motor activities by modifying instructions sent to the skeletal muscles by the primary motor cortex.

Homeostatic Imbalance

Individuals who have problems with their basal nuclei are often unable to walk normally or carry out other voluntary movements in the usual normal way. *Huntington's disease* (or *Huntington's chorea*) and *Parkinson's disease,* two examples of such syndromes, are discussed in the "A Closer Look" box on pages 245–246. ▲

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* (see Figure 7.15). 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. The actual localization and interpretation of the sensation is done by the neurons of the sensory cortex.

The **hypothalamus** (literally, "under the thalamus") makes up the floor of the diencephalon. It is an important autonomic nervous system center because it plays a role in the regulation of 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. (Its function is discussed 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″ĭ-thal′ah-mus) forms the roof of the third ventricle. Important parts of the epithalamus are the **pineal body** (part of the endocrine system) and the **choroid** (ko′roid) **plexus** of the third ventricle. The choroid plexuses, knots of capillaries within each ventricle, 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 are part of the cranial nerves and control vital activities such as breathing and blood pressure. Identify the brain stem areas in Figure 7.15 as you read their descriptions that follow.

Midbrain The **midbrain** is a relatively small part of the brain stem. It extends from the mammillary bodies to the pons inferiorly. The **cerebral aqueduct** is a tiny canal that travels through the midbrain and 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** (literally, "little feet of the cerebrum"), which convey ascending and descending impulses. Dorsally 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. 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. 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. A special group of reticular formation neurons, the **reticular activating system (RAS),** plays a role in consciousness and the awake/sleep

cycles (Figure 7.15b). Damage to this area can result in permanent unconsciousness (coma).

Cerebellum

The large, cauliflowerlike **cerebellum** (ser″e-bel′um) projects dorsally from under the occipital lobe of the cerebrum. Like the cerebrum, it 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 and equilibrium. Because of its activity, body movements are smooth and coordinated. 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 amount of tension in various body parts. When needed, it sends messages to initiate the appropriate corrective measures.

Homeostatic Imbalance

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*. Victims cannot keep their balance and may appear to be 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 normal individuals accomplish easily.

Protection of the Central Nervous System

Nervous tissue is very soft and delicate, and the irreplaceable neurons are injured by even the slightest pressure. Nature has tried to protect the brain and spinal cord by enclosing them within bone (the skull and vertebral column), membranes (the meninges), and a watery cushion (cerebrospinal fluid). Protection from harmful substances in the blood is provided by the so-called blood-brain barrier. Since we have already considered the bony enclosures (Chapter 5), we will focus on the other protective devices here.

Meninges

The three connective tissue membranes covering and protecting the CNS structures are **meninges** (mĕ-nin′jēz) (Figure 7.16). 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 sinuses* that collect venous blood.

In several places, the inner dural membrane extends inward to form a fold that attaches the brain to the cranial cavity. One of these folds, the **falx** (falks) **cerebri,** is shown in Figure 7.16a. Another such fold, the **tentorium cerebelli** separating the cerebellum from the cerebrum, is shown in Figures 7.16b and 7.17c.

The middle meningeal layer is the weblike **arachnoid** (ah-rak′noid) **mater** (see Fig. 7.16). *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. Specialized projections of the arachnoid membrane, **arachnoid villi** (vih′li), protrude through the dura mater. The cerebrospinal fluid is absorbed into the venous blood in the dural sinuses through the arachnoid villi.

Homeostatic Imbalance

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.

Cerebrospinal Fluid

Cerebrospinal (ser″e-bro-spi′nal) **fluid (CSF)** is a watery "broth" similar in its makeup to blood plasma, from which it forms. However, it contains less protein, more vitamin C, and its ion composition is different.

CSF is continually formed from blood by the choroid plexuses. Choroid plexuses are clusters of