3

Internal Anatomy of the Central Nervous System

LEARNING OBJECTIVES

After studying this chapter, students should be able to:

- Identify the shapes of corticospinal fibers at different neuraxial levels

- Recognize the ventricular cavity at various neuroaxial levels

- Recognize major internal anatomic structures of the spinal cord and describe their functions

- Recognize important internal anatomic structures of the medulla and explain their functions

- Recognize important internal anatomic structures of the pons and describe their functions

- Identify important internal anatomic structures of the midbrain and discuss their functions

- Recognize important internal anatomic structures of the forebrain (diencephalon, basal ganglia, and limbic structures) and describe their functions

- Follow the continuation of major anatomic structures and relate them in each sequential section of the brain

The gross anatomic (cortical, subcortical, meninges, ventricles, and medullary centers) structures were discussed in relation to their functions and locations in Chapter 2. The next step is to use specific and easily identified anatomic structures as signposts for developing an orientation to the internal anatomy of the brain in relation to the surrounding structures. Exposure to the internal brain structures often is neglected in teaching neuroscience to students of communicative disorders and human behavior. Learning internal brain anatomy is the most significant part of training in neuroscience, and this knowledge is essential for solving clinical problems and reading brain images. Internal anatomy is best learned by repeated exposure to the serial sections of the spinal cord, brainstem, and forebrain. In this chapter, the spinal cord, brainstem, and diencephalon are examined via stained sections, and the forebrain is studied on unstained sections.

Nuclear structures and fiber tracts related to various functional systems exist side by side at each level of the nervous system. Because disease processes in the brain rarely strike only one anatomic structure or pathway, there is a tendency for a series of related and unrelated clinical symptoms to emerge after a brain injury. A thorough knowledge of the internal brain structures, including their shape, size, location, and proximity, makes it easier to understand their functional significance. In addition, the proximity of nuclear structures and fiber tracts explains multiple symptoms that may develop from a single lesion site.

ANATOMIC ORIENTATION LANDMARKS

Two distinct anatomic landmarks used for visual orientation to the internal anatomy of the brain are the shapes of the descending **corticospinal fibers** and the **ventricular cavity** (Fig. 3-1). Both are present throughout the brain, although their shape and size vary as one progresses caudally from the rostral forebrain (telencephalon) to the caudal brainstem. Consequently, familiarity with the progressively changing shapes and sizes of these structures is essential for identifying the various brain levels that they represent.

Shapes of Corticospinal Fibers

Immediately after their origin in the sensorimotor cortex, the corticospinal fibers fan down through the **corona radiata** (see Fig. 2-38) to enter the wedge-shaped **internal capsule** at the *diencephalic level* (Fig. 3-1*A*; see Figs. 2-15 and 2-16). Along the ventral surface of the midbrain, they form the **pes pedunculi** (crus cerebri), a bilaterally compact fillet-shaped mass of fibers on a cross-sectional view (Fig. 3-1*B*; see Fig. 2-24). The fibers of the corticospinal tract later disperse among the scattered pontine nuclei and appear as many irregular round masses scattered throughout the basal pons (Fig. 3-1*C*; see Fig. 2-25). The corticospinal tract fibers recombine when entering the medulla and form a **pyramid**, which is best viewed in gross and microscopic cross section of the caudal brainstem (Fig. 3-1*D*; see Fig. 2-26). The term *pyramid* gave origin to the term *pyramidal tract,* which is synonymous with *corticospinal tract*. Pyramidal fibers cross the midline at the
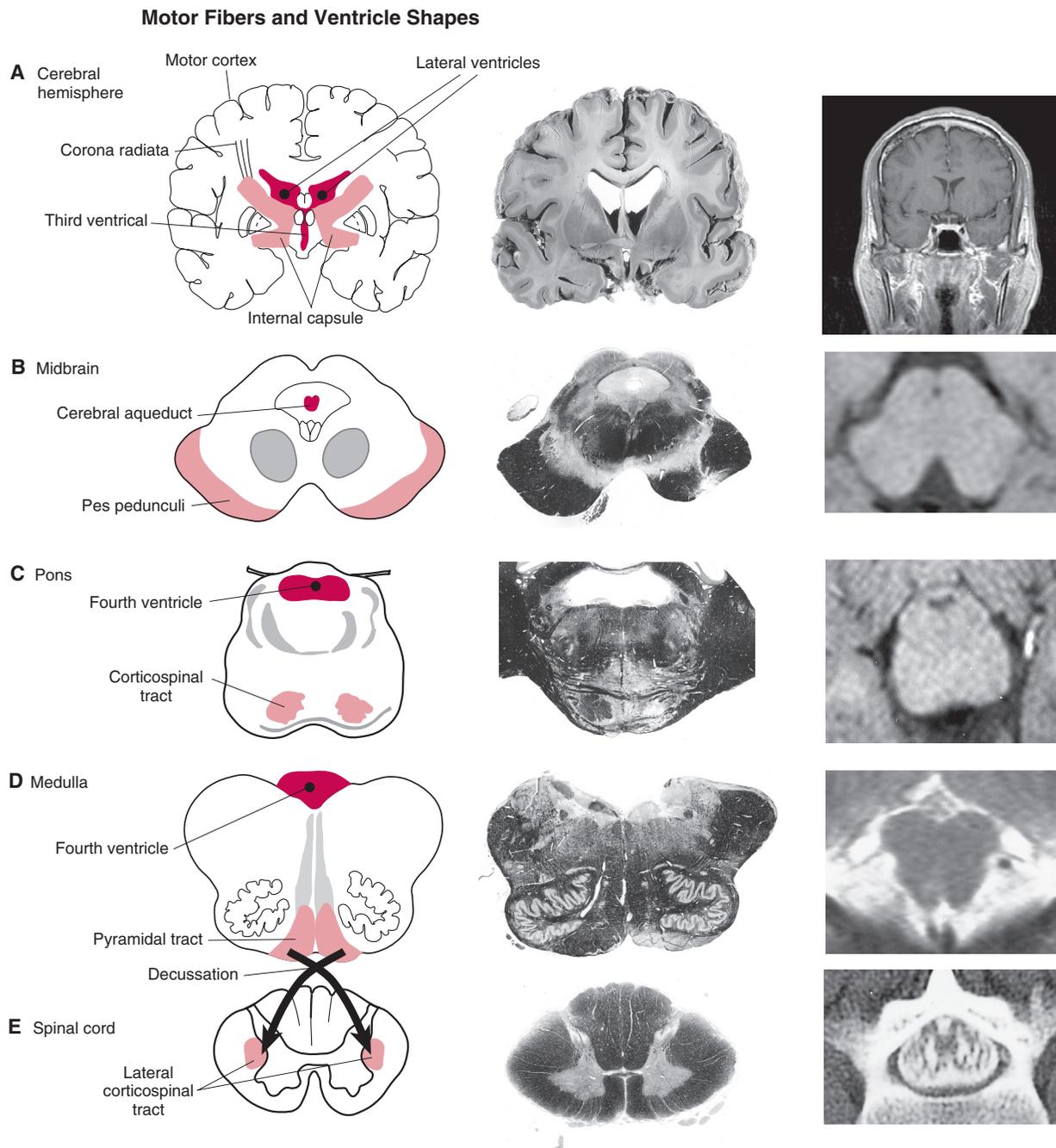
Motor Fibers and Ventricle Shapes

Figure 3-1 **A–E.** The shapes of the corticospinal fibers and the ventricular cavity at various neuroaxial levels.

caudal medulla; after crossing, they enter the **lateral funiculus** of the spinal cord and are known as the **lateral corticospinal tract** (Fig. 3-1*E*).

Shape of the Ventricular Cavity

The **lateral** and **third ventricles** together are butterfly-shaped in a cross-section of the rostral brain (Fig. 3-1*A*; see Fig. 2-16). The wings represent the two lateral ventricles and the body; the narrow slit in the middle marks the third ventricle. The **cerebral aqueduct** of Sylvius is the

small tube-shaped midbrain canal (Fig. 3-1*B*; see Fig. 2-24) that connects the **third** and **fourth ventricles**. The fourth ventricle overlies the pons (Fig. 3-1*D*; see Fig. 2-9); it tapers to end in the rostral medulla (Fig. 3-1*E*).

Important internal anatomic landmarks of central nervous system (CNS) have been serially examined. The spinal cord is examined in cross section. The midbrain, pons, and medulla are reviewed in transverse section. The **forebrain structures** (**cerebral cortex**, **diencephalon**, and **basal ganglia**) are studied in both coronal and horizontal sections.

SPINAL CORD IN CROSS-SECTIONS

The internal anatomy of the spinal cord is studied in four sections; a representative section is taken from each of the following anatomic divisions: **sacral**, **lumbar**, **thoracic**, and **cervical**. The basic internal anatomic pattern of the spinal cord remains the same throughout its extent from sacral to cervical regions. The **central gray matter** of the cord, made up of cell bodies, is shaped like a butterfly and appears gray in freshly cut sections. The outer part of the cord, which looks like the rim of a wheel, consists of ascending and descending fiber tracts (**white matter**) and surrounds the butterfly-shaped *central gray*. The fiber tracts form functionally related longitudinal funiculi, which are demarcated by longitudinal grooves and spinal nerve attachments along the surface of the spinal cord.

The only change in the internal anatomy of the spinal cord is the ratio of *white* to *gray matter* at each of the four spinal levels. That ratio gradually increases, from sacral to cervical, as new fibers are added to the afferent tracts. Additional changes relate to the shape of the gray matter; the spinal cord enlarges in the cervical and lumbar regions because of the relatively great extent of nerve supply needed for the sensory and motor functions of the upper and lower extremities (see Fig. 2-33). The important internal structures of the spinal cord include the sensory and motor nuclei and various ascending and descending tracts (Table 3-1).

Sacral Section

The *sacral structures* of the spinal cord are seen in Figure 3-2. This level of the cord, which is small in diameter, contains a thin mantle of white matter and a larger gray region with bulky **ventral** and **dorsal horns**. The **dorsal lemniscal column** consists of the ascending fibers of the **fasciculus gracilis**, which carry information concerning discriminative touch, pressure, and limb position from the lower half of the body. The fasciculus gracilis contains sensory fibers that enter the cord from the *sacral* to *mid-thoracic level*. The lateral column of the white matter at this level contains the lateral corticospinal tract and fibers of the anterolateral system. The *lateral corticospinal tract* transmits motor commands from the motor cortex via the **lower motor neurons** to the muscles. The **anterolateral system** consists of the **anterior** and **lateral spinothalamic tracts**, which mediate sensations of diffuse touch, pain, and temperature.

The large *ventral horns* are the sites of motor nuclei. The *dorsal horns* contain the sensory nuclei, which include the **substantia gelatinosa** and **nucleus proprius** (see Chapter 7); these nuclei are present throughout the spinal cord and receive input predominantly from spinal sensory nerves. Other sensory spinal cells include the **nucleus dorsalis of Clark**. Many dorsal horn cells give rise to fibers of the *spinocerebellar* (unconscious proprioception) and *anterolateral system* (pain and temperature).

Table 3-1
Anatomic Structures of the Spinal Cord

Dorsal median sulcus

Ventral median sulcus

Dorsal intermediate sulcus

Gray matter

    Dorsal horns

    Ventral horns

White matter

    Dorsal fasciculus

    Lateral fasciculus

    Anterior fasciculus

Dorsal root

Ventral root

Sensory nuclei in gray column

Motor nuclei in gray column

Fasciculus gracilis and cuneatus

Spinothalamic (lateral and anterior) tracts

Spinocerebellar (dorsal and ventral) tracts

Lumbar Section

Figure 3-3 demonstrates the anatomic appearance of the *lumbar level* (at L4) of the spinal cord. The gray matter at this level contains larger *dorsal* and *ventral horns* in relation to the white matter. The *dorsal lemniscal* column continues
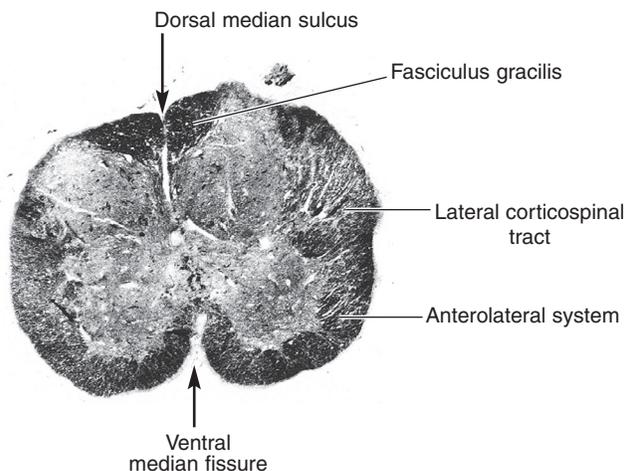

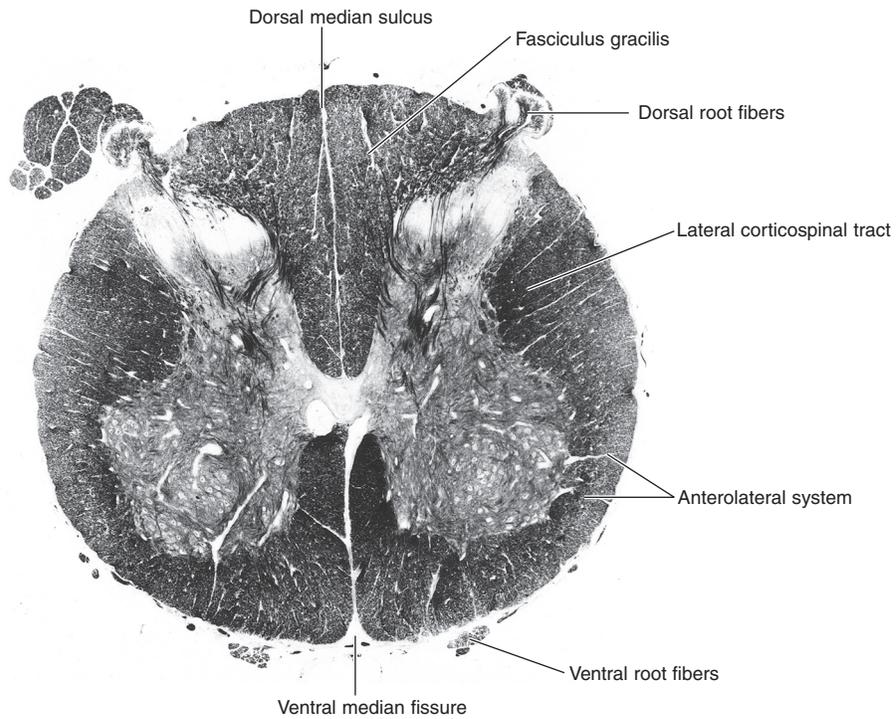**Figure 3-2** Cross-section of the spinal cord at the sacral level.

Figure 3-3 Cross-section of the spinal cord at the L4 level.

to exclusively represent fibers of the *fasciculus gracilis,* which is located lateral to the *dorsal median sulcus.* This level also contains the *lateral corticospinal tract* and the *anterolateral system,* consisting of the *spinothalamic* and *spinocerebellar tracts.* (The *spinocerebellar tract* is not identified in Fig. 3-3.) The dorsal horns contain the sensory nuclei, and the ventral horns contain the motor nuclei. Also present in this cross section are the *dorsal* and *ventral root fibers.*

Thoracic Section

The anatomic characteristics of the *thoracic* region (T4) of the spinal cord are shown in Figure 3-4. This spinal cord
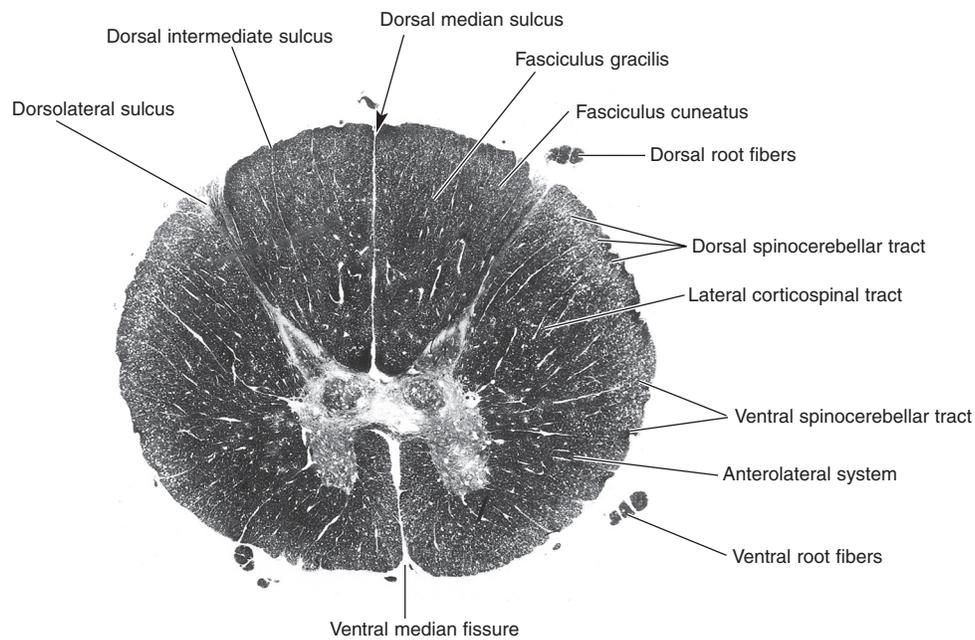

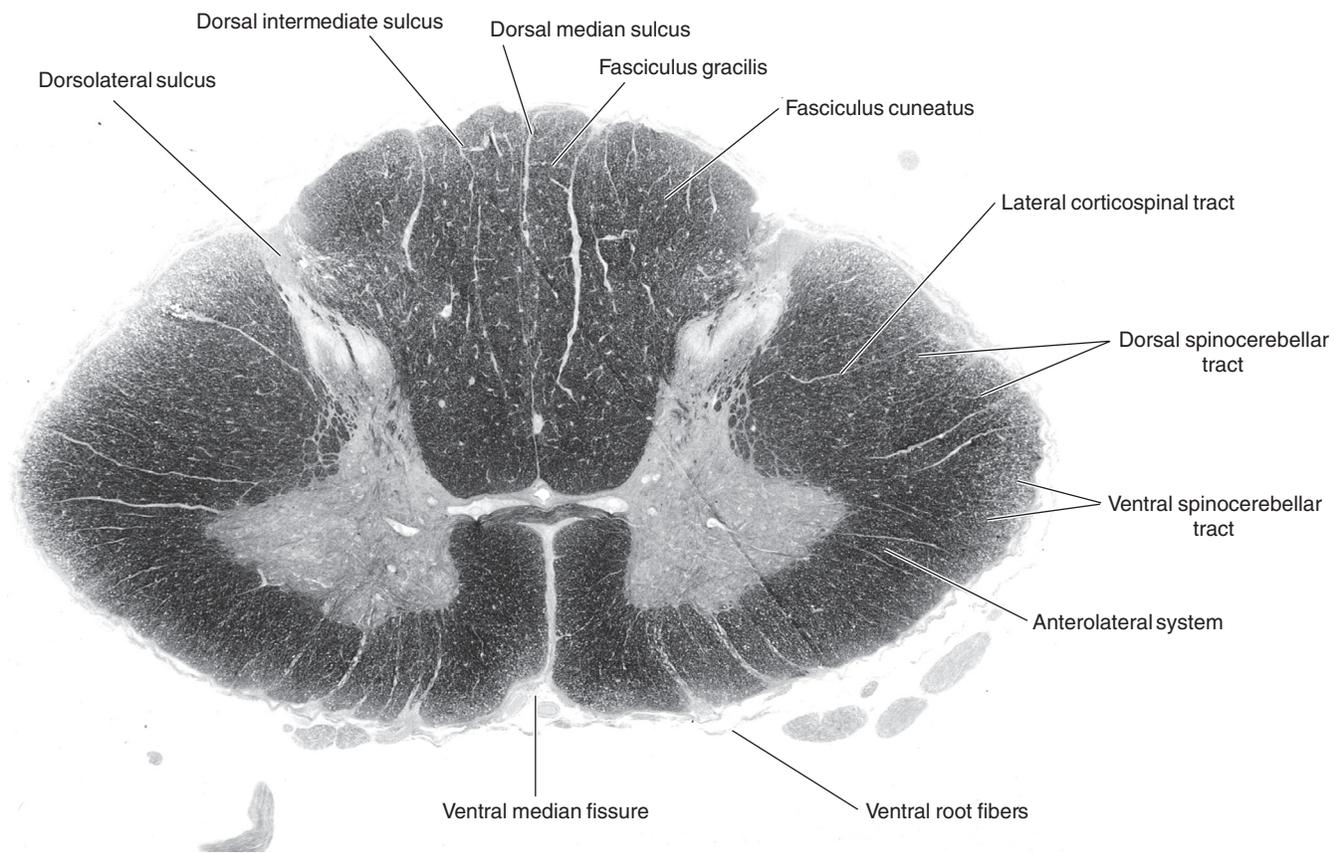**Figure 3-4** Cross-section of the spinal cord at the T4 level.

Figure 3-5 Cross-section of the spinal cord at the C7 level.

level is characterized by the reduced size of the gray matter and the enlarged share of white matter. Compared the previously discussed sections, the *dorsal* and *ventral horns* are smaller and tapered. The *dorsal lemniscal column* at this level is larger because of additional sensory fibers from the higher body levels. The additional sensory fibers form the **fasciculus cuneatus**, which ascend lateral to the *fasciculus gracilis* in the dorsal columns of the spinal cord. The fasciculus cuneatus fibers carry the sensations of fine discriminative touch, pressure, and limb position from the upper body; its fibers enter the spinal cord at the midthoracic through cervical levels. With emergence of the fasciculus cuneatus, the *dorsal intermediate sulcus* is visible as it separates the medially located fasciculus gracilis from the laterally located fibers of the fasciculus cuneatus. The *lateral corticospinal tract* is larger than at lower levels, although it retains the same relative lateral location. Mediating sensations of diffuse touch, pain, and temperature, the fibers of the *spinothalamic tracts* (*anterolateral system*) continue to occupy the same general space throughout the spinal cord.

Appearing along the lateral surface are the **dorsal** and **ventral spinocerebellar tracts**. Fibers of the spinocerebellar tracts mediate unconscious proprioception from the limbs to the cerebellum. Unconscious proprioception plays an important role in the acquisition and maintenance of skilled motor activities.

Cervical Section

Figure 3-5 displays the anatomic characteristics of the *cervical* (C7) region of the spinal cord. The volume of white matter at this level is much greater than at the lower spinal levels. In addition, the *dorsal horns* are slender, whereas the *ventral horns* are large and wing shaped. In the dorsal column, the now-large *fasciculi* of *gracilis* and *cuneatus* are demarcated by the *dorsal intermediate sulcus*. The *corticospinal tract* is relatively larger than at lower levels. This configuration of the lateral corticospinal tract marks the level below the **pyramidal decussation** (soon to take place rostral to this level at the junction of the spinal cord and the medulla). The lateral column of fibers continues to contain the *spinothalamic* and *spinocerebellar pathways*.

BRAINSTEM IN TRANSVERSE SECTIONS

The brainstem, as the axial part of the brain, protrudes from the base of the brain and consists of three structures: medulla oblongata, pons, and midbrain (see Fig. 2-22). Besides containing all ascending (sensory) and descending (motor) fiber tracts, the brainstem includes a large group of nuclei that relate to the sensorimotor functions of the cranial
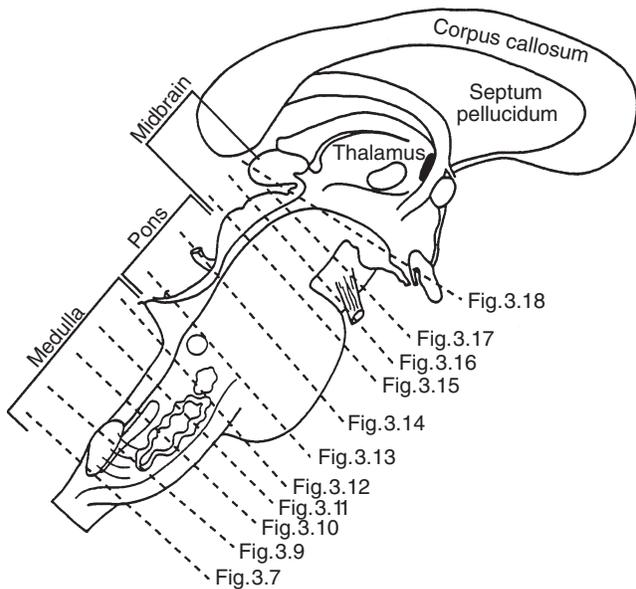
Figure 3-6 Location of the transverse sections of the brainstem shown in the specified figures.

nerves, serve various vital visceral (cardiac and respiratory) functions, and mediate the special senses and reflexive functions. The transverse sections of the brainstem discussed here are indicated in Figure 3-6.

Medulla Oblongata

The *medulla oblongata,* the most caudal portion of the brainstem, begins above the rootlets of the first cervical spinal nerve and gradually increases in size until rostrally it merges with the pons. Important structures in the medulla are the *corticospinal fibers* (pyramidal tract), *pyramidal decussation* (crossing of motor fibers), dorsal lemniscal column (*fasciculus gracilis* and *fasciculus cuneatus*), **sensory decussation**, **medial lemniscus**, **inferior cerebellar peduncle**, **principal** (**inferior**) **olivary nucleus**, **reticular formation**, and many cranial nerve nuclei (Table 3-2).

Caudal Medulla

The transverse section in Figure 3-7 is the most caudal view of the brainstem, where the medulla merges with the spinal cord at the foramen magnum (see Fig. 2-31A). Four important structures in the dorsal medulla are the *nucleus gracilis, fasciculus gracilis, nucleus cuneatus,* and *fasciculus cuneatus.*

The ascending fibers of the fasciculus gracilis synapse on the cells of the nucleus gracilis, and those of the fasciculus cuneatus synapse on the cells of the nucleus cuneatus. In the center of this medullary section is the crossing of the pyramidal fibers. After the crossing, the descending pyramidal fibers move to a lateral position in the spinal column and form the *lateral corticospinal tract* (Fig. 3-5). This crossing of the *corticospinal fibers* accounts for the motor cortex of one side of the brain controlling the opposite

Table 3-2

Anatomic Structures of the Medulla

Caudal (low) medulla
    Pyramid
    Decussation of pyramidal fibers
    Lateral corticospinal tract
    Fasciculus gracilis and cuneatus
    Nucleus gracilis and cuneatus
    Spinal trigeminal nucleus and tract

Middle medulla
    Nucleus gracilis and cuneatus
    Fasciculus gracilis and cuneatus
    Inferior cerebellar peduncle (restiform body)
    Sensory decussation
        Internal arcuate fibers
        Medial lemniscus
    Principal inferior olivary nucleus
    Pyramid
    Spinal trigeminal nucleus and tract

Rostral (high) medulla
    Principal inferior olivary nucleus
    Inferior cerebellar peduncle
    Cochlear nucleus
    Vestibular nucleus
    Medial lemniscus
    Pyramid
    Spinal trigeminal nucleus and tract

side of the body. Lateral to the fasciculus cuneatus is the massive formation of the **spinal trigeminal nucleus** and the **spinal trigeminal tract**.

The *spinal trigeminal tract* consists of fibers of the *trigeminal* (CN V) *nerve,* which mediates pain and temperature from the face. Fibers of this tract enter the brainstem, descend ipsilaterally in the medulla, and terminate in the *spinal trigeminal nucleus.* Secondary fibers from the spinal trigeminal nucleus cross the midline and ascend to the thalamus, from which impulses are relayed to the sensory cortex (see Chapter 7).

Medial to the trigeminal tract and nucleus are diffusely located cellular and fibrous components of the *reticular formation,* which extend throughout the brainstem. The reticular formation integrates complex behaviors and regulates cortical arousal (see Fig. 2-23). The *reticular formation* integrates all sensorimotor stimuli with internally generated thoughts, emotions, and cognition. It is also responsible for maintaining the homeostatic state of the brain, which is essential for regulating visceral (cardiovascular), sensorimotor (respiration), and neuroendocrine activities such as blood pressure and movement.
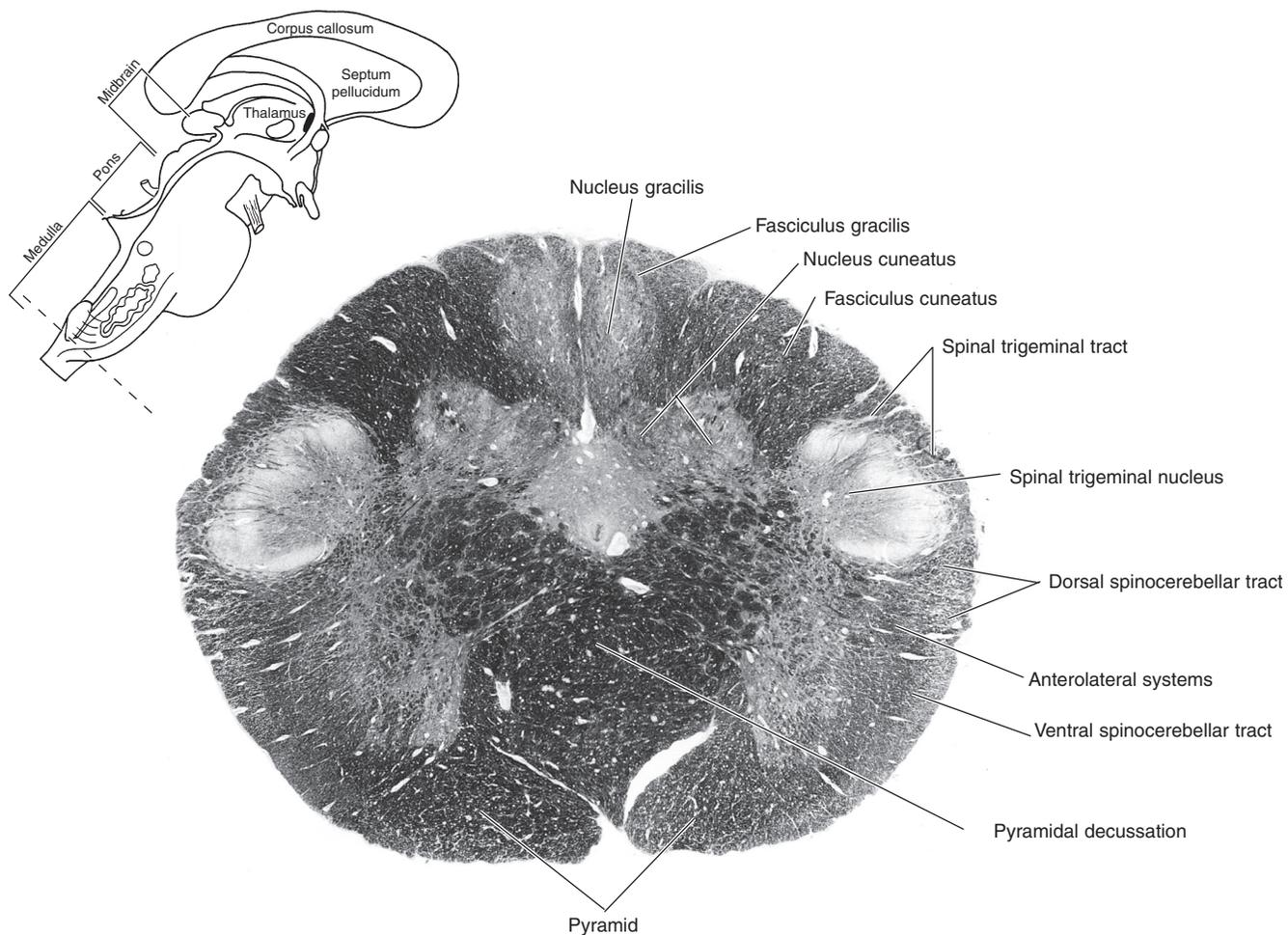
Figure 3-7 Transverse section of the medulla through the pyramidal decussation.

A discussion of the events related to the crossing of sensory fibers is important for an orientation to the course of the *dorsal column fibers* and their level of crossing (Fig. 3-8). The *fasciculi of gracilis* and *cuneatus* are the first-order sensory fibers; their sensory neurons are in the spinal *dorsal root ganglion.* Fibers of these two fasciculi enter the spinal cord and ascend on the same side in the *dorsal lemniscal column* and synapse on their respective nuclei in the medulla. These nuclei project secondary fibers across the midline as the **internal arcuate fibers**, which form the **medial lemniscus** and travel upward to relay information related to fine discriminative touch (deep touch, two-point touch, stereognosis, and proprioception) to the thalamus. The thalamocortical projections transmit the sensory information to the **primary sensory cortex** (Brodmann areas 3, 1, 2). Thus it becomes clear why three different terms (*dorsal lemniscal column, internal arcuate fibers,* and *medial lemniscus*) relate to fibers that mediate the same sensory information received from the *fasciculi of gracilis* and *cuneatus,* which transmit sensation from the lower and the upper body, respectively.

Caudal (Lower) Third of the Medulla

The transverse section in Figure 3-9 provides a better view of the *internal arcuate fibers* that arise from the *gracilis* and *cuneatus nuclei* and cross the midline. The gracile and cuneate nuclei attain their largest size at this level. The internal arcuate fibers from those nuclei cross the midline to form the medial lemniscus and then travel rostrally to the thalamus. At the medullary level, this *decussation* thus allows for the transmission of tactile and discriminative sensation from one side of the body to the opposite half of the brain. The *pyramids* in the ventromedial medulla appear as a compact *bundle* of fibers just rostral to the level at which they decussate. The decussations of the sensory internal arcuate fibers and motor *pyramidal fibers* are two landmarks of the caudal medulla.

The core of the *reticular formation* in the central third of the medulla is continuous with the lower levels. It is a net-like arrangement of cell bodies and interwoven projections that interact with virtually all sensorimotor systems and regulate brain functioning (see Fig. 2-23). The *central gray matter* is the *midbrain reticular–limbic area,* which regulates somatic and visceral functions. Beneath the central gray
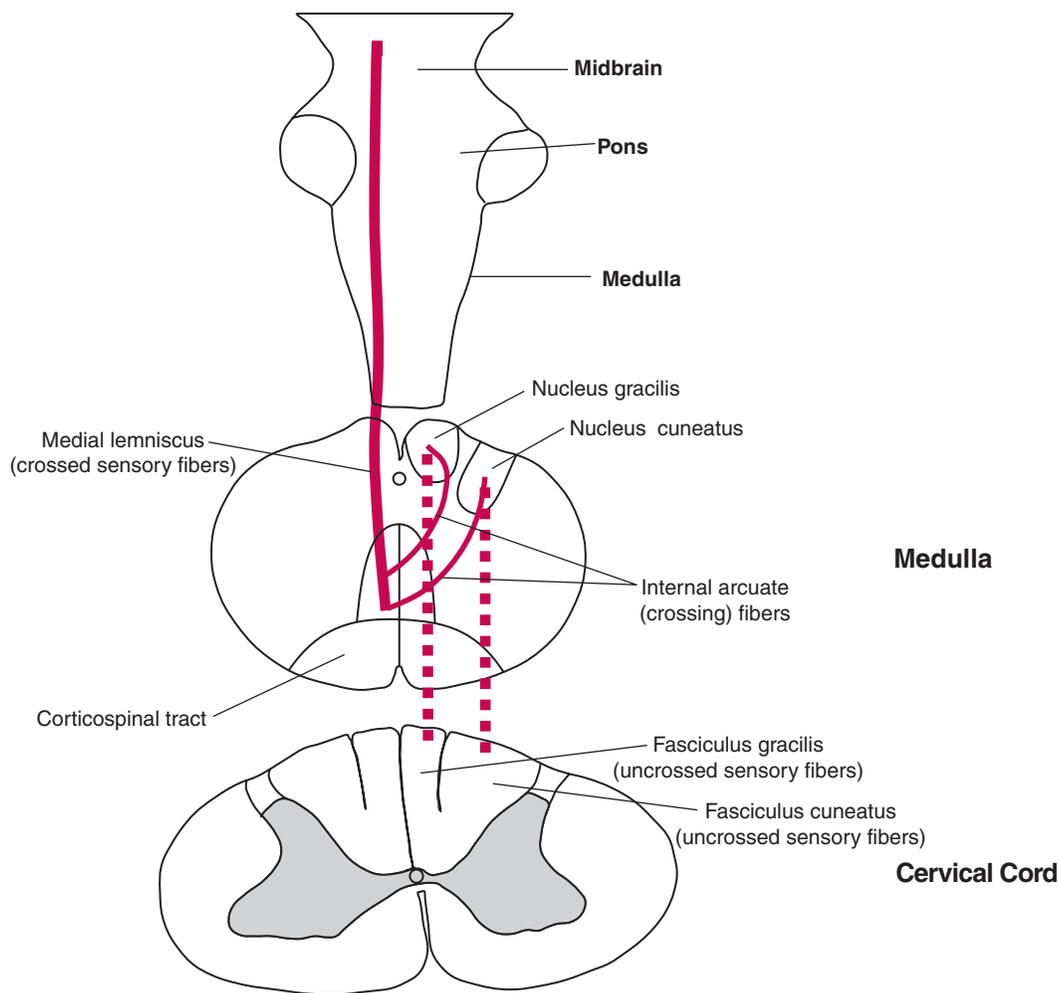
Figure 3-8 Crossing of the dorsal lemniscus fibers in the caudal medulla.

is the nucleus of the **hypoglossal nerve** (CN XII). It controls all intrinsic and most extrinsic tongue muscles and is an important nerve for speech production and swallowing.

The structure below the *hypoglossal nucleus* is the **medial longitudinal fasciculus**; this fiber bundle receives visual and vestibular projections and is located longitudinally from the cervical cord to the brainstem. It interconnects the motor nuclei of four cranial nerves (oculomotor [CN III], trochlear [CN IV], abducens [CN VI], and spinal accessory [CN XI]) and regulates head–eye coordination. The principal (inferior) olivary nucleus, also seen in this area, relays spinal and brainstem afferents to the cerebellum. Some of the previously described structures also appear in this section of the brainstem.

Middle Third of the Medulla

Figure 3-10 presents structures of the middle third of the medulla. The rostral portion of the *hypoglossal nucleus* is larger here than the lower third of the medulla. Located above the pyramidal tract, the *principal (inferior) olivary*

nucleus occupies a major portion of the lower half of the medulla. The principal olivary nucleus, a wrinkled and saggy structure, is an important relay center for motor and proprioceptive information to the cerebellum. This nucleus receives input related to pain, touch, and position of the limbs from the spinal cord (**spino-olivary**) and reticular formation (**reticulo-olivary**). The **olivocerebellar fibers** cross the midline and project to the opposite cerebellar hemisphere through the *inferior cerebellar peduncle* (**restiform body**). The inferior cerebellar peduncle appears along the lateral dorsal surface of the upper half of the medulla. Furthermore, it is the most caudal of the three peduncles that connect the brainstem to the cerebellum (see Figs. 2-29 and 2-30).

The **cranial nerve nuclei**, which are related to the **glossopharyngeal** (CN IX) and **vagus** (CN X) **nerves**, are found in the region between the *inferior cerebellar peduncle* and the *reticular formation*. One of the important nuclei at this level is the **nucleus ambiguus**, the motor nucleus of the glossopharyngeal (CN IX) and vagus (CN X) nerves; it supplies muscles of the soft palate, pharynx, larynx, and
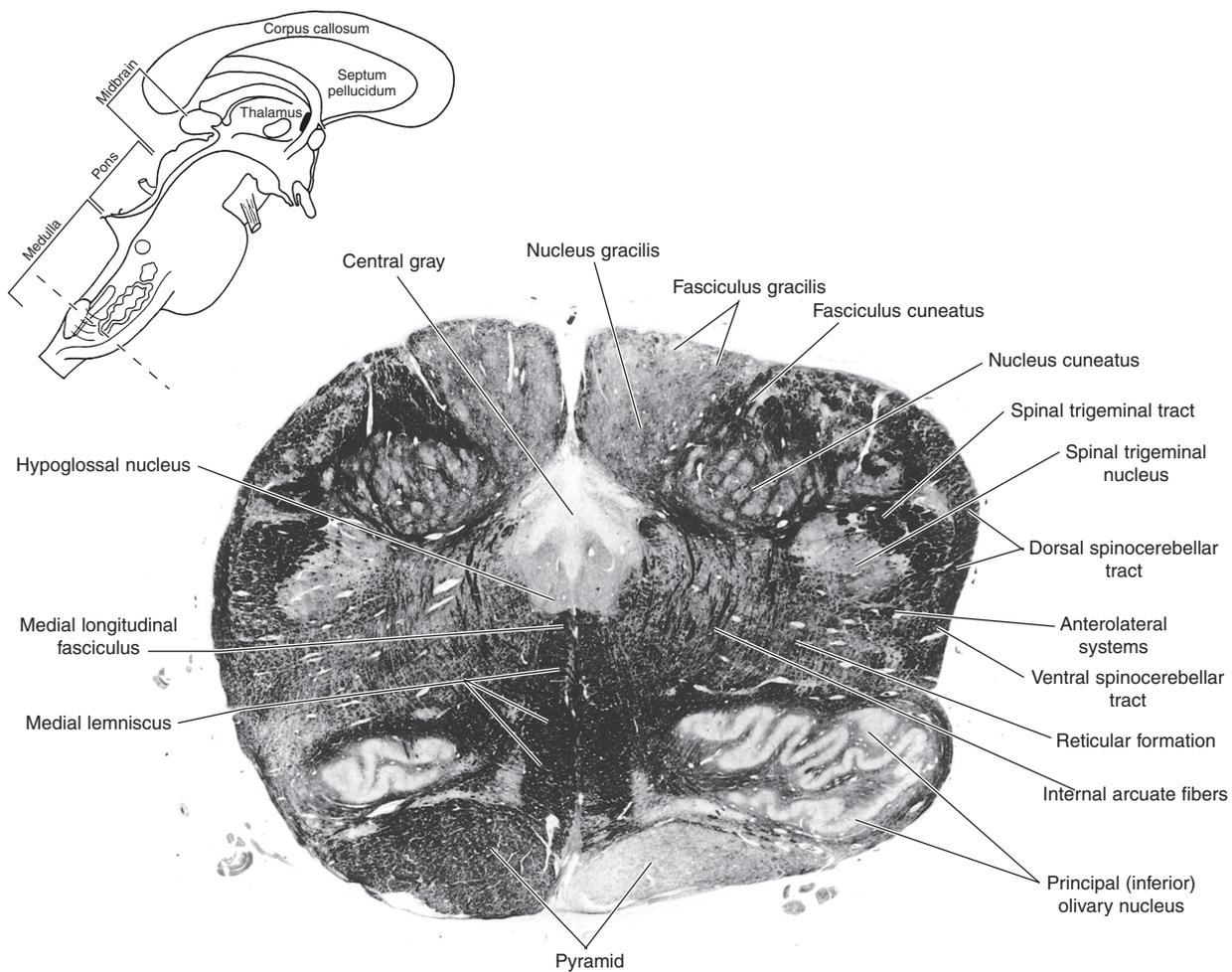
Figure 3-9 Transverse section of the medulla through the dorsal column (gracilis and cuneatus) nuclei, caudal portions of hypoglossal nucleus, caudal end of inferior olivary nucleus, and middle portions of the sensory decussation.

upper esophagus and controls swallowing and phonation. The nuclei of the reticular formation are scattered and occupy a larger core area in the center of the medulla.

Rostral Third of the Medulla

In the transverse section through the rostral third of the medulla shown in Figure 3-11, the *inferior cerebellar peduncle* and *principal (inferior) olivary nucleus* are larger than they are at the level shown in Figure 3-10. Among the newly appearing structures are the **cochlear complex** and glossopharyngeal (CN IX) nerve. The *cochlear (CN IX) nuclear complex,* located above the restiform body in the dorsolateral medulla, receives projections from the inner ear. The *glossopharyngeal nerve* mediates taste and contributes to swallowing.

The compact **pyramidal motor fibers** are in the ventral medulla. The *principal (inferior) olivary nucleus* is present in its fully developed form. The *medial lemniscus* (mediating fine and discriminative touch) and the *medial longitudinal fasciculus* (interconnecting the motor nuclei of the ocular cranial nerves with vestibular input) are present along the

midline in the medulla dorsal to the *pyramids.* The *spinal trigeminal nucleus* and its tract can also be seen in this section. The *reticular formation* occupies a large core in the middle third of the medulla, spanning the area dorsal to the principal (inferior) olivary nucleus.

Pons

The major pontine structures are the corticospinal fibers interspersed with diffused **pontine nuclei**, the crown-shaped cavity of the fourth ventricle, the massive **middle cerebellar peduncle** (**brachium pontis**), the medial lemniscus, the **crossing pontocerebellar fibers**, the **trigeminal nuclear complex**, the spinal trigeminal nucleus and tract, the **superior cerebellar peduncle** (**brachium conjunctivum**), remnants of the inferior cerebellar peduncle, and many cranial nerve structures (Table 3-3).

Lower Pons

The transitional anatomic structures between the medulla and pons are presented in Figure 3-12. The enlarged *fourth*
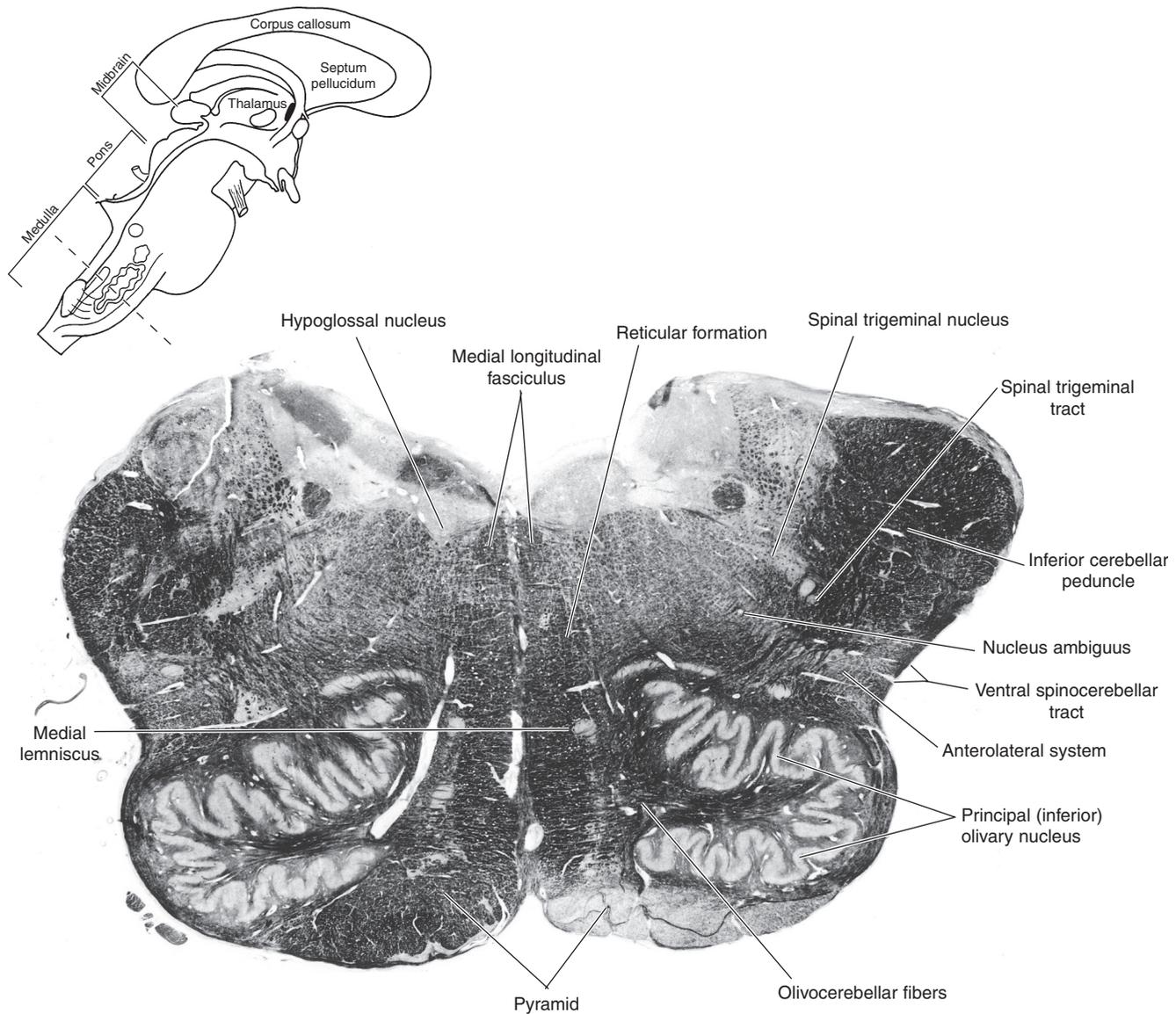
Figure 3-10 Transverse section of the medulla through the rostral portions of the hypoglossal nucleus and middle portions of the principal (inferior) olivary nucleus.

ventricle and diffuse pontine nuclei represent the pons, whereas the *pyramid* characterizes the medulla. The *superior cerebellar peduncle* forms part of the lateral roof of the fourth ventricle. The convex **anterior medullary velum**, in the dorsal area of this section, forms the roof of the fourth ventricle. The ventral teardrop-shaped pyramid does not hug the ventromedial area here, as it does in the lower medullary levels.

The **vestibular nuclear complex** appears beneath the floor of the *fourth ventricle.* The *cochlear nucleus,* seen in Figure 3-11, is no longer present. The *vestibular complex* receives projections from the semicircular canals in the inner ear and plays a role in equilibrium and head–eye coordination (see Chapter 10).

The fibers of the **vestibular branch** of the **vestibulocochlear nerve** exit laterally from the pontomedullary junction along the ventral surface of the *middle* and *inferior cerebellar peduncles.* The structures beneath the vestibular complex are the *spinal trigeminal tract* and *spinal trigeminal nucleus.*

The *spinal tract* fibers of the *trigeminal nerve* descend ipsilaterally to synapse in the *trigeminal nucleus,* which relays somatosensory sensation from the face through its fiber tracts. After crossing, the trigeminal spinal tract fibers join the *medial lemniscus* to terminate in the thalamus. The nucleus of the **facial nerve** (CN VII) is present in the pontine tegmentum. The facial (CN VII) nerve innervates the muscles of facial expression and controls smiling, frowning,
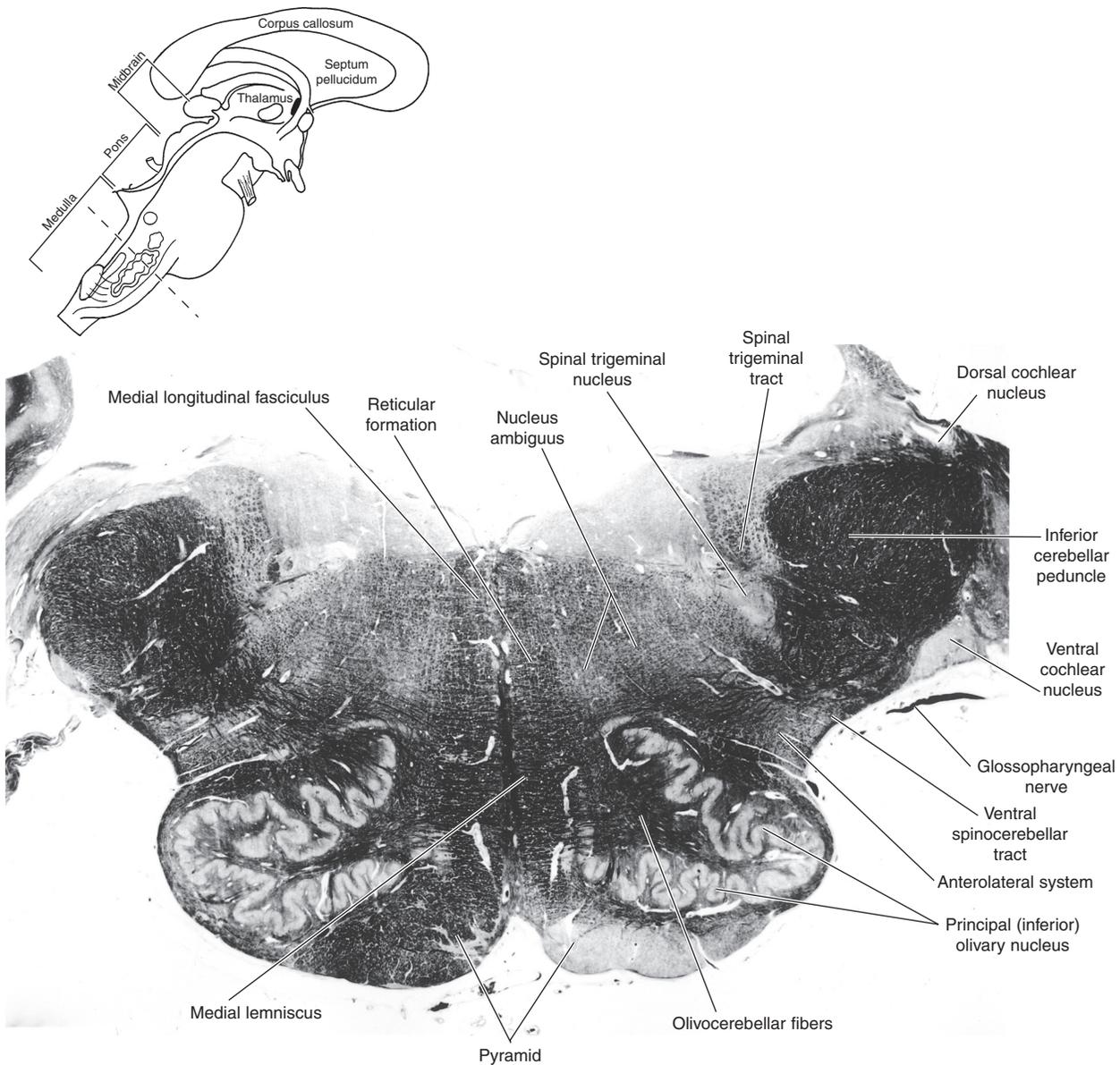
Figure 3-11 Transverse section of the medulla through the dorsal and ventral cochlear nuclei and the root of the glossopharyngeal nerve.

Table 3-3

Anatomic Structures of the Pons

Lower pons
    Full-size crown-shaped fourth ventricle
    Diffuse pyramidal fibers piercing basal pons
    Remnants of inferior cerebellar peduncle
    Facial nucleus and nerve
    Middle cerebellar peduncle (brachium pontis)
    Medial lemniscus (marking upper limit of basal pons)
    Anterior medullary velum
    Spinal trigeminal nucleus and tract
    Superior cerebellar peduncle (brachium conjunctivum)

Middle pons
    Middle cerebellar peduncle
    Trigeminal nuclear complex
    Pontine nuclei
    Superior cerebellar peduncle
    Fourth ventricle cavity
    Anterior medullary velum
    Medial lemniscus
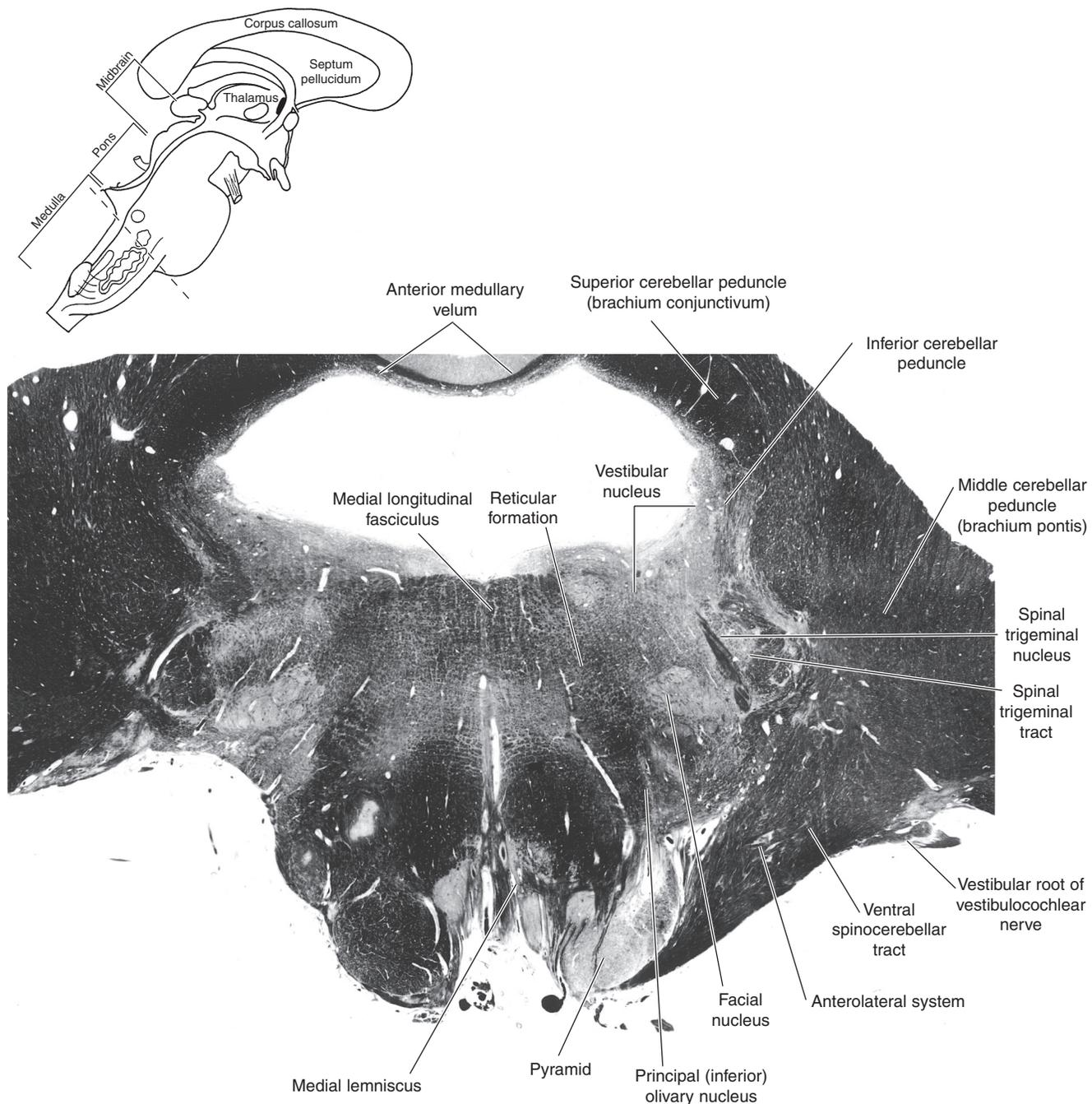   Diffuse corticospinal fibers

Figure 3-12 Transverse section of the pontomedullary junction through the rostral pole of the inferior olivary nucleus and facial nucleus.

and laughing as well as assists in speaking. Fibers of the facial (CN VII) nerve exit laterally from the pontomedullary junction (see Figs. 2-49–2-51).

The massive body of the *middle cerebellar peduncle,* by far the largest of the cerebellar peduncles, is located laterally in this section. Its fibers connect the pons with the cerebellum and mediate information from the motor cortex to the cerebellum. The fibers located medial to the middle cerebellar peduncle belong to the *inferior cerebellar peduncle,* which mediates vestibular and spinal afferents to the cerebellum. The crescent-shaped fibers of the *superior cerebellar peduncle* emerge dorsally and form the dorsolateral roof of the *fourth ventricle.*

Middle Pons

The transverse section of the middle pons shown in Figure 3-13 is at the level of the *trigeminal* (CN V) *nerve* (the principal sensory nerve for the face) as it exits laterally
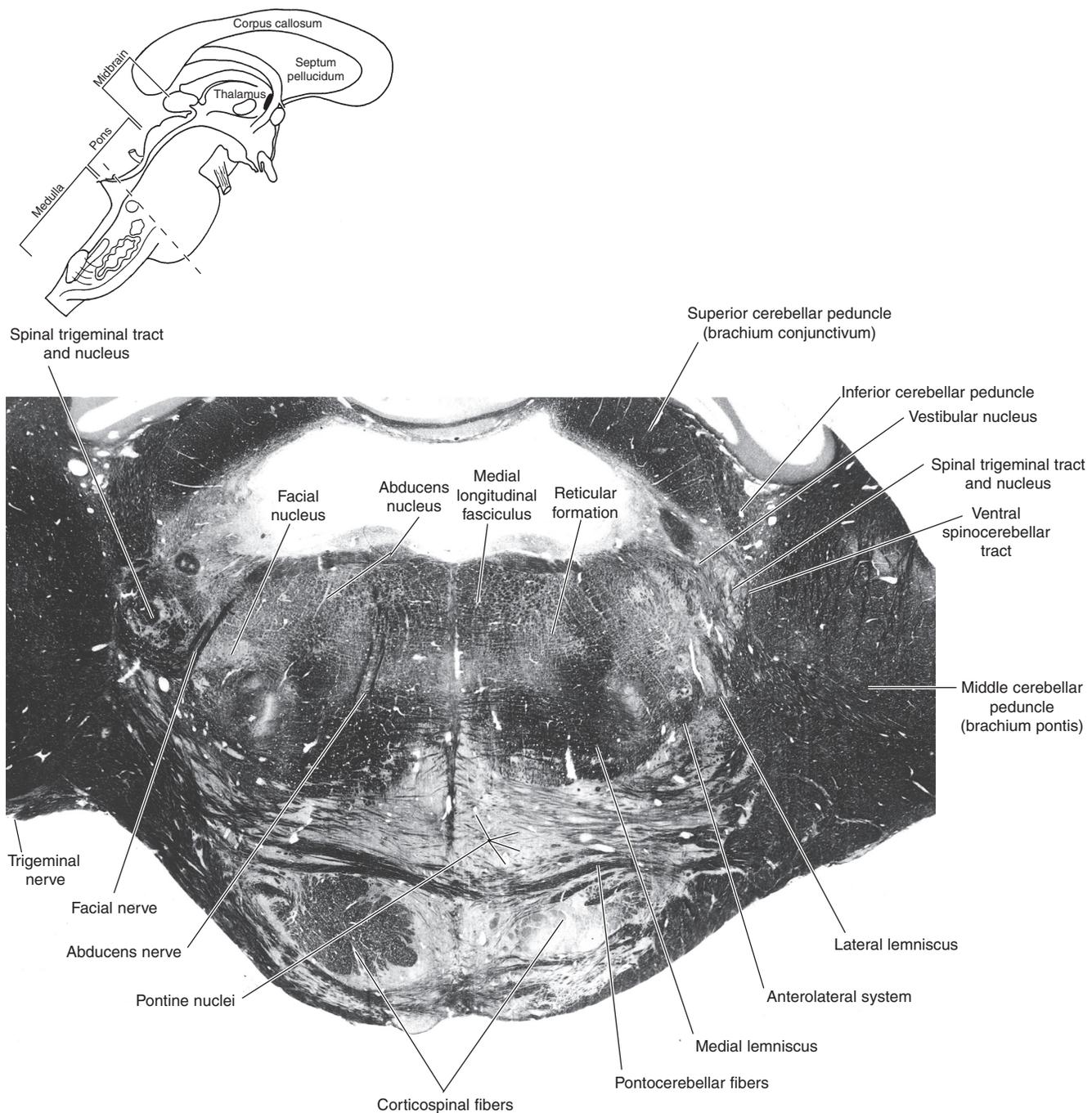
Figure 3-13 Transverse section of the pons through the rostral pole of the facial nucleus and internal genu of the facial nerve.

through the *middle cerebellar peduncle*. The most characteristic features of the pons are the interspersed **corticospinal–corticopontine fibers** and the crown-shaped lumen of the *fourth ventricle*. Fibers of all three *cerebellar peduncles* are present laterally in this section, although the *inferior cerebellar* and *superior cerebellar peduncles* are relatively small.

Scattered pontine nuclei receive massive input from the ipsilateral primary motor and sensory cortices and project the **pontocerebellar fibers** to the cerebellum; these fibers cross the midline before entering the cerebellum via the *middle cerebellar peduncle*. These fibers mediate information from the opposite primary motor, sensory, and visual cortices and are concerned with limb movement during skilled acts. Laterally, the crescent-shaped *superior cerebellar peduncle* provides cerebellar feedback to the primary motor cortex via the **red nucleus**. Located ventrolaterally are fibers of the **lateral lemniscus**, which carry auditory information from both ears to the cortex (see Chapter 9).

This pontine section also demonstrates spatial relationships among the *facial nucleus, facial nerve, abducens nucleus,* and *abducens nerve.* The internal genu refers to fibers of the facial (CN VII) nerve as they curve over the nucleus of the abducens (CN VI) nerve just below the floor of the *fourth ventricle* (see Figs. 15-3 and 15-4).

Pons–Midbrain Junction

The section shown in Figure 3-14 is located at the transition between the rostral pons and the midbrain. This transition is marked by a reduction in the size of the *fourth ventricle.* The ventricular floor is formed by the enlarged *central gray* of the *reticular formation,* which contains important somatic and visceral nuclei. Located dorsally in this section is the **trochlear nerve root**, which is one of three cranial nerves (the other two are **oculomotor** [CN III] and **abducens** [CN VI]) responsible for innervating the eye and is the only motor nerve that exits dorsally. The *medial longitudinal fasciculus* is buried within the central gray substance of the reticular formation. The massive cerebellum is dorsal to the ventricular cavity.

Ventral to the *central gray* of the *reticular formation* are fibers of the *superior cerebellar peduncle,* which occupy the outer third of the tegmentum and decussate at a higher level in the midbrain. These fibers originate in the deep cerebellar nuclei and provide feedback to the opposite thalamic
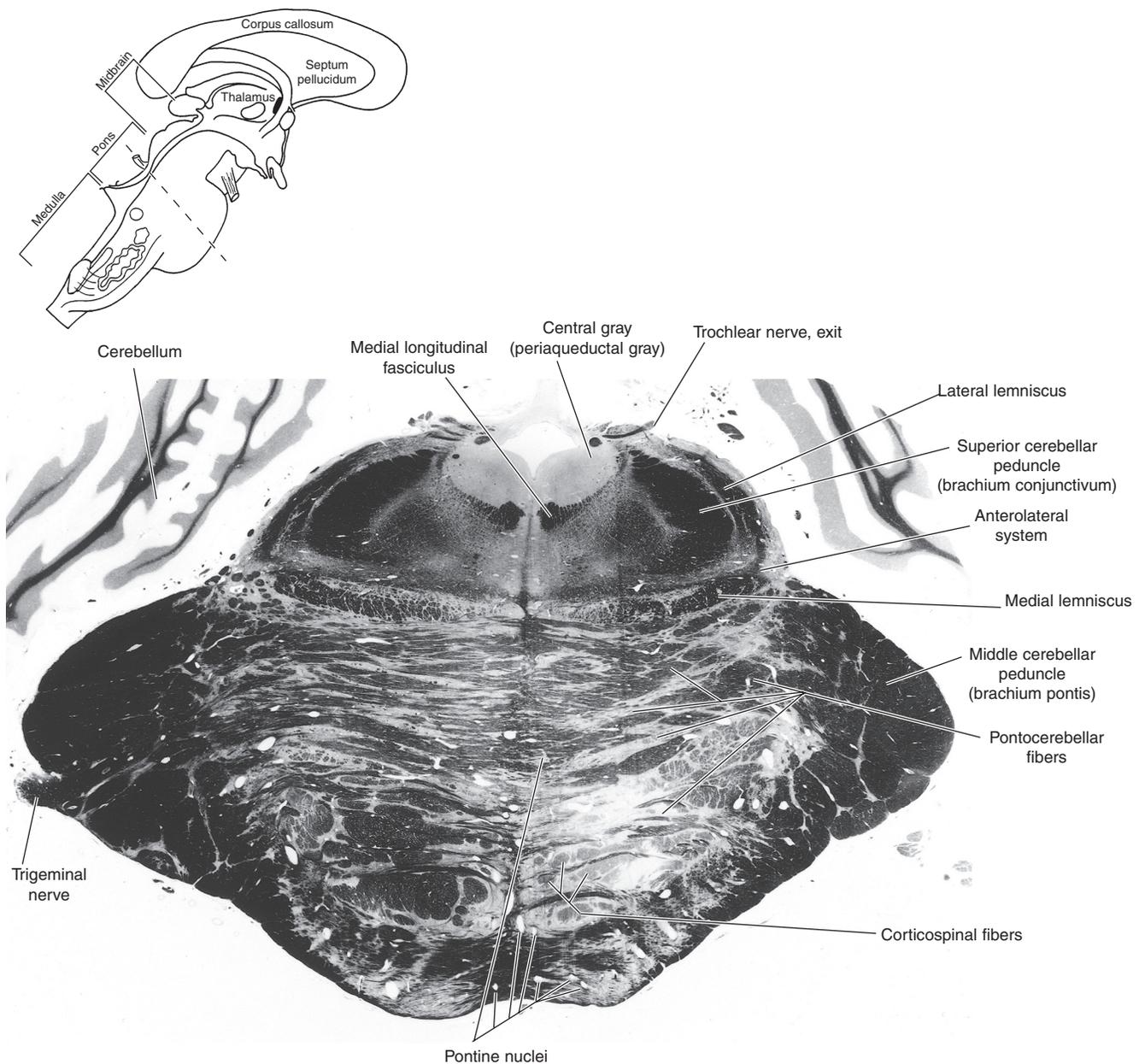

Figure 3-14 Transverse section of the rostral pons through the exits of the trochlear and trigeminal nerves.

and cortical centers. Lateral to the fibers of the superior cerebellar peduncle are the *lateral lemniscus* fibers, which relay information from both ears to the primary auditory cortex in the temporal lobe. The ventral region in this section contains diffuse pontine nuclei and a massive amount of crossing pontocerebellar fibers that make up the large *middle cerebellar peduncles;* also seen here are the scattered corticospinal tract fibers on each side of the midline. Located laterally is the root of the *trigeminal nerve* (CN V).

Midbrain

The midbrain consists of the **tectum**, **tegmentum**, and **basis pedunculi** (see Fig. 2-24). The tectum consists of the **corpora quadrigemina**, which refers to four egg-shaped structures (see Figs. 2-21 and 2-22). The upper two bodies of the corpora quadrigemina are the **superior colliculi**, and the lower two bodies are the **inferior colliculi**. Below the **midbrain tectal structure** is the **cerebral aqueduct**, a narrow canal that connects the third and fourth ventricles.

The *tegmentum* is an elongated mass of nuclei and white matter in the center of the brainstem that includes decussation of the *superior cerebellar peduncle, reticular formation,* and *red nucleus.* The *tectum* and tegmentum are distinguishable by their locations with respect to the *cerebral aqueduct.* The tectum is dorsal to the cerebral aqueduct, whereas the tegmentum is beneath the cerebral aqueduct. The *basis pedunculi* is ventral, and it includes the *substantia nigra* and the wing-shaped fibers of the pes pedunculi (crus cerebri). Important midbrain structures are given in Table 3-4.

Caudal Midbrain

A transverse section through the low midbrain and high pons is presented in Figure 3-15. The two round struc-

Table 3-4

Anatomic Structures of the Midbrain

Caudal (low) midbrain
    Cerebral aqueduct
    Inferior colliculus
    Superior cerebellar peduncle and decussation
    Medial lemniscus

Rostral (high) midbrain
    Pes pedunculi (crus cerebri)
    Substantia nigra
    Red nucleus
    Superior colliculus
    Central gray
    Cerebral aqueduct
    Oculomotor nucleus and nerve
    Medial lemniscus

tures located dorsally are the *inferior colliculi.* The inferior colliculus is a relay center in the transmission of information from the ears to the auditory cortex; it also regulates auditory reflexes. The fibers of the *lateral lemniscus* that carry auditory information are visible as they merge with the inferior colliculus. Rostrally, the *fourth ventricle* communicates with the *cerebral aqueduct,* which is a frequent site of obstruction in congenital hydrocephalus because of its small lumen. The *central gray* region and reticular formation are located around the cerebral aqueduct and mediate affective behavior.

Originating from the deep *dentate cerebellar nucleus* are the fibers of the *superior cerebellar peduncle;* these fibers course ventromedially below the aqueduct to cross the midline before going to the thalamus and cortex. This decussation of the superior cerebellar peduncle fibers accounts for the cerebellar projections to the contralateral motor cortex. Also present is the emerging *pes pedunculi.* The *medial lemniscus, medial longitudinal fasciculus, lateral lemniscus, pontine nuclei, pontocerebellar fibers,* and *corticospinal fibers,* identified earlier, are also seen in this section.

Rostral Midbrain

The slightly oblique section shown in Figure 3-16 reveals the anatomic characteristics of the high midbrain. The tectum consists of two dorsally located round structures, the *superior colliculi,* which also serve as the visual reflex center. The tectum provides the organism with a three-dimensional orientation map according to which eye movements and/or head turn and body rotations occur in response to bright lights (superior colliculus) and loud noises (inferior colliculus). Besides the cortex and thalamus, the superior colliculus also receives light locations from the retina and is where the spatial retinal points are activated. Ascending auditory signals also send collaterals into the inferior colliculus for similar spatial orientation processing.

Tectobulbar and tectospinal projections to the spinal cord and brainstem motor nuclei result in the appropriate turning of the eyes, head, and body toward the sound source. These startle reflexes are quite rapid, occurring before the cerebral cortex becomes aware of them. The *superior colliculus* and the adjacent **pretectal area** mediate reflexes involving intrinsic eye muscles; they also regulate pupil constriction (light reflex) and lens accommodation for near vision (see Chapter 8).

The *superior colliculi* look similar to the *inferior colliculi,* but can be differentiated by relating them to their co-occurring structures. When seen on a cross-section or transverse section, the decussation of the *superior cerebellar peduncle* fibers is the important landmark for identifying the inferior colliculus. The presence of the *red nucleus* and the substantia nigra characterizes the level of the superior colliculus.

Lateral to the *superior colliculus* is the **brachium of the inferior colliculus**, which carries auditory information from the *inferior colliculus* to the **medial geniculate body**,
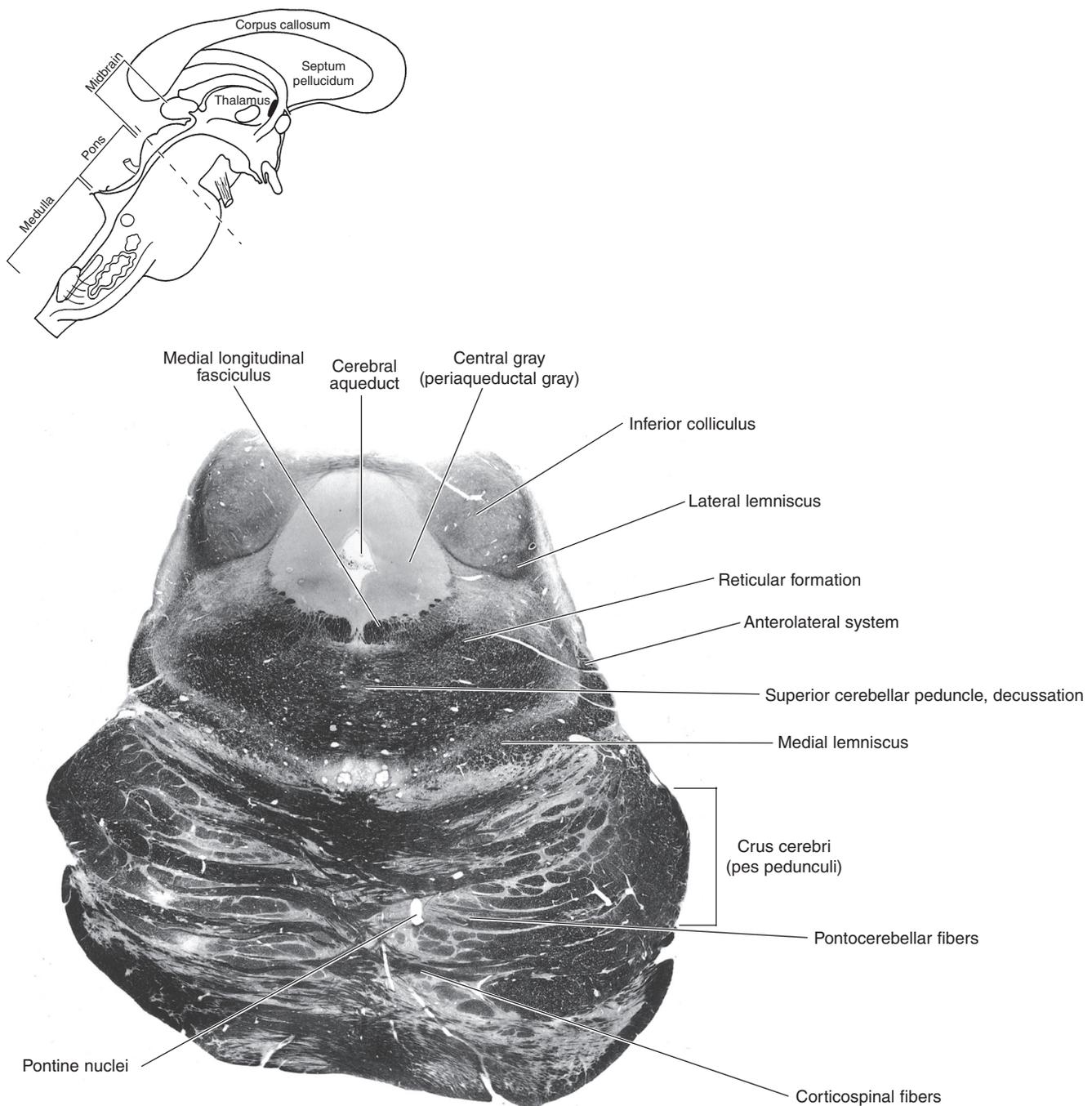
Figure 3-15 Transverse section of the pons–midbrain junction through the inferior colliculus, caudal portions of the decussation of the superior cerebellar peduncle, and rostral parts of the basilar pons.

the thalamic relay nucleus for audition to the brain. The round nucleus in the midbrain tegmentum is the *red nucleus,* which has two important functions. First, it receives the cerebellar projections through the crossed *superior cerebellar peduncle* fibers and sends cerebellar feedback to the thalamus. Second, it transmits descending motor information to the spinal and cranial motor nuclei and regulates muscle tone.

Below the *red nucleus* is the *substantia nigra,* which is important in the extrapyramidal circuitry. Cells of the substantia nigra have been identified as the producers of **dopamine**, an inhibitory basal ganglia neurotransmitter; the nigrostriatal fibers project dopamine from the substantia nigra to the **caudate nucleus** of the **neostriatum**. The degeneration of the substantia nigra's dopamine-producing cells is associated with **Parkinson disease**, a
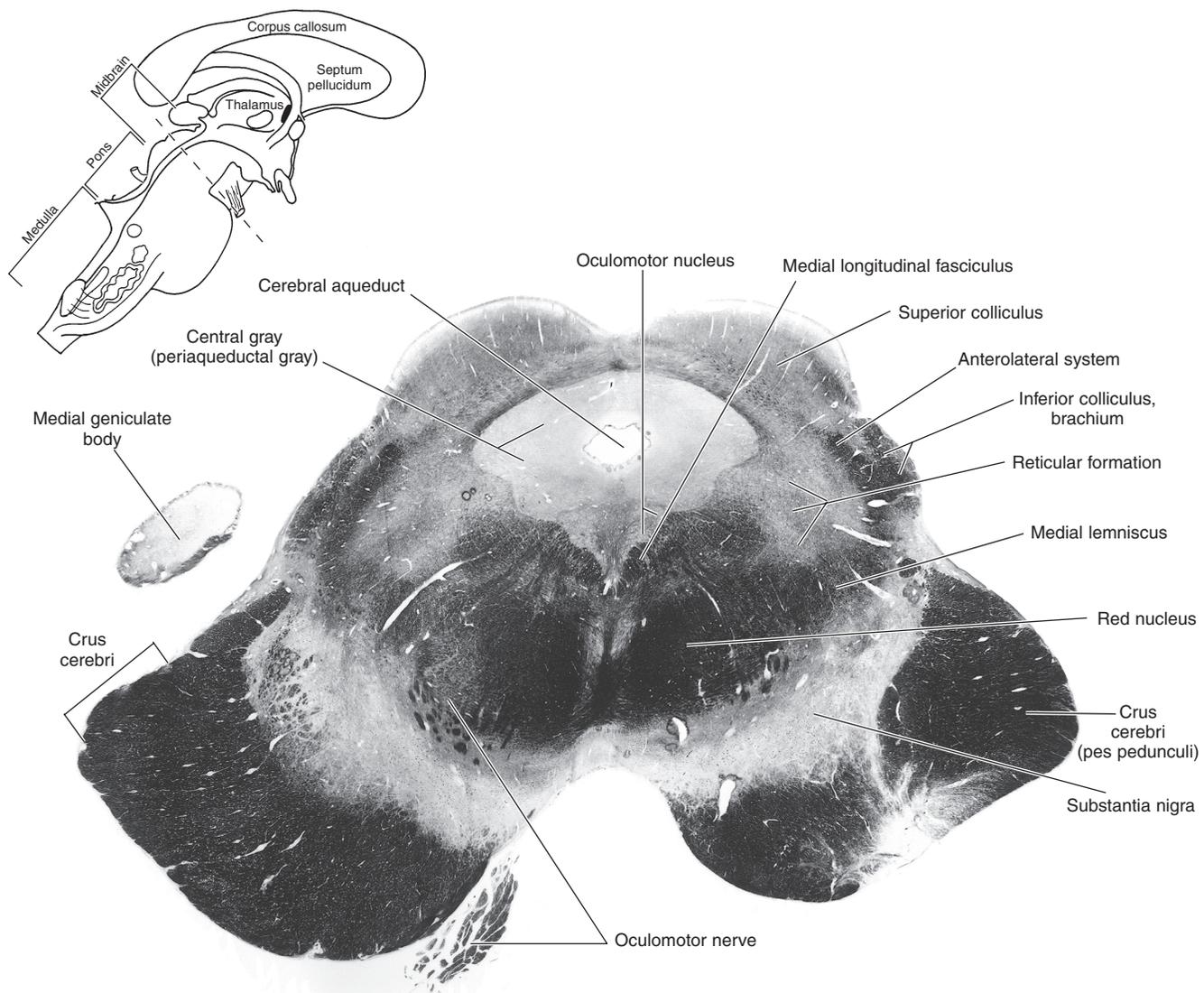
Figure 3-16 Transverse section of the midbrain through the superior colliculus, caudal parts of the oculomotor nucleus, and red nucleus.

slowly progressive degenerative condition characterized by resting tremor, expressionless face, muscular rigidity, flexed posture, and moderate to severe motor speech difficulty (Box 3-1; see Chapter 13).

Ventrally located in this section are the wing-shaped fibers of the *pes pedunculi* (crus cerebri), which indicate the midbrain location of the corticospinal and **corticobulbar fibers**. In the floor of the *central gray* is the *oculomotor nerve nucleus,* one of the three cranial nerves responsible for eye movements. Fibers of the *oculomotor nerve* exit in the interpeduncular fossa (see Fig. 2-50). The *medial longitudinal fasciculus* is below the oculomotor nucleus and is an important fiber bundle, interconnecting three cranial nerves (*oculomotor* [CN III], *trochlear* [CN IV], and *abducens* [CN VI]) with the vestibular system. It is also important in coordinated eye movements.

High Rostral Midbrain

A transverse section through the rostral midbrain contains structures that are not present at lower levels, including the **posterior thalamus**, **optic tract**, and **Edinger-Westphal nucleus** (Fig. 3-17; see Fig. 15-10). The Edinger-Westphal nucleus is the visceral nucleus of the *oculomotor nerve,* which mediates pupillary constriction and lens accommodation reflexes. The posterior thalamus includes **pulvinar**, **lateral geniculate**, and medial geniculate bodies (see Chapter 6). The lateral geniculate body is the thalamic relay center for vision. The medial geniculate body is the thalamic relay for audition. The oculomotor nerve runs along the medial border of the midbrain next to the medial border of the large red nucleus (see Fig. 2-24). The *substantia nigra* sits in the hammock of the pes pedunculi just beneath the red nucleus. The large red nucleus located

BOX 3-1

Parkinson Disease

Parkinson disease is associated with the degeneration of dopaminergic neurons in the pars compacta region of the substantia nigra. Discovery of this underlying neurotransmitter deficiency led to a pharmacologic method of treating the disease; levodopa, a precursor of dopamine, has the ability to pass through the **blood–brain barrier.** Although promising when first introduced; this drug is known to lose its effectiveness in the later stages of the disease.

The lack of adequate treatment for progressive Parkinson disease provided an incentive for surgical intervention involving the neural circuitry of the basal ganglia. The procedure, known as stereotaxic neurosurgery and introduced in 1947, involved placing stereotactic lesions in the pallidum or its efferent pathways or in the ventrolateral thalamic nucleus. More recent surgical treatment focuses on deep-brain stimulation of the subthalamic nucleus using a permanently implanted depth electrode.
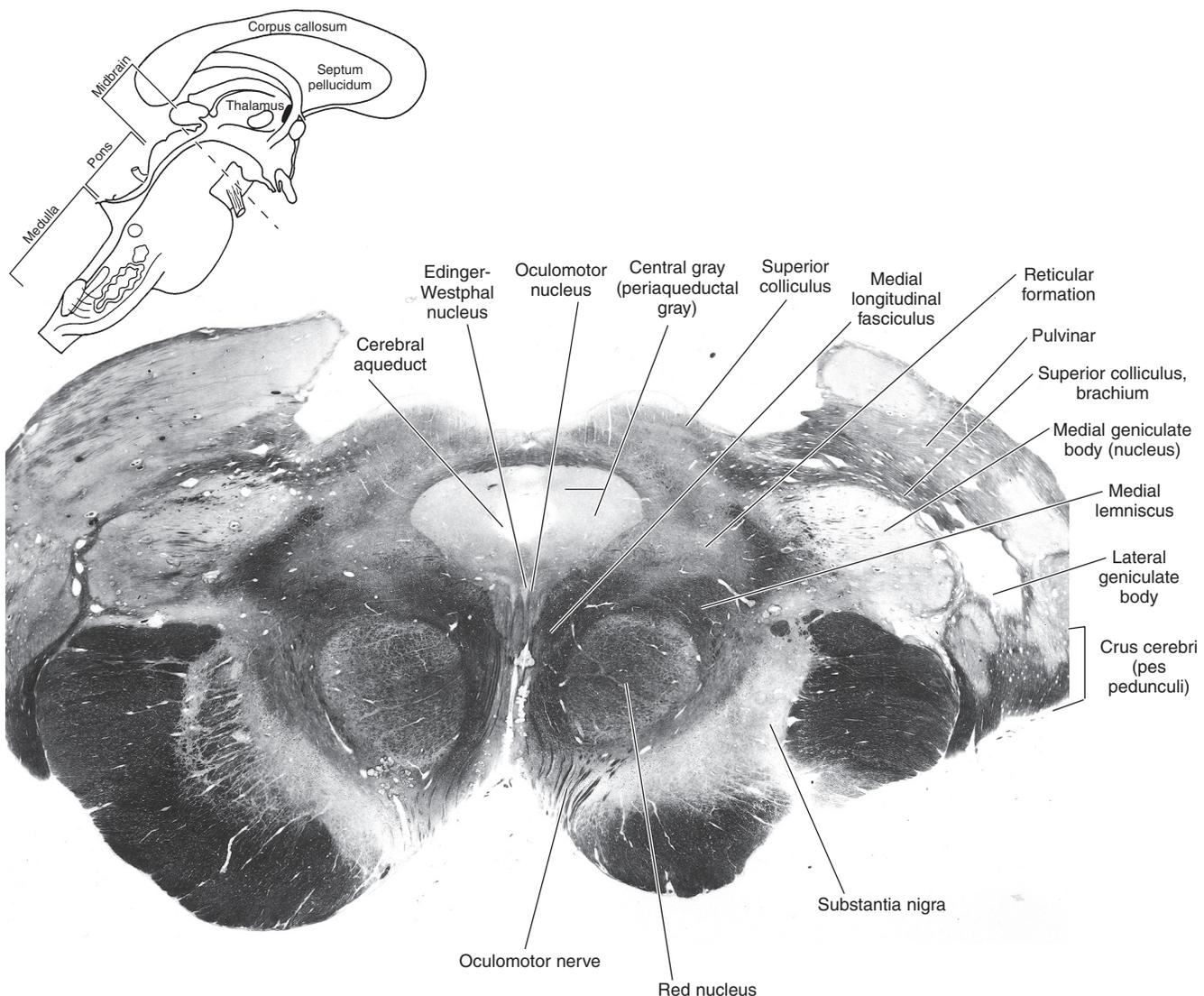

Figure 3-17 Transverse section of the midbrain through the superior colliculus and rostral portions of the oculomotor nucleus.
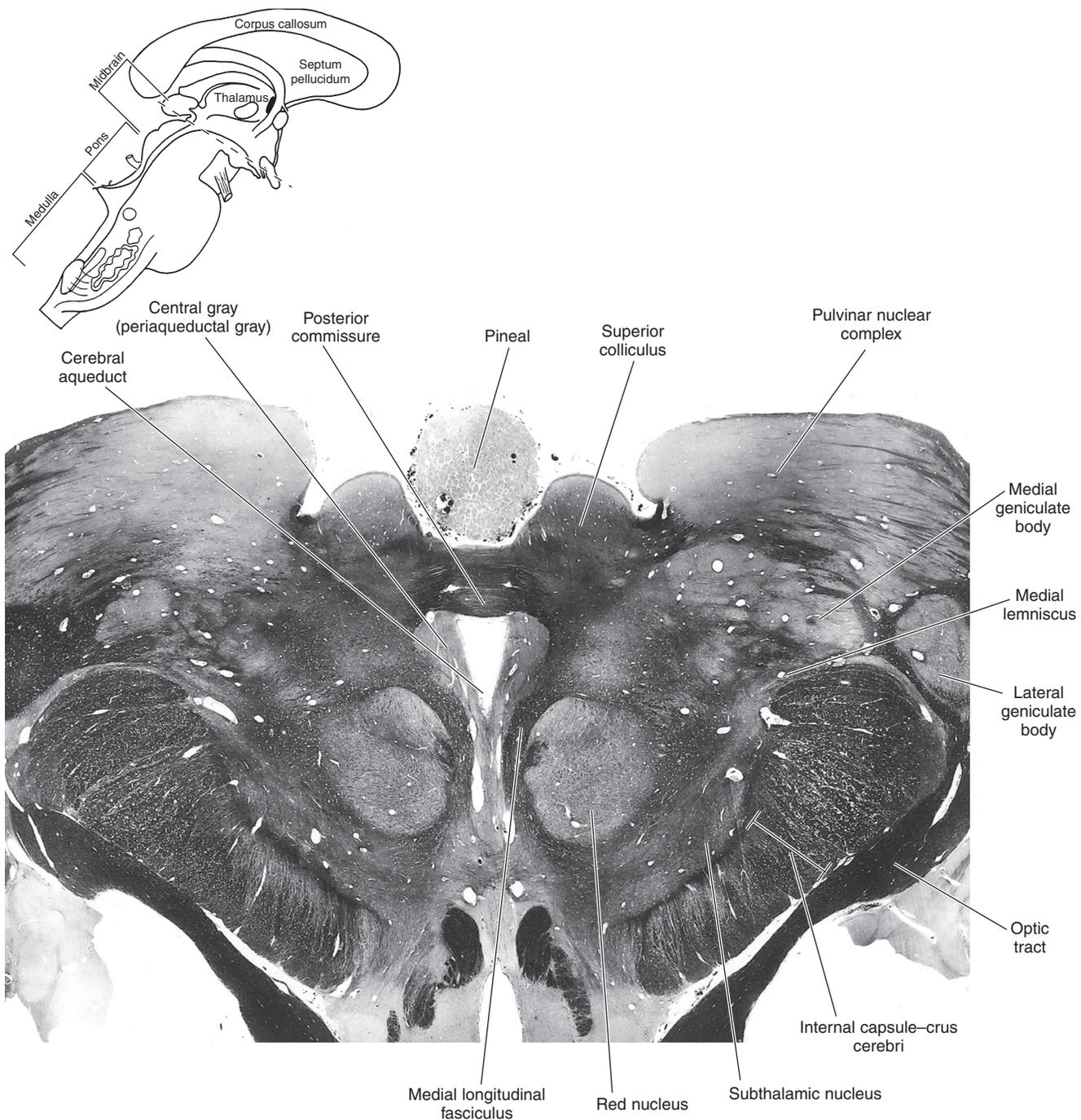
Figure 3-18 Oblique section through the midbrain–diencephalon junction.

between the central gray and the large *pes pedunculi* identifies this level of the midbrain.

Midbrain–Diencephalon Junction

The oblique section in Figure 3-18 is located in a transitional area, revealing structures from both the midbrain and the diencephalon. The important structures are the **posterior commissure** with the overlying **pineal gland** in the dorsal midline, the posterior part of the **pulvinar nucleus**, the rostral end of the *red nucleus* flanked laterally by the *medial*

lemniscus, and the large diagonal internal capsule–pes pedunculi. Fibers of the *internal capsule,* which were identified as the *pes pedunculi* below this level, are hugged by the optic tract that runs along its ventrolateral border. The **subthalamic nucleus** is sandwiched between the *internal capsule* and the red nucleus, the area that was occupied by the *substantia nigra* at the caudal midbrain levels. Both the subthalamic nucleus and substantia nigra are major contributors to movement, and their dysfunction is associated with movement disorders.

The *pineal gland,* an endocrine organ, is located dorsally and is important in the body's diurnal rhythm. Inhibition of its secretion has also been associated with the onset of puberty. The *posterior commissure* is considered to connect the two *superior colliculi.* The posterior thalamus includes the *pulvinar, lateral,* and *medial geniculate bodies.* The lateral geniculate body is the thalamic relay center for vision. The medial geniculate body is the thalamic relay center for audition. The pulvinar—the most caudal part of the thalamus—is reciprocally connected with the parietotemporal association cortex. It also has been associated with speech and language functions (see Chapter 6).

The *subthalamic nucleus,* which is mediodorsal to the *crus cerebri,* is an important extrapyramidal structure; its pathology results in **hemiballism**, a neurologic condition characterized by violent and flinging movements. Ventrally situated in the section is the optic tract.

FOREBRAIN IN CORONAL SECTIONS

Learning the forebrain anatomy entails orientation to the subcortical structures: **basal ganglia** (**caudate nucleus**, **putamen**, **globus pallidus**, and functionally related sub-

thalamic nucleus), **diencephalon** (**thalamus** and **hypothalamus**), **ventricular cavity** (lateral and third ventricles), and **limbic structures** (**amygdala**, **fornix**, **hippocampal formation**, and **cingulate gyrus**). Other important structures are the **corpus callosum**, **optic chiasm**, **insular cortex** (isle of Reil), **septum pellucidum**, **anterior commissure**, **cingulate gyrus**, **internal capsule**, **external capsule**, **extreme capsule**, and **claustrum** (Table 3-5).

These structures are in fixed positions with respect to each other; a review of their relative locations on a horizontal section facilitates the orientation to them on subsequent coronal serial sections of the brain (Figs. 3-19 and 3-20).

Located rostrally in a horizontal section of the brain are the **frontal lobes** on each side of the midline *corpus callosum* (genu) (Fig. 3-19). The fibers of the corpus callosum connect the homologous cortical areas in both hemispheres by corticocortical fibers. The *septum pellucidum* is in the midline extending from the ventral surface of the corpus callosum and ending along the anterior limits of the thalamus. On each side of the septum pellucidum are the **anterior horns** of the *lateral ventricle.* The septal nuclei are located at the base of the anterior ventricular horns. With connections to the limbic (hippocampal formation and

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Table 3-5

Anatomic Structures of the Basal Ganglia and Diencephalon at Different Levels

|	
Posterior thalamus	
Pineal gland	Lateral geniculate body
Corpus callosum, splenium	Medial geniculate body
Pulvinar of thalamus	Internal capsule merging in crus cerebri/pes pedunculi
Cerebral aqueduct	
Midthalamus	
Corpus callosum, body	Third ventricle
Fornix	Hypothalamus
Subthalamic nucleus	Diminishing globus pallidus and putamen
Lateral ventricle	
Anterior thalamus	
Anterior commissure	Internal capsule, genu
Caudate	Corpus callosum, body
Putamen	External capsule
Globus pallidus	Extreme capsule
Third ventricle	Septum pellucidum
Hypothalamus	Claustrum
Anterior limb of internal capsule	
Corpus callosum, body	Septum pellucidum
Head of the caudate nucleus	Internal capsule, anterior limb
Putamen	External capsule
Attachment of the caudate and putamen	Claustrum
Lateral ventricle, anterior horn	Extreme capsule
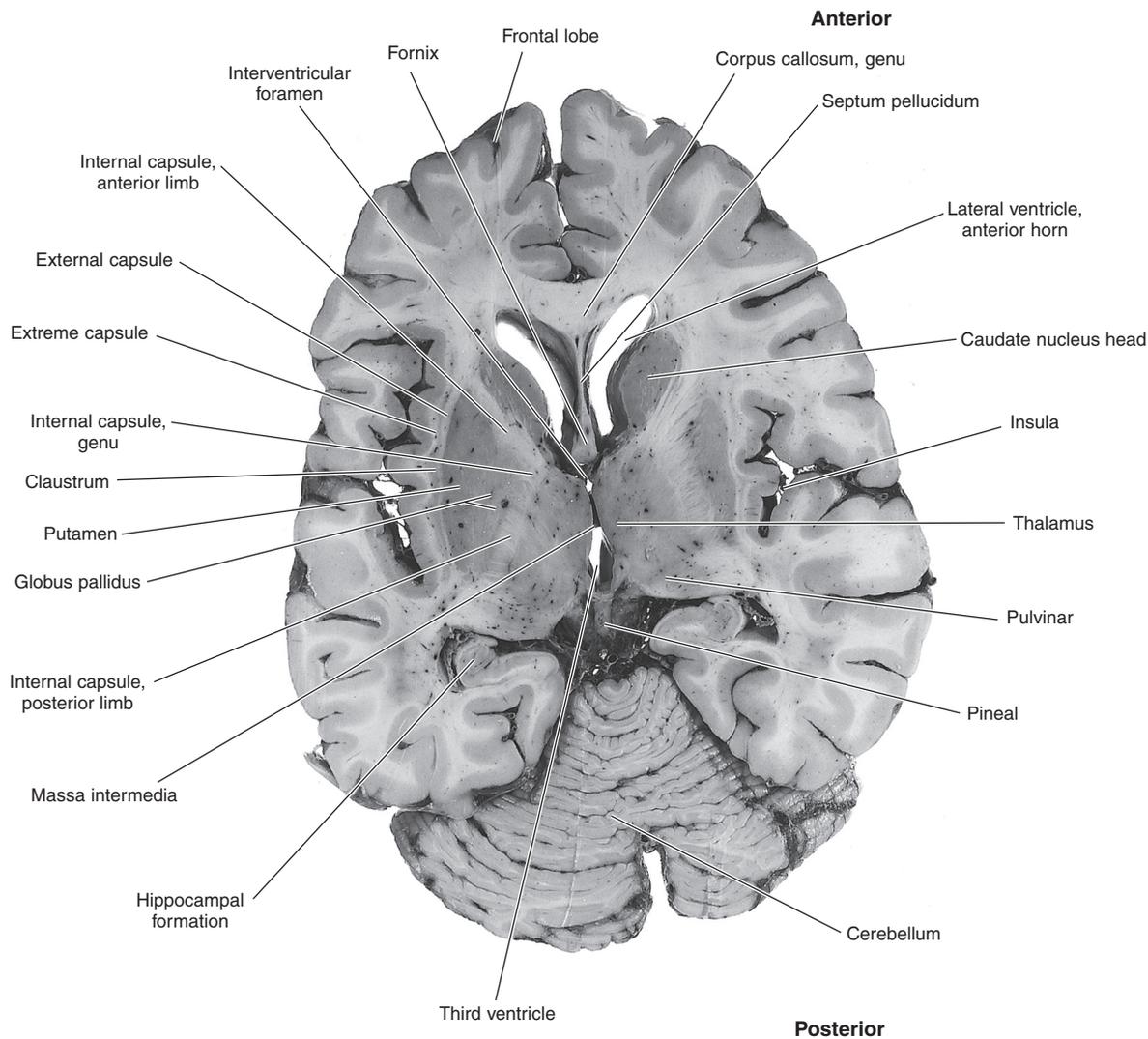
Figure 3-19 Dorsal view of a horizontal section through the interventricular foramina, third ventricle, and pulvinar.

amygdala), hypothalamic (mammillary) structures, and **hippocampus**, the septal nuclei are known to play a role in autonomic (reproductive) behaviors and memory regulation. The *third ventricle* is in the midline between two the thalami. Each lateral ventricle communicates with the midline third ventricle through the **interventricular foramina of Monro**. The interventricular foramen is located at the junction of the septum and thalamus on each side of the midline.

The two large nuclear masses projecting into the *lateral ventricles* are the heads of the *caudate nuclei,* which are important contributors to motor functions. Caudal to the caudate nuclei are the two thalami on each side of the *third ventricle.* The junctional area between the caudate and the thalamus is indented by the **genu** of the *internal capsule,* which connects the **anterior limb** to the **posterior limb**. The anterior limb is associated predominantly with cortical motor projections, and the poste-

rior limb is associated with the ascending (sensory) cortical projections.

The bend of the *internal capsule* is produced in part by the **lenticular nucleus** (putamen and **globus pallidus**). These two nuclei contribute to motor control and, in conjunction with the *caudate nucleus,* constitute the basal ganglia. Just lateral to the *putamen* is the *claustrum,* a thin, wavy line of cells that possesses two-way projections predominantly with the sensory cortical areas of the brain. The **insular cortex**, concerned with visceral functions, overlies the claustrum and lenticular nucleus.

The caudal end of the third ventricle is identified by the **posterior commissure** and the **pineal gland** in the midline. This level is the transitional area between the posterior thalamus and the midbrain. More caudally, the cerebellum is in the midline between the occipital lobes. The cerebellum overlies the *fourth ventricle* and is attached to the brainstem by the *cerebellar peduncles.*
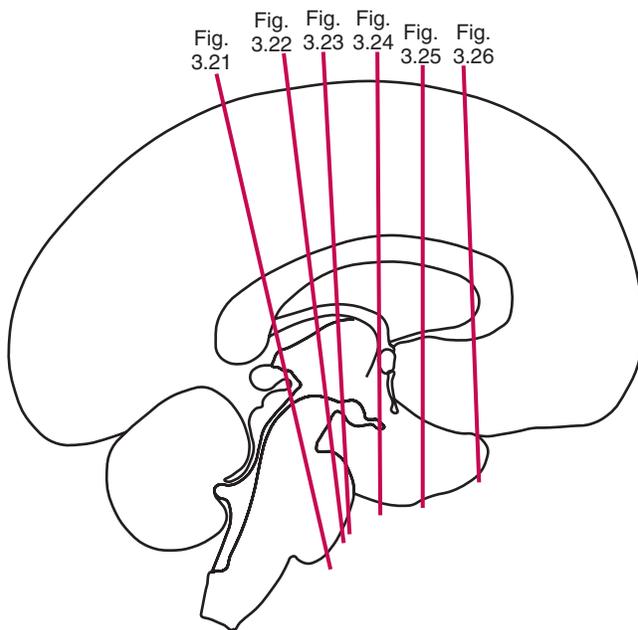
Figure 3-20 Midsagittal view identifying the locations of the coronal brain sections shown in the indicated figures.

Coronal Section Through the Posterior Thalamus

The coronal brain section shown in Figure 3-21 clearly shows the distinction between white and gray matter with sulci and gyri markings. The large fissure in the middle separating the hemispheres is the interhemispheric **longitudinal fissure**. The body of the *corpus callosum* forms the roof of the *lateral ventricles.* The **splenium** of the corpus callosum connects both *occipital lobes.*

The large cavities in this section are the bodies of the *lateral ventricles;* the small cavities in the temporal lobe are the **inferior horns** of the lateral ventricles. In the floor of the lateral ventricle is the fornix, a bundle of fibers that serves as a two-way connection between the hypothalamic structures (mammillary body) and hippocampus. Forming the medial wall of the inferior horn of the lateral ventricles is the **hippocampal formation**, which is thought to serve memory functions by consolidating new information.

The thalamic nucleus in this section is the *pulvinar,* the most posterior nucleus of the thalamus, which is connected reciprocally to the parietal association cortex and participates in language functions. Ventral to the pulvinar are the *geniculate* (medial and lateral) *bodies,* which serve as thalamic relay centers. The medial geniculate body mediates auditory information from the ears to the primary auditory cortices in the **gyrus of Heschl** (Brodmann area 41). The lateral geniculate body transmits visual information from homonymous halves of the retinas to the primary visual cortex in the occipital lobe (Brodmann area 17).

Dorsal to the inferior horn and lateral to the thalamus is the posterior limb of the *internal capsule,* which contains the ascending (sensory) and descending (motor) fibers. In the middle of this section the following brainstem structures can be seen: *cerebral aqueduct, decussation of the superior cerebellar peduncle, basal pons,* and the *pretectal structure.* The *pretectal area* regulates visual reflexes (see Chapters 8 and 15).

Coronal Section Through the Midthalamus

The section of the brain shown in Figure 3-22 retains most of the previously identified structures at the posterior thalamic level and a few newly visible structures. Emerging bilaterally from the walls of the *lateral ventricle* is the larger body of the *caudate nucleus.* The caudate nucleus, with its long tail, is a C-shaped structure in sagittal views of the brain (see Fig. 2-17); it can be seen in many sequential coronal sections of the brain. The caudate is an important nucleus, contributing to motor activity; it may have a role in cognitive processing. Its pathologic involvement of this structure is associated with Huntington chorea, a neurodegenerative disease characterized by dysarthria, chorea, and dementia. This genetically transmitted condition is characterized by dominant inheritance with complete penetrance and onset in the third decade of life. The mutation, a repeat of the Huntington gene (HD) locus, has been mapped to chromosome 4p (Box 3-2).

Forming the floor of the lateral ventricles in this section are the large gray masses of the thalamus. Both thalami are connected through the **massa intermedia**, a thalamic loose fibrous tissue. In the midline between the two lateral ventricles, is the septum pellucidum. Through the base of the septum courses the *fornix*, an important C-shaped limbic structure that connects the mamillary bodies of the *hypothalamus* to the *hippocampus* and *septum* and is involved in autonomic functions. Located lateral to the *internal capsule,* the *lenticular nucleus* consists of the *globus pallidus* and *putamen.* The globus pallidus and putamen are parts of the basal ganglia and are important in regulating motor functions and muscle tone.

The *external capsule* is a thin band of fibers lateral to the *lenticular nucleus.* Lateral to the *external capsule* is the *claustrum,* a thin layer of gray matter. The thin bundle of fibers lateral to the claustrum is the *extreme capsule.* The most lateral structure in this section is the *insular cortex.* The vertical slit in the center is the *third ventricle,* formed by the medial walls of each thalamus. In the center of the section, the remaining brainstem structures include the *crus cerebri* (pes pedunculi), *basilar pons, red nucleus,* and *substantia nigra.*

Coronal Section Through the Anterior Thalamus

The general orientation of the forebrain anatomy in a coronal section through the anterior thalamus is similar to that of the previous section, although the one shown in Figure 3-23
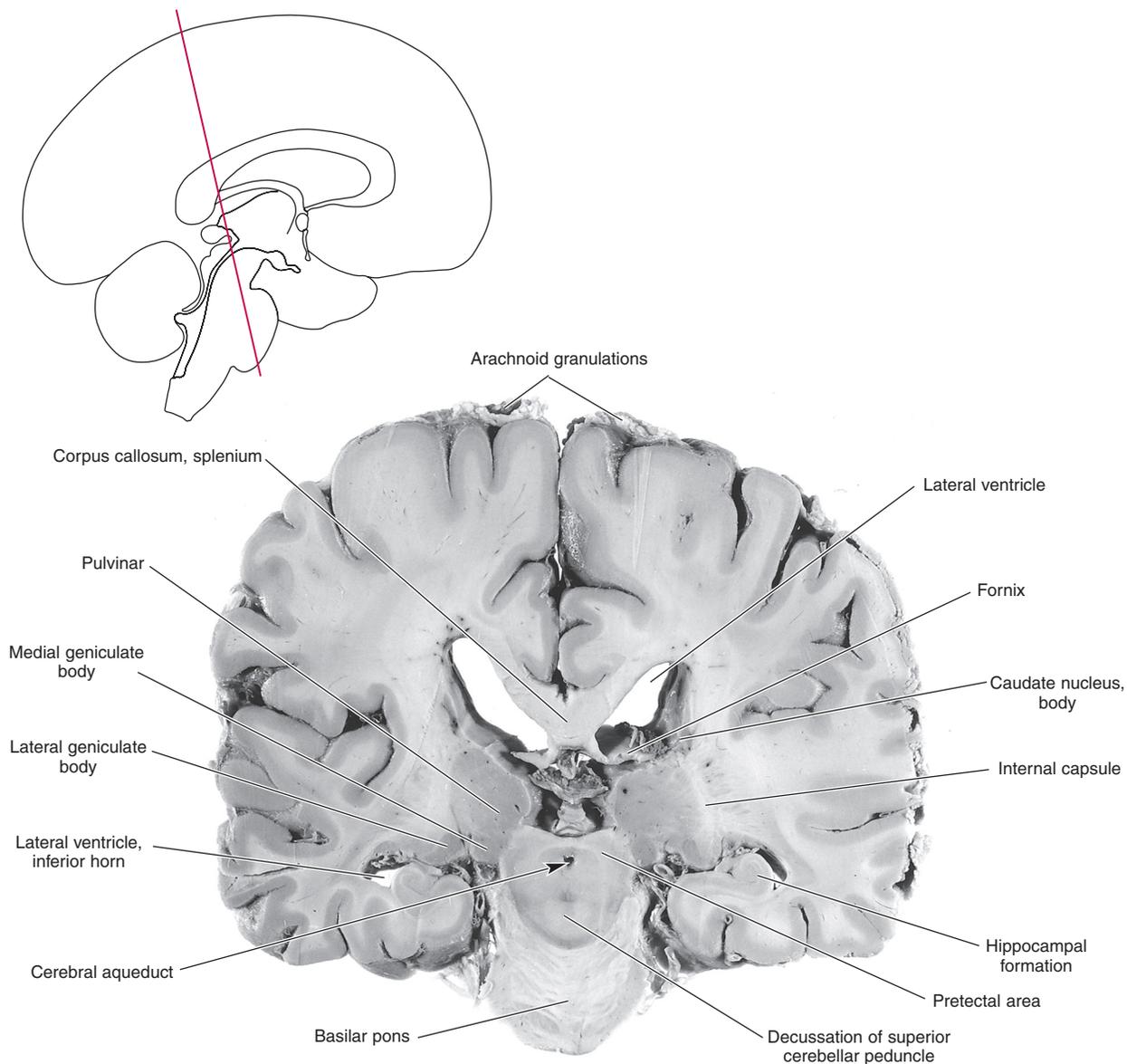
Arachnoid granulations

Corpus callosum, splenium

Pulvinar

Medial geniculate body

Lateral geniculate body

Lateral ventricle, inferior horn

Cerebral aqueduct

Basilar pons

Lateral ventricle

Fornix

Caudate nucleus, body

Internal capsule

Hippocampal formation

Pretectal area

Decussation of superior cerebellar peduncle

Figure 3-21 Caudal surface of a coronal section through the posterior thalamus.

is more rostral at the anterior thalamic nucleus level. The rough, saggy, and worm-shaped structure in the lateral ventricles is the **choroid plexus**, which secretes **cerebrospinal fluid** (CSF). Forming the floor of the lateral ventricle is the **anterior nucleus**, the most rostral nucleus of the thalamus. This nucleus receives afferents from the **mamillary bodies** of the hypothalamus and projects to the cingulate gyrus of the **limbic lobe**. Along the lateral wall of the *lateral ventricles* is the *caudate nucleus,* a C-shaped structure. This section of the forebrain is unique because it simultaneously reveals the dorsal component (body of the caudate nucleus in the lateral ventricle) and ventral component (tail of the *caudate nucleus* in the lateral wall of the temporal horn).

Medial to the *internal capsule* is the biconvex-shaped *subthalamic nucleus,* which receives afferents from the lateral segment of the *globus pallidus* and projects to both of the pal-

lidal segments and to the pars reticulata region of the **substantia nigra**. Subthalamic pathology results in hemiballism.

Coronal Section Through the Anterior Commissure

A coronal section of the forebrain through the *anterior commissure* and the *internal capsule genu,* marks the anterior limit of the thalamus (Fig. 3-24). The head of the *caudate nucleus* emerges in the ventricular cavity as a larger structure than at the more caudal levels. There is a clear view of the anterior commissure and its crossing. The anterior commissure is a small forebrain fiber bundle that contains bidirectional olfactory fibers and connects the temporal cortices. At this level, the internal capsule fibers, which are somewhat diminished, suggest the beginning of its *anterior limb.*
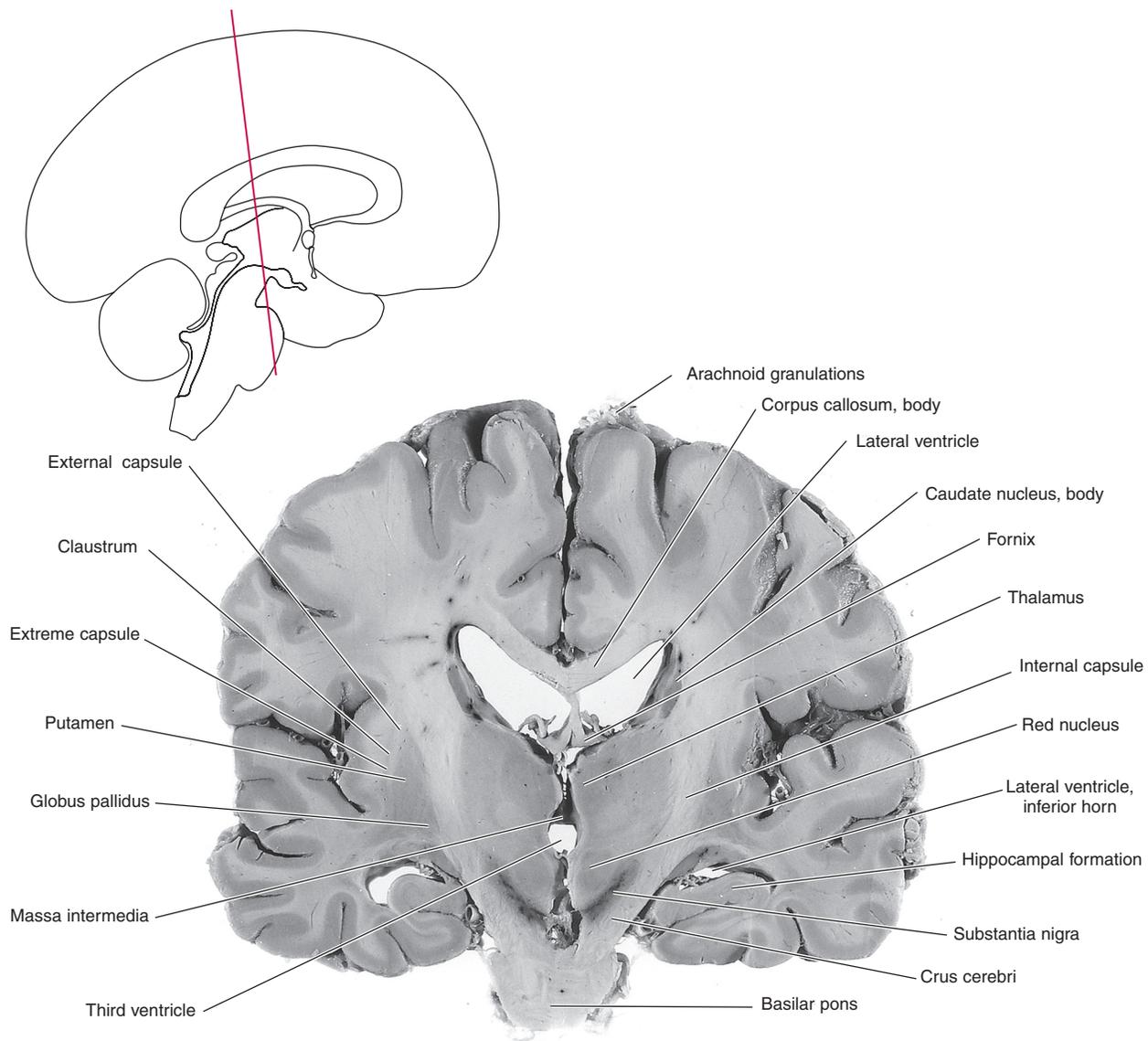
Figure 3-22 Caudal surface of a coronal section through the medial thalamus and massa intermedia.

BOX 3-2

Huntington Chorea

Huntington chorea, a progressive neurodegenerative disease of dominant autosomal inheritance, is associated with complete gene penetration and an onset in the 3rd or 4th decade of life. The disease causes cellular death in the caudate nucleus, putamen, and cerebral cortex. Clinically, it is characterized by choreic movements of the upper and lower limbs, altered personality, dysarthria, and dementia. There is no medical treatment for Huntington chorea; however, dopamine receptor blockers have been used to control the choreic movements.

The *septum,* which anteriorly separates the *lateral ventricles,* is centrally located in the section. All *hippocampal* projections terminate in the *septum verum nuclei,* which are part of the limbic system. Forming the lateral walls of the third ventricle below the level of the *anterior commissure* is the *hypothalamus.* Two important structures of the hypothalamus, not seen in this section, are the *mammillary body* and *pituitary gland. Hypothalamic nuclei* produce neurosecretions that are important in controlling water balance, sugar and fat metabolism, body temperature, and hormone production. The hypothalamus is also the regulator of the autonomic (sympathetic and parasympathetic) nervous system.

The **amygdaloid nucleus** is seen here at the level at which the tail of the *caudate nucleus* terminates (see Fig. 2-17). The *amygdala,* a massive round structure in the medial temporal lobe, is generally responsible for activating
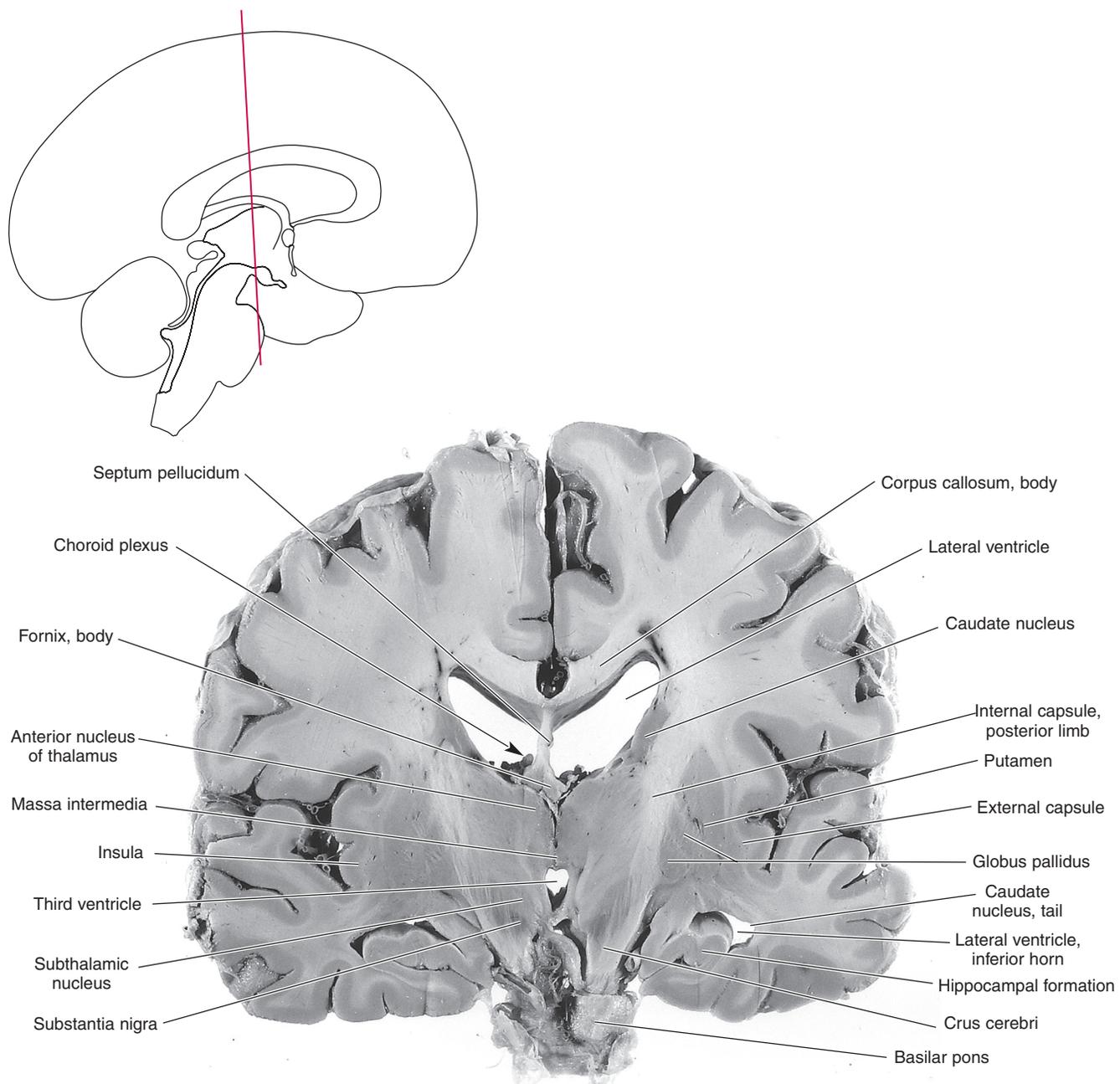
Septum pellucidum

Choroid plexus

Fornix, body

Anterior nucleus of thalamus

Massa intermedia

Insula

Third ventricle

Subthalamic nucleus

Substantia nigra

Corpus callosum, body

Lateral ventricle

Caudate nucleus

Internal capsule, posterior limb

Putamen

External capsule

Globus pallidus

Caudate nucleus, tail

Lateral ventricle, inferior horn

Hippocampal formation

Crus cerebri

Basilar pons

Figure 3-23 Rostral surface of a coronal section through the rostral thalamus, massa intermedia, and subthalamic nucleus.

emotional behavior. Pathology of this structure has been known to lead to aggression and other abnormal behavior, such as hypersexuality; surgical removal in animals has caused aggressive animals to become docile and hyposexual.

The following previously identified structures are also present in this section and are unchanged in basic configuration: *corpus callosum, septum pellucidum, fornix, caudate nucleus, putamen, globus pallidus, internal capsule, external capsule, claustrum, extreme capsule,* and *insular cortex.*

Coronal Section Through the Anterior Limb of the Internal Capsule and Caudate Head

A coronal section of the forebrain at the rostral region of the basal ganglia reveals the large head of the *caudate nucleus,* the *anterior horn* of the *lateral ventricles,* and the *anterior limb* of the *internal capsule* (Fig. 3-25). At this level of the brain, the thalamus and *globus pallidus* are no longer present (Fig. 3-19). The massive caudate nucleus head forms the ventrolateral wall of the lateral ventricle at the level of
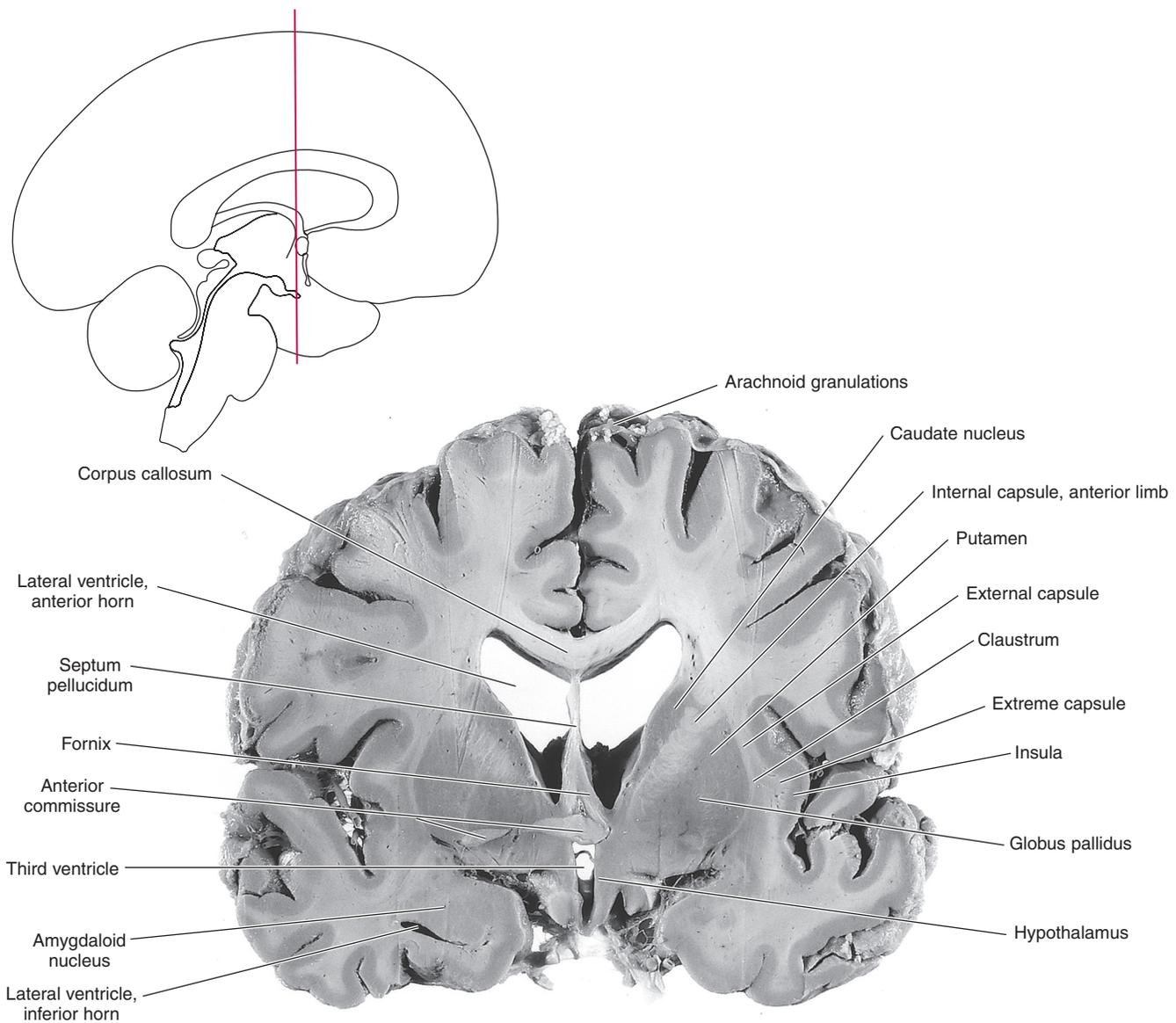
Arachnoid granulations

Caudate nucleus

Internal capsule, anterior limb

Putamen

External capsule

Claustrum

Extreme capsule

Insula

Globus pallidus

Hypothalamus

Corpus callosum

Lateral ventricle, anterior horn

Septum pellucidum

Fornix

Anterior commissure

Third ventricle

Amygdaloid nucleus

Lateral ventricle, inferior horn

Figure 3-24 Rostral surface of a coronal section through the level of the anterior commissure rostral to the genu of the internal capsule.

the anterior horn. Laterally, the ventral component of the caudate nucleus merges with the *putamen* to form the **corpus striatum**.

The portion of the *internal capsule* at this level is the *anterior limb,* which courses between the bodies of the caudate and *putamen.* In the middle, forming the medial ventricular wall, is the *septum pellucidum,* which is attached to the medial basal forebrain area. The *cingulate gyrus,* a limbic structure involved with emotional drive and anxiety, is dorsal to the body of the corpus callosum. The **cingulum**, a bundle of mediofrontal parietal cingulate association fibers, is beneath the cingulate gyrus. Also visible is the *septum pellucidum* with its underlying nucleus, a limbic structure related to visceral functions, reward, and gratification.

The cortical regions rostral to this level undergo only a few changes. The *ventricular cavity* rostrally ends at the *genu* of the *corpus callosum* (see Fig. 2-12). Anterior to the corpus callosum is the massive accumulation of white matter that consists of *callosal radiations* and *corona radiata.* These changes can be seen in Figure 3-26.

Coronal Section Through the Anterior Horn

A coronal section of the forebrain at the *genu* of the *corpus callosum* reveals the end of the *lateral ventricle* (anterior horn) and the *rostral striatum* (caudate head and putamen) (Fig. 3-26). Other previously identified rostral structures seen here include the *septum, internal* and *external capsules, claustrum, cingulate gyrus,* and *cingulum.*
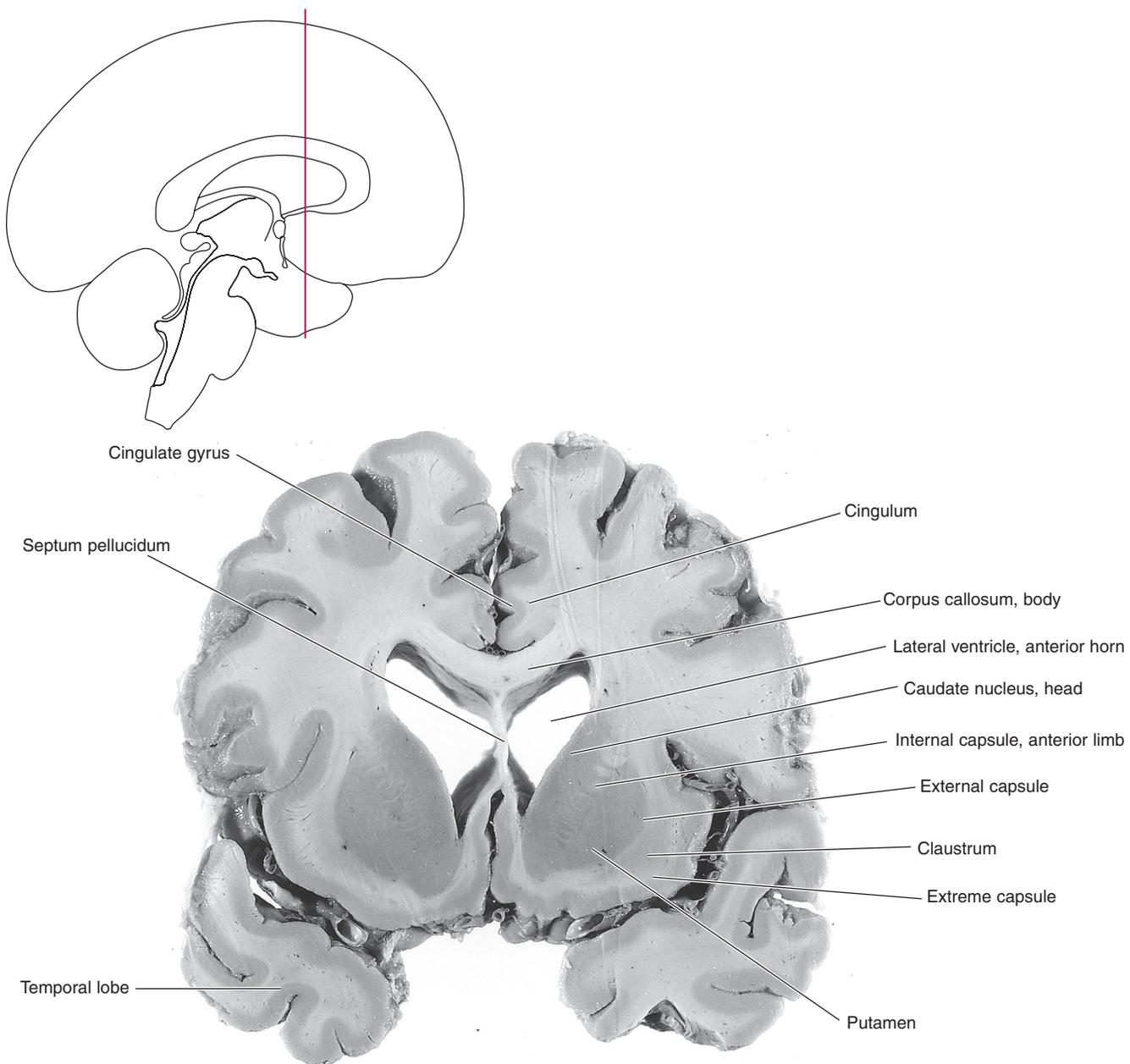
Cingulate gyrus

Septum pellucidum

Cingulum

Corpus callosum, body

Lateral ventricle, anterior horn

Caudate nucleus, head

Internal capsule, anterior limb

External capsule

Claustrum

Extreme capsule

Temporal lobe

Putamen

Figure 3-25   Caudal surface of a coronal section through the head of the caudate nucleus.

FOREBRAIN IN HORIZONTAL SECTIONS

A review of the forebrain anatomy on horizontal sections contributes to the visual orientation of the internal anatomy of the brain and helps consolidate previous learning. In Figures 3-27 to 3-30, the human brain has been dissected horizontally to provide a three-dimensional view of the *corpus callosum, ventricular cavity, thalamus,* and *basal ganglia* structures.

In Figure 3-27, a 1-cm-thick layer of the cerebral cortex has been removed to expose the underlying brain structures. The residual indentation of the interhemispheric longitudinal fissure is evident in the middle, including the *central sulcus;* other sulci and gyri are seen in the periphery

of this section. Each hemisphere contains a **semiovale center**, a massive accumulation of white matter that contains the blended **association**, **commissural**, and **projection fibers** above the *internal capsule* level. The sensorimotor fibers form the *corona radiata,* in which the descending motor fibers fan down toward the internal capsule and the ascending sensory fibers fan out to reach the cerebral cortex. (See Fig. 2-38.)

The removal of an additional 1–2 cm of cortical substance, which includes the *cingulate gyrus* and *cingulum,* exposes the dorsal surface of the *corpus callosum* (Fig. 3-28). Starting rostrally in this section are the *genu, body,* and *splenium* of the corpus callosum. The densely packed radiating fibers of the corpus callosum connect the hemispheres. The
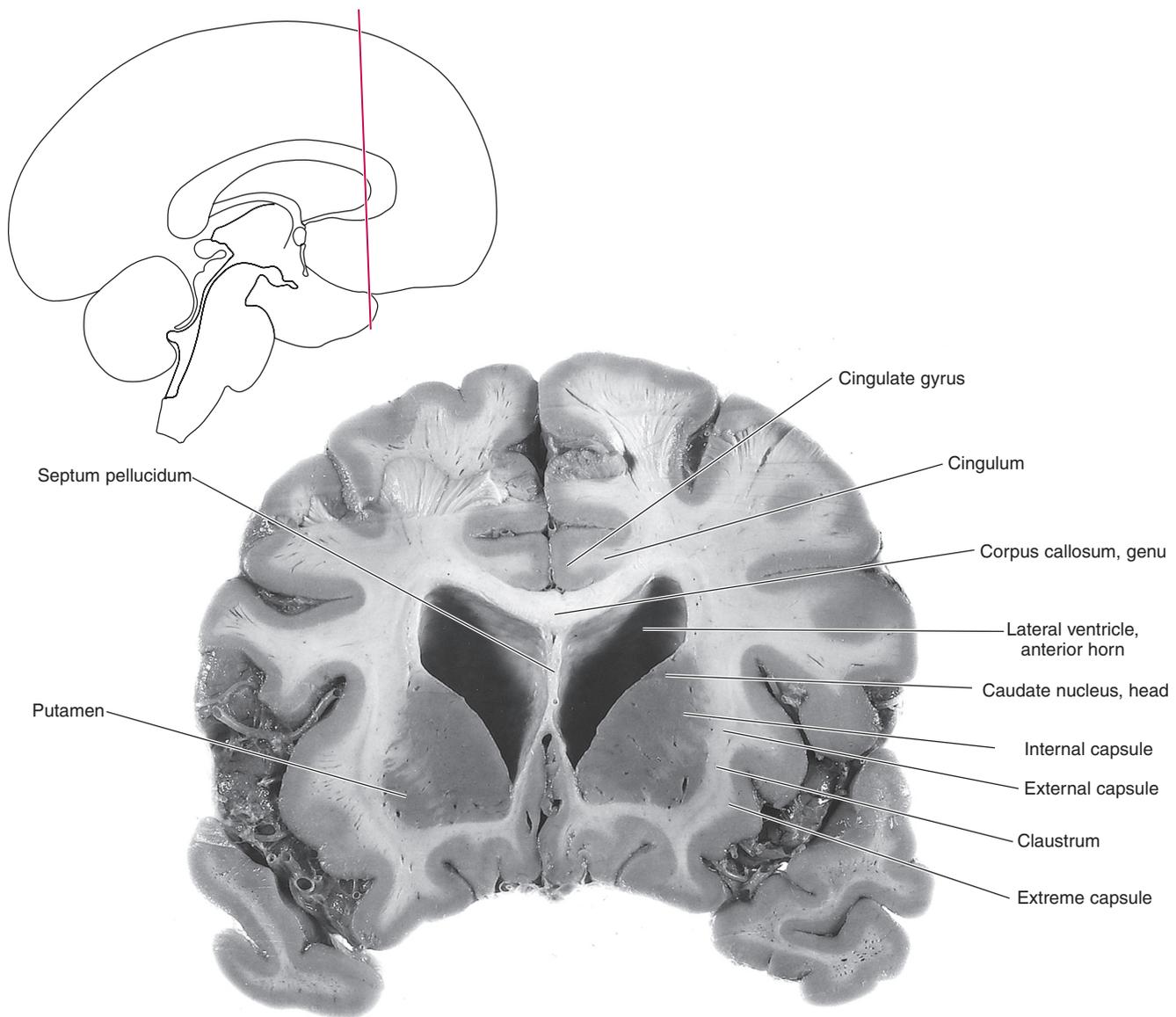
Figure 3-26 Caudal surface of a coronal section just caudal to the genu of the corpus callosum and the rostral end of the anterior horns.

body of the corpus callosum and its lateral radiations form the roof of the *lateral ventricles.*

Further removal of the *corpus callosum* and its radiating cortical fibers reveals the large underlying subcortical structures and *lateral ventricles* (Fig. 3-29). Laterally located are the fibers constituting the *corona radiata,* the condensed projection fibers before they enter the *internal capsule.* The spaces on both sides of the corpus callosum mark the cavities of the lateral ventricles. The two prominent structures in the floor of the ventricles are the *caudate nucleus* and the *thalamus.*

The massive balloon-shaped structure located rostrally and laterally in the ventricular cavity is the head of the *caudate nucleus;* its C-shaped tail is buried within the adjoining white matter. The head of the caudate nucleus forms the lateral anterior wall of the *lateral ventricles.* The

thalamus, the largest diencephalic structure, is located posteriorly in the floor of the ventricular cavity. Removal of *parietal* and *occipital* tissues has also exposed the caudal portion of the lateral ventricles, particularly the posterior horns in the **occipital lobe regions**. The remaining *genu, body,* and *splenium* portions of the *corpus callosum* are identified easily above the lateral ventricles. Also present is the point at which the tail of the caudate nucleus enters the temporal lobe.

Further removal of the overlying white **medullary substance**, *caudate nucleus,* and thalamus by sectioning rostral to the *genu* of the *corpus callosum* exposes the cavity of the *lateral ventricles* and the surrounding subcortical structures (Fig. 3-30). The exposed inner temporal lobe contains the slender temporal horns of the lateral ventricles. The hippo-
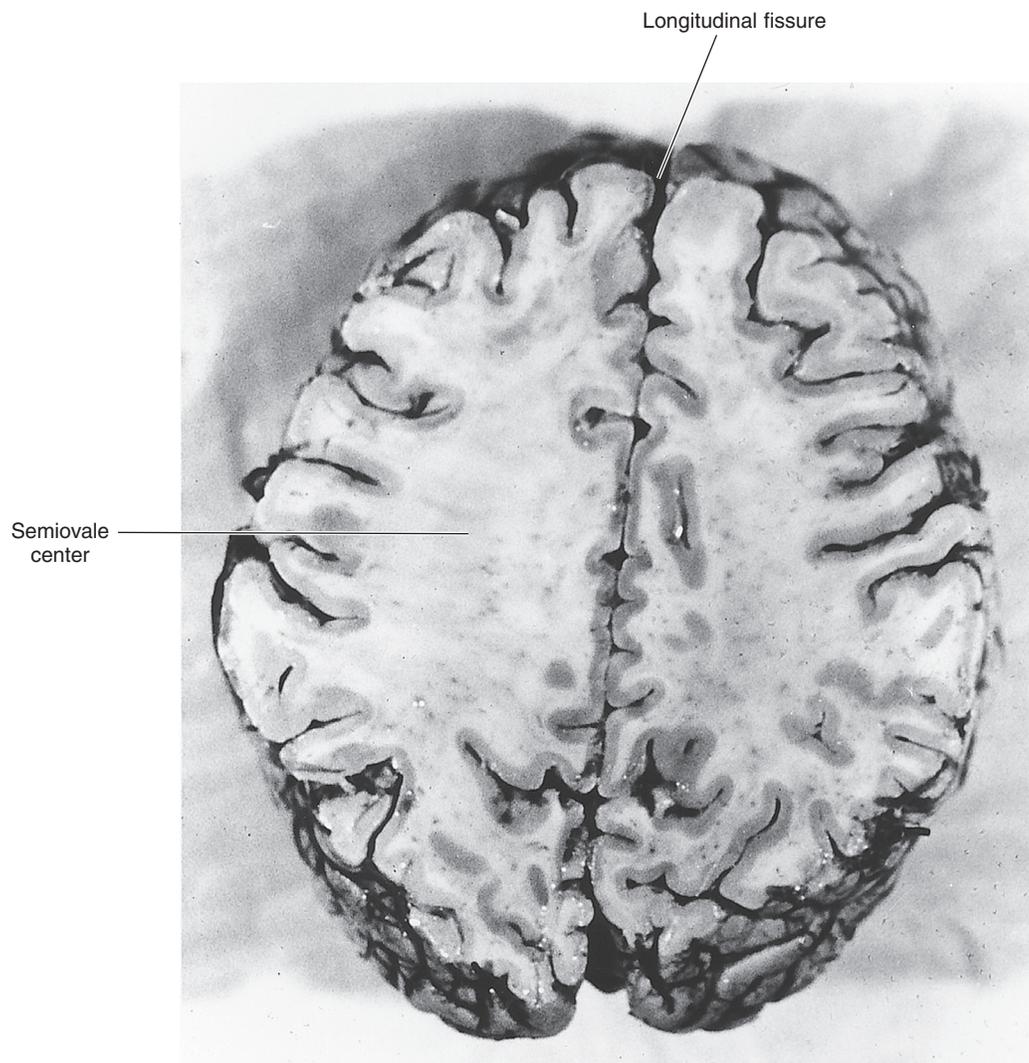
Figure 3-27 Horizontal section of the brain above the corpus callosum.

Corpus callosum, genu

Corpus callosum, body

Semiovale center
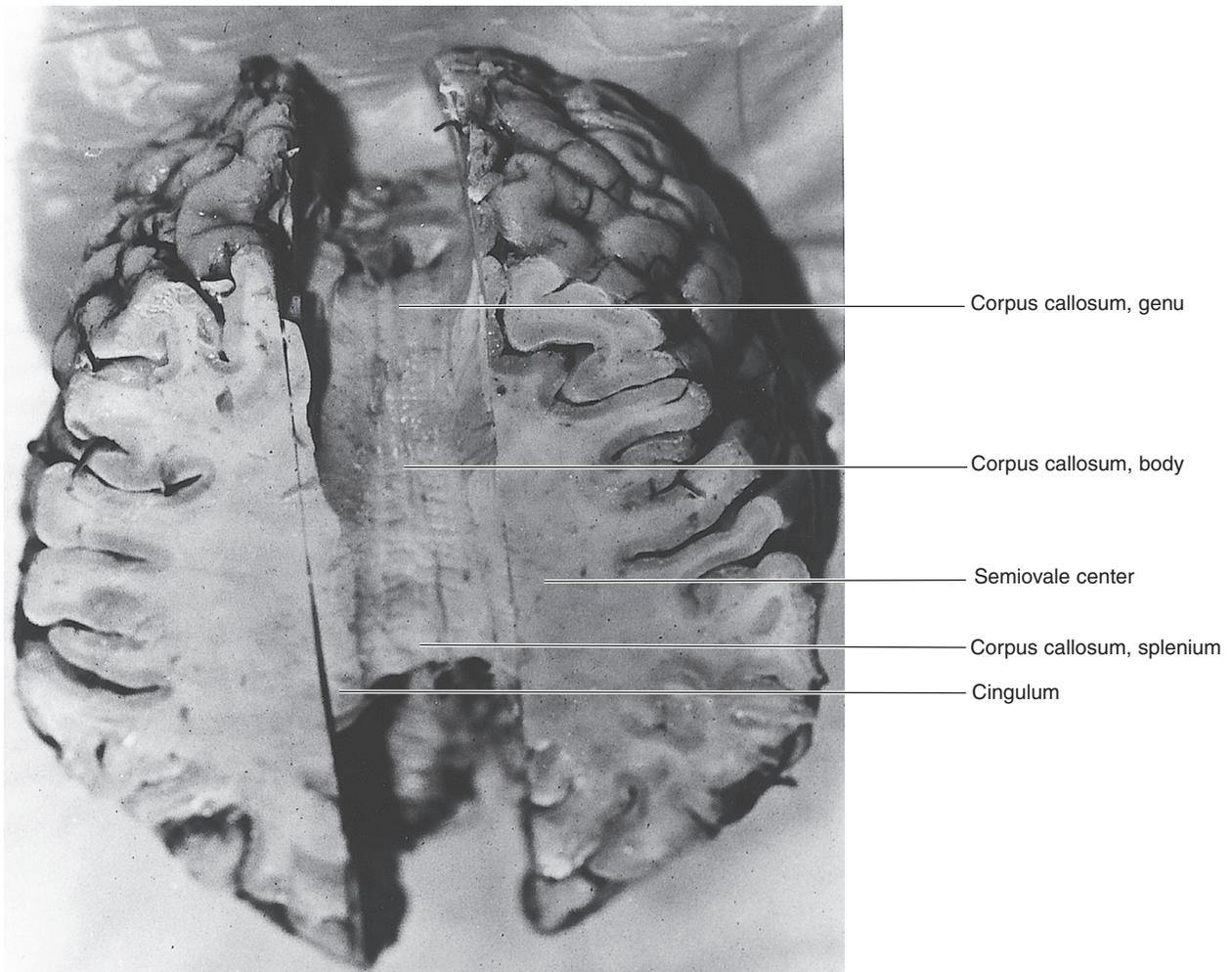
Corpus callosum, splenium

Cingulum

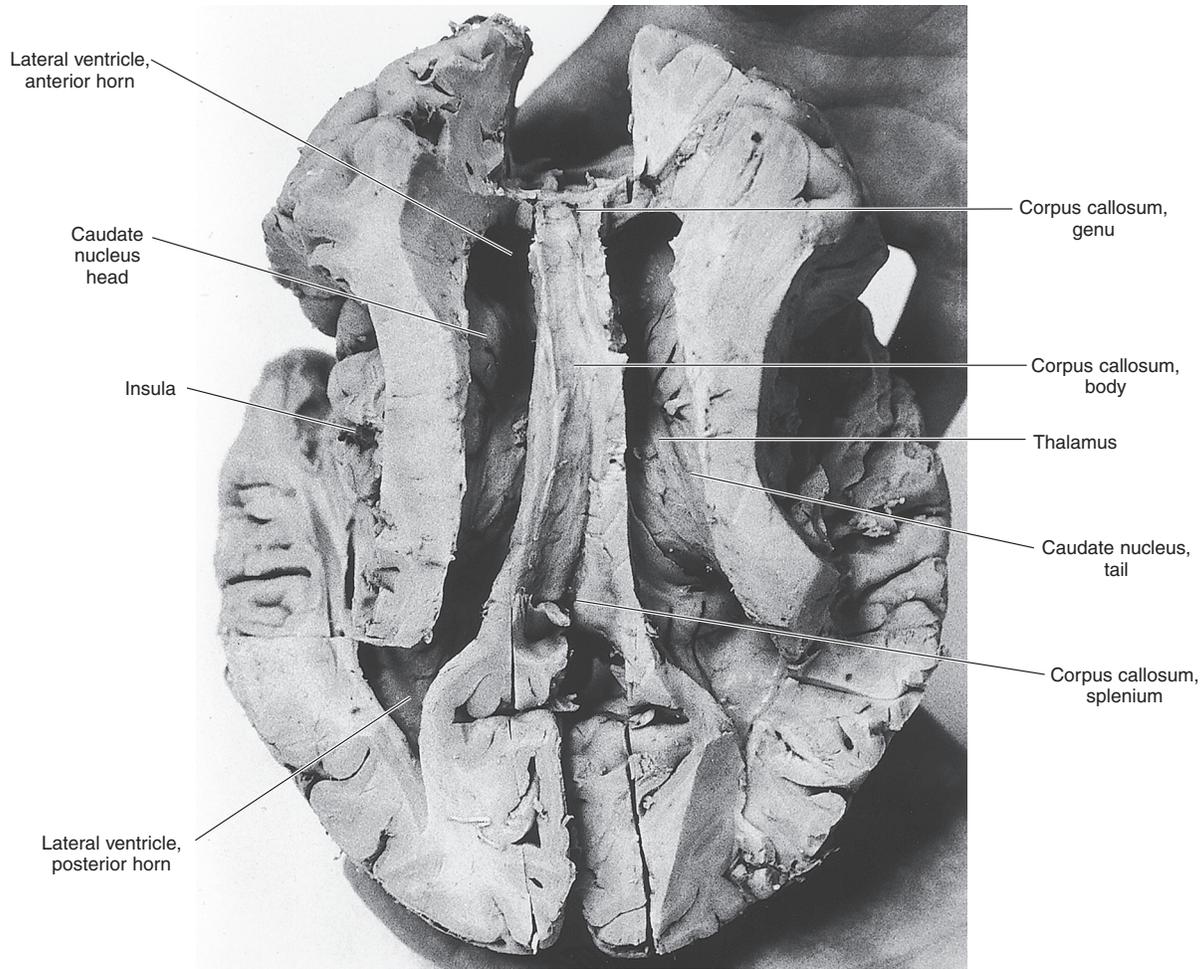**Figure 3-28** Horizontal section exposing the corpus callosum.

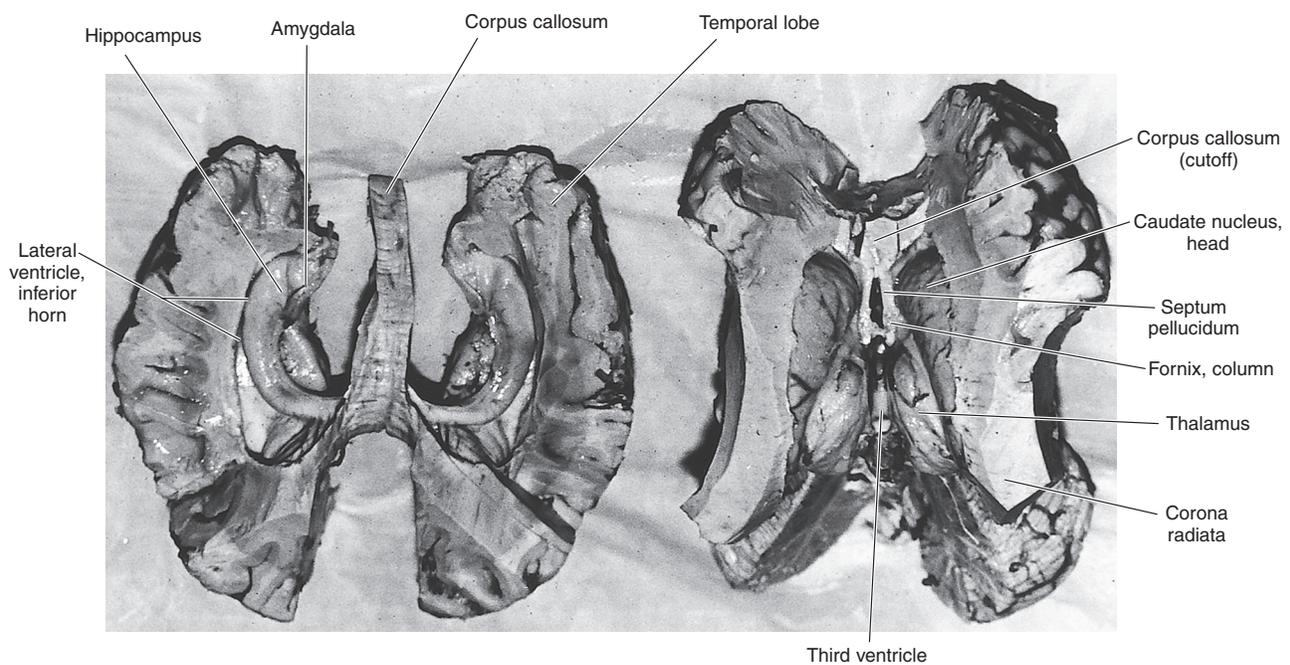**Figure 3-29** Horizontal section exposing the ventricles and basal ganglia.

Figure 3-30 Horizontal section in which sectioning of the corpus callosum from the adjacent cortical structure exposes the hippocampus, ventricular cavity, and basal ganglia structure.

campus, amygdala, and **uncus** are located medially in the *inferior horn.* The *hippocampus* forms the medial wall of the *temporal horns.* It receives direct projections from the fornix and indirect projections from the *cingulum* via the **parahippocampal gyrus**.

Anterior to the tip of the *hippocampus* is the *amygdaloid nucleus,* an important limbic structure with a protruding cortical component called the *uncus.* With a complete removal of the *callosal fibers,* the floor of the *lateral ventricles* becomes fully visible. The *septum* is seen rostrally, separating the *anterior horns* of the lateral ventricles. The structure at the base of the septum is the **fornix column**. Also present are the head of the caudate nucleus, the medial dorsal *thalamus,* and the *third ventricle.*

SUMMARY

Knowledge of the internal brain anatomy is the most important part of training in neuroscience and is essential for solving clinical problems. It is learned best by repeated study of the internal structures on serial sections of the spinal cord, brainstem, and forebrain and by relating the structures to their functions. Visual orientation to the structures and functional knowledge of the internal anatomy are essential because the form the basis for the overall understanding of brain structures and their relation to clinical symptoms.

QUIZ QUESTIONS

1. Define the following terms: cerebral aqueduct, inferior colliculus, lateral geniculate body, medial geniculate body, medial longitudinal fasciculus, pyramidal decussation, red nucleus, substantia nigra, subthalamic nucleus, superior colliculus

2. Identify three landmark structures of the internal medulla and define their functions.

3. What ventricular cavity is located dorsal to the pons?

4. Identify three landmarks of the internal pons and define their functions.

5. What differentiates the tectal and tegmental regions in the midbrain?

6. Name three major internal structures of the midbrain and define their functions.

7. List five structures that are present on a coronal section of the forebrain cut at the caudate head level and define their functions.

8. Explain why a hemorrhage in the right caudal medulla involving the corticospinal fibers will cause a left hemiplegia?

TECHNICAL TERMS

amygdaloid nucleus
anterior medullary velum
caudate nucleus
central gray
cerebral aqueduct
choroid plexus
cingulate gyrus
collateral trigone
corona radiata
fornix
hippocampus
(hippocampal formation)
hypothalamus
inferior cerebellar peduncle
(restiform body)
inferior colliculus
insula (isle of Reil)
internal arcuate fibers
lateral geniculate body
lateral lemniscus
medial geniculate body

medial lemniscus
medial longitudinal
fasciculus
middle cerebellar peduncle
(brachium pontis)
pineal
principal (inferior) olivary
nucleus
pyramidal decussation
red nucleus
reticular formation
semiovale center
spinocerebellar tract
substantia nigra
subthalamic nucleus
superior cerebellar
peduncle (brachium
conjunctivum)
superior colliculus
thalamus