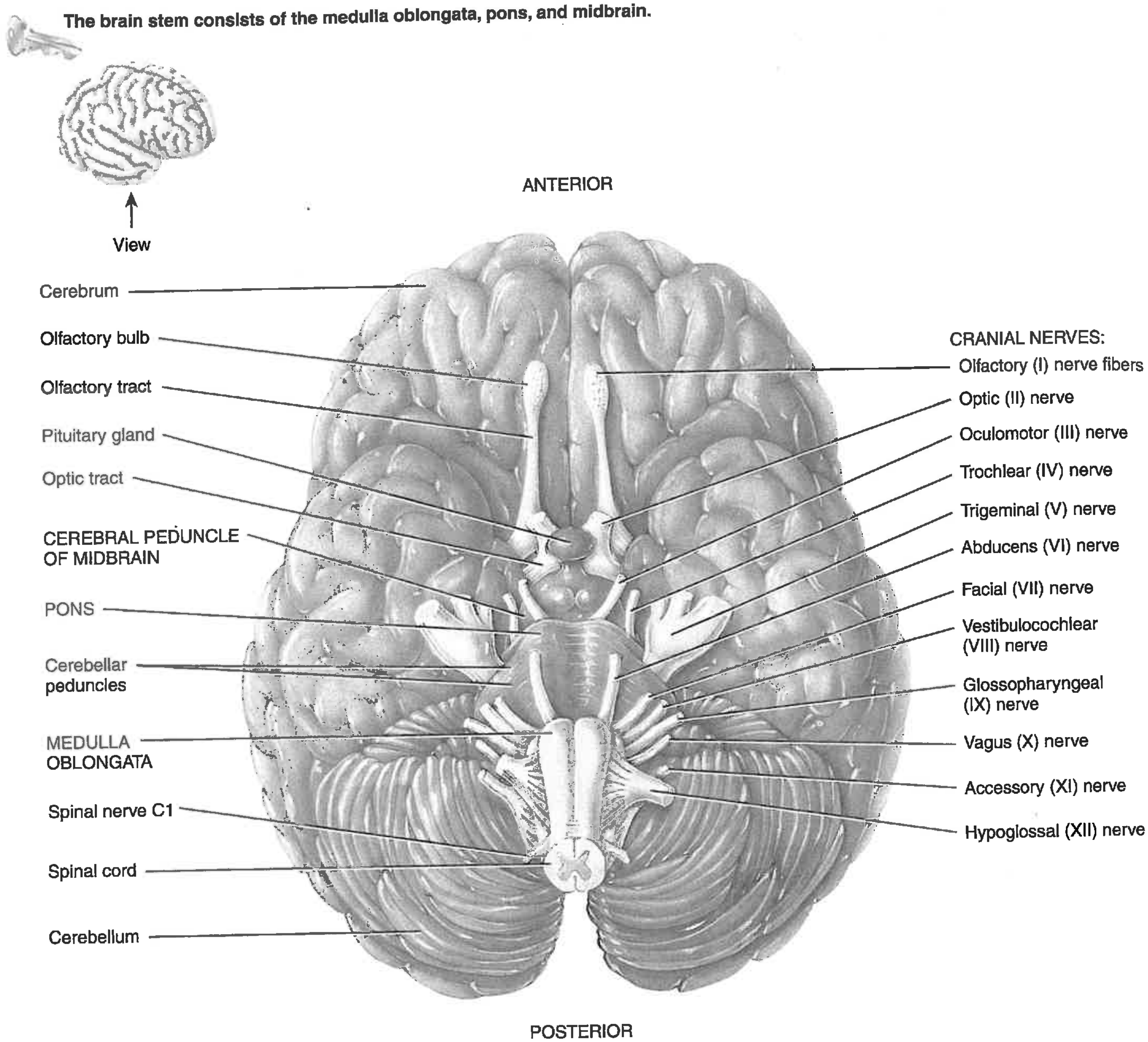
Figure 10.8 Inferior aspect of the brain, showing the brain stem and cranial nerves.

The brain stem consists of the medulla oblongata, pons, and midbrain.



Inferior aspect of brain

Which part of the brain stem contains the cerebral peduncles?

in the posterior part of the medulla. Many ascending sensory axons form synapses in these nuclei (see Figure 10.14a). Other nuclei in the medulla control reflexes for swallowing, vomiting, coughing, hiccupping, and sneezing. Finally, the medulla contains nuclei associated with five pairs of cranial nerves (Figure 10.8): vestibulocochlear (VIII) nerves, glossopharyngeal (IX) nerves, vagus (X) nerves, accessory (XI) nerves (cranial portion), and hypoglossal (XII) nerves.

Given the many vital activities controlled by the medulla, it is not surprising that a hard blow to the back of the head or upper neck can be fatal. **Damage to the medullary rhythmicity area** is particularly serious and can rapidly lead to death. Symptoms of nonfatal injury to the medulla may include paralysis and loss of sensation on the opposite side of the body, and irregularities in breathing or heart rhythm.

Pons

The ***pons*** (= bridge) is above the medulla and anterior to the cerebellum (Figures 10.6, 10.7, and 10.8). Like the medulla, the pons consists of both nuclei and tracts. As its name implies, the pons is a bridge that connects parts of the brain with one another. These connections are bundles of axons. Some axons of the pons connect the right and left sides of the cerebellum. Others are part of ascending sensory tracts and descending motor tracts. Several nuclei in the pons are the sites where signals for voluntary movements that originate in the cerebral cortex are relayed into the cerebellum. Other nuclei in the pons help control breathing. The pons also contains nuclei associated with the following four pairs of cranial nerves (Figure 10.8): trigeminal (V) nerves, abducens (VI) nerves, facial (VII) nerves, and vestibulocochlear (VIII) nerves.

Midbrain

The ***midbrain*** connects the pons to the diencephalon (Figures 10.6, 10.7, and 10.8). The anterior part of the midbrain consists of a pair of large tracts called ***cerebral peduncles*** (pe-DUNK-kuls or PĒ-dung-kuls = little feet; Figure 10.9). They contain axons of motor neurons that conduct nerve impulses from the cerebrum to the spinal cord, medulla, and pons and axons of sensory neurons that extend from the medulla to the thalamus.

Nuclei of the midbrain include the ***substantia nigra*** (sub-STAN-shē-a = substance; NĪ-gra = black), which is large and darkly pigmented. Loss of these neurons is associated with Parkinson disease (see page 266). Also present are the right and left ***red nuclei***, which look reddish due to their rich blood supply and an iron-containing pigment in their neuronal cell bodies. Axons from the cerebellum and cerebral cortex form synapses in the red nuclei, which function with the cerebellum to coordinate muscular movements. Other nuclei in the midbrain are associated with two pairs of cranial nerves (see Figure 10.8): oculomotor (III) nerves and trochlear (IV) nerves.

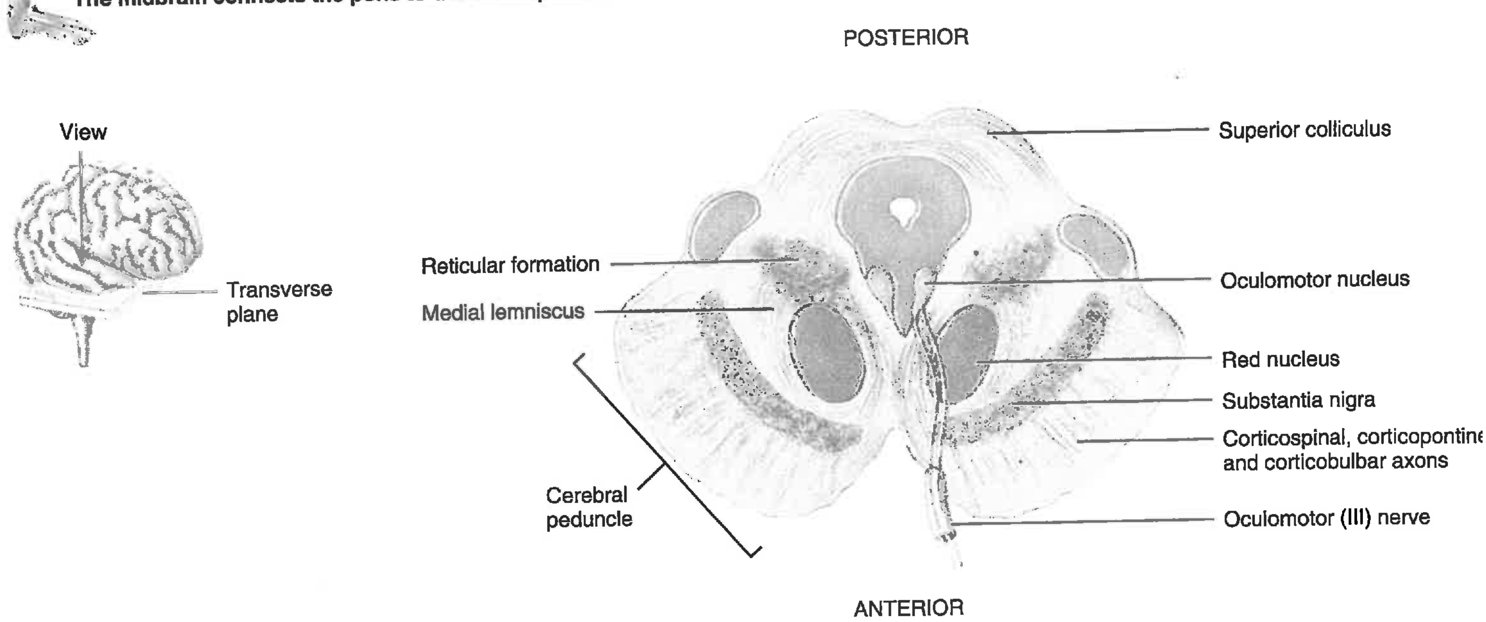
The midbrain also contains nuclei that appear as four rounded bumps on the posterior surface. The two superior bumps are the ***superior colliculi*** (ko-LIK-ū-lī = little hills; singular is *colliculus*) (Figure 10.9). Several reflex arcs pass through the superior colliculi: tracking and scanning movements of the eyes and reflexes that govern movements of the eyes, head, and neck in response to visual stimuli. The two ***inferior colliculi*** are part of the auditory pathway, relaying impulses from the receptors for hearing in the ear to the thalamus. They also are reflex centers for the startle reflex: sudden movements of the head and body that occur when you are surprised by a loud noise.

Reticular Formation

In addition to the well-defined nuclei already described much of the brain stem consists of small clusters of neurona cell bodies (gray matter) intermingled with small bundles o myelinated axons (white matter). This region is known as th ***reticular formation*** (*ret-* = net) due to its netlike arrange

Figure 10.9 **Midbrain.**

The midbrain connects the pons to the diencephalon.



Transverse section of midbrain

What functions are carried out by the superior colliculi?

ment of white matter and gray matter. Neurons within the reticular formation have both ascending (sensory) and descending (motor) functions.

The ascending part of the reticular formation is called the ***reticular activating system (RAS)***, which consists of sensory axons that project to the cerebral cortex. When the RAS is stimulated, many nerve impulses pass upward to widespread areas of the cerebral cortex. The result is a state of wakefulness called ***consciousness***. The RAS helps maintain consciousness and is active during awakening from sleep. Inactivation of the RAS produces ***sleep***, a state of partial unconsciousness from which an individual can be aroused. The reticular formation's main descending function is to help regulate muscle tone, which is the slight degree of contraction in normal resting muscles.

CHECKPOINT

8. What is the significance of the blood–brain barrier?
9. What structures are the sites of CSF production, and where are they located?
10. Where are the medulla, pons, and midbrain located relative to one another?
11. What functions are governed by nuclei in the brain stem?
12. What are two important functions of the reticular formation?

Diencephalon

Major regions of the ***diencephalon*** include the thalamus, hypothalamus, and pineal gland (see Figure 10.6).

Thalamus

The ***thalamus*** (THAL-a-mus = inner chamber) consists of paired oval masses of gray matter, organized into nuclei, with interspersed tracts of white matter (Figure 10.10). Nuclei of the thalamus are important relay stations for sensory impulses that are conducting to the cerebral cortex from the spinal cord, brain stem, cerebellum, and other parts of the cerebrum.

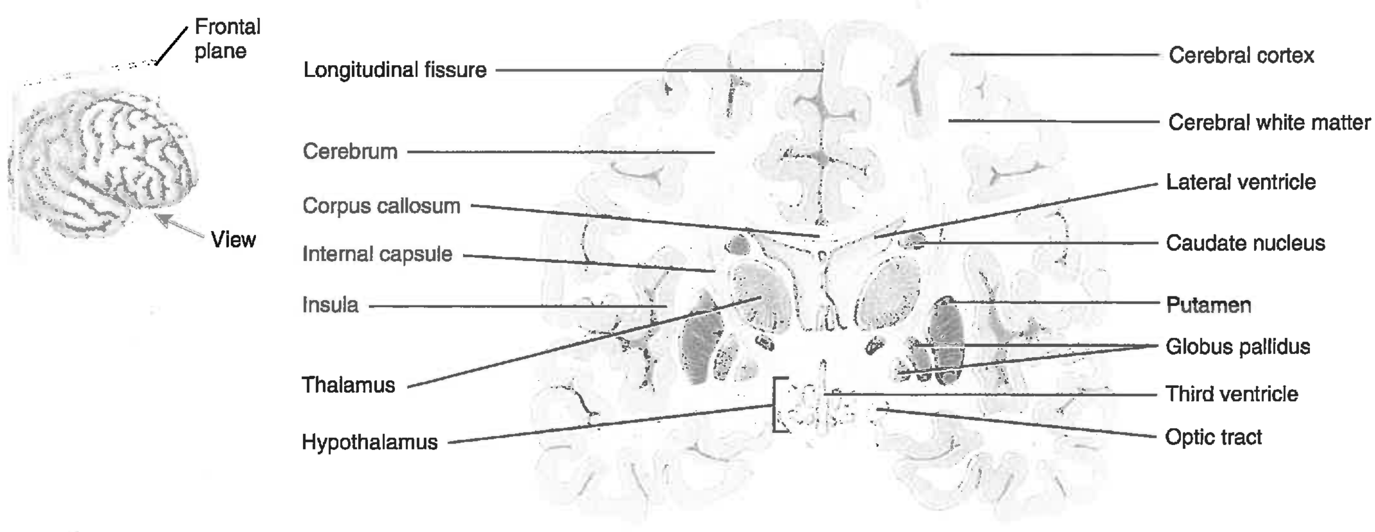
The thalamus contributes to motor functions by transmitting information from the cerebellum and basal ganglia to motor areas of the cerebral cortex. It also relays nerve impulses between different areas of the cerebrum. The thalamus contributes to the regulation of autonomic activities and the maintenance of consciousness.

Hypothalamus

The ***hypothalamus*** (*hypo-* = under) is the small portion of the diencephalon that lies below the thalamus and above the pituitary gland (see Figures 10.6 and 10.10). Although its size is small, the hypothalamus controls many important body activities, most of them related to homeostasis. The chief functions of the hypothalamus are as follows:

Figure 10.10 Diencephalon: thalamus and hypothalamus. Also shown are the basal ganglia—the caudate nucleus, putamen, and globus pallidus.

The thalamus is the principal relay station for sensory impulses that reach the cerebral cortex from other parts of the brain and the spinal cord.



Anterior view of frontal section

In which major part of the brain are the basal ganglia located, and what kind of tissue composes them?

1. **Control of the ANS.** The hypothalamus controls and integrates activities of the autonomic nervous system, which regulates contraction of smooth and cardiac muscle and the secretions of many glands. Through the ANS, the hypothalamus helps to regulate activities such as heart rate, movement of food through the gastrointestinal tract, and contraction of the urinary bladder.
2. **Control of the pituitary gland and production of hormones.** The hypothalamus controls the release of several hormones from the pituitary gland and thus serves as a primary connection between the nervous system and endocrine system. The hypothalamus also produces two hormones that are stored in the pituitary gland prior to their release.
3. **Regulation of emotional and behavioral patterns.** Together with the limbic system (described shortly), the hypothalamus regulates feelings of rage, aggression, pain, and pleasure, and the behavioral patterns related to sexual arousal.
4. **Regulation of eating and drinking.** The hypothalamus regulates eating behavior and also contains a ***thirst center***. When certain cells in the hypothalamus are stimulated by rising osmotic pressure of the interstitial fluid, they cause the sensation of thirst. The intake of water by drinking restores the osmotic pressure to normal, removing the stimulation and relieving the thirst.
5. **Control of body temperature.** If the temperature of blood flowing through the hypothalamus is above normal, the hypothalamus directs the autonomic nervous system to stimulate activities that promote heat loss. If, however, blood temperature is below normal, the hypothalamus generates impulses that promote heat production and retention.
6. **Regulation of circadian rhythms and states of consciousness.** The hypothalamus establishes patterns of awakening and sleep that occur on a circadian (daily) schedule.

Pineal Gland

The ***pineal gland*** (PĪN-ē-al = pinecone-like) is about the size of a small pea and protrudes from the posterior midline of the third ventricle (see Figure 10.6). Because the pineal gland secretes the hormone *melatonin*, it is part of the endocrine system. Melatonin promotes sleepiness and contributes to the setting of the body's biological clock.

Cerebellum

The ***cerebellum*** consists of two ***cerebellar hemispheres***, which are located posterior to the medulla and pons and below the cerebrum (see Figure 10.6). The surface of the cerebellum, called the ***cerebellar cortex***, consists of gray matter. Beneath the cortex is ***white matter*** that resembles the branches of a tree (see Figure 10.7). Deep within the white matter are masses of gray matter, the ***cerebellar nuclei***. The cerebellum attaches to the brain stem by bundles of axons called ***cerebellar peduncles*** (see Figure 10.8).

The cerebellum compares intended movements programmed by the cerebral cortex with what is actually happening. It constantly receives sensory impulses from muscles, tendons, joints, equilibrium receptors, and visual receptors. The cerebellum helps to smooth and coordinate complex sequences of skeletal muscle contractions. It regulates posture and balance and is essential for all skilled motor activities, from catching a baseball to dancing.

Damage to the cerebellum through trauma or disease disrupts muscle coordination, a condition called **ataxia** (*a-* = without; *-taxia* = order). Blindfolded people with ataxia cannot touch the tip of their nose with a finger because they cannot coordinate movement with their sense of where a body part is located. Another sign of ataxia is a changed speech pattern due to uncoordinated speech muscles. Cerebellar damage may also result in staggering or abnormal walking movements. People who consume too much alcohol show signs of ataxia because alcohol inhibits activity of the cerebellum. Alcohol overdose also suppresses the medullary rhythmicity area and may result in death.

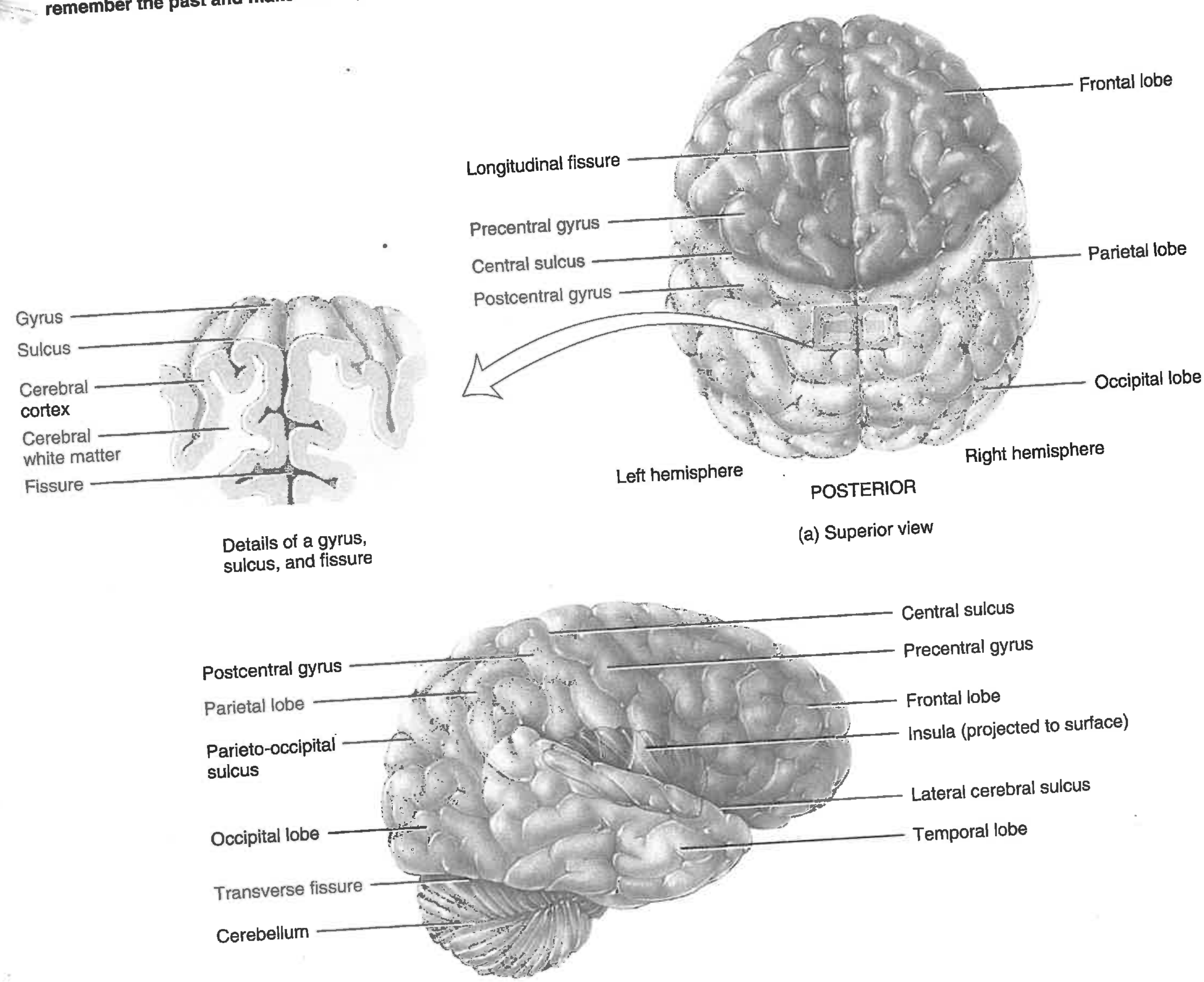
Cerebrum

The ***cerebrum*** consists of the ***cerebral cortex*** (an outer rim of gray matter), an internal region of cerebral white matter, and gray matter nuclei deep within the white matter (Figure 10.10). The cerebrum provides us with the ability to read, write, and speak; to make calculations and compose music; to remember the past and plan for the future; and to create. During embryonic development, when there is a rapid increase in brain size, the gray matter of the cerebral cortex enlarges much faster than the underlying white matter. As a result, the cerebral cortex rolls and folds upon itself so that it can fit into the cranial cavity. The folds are called ***gyri*** (JĪ-rī = circles; singular is *gyrus*) (Figure 10.11). The deep grooves between folds are ***fissures***; the shallow grooves are ***sulci*** (SUL-sī = groove; singular is *sulcus*, SUL-kus). The ***longitudinal fissure*** separates the cerebrum into right and left halves called ***cerebral hemispheres***. The hemispheres are connected internally by the ***corpus callosum*** (kal-LŌ-sum; *corpus* = body; *callosum* = hard), a broad band of white matter containing axons that extend between the hemispheres (see Figure 10.10).

Each cerebral hemisphere has four lobes that are named after the bones that cover them: ***frontal lobe***, ***parietal lobe***, ***temporal lobe***, and ***occipital lobe*** (Figure 10.11). The ***central sulcus*** separates the frontal and parietal lobes. A major gyrus, the ***precentral gyrus***, is located immediately anterior to the central sulcus. The precentral gyrus contains the primary

Figure 10.11 Cerebrum. The inset in (a) indicates the differences among a gyrus, a sulcus, and a fissure. Because the insula cannot be seen externally, it has been projected to the surface in (b).

The cerebrum provides us with the ability to read, write, and speak; make calculations and compose music; remember the past and make future plans; and create.



(a) Superior view

(b) Right lateral view

What structure separates the right and left cerebral hemispheres?

motor area of the cerebral cortex. The ***postcentral gyrus***, located immediately posterior to the central sulcus, contains the primary somatosensory area of the cerebral cortex, which is discussed shortly. A fifth part of the cerebrum, the ***insula***, cannot be seen at the surface of the brain because it lies within the lateral cerebral sulcus, deep to the parietal, frontal, and temporal lobes (see Figure 10.10).

The ***cerebral white matter*** consists of myelinated and unmyelinated axons that transmit impulses between gyri in the same hemisphere, from the gyri in one cerebral hemisphere to the corresponding gyri in the opposite cerebral hemisphere via the corpus callosum, and from the cerebrum to other parts of the brain and spinal cord.

Deep within each cerebral hemisphere are three nuclei (masses of gray matter) that are collectively termed the ***basal ganglia*** (see Figure 10.10). (Recall that "ganglion" usually means a collection of neuronal cell bodies *outside* the CNS. The name here is the one exception to that general rule.

Focus on Wellness

Coffee Nerves—The Health Risks of Caffeine

Caffeine has been enjoyed by people around the world since the beginning of history. Found naturally in over 60 plants, caffeine is the most widely consumed drug in North America, primarily as a component of coffee, tea, cola, and other beverages. It is also found in many over-the-counter drugs and in small amounts in chocolate. The average coffee drinker consumes 3 cups a day, with some people (including many college students) consuming 10 cups or more a day. How is all of this caffeine affecting our health?

The Java Jitters

Caffeine's most obvious effect is on the nervous system. Caffeine mimics the effects of the sympathetic division of the autonomic nervous system. In general, both caffeine and sympathetic arousal tend to wind you up. For example, they both make your heart beat faster and harder. (You will learn more about the autonomic nervous system in Chapter 11.)

The immediate effects of caffeine vary greatly from person to person. Some people find that any amount of caffeine causes undesirable symptoms such as muscle twitches, anxiety, increased blood pressure, an irregular heartbeat, digestive complaints, headache, and difficulty sleeping. Other people get one or more of these symptoms only if their caffeine consumption exceeds a certain threshold. How harmful is caffeine overload? If these symptoms are short-lived, and caffeine consumption is reduced or eliminated, no lasting harm seems to occur in otherwise healthy adults.

How Much Is Too Much?

While caffeine tolerance varies, studies suggest that long-term consumption of moderate amounts of caffeine probably poses little or no risk to long-term health. A moderate amount of caffeine is equivalent to that contained in two cups of coffee per day. This guideline does not apply to people who experience negative symptoms with caffeine; people should avoid caffeine in any amount that leads to unhealthy symptoms. Some animal studies suggest a link between caffeine and birth defects. Thus, the U.S. Food and Drug Administration recommends that women avoid or greatly reduce caffeine intake during pregnancy.

▶ **Think It Over . . .**

▶ *Why might your tolerance for caffeine go down during high-stress times, such as during final exam week? (Hint: Feelings of stress are associated with overactivation of the sympathetic division of the autonomic nervous system.)*

They are the ***globus pallidus*** (*globus* = ball; *pallidus* = pale), the ***putamen*** (pū-TĀ-men = shell), and the ***caudate nucleus*** (*caud-* = tail). A major function of the basal ganglia is to help initiate and terminate movements. They also help regulate the muscle tone required for specific body movements and control subconscious contractions of skeletal muscles, such as automatic arm swings while walking.

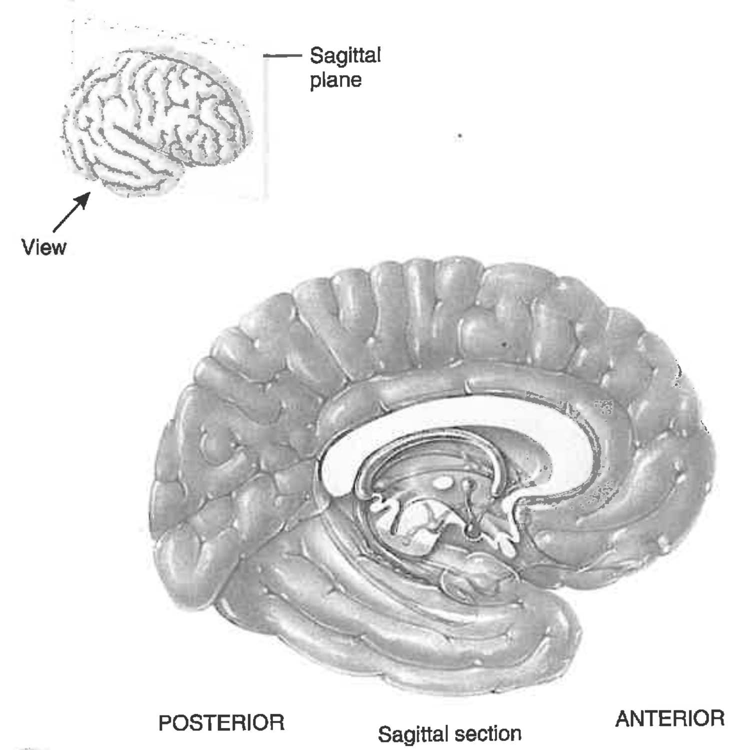
Damage to the basal ganglia results in uncontrollable shaking (tremor), muscular rigidity (stiffness), and involuntary muscle movements. Movement disruptions also are a hallmark of Parkinson disease (see page 266). In this disorder, neurons that extend from the substantia nigra to the putamen and caudate nucleus degenerate, causing the disruptions.

Limbic System

Encircling the upper part of the brain stem and the corpus callosum is a ring of structures on the inner border of the cerebrum and floor of the diencephalon that constitutes the ***limbic system*** (*limbic* = border) (Figure 10.12). The limbic system is sometimes called the "emotional brain" because it plays a primary role in a range of emotions, including pain, pleasure, docility, affection, and anger. Although behavior is a function of the entire nervous system, the limbic system controls most of its involuntary aspects related to survival. Animal experiments suggest that it has a major role in controlling the overall pattern of behavior. Together with parts of the cerebrum, the limbic system also functions in memory; damage to the limbic system causes memory impairment.

Figure 10.12 The limbic system. The components of the limbic system are shaded green.

The limbic system governs emotional aspects of behavior.



Where in the brain is the limbic system located?

Functional Areas of the Cerebral Cortex

Specific types of sensory, motor, and integrative signals are processed in certain regions of the cerebral cortex (Figure 10.13). Generally, ***sensory areas*** receive sensory information and are involved in ***perception***, the conscious awareness of a sensation; ***motor areas*** initiate movements; and ***association areas*** deal with more complex integrative functions such as memory, emotions, reasoning, will, judgment, personality traits, and intelligence.

SENSORY AREAS Sensory input to the cerebral cortex flows mainly to the posterior half of the cerebral hemispheres, to regions behind the central sulci. In the cerebral cortex, primary sensory areas have the most direct connections with peripheral sensory receptors.

The *primary somatosensory area* (sō′-mat-ō-SEN-sō-rē) is posterior to the central sulcus of each cerebral hemisphere in the postcentral gyrus of the parietal lobe (Figure 10.13). It receives nerve impulses for touch, proprioception (joint and muscle position), pain, itching, tickle, and temperature and is involved in the perception of these sensations. The primary somatosensory area allows you to pinpoint where sensations originate, so that you know exactly where on your body to swat that mosquito. The *primary visual area*, located in the occipital lobe, receives visual information and is involved in visual perception. The *primary auditory area*, located in the temporal lobe, receives information for sound and is involved in auditory perception. The *primary gustatory area*, located at the base of the postcentral gyrus, receives impulses for taste and is involved in gustatory perception. The *primary olfactory area*, located on the medial aspect of the temporal lobe (and thus is not visible in Figure 10.13), receives impulses for smell and is involved in olfactory perception.

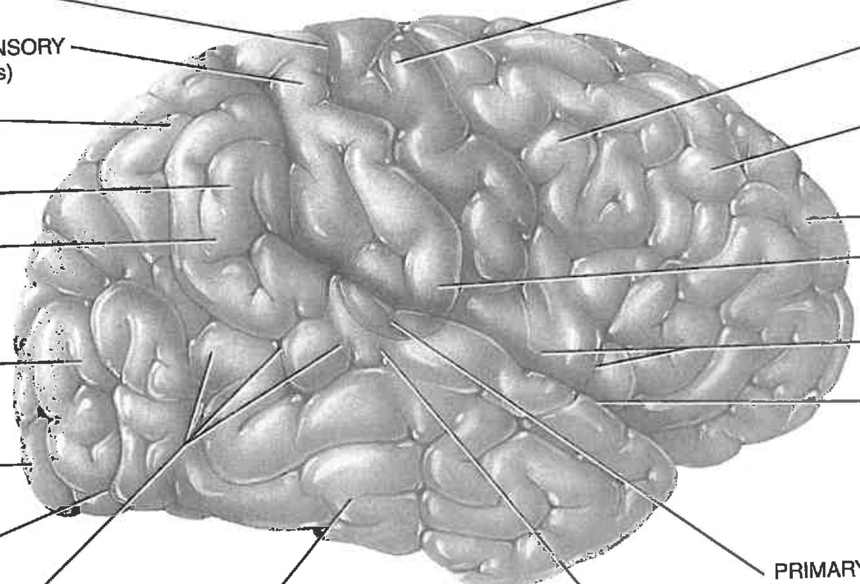
MOTOR AREAS Motor output from the cerebral cortex flows mainly from the anterior part of each hemisphere. Among the most important motor areas are the primary motor area and Broca's speech area (Figure 10.13). The *primary motor area* is located in the precentral gyrus of the frontal lobe in each hemisphere. Each region in the primary motor area controls voluntary contractions of specific muscles on the opposite side of the body. *Broca's speech area* (BRO-kaz) is located in the frontal lobe close to the lateral cerebral sulcus. Speaking and understanding language are complex activities that involve several sensory, association, and motor areas of the cortex. In 97% of the population, these language areas are localized in the *left* hemisphere. Neural connections between Broca's speech area, the premotor area, and primary motor area activate muscles needed for speaking and breathing muscles.

ASSOCIATION AREAS The association areas of the cerebrum consist of some motor and sensory areas, plus large areas on the lateral surfaces of the occipital, parietal, and temporal lobes and on the frontal lobes anterior to the motor areas. Tracts connect association areas to one another. The *somatosensory association area*, just posterior to the primary somatosensory area, integrates and interprets somatic sensations such as the exact shape and texture of an object. Another role of the somatosensory association area is the storage of memories of past sensory experiences, enabling you to compare current sensations with previous experiences. For example, the somatosensory association area allows you to recognize objects such as a pencil and a paperclip simply by touching them. The *visual association area*, located in the occipital lobe, relates present and past visual experiences and is essential for recognizing and evaluating what is seen. The *auditory association area*, located below the primary auditory area in the temporal cortex, allows you to recognize a particular sound as speech, music, or noise.

Wernicke's area, a broad region in the *left* temporal and parietal lobes, interprets the meaning of speech by recognizing spoken words. It is active as you translate words into thoughts. The regions in the *right* hemisphere that correspond to Broca's and Wernicke's areas in the left hemisphere also contribute to verbal communication by adding emotional content, for instance, anger or joy, to spoken words. The *common integrative area* receives and interprets nerve impulses from the somatosensory, visual, and auditory association areas, and from the primary gustatory area, primary ol-

Figure 10.13 Functional areas of the cerebrum. Broca's speech area and Wernicke's area are in the left cerebral hemisphere of most people; they are shown here to indicate their relative locations.

Particular areas of the cerebral cortex process sensory, motor, and integrative signals.



Lateral view of right cerebral hemisphere

Which part of the cerebrum localizes exactly where somatic sensations occur?

factory area, the thalamus, and parts of the brain stem. The *premotor area*, immediately anterior to the primary motor area, generates nerve impulses that cause a specific group of muscles to contract in a specific sequence, for example, to write a word. The *frontal eye field area* in the frontal cortex controls voluntary scanning movements of the eyes, such as those that occur while you are reading this sentence.

Injury to language areas of the cerebral cortex results in **aphasia** (a-FĀ-zē-a; *a-* = without; *-phasia* = speech), an inability to use or comprehend words. Damage to Broca's speech area results in *nonfluent aphasia*, an inability to properly form words. People with nonfluent aphasia know what they wish to say but cannot properly speak the words. Damage to Wernicke's area, the common integrative area or auditory association area, results in *fluent aphasia*, characterized by faulty understanding of spoken or written words. A person experiencing this type of aphasia may produce strings of words that have no meaning ("word salad"). For example, someone with fluent aphasia might say, "I rang car porch dinner light river pencil."

Somatic Sensory and Somatic Motor Pathways

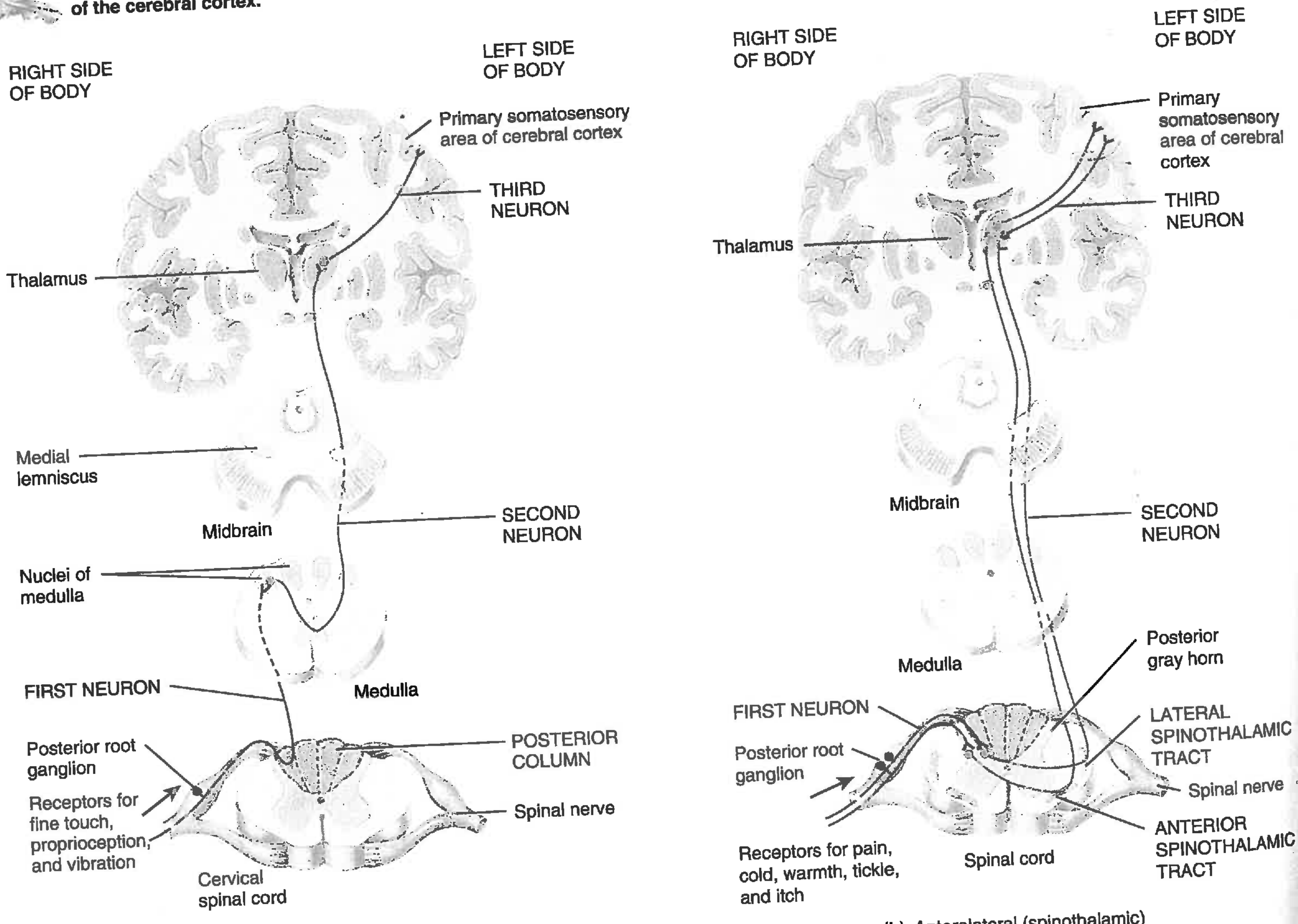
Somatic sensory information from the body ascends to the primary somatosensory area via two main somatic sensory pathways: (1) the posterior column–medial lemniscus pathway and (2) the spinothalamic pathways. By contrast, nerve impulses that cause contraction of skeletal muscles descend along many pathways that originate mainly in the primary motor area of the brain and in the brain stem.

Somatic sensory pathways relay information from somatic sensory receptors to the primary somatosensory area in the cerebral cortex. The pathways consist of thousands of sets of three neurons (Figure 10.14).

Nerve impulses for conscious awareness of the position of muscles and joints (proprioception) and for most touch sensations ascend to the cortex along the ***posterior column–medial lemniscus pathway*** (Figure 10.14a). The name of the pathway comes from the names of two white matter tracts that convey the impulses: the posterior column of the spinal cord and the medial lemniscus of the brain stem. Impulses conducted along the posterior column–medial lemniscus pathway give rise to three main types of sensations:

Figure 10.14 Somatic sensory pathways. Circles represent cell bodies and dendrites, lines represent axons, and Y-shaped forks represent axon terminals. Arrows indicate the direction of nerve impulse conduction. (a) In the posterior column–medial lemniscus pathway, the first-order neuron in the pathway ascends to the medulla oblongata via the posterior column (white matter located on the posterior side of the spinal cord). In the medulla, it synapses with a second-order neuron, which then extends through the medial lemniscus to the thalamus on the opposite side. The third-order neuron extends from the thalamus to the cerebral cortex. (b) In the anterolateral pathway, the first-order neuron synapses with a second-order neuron in the spinal cord gray matter. The second-order neuron extends to the thalamus on the opposite side, and the third-order neuron extends from the thalamus to the cerebral cortex.

Nerve impulses for somatic sensations conduct to the primary somatosensory area (postcentral gyrus) of the cerebral cortex.



(a) Posterior column-medial lemniscus pathway

(b) Anterolateral (spinothalamic) pathways

? **Which somatic sensations could be lost due to damage of the spinothalamic tracts?**

- ***Fine touch*** is the ability to recognize what point on the body is touched plus the shape, size, and texture of the source of stimulation.
- ***Proprioception*** is the awareness of the precise position of body parts, and ***kinesthesia*** is the awareness of directions of movement.
- ***Vibratory sensations*** arise when rapidly fluctuating touch stimuli are present.

The ***spinothalamic pathways*** (spī-nō-tha-LAM-ik) begin in two spinal cord tracts—the ***anterior spinothalamic tract*** and the ***lateral spinothalamic tract*** (Figure 10.14b). These tracts relay impulses for pain, thermal (hot and cold temperature), tickle, and itch sensations.

Neurons in the brain and spinal cord coordinate all voluntary and involuntary movements. Ultimately, all ***somatic motor pathways*** that control movement converge on neurons known as ***lower motor neurons*** (Figure 10.15). The axons of lower motor neurons extend out of the brain stem to stimulate skeletal muscles in the head and out of the spinal cord to stimulate skeletal muscles in the limbs and trunk.

Lower motor neurons receive their instructions from many other neurons in the brain and spinal cord.

1. Nearby *local interneurons* help coordinate rhythmic activity in specific muscle groups, such as alternating flexion and extension of the lower limbs during walking.
2. Local interneurons and lower motor neurons receive input from ***upper motor neurons*** (Figure 10.15). Upper motor neurons plan, initiate, and direct sequences of voluntary movements. Two major tracts that conduct nerve impulses from upper motor neurons in the cerebral cortex are the ***lateral corticospinal tract*** and ***anterior corticospinal tract***. Notice that axons of upper motor neurons from one cerebral hemisphere cross over and synapse with lower motor neurons in the other side of the spinal cord (Figure 10.15).
3. The *basal ganglia* communicate with motor areas of the cerebral cortex, thalamus, and substantia nigra. These connections help initiate and terminate movements, suppress unwanted movements, and establish a normal level of muscle tone.
4. Neurons connect the *cerebellum* with motor areas of the cerebral cortex and the brain stem. The cerebellum coordinates body movements and helps maintain normal posture and balance.

Damage or disease of *lower* motor neurons produces **flaccid paralysis** of muscles on the same side of the body: the muscles lack voluntary control and reflexes, muscle tone is decreased or lost, and the muscle remains flaccid (limp). Injury or disease of *upper* motor neurons causes **spastic paralysis** of muscles on the opposite side of the body. In this condition muscle tone is increased, reflexes are exaggerated, and pathological reflexes appear.

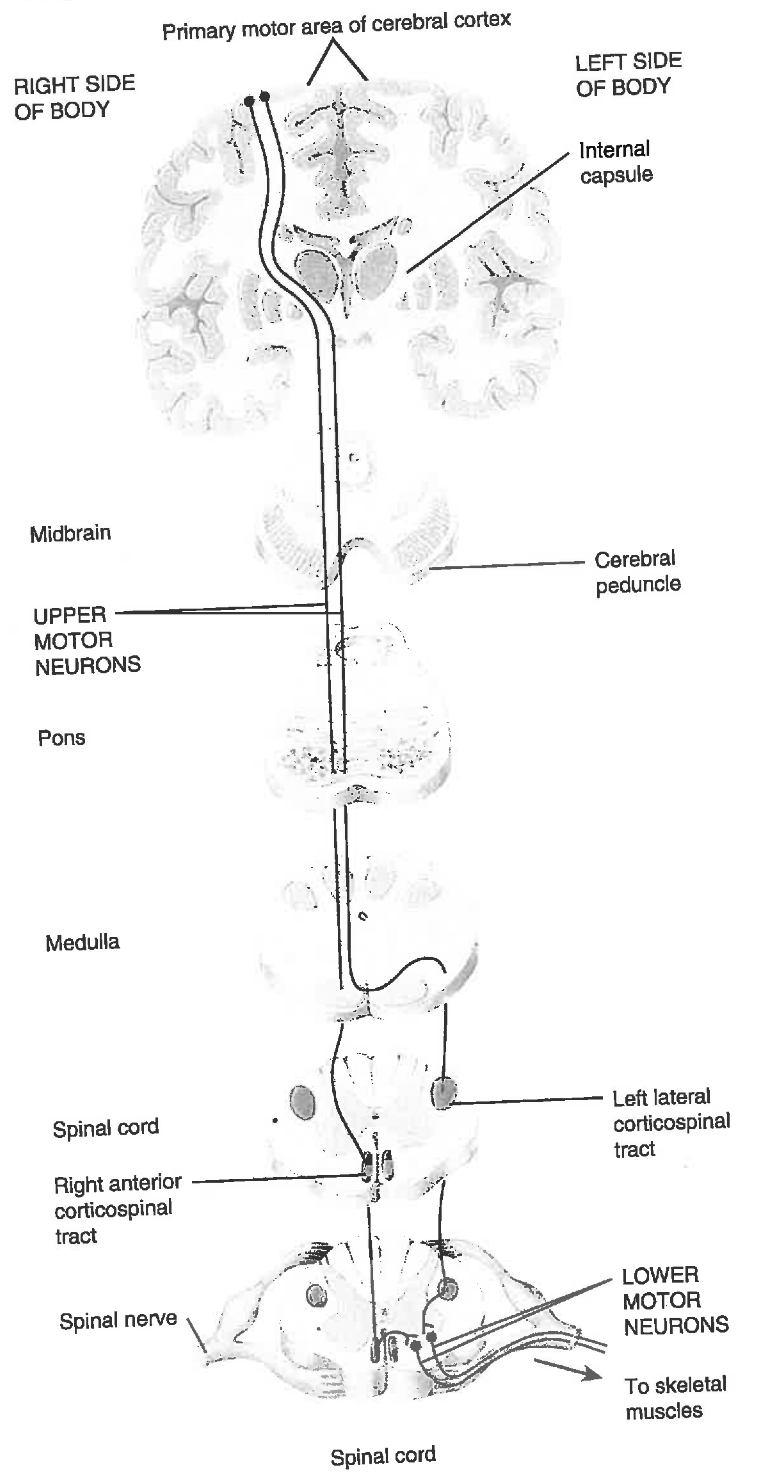
Hemispheric Lateralization

Although the brain is quite symmetrical, there are subtle anatomical differences between the two hemispheres. They are also functionally different in some ways, with each hemisphere specializing in certain functions. This functional asymmetry is termed ***hemispheric lateralization***.

As you have seen, the left hemisphere receives sensory signals from and controls the right side of the body, and the right hemisphere receives sensory signals from and controls the left side of the body. In addition, the left hemisphere is more important for spoken and written language, numerical and scientific skills, ability to use and understand sign language, and reasoning in most people. Patients with damage

Figure 10.15 Somatic motor pathways. Shown here are the two most direct pathways whereby signals initiated by the primary motor area in one hemisphere control skeletal muscles on the opposite side of the body. Circles represent cell bodies and dendrites, lines represent axons, and Y-shaped forks represent axon terminals.

Lower motor neurons stimulate skeletal muscles to produce movements.



What two spinal cord tracts conduct impulses along axons of upper motor neurons?