Central Nervous System

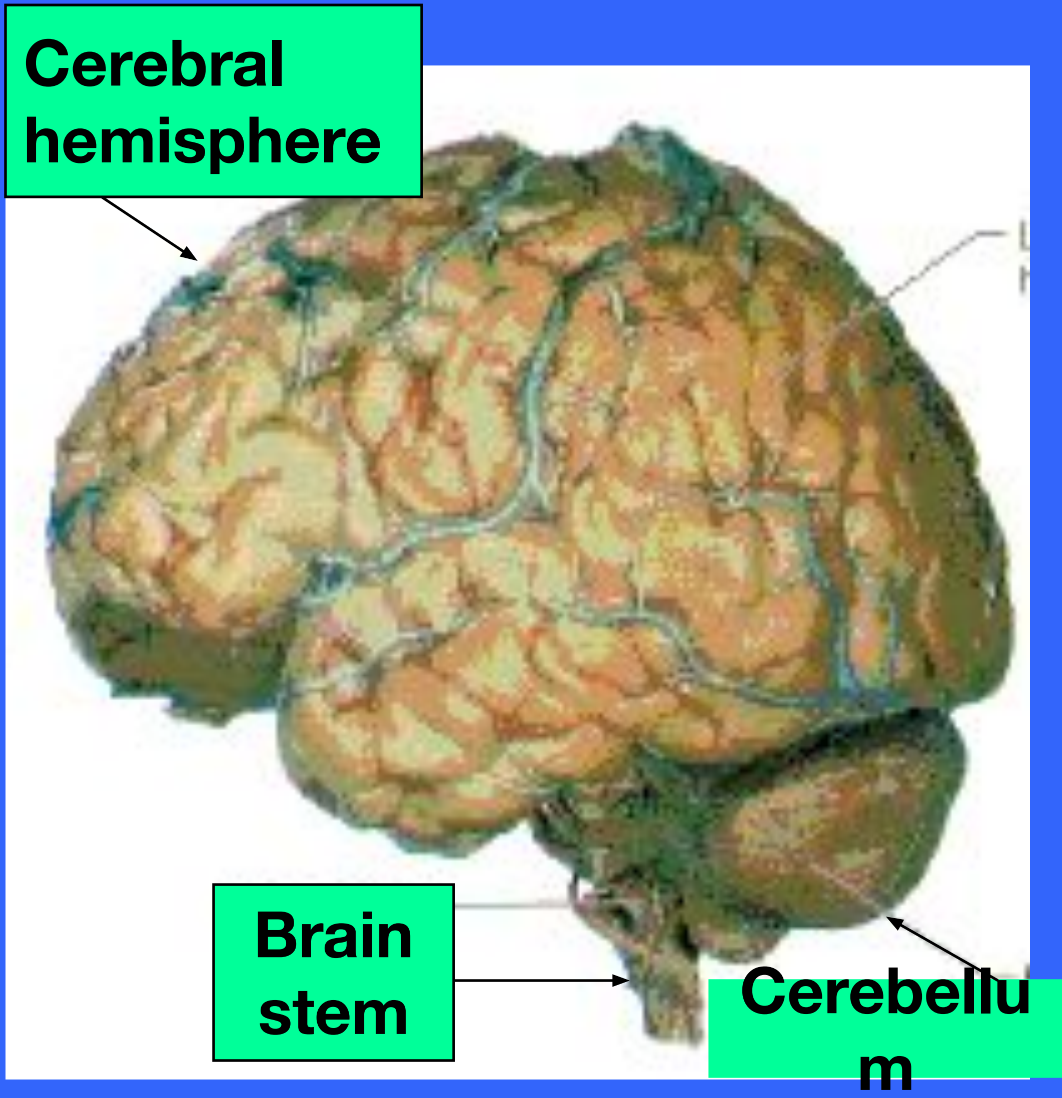
Chapter 13

Introduction

- Analogies; telephone switchboard; computer; miracle
- A fantastically complex and flexible biological organ
- Cephalization become more apparent in higher order species
- Increase in the neurons at the rostral end of the CNS
- Highest level of cephalization is found in humans

The Brain

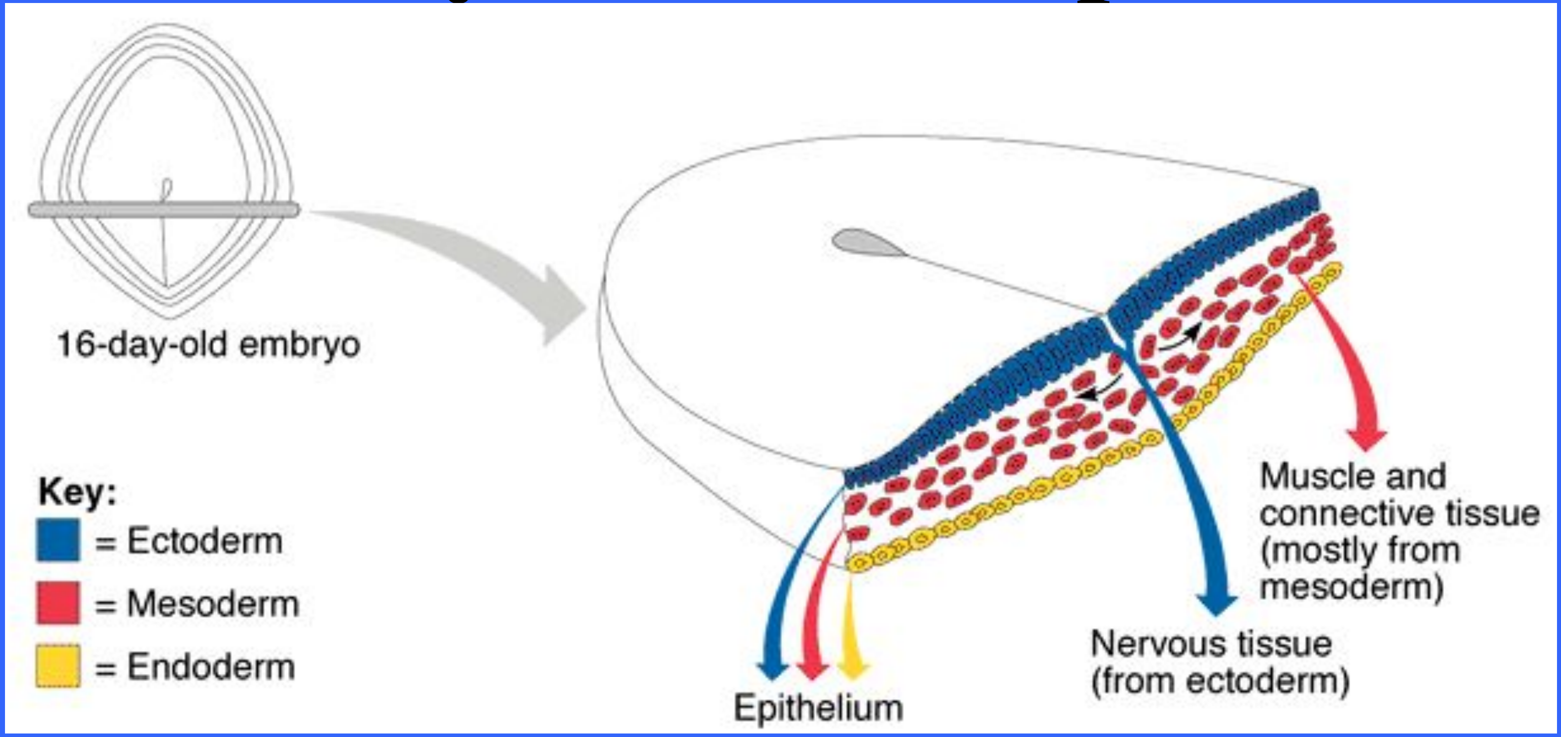
- The unimpressive appearance of the human brain give few hints of its abilities
- It is about two handfuls of delicate pinkish gray tissue
- Wrinkled surface
- Consistency of cold oatmeal



The Brain

- Average adult male's brain weighs about 1600 g (3.5 pounds)
- Average adult female's brain weighs about 1450 g
- Brain size represents a proportional difference in body size
- Brain size is not correlated to intelligence but is related to the complexity of the neural connections within the brain

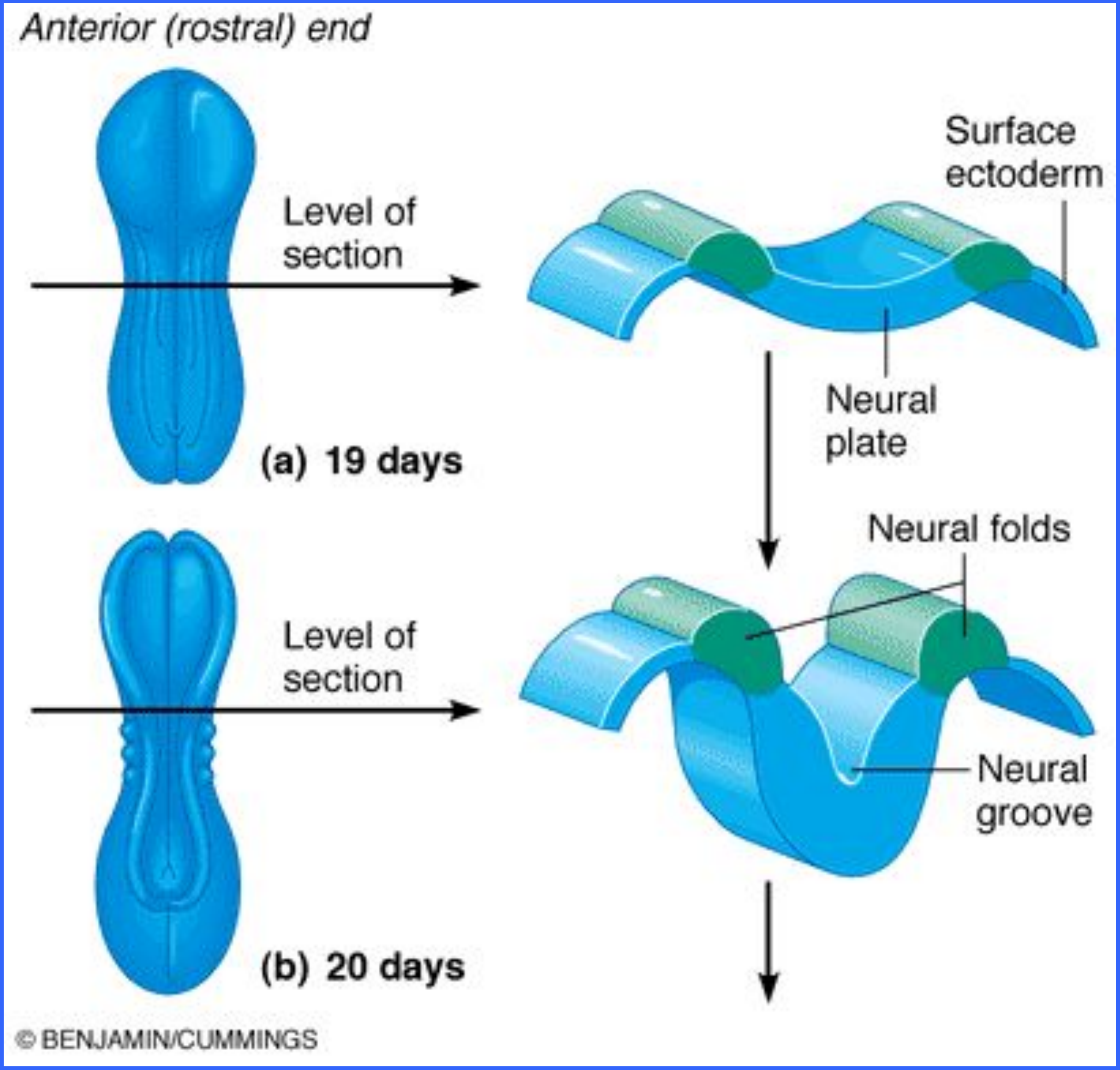
Embryonic Development



- **Starting in the third week of pregnancy, the ectoderm thickens along the dorsal midline axis of the embryo to form a neural plate**
- **The neural plate eventually gives rise to all neural tissues**

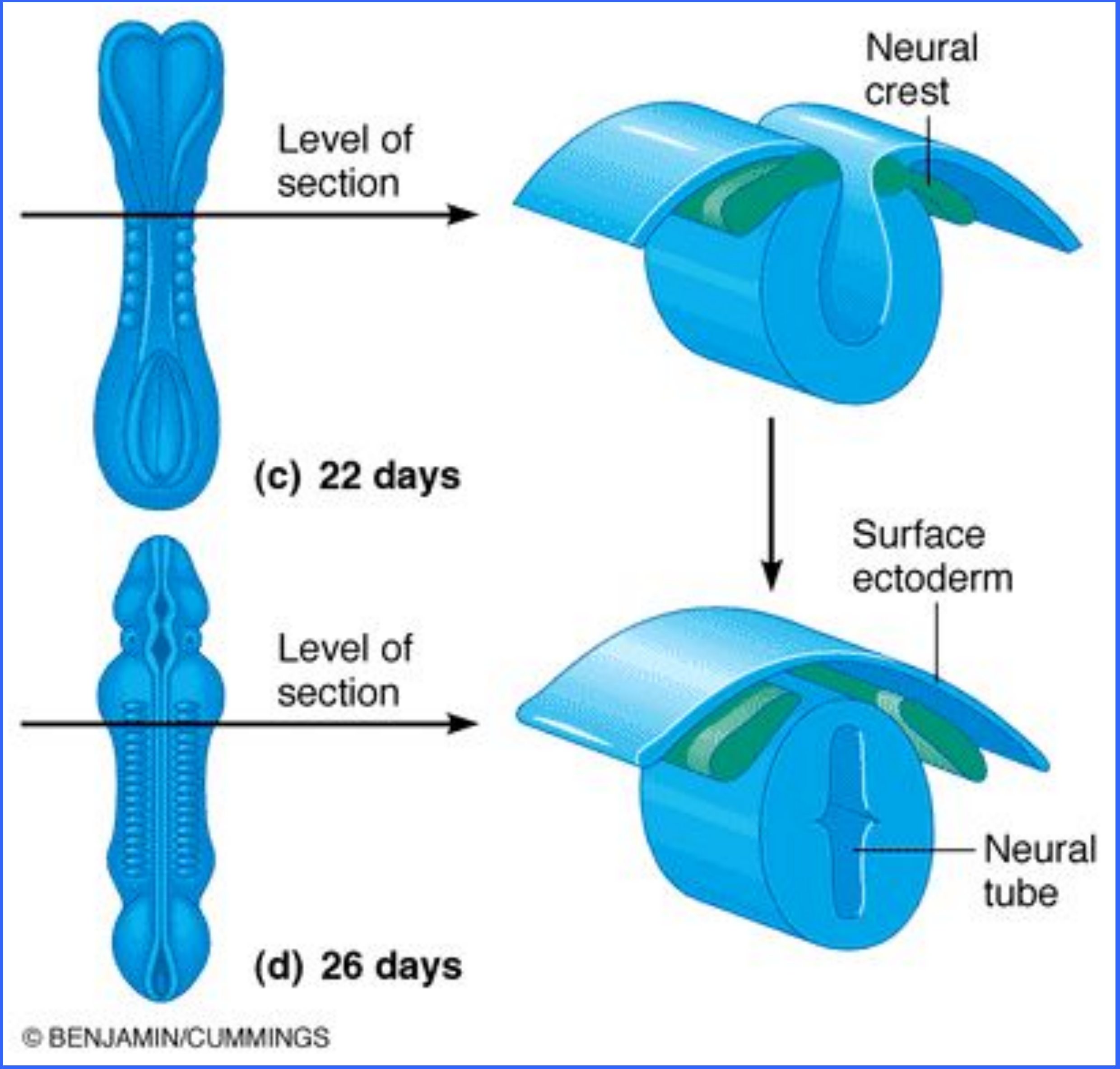
Embryonic Development

- The neural plate then invaginates, forming a groove flanked by neural folds



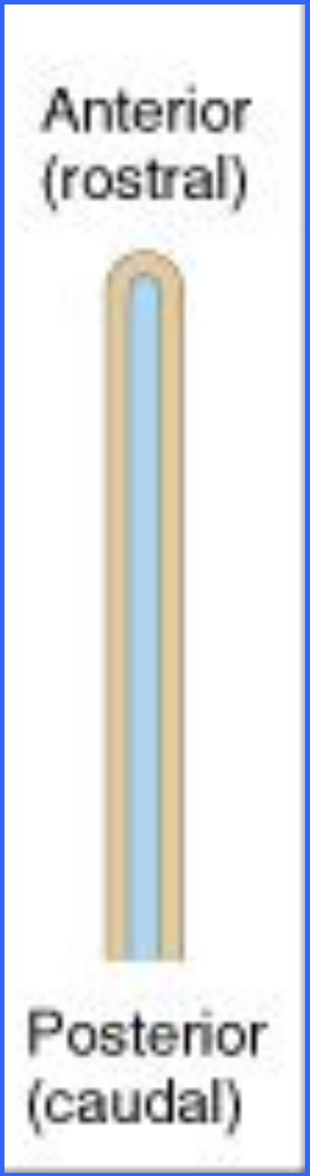
Development of Neural Tube

- As the groove deepens the superior edges of the neural folds fuse, forming the neural tube
- The tube then detaches from the surface ectoderm and assumes a deeper position in the embryo



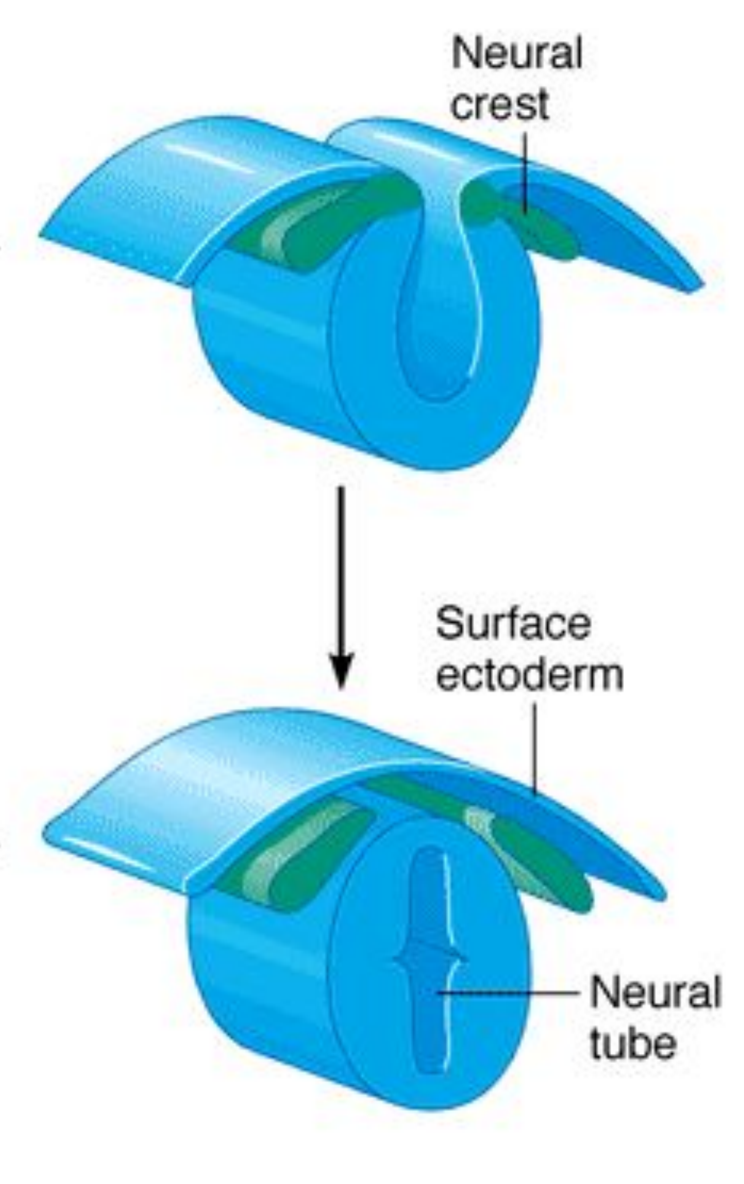
Development of Neural Tube

- The neural tube is formed by the fourth week of pregnancy and differentiates rapidly into the CNS
- The brain forms anteriorly and the spinal cord posteriorly



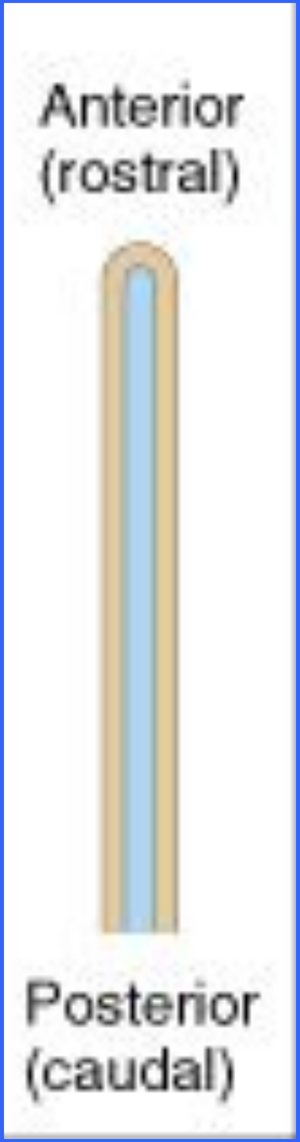
Development of Neural Tube

- **Small groups of neural fold cells migrate laterally and locate between the surface ectoderm and the neural tube to forming the neural crest**
- **The neural crest gives rise to sensory neurons and some autonomic neurons destined to reside in ganglia**



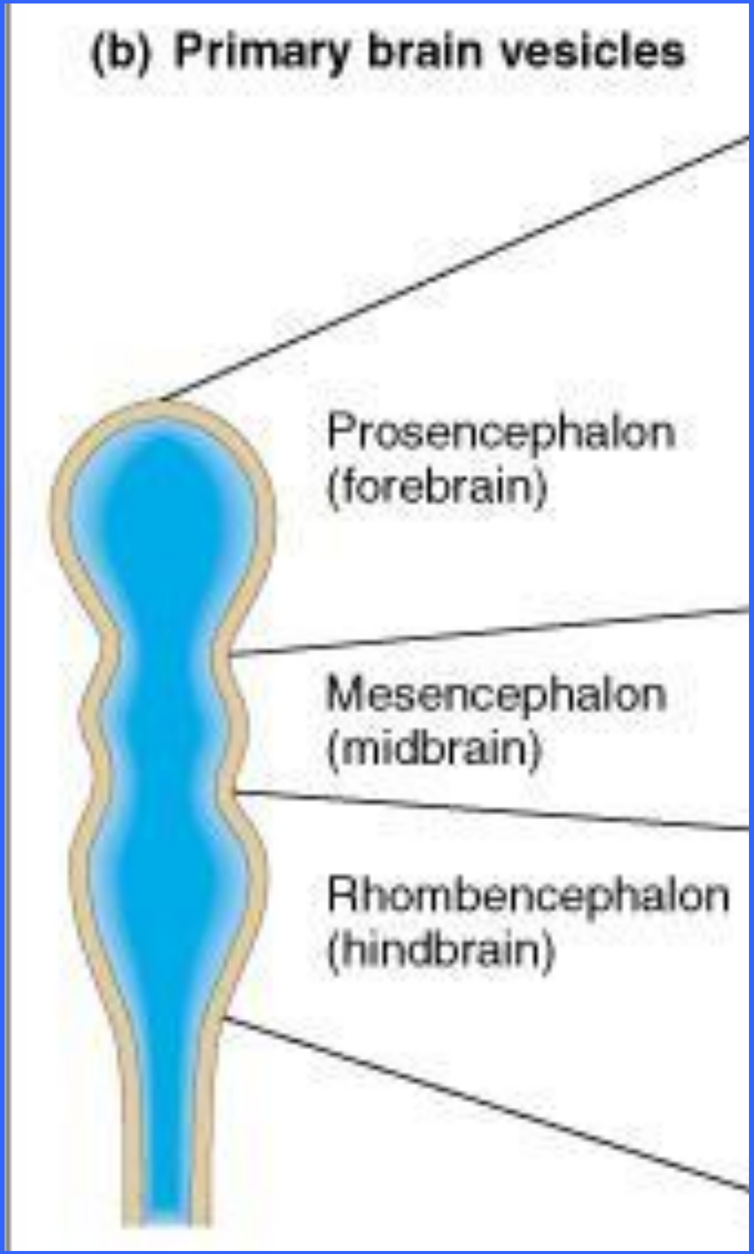
Development of Neural Tube

- As soon as the neural tube is formed, its anterior end begins to expand more rapidly than the remaining portion



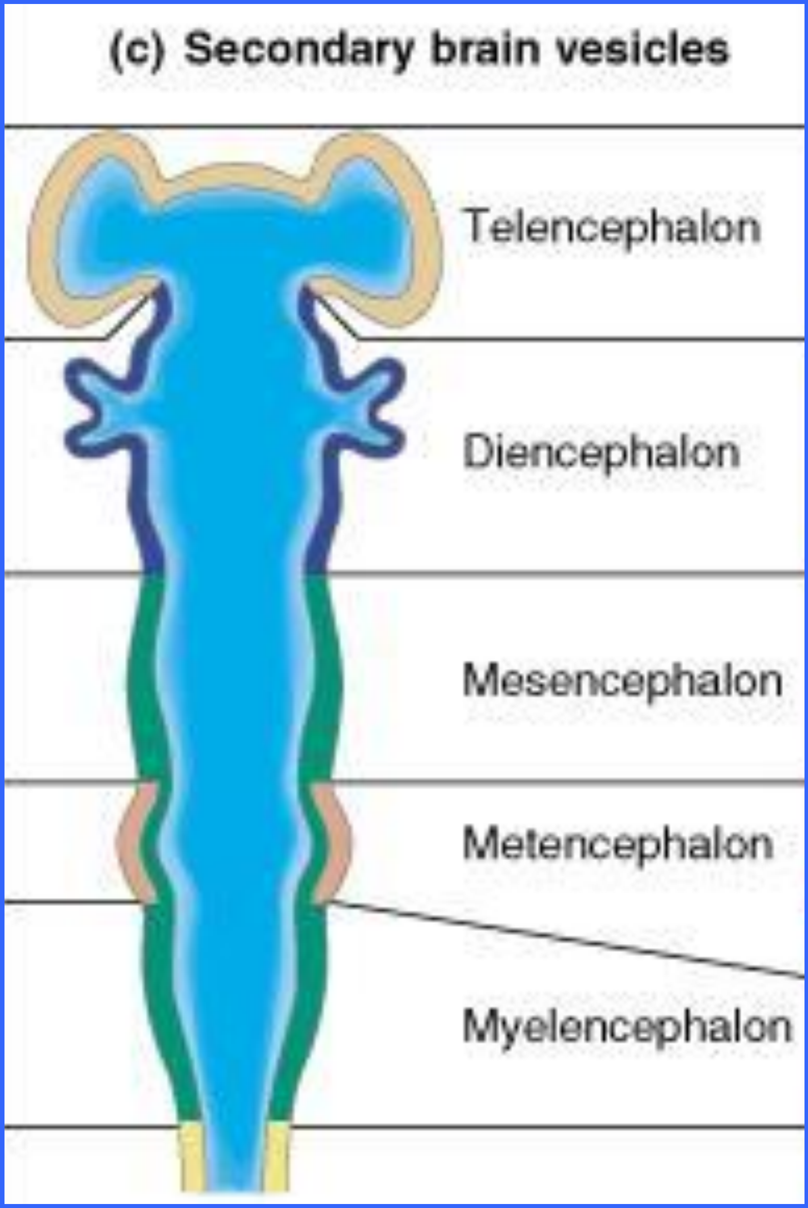
Primary Brain Vesicles

- Constrictions in the neural tube appear to mark off the three primary brain vesicles
  - Prosencephalon
    - (forebrain)
  - Mesencephalon
    - (midbrain)
  - Rhombencephalon
    - (hindbrain)
- The remainder of the neural tube becomes the spinal cord



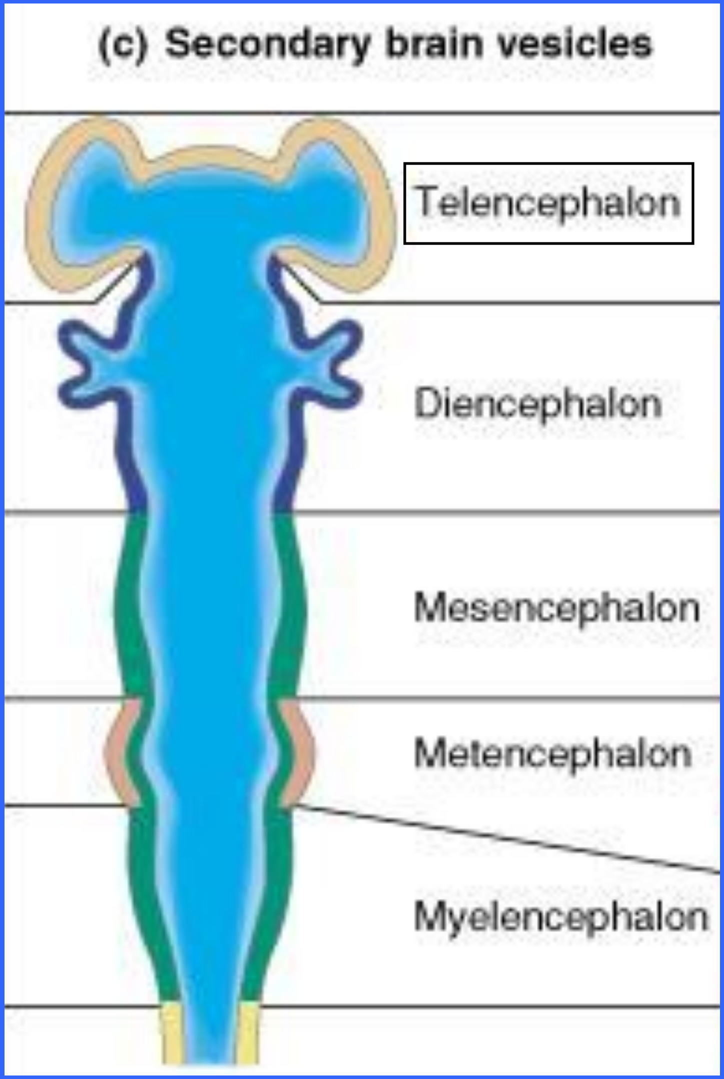
Secondary Brain Vesicles

- By the fifth week, the five brain regions of the secondary brain vesicles are evident
- The forebrain has divided
  - Telencephalon
  - Diencephalon
- The midbrain remains undivided
- The hindbrain has constricted to form
  - Metencephalon
  - Myelencephalon



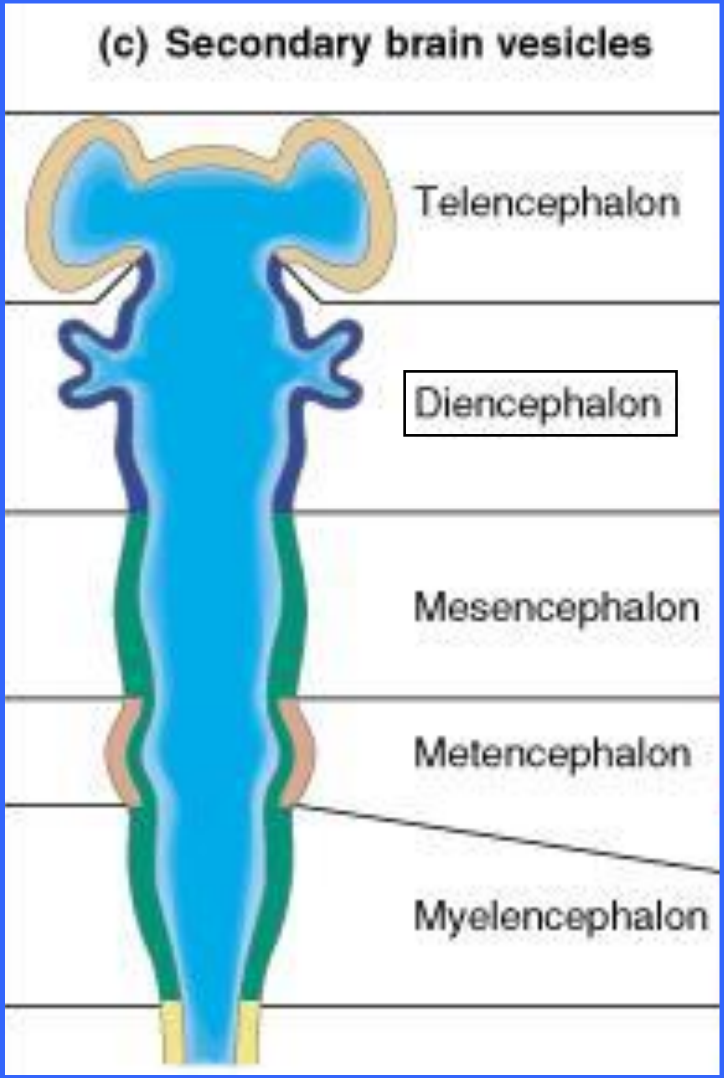
Secondary Brain Vesicles

- Each of the five secondary brain vesicles develops rapidly to produce the major structures of the adult brain
- The greatest change occurs in the telencephalon which sprouts two large swellings which project anteriorly
- These paired expansions become the cerebral hemispheres known collectively as the cerebrum
- Hemispheres house ventricles



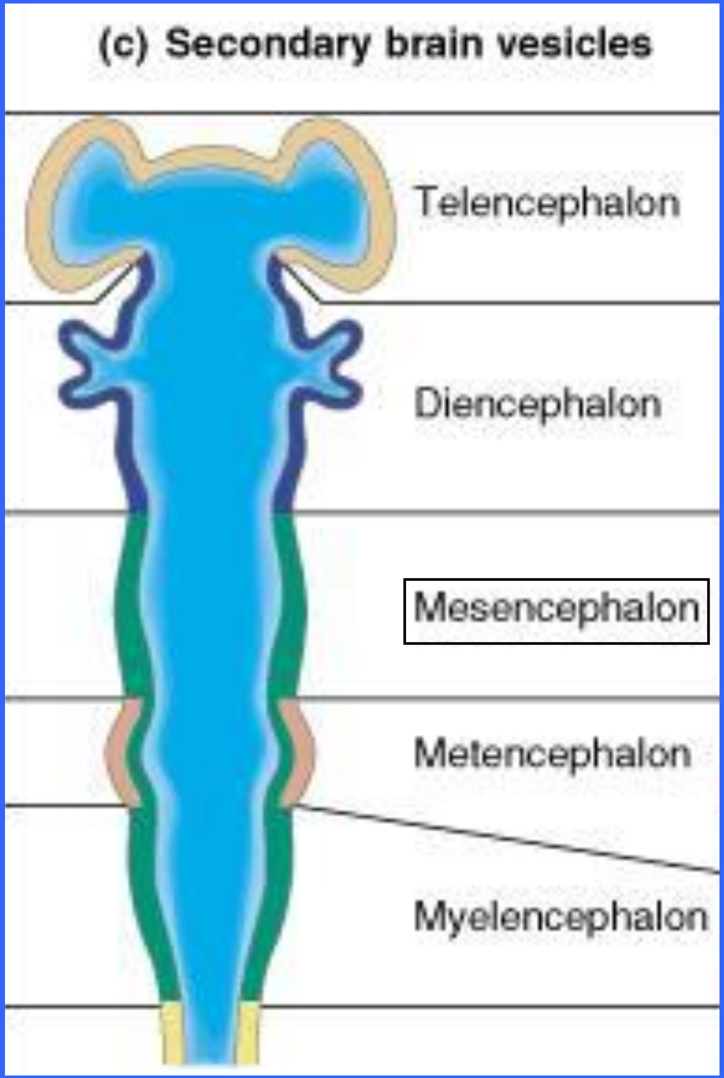
Secondary Brain Vesicles

- Various areas of the diencephalon specialize to form
  - Hypothalamus
  - Thalamus
  - Epithalamus



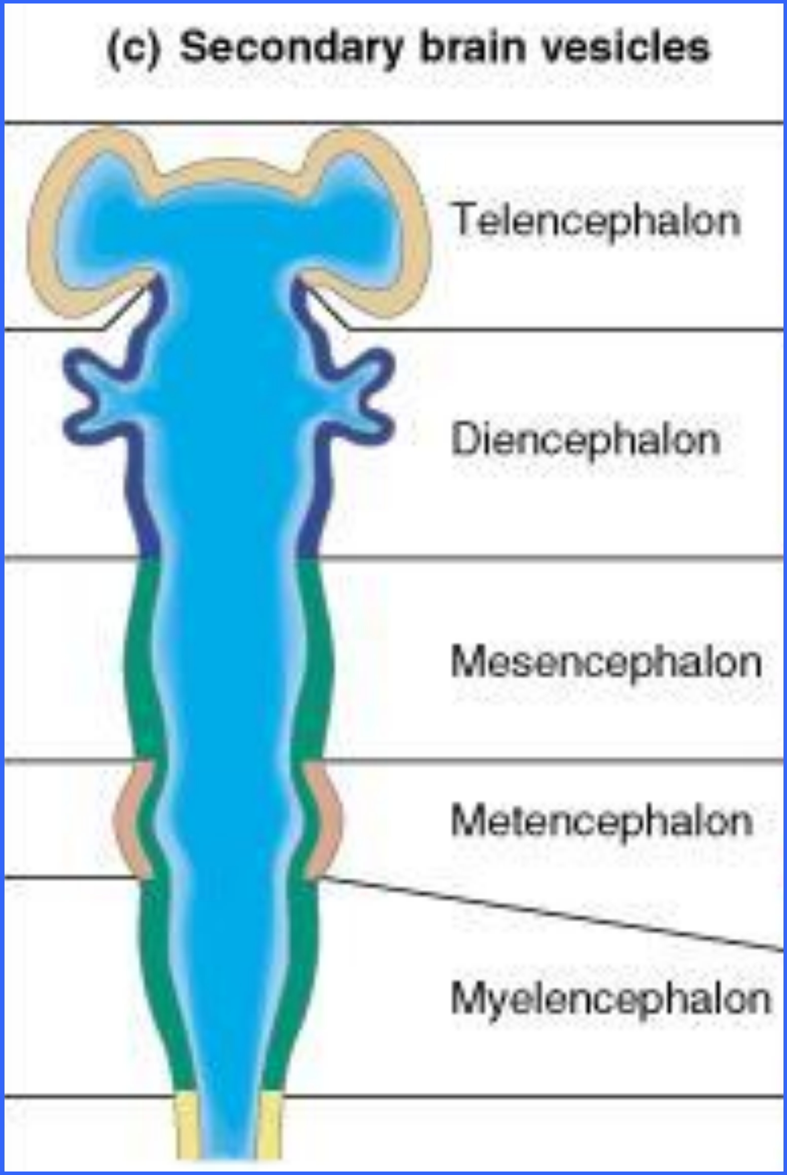
Secondary Brain Vesicles

- The mesencephalon develops into
  - Midbrain
  - Brain stem



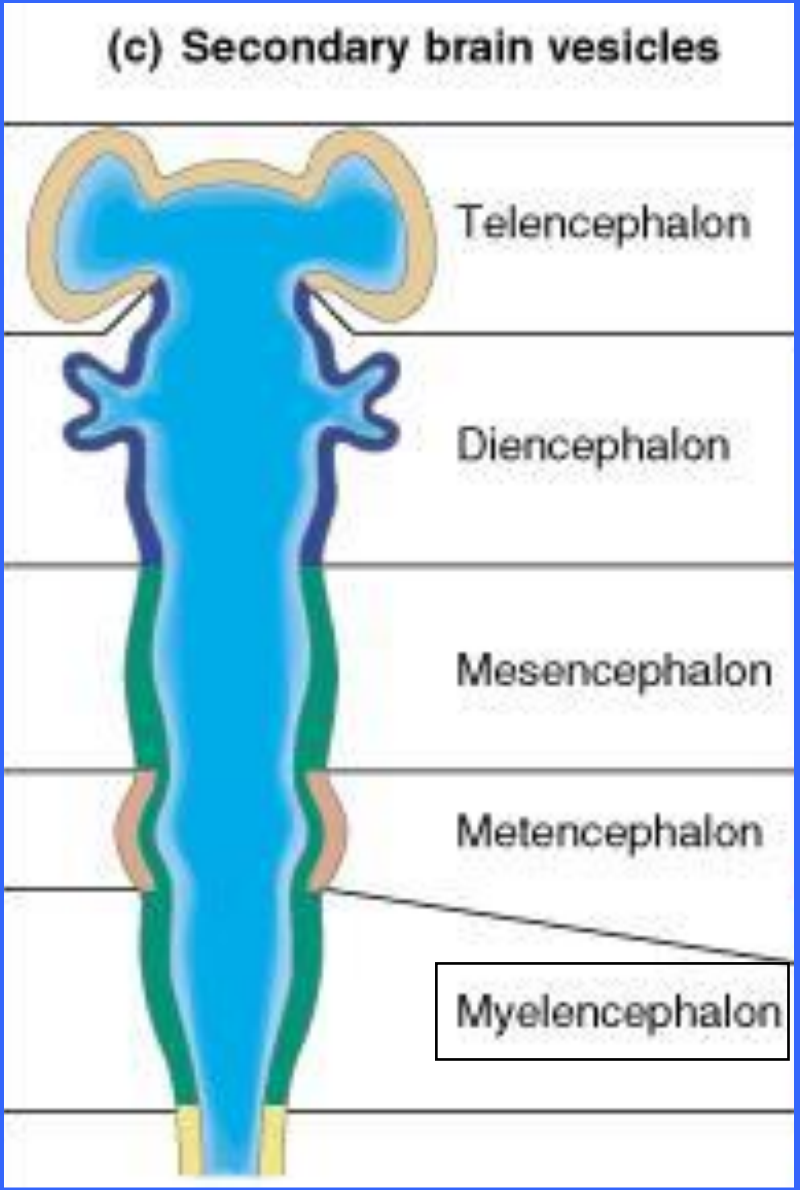
Secondary Brain Vesicles

- Various areas of the Metencephalon specialize to form
  - Brain stem
  - Pons
  - Cerebellum



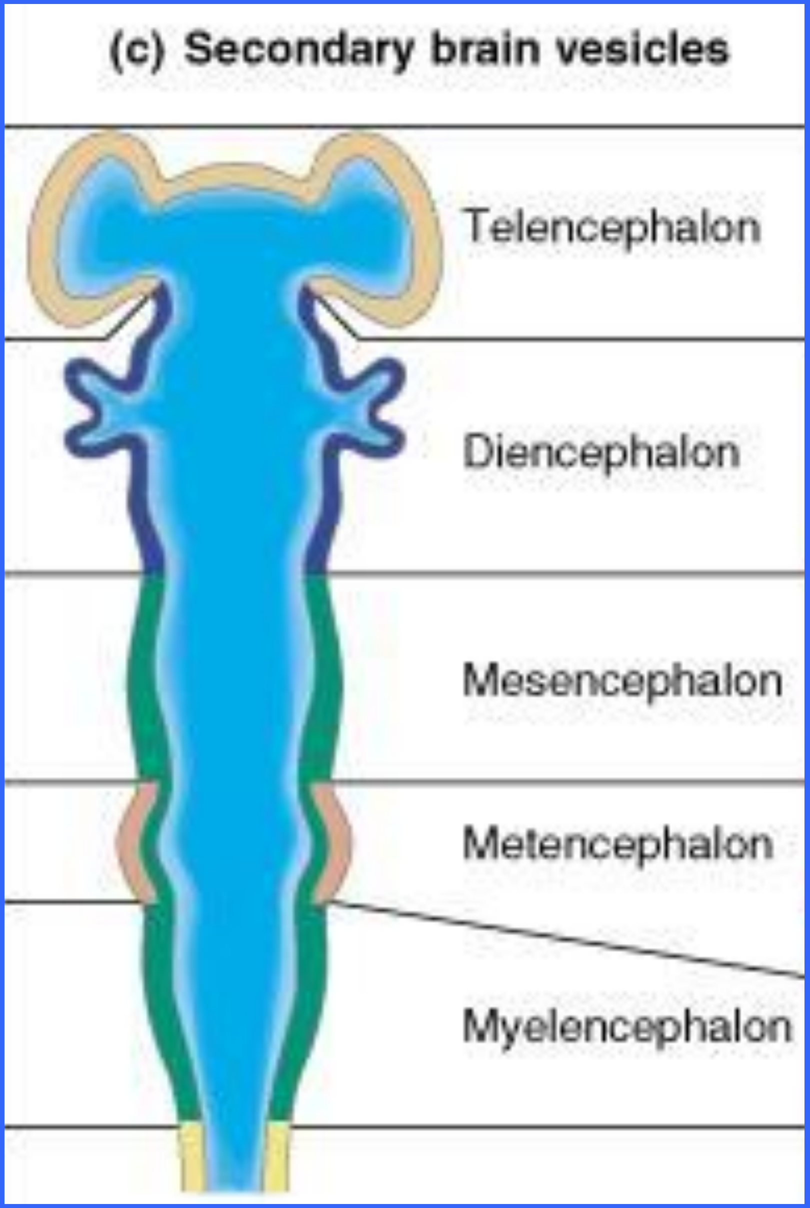
Secondary Brain Vesicles

- Various areas of the Myelencephalon specialize to form
  - Brain stem
  - Medulla oblongata
- All the midbrain and hindbrain structures, with the exception of the cerebellum, form portions of the brain stem

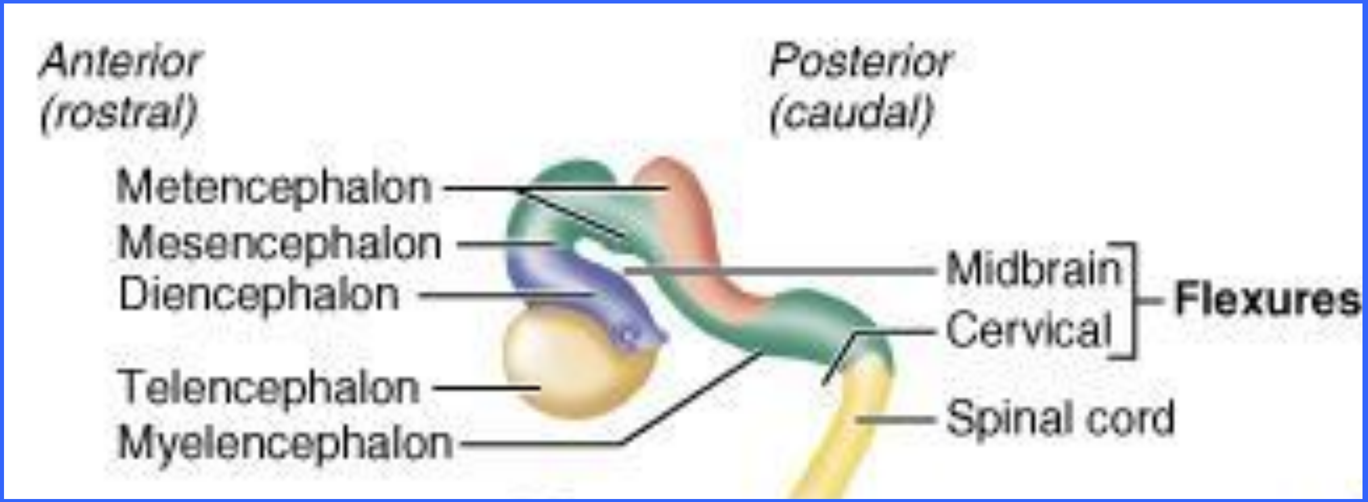


Adult Neural Canal Regions

- The central canal of the neural tube enlarge in four areas to form the fluid filled ventricles
  - Telencephalon
    - Lateral ventricles
    - Superior portion of 3rd
  - Diencephalon
    - Most of third ventricle
  - Mesencephalon
    - Cerebral aqueduct
  - Metencephalon
    - Fourth ventricle
  - Myelencephalon
    - Fourth ventricle



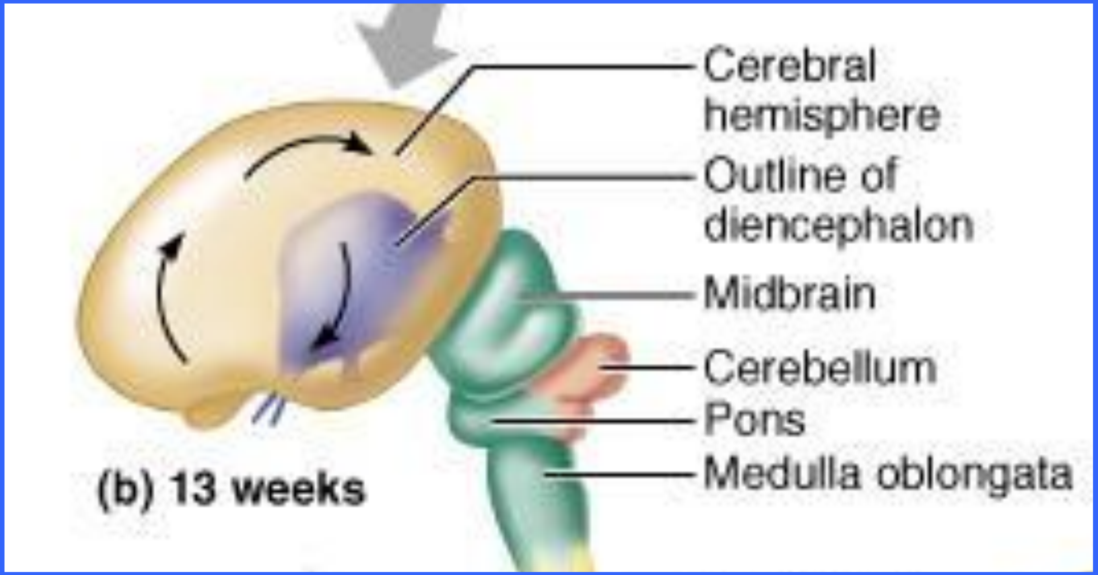
Development of Flexures



- **During this period of rapid brain growth change is also occurring in the relative position of its parts**
- **Because the brain's growth is restricted by the skull, midbrain and cervical flexures develop by the fifth week which bend the forebrain toward the brain stem**

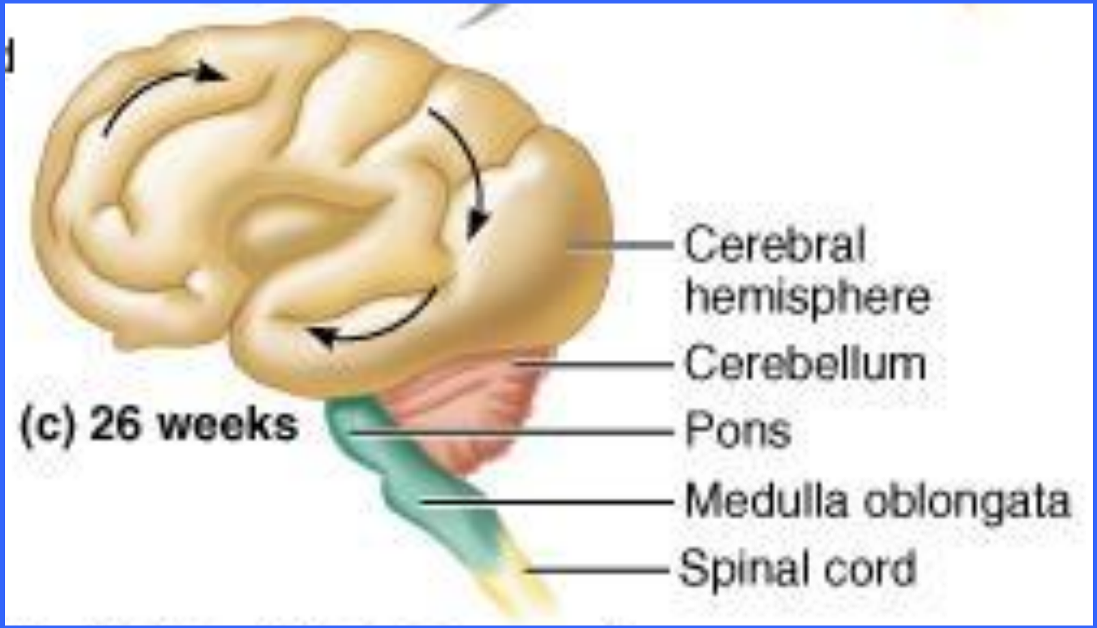
Effects of Space Restriction

- A second consequence of restricted space is that the cerebral hemispheres are forced to take a horseshoe shaped course posteriorly and laterally
- Development of the cerebral hemispheres at 13 weeks



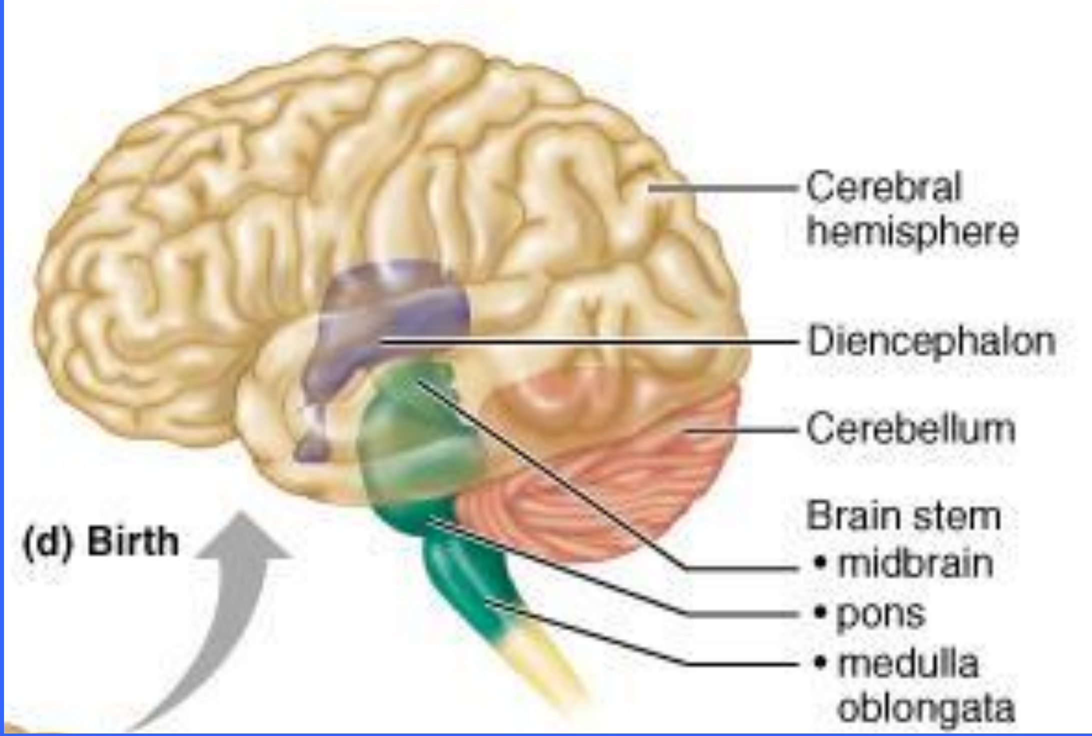
Effects of Space Restriction

- As a result the hemispheres grow back over and almost completely envelop the diencephalon and midbrain
- The cerebral hemispheres at 26 weeks



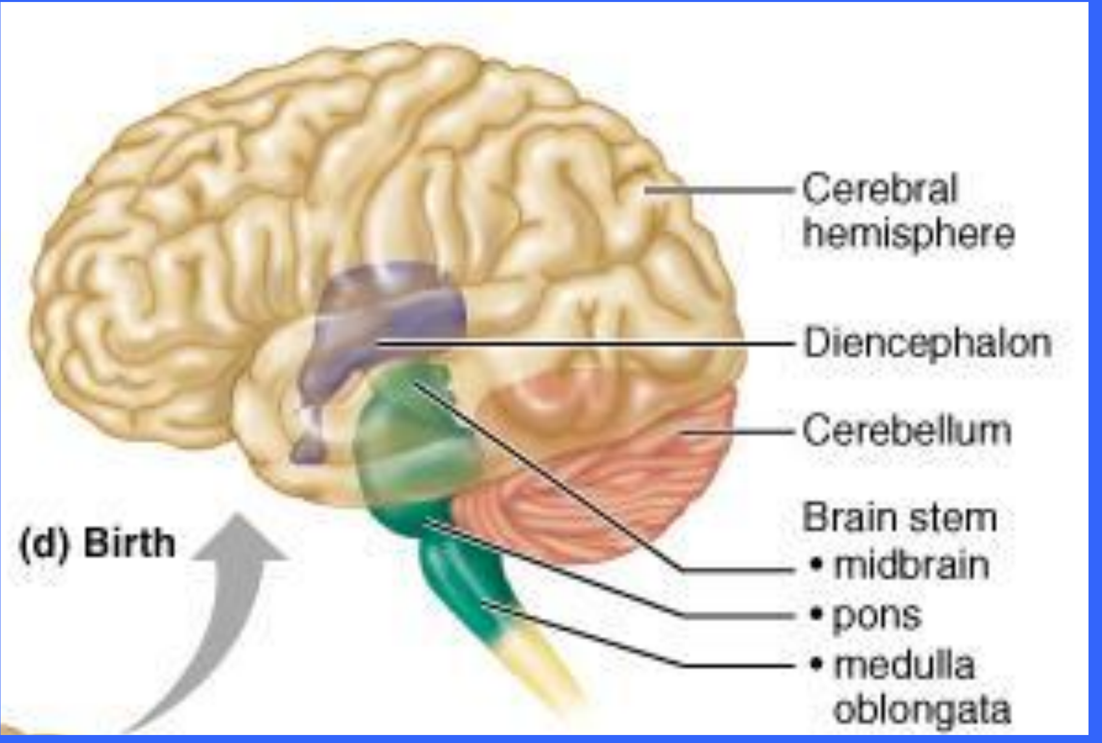
Effects of Space Restriction

- Continued growth of the cerebral hemispheres causes their surfaces to crease and fold
- Folding results in convolutions which increase surface area and allow some 10^{12} neurons to occupy the limited space within the skull



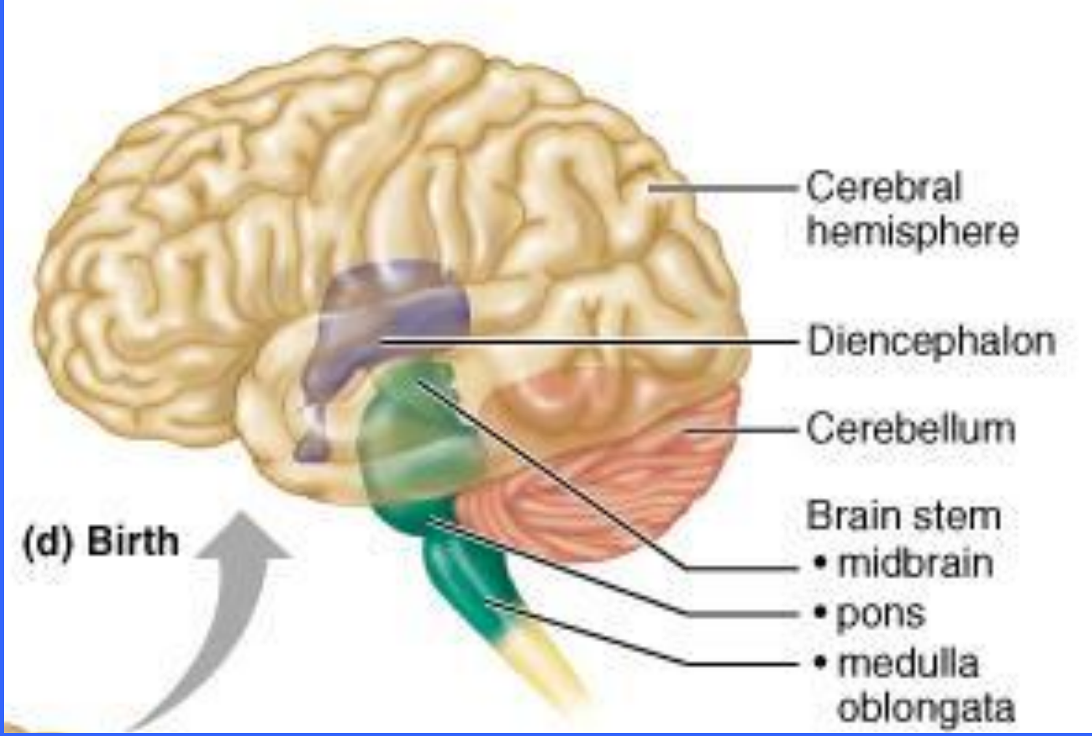
Effects of Space Restriction

- The wrinkling of the hemispheres may result from tension on the young axons as they become arranged in a way that minimizes the length of the interconnections they form among the various parts of the cerebrum



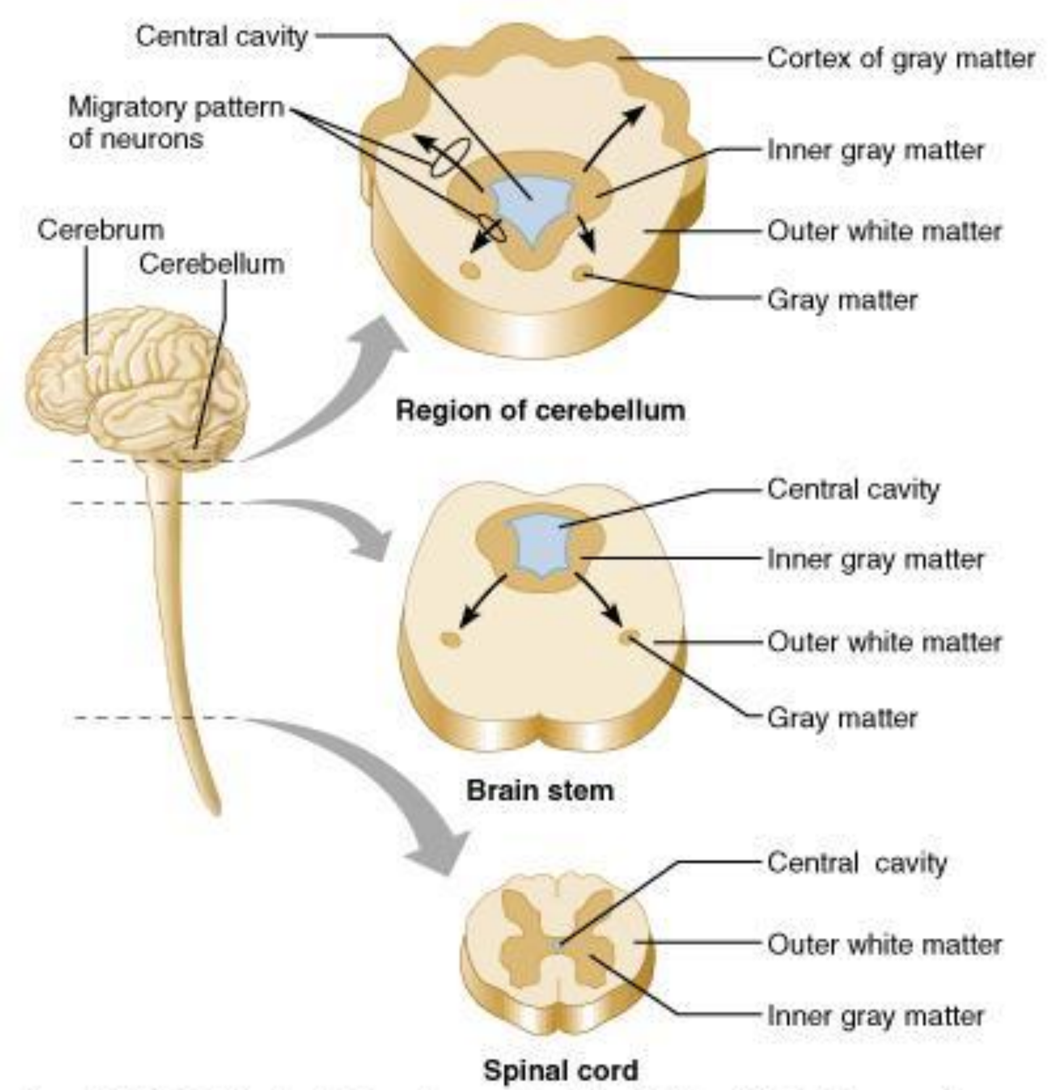
Regions of the Brain

- **The four main regions of the brain are:**
  - Cerebral hemi-spheres
  - Diencephalon
    - Thalamus
    - Hypothalamus
    - Epithalamus
  - Brain stem
    - Midbrain
    - Pons
    - Medulla
  - Cerebellum



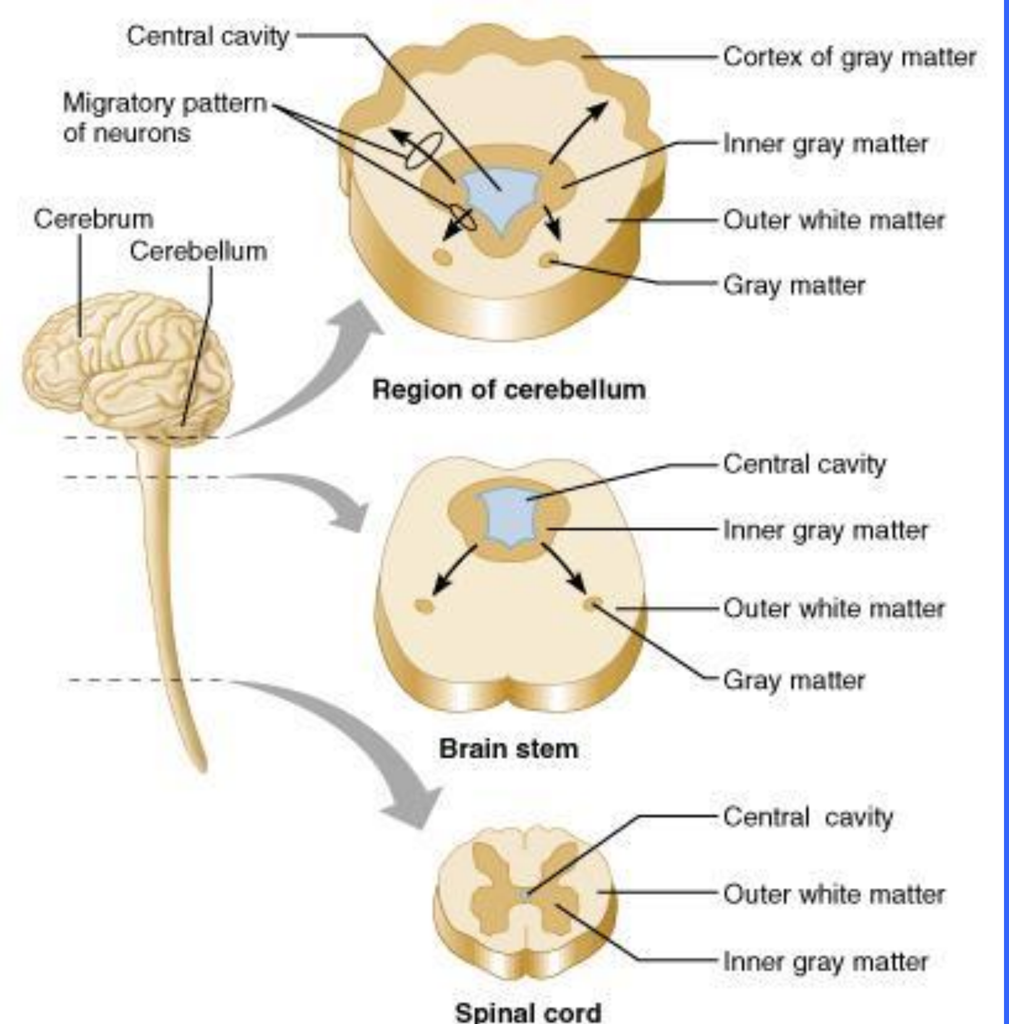
Gray and White Matter in CNS

- The basic pattern of the CNS can be seen in the spinal cord
- A central cavity surrounded by a gray matter core of brain nuclei, external to which is white matter (myelinated fiber tracts)
- Figure 12.29 presents major ascending and descending fiber tracts



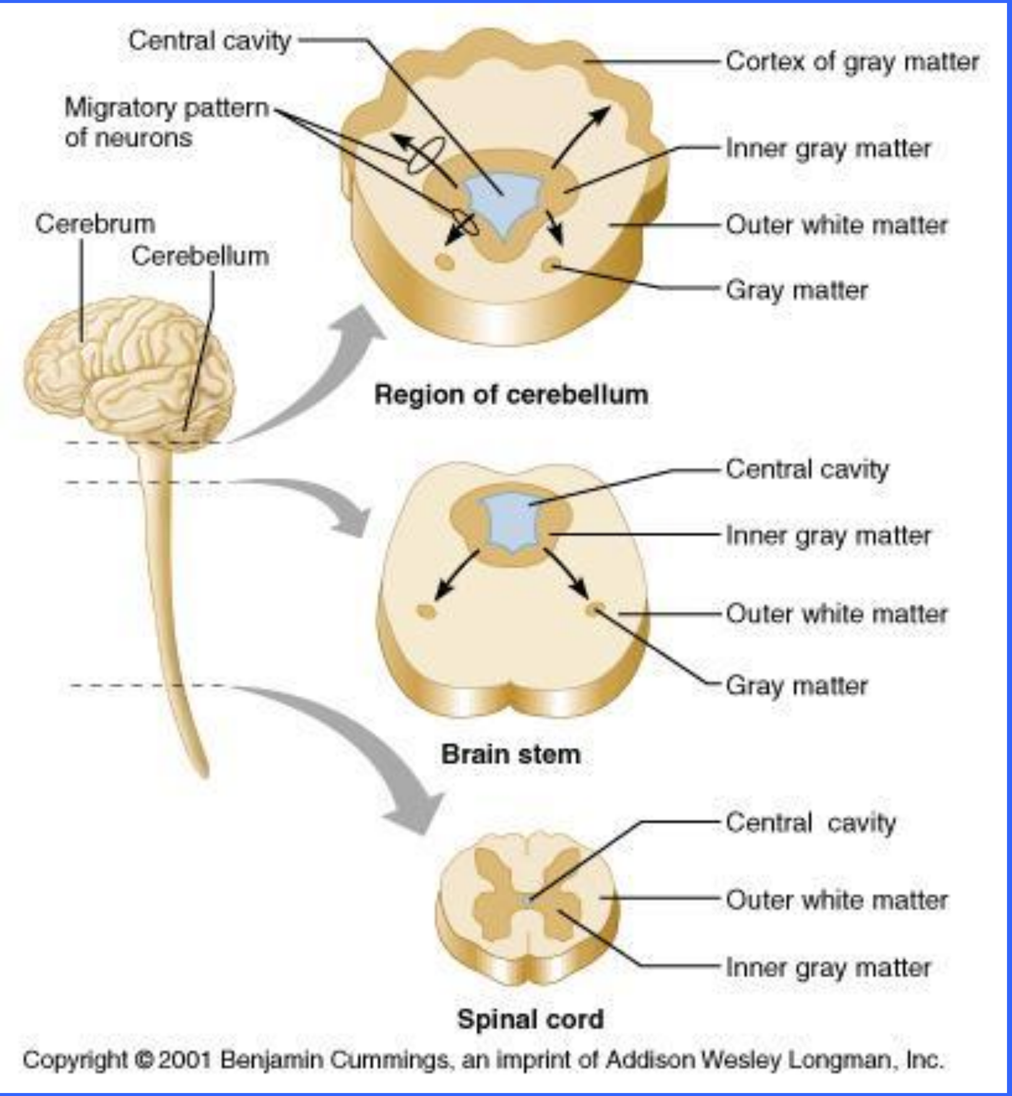
Gray and White Matter in CNS

- The brain has the same basic design except that it also contains additional regions of gray matter that are not evident in the spinal cord
- Both the cerebral hemispheres and the cerebellum have an outer layer or cortex of gray matter consisting of neuron cell bodies



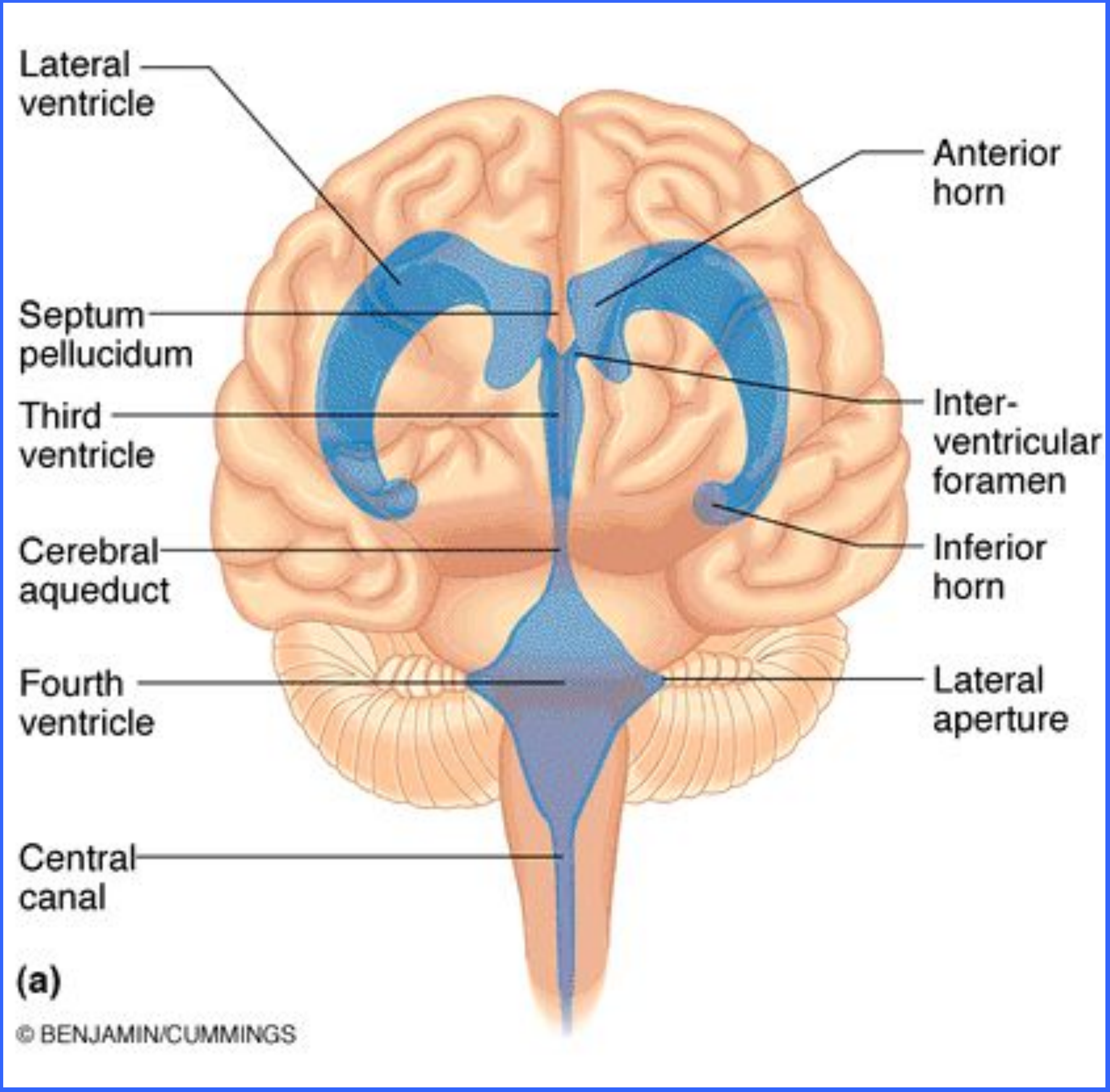
Gray and White Matter in CNS

- The pattern of white and gray matter changes with descent through the brain stem
- The cortex disappears, but scattered gray matter nuclei are seen within the white matter
- At the caudal end of the brain stem the basic pattern is evident



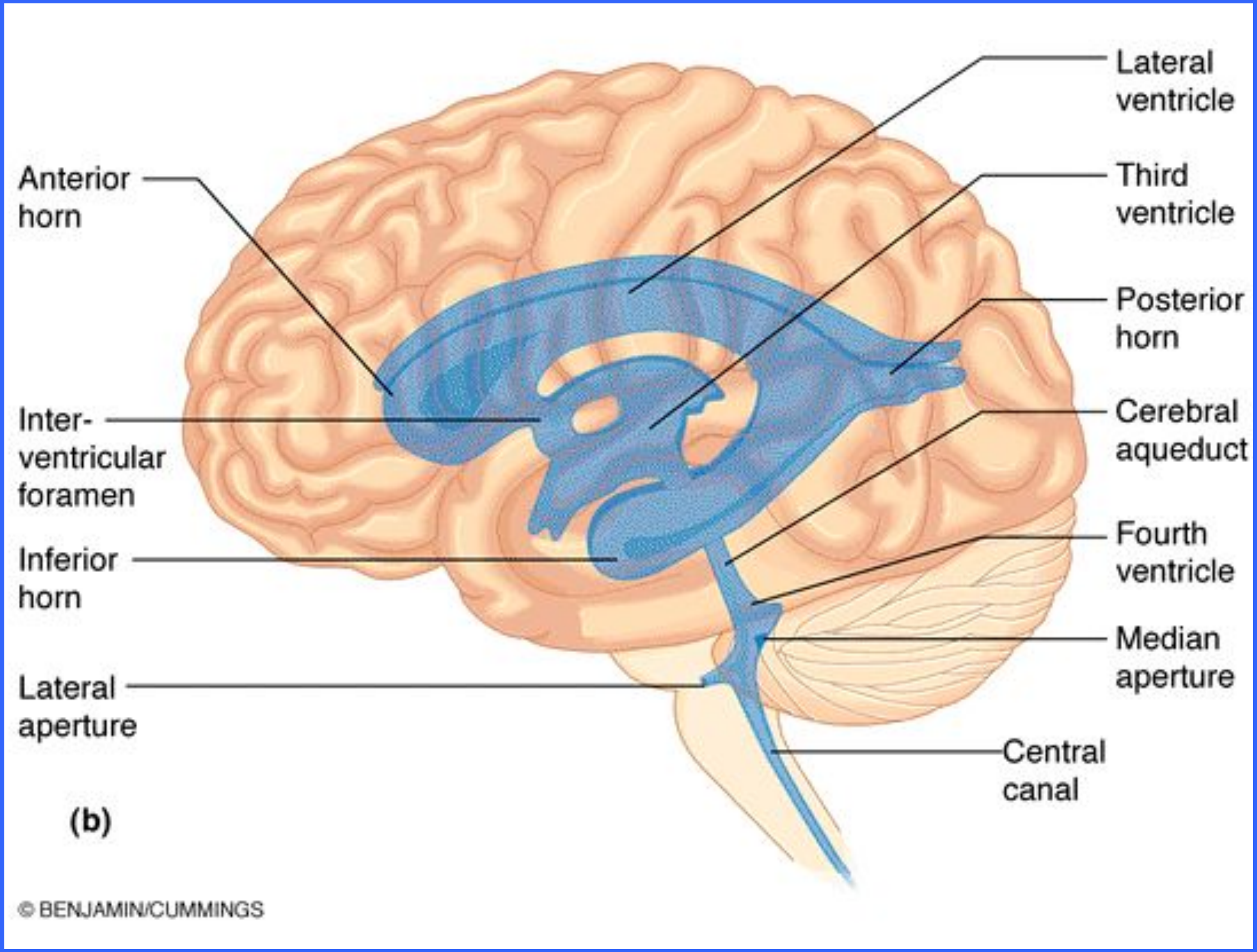
Ventricles of the Brain

- The ventricles of the brain arise from the expansion of the neural tube
- They are continuous with each other and with the central canal of the spinal cord



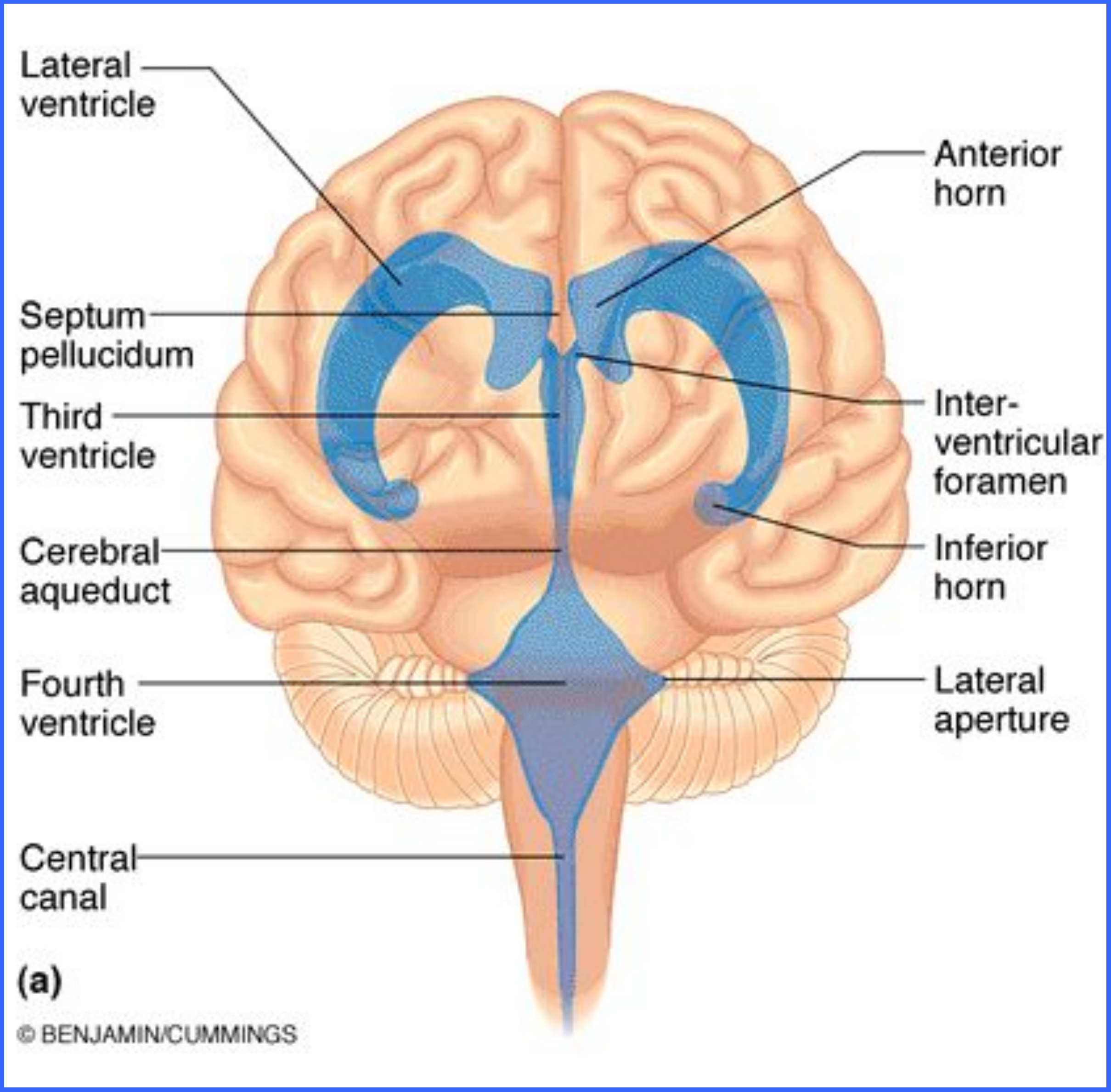
Ventricles of the Brain

- The hollow ventricular chambers are filled with cerebrospinal fluid and lined by ependymal cells



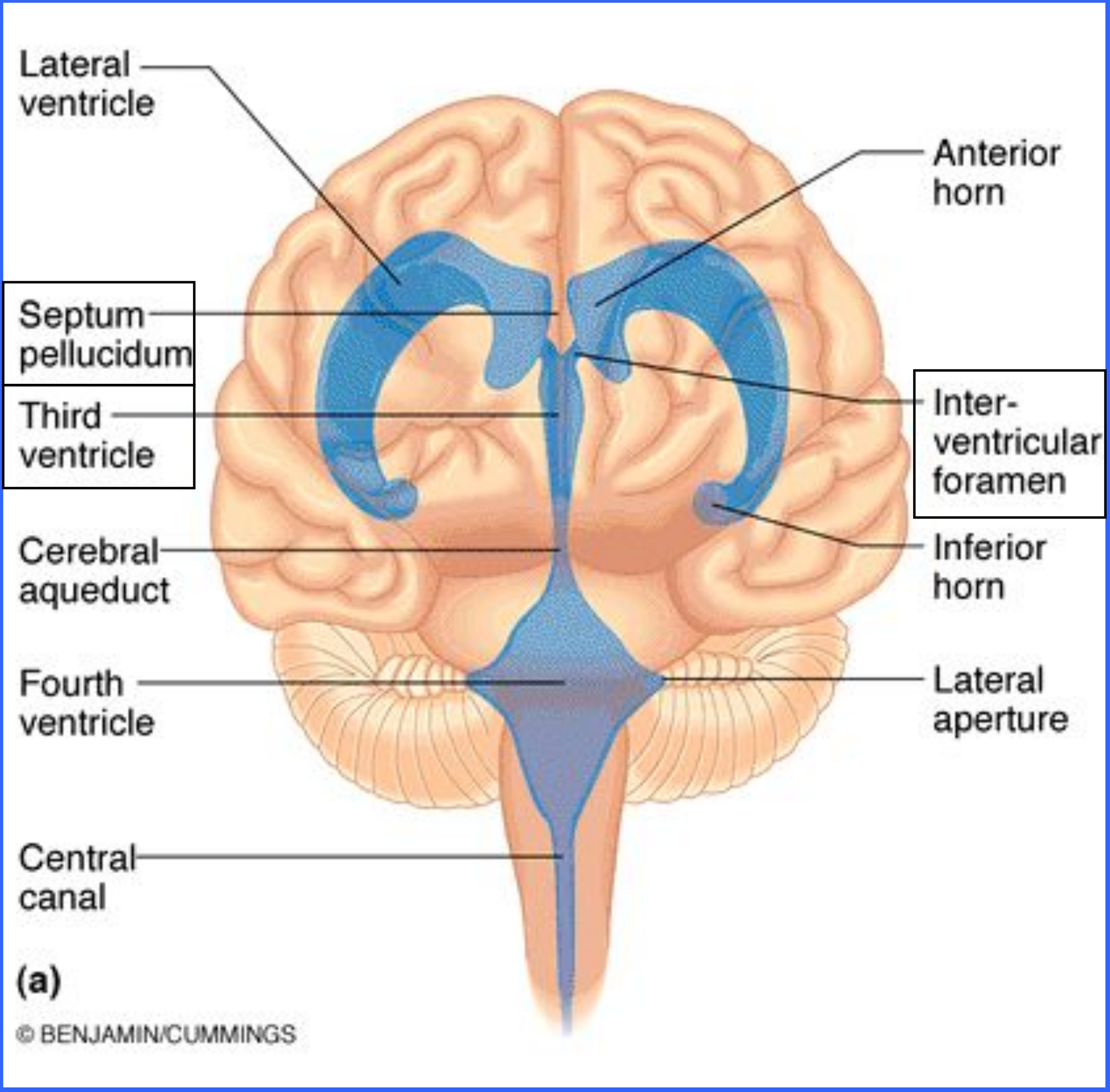
Ventricles of the Brain

- The paired lateral ventricles are large C-shaped chambers that reflect the pattern of cerebral growth
- One lateral ventricle is located in each cerebral hemisphere



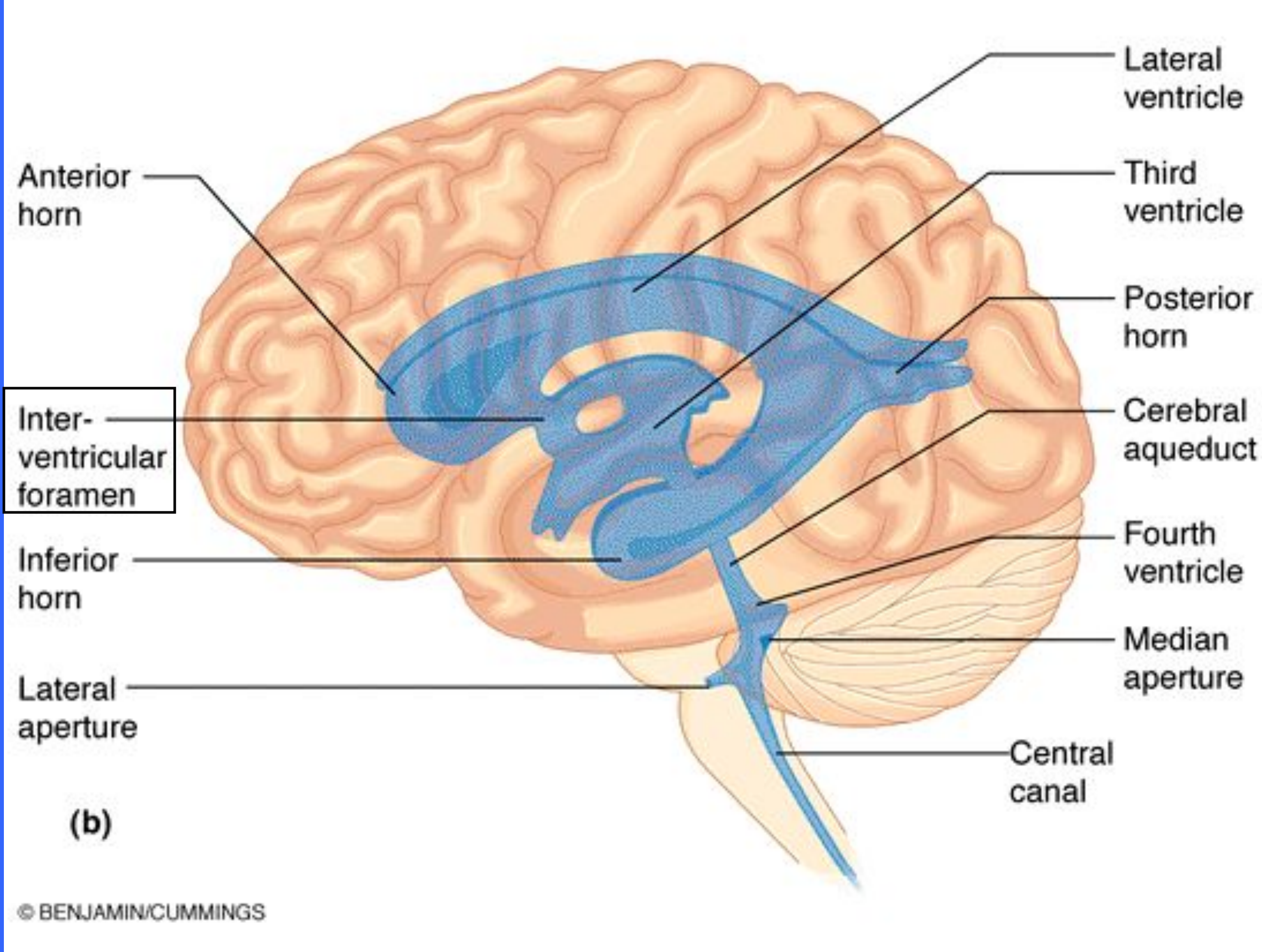
Ventricles of the Brain

- Anteriorly, the lateral ventricles lie close together separated only by a thin median membrane called the septum pellucidum
- Each ventricle communicates with the narrow third ventricle in the diencephalon



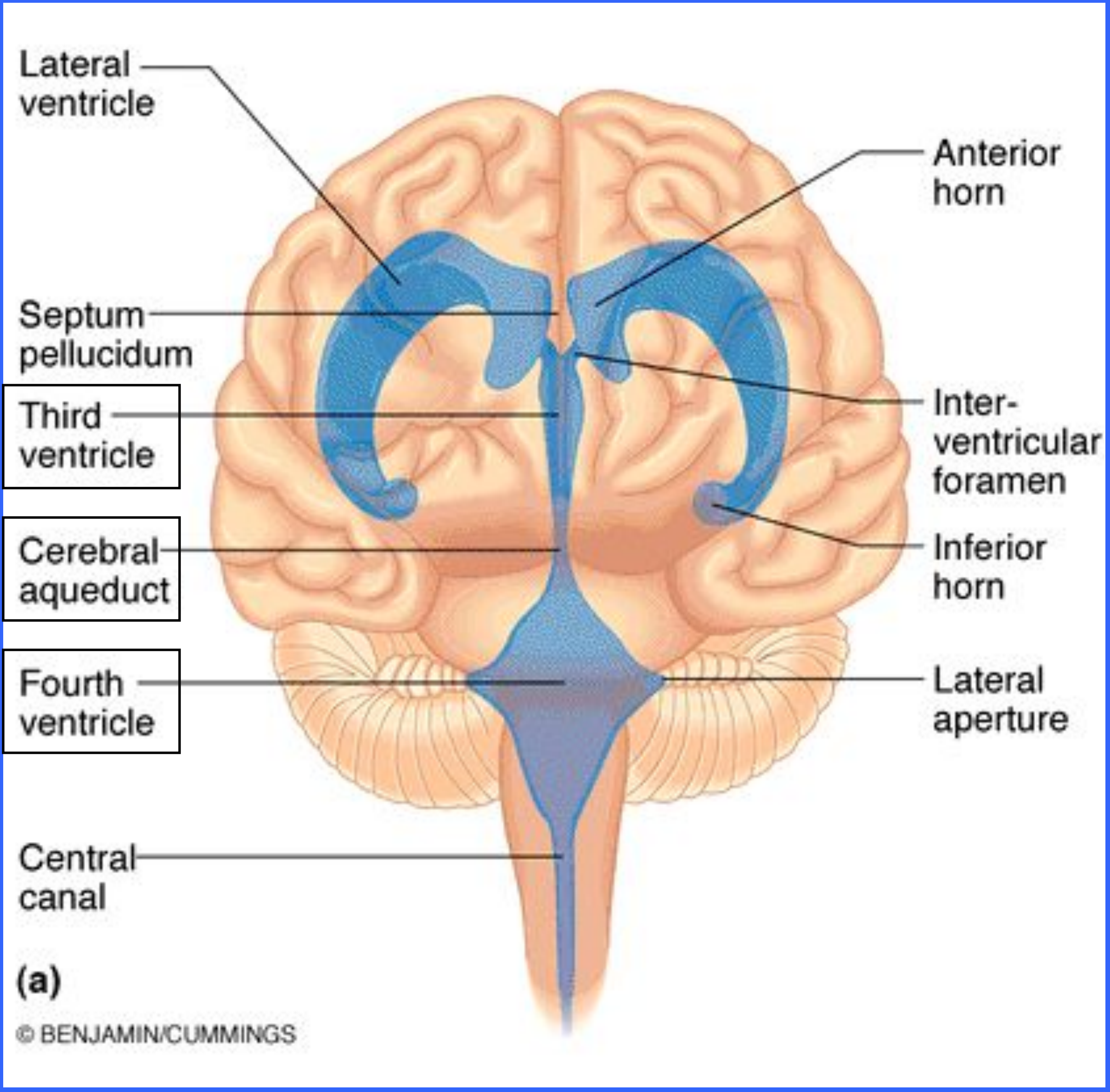
Ventricles of the Brain

- **Communication occurs through the inter-ventricular foramen (foramen of Moro)**



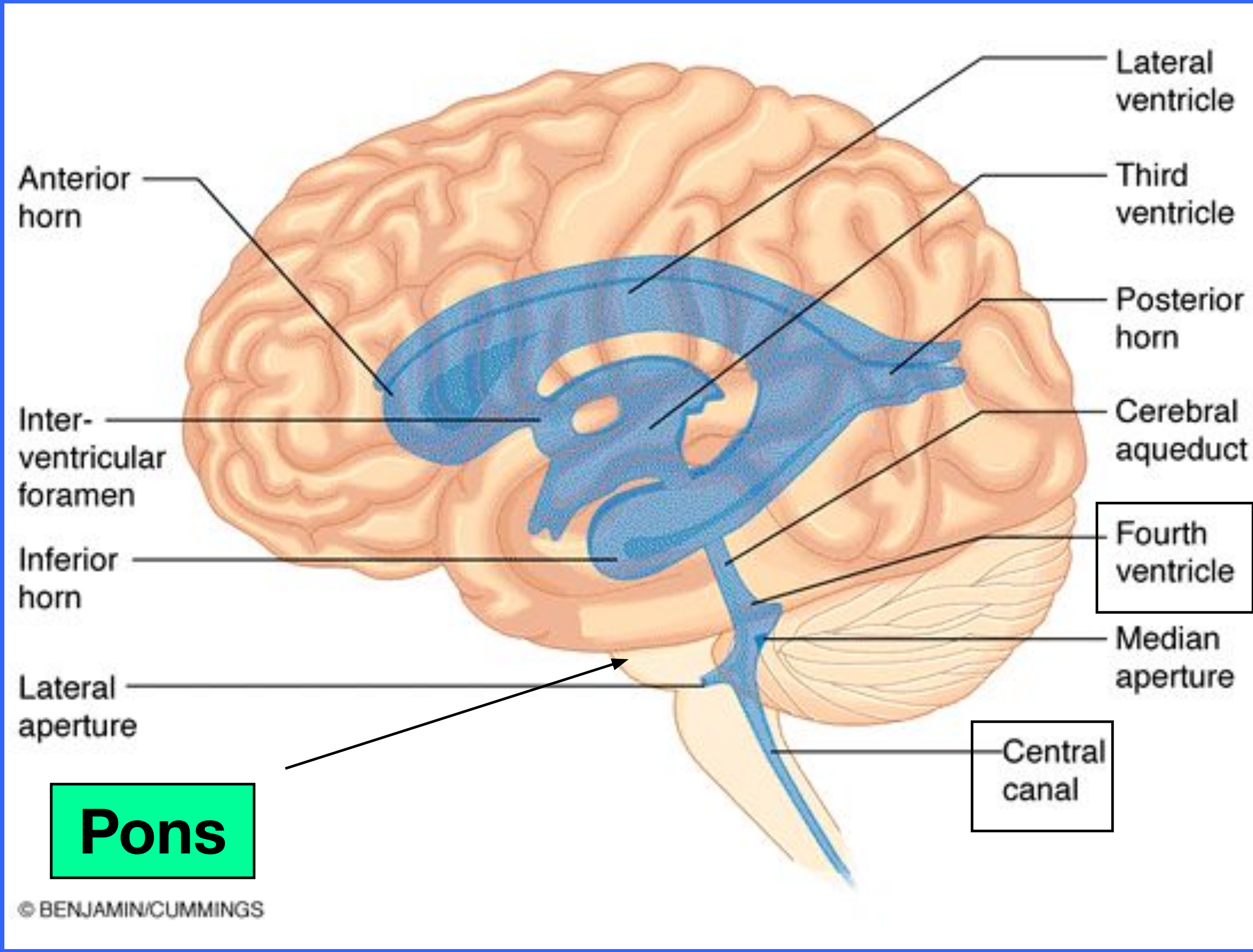
Ventricles of the Brain

- **The third ventricle is continuous with the fourth ventricle via the canal-like cerebral aqueduct that runs through the midbrain**



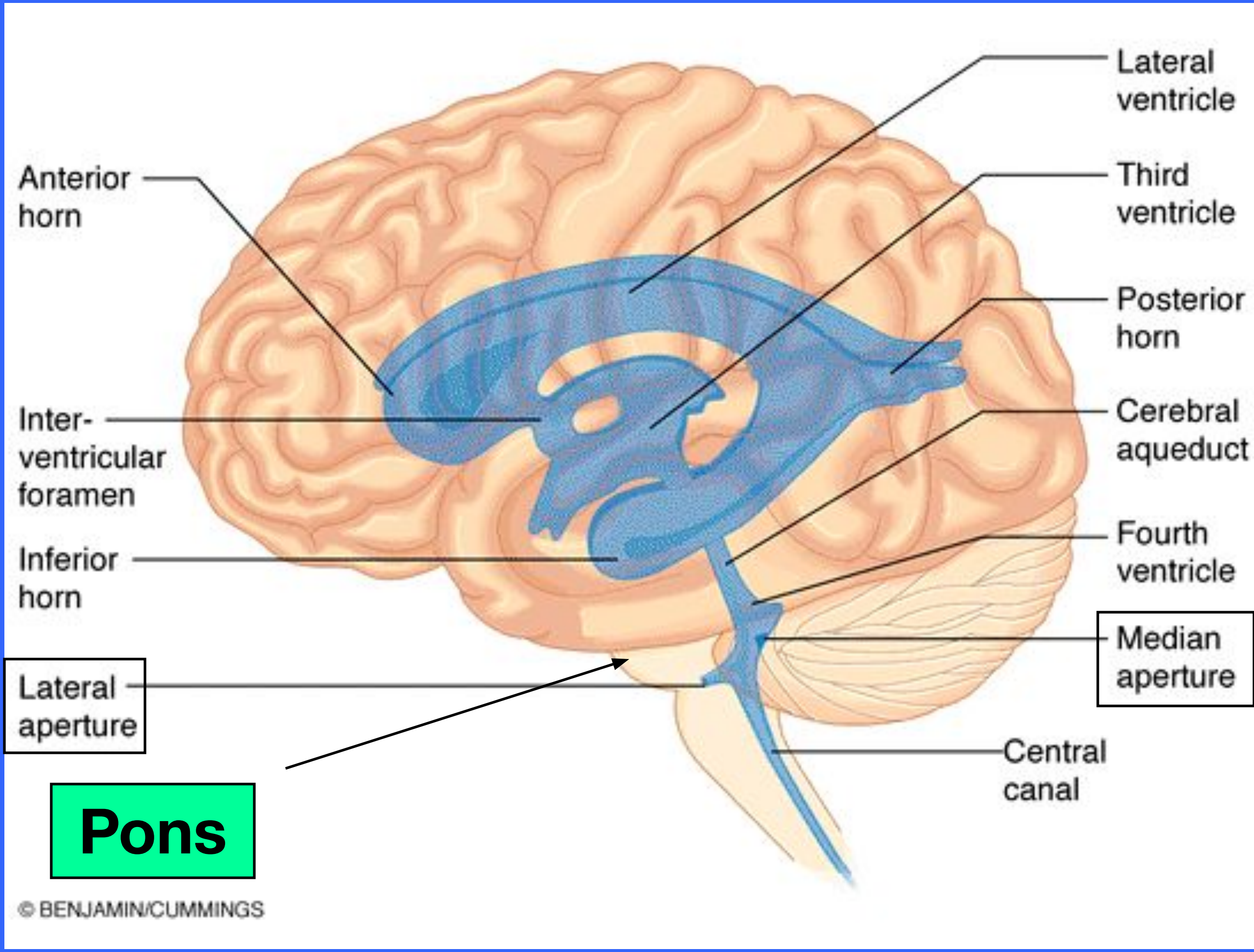
Ventricles of the Brain

- The fourth ventricle which lies dorsal to the pons and posterior to the medulla, is continuous with the central canal of the spinal cord inferiorly



Ventricles of the Brain

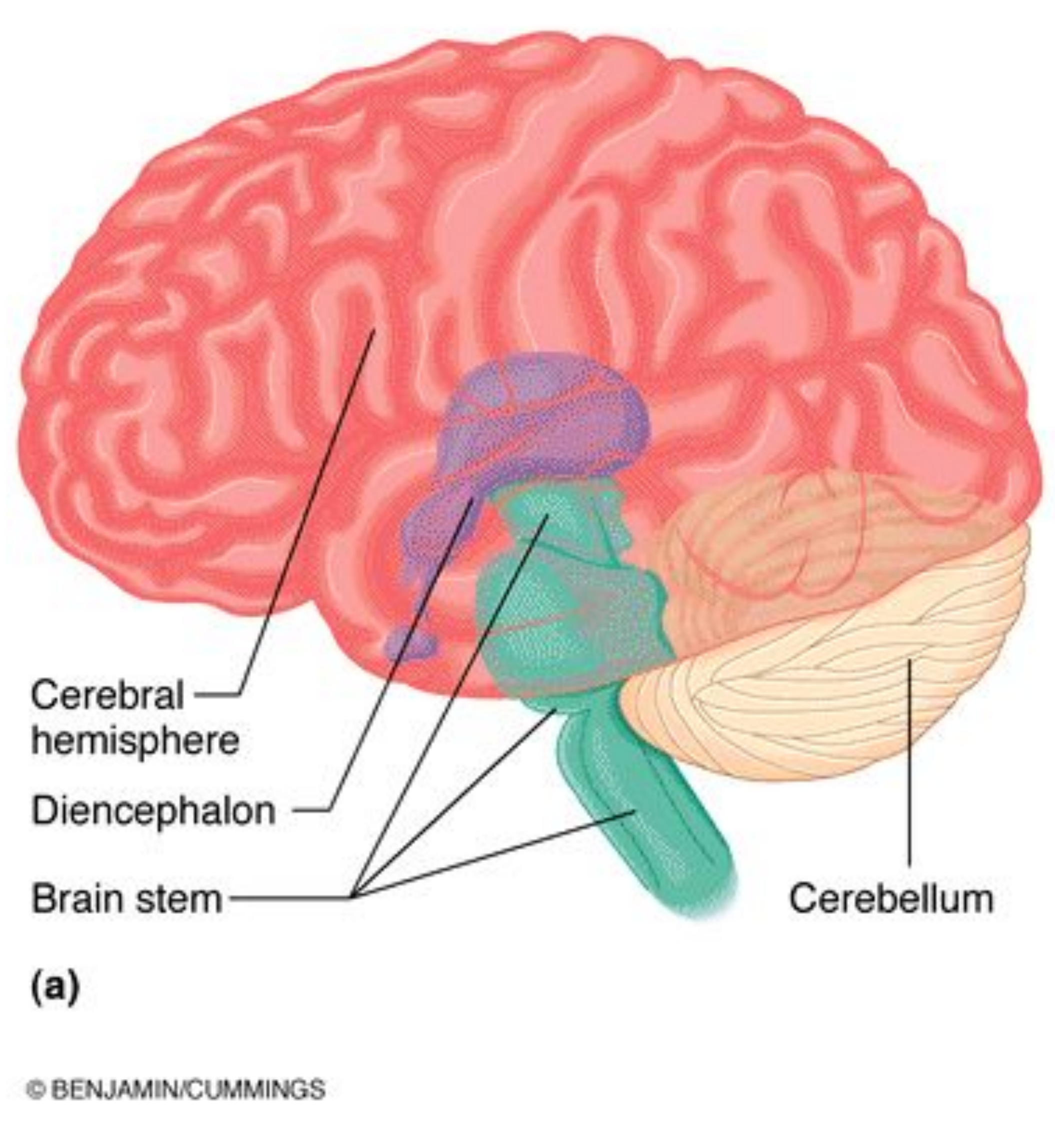
- Three openings mark the walls of the fourth ventricle
  - Paired lateral apertures
  - Median aperture
- Apertures connect the ventricles to the subarachnoid space



Subarachnoid space is filled with cerebrospinal fluid to surround the brain

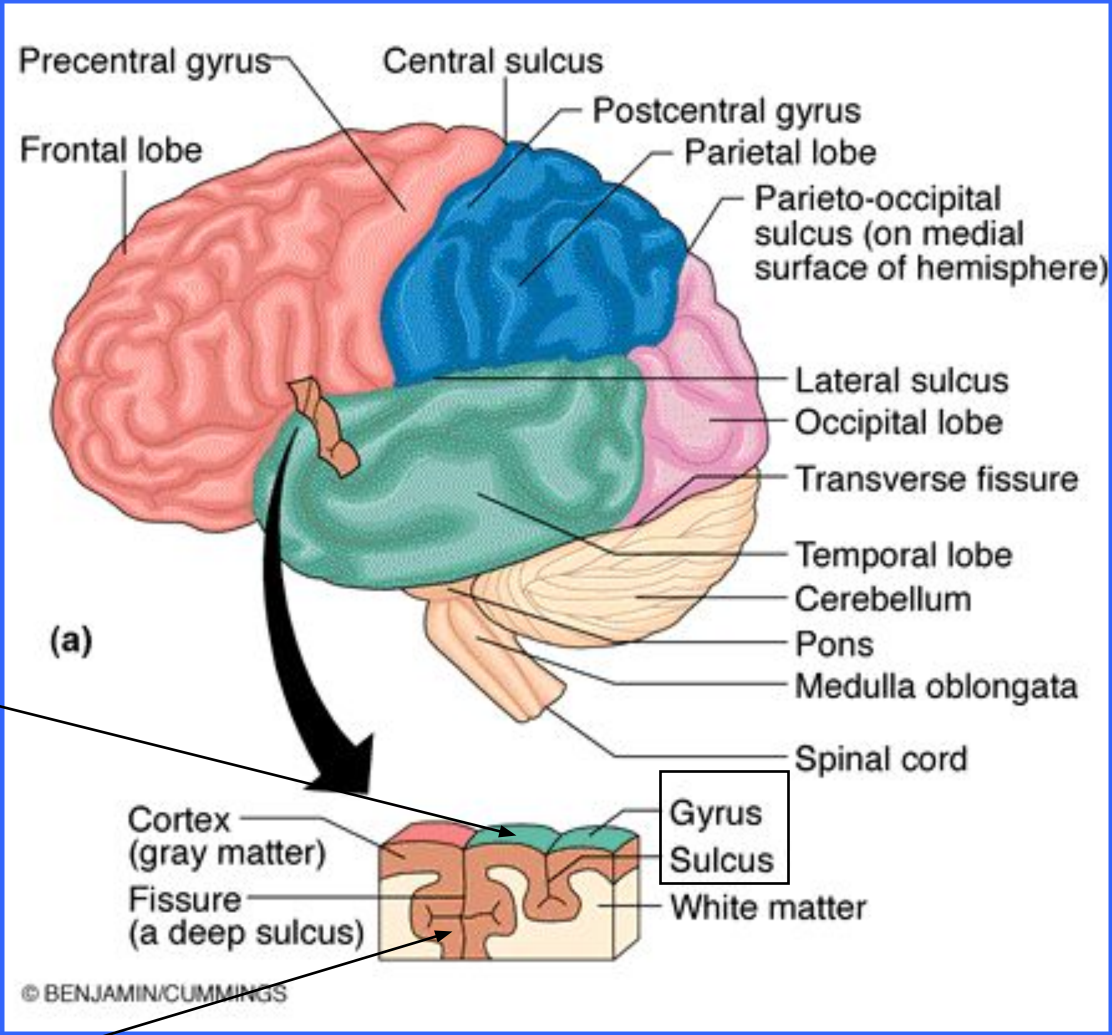
The Cerebral Hemispheres

- The cerebral hemispheres form the superior part of the brain
- These two structures account for about 83% of the mass of the brain
- The two hemispheres cover and obscure the diencephalon and the top of the brain stem



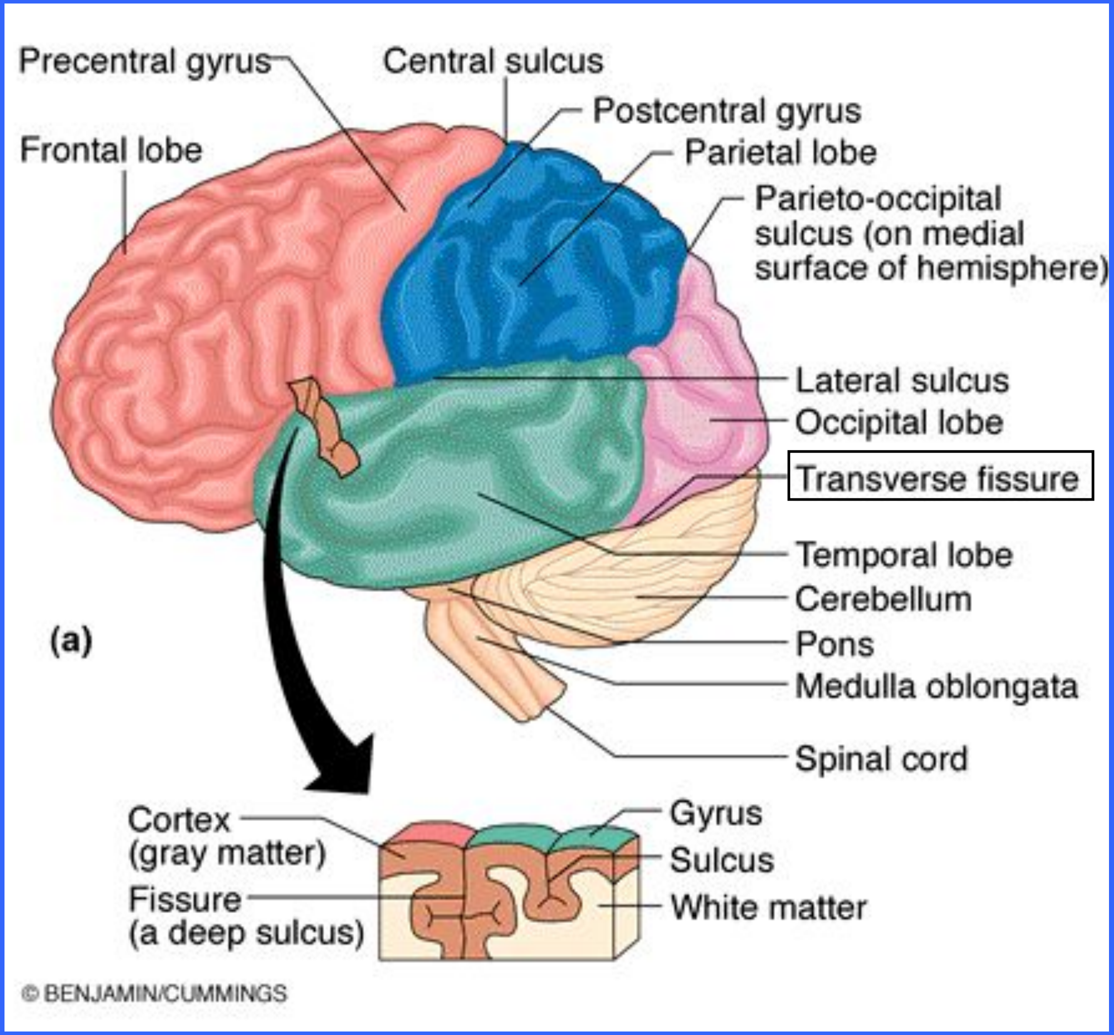
The Cerebral Hemispheres

- Nearly the entire surface of the cerebral hemispheres is marked by elevated ridges of tissues called gyri separated by shallow grooves called sulci
- Deeper grooves called fissures separate larger regions of the brain



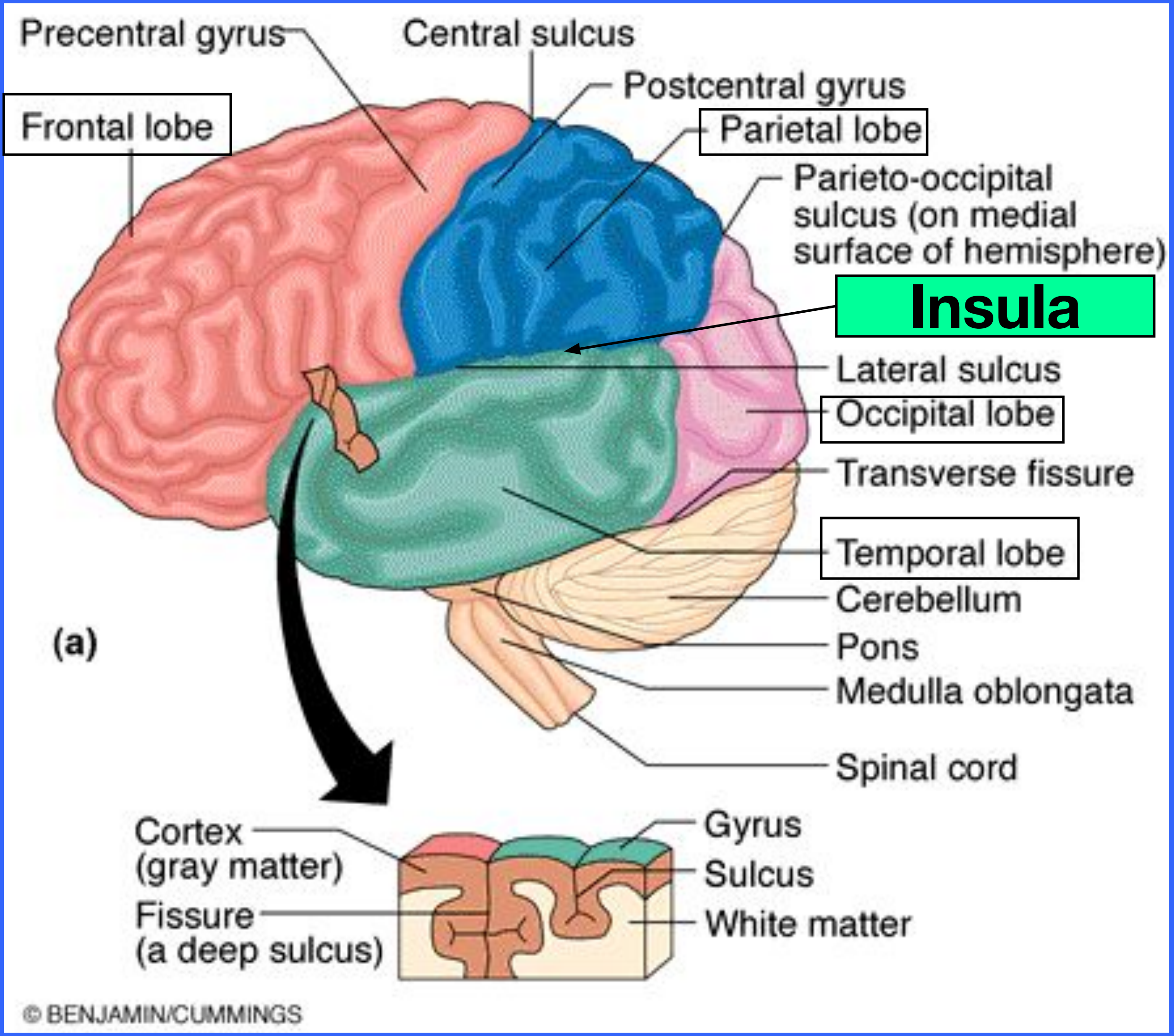
The Cerebral Hemispheres

- Prominent gyri and sulci are similar in all people
- The median longitudinal fissure separates the hemispheres
- The transverse fissure separates the cerebral hemispheres from the cerebellum below



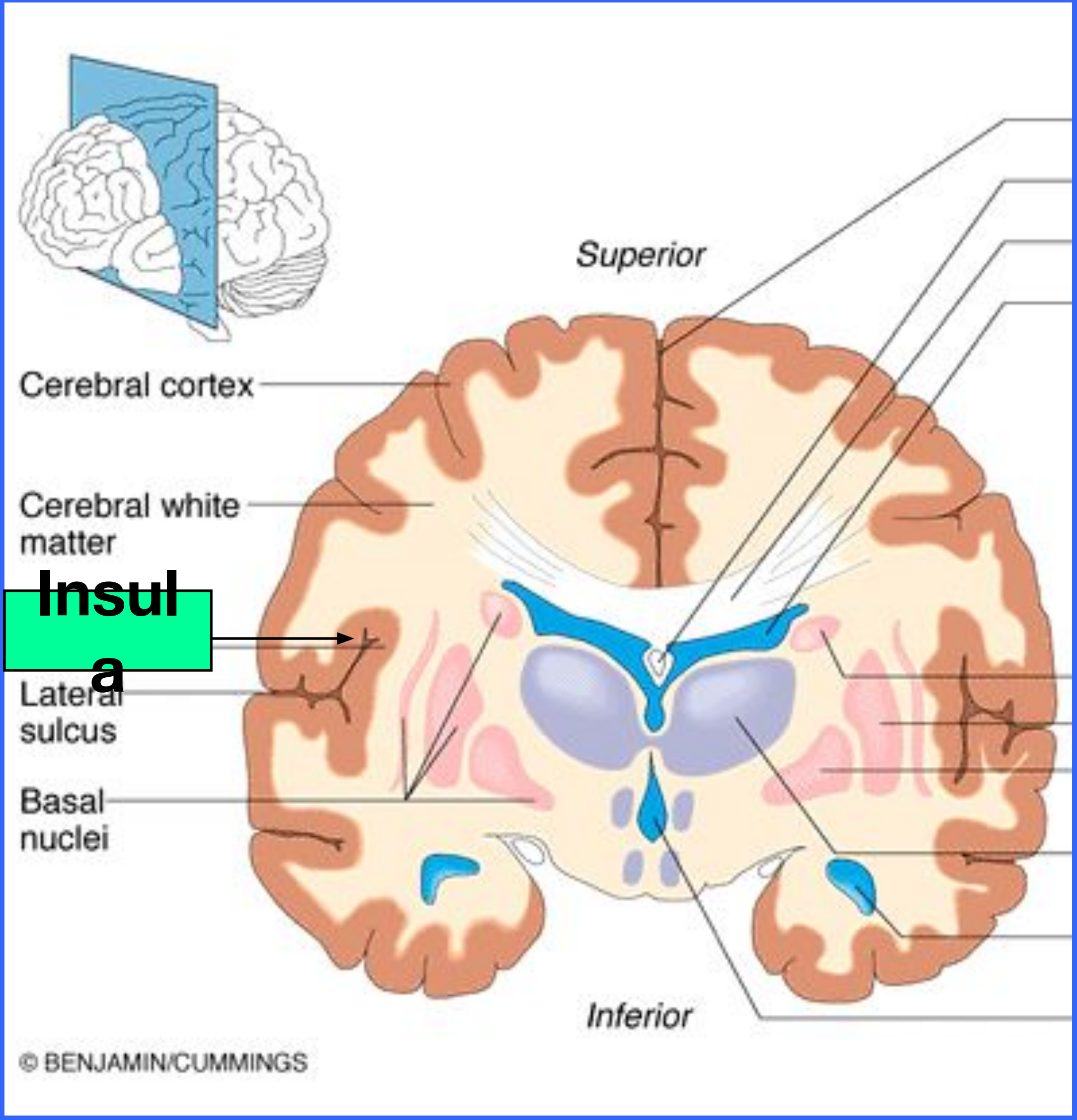
Lobes of Cerebral Hemispheres

- Deeper sulci divide each hemisphere into five lobes
  - Frontal lobe
  - Temporal lobe
  - Parietal lobe
  - Occipital lobe
  - Insula (located within the lateral sulcus)



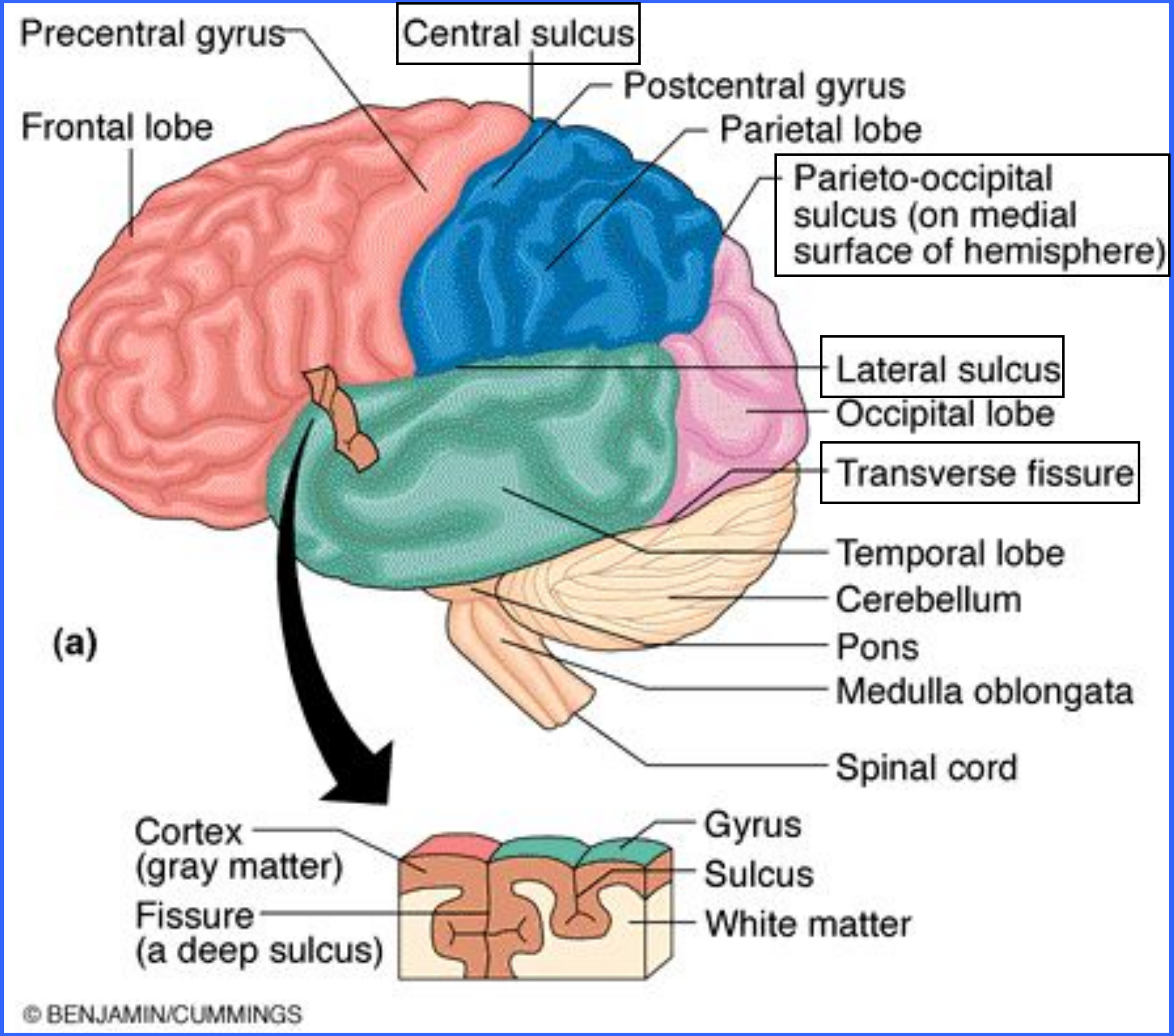
Lobes of Cerebral Hemispheres

- **Location of the insula deep within the Lateral sulcus of the hemisphere**



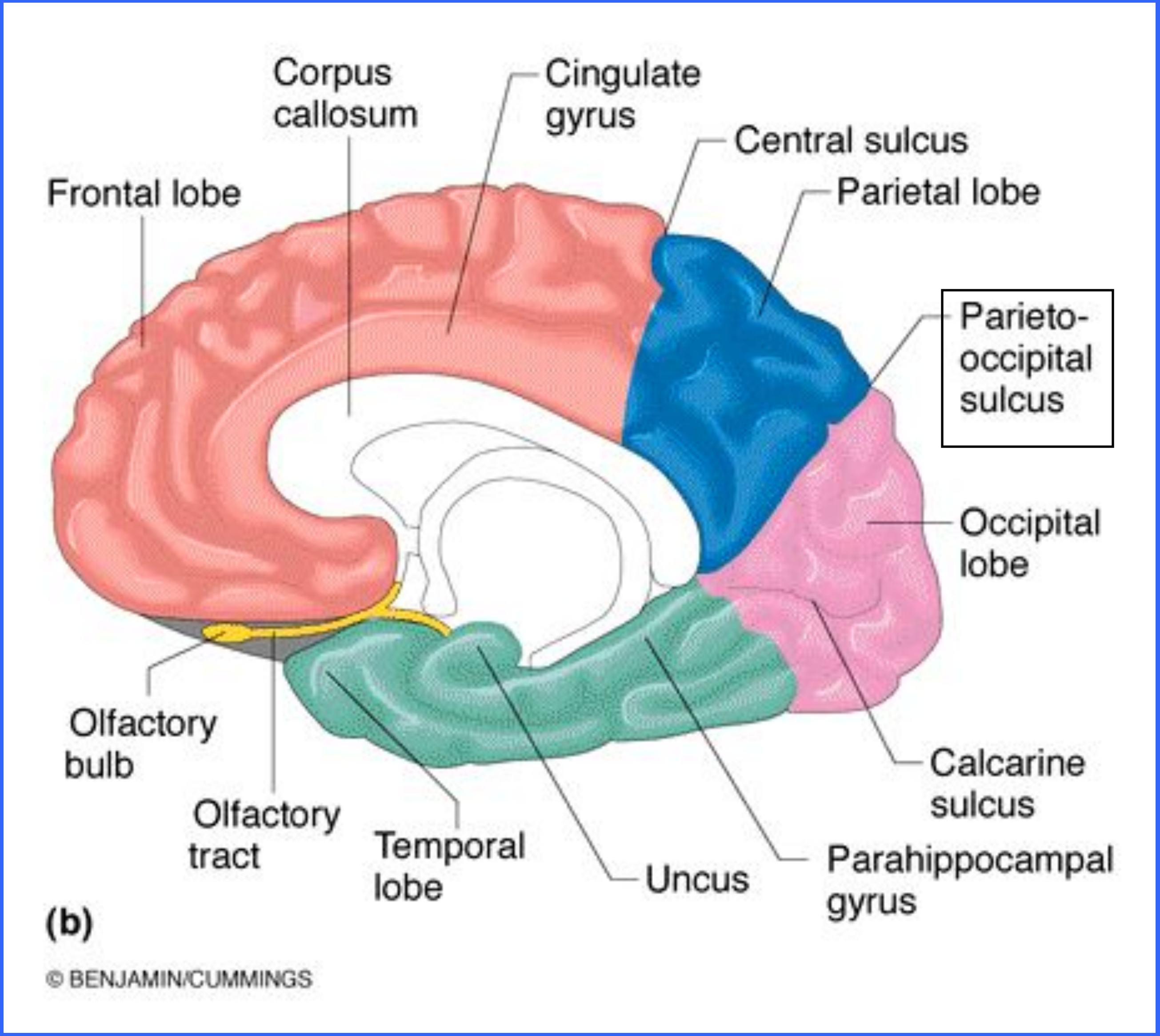
Fissures of Cerebral Hemispheres

- Sulci divide lobes of the hemispheres
  - Central sulcus
  - Parieto-occipital sulcus
  - Lateral sulcus
  - Transverse fissure



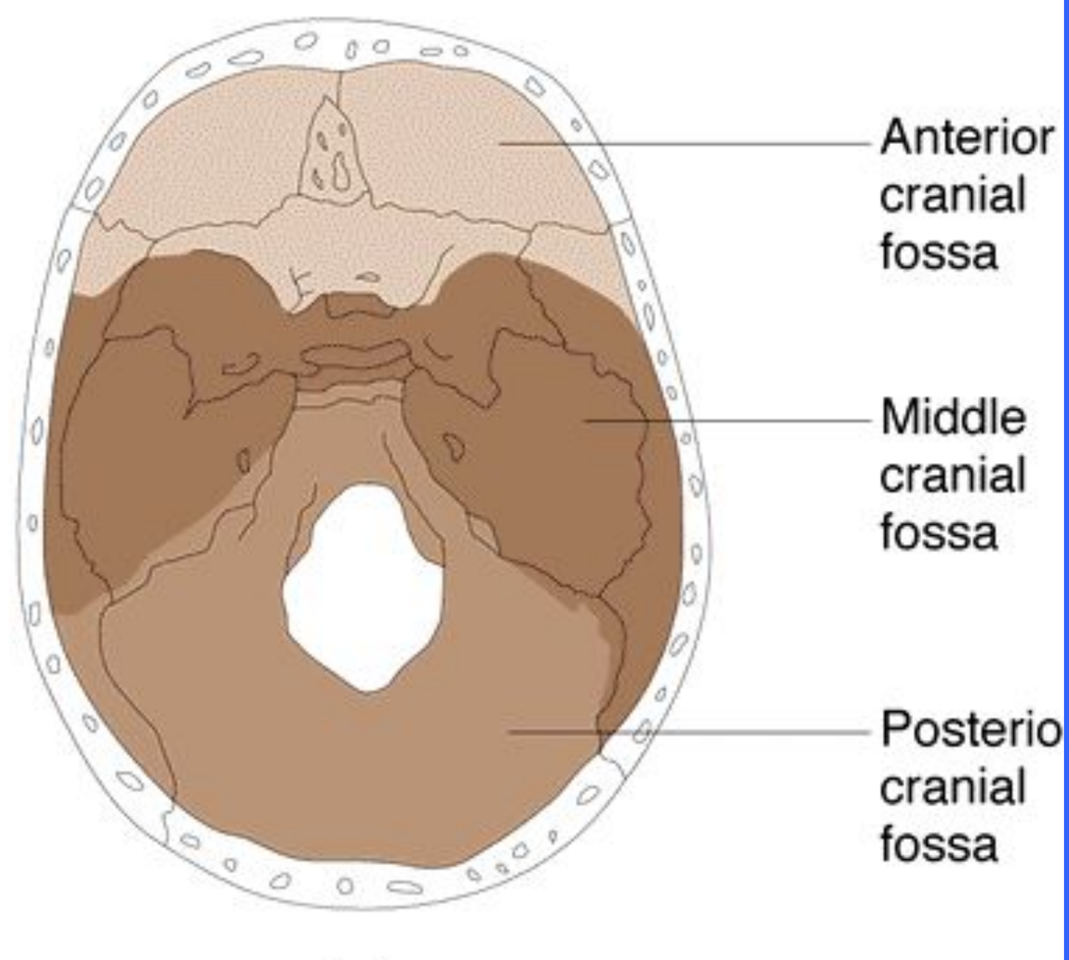
Medial Surface of Right Hemisphere

- **Medial surface of the right hemisphere showing the Parieto-occipital sulcus**



Position of Cerebral Hemispheres

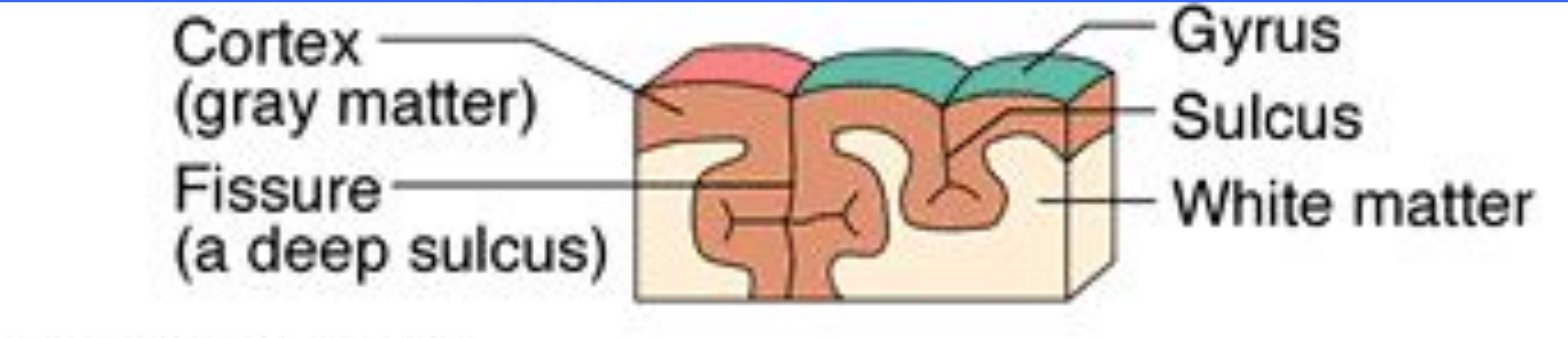
- The frontal lobes occupy the anterior cranial fossa
- The anterior parts of the temporal lobes fill the middle cranial fossa
- The cerebellum and brain stem occupies the posterior cranial fossa and the occipital lobes rests upon it



Cerebral Cortex

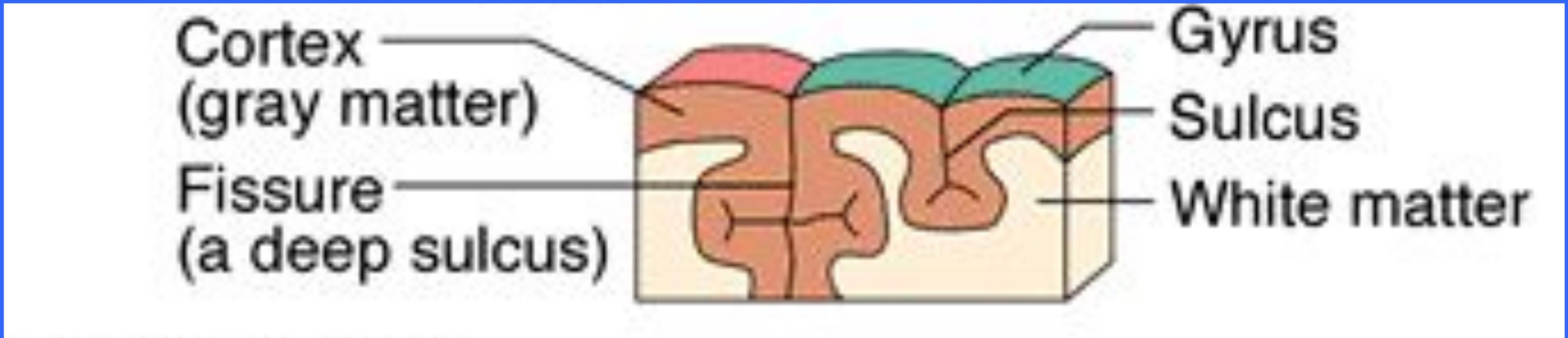
- The cerebral cortex is the “executive suite” of the nervous system
- It enables us to perceive, communicate, remember, understand, appreciate, and initiate voluntary movements
- Literally all qualities associated with conscious behavior or consciousness originate within the cerebral cortex of the various lobes of the brain

Cerebral Cortex



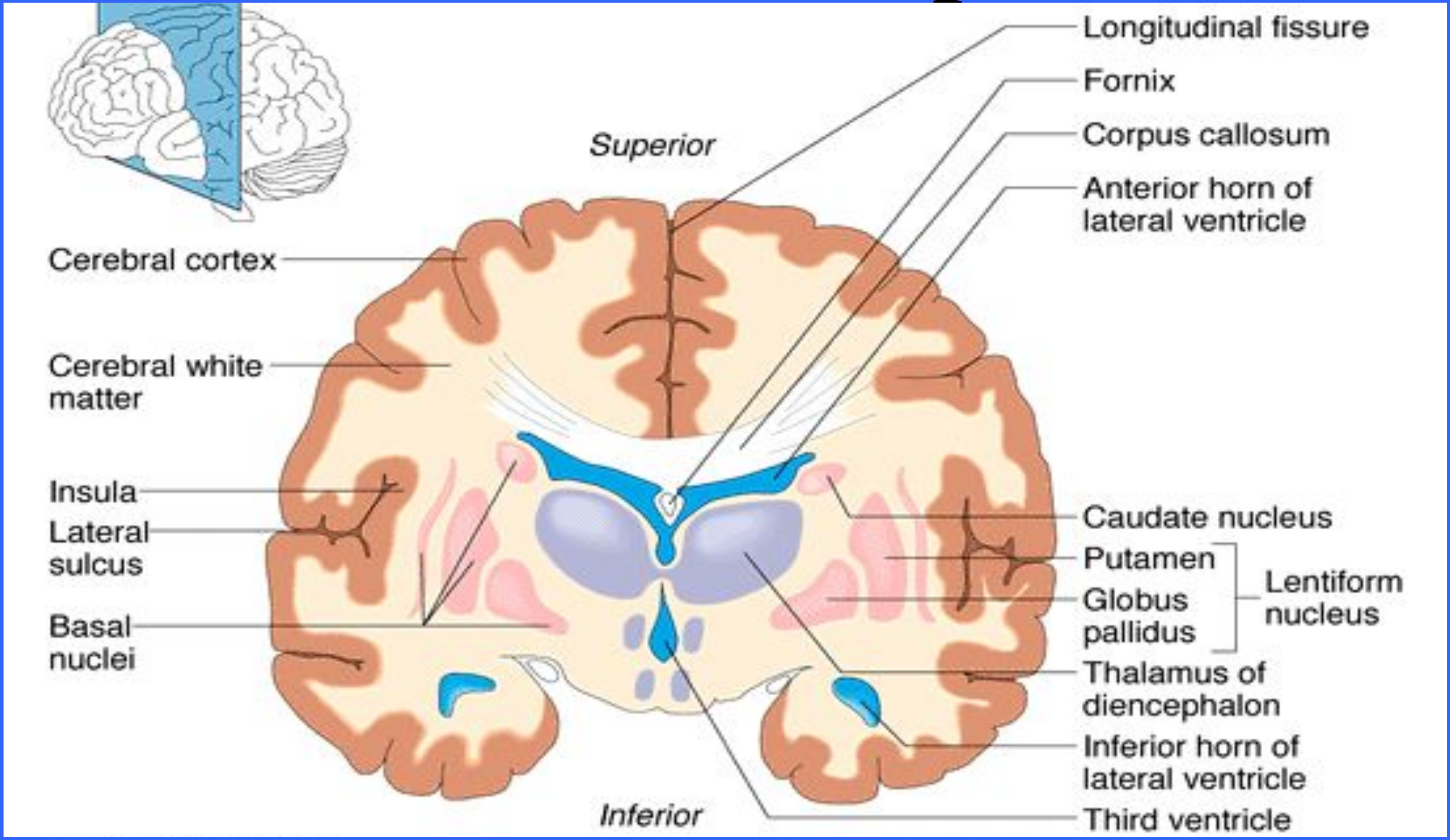
- The cerebral cortex is gray matter composed of neuron cells bodies, dendrites, and unmyelinated axons (plus support cells and blood vessels)
- It is only 2-4 mm thick
- The many convolutions of the brain effectively triple its surface area
- It accounts for roughly 40% of total brain mass

Cerebral Cortex



- The cerebral cortex accounts for roughly 40% of total brain mass
- The cortex contains billions of neurons arranged in six layers
- Ana

Cerebral Hemispheres



- **Coronal section of the brain which reveals the cerebral cortex, white matter, and basal nuclei within the cerebral hemispheres**

Cerebral Cortex

- Research on the structure and function of the brain reveals that there are both specialized and diffuse areas of function
- Motor and sensory areas are localized in discrete cortical areas called domains
- Many higher mental functions such as memory and language appear to have overlapping domains and are more diffusely located
- Broadmann areas are areas of localized function

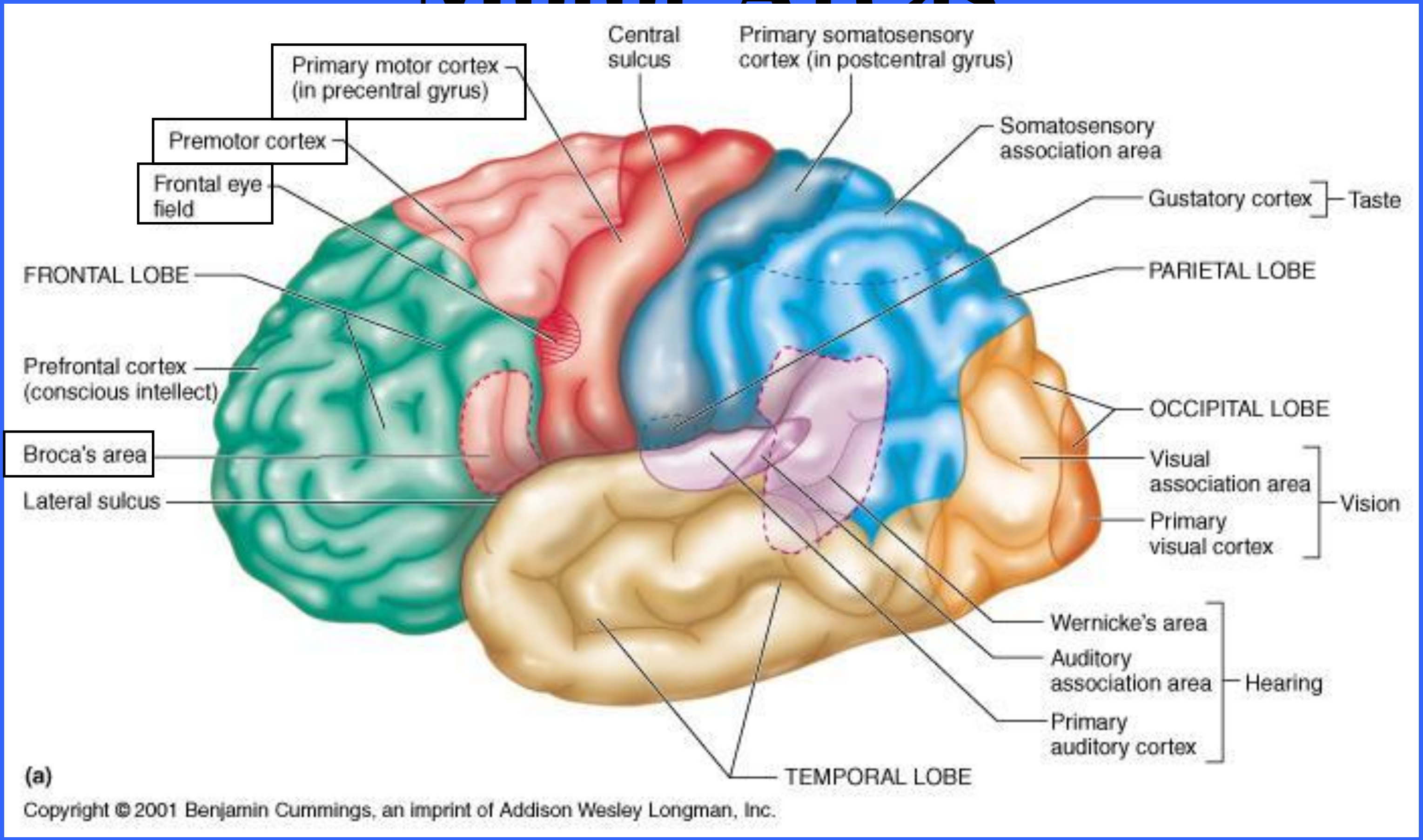
Cerebral Cortex - Generalizations

- The cerebral cortex has three types of functional areas
  - <u>Motor areas</u> / control voluntary motor function
  - <u>Sensory areas</u> / provide conscious awareness of sensation
  - <u>Association areas</u> / act mainly to integrate diverse information for purposeful action
- Each hemisphere is chiefly concerned with the sensory and motor functions of the opposite (contralateral) side of the body

Cerebral Cortex - Generalizations

- Although they are largely symmetrical in structure the two hemispheres are not entirely equal in function, instead there is lateralization of cortical function
- Remember that the information presented is a gross oversimplification to convey and clarify concepts

Motor Areas



- Cortical areas controlling motor functions lie in the posterior part of the frontal lobes
- Motor areas include the primary motor cortex, the premotor cortex, Broca’s area, and the front eye field

Primary Motor Cortex

- The primary motor cortex is located in the precentral gyrus of the frontal lobe of each hemisphere
- Large neurons (pyramidal cells) in these gyri allow us to consciously control the precise or skill voluntary movements of our skeletal muscles

Pyramidal cells

- These long axons, which project to the spinal cord, form the massive voluntary motor tracts called the pyramidal, or corticospinal tracts
- All other descending motor tracts issue from brain stem nuclei and consists of chains of two, three, or more neurons

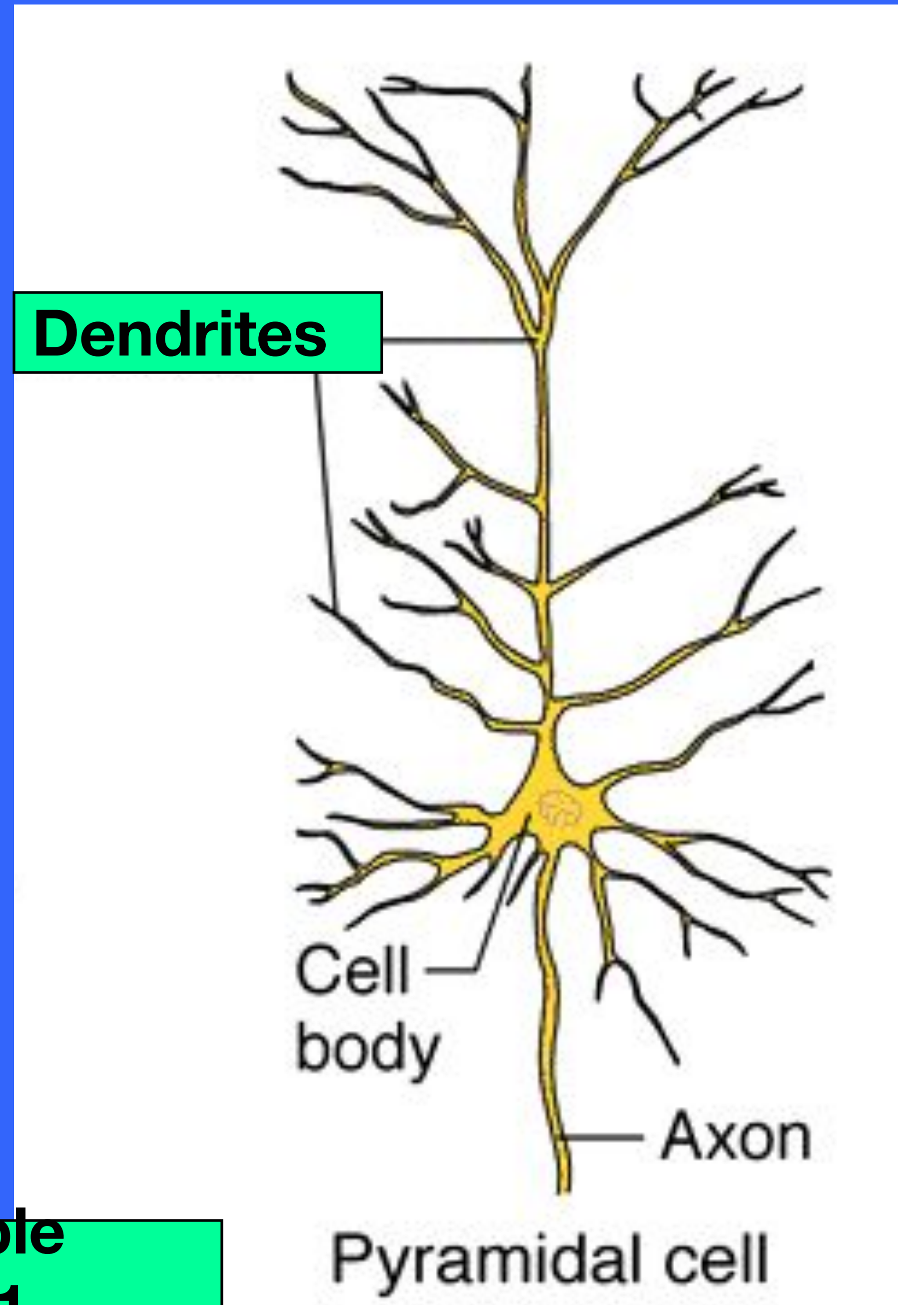
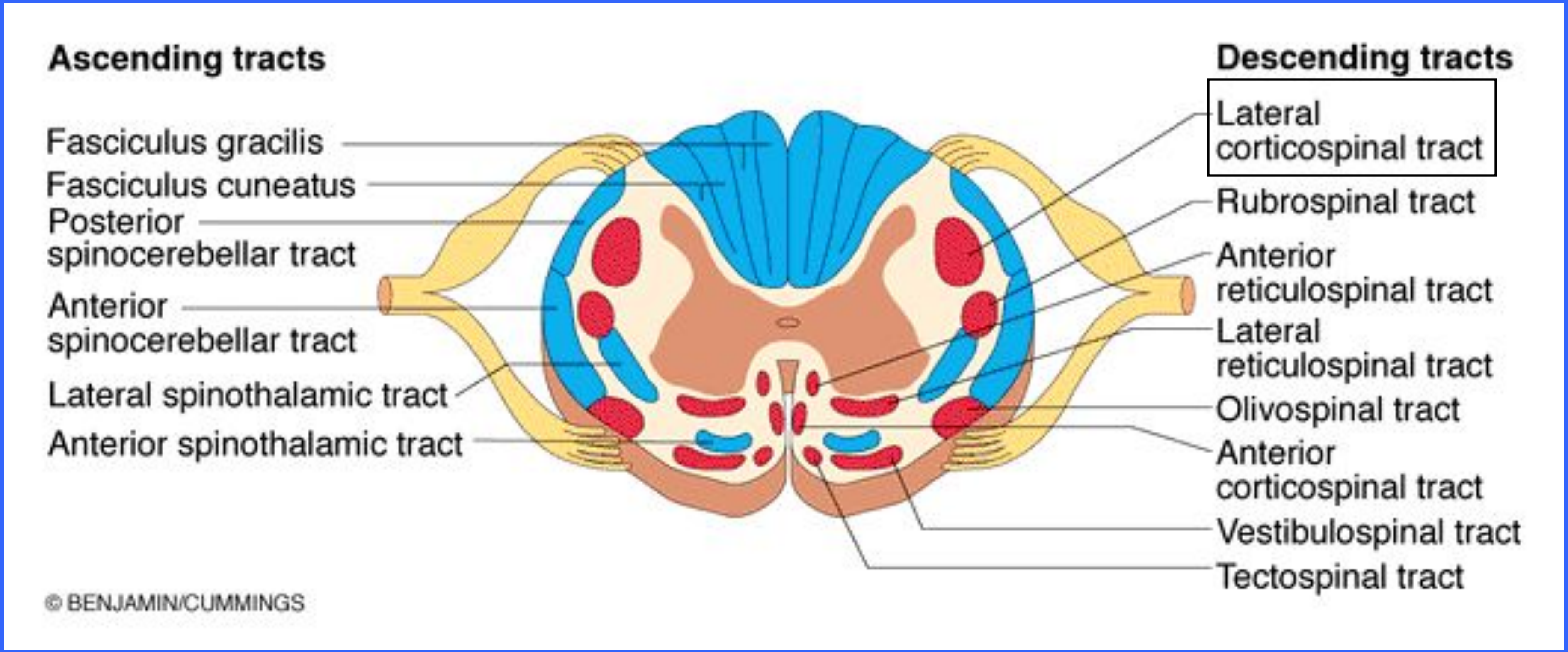


Table 11.1

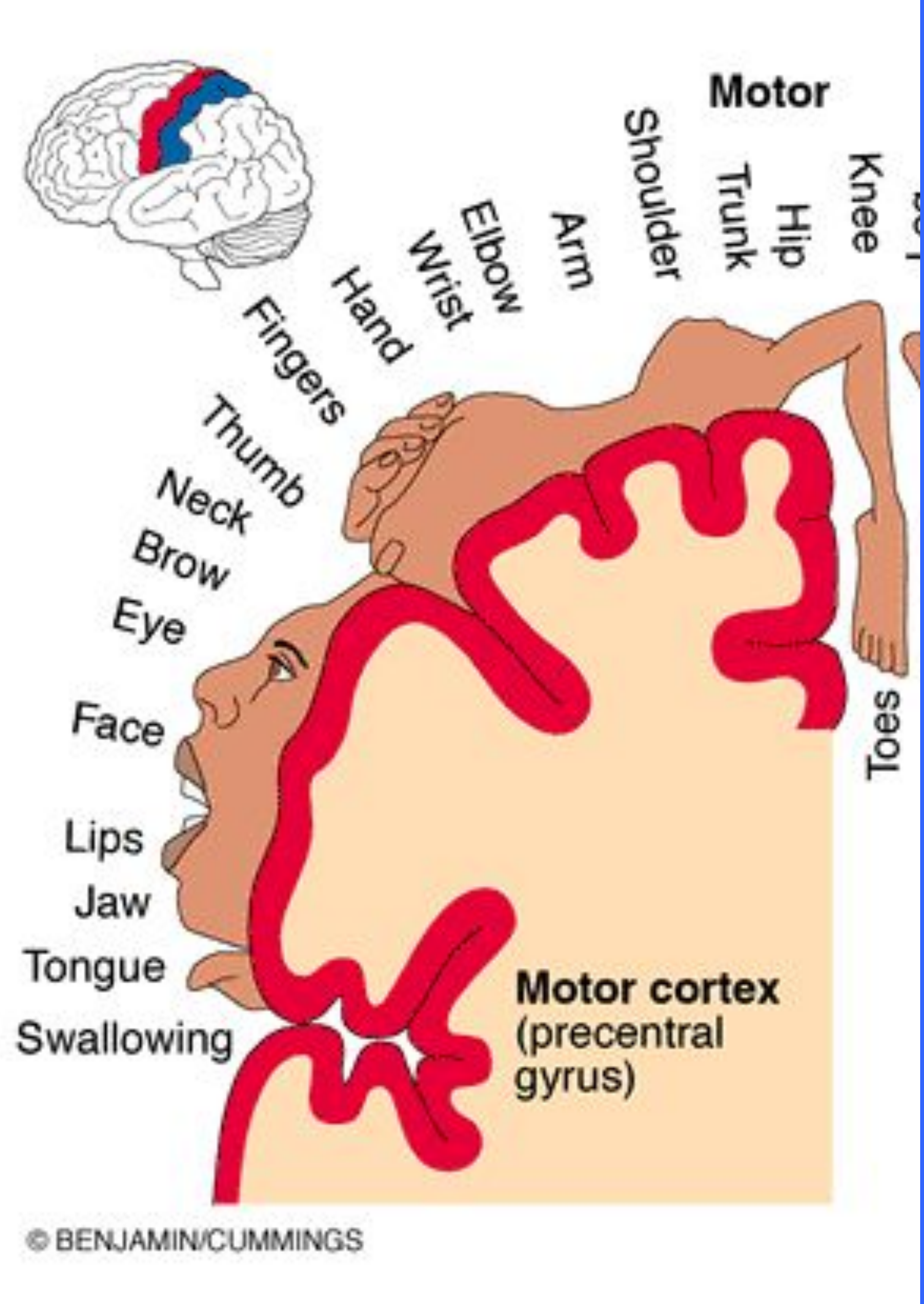
Pyramidal Tracts



- **The lateral corticospinal tract consists of the long axons of the pyramidal cells located within the primary motor cortex**

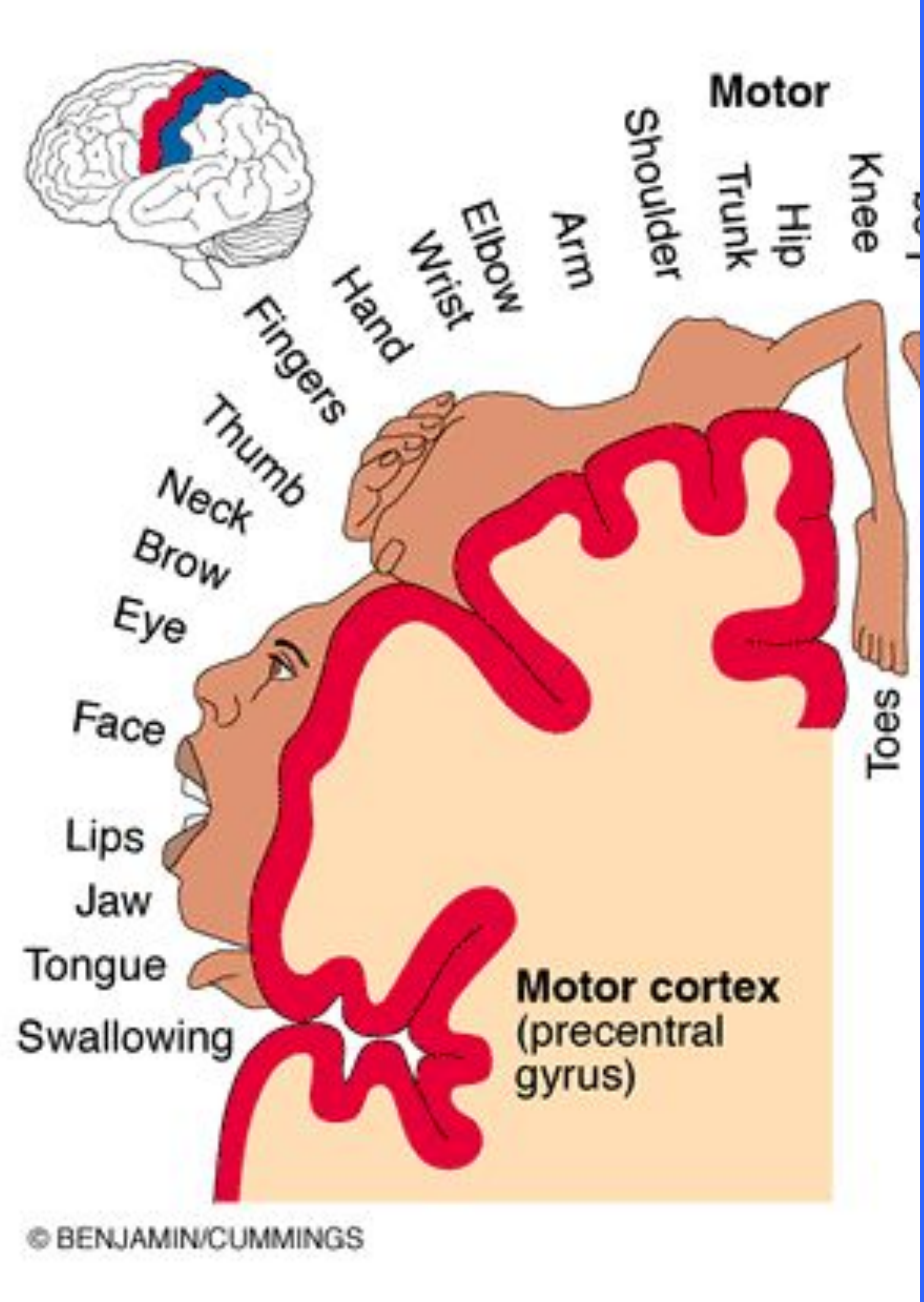
Motor Somatotopy

- Body is represented spatially in the primary motor cortex of each hemisphere
- Most of the neurons in these gyri control muscles in body areas having the most precise motor control
- The areas with the most control (face, tongue, and hands)



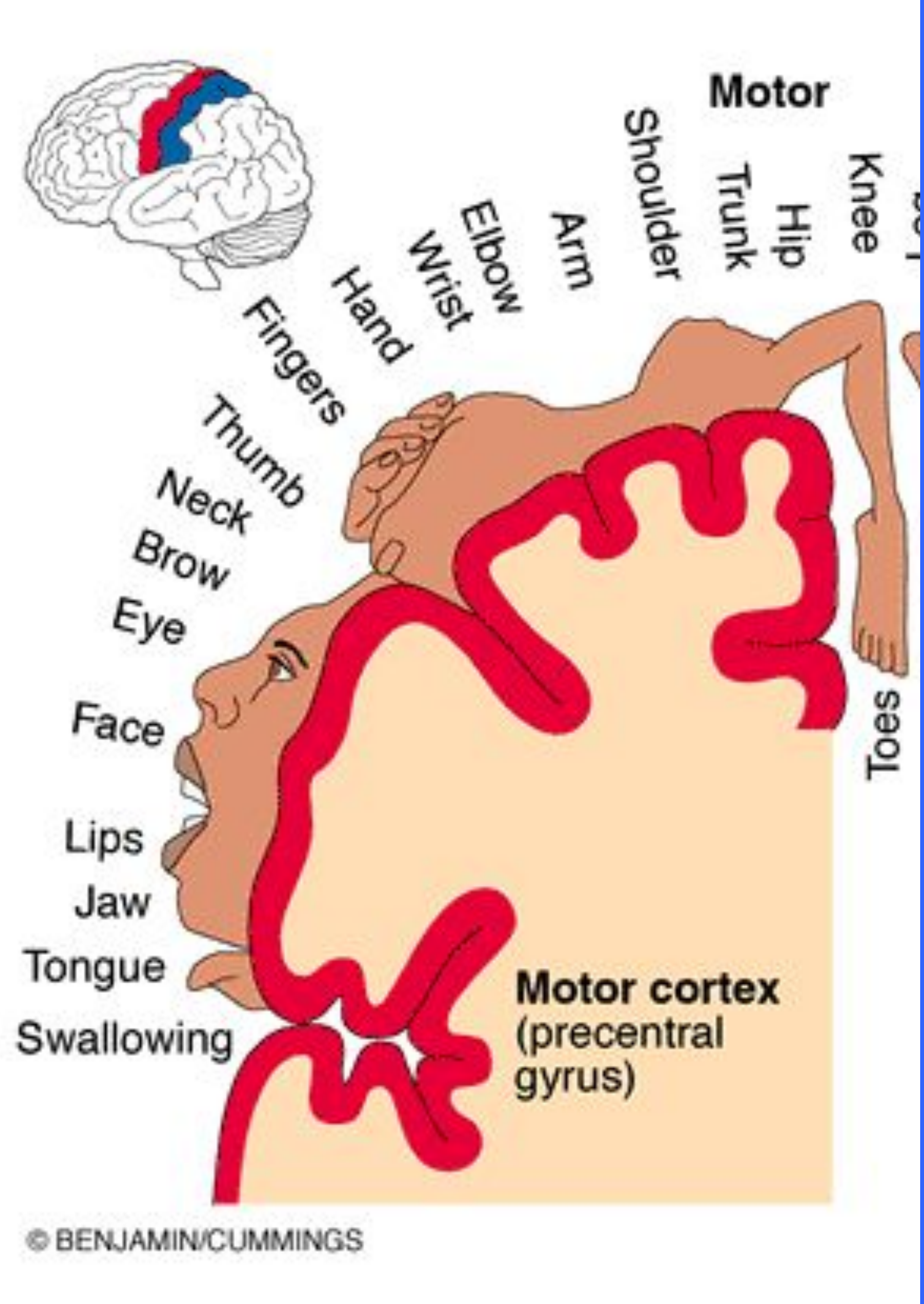
Motor Somatotopy

- Motor innervation is contralateral; left primary motor controls right side of body
- The image is useful to conceptualize areas of synergistic function
- However, a given muscle may be controlled by several cortical neurons recruited for several specific actions



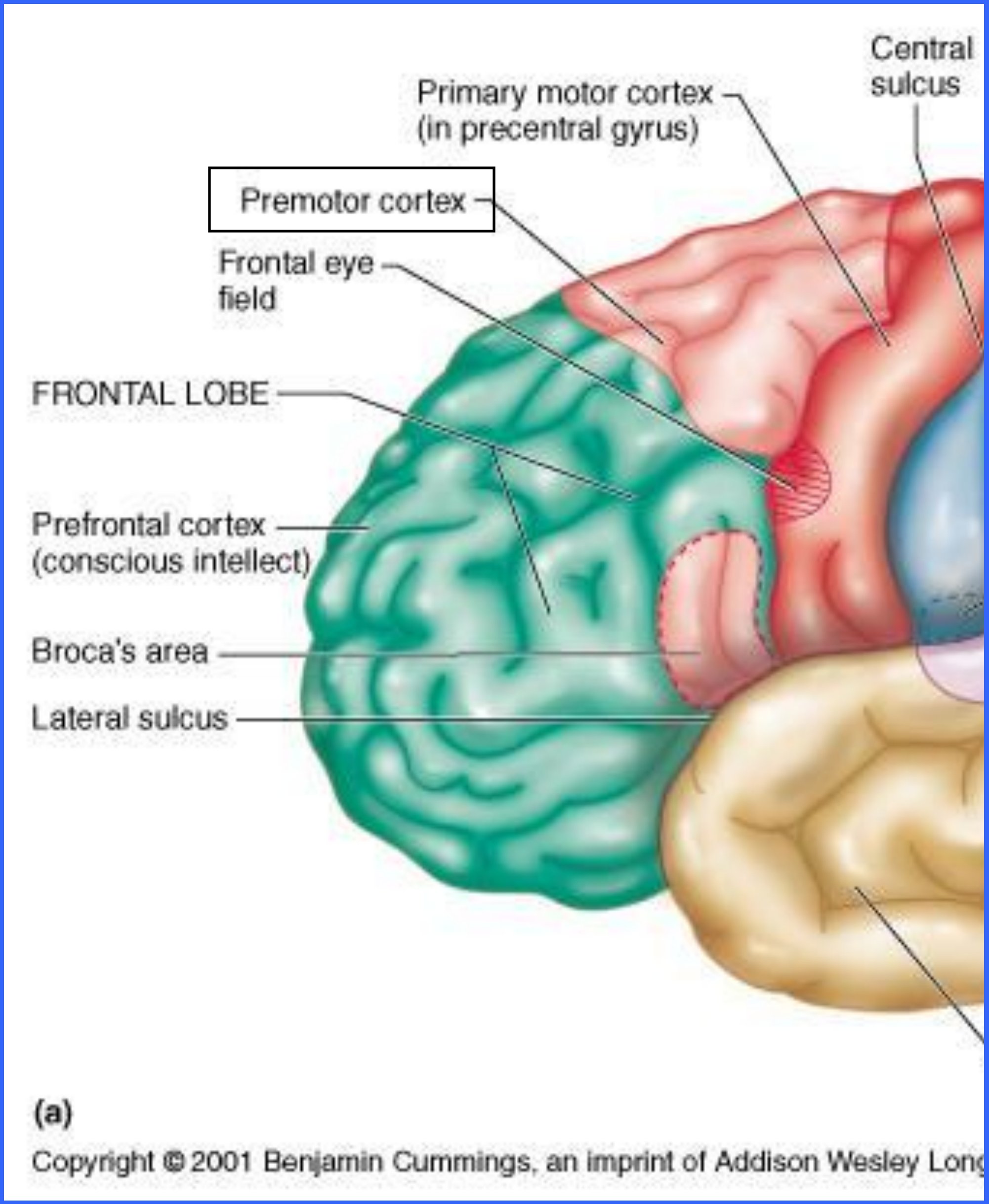
Motor Somatotopy

- Damage to the localized areas of the primary motor cortex paralyzes the muscles controlled by this area
- If the lesion is in the right hemisphere, the left side will be paralyzed
- Only voluntary control is lost as the muscles can still contract reflexively



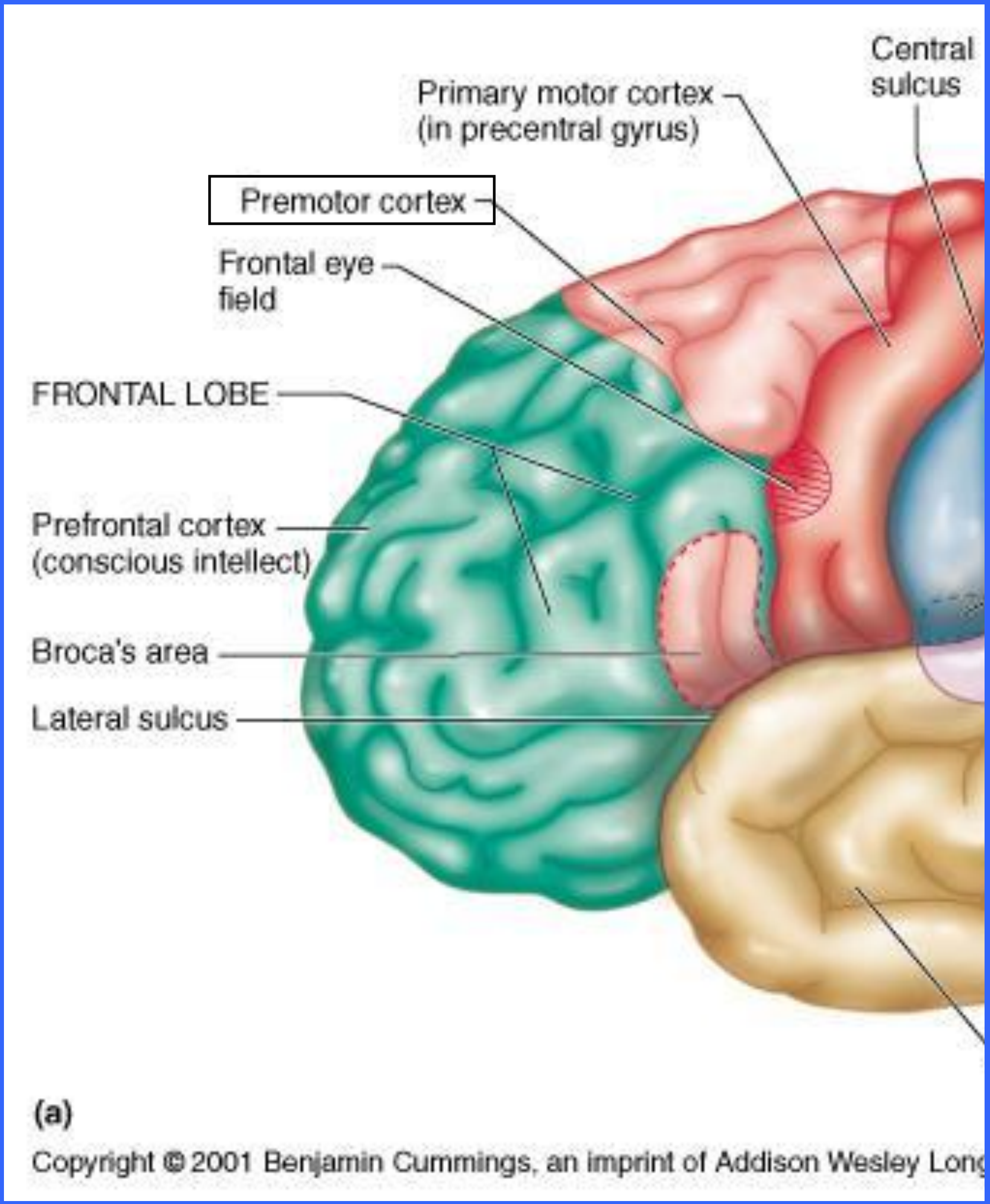
Premotor Cortex

- The premotor cortex controls motor skills of repetitive or patterned nature (typing or piano)
- The premotor cortex coordinates the movement of several muscle groups to act simultaneously or sequentially



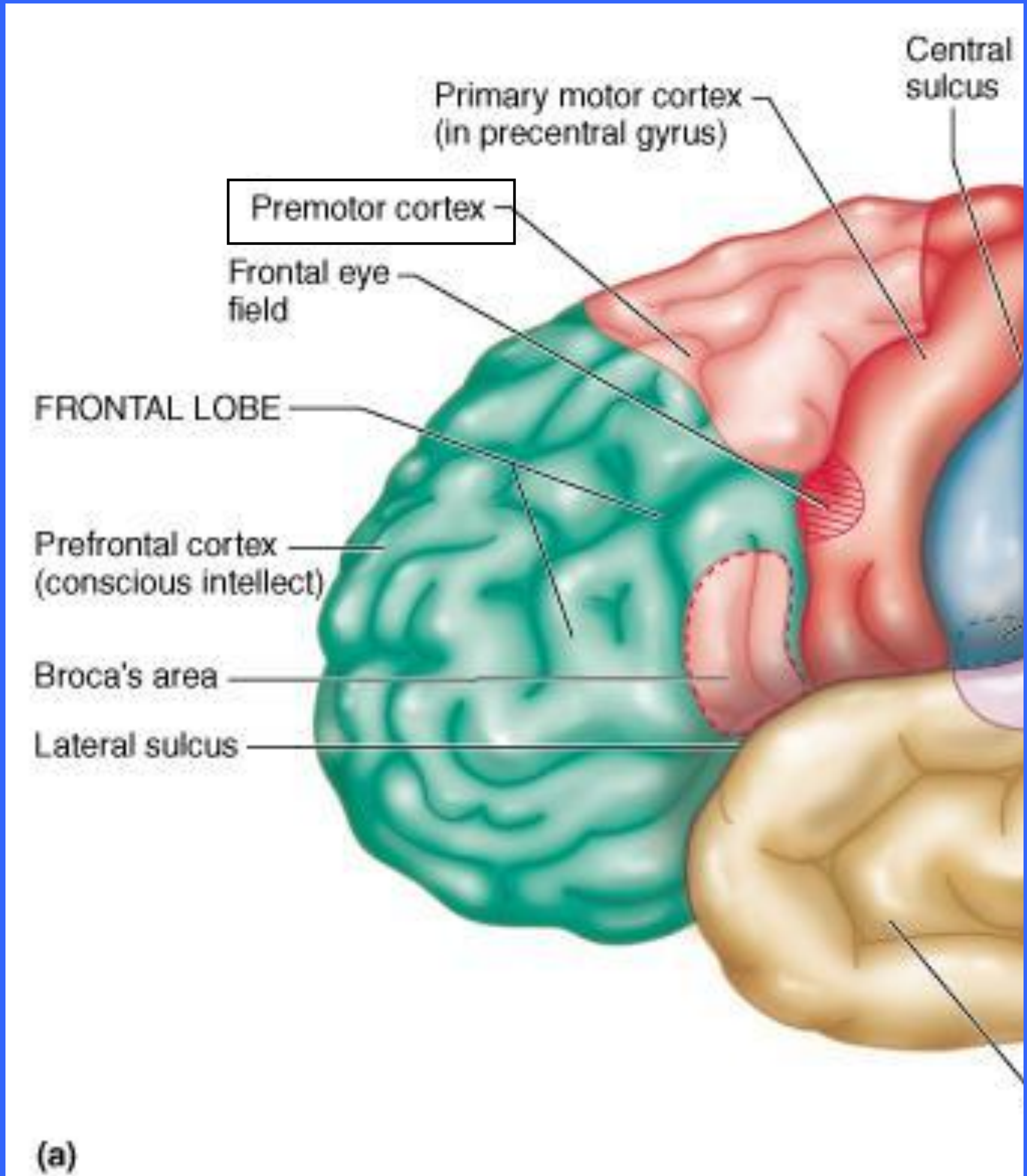
Premotor Cortex

- The premotor cortex sends activating impulses to the primary motor cortex
- Also influences motor actively more directly by supplying about 15% of pyramidal tract fibers
- A memory bank of skilled motor activities



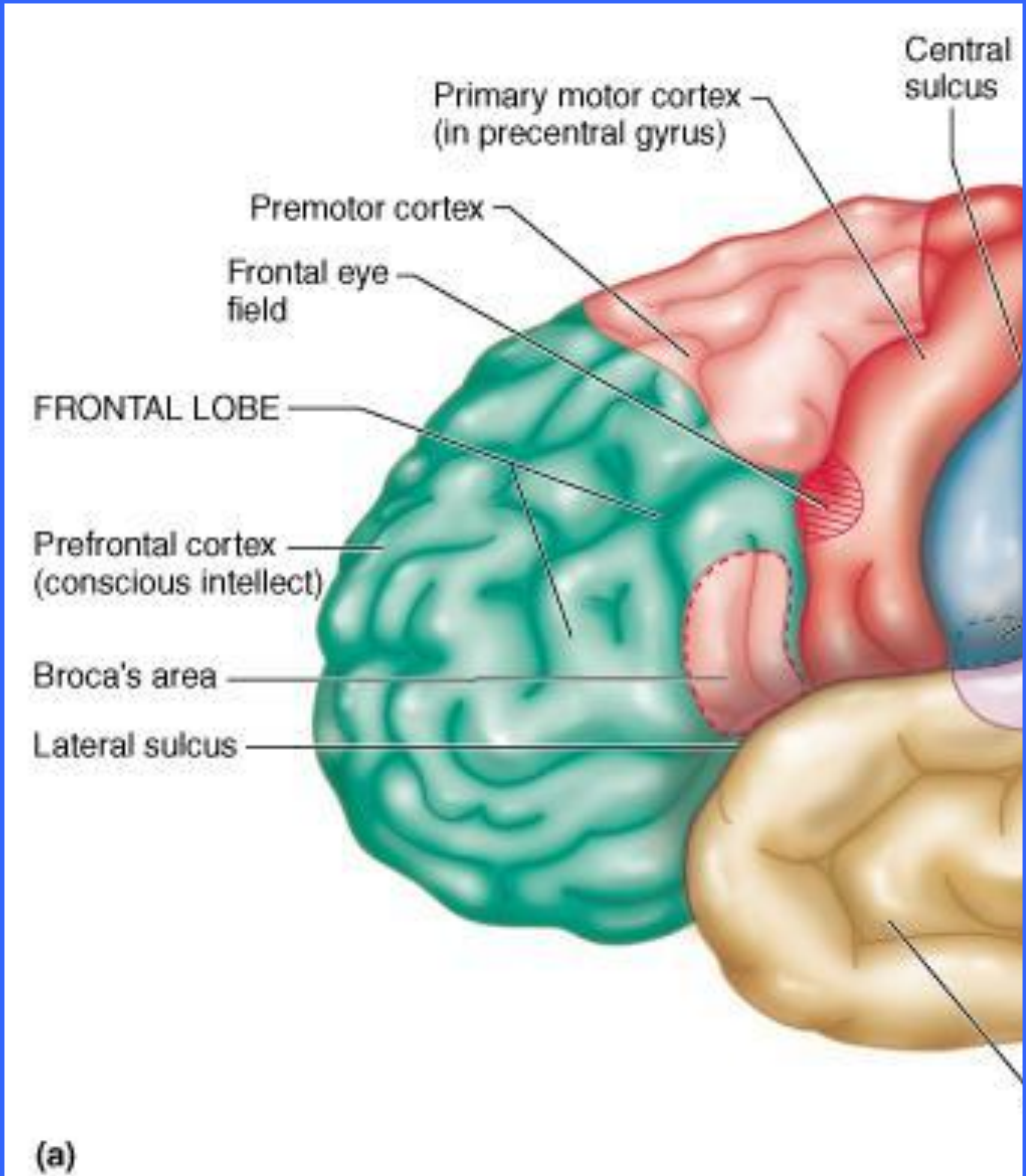
Premotor Cortex

- This area appears to involved with motor planning
- It controls voluntary actions that depend on sensory feedback



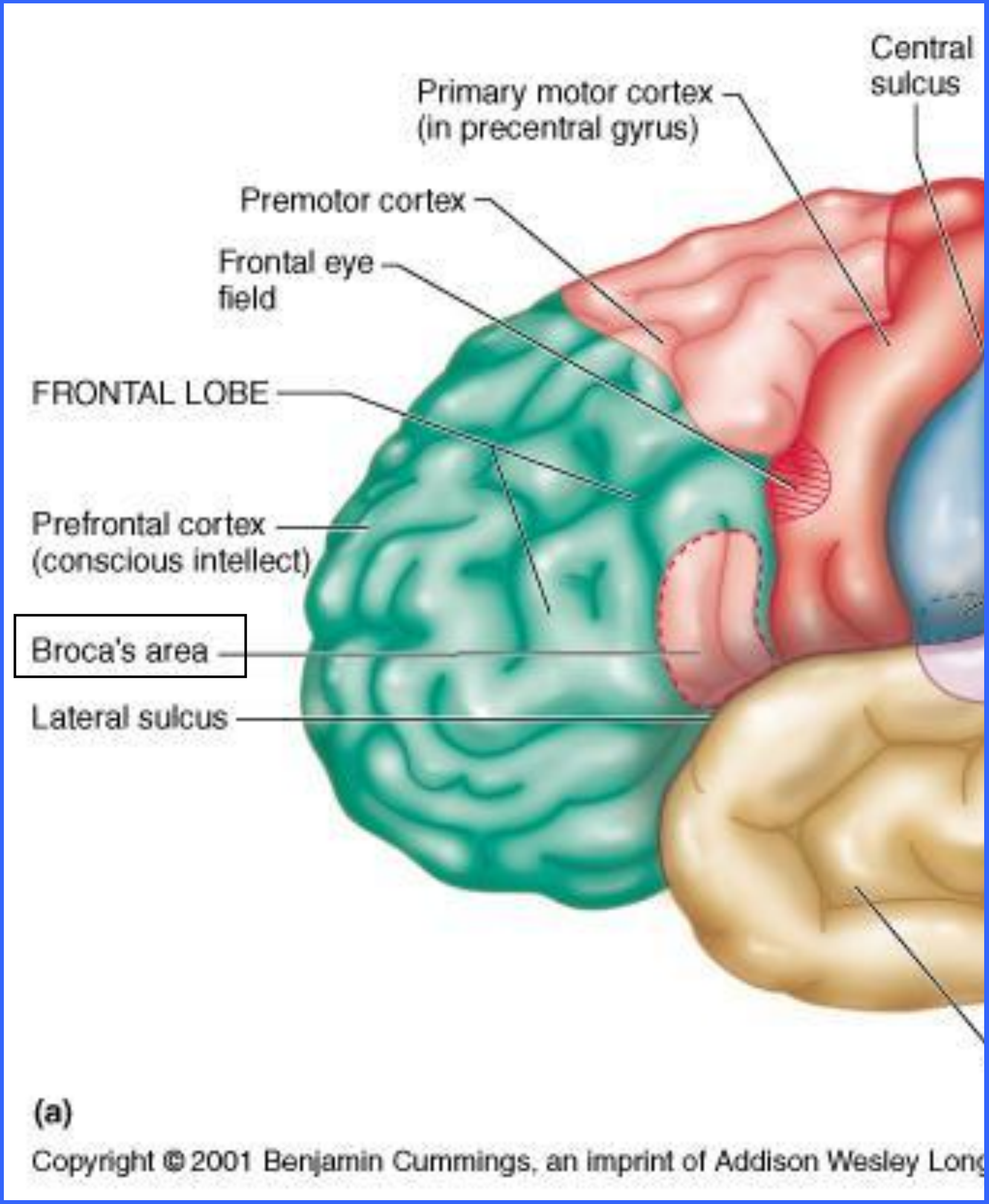
Premotor Cortex

- Damage to the premotor area results in the loss of the motor skills in that region
- Muscle strength and the ability to perform the discrete individual movements are not hindered
- Neurons relearning the skill would require practice



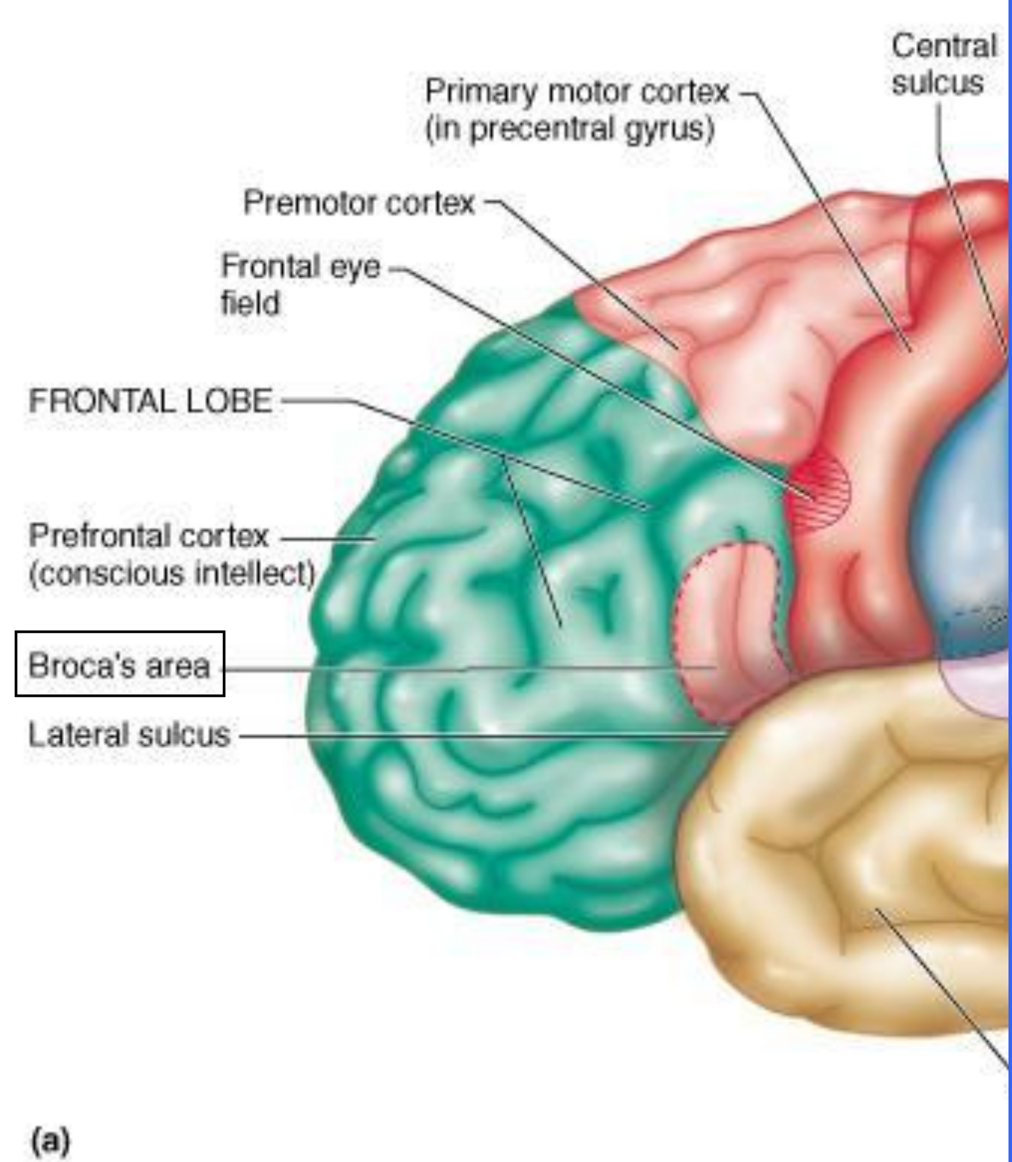
Broca's area

- The area has long been considered to be present in only one hemisphere (usually left)
- A special motor speech area that directs the muscles of the tongue, throat, and lips in articulating words



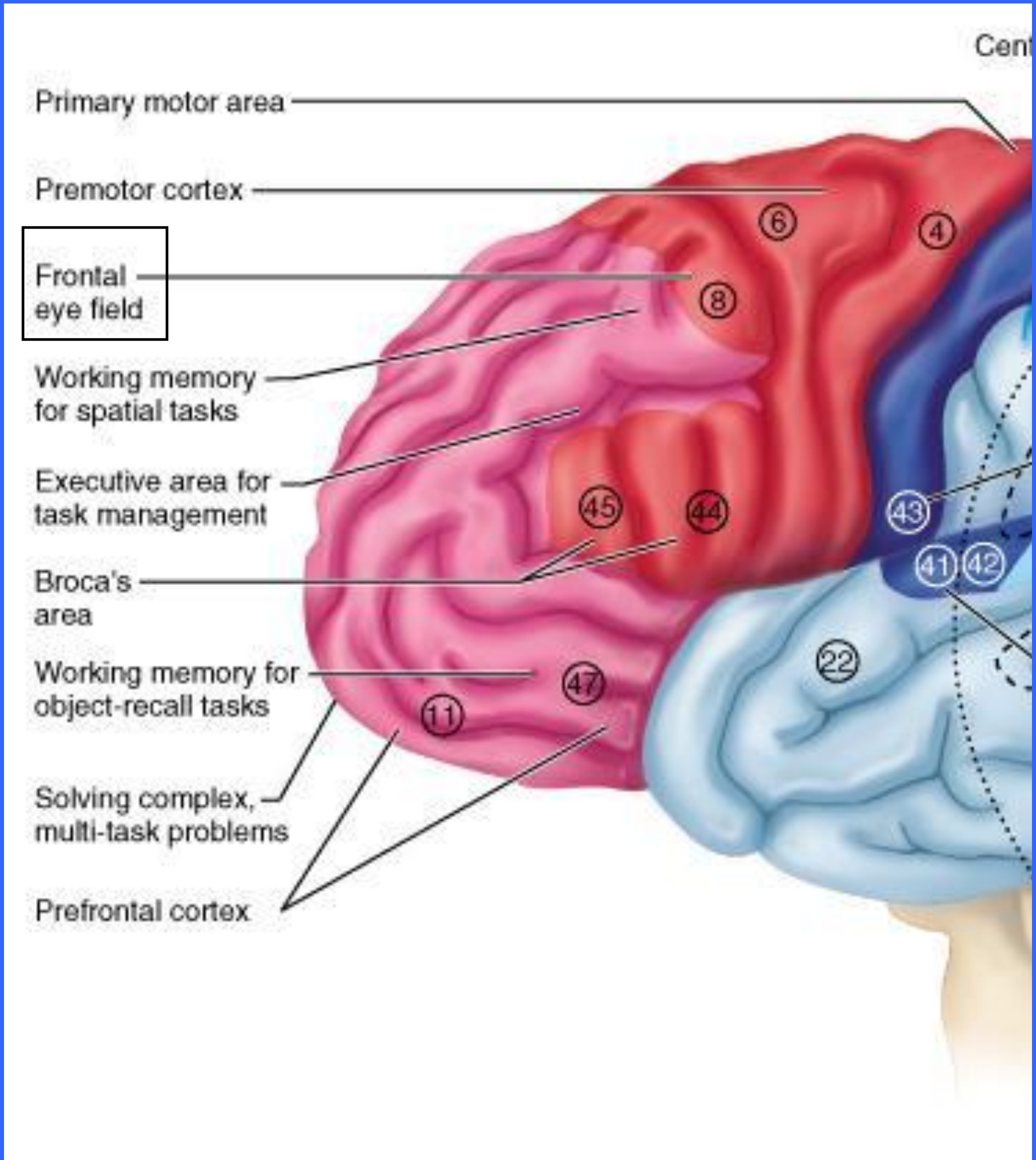
Broca's area

- Recent PET scans indicates that Broca's area and a similar area in the opposite hemisphere become active as we prepare to speak
- The areas may be involved with planning speech and other voluntary motor activities

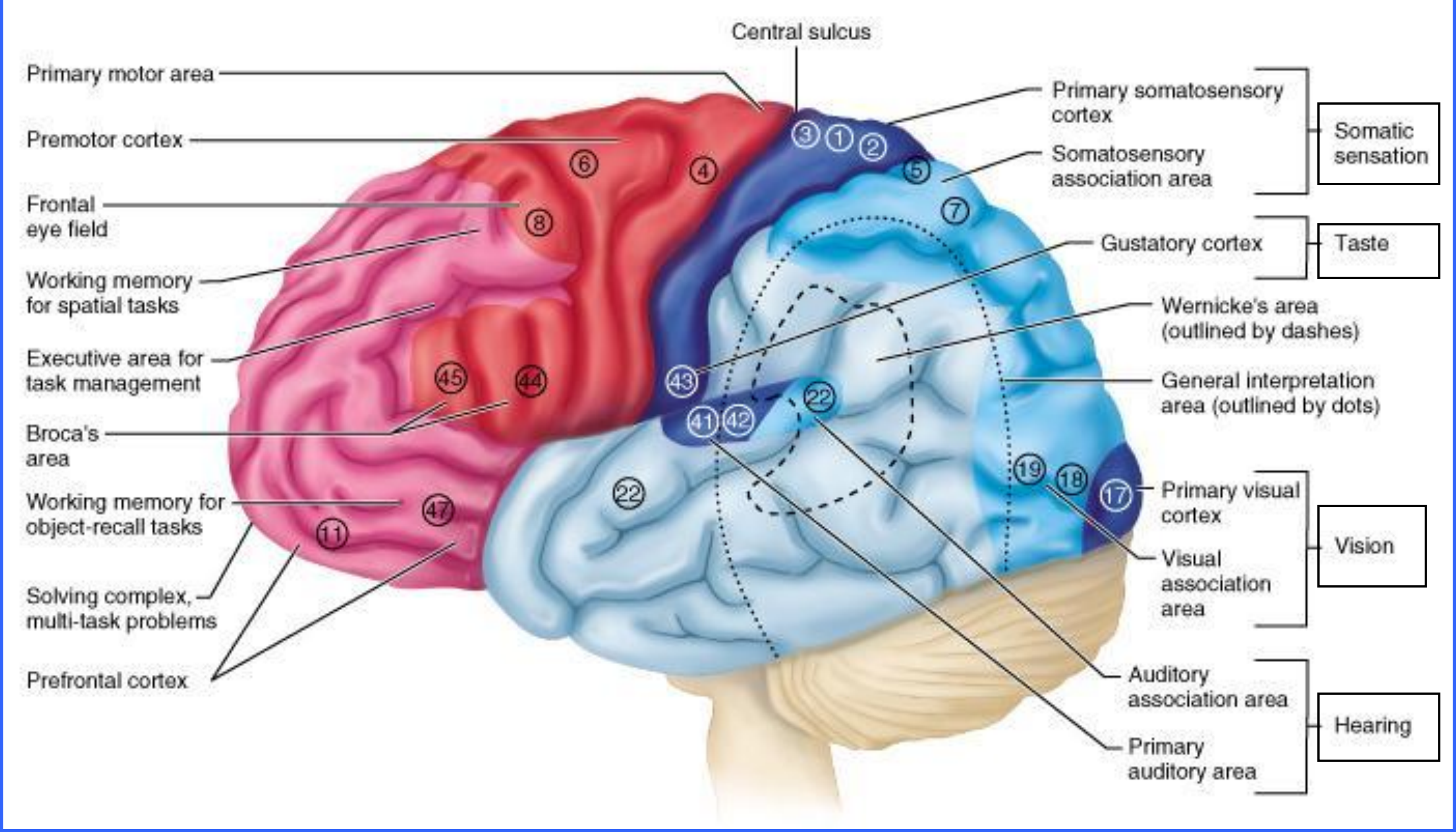


Frontal Eye Field

- This cortical region controls the voluntary movements of the eyes
- Engaged when we look quickly at something, as in moving our eyes to follow a moving target



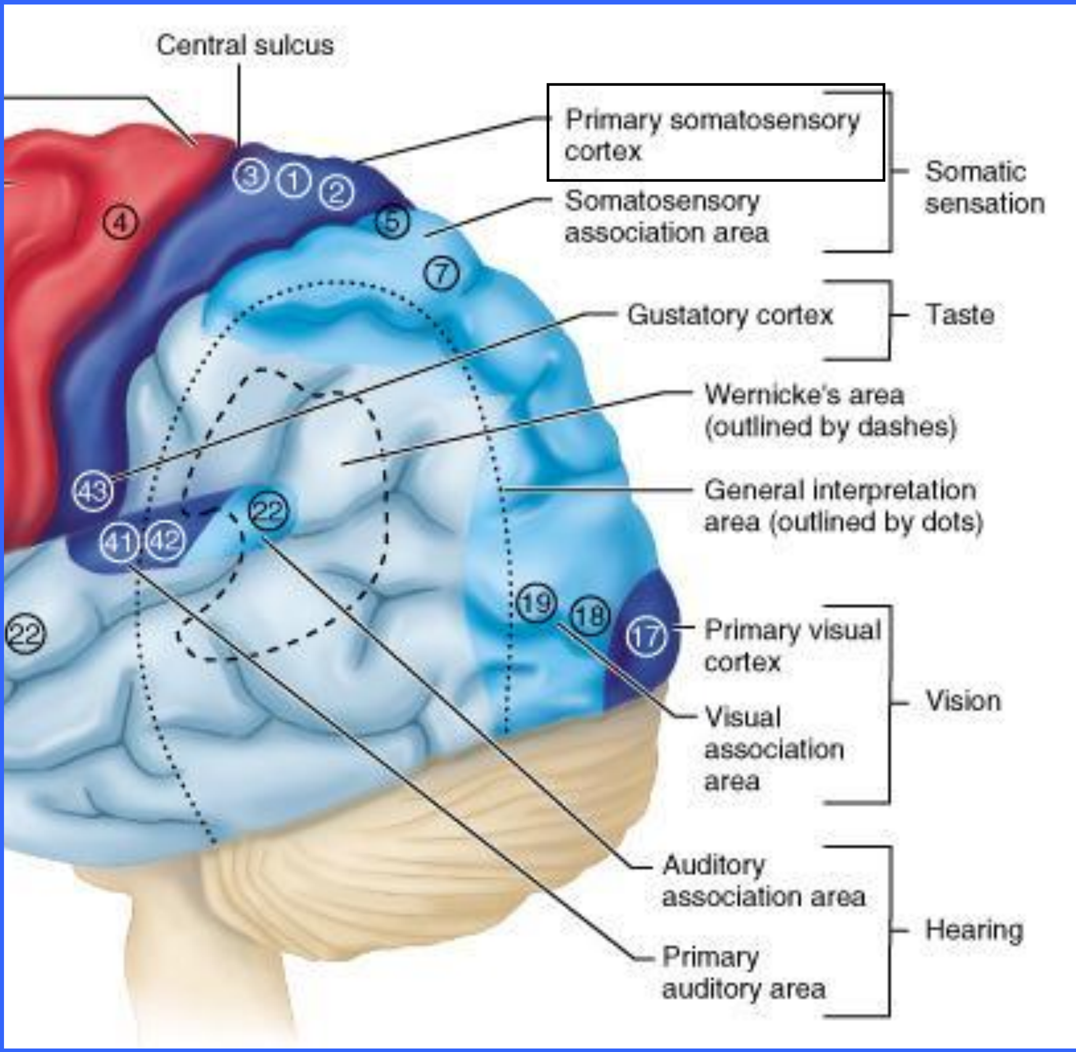
Sensory Areas



- **Areas concerned with the conscious awareness of sensation in the parietal, temporal and occipital lobes**

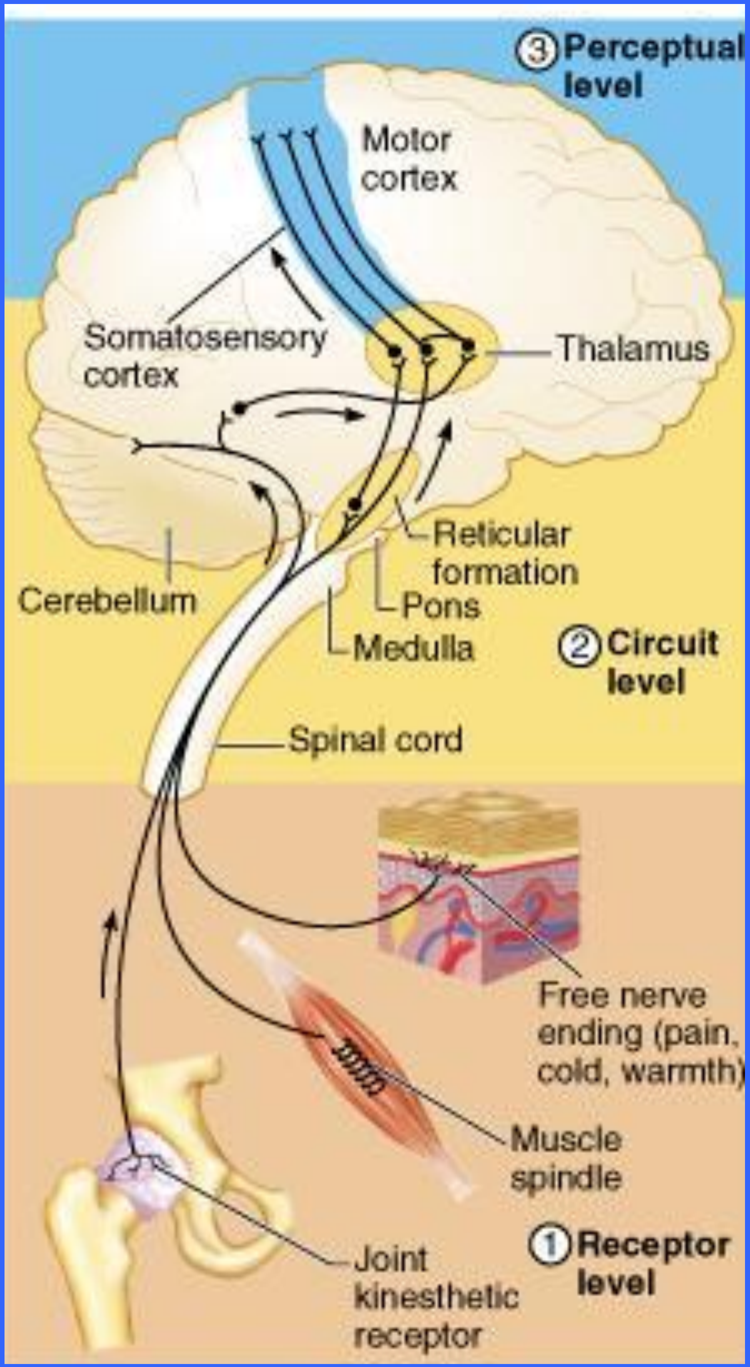
Primary Somato-sensory Cortex

- Primary somato-sensory area resides in the postcentral gyrus of the parietal lobe
- Neurons in this gyrus receive information relayed via a three neuron synaptic chain from general sensory receptors in the skin and proprio- ceptors in muscles



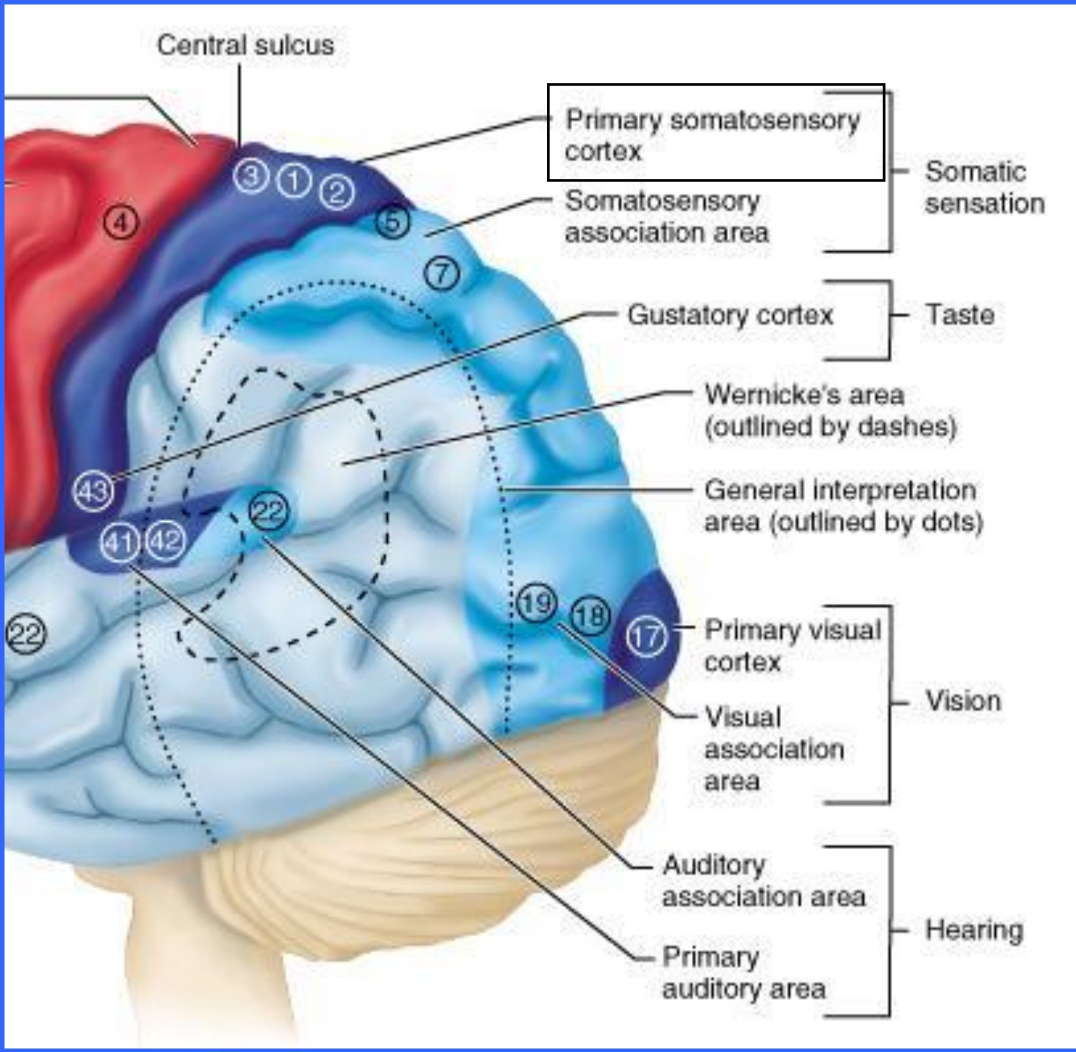
Synaptic Chain

- Central axons of sensory (1st order) neurons enter dorsal root of spinal cord
- Synapse with 2nd order neurons in medial lemniscal tract and ascend to Thalamus
- Synapse with 3rd order neurons which transmit to somato-sensory cortex

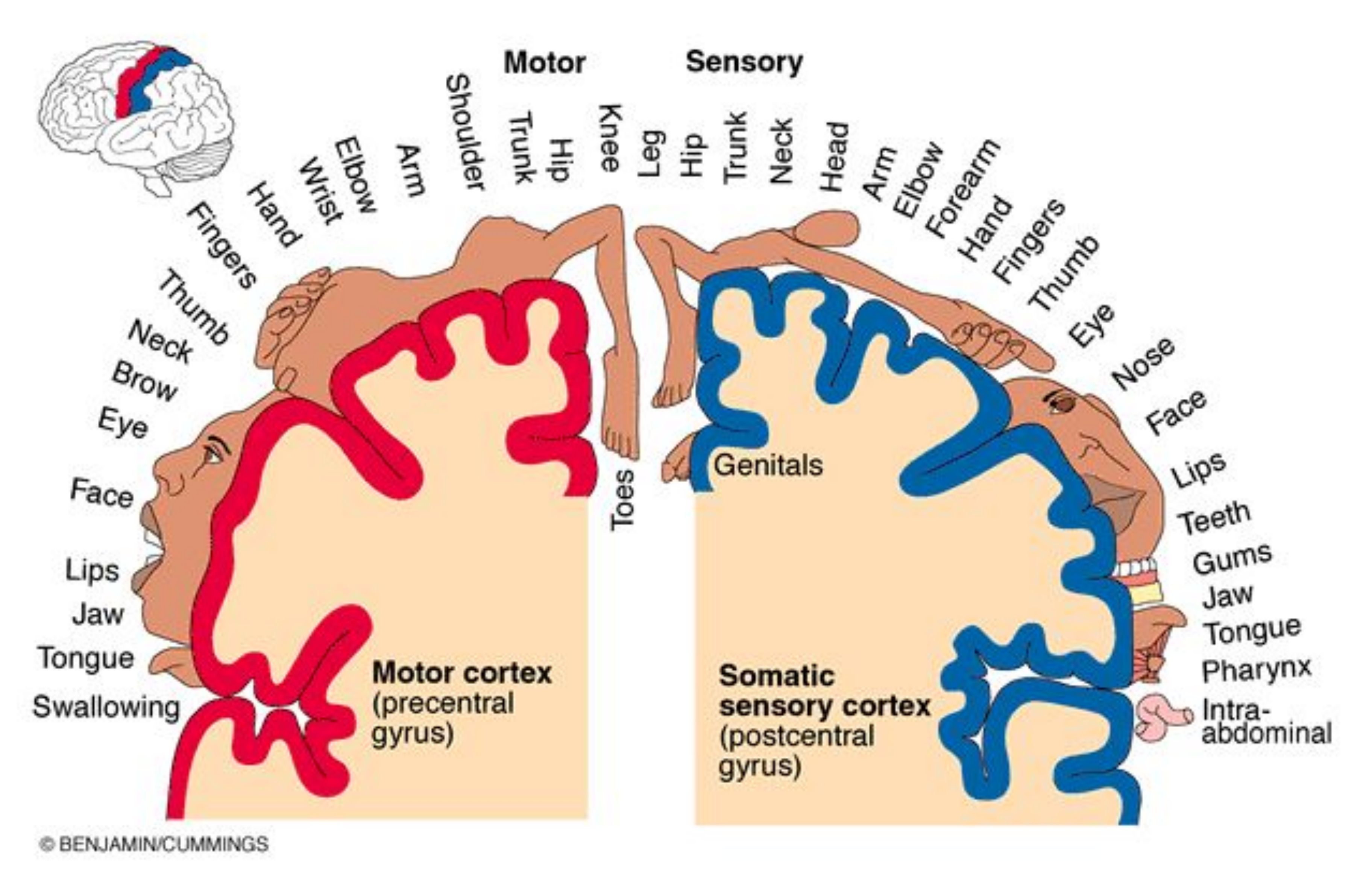


Primary Somato-sensory Cortex

- In the cortex neurons process the sensory information and identify the precise area of the body being stimulated
- This ability to localize (assign a location) a stimulus precisely is called spatial discrimination

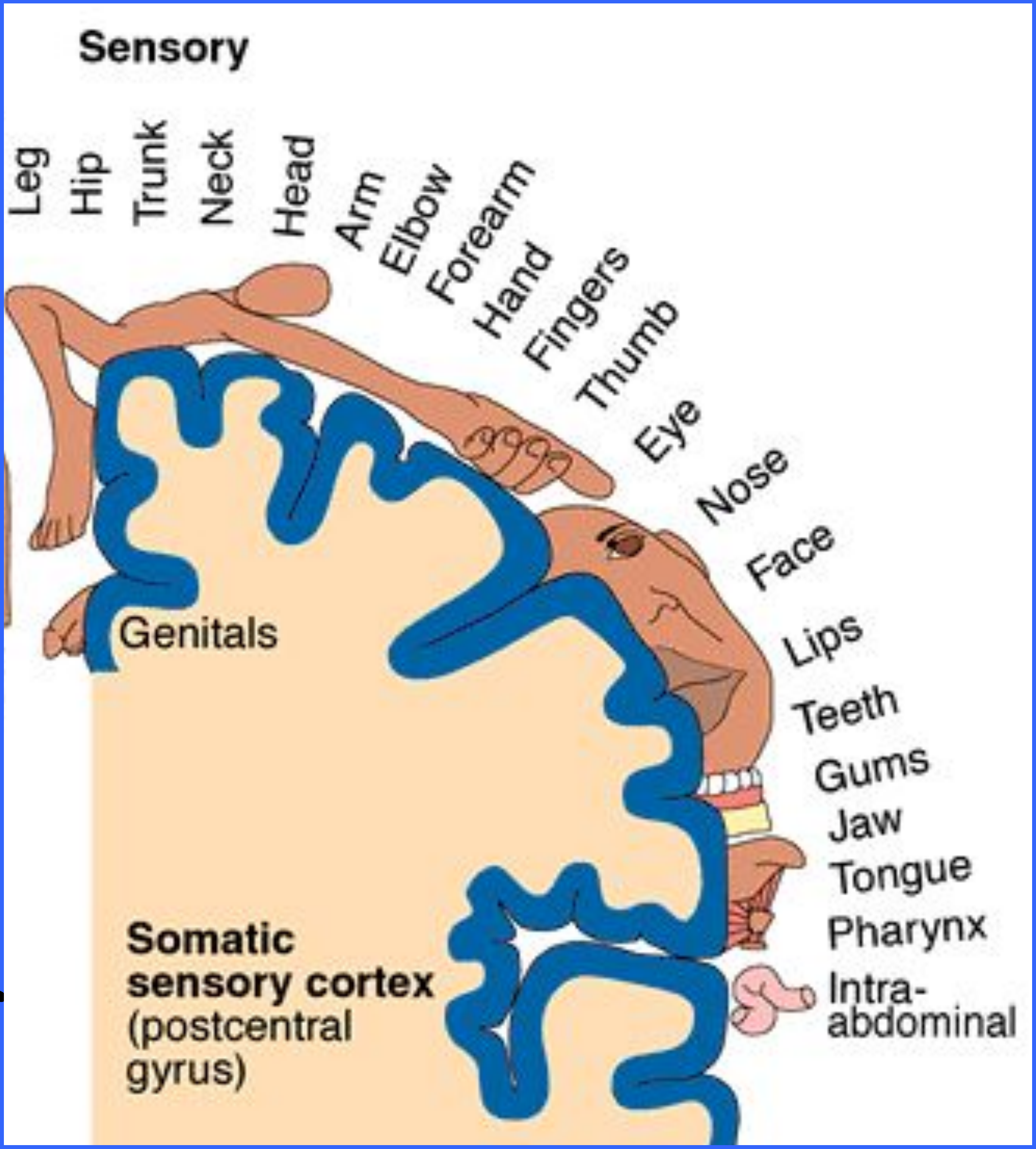


Motor and Sensory Somatotopy



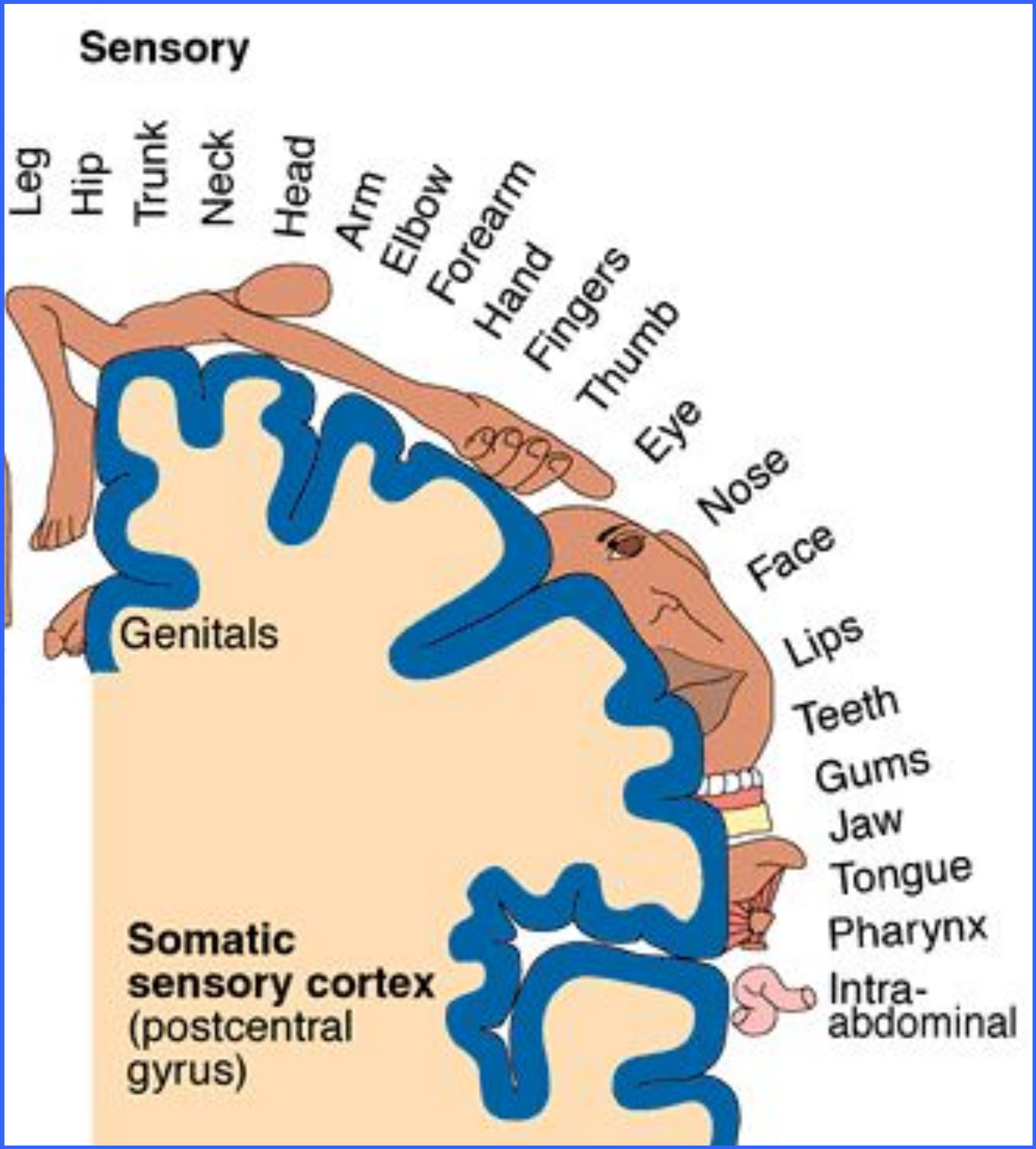
Primary Somato-sensory Cortex

- The sensory spatial discrimination is contralateral with the right hemisphere receiving inputs from the left side of the body
- The entire body is represented spatially in the primary somatosensory area of each hemisphere



Primary Somato-sensory Cortex

- The amount of sensory cortex devoted to a particular body region is related to how many sensory receptors are present
- In humans the face (especially the lips) and fingertips are the most sensitive body areas

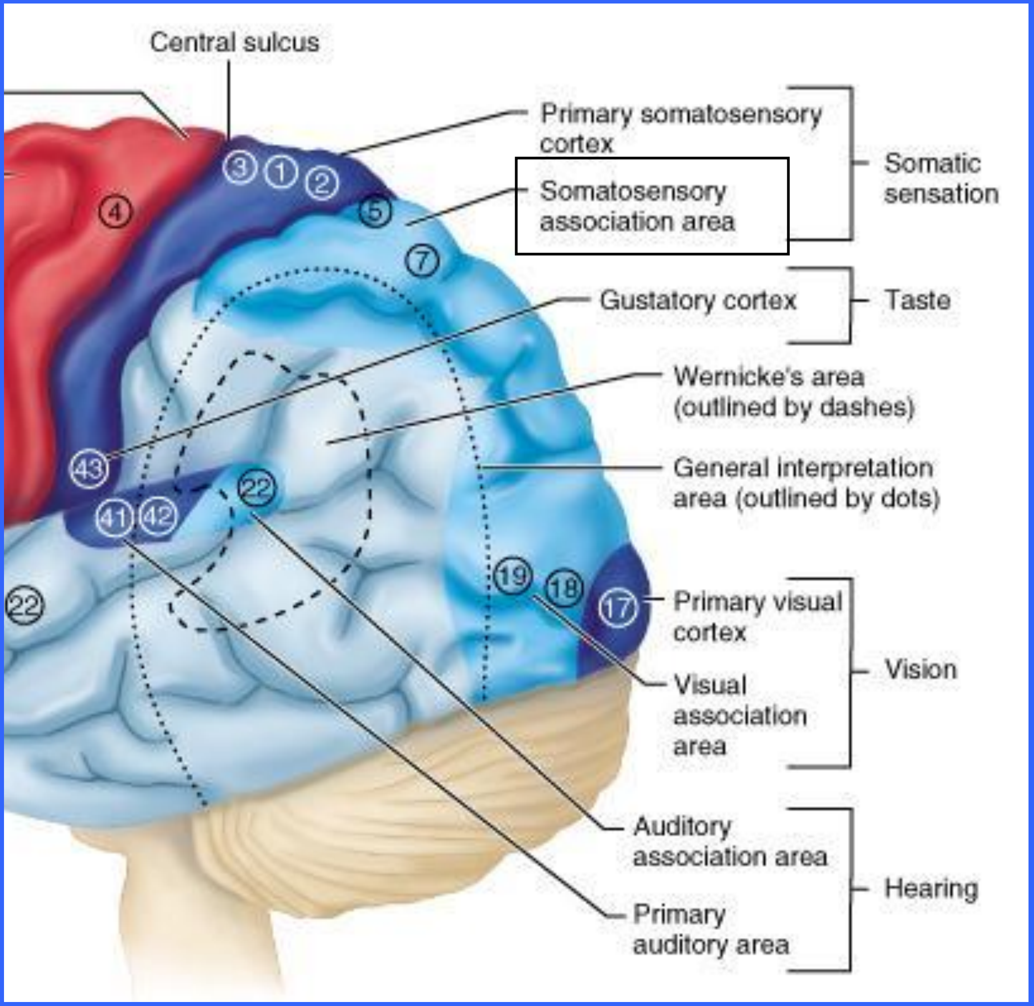


Primary Somatosensory Cortex

- Damage to the primary somatisensory cortex destroys the conscious ability to feel and localize touch, pressure, and vibrations on the skin
- Most ability to feel pain and temperature is also lost, although these can still be felt in a vague, poorly localized way

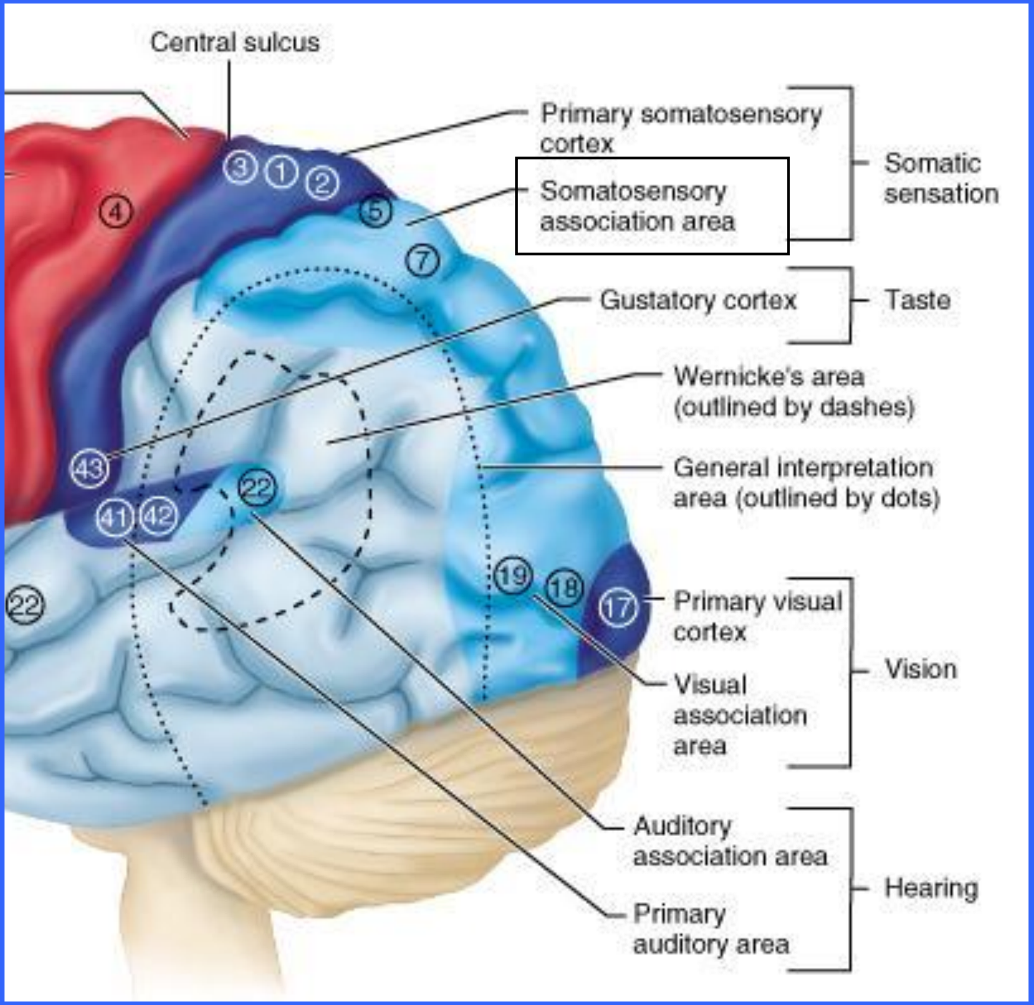
Somatosensory Association Area

- The area lies just posterior to the primary somata-sensory cortex and has many connections with it (Broadmann 5,7)
- The major function of the area is to integrate and analyze different somatic sensory inputs (touch, pressure, others) relayed to it by the primary somato-sensory cortex



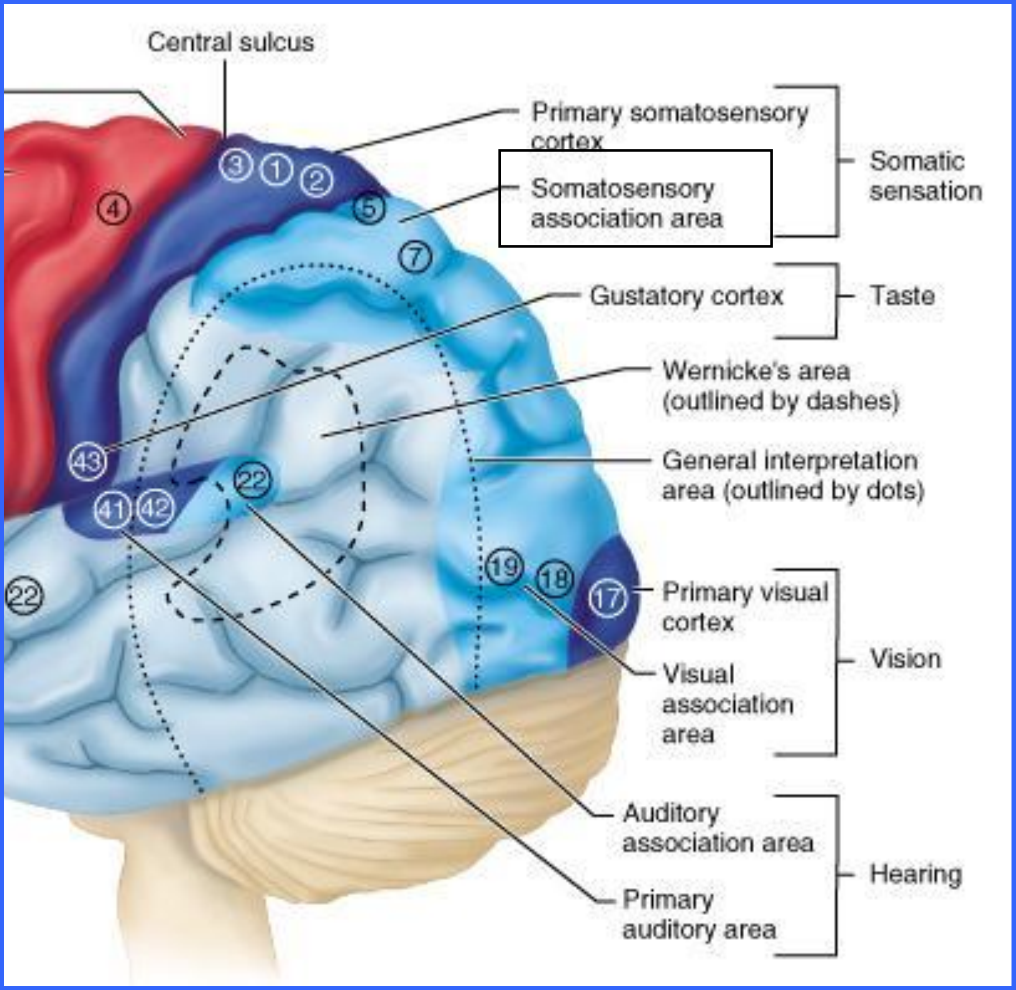
Somatosensory Association Area

- The somatosensory association area forms a comprehensive evaluation of what is being felt relative to its size, texture and parts
- The somatosensory association area draws upon stored memories of past sensory experiences to perceive the object as one you recognize



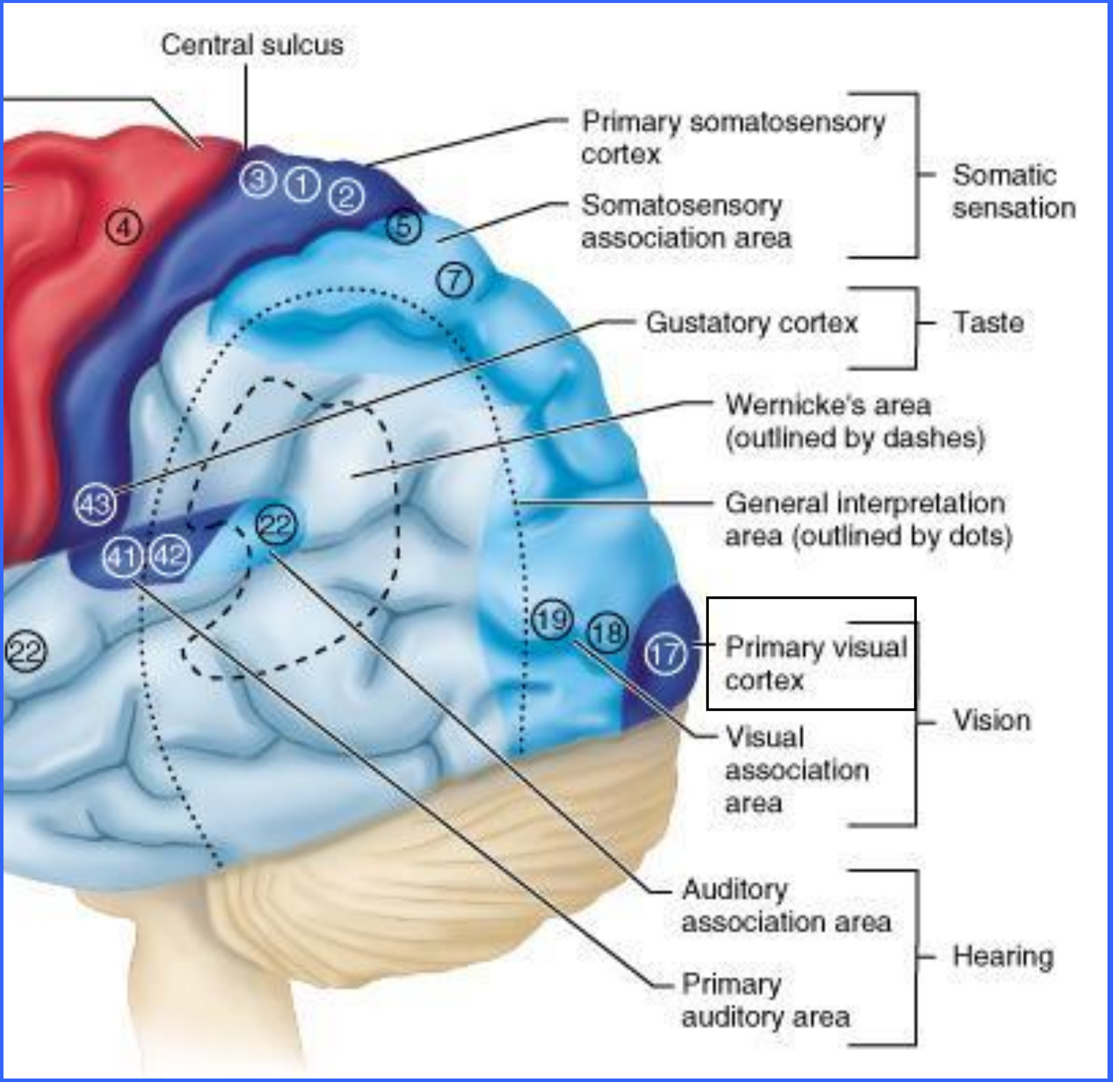
Somatosensory Association Area

- Past associations allow you to recognize familiar objects (coins, keys) without having to look at them
- Someone with damage to this area would not be able to recognize what they are feeling without actually looking at the object

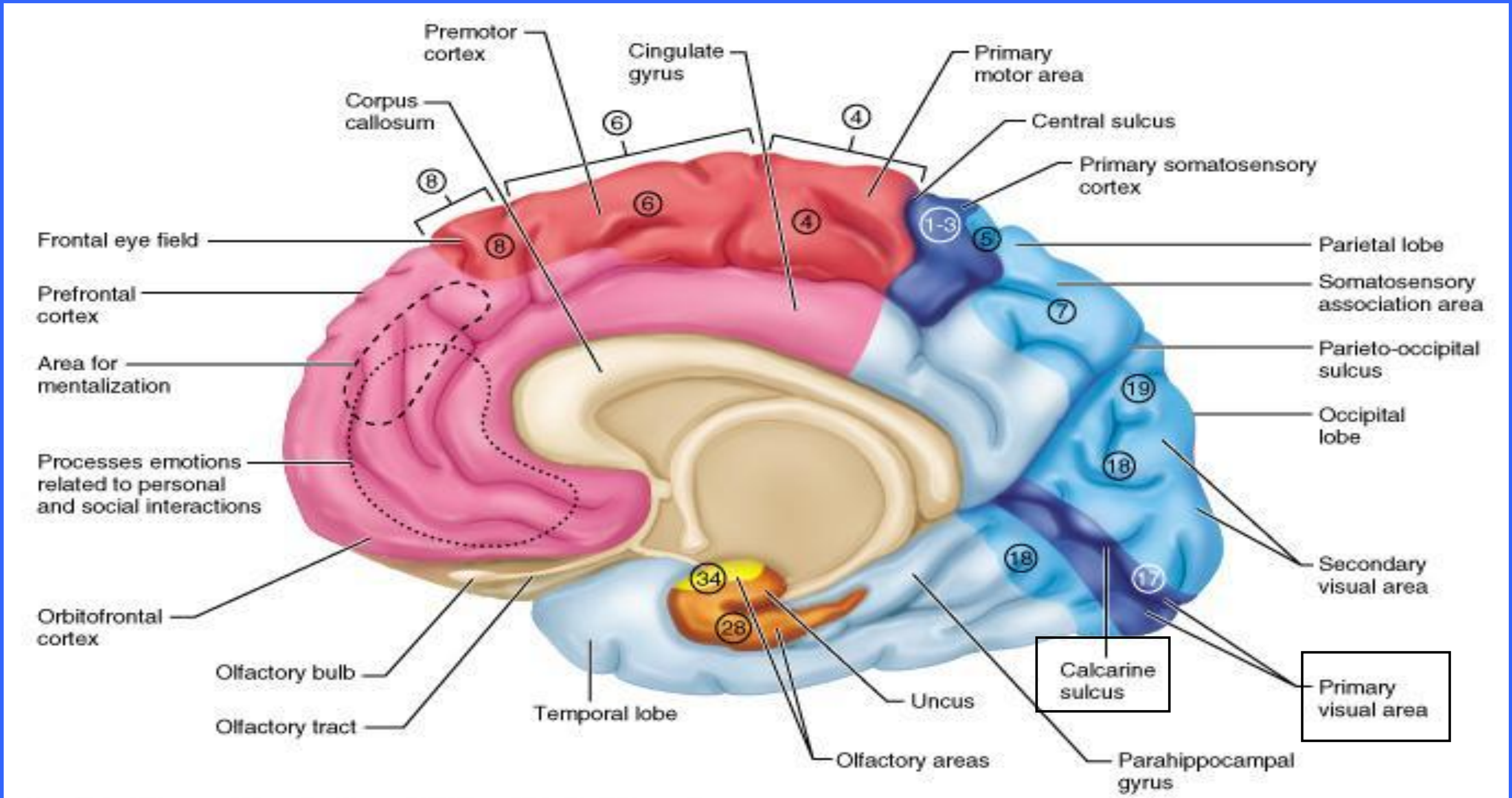


Primary Visual Cortex

- The primary visual cortex (17) is located on the posterior and medial portions of the occipital lobe



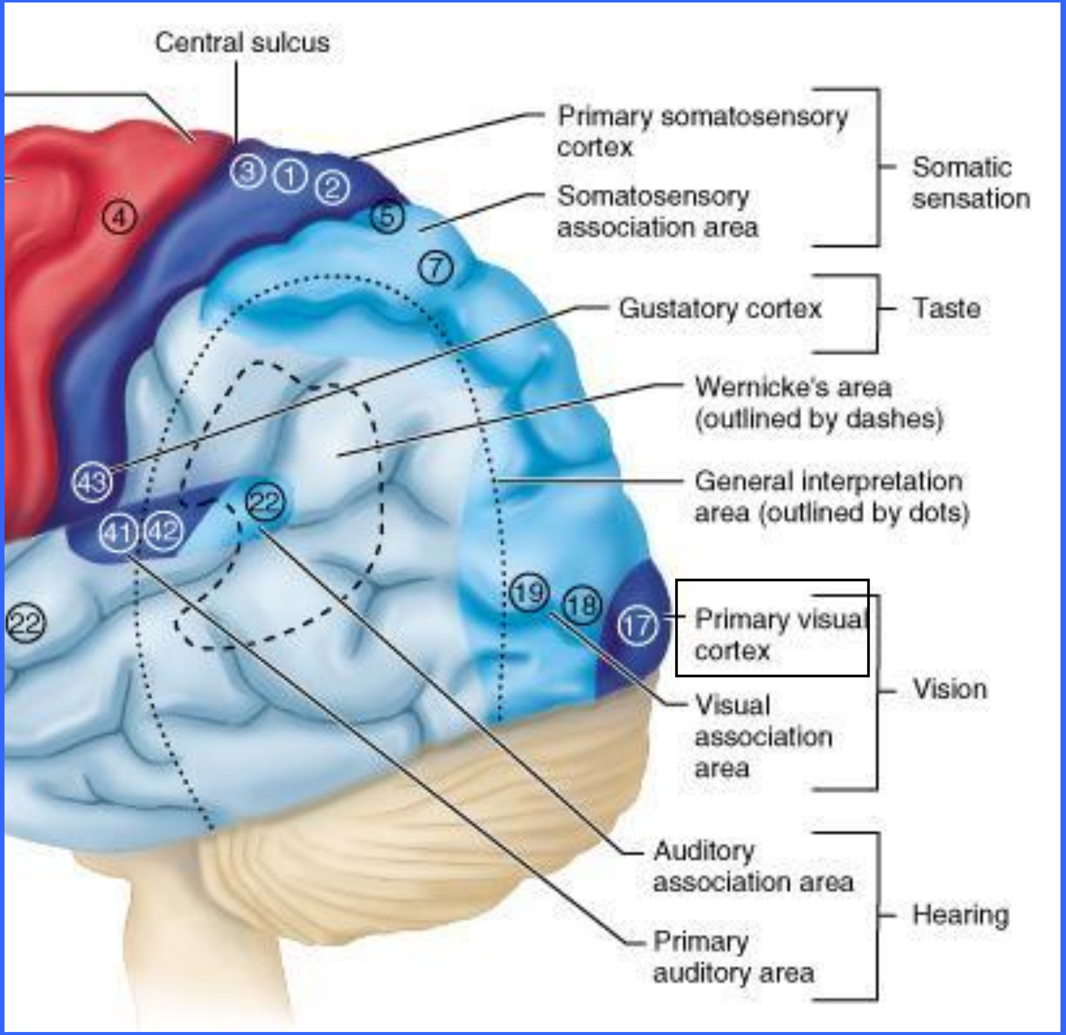
Primary Visual Cortex



- **Most of the primary visual cortex is located on the medial aspect of the occipital lobe buried within the deep calcarine sulcus**

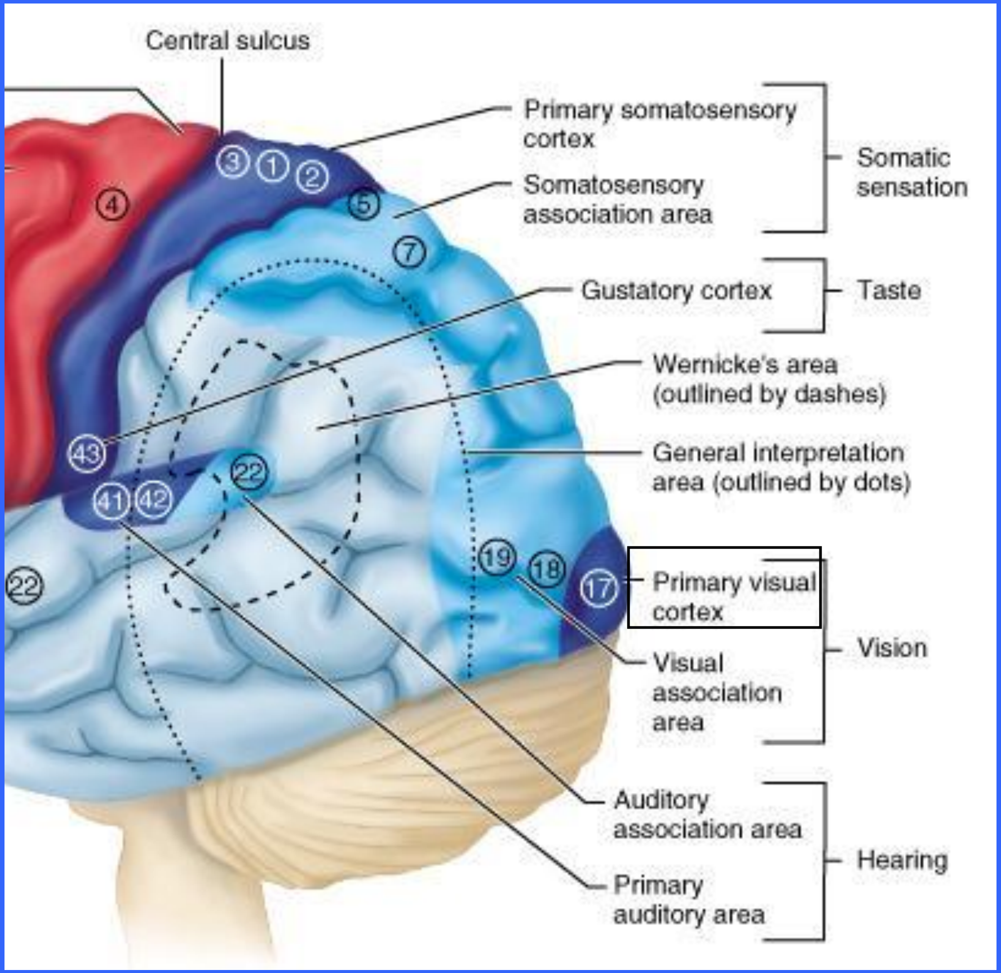
Primary Visual Cortex

- The largest of all cortical sensory areas, the primary visual cortex receives visual information that originates on the retinas of the eyes
- There is a map of visual space on the primary visual cortex analogous to the body map of the somato-sensory cortex



Primary Visual Cortex

- Again, the right half of visual space is represented on the left visual cortex, the left half on the right cortex
- If this cortical area is damaged, the person has no conscious awareness of what is being viewed and is functionally blind

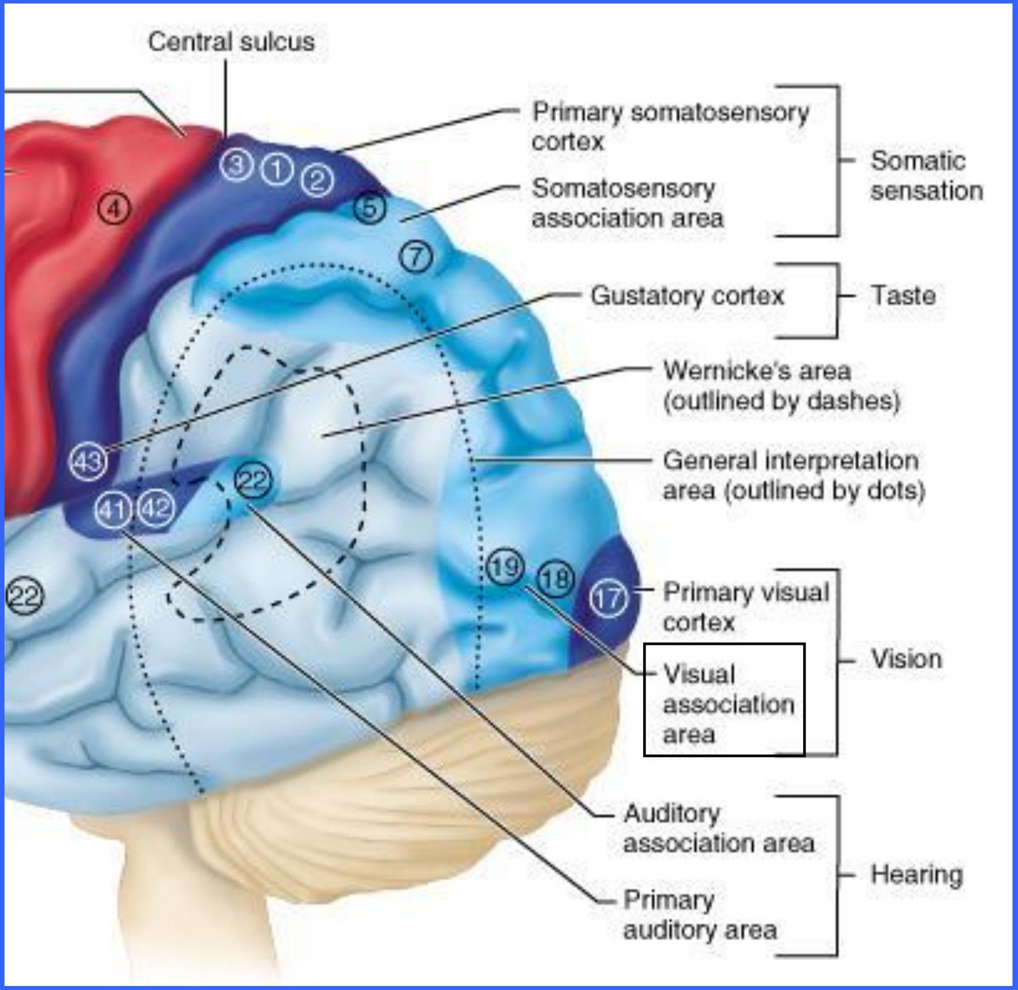


Primary Visual Cortex

- The primary visual cortex is the first of a series of cortical areas that process visual input
- The processing here is at a comparatively low level - noting the orientation of objects being viewed and putting the inputs from the two eyes together

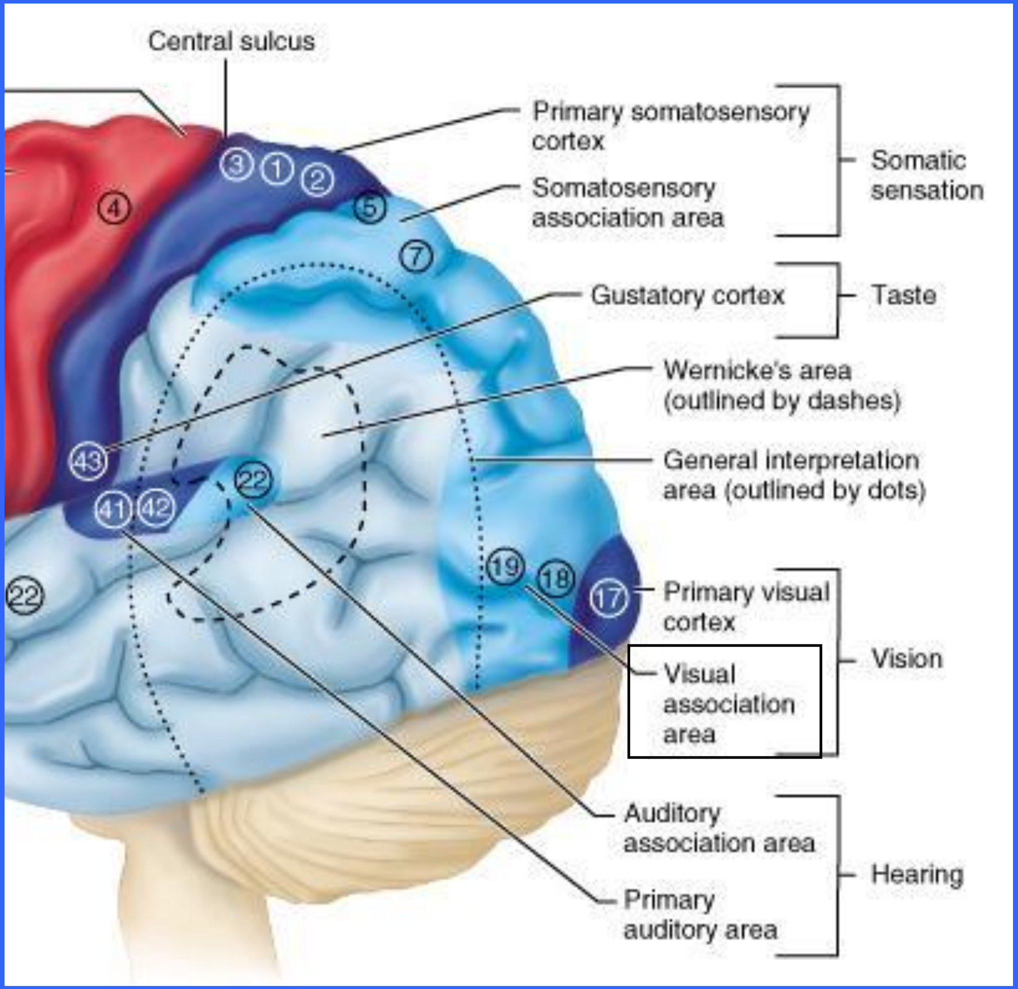
Visual Association Area

- This area surrounds the primary visual area and encompasses much of the occipital lobe (18, 19)
- Communicating with the primary visual area, the visual association area continues the processing of visual information



Visual Association Area

- This area analyzes color, form and movement in light of past visual experiences so that we might recognize & appreciate what we are seeing

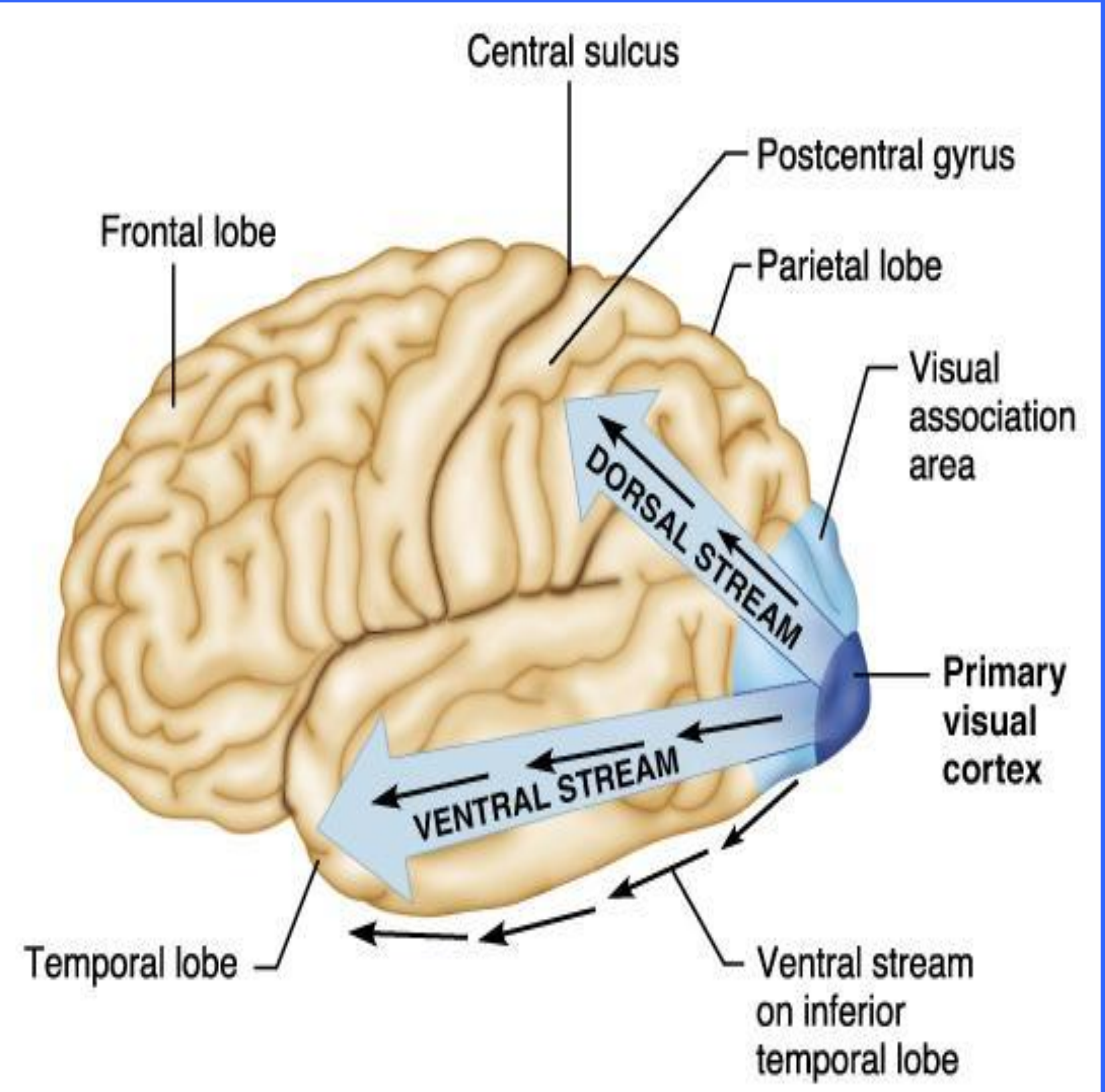


Visual Association Area

- Recent neuroimaging has revealed that complex visual processing far forward from the occipital lobe into the temporal and parietal lobes
- Overall, about 30 cortical areas for visual processing have been identified, with each more sophisticated than the last
- The visual information proceeds anteriorly through these visual areas in two streams

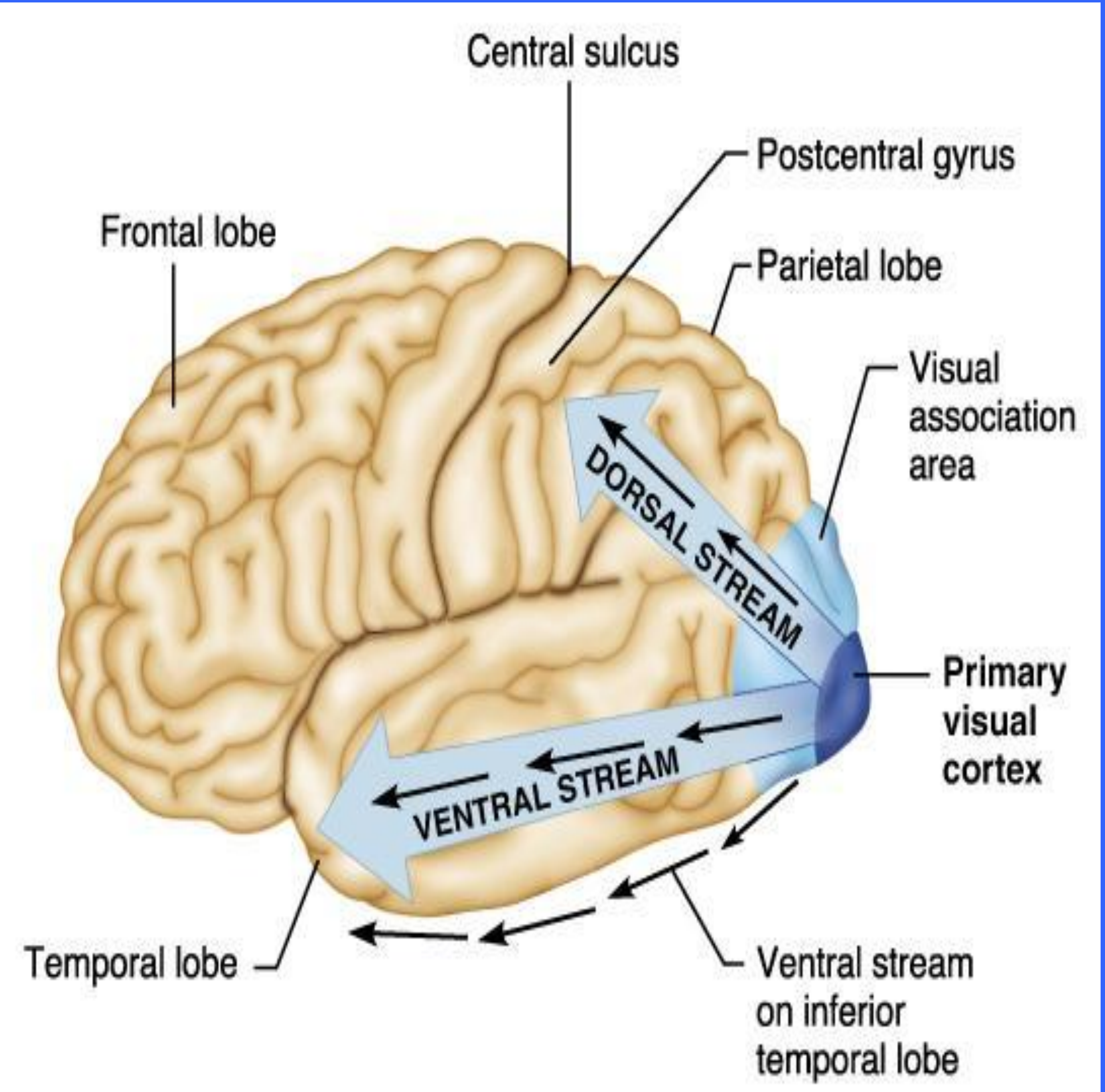
Visual Association Area

- **The ventral stream extends through the inferior part of the entire temporal lobe and is responsible for recognizing objects, words during reading, and faces**
- **Facial recognition is right hemisphere only**
- **The "what"**



Visual Association Area

- The dorsal stream extends through the posterior parietal cortex to the postcentral gyrus and perceives spatial relationships among different objects
- The “where” things are in space

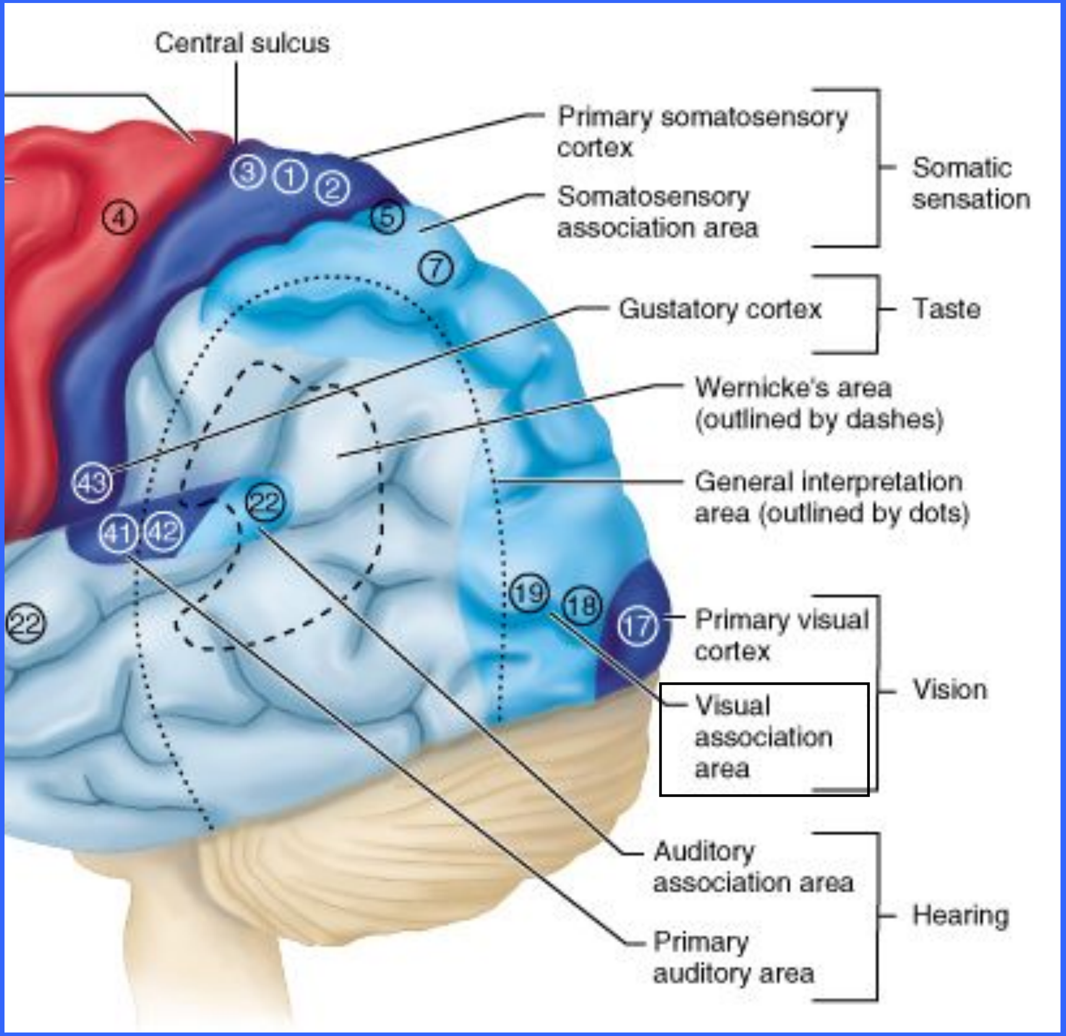


Visual Association Area

- **The dorsal stream in the parietal lobe is important for spatial perception**
- **The superior part of the lobe calculates how we move our limbs through space then sends this information to the motor cortex which dictates these movements**
- **In addition, the parietal lobe is important for abstract mathematical abilities, which are highly visual, spatial in nature**

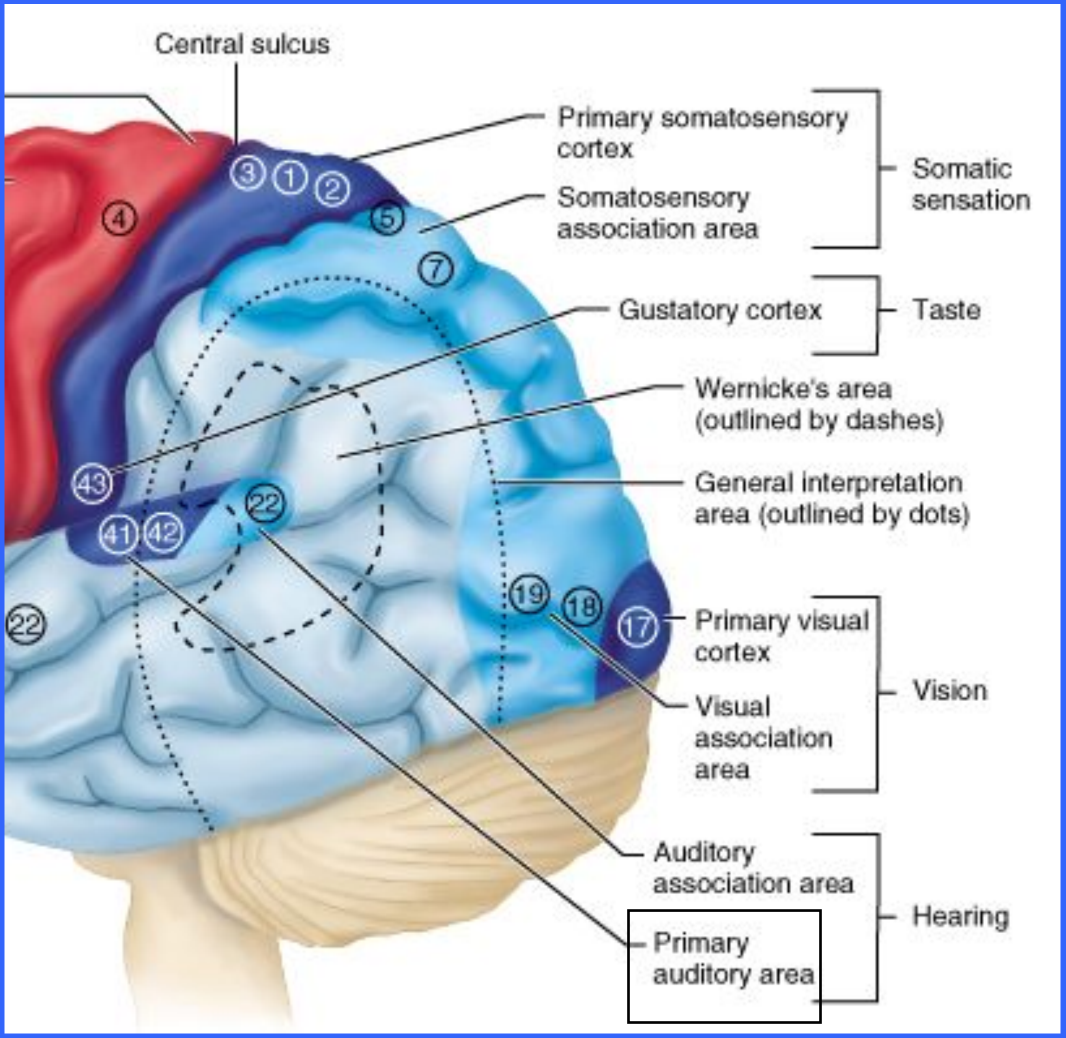
Visual Areas

- Damage to the visual cortex results in functional blindness
- Damage to the visual association areas results in an ability to see but not comprehend what is seen



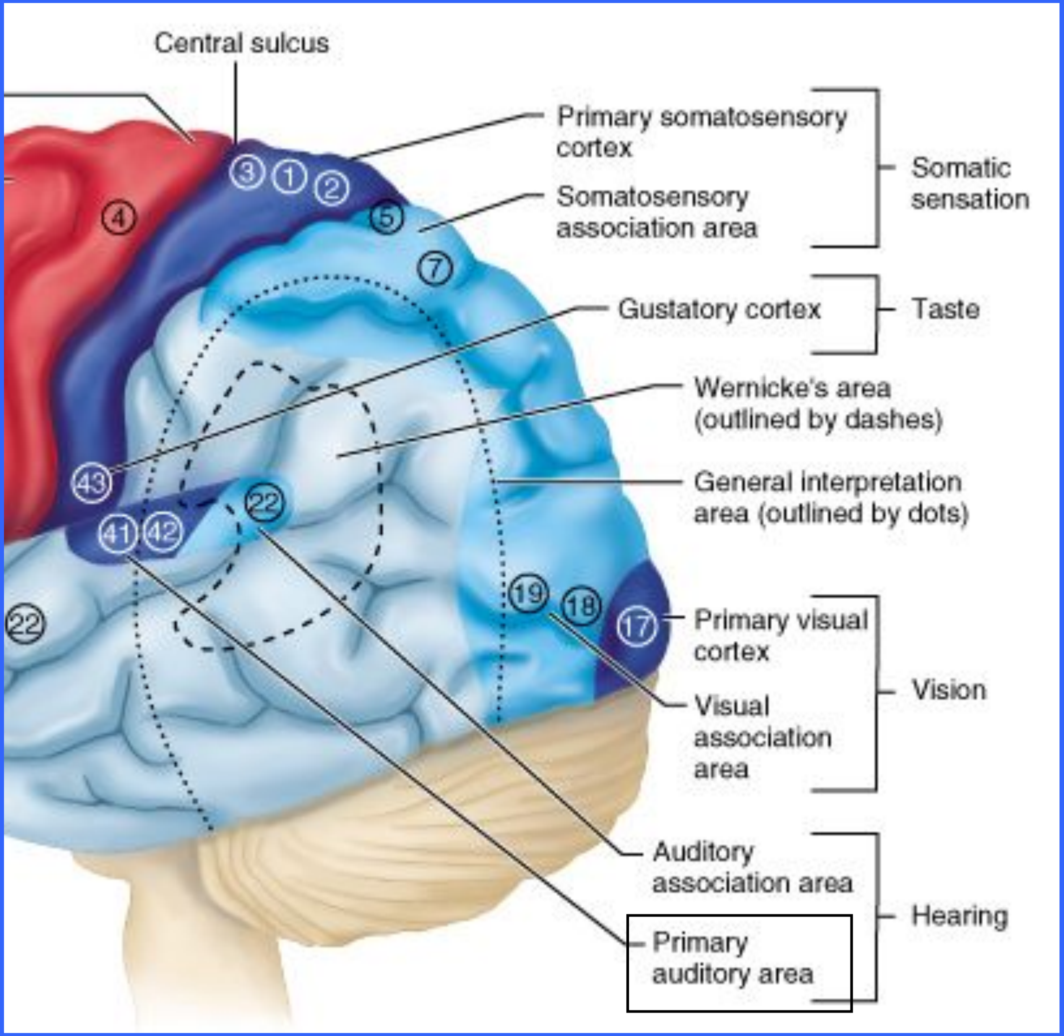
Primary Auditory Cortex

- The primary auditory cortex is located on the superior margin of the temporal lobe, primarily inside the lateral sulcus
- Broadmann 41,42
- It provides us with our conscious awareness of sound



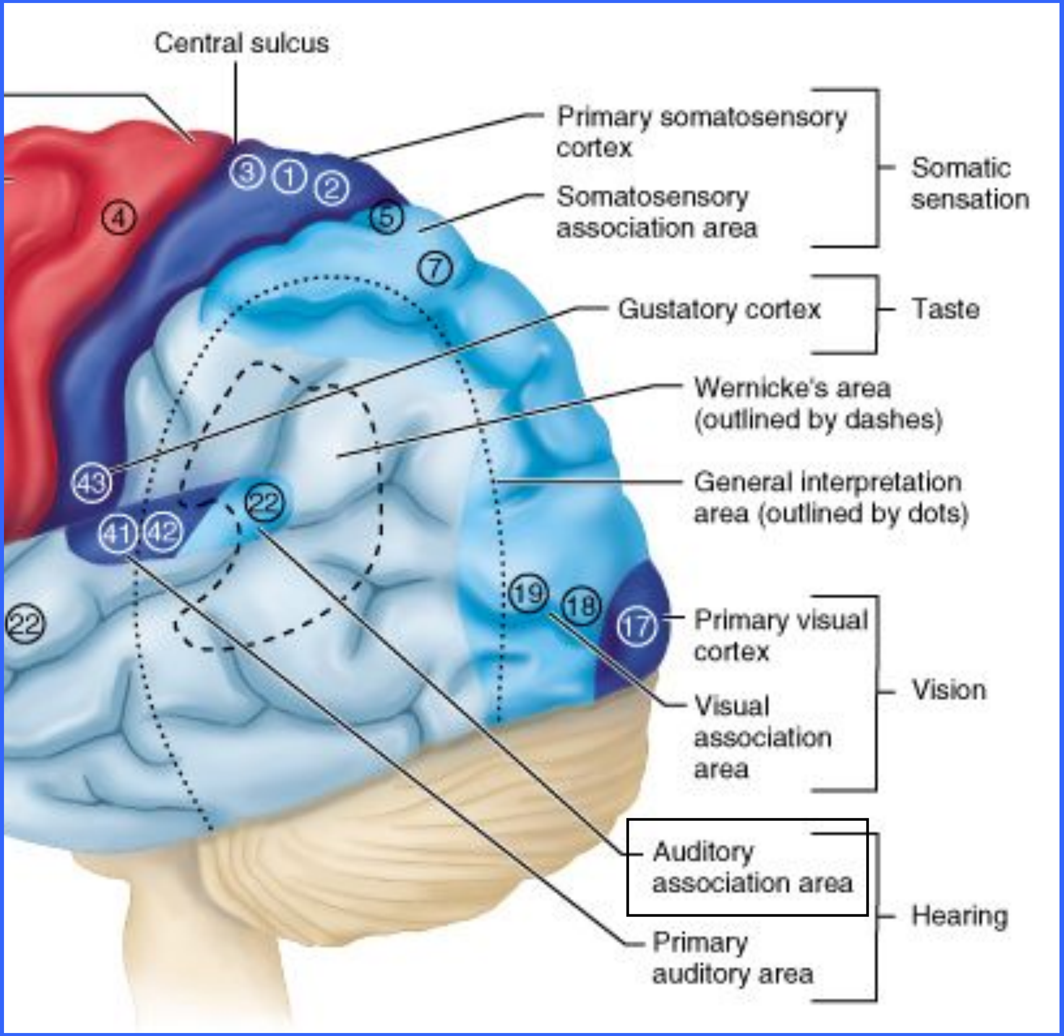
Primary Auditory Cortex

- Hearing receptors in the cochlear of the inner ear transmit impulses to primary auditory cortex
- Impulses related to loudness, rhythm, and especially pitch (high to low notes) is complied



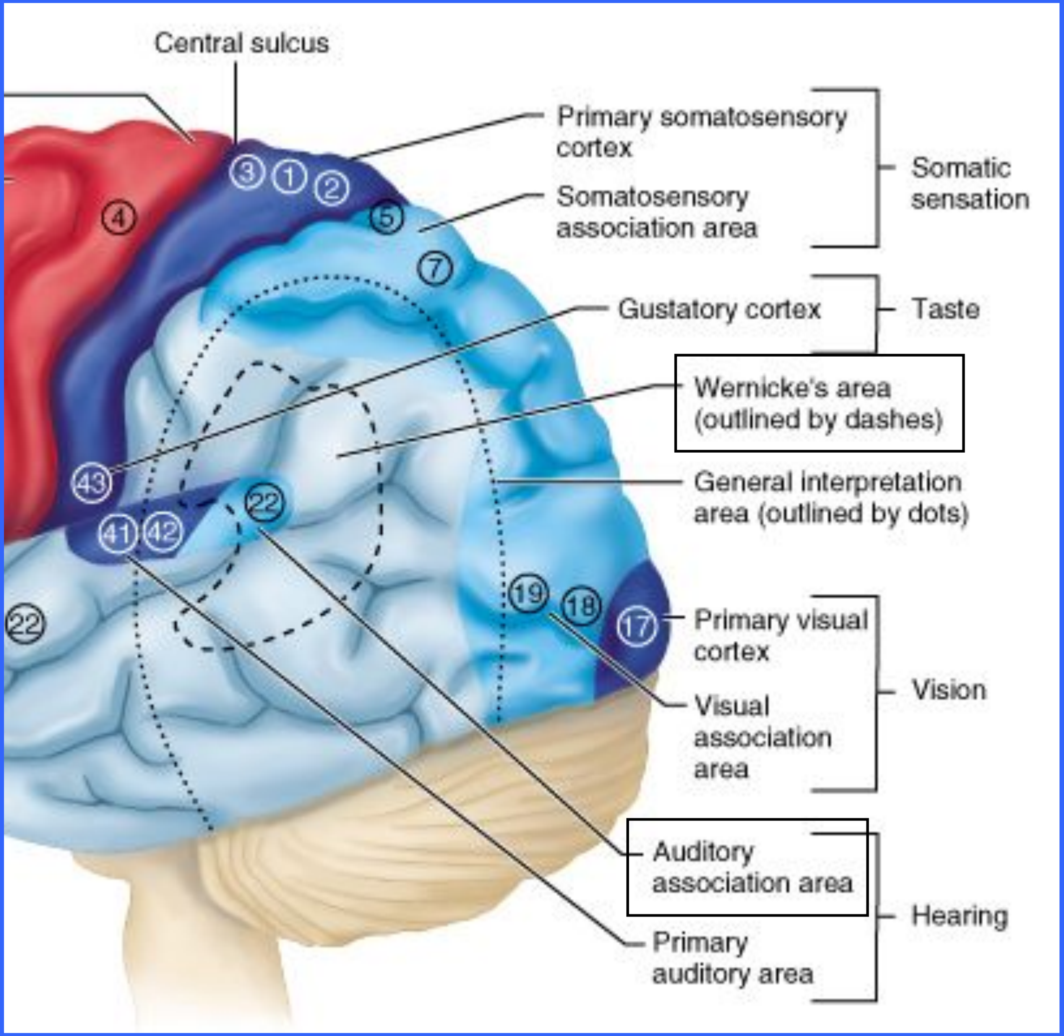
Auditory Association Area

- The auditory association area lies just posterior to the primary auditory area Broadmann 22
- This area evaluates and classifies sound
- Memories of past sounds seem to be stored here



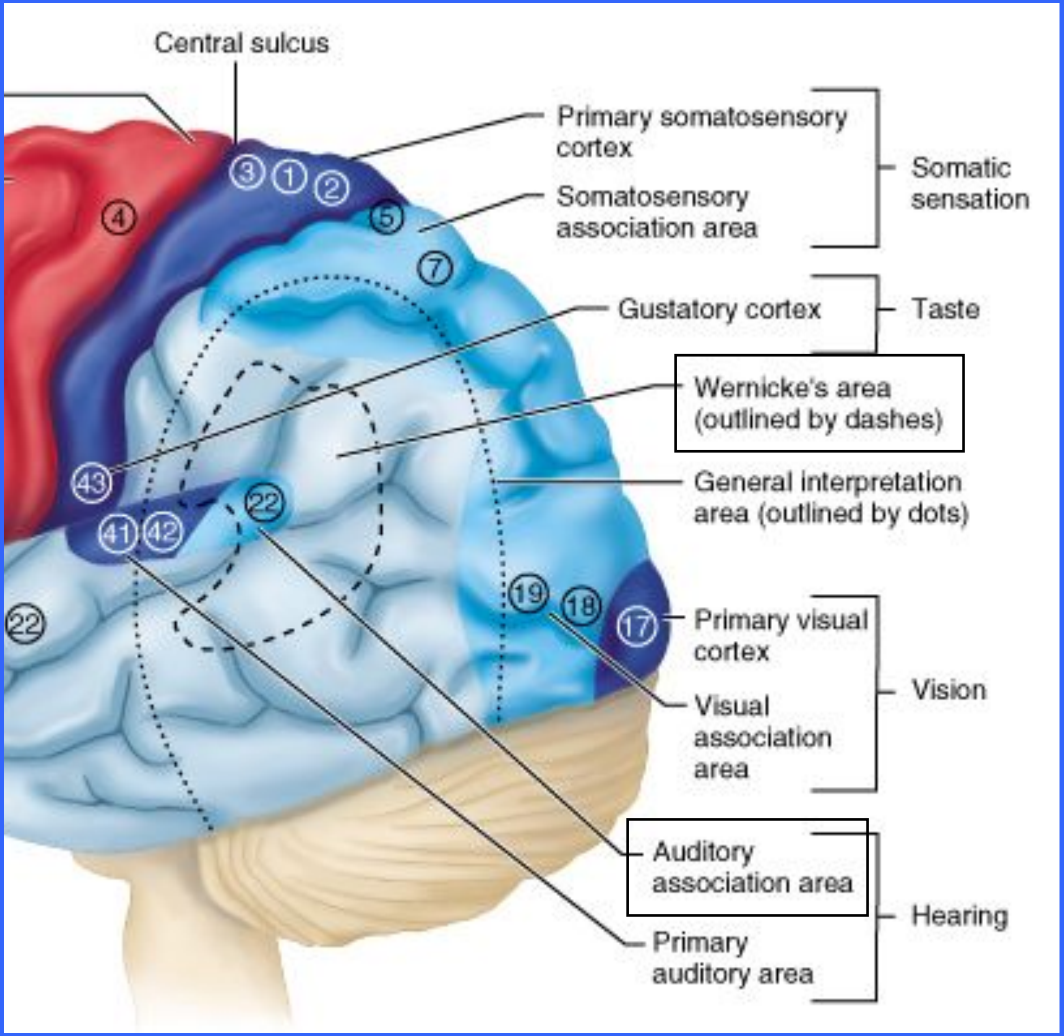
Auditory Association Area

- In one hemisphere (usually the left), the auditory association areas lies in the center of Wernicke's area
- This functional area is involved in recognizing and understanding spoken words



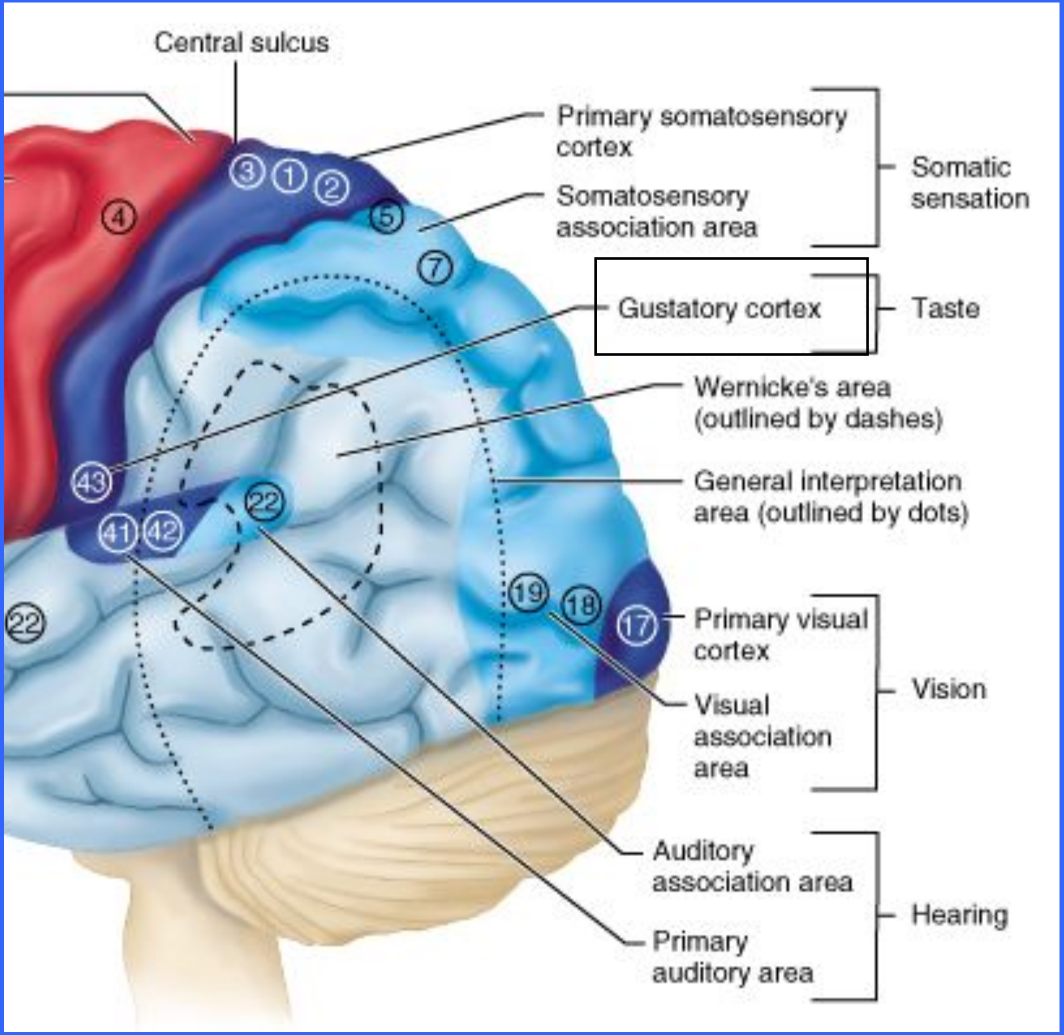
Auditory Association Area

- Damage to Wernicke's area interferes with the ability to comprehend speech



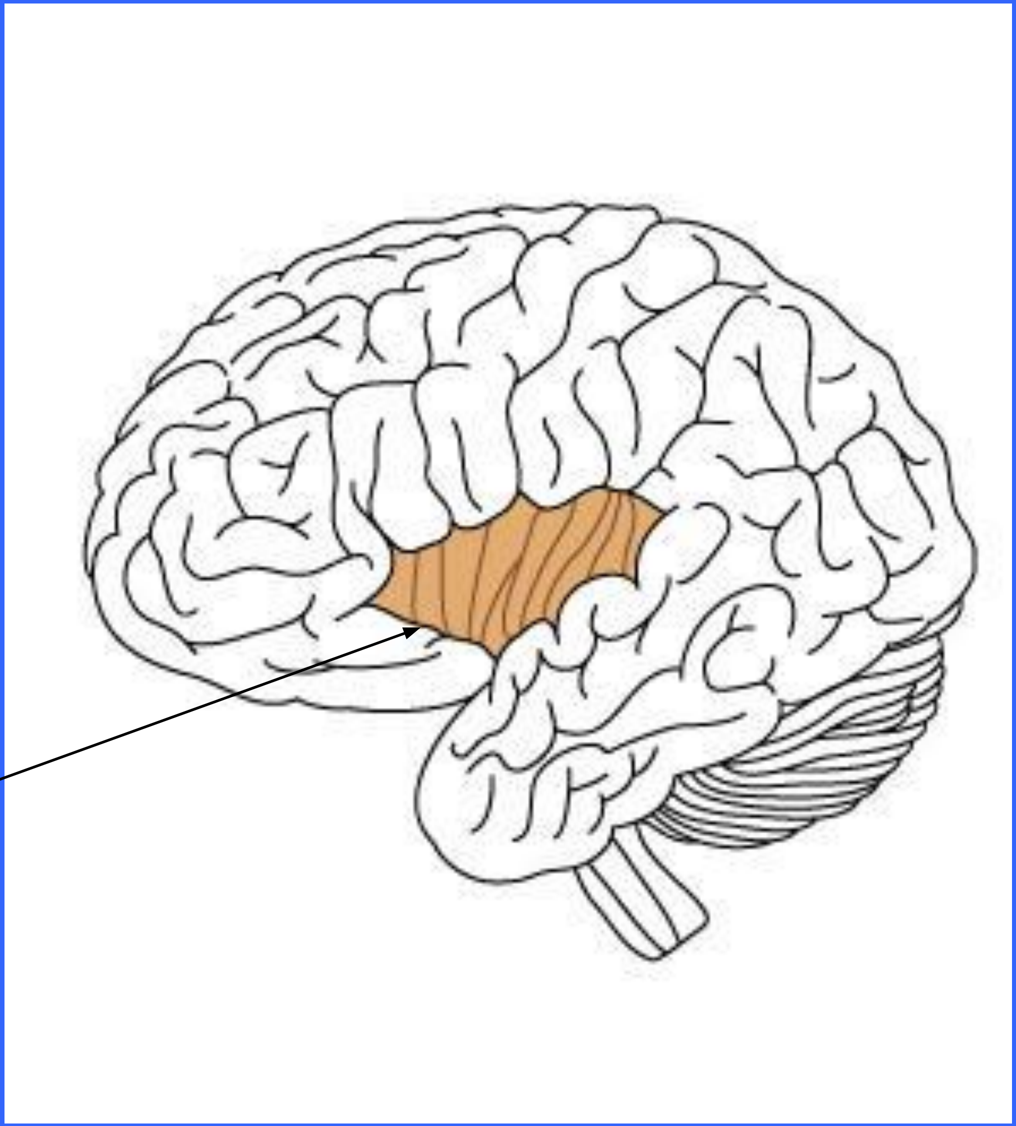
Gustatory (taste) Cortex

- The gustatory cortex is involved in the conscious awareness of tase stimuli
- Broadmann 43
- It lies on the roof of the lateral sulcus
- This taste area occurs on the tongue in the somatosensory homunculus

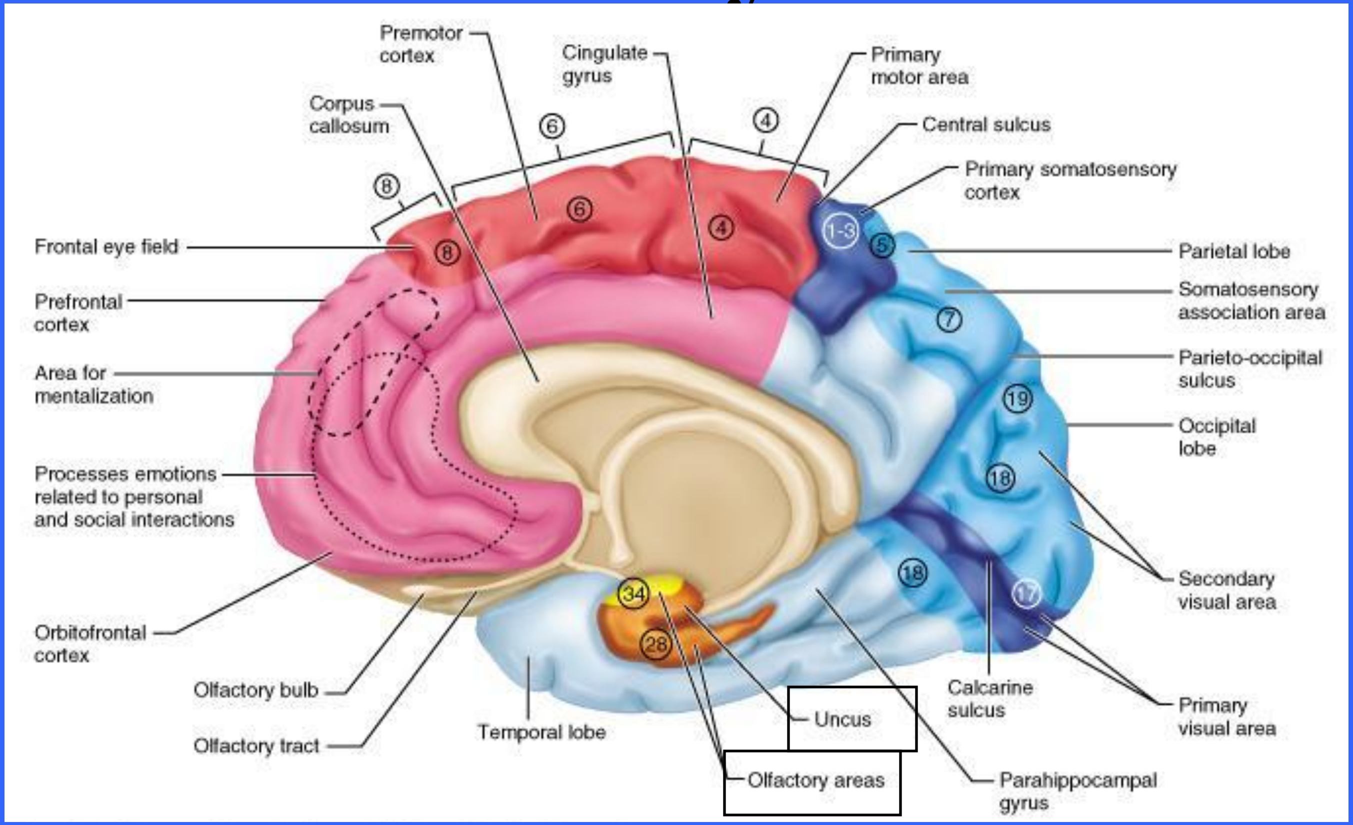


Vestibular (equilibrium) Cortex

- The cortex is responsible for conscious aware-ness of the sense of balance; specifically the position of the head in space
- Recent studies have placed this region in the posterior insula deep in the lateral sulcus

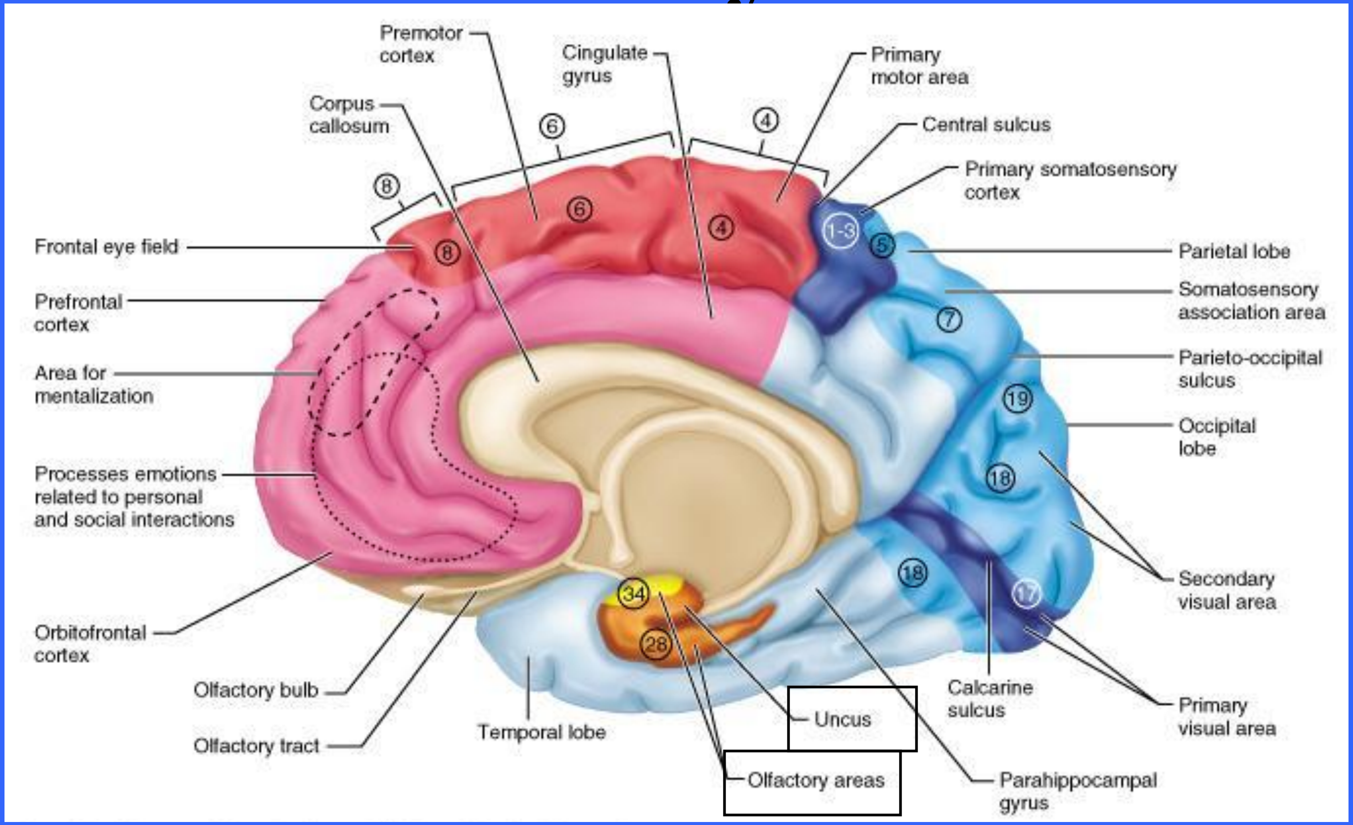


Olfactory Area



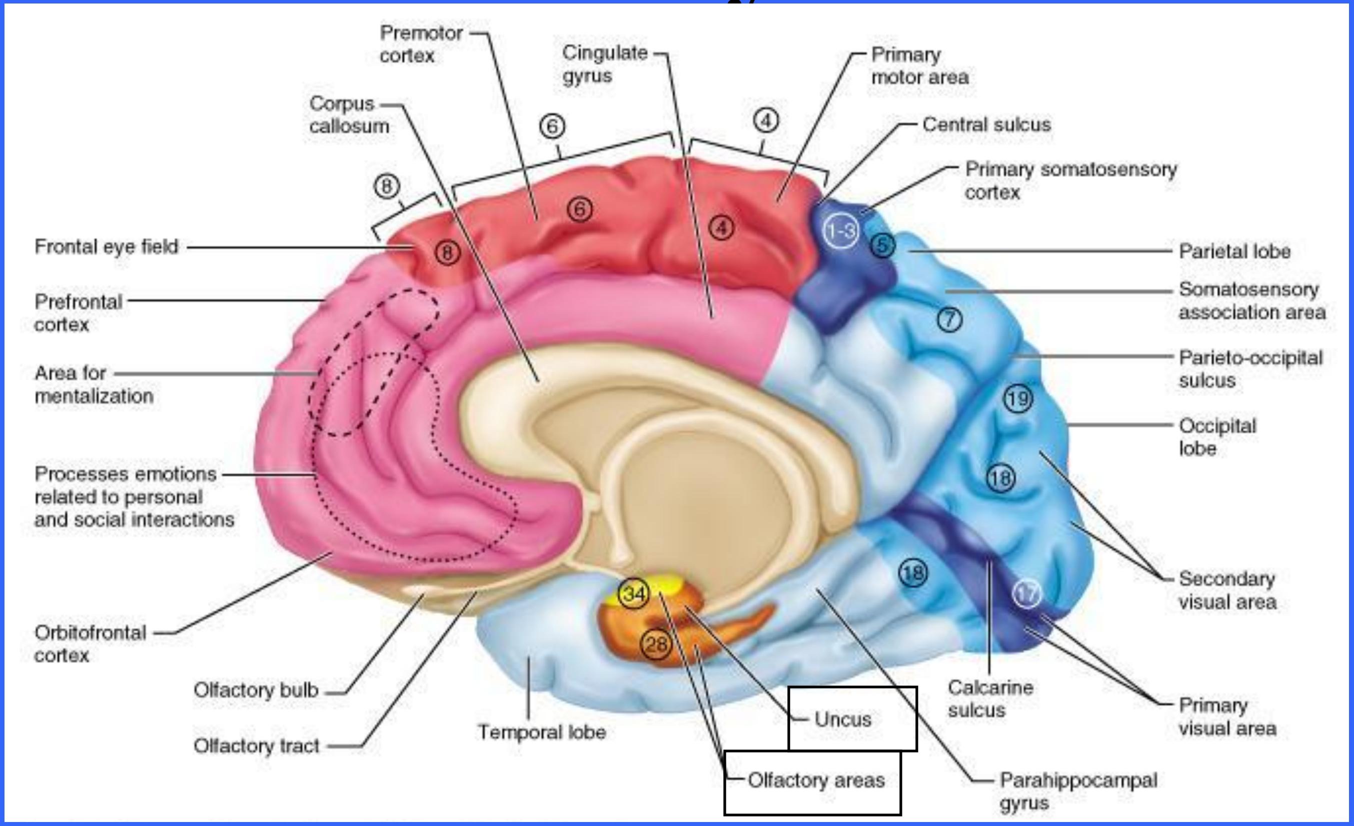
- The primary olfactory cortex lie on the medial aspects of the cerebrum in a small region called the piriform lobe of which the hook-like uncus is the dominant feature

Olfactory Area



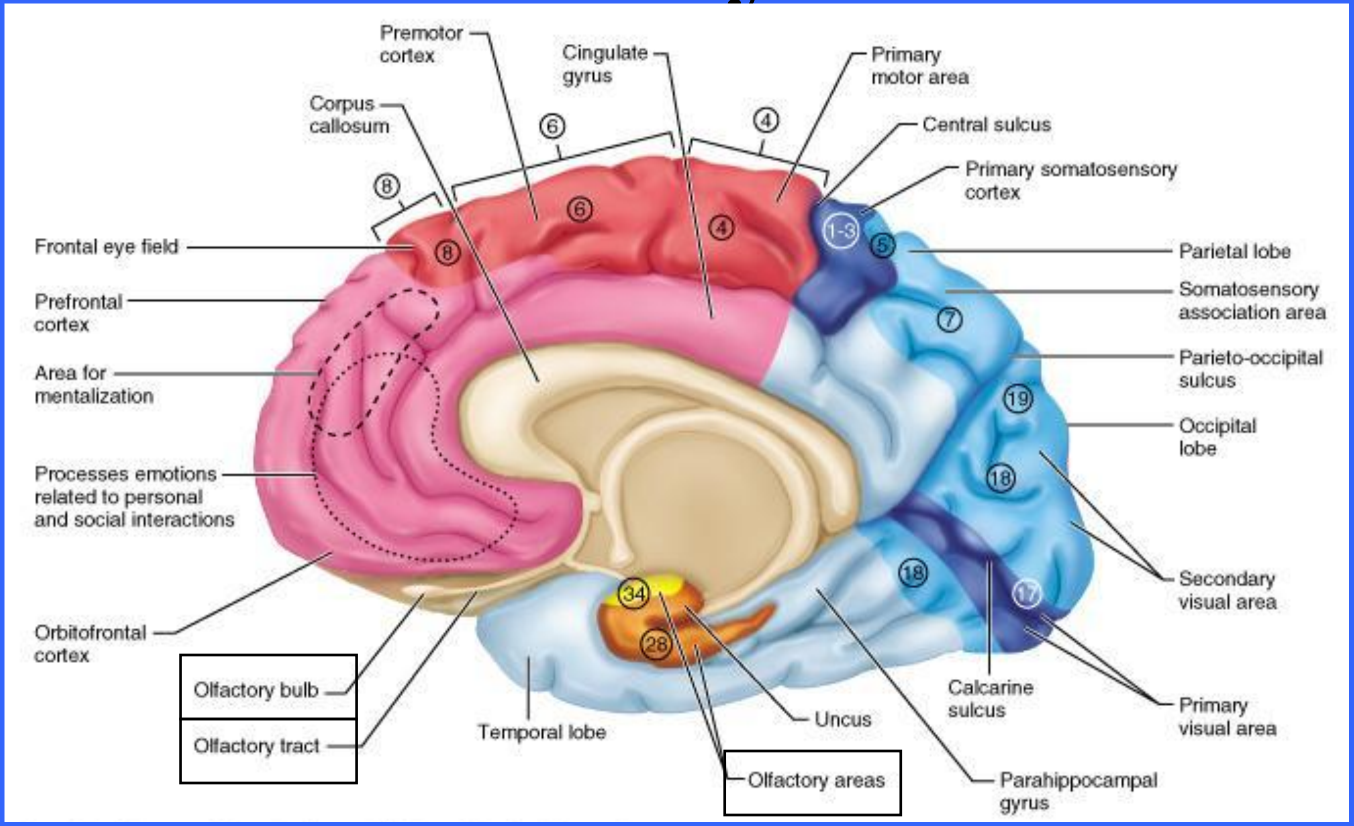
- The olfactory nerves (Cranial nerve I) from the nasal cavity transmit impulses that are ultimately relayed to the olfactory cortex
- The outcome is conscious awareness of smells

Olfactory Area



- **The olfactory cortex is part of a brain area called the rhinencephalon (nose brain) which includes all parts of the cerebrum that directly receive olfactory signals**

Olfactory Area

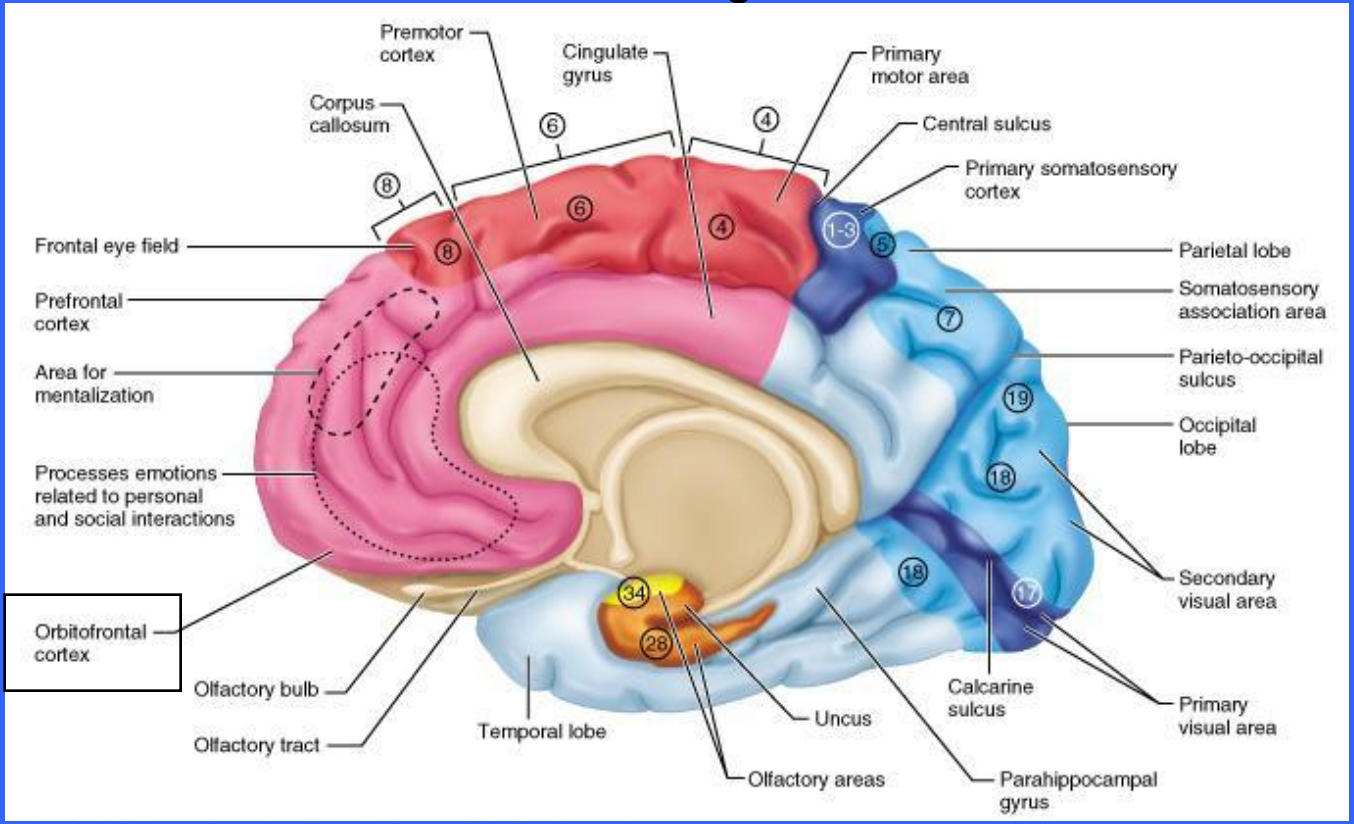


- The piriform lobe, the olfactory tract, the olfactory bulb, and some nearby structures are all components of the rhinencephalon

Olfactory Area

- **The rhinencephalon connects to the brain area that is involved in emotions, the limbic system, which explains why smells often trigger emotions**

Olfactory Area



- **Part of the frontal lobe, the orbitofrontal cortex, is involved in higher-order processing of smells**
- **Consciously identifying and recalling specific odors and telling different smells apart**

Association Areas

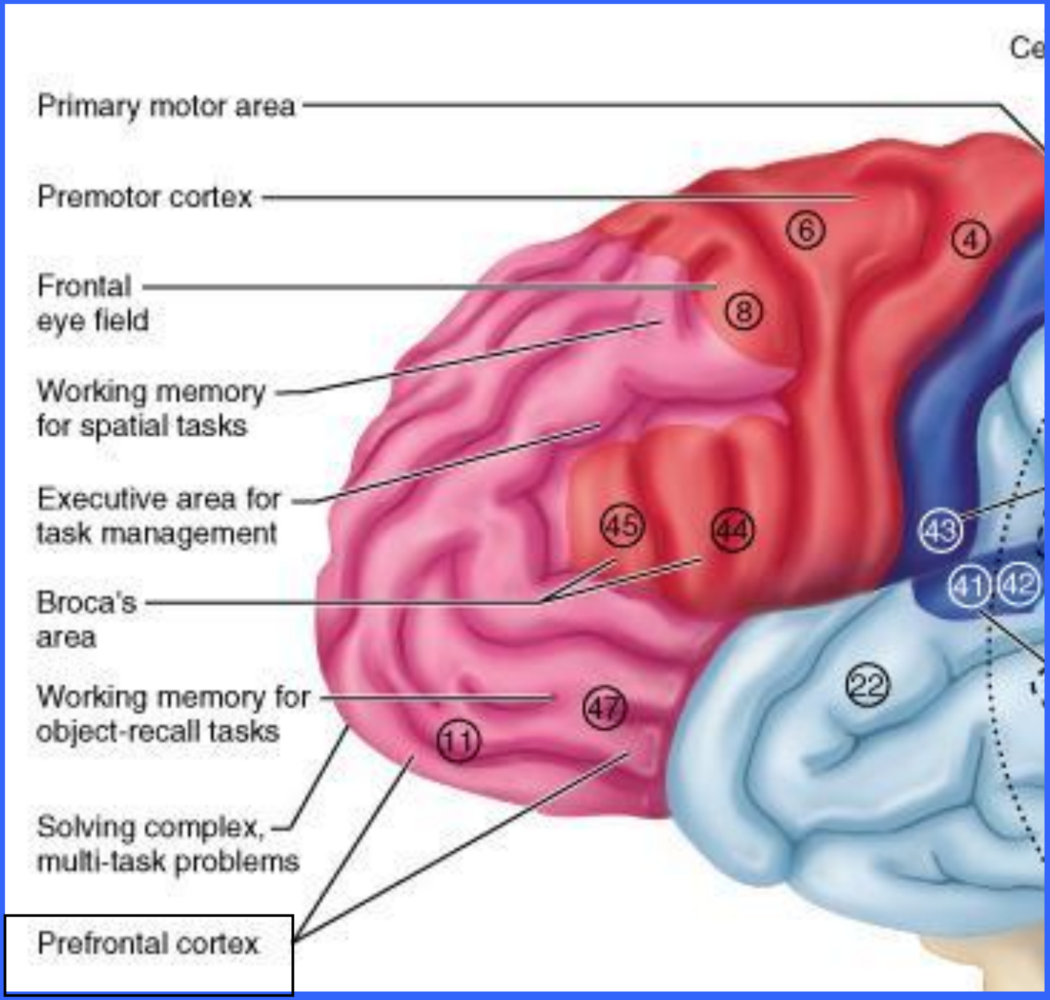
- Association areas include all cortical areas other than primary sensory and motor areas
- The name reflects the fact that some of these areas tie together, or make associations between different kinds of sensory information
- They also seem to associate new sensory inputs with memories of past experiences

Association Areas

- The term association area is fading from use and will probably be replaced by higher-order processing areas
- Higher-order processing areas is a more accurate name as these areas, which are nearby the primary sensory areas, have the ability to analyze, recognize, and act on the sensory input received

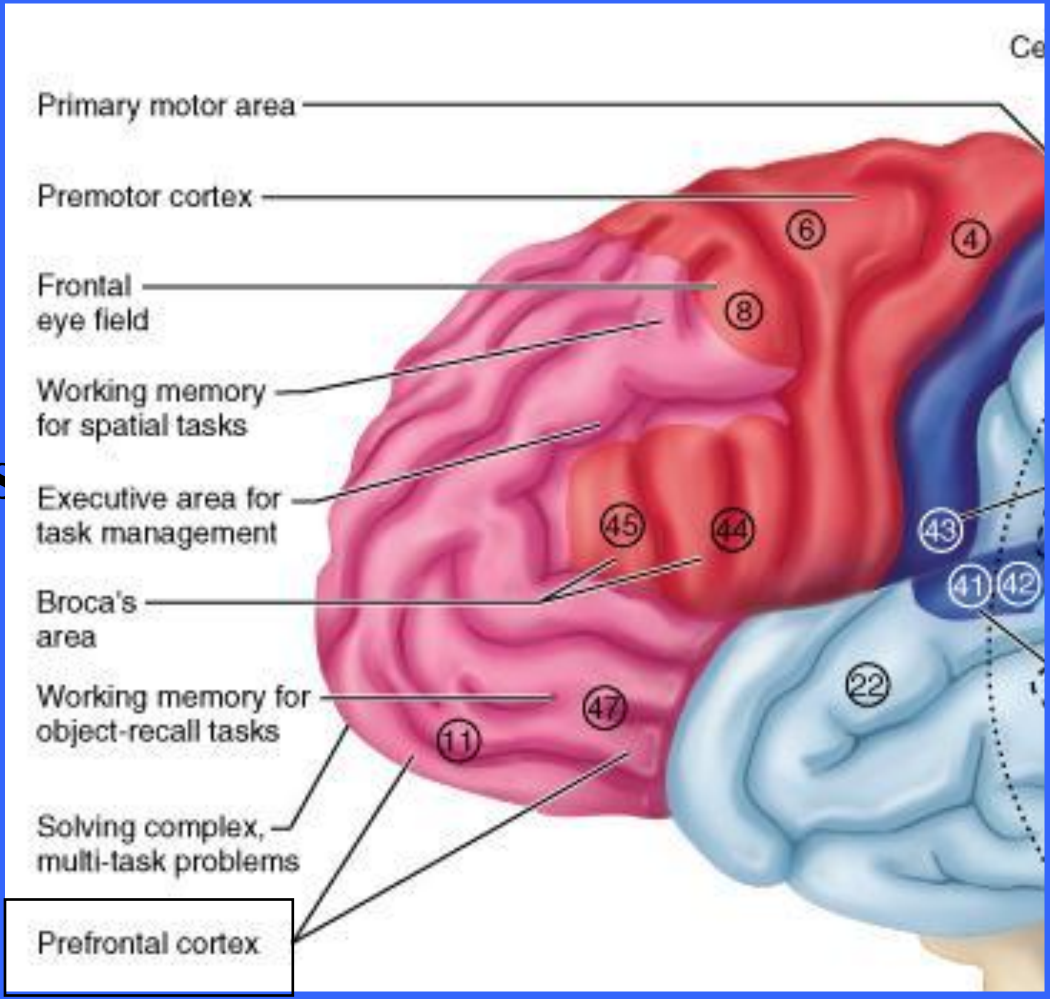
Prefrontal Cortex

- The prefrontal cortex occupies the large region of the frontal lobe anterior to the motor area
- The most complicated cortical region
- It performs many cognitive functions



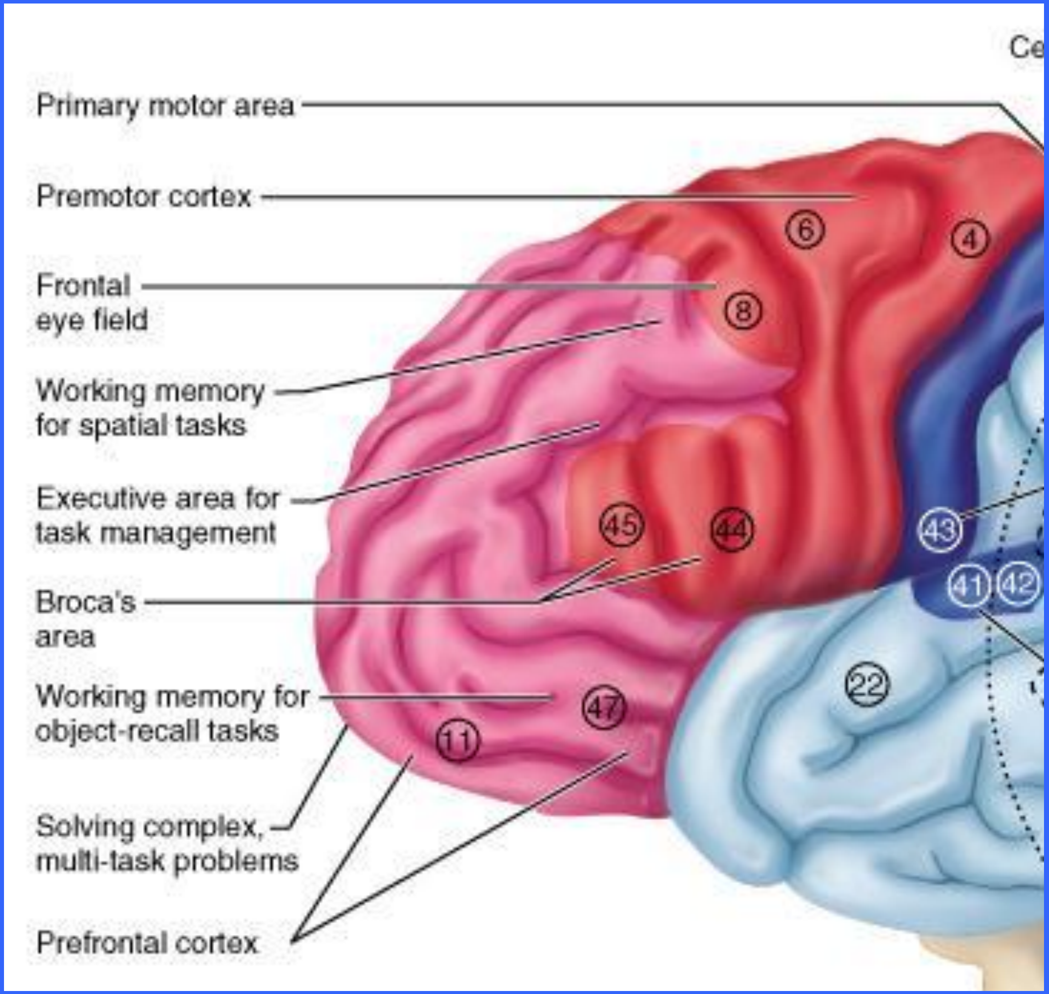
Prefrontal Cortex

- Cognition is all aspects of thinking, perceiving and of intentionally remembering and recalling information
- The prefrontal cortex is necessary for abstract ideas, reasoning and judgment, impulse control, persistence, long term planning



Prefrontal Cortex

- The prefrontal cortex also is used for long-term planning, complex problem solving, mental flexibility, social skills, appreciating humor, empathy, and conscience



Prefrontal Cortex

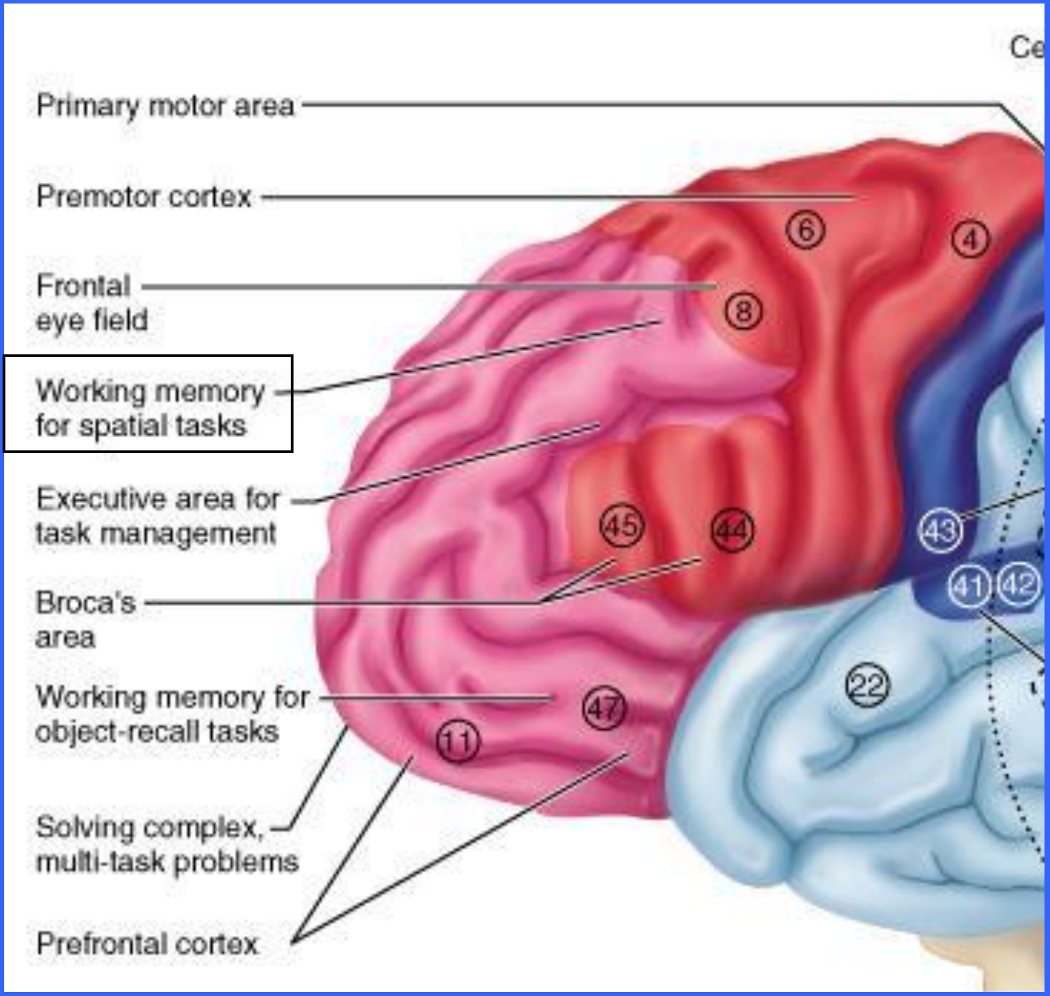
- The prefrontal cortex also seems to be related to mood and has close links to the emotional (limbic) part of the forebrain
- Tumors in this region may cause mental and personality disorders
- The tremendous elaboration of this prefrontal region distinguishes humans from animals

Prefrontal Cortex

- Functional neuro-imaging techniques have begun to reveal the functions of specific parts of the prefrontal cortex
- Completion of multi-step problem solving tasks requires the temporary storage of information in working memory

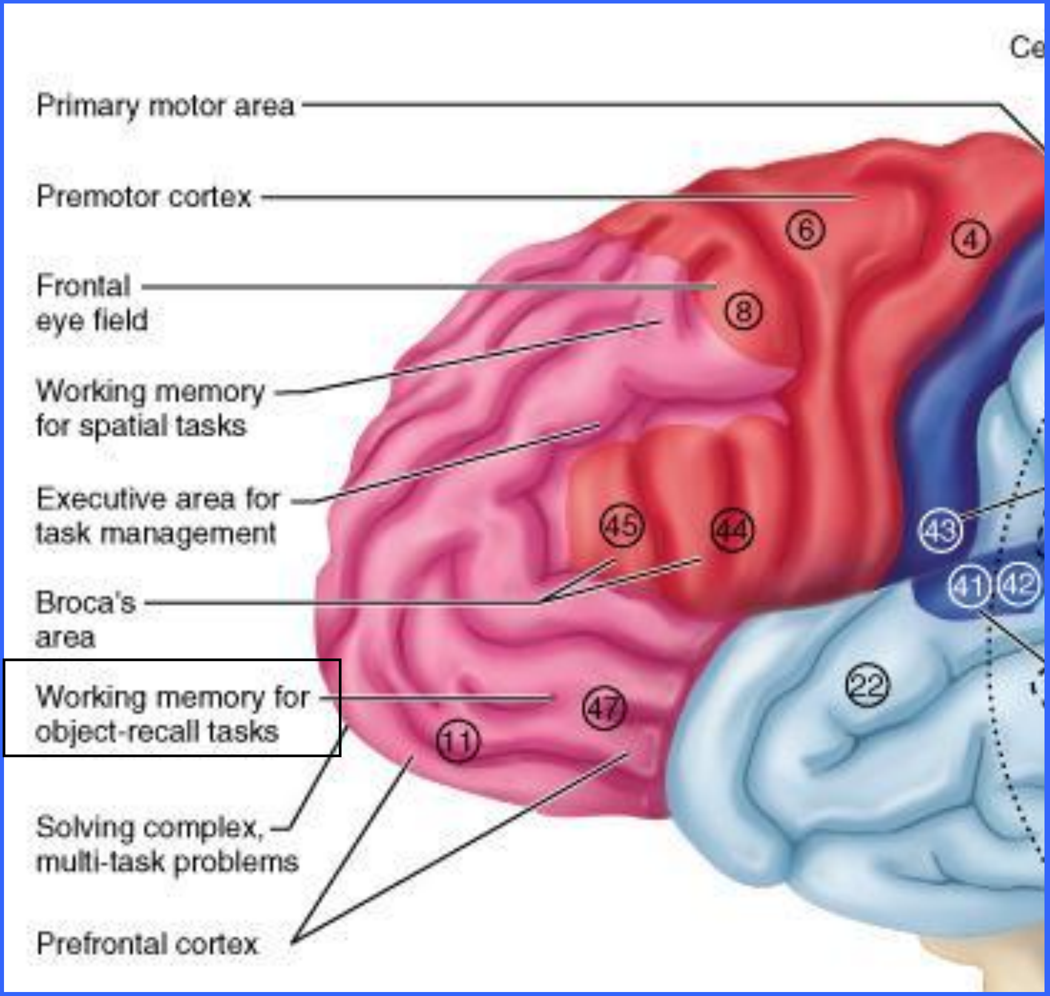
Prefrontal Cortex

- The working memories of spatial relations are stored in the dorsolateral prefrontal cortex just anterior to the frontal eye field



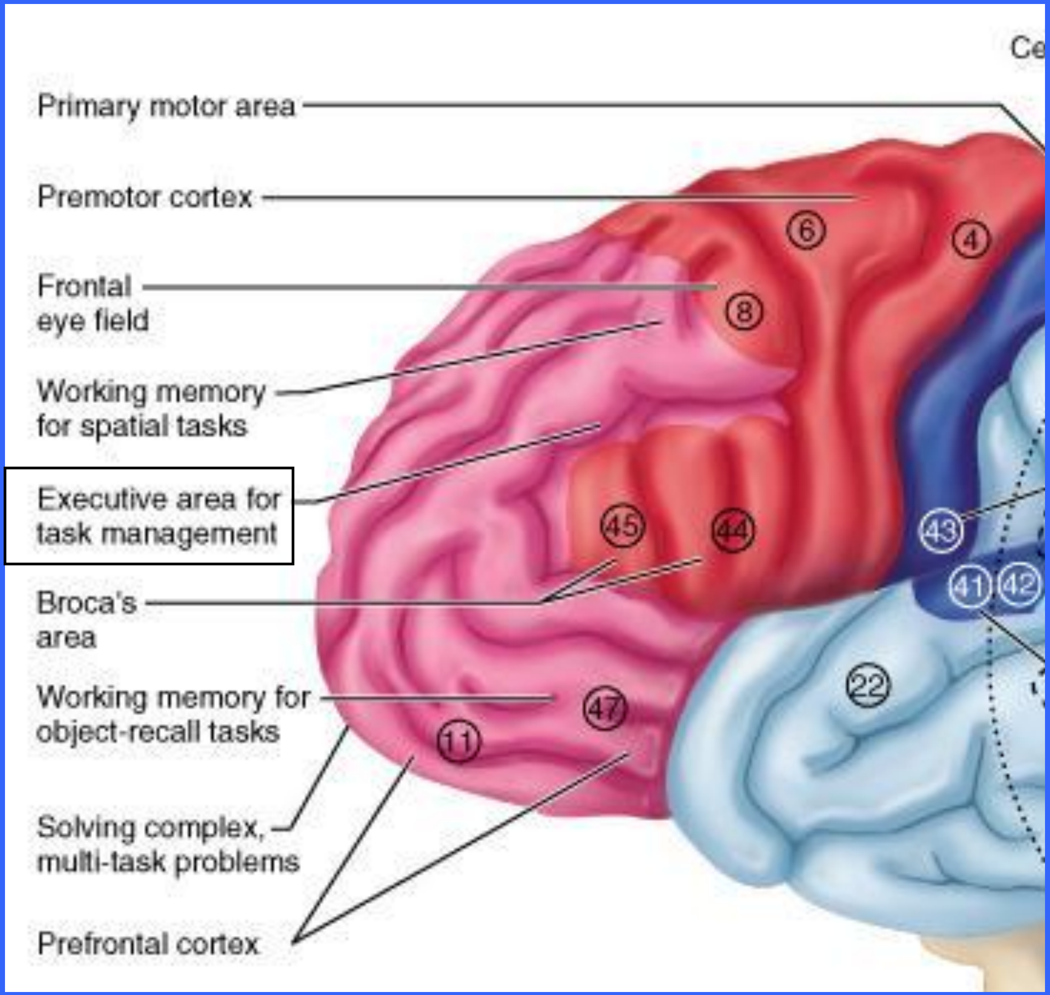
Prefrontal Cortex

- **Working memories of objects and faces are stored farther ventrally, below Broca's area**



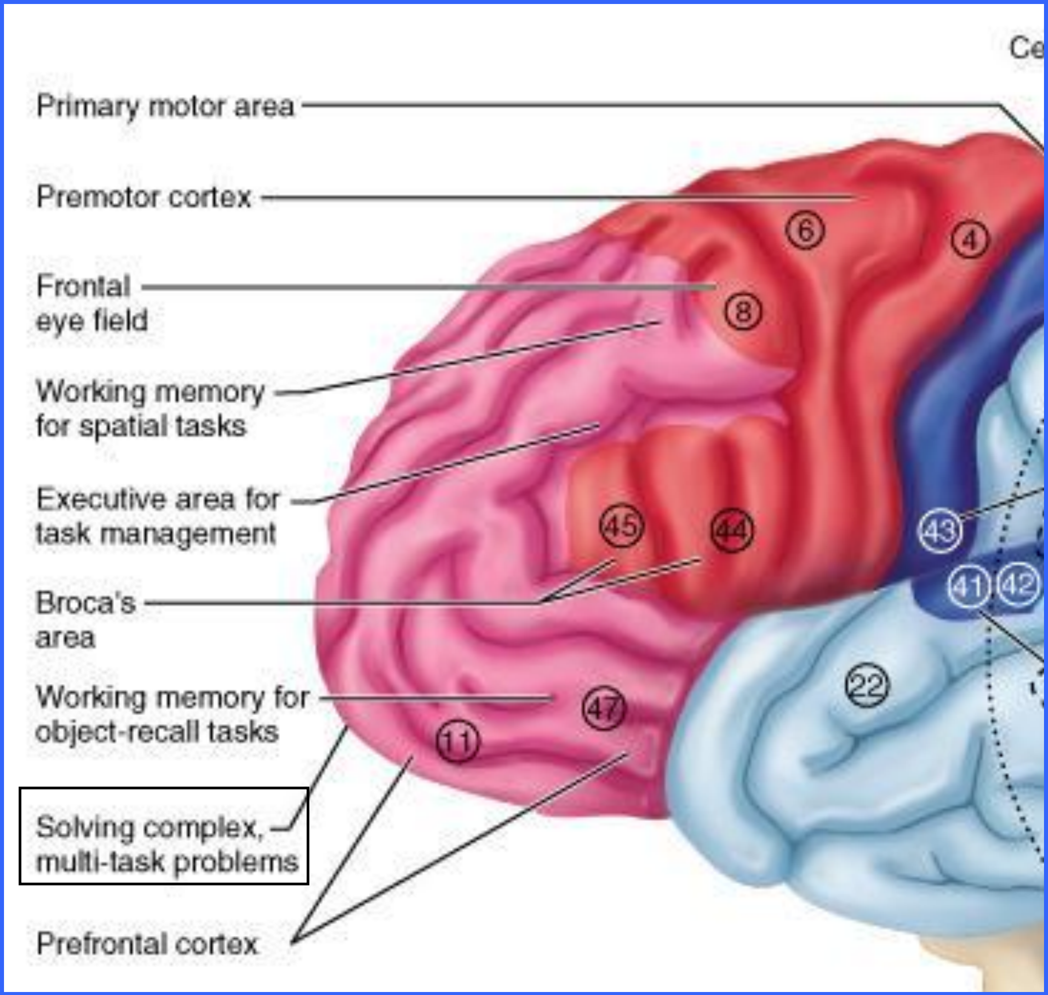
Prefrontal Cortex

- More significant is the region that manages cognitive tasks by directing our attention to the relevant information in the working memory
- This executive area lies between the working-memory sites, just anterior to Broca's area



Prefrontal Cortex

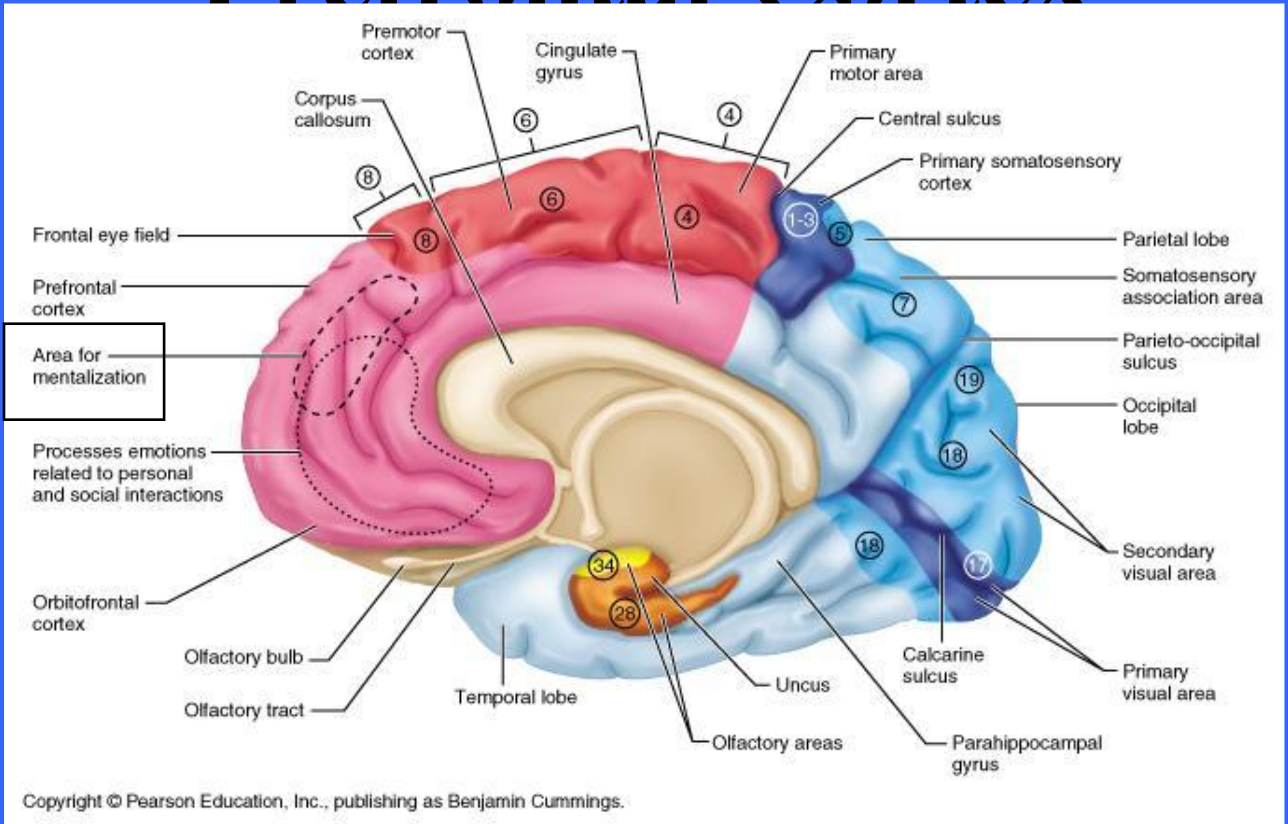
- **The extreme anterior pole of the frontal cortex was found to be active in solving the most complex problems - problems in which many sub-problems had to be completed before a solution could be obtained**



Prefrontal Cortex

- **The new findings suggest support for a general rule of neuroscience that says the farther rostrally one goes in the CNS, the more complex are the neuron functions performed**

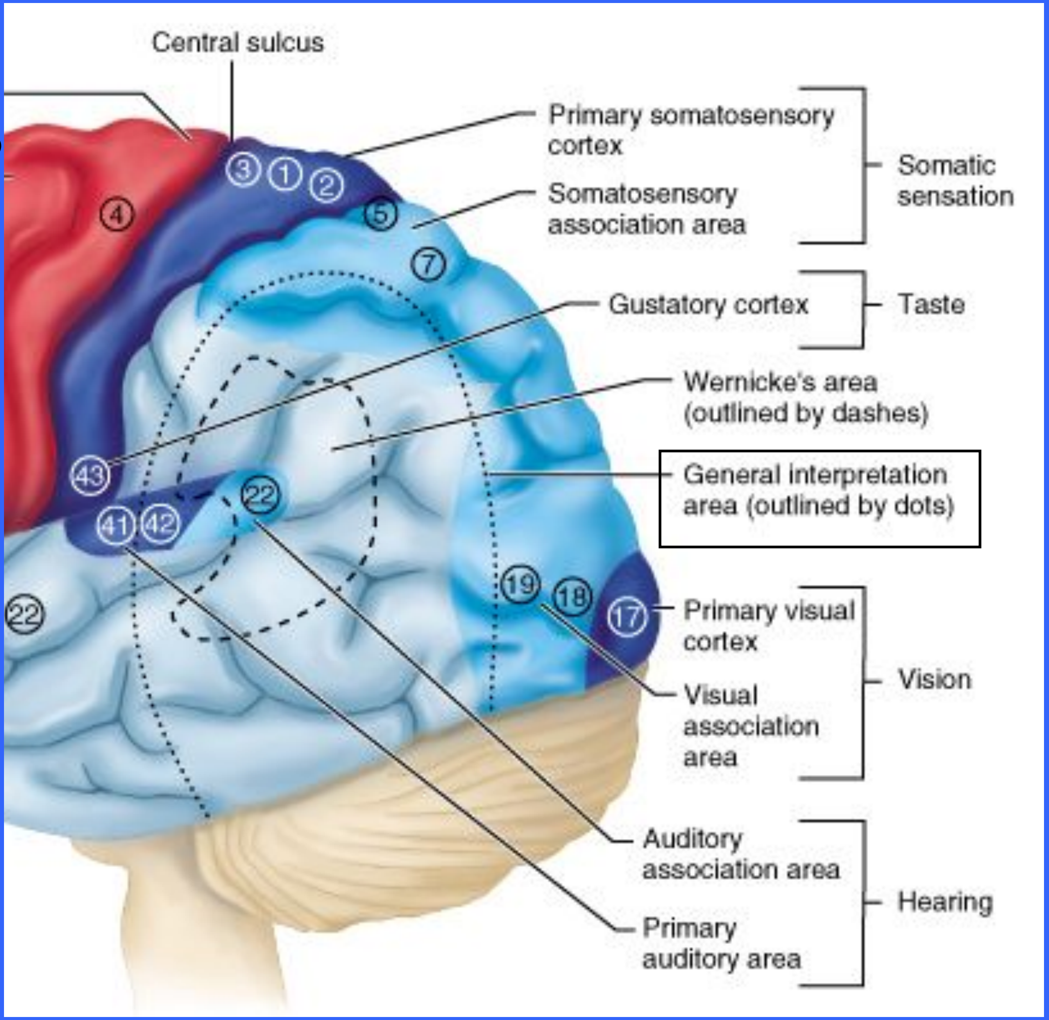
Prefrontal Cortex



- The area just anterior to the corpus callosum may process emotions involved in “mentalization”, the ability to understand and manipulate other people’s thoughts and emotions

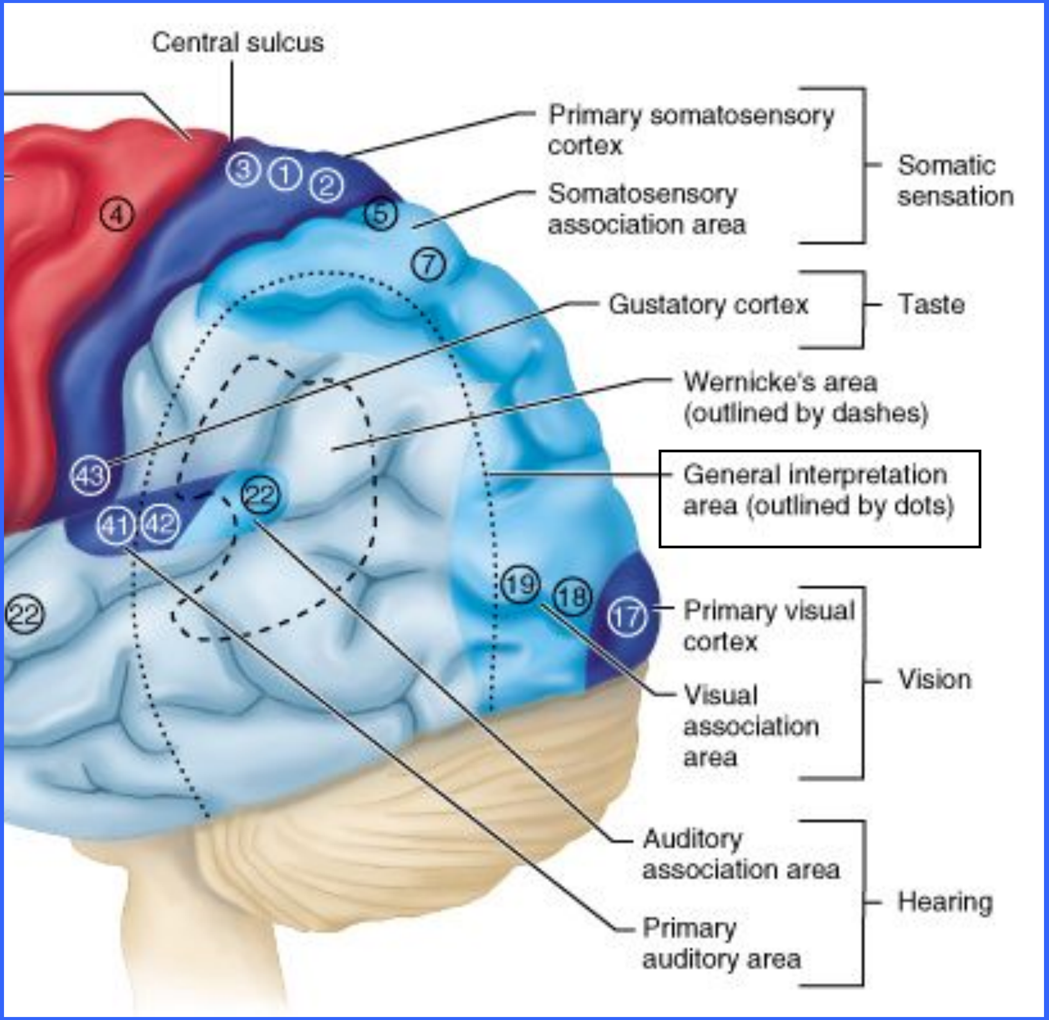
General Interpretation Area

- The existence of this area within the brain is debated
- Once thought to be an area of integration of all types of sensory information, its existence was mainly substantiated by agnosia (not knowing)
- Recent studies do not support its presence

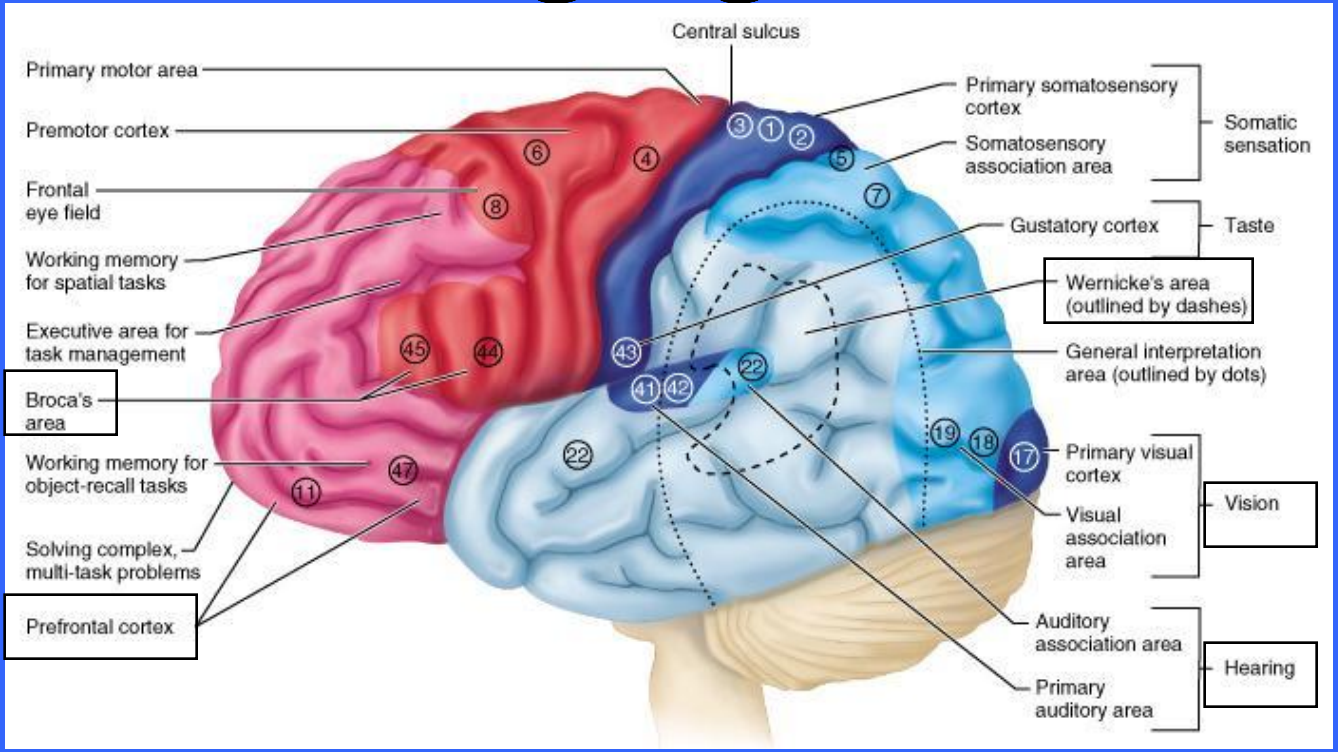


Language Area

- **The large area surrounding the lateral sulcus in the left cerebral hemisphere is involved in various functions related to language**

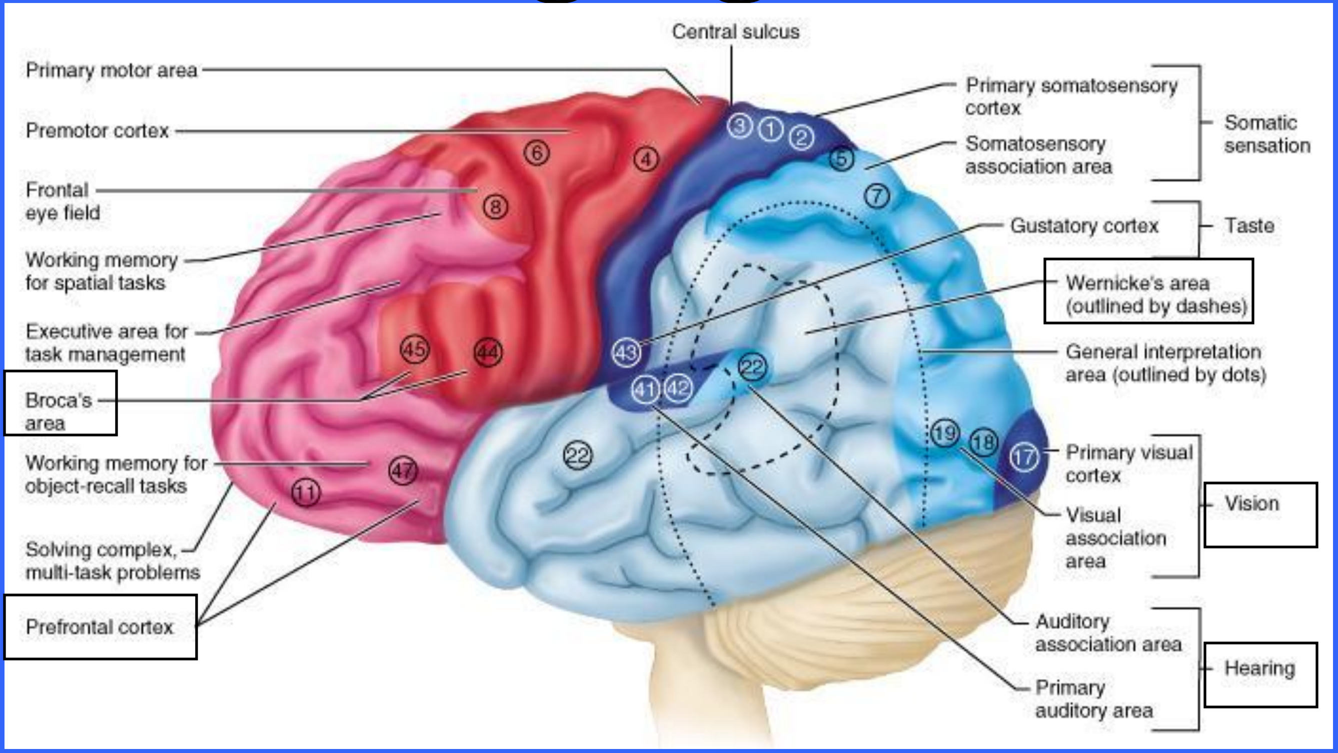


Language Area



- **Five areas have been identified with language; Broca's area (speech production); Wernicke's area (speech comprehension); prefrontal cortex (conceptual analysis); temporal lobe (visual and auditory aspects of language); the insula (recognition of rhythms)**

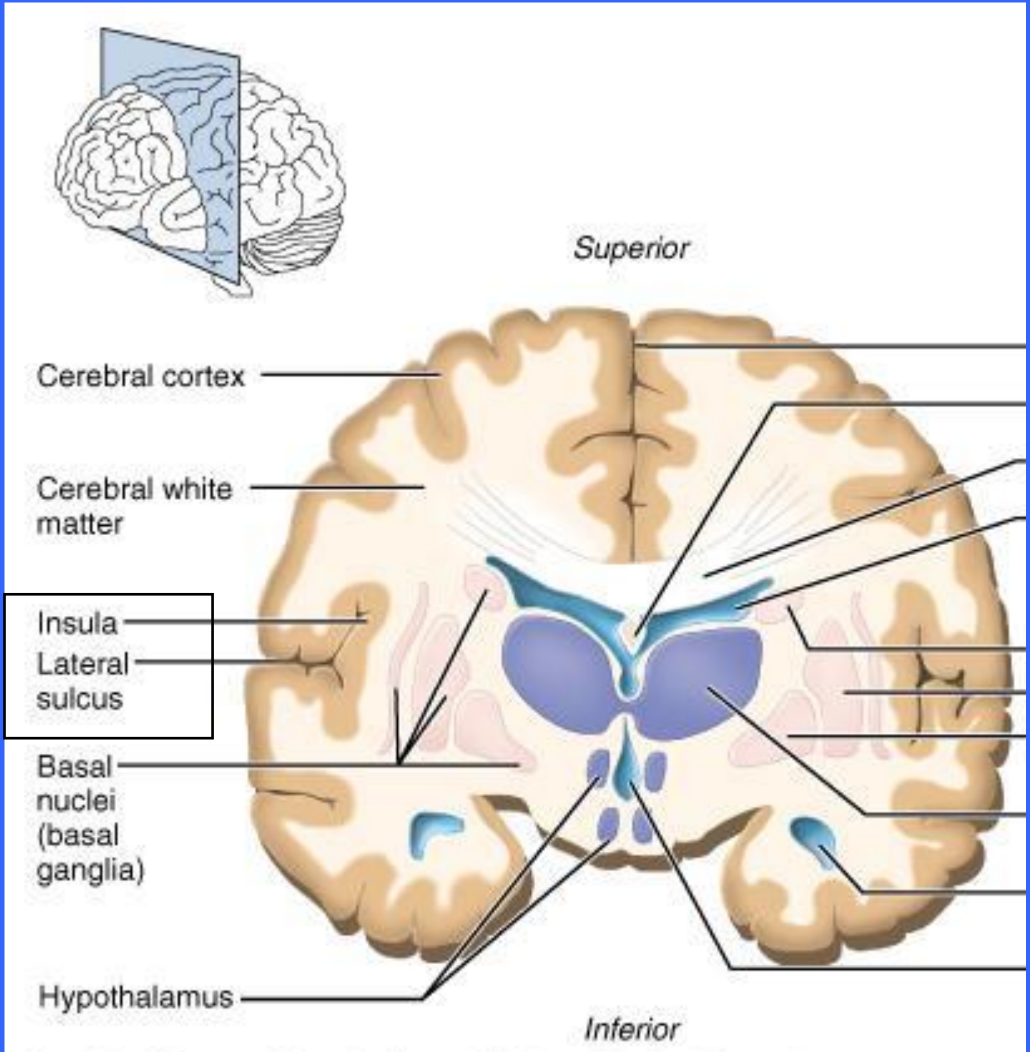
Language Area



- The corresponding areas on the right hemisphere, although not involved in the mechanics of language, act in the creative interpretation of words and in controlling the emotional overtones of speech

Insula

- The insula is large and the functions of its cortex are not well understood
- Some parts function in language and some in the sense of balance
- Other parts have visceral function including the perception of upset stomach, full bladder



Lateralization of Cortical Function

- We use both cerebral hemispheres for almost every task and it appears the hemispheres share memories and appear nearly identical
- However, there are differences and unique abilities that are found in one hemisphere and not the other
- This phenomenon is call lateralization
- Cerebral dominance suggest that there is one hemisphere that dominates each task

Lateralization of Cortical Function

- In most people (Approx. 90%) the left hemisphere has greater control over language abilities, mathematical abilities, and logic
- The other hemisphere (usually the right) is involved in visual-spatial skills, intuition, emotion, and appreciation of art and music

Lateralization of Cortical Function

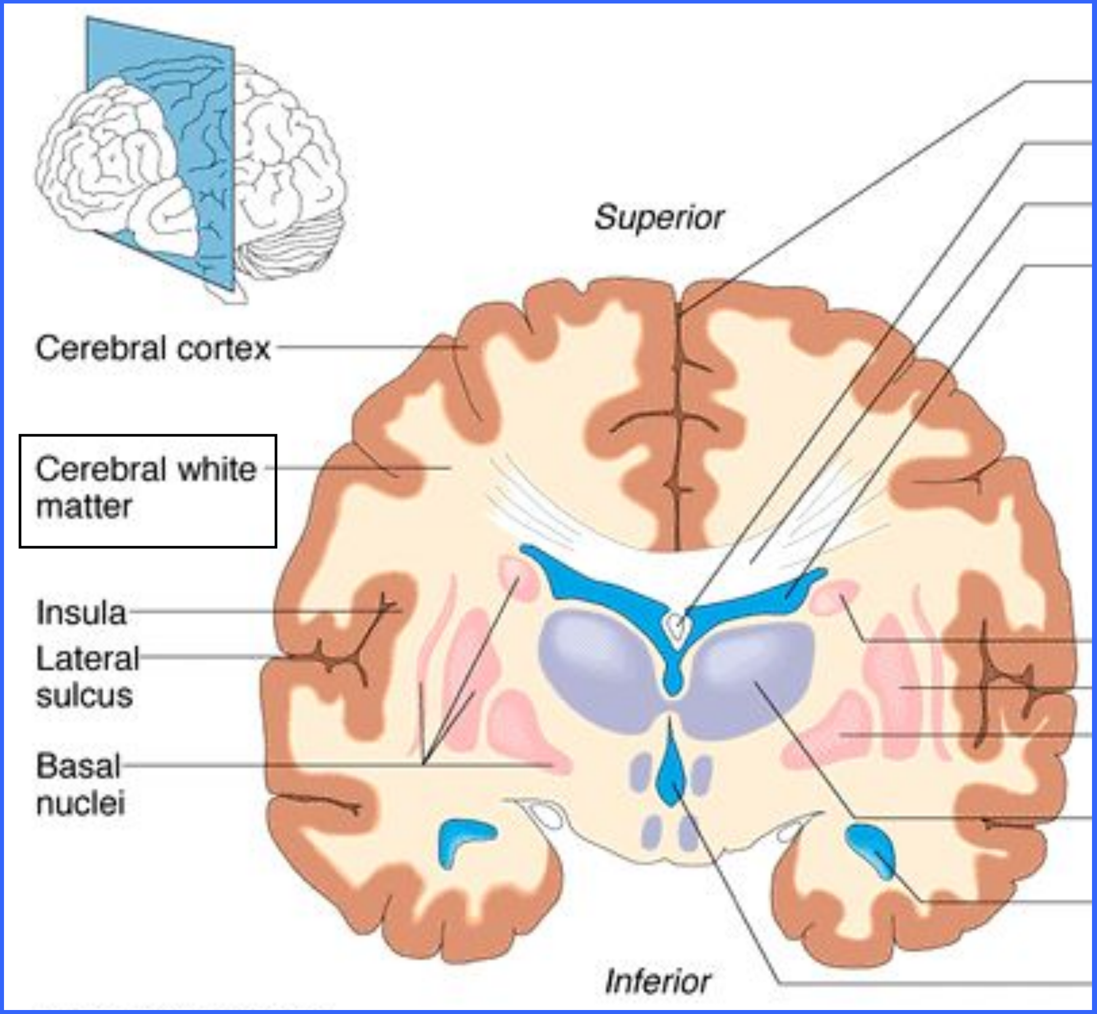
- Most individuals (90%) with left cerebral dominance are right-handed
- In the remaining 10% the roles of the hemispheres are reversed or the hemispheres share their functions equally
- Typically, many right cerebral dominant people are left handed and more often male
- In lefties the cerebral cortex functions bilaterally, the mutuality of brain control sometimes result in ambidexterity or dyslexia

Lateralization of Cortical Function

- The two cerebral hemispheres have perfect and almost instantaneous communication with one another via connecting fiber tracts as well as complete integration of their functions
- Lateralization means that each hemisphere is better than the other at certain functions, neither side is better at everything

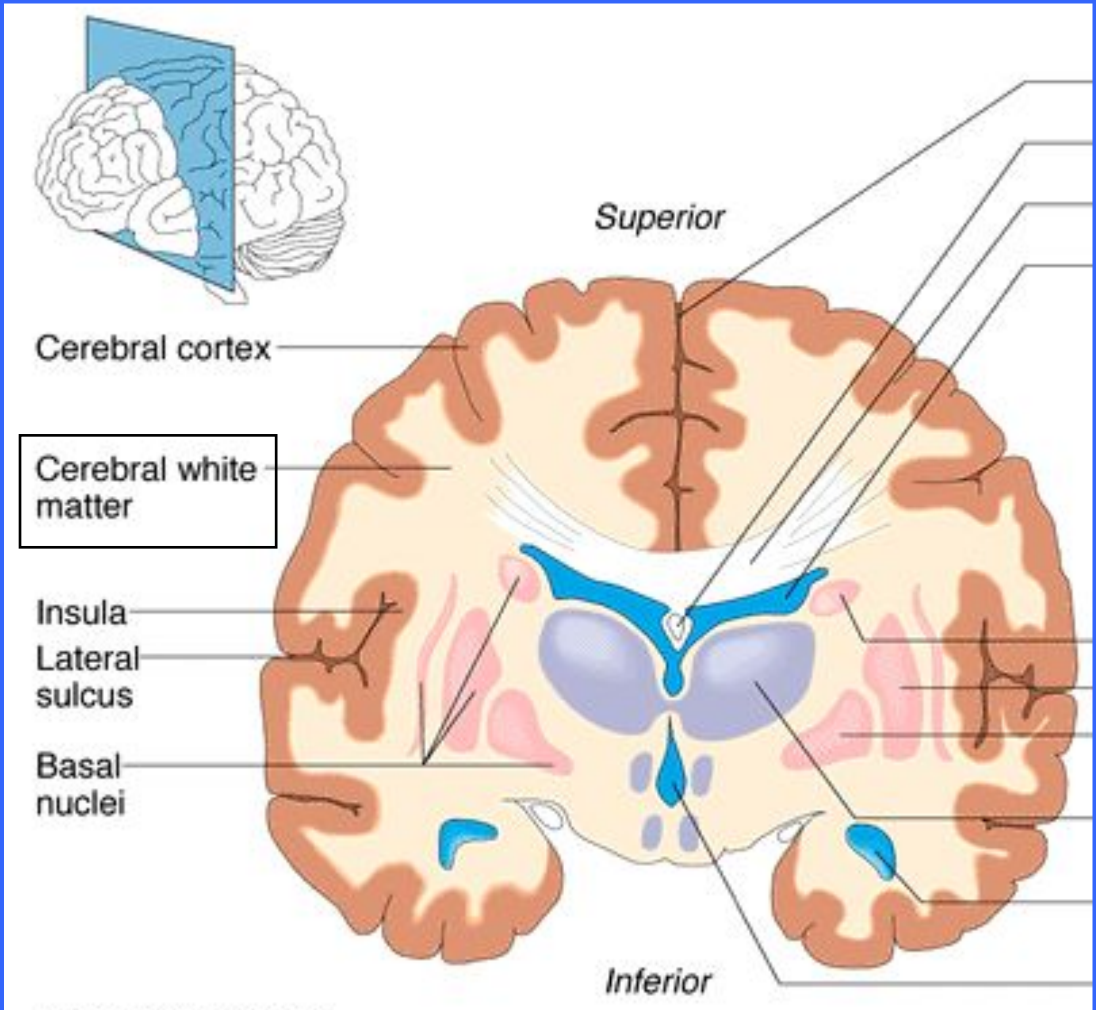
Cerebral White Matter

- Communication within the brain is extensive
- The cerebral white matter deep to the gray matter of the cortex provides for communication between cerebral areas and between the cortex and the lower CNS centers

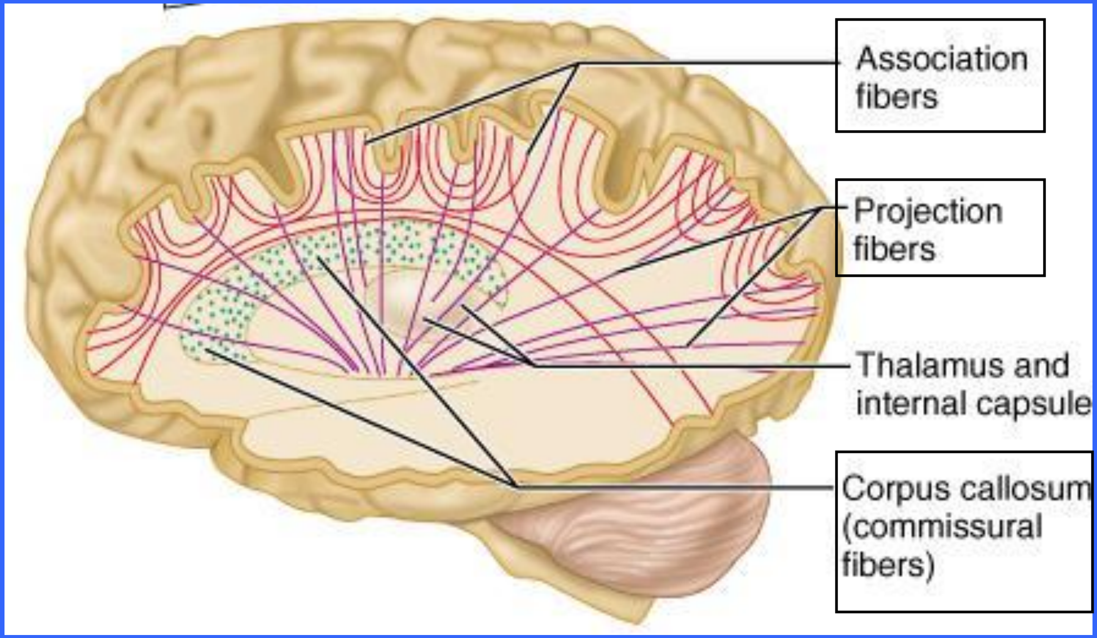


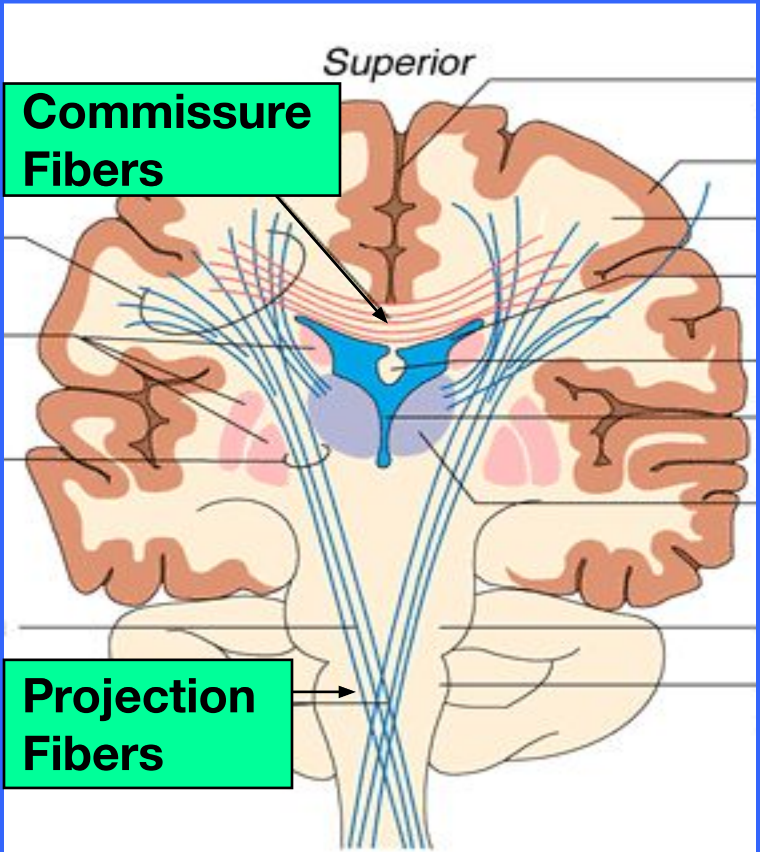
Cerebral White Matter

- The white matter largely consists of myelinated fibers bundled into large tracts
- These fibers and the tracts they form are classified according to the direction in which they run as
  - Commissural
  - Association
  - Projection



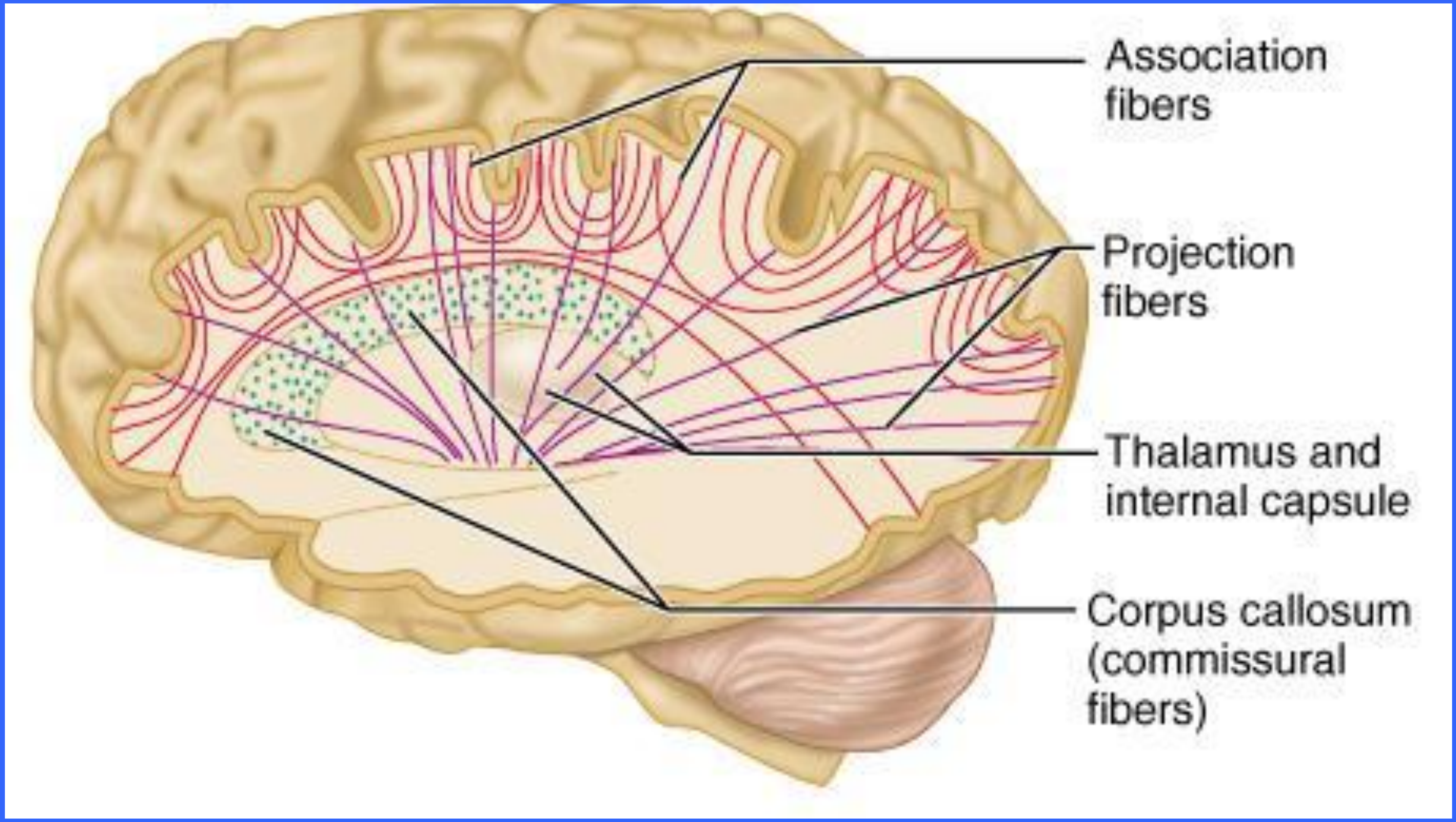
Cerebral White Matter





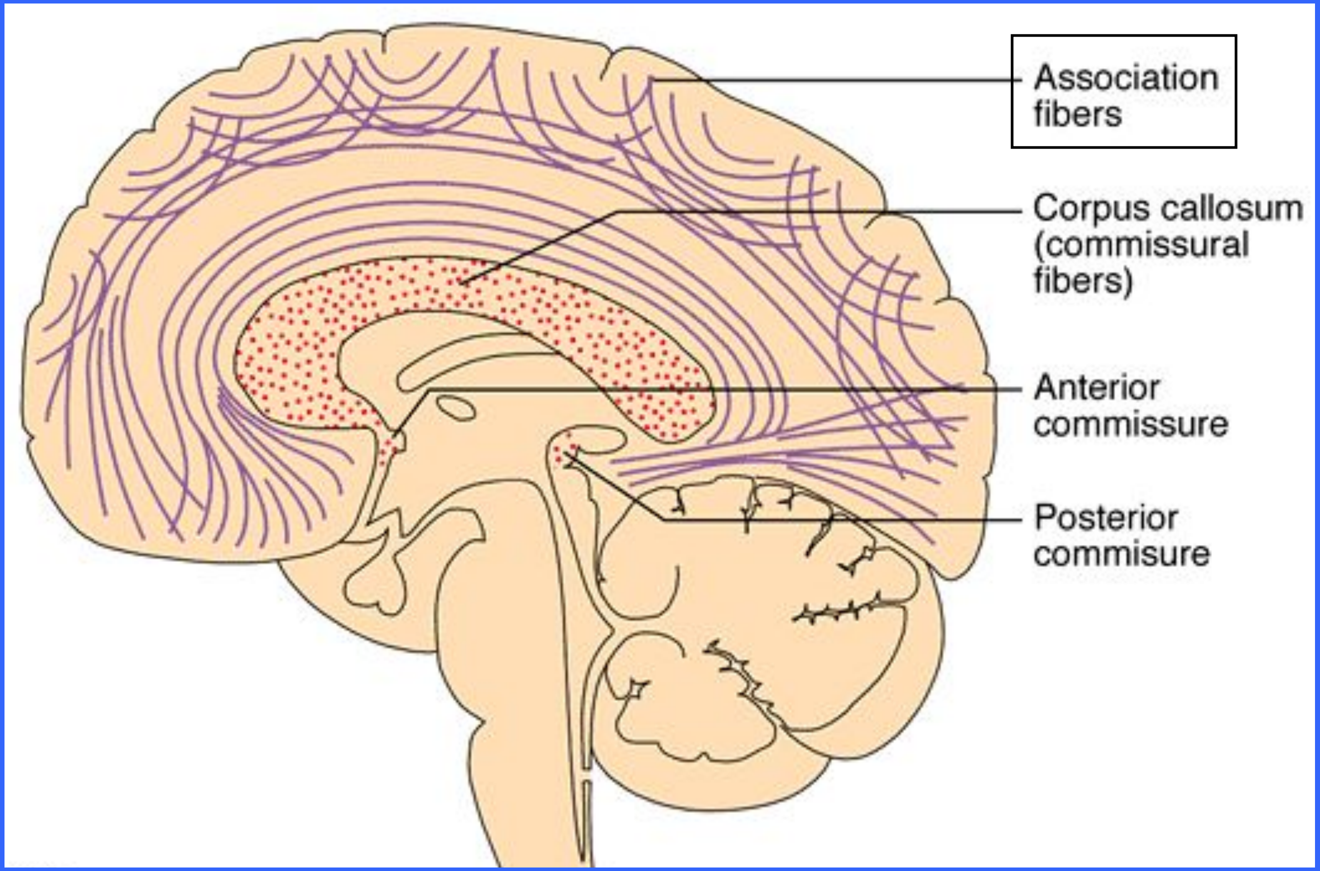
- **Commissures connect the hemispheres**
- **Association fibers connect areas within hemispheres**
- **Projection tracts connect higher & lower areas of CNS**

Cerebral White Matter



- **Commissures connect the corresponding areas of two hemispheres enabling them to function as a whole**
- **The Corpus callosum is the largest commissure**

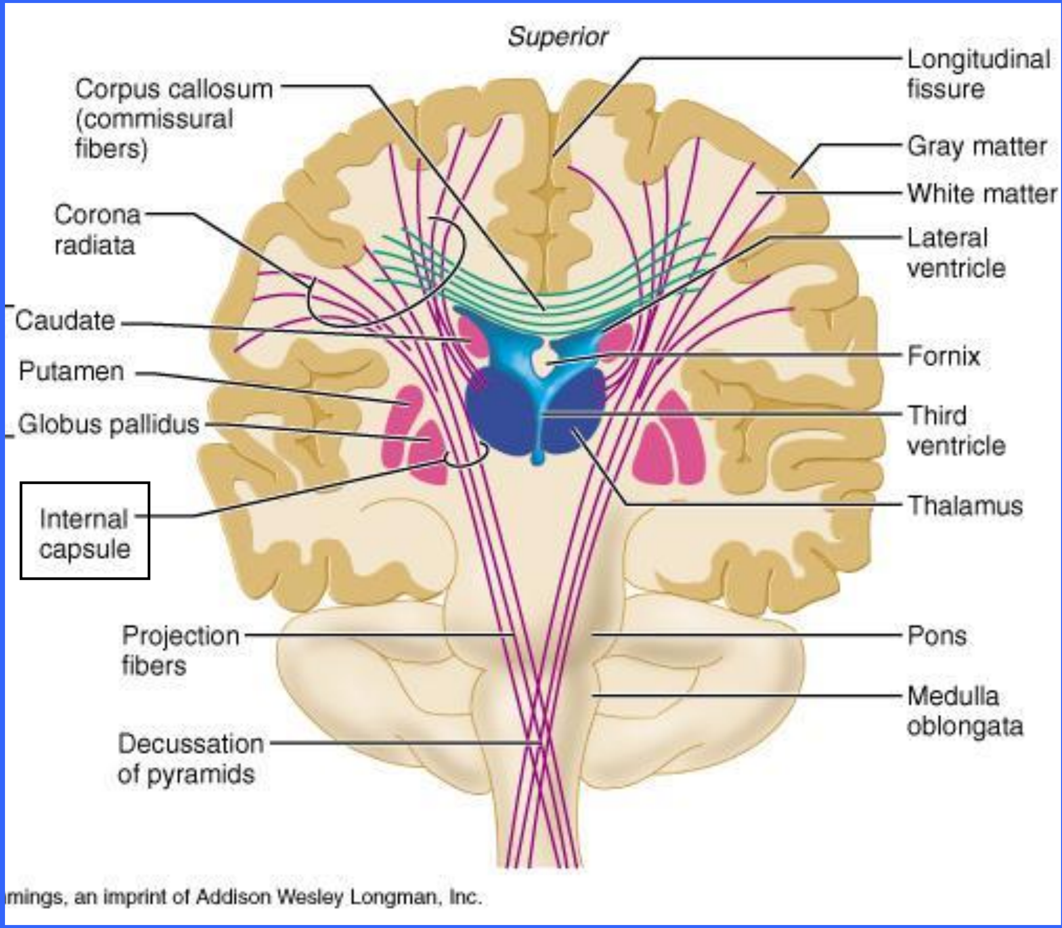
Cerebral White Matter



- Association fibers transmit within a single hemisphere
- Short fibers connect adjacent gyri or cortical areas
- Long fibers are bundled into tracts and connect different cortical lobes

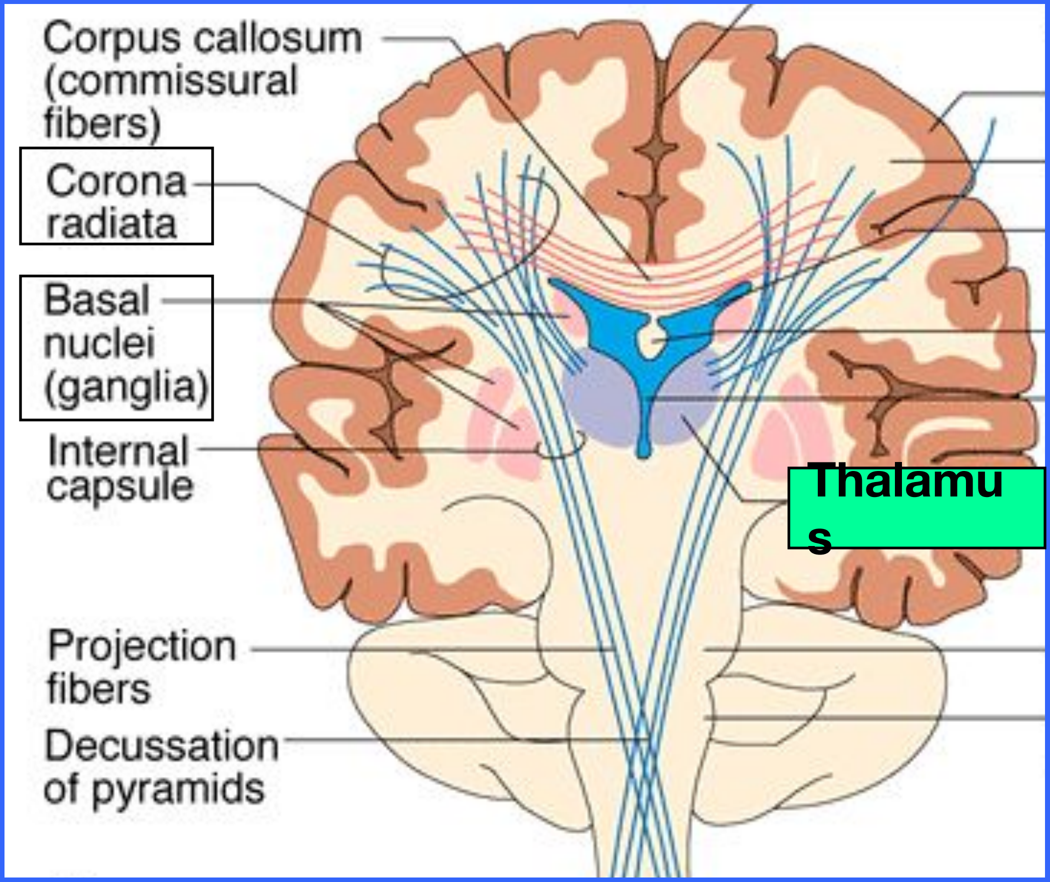
Cerebral White Matter

- Projection fibers run vertically to connect levels of the CNS
- Impulses from receptors and to effectors move within these tracts
- At the upper limits of the brain stem, the projection fibers on each side form a compact band called the internal capsule

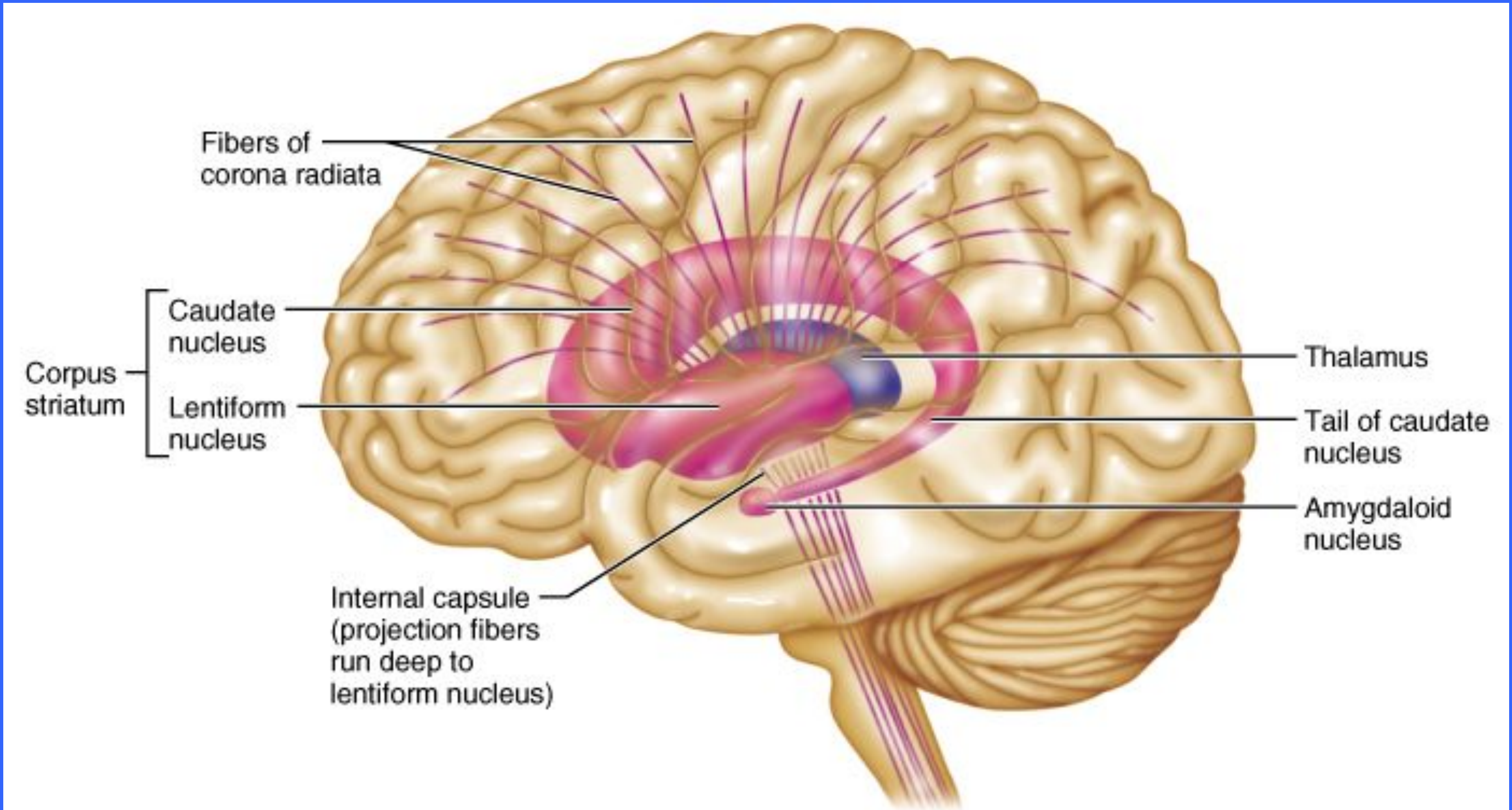


Cerebral White Matter

- **Ascending projection tracts pass between the thalamus and the basal nuclei beyond which the radiate through the cerebral white matter to the cortex**
- **This distinctive arrangement of projection tract fibers is called the corona radiata**

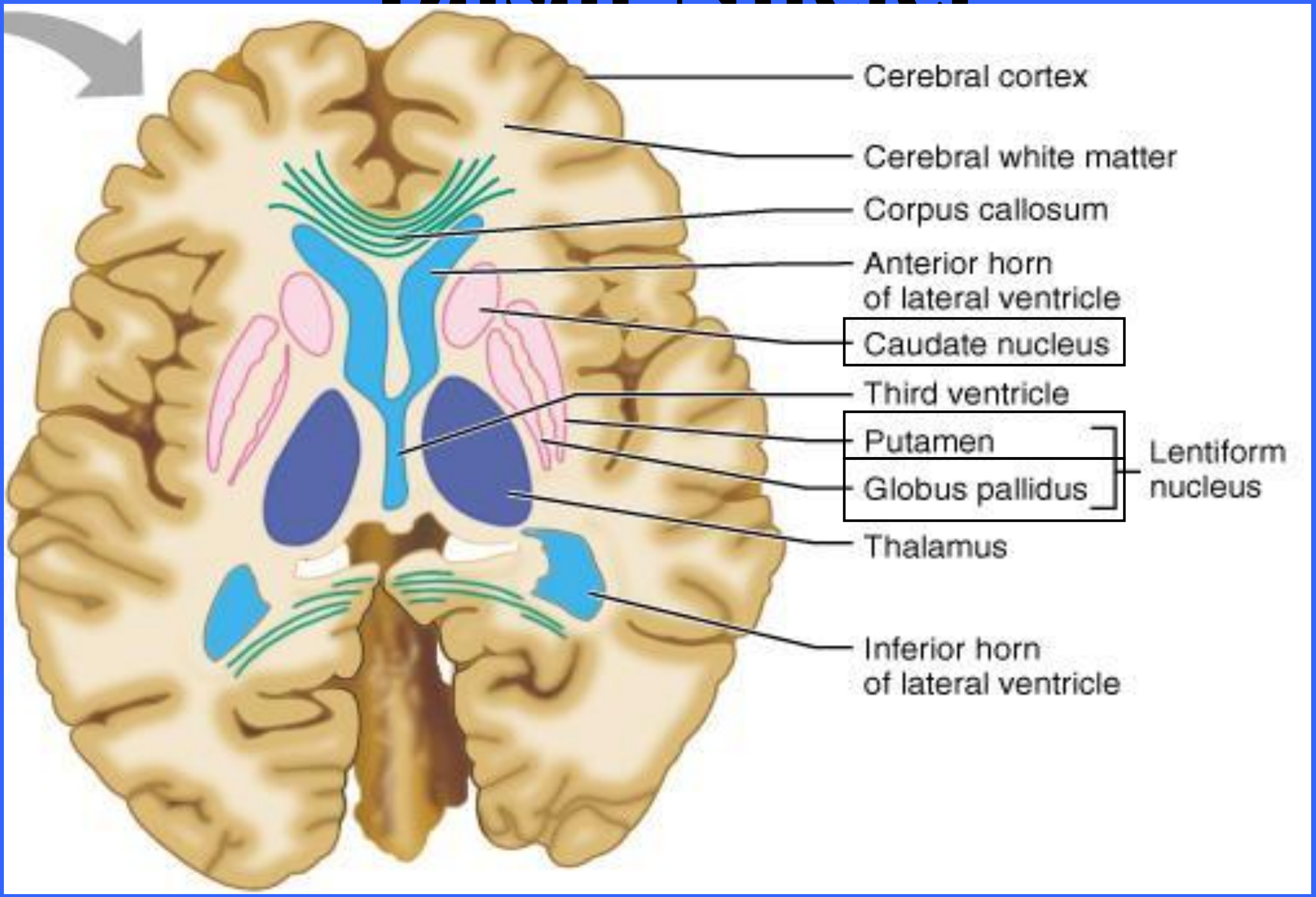


Cerebral White Matter



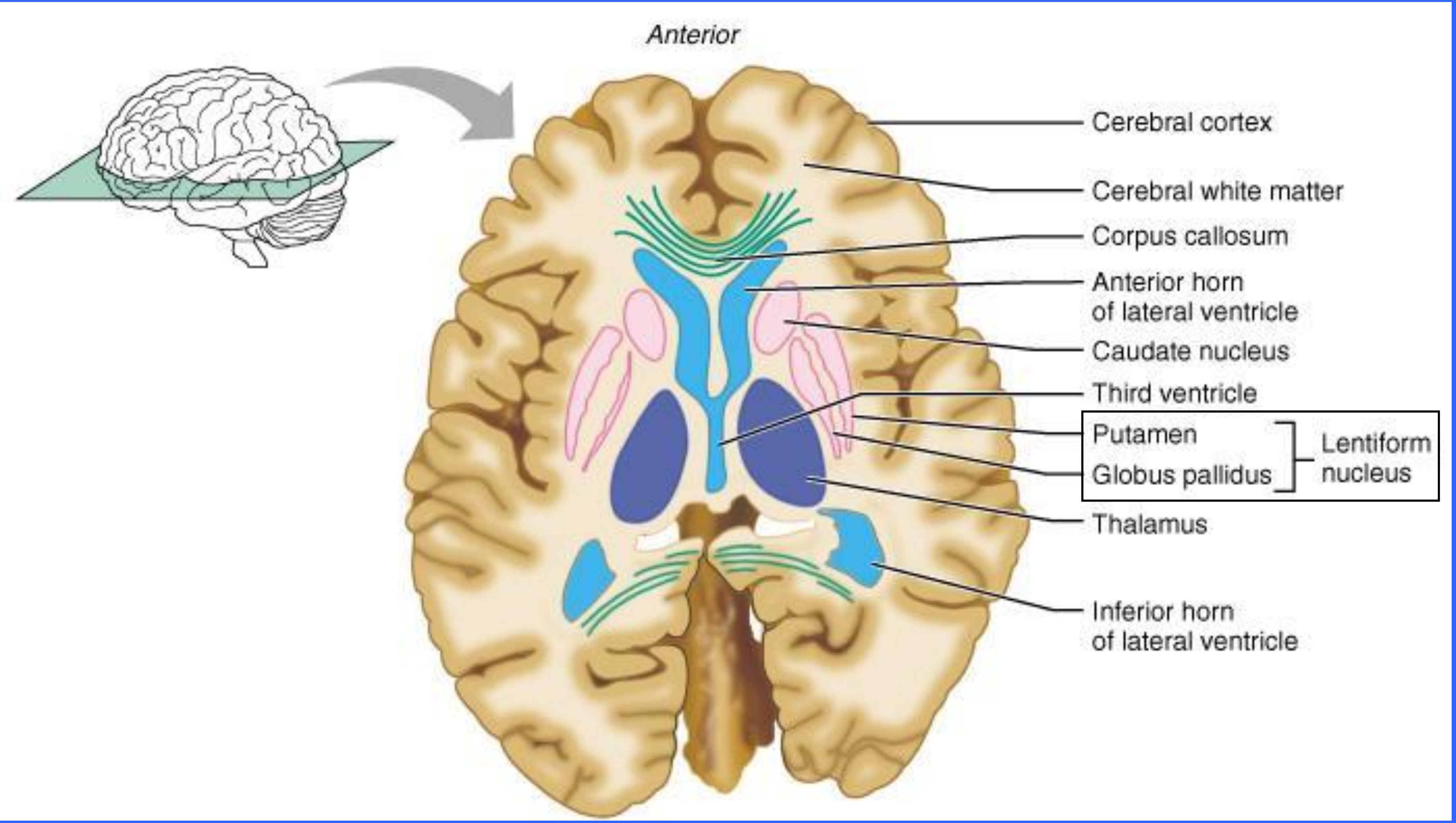
- The fibers of the corona radiata fan out into the white matter of the cerebral hemisphere

Basal Nuclei



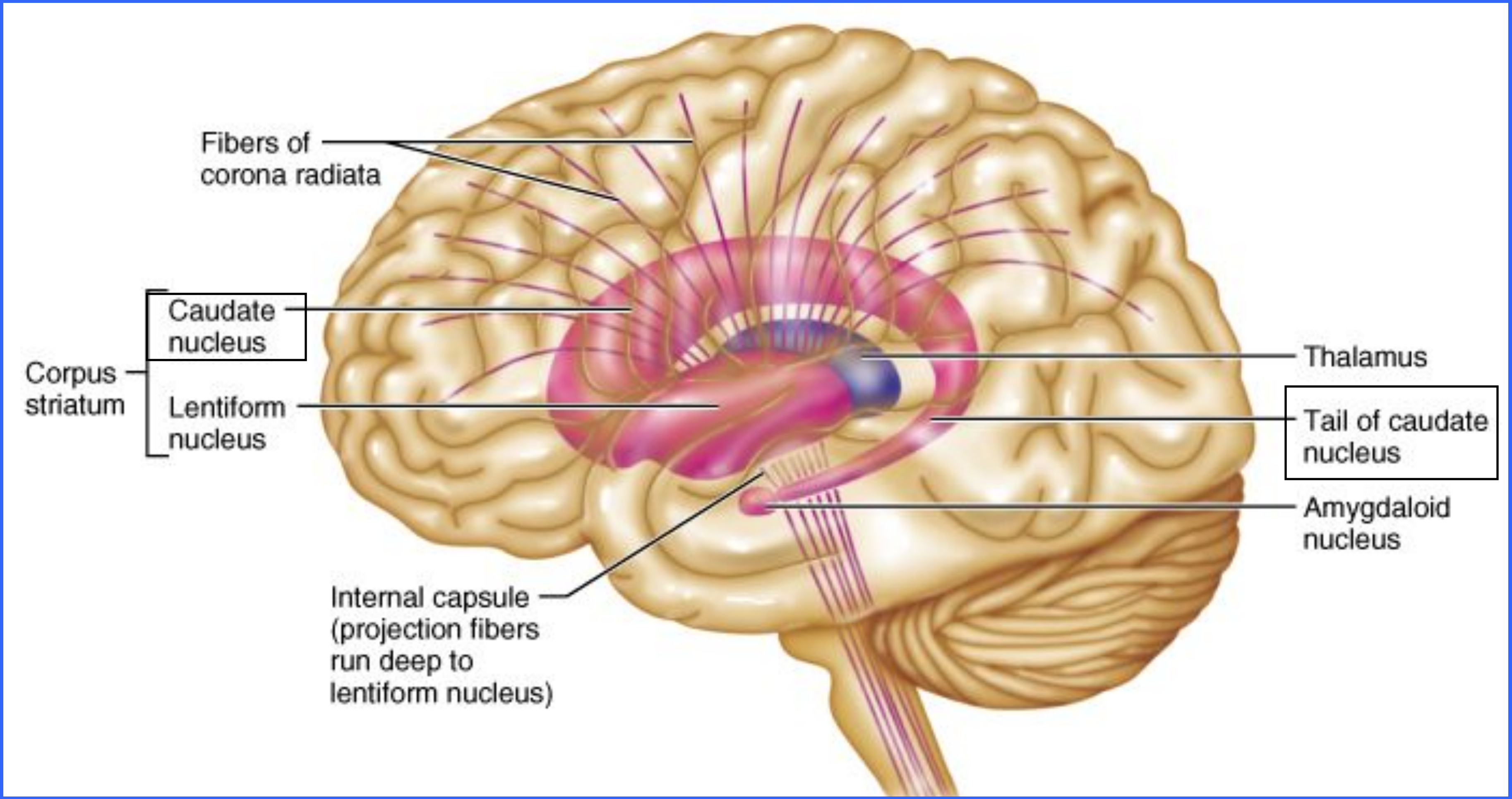
- In the cerebral white matter of each hemisphere are a groups of subcortical nuclei called the basal nuclei
- The main mass of this tissue include the caudate nucleus, putamen, and the globus pallidus

Basal Nuclei



- **The putamen and globus pallidus together form a mass called the lentiform nucleus**

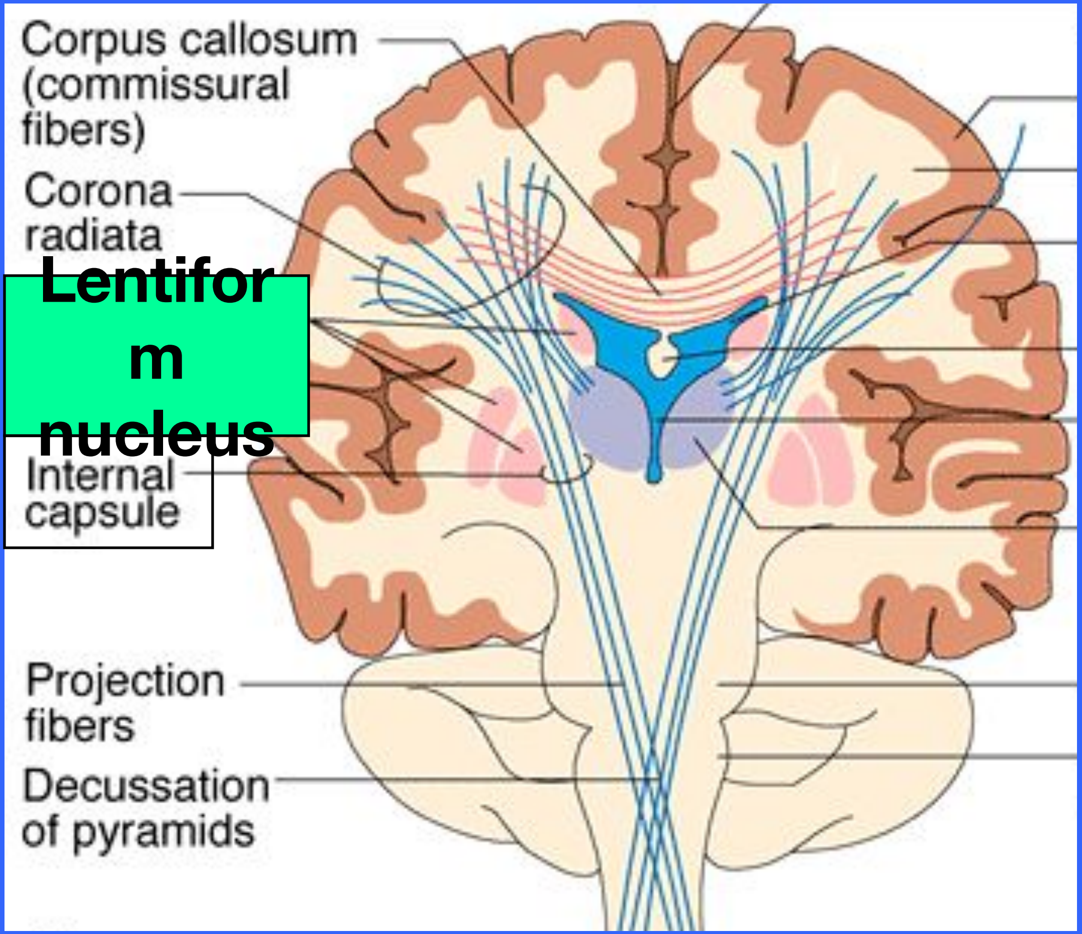
Basal Nuclei



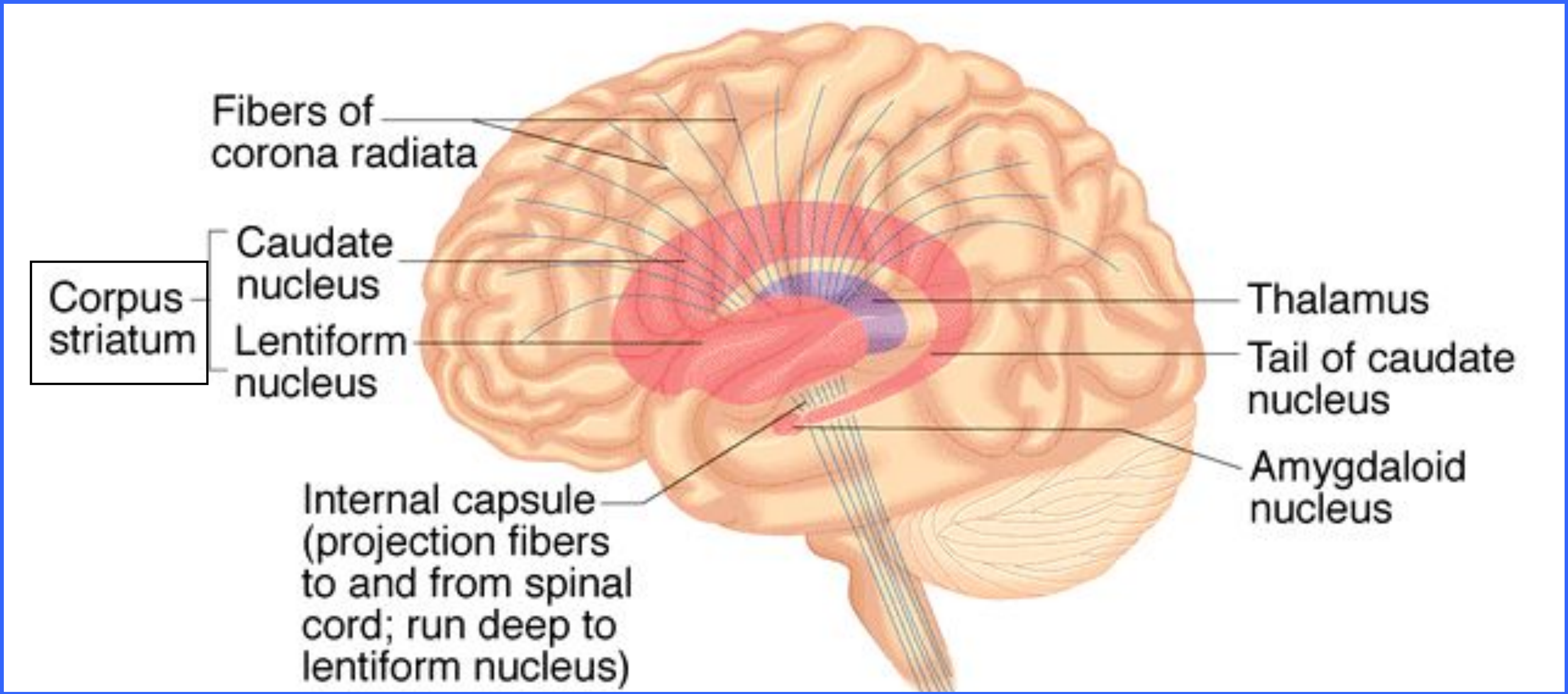
- **The comma shaped caudate nucleus arches superiorly over the diencephalon**

Basal Nuclei

- The lentiform nucleus flanks the internal capsule laterally

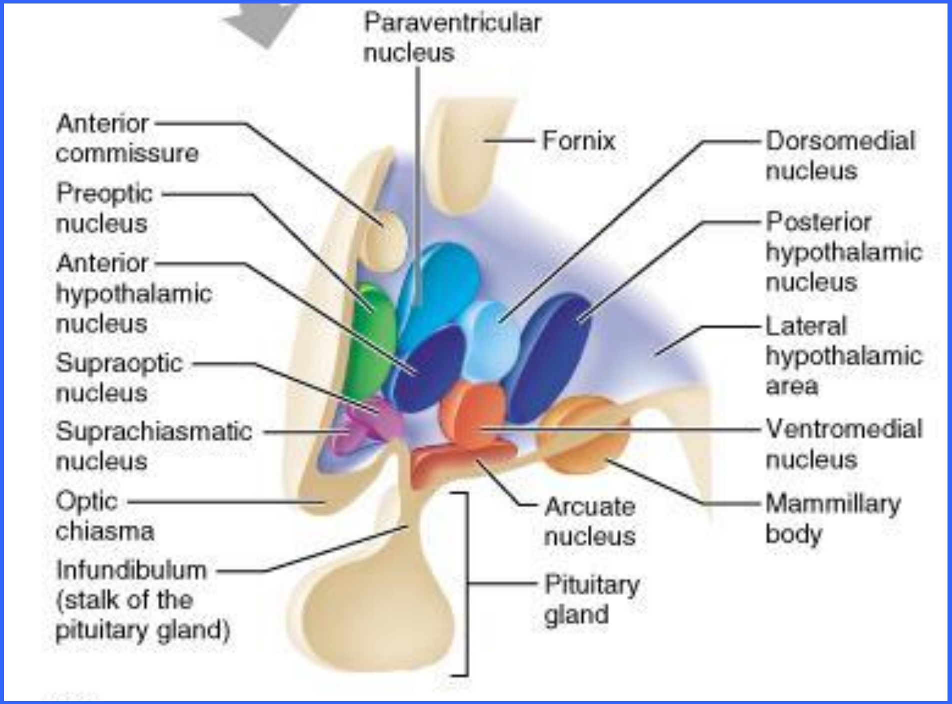


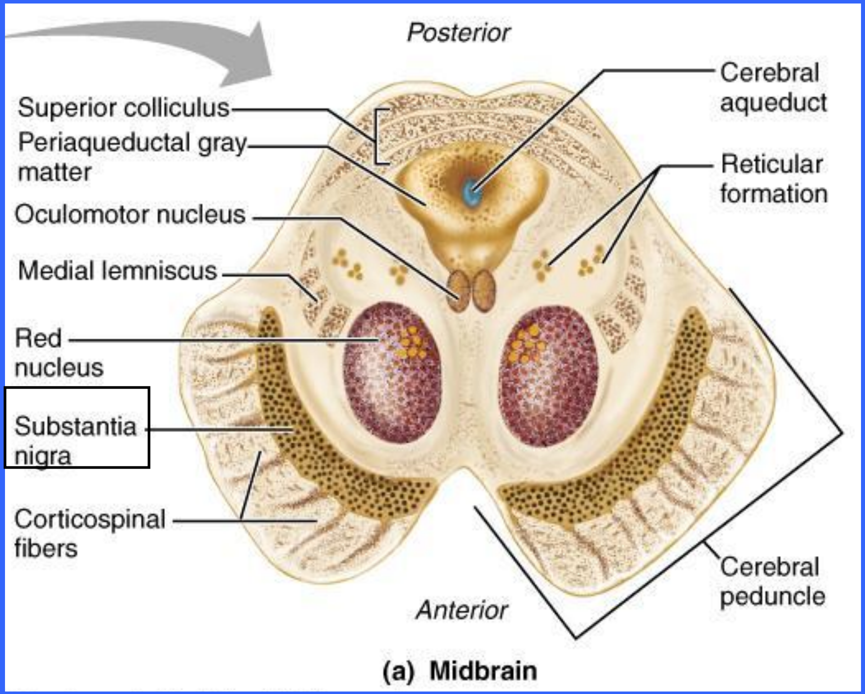
Basal Nuclei



- **Collectively the caudate nucleus and the lentiform nuclei are called the corpus striatum because the fibers of the internal capsule that course past these nuclei give them a striped appearance**

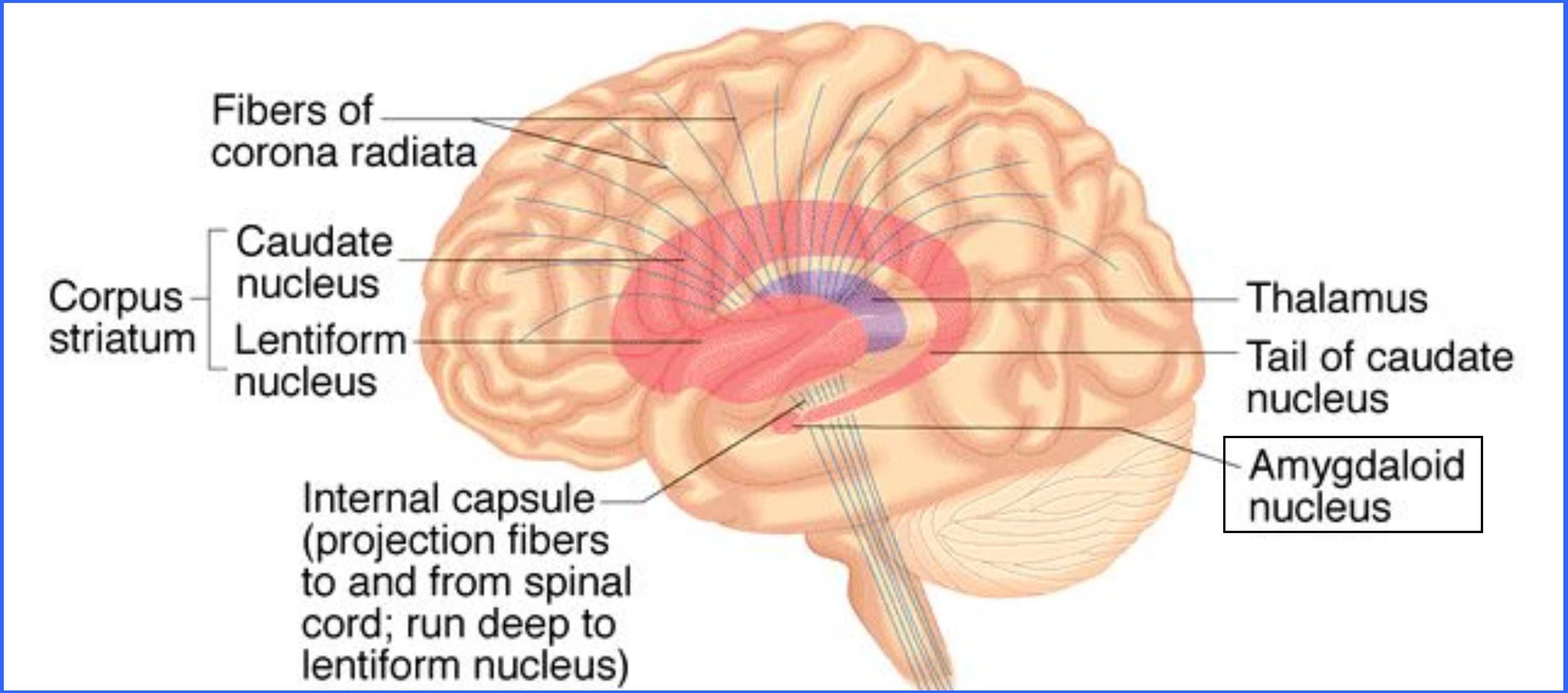
Basal Nuclei





- **The basal nuclei are functionally associated with the subthalamic nuclei (located in the floor of the diencephalon) and the substantia nigra of the midbrain**

Basal Nuclei

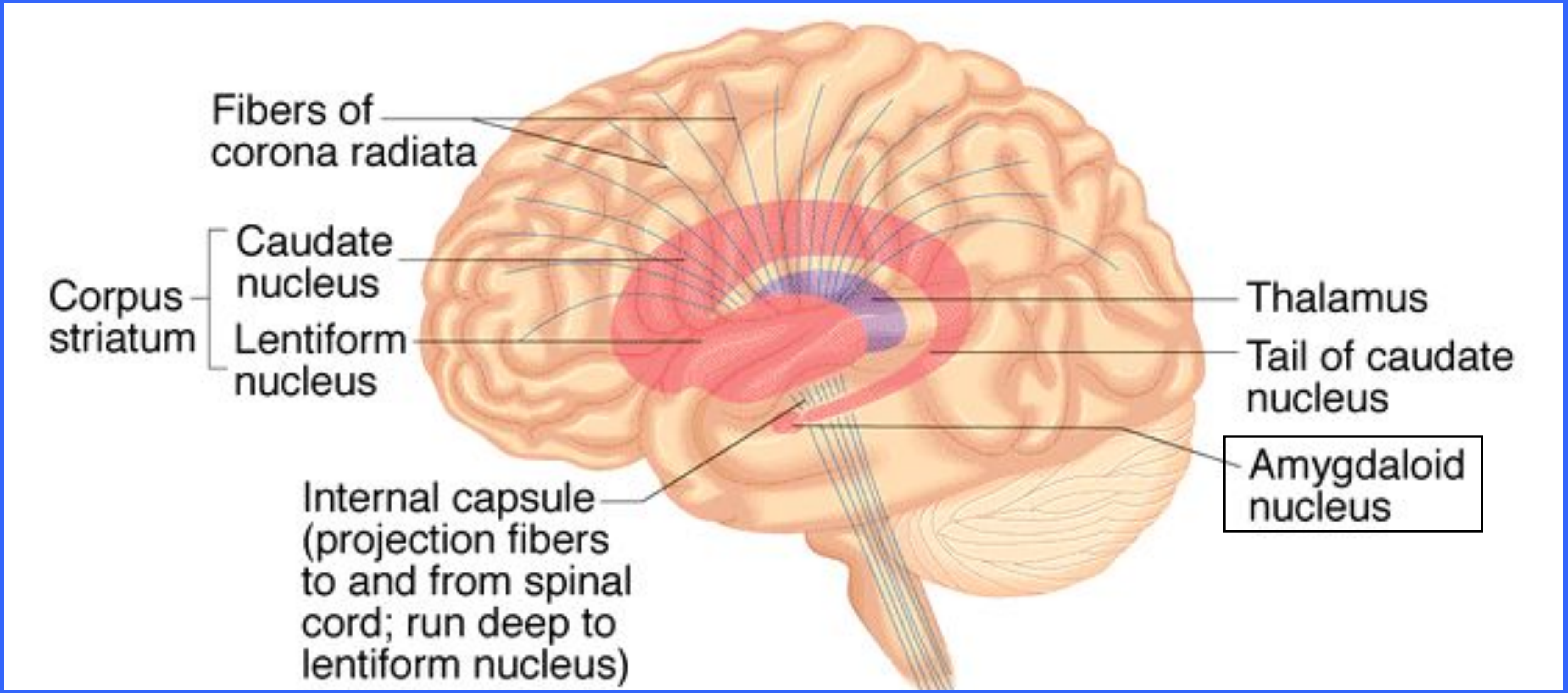


- **The amygdaloid nucleus sits on the tail of the caudate nucleus, functionally it belongs to the limbic system**

Basal Nuclei

- Functionally, the basal nuclei can be viewed as complex neural calculators that cooperate with the cerebral cortex in controlling movement

Basal Nuclei



- **The basal nuclei receive inputs from the entire cerebral cortex as well as from other subcortical nuclei**
- **Via relays through the thalamus, the basal nuclei project to the premotor and prefrontal cortices**

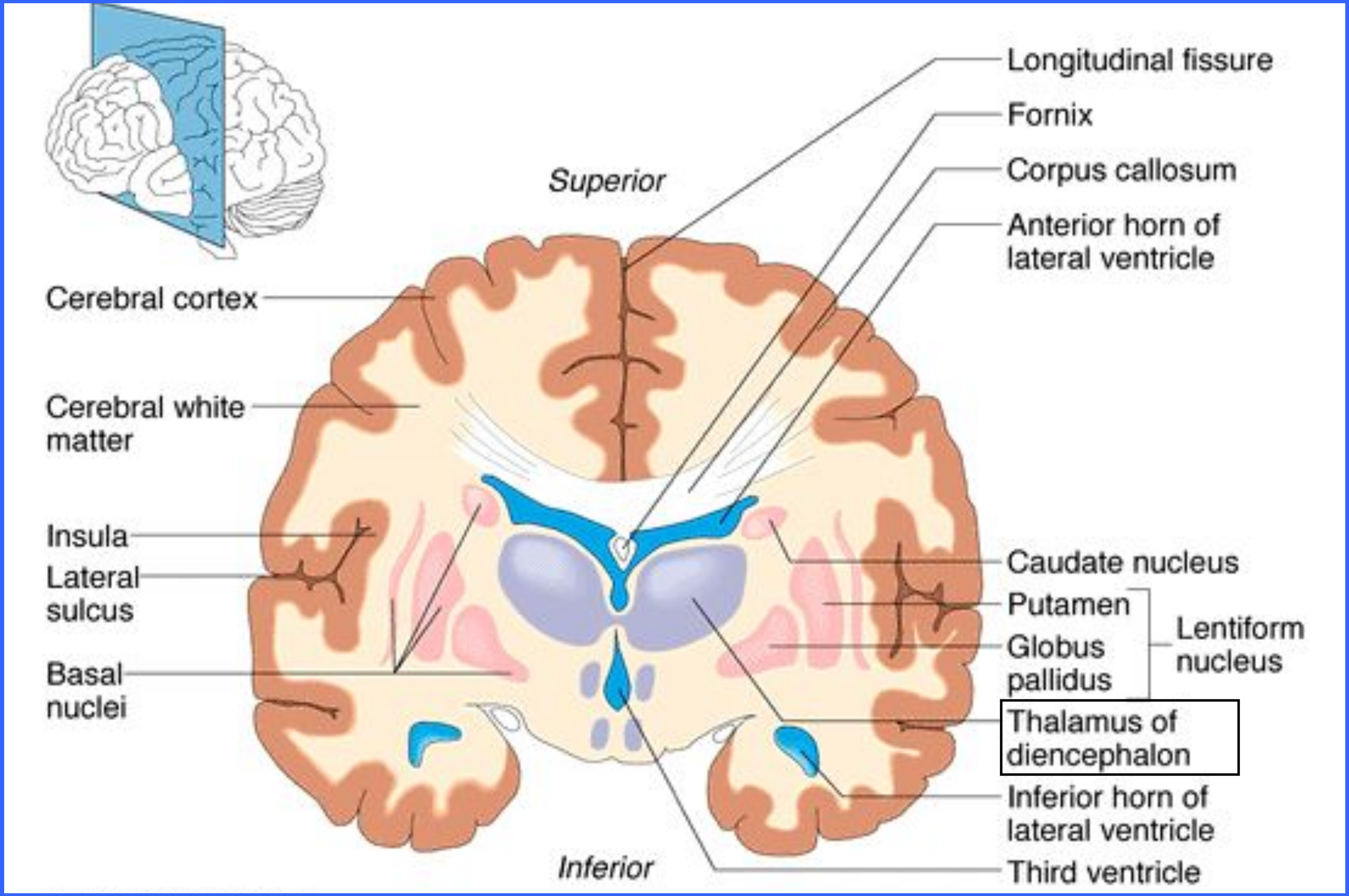
Basal Nuclei

- Via relays the basal nuclei influence muscle movements directed by the primary motor cortex
- The basal nuclei has no direct access to the motor pathways
- The precise role of the basal nuclei is difficult to determine since their function overlaps to some extent with the cerebellum
- The basal nuclei are particularly important in starting, stopping, and monitoring movements executed by the by the cortex

Basal Nuclei

- The nuclei are involved in monitoring muscle movements that are relatively slow and sustained or patterned
- The nuclei also regulated the intensity of these movements
- Additionally, they inhibit antagonistic or unnecessary movements
- When the basal nuclei are impaired, the result is disturbances in posture and muscle tone, involuntary movements including tremors, and abnormal slowness

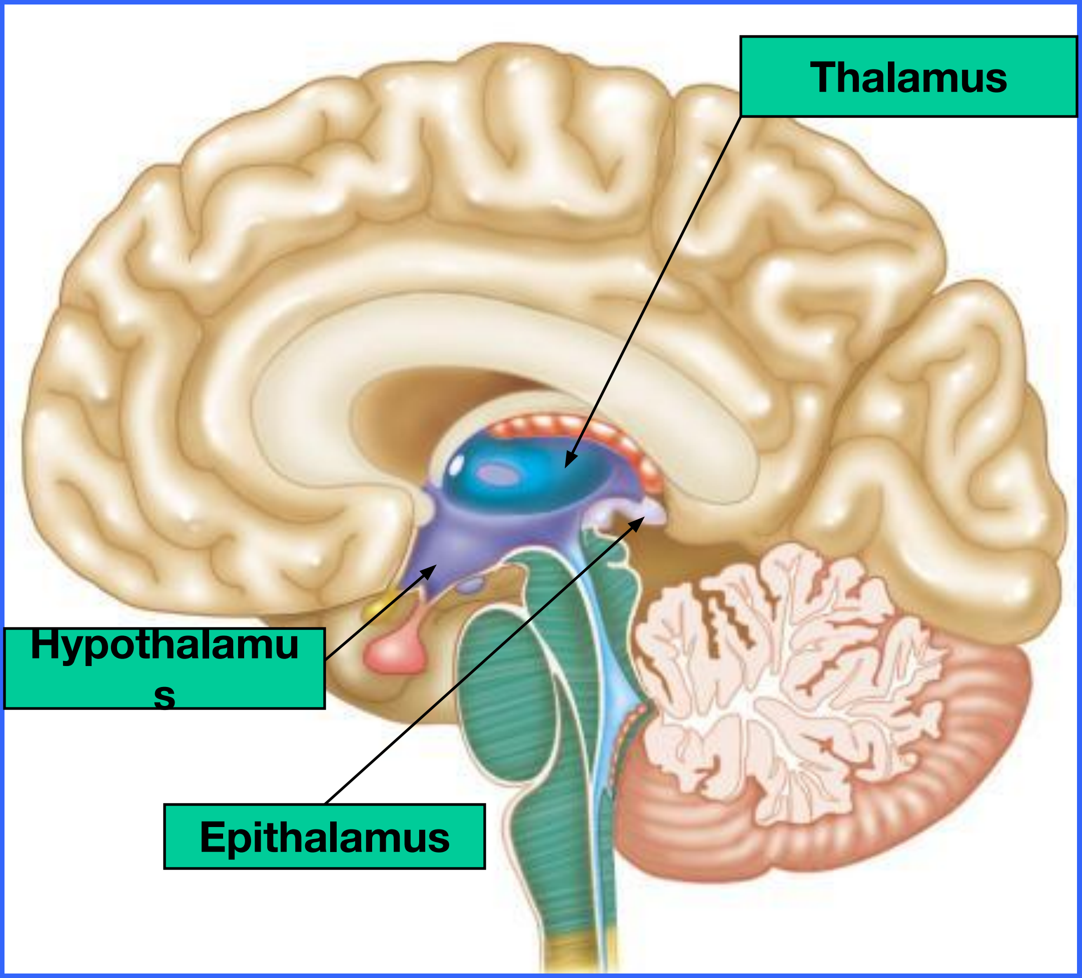
The Diencephanlon



- Forms the central core of the forebrain and is surrounded by the cerebral hemispheres

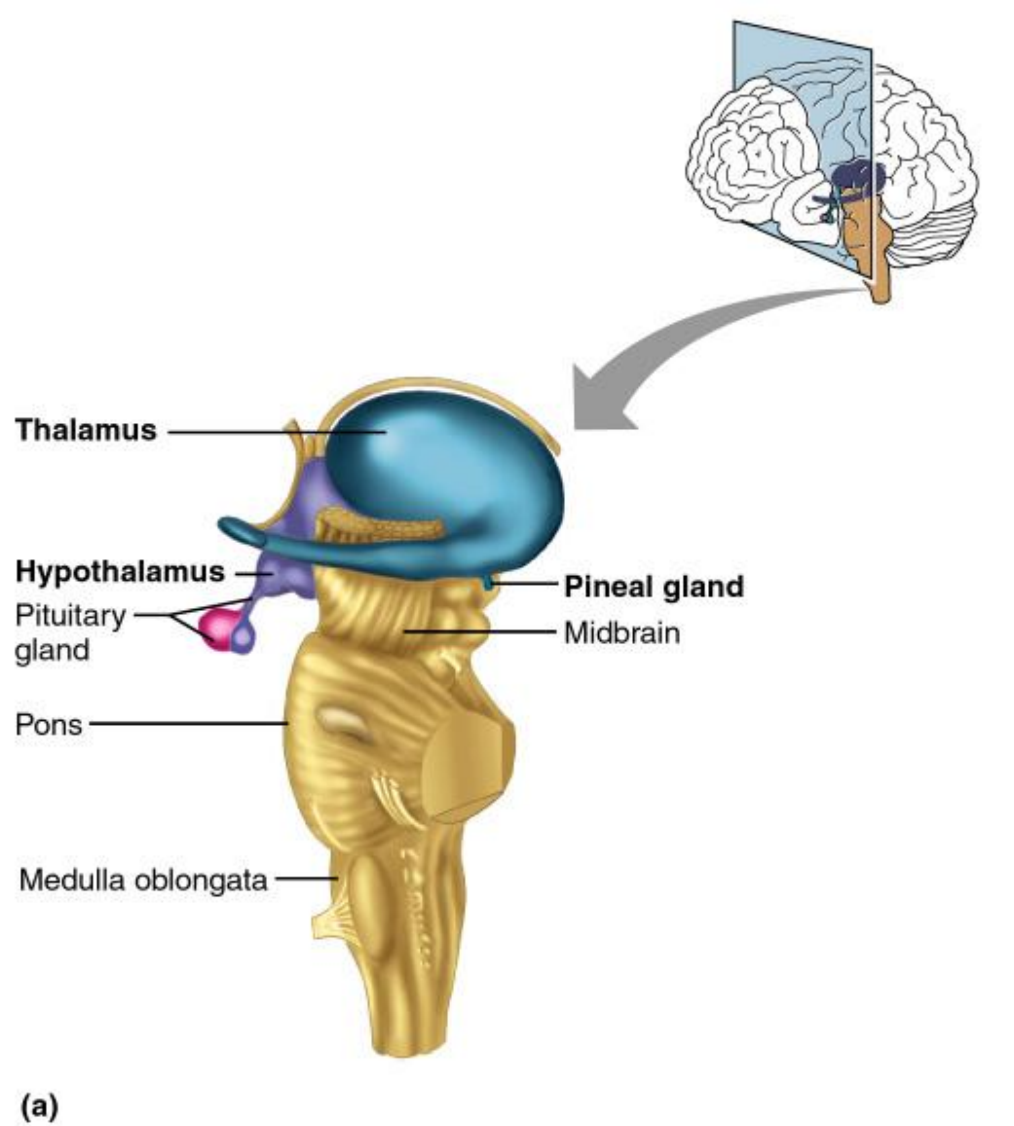
The Diencephalon

- The diencephalon consists of three structures
  - Thalamus
  - Hypothalamus
  - Epithalamus
- These structures effectively enclose the third ventricle

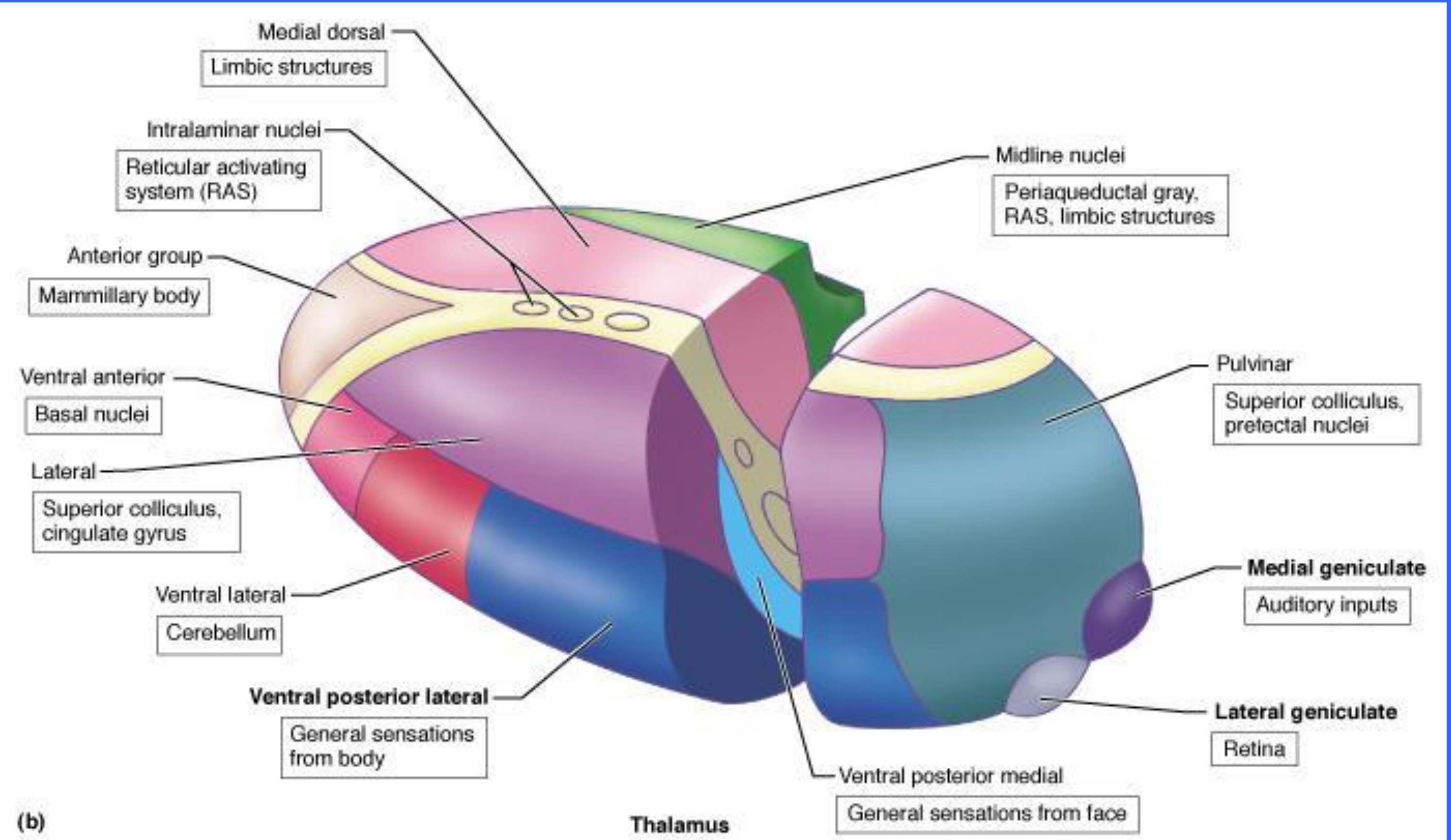


The Diencephalon

- The three structures of the diencephalon
  - Thalamus
  - Hypothalamus
  - Epithalamus
- These structures are shown with the hemispheres removed



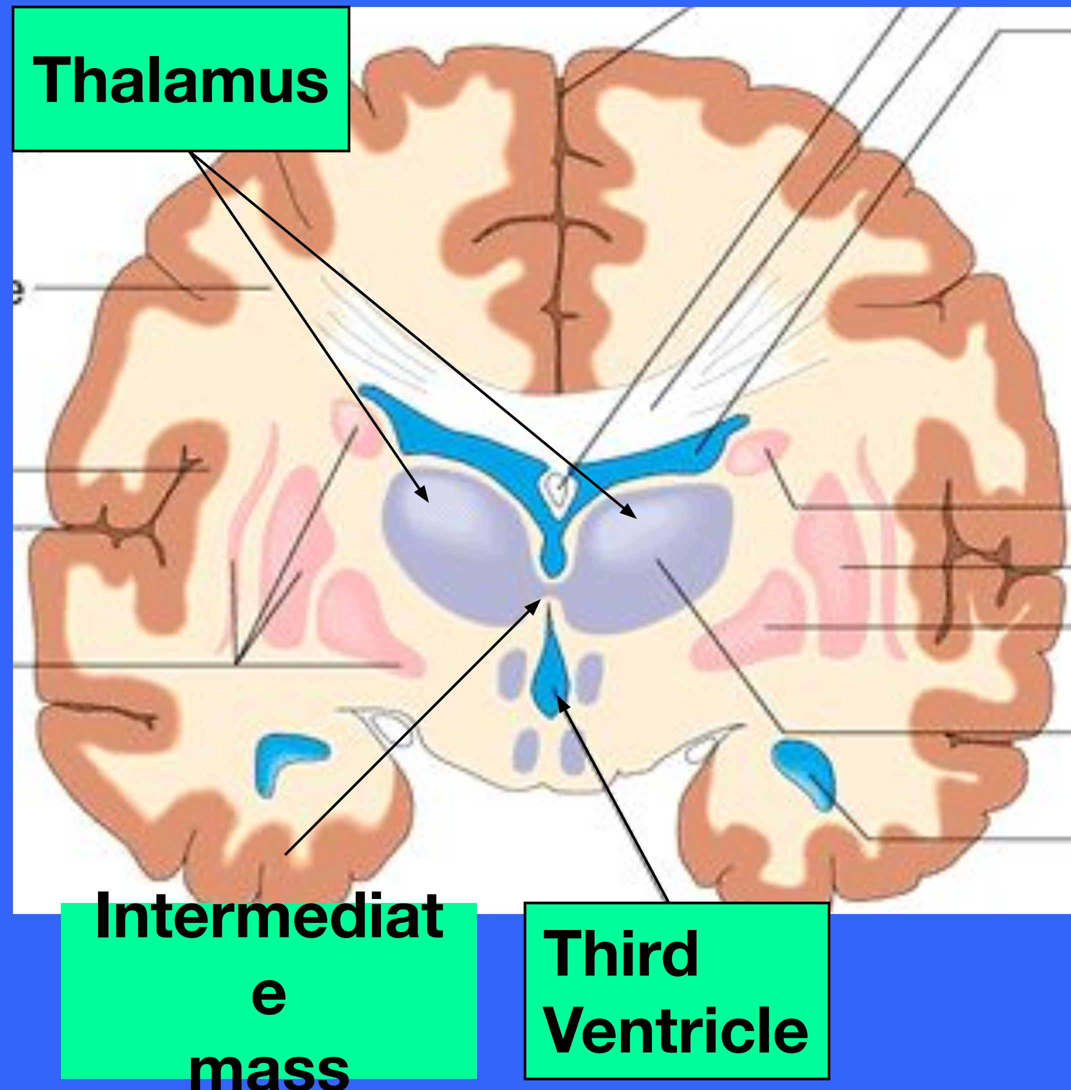
Thalamus



- The egg shaped thalamus makes up 80% of the diencephalon and forms the superolateral walls of the third ventricle

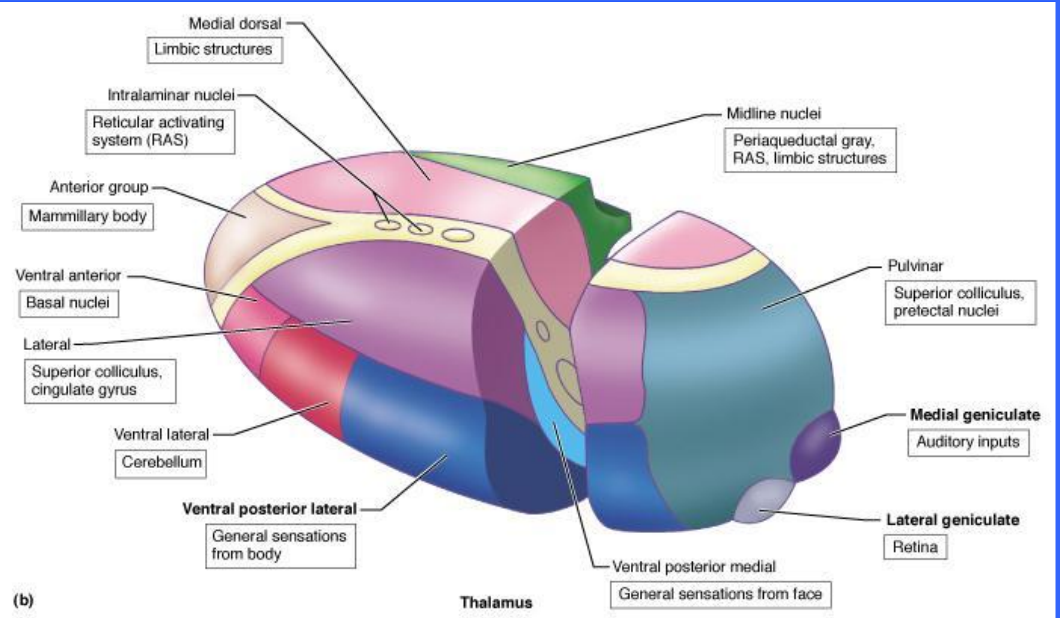
Thalamus

- The thalamus is composed of bilateral masses of gray matter held together by a mid-line commissure called the intermediate mass



Thalamus

- The thalamus has many different nuclei, most named for their location
- Each of these nuclei has a functional specialization
- Each projects fibers to and receives fibers from a specific region of the cerebral cortex

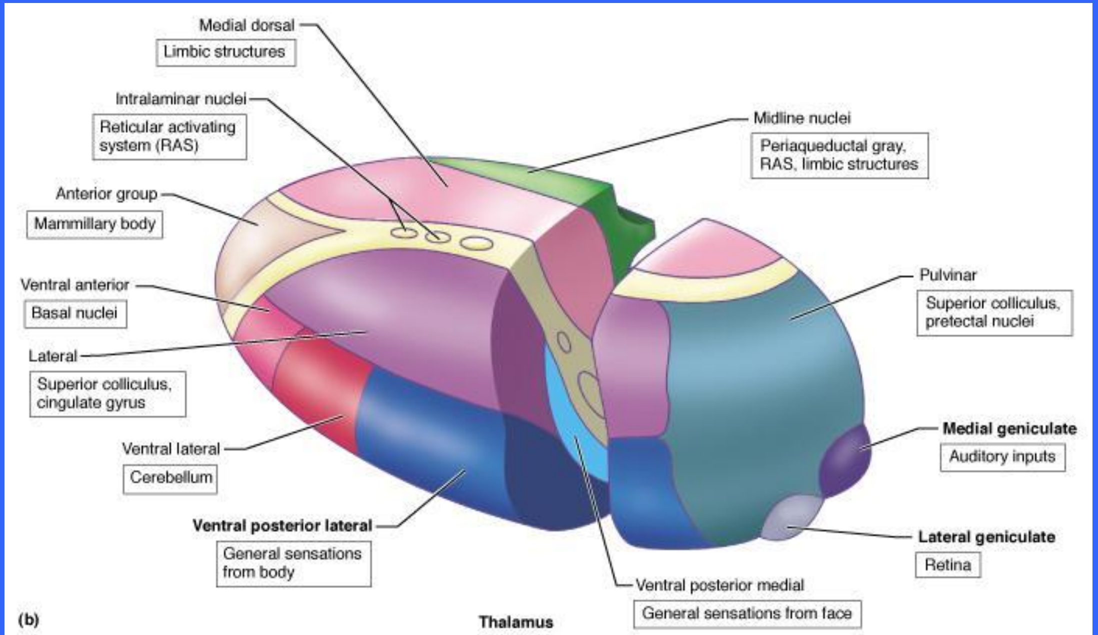


The Thalamus

- Sensory inputs are not the only type of information relayed through the thalamus
- Every part of the brain that communicates with the cerebral cortex must relay signals through the nucleus of the thalamus
- The thalamus can therefore be thought of as the gateway to the cerebral cortex

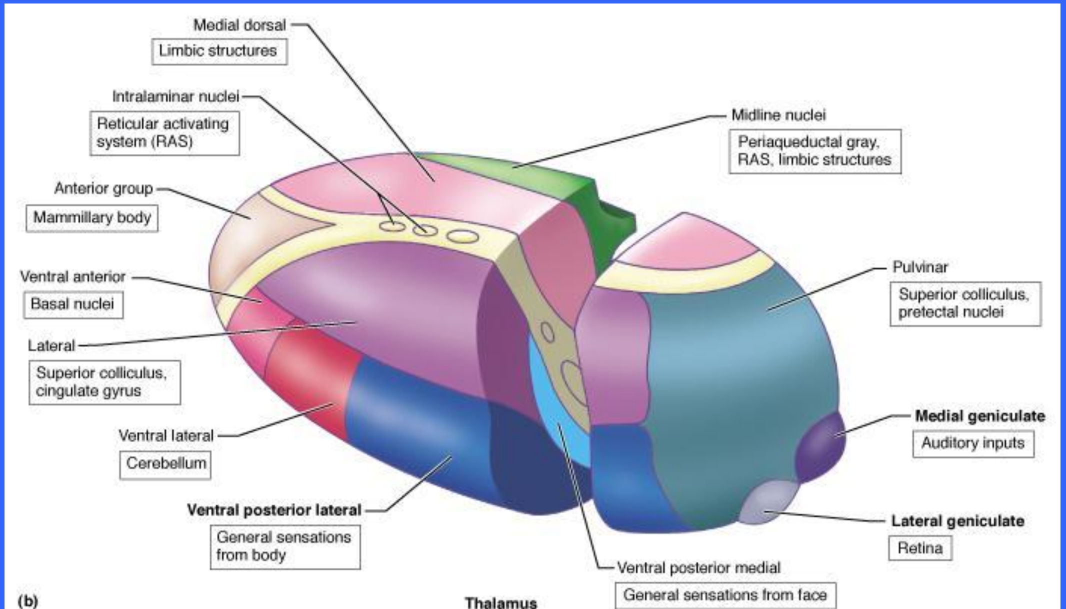
Thalamus

- **Afferent impulses from all senses and all parts of the body converge on the thalamus and synapse with at least one of its nuclei**
- **Within the thalamus, a sorting-out and information "editing" process occurs**



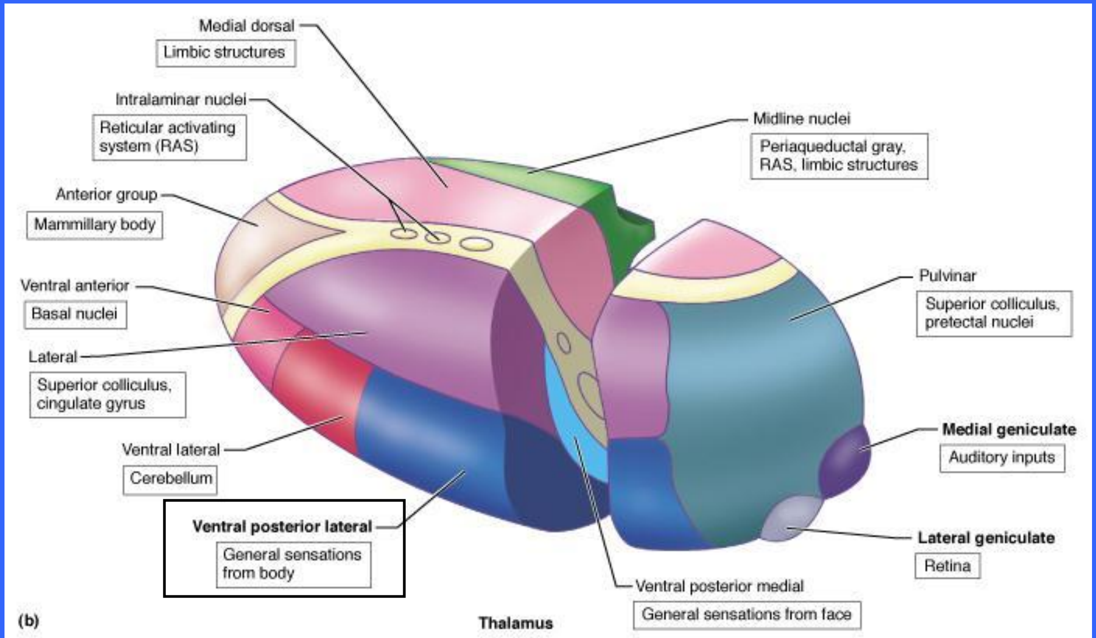
Thalamus

- Impulses having to do with similar functions are grouped together and relayed via the internal capsule to the appropriate area of the sensory cortex as well as specific cortical association areas



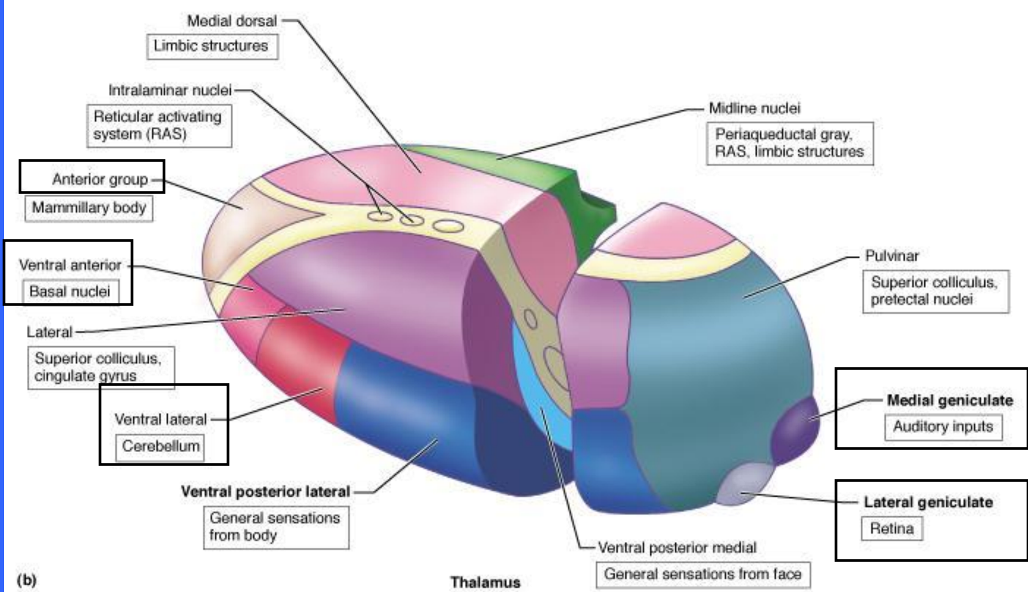
Thalamus

- In addition to sensory inputs, virtually all inputs ascending to the cerebral cortex funnel through thalamic nuclei
- Ventral posterior lateral nucleus
  - General somatic sensory receptors (touch, pain pressure)



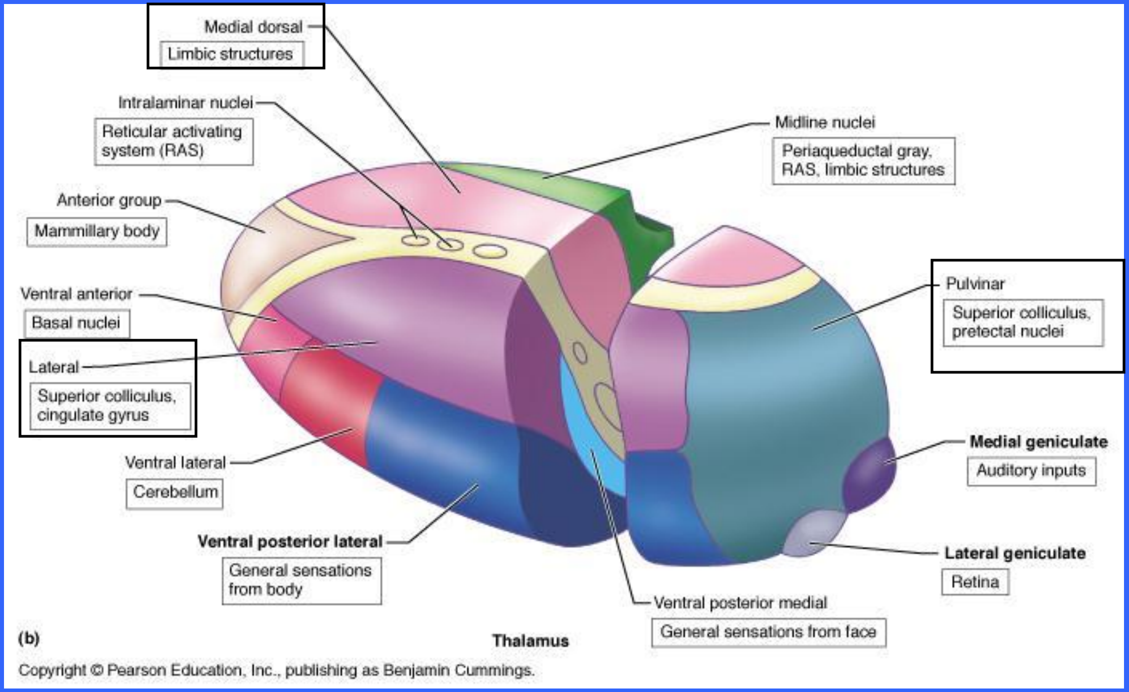
Thalamus

- Lateral geniculate body
  - Visual relay from retina
- Medial geniculate body
  - Auditory inputs
- Anterior nuclear group
  - Regulation of emotion and visceral function
- Ventral lateral nuclei
  - Direct motor activity of cerebellum
- Ventral anterior nuclei
  - Direct motor activity of basal nuclei



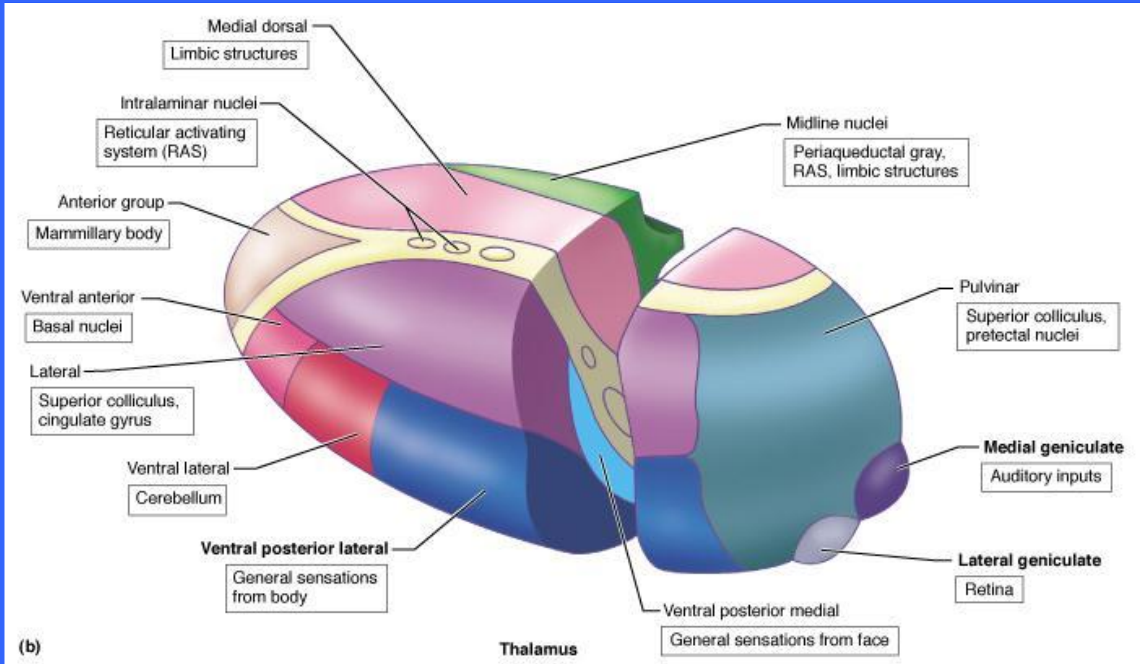
Thalamus

- Pulvinar, medial dorsal and lateral nuclei are involved in the integration of sensory information and projection to specific association cortices

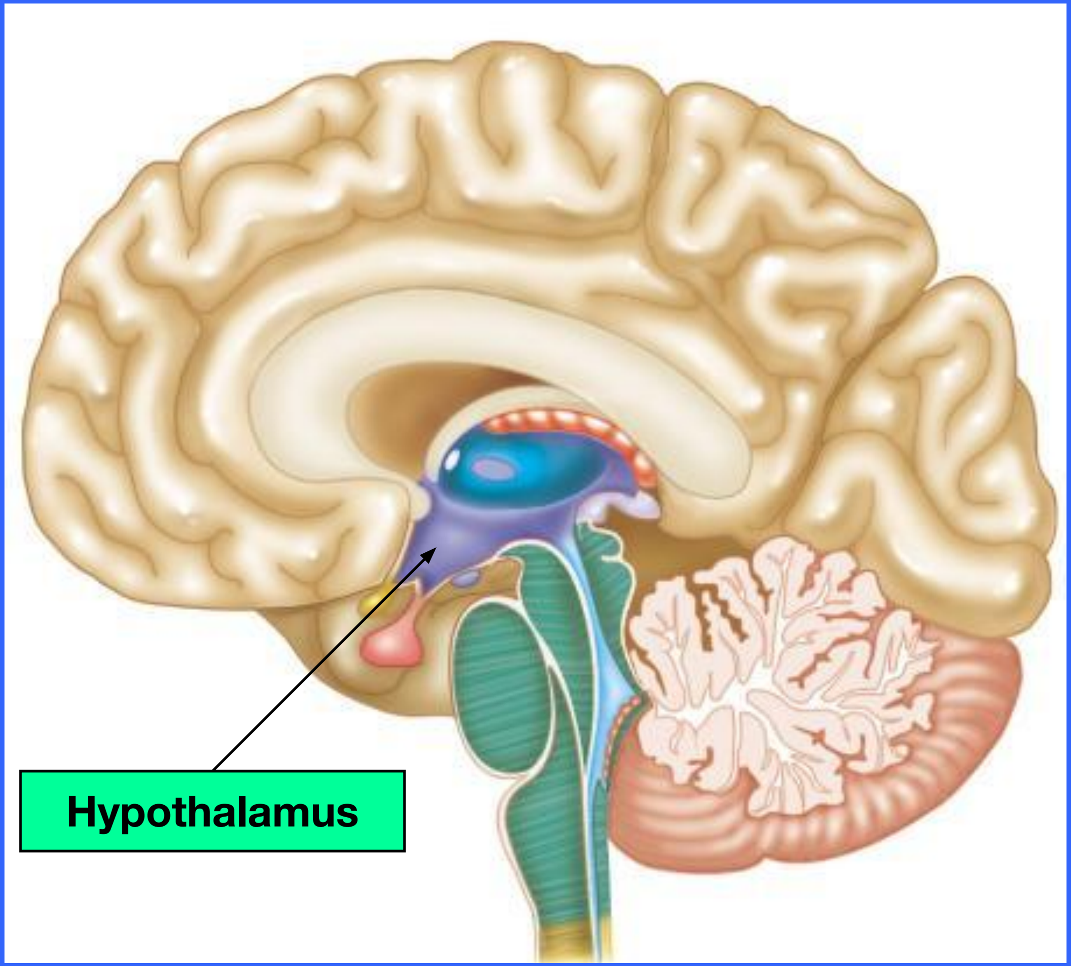


Thalamus

- The thalamus plays a key role in mediating sensation, motor activities, cortical arousal, learning, and memory
- It is truly the gateway to the cerebral cortex

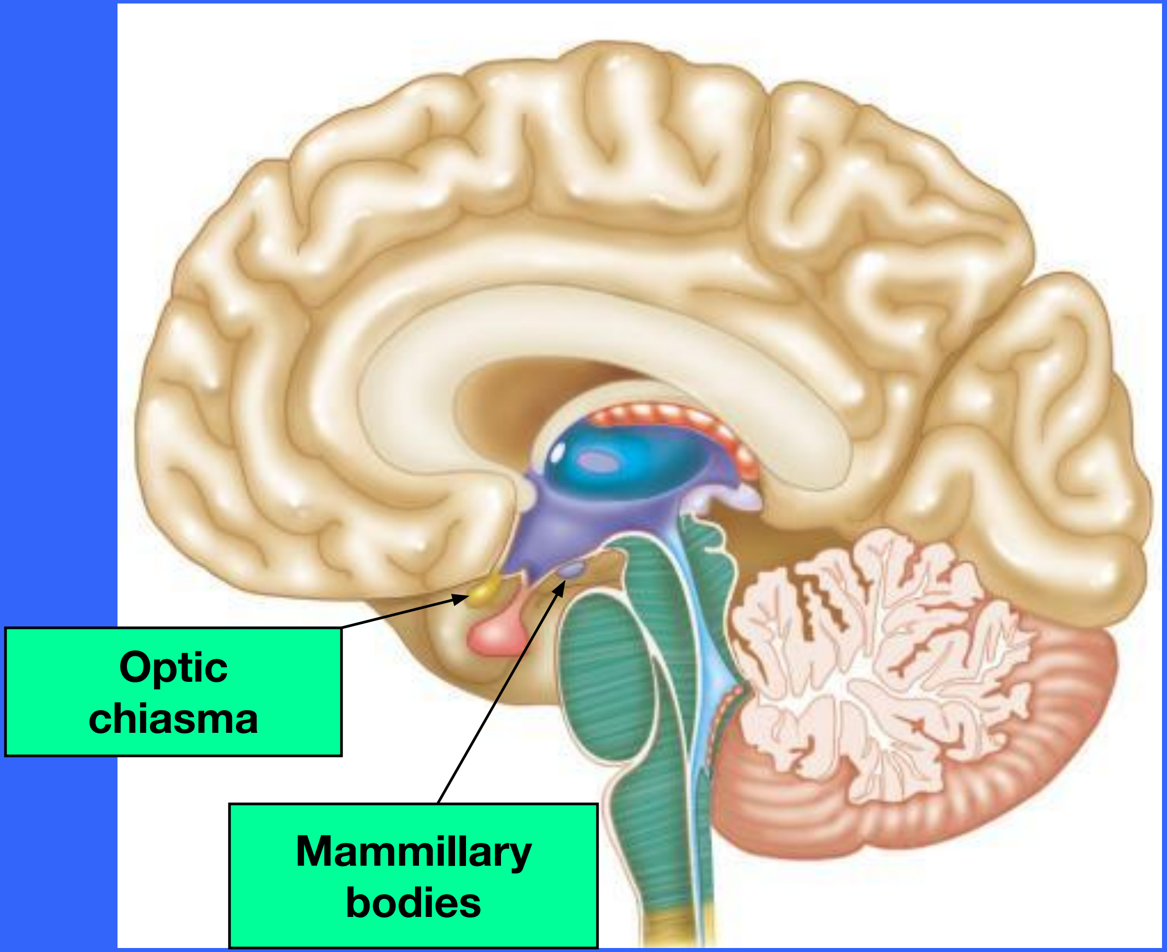


The Hypothalamus



- The hypothalamus is located below the thalamus, capping the brain stem

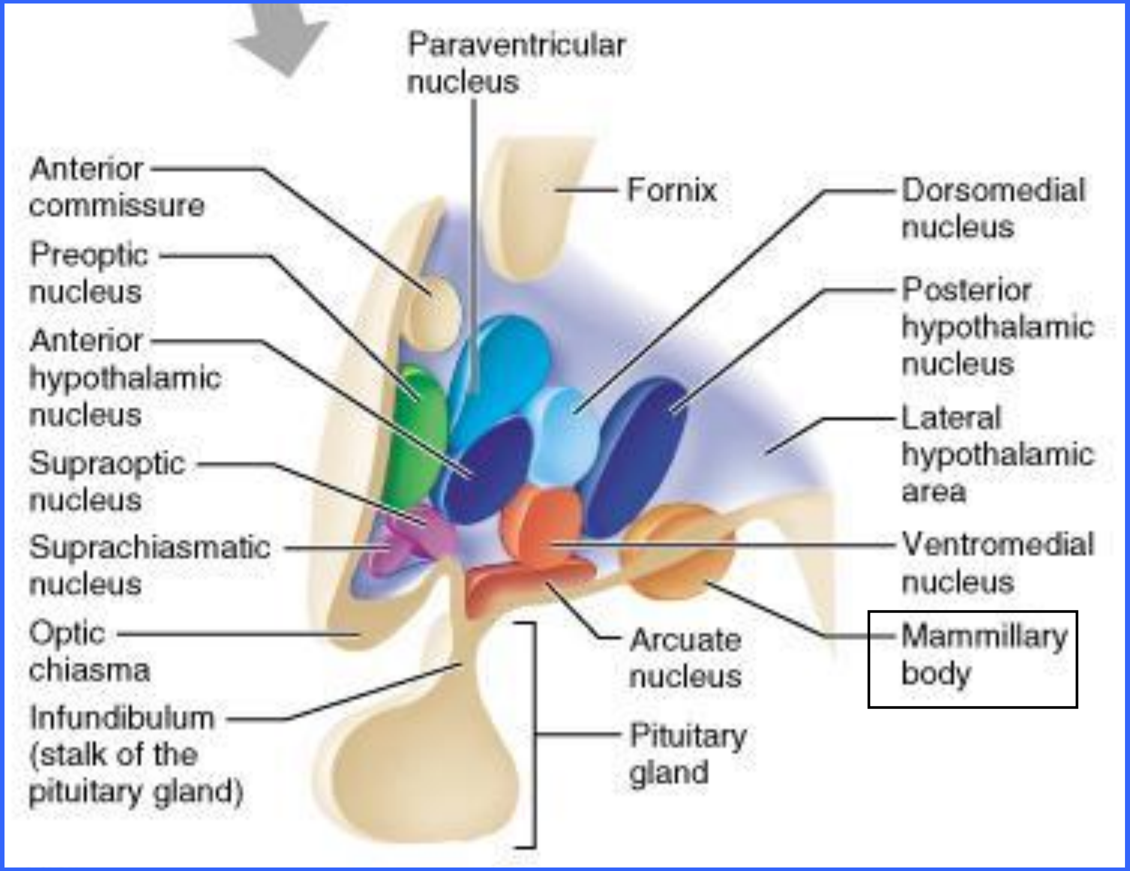
Hypothalamus



- Merging into the midbrain inferiorly, it extends from the optic chiasma to the posterior margin of the mammillary bodies

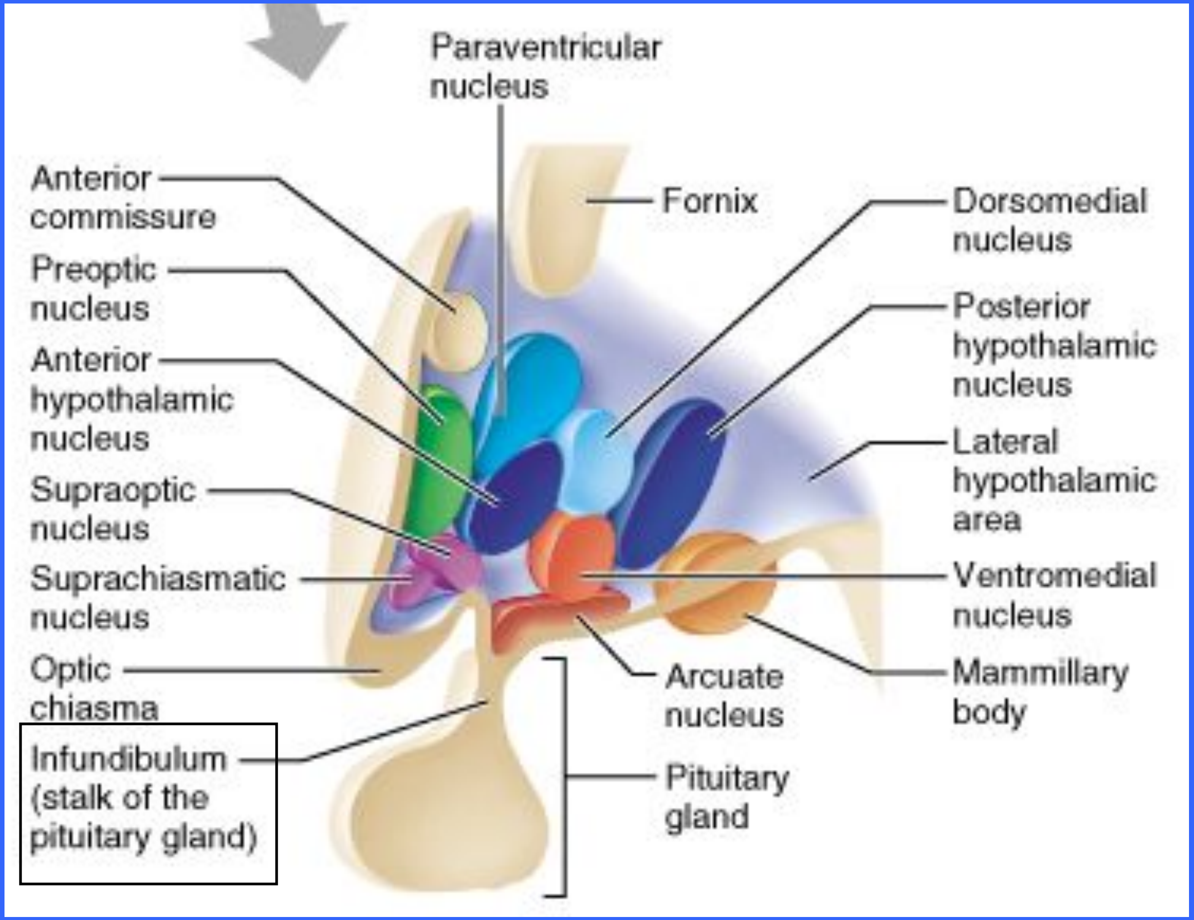
Mammillary Bodies

- **The mammillary bodies are paired nuclei that bulge anteriorly from the hypothalamus that serve as relay stations in the olfactory pathways**



Hypothalamus

- **Between the optic chiasma and the mammillary bodies is the infundibulum**
- **A stalk of the hypothalamic tissue connects the pituitary gland to the base of hypothalamus**



Hypothalamus

- The hypothalamus contains about a dozen functionally important nuclei
- Despite its small size, the hypothalamus is the main visceral control center of the body and is vitally important to overall body homeostasis

Autonomic Control Center

- The hypothalamus regulates involuntary nervous activity by controlling the activity of autonomic centers in the brain stem and spinal cord
- In this role the hypothalamus influences
  – Blood pressure
  – Rate and force of heart contraction
  – Motility of the digestive system
  – Respiratory rate and depth
  – Secretion of sweat and salivary glands

Center for Emotional Response

- The hypothalamus has numerous connections with cortical association areas, lower brain stem centers, and it lies at the center of the limbic system which is the emotional part of the brain
- Nuclei involved in the perception of fear, pleasure, and rage, as well as those involved in the biological rhythms and drives of sex are found in the hypothalamus

Center for Emotional Response

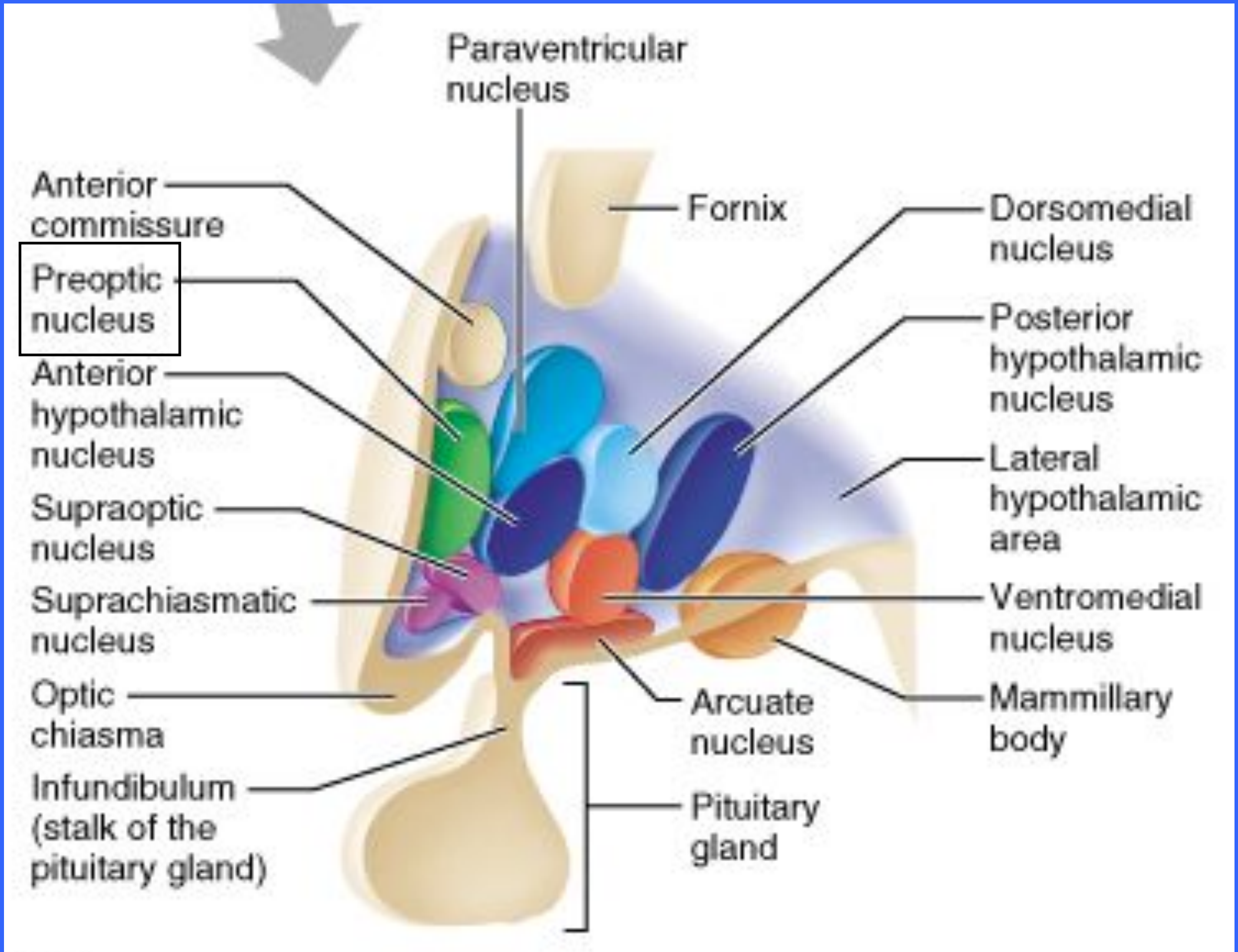
- The hypothalamus acts through the autonomic nervous system to initiate most physical expressions of emotion
  - Physical manifestations of fear
    - Pounding heart
    - Elevated blood pressure
    - Pallor
    - Sweating
    - Dry mouth

Body Temperature Regulation

- The body's thermostat is in the hypothalamus
- The hypothalamus receives input from the thermoreceptors located in other parts of the brain as well as in the body periphery
- Homeostatic adjustments are then made to either cool or heat the body (sweating or shivering)
- Hypothalamic centers also induce fever

Body Temperature Regulation

- **Hypothalamic receptors in the preoptic region monitor the temperature of the blood flowing through the hypothalamus**

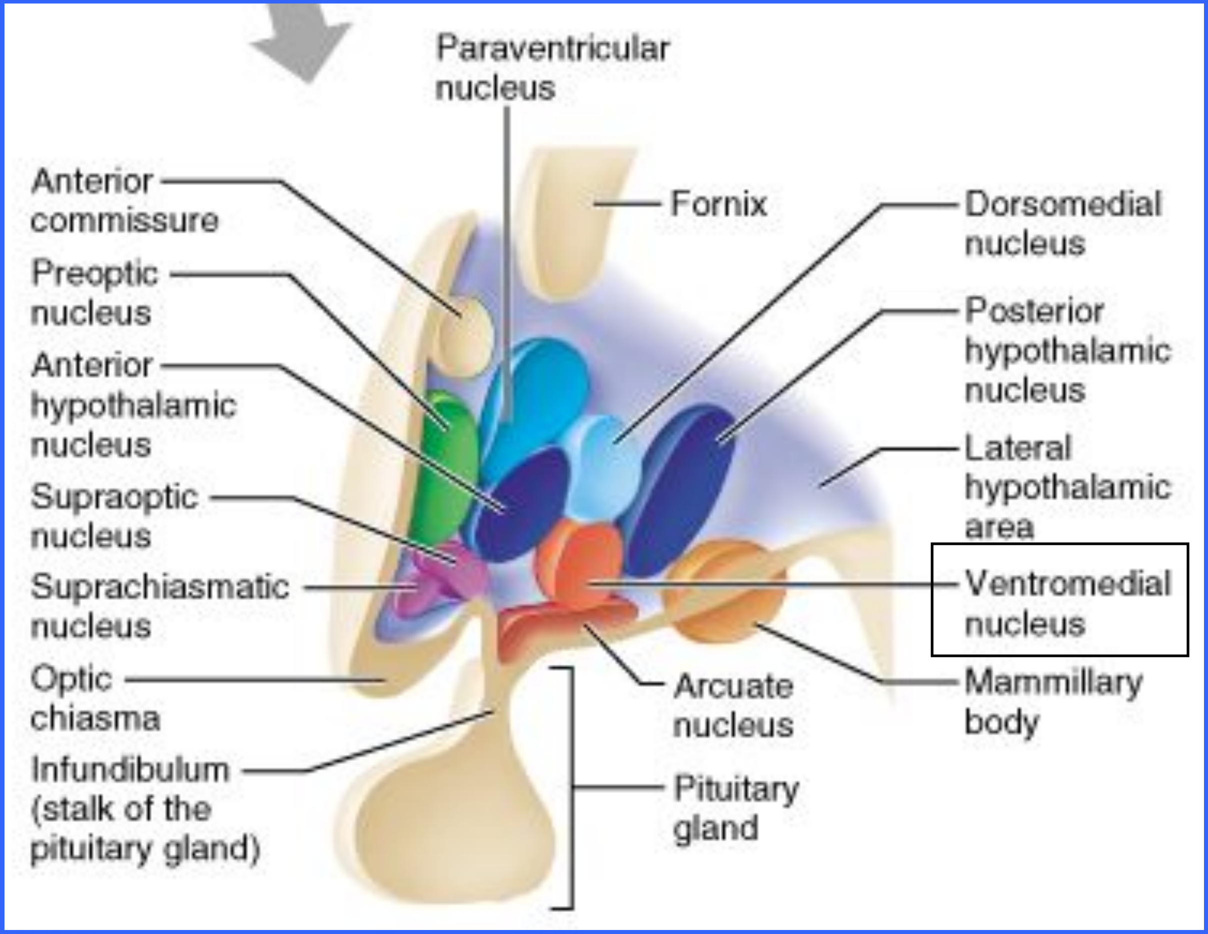


Body Temperature Regulation

- **According to signals received by the preoptic nuclei the hypothalamus initiates mechanisms to maintain relatively constant body temperature**
  - **Cooling / sweating**
  - **Heat generation / shivering**

Regulation of Hunger & Thirst

- In response to changing levels of glucose, amino acids, hormones, and salts in the blood, the hypothalamus regulates feelings of hunger and satiety (ventro-medial nuclei)



Regulation of Water Balance

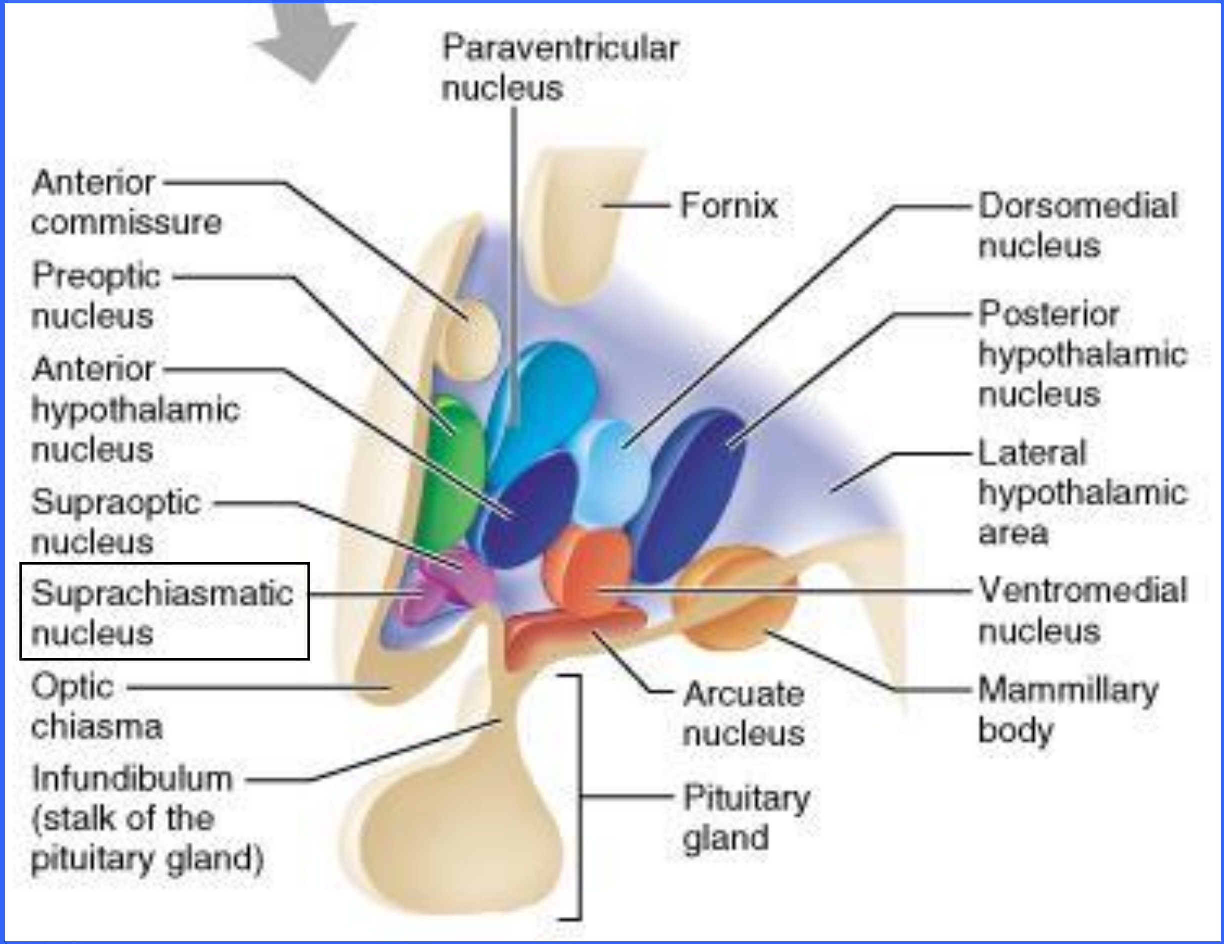
- When body fluids become too concentrated, hypothalamic neurons called osmoreceptors are activated
- These receptors excite hypothalamic nuclei that trigger the release of antidiuretic hormone (ADH) from the posterior pituitary
- ADH causes the kidneys to retain water
- The same conditions also stimulate hypothalamic neurons in the thirst center, causing us to drink fluids

Regulation of Sleep-Wake Cycles

- **Acting with other brain regions, the hypothalamus helps regulate the complex phenomenon of sleep**
- **It is responsible for the timing of the sleep wake cycle**

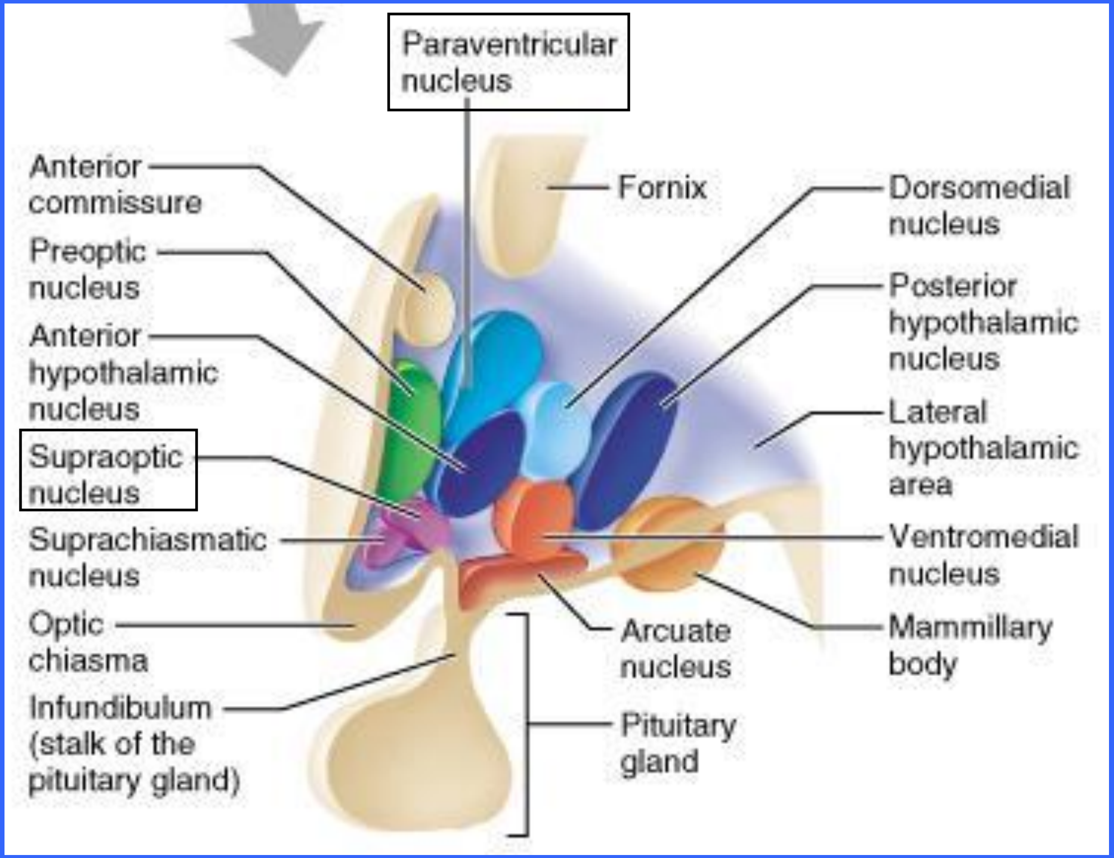
Regulation of Sleep-Wake Cycles

- **Hypothalamus through the operation of its suprachiasmatic nucleus (our biological clock) sets the timing of the sleep-wake cycle in response to day-light darkness cues from visual pathways**

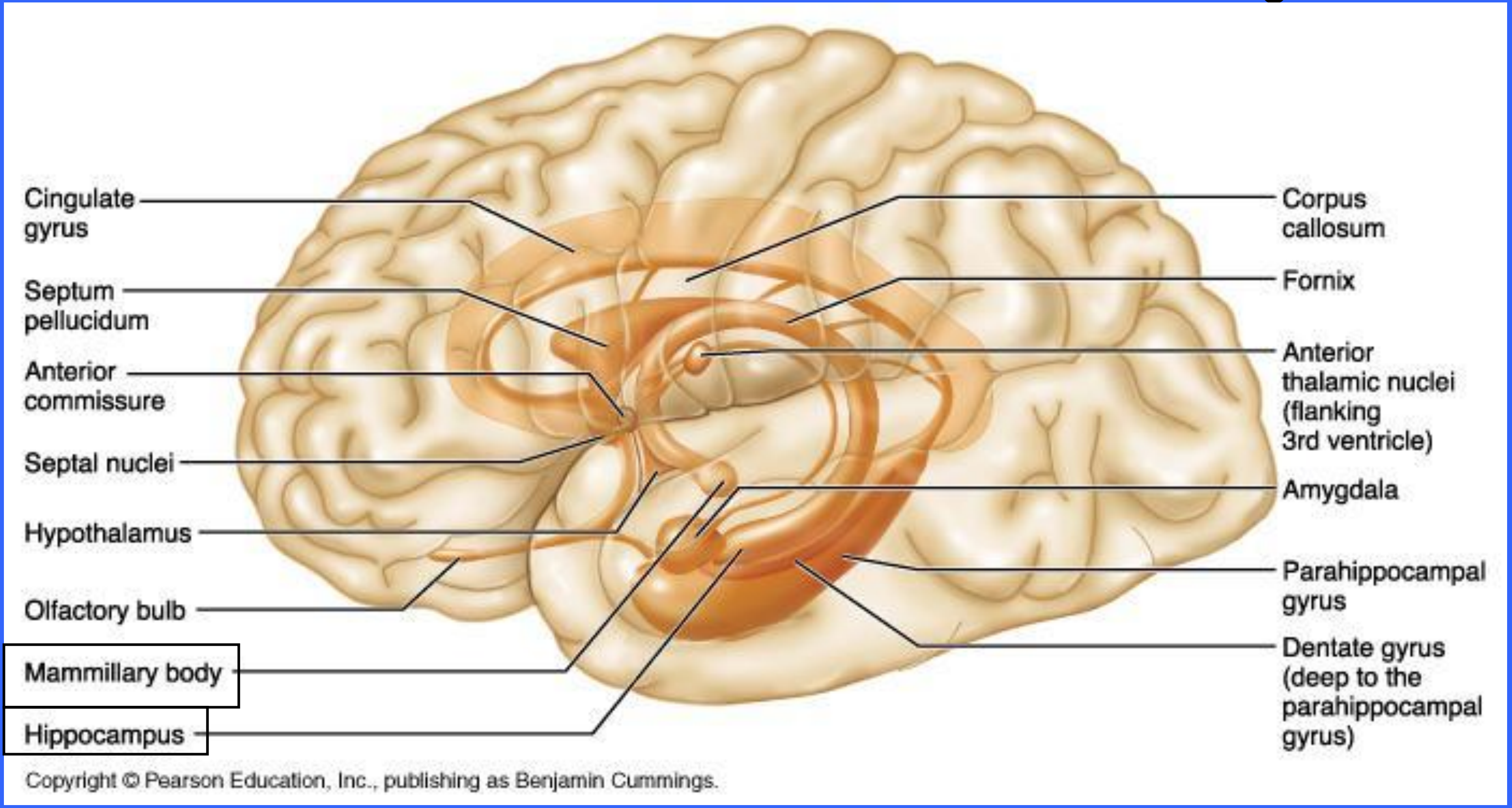


Control of Endocrine Functioning

- The hypothalamus acts as the helmsman of the endocrine system
  - By producing *releasing* hormones, it controls the secretion of hormones by the anterior pituitary gland
  - The supraoptic and paraventricular nuclei produce hormones (ADH and oxytocin)

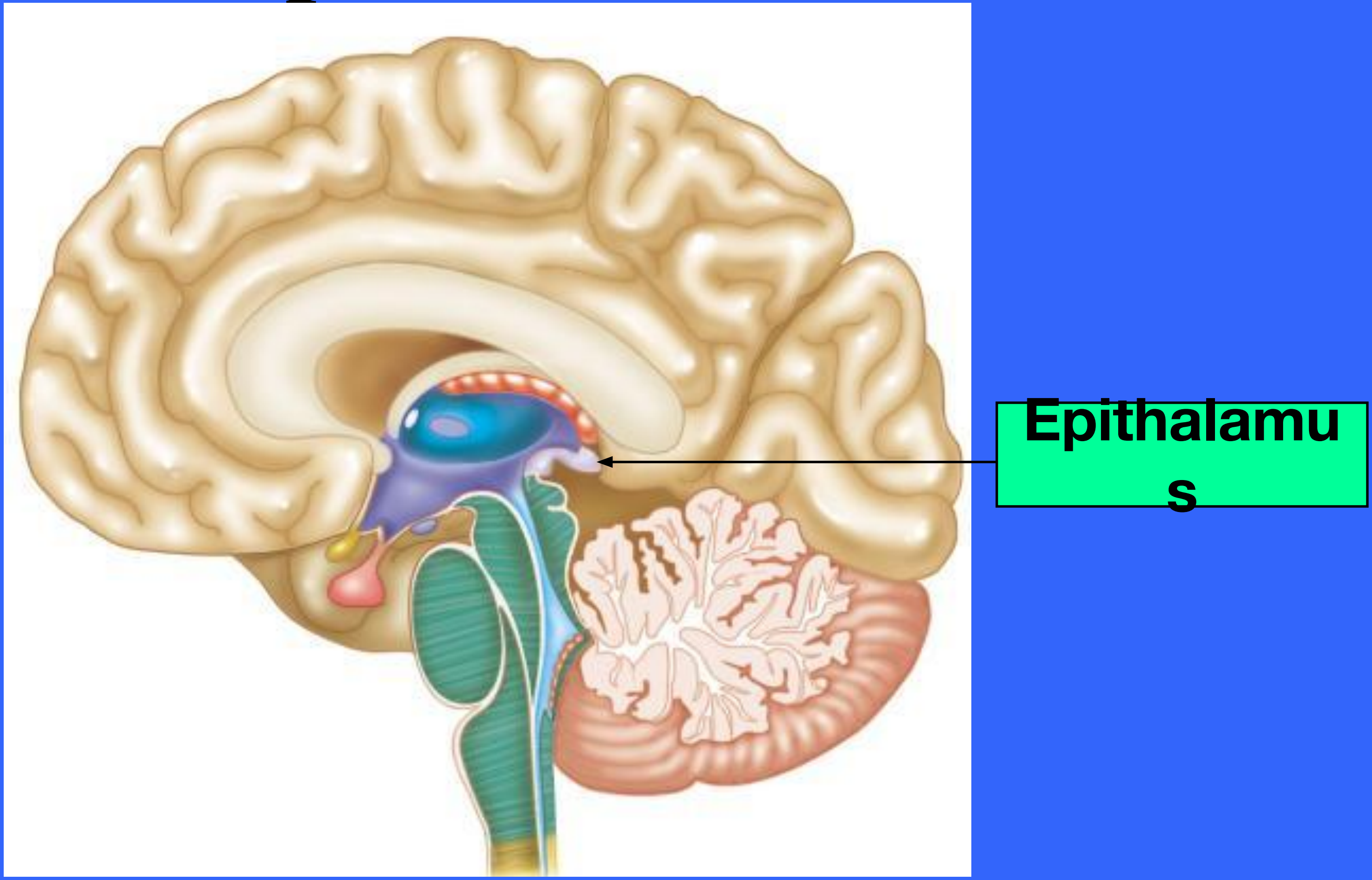


Formation of Memory



- **The nucleus of the mammillary body receives many inputs from the major memory-processing structures of the cerebrum, the hippocampal formation and therefore may relate to memory formation**

Epithalamus



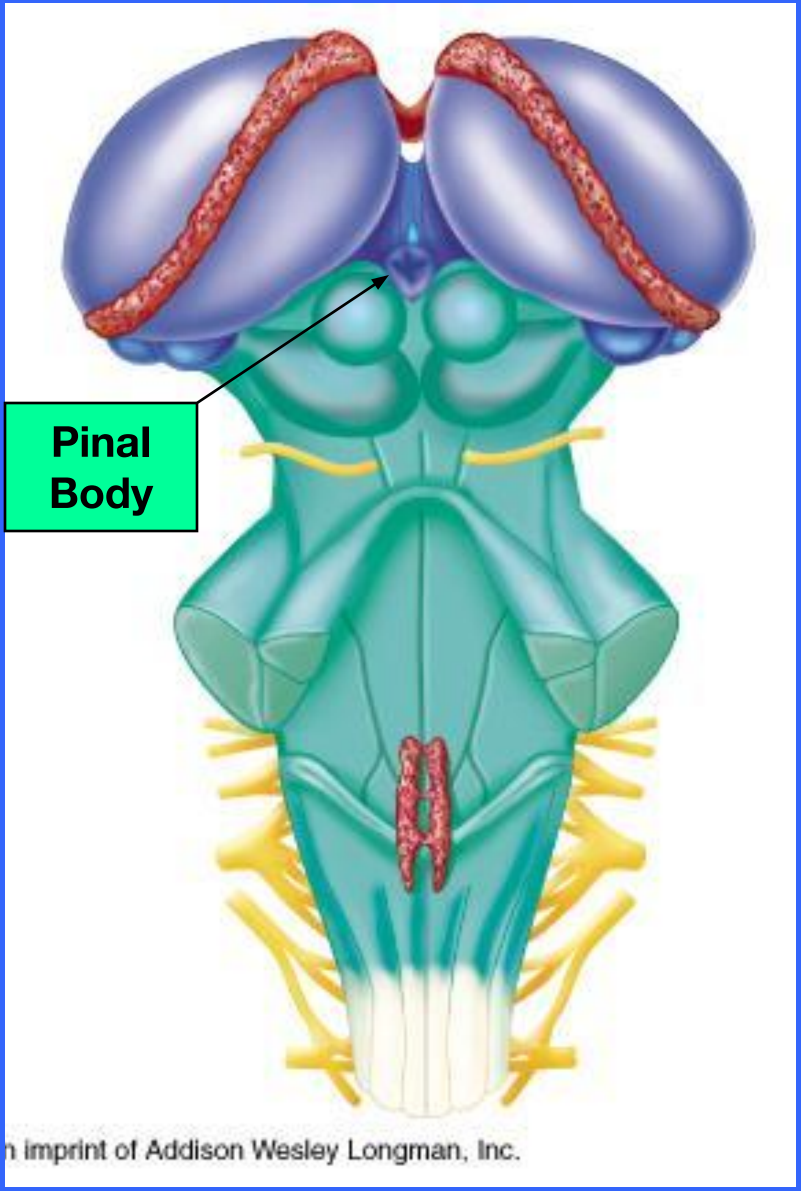
- The epithalamus is the posterior portion of the diencephalon
- It forms the roof of the third ventricle

The Epithalamus

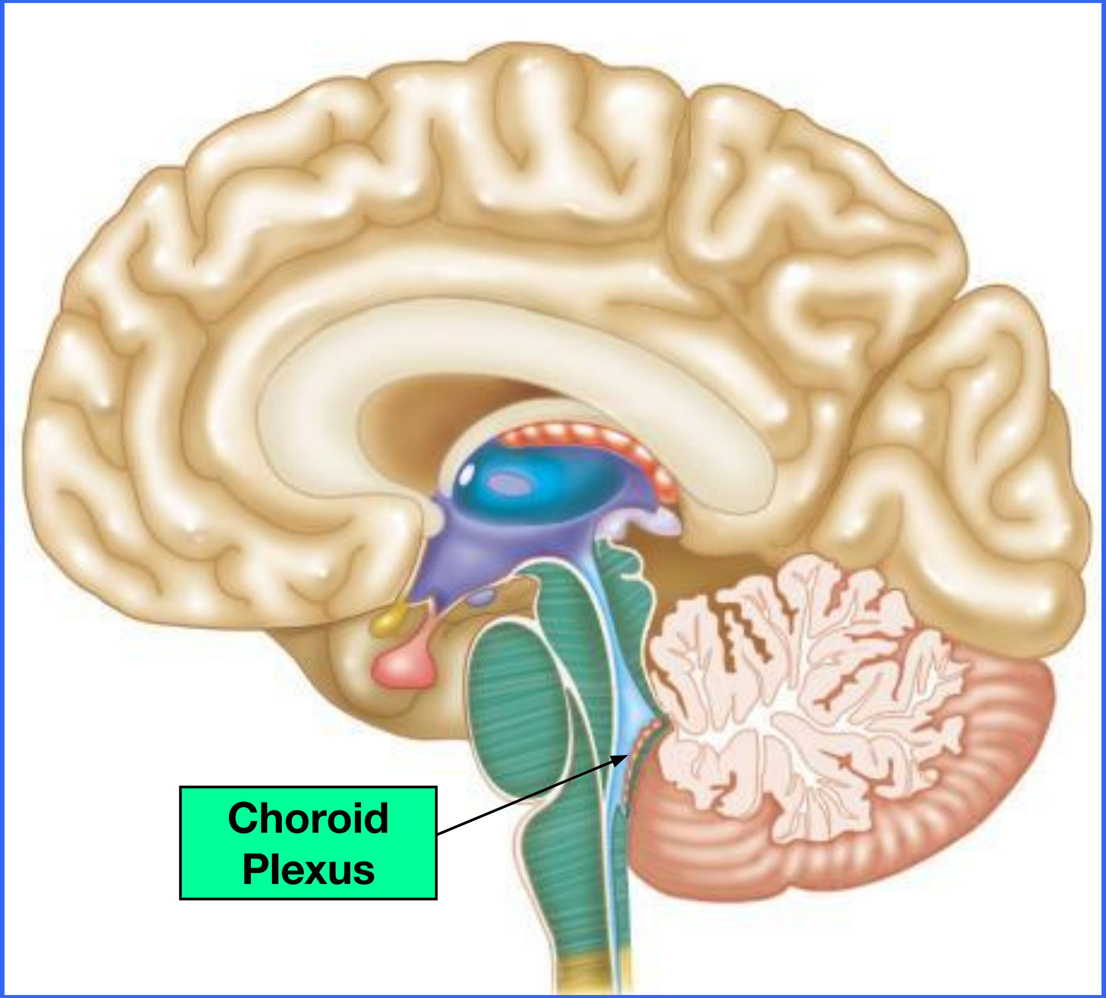
- **The epithalmus consists of one tiny group of nuclei and a small, unpaired knob called the pineal body**
- **This gland, which derives from ependymal glial cells, is a hormone secreting organ**

Epithalamus

- The pineal gland extends from the posterior border of the epithalamus
- The pineal gland secretes the hormone melatonin which signals the sleep-wake cycle



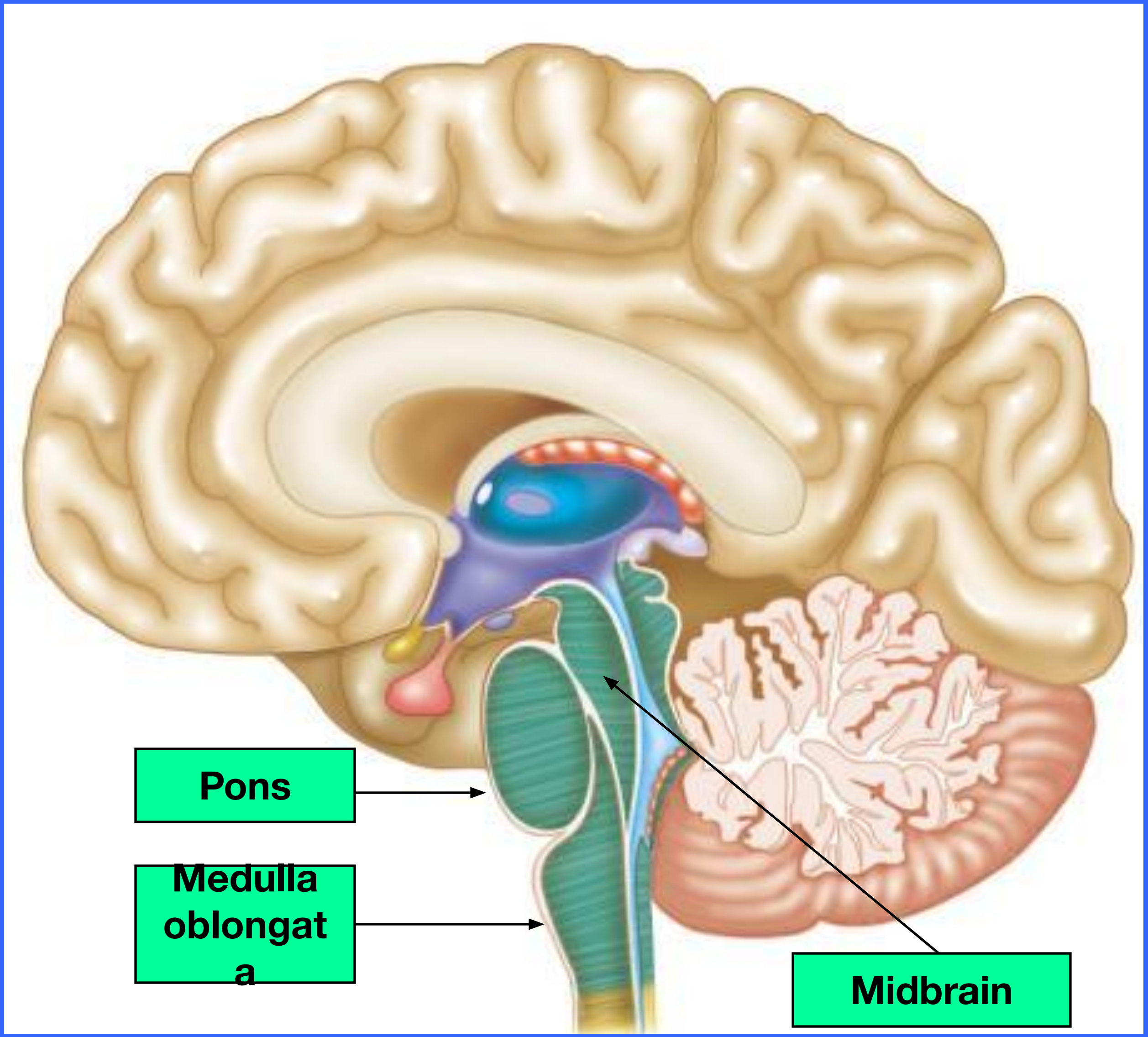
The Epithalamus



- A cerebrospinal fluid-forming structure called a choroid plexus is also part of the epithalamus

The Brain Stem

- The third of the four major parts of the brain is the brain stem
- From superior to inferior, the brain stem is divided into;
  - Midbrain
  - Pons
  - Medulla oblongata

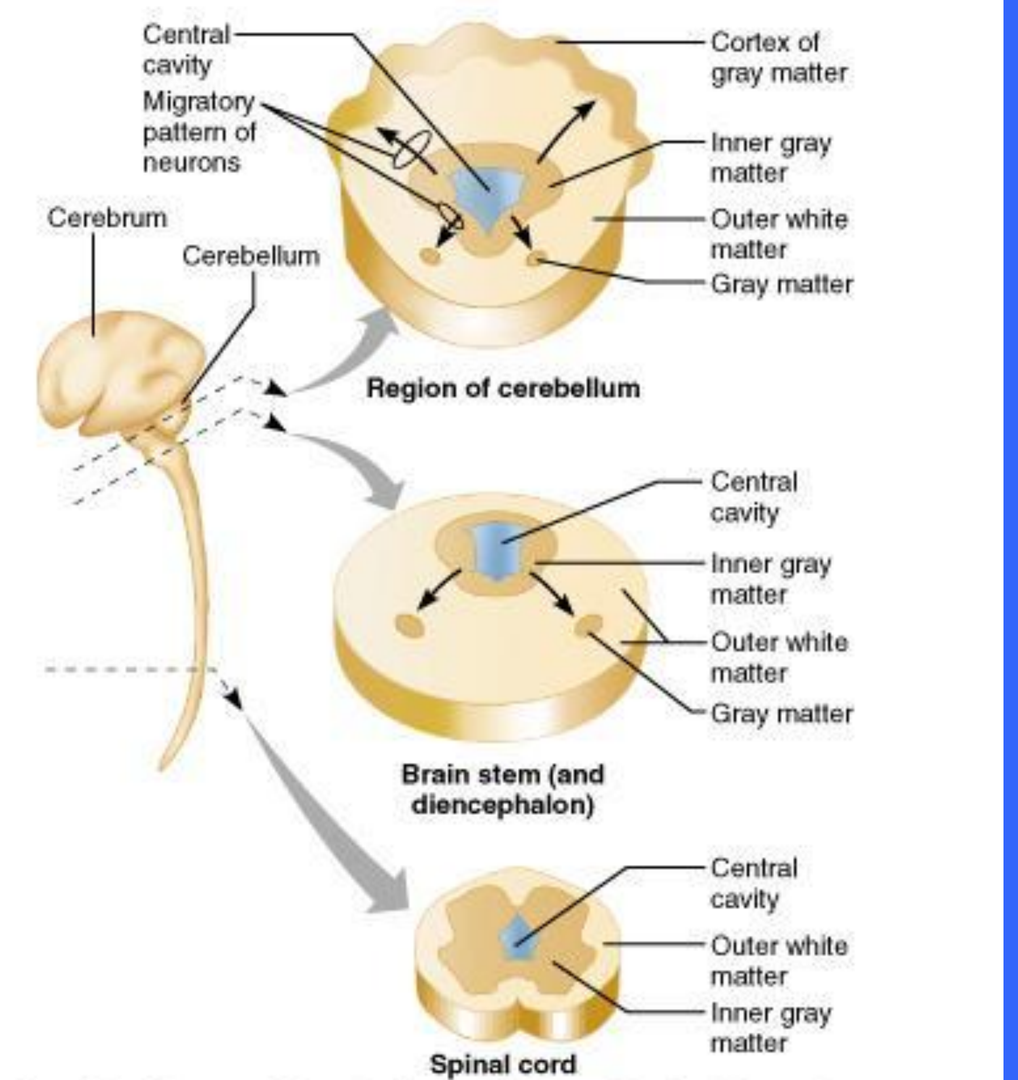


The Brain Stem

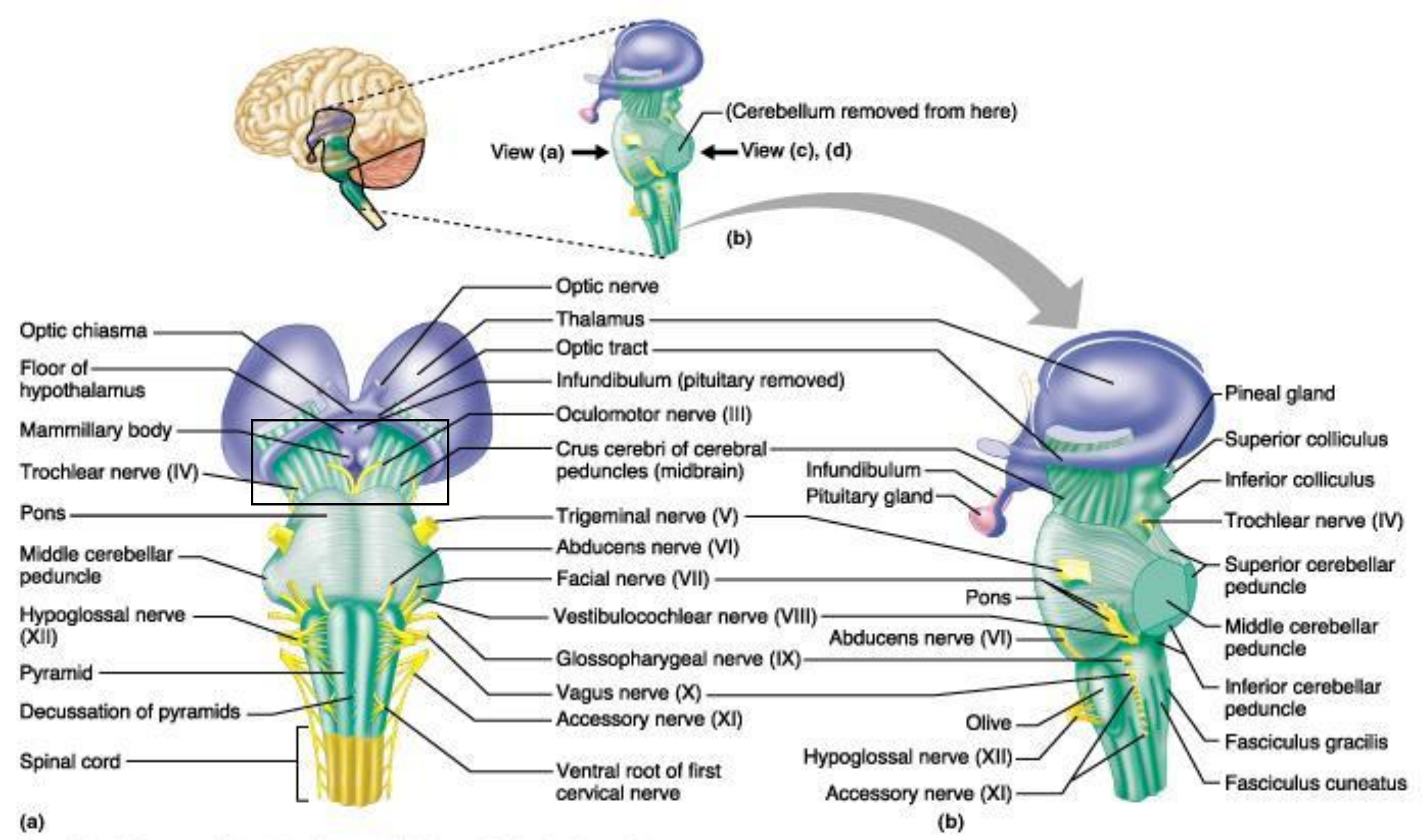
- **Each region is roughly an inch long**
- **Together than constitute 2.5% of total brain mass**
- **The brain stem has several functions**
  - **It produce the rigidly programmed, automatic behaviors necessary for our survival**
  - **Acts as a passageway for all the fiber tracts running between the cerebrum and spinal cord**
  - **It is heavily involved with the innervation of the face and head as 10 of the 12 cranial nerve attach to it**

The Brain Stem

- The brain stem has the same structural plan as the spinal cord, with outer white matter surrounding an inner region of gray matter
- However, there are also nuclei of gray matter located within the white matter



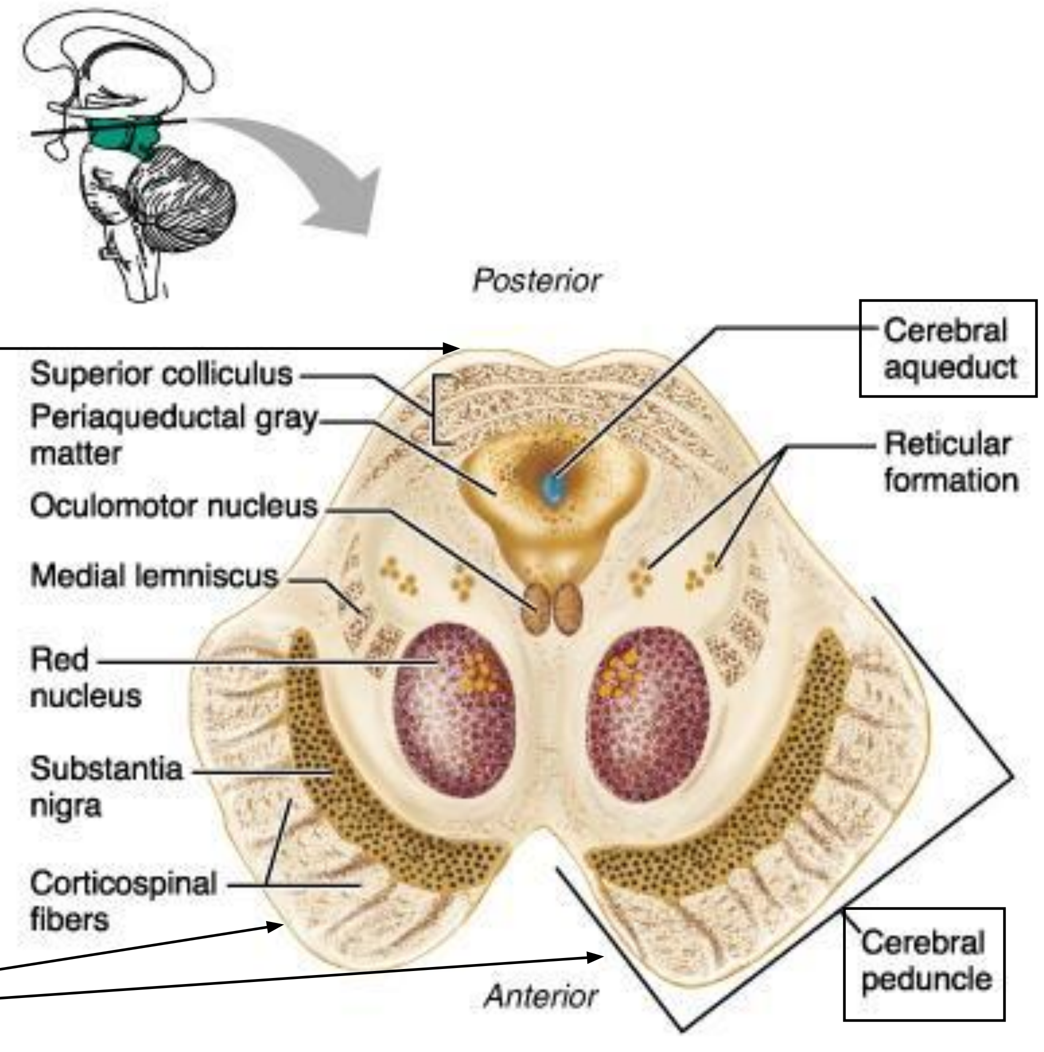
The Midbrain



- The midbrain is located between the diencephalon superiorly and the pons inferiorly

The Midbrain

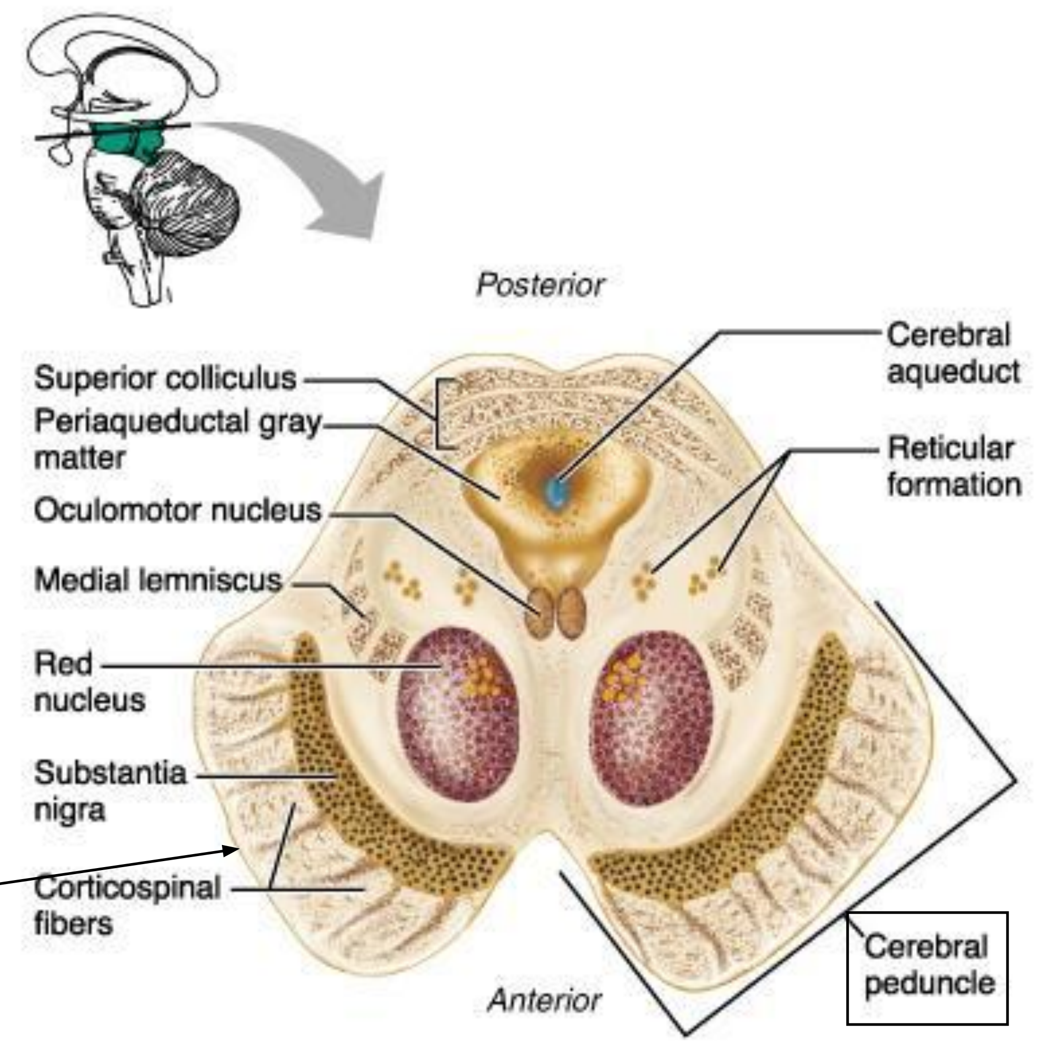
- Its central cavity is the cerebral aqueduct, which divides it into a tectum (dorsal surface) and paired cerebral peduncles
- From an anterior view the cerebral peduncles appear as columns that hold up the cerebrum



(a) Midbrain

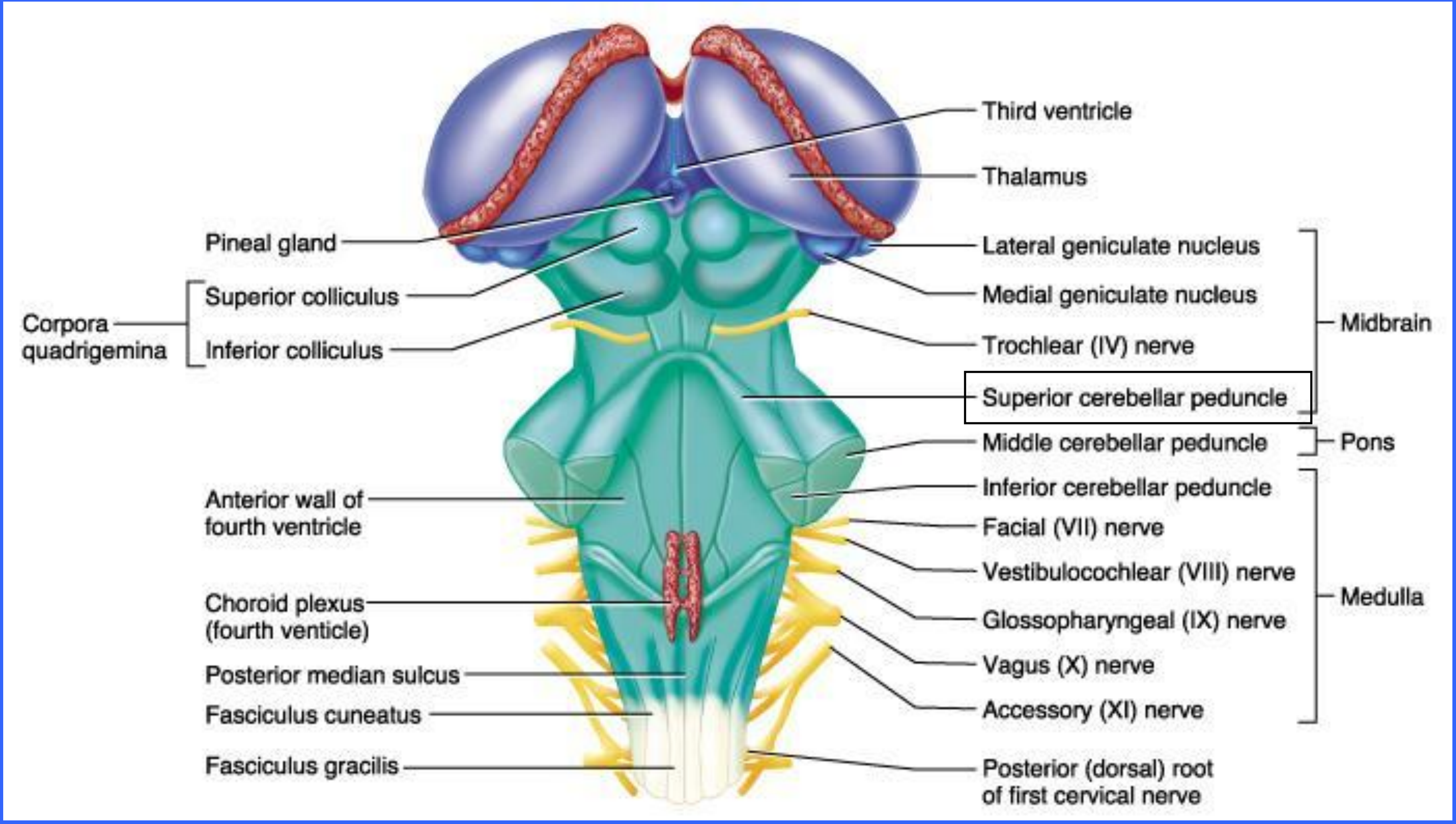
The Midbrain

- These peduncles contain the pyramidal (corticospinal) motor tracts descending toward the spinal cord
- The ventral part of each peduncle contains the tract called the crus cerebri



(a) Midbrain

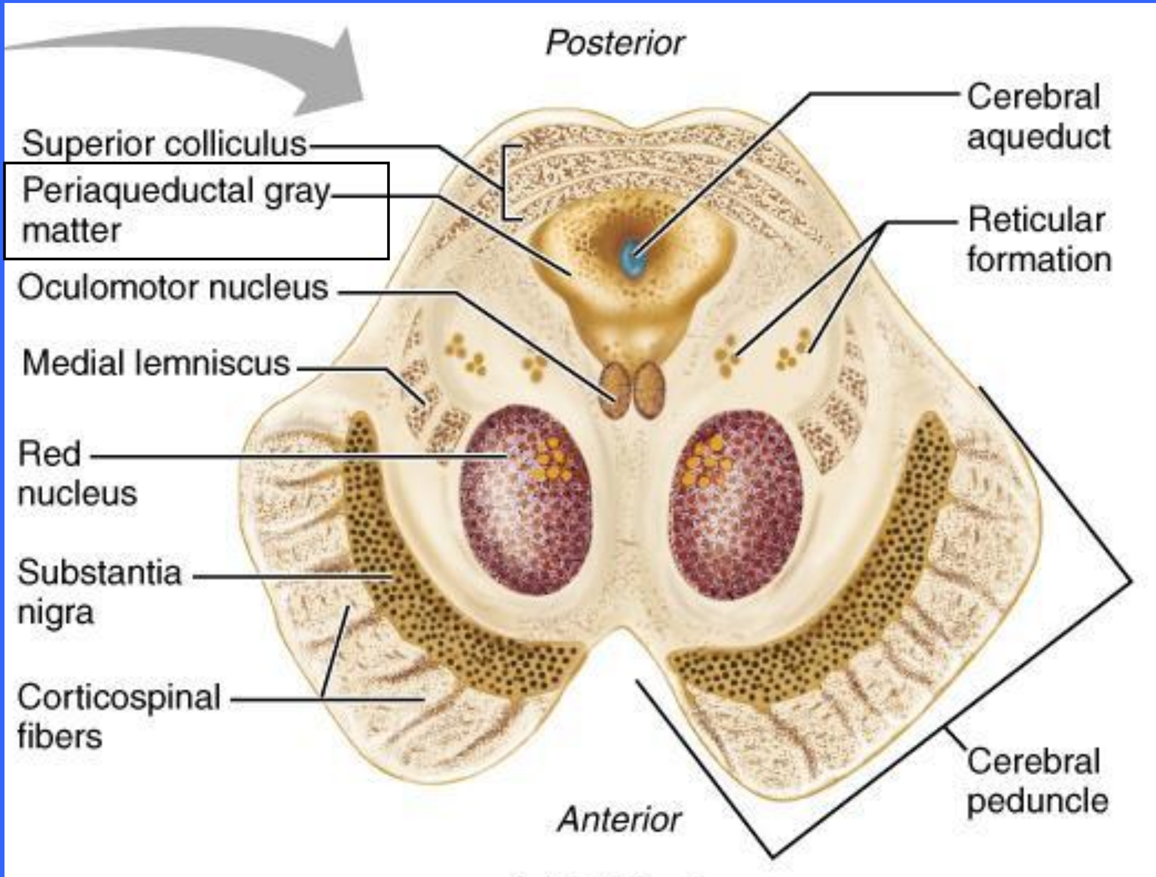
The Midbrain



- **Dorsally, the midbrain has the superior cerebellar peduncles which connect midbrain to the cerebellum**

The Midbrain

- Surrounding the cerebral aqueduct is the peri-aqueductal gray matter that has two somewhat related functions



(a) Midbrain

The Midbrain

- The periaqueductal gray matter is involved in the “fright-and-flight” sympathetic reaction
- The gray matter is a link between the amygdala of the forebrain (which perceives fear) and the autonomic pathway (which directly signals the physiological reactions associated with fear)

The Midbrain

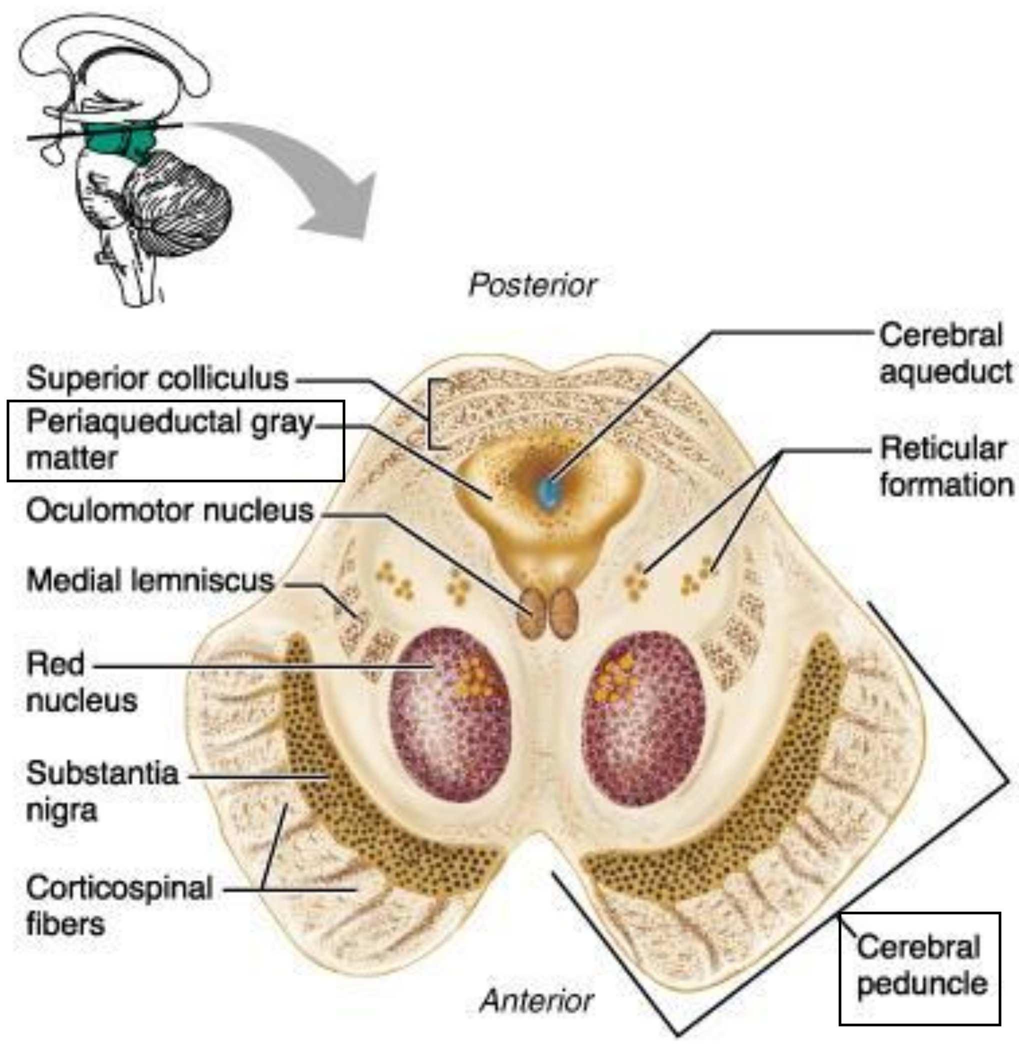
- The gray matter elicits
  - A terror-induced increase in heart rate
  - Skyrocketing blood pressure
  - Wild fleeing or defensive freezing
  - The flexing of the spine as in curling into a ball for protection
  - The suppression of pain upon injury

The Midbrain

- The periaqueductal gray matter also seems to mediate our response to visceral pain (as when nauseous) during which it
  – Decreases heart rate and blood pressure
  – Produce a cold sweat
  – Discourages movement

The Midbrain

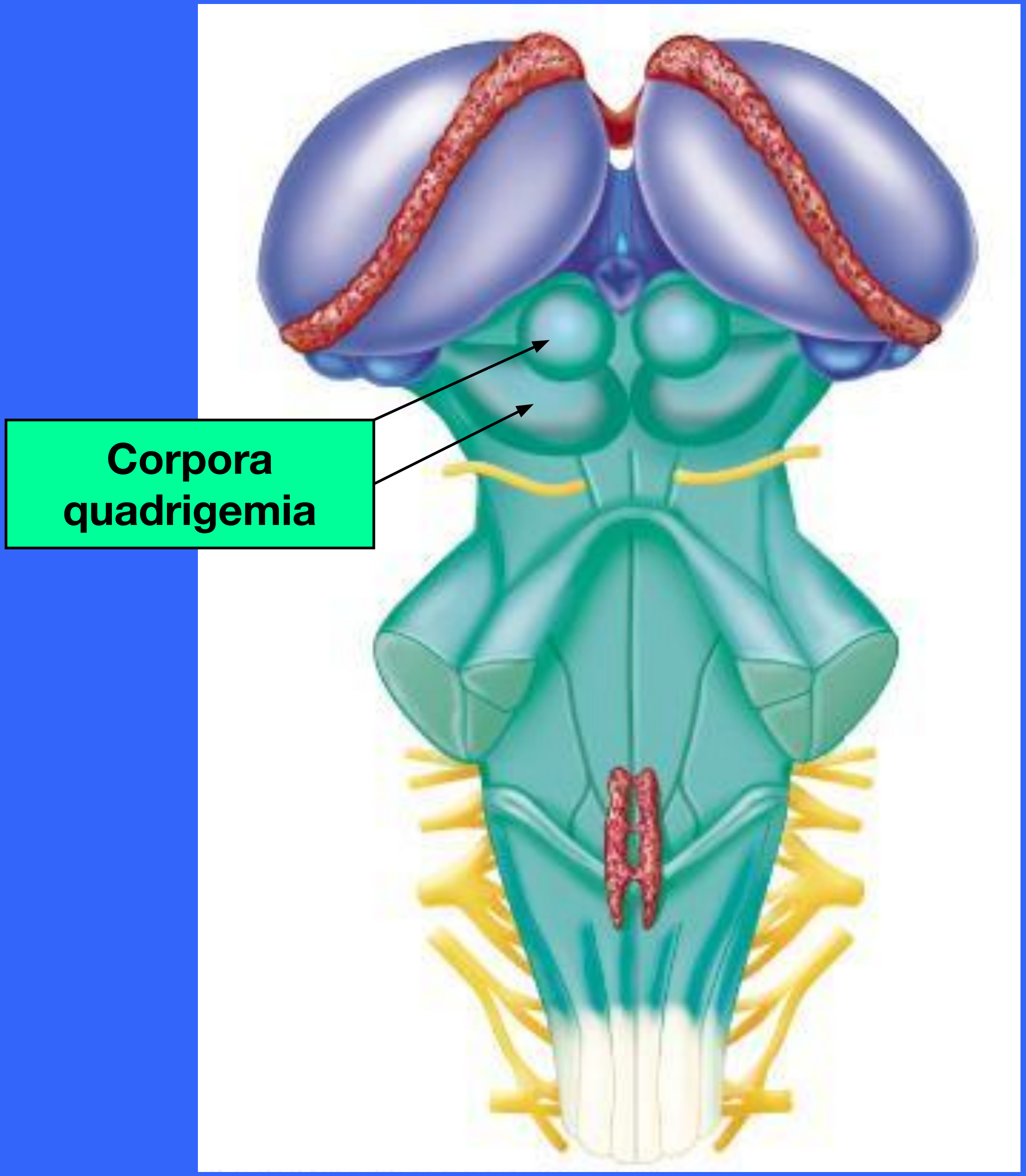
- The most ventral part of the para-aqueductal gray mattercontains cell bodies of motor neurons that contribute to two cranial nerves
  - Oculomotor (III)
  - Trochlear (IV)
- These cranial nerves control most muscles that move the eyes



(a) Midbrain

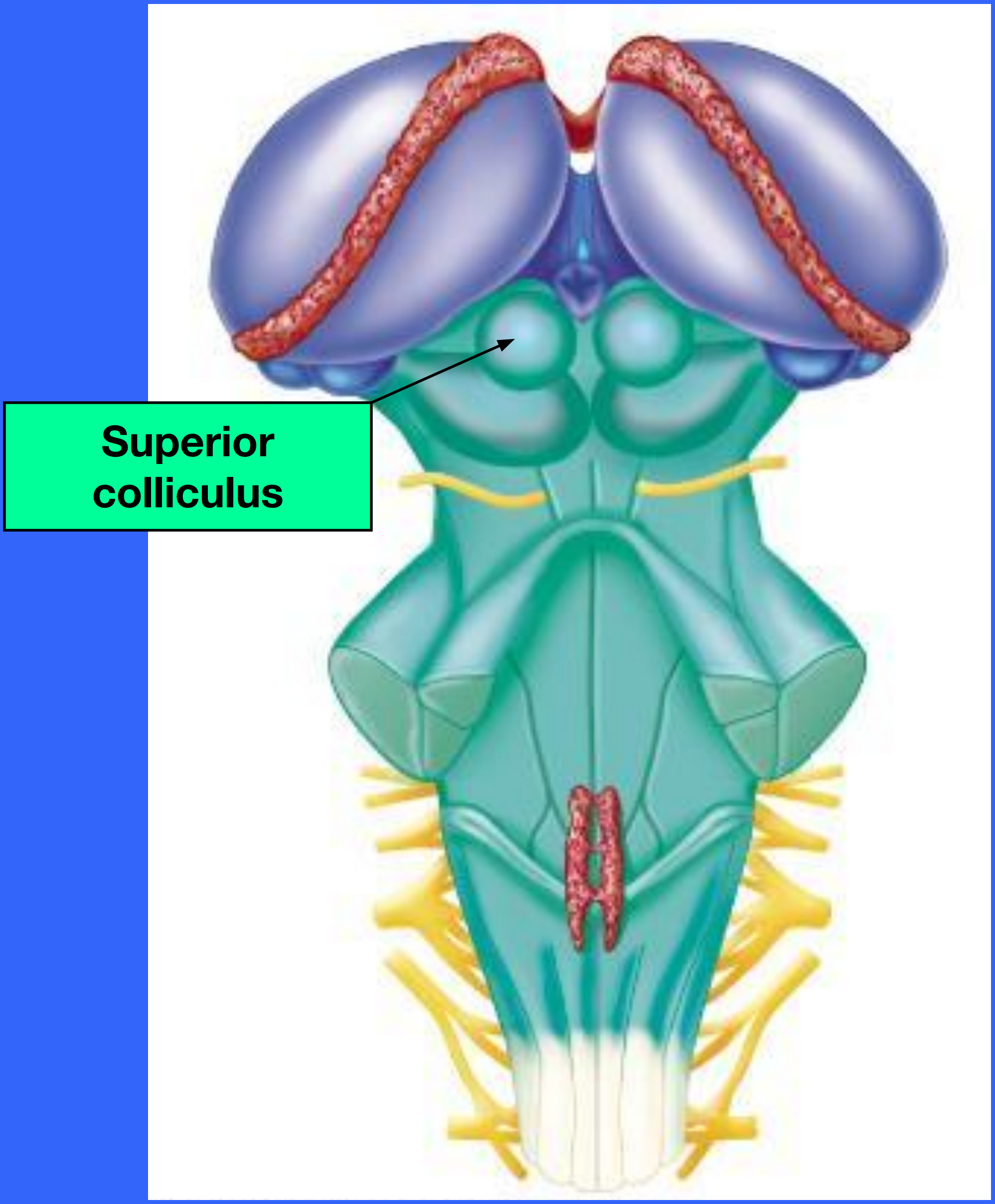
The Midbrain

- Nuclei are also scattered in the surrounding white matter
- The largest of these nuclei are the corpora quadrigemia which raise four dome like protrusions on the dorsal midbrain surface



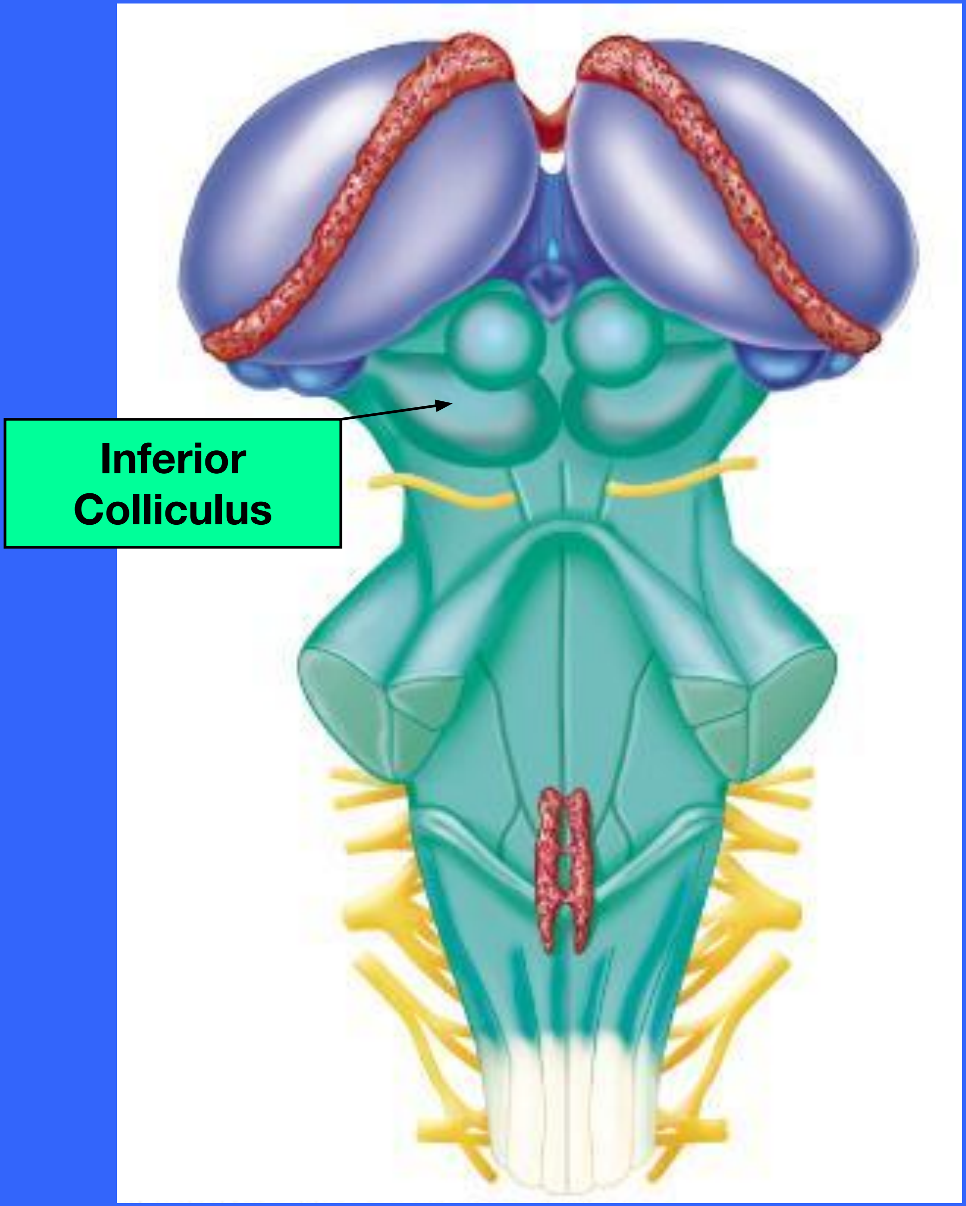
The Midbrain

- The superior pair of nuclei, the superior colliculus are visual reflex centers that
  - coordinate head and eye movements when following a moving object
  - Make us turn our head involuntarily when we detect movement in our peripherial vision



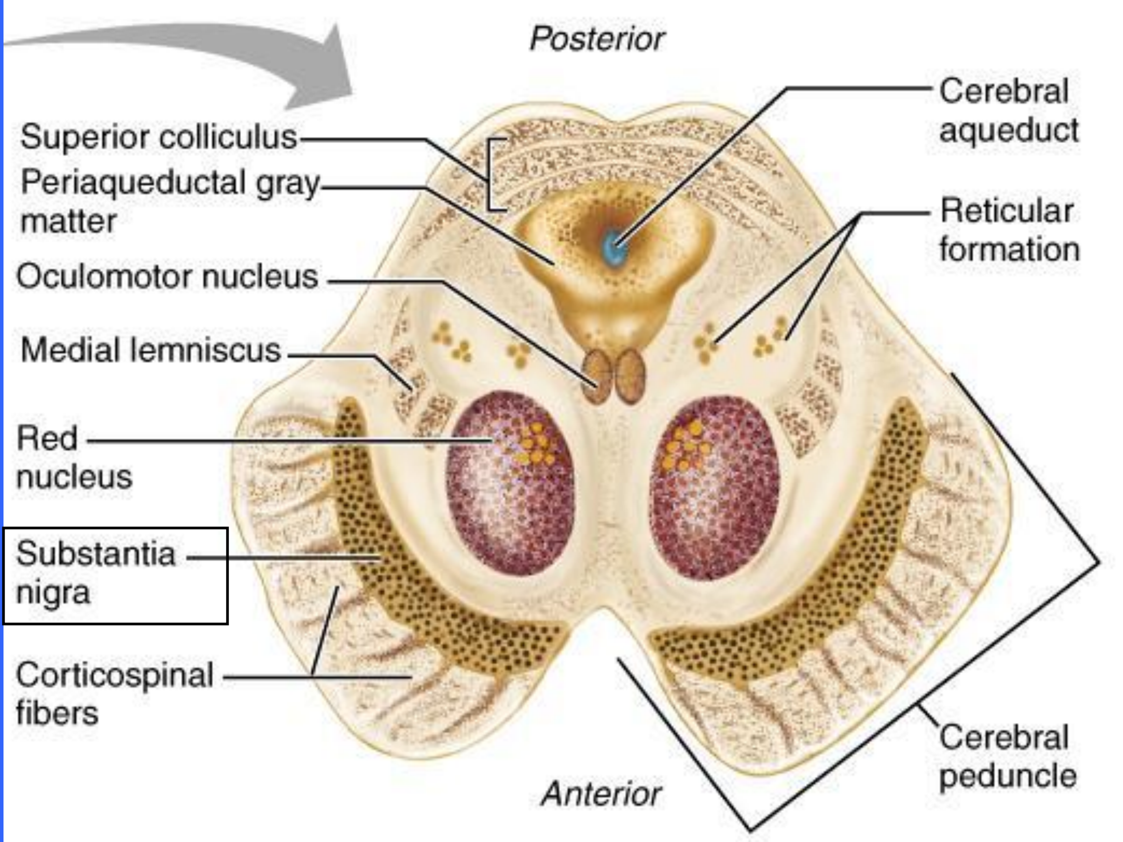
The Midbrain

- The inferior colliculus are part of the auditory relay from the hearing receptors of the ear to the sensory cortex
  - Act in reflexive response to sound as in the startle reflex
  - Turn your head toward unexpected source of sound



The Midbrain

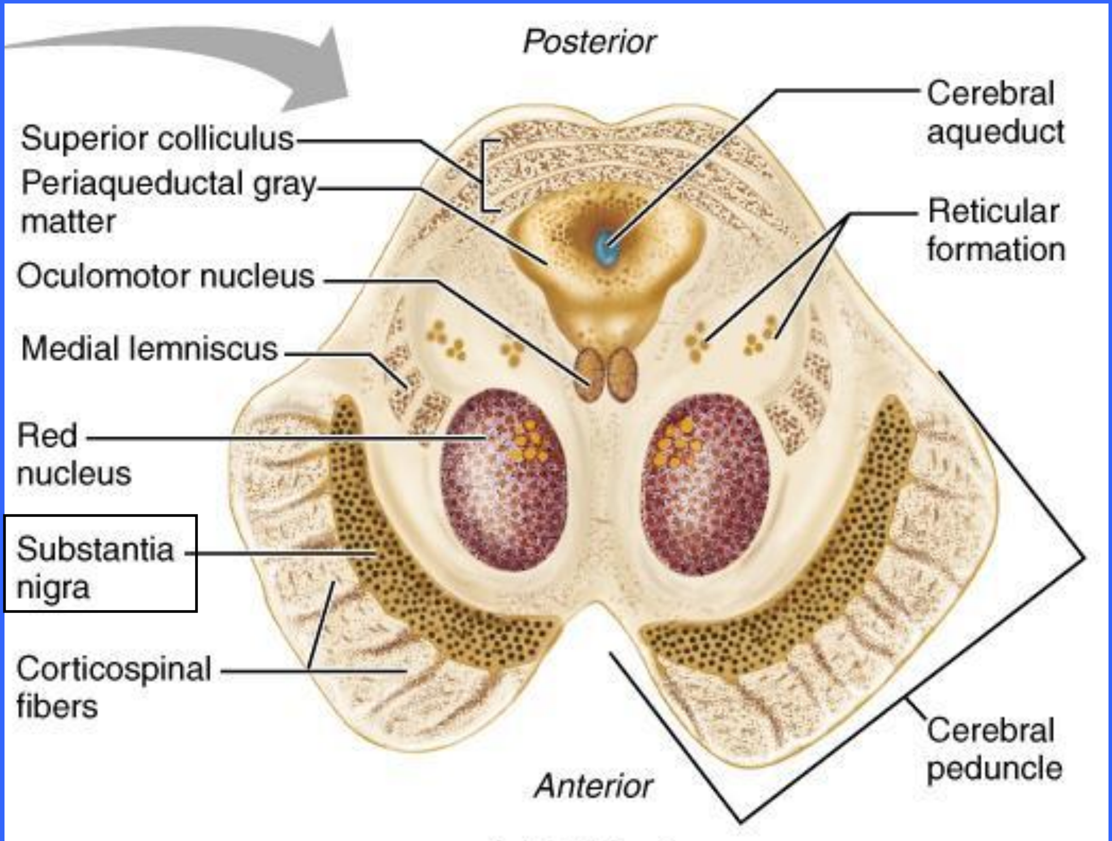
- **Also imbedded in the white matter of the midbrain are two pigmented nuclei, the substantia nigra and the red nucleus**



(a) Midbrain

The Midbrain

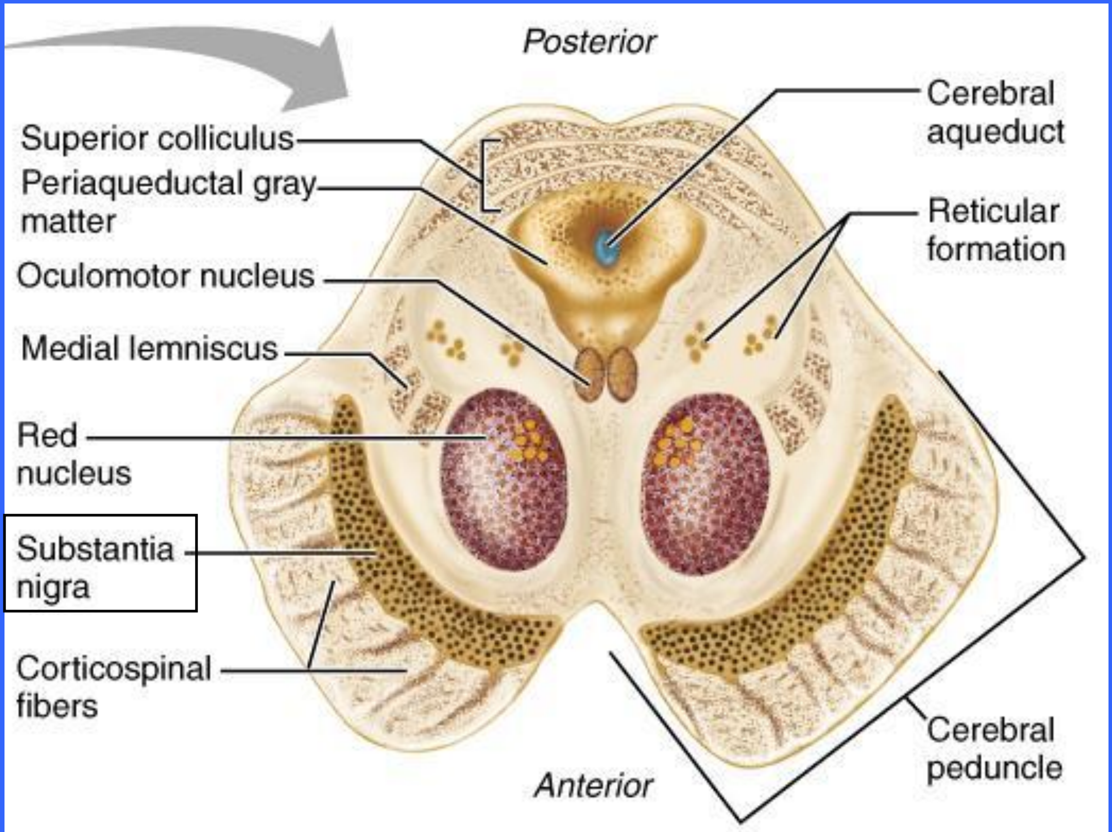
- The substantia nigra is a bandlike nucleus located deep to the cerebral peduncle
- It is the largest nuclear mass in the midbrain



(a) Midbrain

The Midbrain

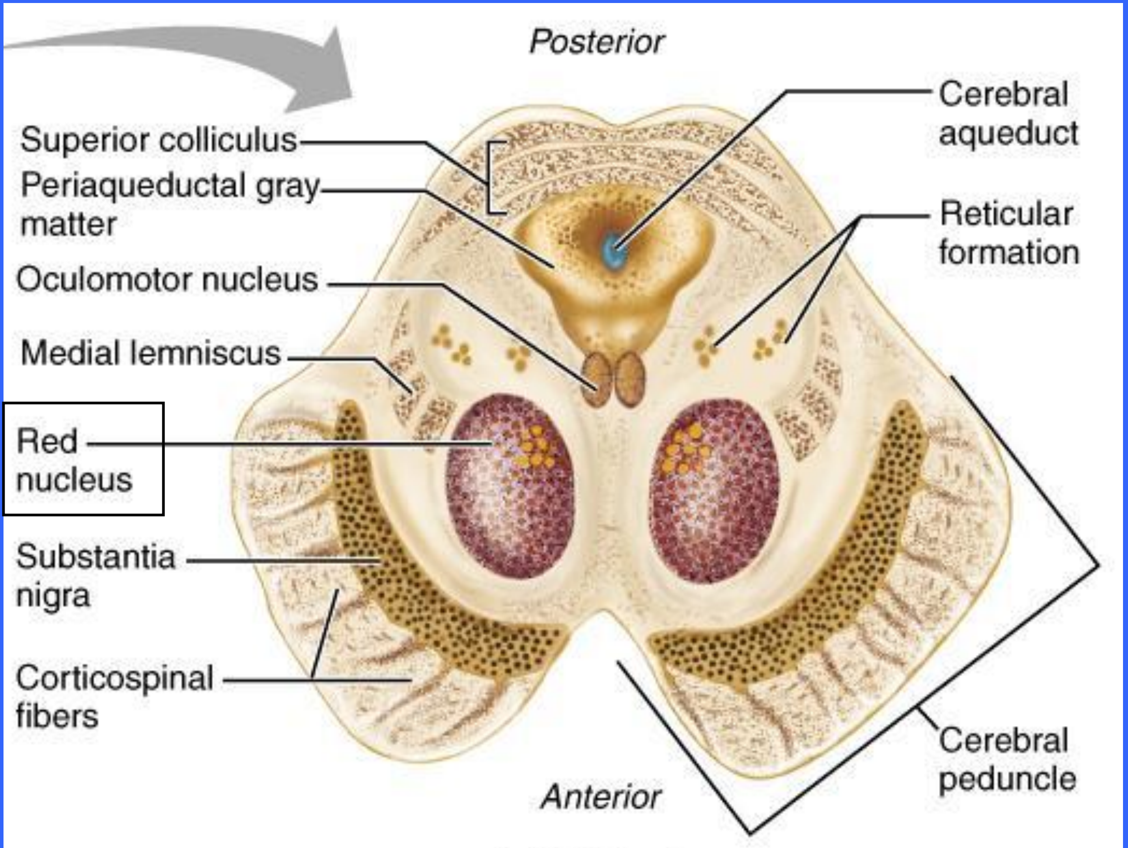
- Its dark color reflects its high content of melanin pigment, a precursor of dopamine a neurotransmitter released by these neurons
- The substantia nigra is functionally linked to the basal nuclei of the cerebral hemispheres



(a) Midbrain

The Midbrain

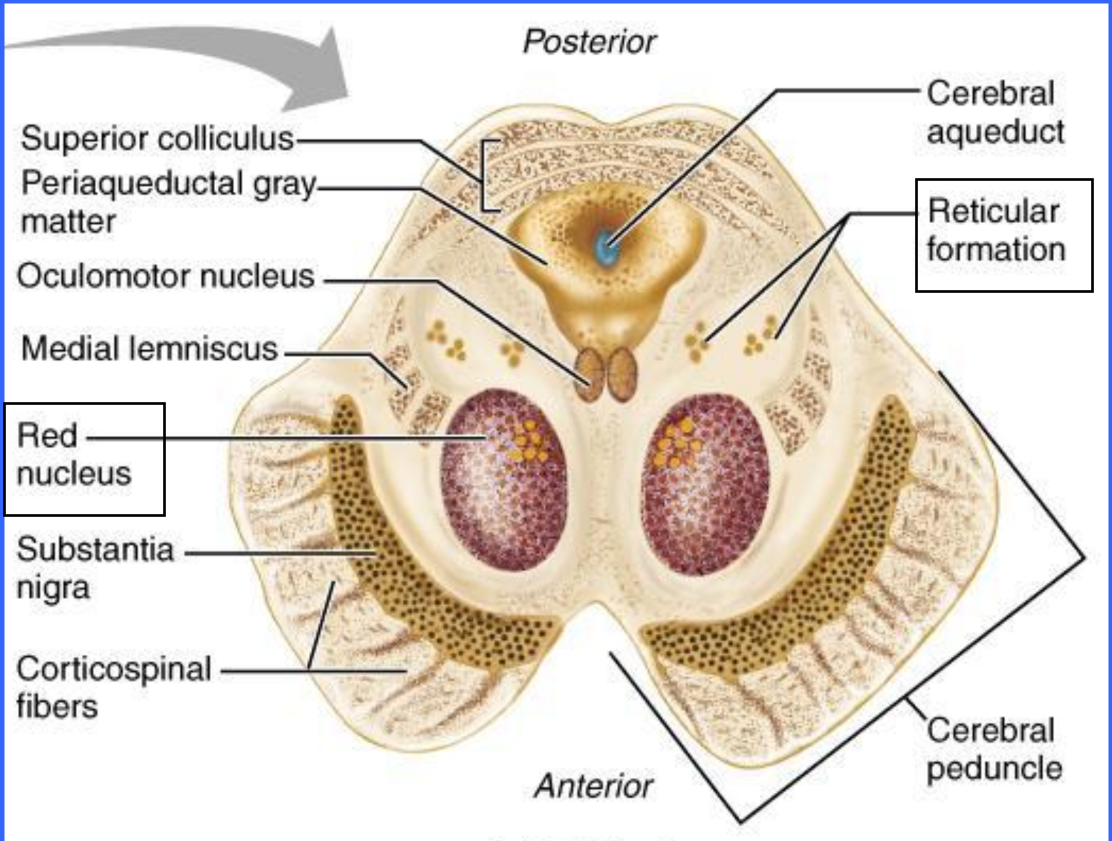
- The red nucleus is found between the substantia nigra and the cerebral aqueduct
- It reddish hue is due to its vascular supply and the presence of iron pigment in the cell bodies of its neurons



(a) Midbrain

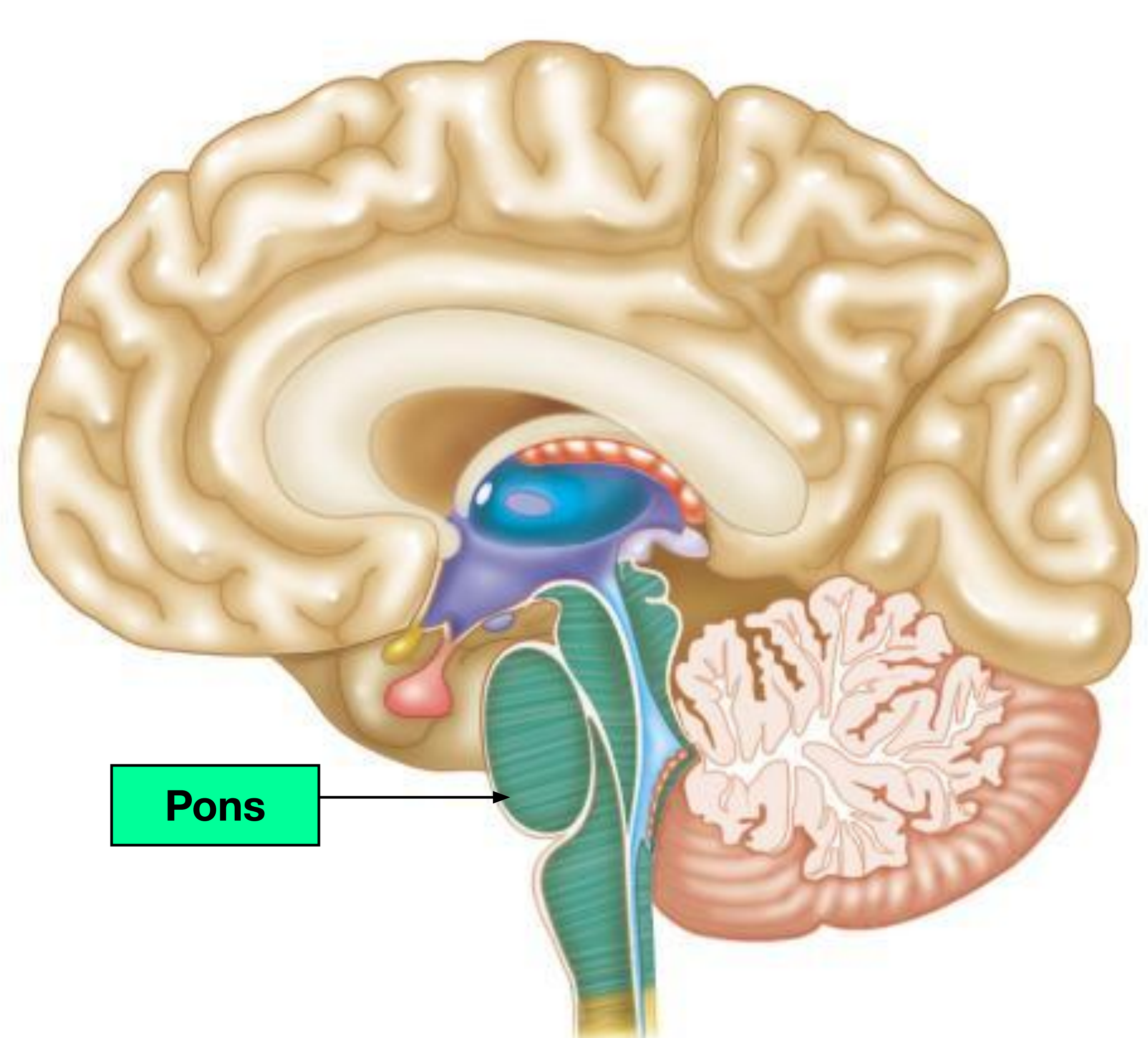
The Midbrain

- The red nuclei are relay nuclei in some descending motor pathways that effect limb flexion
- The red nuclei is the largest nucleus in the reticular formation, a system of small nuclei scattered through the core of the brain stem



(a) Midbrain

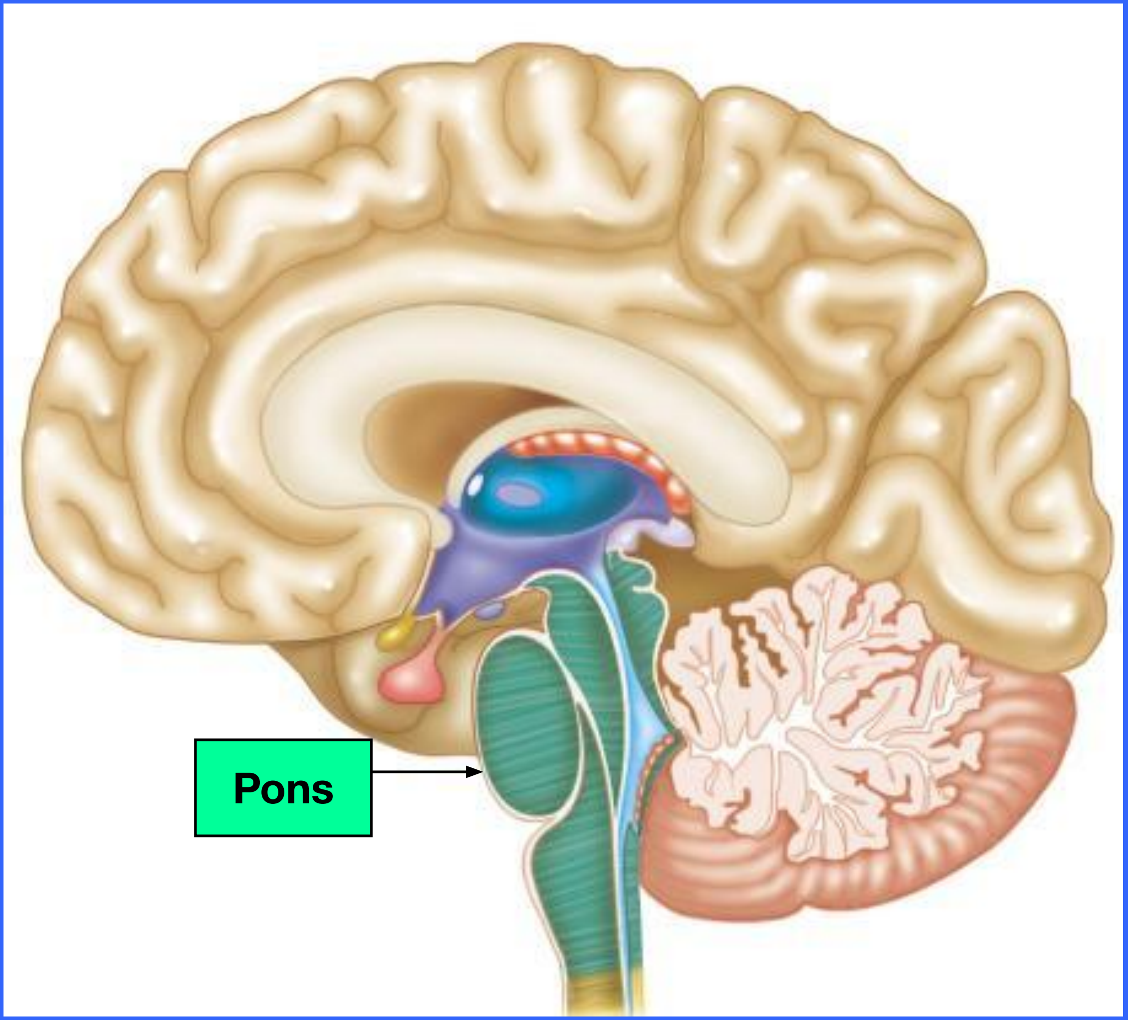
The Pons



- The pons is the bulging brain stem region wedged between the midbrain and the medulla oblongata

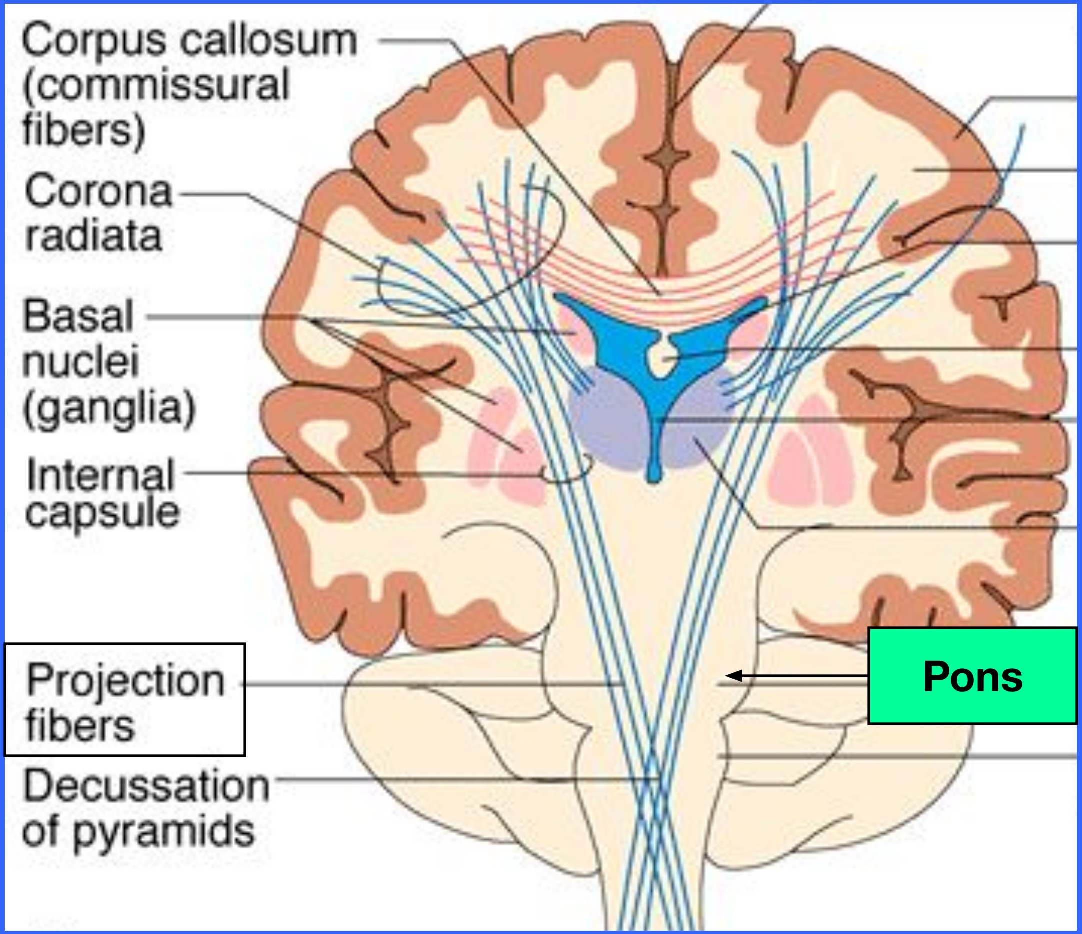
The Pons

- It forms part of the anterior wall of the fourth ventricle
- It is chiefly composed of conduction tracts
- The deep projection fibers run longitudinally and complete the pathway between higher brain centers and spinal cord



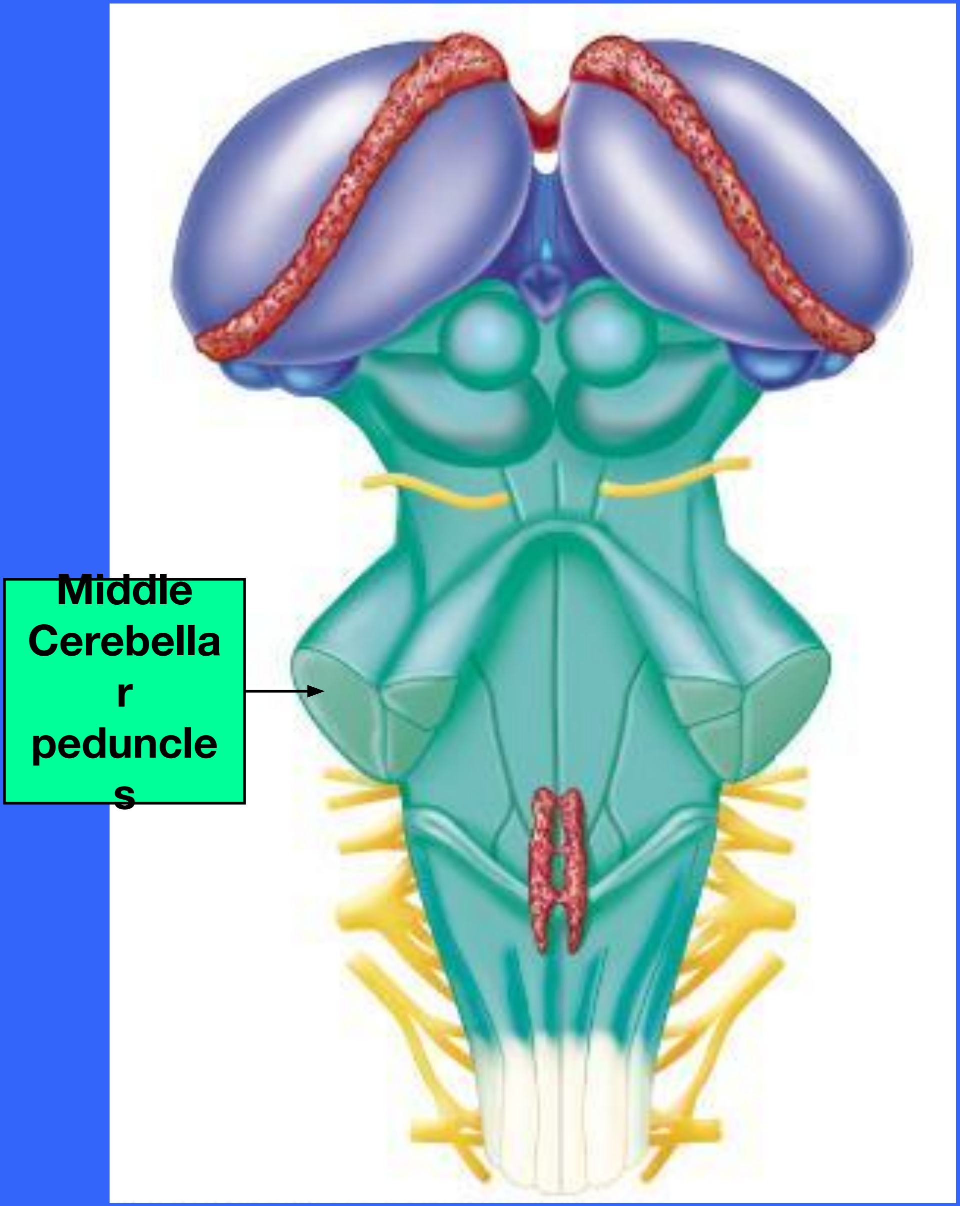
The Pons

- The deep projection fibers run longitudinally and complete the superior-inferior pathway between the higher brain centers and the spinal cord

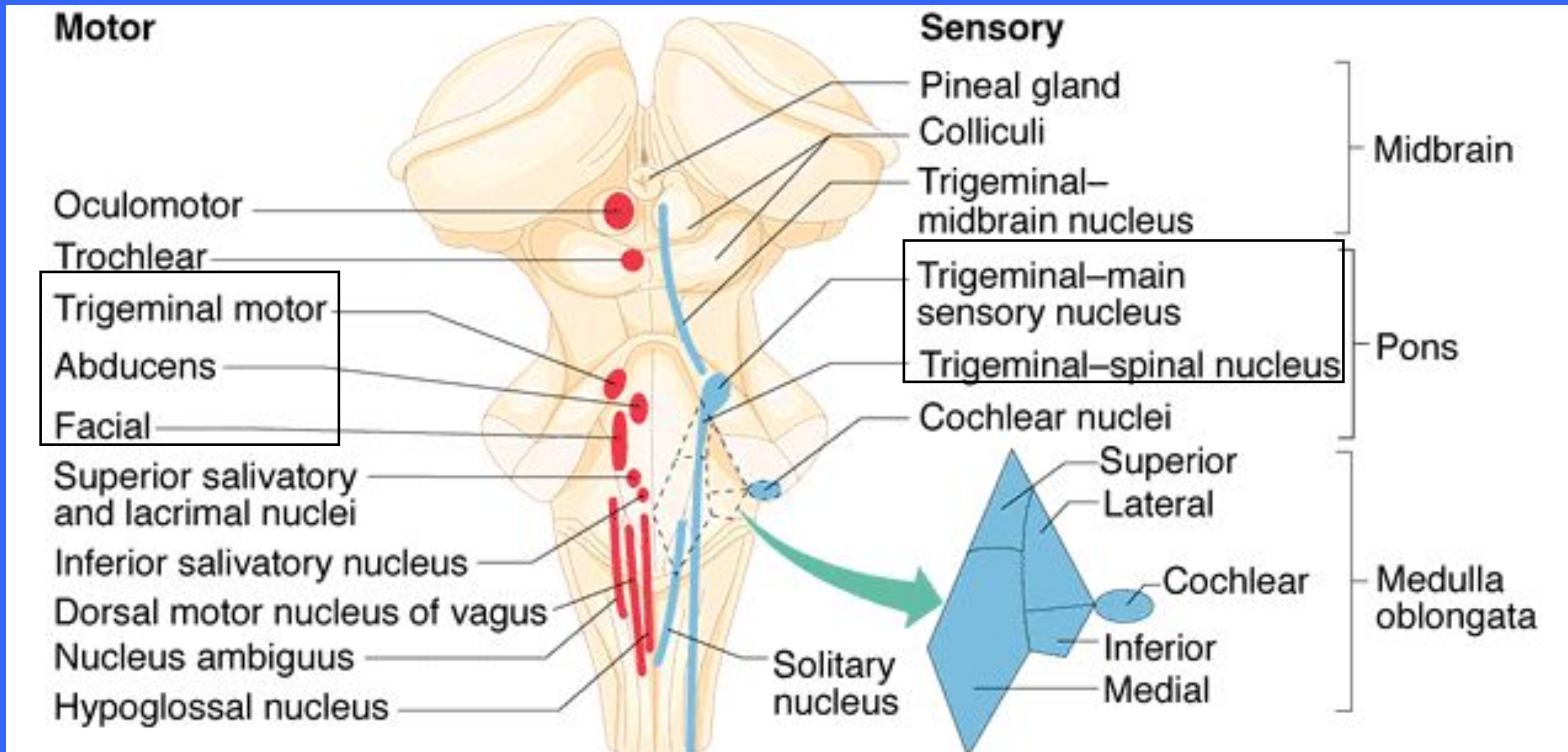


The Pons

- The more superficial nuclei are relays for conversations between the motor cortex and the cerebellum
- These fibers are orientated dorsally and transversely and connect the pons bilaterally with the cerebellum



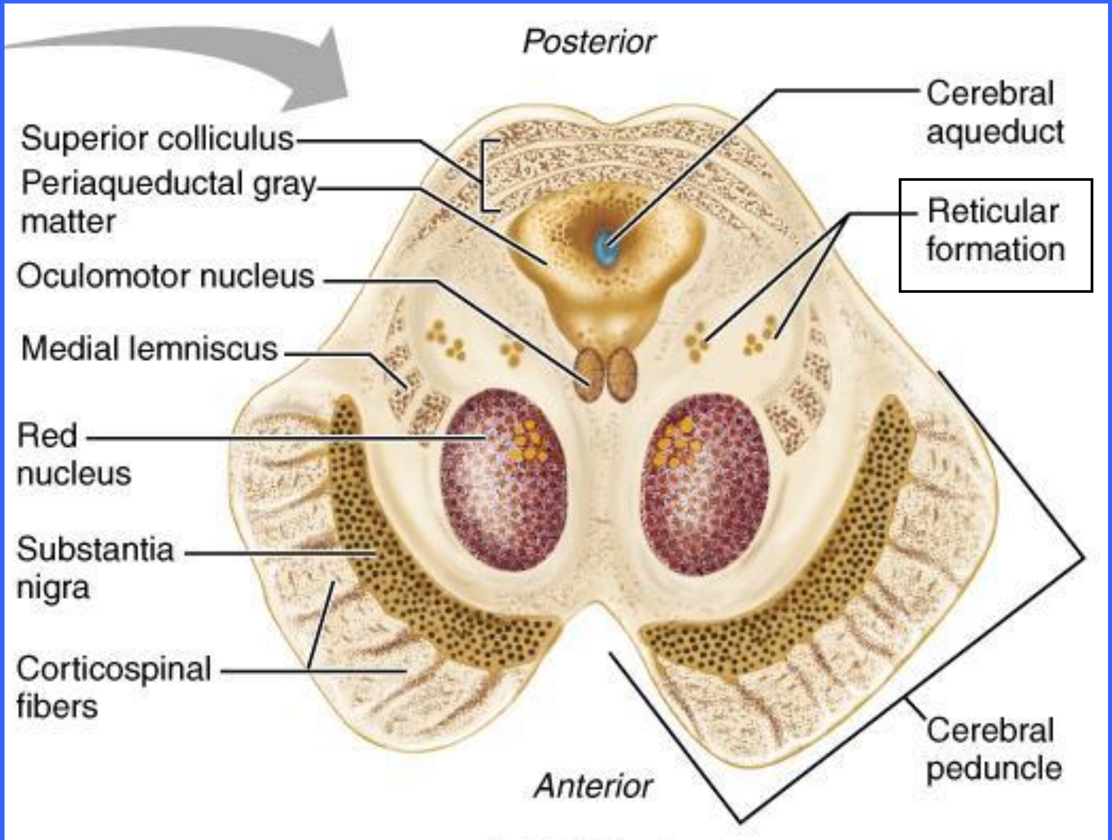
The Pons



- Several cranial nerves issue from pons nuclei
  - Trigeminal nerve
  - Abducens nerve
  - Facial nerves

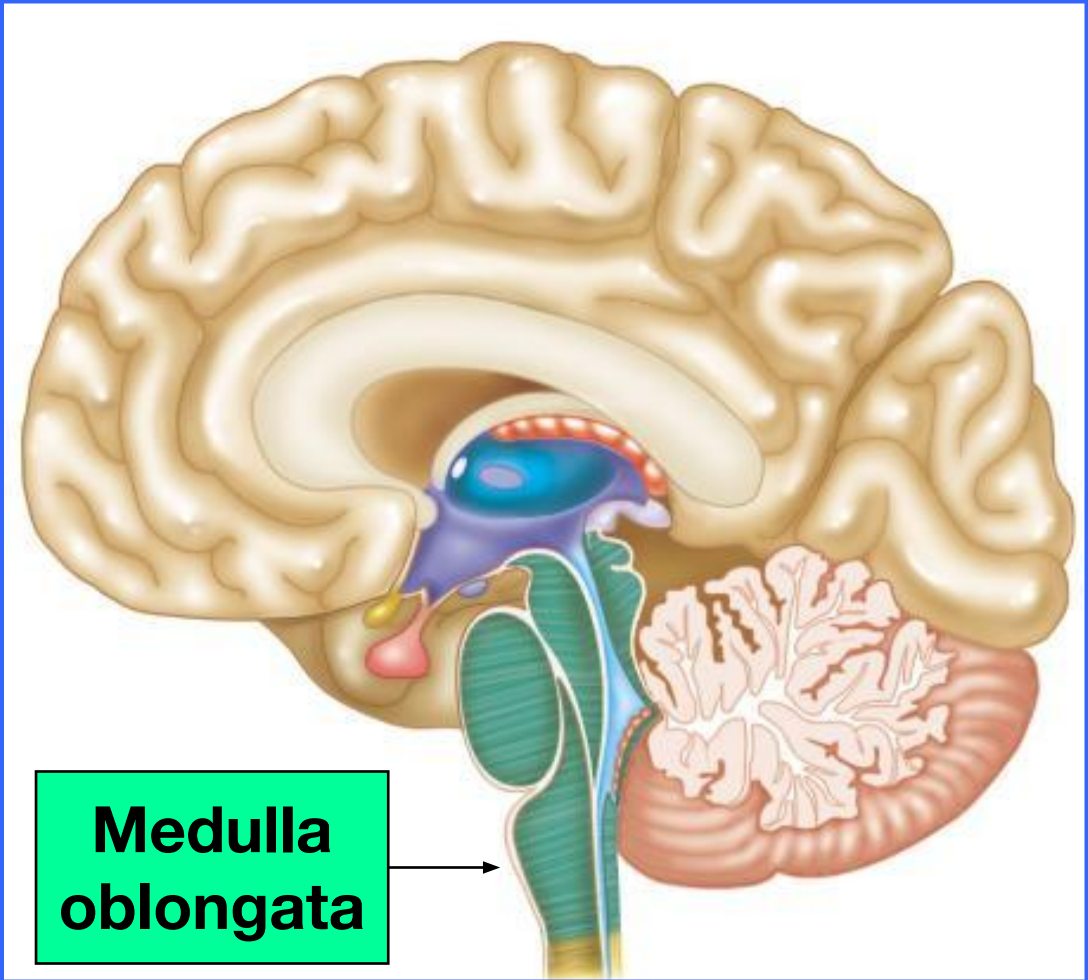
The Pons

- **Other important pons nuclei are part of the reticular formation**
  - **The pneumotaxic center is a respiratory center**
  - **Functioning with medullary respiratory centers it helps to maintain the normal rhythm of breathing**



(a) Midbrain

The Medulla Oblongata



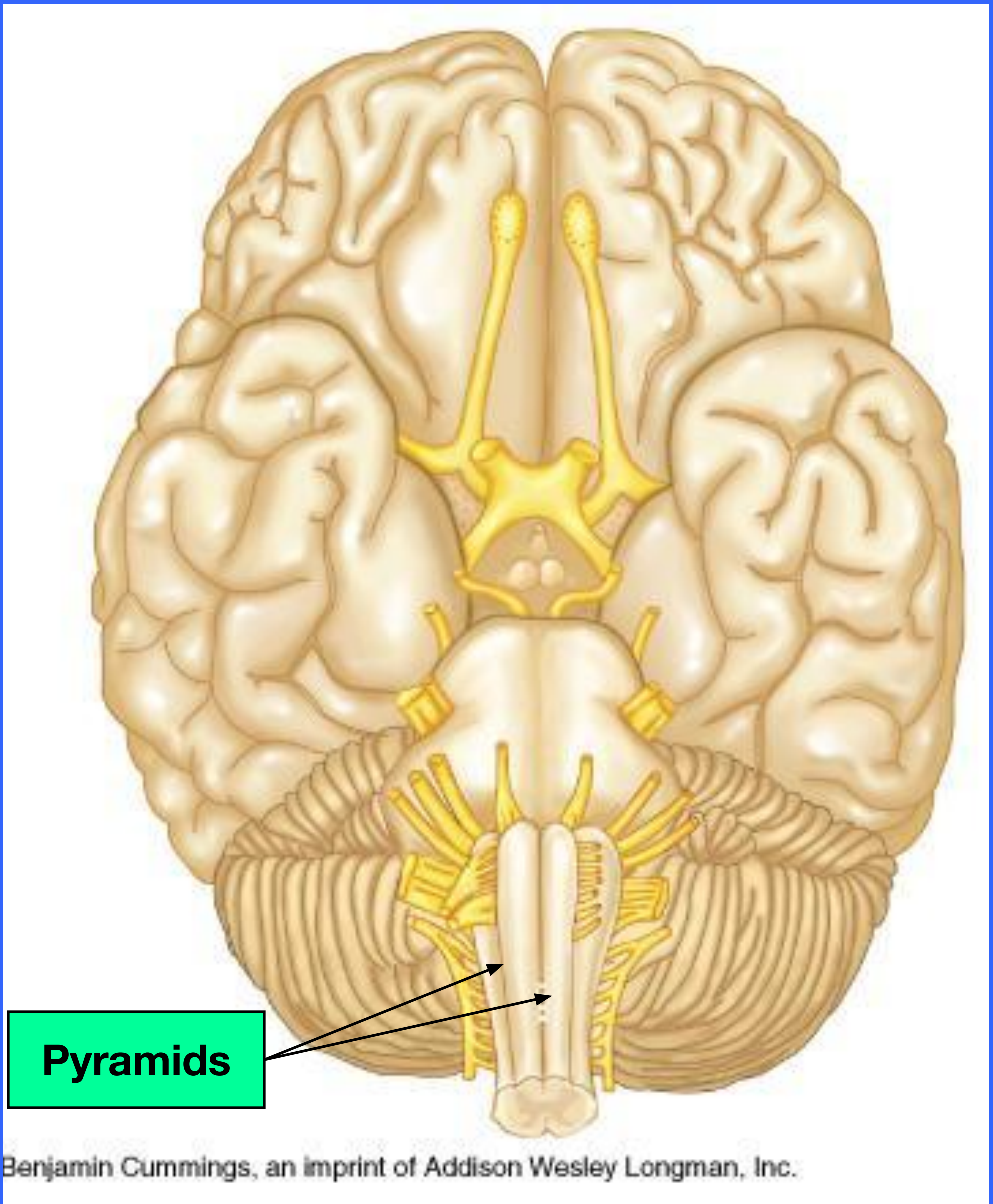
- The medulla oblongata is the most inferior part of the brain stem

The Medulla Oblongata

- The medulla blends into the spinal cord at the level of the foramen magnum
- The central canal of the spinal cord continues upward into the medulla where it broaden to form the fourth ventricle

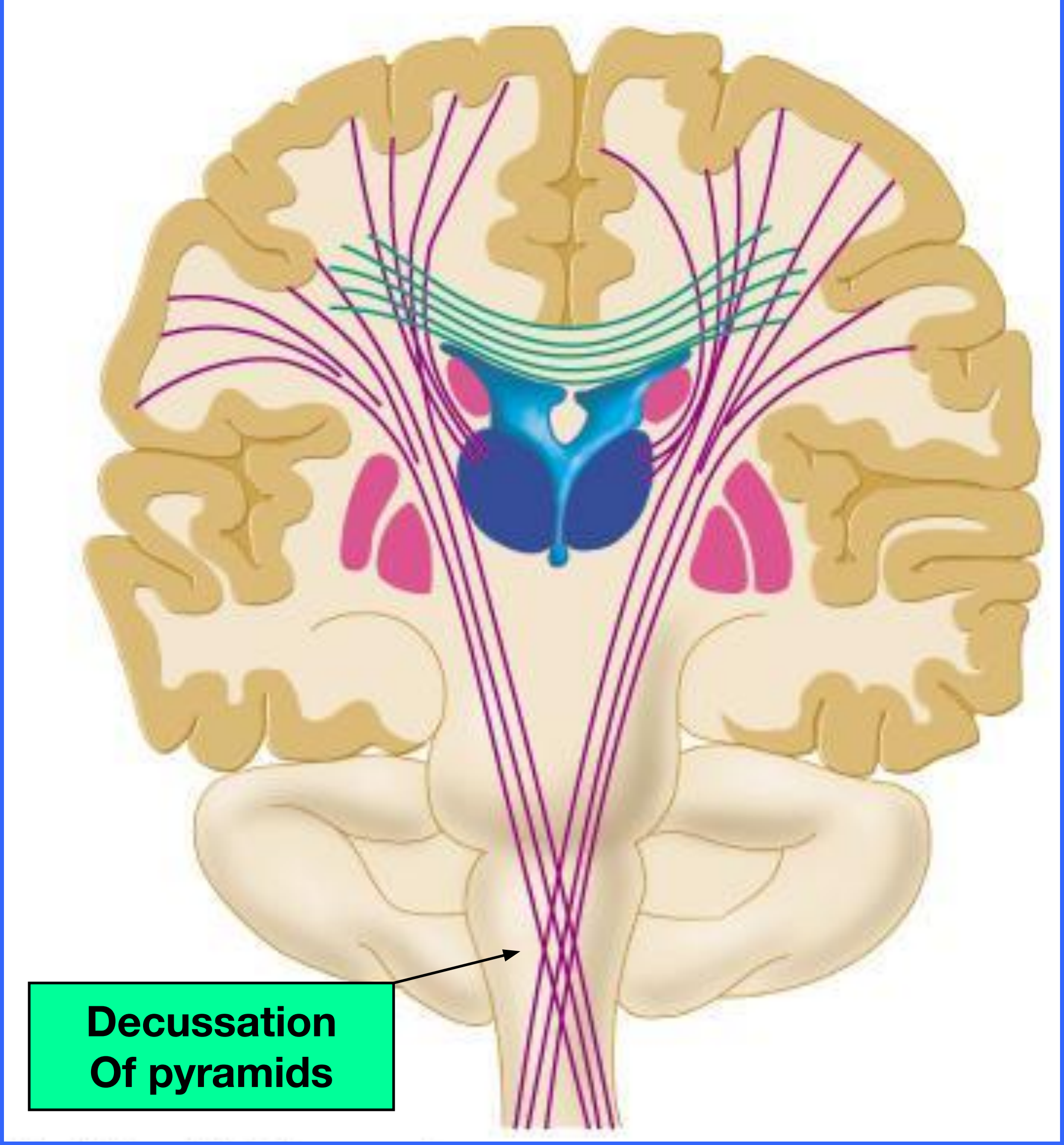
The Medulla Oblongata

- The medulla has several externally visible landmarks which form longitudinal ridges on the ventral surface called the pyramids
- These are formed by the large pyramidal tracts descending from the motor cortex



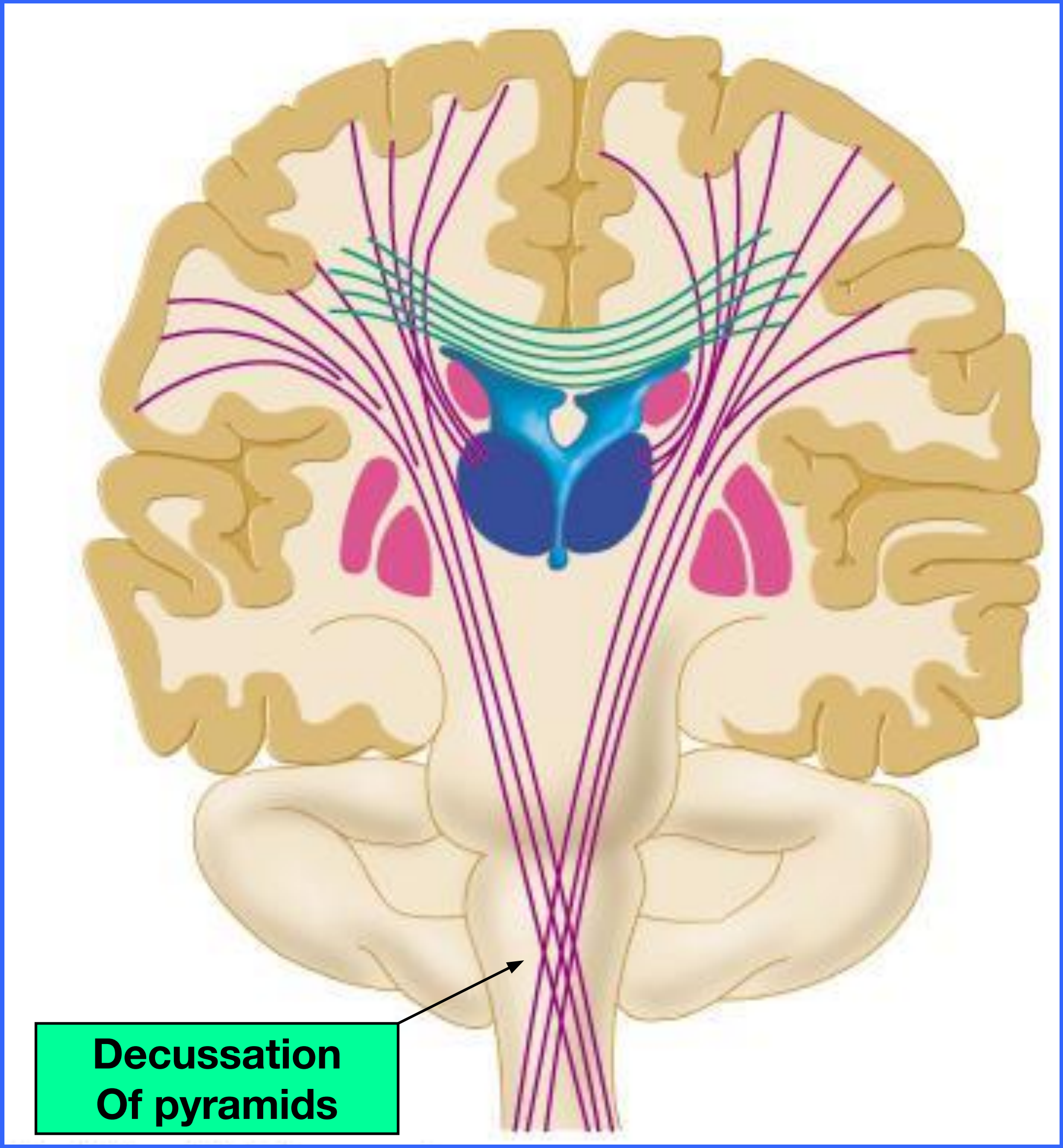
The Medulla Oblongata

- Just above the medulla-spinal cord junction most of the fibers cross over to the opposite side before continuing their descent into the spinal cord
- The crossover point is called the decussation of the pyramids



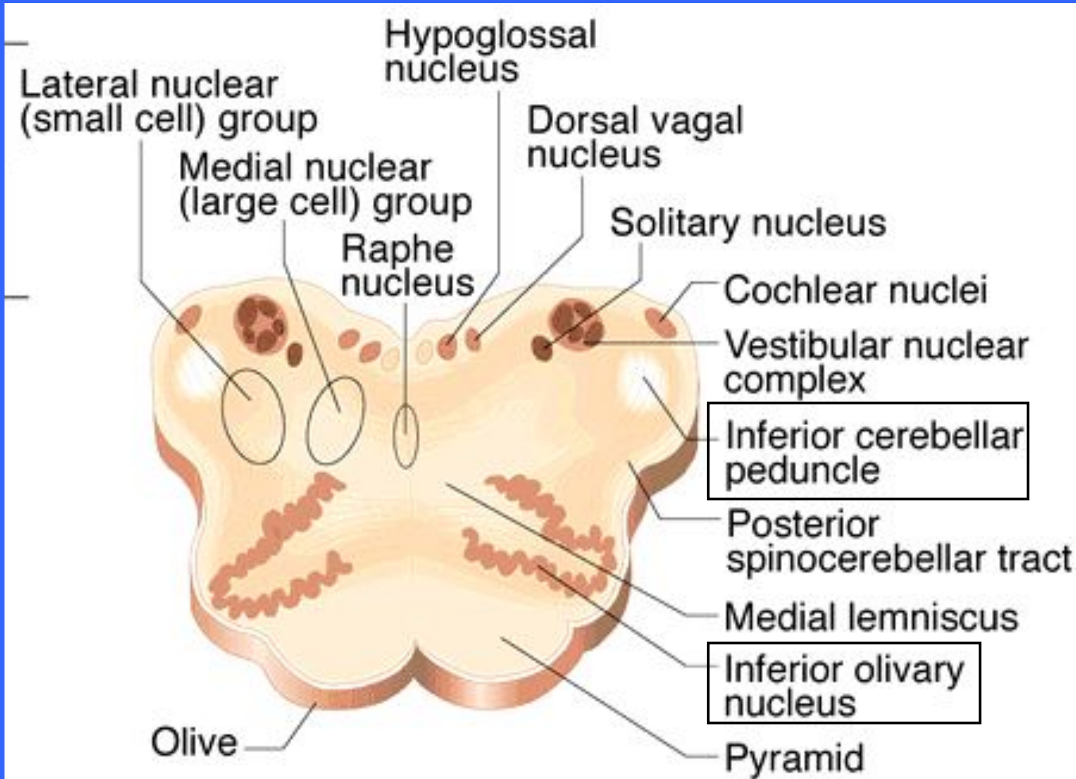
The Medulla Oblongata

- The consequence of this crossover is that each hemisphere chiefly controls the voluntary movements of muscles on the opposite or contralateral side of the body



The Medulla Oblongata

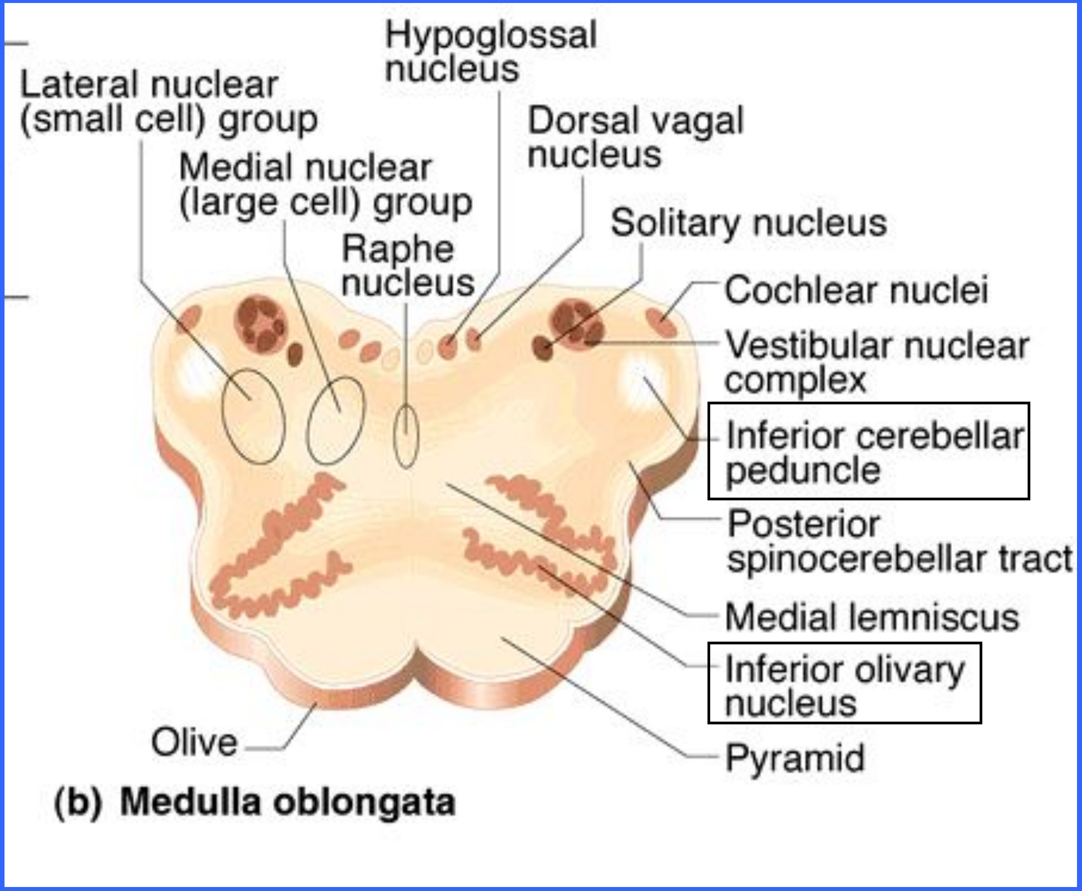
- The inferior cerebellar peduncles are fiber tracts that connect the medulla to the cerebellum dorsally
- The olives are oval swellings produced by the underlying inferior olivary nuclei



(b) Medulla oblongata

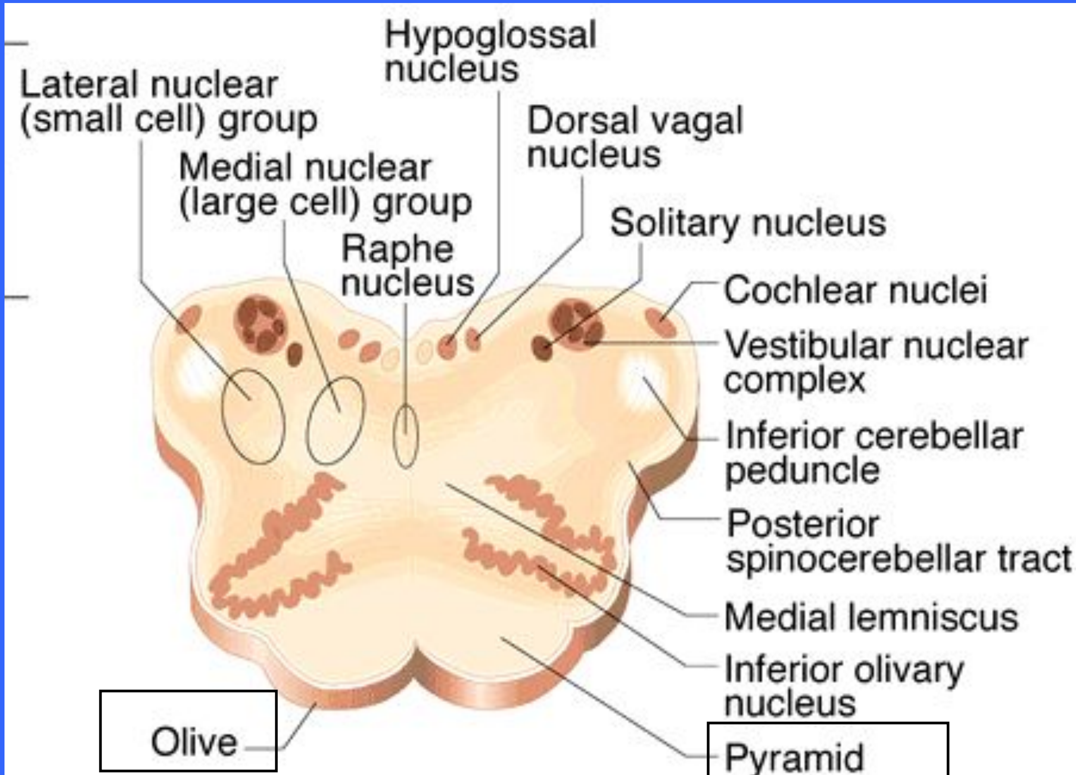
The Medulla Oblongata

- **The olivary nuclei relay sensory information on the state of stretch of our muscles and joints to the cerebellum**



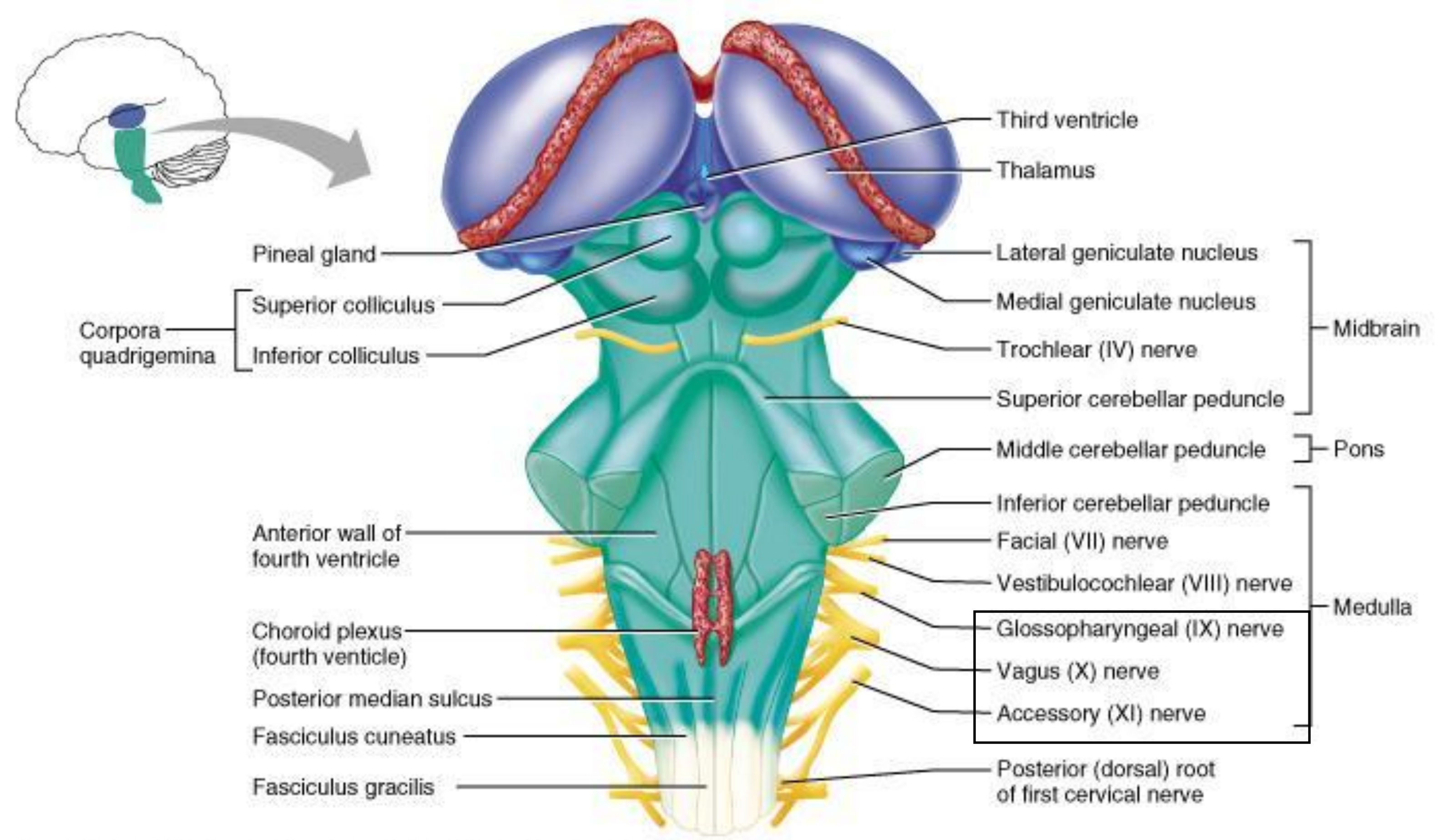
The Medulla Oblongata

- **The rootlets of the hypoglossal nerves emerge from the groove between the pyramid and olive on each side of the brain stem**



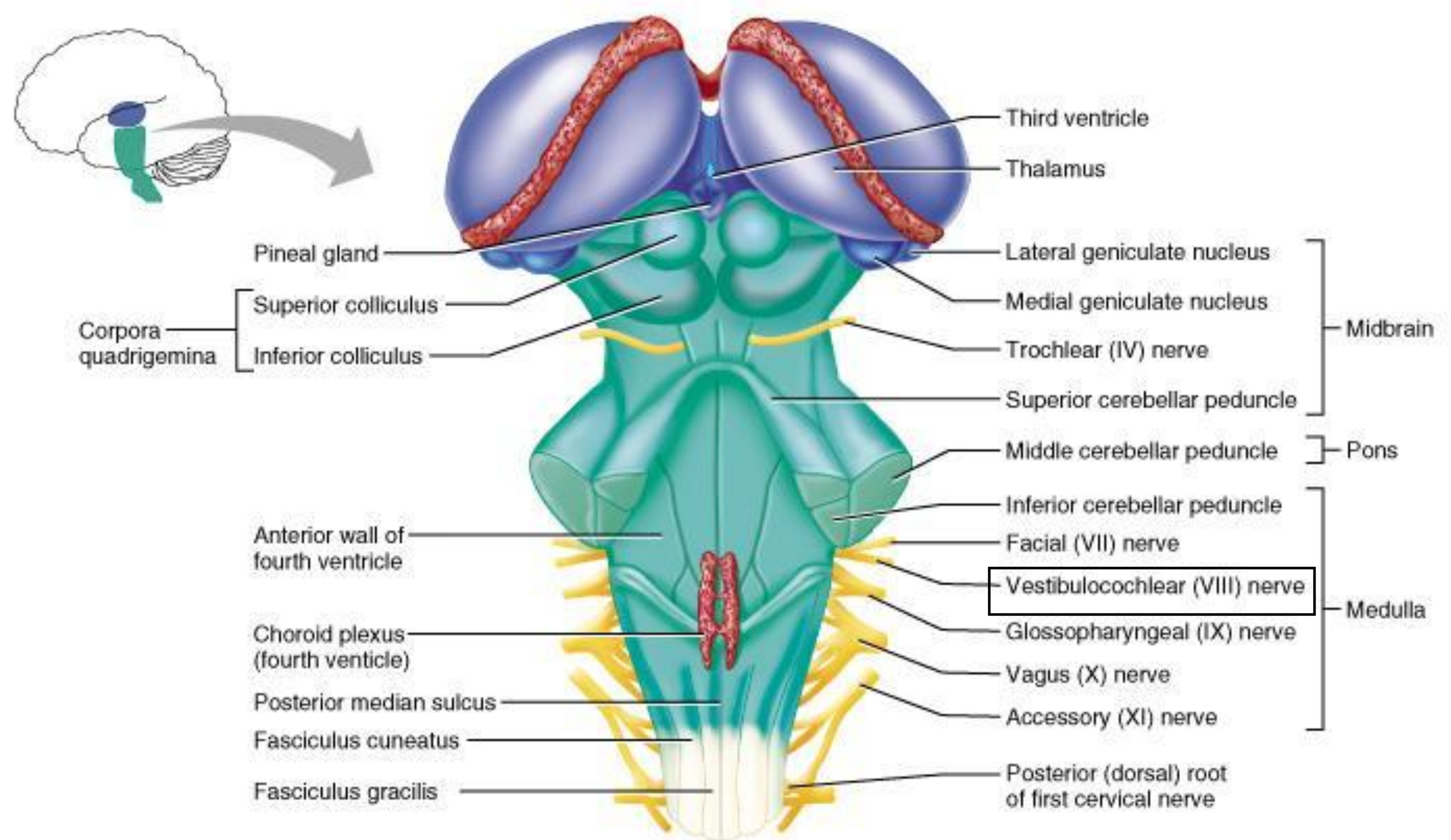
(b) Medulla oblongata

The Medulla Oblongata



- Other cranial nerves associated with the medulla are the Glossopharyngeal, Vagus, and portions of the Accessary nerves

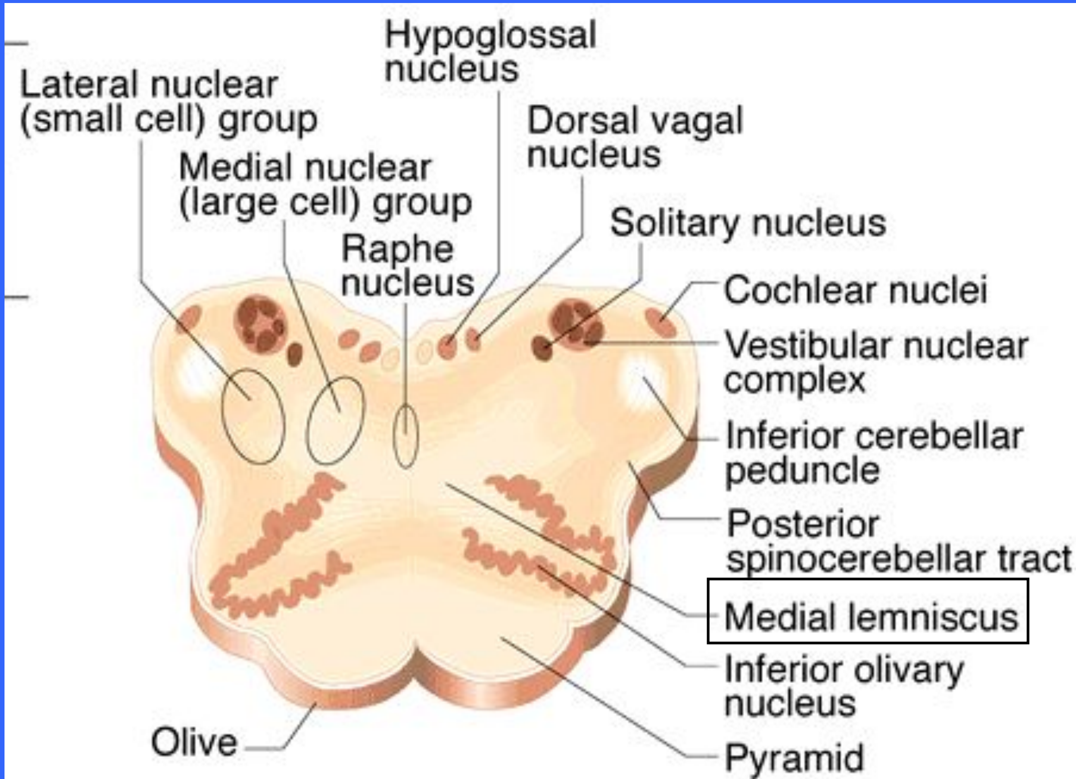
The Medulla Oblongata



- **The fibers of the vestibulocochlear synapse with the cochlear nuclei which receive information on auditory inputs**

The Medulla Oblongata

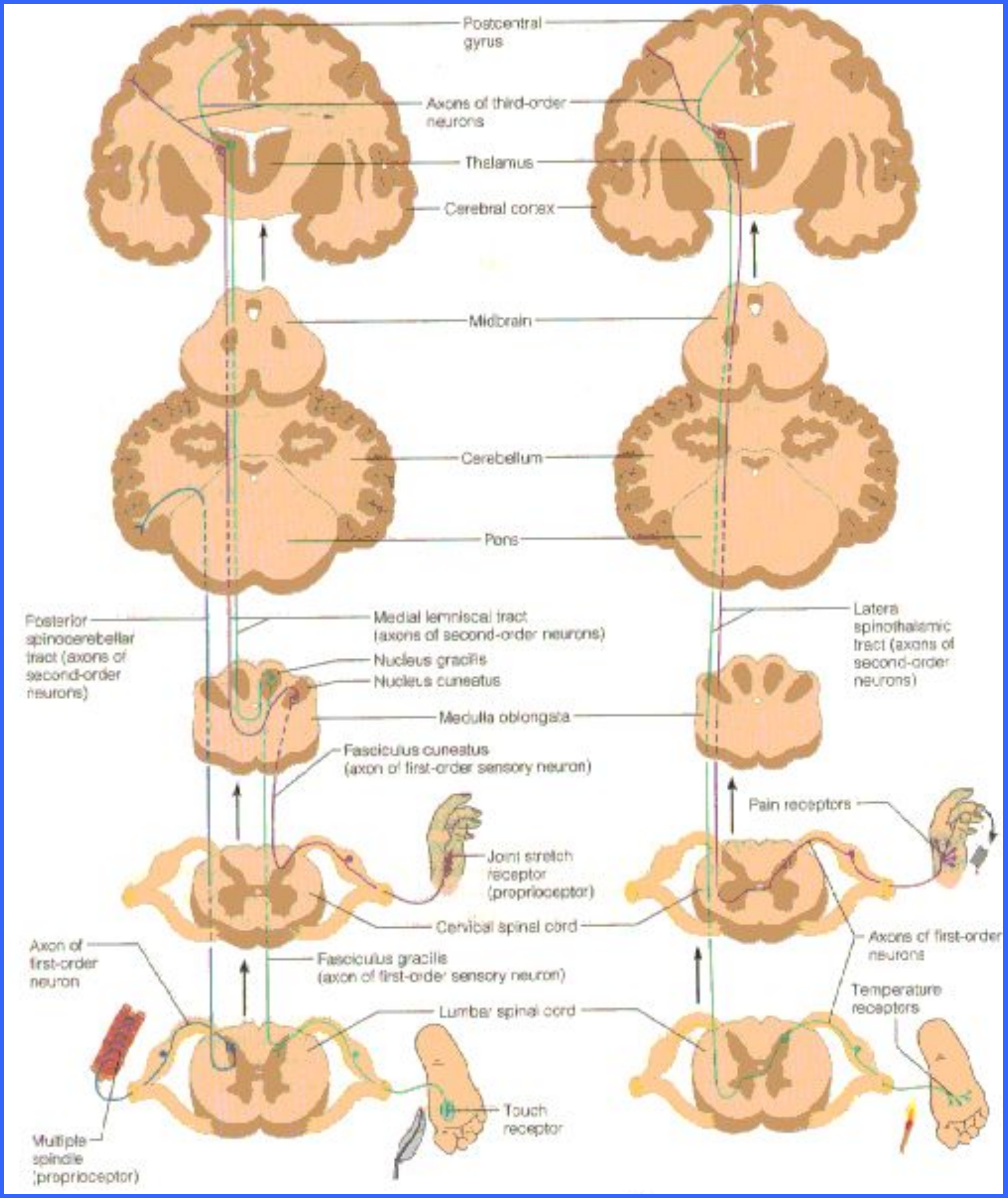
- **Also housed within the medulla are several nuclei associated with ascending sensory tracts**
- **The most dominant of these are the dorsally located nucleus gracilis and nucleus cuneatus associated with the medial lemniscal tract**



(b) Medulla oblongata

Medulla Oblongata

- These serve as relay nuclei in a pathway by which general somatic sensory information ascends from the spinal cord to the somatosensory cortex



The Medulla Oblongata

- The medulla has a critical role as an autonomic reflex center involved in maintaining body homeostasis
  - The cardiovascular center
  - The respiratory centers
  - Other centers

The Medulla Oblongata

- The cardiac center
  - The cardiac center adjusts the force and rate of heart contraction to meet bodily needs

The Medulla Oblongata

- The vasomotor center
  - The vasomotor center regulates blood pressure by acting on smooth muscle in the walls of the blood vessels to effect changes in blood vessel diameter
  - Vasoconstriction causes blood pressure to rise; dilation reduces blood pressure

The Medulla Oblongata

- The respiratory centers
  - The medullary respiratory centers control the rate and depth of breathing and maintains respiratory rhythm

The Medulla Oblongata

- Other centers
  - Additional centers regulate activities such as
    - Vomiting
    - Hiccuping
    - Swallowing
    - Coughing
    - Sneezing

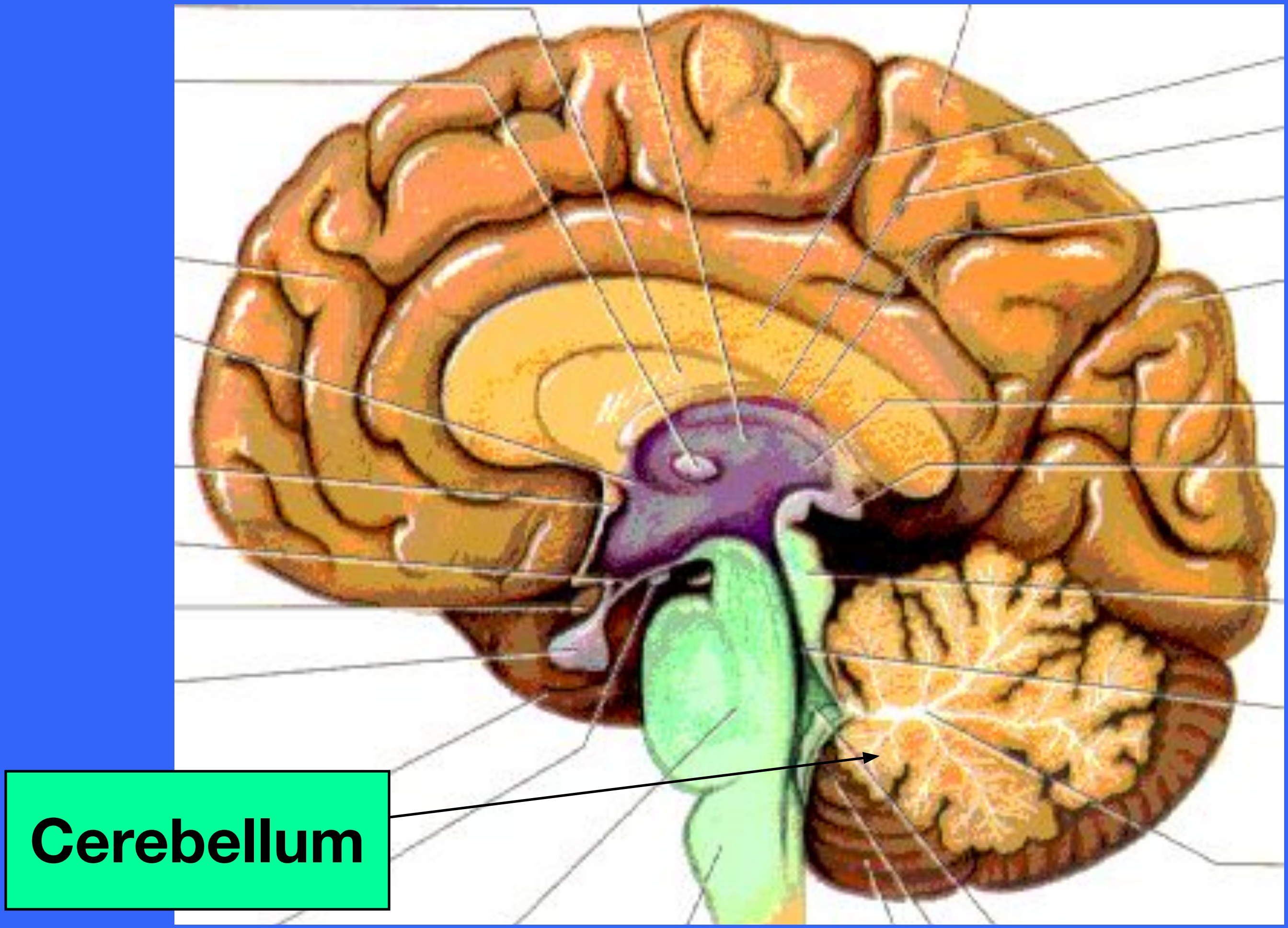
The Medulla Oblongata

- Many functions of the medulla overlap with those attributed to the hypothalamus
- The overlap is easily explained
- The hypothalamus exerts its control over most visceral functions by relaying its instructions through the medulla’s reticular centers (within the Medulla oblongata) which carry them out

The Cerebellum

- The cerebellum is exceeded in size only by the cerebrum
- It accounts for about 11% of total brain mass

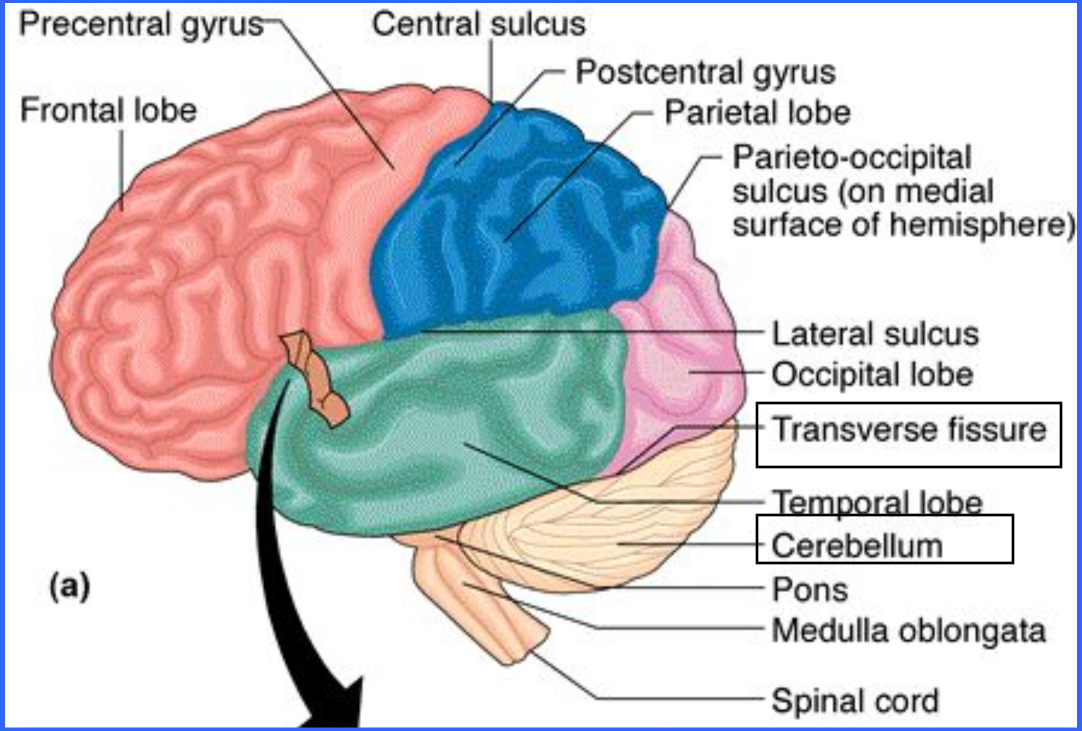
The Cerebellum



- The cerebellum is located dorsal to the pons and medulla under the occipital lobe of the cerebral hemispheres

The Cerebellum

- It is separated from the occipital lobe by the transverse fissure
- It rests in the posterior cranial fossa of the skull

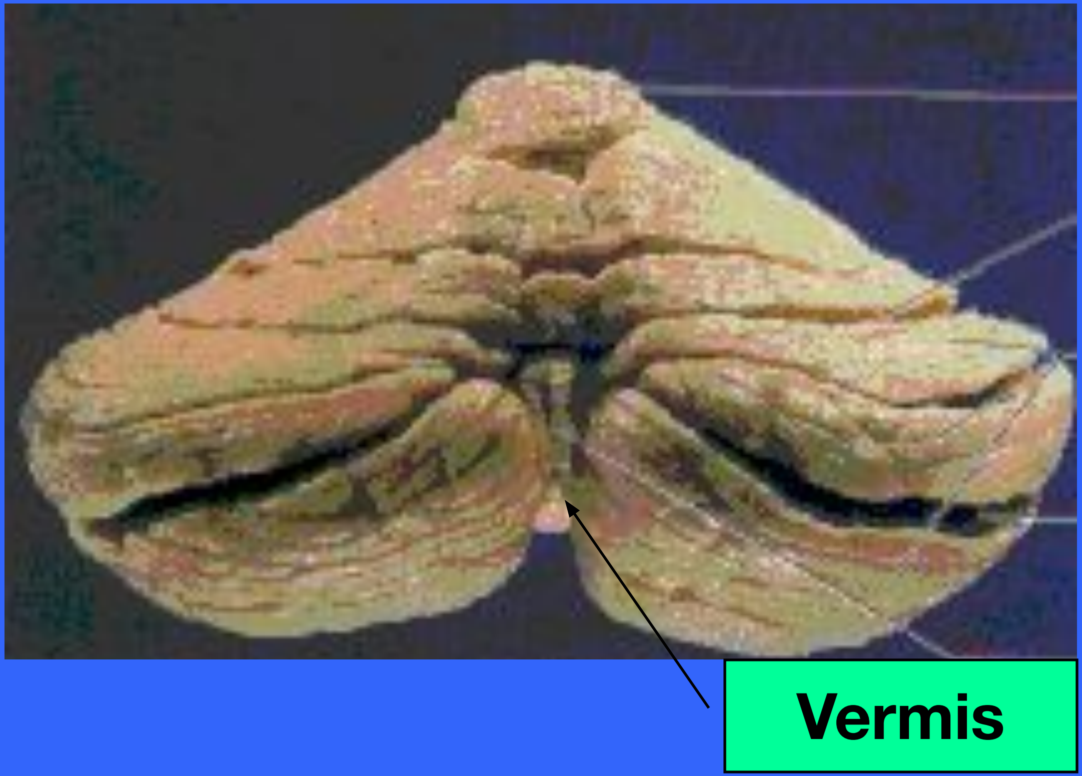


The Cerebellum

- The cerebellum processes inputs received from
  - Cerebral motor cortex
  - Various brain stem nuclei
  - Sensory receptors
- The cerebellum provides precise timing and appropriate patterns of skeletal muscle contraction
- Need for the smooth, coordinated movements of daily living
- Cerebeller activity occurs subconsciously; we have no awareness of its functioning

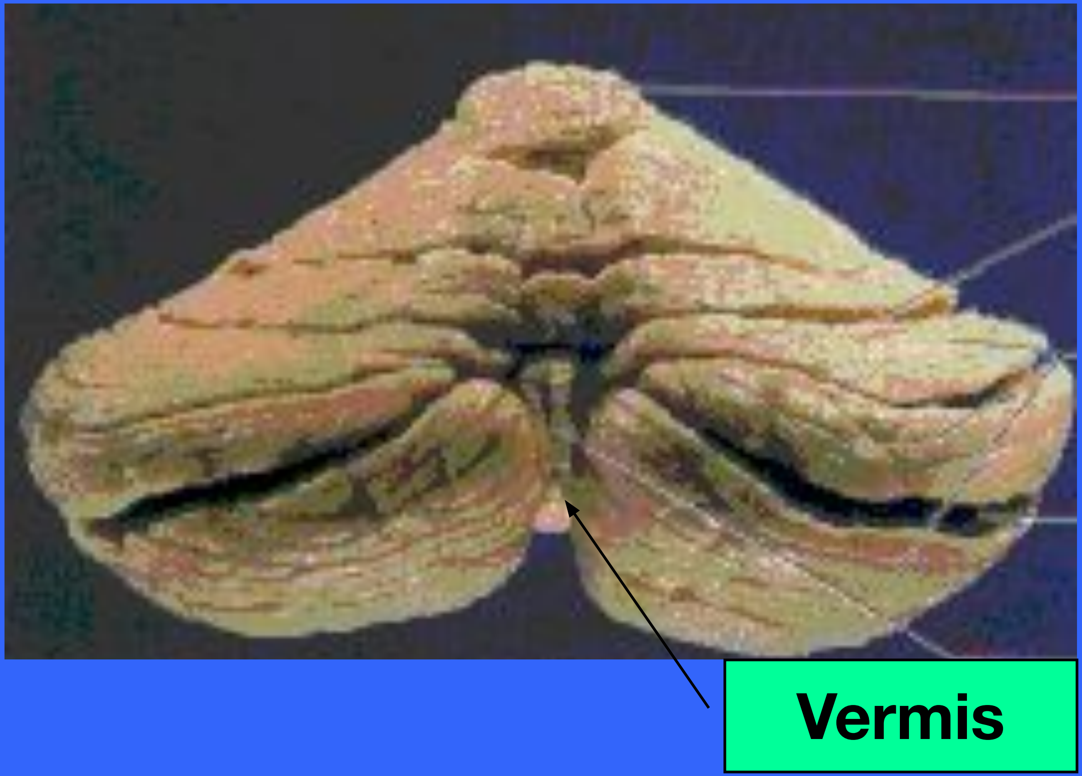
The Cerebellum

- The cerebellum is bilaterally symmetrical
- Its two cerebellar hemispheres are connected medially by the wormlike vermis



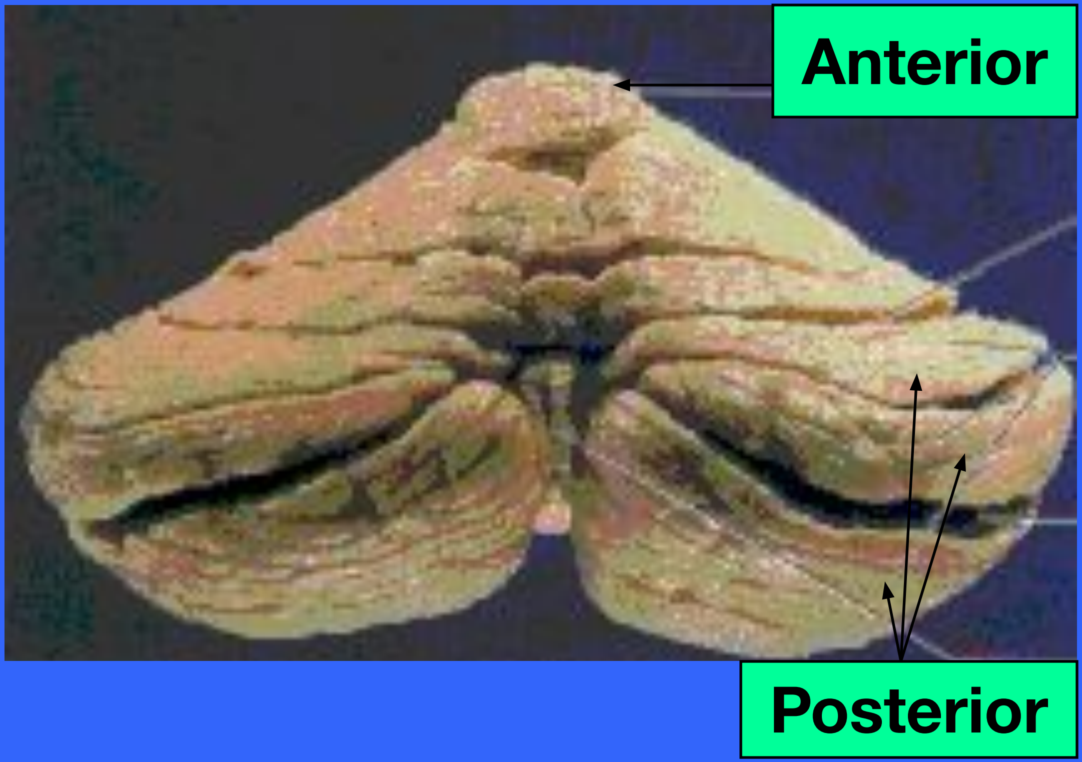
The Cerebellum

- Its surface is heavily convoluted
- Fissure are all transversely orientated
- The surface exhibits fine, parallel, pleatlike gyri known as folia



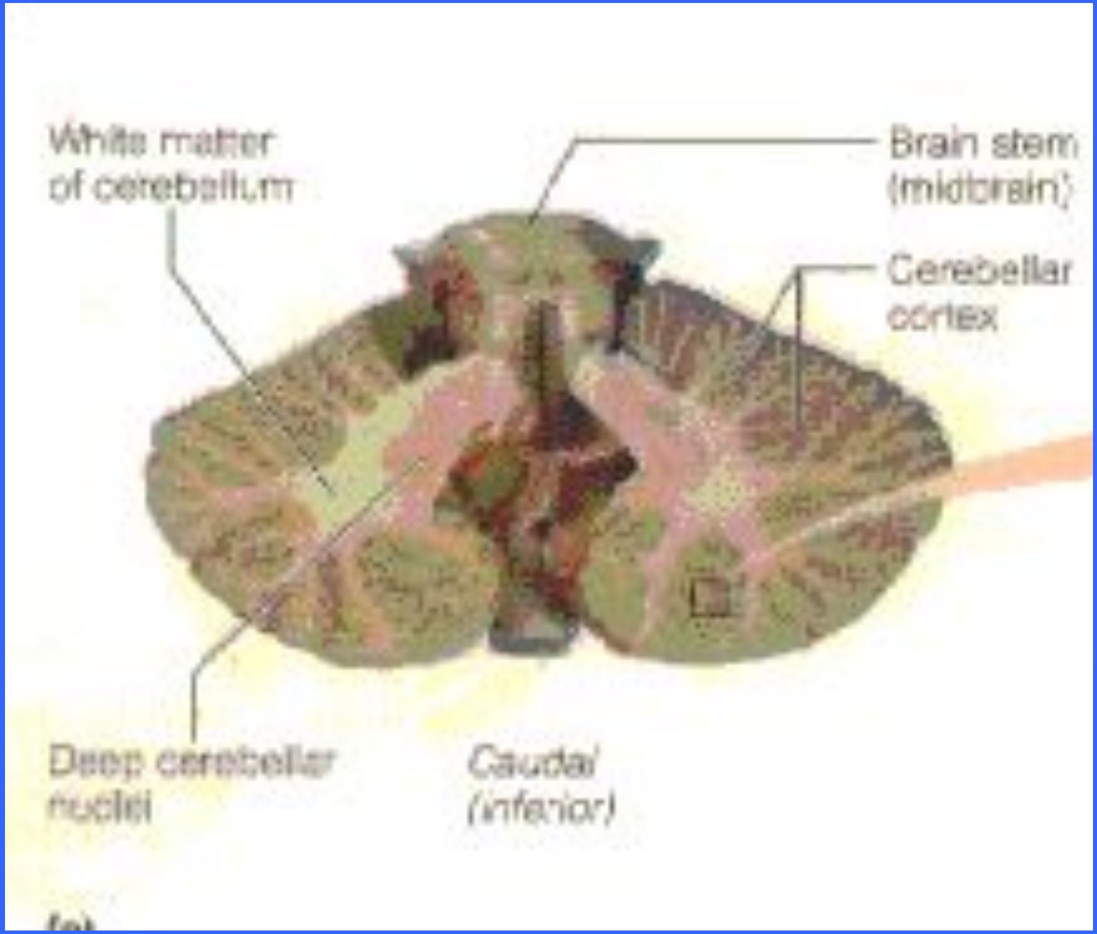
The Cerebellum

- Deep fissures divide each hemisphere into three lobes
  - Anterior lobe
  - Posterior lobe
  - Flocculonodular lobe* (Cannot be seen in a surface view)



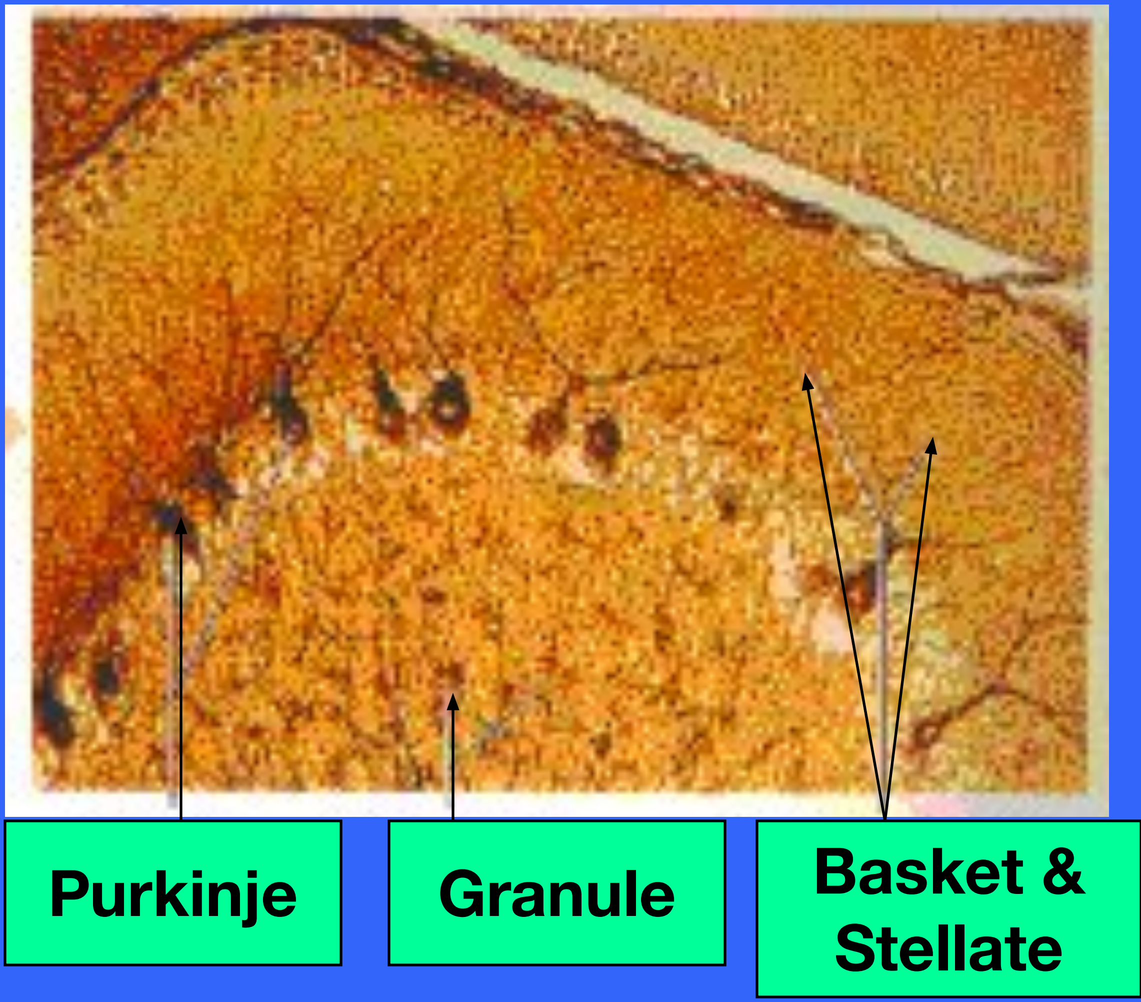
The Cerebellum

- The cerebellum has a thin outer cortex of gray matter
- Internal white matter
- Small, deeply situated paired masses of gray matter



The Cerebellum

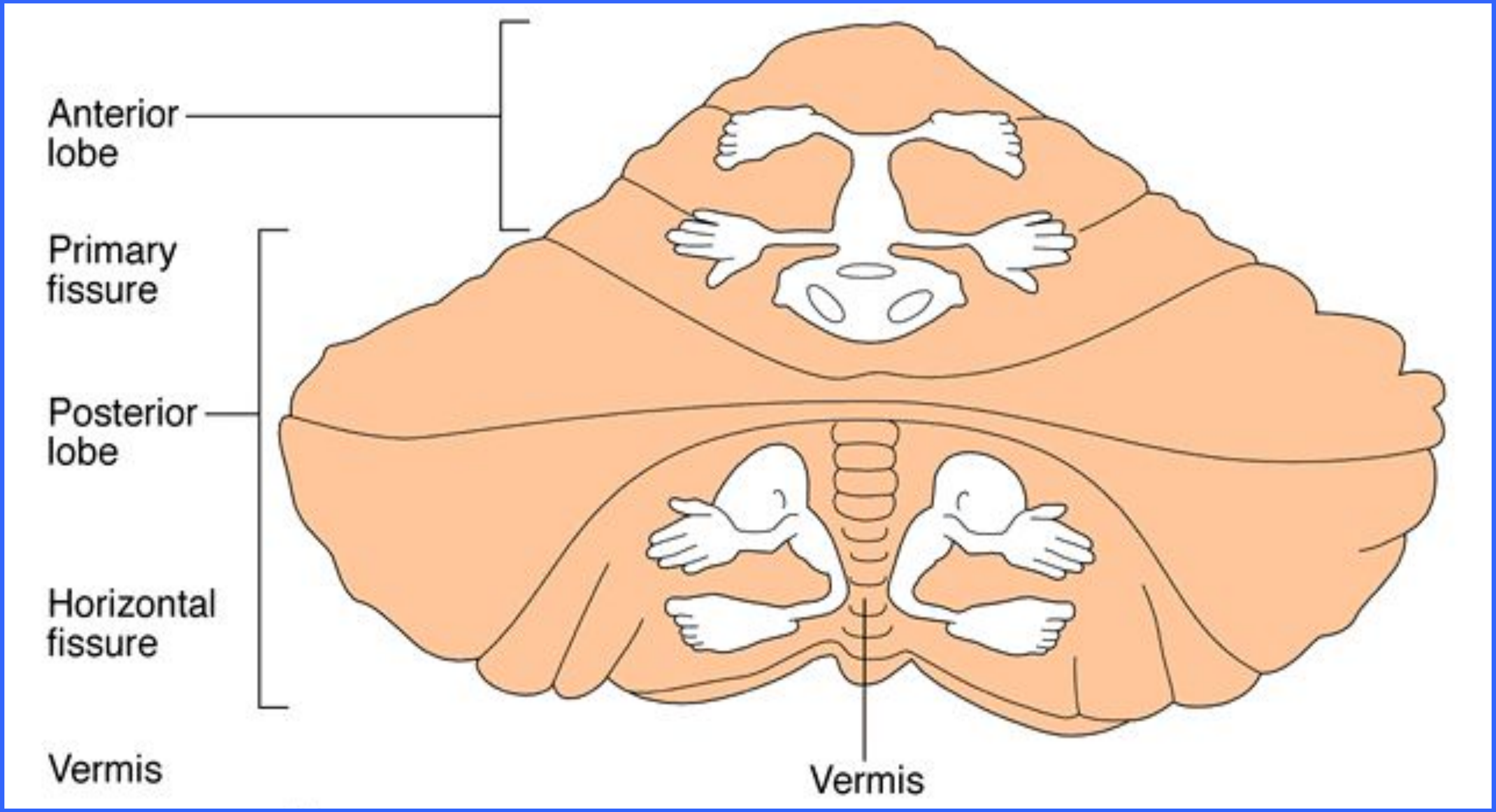
- Several types of neurons are found in the cerebellur cortex
  - Stellate
  - Basket
  - Granule
  - Purkinje



The Cerebellum

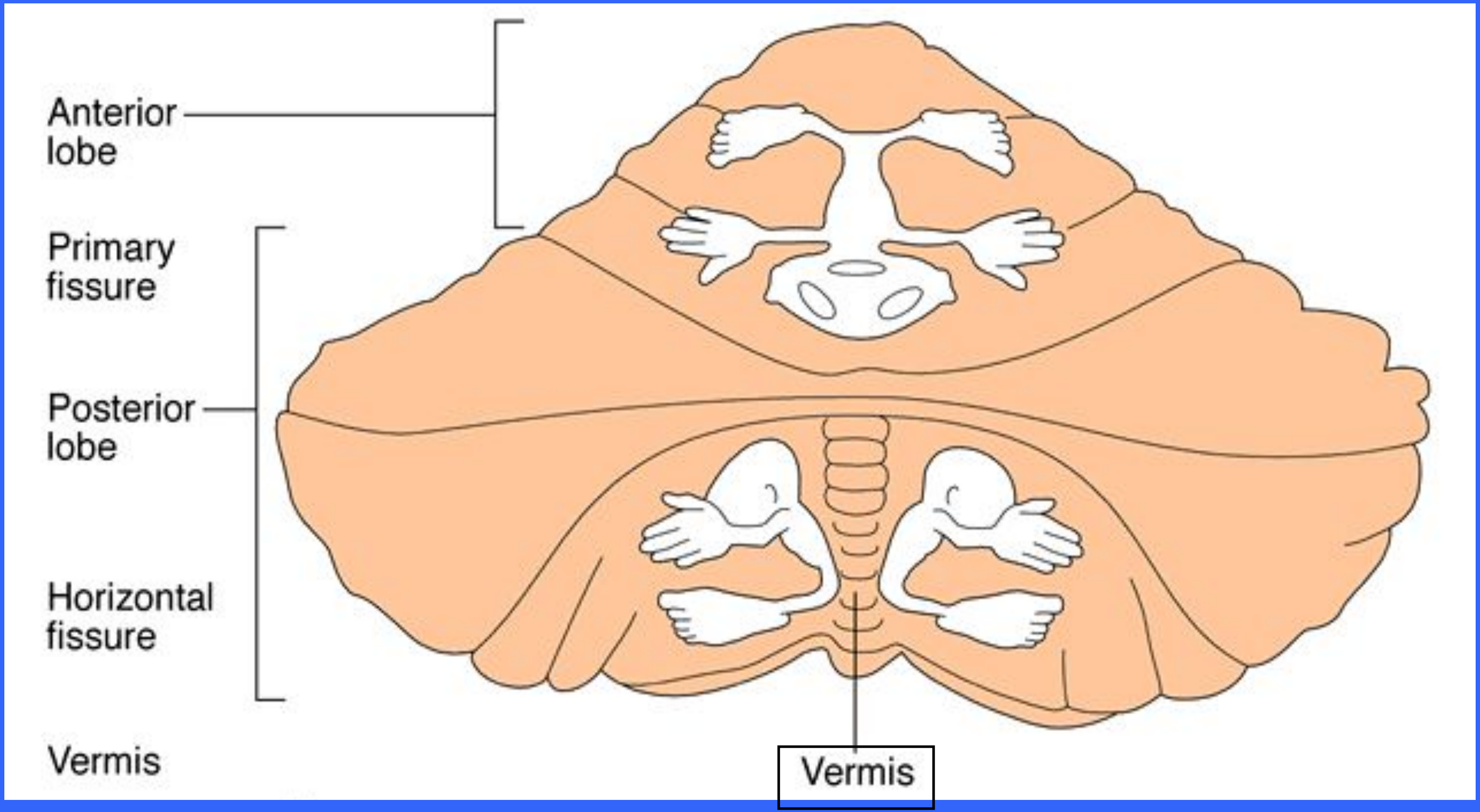
- The large Purkinje cells with their extensively branched dendrites are the only cortical neurons that send their axons through the white matter to synapse with the central nuclei of the cerebellum
- These nuclei mediate most of the output of the cerebellum

The Cerebellum



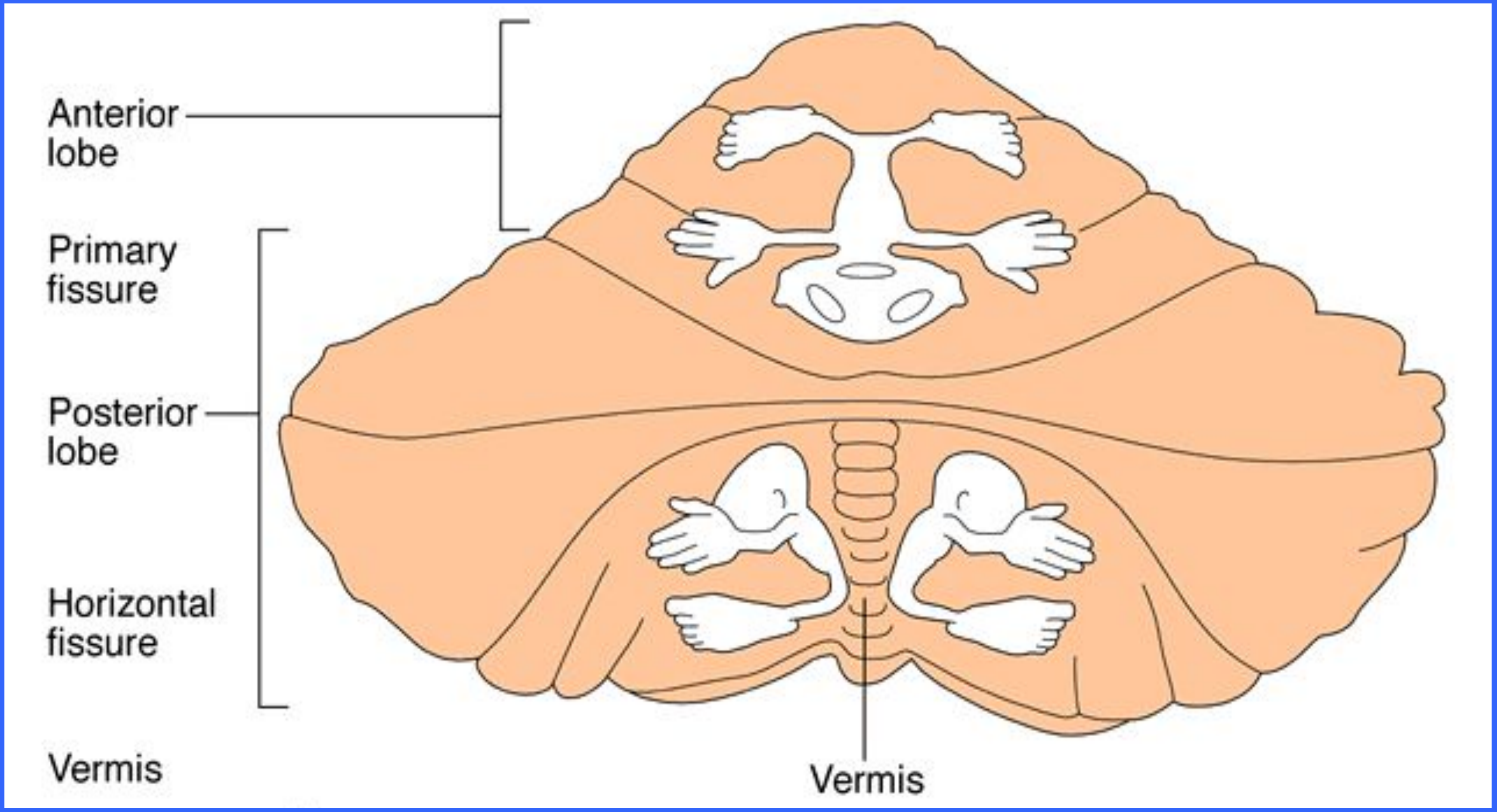
- The anterior and posterior lobes of the cerebellum act to coordinate body movements
- The lobes have completely overlapping sensory and motor maps of the entire body

The Cerebellum



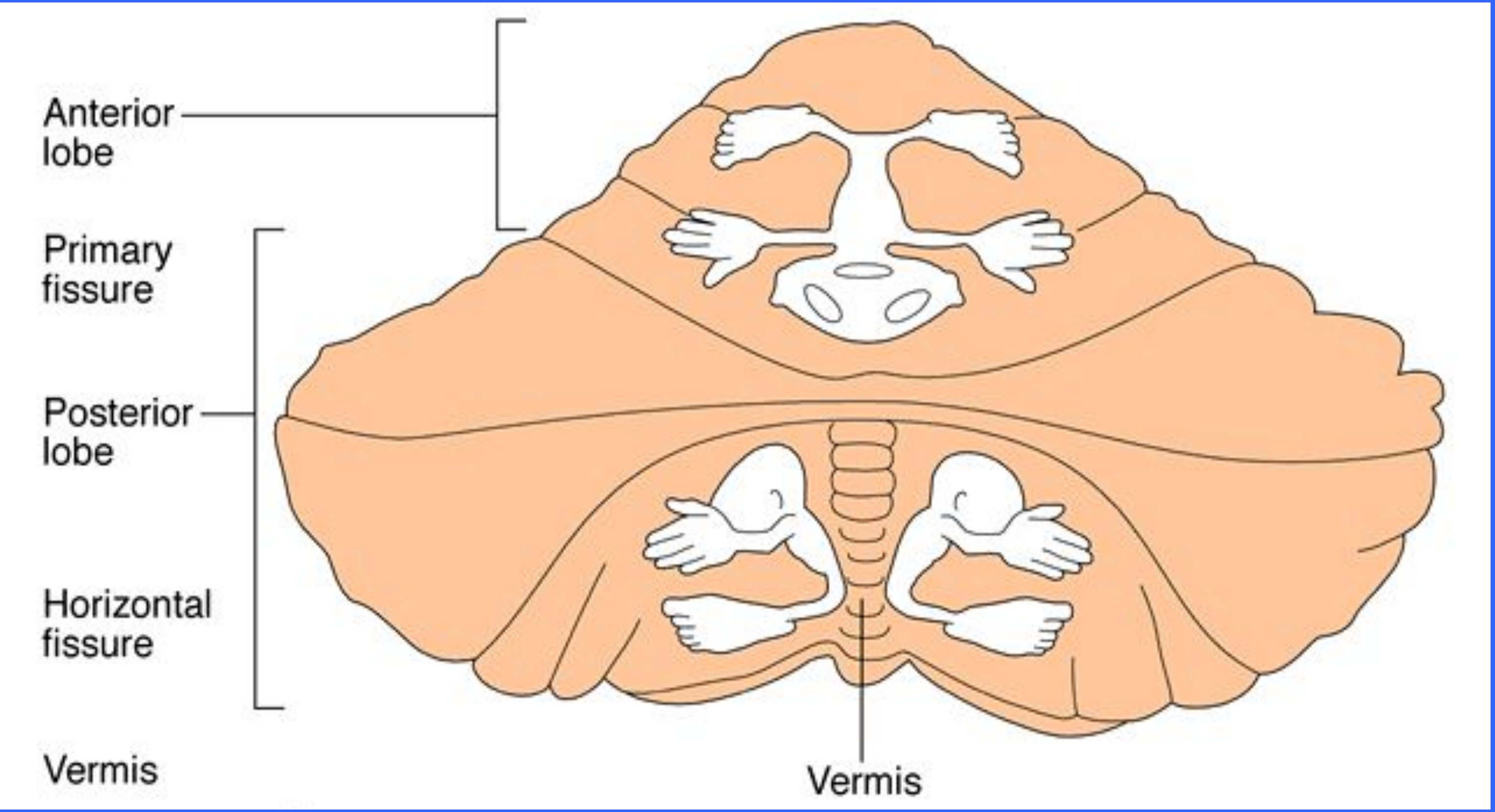
- The medial portions receive information from the axial portion of the body and influence the motor activities of the trunk and girdle muscles by relaying information to the cerebral motor cortex

The Cerebellum



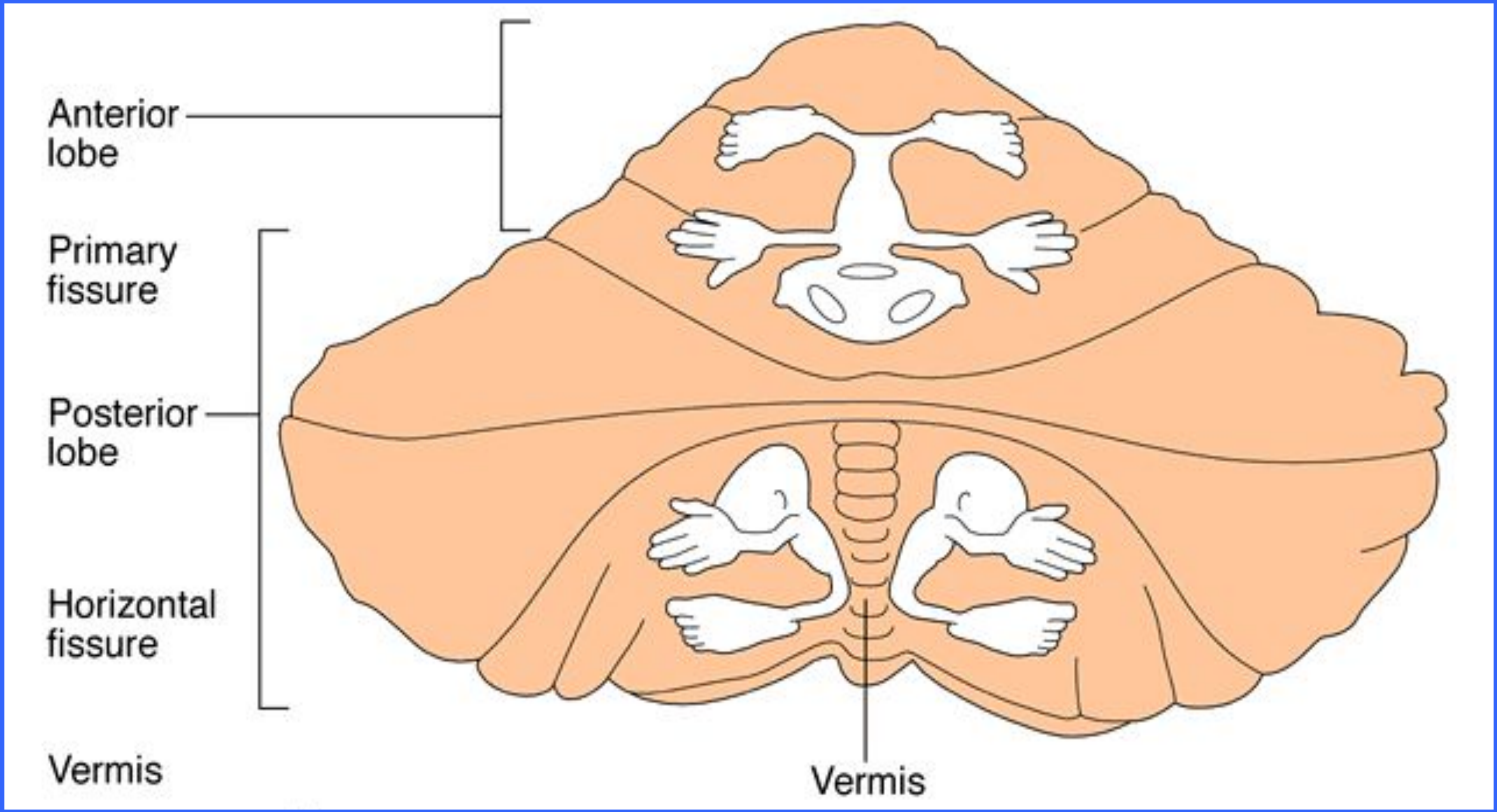
- **The intermediate parts of each hemisphere are more concerned with the distal parts of the limbs and skilled movements**

The Cerebellum



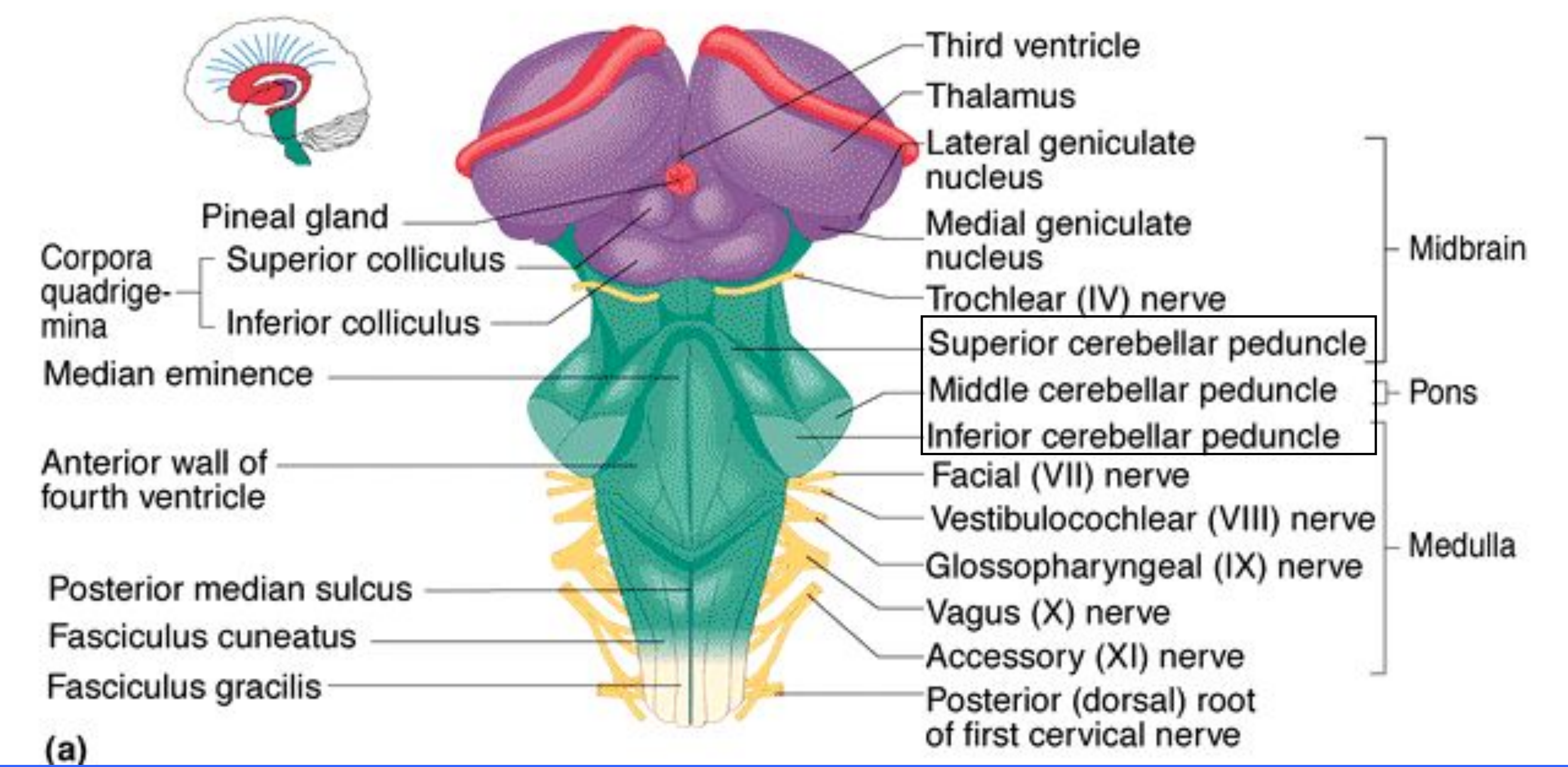
- **The lateral parts of each hemisphere receive inputs from the association areas of the cerebral cortex and appear to play a role in planning rather than executing movements**

The Cerebellum



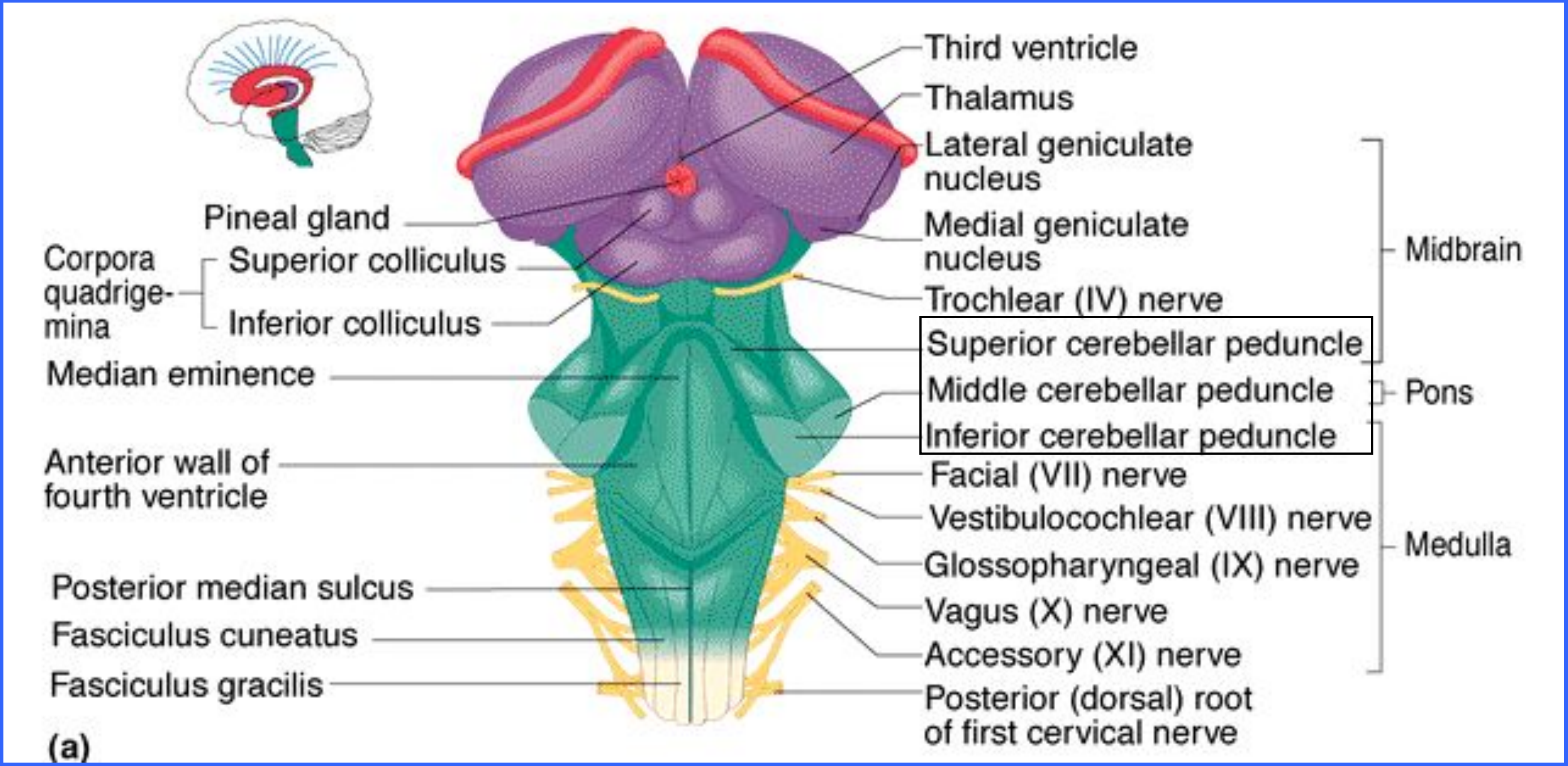
- **The small flocculonodular lobes receive inputs from the equilibrium apparatus of the inner ears, are concerned with maintaining balance and controlling certain eye movements**

The Cerebellum



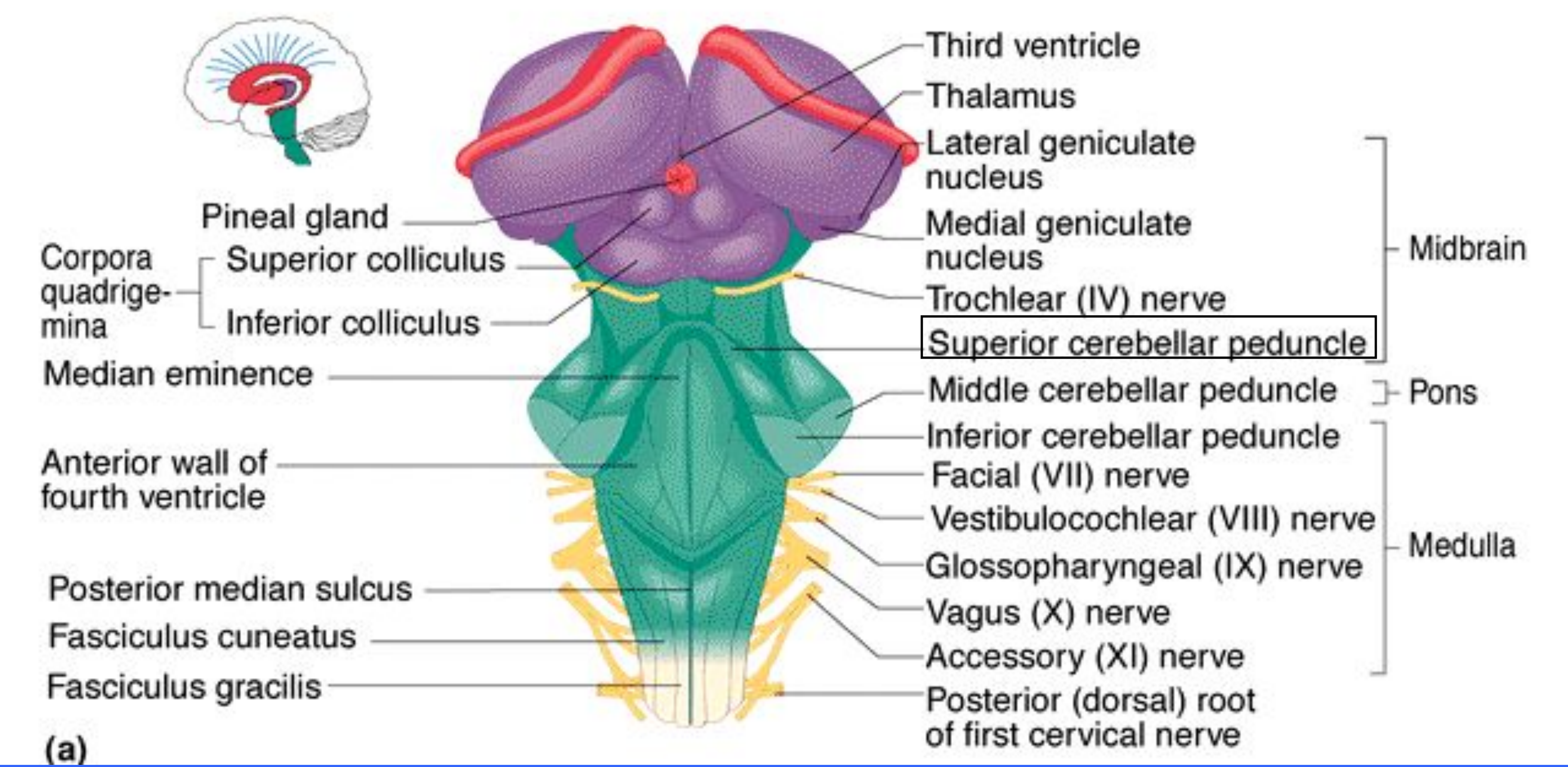
- **Three pairs of fiber tracts, cerebellur peduncles connect the the cerebellum to the brain stem**

The Cerebellum



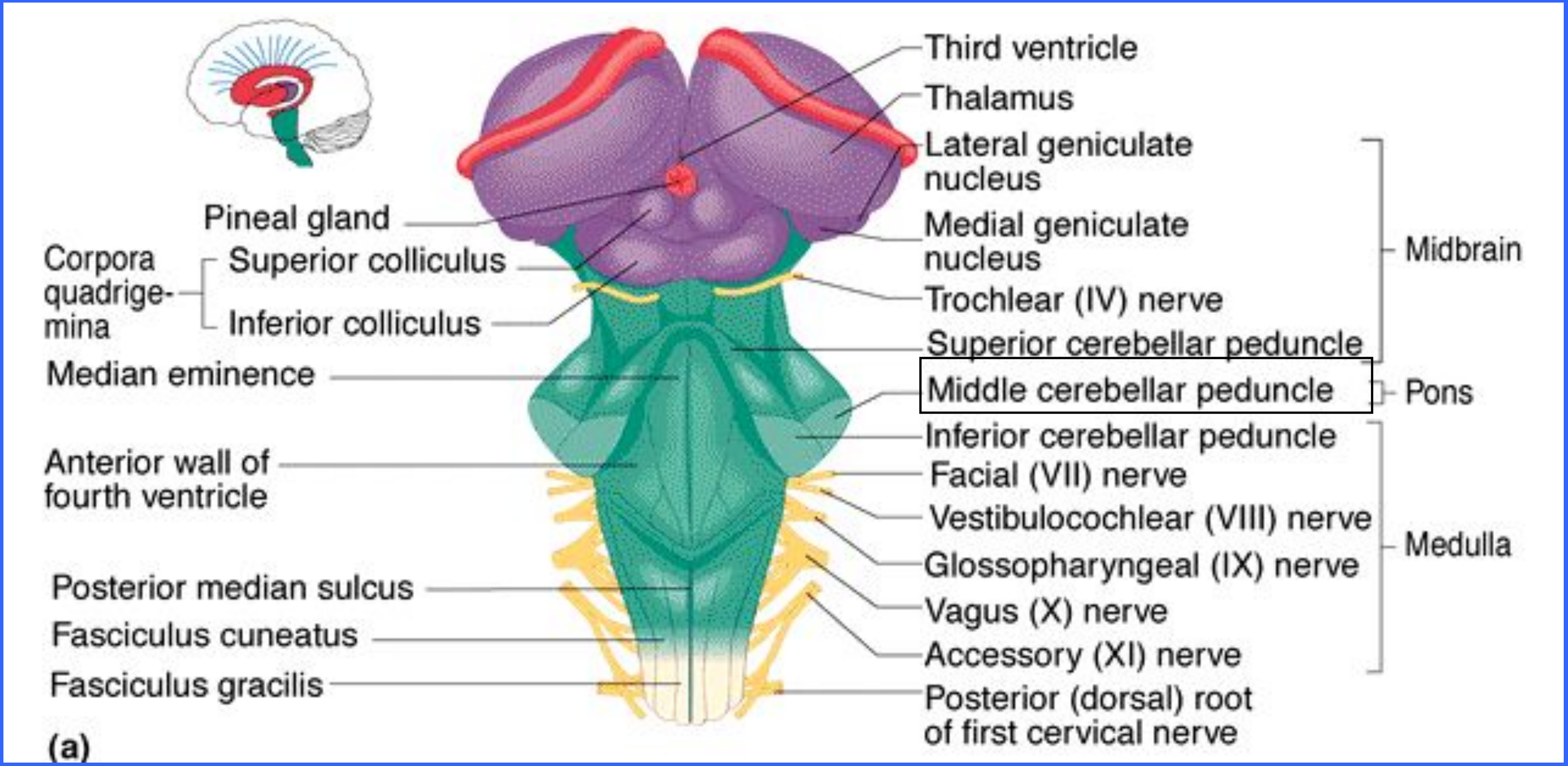
- Virtually all fibers entering and leaving the cerebellum are ipsilateral; from and to the same side of the body

The Cerebellum



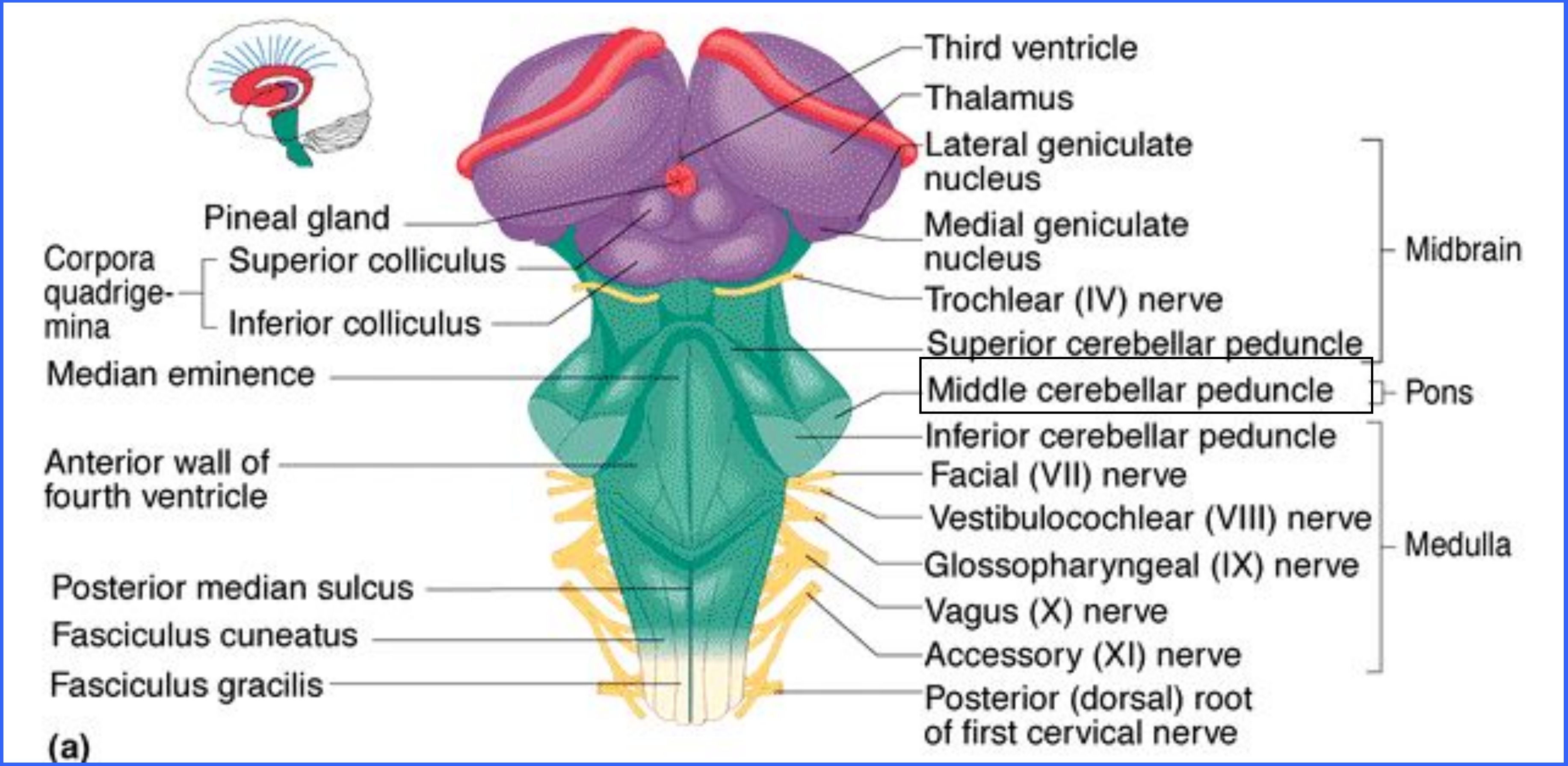
- The superior cerebellar peduncles connect the cerebellum and the midbrain. Fibers in these peduncles originate in the deep cerebellar nuclei and communicate with the cerebral motor cortex via thalamic relays

The Cerebellum



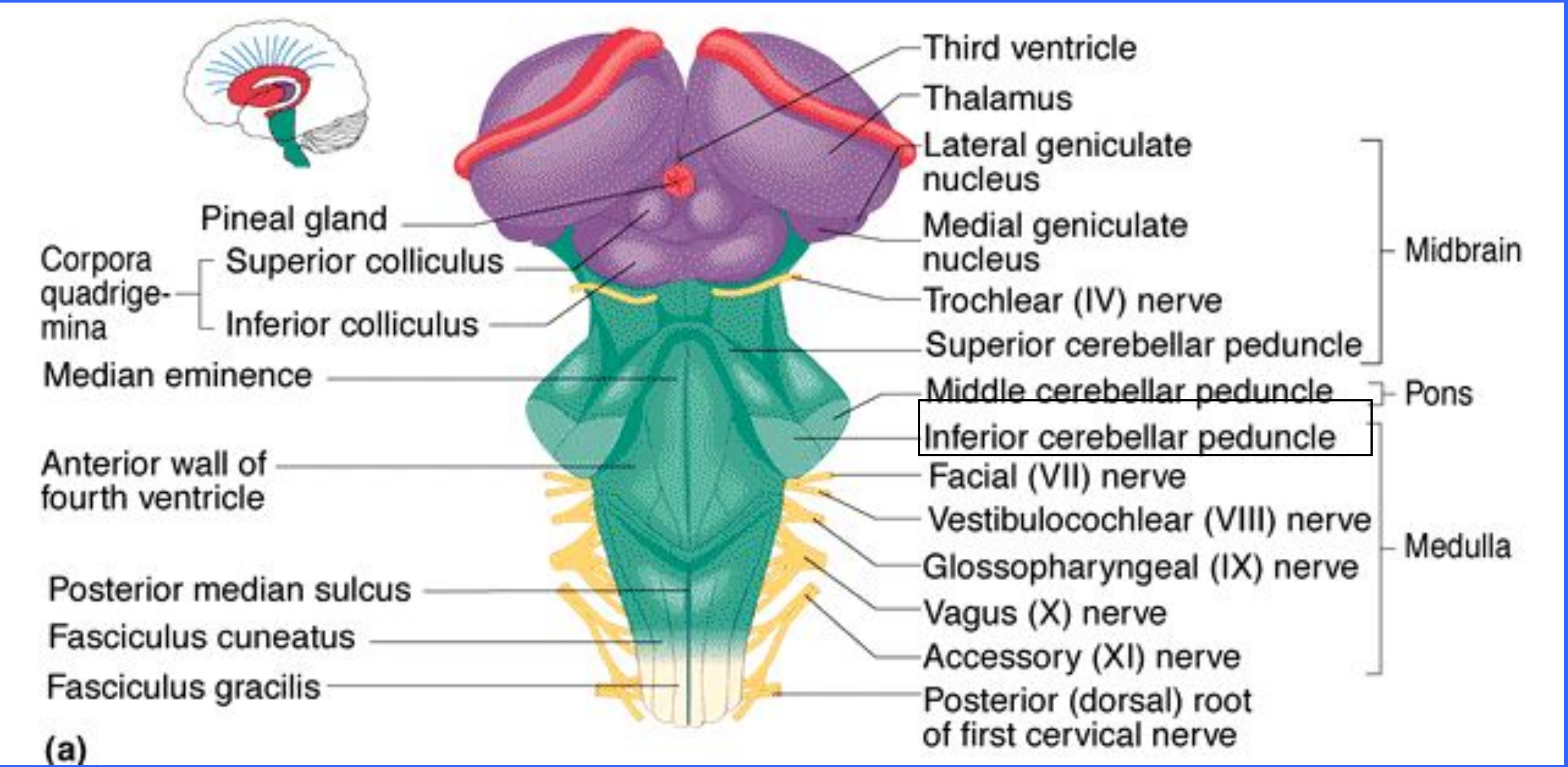
- **The middle cerebellar peduncles connect the pons the cerebellum.**

The Cerebellum



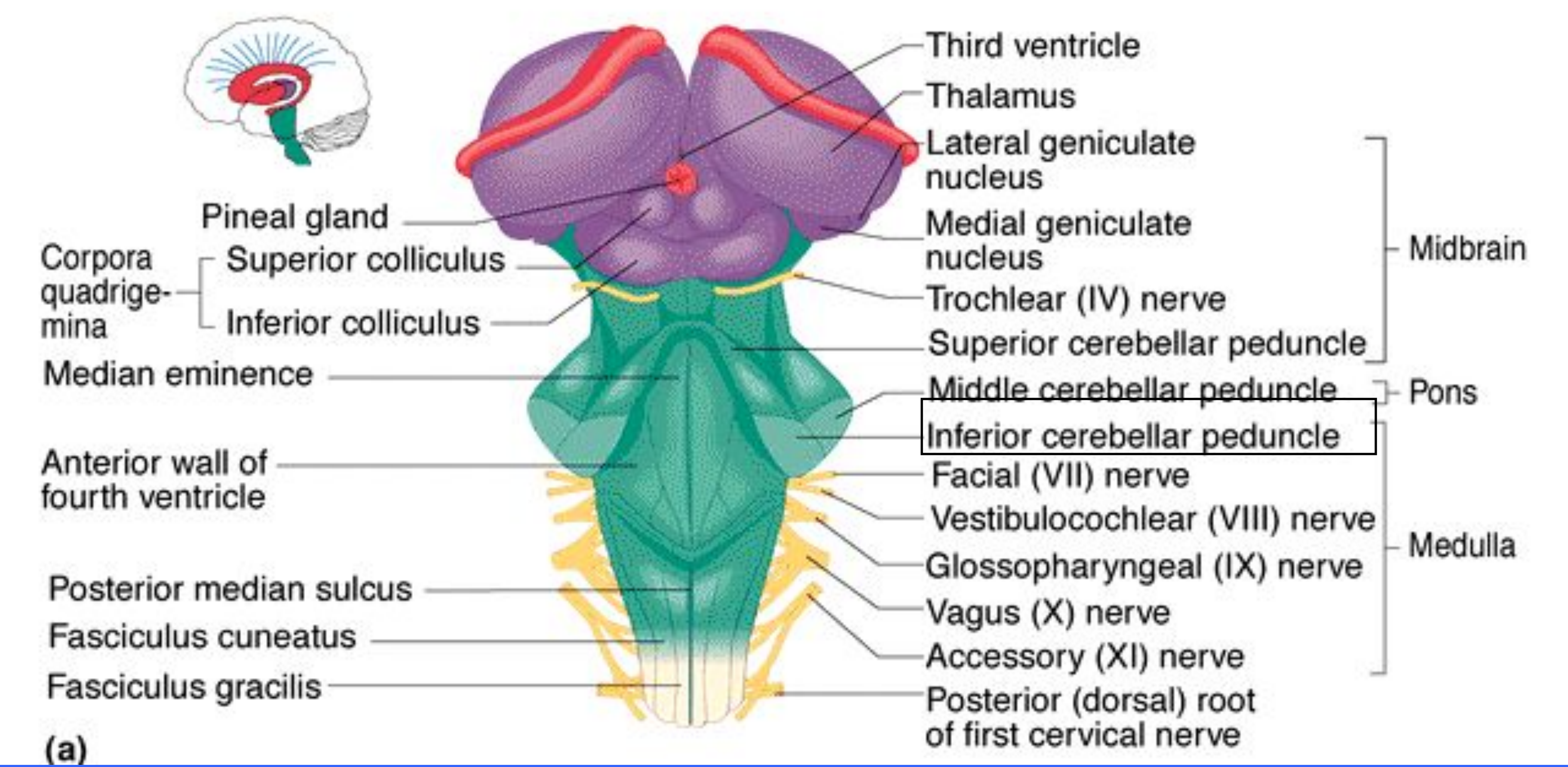
- These fibers allow one-way communication from the pons to the cerebellar neurons, which enables the cerebellum to be advised of coluntary motor activities initiated by the motor cortex

The Cerebellum



- **The inferior cerebellar peduncles connect the cerebellum and the medulla**

The Cerebellum



- These peduncles contain afferent tracts conveying sensory information to the cerebellum from (1) muscle proprioceptors throughout the body and (2) vestibular nuclei of the brain stem concerned with balance & equil.

Cerebellar Processing - 1

- The frontal motor association areas of the cerebral cortex indicates its intents to initiate voluntary muscle contractions
- Through collateral fibers of the pyramdial tracts, it notifies the cerebellum of its activity

Cerebellar Processing - 2

- At the same time, the cerebellum receives information from the proprioceptors throughout the body
  - Tension in muscles, tendons, and joint positions
  - From visual and equilibrium pathways
- This information enables the cerebellum to determine where the body is and where it is going
  - More specifically where the parts of the body are located in space and how are they moving

Cerebellar Processing - 3

- The cerebellar cortex assesses this information and calculates the best way to coordinate the force, direction, and extent of muscle contraction
  - Prevents overshoot
  - Maintains posture
  - Ensures smooth, coordinated movements

Cerebellar Processing - 4

- Via the superior peduncles, the cerebellum dispatches its “blueprint” for coordination to the cerebral motor cortex which makes appropriate adjustments in its motor plan
- Cerebellar fibers also flow to brain stem nuclei, such as the red nuclei of the midbrain, which in turn project to motor neurons of the spinal cord

The Cerebellum

- The cerebellum continually compares the higher brain's intention with the body's performance and sends out messages to initiate the appropriate measures
- In this way, it helps to promote smooth voluntary movements that are precise and economical in terms of muscular effort

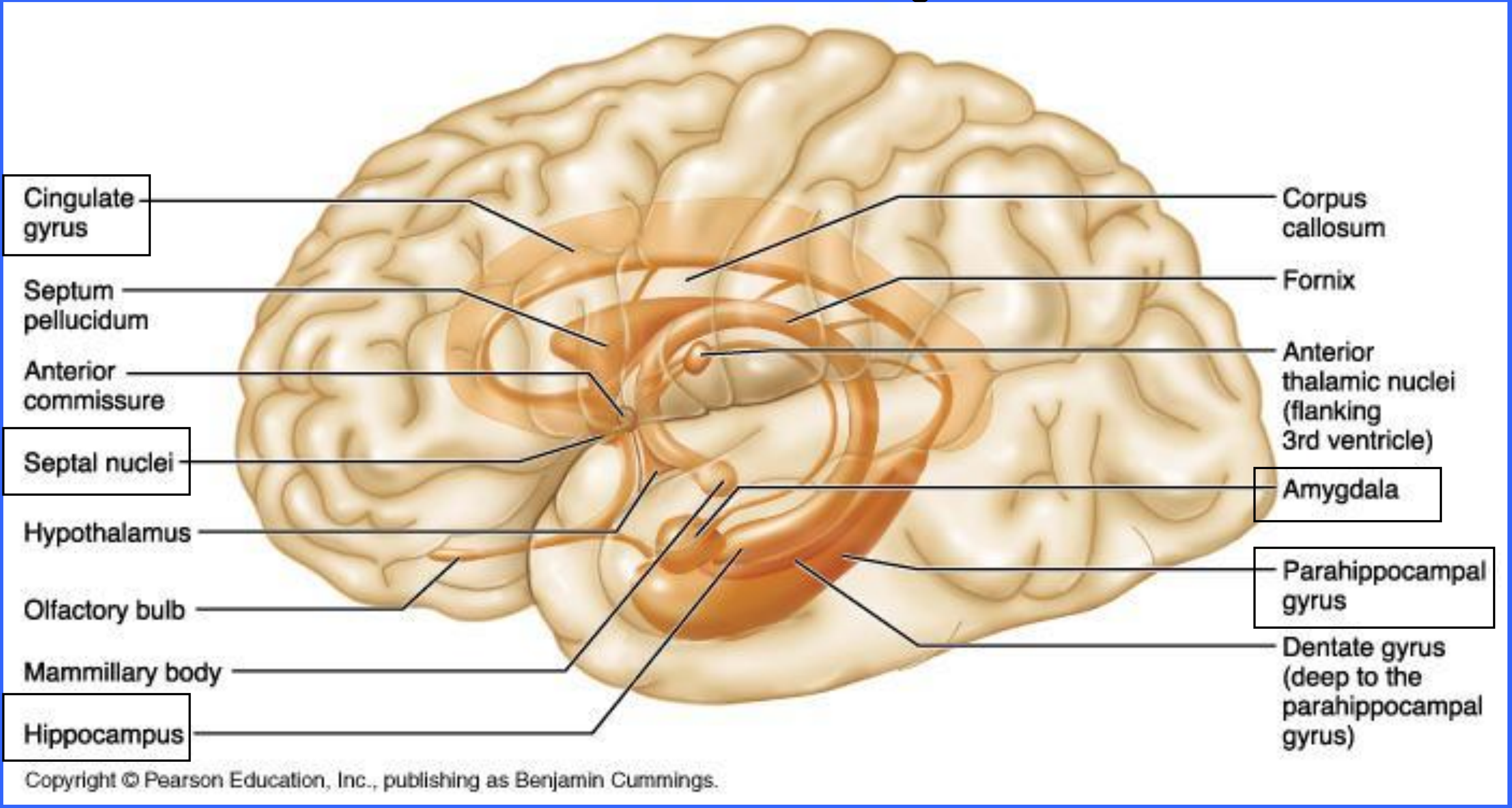
The Cerebellum

- Cerebellar injury results in the loss of muscle tone and clumsy, unsure movements, and sometimes even impaired thoughts about movements

Functional Brain Systems

- Functional brain systems are networks of neurons that work together but span relatively large distances with the brain
- They are not localized to a specific region of the brain
  - The Limbic System (distributed within forebrain)
  - The Reticular Formation (distributed within the brainstem)

The Limbic System



- The limbic system is a group of structures located on the medial aspect of each cerebral hemisphere and diencephalon

The Limbic System

- The limbic system encircles the upper part of the brain stem and includes
  - Septal nuclei, Cingulate gyrus, hippocampal formation, and part of the Amygdala,
- In the diencephalon the limbic system structures are the hypothalamus and the anterior thalamic nuclei of the thalamus
- The fornix and other fiber tracts link these limbic system regions together

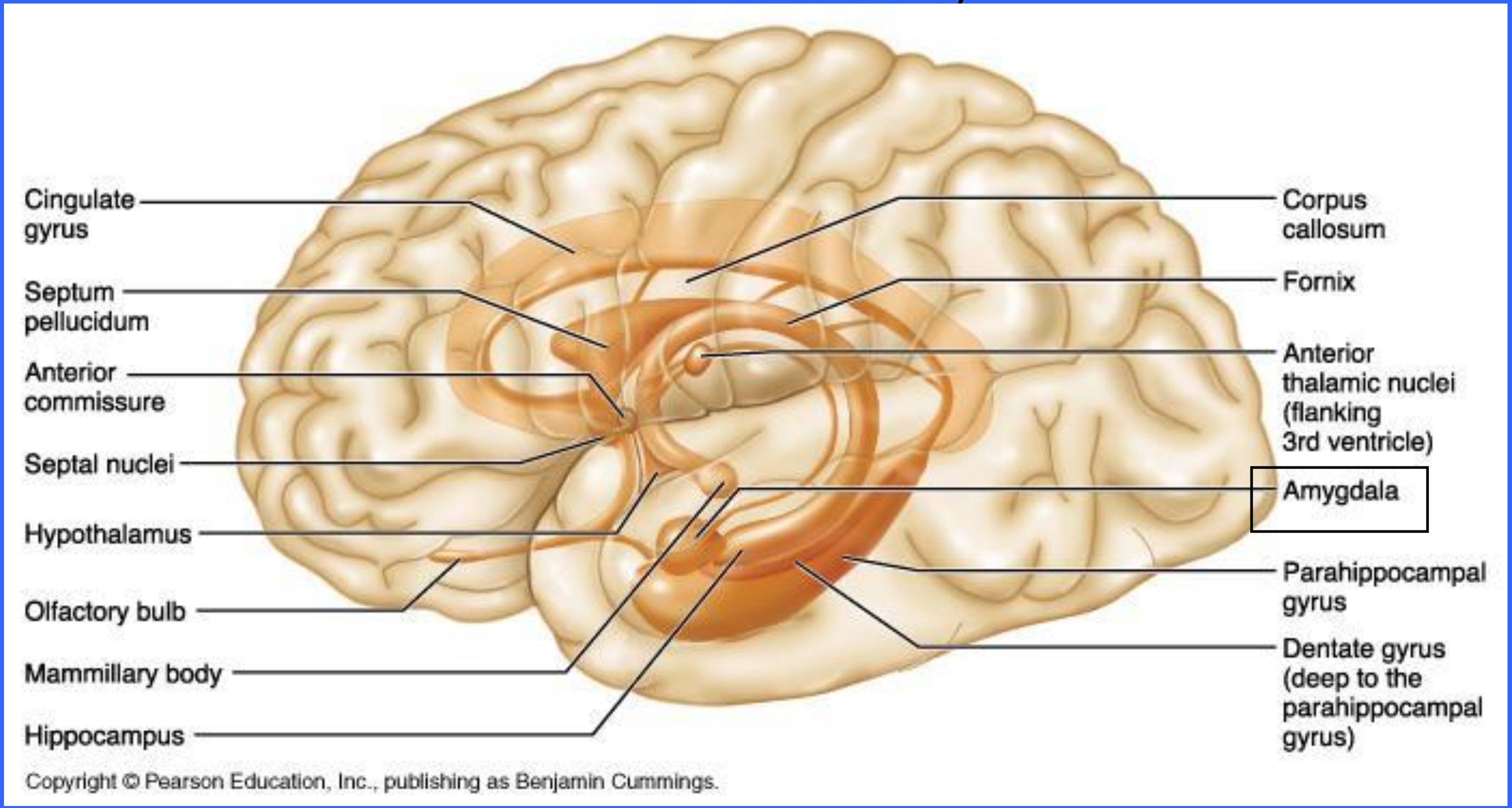
The Limbic System

- The observation that odors evoke emotional reactions and memories reflects the fact that these structures are linked to the rhinencephalon

The Limbic System

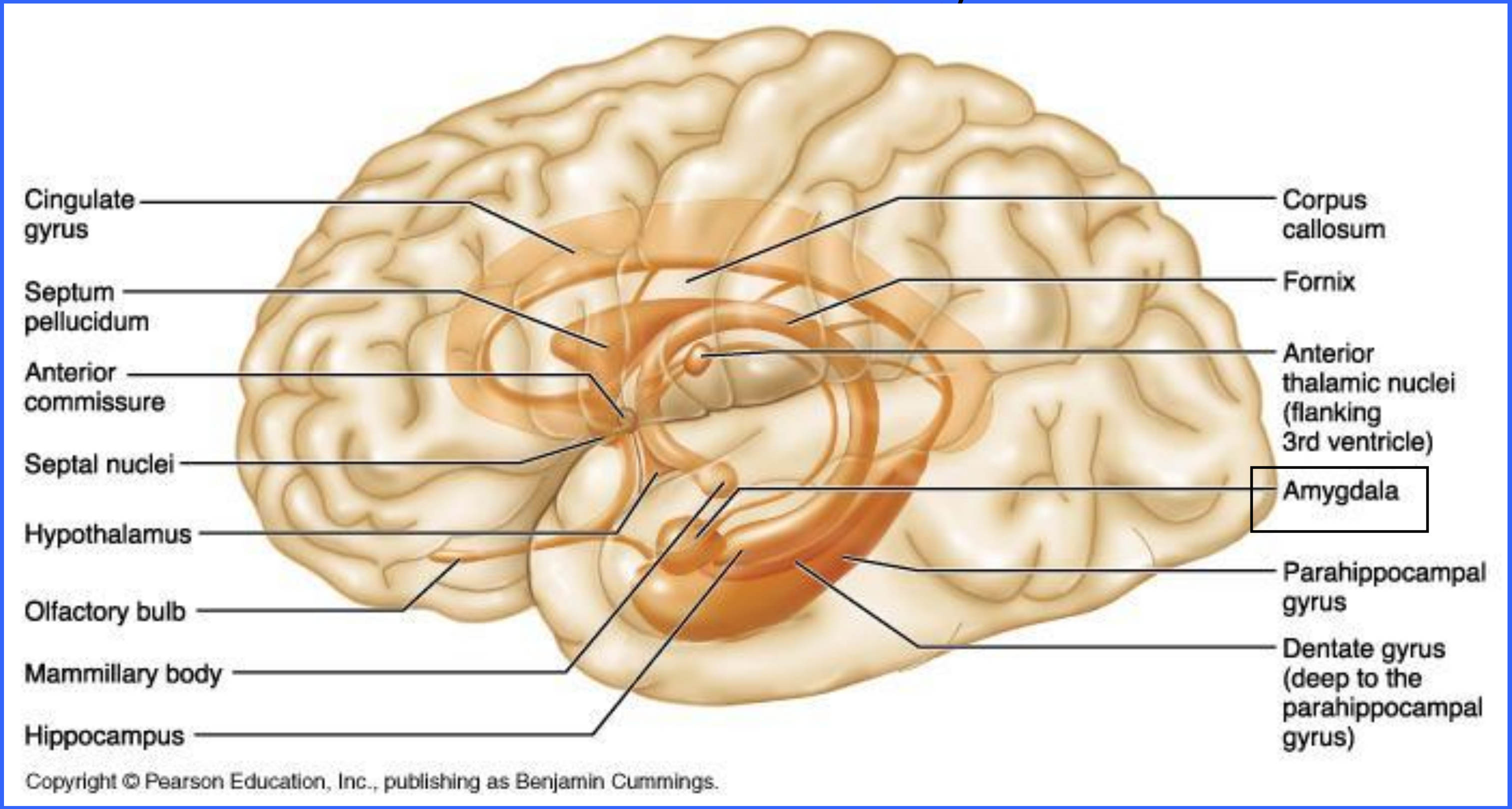
- The limbic system is our emotional or affective brain
- Two parts seem especially important in emotions
  - The amygdala
  - The cingulate gyrus

The Limbic System



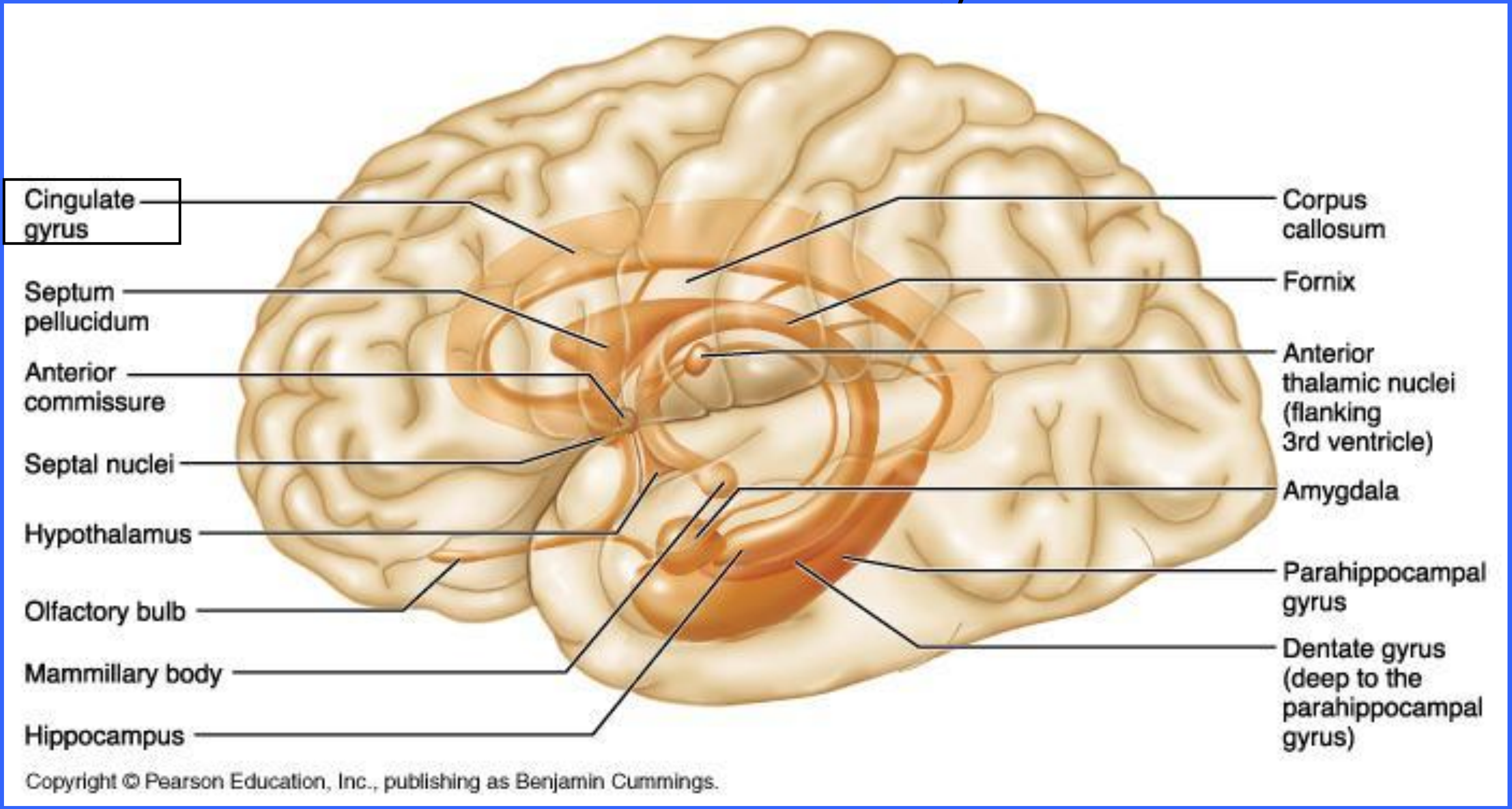
- **The amygdala contains the key nuclei for processing fear and then stimulating the appropriate sympathetic response to fear**

The Limbic System



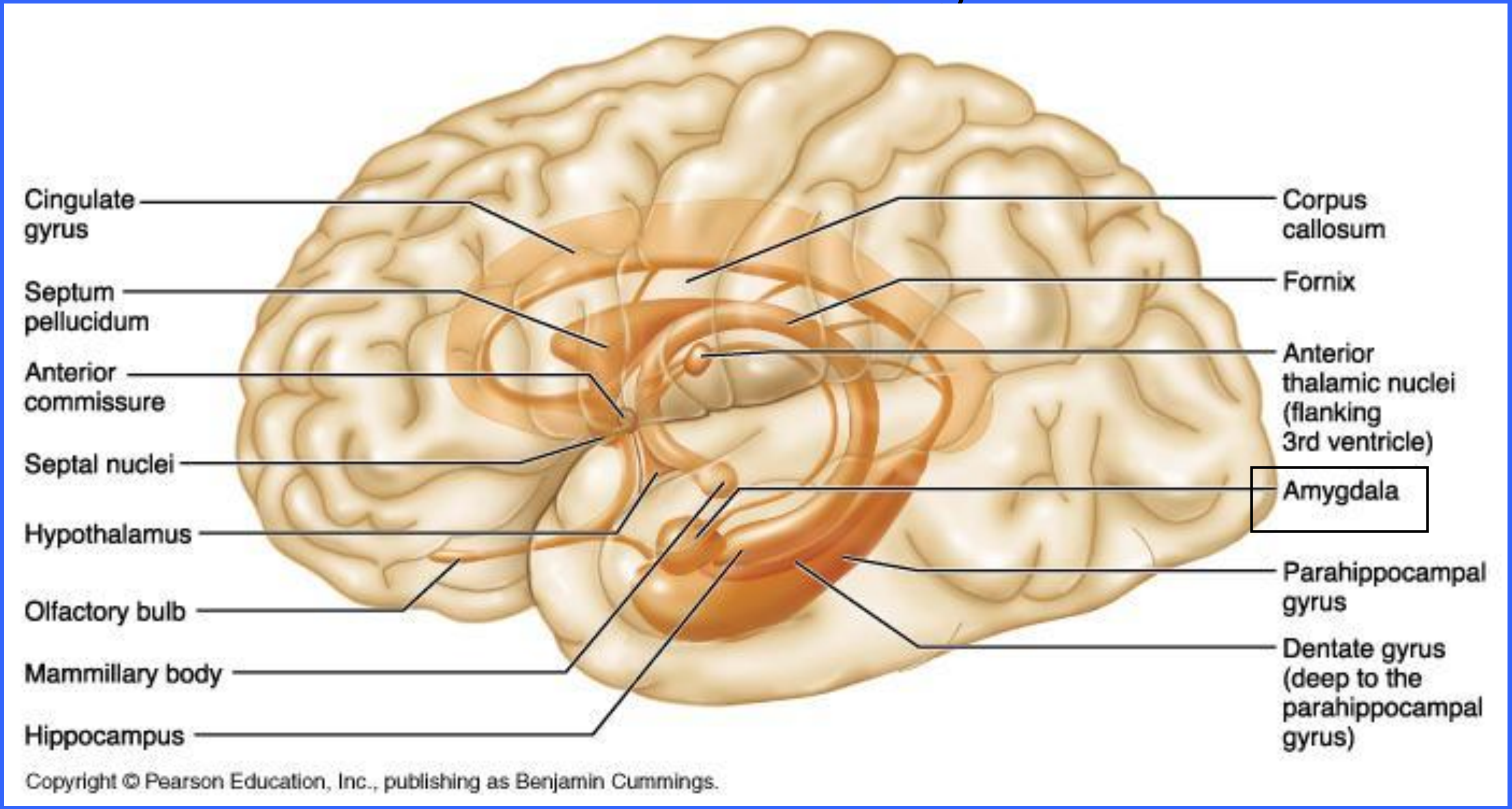
- The amygdala also enables us to recognize menacing facial expression in others and to detect the precise direction of the gaze of someone who is looking at us

The Limbic System



- **The cingulate gyrus allows us to shift between thoughts and to express our emotions through gestures**

The Limbic System



- **The anterior part of the gyrus interprets pain as unpleasant and resolves mental conflict during frustrating tasks**

The Limbic System

- The limbic system also functions in consolidating and retrieving memories
- The structures involved, both of which are in the medial aspect of the temporal lobe, are the amygdala and the hippocampal formation
- The hippocampal formation consists of the hippocampus and the parahippocampal gyrus

The Limbic System

- **The hippocampal formation encodes, consolidates, and later retrieves memories of facts and events**
- **It first receives information to be remembered from the rest of the cerebral cortex; then it processes these data and returns then to the cortex, where they are stored as long-term memories**

The Limbic System

- The amygdala forms memories of experiences that are based entirely on their emotional impact, especially if related to fear
- If we later are reminded of these experiences, the amygdala retreives the memories and causes us to re-experience the original emotion
- The benefit is that it lets us make difficult and risky decisions correctly, based on memories of our past emotional experiences

The Limbic System

- The limbic system communicates with many other regions of the brain
- Most output from the limbic system is relayed through the hypothalamus and the reticular formation, the portions of our brain that control our visceral responses

The Limbic system

- This fact explains why people under emotional stress experience visceral illnesses such as high blood pressure and heartburn
- The limbic system also interacts heavily with the prefrontal lobes of the cerebral cortex
- Thus, our feelings (mediated by the emotional brain) and our thoughts (mediated by the thinking brain) interact closely

The Limbic System

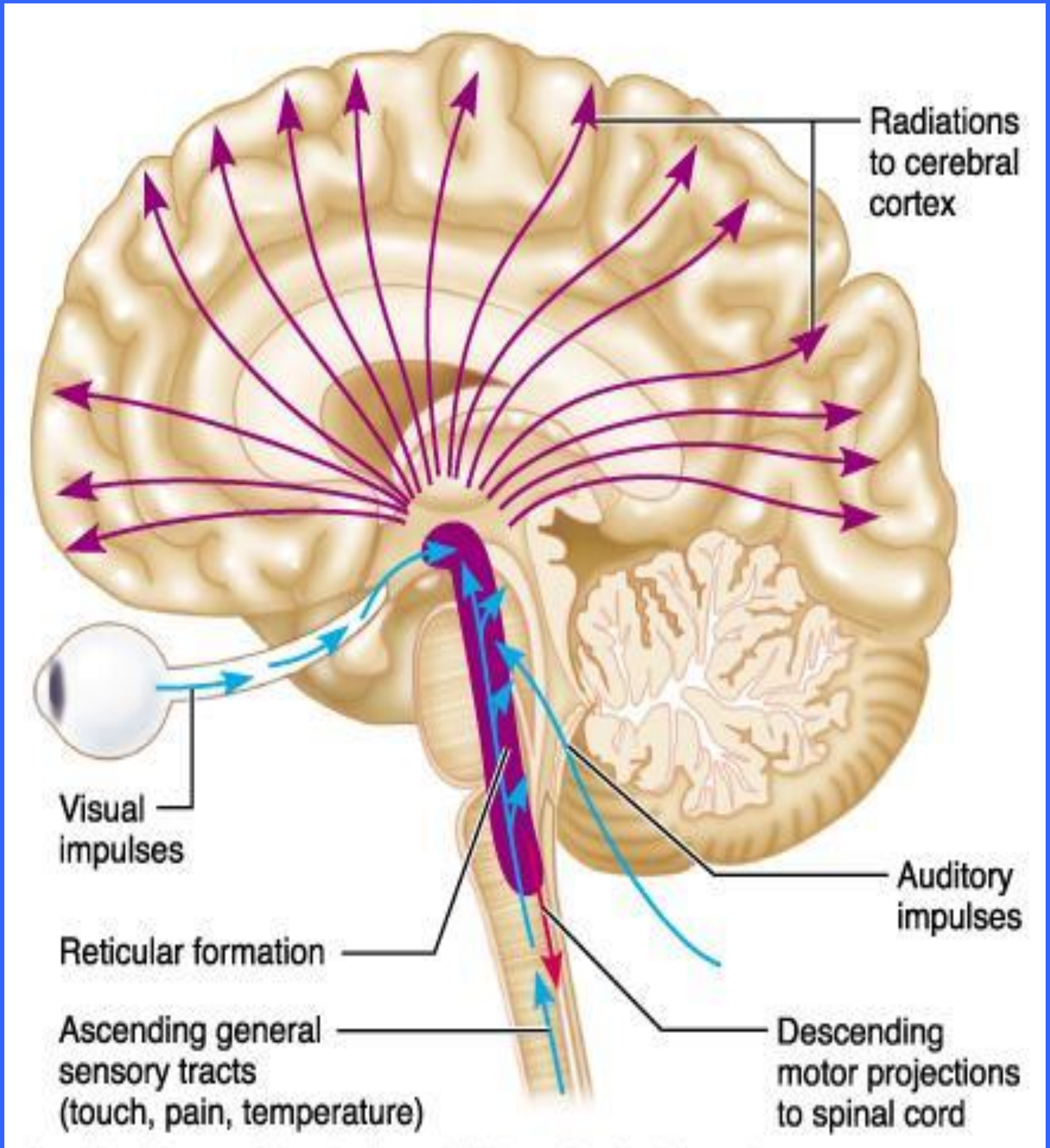
- We react emotionally to things we consciously understand to be happening
- We are consciously aware of the emotional aspect of our lives

The Limbic System

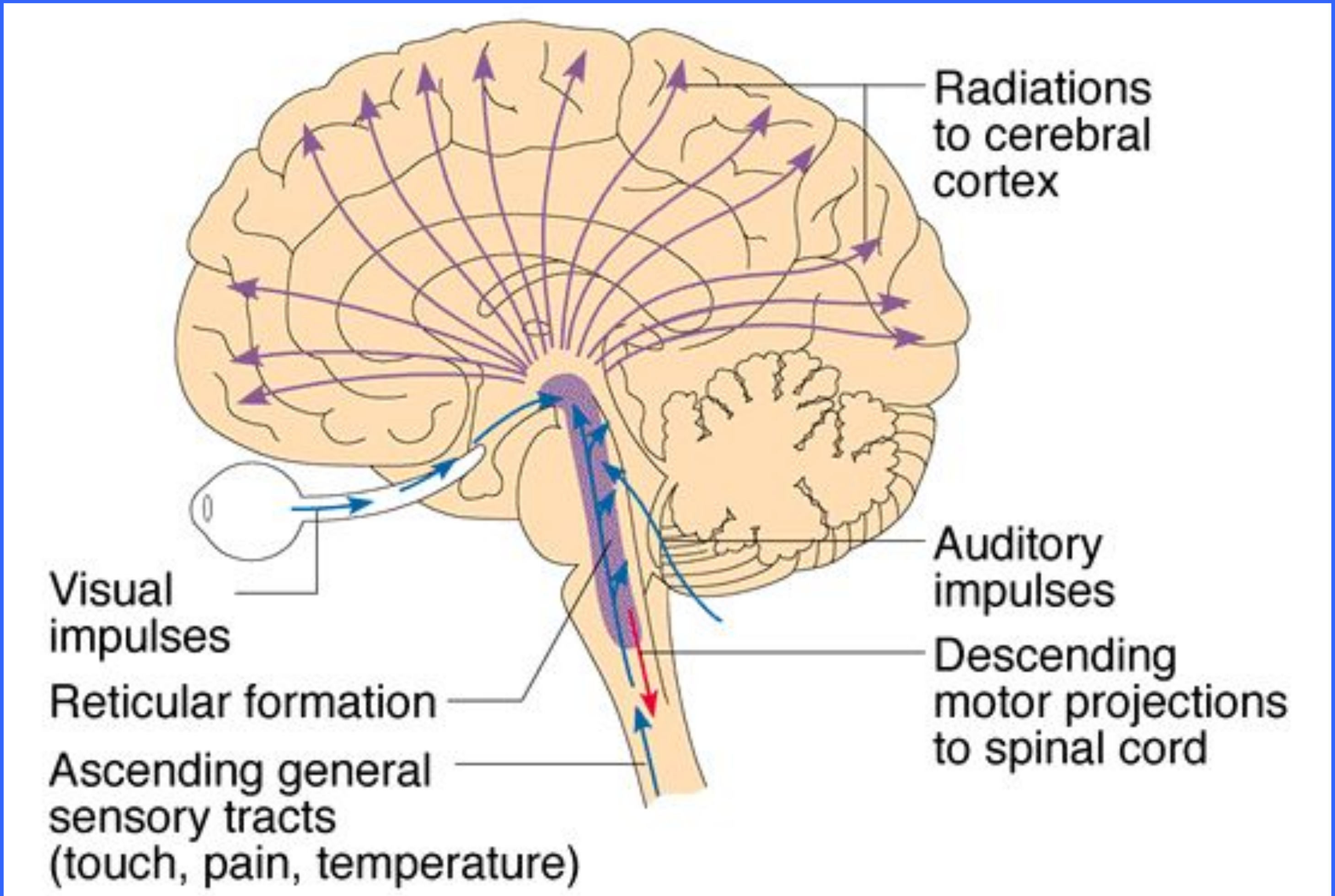
- Communication between the cerebral cortex and the limbic system explains why emotions sometimes override logic
- It also explains why reason can stop us from expressing our emotions in inappropriate ways

The Reticular Formation

- **The reticular formation extends through the central core of the medulla oblongata, pons, and midbrain**



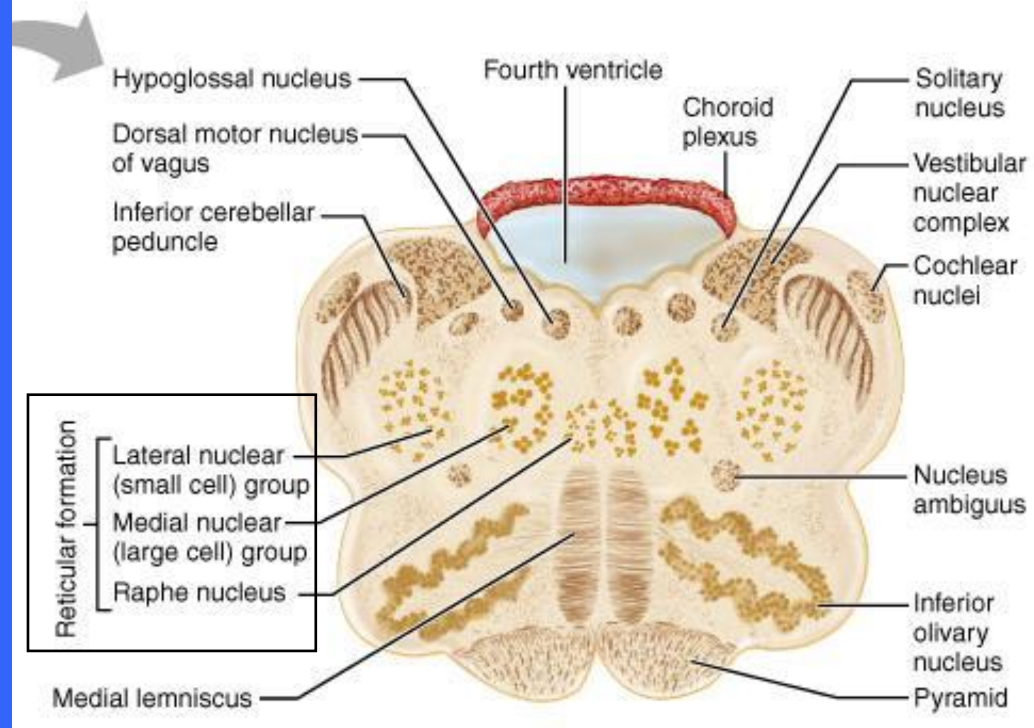
The Reticular Formation



- It is an intricate system composed of loosely clustered neurons in what is otherwise white matter

The Reticular Formation

- **Reticular neurons can be localized into three broad columns along the length of the brain stem**
  - **Raphe**
  - **Medial nuclear (large cell) group**
  - **Lateral nuclear (small cell) group**



(c) Medulla oblongata

The Reticular Formation

- The outstanding feature of the reticular neurons is their far-flung axonal connections
- Individual reticular neurons project to the thalamus, cerebellum, and spinal cord
- Widespread connections make reticular neurons ideal for governing the arousal of the brain as a whole

The Reticular Formation

- Certain reticular neurons send a continuous stream of impulses to the cerebrum (through relays in the thalamus) thereby maintaining the cerebral cortex in an alert state
- This arm of the reticular formation is called the reticular activating system or RAS

The Reticular Activating System

- The RAS synapses with all major ascending sensory tracts enhancing arousal of the cerebrum
- The RAS functions in sleep and in arousal from sleep
- It can be affected by general anesthesia, alcohol, tranquilizers, and sleep inducing drugs
- Head trauma can also lead to loss of consciousness

Reticular Formation

- The RAS also acts as a filter to dampen repetitive, familiar, or weak signals
- It is estimated that 99% of all sensory stimuli is disregarded as unimportant

The Reticular Activating System

- The activity of the RAS is inhibited by sleep centers in the hypothalamus and other neural regions
- Damage to the RAS limits arousal and can result in coma

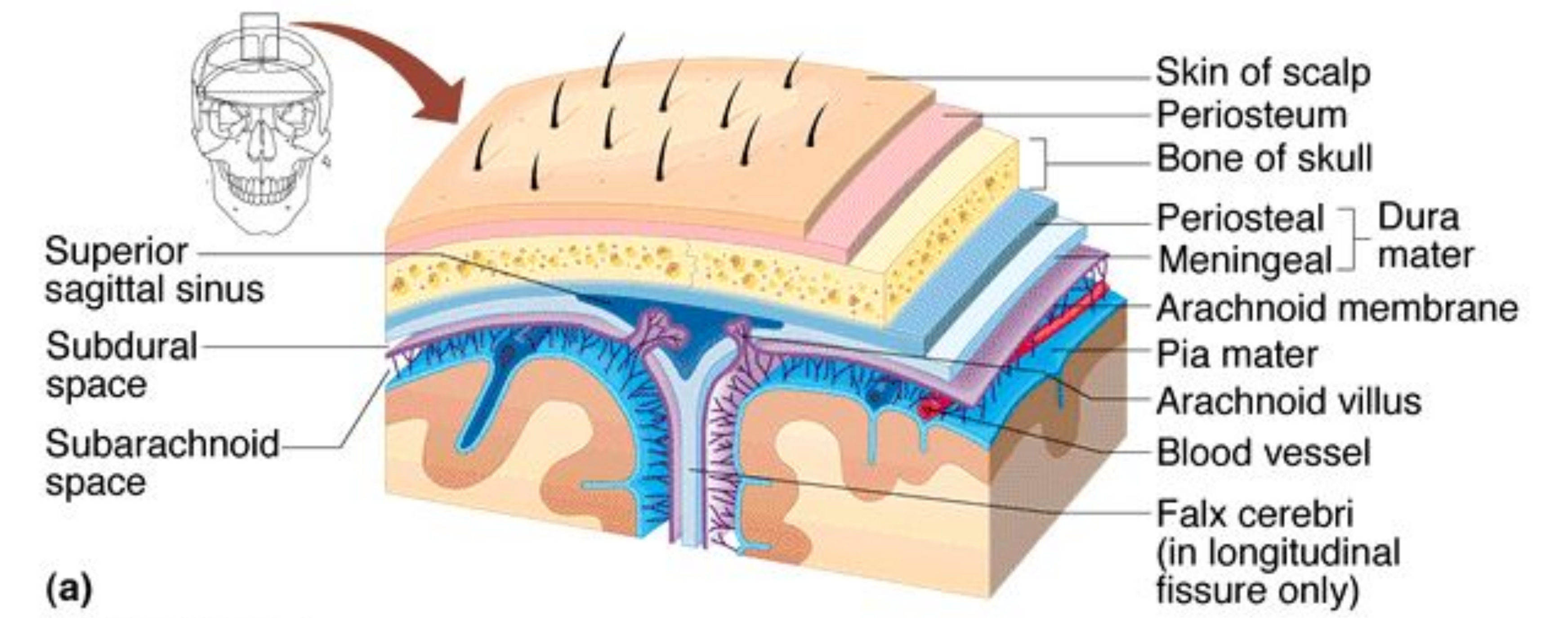
The Reticular Formation

- The reticular formation also has a motor component
- Some if its motor nuclei project to motor neurons in the spinal cord via the reticulospinal tracts
- These help control the skeletal muscles during coarse movements of the limbs
- Other reticular motor nuclei are autonomic centers that regular visceral motor functions (heart rate & respiration)

Protection of the Brain

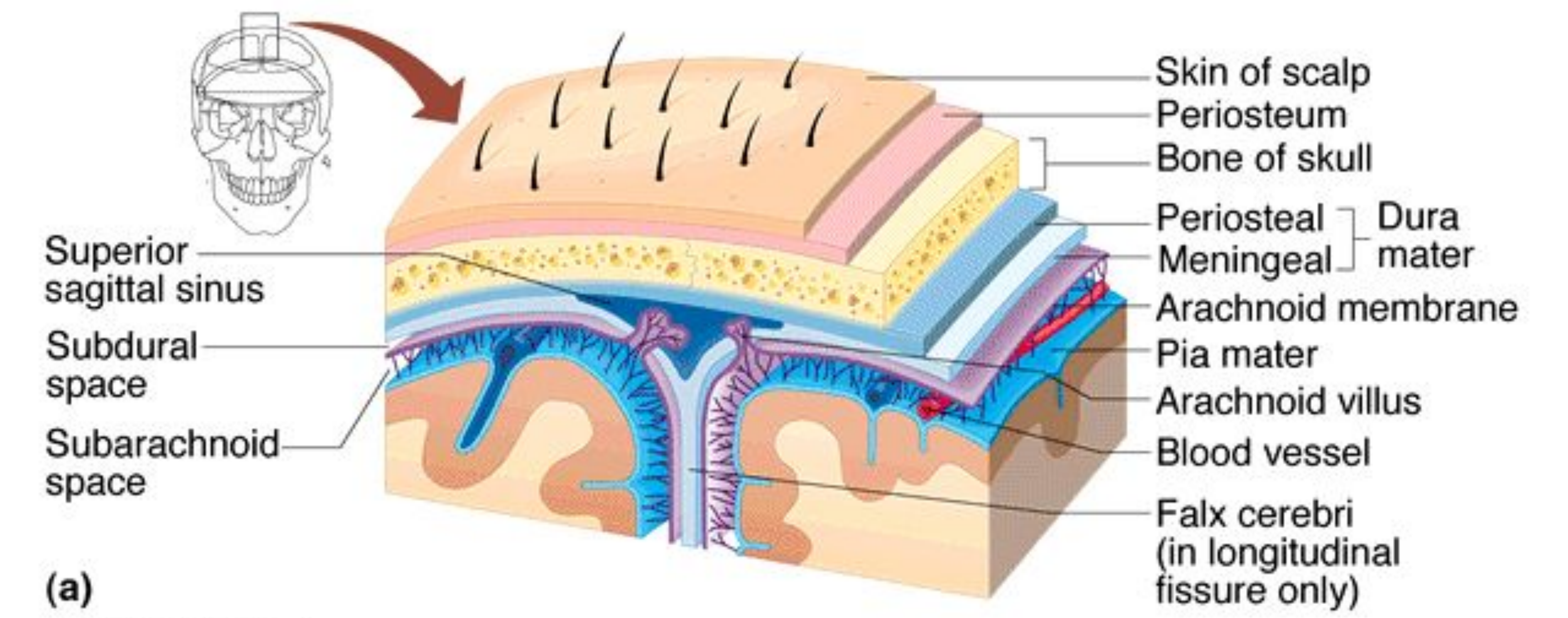
- Nervous tissue is soft and vulnerable
- The brain is protected by
  - Bony enclosure / skull
  - Menbranes / meninges
  - Watery cushion / cerebrospinal fluid
- Collectively these tissues protect the brain from trauma and pressure
- Furthermore, the brain is protected from harmful substances in the blood by the blood-brain barrier

Meninges



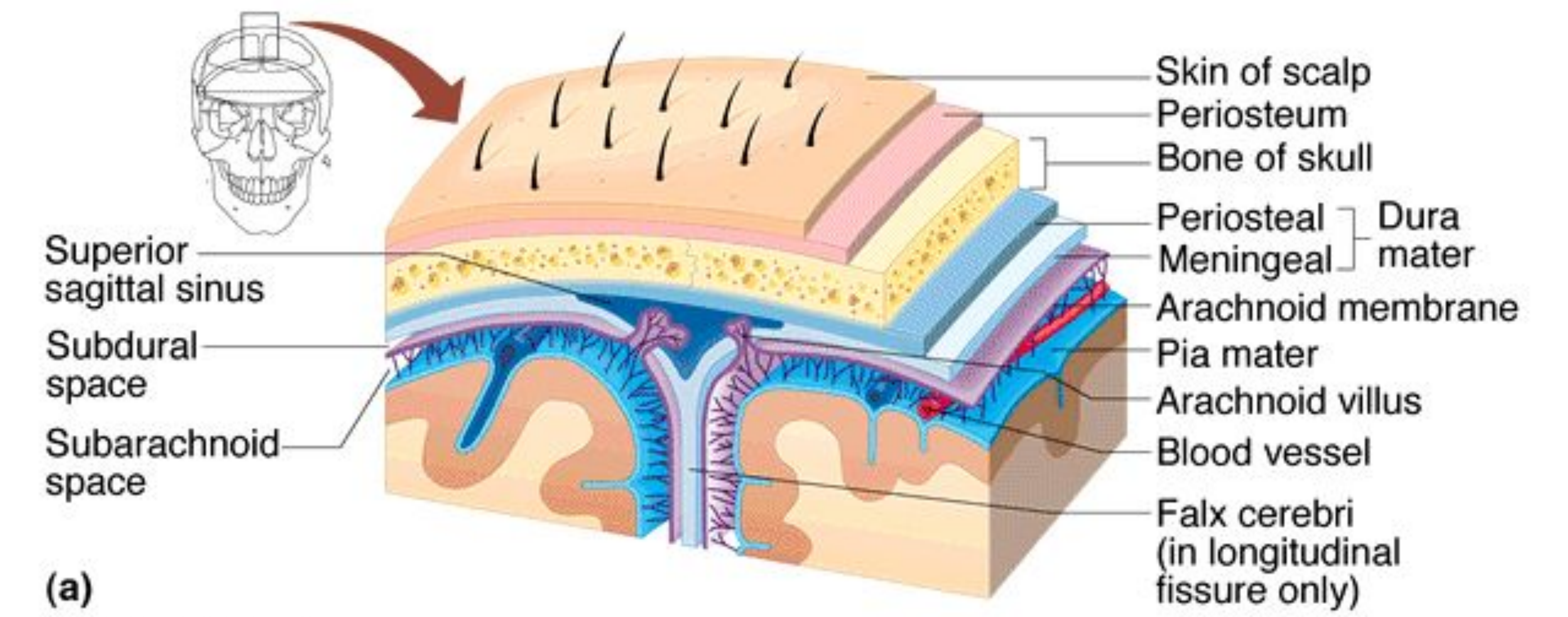
- The meninges are three connective tissue membranes that lie just external to the central nervous system organs

Meninges



- **The meningeal membranes**
  - **Cover and protect the CNS organs**
  - **Protect blood vessels and enclose venous sinuses**
  - **Contain cerebrospinal fluid**
  - **Form partitions within the skull**

Meninges



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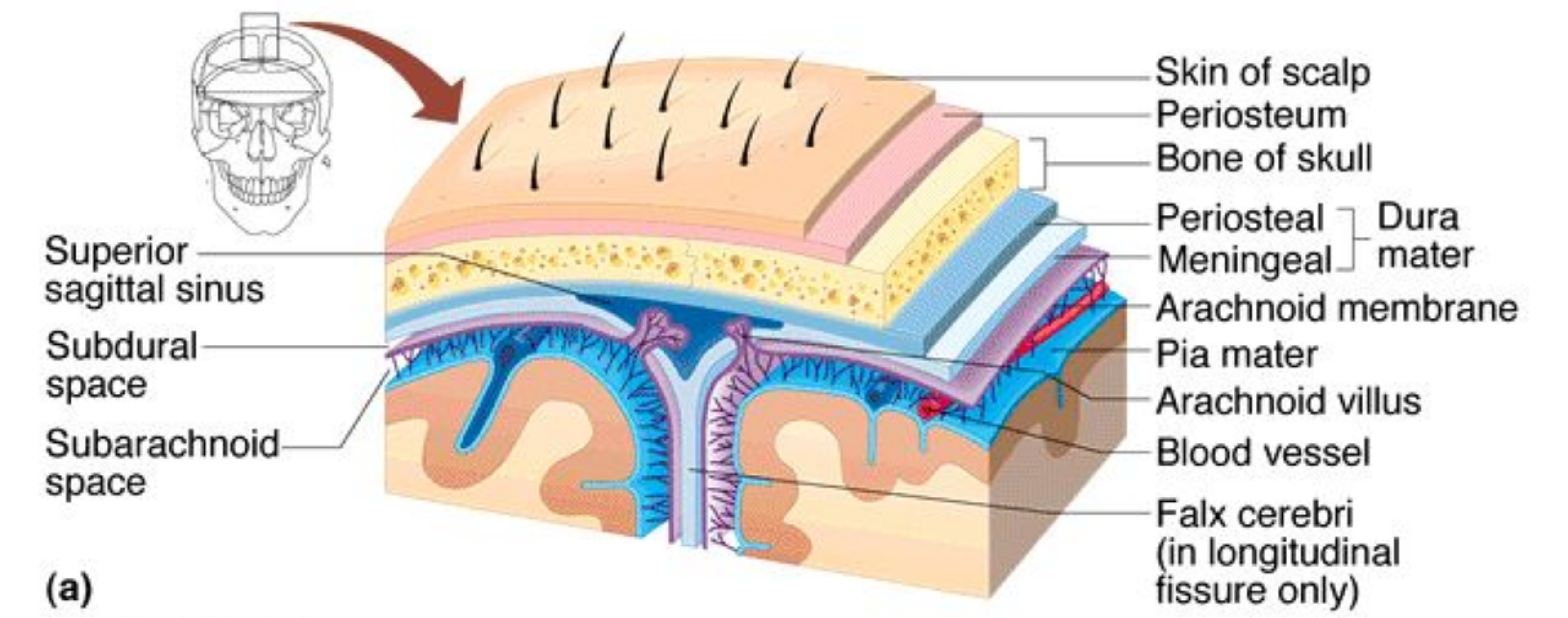
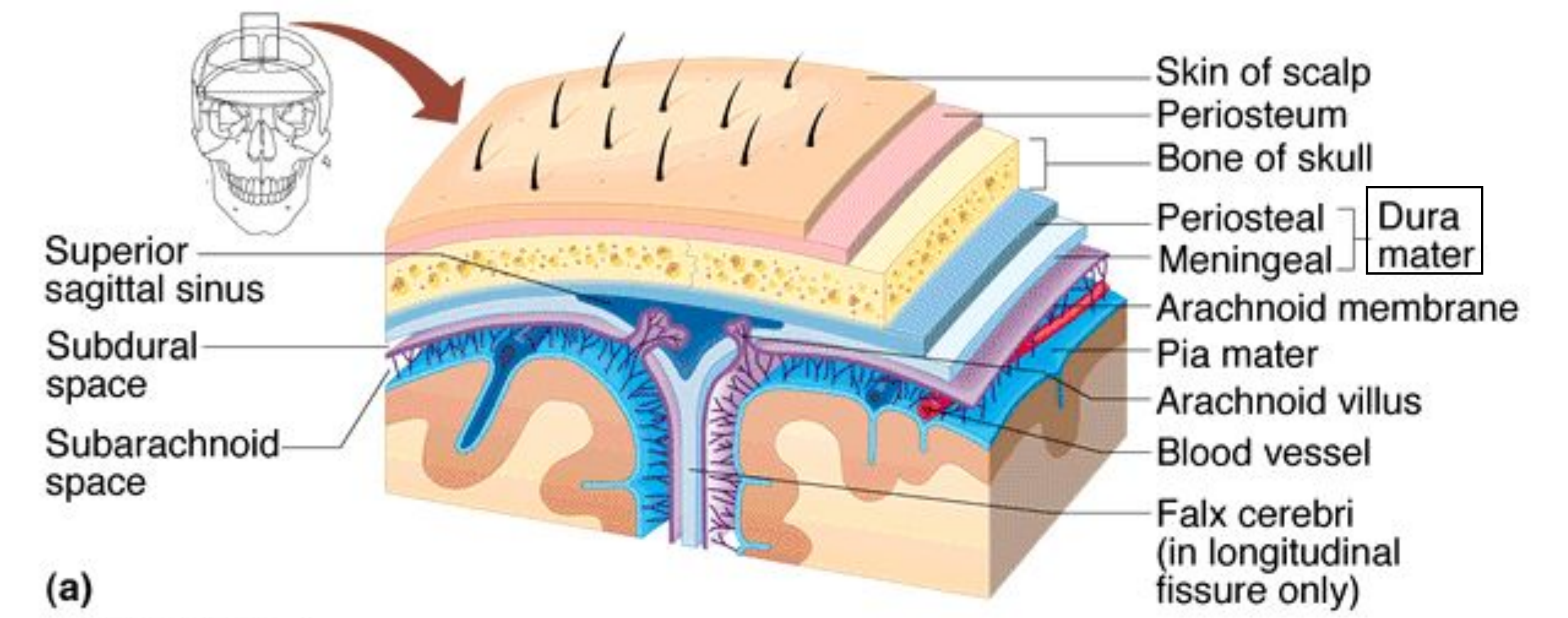
Meninges



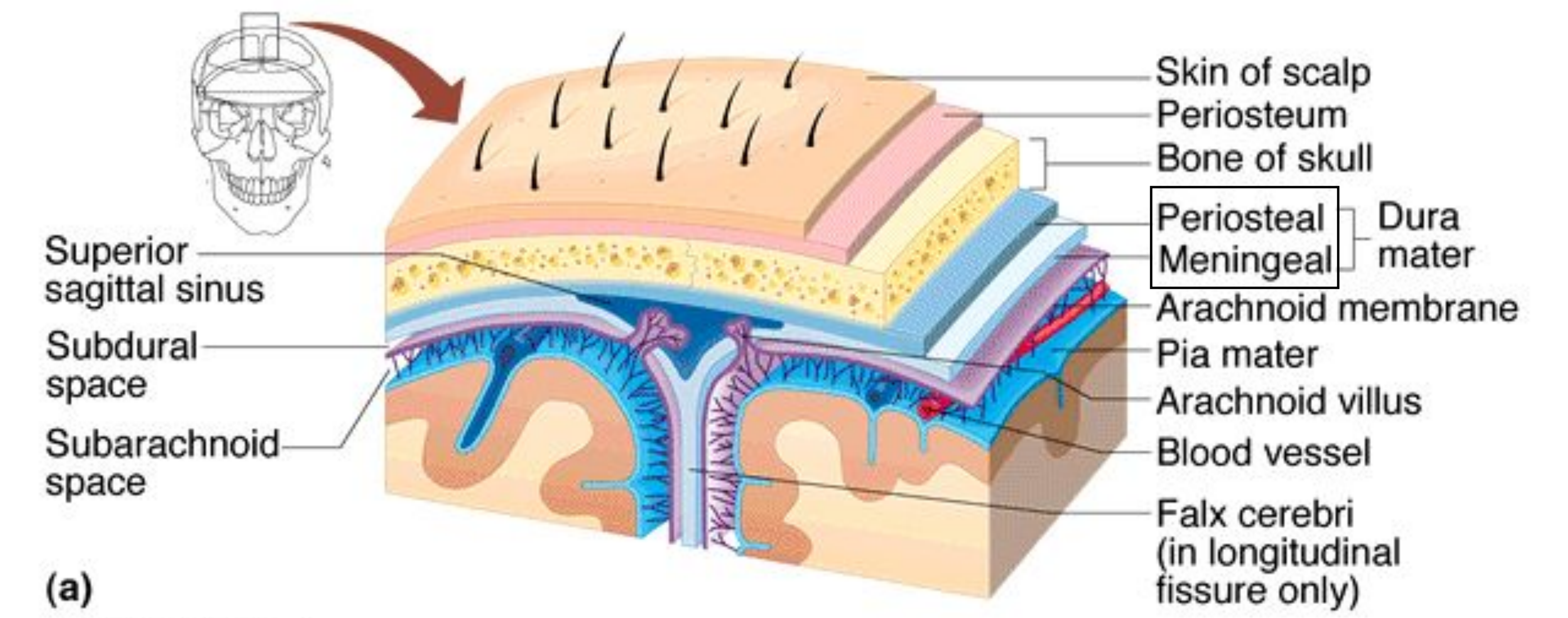
- From external to internal, the meningeal layers are
  - Dura mater
  - Arachnoid
  - Pia mater

The Dura Mater



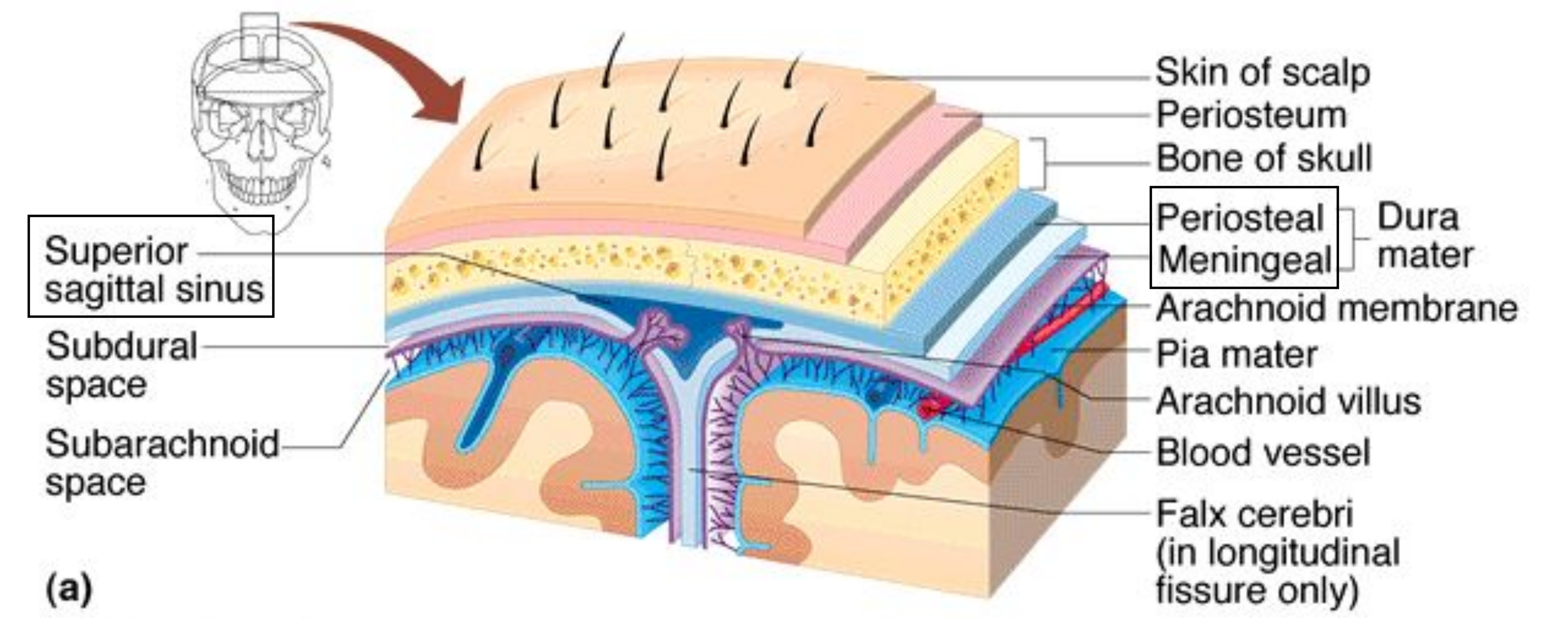
- The leathery dura mater is by far the strongest of the meninges
- Where it surrounds the brain it is a double layer membrane

The Dura Mater



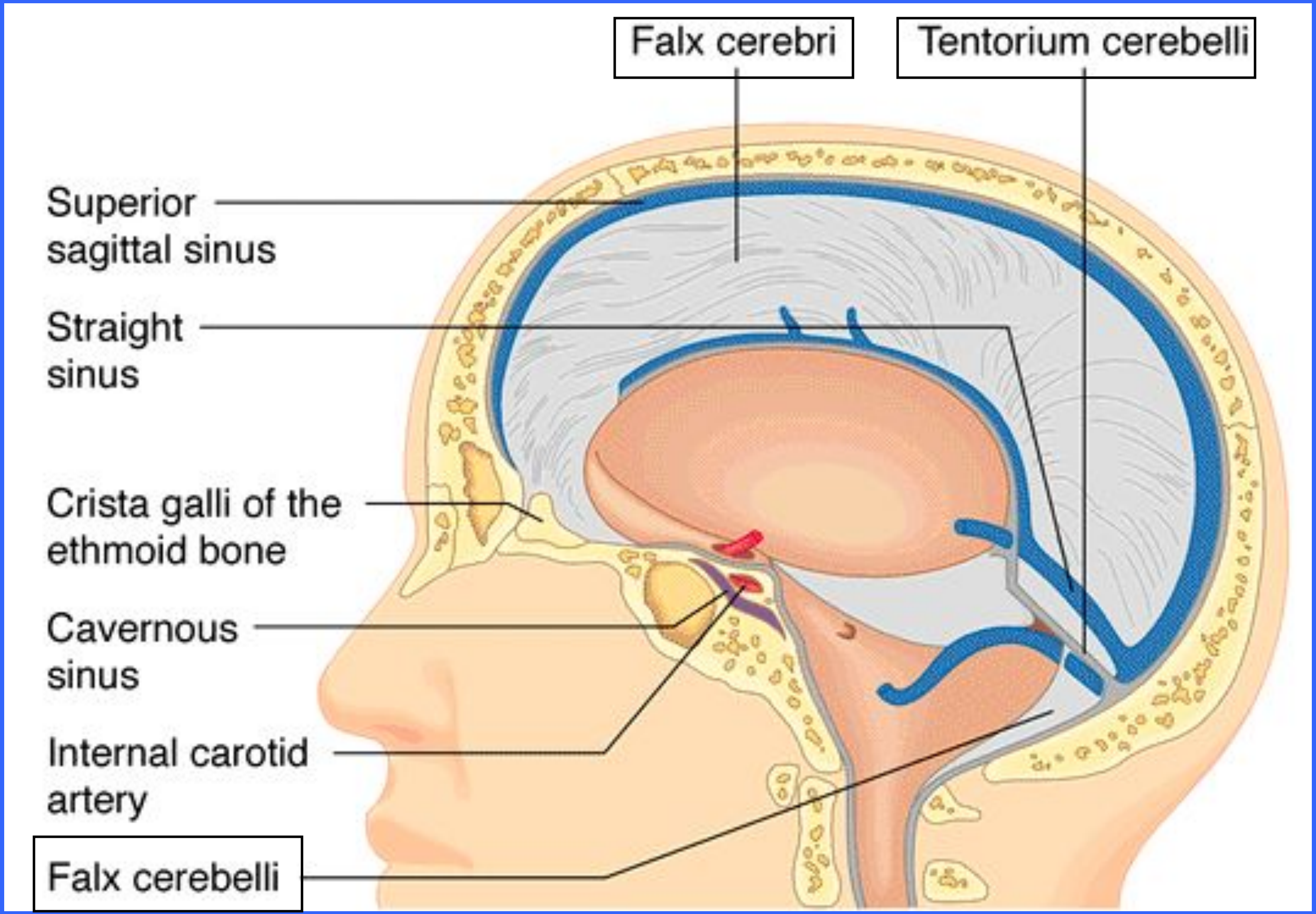
- The periosteal layer is the superficial and lines the inner surface of the skull
- The deeper meningeal layer forms the true external covering of the brain and continues caudally in the vertebral canal as the dural sheath of the spinal cord

The Dura Mater



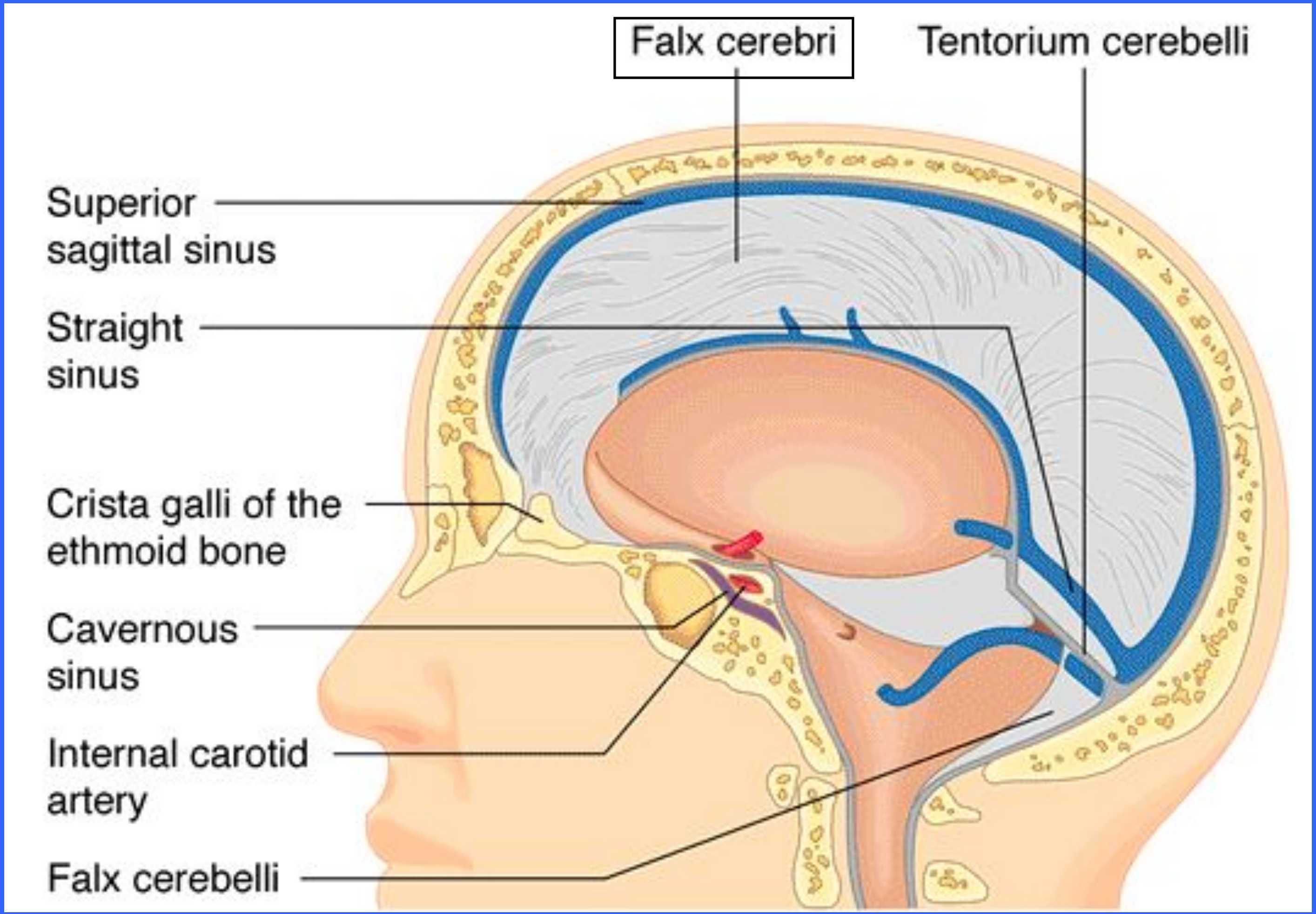
- The brain's dural layers are fused together except in certain areas where they enclose the dural sinuses
- The dural sinuses collect venous blood and direct it into the internal jugular veins of the neck

The Dura Mater



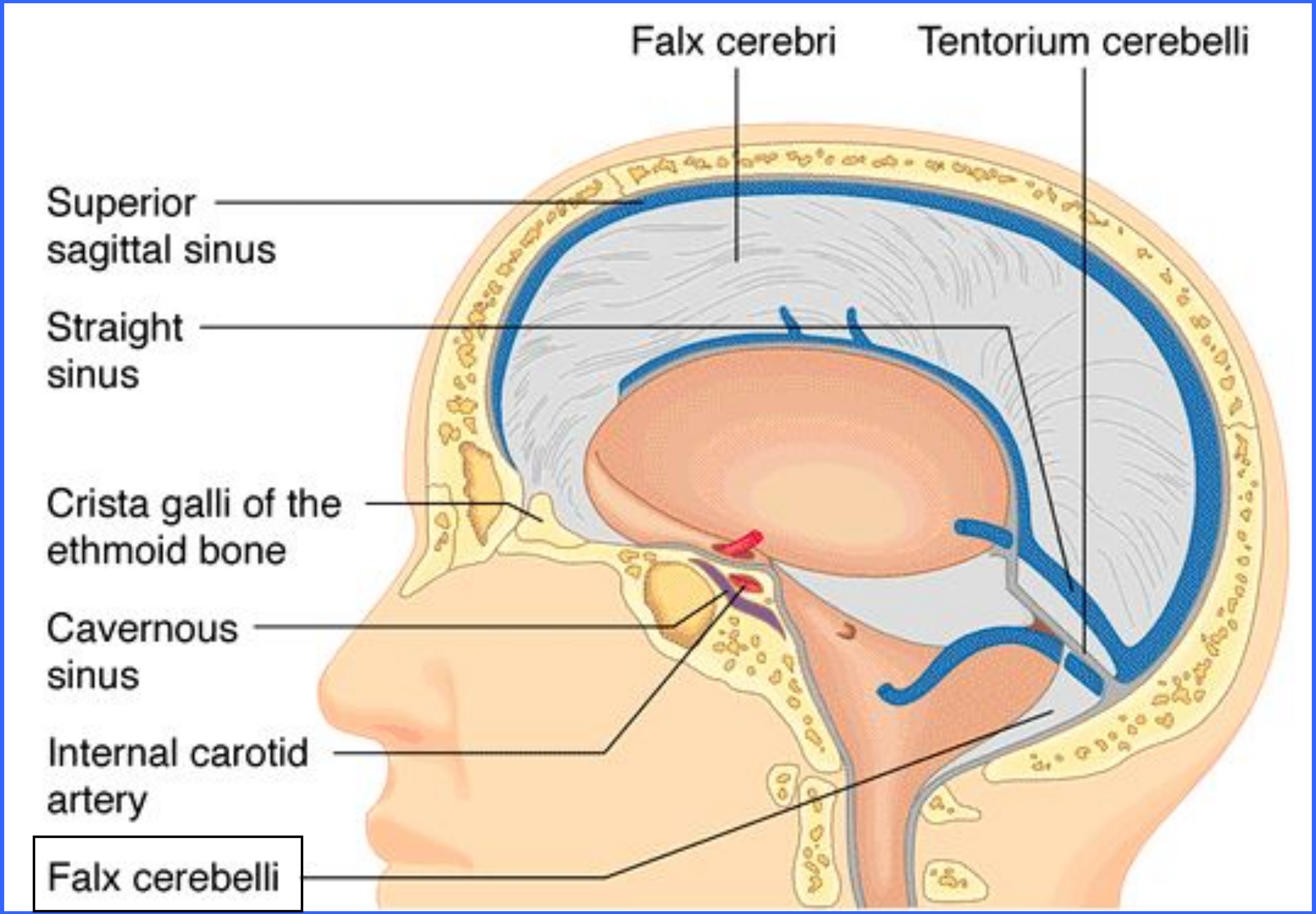
- **In several places the meningeal dura mater extends inward to form flat septa that anchor the brain to the skill**

The Dura Mater



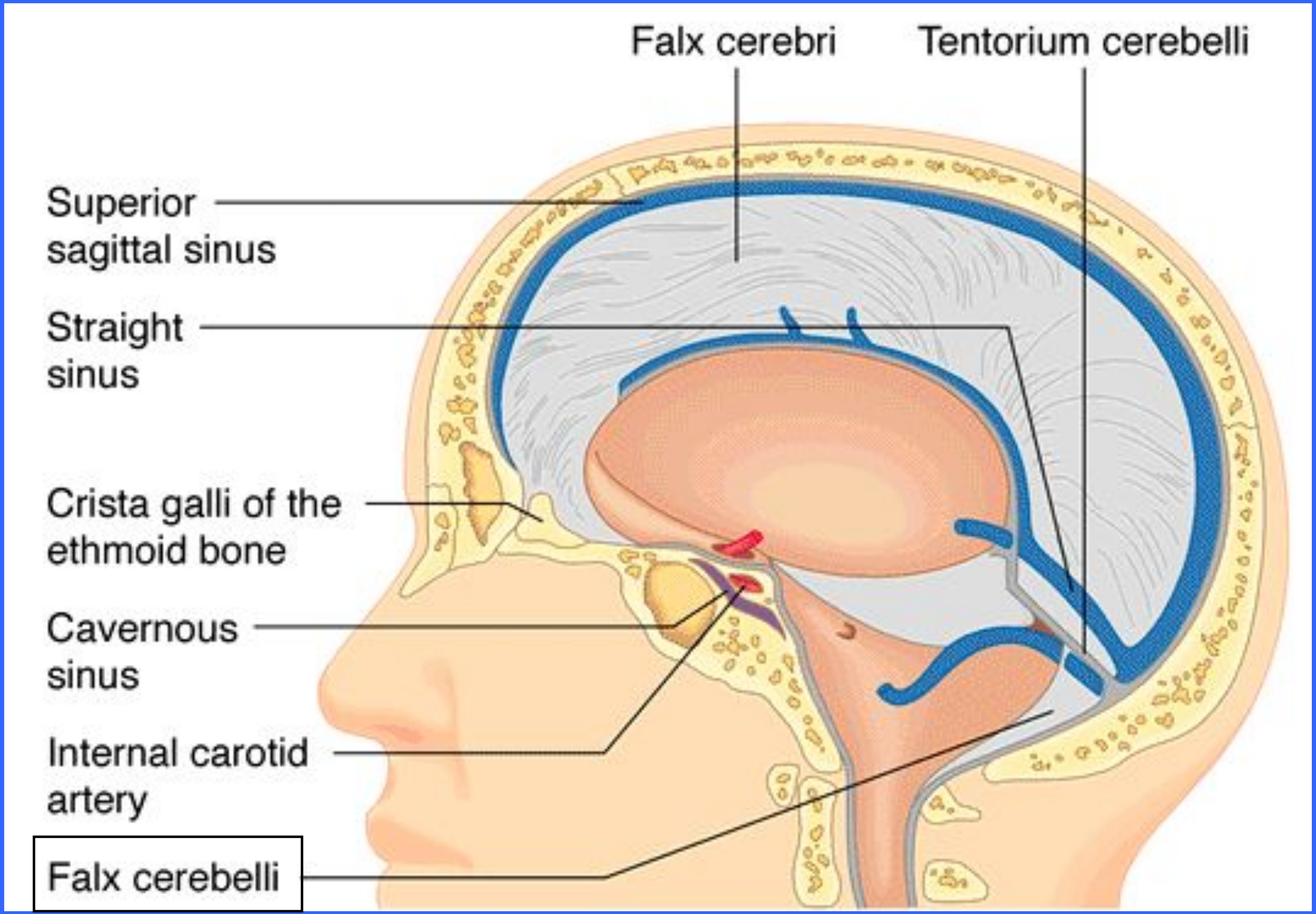
- The falx cerebri dips into the longitudinal fissue
- It attaches to the crista galli of the ethmoid bone

The Dura Mater



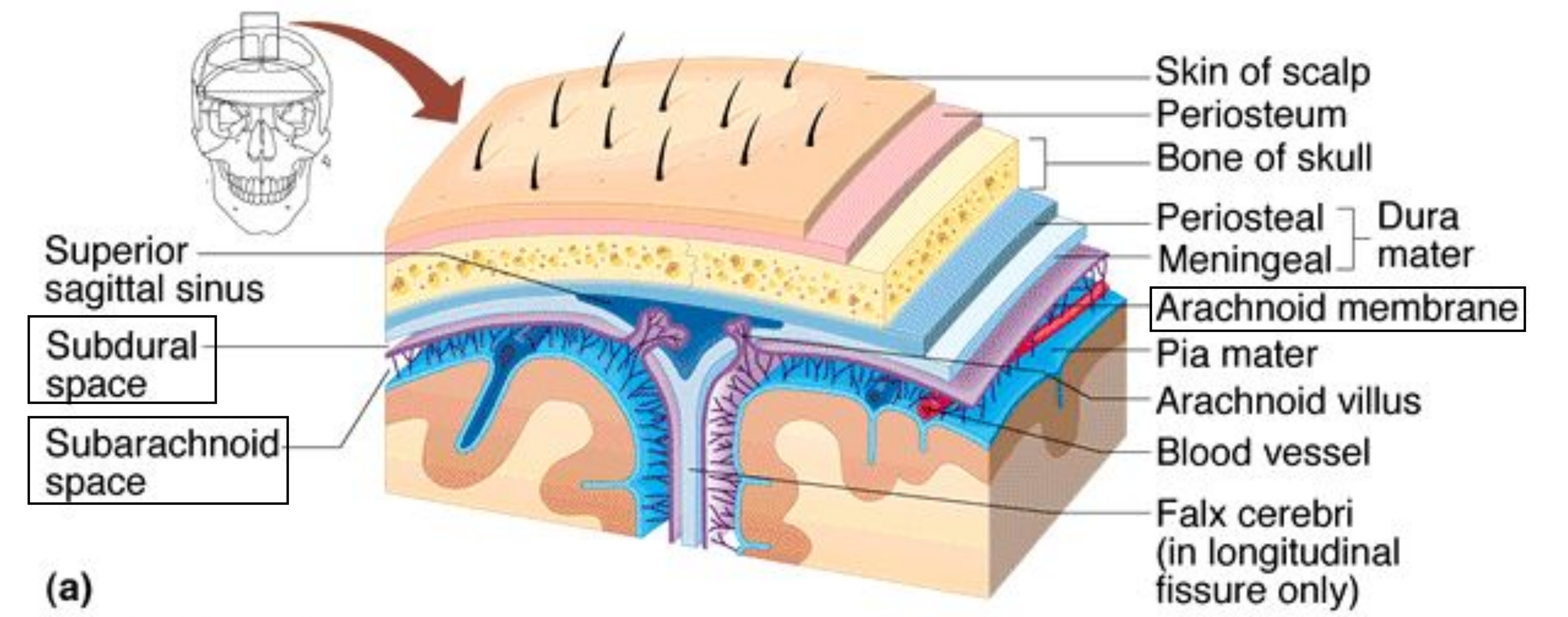
- **The falx cerebelli forms a midline partition that runs along the vermis of the cerebellum**

The Dura Mater



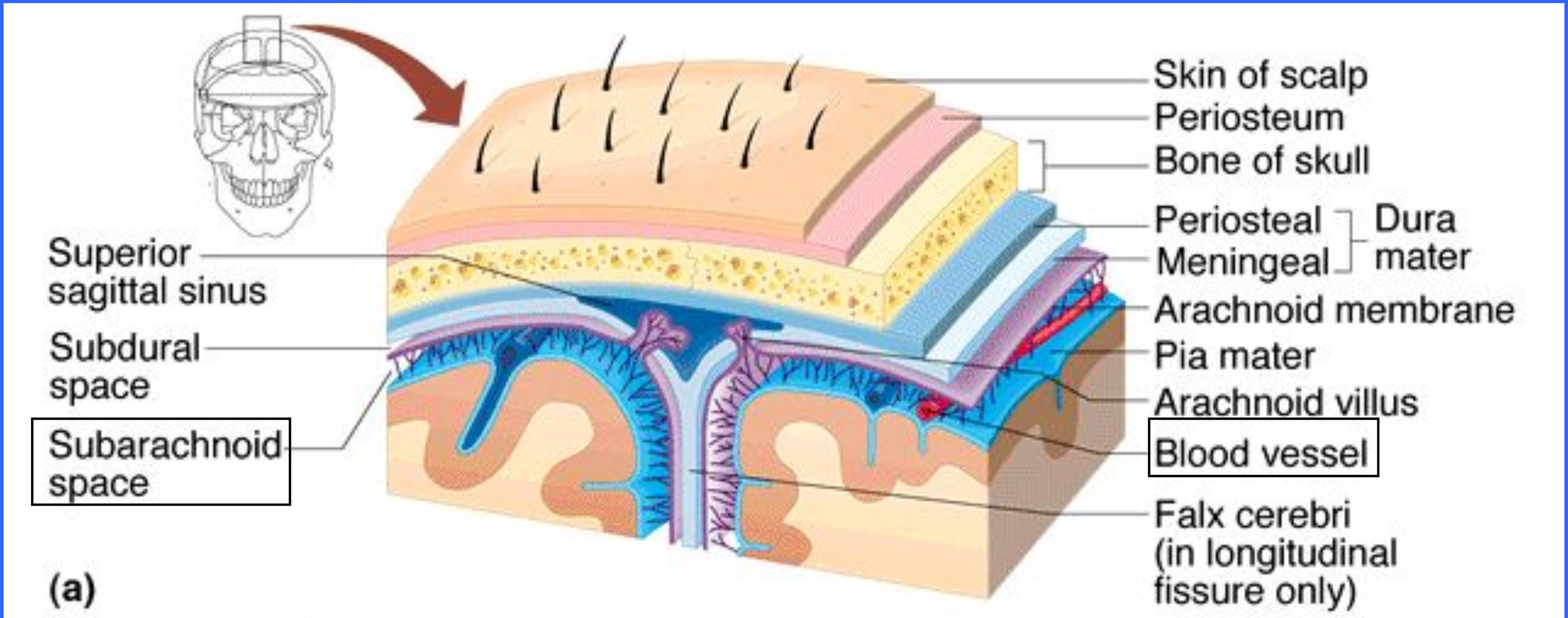
- **The tentorium cerebelli extends into the transverse fissue between the cerebral hemispheres and the cerebellum**

The Arachnoid Mater



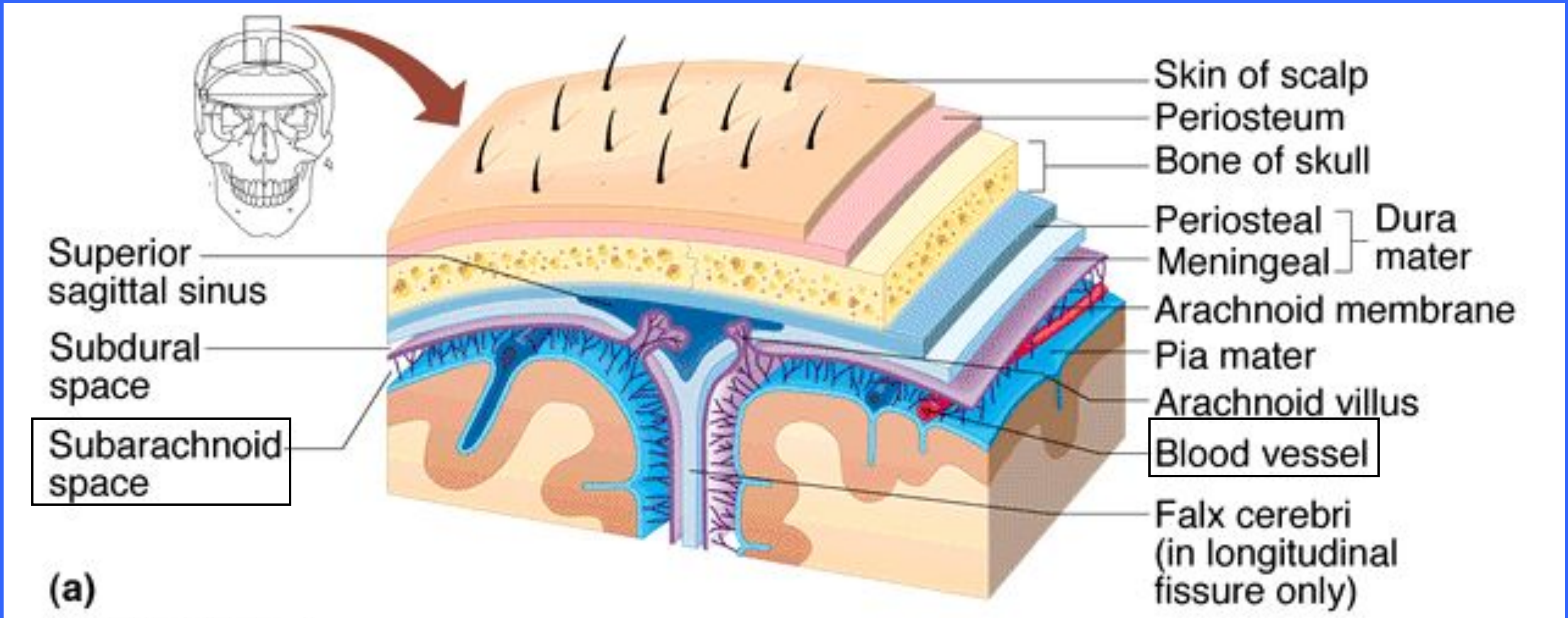
- The middle membrane forms a loose brain covering over the surface of the cerebrum
- It is separated from the dura mater by a narrow serous cavity, the subdural space
- Beneath the arachnoid membrane is the wide subarachnoid space

The Arachnoid Mater



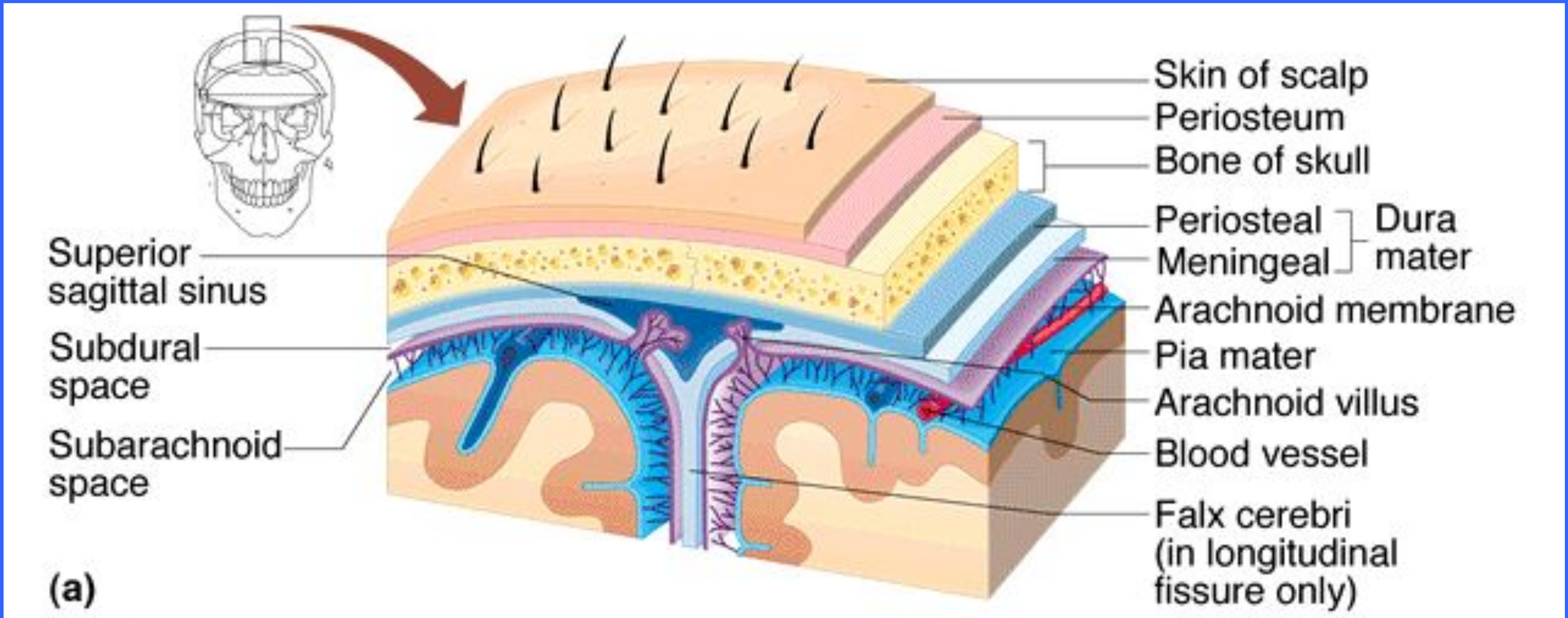
- **The subarachnoid space is filled with cerebrospinal fluid and contains the largest blood vessels serving the brain**
- **Since the arachnoid is fine and elastic, these blood vessels are rather poorly protected**

The Arachnoid Mater



- **Arachnoid villi protrude through the overlying dura mater and into the dural sinuses overlying the superior aspect of the brain**
- **Cerebrospinal fluid is absorbed into the venous blood sinuses through these valvelike villi**

The Pia Mater



- The pia mater is a delicate connective tissue that is richly invested with tiny blood vessels
- It is the only membrane that clings tightly to the brain, following its every convolution

Cerebrospinal Fluid (CSF)

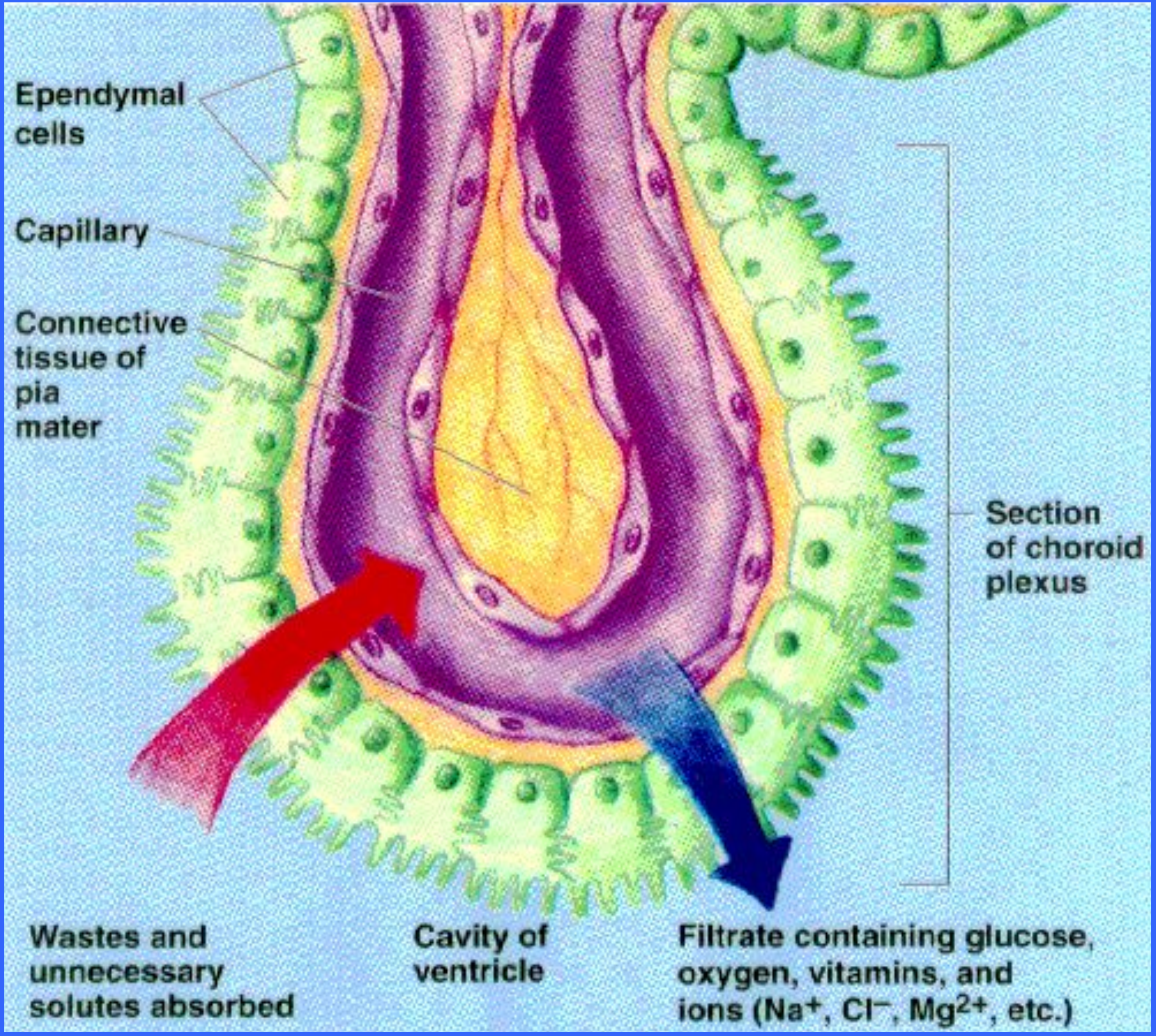
- CSF is found in and around the brain and spinal cord
- It forms a liquid cushion that gives bouyancy to the CNS organs
- By floating the brain, the CPF reduces brain weight by 97% and thus prevents the brain from crushing under its own weight
- CSF also protects the brain and spinal cord from trauma
- CSF also helps to nourish the brain

Cerebrospinal Fluid (CSF)

- CSF is a similar in composition to blood plasma, from which it arises
- It contains less protein and more vitamin C and its ion concentration is different
- CSF composition is important in the control of cerebral blood flow

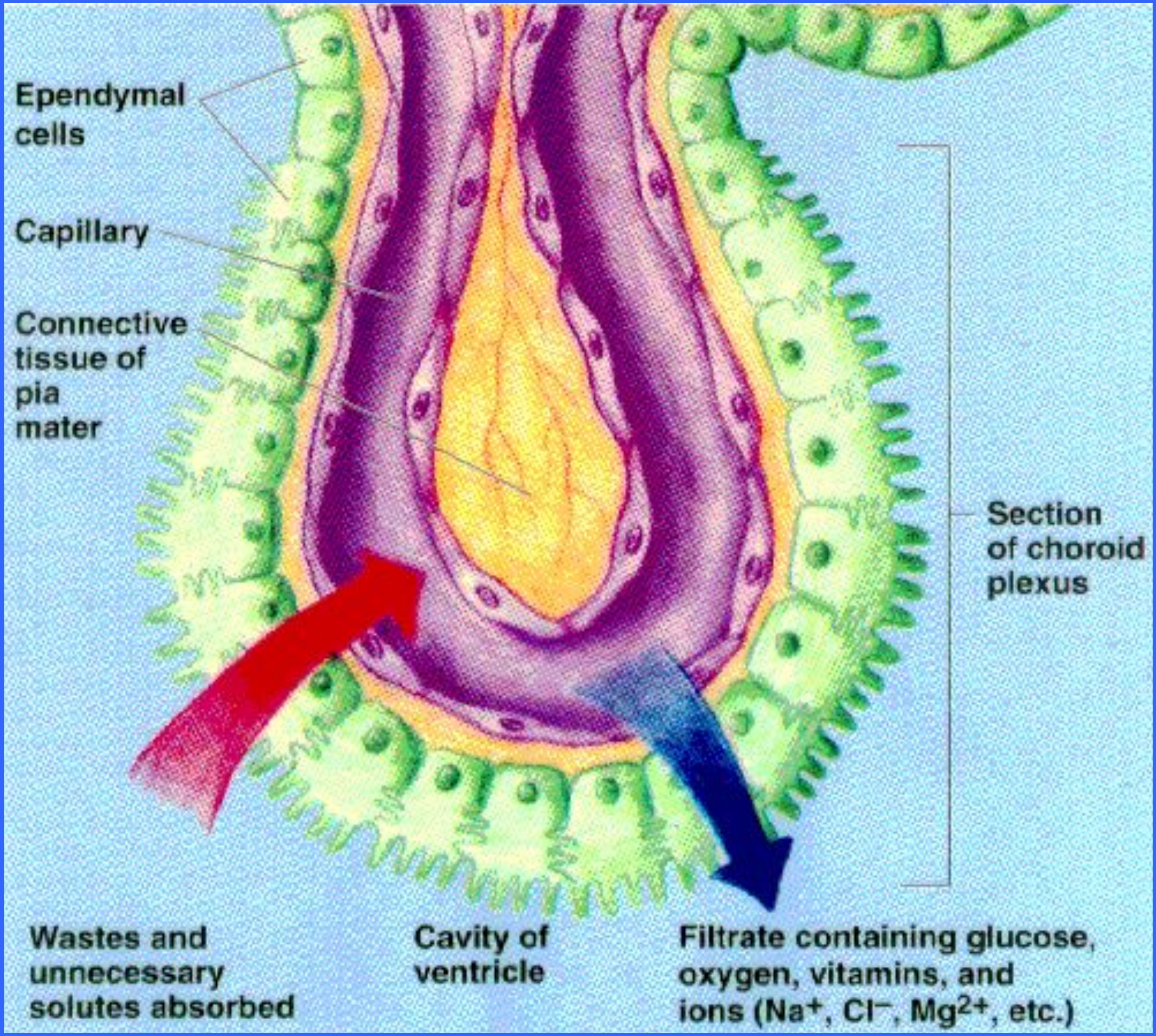
Choroid Plexus

- Choroid plexus hang from the roof of each ventricle
- These plexuses form CSF
- The plexuses are clusters of thin walled capillaries enclosed by a layer of ependymal cells



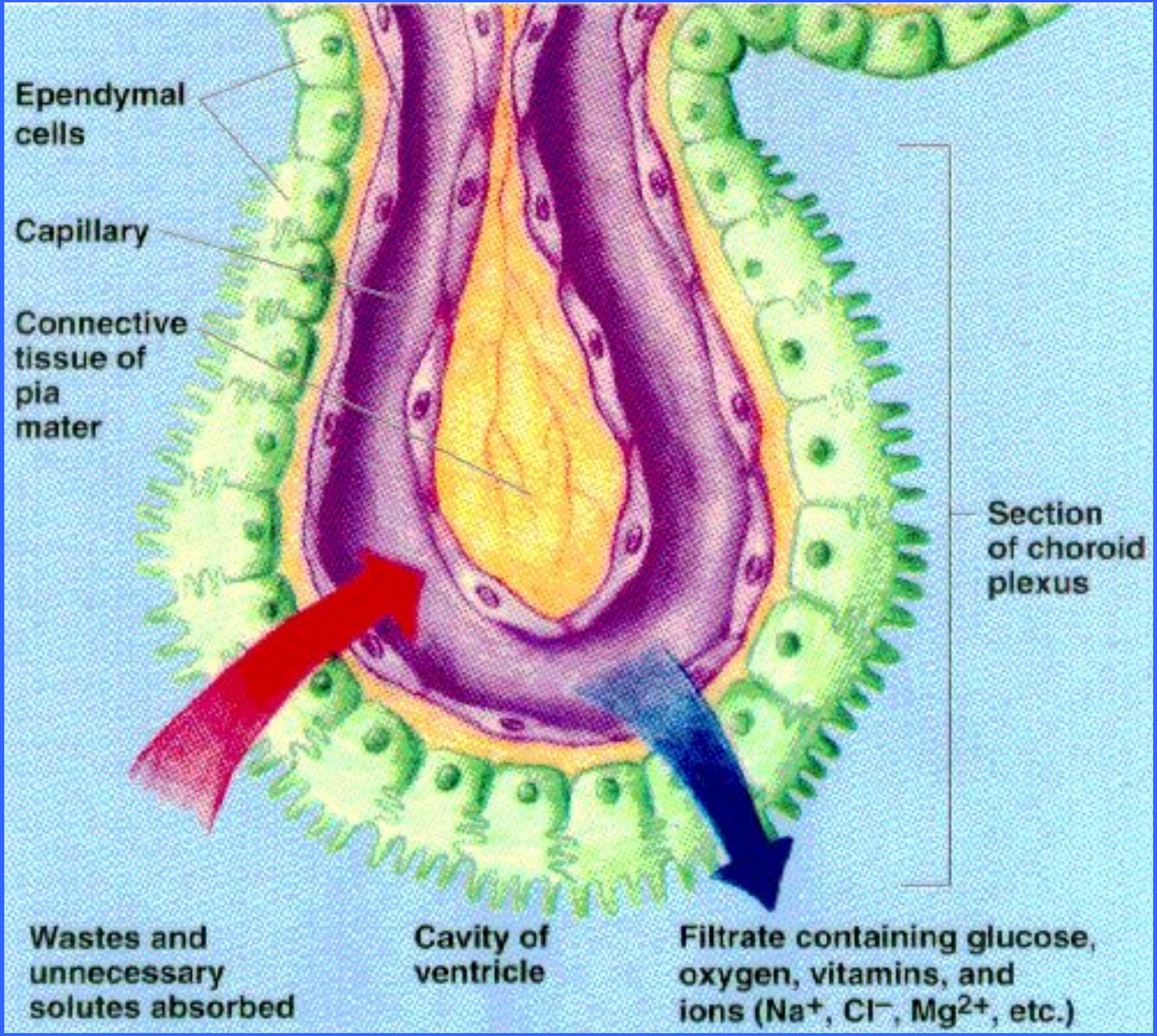
Choroid Plexus

- The capillaries of the choroid plexus are fairly permeable and tissue fluid filter continuously from the bloodstream



Choroid Plexus

- The choroid plexus cells are joined by tight junctions and have ion pumps that allow them to modify this filtrate by actively transporting only certain ions across their membranes into the CSF pool



The Choroid Plexus

- In adults, the total CSF volume of about 150 ml is replaced every 3-4 hours
- 900 ml is produced daily
- The choroid plexus also helps to cleanse the CSF by removing waste products and other unnecessary solutes
- Once produced CSF moves freely through the ventricles

CSF Circulation

- Most CSF enters the subarachnoid space via the apertures in the walls of the fourth ventricle
- The motion of the CSF is aided by the long microvilli of the ependymal cells lining the ventricles
- Some CSF enters the central canal of the spinal cord

CSF Circulation

- In the subarachnoid space the CSF bathes the outer surface of the brain and cord and then returns to the blood in the dural sinuses via the arachnoid villi

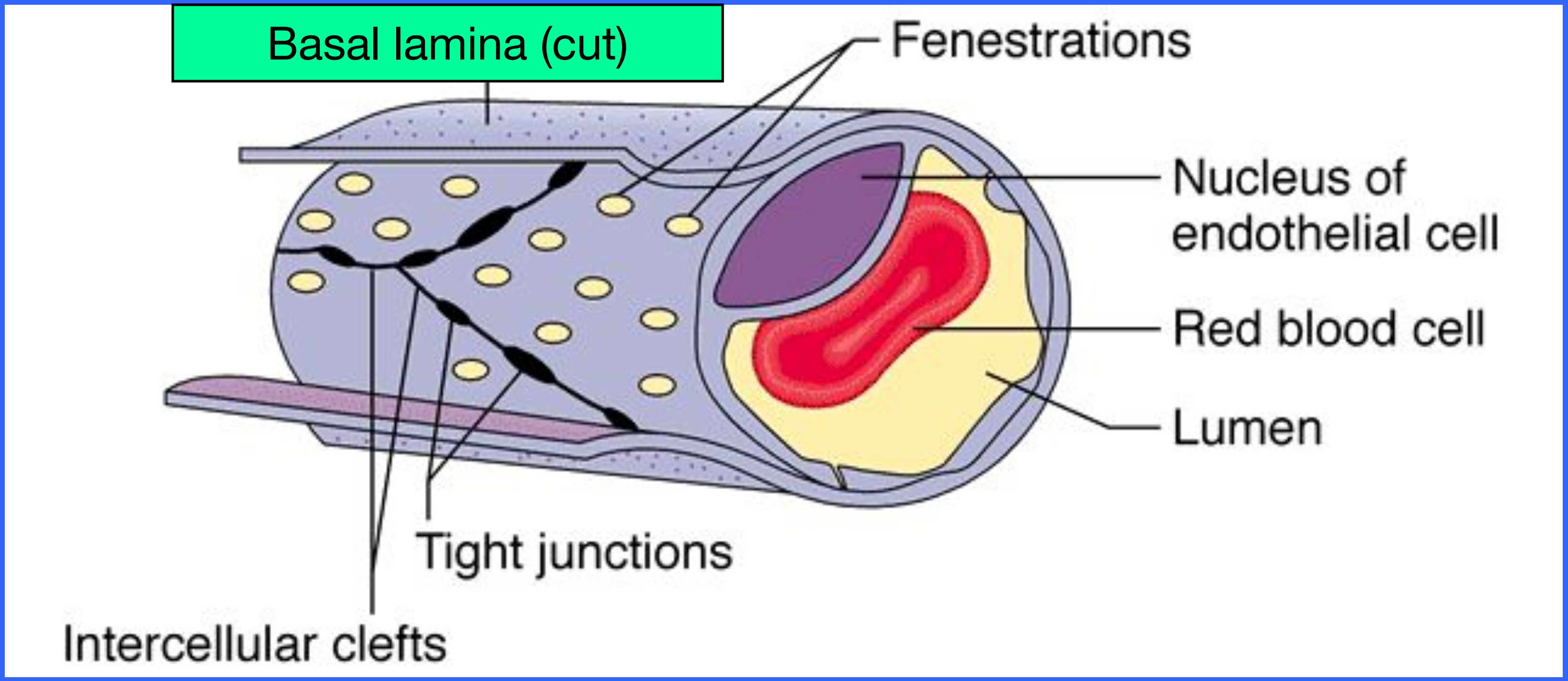
Blood-Brain Barrier

- The barrier is a protective mechanism that helps maintain a stable environment for the brain
- The brain is very dependent on a contant internal environment
- Fluctuations in the concentration of ions, hormones, or amino acids, would alter the brain's function
  - Hormones and amion acids / neurotransmitters
  - Ions / neuron thresholds (K+)

Blood-Brain Barrier

- Bloodborne substances within the brain's capillaries are separated from the extra-cellular space and neurons by
  - Continuous endothelium of the capillary walls
  - Relatively thick basal lamina surrounding the external face of the capillary
  - To a limited extend the "feet" of the astrocytes that cling to the capillaries

Blood-Brain Barrier



- The capillary endothelial cells are joined almost seamlessly by tight junctions
- They are the least permeable capillaries in the body
- The relative impermeability of brain capillaries accounts for most of the blood brain barrier

Blood-Brain Barrier

- The blood-brain barrier is a selective, rather than absolute barrier
- Nutrients, such as glucose, essential amino acids, and some electrolytes, move passively by facilitated diffusion through the endothelial cell membranes
- Bloodborne metabolic wastes, such as urea and creatinine as well as proteins, certain toxins, and most drugs, are prevented from entering brain tissue

Blood-Brain Barrier

- The barrier is ineffective against fats, fatty acids, oxygen, and carbon dioxide, and other fat-soluble molecules that diffuse easily through all plasma membranes
- This explains why bloodborne alcohol, nicotine, and anesthetics can affect the brain
- The barrier is not completely uniform and not completely developed in infants

Homeostatic Imbalances

- Traumatic Brain Injuries
  - Concussion / Contusion
- Cerebrovascular Accidents
  - Strokes / Transient ischemic attacks
- Degenerative Brain Diseases
  - Alzheimer's Disease / Ach deficits
  - Parkinson's Disease / Degeneration of the substantia nigra
  - Huntington's Disease / Degeneration of the basal nuclei

The Brain

End of this section
Chapter 12 Continues