chapter

11 Nervous System: Spinal Cord and Peripheral Nerves

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Key Terms

afferent neuron (p. 205)
cranial nerves (p. 207)
dermatome (p. 214)
efferent neuron (p. 205)
gray matter (p. 201)
mixed nerves (p. 206)
motor nerves (p. 206)
nerve tracts (p. 206)
peripheral nervous system (p. 206)
plexus (p. 210)
reflex arc (p. 205)
sensory nerves (p. 206)
spinal nerves (p. 203)
white matter (p. 201)

Objectives

1. Describe the anatomy of the spinal cord and list its three functions.
2. Discuss reflexes and list four components of the reflex arc.
3. List and describe the functions of the 12 pairs of cranial nerves.
4. Do the following regarding the peripheral nervous system:
   - Identify the classification of spinal nerves.
   - List the functions of the three major plexuses.
   - Describe a dermatome.
   - Provide the functional classification of the peripheral nervous system.

The brain, spinal cord, and peripheral nervous system work together as an intricate communication system. The spinal cord continuously carries information to and from the brain. In the absence of spinal cord function, no sensory activity is present and the person cannot feel. The person also lacks voluntary motor activity and cannot move. The spinal cord plays a crucial role in reflex activity, and many of our rapid and patterned responses are processed by the spinal cord.

WHAT THE SPINAL CORD IS

LOCATION AND SIZE

The spinal cord is a continuation of the brain stem. It is a tubelike structure located within the spinal cavity. The diameter of the spinal cord is similar to the thickness of your thumb. The spinal cord is about 17 inches (43 cm) long and extends from the foramen magnum of the occipital bone to the level of the first lumbar vertebra (L1), just below the bottom rib. Like the brain, the spinal cord is well protected by bone (vertebrae), meninges, cerebrospinal fluid (CSF), and the blood–brain barrier (Figure 11-1).

An infant's spinal cord extends the full length of the spinal cavity. As the infant grows, however, the vertebral column grows faster than the cord. Because of the different rates of growth, the spinal cavity eventually becomes longer than the spinal cord, with the cord extending only to L1 in the adult. The meningeal membranes, however, extend the length of the spinal cavity.

This anatomical arrangement forms the basis for the site of a *lumbar puncture* (see Figure 11-1, *B* and *C*). In this procedure, a hollow needle is inserted into the subarachnoid space, between L3 and L4, at about the level of the top of the hip bone. A sample of CSF is withdrawn from the subarachnoid space. The CSF is then examined for pathogens, blood, or other abnormal signs. Because the spinal cord ends at L1, there is no danger of injuring the cord with the needle.

? Re-Think

1. Describe the length and location of the adult spinal cord.
2. Why is a lumbar puncture performed between L3 and L4?

Go Figure

1. **According to Figure 10-4**
   a. All axon terminals are myelinated.
   b. The electrical signal runs from the cell body, along the axon, to the axon terminals.
   c. Nodes of Ranvier are myelinated axonal membrane.
   d. All dendrites are myelinated.

2. **According to Figure 10-6**
   a. Panel B illustrates the influx of Na^+ and depolarization.
   b. Panel B illustrates the influx of Na^+ and repolarization.
   c. Panel C illustrates the influx of K^+ and depolarization.
   d. Panel C illustrates the efflux of K^+ and depolarization.

3. **Figure 10-8 illustrates**
   a. The formation of a nerve impulse at each node.
   b. The effect of myelination on conduction velocity (the speed that the nerve impulse travels along the axon).
   c. Saltatory conduction.
   d. All of the above are true.

4. **According to Figure 10-9**
   a. Acetylcholine (ACh) is an enzyme that inactivates acetylcholinesterase.
   b. Acetylcholinesterase inactivates ACh immediately after its release from the axon terminal.
   c. The receptors on the membrane of neuron B are activated by ACh.
   d. Both acetylcholine and acetylcholinesterase are stored within the vesicles of the axon terminal.

5. **According to Figures 10-10 and 10-11**
   a. The brain stem is located superior to the diencephalon.
   b. The primary motor cortex and the primary somatosensory area are separated by the lateral sulcus.
   c. The primary visual cortex is located within the cerebrum.
   d. The cerebellum is located anterior to the brain stem and superior to the diencephalon.

6. **According to Figures 10-12 and 10-13**
   a. The homunculus in Figure 10-12 is a sensory homunculus.
   b. The homunculus in Figure 10-12 lies over the cerebellum.
   c. The brain stem refers to the midbrain, pons, and medulla oblongata.
   d. The diencephalon is superior to the thalamus.

7. **According to Figures 10-14 and 10-15**
   a. Cerebrospinal fluid is secreted by the arachnoid villi and drained by the choroid plexus.
   b. The arachnoid villi protrude into the lateral ventricles where they are bathed in cerebrospinal fluid.
   c. Cerebrospinal fluid is secreted by Broca's area into the dural sinuses.
   d. The cerebral aqueduct drains cerebrospinal fluid from the third ventricle.

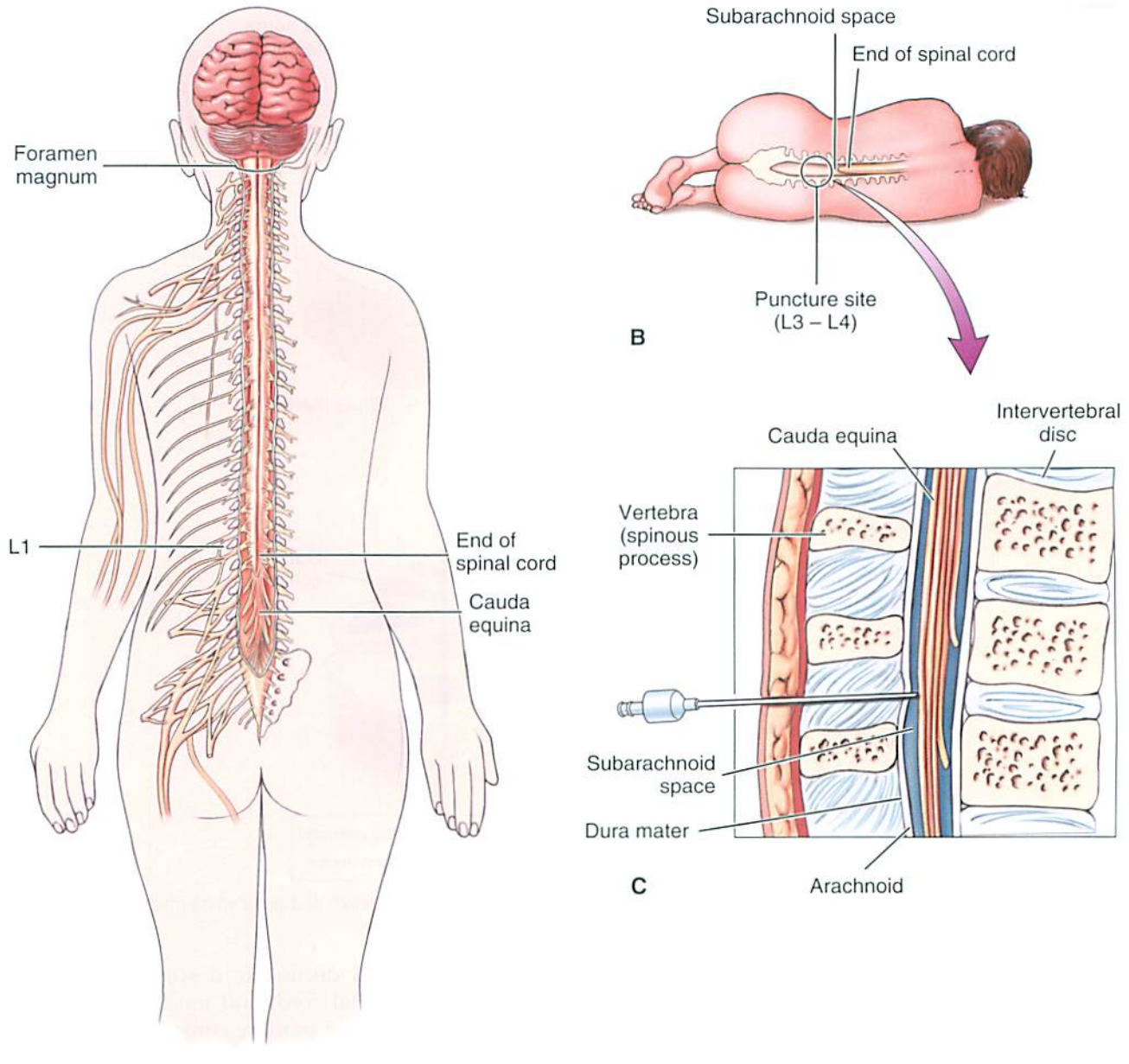


FIGURE 11-1 **A,** Location and length of the spinal cord. **B** and **C,** Lumbar puncture (spinal tap).

GRAY ON THE INSIDE, WHITE ON THE OUTSIDE

GRAY MATTER

A cross-section of the spinal cord shows an area of gray matter and an area of white matter (Figure 11-2). The **gray matter** is located in the center and is shaped like a butterfly. It is composed primarily of cell bodies, interneurons, and synapses. Two projections of the gray matter are the dorsal (posterior) horn and the ventral (anterior) horn. In the middle of the gray matter is the central canal. The central canal is an opening, or hole, that extends the entire length of the spinal cord. It is open to the ventricular system in the brain and to the subarachnoid space at the bottom of the spinal cord. CSF flows from the ventricles in the brain down through the central canal into the subarachnoid space at the base of the spinal cord. The CSF then circulates throughout the subarachnoid space surrounding the spinal cord and brain.

WHITE MATTER

The **white matter** of the spinal cord is composed of myelinated and unmyelinated axons. These neuronal axons are grouped together into sensory and motor nerve tracts.

Sensory tracts carry information from the periphery, up the spinal cord, and toward the brain (see Figure 11-2). They are therefore called *ascending tracts*. The

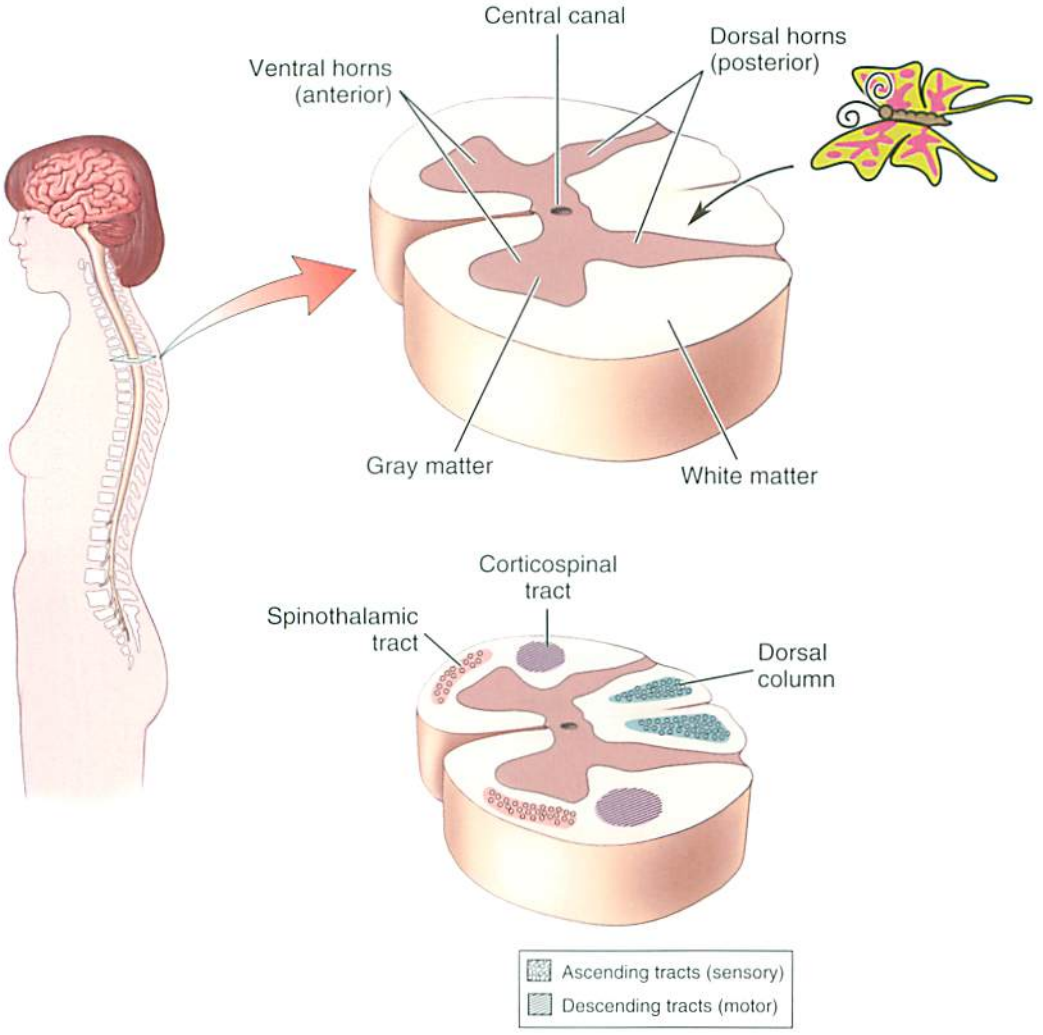


FIGURE 11-2 Cross-section of the spinal cord: inner gray matter ("butterfly") and outer white matter.

spinothalamic (spy-no-thah-LAM-ik) tract is an example of an ascending tract. It carries sensory information for touch, pressure, and pain from the spinal cord to the thalamus in the brain. Note that the name of the tract (spinothalamic) often indicates its origin (spinal cord) and destination (thalamus).

Motor tracts carry information from the brain, down the spinal cord, and toward the periphery. They are called *descending tracts*. The major descending tracts are the pyramidal and extrapyramidal tracts. The pyramidal tract, or corticospinal tract, is the major motor tract, originating in the precentral gyrus of the frontal lobe of the cerebrum. As its name (corticospinal) implies, motor information is carried from the cortex (origin) of the brain to the spinal cord (destination). Additional information concerning tracts and their functions is in Table 11-1.

Decussation

Most nerve tracts decussate (de-KUS-ate), or cross over, from one side to the other. For example, the corticospinal tract that originates in the left frontal lobe descends to the medulla oblongata, in the brain stem. The fibers then decussate, descend down the right side of the spinal cord, and innervate the right side of the body. Stated in more clinical terms, the corticospinal tract decussates within the medulla oblongata and descends on the contralateral (opposite) side.

Table 11-1 Major Spinal Cord Tracts

TRACTS	FUNCTIONS
Ascending	
Spinothalamic	Temperature, pressure, pain, light touch
Dorsal column	Touch, deep pressure, vibration
Spinocerebellar	Proprioception
Descending	
Pyramidal (corticospinal)	Skeletal muscle tone, voluntary muscle movement
Extrapyramidal	Skeletal muscle activity (balance and posture)

Decussation accounts for the right-sided paralysis (hemiparalysis) in a person who has experienced a stroke on the left side of the brain. Some motor fibers do not decussate and therefore descend on the same (ipsilateral) side. Thus, a patient who has sustained a stroke in the left brain may experience both a right-sided paralysis and left-sided weakness. Whereas most motor tracts decussate at the level of the brain stem, most sensory tracts decussate in the spinal cord and travel contralaterally to the brain.

If injured, the neurons of the brain and spinal cord do not regenerate. If the neck is broken, the spinal cord might be severed. If the spinal cord is severed at the neck region, the trunk and all four extremities are paralyzed. This condition is called *quadriplegia*. This type of spinal cord injury is common in automobile, football, and diving accidents in which the neck is either compressed or bent excessively (Figure 11-3). If the spinal cord injury is lower, involving only the lumbar region of the spinal cord, the person has full use of the upper extremities but is paralyzed from the waist down. Paralysis of the lower extremities is called *paraplegia*.

2+2 Sum It Up!

The spinal cord and the peripheral nervous system allow the brain to communicate with the body and external environment. The spinal cord transmits information up and down the cord. Sensory information is brought to the brain from the lower cord region, whereas motor information is transmitted away from the brain, down the cord toward the periphery. Major spinal cord tracts are identified in Table 11-1. In addition to providing pathways for the flow of information, the spinal cord acts as a center of reflex activity.

? Re-Think

1. Differentiate between ascending and descending tracts.
2. What clue identifies the corticospinal tract as a motor tract?
3. What clue identifies the spinothalamic tract as a sensory tract?

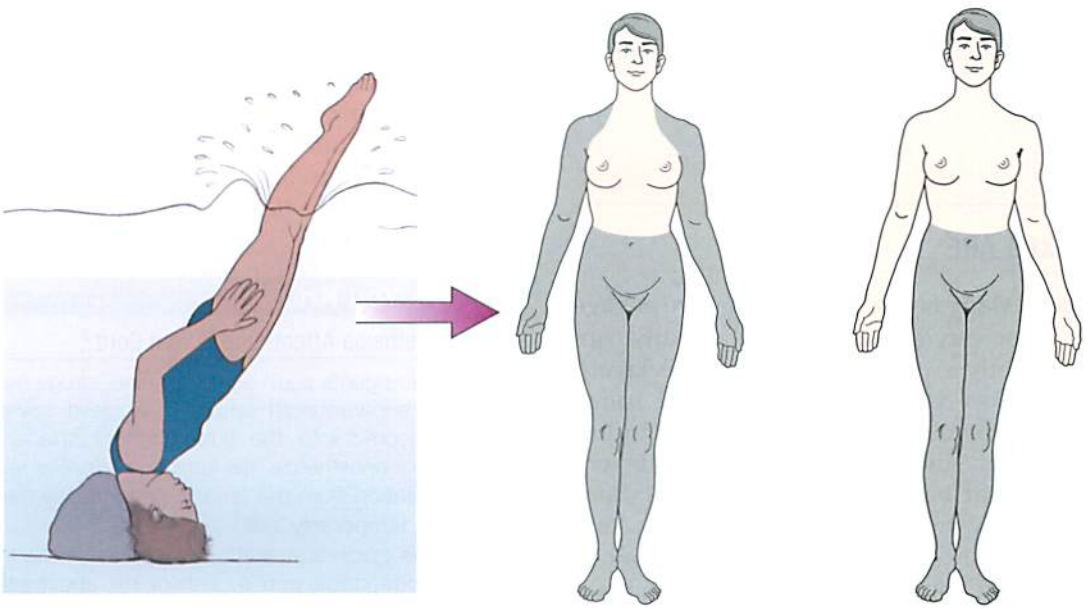
SPINAL NERVES ATTACHED TO THE SPINAL CORD

Attached to the spinal cord are the **spinal nerves**. Each nerve is attached to the spinal cord by two roots: the dorsal root and the ventral root (Figure 11-4). Sensory nerve fibers from the periphery travel to the cord through the dorsal root. The cell bodies of the sensory fibers are gathered together in the dorsal root ganglia. The ventral root is composed of motor fibers. These motor fibers are distributed to muscles and glands. The dorsal and ventral roots are packaged together to form a spinal nerve.

WHAT THE SPINAL CORD DOES

The spinal cord serves three major functions: sensory pathway, motor pathway, and reflex center.

- *Sensory pathway.* The spinal cord provides pathways (ascending) for sensory information traveling from the periphery to the brain. For example, when you stick your finger with a sharp tack, sensory information travels from the finger toward the spinal cord. The information then ascends the spinal cord to the brain, where you experience the information as pain.
- *Motor pathway.* The spinal cord provides pathways (descending tracts) for motor information coming



Broken neck Quadriplegia Paraplegia

FIGURE 11-3 Spinal cord injuries. Diving into a shallow pool can result in a damaged spinal cord (quadriplegia and paraplegia).

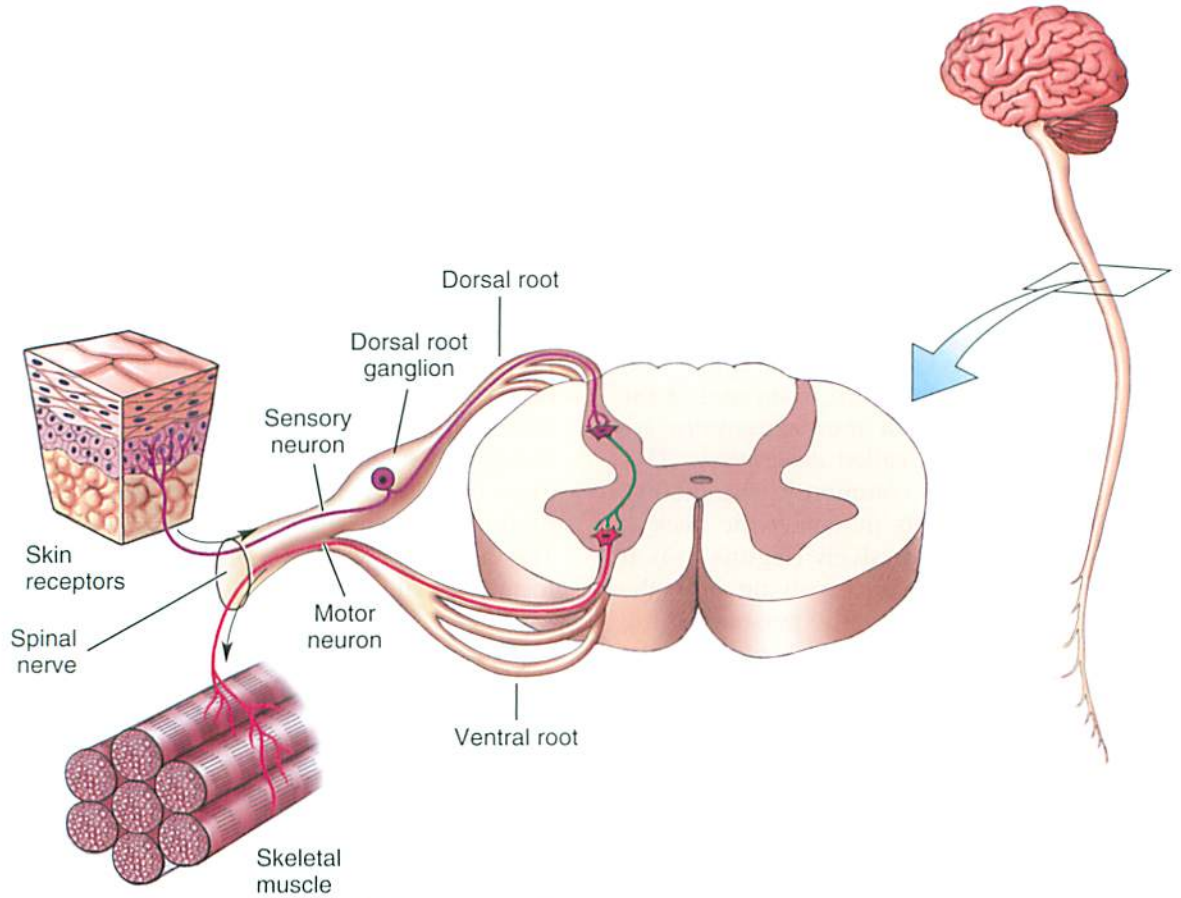


FIGURE 11-4 Attachment of the spinal nerves to the spinal cord.

from the brain and going to the periphery. For example, you decide to move your foot as in kicking a football. The information travels from the brain, down the spinal cord, and to the muscles of the leg and foot.

- *Reflex center.* The spinal cord acts as a major reflex center.

REFLEXES

WHAT REFLEXES ARE

What is a reflex? Many of the activities that we engage in every day occur very rapidly and without any conscious control. In other words, they happen reflexively. Many of the reflexes occur at the level of the spinal cord. A reflex is an involuntary response to a stimulus. If you touch a hot surface, for example, you very quickly remove your hand (withdrawal reflex). Your hand is safely away from the source of injury long before you consciously say, "This is hot. I must remove my hand!" Similarly, your ability to walk and maintain your balance requires hundreds of reflex movements. For example, you don't have to think about swinging your arms as you walk.

A typical reflex response is demonstrated by the patellar tendon, or knee-jerk, reflex (Figure 11-5). During a physical examination, the doctor taps the quadriceps ligament below your kneecap. In response to the tap, your leg quickly and involuntarily pops up. The physician has elicited the patellar tendon reflex. How does this reflex help you? If you are standing erect and your knee bends, even slightly, the patellar reflex is stimulated. In response to the bending, the quadriceps muscle in the thigh contracts, thereby straightening the leg and helping you maintain an upright position.

Do You Know...

How Anesthesia Affects the Spinal Cord?

Anesthetic agents such as the "-caine" drugs may be injected into the subarachnoid space to achieve spinal anesthesia. When injected into the subarachnoid space, these drugs deaden, or anesthetize, the lumbar and sacral sensory nerves. Pain sensation from the areas innervated by these deadened nerves is temporarily lost.

How is epidural anesthesia used in childbirth? During the last, uncomfortable phase of childbirth, anesthetic agents may be continuously infused into the epidural space. The nerves that are deadened by the anesthesia supply the lower pelvic region of the body, thereby relieving the pain of childbirth.

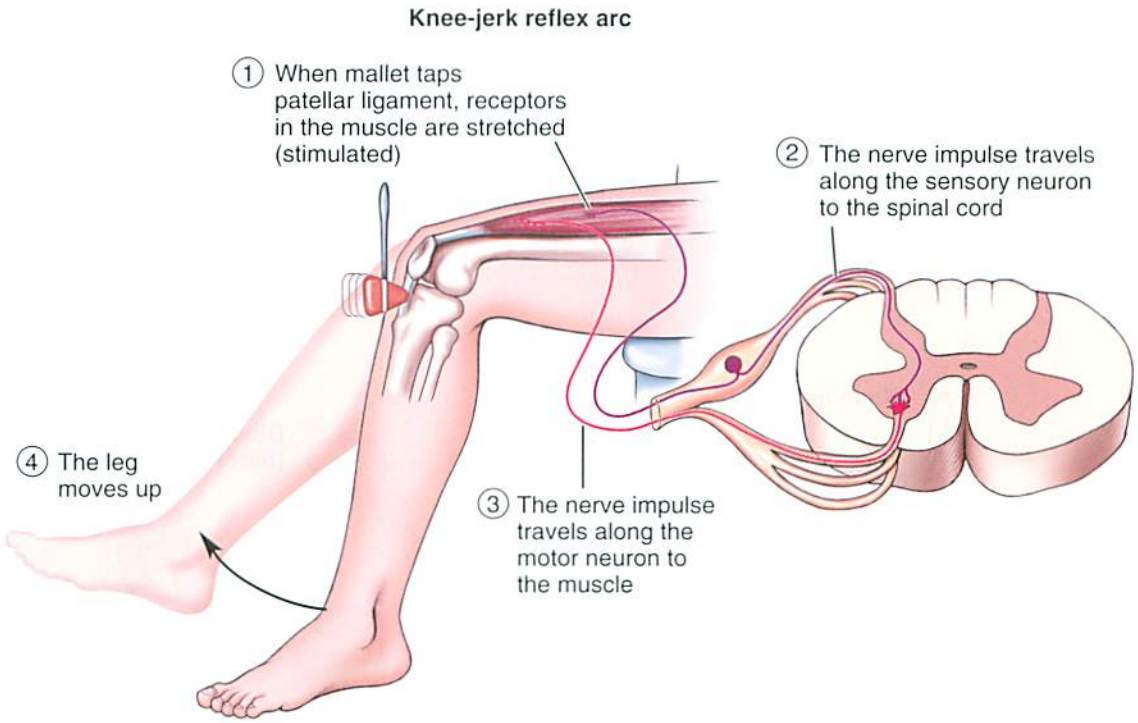


FIGURE 11-5 Reflex arc. The knee-jerk reflex illustrates the components of the reflex arc.

THE REFLEX ARC

The knee-jerk reflex illustrates the four basic components of the reflex arc (see Figure 11-5). The **reflex arc** is the nerve pathway involved in a reflex. The four basic components of the reflex arc include the following:

1. *A sensory receptor.* By tapping the patellar ligament, the mallet stimulates sensory receptors in the anterior thigh muscles (quadriceps femoris).
2. *An* **afferent**, *or sensory,* **neuron.** The nerve impulse is carried from the receptors along a sensory neuron to the spinal cord. *An integrating center.* The gray matter of the spinal cord contains interneurons that determine the motor response to the sensory input. In the simplest reflex arc (knee jerk reflex), there is a single synapse with no interneuron. All other reflexes require two or more interneurons.
3. *An* **efferent**, *or motor,* **neuron.** The nerve impulse is carried by a motor nerve to the muscles of the thigh.
4. *An effector organ.* The muscles of the thigh, the quadriceps femoris, are effector organs for this reflex. In response to the motor nerve impulse, the muscles contract and move the leg in an upward movement (extension of the leg).

MANY, MANY REFLEXES

OUCH! THE WITHDRAWAL REFLEX

The withdrawal reflex (Figure 11-6, *A*) helps protect you from injury. For example, this reflex quickly moves your finger away from a hot iron, thereby preventing a severe burn. The "ouch" occurs after your finger is safely away from the hot iron.

Organ Reflexes

Reflexes also help regulate organ function. Figure 11-6 illustrates some of the reflexes that regulate body function. The pupillary reflex, for example, regulates the amount of light that enters the eye. When a bright light is directed at the eye, the muscles that control pupillary size constrict. The size of the pupil diminishes, thereby restricting the amount of additional light entering the eye. Blood pressure is also under reflex control. When blood pressure changes abruptly, the baroreceptor reflex causes the heart and blood vessels to respond in a way that restores blood pressure to normal.

In addition to performing important physiological functions, some reflexes are used diagnostically to assess nerve function. Abnormal findings may indicate central nervous system (CNS) lesions, tumors, and other neurological diseases such as multiple sclerosis. You may have observed a physician elicit the Babinski reflex (Figure 11-6, *D*) by stroking the lateral sole of the foot in the direction of heel to toe with a hard blunt object. In the adult, the Babinski reflex is normal, or negative, if the response to the stroking is plantar flexion, or a curling of the toes. An abnormal, or positive, Babinski reflex is dorsiflexion of the big toe, sometimes with fanning of the other toes. An infant normally dorsiflexes the big toe, an indicator of the immaturity of the infant's nervous system. Some clinically significant reflexes and their functions are listed in Table 11-2.

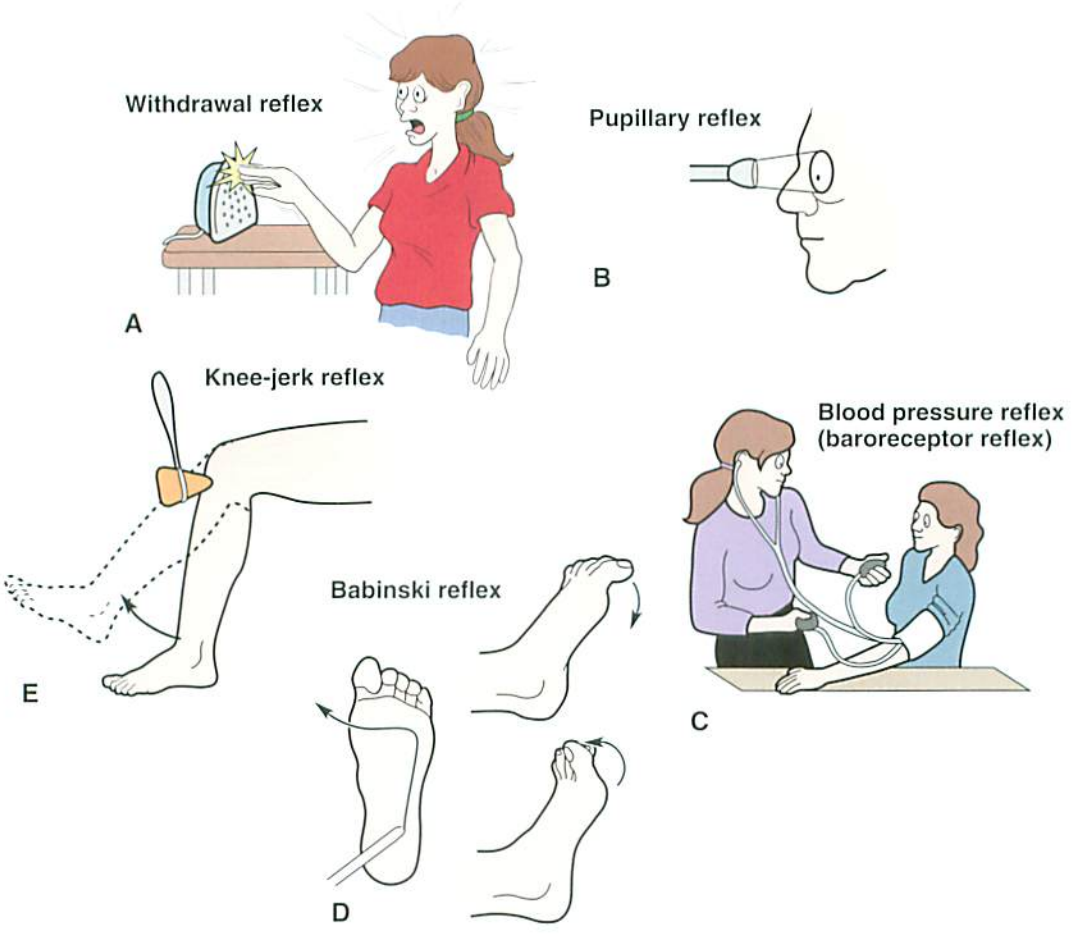


FIGURE 11-6 Many reflexes. **A,** Withdrawal reflex. **B,** Pupillary reflex. **C,** Blood pressure, or baroreceptor, reflex. **D,** Babinski reflex. **E,** Knee-jerk reflex.

2+2 Sum It Up!

The spinal cord and the peripheral nervous system allow the brain to communicate with the body and the external environment. The spinal cord transmits sensory and motor information to and from the brain. It also acts as a reflex center. A reflex is an involuntary response to a stimulus. A reflex arc has four components: sensory receptor, afferent neuron, efferent neuron, and effector organ. Clinically significant reflexes are identified in Table 11-2.

? Re-Think

Describe the steps of the withdrawal reflex in response to sticking your finger on a sharp tack.

PERIPHERAL NERVOUS SYSTEM

The **peripheral nervous system** consists of the nerves and ganglia located outside the CNS.

NERVES

Before classifying the nerves, you need to differentiate between a nerve and a neuron (see Chapter 10). A neuron is a single nerve cell. The nerve contains many neurons bundled together with blood vessels and then wrapped in connective tissue (Figure 11-7). Nerves are located outside the CNS. Within the CNS, bundles of nerve fibers are called **nerve tracts**. Nerves are classified as the following:

- **Sensory nerves**, composed only of sensory neurons
- **Motor nerves**, composed only of motor neurons
- **Mixed nerves**, containing both sensory and motor neurons. Most nerves are mixed and all spinal nerves are mixed.

CLASSIFYING THE PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system can be classified in two ways: structurally (by the anatomy) or functionally (according to what they do).

STRUCTURAL CLASSIFICATION OF THE PERIPHERAL NERVOUS SYSTEM

The structural classification of the peripheral nervous system divides the nerves into cranial and spinal nerves. The classification is based on the origin of the fiber (where it originates).

Table 11-2 Clinically Significant Reflexes

REFLEX	DESCRIPTION	MEANING OF ABNORMAL RESPONSE
Patellar tendon (knee-jerk reflex)	A stretch reflex. The mallet strikes the patellar ligament below the knee; in response, the leg kicks up.	Impaired in damage to nerves involved in the reflex Impaired in damage to lumbar region of spinal cord Impaired in patients with diseases that affect the nerves and spinal cord (e.g., diabetes mellitus, neurosyphilis, and chronic alcoholism)
Achilles tendon (ankle-jerk reflex)	A stretch reflex. The mallet strikes the Achilles tendon, causing plantar flexion.	Impaired in damage to nerves involved in the reflex Impaired in damage to lower spinal cord (L5–S2)
Abdominal	With stroking of the lateral abdominal wall, the abdominal wall contracts and moves the umbilicus toward the stimulus.	Impaired in lesions of peripheral nerves Impaired in lesions of spinal cord (thoracic) and in patients with multiple sclerosis
Babinski	With stroking of the lateral sole of the foot from heel to toe, the toes curl, with slight inversion of the foot (see text).	Impaired in lesions or damage of the spinal cord In children younger than 2 years old, the Babinski reflex appears positive.

Cranial Nerves

Names and Numbers of Cranial Nerves. Twelve pairs of **cranial nerves** are shown in Figure 11-8. Each cranial nerve has a specific number, always designated by a Roman numeral, and a name. The numbers indicate the order in which the nerves exit the brain from front to back. Ten of the twelve cranial nerves originate in the brain stem.

In general, the name of the nerve indicates the specific anatomical area served by the nerve. For example, the optic nerve serves the eye. The cranial nerves primarily serve the head, face, and neck region, but one pair—the vagus—branches extensively and extends throughout the thoracic and abdominal cavities.

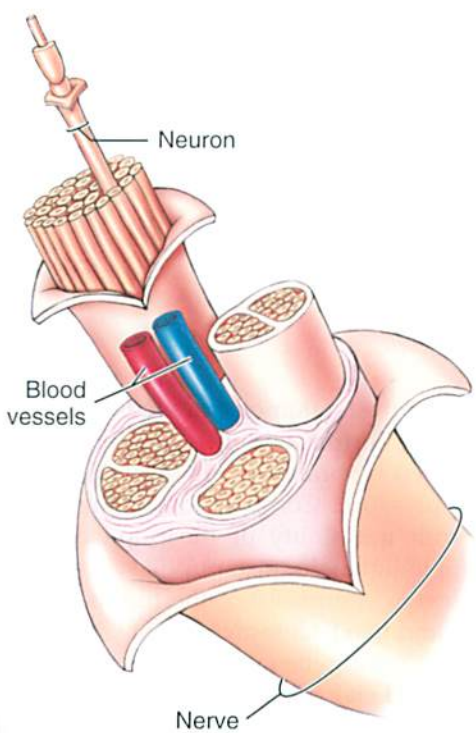


FIGURE 11-7 Difference between a neuron and nerve.

A common mnemonic used to memorize the cranial nerves in proper order is shown in Table 11-3: On Old Olympus Towering Tops A Finn Viewed Germans Vaulting And Hopping. The first letter of each word is the same as the first letter of each cranial nerve. (My personal mnemonic is Oh! Oh! Oh! Tough, Tricky Anatomy Final … Very Grave Vibes … Aching Head.) Try to develop your own creative mnemonic, or search the Web for others. Unfortunately, you must know the name and Roman numeral of each cranial nerve. For instance, the vestibulocochlear nerve is CN VIII.

Functions of Cranial Nerves. Cranial nerves perform four general functions that carry different types of information:

- Sensory information for the special senses: smell, taste, vision, and hearing
- Sensory information for the general senses: touch, pressure, pain, temperature, and vibration
- Motor information that results in contraction of skeletal muscles
- Motor information that results in the secretion of glands and the contraction of cardiac and smooth muscle

Cranial nerve function is summarized in Table 11-3. Locate each cranial nerve on Figure 11-8 as it is described below.

CN I, olfactory nerve. A sensory nerve that carries information from the nose to the temporal lobe of the cerebrum. The olfactory nerve is concerned with the sense of smell. A person who damages the olfactory nerve may lose the sense of smell (anosmia). In addition, the person may complain of loss of taste

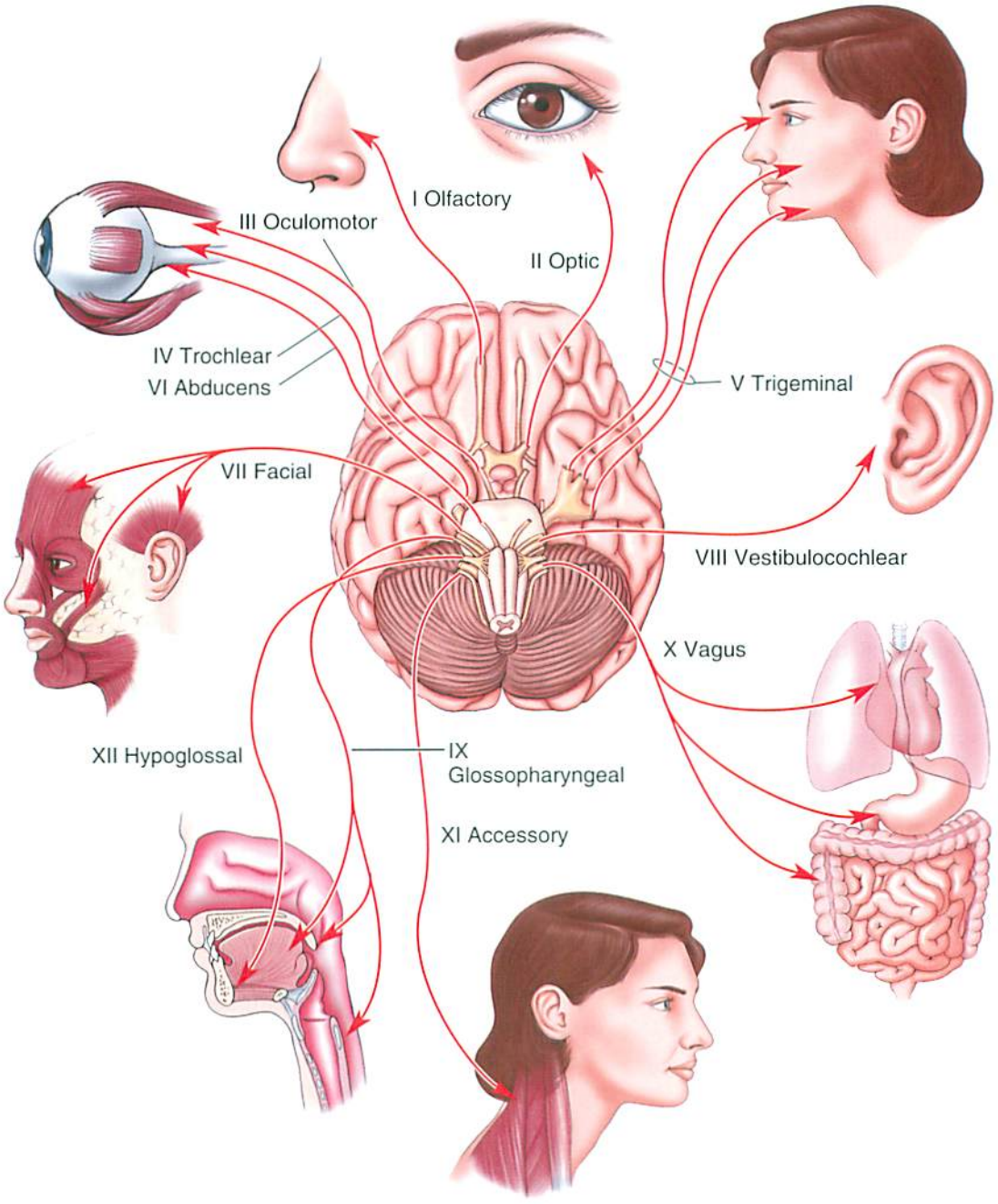


FIGURE 11-8 Cranial nerves.

because the appeal of food is determined by both taste and smell.

CN II, optic nerve. A sensory nerve that carries visual information from the eye to the primary visual cortex of the occipital lobe of the cerebrum. Damage to the optic nerve causes diminished vision or blindness in the affected eye.

CN III, oculomotor nerve. Primarily a motor nerve that causes contraction of most of the extrinsic eye muscles, thereby moving the eyeball in its socket. The oculomotor nerve also raises the eyelid and constricts the pupil of the eye.

Because the oculomotor nerve is located close to the hard tentorium within the cranium, it is easily compressed by brain tumors or by increased intracranial pressure. Compression of the nerve interferes with the ability of the pupil of the eye to respond to light (sluggish pupillary response). With more severe compression, the pupils may become dilated and fixed. Compression of CN III also interferes with raising the eyelid; the person experiences ptosis (TOH-sis) of the eyelid. Observation of the eyes provides excellent clinical clues to neurological status.

Table 11-3 Cranial Nerves

MNEMONIC	NUMBER/NERVE	TYPE	FUNCTION
On	I/Olfactory	Sensory	Sense of smell
Old	II/Optic	Sensory	Sense of sight
Olympus	III/Oculomotor	Mixed (mostly motor)	Movement of eyeball, raising of eyelid, change in pupil size
Towering	IV/Trochlear	Mixed (mostly motor)	Movement of eyeball
Tops	V/Trigeminal	Mixed	Chewing of food; sensations in face, scalp, cornea (eye), and teeth
A	VI/Abducens	Mixed (mostly motor)	Movement of eyeball
Finn	VII/Facial	Mixed	Facial expressions, secretion of saliva and tears, taste, blinking
Viewed	VIII/Vestibulocochlear	Sensory	Sense of hearing and balance
Germans	IX/Glossopharyngeal	Mixed	Swallowing, secretion of saliva, taste, sensory for the reflex regulation of blood pressure, part of the gag reflex
Vaulting	X/Vagus	Mixed	Visceral muscle movement and sensations, especially movement and secretion of the digestive system; sensory for reflex regulation of blood pressure
And	XI/Accessory	Mixed (mostly motor)	Swallowing, head and shoulder movement, speaking
Hopping	XII/Hypoglossal	Mixed (mostly motor)	Speech and swallowing

CN IV, trochlear nerve. Primarily a motor nerve that innervates one of the extrinsic muscles of the eyeball, thereby helping move the eyeball. Damage may cause double vision and an inability to rotate the eye properly.

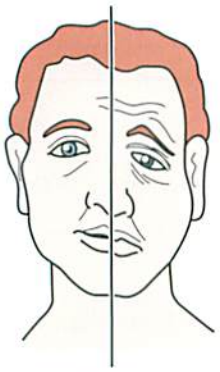
CN V, trigeminal nerve. A mixed nerve with three branches supplying the facial region. The two sensory branches carry information regarding touch, pressure, and pain from the face, scalp, eye, and teeth to the brain. The ophthalmic branch of the trigeminal nerve detects sensory information from the cornea. For example, if you touch the surface of the cornea, the ophthalmic branch is stimulated and sends information to the brain. In response to the corneal irritation, motor fibers of the facial nerve (CN VII) respond by eliciting blinking and the secretion of tears. Thus, both the trigeminal and facial nerves help to relieve the irritation. The motor branch of the trigeminal nerve innervates the muscles of mastication (chewing). Nerve damage causes a loss of sensation and impaired movement of the mandible (lower jaw).

A person may experience an inflammation of the trigeminal nerve. This condition is called *trigeminal neuralgia*, or *tic douloureux*. It is characterized by bouts of severe facial pain. The pain may be triggered by events such as eating, shaving, and exposure to cold temperatures. In an effort to avoid these triggers, the patient often becomes a prisoner of the disease, refusing to eat, shave, or leave the house in cold weather.

CN VI, abducens nerve. Primarily a motor nerve that, like the trochlear, controls eye movement by innervating only one of the extrinsic eye muscles. Nerve damage prevents a lateral rotation of the eye; at rest, the eye drifts medially (toward the nose).

CN VII, facial nerve. A mixed nerve that performs mostly motor functions. It is called the nerve of facial expression and allows you to smile, frown, and "make other faces." It also stimulates the secretion of saliva and tears. The facial nerve innervates the orbicularis oculi, the muscle involved in blinking. Blinking not only protects the eye from foreign objects, such as dust, but also washes tears over the cornea, thereby keeping the cornea moist and preventing corneal ulceration. Its sensory function is taste.

If the facial nerve is damaged, facial expression is absent on the affected side of the face. This condition is called *Bell's palsy* (see next page). Cosmetically, this condition is very distressing because one side of the face may smile and look alive, but the other side of the face sags, drools, and is expressionless. Salivation and the secretion of tears are diminished, thereby requiring the use of eyedrops to protect the cornea. Fortunately, Bell's palsy often responds well to steroid therapy.



Bell's palsy

CN VIII, vestibulocochlear nerve. A sensory nerve that carries information for hearing and balance from the inner ear to the brain. The vestibular branch of this nerve is responsible for equilibrium, or balance, and the cochlear branch is responsible for hearing. Damage to this nerve may cause loss of hearing or balance or both (see Chapter 13).

CN IX, glossopharyngeal nerve. A mixed nerve that carries taste sensation from the posterior tongue to the brain. Motor fibers stimulate the secretion of salivary glands in the mouth. Other motor fibers innervate the throat and aid in swallowing. The glossopharyngeal nerve is also associated with the gag reflex. The gag reflex plays an important role in preventing food and water from entering the respiratory passages. Normally, when something goes down the wrong way, you gag and cough until the airway is cleared. Gagging is a good thing—and clinically important when depressed. Loss of the gag reflex places you at risk for choking. A second sensory function of this nerve involves the regulation of blood pressure via the baroreceptor reflex (see Chapter 19).

CN X, vagus nerve. A mixed nerve that innervates the tongue, pharynx (throat), larynx (voice box), and many organs in the thoracic and abdominal cavities (lungs, stomach, intestines). Nerve damage causes hoarseness or loss of voice, impaired swallowing, and diminished motility of the digestive tract. Damage to both vagus nerves can be fatal. The word *vagus* literally means wanderer; the name refers to the far-reaching distribution of this nerve. The sensory fibers of the vagus nerve also participate in the regulation of blood pressure via the baroreceptor reflex (see Chapter 19).

CN XI, accessory nerve. Primarily a motor nerve that supplies the sternocleidomastoid and the trapezius muscles, thereby controlling movement of the head and shoulder regions. Nerve damage impairs your ability to shrug your shoulders and rotate your head.

CN XII, hypoglossal nerve. Primarily a motor nerve that controls movement of the tongue, thereby affecting speaking and swallowing activities. Nerve damage causes the tongue to deviate toward the injured side.

A neurological assessment includes simple procedures that test the ability of each cranial nerve to perform these functions. Table 11-4 illustrates some methods used to test cranial nerve function. The table also includes common disorders and abnormal findings involving the cranial nerves.

Do You Know...

About the "Wandering" Characteristics of the Tenth Cranial Nerve?

Check the local jail, and you will find a couple of unsavory characters locked up on charges of vagrancy—the habit of wandering around and generally getting into trouble. (The word *vagrant* means someone who wanders about.) The vagus nerve, the tenth cranial nerve (CN X), is also a wanderer. Unlike the other cranial nerves that are confined to the head and shoulder area, the vagus nerve leaves the head and wanders, or makes its way through, the thoracic and abdominal cavities. The vagus nerve is named for these vagrant or wandering characteristics.

Re-Think

1. CNs II, III, IV, and VI all innervate eye structures. What is the difference in function of each?
2. List two effects of a damaged CN VIII.
3. Why is the vagus nerve called the "wanderer" nerve?

SPINAL NERVES

Names and Numbers of Spinal Nerves

Thirty-one pairs of spinal nerves emerge from the spinal cord (Figure 11-9). Each pair is numbered according to the level of the spinal cord from which it arises. The 31 pairs are grouped as follows: 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, 5 pairs of sacral nerves, and 1 pair of coccygeal nerves. The lumbar and sacral nerves at the bottom of the cord extend the length of the spinal cavity before exiting from the vertebral column. These nerves are called the *cauda equina* because they look like a horse's tail. The nerves exit from the bony vertebral column through tiny holes in the vertebrae called *foramina*.

Spinal Nerve Plexuses

As the spinal nerves exit from the vertebral column, they divide into many fibers. At various points, most nerve fibers converge, or come together again, into nerve **plexuses** (PLEX-sus-ez), or networks. The three major nerve plexuses are the cervical plexus, the brachial plexus, and the lumbosacral plexus (see Figure 11-9). Each plexus sorts out the many fibers and sends them to a specific part of the body. The three plexuses and the major nerves that emerge from each plexus are

Table 11-4 Cranial Nerves: Assessment and Disorders

NERVE	ASSESSMENT	SOME DISORDERS
I Olfactory	Person is asked to sniff and identify various odors (e.g., vanilla).	Inability to smell (anosmia)
II Optic	Examination of the interior of the eye by ophthalmoscopic visualization. Use of eye charts and tests of peripheral vision.	Diminished or loss of vision
III Oculomotor	Observation of eyelids. Test the ability of the eyes to follow a moving object. Examination of pupils for size, shape, and size equality. Pupillary reflex is tested with a penlight (the pupils should constrict). Test the ability of the eyes to converge.	Drooping upper eyelids (ptosis) Difficulty in focusing eyes on an object Absence of pupillary reflex (e.g., dilated and fixed pupils that may indicate an increase in intracranial pressure)
IV Trochlear	Test ability of the eyes to follow a moving object.	Inability to move eyeball in a particular direction
V Trigeminal	Sensations (pain/touch/temperature) are tested with sharp pin and hot/cold objects. Corneal reflex (sensory) is tested with a cotton wisp. Motor function is tested by asking the person to open the mouth (against resistance) and to move the jaw from side to side.	Loss of sensation (pain/touch); paresthesias (tingling, itching, and numbness) Pain, tearing, and blinking Shift of jaw to side of lesion when opened Difficulty in chewing
VI Abducens	Test ability of the eyes to follow a moving object.	Inability to move eyes laterally
VII Facial	Person is asked to cause facial muscle movement (e.g., smile, close eyes, wrinkle forehead, whistle). Test anterior two thirds of tongue for sweet, salty, sour, and bitter taste. Ability to secrete tears is tested by asking person to sniff ammonia fumes.	Bell's palsy (expressionless face, drooping mouth and drooling, inability to close eyes and blink) Loss of taste on anterior two thirds of tongue on side of lesion
VIII Vestibulocochlear	Hearing is checked by air and bone conduction (use of tuning fork).	Loss of hearing, noises in ear (tinnitus) Loss of balance (vertigo)
IX Glossopharyngeal	Check gag and swallowing reflex. Test posterior two thirds of tongue for taste. Person is asked to speak and cough.	Loss of gag reflex Difficulty in swallowing (dysphagia) Loss of taste on posterior two thirds of tongue Decreased salivation Hoarseness of voice
X Vagus	Similar to testing for CN IX (because they both innervate throat).	Sagging of soft palate Hoarseness of voice resulting from paralysis of vocal fold
XI Accessory	Ask person to rotate head from side to side and to shrug shoulders (against resistance).	Drooping shoulders Inability or difficulty in rotating head (wryneck)
XII Hypoglossal	Person is asked to stick out tongue—note any deviation in position of the protruded tongue.	Some difficulty in speaking (dysarthria), chewing, and swallowing (dysphagia)

listed in Table 11-5 and described as follows. The results of damage to major peripheral nerves are listed in Table 11-6.

Cervical plexus (C1 to C4). Fibers from the cervical plexus supply the muscles and skin of the neck. Motor fibers from this plexus also pass into the phrenic nerve. The phrenic nerve stimulates the contraction of the diaphragm, the major breathing muscle (Figure 11-10; see Figure 11-9).

If the spinal cord is severed below the C5 level, the person is paralyzed but can breathe without ventilator assistance. If the level of injury is higher, at C2, the phrenic nerve is injured, motor impulses to the diaphragm are interrupted, and the person cannot breathe normally. To breathe, the injured person generally needs the assistance of a ventilator.

Brachial plexus (C5 to C8, T1). The nerves that emerge from the brachial plexus supply the muscles and

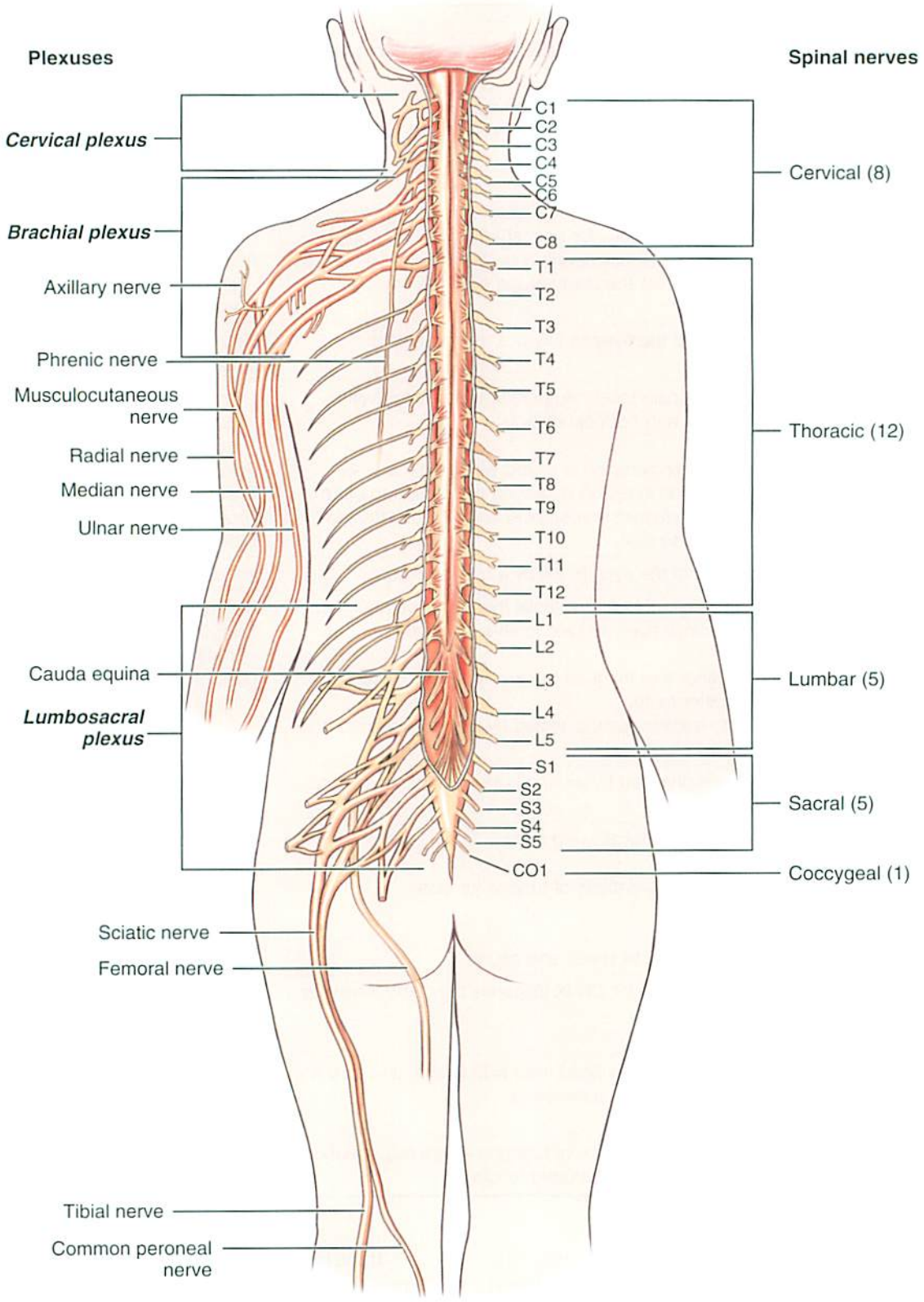


FIGURE 11-9 Spinal nerves: cervical, thoracic, lumbar, sacral, and coccygeal. Nerve plexuses: cervical, brachial, and lumbosacral plexuses.

Table 11-5 Spinal Nerve Plexuses

PLEXUS	SPINAL NERVE ORIGIN	REGION INNERVATED	MAJOR NERVES EMERGING FROM PLEXUS
Cervical	C1 to C4	Skin and muscles of the neck and shoulder, diaphragm	Phrenic
Brachial	C5 to C8, T1	Skin and muscles of the upper extremities	Axillary Radial Median Musculocutaneous Ulnar
Lumbosacral	T12, L1 to L5, S1 to S4	Skin and muscle of lower torso and lower extremities	Femoral Obturator Sciatic Pudendal

Table 11-6 Major Peripheral Nerves: Results of Damage

NERVE	BODY AREA SERVED	RESULTS OF NERVE DAMAGE
Phrenic	Diaphragm	Impaired breathing
Axillary	Muscles of shoulder	Crutch palsy
Radial	Posterior arm, forearm, hand; thumbs and first two fingers	Wristdrop (inability to lift or extend hand at wrist)
Median	Forearm and some muscles of the hand	Inability to pick up small objects
Ulnar	Wrist and many muscles in hand	Clawhand—inability to spread fingers apart
Intercostal	Rib cage	Impaired breathing
Femoral	Lower abdomen, anterior thigh, medial leg, foot	Inability to extend leg and flex hip
Sciatic	Lower trunk; posterior thigh and leg	Inability to extend hip and flex knee
Common peroneal	Lateral area of leg and foot	Footdrop—inability to dorsiflex foot
Tibial	Posterior area of leg and foot	Shuffling gait caused by inability to invert and dorsiflex foot

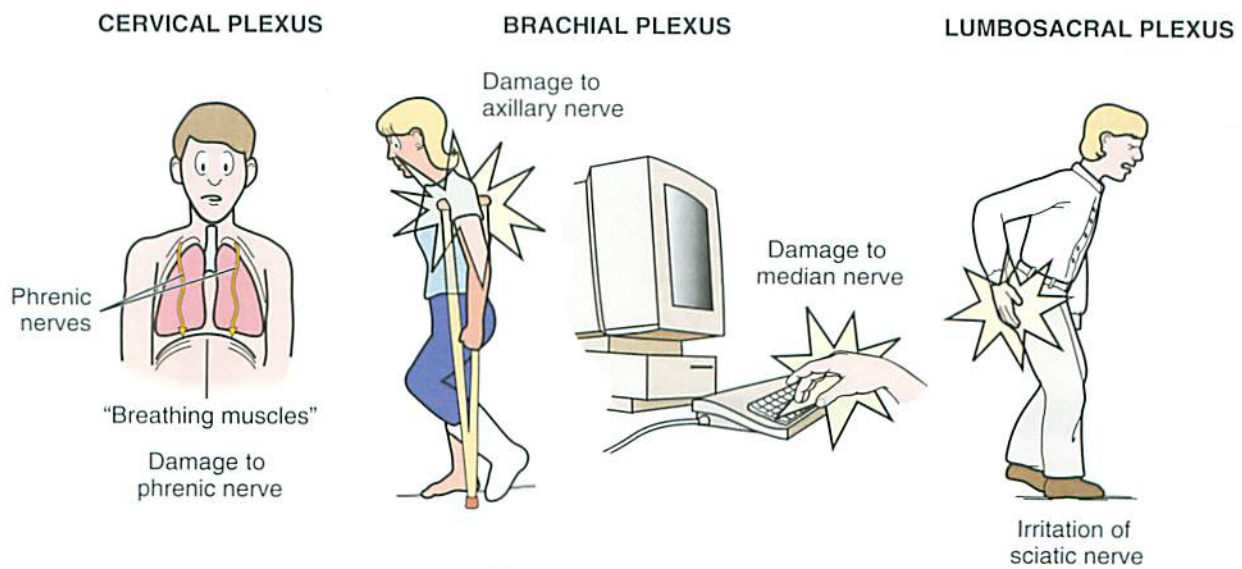


FIGURE 11-10 Examples of nerve damage.

skin of the shoulder, arm, forearm, wrist, and hand. The axillary nerve emerges from this plexus and travels through the shoulder into the arm.

The axillary nerve in the shoulder region is susceptible to damage. For example, a person using crutches should be taught to bear the weight of the body on the hands and not on the armpit, or axillary region. The weight of the body can damage the axillary nerve, causing crutch palsy.

The radial and ulnar nerves, which serve the forearm, wrist, and hand, also emerge from the brachial plexus. Damage to the radial nerve can cause a wristdrop, and injury to the ulnar nerve causes the hand to appear clawlike; the person is unable to spread the fingers apart.

Lumbosacral plexus (T12, L1 to L5, S1 to S4). The lumbosacral plexus gives rise to nerves that supply the muscles and skin of the lower abdominal wall, external genitalia, buttocks, and lower extremities. The sciatic nerve, the longest nerve in the body, arises from this plexus. The sciatic nerve supplies musculature of the thigh, leg, and foot. The sciatic nerve can become inflamed and cause intense pain in the buttock and posterior thigh region. A common cause of sciatica is a ruptured or herniated vertebral disc (see Figure 11-10).

What a Dermatome Is

A dermatome is a sensory thing. Each dorsal root of a spinal nerve innervates a particular area of the skin; this distribution of nerves is called a **dermatome** (DER-mah-tohm). Figure 11-11 illustrates the dermatomes for the entire body. Each dermatome is named for the particular nerve that serves it. For example, the C4 dermatome is innervated by the C4 spinal nerve. Dermatomes are useful clinically; for example, if the skin of the shoulder region is stimulated with the tip of a pin and the person cannot feel it, the clinician has reason to believe that the C4 nerve is impaired.

Do You Know...

About Tingling Thigh Syndrome?

Although tight, low-slung jeans are "in," your thigh nerves are on edge about this fashion craze. The snug jeans are compressing nerves in your thighs, causing a tingling sensation. The "tingling thigh syndrome" is easily cured, but the jeans have to go—or go higher.

Re-Think

1. Explain the difference between a cranial and spinal nerve.
2. What happens at a nerve plexus?
3. Explain why a quadriplegic with a C2 injury is ventilator-dependent, whereas a quadriplegic with a C5 injury is not ventilator-dependent.

Do You Know...

What Was on Dr. Herby Zoster's Shingle?

The doctor's shingle indicates that he specializes in chickenpox, shingles, and postherpetic neuralgia; all three are caused by the herpes zoster virus. Following a chickenpox infection, the herpes virus "hides out" in nerves and often reactivates in later life, causing shingles. Clusters of vesicles develop along cranial or spinal dermatomes. The painful lesions eventually crust over. For months after the "crusting over period," a significant number of patients with shingles develop a persistent and painful neuralgia, called *postherpetic neuralgia*. The term *shingles* comes from a word meaning "girdle," a reference to the usual appearance of lesions around the waist.

Any pharmacological help for shingles? Yes! Analgesics are prescribed for pain. Antiviral drugs may be used if the shingles is diagnosed quickly. On a preventive note, a shingles vaccine is now available.

Are shingles contagious? No! However, a person with shingles can transmit chickenpox to a person with no immunity to the disease. Also, a child with chickenpox can activate the dormant herpes virus in a person who has had chickenpox in the past.

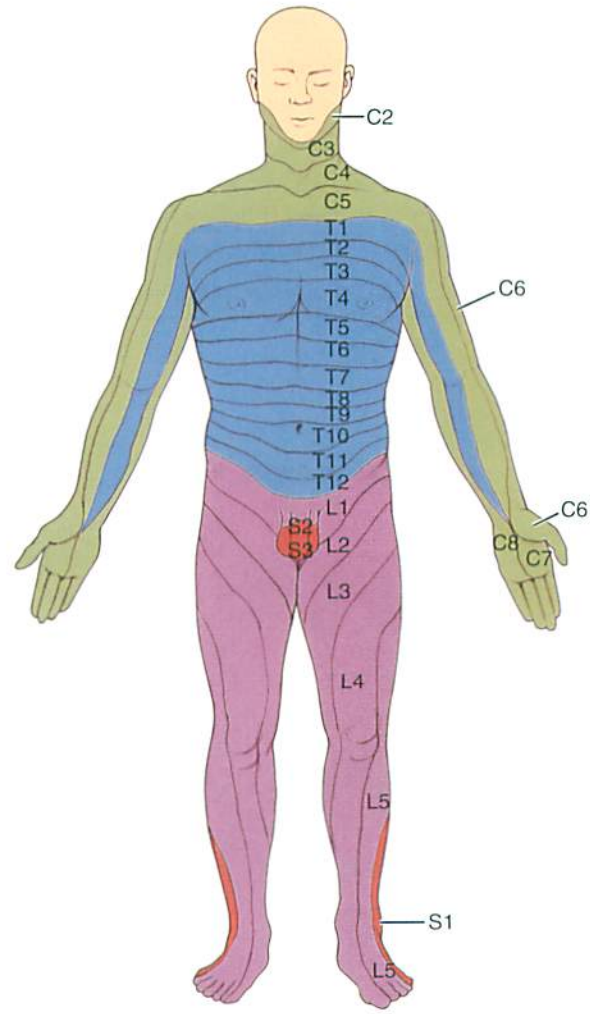


FIGURE 11-11 Dermatomes.

FUNCTIONAL CLASSIFICATION OF THE PERIPHERAL NERVOUS SYSTEM

The functional classification explains where the nerves go and what they do. The functional classification for the peripheral nervous system includes the following:

- The somatic afferent nerves, which bring sensory information from the different parts of the body, particularly the skin and muscles, to the CNS (see Chapter 13).
- The somatic efferent nerves, which bring motor information from the CNS to the skeletal muscles throughout the body (see Chapter 9).
- The autonomic nervous system (ANS) is composed of nerves that supply the organs (viscera), smooth muscle, and glands. The ANS is the topic of Chapter 12.

2+2 Sum It Up!

The peripheral nervous system consists of the nerves and ganglia located outside the CNS. Nerves are sensory, motor, or mixed. Mixed nerves carry both sensory and motor neurons. The peripheral nervous system can be classified structurally and functionally. The structural classification divides the nerves into cranial and spinal nerves. The 12 pairs of cranial nerves contain fibers that originate in the brain (see Figure 11-8 and Table 11-3). There are 31 pairs of spinal nerves; their fibers originate in the spinal cord (see Figure 11-9 and Tables 11-5 and 11-6). Most spinal nerve fibers converge into nerve plexuses, or networks. The three major nerve plexuses are the cervical plexus, brachial plexus, and lumbosacral plexus. The functional classification of nerves include: somatic afferent nerves, somatic efferent nerves, and autonomic nerves.

Note: The As You Age box and the Medical Terminology and Disorders table appear in Chapter 12.

Get Ready for Exams!

Summary Outline

The brain, spinal cord, and peripheral nerves act as a vast communication system. The spinal cord transmits information to and from the brain. The peripheral nervous system brings information to the CNS (its sensory role) and delivers information from the CNS to the periphery (its motor role).

I. What the Spinal Cord Is

A. The spinal cord is a tubelike structure located in the spinal cavity, extending from the foramen magnum (occipital bone) to L1.

B. Arrangement of nervous tissue

1. The gray matter is a butterfly-shaped area located centrally; it is composed primarily of cell bodies, interneurons, and synapses.
2. The white matter is composed of myelinated and unmyelinated fibers arranged in tracts. Ascending tracts are sensory tracts; descending tracts are motor tracts.
3. Spinal nerves are attached to the spinal cord. All spinal nerves are mixed (they contain sensory and motor fibers).
4. Sensory nerve fibers travel to the cord through the dorsal root. Motor nerve fibers travel in the ventral root.

II. What the Spinal Cord Does: Functions

A. The spinal cord relays sensory information (ascending tracts).

B. The spinal cord relays motor information (descending tracts).

C. The spinal cord acts as a major reflex center.

III. Reflexes

A. A reflex is an involuntary response to a stimulus.

B. The four components of a reflex are a sensory receptor, an afferent neuron, an efferent neuron, and an effector organ.

IV. Peripheral Nervous System

A. Nerve

1. A nerve is a group of neurons, blood vessels, and connective tissue.
2. There are sensory nerves, motor nerves, and mixed nerves.

B. Structural classification of nerves

1. A classification of nerves on the basis of structure (anatomy) divides nerves into cranial nerves and spinal nerves. There are 12 pairs of cranial nerves (see Table 11-3) and 31 pairs of spinal nerves (see Figure 11-9).
2. Spinal nerves are sorted out at nerve plexuses. The three major plexuses are the cervical plexus, the brachial plexus, and the lumbosacral plexus.
3. A dermatome is the area of skin innervated by each spinal nerve; a dermatome is purely sensory.

C. Functional classification of nerves

1. Somatic afferent nerves carry sensory information to the CNS.
2. Somatic efferent nerves carry motor information to skeletal muscles.
3. Autonomic nerves carry motor information to the organs (viscera).

Review Your Knowledge

Matching: Reflexes

Directions: Match the following words with their descriptions below.

a. gag reflex
b. baroreceptor reflex
c. withdrawal reflex
d. Achilles tendon reflex
e. pupillary reflex
f. patellar tendon reflex

1. ___ Helps you maintain balance; also called the *knee-jerk reflex*
2. ___ Regulates blood pressure
3. ___ Controls the amount of light that enters the eye
4. ___ When you pull your finger away from a sharp object
5. ___ Helps prevent food and water from entering the respiratory passages
6. ___ Tapping of the calcaneal tendon; causes plantar *flexion*

Matching: Nerves

Directions: Match the following words with their descriptions below. Some words may be used more than once.

a. oculomotor
b. optic
c. vagus
d. facial
e. sciatic
f. olfactory
g. phrenic
h. vestibulocochlear

1. ___ Innervates the skeletal muscles that move the eyeball
2. ___ Carries sensory information to the primary visual cortex of the occipital lobe
3. ___ Carries sensory information for hearing and balance
4. ___ Innervates the diaphragm, causing it to contract
5. ___ Innervates muscles of the thigh
6. ___ "Wanderer" nerve that is distributed throughout the thoracic and abdominopelvic cavities
7. ___ The "smell" nerve
8. ___ The nerve of facial expression
9. ___ Ototoxicity refers to this damaged nerve
10. ___ "Fixed and dilated" describes this injured nerve

Multiple Choice

1. Which of the following does not describe the oculomotor nerve?
   a. It is also CN III.
   b. It innervates the skeletal muscles that move the eyeball.
   c. It is the carrier of information to the primary visual cortex in the occipital lobe.
   d. It innervates skeletal muscle that raises the eyelids.
2. The trigeminal nerve
   a. is CN V.
   b. has both sensory and motor fibers.
   c. affects chewing.
   d. All of the above are true.
3. The sciatic nerve
   a. is a motor nerve that innervates thigh muscles.
   b. is a cranial nerve.
   c. enters the cervical plexus for distribution to the periphery.
   d. travels within the spinothalamic tract.
4. Which of the following is descriptive of the spinothalamic tract?
   a. It carries sensory information regarding touch, pressure, and pain.
   b. It is the major motor tract.
   c. It is also called the *pyramidal tract*.
   d. It is a descending tract.
5. Which of the following is least descriptive of the corticospinal tract?
   a. Descending tract
   b. Major motor tract
   c. Pyramidal tract
   d. Carries information from the spinal cord to the thalamus
6. What is the final step in the reflex arc?
   a. Response of the effector organ(s)
   b. Activation of the sensory receptor
   c. Communication of the sensory neuron with an interneuron within the spinal cord
   d. Traveling of the nerve impulse along the motor neuron
7. Which of the following is not true of the gag reflex?
   a. It is impaired in a paraplegic person.
   b. It is associated with CN IX.
   c. It is associated with the glossopharyngeal nerve.
   d. It prevents food and water from entering the respiratory passages.
8. Damage to the phrenic nerve
   a. interferes with the pupillary response to light.
   b. impairs breathing.
   c. eliminates the gag reflex.
   d. causes dysphagia.
9. CN IX, CN X, and the baroreceptor reflex are concerned with the regulation of
   a. the amount of light that enters the eye.
   b. facial expression.
   c. the movement of the eyeballs and elevation of the eyelids.
   d. blood pressure.
10. Which of the following cranial nerves is not classified as sensory?
    a. Olfactory
    b. CN II
    c. Vestibulocochlear
    d. Vagus

Go Figure

1. **According to Figure 11-1**
   a. The spinal cord fills the entire spinal cavity.
   b. The usual lumbar puncture site is between L6 to L7.
   c. The cauda equina exits from the distal end of the spinal cord.
   d. The subarachnoid space ends at L1.