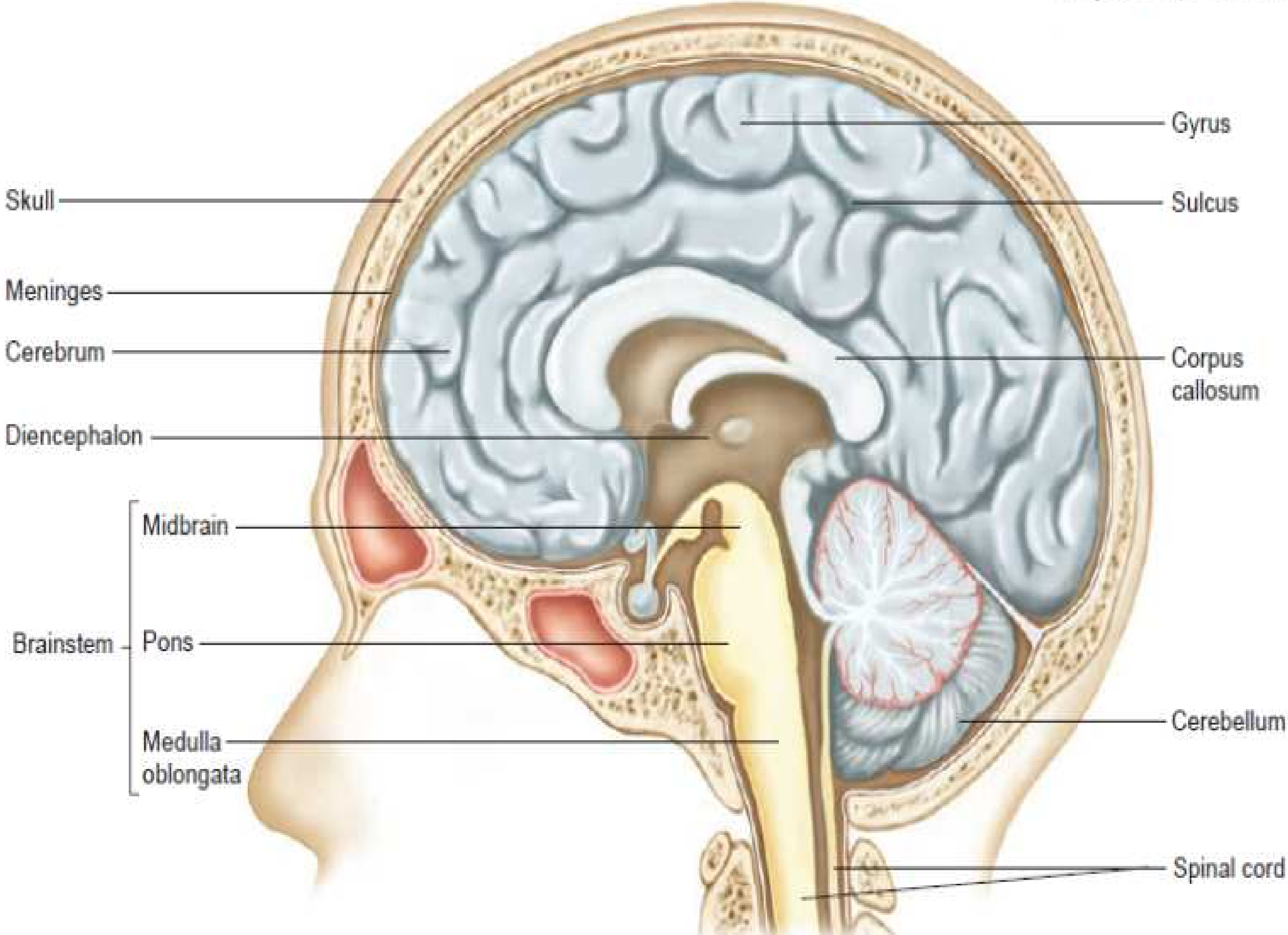
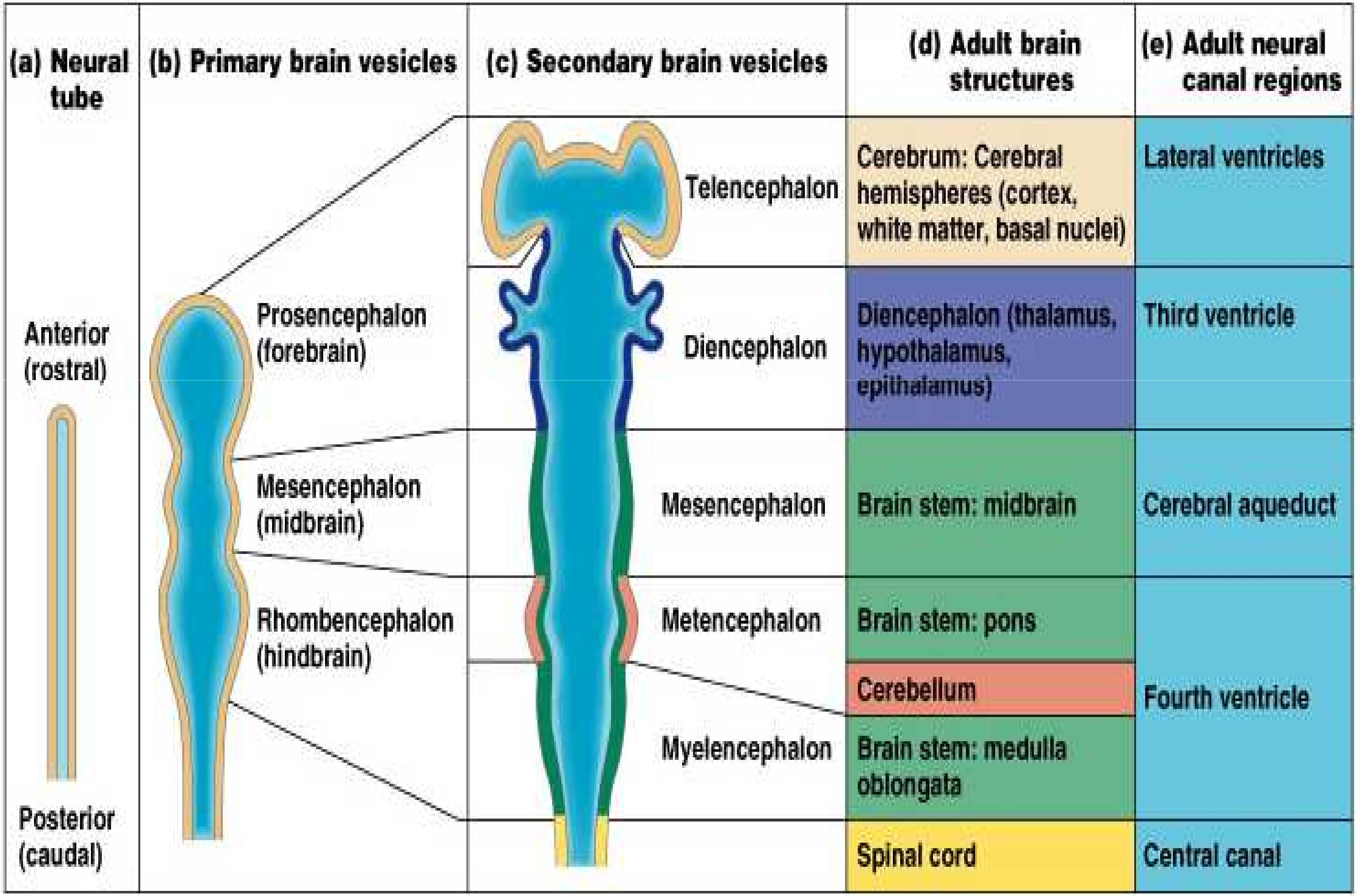
Central Nervous System


Gyrus
Sulcus
Skull
Meninges
Cerebrum
Corpus callosum
Diencephalon
Midbrain
Brainstem
Pons
Medulla oblongata
Cerebellum
Spinal cord

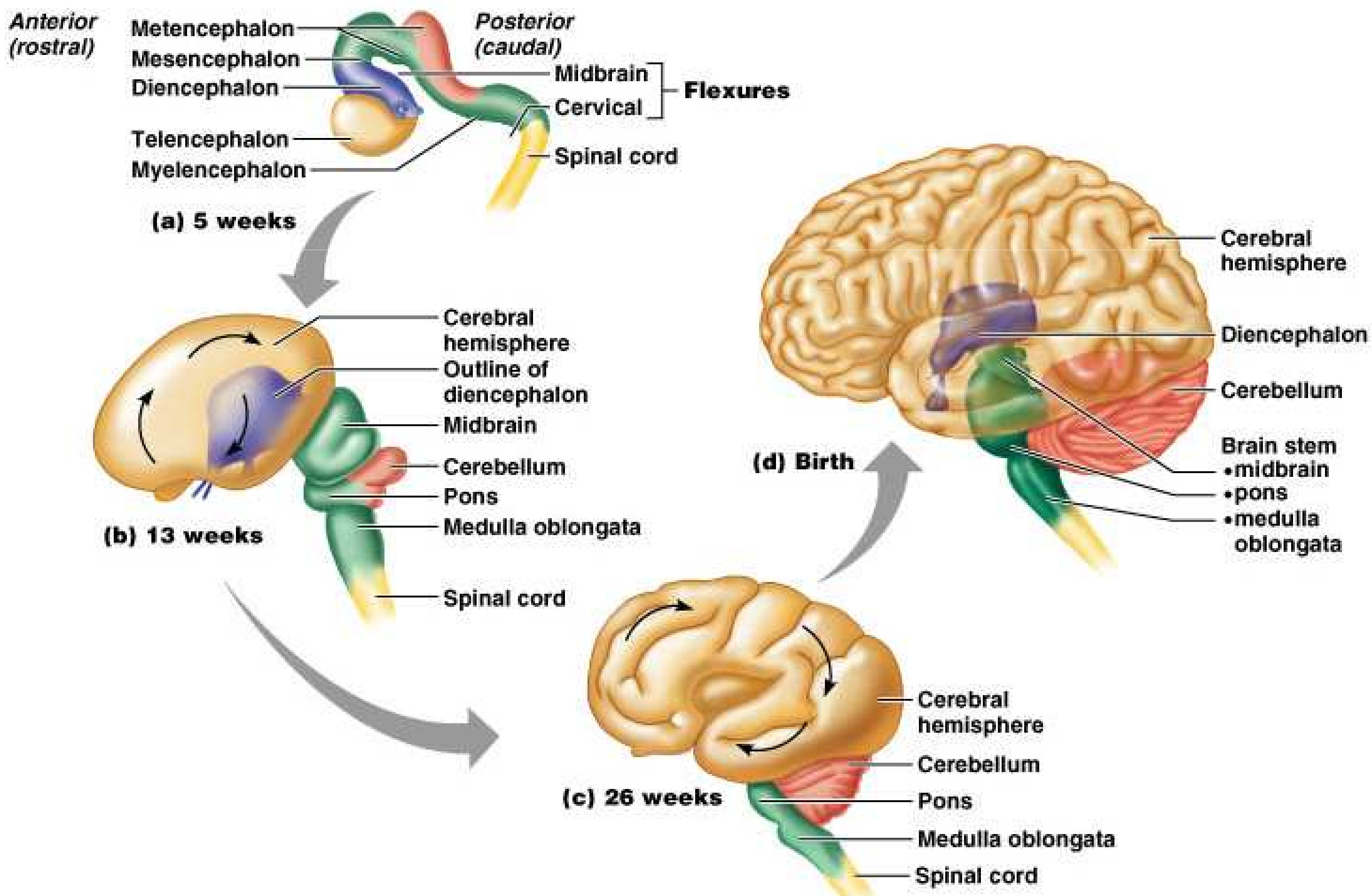
The Brain

- Develops from neural tube
- Brain subdivides into
  – Forebrain
  – Midbrain
  – Hindbrain
- These further divide, each with a fluid filled region: ventricle, aqueduct or canal
  – Spinal cord also has a canal
- Two major bends, or flexures, occur (midbrain and cervical)

Brain development

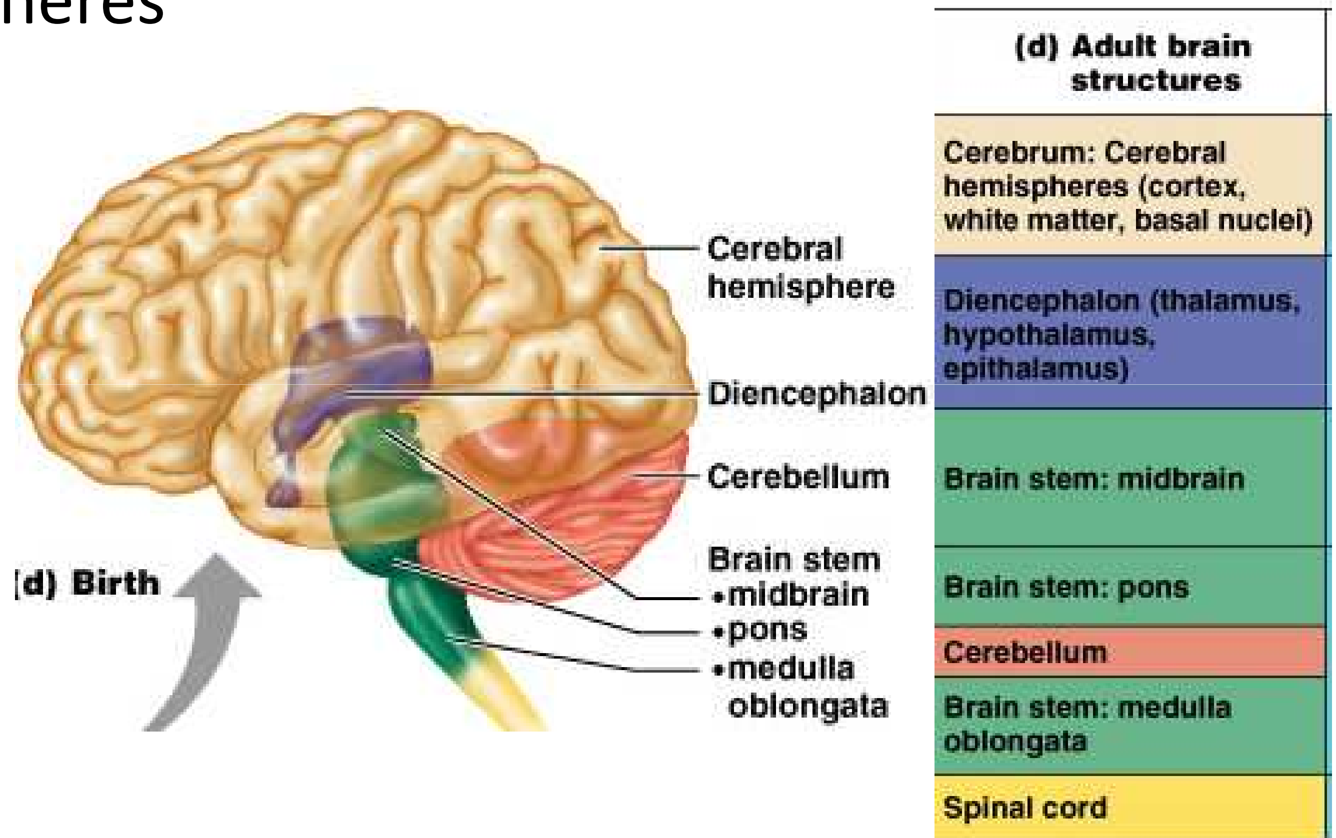


- Space restrictions force cerebral hemispheres to grow posteriorly over rest of brain, enveloping it
- Cerebral hemispheres grow into horseshoe shape (b and c)
- Continued growth causes creases, folds and wrinkles



Anatomical classification

- Cerebral hemispheres
- Diencephalon
  - Thalamus
  - Hypothalamus
- Brain stem
  - Midbrain
  - Pons
  - Medulla
- Cerebellum
- Spinal cord



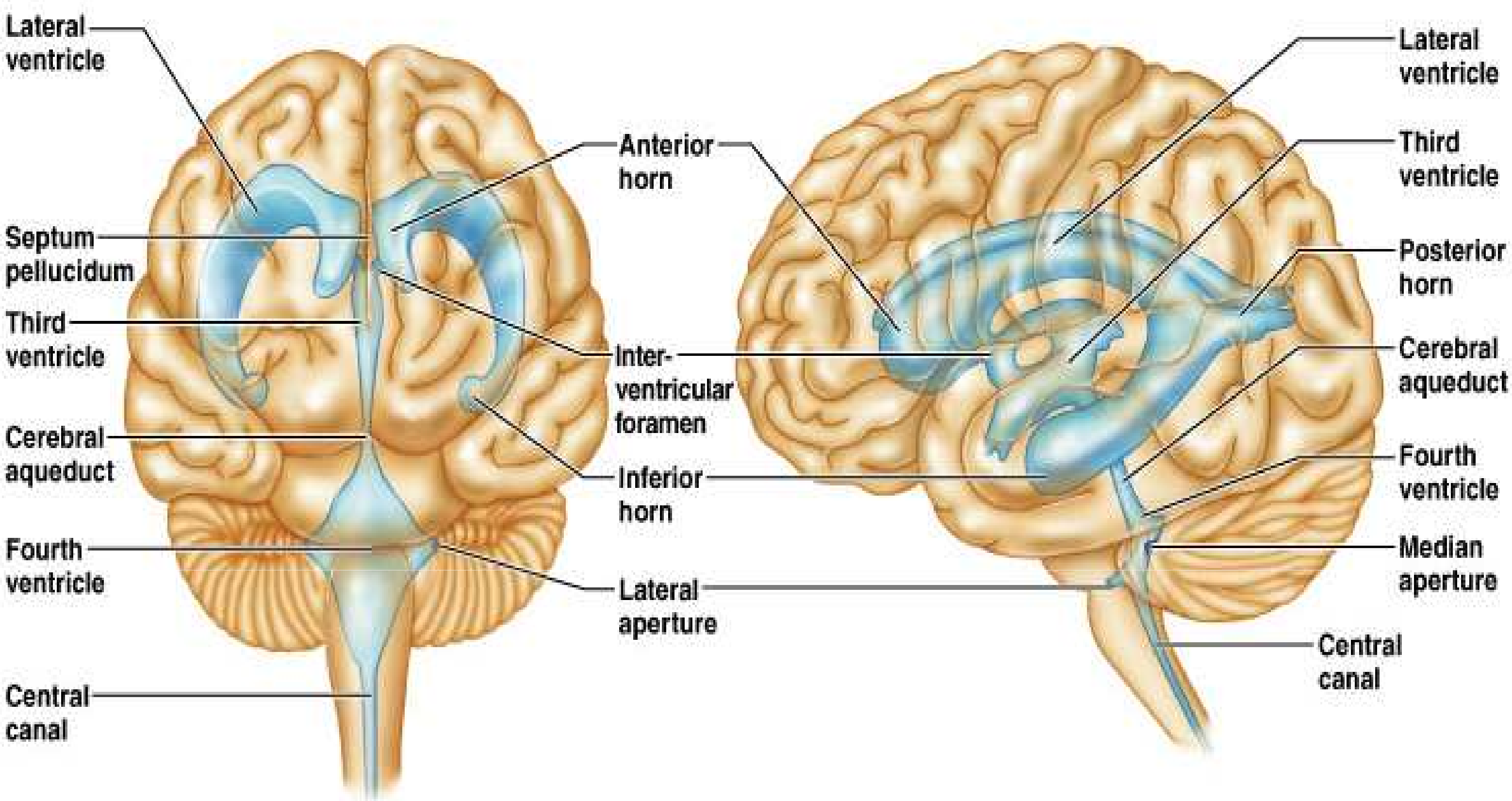
Ventricles

- Interconnected cavities called ventricles lie within the cerebral hemispheres and brainstem. These spaces are continuous with the central canal of the spinal cord, and like it, they contain cerebrospinal fluid. The ventricles of the brain are a communicating network of cavities and located within the brain parenchyma. The ventricular system is embryologically derived from the neural canal, forming early in the development of the neural tube.

- The largest ventricles are the *lateral ventricles* (first and second ventricles), which extend into the cerebral hemispheres and occupy parts of the frontal, temporal, and occipital lobes.
- A narrow space that constitutes the *third ventricle* is in the midline of the brain, beneath the corpus callosum. This ventricle communicates with the lateral ventricles through openings (interventricular foramina) in its anterior end.

- The *fourth ventricle* is in the brainstem just anterior to the cerebellum. A narrow canal, the *cerebral aqueduct,* connects it to the third ventricle and passes lengthwise through the brainstem. The fourth ventricle is continuous with the central canal of the spinal cord and has openings in its roof that lead into the subarachnoid space of the meninges.

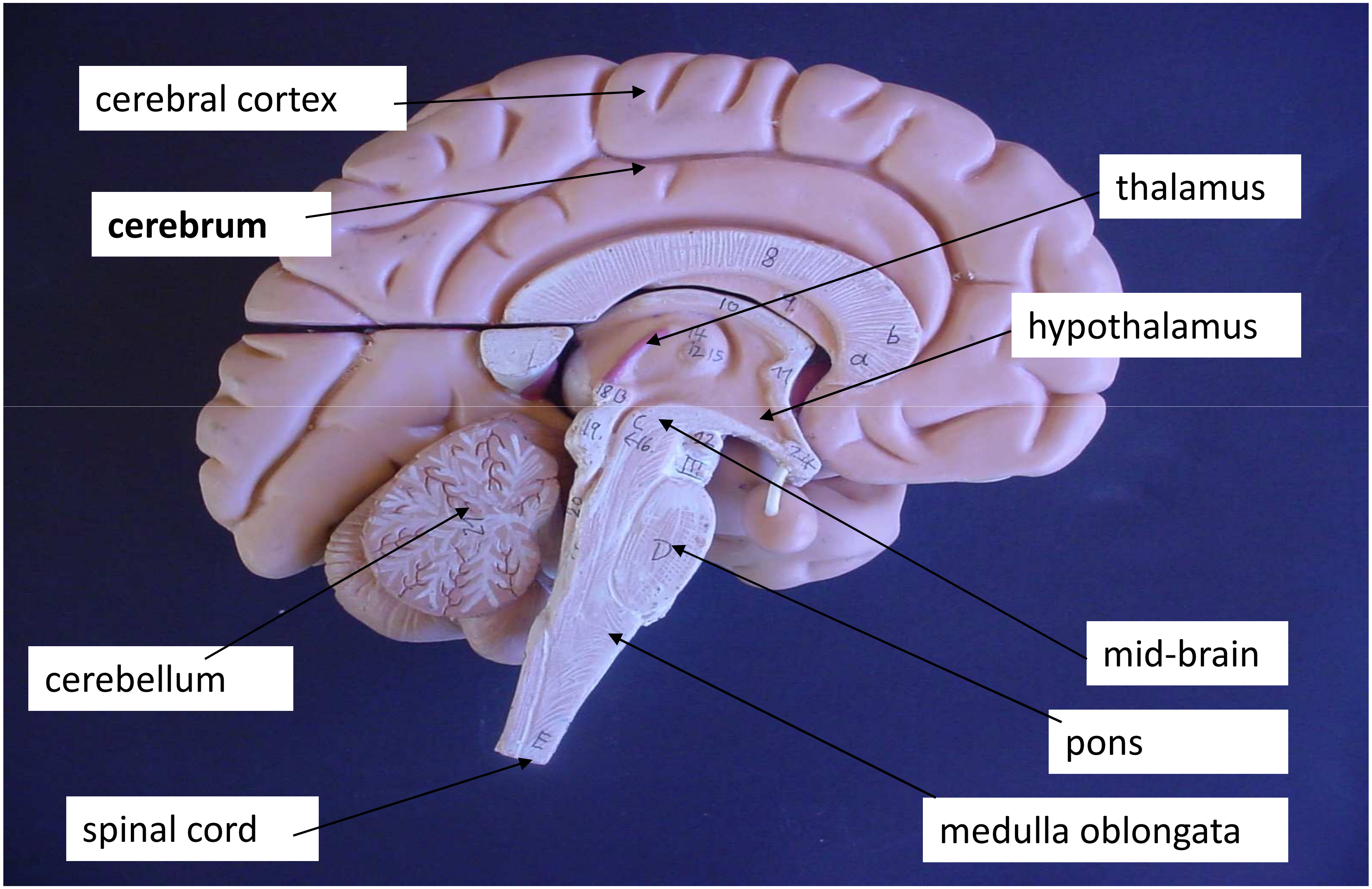
- Tiny, reddish, cauliflower-like masses of specialized capillaries from the pia mater, called choroid plexuses, secrete cerebrospinal fluid. These structures project into the ventricles. Most of the cerebrospinal fluid is formed in the lateral ventricles.
- From there, it circulates slowly into the third and fourth ventricles and into the central canal of the spinal cord. Cerebrospinal fluid also enters the subarachnoid space of the meninges through the wall of the fourth ventricle near the cerebellum and completes its circuit by being reabsorbed into the blood.



(a) Anterior view

(b) Left lateral view

Cerebrum



Acknowledgement: Picture of model from Mentone Educational Centre C15

The functional areas of the cerebrum

- sensory areas interpret impulses from receptors.
- motor areas control muscular movements.
- association areas are involved with intellectual and emotional processes.

Cerebrum features

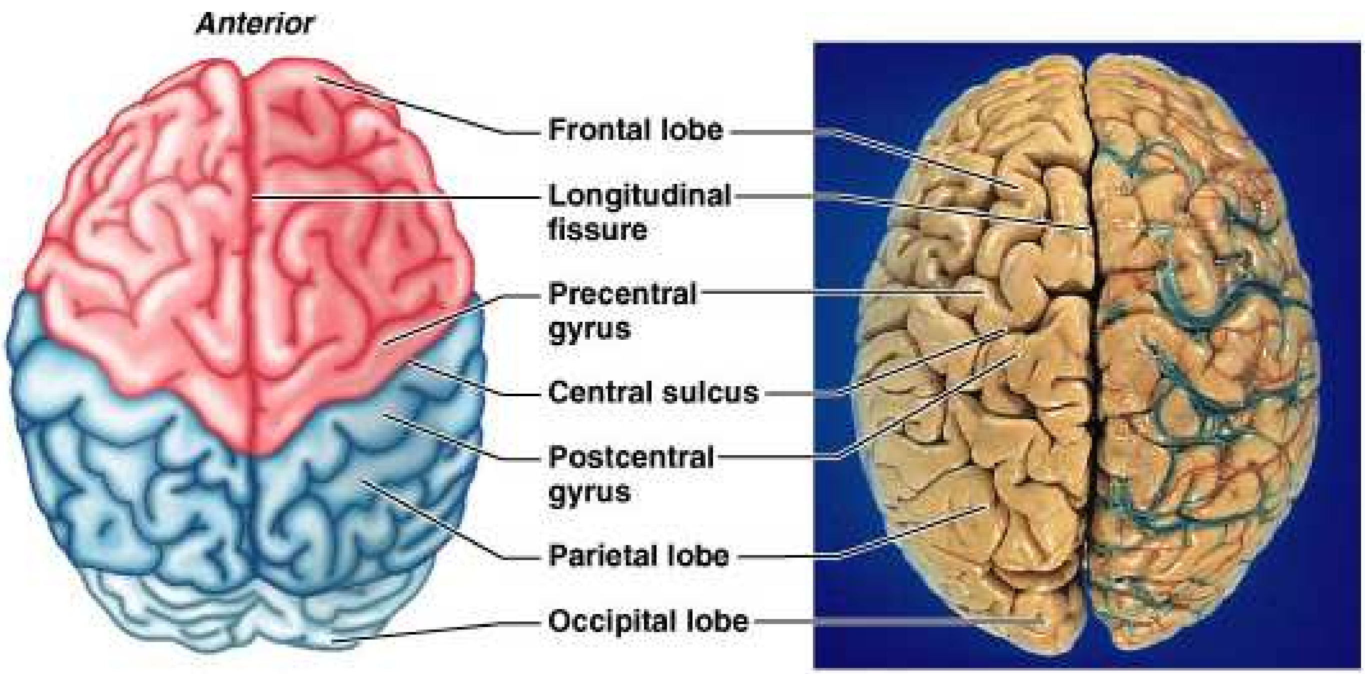
- outermost layer contains the cerebral cortex (grey matter)
- middle layer contains the white matter
- innermost layer contains grey matter called the basal ganglia
- The cerebrum is composed of the following sub-regions:
- Cerebral cortex, or cortices of the cerebral hemispheres
- Basal ganglia, or basal nuclei
- Limbic System

Cerebral hemispheres

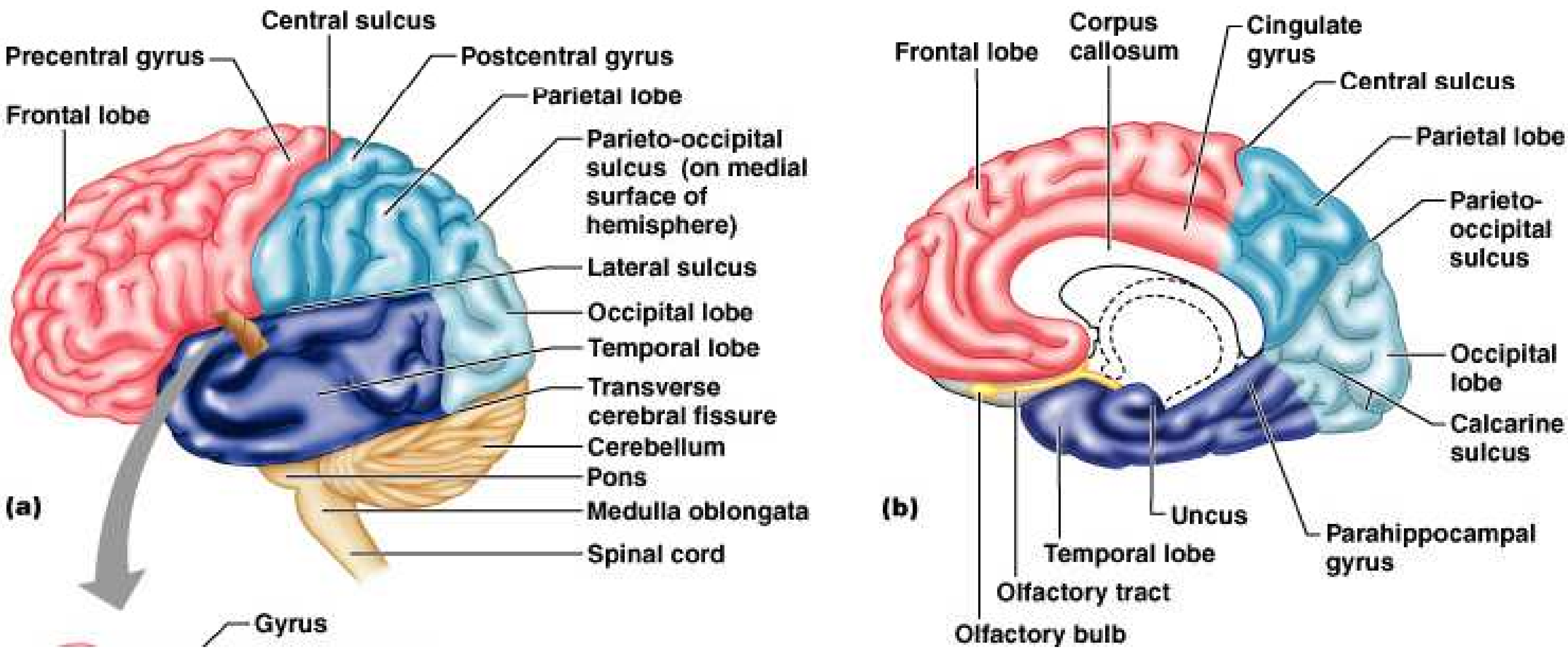
- Lobes: under bones of same name
  - Frontal
  - Parietal
  - Temporal
  - Occipital
  - Plus: Insula (buried deep in lateral sulcus)

Cerebral hemispheres

- Divided by ***longitudinal fissure*** into right & left sides
- ***Central sulcus*** divides frontal from parietal lobes



- ***Lateral sulcus*** separates temporal lobe from parietal lobe
- ***Parieto-occipital sulcus*** divides occipital and parietal lobes (not seen from outside)
- ***Transverse cerebral fissure*** separates cerebral hemispheres from cerebellum



- Sensory areas located in several lobes of the cerebrum interpret impulses that arrive from sensory receptors, producing feelings or sensations. For example, sensations from all parts of the skin (cutaneous senses) arise in the anterior parts of the parietal lobes along the central sulcus

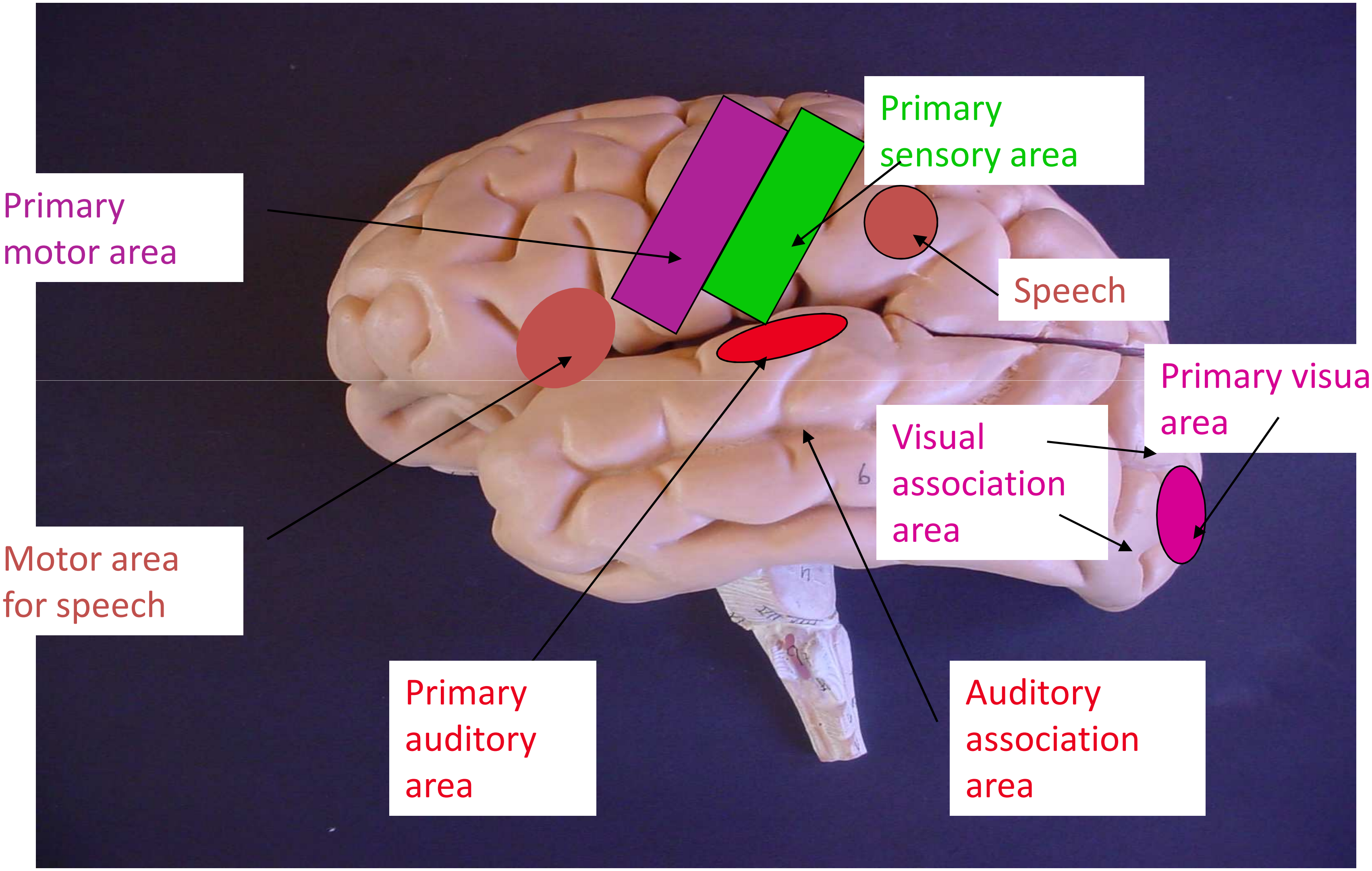
Functions

- **Movement**
- The cerebrum directs the conscious motor functions of the body. These functions originate within the primary motor cortex and other frontal lobe motor areas where actions are planned.
- **Sensory processing**
- The primary sensory areas of the cerebral cortex receive and process visual, auditory, somatosensory, taste , and olfactory information.

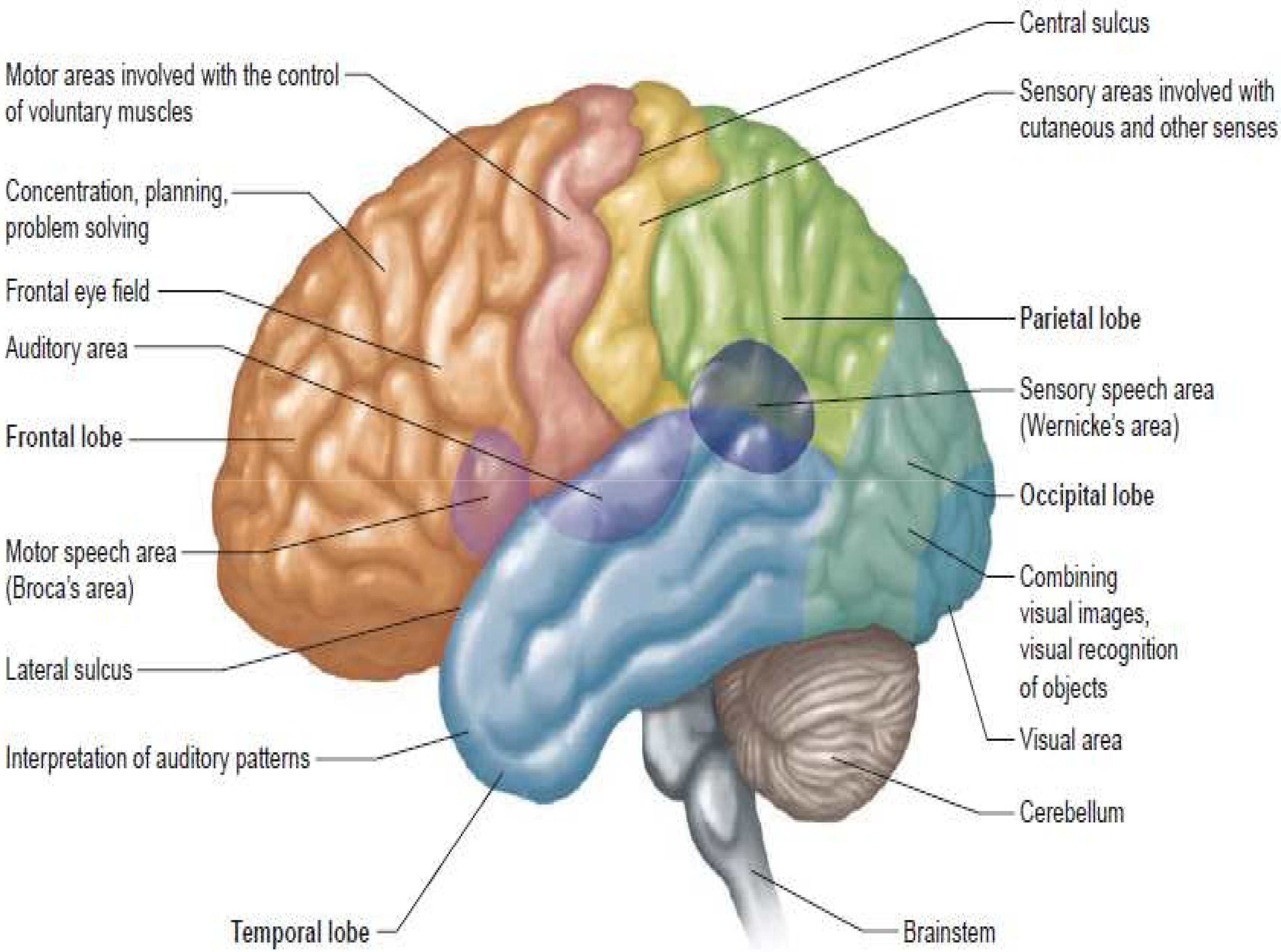
- **Language and communication**
- Speech and language are mainly attributed to parts of the cerebral cortex. Motor portions of language are attributed to Broca's area within the frontal lobe.
- **Learning and memory**
- Explicit or declarative (factual) memory formation is attributed to the hippocampus and associated regions of the medial temporal lobe.

- Association areas are neither primarily sensory nor primarily motor. They connect with one another and with other brain structures. These areas analyze and interpret sensory experiences and oversee memory, reasoning, verbalizing, judgment, and emotion. Association areasoccupy the anterior portions of the frontal lobes and are widespread in the lateral parts of the parietal, temporal, and occipital lobes

Functional areas of the cerebral cortex



Acknowledgement: Picture of model from Mentone Educational Centre C15



Central sulcus
Motor areas involved with the control of voluntary muscles
Sensory areas involved with cutaneous and other senses
Concentration, planning, problem solving
Frontal eye field
Parietal lobe
Auditory area
Sensory speech area (Wernicke's area)
Frontal lobe
Occipital lobe
Motor speech area (Broca's area)
Combining visual images, visual recognition of objects
Lateral sulcus
Visual area
Interpretation of auditory patterns
Cerebellum
Temporal lobe
Brainstem

- Wernicke’s area corresponds closely to a brain region that has been referred to as a “general interpretive area,” near where the occipital, parietal, and temporal lobes meet. It plays a role in integrating visual, auditory, and other sensory information, and then interpretating a situation. For example, you hear a familiar voice, look up from your notes, see a friend from class, and realize that it is time for your study group.

- The primary motor areas of the cerebral cortex lie in the frontal lobes, just in front of the central sulcus. The nervous tissue in these regions contain many large *pyramidal cells,* named for their pyramid shaped cell bodies. These cells are also termed *upper motor neurons,* because of their location. Impulses from the pyramidal cells travel downward through the brainstem and into the spinal cord on the corticospinal tracts. Here they form synapses with *lower motor neurons* whose axons leave the spinal cord and reach skeletal muscle fibers.

- Most of the axons these tracts cross over from one side of the brain to the other within the brainstem. As a result, the motor area of the right cerebral hemisphere generally controls skeletal muscles on the left side of the body, and vice versa.
- In addition to the primary motor areas, certain other regions of the frontal lobe affect motor functions. For example, a region called the *motor speech area,* or *Broca's area,* is usually in the left hemisphere, just anterior to the primary motor cortex and superior to thelateral sulcus. This area generates the movements of muscles necessary for speech

- Above the motor speech area is a region called the *frontal eye field.* The motor cortex in this area controls voluntary movements of the eyes and eyelids. Another region just in front of the primary motor area controls the muscular movements of the hands and fingers that make skills such as writing possible

Cerebral cortex

- The **cerebral cortex** is a sheet of neural tissue that is outermost to the cerebrum of the mammalian brain. This is the gray area of the brain hence the name. This is caused by the nerves that lack insulation. The cerebral cortex covers the cerebrum and cerebellum. The cerebral cortex is divided into left and right hemisphere. The cerebral cortex is where the information processing takes place. It plays a key role in memory, attention, perceptual awareness, thought, language, and consciousness. It is constituted of up to six horizontal layers, each of which has a different composition in terms of neurons and connectivity

Cerebral cortex

- All the neurons are ***interneurons***
  - They have to synapse somewhere before the info passes to the peripheral nerves
- Three kinds of functional areas
  - ***Motor*** areas: movement
  - ***Sensory*** areas: perception
  - ***Association*** areas: integrate diverse information to enable purposeful action

Cerebral cortex

- Executive functioning capability
- Gray matter: of neuron cell bodies, dendrites, short unmyelinated axons
  - 100 billion neurons with average of 10,000 contacts each
- No fiber tracts
- 2-4 mm thick (about 1/8 inch)

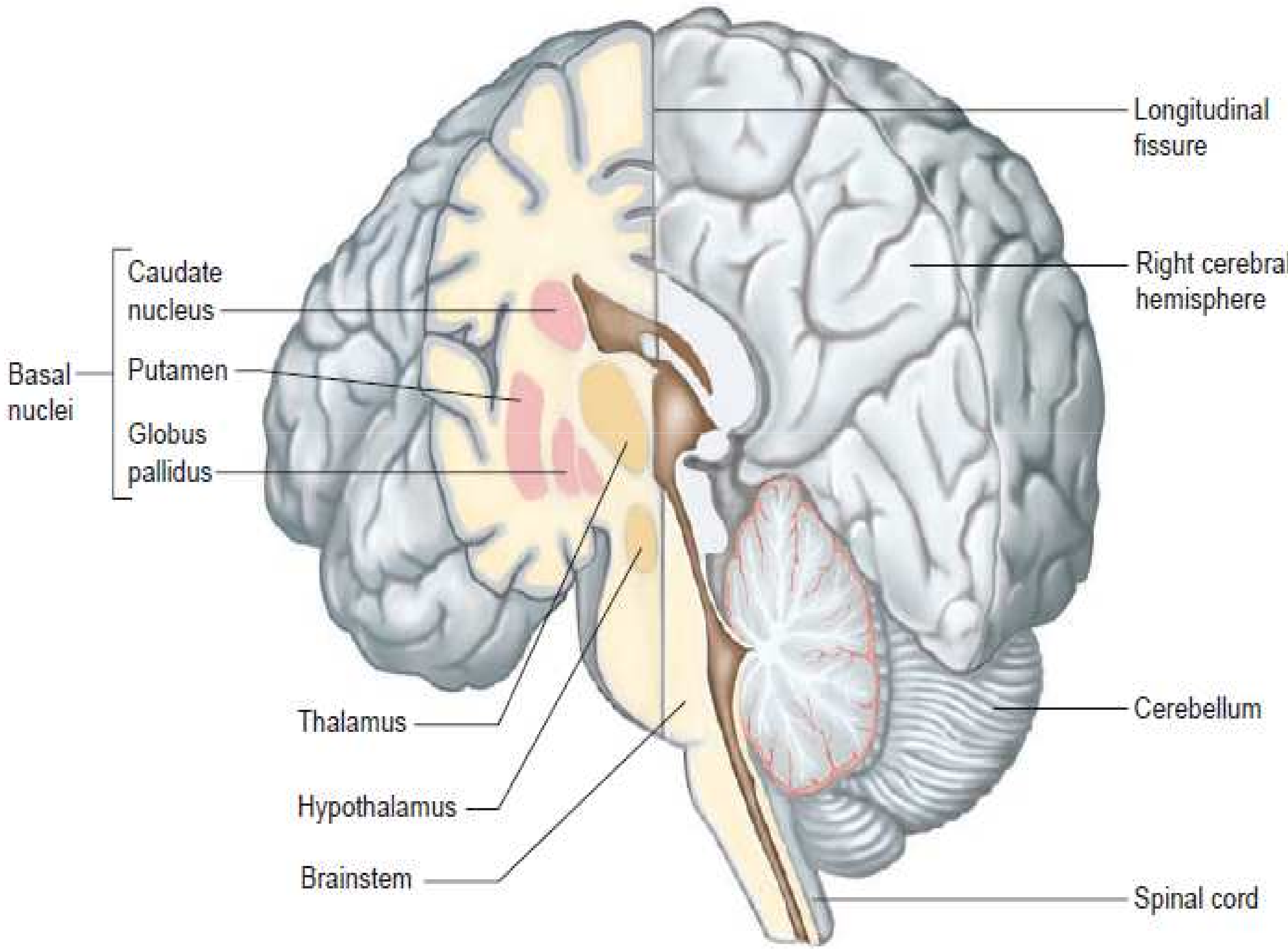
The functional areas of the cerebral cortex

- thinking
- reasoning
- learning
- memory
- intelligence
- sense of responsibility
- perception of the senses
- initiation and control of voluntary muscle contraction

- The **basal ganglia** (or **basal nuclei**) are a group of nuclei of varied origin in the brains of vertebrates that act as a cohesive functional unit. They are situated at the base of the forebrain and are strongly connected with the cerebral cortex, thalamus and other brain areas. The basal ganglia are associated with a variety of functions, including voluntary motor control, procedural learning relating to routine behaviors or "habits" such as bruxism, eye movements, and cognitive, emotional functions

- The main components of the basal ganglia are the striatum, or neostriatum (composed of the caudate and putamen), the globus pallidus, or pallidum (composed of globus pallidus externa (GPe) and globus pallidus interna (GPi)), the substantia nigra, and the subthalamic nucleus.
- The basal ganglia play a central role in a number of neurological conditions, including several movement disorders. The most notable are Parkinson's disease.

- The basal nuclei produce the inhibitory neurotransmitter *dopamine.* The neurons of the basal nuclei interact with other brain areas, including the motor cortex, thalamus, and cerebellum. These interactions, through a combination of stimulation and inhibition, facilitate voluntary movement.

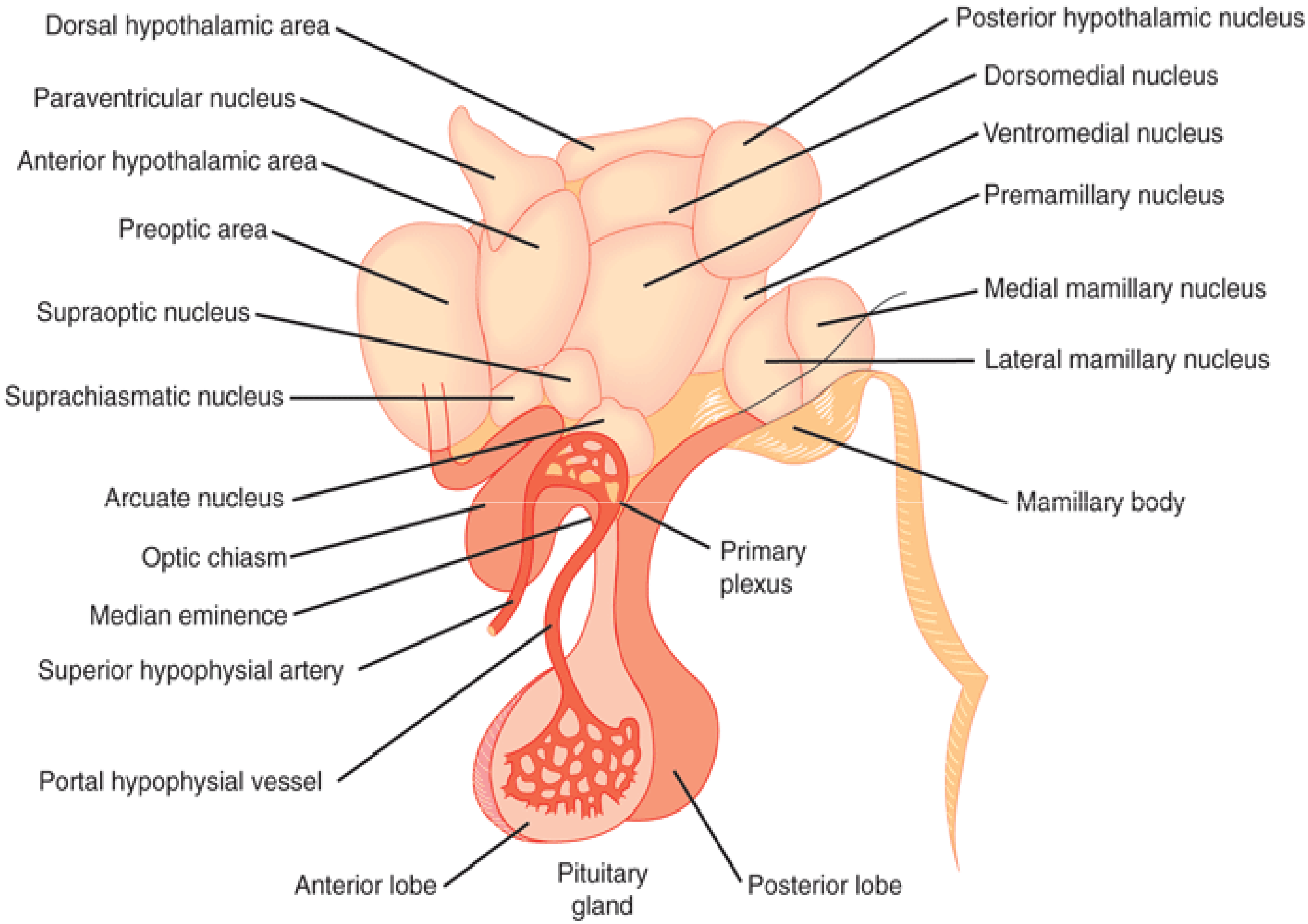


Longitudinal fissure
Right cerebral hemisphere
Caudate nucleus
Putamen
Globus pallidus
Basal nuclei
Thalamus
Hypothalamus
Brainstem
Cerebellum
Spinal cord

- The **limbic system** is a set of brain structures, including the
- Hippocampus (long and short term memory)
- amygdala (memory of emotional reactions)
- anterior thalamic nuclei (alertness, learning, learning)
- Septum (separates left and right ventricles of brain), limbic cortex and
- Fornix (carries signals from hippopcampus to hypothalamus)

Hypothalamus

- The hypothalamus is located below the thalamus, just above the brain stem
- One of the most important functions of the hypothalamus is to link the nervous system to the endocrine system via the pituitary gland (hypophysis).
- The hypothalamus receives many inputs from the brainstem; notably from the nucleus of the solitary tract and the locus coeruleus.



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

Afferent & Efferent Connections of the Hypothalamus

- The principal afferent and efferent neural pathways to and from the hypothalamus are mostly unmyelinated. Many connect the hypothalamus to the limbic system. Important connections also exist between the hypothalamus and nuclei in the midbrain tegmentum, pons, and hindbrain

- Norepinephrine-secreting neurons with their cell bodies in the hindbrain end in many different parts of the hypothalamus. Paraventricular neurons that probably secrete oxytocin and vasopressin project in turn to the hindbrain and the spinal cord. Neurons that secrete epinephrine have their cell bodies in the hindbrain and end in the ventral hypothalamus.

Relation to the Pituitary Gland

- There are neural connections between the hypothalamus and the posterior lobe of the pituitary gland and vascular connections between the hypothalamus and the anterior lobe.
- Embryologically, the posterior pituitary arises as an evagination of the floor of the third ventricle. It is made up in large part of the endings of axons that arise from cell bodies in the supraoptic and paraventricular nuclei and pass to the posterior pituitary (Figure 18–2) via the **hypothalamohypophysial tract.**

The hypothalamus regulates:

- heart rate
- body temperature
- movement of food through the alimentary canal
- food and water intake
- patterns of waking and sleeping
- contraction of the urinary bladder
- sexual cycles
- sensory information from internal organs
- associated with fear and anger
- the release of hormones from the pituitary gland

Function	Afferents from	Integrating Areas
Temperature regulation	Temperature receptors in the skin, deep tissues, spinal cord, hypothalamus, and other parts of the brain	Anterior hypothalamus, response to heat; posterior hypothalamus, response to cold
Control of body rhythms	Retina via retinohypothalamic fibers	Retina via retinohypothalamic fibers

Function	Afferents froms	Integrating Areas
Neuroendocrine control of:		
Catecholamines	Limbic areas concerned with emotion	Dorsal and posterior hypothalamus
Thyroid-stimulating hormone (thyrotropin, TSH) via TRH	Temperature receptors in infants, perhaps others	Paraventricular nuclei and neighboring areas

Adrenocorticotropic hormone (ACTH)	Limbic system (emotional stimuli); reticular formation ("systemic" stimuli); hypothalamic and anterior pituitary cells sensitive to circulating blood cortisol level;	Paraventricular nuclei
Follicle-stimulating hormone (FSH) and luteinizing hormone (LH)	Hypothalamic cells sensitive to estrogens, eyes, touch receptors in skin and genitalia of reflex ovulating species	Preoptic area
Prolactin	Touch receptors in breasts	Arcuate nucleus; other areas (hypothalamus inhibits secretion)

"Appetitive" behavior		
Thirst	Osmoreceptors, probably located in the organum vasculosum of the lamina terminalis; angiotensin II uptake in the subfornical organ	Lateral superior hypothalamus
Hunger	Glucostat cells sensitive to rate of glucose utilization; leptin receptors; receptors for other polypeptides	Ventromedial, arcuate, and paraventricular nuclei; lateral hypothalamus
Sexual behavior	Cells sensitive to circulating estrogen and androgen, others	Anterior ventral hypothalamus plus, in the male, piriform cortex
Defensive reactions (fear, rage)	Sense organs and neocortex, paths unknown	Diffuse, in limbic system and hypothalamus

Relation to Autonomic Function

- Many years ago, Sherrington called the hypothalamus "the head ganglion of the autonomic system." Stimulation of the hypothalamus produces autonomic responses, but the hypothalamus does not seem to be concerned with the regulation of visceral function

- the autonomic responses triggered in the hypothalamus are part of more complex phenomena such as eating, and emotions such as rage. For example, stimulation of various parts of the hypothalamus, especially the lateral areas, produces diffuse sympathetic discharge and increased adrenal medullary secretion, the mass sympathetic discharge seen in animals exposed to stress (the flight or fight reaction)

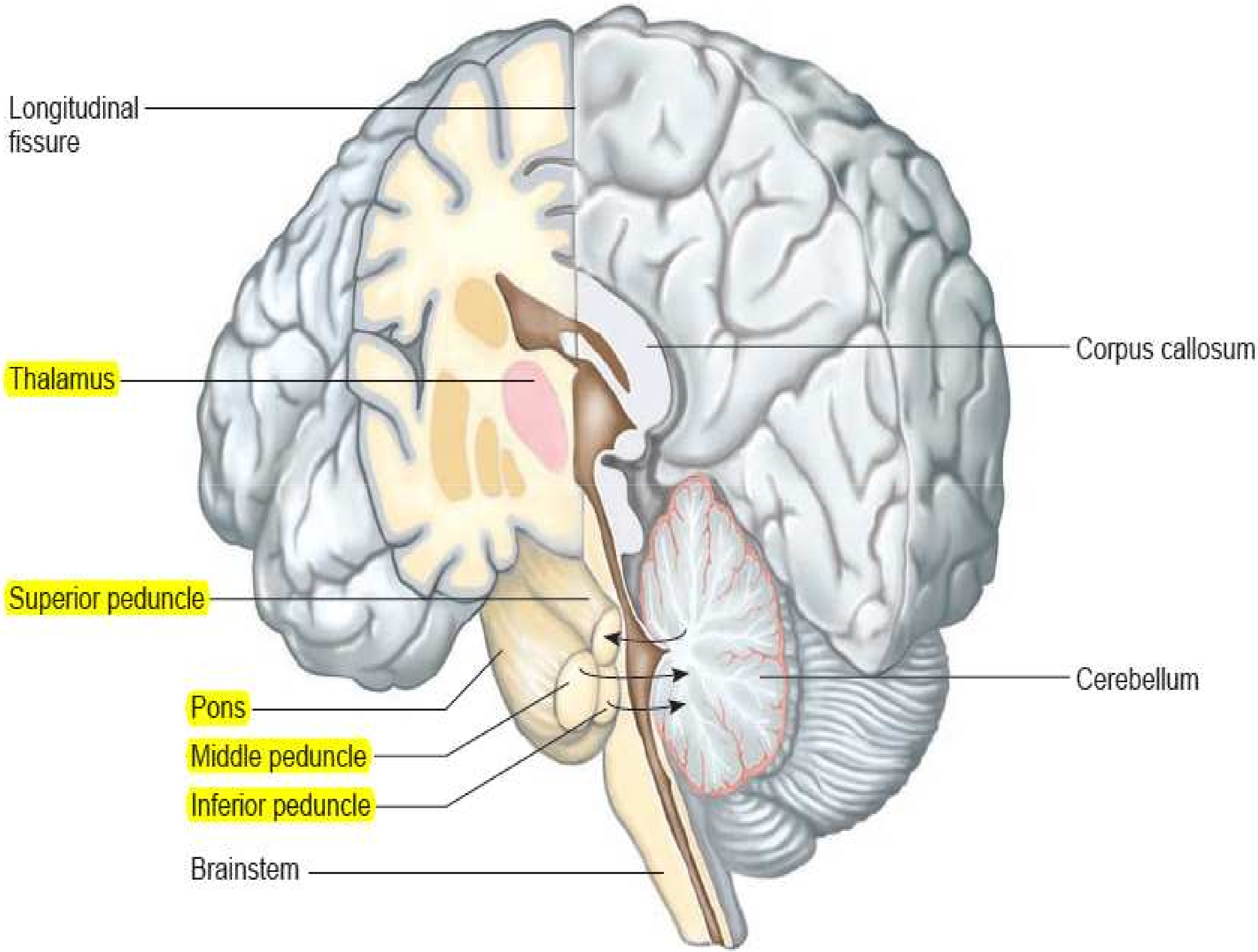
- Separate hypothalamic areas control epinephrine and norepinephrine secretion. Differential secretion of one or the other of these adrenal medullary catecholamines does occur in certain situations
- Body weight depends on the balance between caloric intake and utilization of calories. Obesity results when the former exceeds the latter. The hypothalamus and related parts of the brain play a key role in the regulation of food intake.
- Hypothalamic regulates sleep and circadian rhythms

Cerebellum

- The cauliflower like cerebellum is a large mass of tissue located below the occipital lobes of the cerebrum and posterior to the pons and medulla oblongata.
- It consists of two lateral hemispheres partially separated by a layer of dura mater (falx cerebelli) and connected in the midline by a structure called the *vermis.* Like the cerebrum, the cerebellum is composed primarily of white matter, with a thin layer of gray matter, the cerebellar cortex, on its surface.

- The cerebellum communicates with other parts of the CNS and brain stem by means of three pairs of nerve tracts called *cerebellar peduncles*
- One pair (the inferior peduncles) brings sensory information concerning the position of the limbs, joints, and other body parts to the cerebellum

- Another pair (the middle peduncles) transmits signals from the cerebral cortex to the cerebellum concerning the desired positions of these parts. After integrating and analyzing this information, the cerebellum sends correcting impulses via a third pair (the superior peduncles) to the midbrain. These corrections are incorporated into motor impulses that travel downward through the pons, medulla oblongata, and spinal cord in the appropriate patterns to move the body in the desired way.


Longitudinal fissure
Thalamus
Superior peduncle
Pons
Middle peduncle
Inferior peduncle
Brainstem
Corpus callosum
Cerebellum

- The cerebellum is a reflex center for integrating sensory information concerning the position of body parts and for coordinating complex skeletal muscle movements. It also helps maintain posture. Damage to the cerebellum is likely to result in tremors, inaccurate movements of voluntary muscles, loss of muscle tone, a reeling walk, and loss of equilibrium.

Functions of Cerebellum

- The motor areas of the cerebral cortex, via relay nuclei in the brain stem, notify the cerebellum of their intent to initiate voluntary muscle contractions.
- At the same time, the cerebellum receives information from proprioceptors throughout the body (regarding tension in the muscles and tendons, and joint position) and from visual and equilibrium pathways. This information enables the cerebellum to evaluate body position and momentum, that is, where the body is and where it is going.

- The cerebellar cortex calculates the best way to coordinate the force, direction, and extent of muscle contraction to prevent overshoot, maintain posture, and ensure smooth, coordinated movements.
- Then, via the superior peduncles, the cerebellum dispatches to the cerebral motor cortex its “blueprint” for coordinating movement. Cerebellar fibers also send information to brain stem nuclei, which in turn influence motor neurons of the spinal cord.

- The cerebellum continually compares the higher brain’s intention with the body’s performance and sends out messages to initiate the appropriate corrective measures. Cerebellar injury results in loss of muscle tone and clumsy, unsure movements.

- Cognitive Function of the Cerebellum
  Functional imaging studies indicate that the cerebellum plays a role in cognition. The cerebellum recognizes and predicts sequences of events so that it may adjust for the multiple forces exerted on a limb during complex movements involving several joints. Some nonmotor functions, including word association and puzzle solving, also appear to involve the cerebellum.

Control of Posture & Movement

- Introduction
- Somatic motor activity depends ultimately on the pattern and rate of discharge of the spinal motor neurons and homologous neurons in the motor nuclei of the cranial nerves. These neurons, the final common paths to skeletal muscle, are bombarded by impulses from an immense array of descending pathways, other spinal neurons, and peripheral afferents.

- Some of these inputs end directly on alpha motor neurons, but many exert their effects via interneurons or via gamma motor neurons to the muscle spindles and back through the 1a afferent fibers to the spinal cord. It is the integrated activity of these multiple inputs from spinal, medullary, midbrain, and cortical levels that regulates the posture of the body and makes coordinated movement possible

- The inputs converging on motor neurons subserve three functions: they bring about voluntary activity, they adjust body posture to provide a stable background for movement, and they coordinate the action of the various muscles to make movements smooth and precise. The patterns of voluntary activity are planned within the brain, and the commands are sent to the muscles primarily via the corticospinal and corticobulbar systems.

- Posture is continually adjusted not only before but also during movement by descending brain stem pathways and peripheral afferents. Movement is smoothed and coordinated by the medial and intermediate portions of the cerebellum (spinocerebellum) and its connections. The basal ganglia and the lateral portions of the cerebellum (cerebrocerebellum) are part of a feedback circuit to the premotor and motor cortex that is concerned with planning and organizing voluntary movement.

- Organization
- There are two types of motor output: reflexive (involuntary) and voluntary. A subdivision of reflex responses includes some rhythmic movements such as swallowing, chewing, scratching, and walking, which are largely involuntary but subject to voluntary adjustment and control.

- To move a limb, the brain must plan a movement, arrange appropriate motion at many different joints at the same time, and adjust the motion by comparing plan with performance. The motor system "learns by doing" and performance improves with repetition. This involves synaptic plasticity.

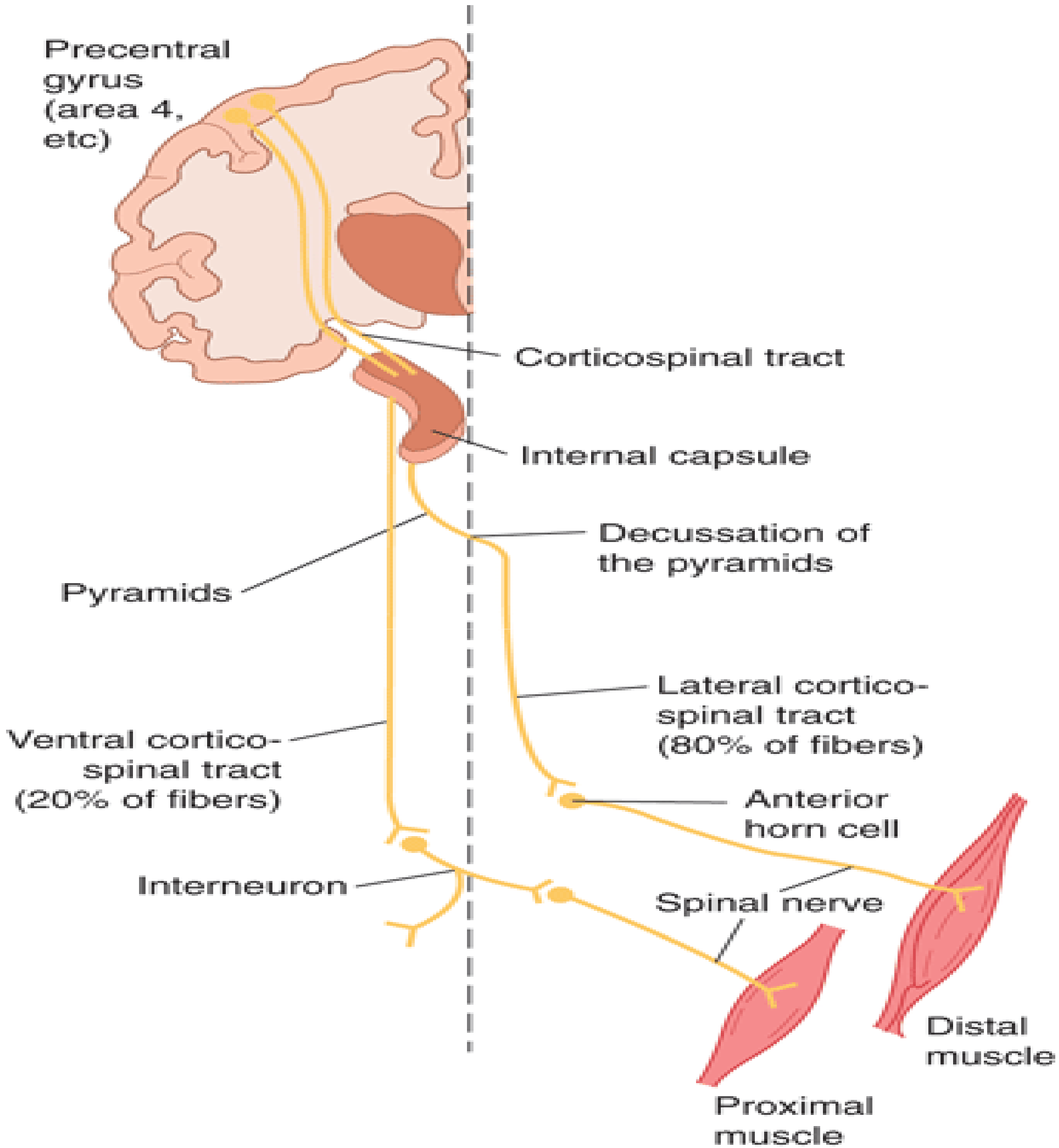
- Commands for voluntary movement originate in cortical association areas. The movements are planned in the cortex as well as in the basal ganglia and the lateral portions of the cerebellar hemispheres, as indicated by increased electrical activity before the movement. The basal ganglia and cerebellum funnel information to the premotor and motor cortex by way of the thalamus. Motor commands from the motor cortex are relayed in large part via the corticospinal tracts to the spinal cord and the corresponding corticobulbar tracts to motor neurons in the brain stem.

- However, collaterals from these pathways and a few direct connections from the motor cortex end on brain stem nuclei, which also project to motor neurons in the brain stem and spinal cord. These pathways can also mediate voluntary movement. Movement sets up alterations in sensory input from the special senses and from muscles, tendons, joints, and the skin.

- This feedback information, which adjusts and smoothes movement, is relayed directly to the motor cortex and to the spinocerebellum. The spinocerebellum projects in turn to the brain stem. The main brain stem pathways that are concerned with posture and coordination are the rubrospinal, reticulospinal, tectospinal, and vestibulospinal tracts.

Corticospinal & Corticobulbar Tracts

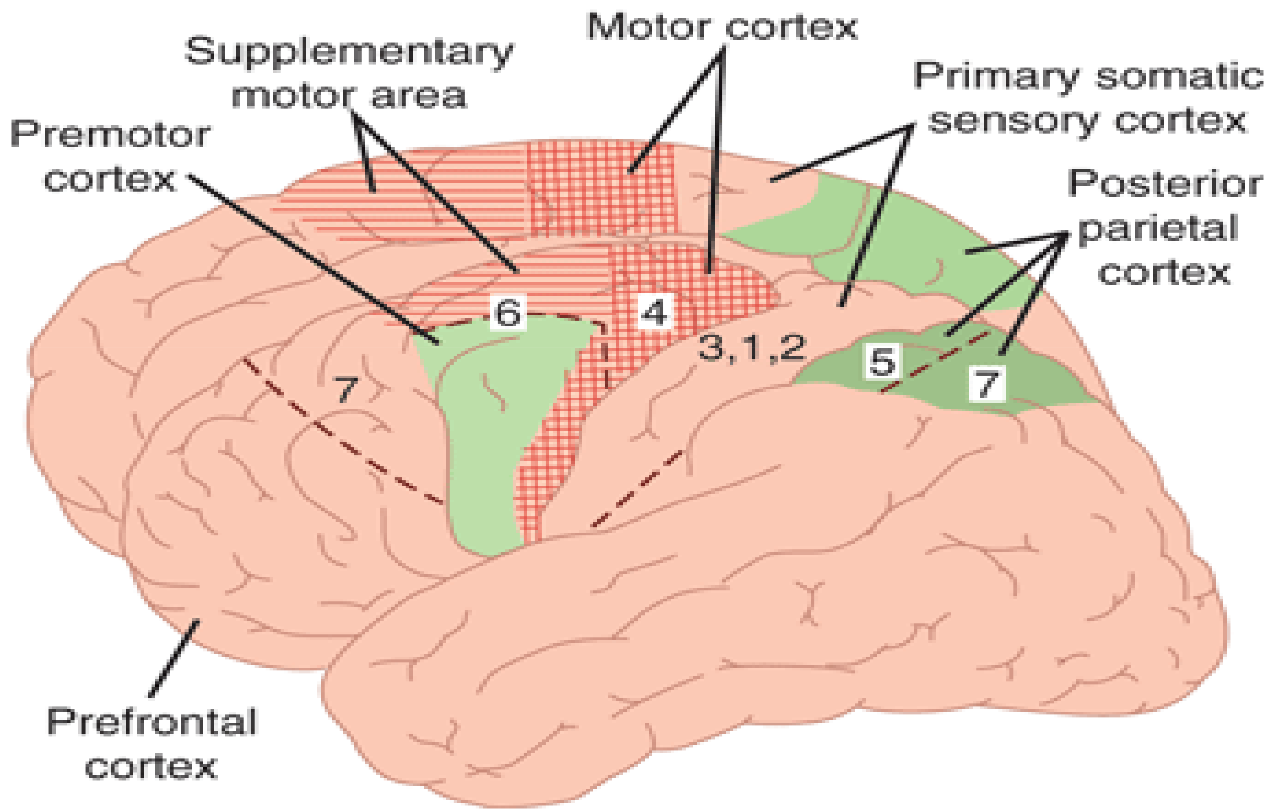
- Descending Projections
- The axons of neurons from the motor cortex that project to spinal motor neurons form the **corticospinal tracts,** a large bundle of about 1 million fibers. About 80% of these fibers cross the midline in the medullary pyramids to form the **lateral corticospinal tract.**The remaining 20% make up the **ventral corticospinal tract,** which does not cross the midline until it reaches the level of the spinal cord at which it terminates. Lateral corticospinal tract neurons make monosynaptic connections to motor neurons, especially those concerned with skilled movements. Corticospinal tract neurons also synapse on spinal interneurons antecedent to motor neurons; this indirect pathway is important in coordinating groups of muscles.



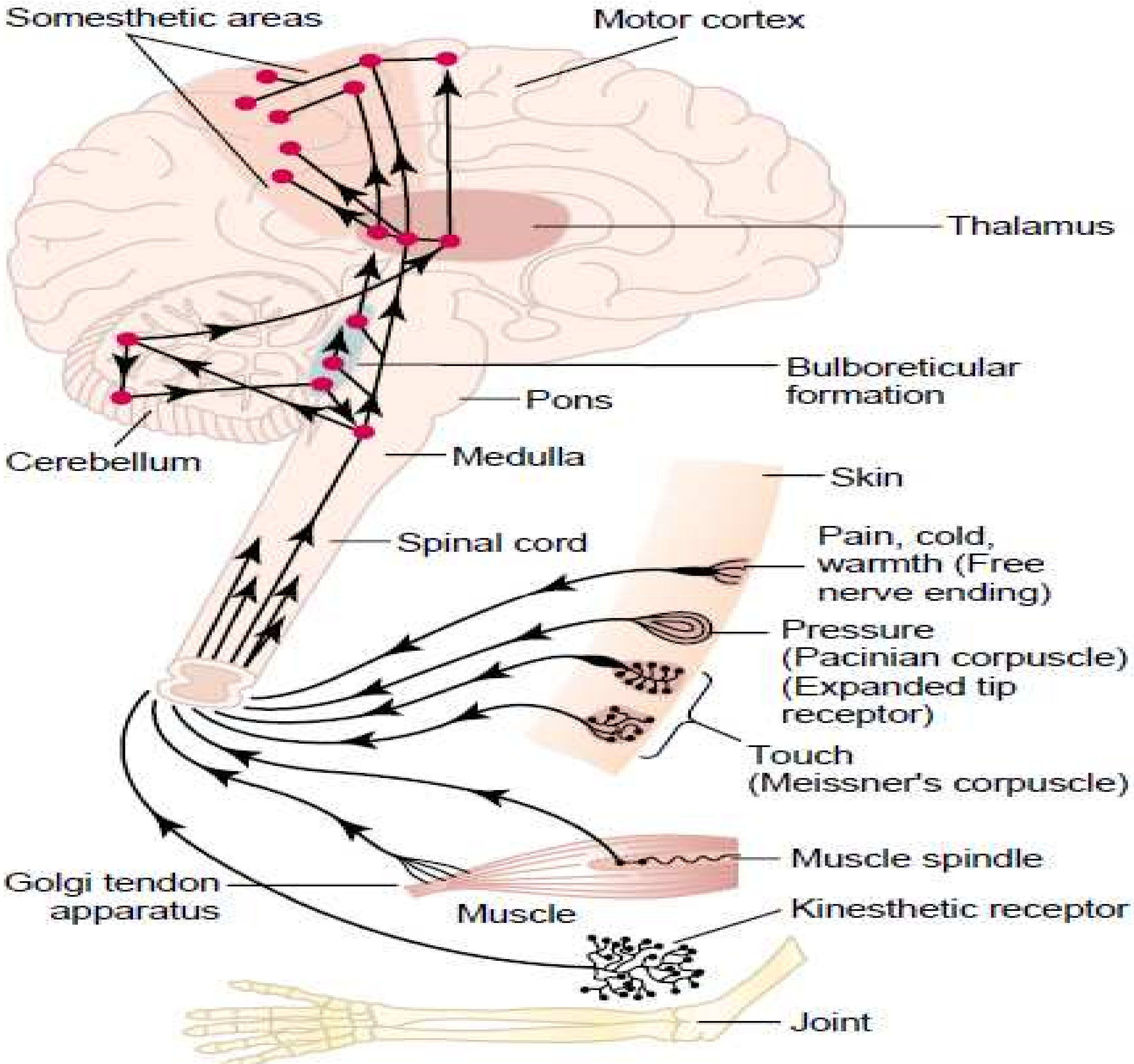
Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

- The **corticobulbar tract** is composed of the fibers that pass from the motor cortex to motor neurons in the trigeminal, facial, and hypoglossal nuclei. Corticobulbar neurons end either directly on the cranial nerve nuclei or on their preceding interneurons within the brain stem. Their axons traverse through the genu of the internal capsule, the cerebral peduncle (medial to corticospinal tract neurons), to descend with corticospinal tract fibers in the pons and medulla.

Origins of Corticospinal & Corticobulbar Tracts



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com



er

Figure 45–2

Somatosensory axis of the nervous system.

- About 31% of the corticospinal tract neurons are from the **primary motor cortex (M1; Brodmann's area 4).** This region is in the precentral gyrus of the frontal lobe, extending into the central sulcus. The **premotor cortex** and **supplementary motor cortex (Brodmann's area 6)** account for 29% of the corticospinal tract neurons. The premotor area is anterior to the precentral gyrus, on the lateral and medial cortical surface; and the supplementary motor area is on and above the superior bank of the cingulate sulcus on the medial side of the hemisphere. The other 40% of corticospinal tract neurons originate in the **parietal lobe (Brodmann's area 5, 7)** and **primary somatosensory area (Brodmann's area 3, 1, 2)** in the postcentral gyrus.

Thalamus

- The thalamus is a large, dual lobed mass of grey matter buried under the cerebral cortex. It is involved in sensory perception and regulation of motor functions. The thalamus is a limbic system structure and it connects areas of the cerebral cortex that are involved in sensory perception and movement with other parts of the brain and spinal cord that also have a role in sensation and movement. As a regulator of sensory information, the thalamus also controls sleep and awake

- Its basic function in the brain is to process and relay movement and sensory information. It can be called the relay station of the body, which takes in sensory information from different parts of the body and passes it on to the cerebral cortex. The passing of information also happens in the reverse direction. Information is also passed from the cerebral cortex to the thalamus, which is then in turn sent out to the other parts of the body. To take an example, inputs from the retina are sent to the lateral geniculate nucleus region of the thalamus, which in turn projects the primary visual cortex in the occipital lobe. Each of the sensory relay areas receive strong projections from the cerebral cortex.

- It regulates the sleeping and wakefulness states. The thalamus has strong reciprocal connections with the cerebral cortex, which in turn form the thalamo-cortico-thamlamic circuits, which take care of consciousness. The thalamus also has a major role to play in regulating arousal, level of awareness and activity.

- Any damage to the thalamus can result in comatose situation, which can be reversible or irreversible or can affect the motor activities of the person. The very fact, that the person may lose his/her consciousness, stress its importance in the body. To sum up, it relays sensations, special sense and motor signals to the cerebral cortex and regulate the states of consciousness, sleep and alertness

Specific Relay Nuclei

- The specific relay nuclei basically, project fibers to and receive fibers from well defined areas on the cerebral cortex that are considered to be related to specific function.

a) Medial Geniculate Body

- Input - auditory information; mostly arising from the inferior colliculi.
  Output - sends information via the auditory radiations to the auditory cortex

b) Lateral Geniculate Body

- Input - information dealing with vision, arising from the optic tract.
  Output - projects information via visual radiations to the calcarine cortex of the occipital lobe

c) *Ventral Posterior Nucleus* (VP)

- The ventral posterior nucleus is broken down into the ventral posterior lateral nucleus (VPL), the ventral posterior medial nucleus (VPM), and the ventral medial nucleus (VM).

- Ventral Posterior Lateral Nucleus
- <u>Input</u> - receives information regarding pain, temperature, touch, pressure, vibration, and conscious proprioception from the extremities, neck and trunk via major afferent pathways
- <u>Output</u> - projects information to the primary somatosensory cortex area in the post central gyrus

- Ventral Posterior Medial Nucleus (VPM)
- <u>Input</u> - receives information of the same nature as the VPL, from the face and head area via the 5th cranial nerve. <u>Output</u> - to primary somesthetic area in the post-central gyrus
- Ventral Medial Nucleus (VM)
- <u>Input</u> - receives information dealing with the sense of taste from the parabrachial nuclei of the reticular formation.
  <u>Output</u> - to the primary receiving area for taste

- *Ventral Lateral Nucleus* (VL) and Ventral Anterior Nucleus (VA)
- Input - receive information dealing with motor control from the contralateral cerebellar cortex (via the superior cerebellar peduncle) and the ipsilateral corpus striatum.
  Output - sends information to the primary motor areas in the cerebral cortex, to complete the feedback system of the motor control mechanism.

SPINAL CORD

- The spinal cord is a slender nerve column that passes downward from the brain into the vertebral canal. Although continuous with the brain, the spinal cord begins where nervous tissue leaves the cranial cavity at the level of the foramen magnum. The spinal cord tapers to a point and terminates near the intervertebral disc that separates the first and second lumbar vertebrae

- The spinal cord is a slender nerve column that passes downward from the brain into the vertebral canal. Although continuous with the brain, the spinal cord begins where nervous tissue leaves the cranial cavity at the level of the foramen magnum. The spinal cord tapers to a point and terminates near the intervertebral disc that separates the first and second lumbar vertebrae

Structure of the Spinal Cord

- The spinal cord consists of thirty-one segments, each of which gives rise to a pair of spinal nerves. These nerves (part of the peripheral nervous system) branch to various body parts and connect them with the CNS.
- In the neck region, a thickening in the spinal cord, called the *cervical enlargement,* supplies nerves to the upper limbs.

- A similar thickening in the lower back, the
- *lumbar enlargement,* gives off nerves to the lower limbs
- Two grooves, a deep *anterior median fissure* and a shallow *posterior median sulcus,* extend the length of the spinal cord, dividing it into right and left halves

- A cross section of the cord reveals a core of gray matter within white matter. The pattern of gray matter roughly resembles a butterfly with its wings spread. The upper and lower wings of gray matter are called the *posterior horns* and *anterior horns,* respectively. Between them on either side in the thoracic and upper lumbar segments is a protrusion of gray matter called the *lateral horn.*

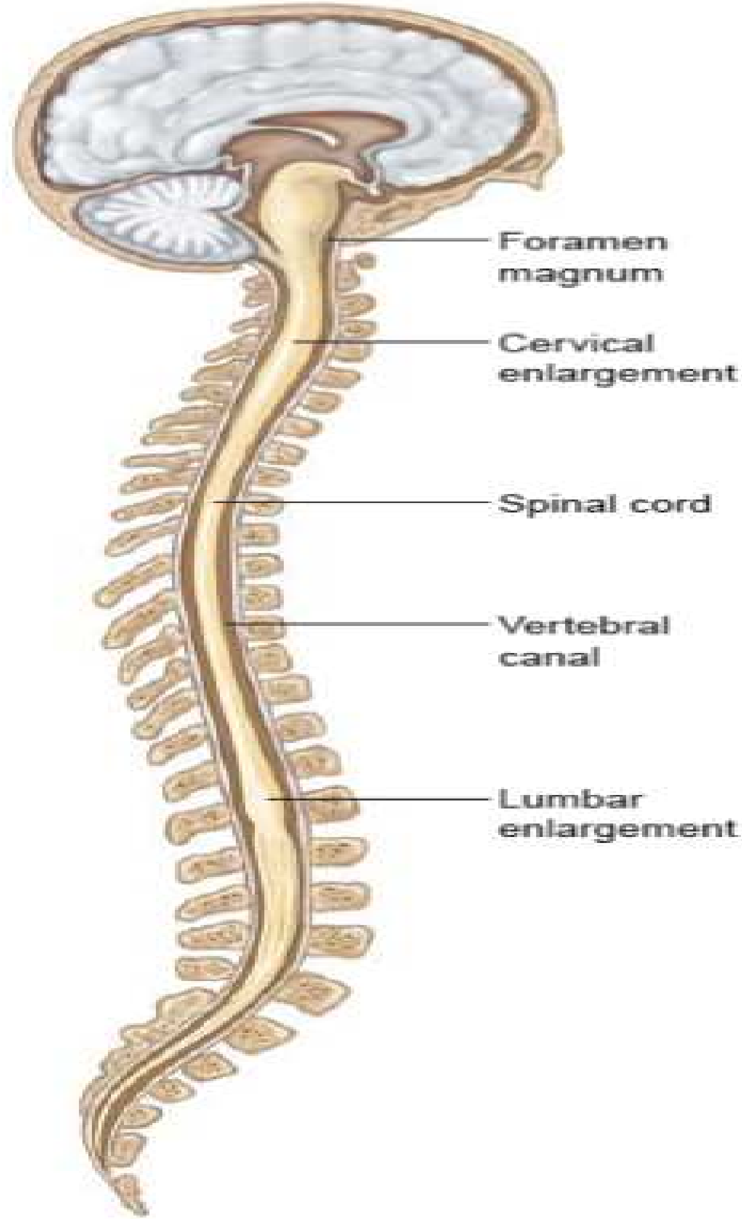
- Neurons with large cell bodies located in the anterior horns give rise to motor fibers that pass out through spinal nerves to skeletal muscles. However, the majority of neurons in the gray matter of the spinal cord are interneurons. Gray matter divides the white matter of the spinal cord into three regions on each side—the *anterior, lateral,* and *posterior funiculi*

- Ascending Pathways to the Brain
  Neuronal Composition The ascending pathways conduct sensory impulses upward, typically through chains of three successive neurons (first-, second-, and third-order neurons) to various areas of the brain. Both second- and third-order neurons are interneurons.
- First-order neurons, whose cell bodies reside in a ganglion (dorsal root or cranial), conduct impulses from the cutaneous receptors of the skin and from proprioceptors to the spinal cord or brain stem, where they synapse with second-order neurons. Impulses from the facial area are transmitted by cranial nerves; spinal nerves conduct somatic sensory impulses from the rest of the body to the CNS.

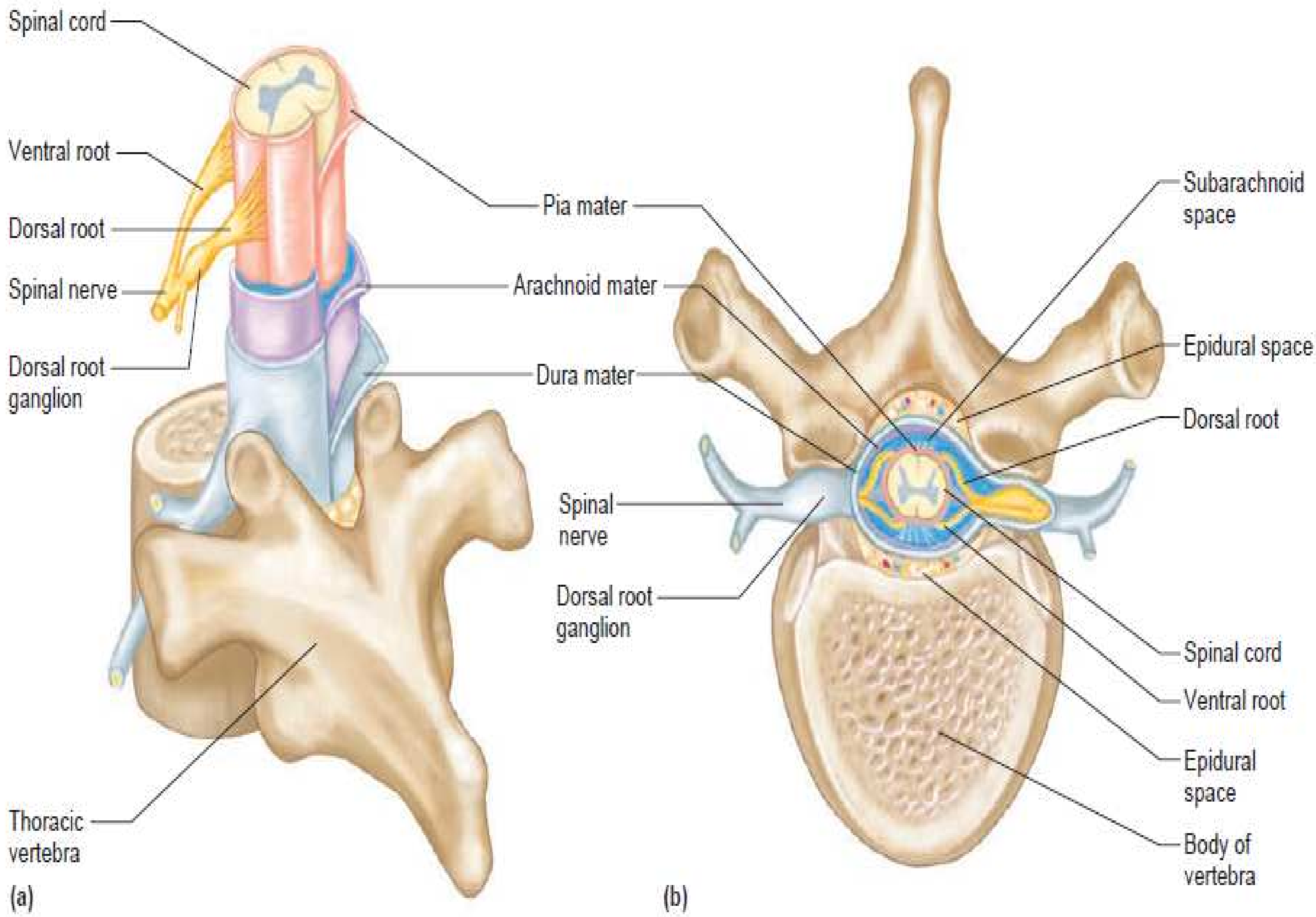
- Second-order neurons, whose cell bodies reside in the dorsal horn of the spinal cord or in medullary nuclei, transmit impulses to the thalamus or to the cerebellum where they synapse.

- Third-order neurons, whose cell bodies reside in the thalamus, conduct impulses to the somatosensory cortex of the cerebrum. (There are no third-order neurons in the cerebellum.)

- Each funiculus consists of longitudinal bundles of myelinated axons that comprise major neural pathways. In the central nervous system, such bundles of axons are called tracts. A horizontal bar of gray matter in the middle of the spinal cord, the *gray commissure,* connects the wings of the gray matter on the right and left sides. This bar surrounds the central canal, which contains cerebrospinal fluid.



Foramen magnum
Cervical enlargement
Spinal cord
Vertebral canal
Lumbar enlargement


Spinal cord
Ventral root
Dorsal root
Spinal nerve
Dorsal root
ganglion
Thoracic
vertebra
(a)
Pia mater
Arachnoid mater
Dura mater
Spinal
nerve
Dorsal root
ganglion
(b)
Subarachnoid
space
Epidural space
Dorsal root
Spinal cord
Ventral root
Epidural
space
Body of
vertebra

Functions of the Spinal Cord

- The spinal cord has two major functions—conducting nerve impulses and
- serving as a center for spinal reflexes.
- The tracts of the spinal cord consist of axons that provide a two-way communication system between the brain and the body parts outside the nervous system. The tracts that carry sensory information to the brain are called ascending tracts and those that conduct motor impulses from the brain to muscles and glands are called descending tracts

- All the axons in a given tract typically originate from neuron cell bodies in the same part of the nervous system and terminate together in some other part. The names that identify tracts often reflect these common origins and terminations. For example, a ***spinothalamic*** *tract* begins in the spinal cord and carries sensory impulses associated with the sensations of pain, touch, and temperature to the thalamus of the brain. A ***corticospinal tract*** originates in the cortex of the brain and carries motor impulses downward through the spinal cord and spinal nerves. These impulses control skeletal muscle movements.

TABLE 12.2 Major Ascending (Sensory) Pathways and Spinal Cord Tracts				
SPINAL CORD TRACT	LOCATION (FUNICULUS)	ORIGIN	TERMINATION	FUNCTION
SPECIFIC ASCENDING (LEMNISCAL) PATHWAYS				
Fasciculus cuneatus and fasciculus gracilis (dorsal white column)	Posterior	Central axons of sensory (first-order) neurons enter dorsal root of the spinal cord and branch; branches enter dorsal white column on same side without synapsing	By synapse with second-order neurons in nucleus cuneatus and nucleus gracilis in medulla; fibers of medullary neurons cross over and ascend in medial lemniscal tracts to thalamus, where they synapse with third-order neurons; thalamic neurons then transmit impulses to somatosensory cortex	Both tracts transmit sensory impulses from general sensory receptors of skin and proprioceptors, which are interpreted as discriminative touch, pressure, and "body sense" (limb and joint position) in opposite somatosensory cortex. Cuneatus transmits afferent impulses from upper limbs, upper trunk, and neck; it is not present in spinal cord below level of T_6. Gracilis carries impulses from lower limbs and inferior body trunk
NONSPECIFIC ASCENDING (ANTEROLATERAL) PATHWAYS				
Lateral spinothalamic	Lateral	Interneurons (second-order neurons) of dorsal horn; fibers cross to opposite side before ascending	By synapse with third-order neurons in thalamus; impulses then conveyed to somatosensory cortex by thalamic neurons	Transmits impulses concerned with pain and temperature to opposite side of brain; eventually interpreted in somatosensory cortex
Anterior spinothalamic	Anterior	Interneurons (second-order neurons) in dorsal horns; fibers cross to opposite side before ascending	By synapse with third-order neurons in thalamus; impulses eventually conveyed to somatosensory cortex by thalamic neurons	Transmits impulses concerned with crude touch and pressure to opposite side of brain for interpretation by somatosensory cortex
SPINOCEREBELLAR PATHWAYS				
Posterior spinocerebellar*	Lateral (posterior part)	Interneurons (second-order neurons) in dorsal horn on same side of cord; fibers ascend without crossing	By synapse in cerebellum	Transmits impulses from trunk and lower limb proprioceptors on one side of body to same side of cerebellum; subconscious proprioception
Anterior spinocerebellar*	Lateral (anterior part)	Interneurons (second-order neurons) of dorsal horn; contains crossed fibers that cross back to the opposite side in the pons	By synapse in cerebellum	Transmits impulses from the trunk and lower limb on the same side of body to cerebellum; subconscious proprioception

Descending Tracts

- Corticospinal tracts are also called *pyramidal tracts* after the pyramid-shaped areas in the medulla oblongata of the brain through which they pass. Other descending tracts, called *extrapyramidal tracts,* control motor activities associated with maintaining balance and posture.

TABLE 12.3 Major Descending (Motor) Pathways and Spinal Cord Tracts

SPINAL CORD TRACT	LOCATION (FUNICULUS)	ORIGIN	TERMINATION	FUNCTION
DIRECT (PYRAMIDAL)				
Lateral corticospinal	Lateral	Pyramidal neurons of motor cortex of the cerebrum; decussate in pyramids of medulla	By synapse directly with ventral horn motor neurons and with ventral horn interneurons that influence motor neurons	Transmits motor impulses from cerebrum to spinal cord motor neurons (which activate skeletal muscles on opposite side of body); voluntary motor tract
Anterior corticospinal	Anterior	Pyramidal neurons of motor cortex; fibers cross over at the spinal cord level	Ventral horn (as above)	Same as lateral corticospinal tract
INDIRECT (EXTRAPYRAMIDAL) PATHWAYS				
Tectospinal	Anterior	Superior colliculus of midbrain of brain stem (fibers cross to opposite side of cord)	By synapse with ventral horn interneurons that influence motor neurons	Transmits motor impulses from midbrain that are important for coordinated movement of head and eyes toward visual targets
Vestibulospinal	Anterior	Vestibular nuclei in medulla of brain stem (fibers descend without crossing)	By synapse, directly with ventral horn motor neurons and with ventral horn interneurons that influence motor neurons	Transmits motor impulses that maintain muscle tone and activate ipsilateral limb and trunk extensor muscles and muscles that move head; in this way helps maintain balance during standing and moving
Rubrospinal	Lateral	Red nucleus of midbrain of brain stem (fibers cross to opposite side just inferior to the red nucleus)	Ventral horn (as above)	In experimental animals, transmits motor impulses concerned with muscle tone of distal limb muscles (mostly flexors) on opposite side of body; in humans, functions largely assumed by corticospinal tracts except for some upper limb movement
Reticulospinal (anterior, medial, and lateral)	Anterior and lateral	Reticular formation of brain stem (medial nuclear group of pons and medulla); both crossed and uncrossed fibers	Ventral horn (as above)	Transmits impulses concerned with muscle tone and many visceral motor functions; may control most unskilled movements

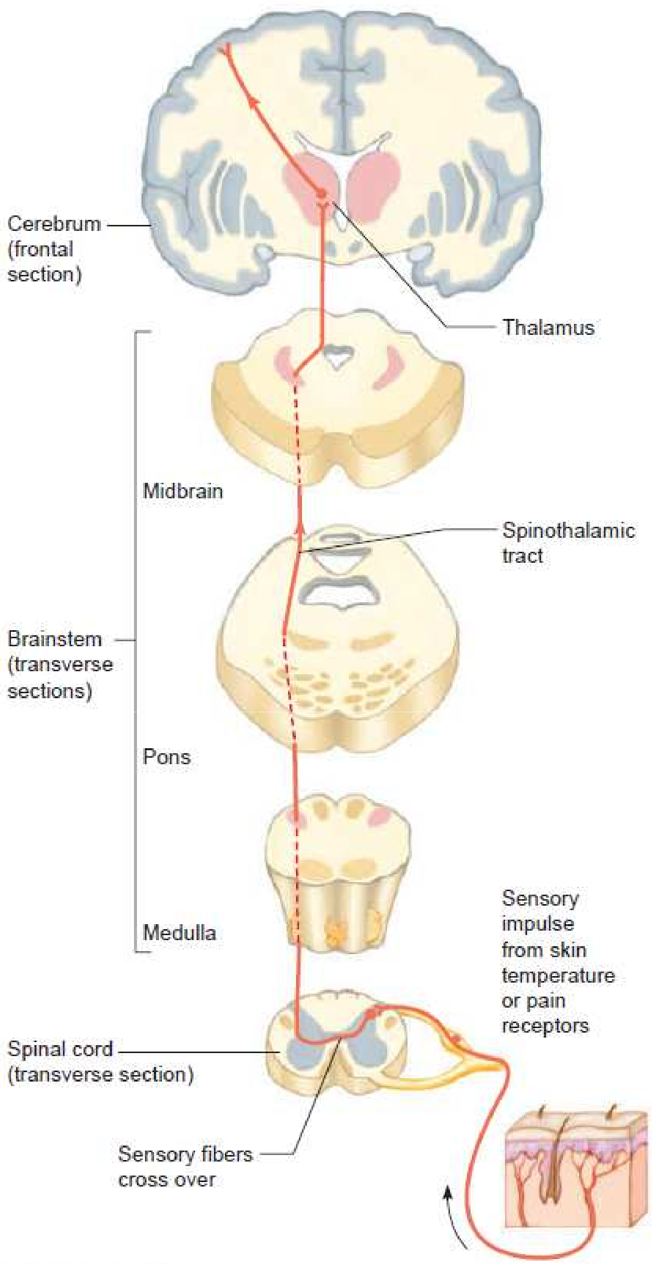


Figure 9.25

Ascending tracts. Sensory impulses originating in skin receptors cross over in the spinal cord and ascend to the brain. Other sensory tracts cross over in the medulla oblongata.

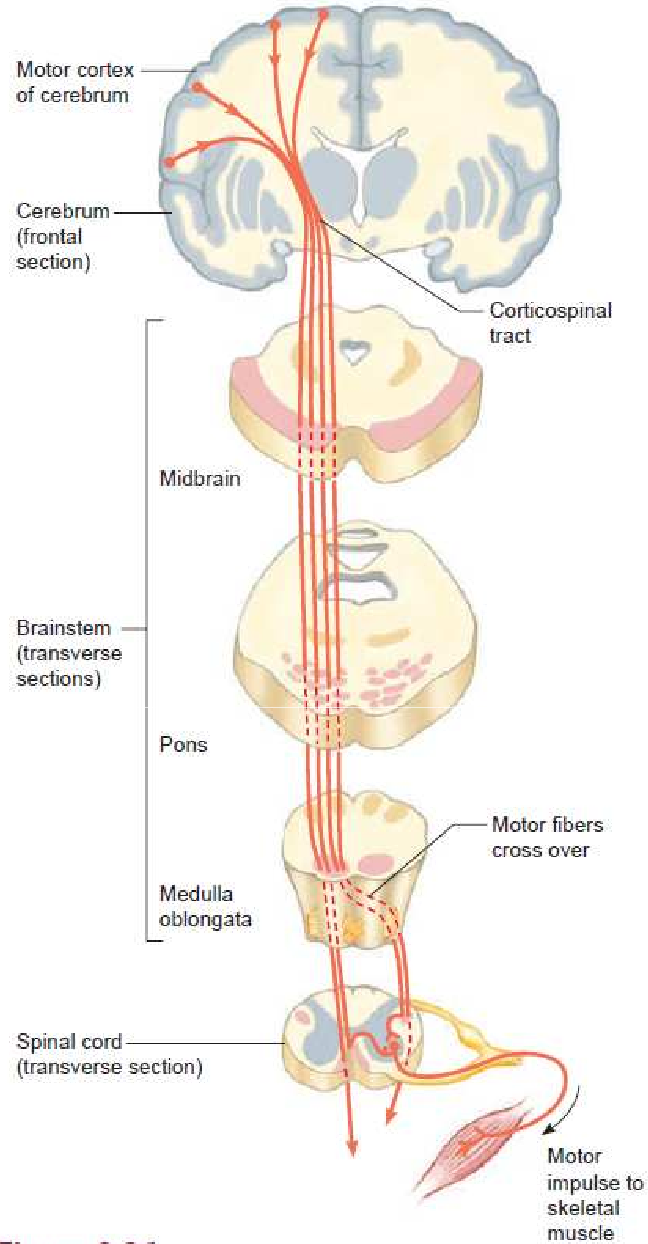


Figure 9.26

Descending tracts. Motor fibers of the corticospinal tract begin in the cerebral cortex, cross over in the medulla oblongata, and descend in the spinal cord. There, they synapse with neurons whose fibers lead to the spinal nerves that supply skeletal muscles.

- In addition to providing a pathway for tracts, the spinal cord functions in many reflexes, including the patellar and withdrawal reflexes. These are called spinal reflexes because their reflex arcs pass through the spinal cord.

Brainstem

- The brainstem is a bundle of nervous tissue that connects the cerebrum to the spinal cord. It consists of many tracts and several nuclei. The parts of the brainstem include the midbrain, pons, and medulla oblongata

Midbrain

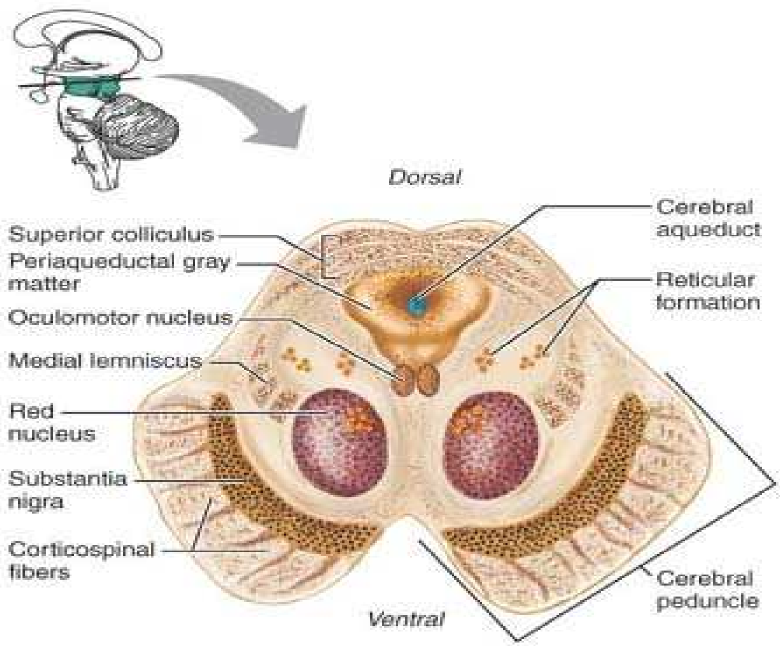
- The midbrain is a short section of the brainstem between the diencephalon and the pons. It contains bundles of myelinated axons that join lower parts of the brainstem and spinal cord with higher parts of the brain. Two prominent bundles of axons on the underside of the midbrain are the corticospinal tracts and are the main motor pathways between the cerebrum and lower parts of the nervous system.

- The midbrain includes several masses of gray matter that serve as reflex centers. For example, the midbrain contains the centers (superior colliculi) for certain visual reflexes, such as those responsible for moving the eyes to view something as the head turns. It also contains the auditory reflex centers (inferior colliculi) that enable a person to move the head to hear sounds more distinctly.

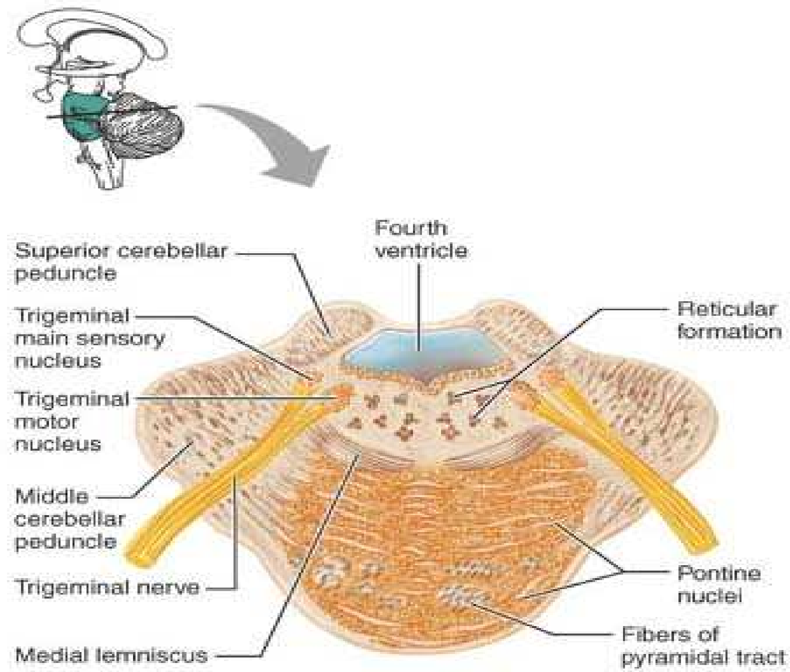
- Running through the midbrain is the hollow cerebral aqueduct, which connects the third and fourth ventricles, and delineates the cerebral peduncles ventrally from the tectum, the midbrain’s roof. Surrounding the aqueduct is the periaqueductal gray matter, which is involved in pain suppression and serves as the link between the fear-perceiving amygdala and ANS pathways that control the “fight-or-flight” response. The periaqueductal gray matter also includes nuclei that control two cranial nerves, the oculomotor and the trochlear nuclei.

- Also embedded in each side of the midbrain white matter are two pigmented nuclei, the substantia nigra and red nucleus . The bandlike substantia nigra is located deep to the cerebral peduncle. Its dark color reflects a high content of melanin pigment, a precursor of the neurotransmitter (dopamine) released by these neurons. The substantia nigra is functionally linked to the basal nuclei (its axons project to the globus pallidus), and is considered part of the basal nuclear complex by many authorities. Degeneration of the dopamine-releasing neurons of the substantia nigra is the ultimate cause of Parkinson’s disease.

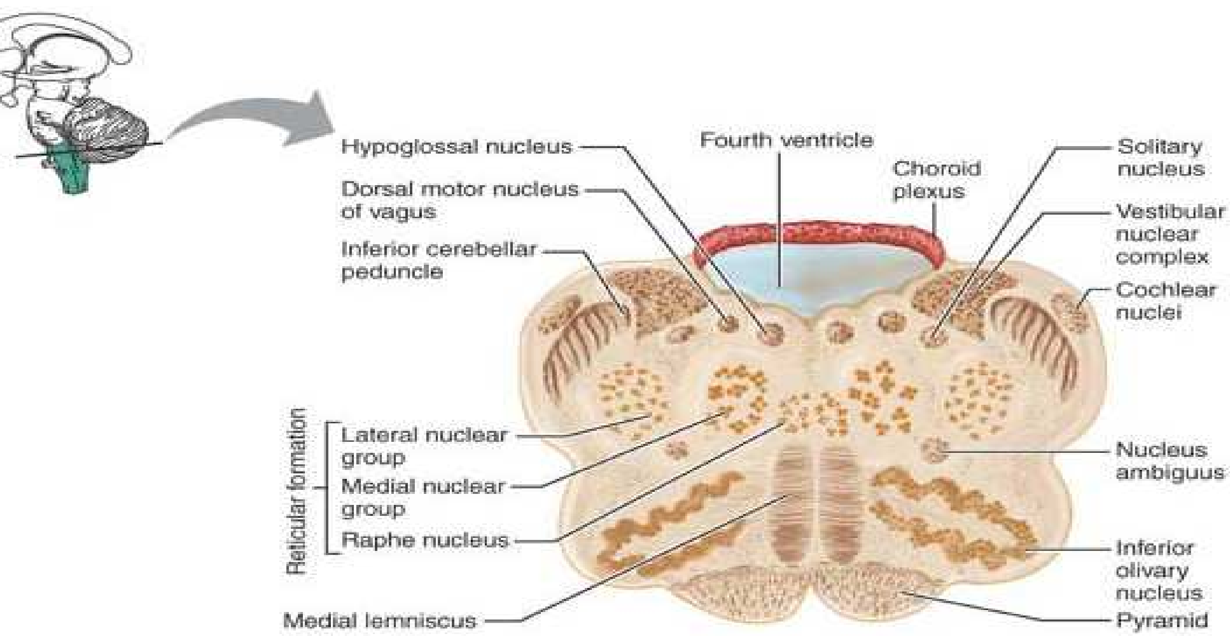
- The oval red nucleus lies deep to the substantia nigra. Its reddish hue is due to its rich blood supply and to the presence of iron pigment in its neurons. The red nuclei are relay nuclei in some descending motor pathways that effect limb flexion, and they are embedded in the reticular formation, a system of small nuclei scattered through the core of the brain stem.



(a) Midbrain



(b) Pons



(c) Medulla oblongata

Pons

- The pons is a rounded bulge on the underside of the brainstem, where it separates the midbrain from the medulla oblongata. The dorsal part of the pons consists largely of longitudinal nerve fibers, which relay impulses to and from the medulla oblongata and the cerebrum. The ventral part of the pons has large bundles of transverse nerve fibers, which transmit impulses from the cerebrum to centers in the cerebellum. Several nuclei of the pons relay sensory impulses from peripheral nerves to higher brain centers. Other nuclei may contribute to the rhythm of breathing

Medulla Oblongata

- The medulla oblongata extends from the pons to the foramen magnum of the skull Its dorsal surface flattens to form the floor of the fourth ventricle, and its ventral surface is marked by the corticospinal tracts, most of whose fibers cross over at this level All of the ascending and descending nerve fibers connecting the brain and spinal cord must pass through the medulla oblongata because of its location. As in the spinal cord, the white matter of the medulla oblongata surrounds a central mass of gray matter.

- Here, however, nerve fibers separate the gray matter into nuclei, some of which relay ascending impulses to the other side of the brainstem and then on to higher brain centers. Other nuclei in the medulla oblongata control vital visceral activities. These centers include:

- Cardiac center Impulses originating in the cardiac center are transmitted to the heart on peripheral nerves, altering heart rate.
- Vasomotor center Certain cells of the vasomotor center initiate impulses that travel to smooth muscles in the walls of certain blood vessels and stimulate them to contract. This constricts the blood vessels (vasoconstriction), maintaining blood pressure. Other cells of the vasomotor center produce the opposite effect—dilating blood vessels (vasodilation) and consequently dropping blood pressure.

- Respiratory center The respiratory center act to maintain the rhythm of breathing and adjusts the rate and depth of breathing. Still other nuclei in the medulla oblongata are centers for the reflexes associated with coughing, sneezing, swallowing, and vomiting.

Somatic sensations

- *Somatic* portion of the sensory system, transmits sensory information from the receptors of the entire body surface and from some deep structures. This information enters the central nervous system through peripheral nerves and is conducted immediately to multiple sensory areas in
- (1) the spinal cord at all levels;
- (2) the reticular substance of the medulla, pons, and mesencephalon of the brain;
- (3) the cerebellum;
- (4) the thalamus;
- (5) areas of the cerebral cortex.