern muscular movement. The association areas are concerned with emotional and intellectual processes.
20. Somatic sensory pathways from receptors to the cerebral cortex involve sets of three neurons. The posterior column–medial lemniscus pathway relays nerve impulses for sensations of fine touch, proprioception, and vibrations. The lateral and anterior spinothalamic tracts relay impulses for pain, thermal, tickle, and itch sensations.
21. All somatic motor pathways that control movement converge on lower motor neurons. Input to lower motor neurons comes from local interneurons, upper motor neurons, basal ganglia neurons, and cerebellar neurons.
22. Subtle anatomical differences exist between the two cerebral hemispheres, and each has some unique functions.
23. Memory, the ability to store and recall thoughts, involves persistent changes in the brain.
24. Brain waves generated by the cerebral cortex are recorded as an electroencephalogram (EEG), which may be used to diagnose epilepsy, infections, and tumors.

Cranial Nerves (p. 263)

1. Twelve pairs of cranial nerves emerge from the brain.
2. Like spinal nerves, cranial nerves are part of the PNS. See Table 10.2 on pages 263–265 for the names, components, and functions of each of the cranial nerves.

Aging and the Nervous System (p. 265)

1. The brain grows rapidly during the first few years of life.
2. Age-related effects involve loss of brain mass and decreased capacity for sending nerve impulses.

SELF-QUIZ

1. Which sequence best represents a reflex arc from the stimulus to the response?
   1. effector
   2. integrating center
   3. motor neuron
   4. receptor
   5. sensory neuron

   a. 3, 1, 4, 5, 2 b. 1, 5, 2, 3, 4 c. 4, 3, 2, 5, 1
   d. 5, 2, 3, 4, 1 e. 4, 5, 2, 3, 1

2. Which of the following would carry sensory nerve impulses?
   a. anterior spinothalamic tract b. anterior root
   c. lateral corticospinal tract d. direct pathways
   e. pyramids

3. An inability to distinguish keys in your pocket by touch could indicate damage to the
   a. gray matter of the cerebellum
   b. lateral spinothalamic tract
   c. posterior column–medial lemniscus pathway
   d. anterior ramus
   e. primary motor cortex

4. Carpal tunnel syndrome is due to damage to a nerve in the
   a. lumbar plexus b. cervical plexus c. brachial plexus
   d. cauda equina e. sacral plexus

5. A needle used in a spinal tap would penetrate (in order):
   1. arachnoid 2. dura mater 3. epidural space
   4. subarachnoid space

   a. 1, 2, 3, 4 b. 2, 3, 1, 4 c. 3, 1, 4, 2 d. 3, 2, 1, 4
   e. 4, 1, 2, 3

6. The diencephalon is composed of the
   a. medulla, pons, and hypothalamus
   b. midbrain, hypothalamus, and thalamus
   c. cerebellum and midbrain
   d. medulla, pons, and midbrain
   e. hypothalamus and thalamus

7. Which of the following statements about the blood supply to the brain is NOT true?
   a. The brain needs a constant supply of glucose delivered by the blood.
   b. The structure of the brain capillaries allows selective passage of certain materials from the blood into the brain.
   c. The glucose brought to the brain can be stored for future use
   d. Brain neurons that are totally deprived of oxygen for four minutes or more may be permanently injured.
   e. The brain requires about 20% of the body's oxygen supply. ✓

8. After a car accident, Joe exhibits severe dizziness, difficulty in walking, and slurred speech. He may have damaged his
   a. cerebellum b. pons c. reticular activating system
   d. fifth cranial nerve e. midbrain

9. Which of the following is NOT a function of cerebrospinal fluid?
   a. protection b. circulation c. conduction of nerve impulses d. nutrition e. shock absorption

10. Which part of the brain contains the centers that control the heart rate and breathing rhythm?
    a. medulla b. midbrain c. cerebellum
    d. thalamus e. pons

11. The part of the brain that serves as a link between the nervous and endocrine systems is the
    a. reticular formation b. hypothalamus c. pons
    d. brain stem e. cerebellum

12. Which of the following is NOT a function of the hypothalamus?
    a. regulates food intake b. controls body temperature
    c. regulates feelings of rage and aggression
    d. helps establish sleep patterns
    e. allows crude interpretation of pain and pressure

13. The part(s) of the brain concerned with memory, reasoning, judgment, and intelligence is (are) the
    a. sensory areas b. limbic system c. motor areas
    d. cerebellum e. association areas

14. A broad band of white matter that connects the two cerebral hemispheres is the
    a. corpus callosum b. gyrus c. insula
    d. ascending tract e. basal ganglia

15. The ringing of your alarm clock in the morning wakes you up by stimulating the
    a. thalamus b. reticular activating system
    c. Broca's area d. basal ganglia e. spinal cord

16. Match the following functions to the primary lobe in which they are located:

    C a. contains primary visual area that allows interpretation of shape and color
    ___ b. receives impulses for smell
    ___ c. contains primary motor area that controls muscle movement
    ___ d. receives sensory impulses for touch, pain, and temperature

    A. frontal lobe
    B. parietal lobe
    C. occipital lobe
    D. temporal lobe

17. When entering a restaurant, you are bombarded with many different sensory stimuli. The part of the brain that combines all of those sensory inputs so that you can respond appropriately is the
    a. somatosensory association area
    b. common integrative area
    c. premotor area
    d. Wernicke's area
    e. hypothalamus

18. Which cranial nerves contain only sensory fibers?
    a. olfactory, optic, and glossopharyngeal
    b. optic and oculomotor
    c. optic and trochlear
    d. optic and olfactory
    e. vagus and facial

19. Which two of the following cranial nerves are NOT involved in controlling movement of the eyeball?
    a. oculomotor
    b. trochlear
    c. facial
    d. abducens
    e. trigeminal

20. Match the following:

___ a. organization of white matter in the spinal cord	A. longitudinal fissure
___ b. absorb cerebrospinal fluid	B. sulci
___ c. extension of nerves beyond the end of the spinal cord	C. ventricles
___ d. folds of the cerebral cortex	D. anterior median fissure
___ e. contains the sensory fibers of a spinal nerve	E. central canal
___ f. contains the motor fibers of a spinal nerve	F. posterior (dorsal) root
___ g. separates the cerebrum into right and left halves	G. columns
___ h. divides spinal cord into right and left sides	H. arachnoid villi
___ i. brain cavities where CSF circulates	I. anterior (ventral) root
___ j. shallow grooves in the cerebrum	J. gyri
___ k. contains CSF in the spinal cord	K. cauda equina

CRITICAL THINKING APPLICATIONS

1. After a few days of using her new crutches, Kate's arms and hands felt tingly and numb. The physical therapist said Kate had a case of "crutch palsy" from improper use of her crutches. Kate had been leaning her armpits on the crutches while hobbling along. What caused the numbness in her arms and hands?
2. Dennis was a little nervous. It was his first visit to the dentist in 10 years. "You won't feel a thing," said the dentist as she injected several doses of "numbing" medication. While having lunch right after the visit, soup drips down Dennis' chin because he still doesn't feel a thing in his lower lip and right upper lip. What happened to Dennis?
3. An elderly relative suffered a stroke and now has difficulty with the movement of her right upper limb. She is also working with a therapist due to some speech problems. What areas of the brain were damaged by the stroke?
4. Lynn flicked on the light when she heard her husband's yell. Kyle was bouncing on his left foot while holding his right foot in his hand. A pin was sticking out of the bottom of his foot. Explain Kyle's response to stepping on the pin.

ANSWERS TO FIGURE QUESTIONS

10.1 CSF circulates in the subarachnoid space.

10.2 Spinal nerves are part of the PNS (peripheral nervous system).

10.3 A horn is an area of gray matter, and a column is a region of white matter in the spinal cord.

10.4 All spinal nerves are mixed (have sensory and motor components) because the posterior root containing sensory axons and the anterior root containing motor axons unite to form the spinal nerve.

10.5 Axons of sensory neurons are part of the posterior root, and axons of motor neurons are part of the anterior root.

10.6 The medulla oblongata of the brain attaches to the spinal cord.

10.7 CSF is formed in the choroid plexuses and is reabsorbed through arachnoid villi into blood in the superior sagittal sinus.

10.8 The midbrain contains the cerebral peduncles.

10.9 The superior colliculi govern eye movements for tracking moving images and scanning stationary images and are responsible for reflexes that govern movements of the eyes, head, and neck in response to visual stimuli.

10.10 The basal ganglia are located in the cerebrum and are composed of gray matter.

10.11 The longitudinal fissure separates the right and left cerebral hemispheres.

10.12 The limbic system is located on the inner border of the cerebrum and floor of the diencephalon.

10.13 The primary somatosensory area localizes somatic sensations.

10.14 Damage to the spinothalamic tracts could produce loss of pain, thermal, tickle, and itch sensations.

10.15 In the spinal cord, the lateral and anterior corticospinal tracts conduct impulses along axons of upper motor neurons.