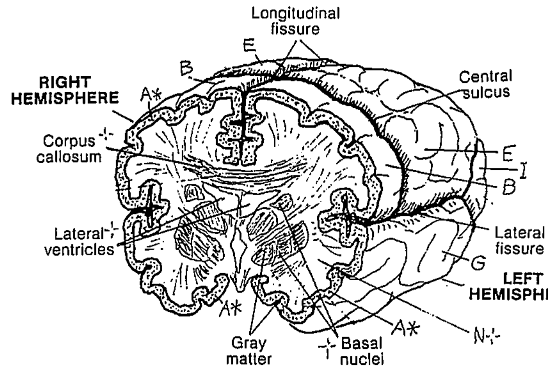
See 70

CEREBRAL HEMISPHERES

CN: Use light colors for B, E, I, and J. (1) Color the coronal section; most of the frontal lobe and part of the temporal lobe have been removed. Color the cerebral cortex (A) gray. In the two large hemispheres the stippled areas of specialized function are parts of lobes, but receive their own colors. Color the arrows identifying the major fissures and sulcus. (3) Color gray the diagram illustrating how the convolutions provide increased surface area in a smaller space.

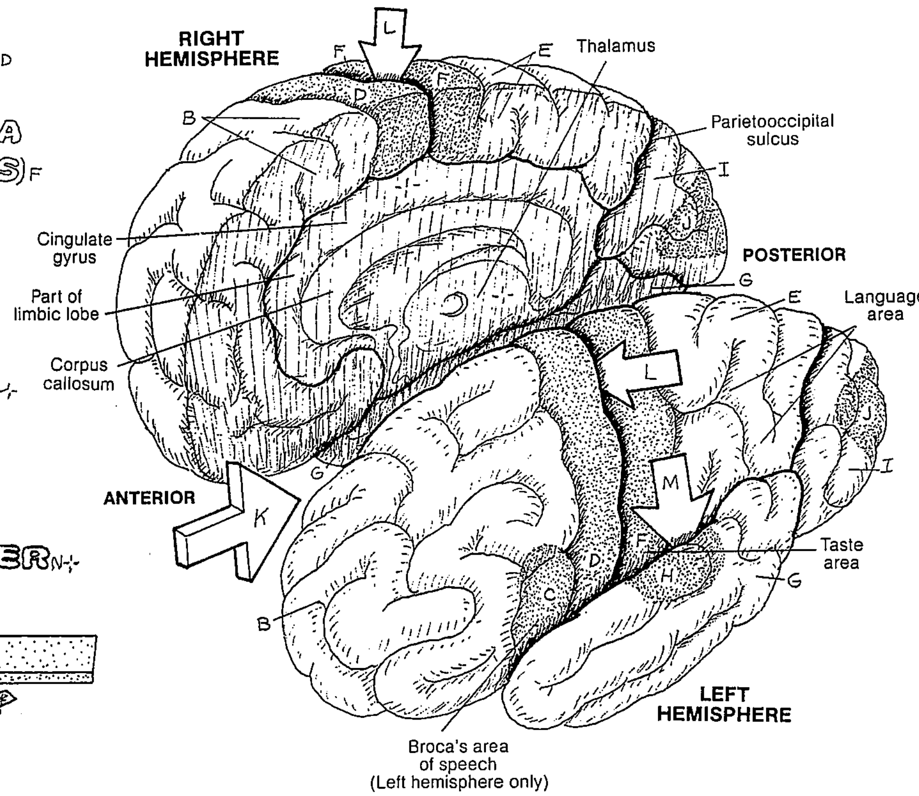


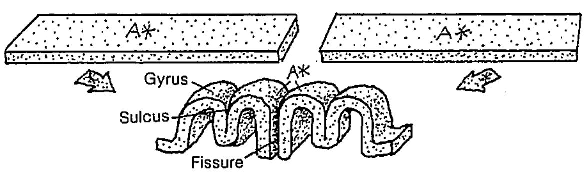
CORONAL SECTION (Modified)

CEREBRAL CORTEX (GRAY MATTER) A*
- FRONTAL LOBE B
  - PRINCIPAL SPEECH AREA C
  - PRIMARY MOTOR AREA (PRECENTRAL GYRUS) D
- PARIETAL LOBE E
  - PRIMARY SENSORY AREA (POSTCENTRAL GYRUS) F
- TEMPORAL LOBE G
  - AUDITORY AREA H
- OCCIPITAL LOBE I
  - VISUAL AREA J

MAJOR FISSURES/SULCUS
- LONGITUDINAL FISSURE K
- CENTRAL SULCUS L
- LATERAL FISSURE M

SUBCORTICAL WHITE MATTER N





CORTICAL CONVOLUTIONS: INCREASED SURFACE AREA

The paired cerebral hemispheres (cerebrum), derivatives of the embryonic telencephalon (see Plate 169), consist of four major elements: (1) an outer cerebral cortex of gray matter, the topography of which reveals fissures (deep grooves), gyri (hills), and sulci (furrows); (2) underlying white matter consisting of numerous tracts destined for or leaving the cortex and oriented along three general directions (Plate 74); (3) discrete masses of gray matter at the base of the cerebrum (basal nuclei) that subserve motor areas of the cortex (Plate 74); (4) paired cavities called lateral ventricles (Plate 80). The cerebral cortex is the most highly evolved area of the brain. About 2–4 mm (roughly 1/6 inch) thick, the cortex is divided into lobes distinctly bordered by sulci; the lobes are generally related to the cranial bones that cover them: frontal, parietal, temporal, occipital. The exception is the limbic lobe (part of which is shown); it incorporates parts of other (frontal, temporal, parietal) lobes.

Cortical mapping experiments (based on electrical stimulation and clinical/pathologic data) have been the principal methods by which functions of the cortex have been discovered. All parts of the cortex are concerned with storage of experience (memory), exchange of impulses with other cortical areas (association), and the two-way transmission of impulses with subcortical areas (afferent/efferent projections).

The frontal lobe is concerned with intellectual functions such as reasoning and abstract thinking, aggression, sexual behavior, olfaction (smell), articulation of meaningful sound (*speech*), and voluntary movement (*precentral gyrus*). The *central sulcus* separates the frontal lobe from the parietal lobe. The *parietal lobe* is concerned with body sensory awareness, including taste (*postcentral gyrus*), the use of symbols for communication (language), abstract reasoning (e.g., mathematics), and body imaging. The *temporal lobe* is partly limbic and here is concerned with the formation of emotions (love, anger, aggression, compulsion, sexual behavior); the non-limbic portion of the temporal lobe is concerned with interpretation of language and awareness and discrimination of sound (hearing; *auditory area*); it constitutes a major memory processing area. The *occipital lobe* is concerned with receiving, interpreting, and discriminating visual stimuli from the optic tract and associating those visual impulses with other cortical areas (e.g., memory).

The limbic lobe or system is the oldest part of the cortex, in evolutionary terms. It is the center of emotional behavior. The limbic neurons occupy parts of the inferior and medial cortices of each hemisphere, and some subcortical areas as well. Certain limbic areas are closely related topographically to the olfactory tracts.

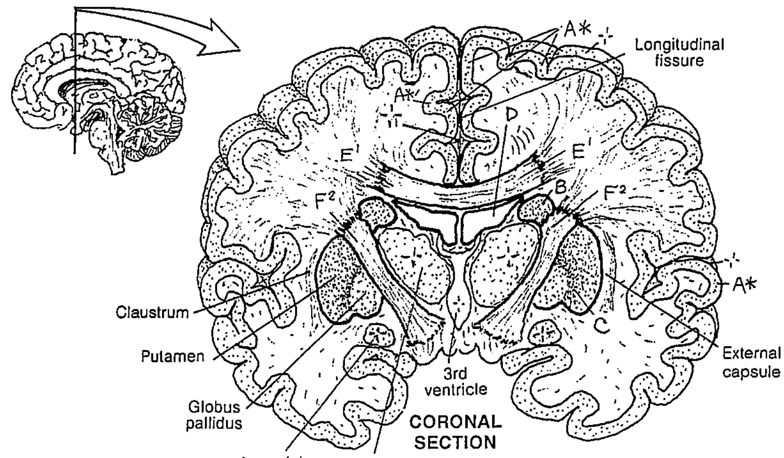
The cerebral hemispheres appear structurally as mirror images of one another; functionally they are not. The speech area develops fully only on one side, usually the left. In general, the left hemisphere tends to deal with certain higher functions (mathematical, analytical, verbal) while the right concentrates on visual, spatial, and musical orientations. The matter of cerebral "dominance" (left hemisphere, left speech center, righthandedness, or vice versa) is quite controversial.

See 75

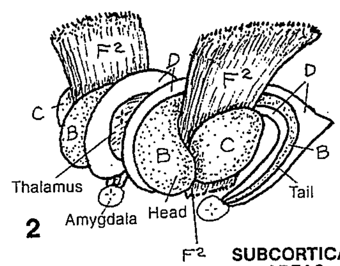
TRACTS/NUCLEI OF CEREBRAL HEMISPHERES

CN: Use very light colors for F and G. (1) Color gray the various sections of cerebral cortex without coloring the cortical surfaces.

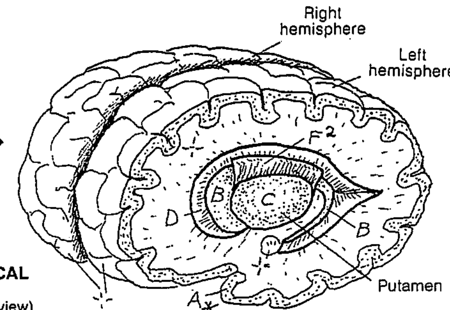
CEREBRAL CORTEX A*
SUBCORTICAL AREAS ∴
BASAL NUCLEI ∴
CAUDATE NUCLEUS B
LENTICULAR NUCLEUS C
LATERAL VENTRICLE D
WHITE MATTER TRACTS ∴
COMMISSURES E
CORPUS CALLOSUM E'
PROJECTION TRACTS F
CORONA RADIATA F'
INTERNAL CAPSULE F²
ASSOCIATION TRACTS G



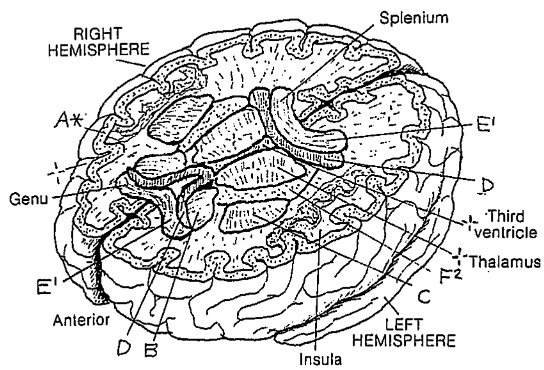
CORONAL SECTION
1



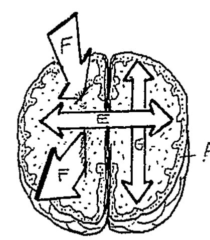
2
SUBCORTICAL AREAS
(Anteriolateral view)



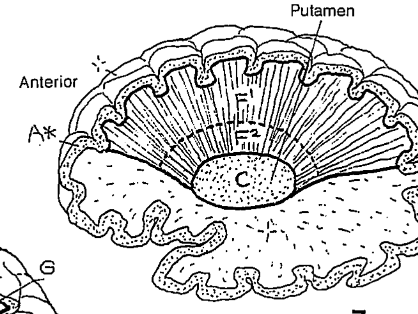
3



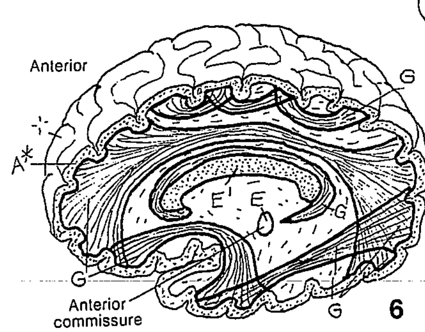
4
HORIZONTAL SECTION



TRACT DIRECTIONS
(Superior view)
5



7
MEDIAL VIEW
(Right hemisphere section)



6

Below the cerebral cortex, the cerebral hemispheres embody centrally placed cavities, masses of gray matter at the base of the cerebrum, and bundles of white matter. These structures can be colored in the coronal section at upper right cerebrum (1).

The basal nuclei are discrete, bilateral islands of gray matter on either side of and above the diencephalon (Plate75). They consist primarily of the tail-shaped *caudate nucleus* and the lens-shaped *lenticular nucleus* (2). These structures can be colored in illustrations 1, 2, 3, and 4. The lenticular nucleus is further divided into the medial globus pallidus and the more lateral putamen (1). Each of these nuclei is part of the extra-pyramidal system (Plate 79). They have extensive connections among themselves, with the cerebral cortex, and with nuclei of the diencephalon. They are concerned with the maintenance of muscle tone and the programming of subconscious, sequential postural adjustments. They monitor and mediate descending motor commands from the cerebral cortex.

The subcortical white matter of the hemispheres is arranged into bundles or bands (tracts) of largely myelinated axons essentially arranged in three axes (5). They conduct impulses among various areas of the cortex. The largest commissure is the *corpus-callosum*, forming a roof over the subcortical nuclei (1). It is bent caudally at both anterior and posterior ends (genu and splenium) (4, 6). Association tracts connect anterior and posterior cerebral cortices (5). They exist as both short and long tracts (6).

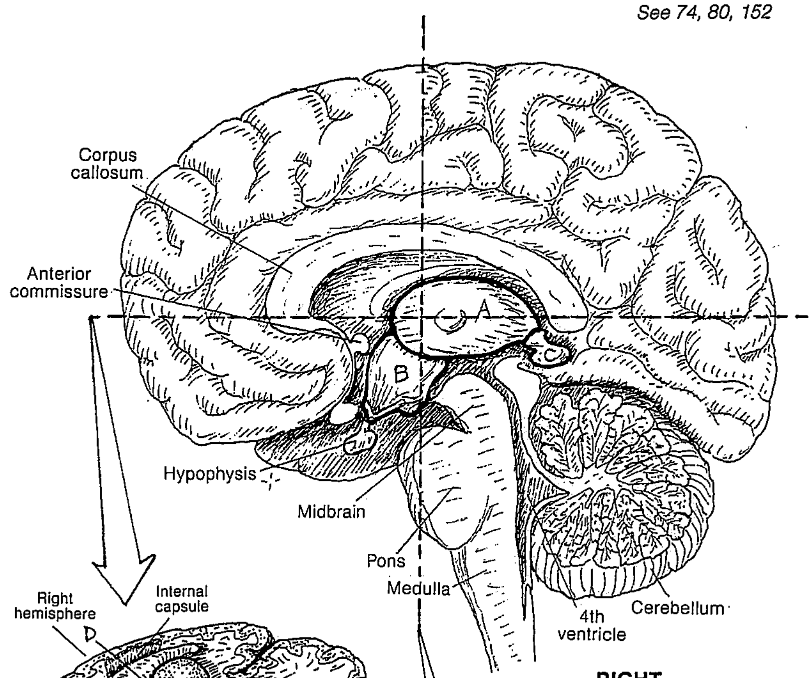
The most spectacular tract is the fan-shaped array of fibers called the *corona radiata* (5, 7). This projection system radiates caudally from all areas of the cortex. It narrows into a curved band (internal capsule; 1, 2, 3, 4) as it descends between the caudate nucleus and the thalamus medially, and the putamen laterally. The term "internal capsule" refers to the inner wall of the figurative encapsulation of the basal nuclei (1, note external capsule). The axons of the projection tract continue through the diencephalon into the brain stem and spinal cord; many make connections en route (Plates 78, 79).

See 74, 80, 152

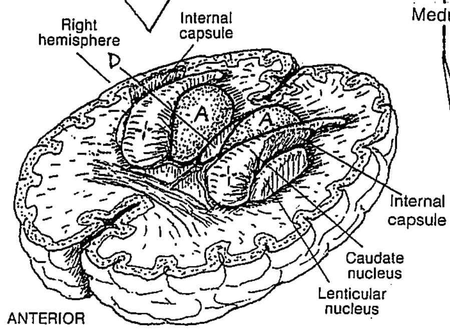
DIENCEPHALON

CN: Use light colors for A and B, and a very bright color for C. (1) Color each structure wherever it appears before going on to the next title. (2) Although not colored, the neighboring relations of the diencephalic structures are important and have been identified by name. These should be given special attention.

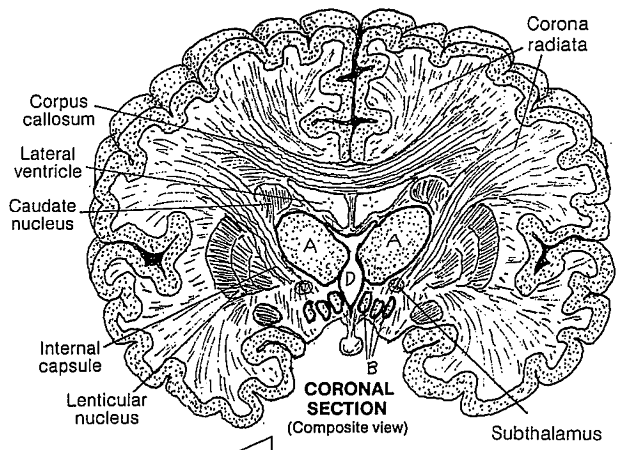
DIENCEPHALON ✣
THALAMUS A
HYPOTHALAMUS B
EPITHALAMUS
(PINEAL GLAND) C
THIRD VENTRICLE D



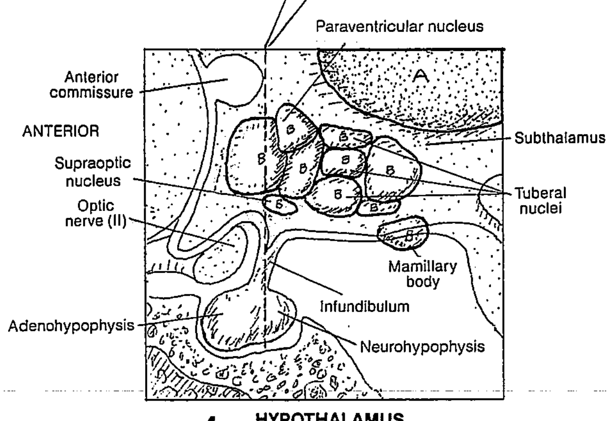
RIGHT HEMISPHERE
(Medial view)
1



HORIZONTAL SECTION
(Modified view)
2



CORONAL SECTION
(Composite view)
3



4 **HYPOTHALAMUS**
(Medial view)

The diencephalon, the smaller of two derivatives of the early forebrain, fits between but is not part of the surrounding cerebral hemispheres (see drawings 2 and 3). It consists largely of paired masses of nuclei and related tracts of white matter arranged around the thin, purse-like third (III) ventricle (2 and 3). The nature of this cavity can be seen in Plate 80.

On each side of the third ventricle, note the *thalamus, subthalamus,* and *hypothalamus* (2 and 3). The *epithalamus* or *pineal gland* is a midline structure seeming to hang off the posterior thalamus. The relationship of these nuclei to the basal nuclei and internal capsule should be carefully studied while coloring to ensure orientation (recall Plate 74).

The thalamus (1–4) consists of several groups of cell bodies and processes that, in part, process all incoming impulses from sensory pathways (except olfactory). It has broad connections with the motor, general sensory, visual, auditory, and association cortices. Not surprisingly, the corticothalamic (cortex to thalamus) fibers contribute significantly to the *corona radiata.* Still other thalamic nuclei connect to the *hypothalamus* and other brainstem nuclei. Thalamic activity (1) integrates sensory experiences resulting in appropriate motor responses, (2) integrates specific sensory input with emotional (motor) responses (e.g., a baby crying in response to hunger), and (3) regulates and maintains the conscious state (awareness), subject to facilitating/inhibiting influences from the cortex. *Subthalamic nuclei* (3) are concerned with motor activity and have connections with the basal ganglia.

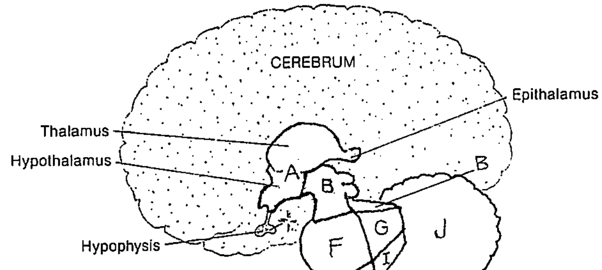
The hypothalamus (1, 3, and 4) consists of nuclear masses and associated tracts on either side of the lower third ventricle. The hypothalamus maintains neuronal connections with the frontal and temporal cortices, thalamus, neurohypophysis, and brainstem. Its neurosecretions (hormones) are also directed to the *adenohypophysis* via the hypophyseal portal system. In addition, the hypothalamus is concerned with emotional behavior, regulation of the autonomic (visceral) nervous system and related integration of visceral (autonomic) reflexes with emotional reactions, and activation of the drive to eat (hunger) and the subsequent feeling of satisfaction (satiety) following fulfillment of that drive. Finally, it mediates descending impulses related to both reflexive and skilled movement—all of this in an area the size of four peas!

The epithalamus (pineal gland) (1) consists primarily of the pineal body and related nuclei and tracts that have connections with the thalamus, hypothalamus, basal nuclei, and the medial temporal cortex. It produces melatonin (a pigment-enhancing hormone), the synthesis of which is related to diurnal cycles or rhythms (body activity in day or sunlight as opposed to dark or nocturnal periods). It may influence the onset of puberty through inhibition of testicular/ovarian function. Remarkably, the pineal is the only unpaired structure in the brain.

See 70, 75

BRAIN STEM / CEREBELLUM

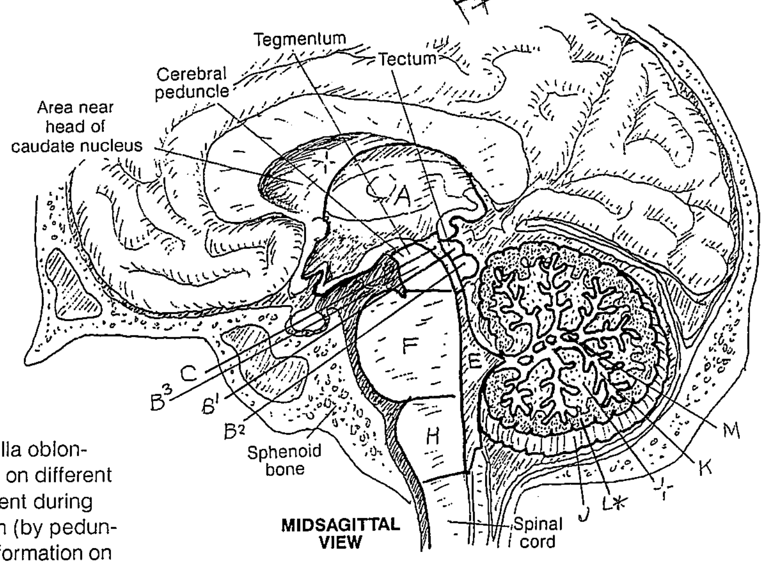
CN: Use darker colors for C, E, and M and the lightest for K. (1) As you color each structure in as many views as it is shown, take particular note of the orientation of the view. (2) Note that the fourth ventricle is located in both parts of the hindbrain and receives the same color in both parts. The diencephalon has been presented on the previous plate and is shown here only for orientation.



ORIENTATION VIEW OF BRAINSTEM AND CEREBELLUM (sagittal section)

BRAIN STEM ✣

- DIENCEPHALON A
- MIDBRAIN B
  - CEREBRAL AQUEDUCT C
  - SUPERIOR COLLICULUS B¹
  - INFERIOR COLLICULUS B²
  - CEREBRAL PEDUNCLE F
  - SUP. CEREBELLAR PEDUNCLE D
- HINDBRAIN ✣
  - 4TH VENTRICLE E
  - PONS F
    - MID. CEREBELL. PED. G
  - MEDULLA OBLONGATA H
    - INF. CEREBELL. PED. I



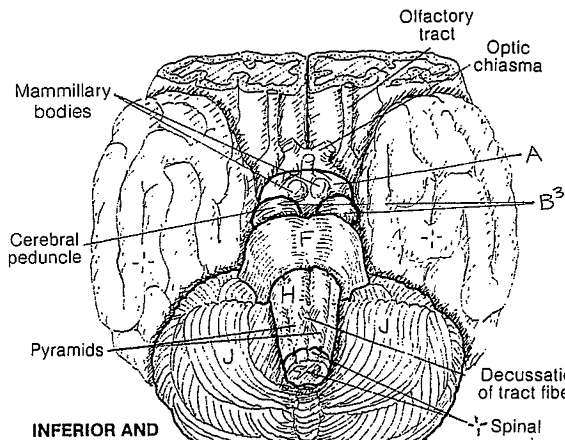
MIDSAGITTAL VIEW

The brain stem includes the diencephalon, midbrain, pons, and medulla oblongata. Throughout the brain stem, the brain cavity (Plates 80, 82) takes on different shapes, a reflection of the kind of differential growth the brain underwent during development (Plate 169). The cerebellum is attached to the brain stem (by peduncles) but is not considered a part of the brain stem. See Plate 75 for information on the diencephalon.

In the midbrain, the *cerebral peduncles* are composed of long descending tracts that originate in the cerebral cortex, descend through the internal capsule (recall Plate 74), and continue caudally to the pons and medulla (for cranial nerves) and the spinal cord (for spinal nerves). Immediately posterior to these tracts in the midbrain is the tegmentum, an area of neurons associated with the reticular formation and cranial nerves III and IV, and multiple tracts. The superior cerebellar peduncles transmit fibers to the *cerebellum* from the spinal cord, and fibers to the thalamus and medulla from the cerebellum. The superior colliculi are centers for visual reflexes; the inferior colliculi make possible auditory reflexes (e.g., rapid, involuntary movements in response to visual and auditory stimuli).

The pons is characterized by its massive anterior bulge consisting of stalks of white matter that bridge the 4th ventricle (pons = bridge) to reach the cerebellum as the middle cerebellar peduncles. These fibers largely arise from neurons in the pons—neurons that convey impulses from both motor and sensory areas of the cerebral cortex. Cranial nerve nuclei V, VI, VII, and VIII are located here. Both ascending and descending tracts pass through here, including the neurons of the reticular formation.

The medulla contains life-sustaining control centers of respiration, heart rate, and vasomotor function. Nuclei for cranial nerves VIII, IX, X, XI, and XII exist here. The inferior cerebellar peduncles carry fibers to the cerebellum from the spinal cord and brain stem vestibular and reticular systems, as well as fibers from the cerebellum to the vestibular system.

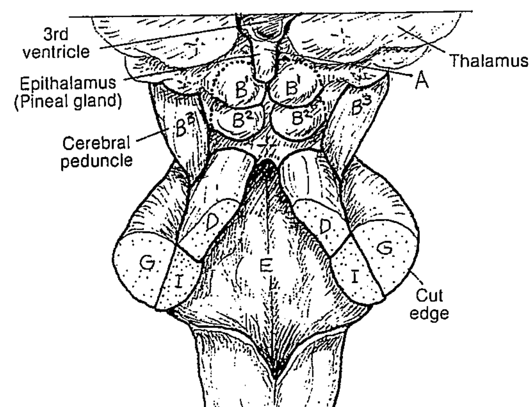


INFERIOR AND ANTERIOR VIEW (Cranial nerves removed)

CEREBELLUM J

- ARBOR VITAE K
- CEREBELLAR CORTEX L*
- DEEP CEREB. NUCLEUS M

The cerebellum consists of two hemispheres, with a cortex of gray matter on its surface (*cerebellar cortex*), central masses of motor-related (*deep cerebellar nuclei*, and bands of white matter forming a treelike appearance (*arbor vitae* = tree of life) when the cerebellum is cut in section. The cerebellum is attached to the brain stem by the three cerebellar peduncles. The cerebellum is concerned with equilibrium and position sense, fine movement, control of muscle tone, and overall coordination of muscular activity in response to proprioceptive input and descending traffic from higher centers.



POSTERIOR VIEW (Cerebellum removed)

See 81

SPINAL CORD

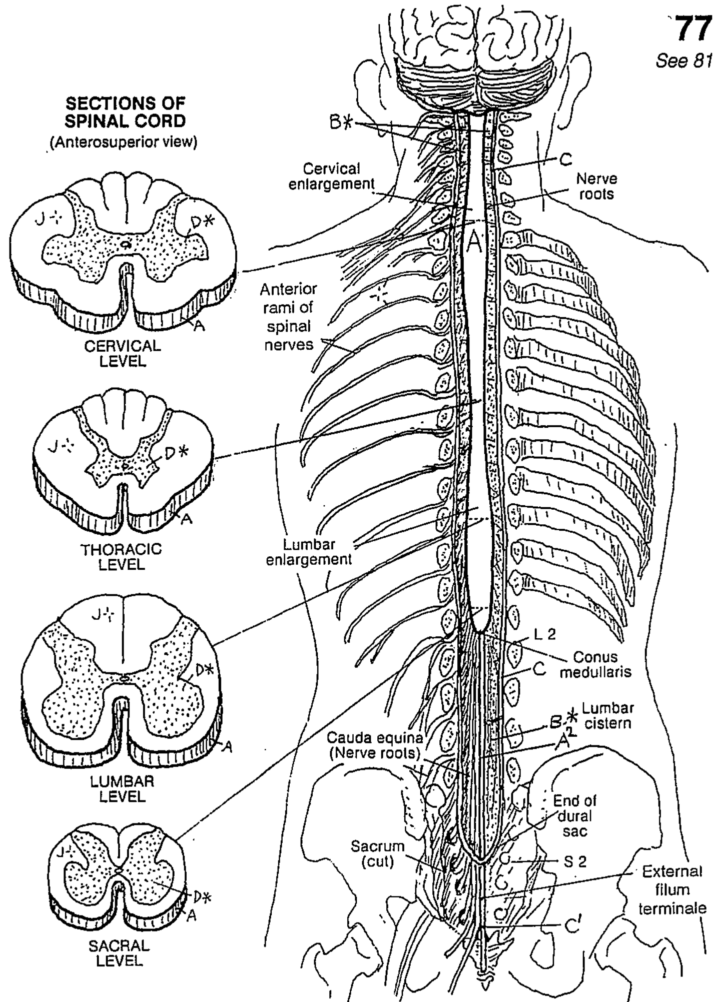
CN: Use bright colors for A–C (except where indicated by asterisk (*) or no-color symbol (-|-). Use gray for D*, medium dark colors for E–I, and light colors for K–M. (1) In the upper drawing, color B* gray over the nerve roots within the dura mater and outside the spinal cord. (2) Color the cord sections taken at various levels. (3) Color the meninges of the spinal cord. What is not shown (due to space limitations) is the presence of the arachnoid and subarachnoid space (and cerebrospinal fluid) around the nerve roots. (4) Do not color the structures within the subarachnoid space or the central canal in the drawing at the bottom of the plate.

SPINAL CORD A
MENINGES -|-
PIA MATER A'
INTERNAL FILUM TERMINALE A²
SUBARACHNOID SPACE B*
ARACHNOID B'
DURA MATER C
EXTERNAL FILUM TERMINALE C'
EPIDURAL SPACE C²-|-

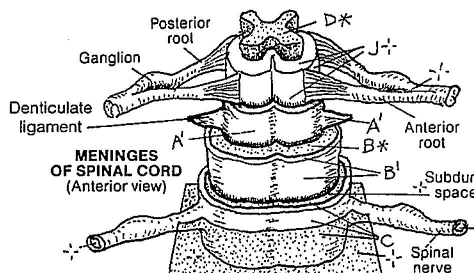
The spinal cord is the lower extension of the central nervous system. It takes off from the medulla oblongata at the foramen magnum of the skull and ends as the *conus medullaris* at the vertebral level of L1 or L2. It bulges slightly in the lower cervical and lumbar segments where it gives off the roots of spinal nerves destined for the upper and lower limbs, respectively. The cord is ensheathed by *three coverings (meninges)*: the thin, vascular *pia mater* closely applied to the spinal cord, the translucent *arachnoid* separated from the pia by the subarachnoid space, and the tough, fibrous *dura mater* that is a prolongation of the dura surrounding the brain.

The pia forms triangular sheets that project away from the cord between the pairs of nerve roots. These sheets extend to the dura and are called *denticulate ligaments*. The pia extends below the conus medullaris as the thin cord-like *filum terminale internum*, ending at the dural sac at the vertebral level of S2. The subarachnoid space is filled with *cerebrospinal fluid (CSF)*; the space ends inferiorly as the dural sac; its CSF-containing cavity is the lumbar cistern. Outside the dura is the *epidural space*, containing fat and veins.

SECTIONS OF SPINAL CORD
(Anterosuperior view)



VERTEBRAL CANAL AND CONTENTS
(Posterior view)

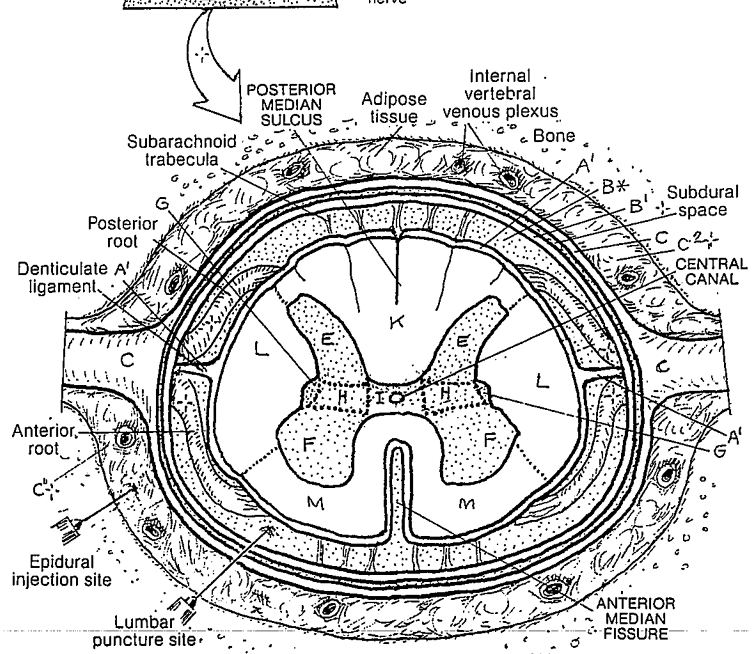


MENINGES OF SPINAL CORD
(Anterior view)

GRAY MATTER D*
POSTERIOR HORN E
ANTERIOR HORN F
LATERAL HORN (T1–L2) G
INTERMEDIATE ZONE H
GRAY COMMISSURE I

WHITE MATTER J-|-
POSTERIOR FUNICULUS K
LATERAL FUNICULUS L
ANTERIOR FUNICULUS M

The spinal cord consists of a central mass of gray matter arranged into the form of an H and a peripheral array of white matter *(funiculi)* consisting of descending and ascending tracts. The amount of white matter decreases as the cord progresses distally, seen especially well in the sacro-coccygeal region. The gray *posterior horns* (actually columns when seen in three dimensions) receive the central processes of sensory neurons (recall Plate 71) and direct incoming impulses to the adjacent white matter for conduction to other cord levels or higher centers. The *anterior horns* include lower motor neurons that represent the "final common pathway" for motor commands to muscle. *Lateral horns* exist only in the thoracic and upper lumbar cord and include autonomic motor neurons supplying smooth muscle (in vessels and viscera) and glands. It is in the gray matter that spinal reflexes occur in conjunction with facilitory and inhibitory influences from higher centers.

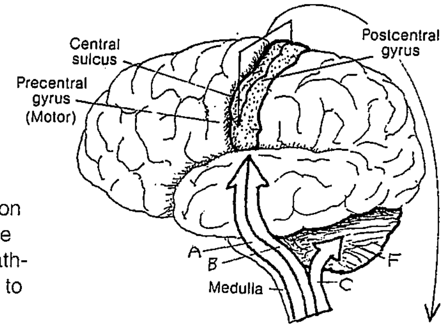


SPINAL CORD AND MENINGES
(Cross section)

See 71

ASCENDING TRACTS

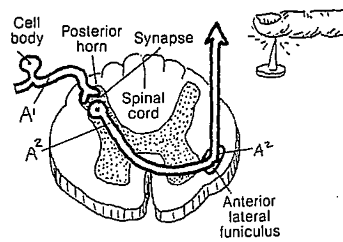
CN: Use bright colors for A–C and a light color for F. (1) Color the pain/temperature pathway, which is shown on one side only for visual simplicity. Note that the sensory cortex and the thalamus are to be colored gray. (2) In the muscle stretch/position sense pathways, note there are two different cerebellar peduncles, each receiving a different color.



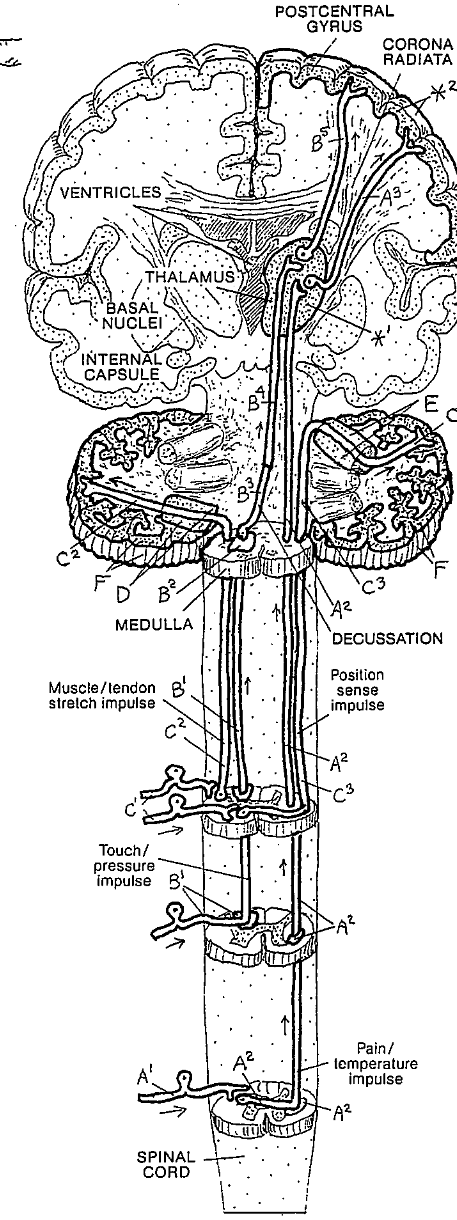
Ascending pathways consist of linearly arranged neurons, the axons of which travel in a common bundle (tract) conducting impulses toward the thalamus, cerebral cortex, or cerebellum. In the examples shown here, each of the pathways begins with a sensory neuron. These sensory pathways permit body surface sensations and muscle/tendon stretch information (below the head) to reach brain stem and cerebellar centers for response and cortical centers for awareness.

PAIN/TEMPERATURE $_A$

SENSORY NEURON $_{A^1}$
LAT. SPINOTHALAMIC TRACT $_{A^2}$
THALAMUS $_{*^1}$
THALAMOCORTICAL TRACT $_{A^3}$
SENSORY CORTEX $_{*^2}$



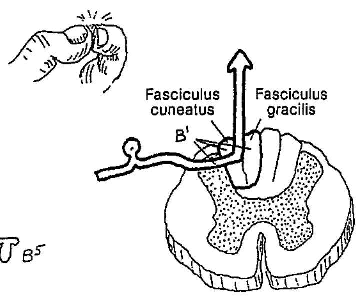
Pain and temperature receptors on the body surface and elsewhere below the head generate impulses that travel to the spinal cord by axons of *sensory neurons* (1st-order neuron). The central process ("axon") of each sensory neuron enters the posterior horn and synapses with the 2nd-order neuron whose axon crosses (decussates) to the contralateral side, enters the lateral funiculus, and ascends as part of the *lateral spinothalamic tract*. This neuron ascends to the thalamus, where it synapses with relay (3rd-order) neurons, the axons of which traverse the internal capsule and corona radiata (*thalamocortical tract*) to reach the postcentral gyrus of the cerebral cortex ("sensory cortex").



CEREBRAL CORTEX, CEREBELLUM, AND SPINAL CORD
(Schematic)

TOUCH/PRESSURE $_B$

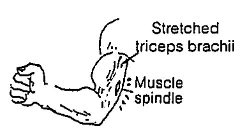
SENSORY NEURON $_{B^1}$
N. CUNEATUS & GRACILIS $_{B^2}$
INT. ARCUATE FIBERS $_{B^3}$
MED. LEMNISCUS $_{B^4}$
THALAMUS $_{*^1}$
THALAMOCORTICAL TRACT $_{B^5}$
SENSORY CORTEX $_{*^2}$

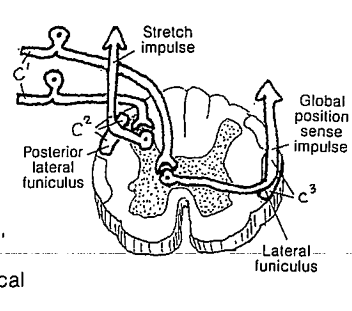


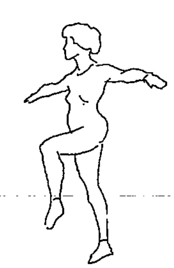
Touch and pressure receptors below the head generate electrochemical impulses that travel to the spinal cord through *sensory neurons* that enter the posterior horn and join/ascend the posterior funiculus (posterior columns) to the medulla. Here they synapse with 2nd-order neurons in the *nuclei cuneatus* and *gracilis*. The axons of these neurons sweep to the opposite side (as *internal arcuate fibers*) to form an ascending bundle (*medial lemniscus*) in the brain stem that terminates in the thalamus. There these axons synapse with 3rd-order relay neurons whose axons reach the postcentral gyrus of the cerebral cortex via the *thalamocortical tract*.

MUSCLE STRETCH/POSITION SENSE $_C$

SENSORY NEURON $_{C^1}$
POST. SPINOCEREBELLAR TRACT $_{C^2}$
INF. CEREBELLAR PED. $_D$
ANT. SPINOCEREBELLAR TR. $_{C^3}$
SUP. CEREBELLAR PED. $_E$
CEREBELLAR CORTEX $_F$







Impulses from muscle spindles and other proprioceptors (receptors responsive to muscle stretch/loads) are conducted by *sensory neurons* to the spinal cord. Single receptor input is conducted by 2nd-order neurons that ascend the ipsilateral lateral funiculus (*posterior spinocerebellar tract*) and enter the cerebellum via the *inferior cerebellar peduncle*. More global proprioceptive input ascends the contralateral anterior *spinocerebellar tract* and enters the cerebellum via the *superior cerebellar peduncle*. By these and similar pathways that function in the absence of awareness, the cerebellum maintains an ongoing assessment of body position, muscle tension, muscle overuse, and movement. In turn, it mediates descending impulses from cortical and subcortical centers destined for motor neurons.

See 16, 45

DESCENDING TRACTS

CN: Use light colors for H, I, and K. (1) Color the pyramidal tract in the sagittal view. (2) Color the pyramidal tract in the schematic coronal section at upper right, including the percentage figures. (3) Color the extra-pyramidal system.

PYRAMIDAL TRACT$_A$ / RELATED AREAS -:-

MOTOR CORTEX *

CORTICOSPINAL TRACT A¹

LAT. A² / ANT. CORTICOSPINAL TRACT A³

MEDULLARY PYRAMID A⁴

LATERAL FUNICULUS B

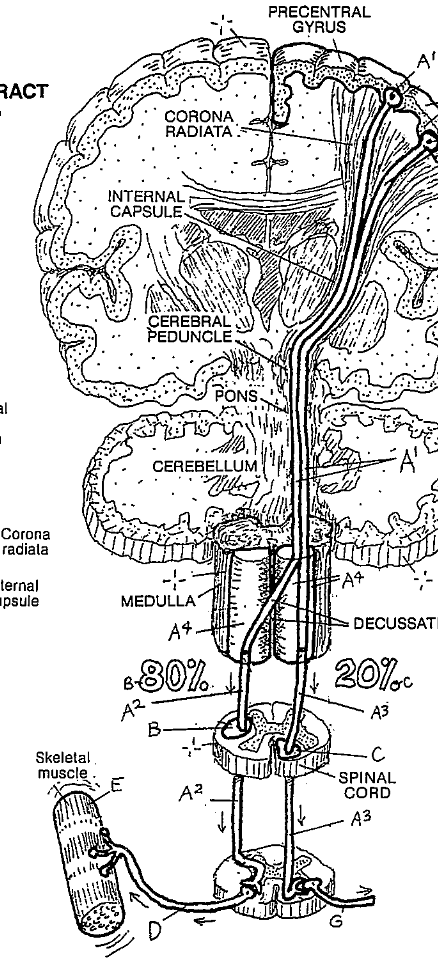
ANTERIOR FUNICULUS C

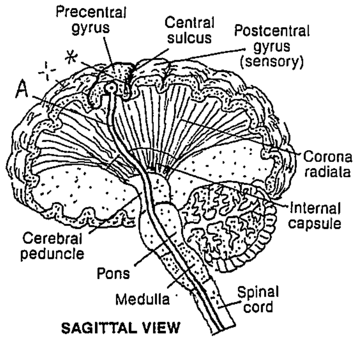
FINAL COMMON PATHWAY -:-

LOWER MOTOR NEURON D

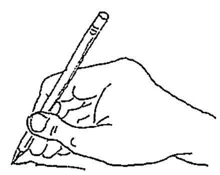
EFFECTOR E

PYRAMIDAL TRACT
(Schematic)





SAGITTAL VIEW



Skilled/discrete movements

The principal neural pathway for voluntary movement is the *corticospinal tract.* Its neuronal cell bodies are in the pre-central gyrus of each frontal lobe (motor cortex). The axons of these neurons descend—without synapse—through the corona radiata, internal capsule, cerebral peduncles, pons, and medulla into the spinal cord. Pathways are often named according to their origin and their termination, and in that order; hence, cortico- (referring to cortex) spinal (referring to the spinal cord). The corticospinal tracts form bulges, called pyramids, on the anterior surface of the medulla, hence the name "*pyramidal tract.*" Eighty percent of these tracts cross (decussate) to the contralateral side in the medulla (*decussation of the pyramids*); 20% do not. In the spinal cord, many corticospinal fibers terminate on inter-neurons (recall Plate 71) at the base of the posterior horn (not shown); the majority end by synapsing with anterior horn motor neurons. Corticospinal input to the lower motor (anterior horn) neurons, however, is only one input for desired skeletal muscle function.

EXTRAPYRAMIDAL SYSTEM -:-

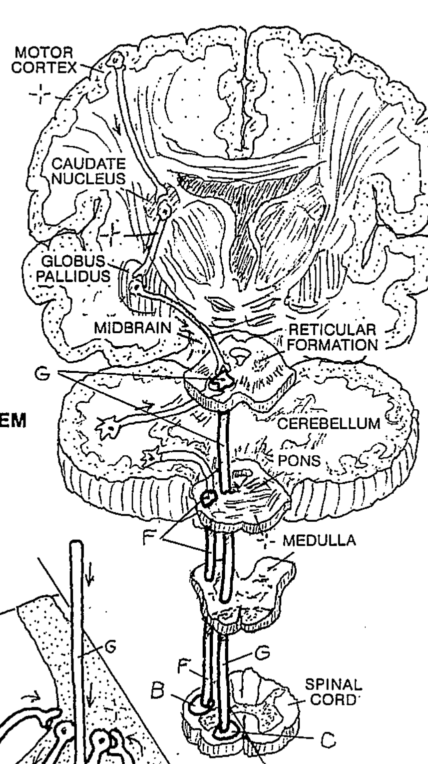
PONTINE RETICULOSPINAL TRACT F

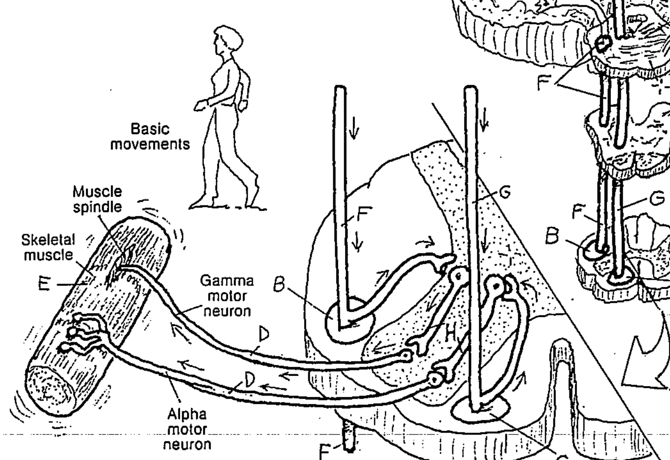
VESTIBULOSPINAL TRACT G

INTERNEURON H

Each lower motor neuron receives axons from multiple descending tracts, many of which conduct impulses related to body position, memory, and a host of other commands necessary for any given movement at any given time. These collective inputs from the cerebral cortex, basal nuclei, cerebellum, and elsewhere arrive at the appropriate lower motor neurons by a number of descending pathways, none of which pass through the medullary pyramids (hence, extrapyramidal system or tracts). Two major extrapyramidal tracts are shown here: the *reticulospinal tract* from the brain stem reticular nuclei and the *vestibulospinal tract* from the vestibular nuclei in the brain stem. Other tracts include the rubrospinal and tectospinal tracts (not shown, but see glossary). The synaptic connections of these axons with each lower motor neuron (often by way of *interneurons*) are in the thousands. Depending on the neurotransmitter produced by the presynaptic neuron, the synapse may facilitate or inhibit production of an excitatory impulse from the lower motor neuron. Discharge of the lower motor neuron, or lack of it, is dependent on the sum of the facilitory and inhibitory impulses impinging on it at any moment. Once generated, the electrochemical impulse moving down the axon of the lower motor neuron reaches the effector without further mediation. Thus, the anterior horn motor neuron is truly the final common pathway for the ultimate expression of all nervous activity: muscular contraction.

PARTS OF THE EXTRAPYRAMIDAL SYSTEM
(Schematic)





Basic movements

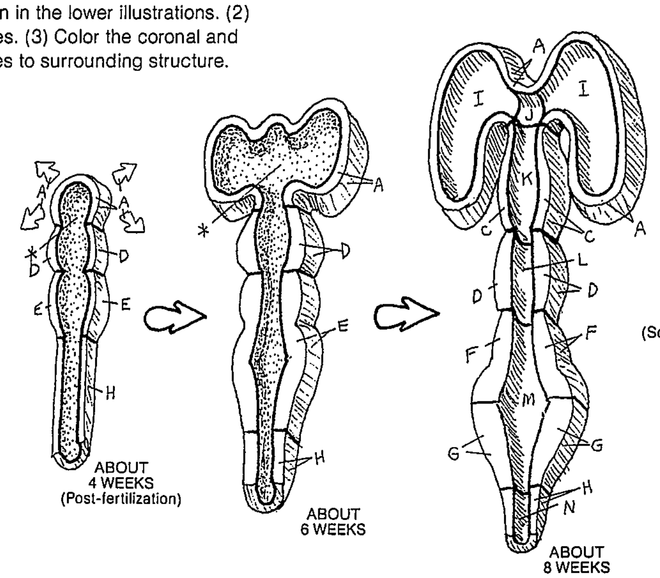
See 74, 75, 76, 169

VENTRICLES OF THE BRAIN

CN: Use a light color for A. (1) Color the drawings of ventricular development; note that the neural cavity in the "8 weeks" drawing corresponds to the color pattern in the lower illustrations. (2) Color the lateral and superior views of the fully developed ventricles. (3) Color the coronal and modified sagittal sections revealing the relationship of the ventricles to surrounding structure.

VENTRICLE DEVELOPMENT:-

NEURAL CAVITY OF THE:-
- FOREBRAIN A
  - TELENCEPHALON B
  - DIENCEPHALON C
- MESENCEPHALON D
- HINDBRAIN E
  - METENCEPHALON F
  - MYELENCEPHALON G
- SPINAL CORD H



VENTRICLE DEVELOPMENT
(Schematic longitudinal section)

The central nervous system develops from a hollow neural tube near the dorsal surface of the embryo (Plate 169). The neural cavity undergoes extraordinary revision in association with development of the brain regions. The shape of the cavity in each brain region reflects the local changes and mechanical pressures imposed by the developing brain. The ventricles may be identified by name, roman numerals, or arabic numerals.

The cavity of the developing forebrain expands into the lateral (first and second) ventricles with the outpocketings of the growing cerebral hemispheres. Each projection of the lateral ventricles reflects the direction of growth of that part of the cerebrum. The lateral ventricles retain connections to the neural cavity of the diencephalon by means of the bilateral tubular *interventricular foramina.*

The neural tube of the diencephalon is compressed by the developing bilateral thalami into a thin *third ventricle*. The front of the third ventricle is drawn out anteriorly and caudally into an infundibular recess in the region of the hypothalamus. The tubular infundibulum projects into the hypophysis (Plate 152). Posteriorly, the third ventricle projects a small recess into the pineal gland.

The neural cavity of the mesencephalon or midbrain undergoes relatively little distortion during development, retaining its tubular shape as the *cerebral aqueduct*.

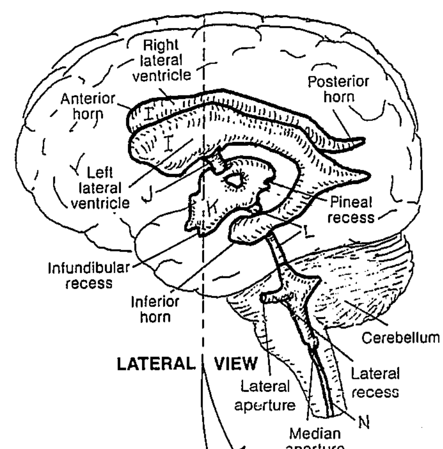
The neural cavity of the metencephalon or hindbrain undergoes lateral and posterior expansion as a consequence of the developing cerebellum, forming the diamond-shaped 4th ventricle. The thin roof of these two lateral recesses develops breaks (called apertures) that permit the passage of cerebrospinal fluid (CSF) from the 4th ventricle into the subarachnoid space. Another, more median, aperture, near the beginning of the spinal canal, permits passage of CSF into the subarachnoid space.

The 4th ventricle narrows caudally to become the *central canal* of the spinal cord. This canal is narrow and is often occluded.

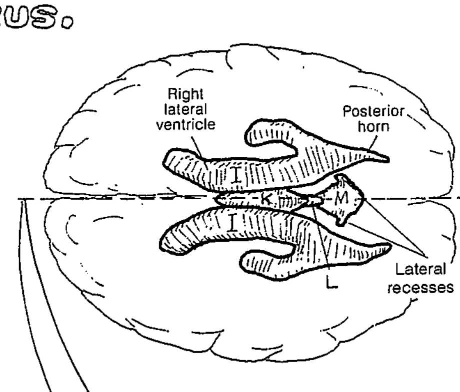
In the medial walls of the lateral ventricles and the roof of the 3rd and 4th ventricles, the pia mater comes in contact with the single layer of neuroglia-derived cells that line the ventricles (ependymal cells) to form a delicate, highly vascular tissue called the *choroid plexus*, which secretes CSF into the ventricles.

DERIVATIVES:-
- LATERAL VENTRICLE (1&2) I
  - INTERVENTRICULAR FORAMEN J
- 3RD VENTRICLE K
- CEREBRAL AQUEDUCT L
- 4TH VENTRICLE M
- CENTRAL CANAL N

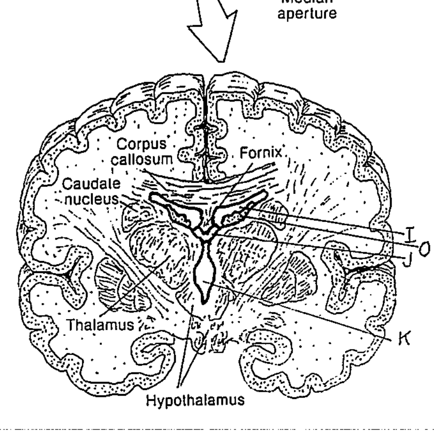
CHOROID PLEXUS O



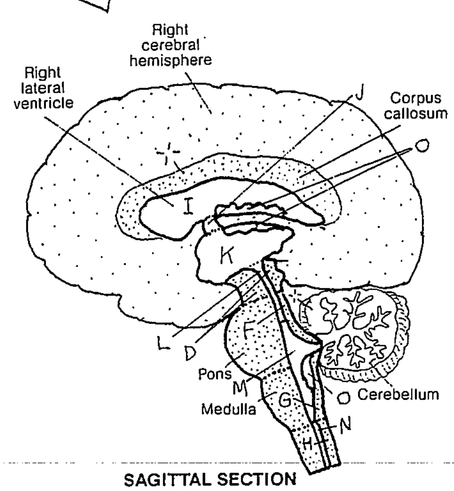
LATERAL VIEW



SUPERIOR VIEW



CORONAL SECTION

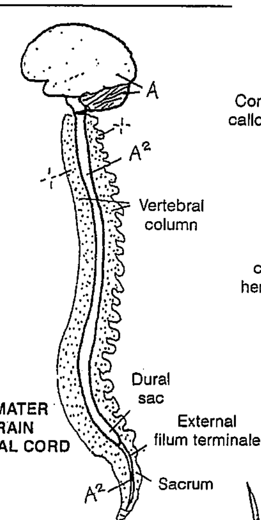


SAGITTAL SECTION
(Modified)

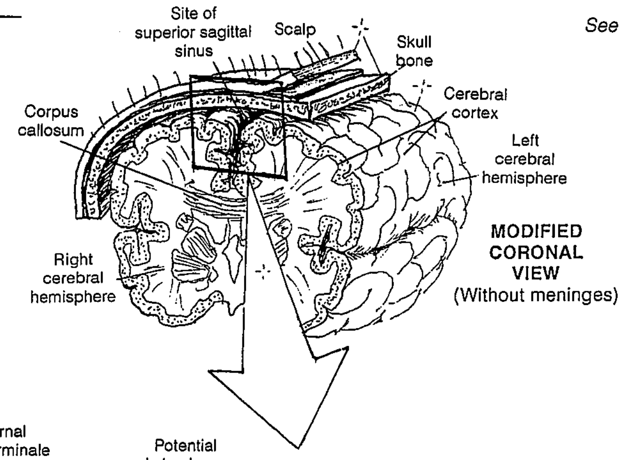
See 77, 82, 116

MENINGES

CN: Use very light colors for A–D. (1) Begin with the dura mater of the brain (A) and spinal cord (A^2). (2) Color the meninges of the brain in the enlargement of the coronal section (meniniges are not present in the smaller drawing). In the same enlargement, color the superior sagittal sinus gray (3) Color the infoldings of the dura mater (B–D). These coverings have been thickened and separated from each other for coloring purposes. Color over the darkened sinuses located within the falx cerebri (C). Much of the left half of the overlying inner dura layer (B) has been cut away to reveal inner structures. Visualize how the right and left cerebral hemispheres would fit within these coverings.



DURA MATER OF BRAIN AND SPINAL CORD



MODIFIED CORONAL VIEW
(Without meninges)

CRANIAL MENINGES -:-

DURA MATER A

OUTER (PERIOSTEAL) LAYER A'

INNER (MENINGEAL) LAYER B

FALX CEREBRI C

TENTORIUM CEREBELLI D

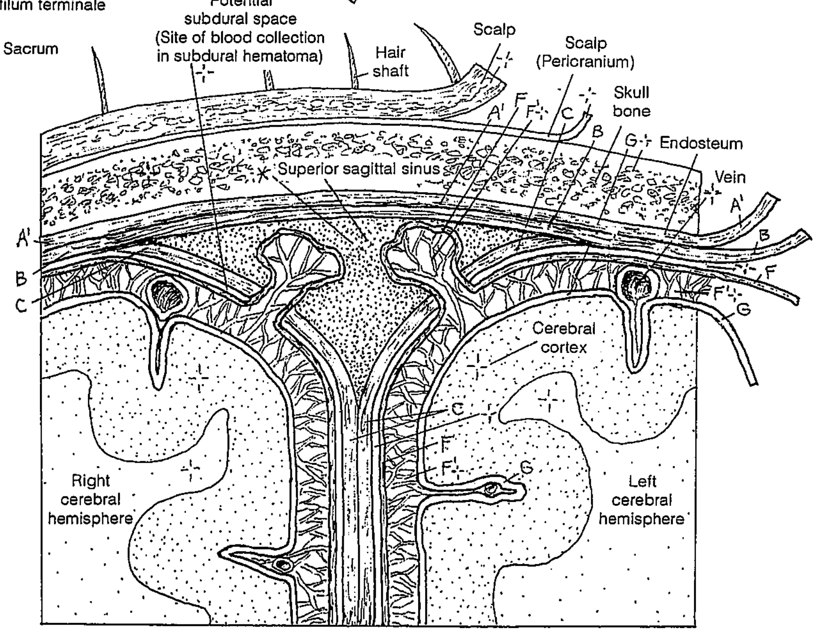
FALX CEREBELLI E-:- (N.S.)

ARACHNOID F

SUBARACHNOID SPACE F'-:-

PIA MATER G

SPINAL DURA MATER A^2



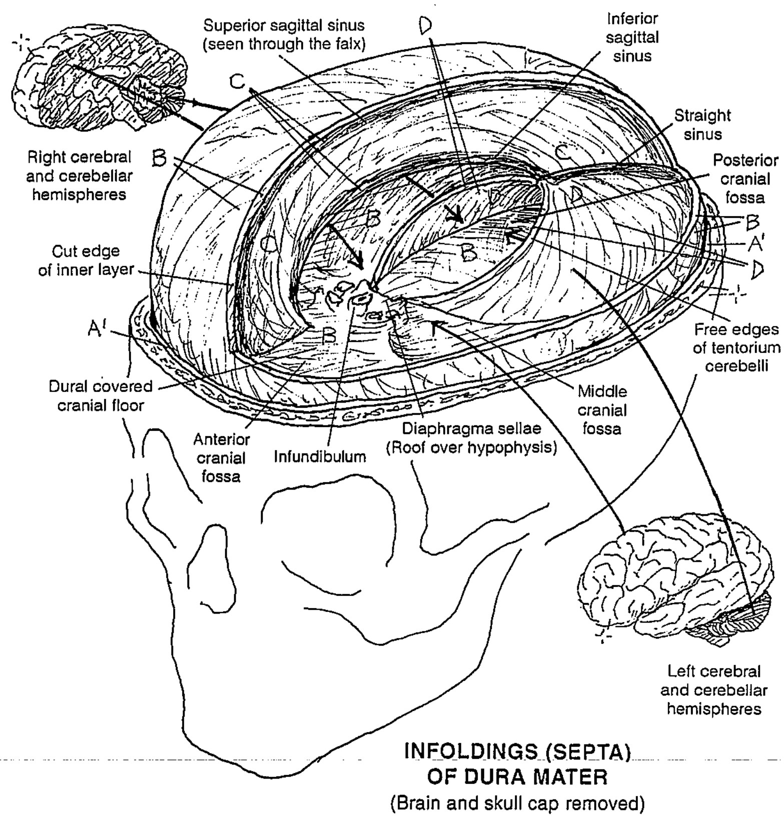
MENINGES OF THE BRAIN
(Modified coronal section)

The brain and spinal cord are enveloped in fibrous coverings called *meninges*. The meninges of the spinal cord, which were presented in Plate 77, are the inferior extent of the cranial membranes presented here.

The outermost covering of the brain and spinal cord is the *dura mater.* It has two layers: the *outer periosteal layer* lining the internal surface of the cranium and vertebral canal (endosteum), and the inner or meningeal layer, split off from the endosteum, enclosing the entire brain (cranial dura mater) and spinal cord (spinal dura mater). Three partitions form from the cranial dura. The falx cerebri (1) is formed from the joining of two layers of dura. Superiorly, the two layers arise from the cranial roof and enclose the superior sagittal sinus. Inferiorly, the falx is formed from the dura on the floor of the anterior cranial fossae and posteriorly from the two sides of the "tent-like" tentorium cerebelli. The falx descends between the two cerebral hemispheres in the longitudinal cerebral fissure, its free edge ending just above the corpus callosum.

The tentorium cerebelli (2) supports the occipital lobes and separates them from the cerebellum set deeply in the posterior cranial fossae. The free edges of the tentorium create a notch (incisura) for the midbrain, and run anteriorly to the dorsum sellae (posterior wall of the sella turcica). Notice the dural roof of the sella (diaphragma sellae), perforated to transmit the infundibulum; see Plate 152. Extending vertically downward from the midline of the tentorium is the falx cerebelli (3; not shown), separating the cerebellar hemispheres. It is continuous with the dura lining the posterior cranial fossa.

The filmy, vulnerable arachnoid lies deep to and flush with the inner dura. The arachnoid is separated from the deeper pia mater by the subarachnoid space, filled with cerebrospinal fluid (CSF). This space becomes voluminous at various locations (cisterns; Plate 82). The pia is a vascular layer of loose fibrous connective tissue, supporting the vessels reaching the brain (and spinal cord). It is inseparable from the surface of the brain and cord.

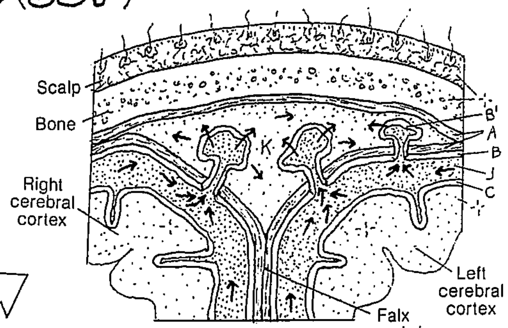


INFOLDINGS (SEPTA) OF DURA MATER
(Brain and skull cap removed)

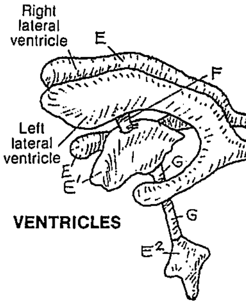
CIRCULATION OF CEREBROSPINAL FLUID (CSF)

See 80, 81

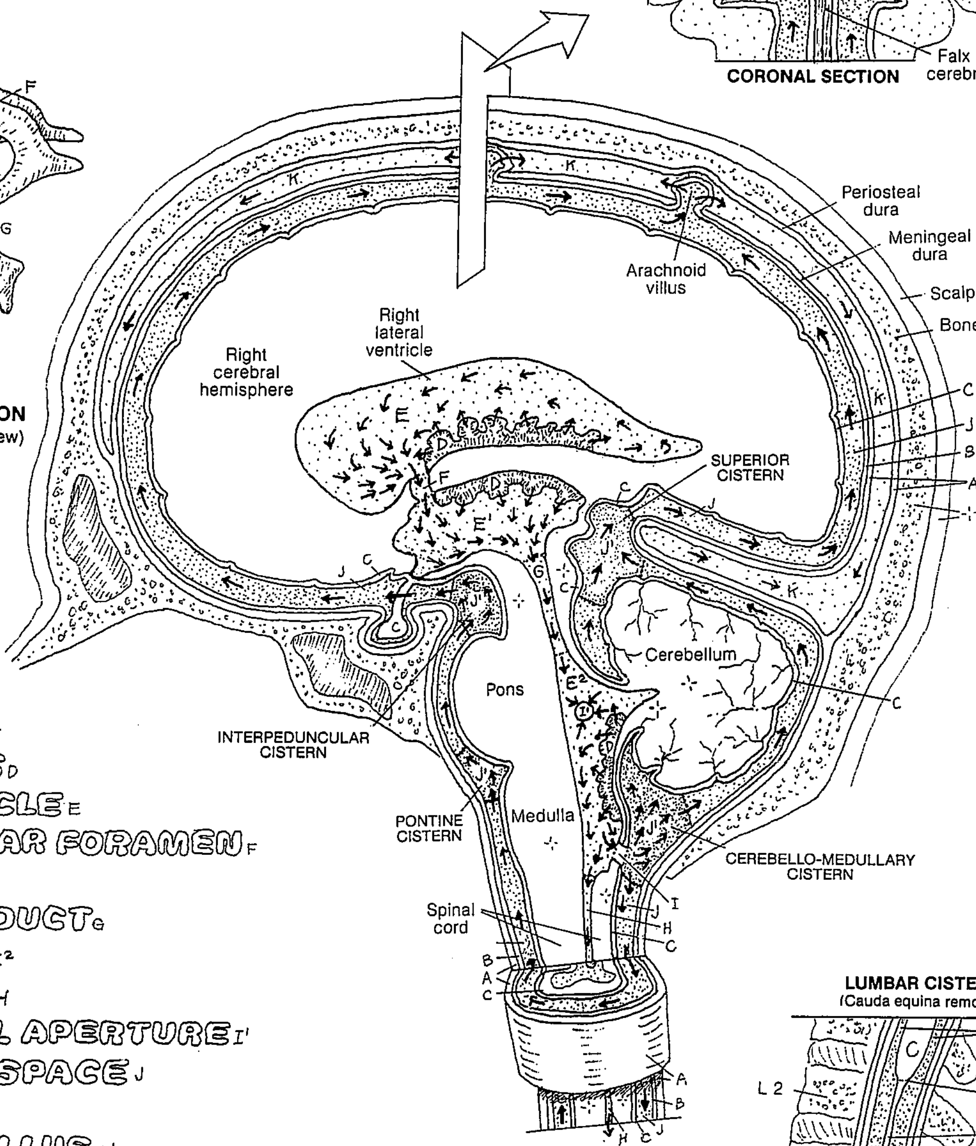
CN: Use the same colors as were used on the previous plate for the three meninges. Use blue for L and light colors for E through H, J, and K. (1) Color the large illustration and the coronal section simultaneously, paying close attention to the arrows of directional flow. Note that both layers of dura (A) are given one color. (2) The four cisterns, part of the subarachnoid space, all receive one color (J^1), including the lumbar cistern at lower right. (3) Color the median and lateral apertures of the IV ventricle.



CORONAL SECTION



VENTRICLES

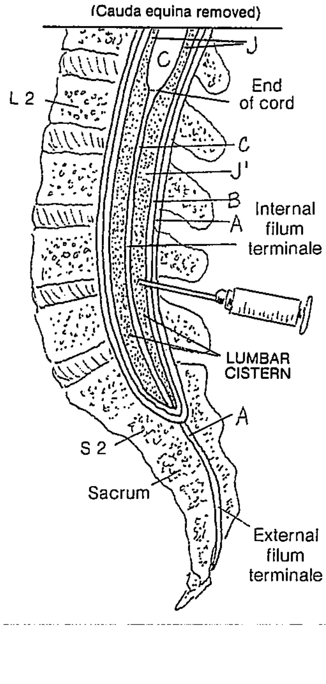


SCHEME OF CSF CIRCULATION
(Modified sagittal view)

MENINGES
- DURA MATER A
- ARACHNOID B
- PIA MATER C

CSF CIRCULATION
- CHOROID PLEXUS D
- LATERAL VENTRICLE E
- INTERVENTRICULAR FORAMEN F
- 3RD VENTRICLE E'
- CEREBRAL AQUEDUCT G
- 4TH VENTRICLE E2
- CENTRAL CANAL H
- MEDIAN I LATERAL APERTURE I'
- SUBARACHNOID SPACE J
  - CISTERN J'
  - ARACHNOID VILLUS B'
- SUPERIOR SAGITTAL SINUS K

LUMBAR CISTERN
(Cauda equina removed)



Cerebrospinal fluid (CSF) is a clear, largely acellular fluid secreted by the *choroid plexus* (70%) and vessels near the ventricular walls (30%) into the *lateral, third,* and *fourth ventricles.* About 150 ml of CSF circulates through the ventricles and around the *subarachnoid spaces* (including *cisterns*). CSF flow through the *central canal* is minimal to nonexistent. Although the fluid is an exudate of plasma from the capillaries (in the pia mater enfolded with ependymal cells lining the ventricles), it has significantly less density and protein than plasma. CSF drains into the subarachnoid space via *median* and *lateral apertures* located in the roof of the fourth ventricle. Cisterns are dilated subarachnoid spaces formed at flexures of the brain. The most notable of the cisterns is the lumbar cistern, in which float the lumbar and lower nerve roots (cauda equina). This cistern is a frequent site of puncture (at a level of about the 4th lumbar vertebra) for withdrawal and diagnostic testing of CSF. Anesthetic agents and radiopaque dyes also can be introduced at this site. Cerebrospinal fluid is resorbed by cauliflower-shaped outpocketings of arachnoid called *villi.* These villi project into the *superior sagittal sinus,* one of the large veins draining the brain.

CSF suspends the brain and spinal cord within the *dura mater* in virtually a no-load condition, preserving their structural integrity. That is, the brain and spinal cord do not experience a gravitational force from the base of the skull or the sacrum. In forceful movements of the head and torso, up to a point, the CNS is protected from striking the skull or vertebral column by its fluid-filled container functioning as a cushion.