

The simple *patellar* (pah-tel'ar), or *knee-jerk, reflex* is an example of a two-neuron reflex arc, the simplest type in humans (Figure 7.11b). The patellar reflex (in which the quadriceps muscle attached to the hit tendon is stretched) is familiar to most of us. It is usually tested during a physical exam to determine the general health of the motor portion of our nervous system.

Most reflexes are much more complex than the two-neuron reflex, involving synapses between one or more interneurons in the CNS (integration center). The *flexor, or withdrawal, reflex* is a three-neuron reflex arc in which the limb is withdrawn from a painful stimulus (see Figure 7.11c). A three-neuron reflex arc also consists of five elements—receptor, sensory neuron, interneuron, motor neuron, and effector. Because there is always a delay at synapses (it takes time for neurotransmitter to diffuse through the synaptic cleft), the more synapses there are in a reflex pathway, the longer the reflex takes to happen.

Many spinal reflexes involve only spinal cord neurons and occur without brain involvement. As long as the spinal cord is functional, spinal reflexes, such as the flexor reflex, will work. By contrast, some reflexes require that the brain become involved because many different types of information have to be evaluated to arrive at the “right” response. The response of the pupils of the eyes to light is a reflex of this type.

As noted earlier, reflex testing is an important tool in evaluating the condition of the nervous system. Reflexes that are exaggerated, distorted, or absent indicate damage or disease in the nervous system. Reflex changes often occur before a pathological condition becomes obvious in other ways.

### Did You Get It?

8. What is the difference between a graded potential and an action potential?
9. Explain the difference between a synaptic cleft and a synapse. How is a stimulus transmitted across a synapse?
10. Which portion(s) of a neuron is (are) likely to be associated with a sensory receptor or a sensory organ?
11. What is a reflex?

For answers, see Appendix A.

## Central Nervous System

### Functional Anatomy of the Brain

#### → Learning Objective

- Identify and indicate the functions of the major regions of the cerebral hemispheres, diencephalon, brain stem, and cerebellum on a human brain model or diagram.

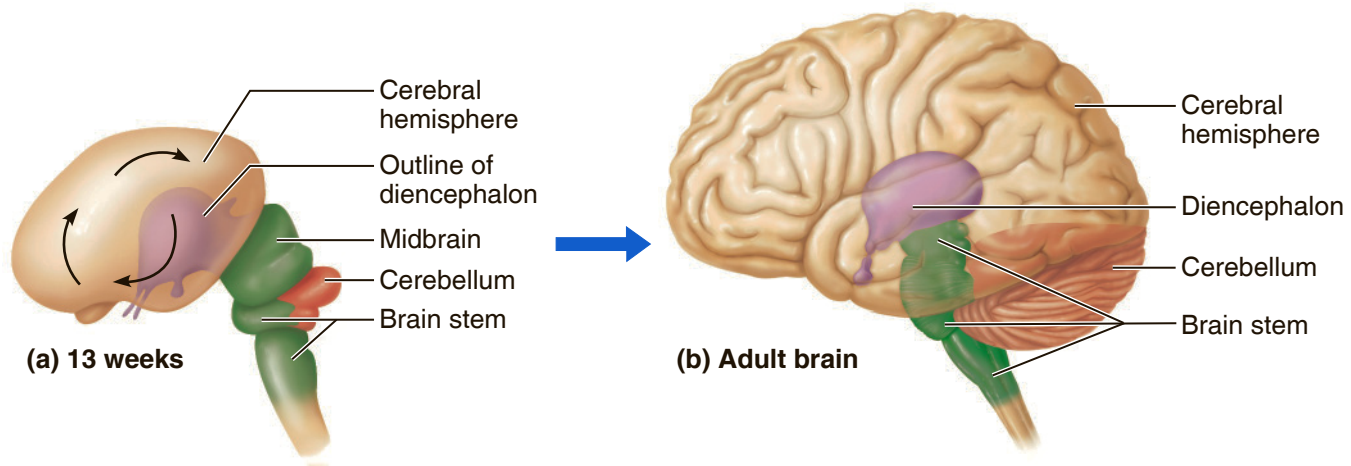
The adult brain's unimpressive appearance gives few hints of its remarkable abilities. It is about two good fistfuls of pinkish gray tissue, wrinkled like a walnut and with the texture of cold oatmeal. It weighs a little over 3 pounds. Because the brain is the largest and most complex mass of nervous tissue in the body, we commonly discuss it in terms of its four major regions—*cerebral hemispheres, diencephalon* (di'en-sef'ah-lon), *brain stem*, and *cerebellum* (Figure 7.12, p. 266 and Table 7.1, p. 269).

#### Cerebral Hemispheres

The paired **cerebral** (suh re'bral) **hemispheres**, collectively called the **cerebrum**, are the most superior part of the brain and together are a good deal larger than the other three brain regions combined. In fact, as the cerebral hemispheres develop and grow, they enclose and obscure most of the brain stem, so many brain stem structures cannot normally be seen unless a sagittal section is made. Picture how a mushroom cap covers the top of its stalk, and you have an idea of how the cerebral hemispheres cover the diencephalon and the superior part of the brain stem (see Figure 7.12).

The entire surface of the cerebrum exhibits elevated ridges of tissue called **gyri** (ji're; *gyrus*, singular; “twisters”), separated by shallow grooves called **sulci** (sul'ki; *sulcus*, singular; “furrows”). Less numerous are the deeper grooves called **fissures** (Figure 7.13a, p. 267), which separate large regions of the brain. Many of the fissures and gyri are important anatomical landmarks. The cerebral hemispheres are separated by a single deep fissure, the *longitudinal fissure*. Other fissures or sulci divide each cerebral hemisphere into a number of **lobes**, named for the cranial bones that lie over them (see Figure 7.13a and b).

Each cerebral hemisphere has three basic regions: a superficial *cortex* of gray matter, which looks gray in fresh brain tissue; an internal area of *white matter*; and the *basal nuclei*, islands of gray



**Figure 7.12 Development and regions of the human brain.** The brain can be considered in terms of four main parts: cerebral hemispheres, diencephalon, brain stem, and cerebellum. **(a)** In the developing brain, the cerebral

hemispheres, initially smooth, are forced to grow posteriorly and laterally over the other brain regions by the bones of the skull. **(b)** In the adult brain, the cerebral hemispheres, now highly convoluted, enclose the diencephalon and the

superior part of the brain stem. The left cerebral hemisphere is drawn so that it looks transparent, to reveal the location of the deeply situated diencephalon and superior part of the brain stem.

matter situated deep within the white matter. We consider these regions next.

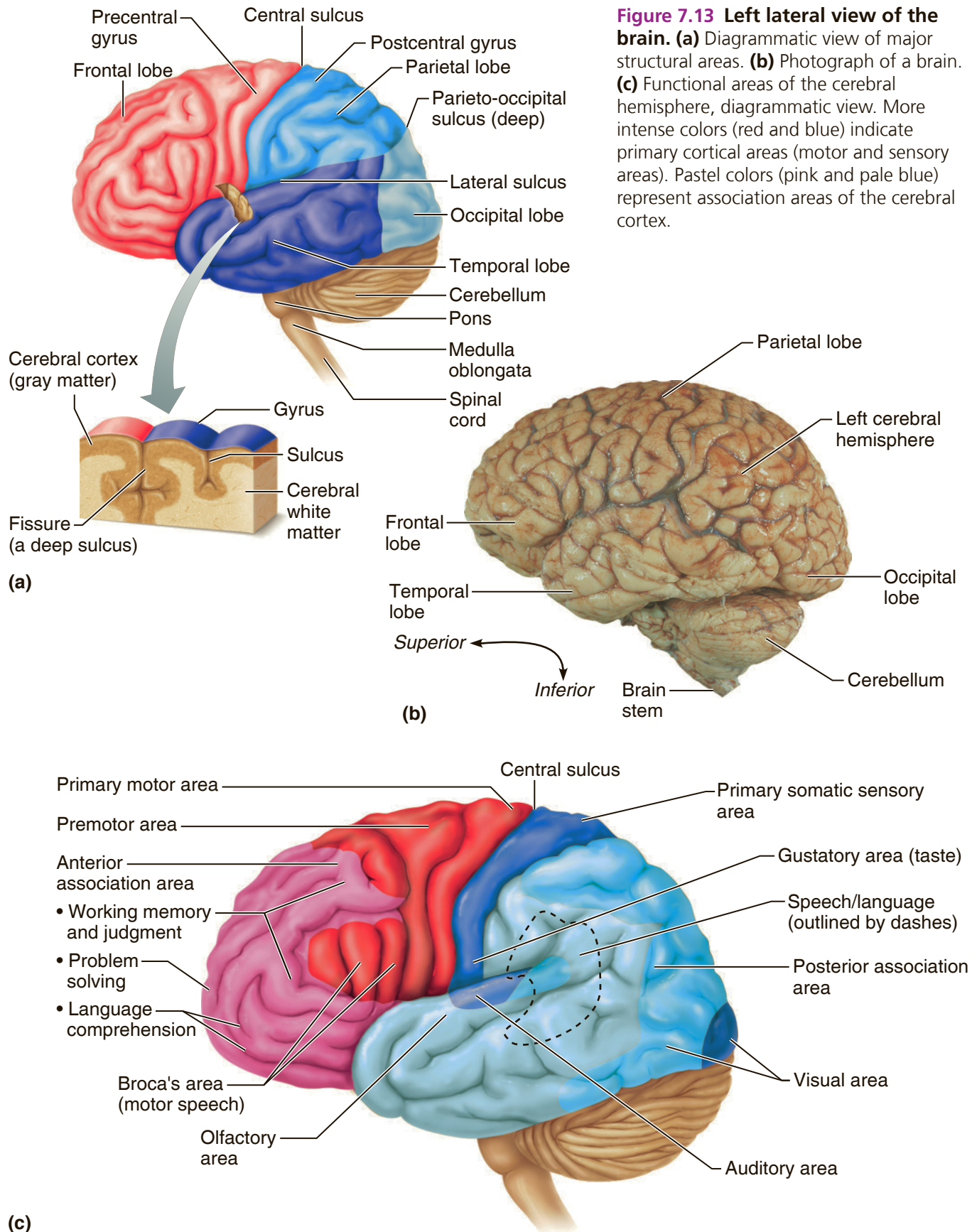
**Cerebral Cortex** Speech, memory, logical and emotional responses, consciousness, the interpretation of sensation, and voluntary movement are all functions of the **cerebral cortex**. Many of the functional areas of the cerebral hemispheres have been identified (Figure 7.13c). The **primary somatic sensory area** is located in the **parietal lobe** posterior to the **central sulcus**. Impulses traveling from the body's sensory receptors (except for the special senses) are localized and interpreted in this area of the brain. The primary somatic sensory area allows you to recognize pain, differences in temperature, or a light touch.

A spatial map, the **sensory homunculus** (ho-mung'ku-lus; "little man"), has been developed to show how much tissue in the primary somatic sensory area is devoted to various sensory functions. (Figure 7.14, p. 268; note that the body is represented in an upside-down manner). Body regions with the most sensory receptors—the lips and fingertips—send impulses to neurons that make up a large part of the sensory area. Furthermore, the sensory pathways are crossed pathways—meaning that the left side of the primary somatic sensory area receives impulses from the right side of the body, and vice versa.

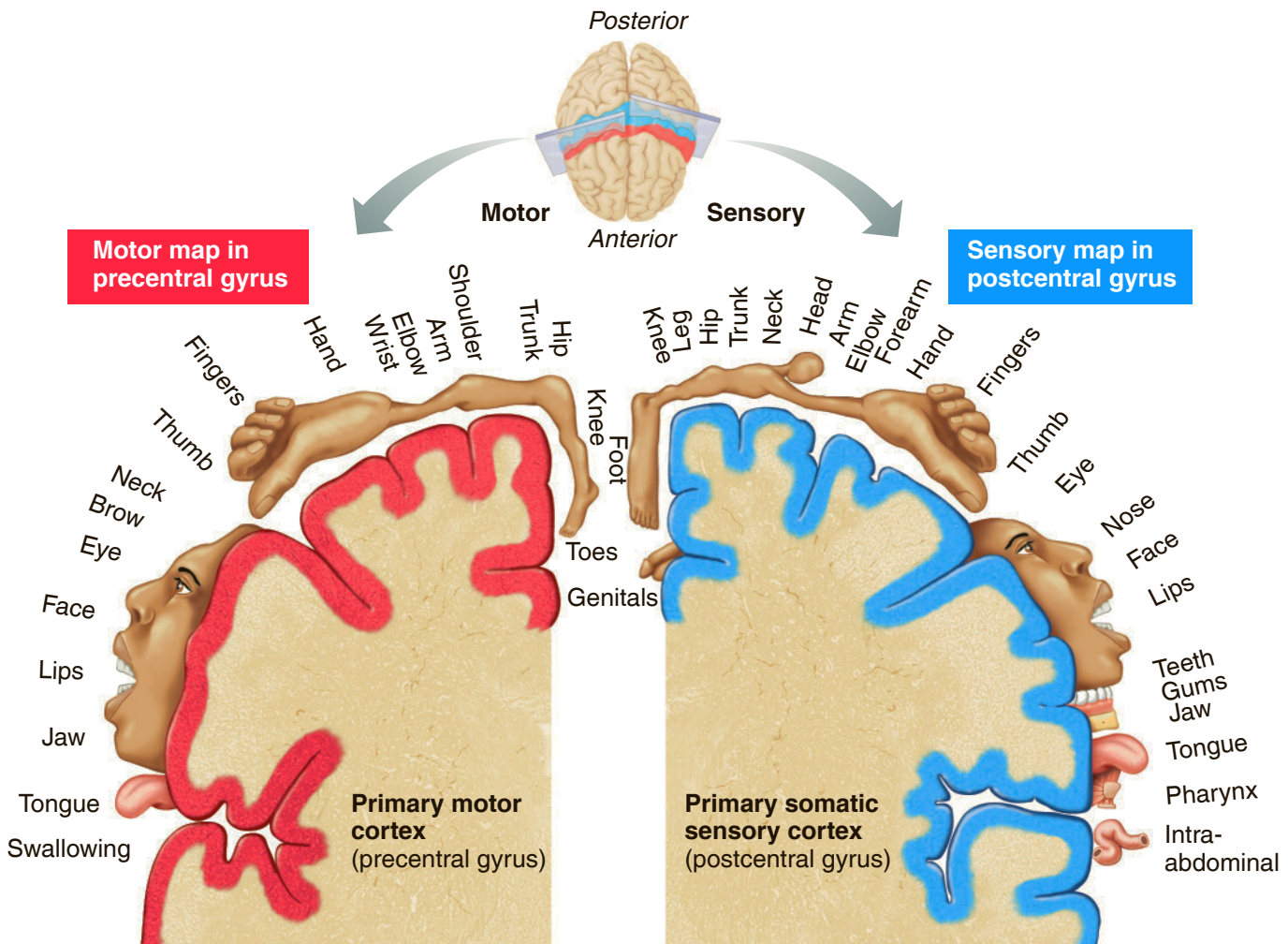
Impulses from the special sense organs are interpreted in other cortical areas (see Figure 7.13b and c). For example, the visual area is located in the posterior part of the **occipital lobe**, the auditory area is in the **temporal lobe** bordering the *lateral sulcus*, and the olfactory area is deep inside the temporal lobe.

The **primary motor area**, which allows us to consciously move our skeletal muscles, is anterior to the central sulcus in the *frontal lobe*. The axons of these motor neurons form the major voluntary motor tract—the **pyramidal tract**, or **corticospinal** (kor'tī-ko-spi'nal) **tract**, which descends to the cord. As in the primary somatic sensory cortex, the body is represented upside-down, and the pathways are crossed. Most of the neurons in the primary motor area control body areas having the finest motor control; that is, the face, mouth, and hands (see Figure 7.14). The body map on the motor cortex, as you might guess, is called the **motor homunculus**.

A specialized cortical area that is very involved in our ability to speak, **Broca's area** (bro'kahz) **area**, or *motor speech area* (see Figure 7.13c), is found at the base of the precentral gyrus (the gyrus anterior to the central sulcus). Damage to this area, which is located in only one cerebral hemisphere (usually the left), causes the inability to say words properly. You know what you want to say, but you can't vocalize the words.



**Figure 7.13 Left lateral view of the brain.** (a) Diagrammatic view of major structural areas. (b) Photograph of a brain. (c) Functional areas of the cerebral hemisphere, diagrammatic view. More intense colors (red and blue) indicate primary cortical areas (motor and sensory areas). Pastel colors (pink and pale blue) represent association areas of the cerebral cortex.



**Figure 7.14 Sensory and motor areas of the cerebral cortex.** The relative amount of cortical tissue devoted to each function is indicated

by the amount of the gyrus occupied by the body area diagrams (homunculi). The primary motor cortex is shown on the left side of


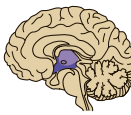




the diagram, and the somatic sensory cortex is on the right.

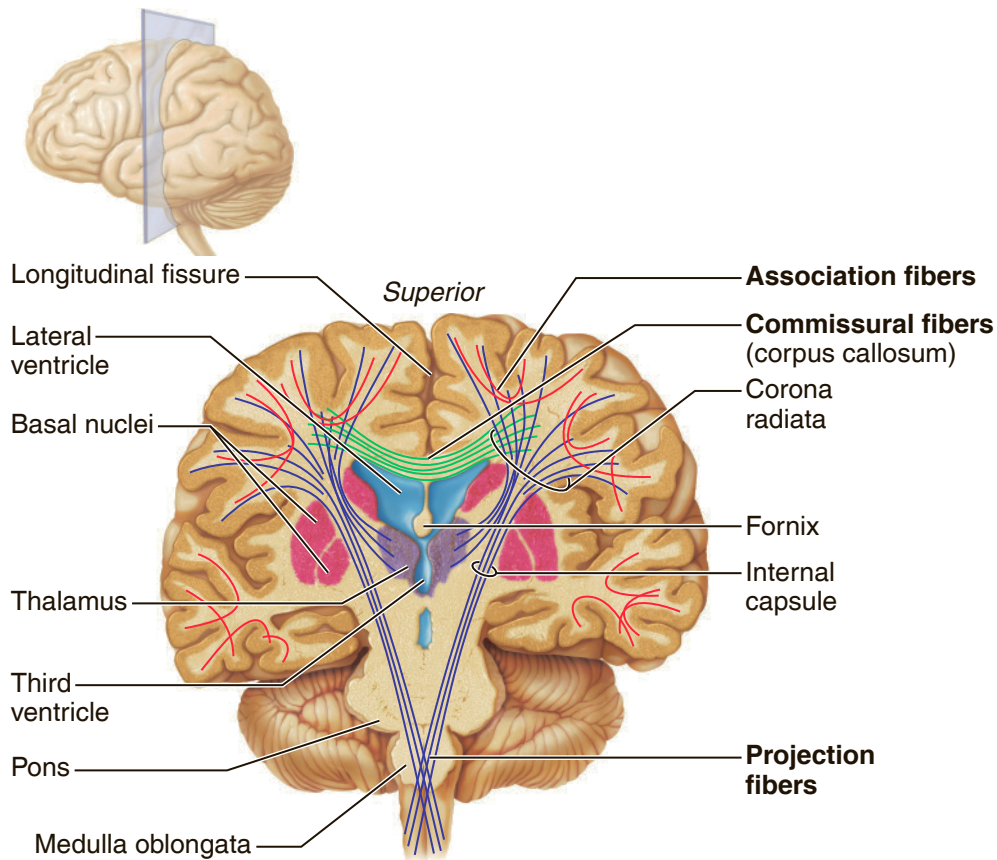
Areas involved in higher intellectual reasoning and socially acceptable behavior are believed to be in the anterior part of the frontal lobes, the **anterior association area**. The frontal lobes also house areas involved with language comprehension. Complex memories appear to be stored in the temporal and frontal lobes.

The **posterior association area** encompasses part of the posterior cortex. This area plays a role in recognizing patterns and faces, and blending several different inputs into an understanding of the whole situation. Within this area is the **speech area**, located at the junction of the temporal, parietal, and occipital lobes. The speech area allows you to sound out words. This area (like Broca's area) is usually in only one cerebral hemisphere.

**Cerebral White Matter** Most of the remaining cerebral hemisphere tissue—the deeper **cerebral white matter** (see Figures 7.13a and 7.15)—is composed of fiber tracts carrying impulses to, from, or within the cortex. One very large fiber tract, the **corpus callosum** (kah-lo'sum), connects the cerebral hemispheres (Figure 7.15). Such fiber tracts are called *commissures*. The corpus callosum arches above the structures of the brain stem and allows the cerebral hemispheres to communicate with one another. This is important because, as already noted, some of the cortical functional areas are in only one hemisphere. *Association fiber tracts* connect areas within a hemisphere, and *projection fiber tracts* connect the cerebrum with lower CNS centers, such as the brain stem.

Table 7.1 Functions of Major Brain Regions


Region	Function
<b>Cerebral hemispheres</b>	
	<p><b>Cortex: Gray matter:</b></p> <ul style="list-style-type: none"> <li>• Localizes and interprets sensory inputs</li> <li>• Controls voluntary and skilled skeletal muscle activity</li> <li>• Acts in intellectual and emotional processing</li> </ul> <p><b>Basal nuclei:</b></p> <ul style="list-style-type: none"> <li>• Subcortical motor centers help control skeletal muscle movements (see Figure 7.14)</li> </ul>
<b>Diencephalon</b>	
	<p><b>Thalamus:</b></p> <ul style="list-style-type: none"> <li>• Relays sensory impulses to cerebral cortex</li> <li>• Relays impulses between cerebral motor cortex and lower motor centers</li> <li>• Involved in memory</li> </ul> <p><b>Hypothalamus:</b></p> <ul style="list-style-type: none"> <li>• Chief integration center of autonomic (involuntary) nervous system</li> <li>• Regulates body temperature, food intake, water balance, and thirst</li> <li>• Regulates hormonal output of anterior pituitary gland and acts as an endocrine organ (producing ADH and oxytocin)</li> </ul>
	<p><b>Limbic system—A functional system:</b></p> <ul style="list-style-type: none"> <li>• Includes cerebral and diencephalon structures (e.g., hypothalamus and anterior thalamic nuclei)</li> <li>• Mediates emotional response; involved in memory processing</li> </ul>
<b>Brain stem</b>	
	<p><b>Midbrain:</b></p> <ul style="list-style-type: none"> <li>• Contains visual and auditory reflex centers</li> <li>• Contains subcortical motor centers</li> <li>• Contains nuclei for cranial nerves III and IV; contains projection fibers (e.g., fibers of the pyramidal tracts)</li> </ul> <p><b>Pons:</b></p> <ul style="list-style-type: none"> <li>• Relays information from the cerebrum to the cerebellum</li> <li>• Cooperates with the medullary centers to control respiratory rate and depth</li> <li>• Contains nuclei of cranial nerves V–VII; contains projection fibers</li> </ul> <p><b>Medulla oblongata:</b></p> <ul style="list-style-type: none"> <li>• Relays ascending sensory pathway impulses from skin and proprioceptors</li> <li>• Contains nuclei controlling heart rate, blood vessel diameter, respiratory rate, vomiting, etc.</li> <li>• Relays sensory information to the cerebellum</li> <li>• Contains nuclei of cranial nerves VIII–XII; contains projection fibers</li> <li>• Site of crossover of pyramids</li> </ul>
	<p><b>Reticular formation—A functional system:</b></p> <ul style="list-style-type: none"> <li>• Maintains cerebral cortical alertness; filters out repetitive stimuli</li> <li>• Helps regulate skeletal and visceral muscle activity</li> </ul>
<b>Cerebellum</b>	
	<p><b>Cerebellum:</b></p> <ul style="list-style-type: none"> <li>• Processes information from cerebral motor cortex, proprioceptors, and visual and equilibrium pathways</li> <li>• Provides “instructions” to cerebral motor cortex and subcortical motor centers, resulting in smooth, coordinated skeletal muscle movements</li> <li>• Responsible for proper balance and posture</li> </ul>



**Figure 7.15** Frontal section (facing posteriorly) of the brain showing commissural, association, and projection fibers running through the cerebrum and the lower CNS. Notice the *internal capsule* that passes between the thalamus and the basal nuclei.

**Basal Nuclei** Although most of the gray matter is in the cerebral cortex, there are several “islands” of gray matter, called the **basal nuclei**, buried deep within the white matter of the cerebral hemispheres (see Figure 7.15). The basal nuclei help regulate voluntary motor activities by modifying instructions (particularly in relation to starting or stopping movement) sent to the skeletal muscles by the primary motor cortex. A tight band of projection fibers, called the *internal capsule*, passes between the thalamus and the basal nuclei.

### Homeostatic Imbalance 7.3

Individuals who have problems with their basal nuclei are often unable to walk normally or carry out other voluntary movements in a normal way. *Huntington’s disease* and *Parkinson’s disease* are two examples of such syndromes. (See “A Closer Look” on pp. 278–279. 

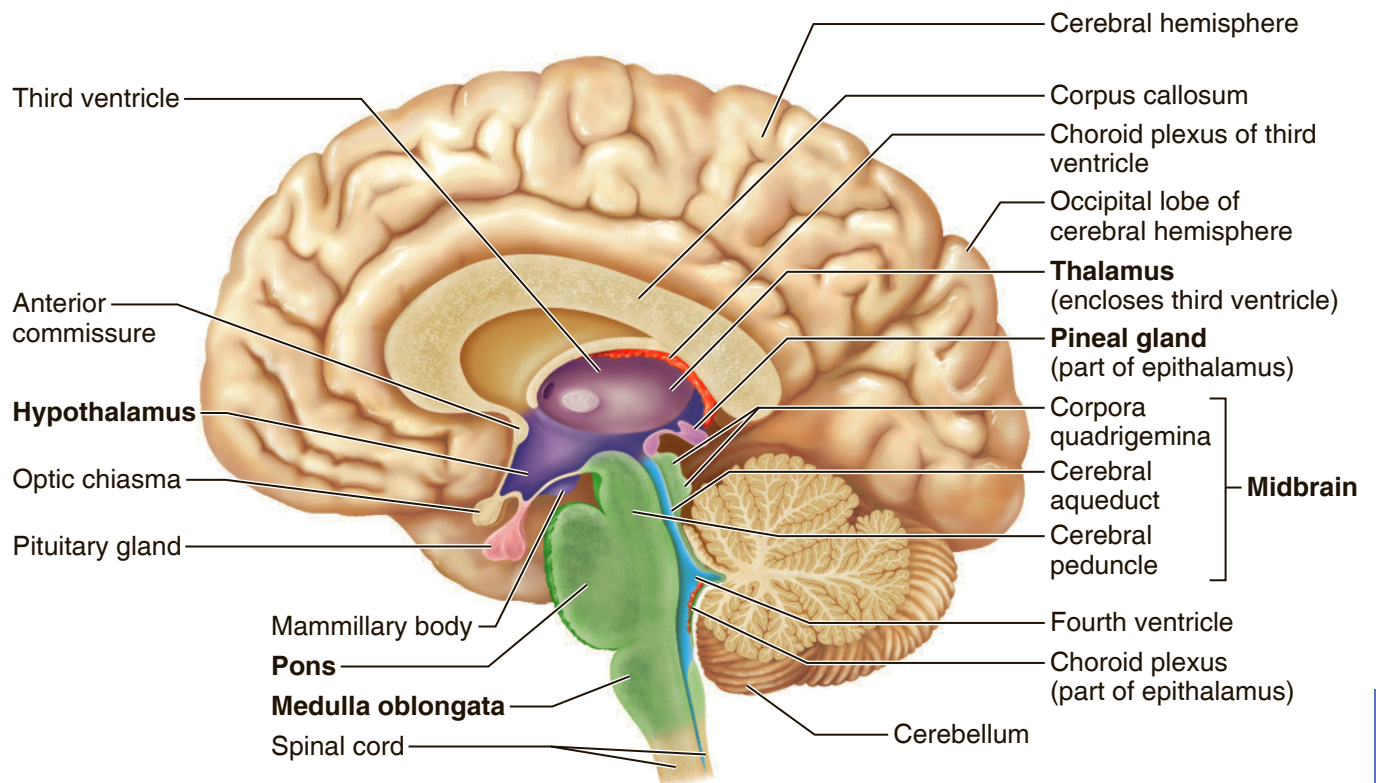
### Did You Get It?

12. What are the three major regions of the cerebrum?
13. What is the composition of white matter of the brain?

For answers, see Appendix A.

### Diencephalon

The **diencephalon**, or **interbrain**, sits atop the brain stem and is enclosed by the cerebral hemispheres (see Figure 7.12). The major structures of the diencephalon are the *thalamus*, *hypothalamus*, and *epithalamus* (Figure 7.16). The **thalamus**, which encloses the shallow *third ventricle* of the brain, is a relay station for sensory impulses passing upward to the sensory cortex. As impulses surge through the thalamus, we have a crude recognition of whether the sensation we are about to have is pleasant or unpleasant. It is the neurons of the sensory cortex that actually localize and interpret the sensation.



(a)

**Figure 7.16 Diencephalon and brain stem structures.** (a) A midsagittal section of the brain illustrating the diencephalon (purple) and brain stem (green).

(Figure continues on page 272.)

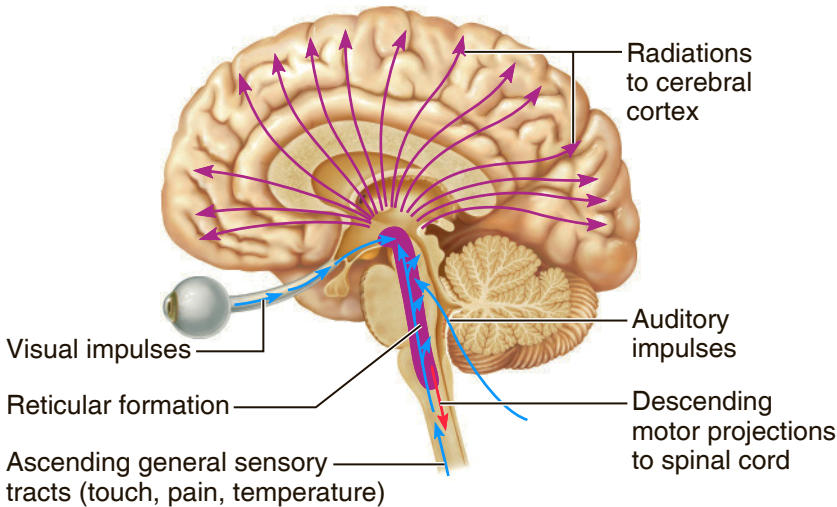
The **hypothalamus** (literally, “under the thalamus”) makes up the floor of the diencephalon. It is an important autonomic center because it plays a role in regulating body temperature, water balance, and metabolism. The hypothalamus is also the center for many drives and emotions, and as such it is an important part of the so-called **limbic system**, or “emotional-visceral brain.” For example, thirst, appetite, sex, pain, and pleasure centers are in the hypothalamus. Additionally, the hypothalamus regulates the pituitary gland (an endocrine organ) and produces two hormones of its own. The **pituitary gland** hangs from the anterior floor of the hypothalamus by a slender stalk. (We discuss its function in Chapter 9.) The **mammillary bodies**, reflex centers involved in olfaction (the sense of smell), bulge from the floor of the hypothalamus posterior to the pituitary gland.

The **epithalamus** (ep’i-thal’ah-mus) forms the roof of the third ventricle. Important parts of the epithalamus are the **pineal gland** (part of the endocrine system) and the **choroid plexus** of the third ventricle. The choroid plexuses, which are knots of capillaries within each of the four ventricles, form the cerebrospinal fluid.

### Brain Stem

The **brain stem** is about the size of a thumb in diameter and approximately 3 inches (approximately 7.5 cm) long. Its structures are the *midbrain*, *pons*, and *medulla oblongata*. In addition to providing a pathway for ascending and descending tracts, the brain stem has many small gray matter areas. These nuclei produce the rigidly programmed autonomic behaviors necessary for survival. In addition, some are associated with the cranial nerves and control vital activities such as breathing and blood pressure. Identify the brain stem areas (see Figure 7.16) as you read the descriptions that follow.

**Midbrain** A relatively small part of the brain stem, the **midbrain** extends from the mammillary bodies to the pons inferiorly. The **cerebral aqueduct**, a tiny canal that travels through the midbrain, connects the third ventricle of the diencephalon to the fourth ventricle below. Anteriorly, the midbrain is composed primarily of two bulging fiber tracts, the **cerebral peduncles** (pe’dun klz) (literally, “little feet of the cerebrum”), which convey ascending and descending impulses. Dorsally



(b)

located are four rounded protrusions called the **corpora quadrigemina** (kor'por-ah kwah'drĭ-jem'ĭ-nah) because they reminded some anatomist of two pairs of twins (*gemini*). These bulging nuclei are reflex centers involved with vision and hearing.

**Pons** The **pons** (ponz) is the rounded structure that protrudes just below the midbrain. *Pons* means “bridge,” and this area of the brain stem is mostly fiber tracts (bundles of nerve fibers in the CNS). However, it does have important nuclei involved in the control of breathing.

**Medulla Oblongata** The **medulla oblongata** (mĕ-dul'ah ob'long-gă'tah) is the most inferior part of the brain stem. It merges into the spinal cord below without any obvious change in structure. Like the pons, the medulla is an important fiber tract area. Additionally, the medulla is the area where the important pyramidal tracts (motor fibers) cross over to the opposite side. The medulla also contains many nuclei that regulate vital visceral activities. It contains centers that control heart rate, blood pressure, breathing, swallowing, and vomiting, among others. The **fourth ventricle** lies posterior to the pons and medulla and anterior to the cerebellum.

**Reticular Formation** Extending the entire length of the brain stem is a diffuse mass of gray matter, the **reticular formation**. The neurons of the reticular formation are involved in motor control of the visceral organs—for example, controlling smooth

**Figure 7.16 (continued) (b)** The reticular formation, which extends the length of the brain stem. Ascending arrows indicate sensory input to the cerebrum. Descending arrows indicate efferent output of reticular neurons.

muscle in the digestive tract. A special group of reticular formation neurons, the **reticular activating system (RAS)**, plays a role in consciousness and the awake/sleep cycle (Figure 7.16b). The RAS also acts as a filter for the flood of sensory inputs that streams up the spinal cord and brain stem daily. Weak or repetitive signals are filtered out, but unusual or strong impulses do reach consciousness. Damage to this area can result in prolonged unconsciousness (coma).

### Cerebellum

The large, cauliflower-like **cerebellum** (ser'e-bel'um) projects dorsally from under the occipital lobe of the cerebrum. Like the cerebrum, the cerebellum has two hemispheres and a convoluted surface. The cerebellum also has an outer cortex made up of gray matter and an inner region of white matter.

The cerebellum provides the precise timing for skeletal muscle activity and controls our balance. Thanks to its activity, body movements are smooth and coordinated. It plays its role less well when it is sedated by alcohol. Fibers reach the cerebellum from the equilibrium apparatus of the inner ear, the eye, the proprioceptors of the skeletal muscles and tendons, and many other areas. The cerebellum can be compared to an automatic pilot, continuously comparing the brain's “intentions” with actual body performance by monitoring body position and the amount of tension in various body parts. When needed, the cerebellum sends messages to initiate the appropriate corrective measures.

### Homeostatic Imbalance 7.4

If the cerebellum is damaged (for example, by a blow to the head, a tumor, or a stroke), movements become clumsy and disorganized—a condition called **ataxia** (uh tax'e uh). Victims cannot keep their balance and may appear drunk because of the loss of muscle coordination. They are no longer able to touch their finger to their nose with eyes closed—a feat that healthy individuals accomplish easily. \_\_\_\_\_+

#### Did You Get It?

14. Which brain region controls such vital activities as breathing and blood pressure—cerebrum, brain stem, or cerebellum?
15. What is the function of the cerebellum?
16. In what major brain region are the thalamus, hypothalamus, and pineal gland found?

For answers, see Appendix A.

## Protection of the Central Nervous System

### → Learning Objectives

- Name the three meningeal layers, and state their functions.
- Discuss the formation and function of cerebrospinal fluid and the blood-brain barrier.

Nervous tissue is soft and delicate, and even slight pressure can injure the irreplaceable neurons. As we saw in Chapter 5, nature tries to protect the brain and spinal cord by enclosing them within bone (the skull and vertebral column). Now, let's focus on three additional protections for the CNS: the meninges, cerebrospinal fluid, and blood-brain barrier.

### Meninges

The three connective tissue membranes covering and protecting the CNS structures are **meninges** (mě-nin'jēz) (Figure 7.17, p. 274). The outermost layer, the leathery **dura mater** (du'rah ma'ter), meaning “tough or hard mother,” is a double-layered membrane where it surrounds the brain. One of its layers is attached to the inner surface of the skull, forming the periosteum (*periosteal layer*). The other, called the *meningeal layer*, forms the outermost covering of the brain and continues as the dura mater of the spinal cord. The dural layers are fused together except in three areas where they separate to enclose *dural venous sinuses* that

collect venous blood, such as the superior sagittal sinus.

In several places, the inner dural membrane extends inward to form a fold that attaches the brain to the cranial cavity. Two of these folds, the **falx** (falks) **cerebri** and the **tentorium cerebelli**, separate the cerebellum from the cerebrum (shown in Figure 7.17).

The middle meningeal layer is the weblike **arachnoid** (ah-rak'noïd) **mater** (see Figure 7.17). *Arachnida* means “spider,” and some think the arachnoid membrane looks like a cobweb. Its threadlike extensions span the **subarachnoid space** to attach it to the innermost membrane, the **pia** (pi'ah) **mater** (“gentle mother”). The delicate pia mater clings tightly to the surface of the brain and spinal cord, following every fold.

The subarachnoid space is filled with cerebrospinal fluid. (Remember that the choroid plexuses produce CSF). Specialized projections of the arachnoid membrane, **arachnoid granulations**, protrude through the dura mater. The cerebrospinal fluid is absorbed into the venous blood in the dural sinuses through the arachnoid granulations. Next, we will discuss the production and flow of cerebrospinal fluid.

### Homeostatic Imbalance 7.5

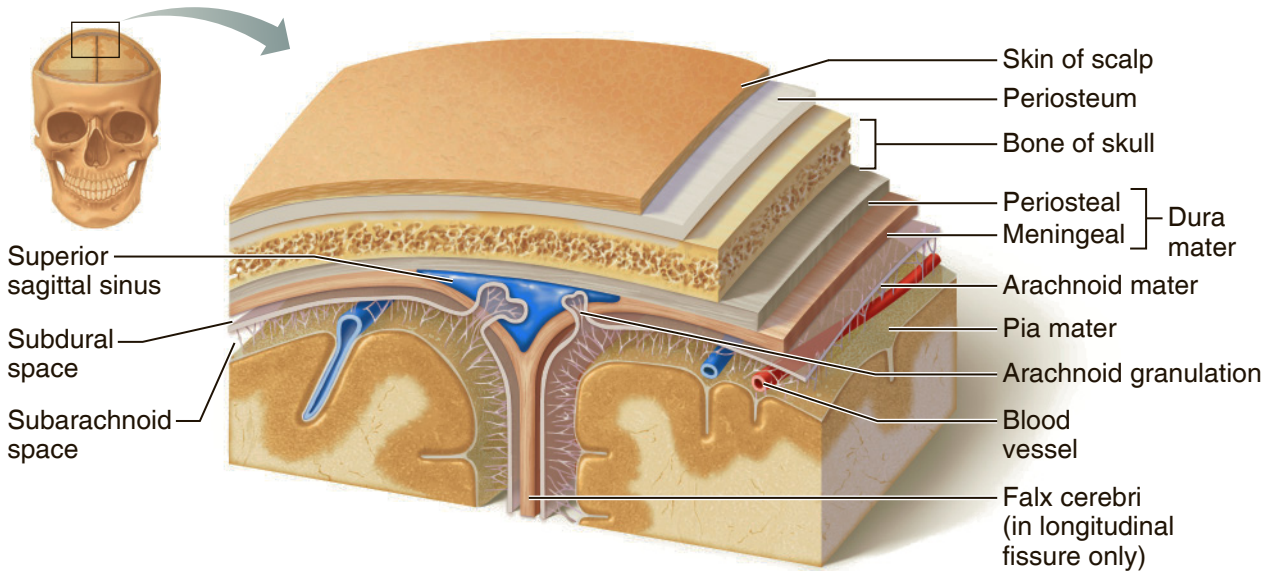
**Meningitis**, an inflammation of the meninges, is a serious threat to the brain because bacterial or viral meningitis may spread into the nervous tissue of the CNS. This condition of brain inflammation is called **encephalitis** (en-sef-ah-li'tis). Meningitis is usually diagnosed by taking a sample of cerebrospinal fluid from the subarachnoid space surrounding the spinal cord. \_\_\_\_\_+

### Cerebrospinal Fluid

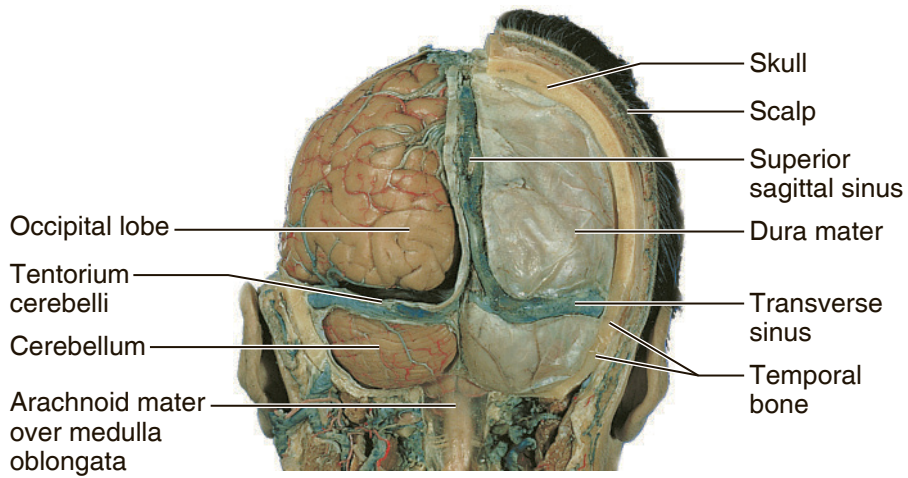
**Cerebrospinal** (ser'e-bro-spi'nal) **fluid (CSF)** is a watery “broth” with components similar to blood plasma, from which it forms. However, it contains less protein and more vitamin C, and its ion composition is different.

The choroid plexuses—clusters of capillaries hanging from the “roof” in each of the brain's **ventricles**, or enlarged chambers—continually form CSF from blood. The CSF in and around the brain and cord forms a watery cushion that protects the fragile nervous tissue from blows and other

**Q:** What would be the consequence of blocked arachnoid granulations?



(a)



(b)

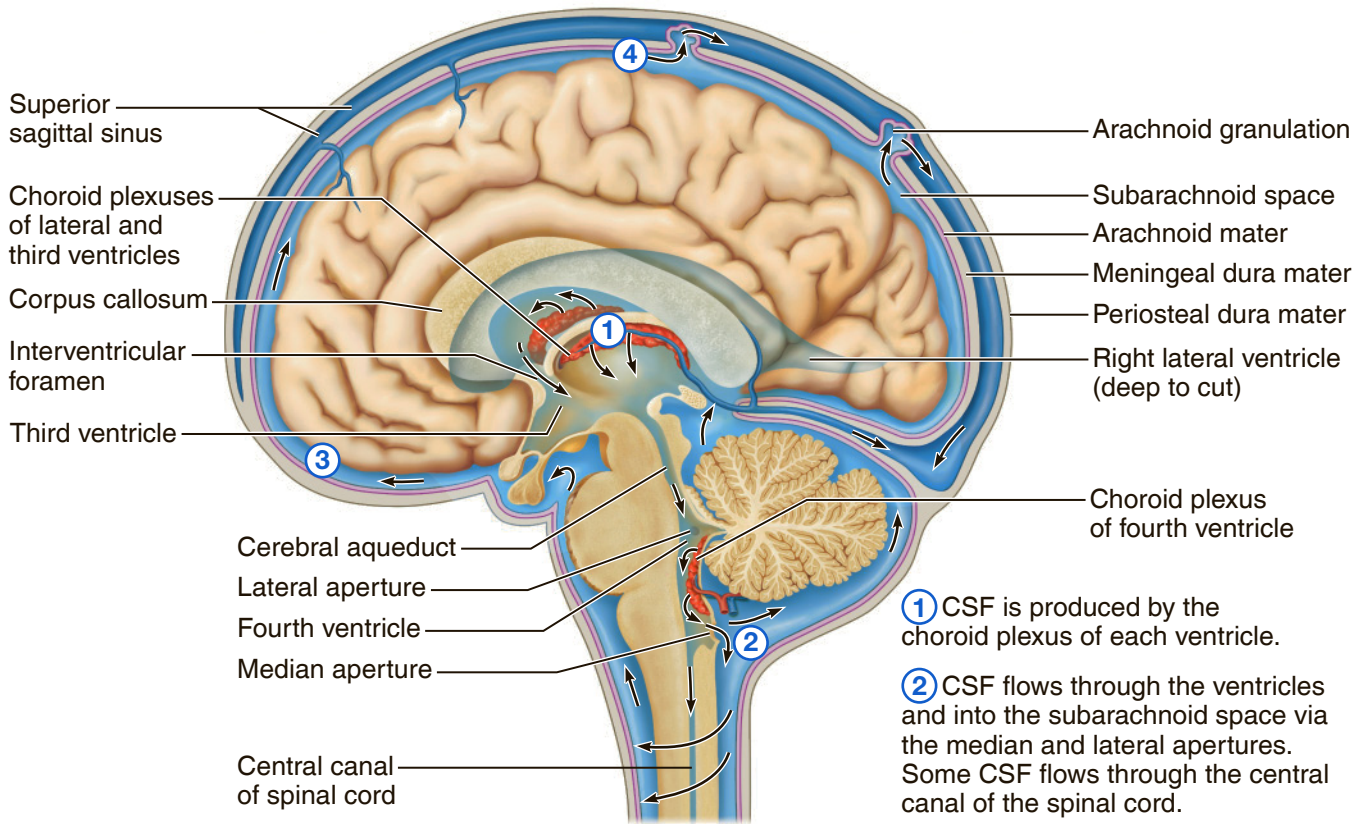
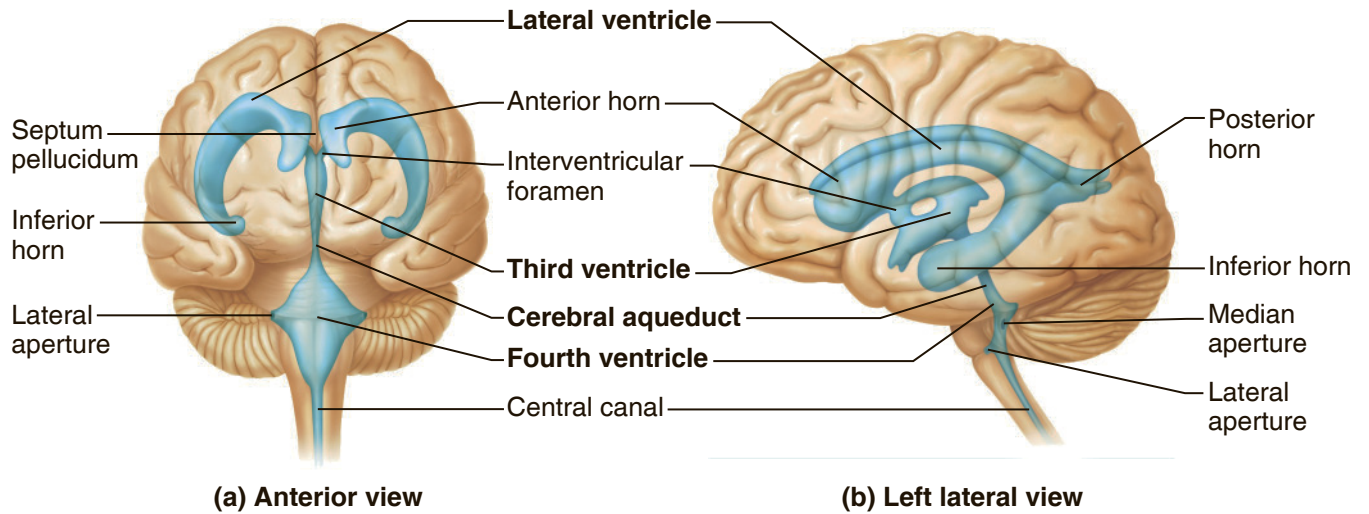
**Figure 7.17 Meninges of the brain.** (a) Three-dimensional frontal section showing the meninges—the dura mater, arachnoid mater, and pia mater—that surround and protect the brain. The relationship of the dura mater to the falx cerebri and the superior sagittal (dural) venous sinus is also shown. (b) Posterior view of the brain in place surrounded by the dura mater.

trauma, and helps the brain “float” so it is not damaged by the pressure of its own weight.

Inside the brain, CSF is continually moving (as indicated by the numbered pathway in **Figure 7.18c**).

It circulates from the two lateral ventricles (in the cerebral hemispheres) into the third ventricle (in the diencephalon) and then through the cerebral aqueduct of the midbrain into the fourth ventricle dorsal to the pons and medulla oblongata. Some of the fluid reaching the fourth ventricle simply continues down into the spinal cord, but most of it

**A:** Hydrocephalus (“water on the brain”). The ventricles would expand as cerebrospinal fluid, unable to drain into the dural venous sinus, accumulated.



**(c) CSF circulation**

- ① CSF is produced by the choroid plexus of each ventricle.
- ② CSF flows through the ventricles and into the subarachnoid space via the median and lateral apertures. Some CSF flows through the central canal of the spinal cord.
- ③ CSF flows through the subarachnoid space.
- ④ CSF is absorbed into the dural venous sinuses via the arachnoid granulations.

**Figure 7.18 Ventricles and location of the cerebrospinal fluid.** (a, b) Three-dimensional views of the ventricles of the brain.

**(c)** Circulatory pathway of the cerebrospinal fluid (indicated by arrows) within the central nervous system and the subarachnoid space.

(The relative position of the right lateral ventricle is indicated by the pale blue area deep to the corpus callosum.)

circulates into the subarachnoid space through three openings, the paired lateral apertures and the median aperture (*aper* = open), in the walls of the fourth ventricle. The CSF returns to the blood in the dural venous sinuses through the arachnoid granulations. In this way, CSF is continually replaced.

Ordinarily, CSF forms and drains at a constant rate so that its normal pressure and volume (150 ml—about half a cup) are maintained. Any significant changes in CSF composition (or the appearance of blood cells in it) could indicate meningitis or certain other brain pathologies (such as tumors or multiple sclerosis). A procedure called a *lumbar (spinal) puncture* can obtain a sample of CSF for testing. Because the withdrawal of fluid decreases CSF fluid pressure, the patient must remain horizontal (lying down) for 6 to 12 hours after the procedure to prevent an agonizingly painful “spinal headache.”

### Homeostatic Imbalance 7.6

If something obstructs its drainage (for example, a tumor), CSF begins to accumulate and exert pressure on the brain. This condition is **hydrocephalus** (hi-dro-sef’ah-lus), literally, “water on the brain.” Hydrocephalus in a newborn baby causes the head to enlarge as the brain increases



Hydrocephalus in an infant.

in size. This is possible in an infant because the skull bones have not yet fused. However, in an adult this condition is likely to result in brain damage because the skull is hard, and the accumulating fluid creates pressure that crushes soft nervous tissue and could restrict blood flow into the brain. Today hydrocephalus is treated surgically by inserting a shunt (a plastic tube) to drain the excess fluid into a vein in the neck or abdomen. \_\_\_\_\_+

### The Blood-Brain Barrier

No other body organ is so absolutely dependent on a constant internal environment as is the brain. Other body tissues can withstand the rather small fluctuations in the concentrations of hormones, ions, and nutrients that continually occur, particularly after eating or exercising. If the brain were exposed to such chemical changes, uncontrolled neural activity might result—remember that certain ions (sodium and potassium) are involved in initiating nerve impulses and that some amino acids serve as neurotransmitters.

Consequently, neurons are kept separated from bloodborne substances by the **blood-brain barrier**, composed of the *least* permeable capillaries in the whole body. These capillaries are almost seamlessly bound together by tight junctions all around. Of water-soluble substances, only water, glucose, and essential amino acids pass easily through the walls of these capillaries. Metabolic wastes, such as urea, toxins, proteins, and most drugs, are prevented from entering brain tissue. Nonessential amino acids and potassium ions not only are prevented from entering the brain, but also are actively pumped from the brain into the blood across capillary walls. Although the bulbous “feet” of the astrocytes that cling to the capillaries may contribute to the barrier, the relative impermeability of the brain capillaries is most responsible for providing this protection.

The blood-brain barrier is virtually useless against fats, respiratory gases, and other fat-soluble molecules that diffuse easily through all plasma membranes. This explains why bloodborne alcohol, nicotine, and anesthetics can affect the brain.

### Did You Get It?

17. What name is given to the cerebrospinal fluid-filled cavities within the brain?
18. What name is given to the barrier that protects the brain from toxic chemicals?