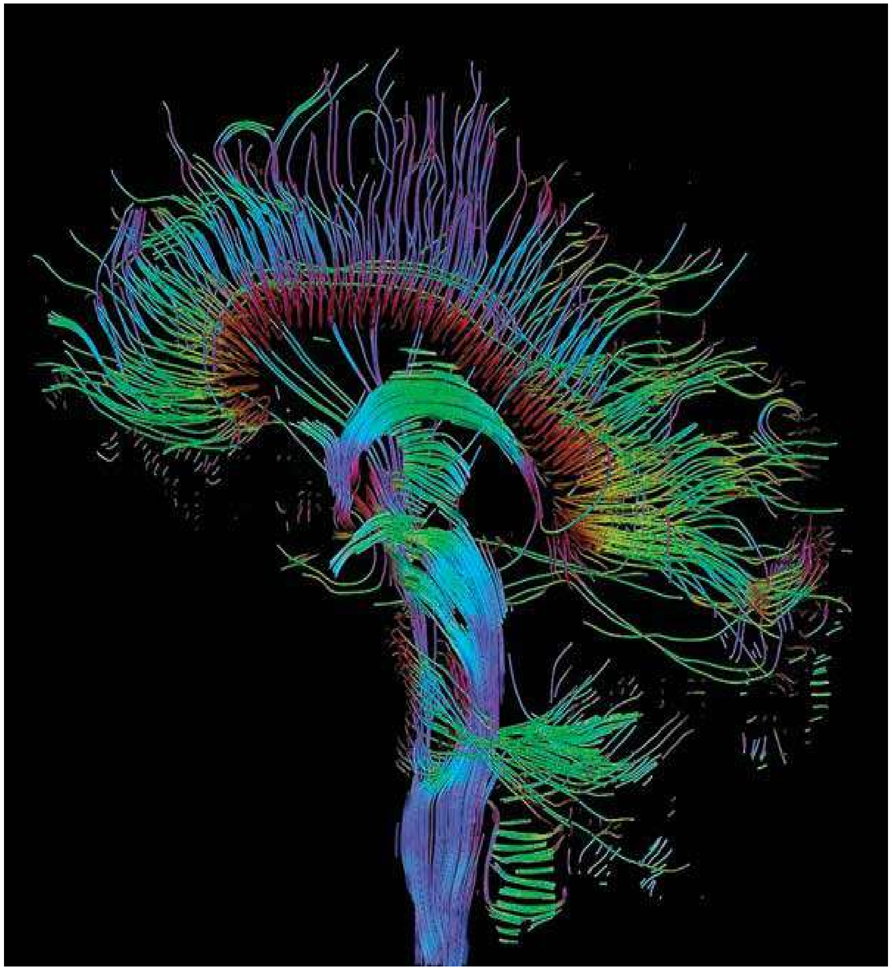
Chapter 14

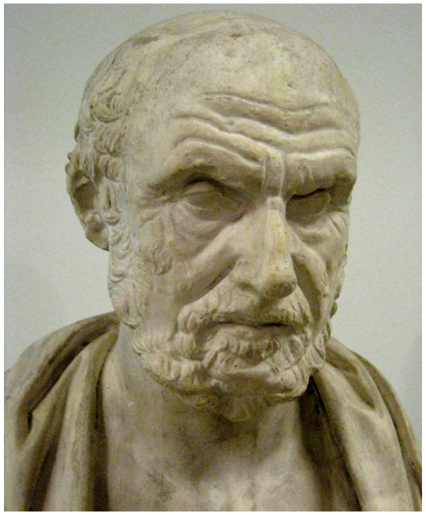
Introduction to the Brain Structure

(With Introduction to the Brain Formation)

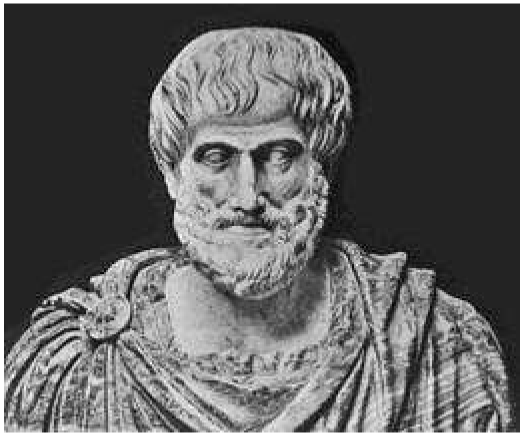


Introduction to the Nervous System

- Hipppoctrates (460 BCE, Kos, Greeece – philosopher and scientist /// about physiology - "from the brain only, arises our pleasures, joys, laughter, and jests, as well as our sorrows, pains, griefs, and tears"
  - *Famous Quotes: Let food be thy medicine and medicine be thy food. // Wherever the art of medicine is loved, there is also a love of humanity. // Life is short, the art long.*



- Aristotle (384 BCE, Stagira, Greece) – philosopher and scientist /// about physiology - thought brain was a 'radiator' to cool blood
  - *Famous Quotes: We are what we repeatedly do. Excellence, then, is not an act, but a habit. // The whole is more than the sum of its parts.*



- Today the cessation of brain activity = clinical criterion of death

The Evolution of the CNS

- Spinal cord changed very little throughout vertebrate evolution // first vertebrae occurred about 550 million yrs ago

- Brain has changed a great deal over the last 20 million years.

  - greatest growth in areas occurred in vision, memory, and motor control of the prehensile (able to grasp) hand. /// our hands allow us to build what our brain can imagine!

  - Human brain functions developed as "layers" (Triune Brain Theory)

    - "primitive functions" placed lower in the brain (e.g. medulla oblongata)

    - more "advanced functions" placed higher in the brain architecture (e.g. cerebrum)

Triune Brain Theory

- The modern brain evolved in three evolutionary stages also referred to as brain formations.

- Each formation existed for relatively long stable periods followed by the development of another formation. This pattern existed throughout the evolution of the vertebrate brain.

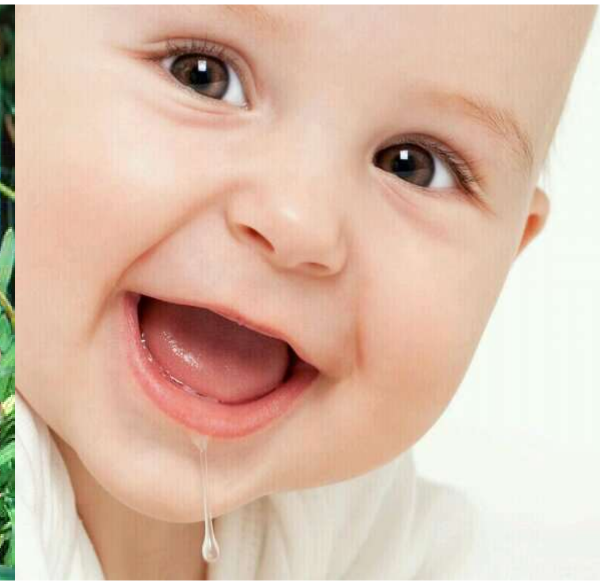
- These are the "Three Brain Formations"

  - Protoreptilian Brain Formation
  - Paleomammalian Brain Formation (Limbic System)
  - Neomammalian Brain Formation (Neocortex)

Summary of Brain Formations

Protoreptilian Formation

Paleomammalian Formation

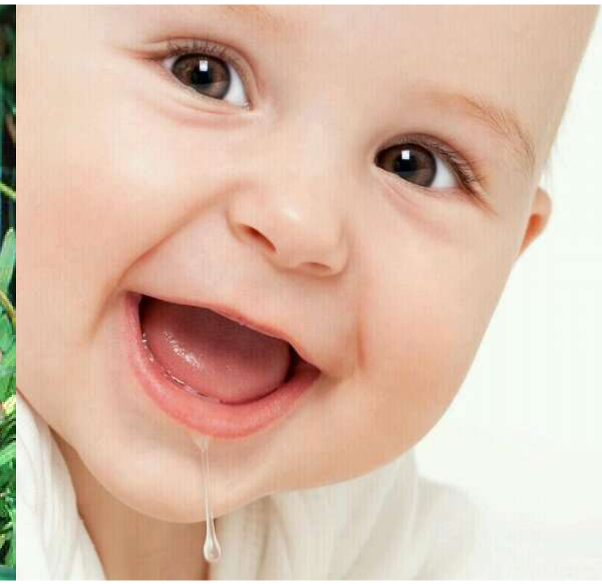


Neocortex Formation

The most efficient way to understand how our brain works today is to understand how the brain evoled as summarized by the **Triune Brain Theory** develop by Paul MacLean in the 1970s. According to his theory, the following three distinct formations emerged successively in the course of evolution. These three distinct brain formations now co-exist in our modern human brain.

Protoreptilian Formation

Paleomammalian Formation

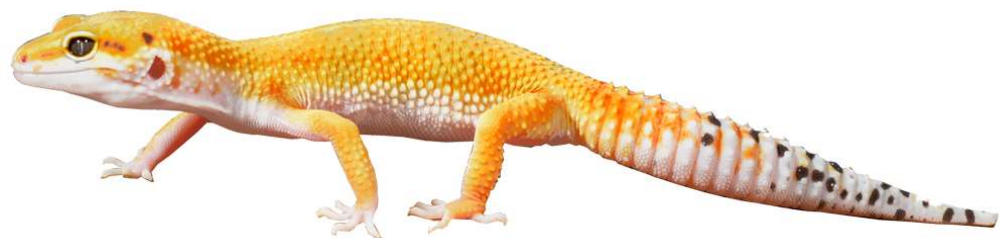


Neocortex Formation

The **reptilian brain (or Protoreptilian) is** the oldest of the three brain formations. It controls the body's vital functions such as heart rate, breathing, body temperature and balance.

Our reptilian brain includes the main structures found in a reptile's brain: the brainstem and the cerebellum (and much later in the evolutionary development - the reptilian brain included the basal nuclei and mid-brain).

How do we characterize the reptilian brain? It is extremely dependable, perdictable, and reliable. It responds to stimuli with genetically encoded instinctual action plans required for primitive survival behaviors -- like exploration, feeding, aggression, dominance, and sexuality. The RB tends to be somewhat rigid and compulsive.



The **Paleomammalian formation (also called the limbic brain)** emerged with the first “stem mammals” (over 200 mya). For the first time, *emotional instincts where encoded as innate structural entities* (i.e. as nuclei). Of equal importance, for the first time stem mammels *developed the ability to remember these innate emotional experiences subconsciously as either being agreeable or unagreeable.*

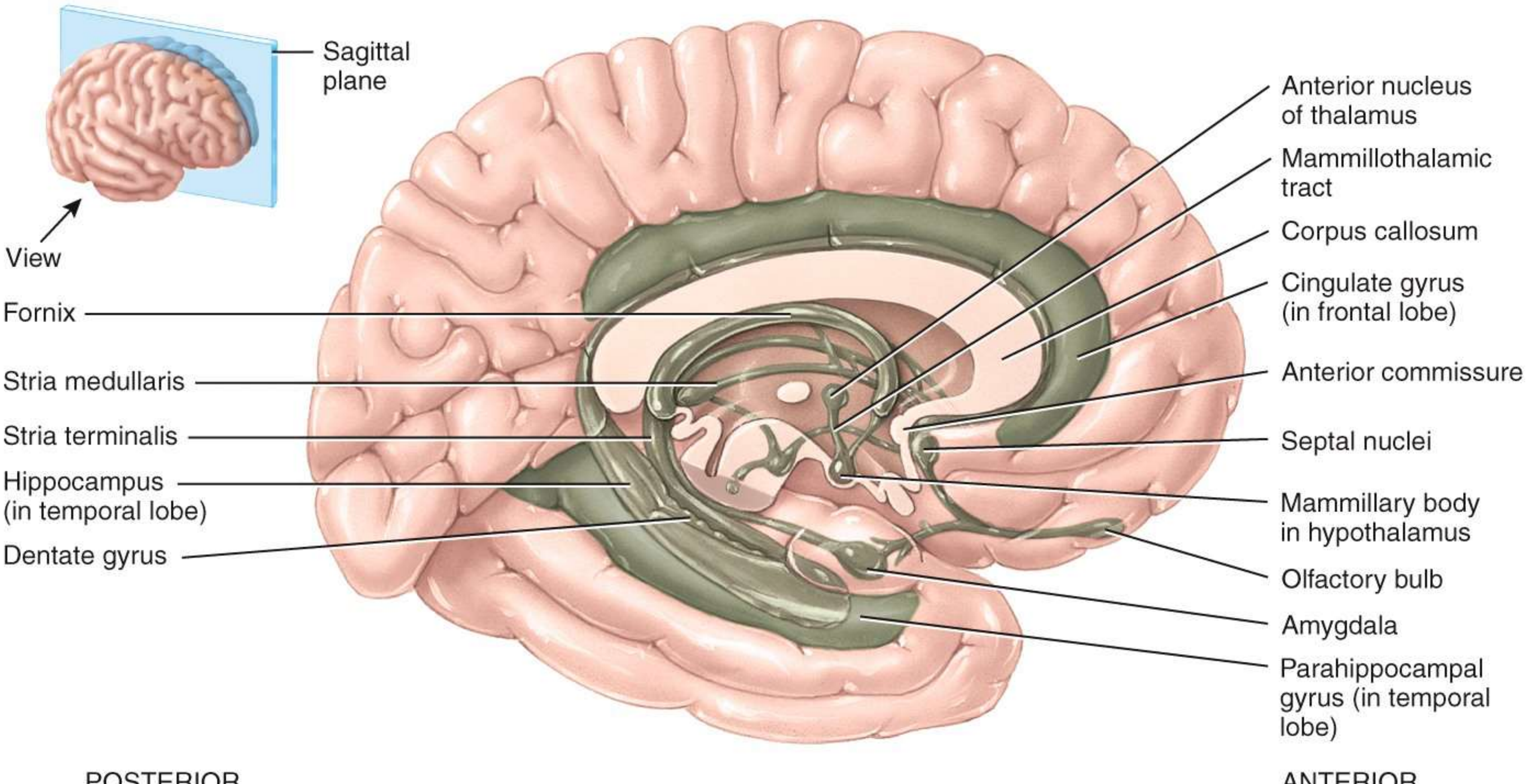
These memory experiences now could help shape the behavior of mammals in terms of their experience. It is responsible for now what we called emotions in human beings .

The main structures of the limbic brain are the hippocampus, the amygdala, and the hypothalamus (includes other interconnected structures – parts of the thalamus, nucleus accubens, septal nuclei, mammillary bodies, and other structures which are called the limbic lobe or simply the limbic system). The limbic brain is the location of our value judgments. These are decisions that are made as part of our subconscious brain activity.   The limbic system exert a strong influence on our conscious behavior because there are nerve tracts connecting the limbic system to the neocortex..

The limbic brain processes innate emotions (fear, aggression, pleasure), remembers the experiences, and process these experiences into a motivational system (i.e. reward or pleasure pathways). This then helps to shape our behavioral responses to new experiences from incoming stimuli based on innate instincts and past experience remembered as pleasant or unpleasant.

The Limbic System

(The Paleo-Mammalian Formation)



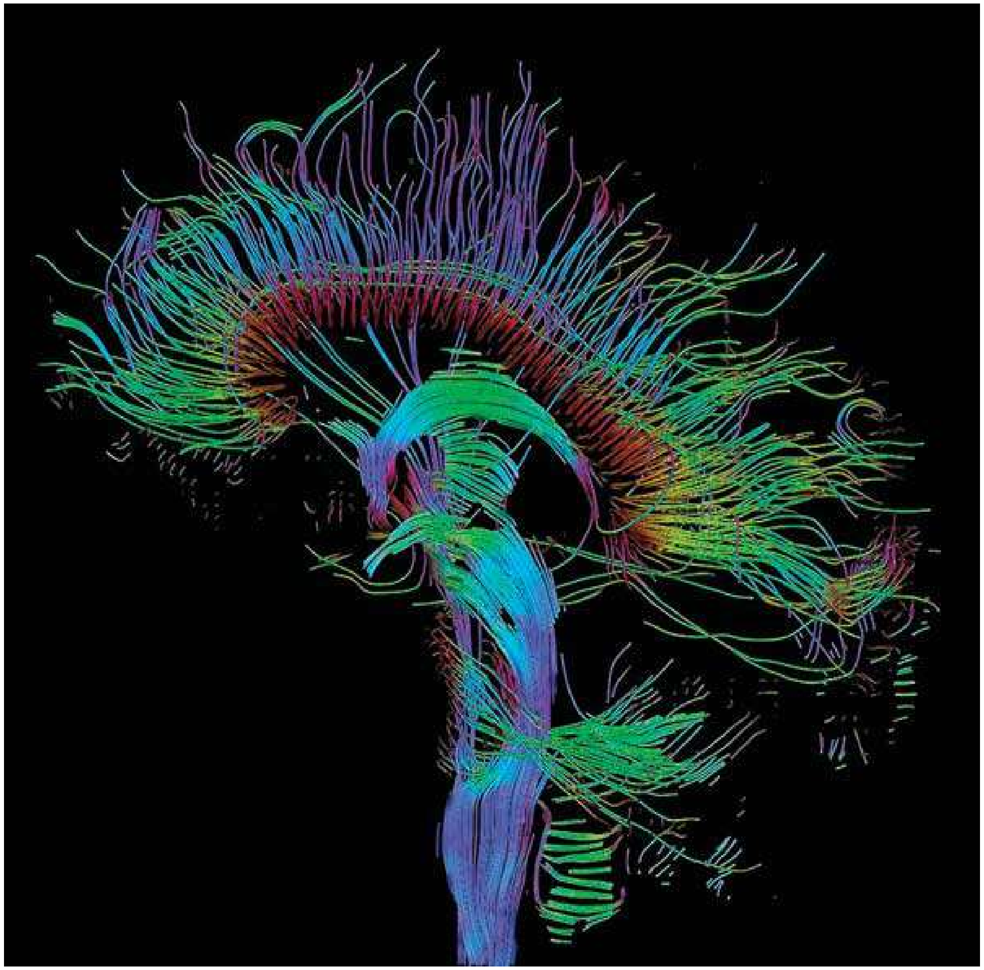
Sagittal section

If you want to learn more about the structure and function of the limbic system then go to the links to Dr. Robert Sapolsky's videos on my Web site's Home Page.

The **neocortex (also called Neomammalian formation)** first assumed importance in whales, primates and reaches it highest development in the human brain. Two large cerebral hemispheres are the dominate structures of the neocortex. This is the location responsible for the development of human language, abstract thought, imagination, and consciousness. The neocortex is flexible and has almost infinite learning abilities .

The neocortex is also the location for Declarative Knowledge. This is the knowledge we learn about from the world that we live in. It is knowledge derived especially from sight, sound and touch. The neocortex with its declarative knowledge is most developed in humans. Without a neocortex, we would not have a culture. (note: difference between procedural vs declarative memory)

These <u>three parts of the brain are still functional in today's human brain</u>. They do not operate independently but have established numerous interconnections between the three formations and influence one another.



Human brain showing nerve tracks that connect the three brain formations.

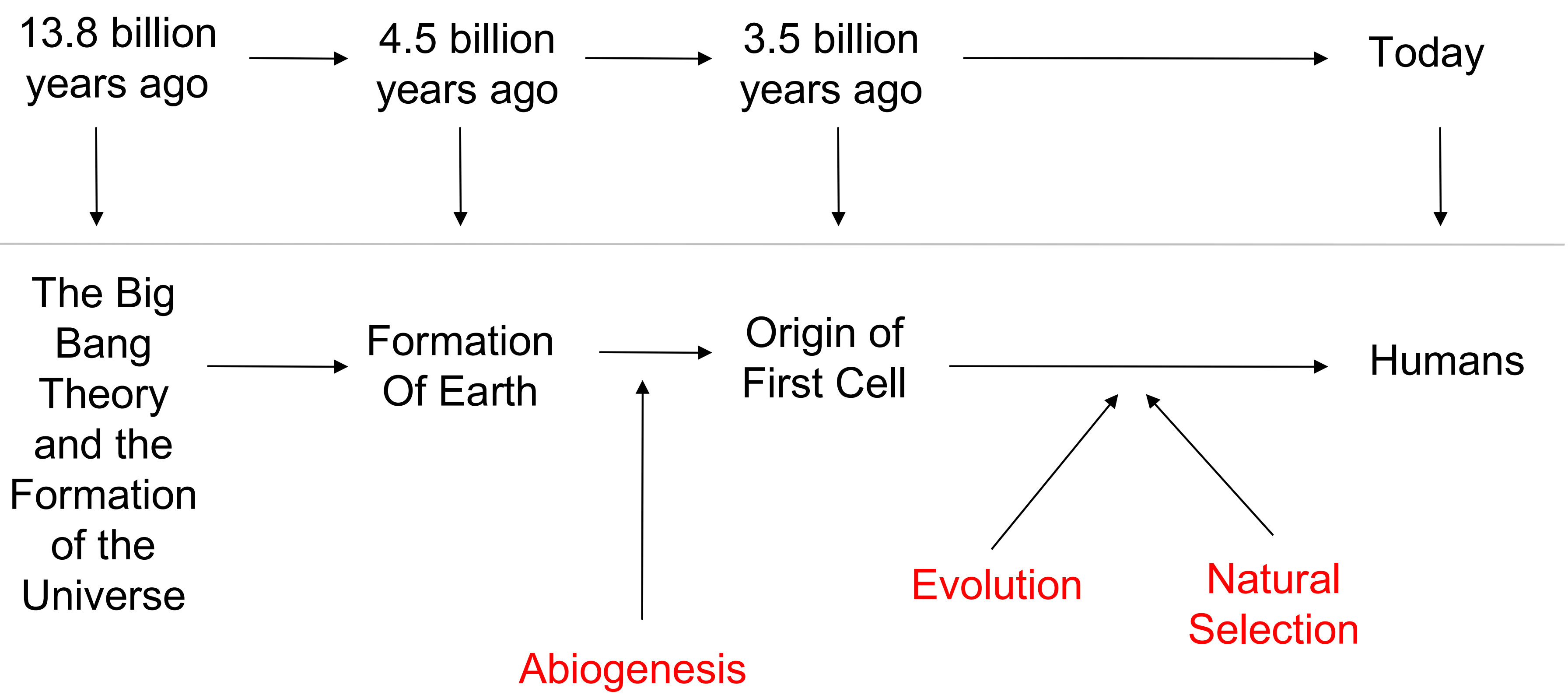
So now we can understand how the unconscious emotional brain of the limbic system is able to make our value judgments, and then send them to our prefrontal cortex which processes our conscious thoughts (note: the orbitalfrontal cortex makes conscious decisions based on outcomes which are based on expected rewards and punishments then remembers these decisions as part of adaptive learning.)

Neural pathways between the limbic system and the orbitalfrontal cortex compete to shape the outcome of our experiences. (E.g. - Will you throw your drink into your bosses' face because you don't like your boss?)

How may the emotional brain cripple the neocortex? Will the experience leave you paralyzed in fear and anxiety? Or are you left with rage and then will fight to your death?

The Forces That Created Life

Physics – Chemistry - Time

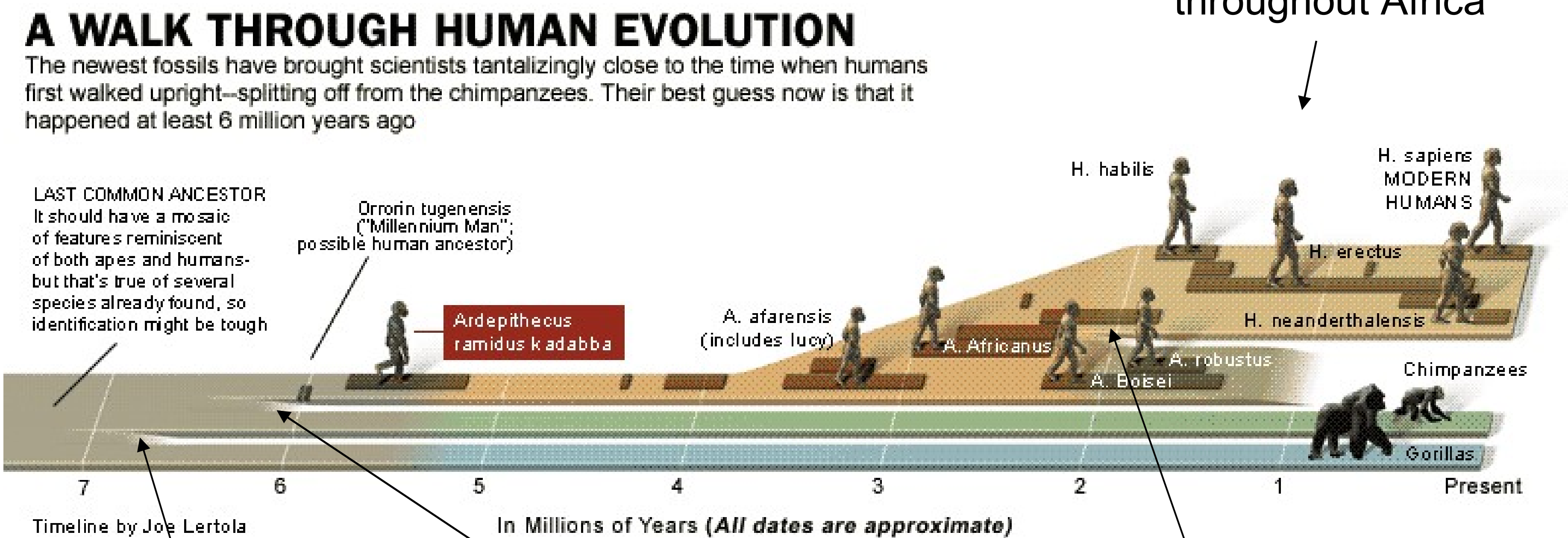


Key Steps in Evolution of Humans from Single Cell to Today

- 13.8 billion years ago (bya) // universe formed (The Big Bang Theory)
- 4.5 bya // earth formed
- 3.5 bya // It took 1 billion years for earth's molten rock to cool and for comets striking earth to fill the oceans with water // period of abiogenisis
- 3.5 bya // first fossil evidence for prokaryotic cells
- 2.5 bya // endosymbiosis
- 2 bya // first fossil evidence for karyotic cells
- 2 bya // three domains exist // bacteria – achaea- eukaryotes
- 2 bya // *Grypania spiralis* - first multicellular organism
- 540 – 488 mya // Cambrian Period (Explosion)
- 500 mya //First fish
- 350 mya // insects and plants on land
- 300 mya // First reptiles
- 250 mya // First mammals
- 225 mya // First dinosaurs
- 65 mya // KT Extinction // mass extinction of dinosaurs
- 65 mya // divergence of the primate family tree
- 40 mya / divergence of old world and new world monkeys
- 7 mya // divergence of gorillas and chimpanzees
- 6 mya // divergence of chimpanzees and Ardipethicus ramidus (would lead to hominids)
- 4 mya // Australiopithecus anamensis
- 2 mya // Australopithecus afarensis (Lucy)
- 1.75 mya // Homo habilis // first hominid
- 1.5 mya // Homo erectus
- 750,000 – 40,000 yr ago // Homo neandethalensis
- 200,000 years ago // Homo sapiens // Today, it is the only surviving hominid, that's us!

Note: Dates are approximate to reference significant evolutionary events. Some events occurred over millions of years and many events co-existed with extended periods of overlap.

Over periods of millions of years different populations of hominids co-existed primarily throughout Africa



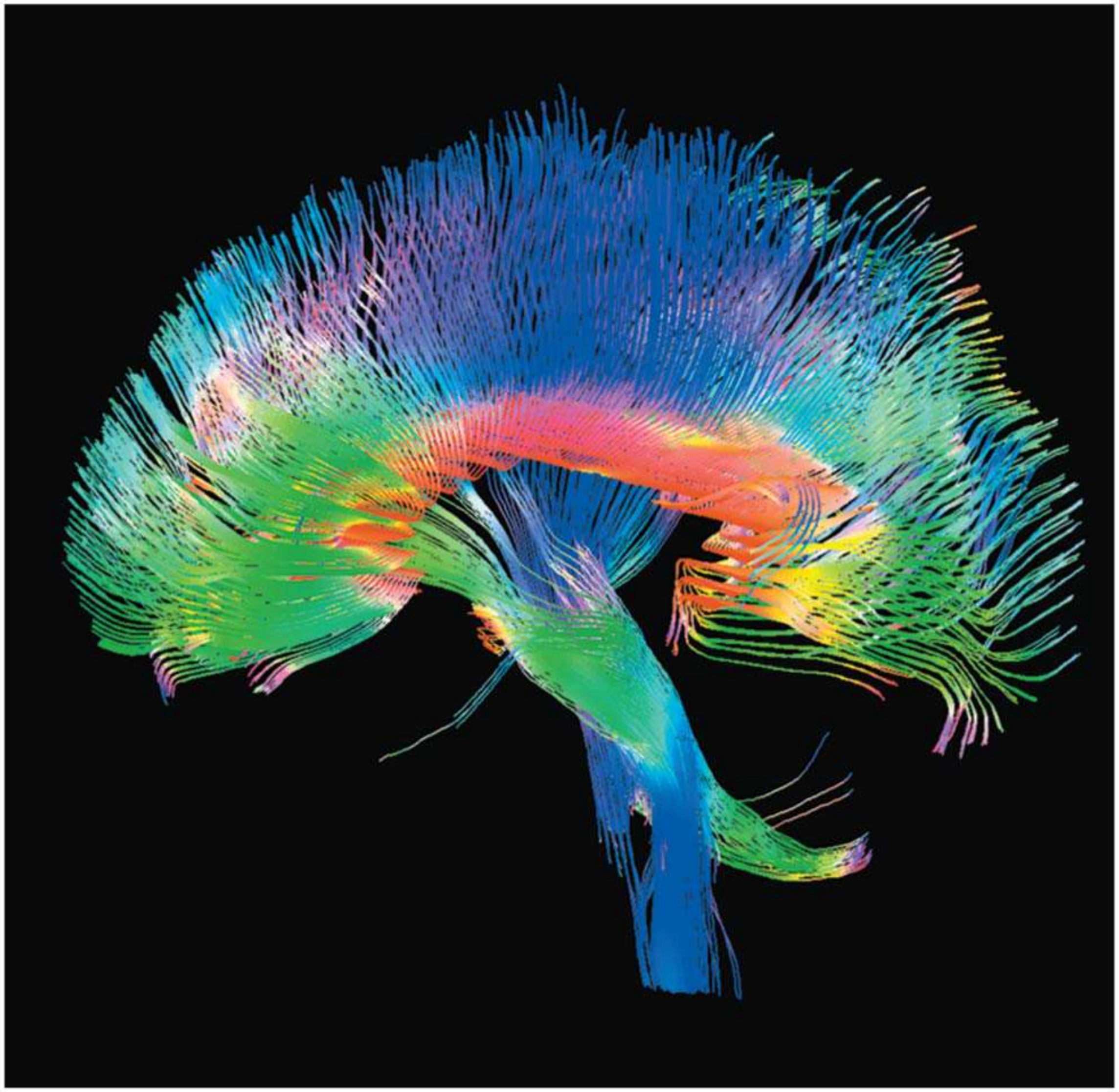
Gorillas and Chimpanzees Divergence

Chimpanzees and Proto-hominids Divergence

Australopithecus and Homo Divergence

- **For more information about the Triune Brain Theory see www.mc3cb.com**
  - **Go to Archival Articles Link / see brain reference articles / Triune Theory**

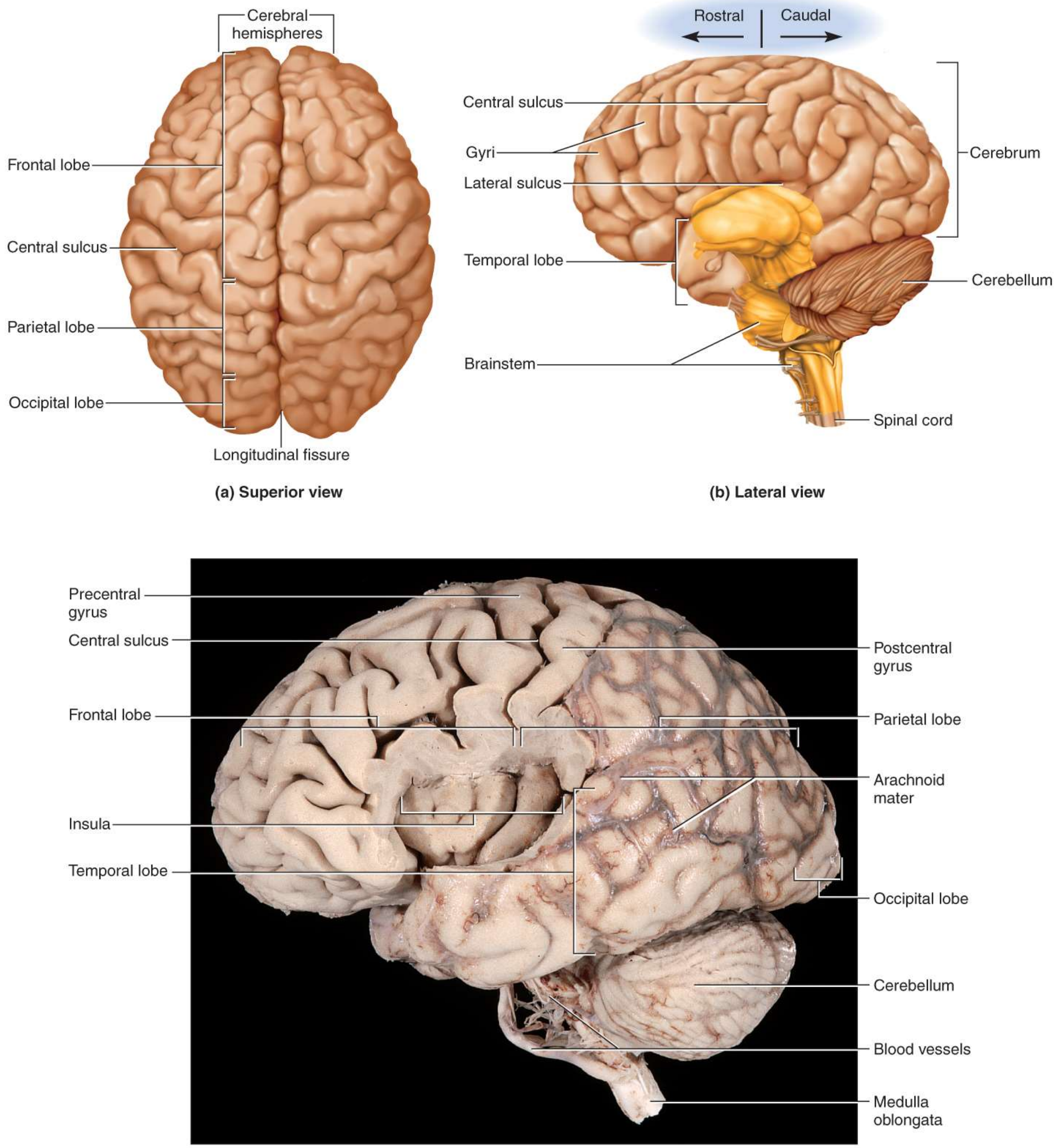
Human Brain Structure



This structural arrangement is commonly used in the study of embryonic growth and development.

- Forebrain
  - Diencephalon
  - Cerebrum
- Midbrain
- Hindbrain
  - Brain Stem
  - Pons
  - Midbrain
  - Cerebellum

To study the adult brain, we will use a different method. (see next slide)



(a) Superior view

(b) Lateral view

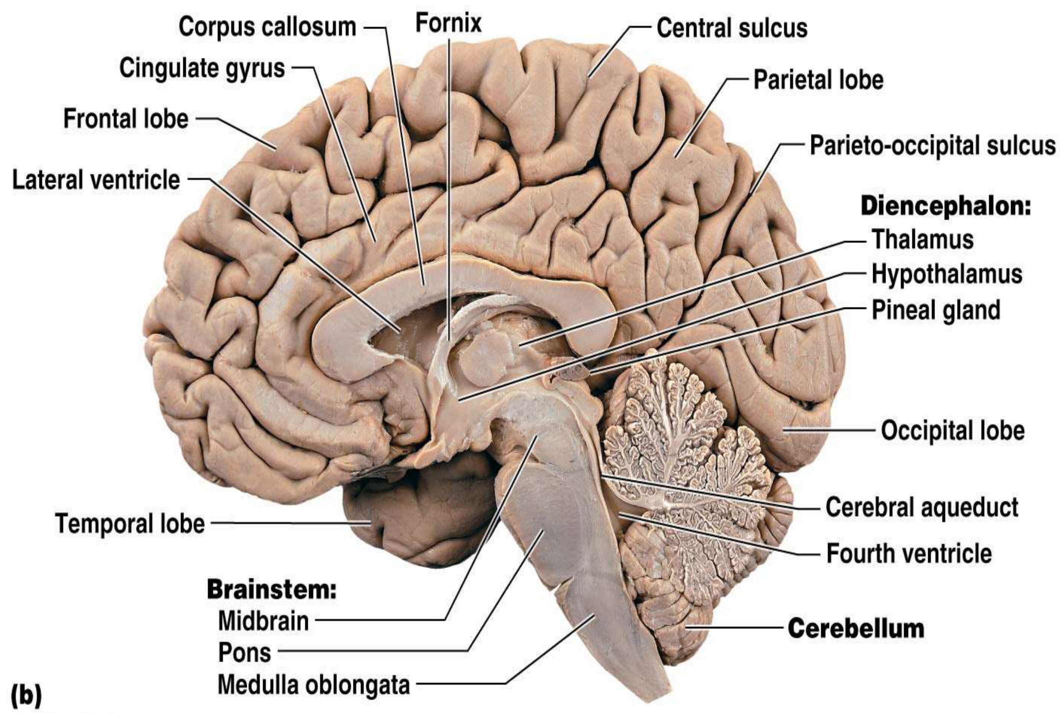
(c) Lateral view

The Three Divisions of the Adult Brain

cerebrum is 83% of brain volume; cerebral hemispheres, gyri and sulci, longitudinal fissure, corpus callosum

cerebellum contains 50% of the neurons; second largest brain region, located in posterior cranial fossa

brainstem the portion of the brain that remains if the cerebrum and cerebellum are removed;

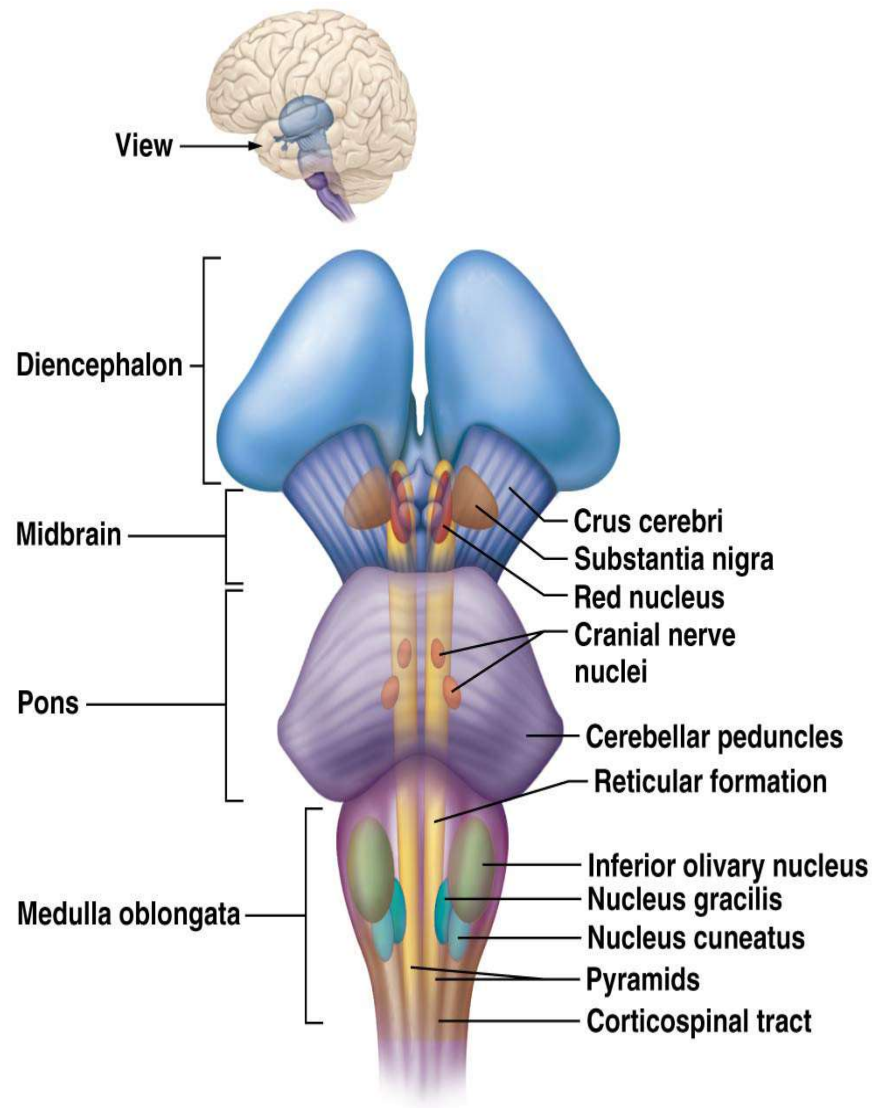


Know This For Your Exam

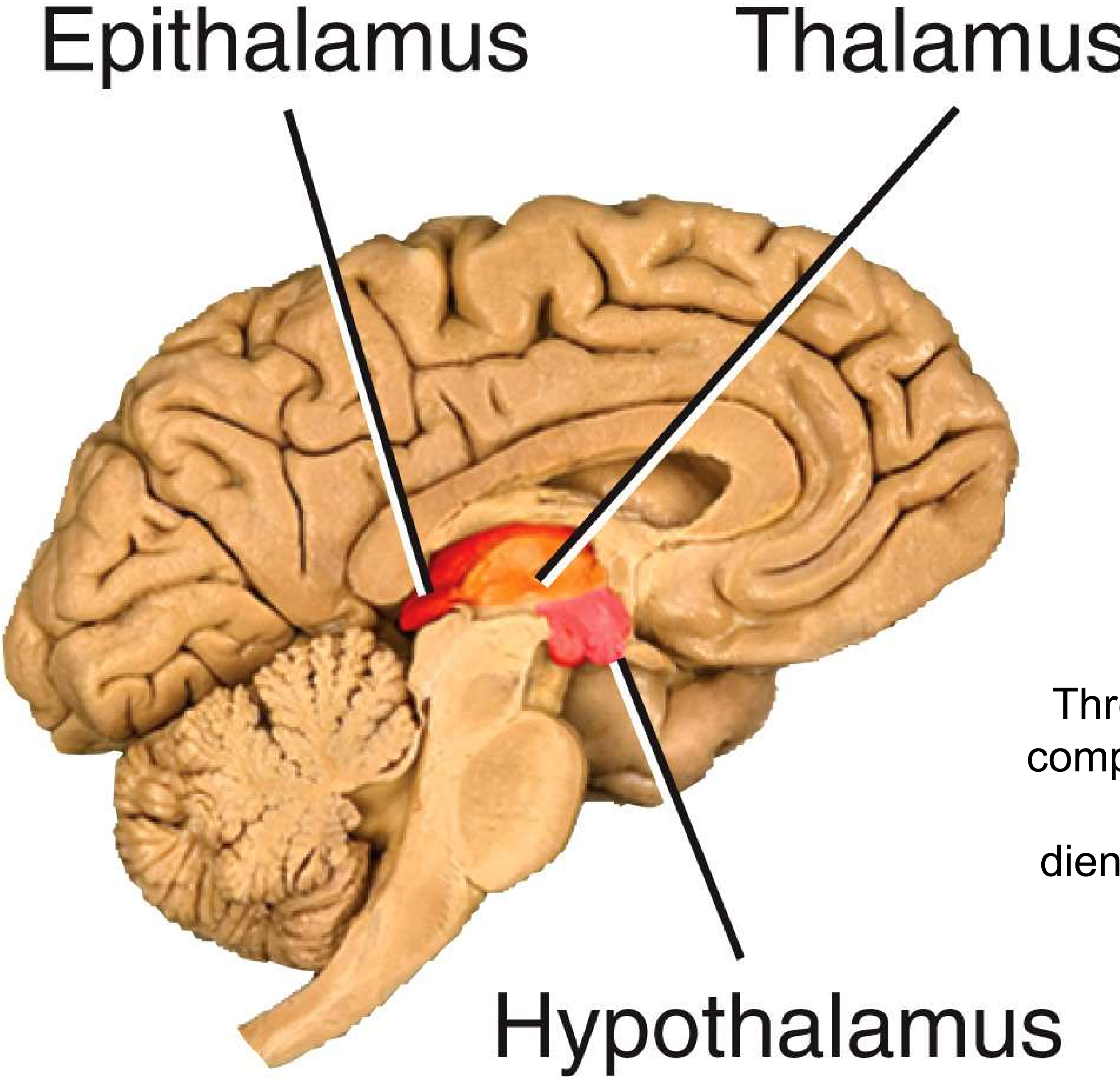
Brainstem

- After the cerebrum and cerebellum are removed from the brain, you are left with the brainstem.

- major components
  - diencephalon
  - midbrain
  - pons
  - medulla oblongata

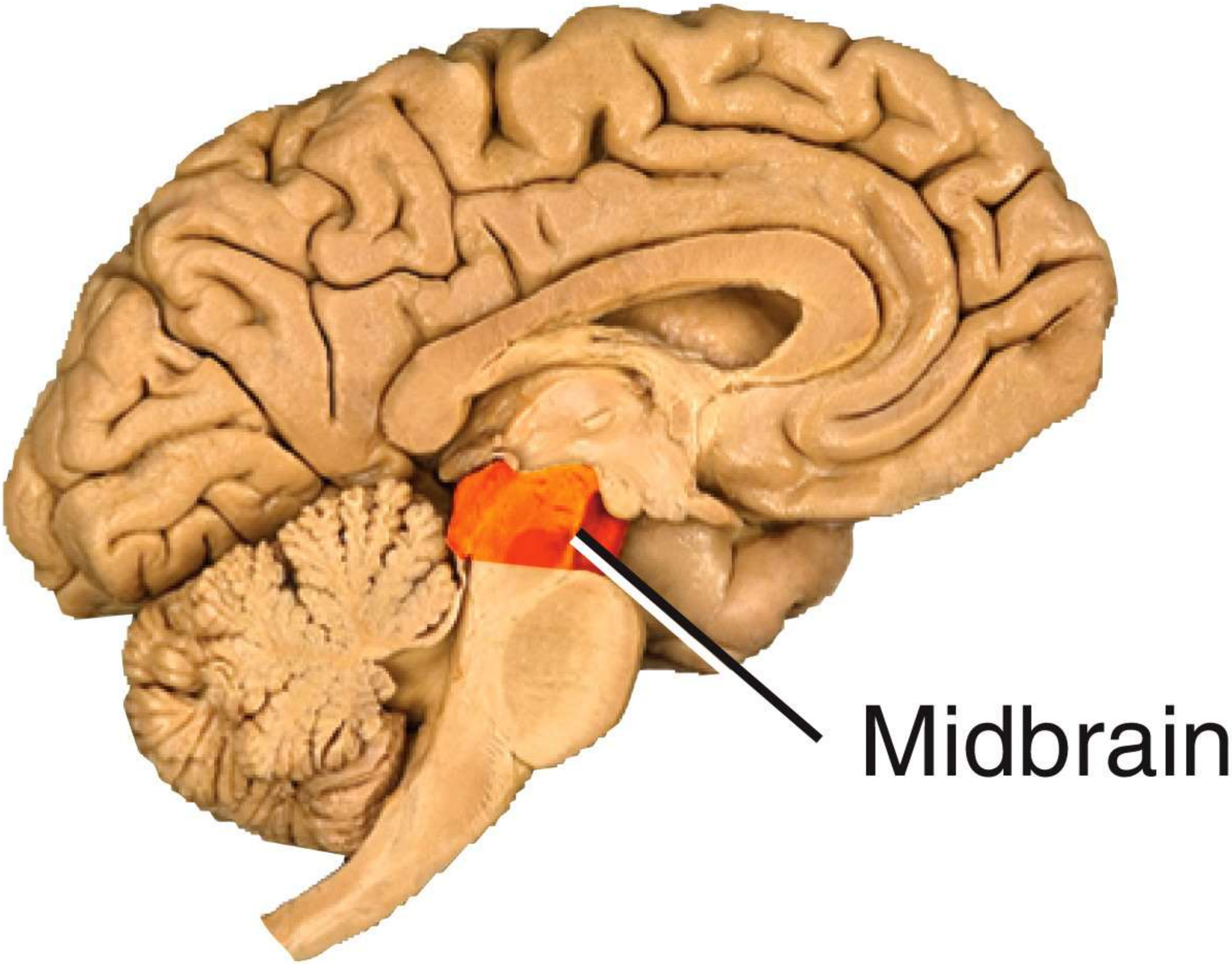


(a) Brainstem, anterior view

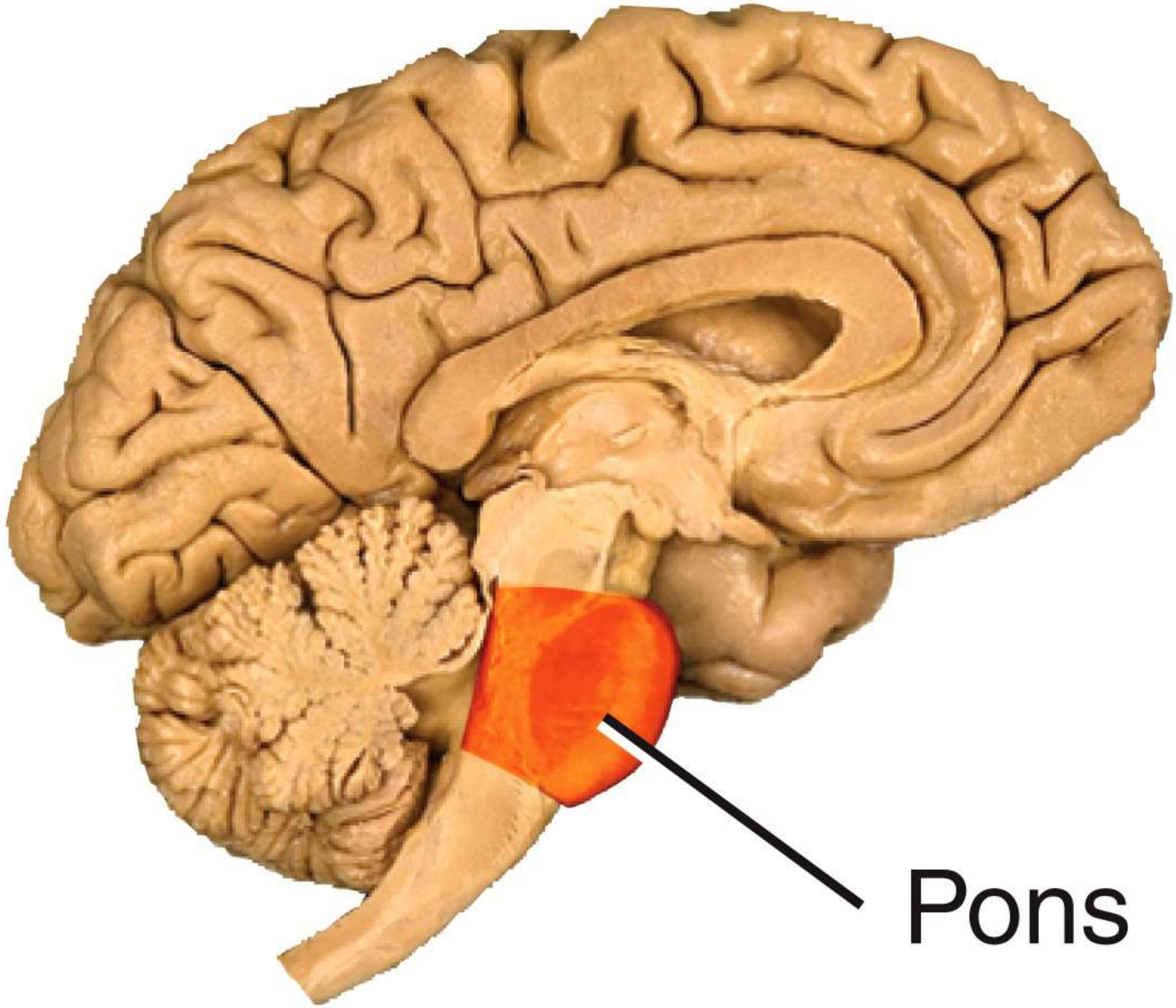


Three major components of the diencephalon

Dissection Shawn Miller, Photograph Mark Nielsen



Dissection Shawn Miller, Photograph Mark Nielsen



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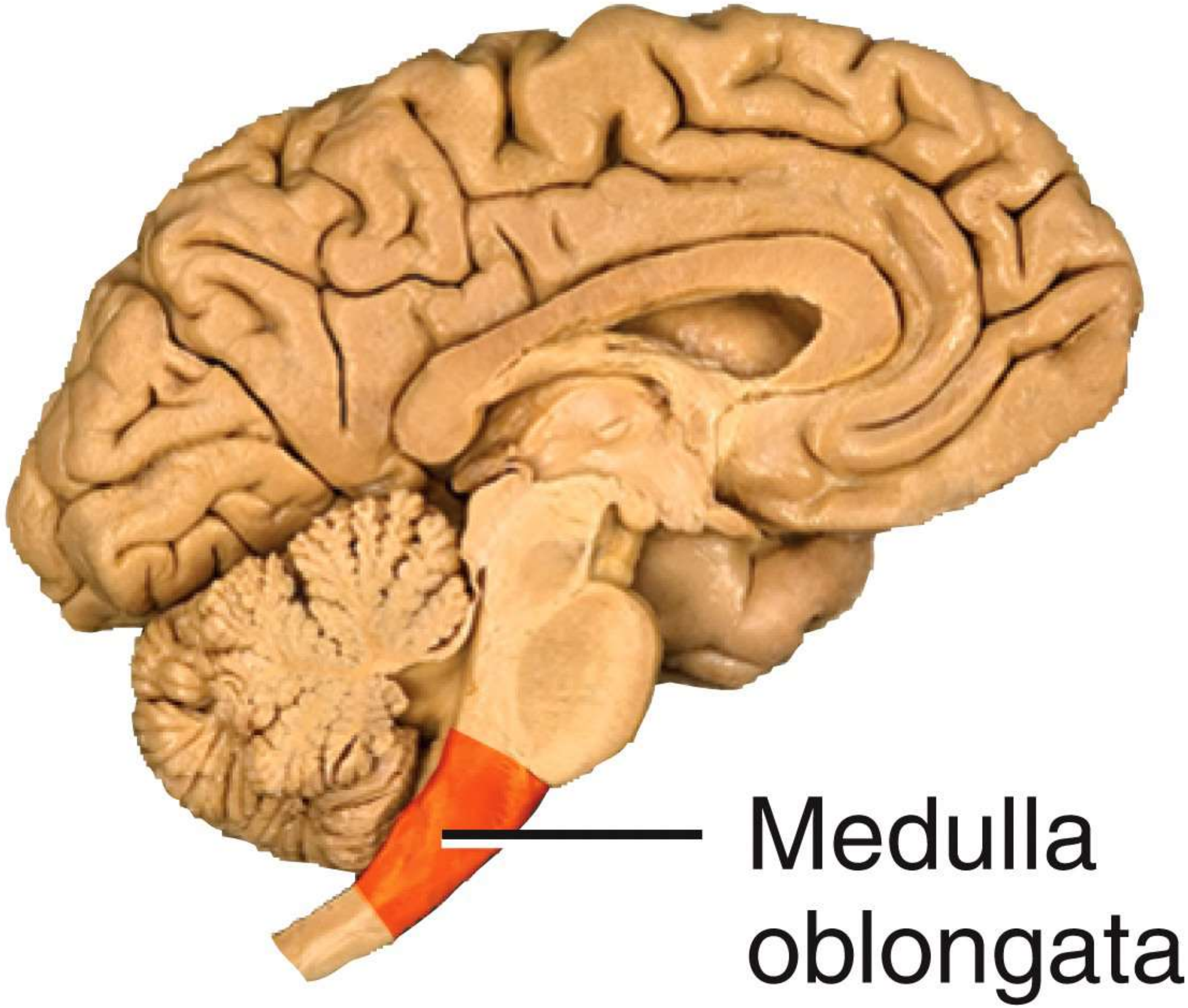

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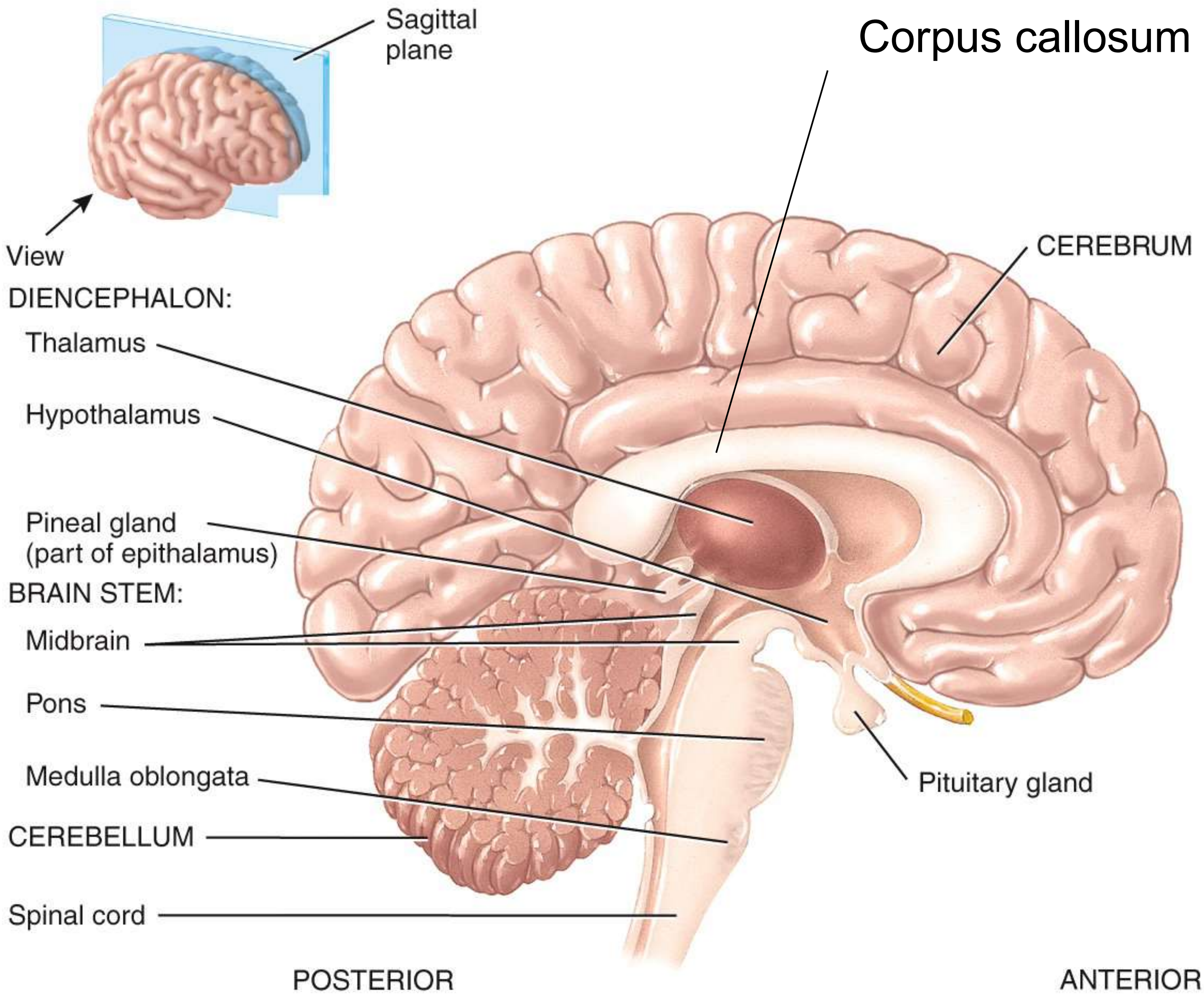
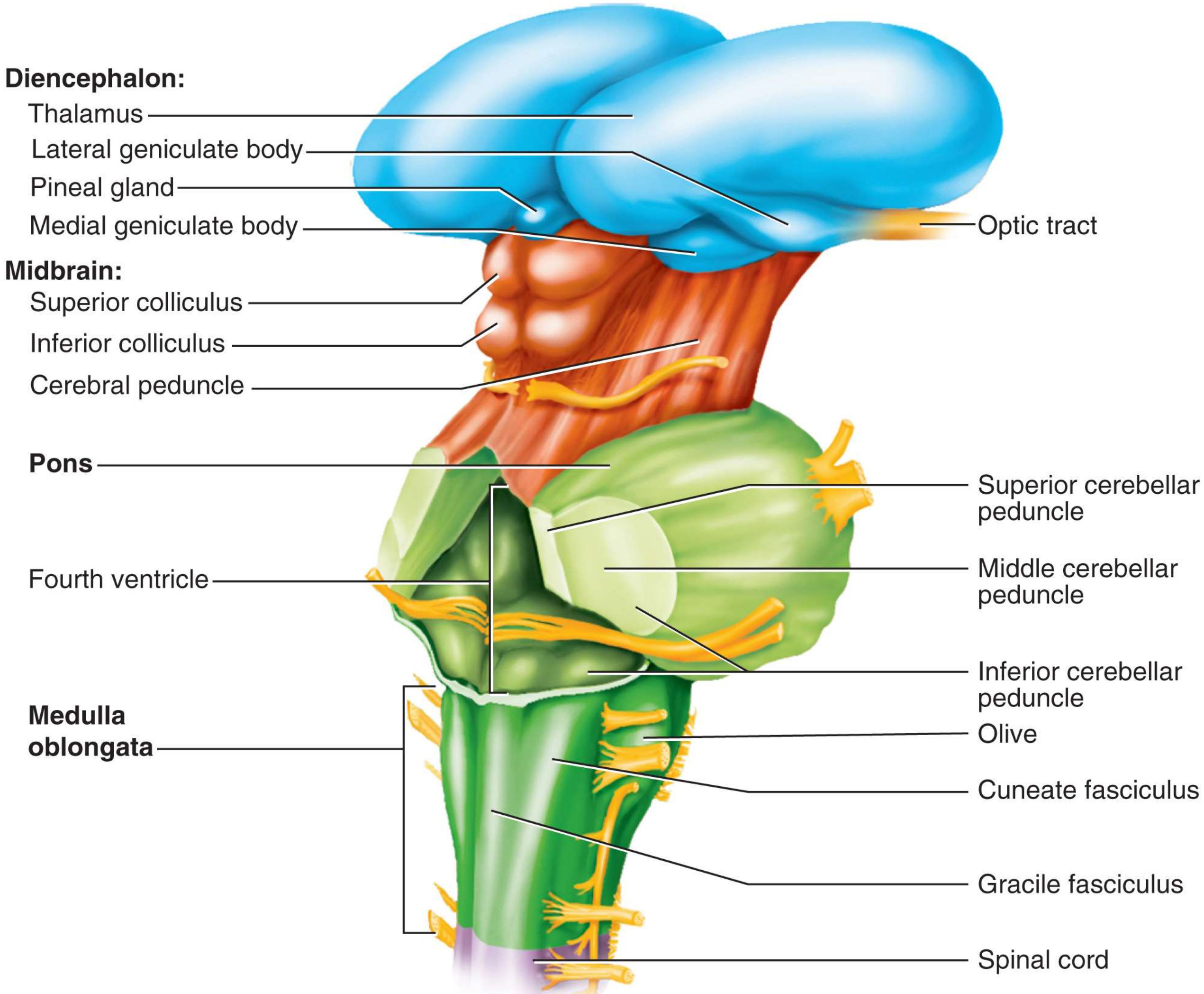
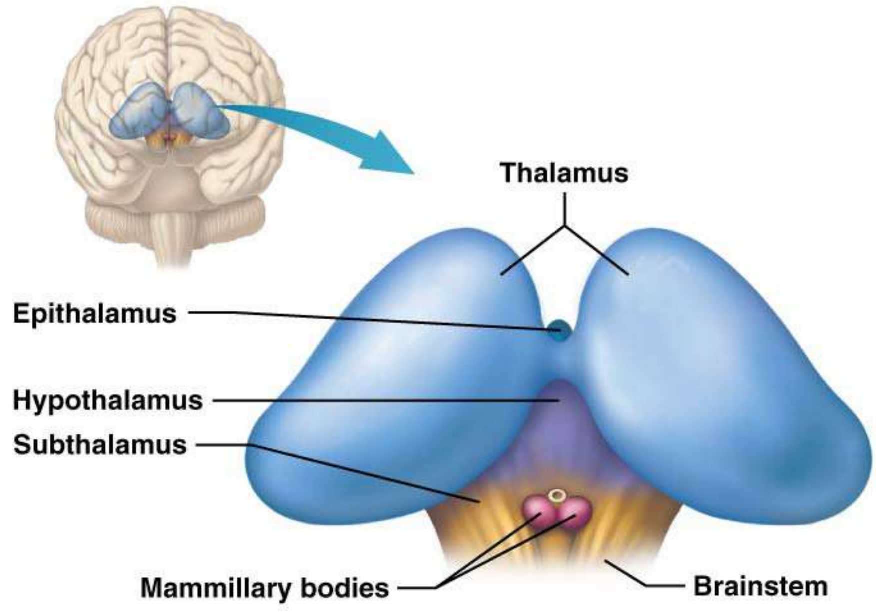


(a) Sagittal section, medial view

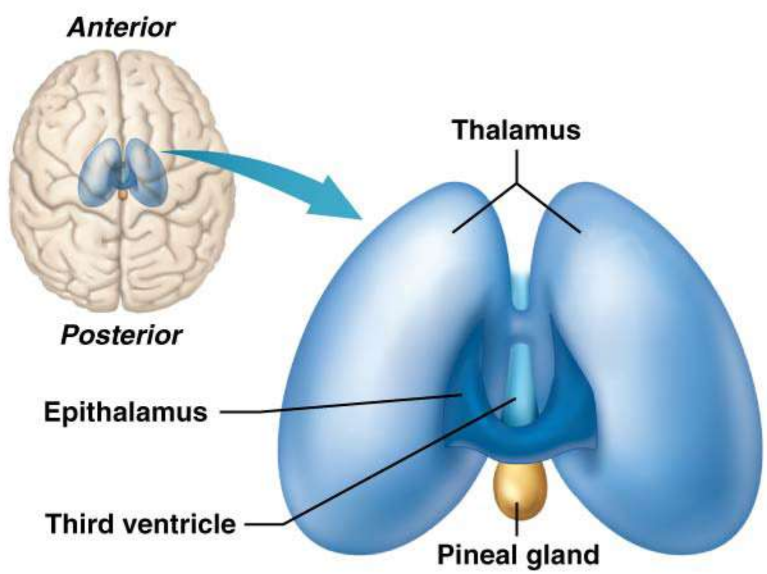


(b) Dorsolateral view

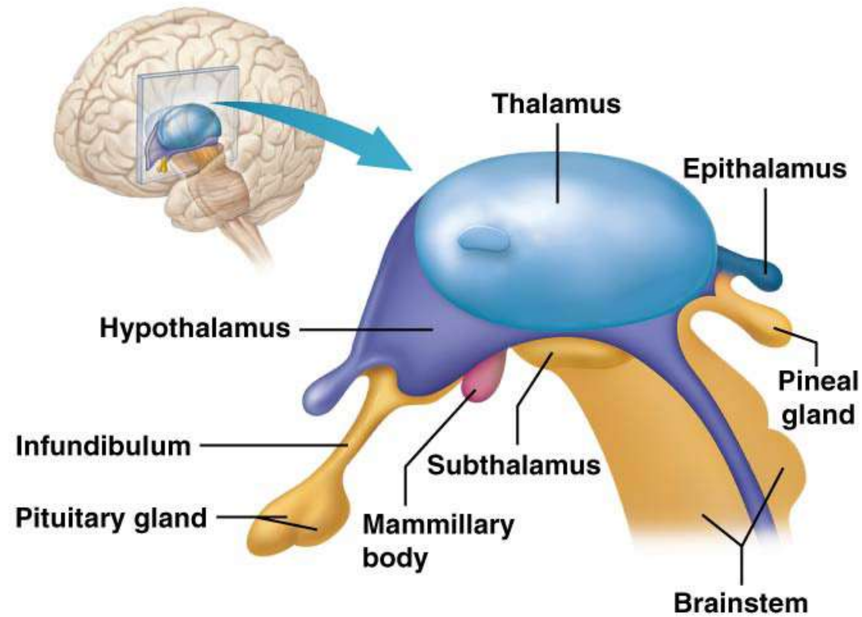
Note: Diencephalon also includes hypothalamus and epithalamus (pineal gland & habenula)



(a) Diencephalon, anterior view



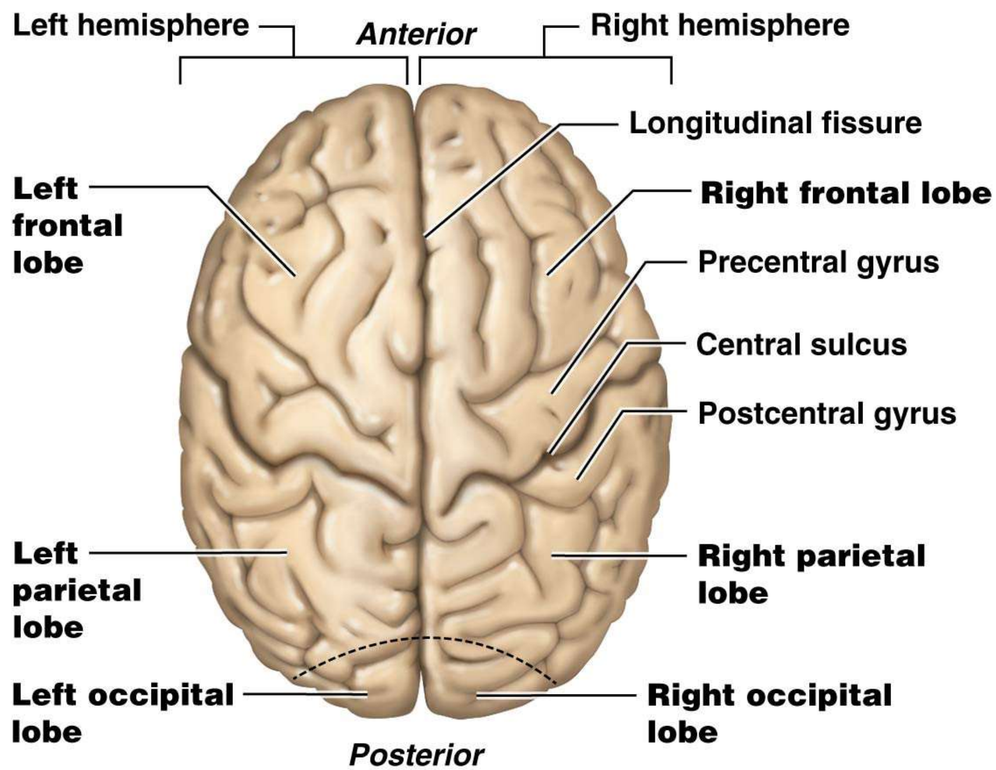
(b) Diencephalon, superior view



(c) Diencephalon, midsagittal section

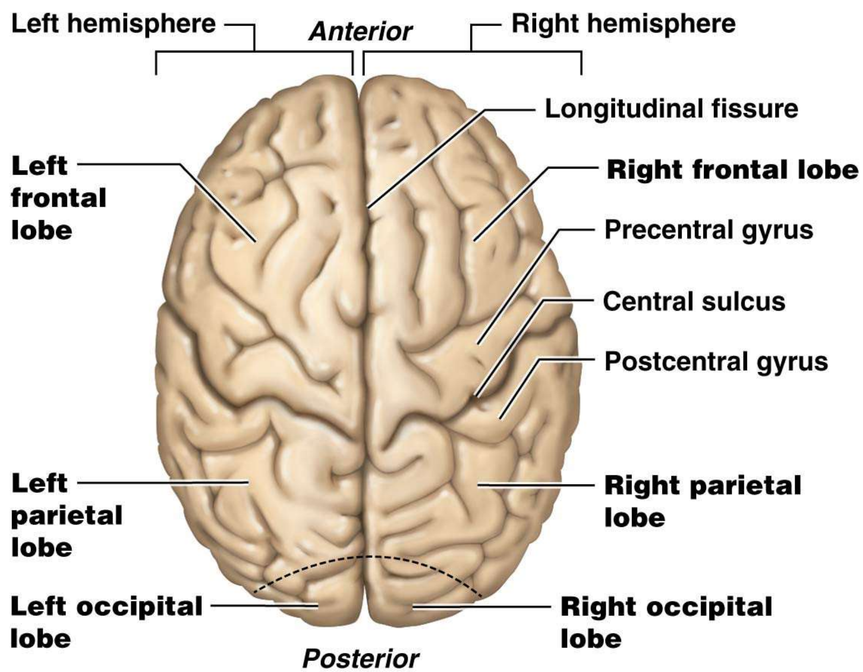
Cerebrum

- **longitudinal fissure** – deep groove that separates cerebral hemispheres
- **central sulcus** – shallow groove // separates motor and sensory functions
- **gyri** - thick folds
- **sulci** - shallow grooves



(b) Superior view

The Gross Anatomy of the Cerebrum

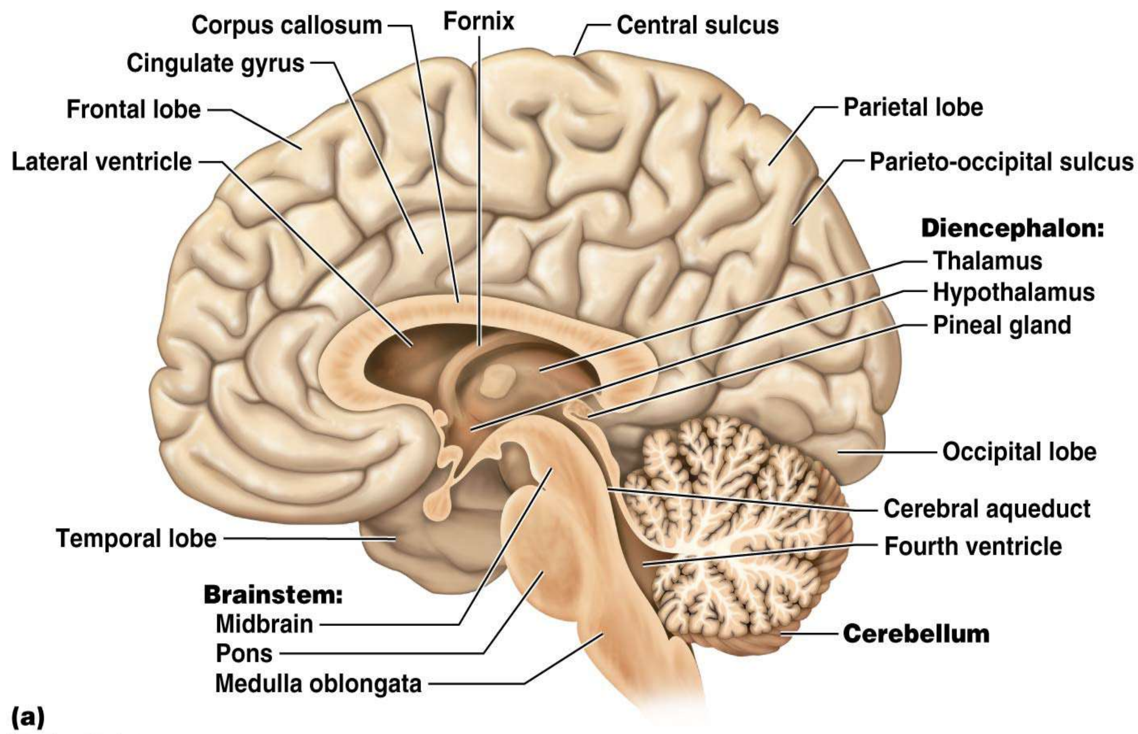


(b) Superior view

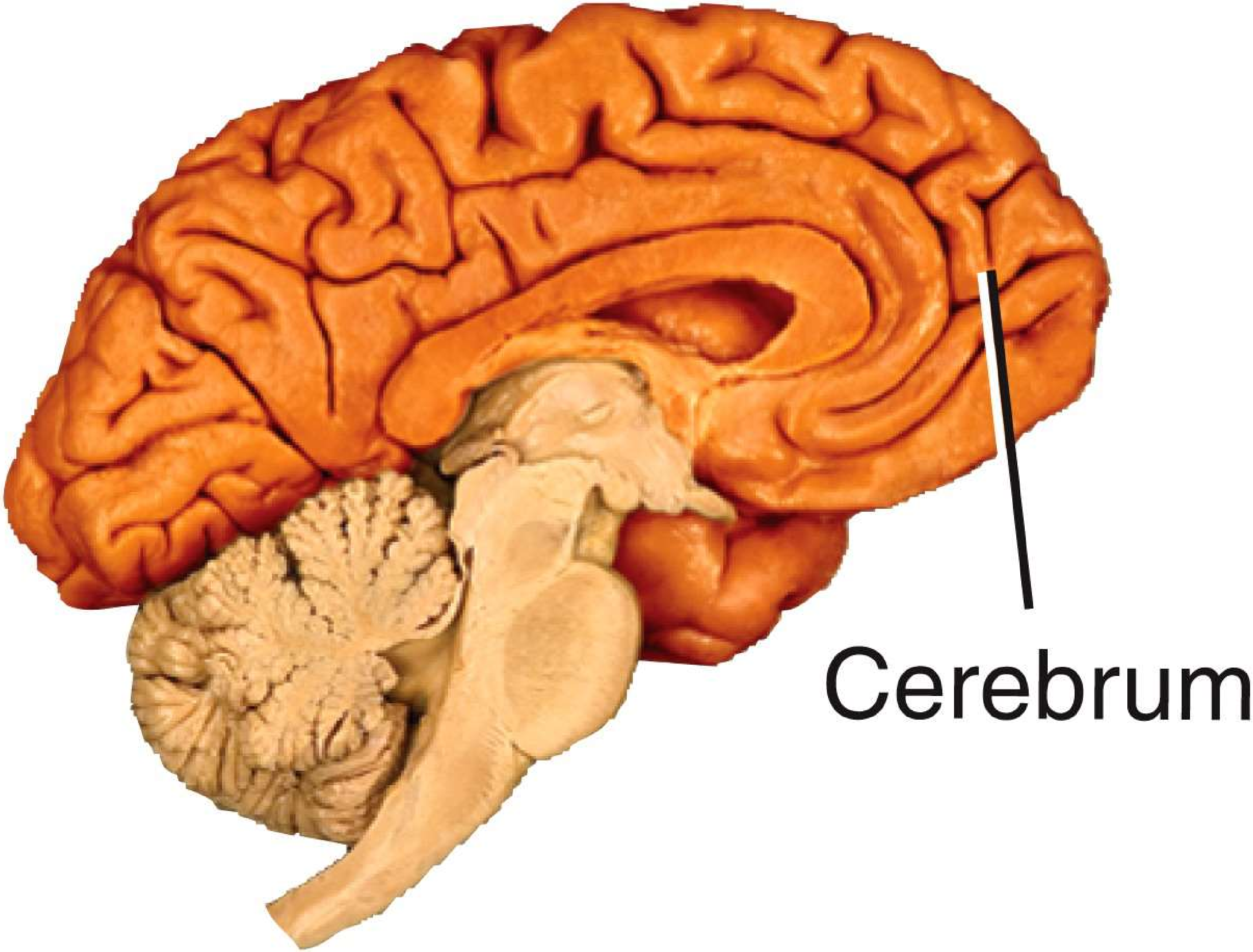
- Consist of two cerebral hemispheres // divided by longitudinal fissure
  - hemispheres connected by white fibrous tract the corpus callosum
  - gyri and sulci – increases amount of cortex in the cranial cavity
  - gyri increases surface area for information processing capability
  - sulci divide each hemisphere into five lobes named for the cranial bones that overlie them
  - cerebral cortex = tissue directly beneath pia matter / 4 mm

Directional Terms, Landmarks, and Divisions

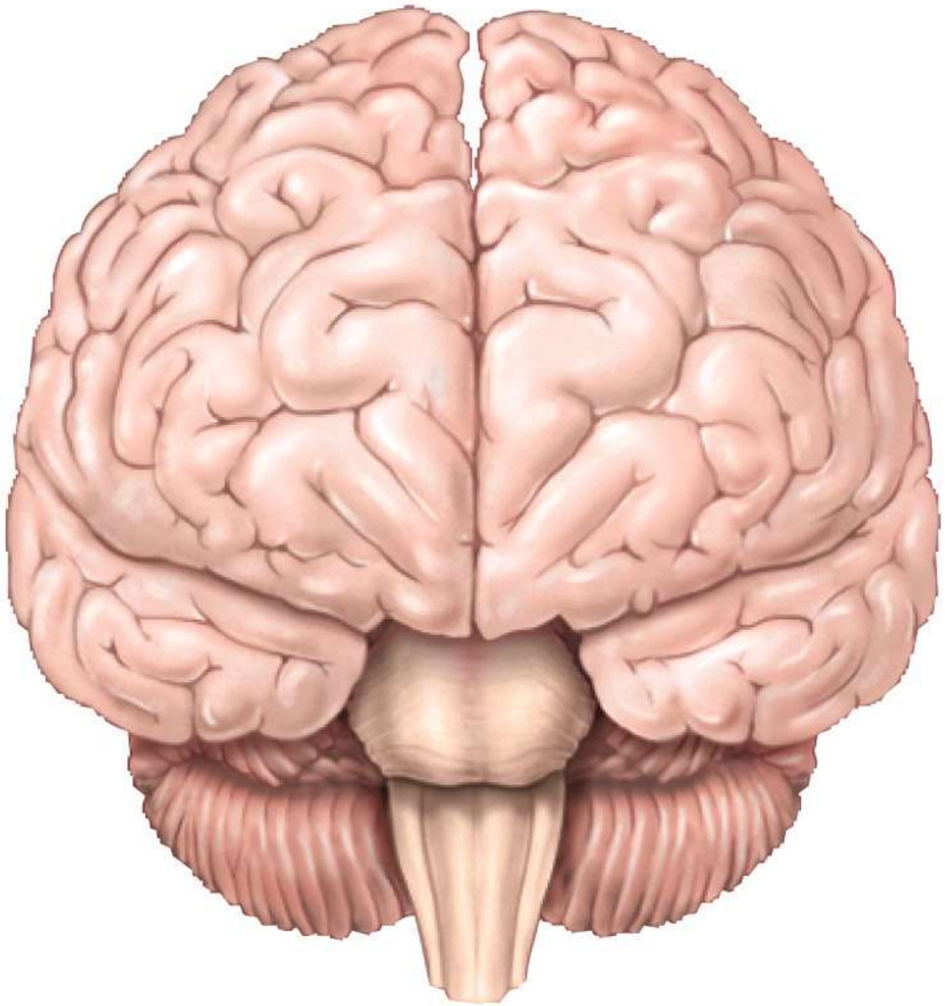
- **corpus callosum** – thick nerve bundle at bottom of longitudinal fissure that connects hemispheres
- rostral - toward the forehead
- caudal - toward the occipital lobe / spinal cord
- adult human brain weighs about
  - 1600 g (3.5 lb) in men
  - 1450 g in women



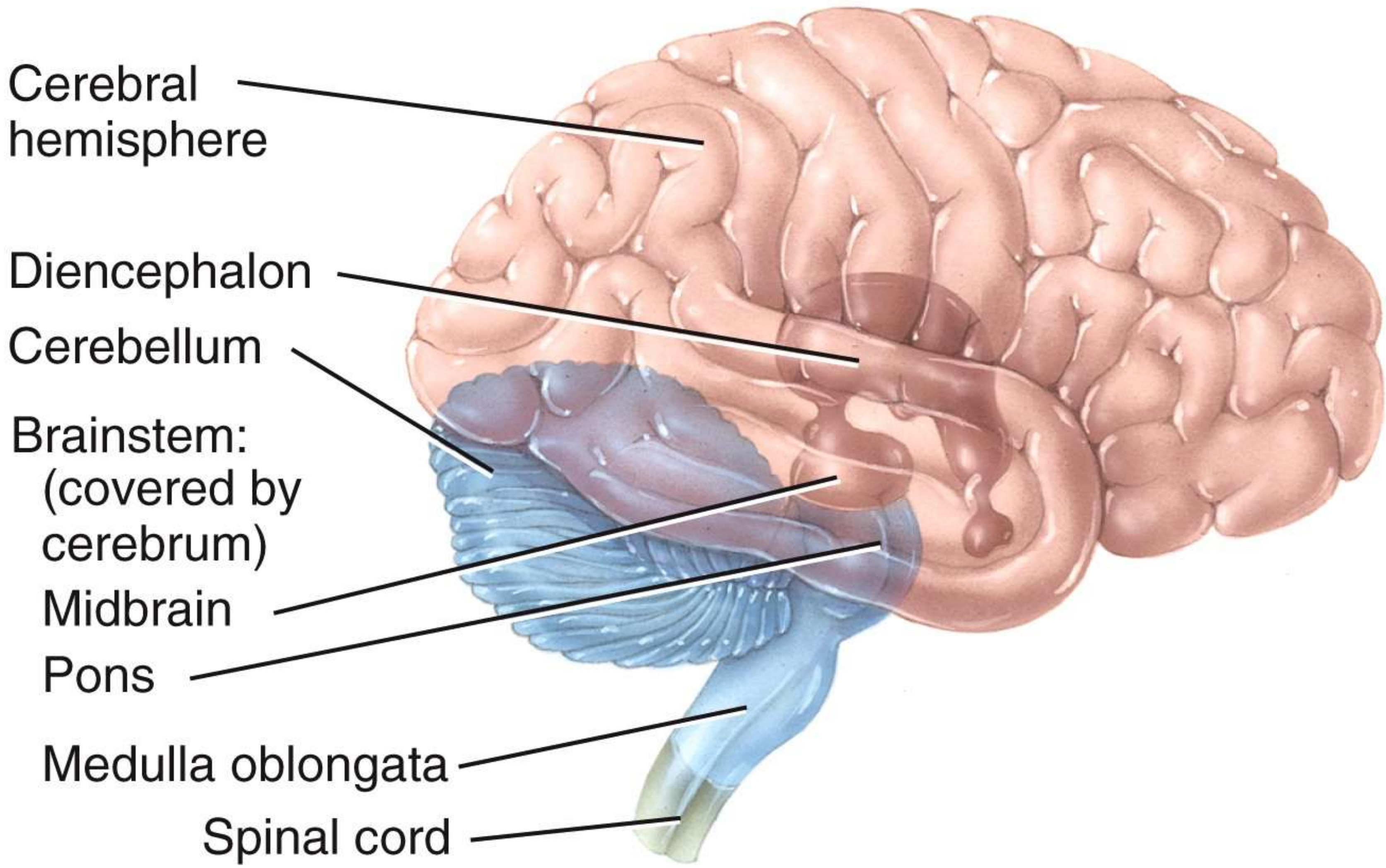
(a)



Dissection Shawn Miller, Photograph Mark Nielsen

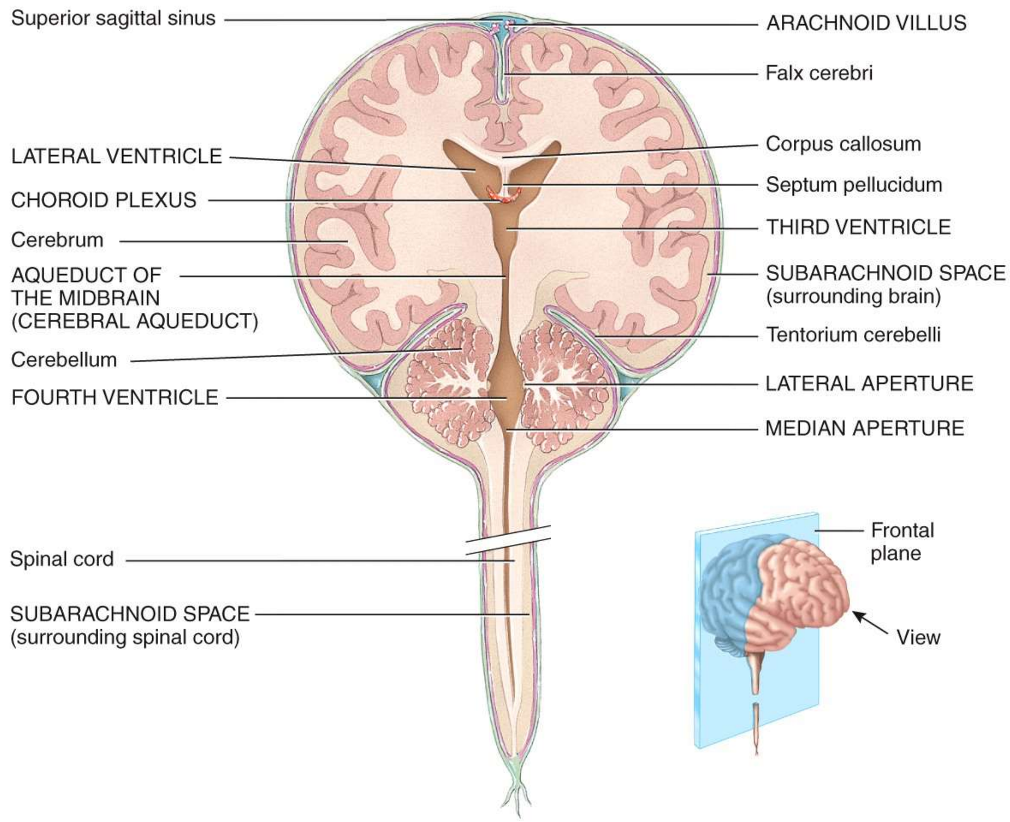


Anterior view


Cerebral hemisphere
Diencephalon
Cerebellum
Brainstem:
(covered by cerebrum)
Midbrain
Pons
Medulla oblongata
Spinal cord

Gray and White Matter

- **gray matter** – consists of the neuron cell bodies, dendrites, and synaptic knobs
  - dull grey-white color when fresh
  - due to little myelin on the surface of the cell bodies, dendrites and synaptic knobs
  - grey matter forms surface layer of cerebrum - **"the cortex" is about 4mm thick**
  - **cerebral cortex** covers the entire superficial surface of the cerebrum (similar cortex associated with cerebellum)
  - clusters of soma also form **nuclei** deep within brain (i.e. grey islands // control specific function like heart rate, sneezing, etc.)

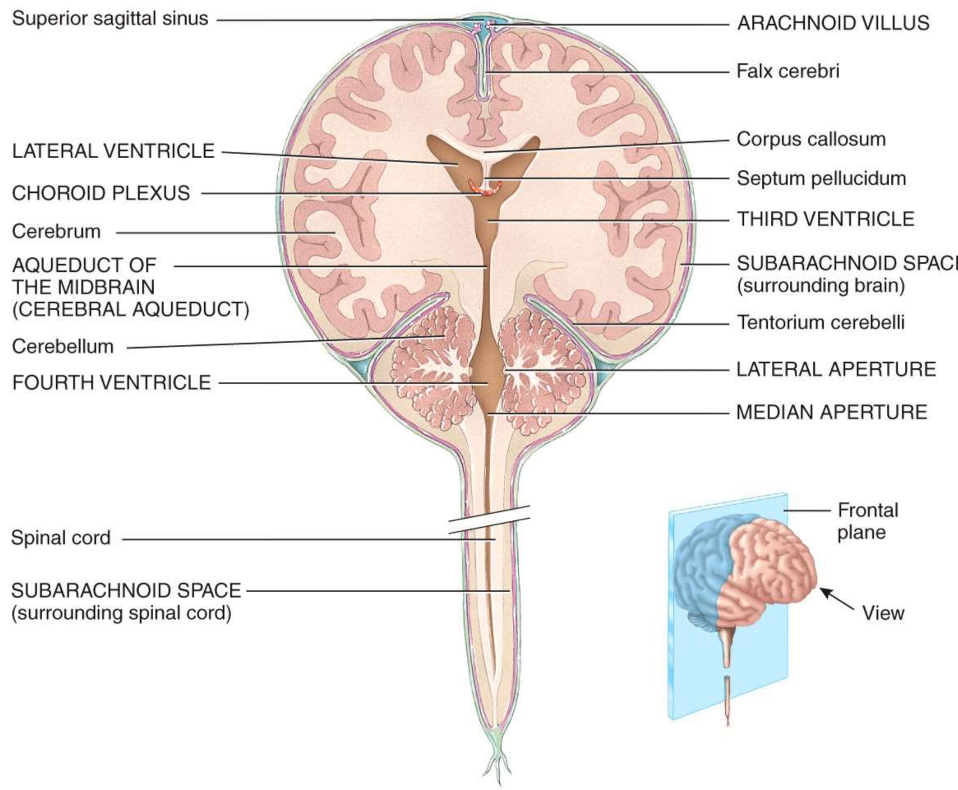


(c) Frontal section of brain and spinal cord

Gray and White Matter

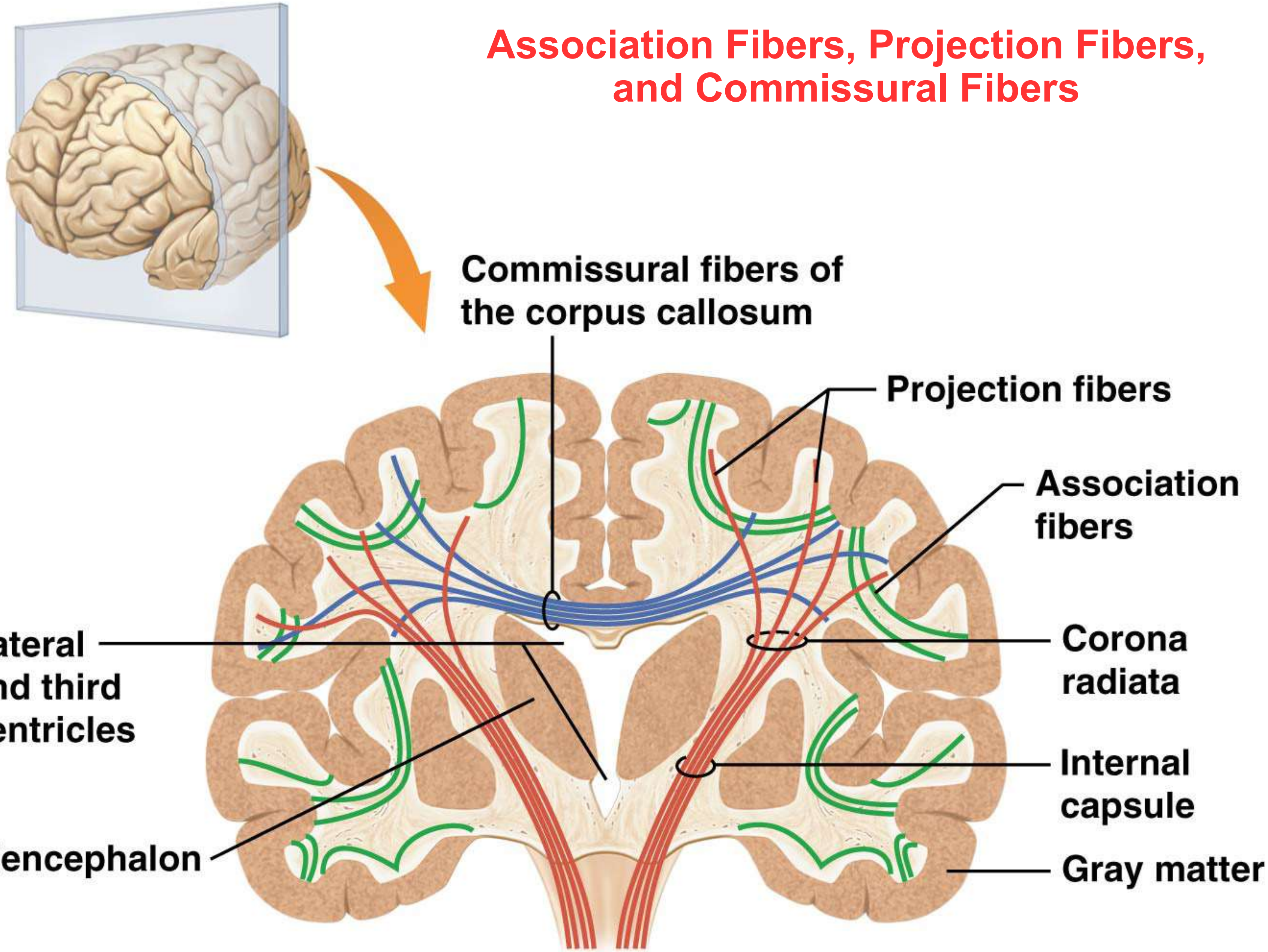
White matter = bundles of myalinated axons

- lies deep to cortical gray matter, opposite relationship in the spinal cord
- pearly white color from myelin around nerve fibers
- this myelin arranged as tracts = bundles of axons
- within cerebrum connect one part of the brain to another, and to the spinal cord



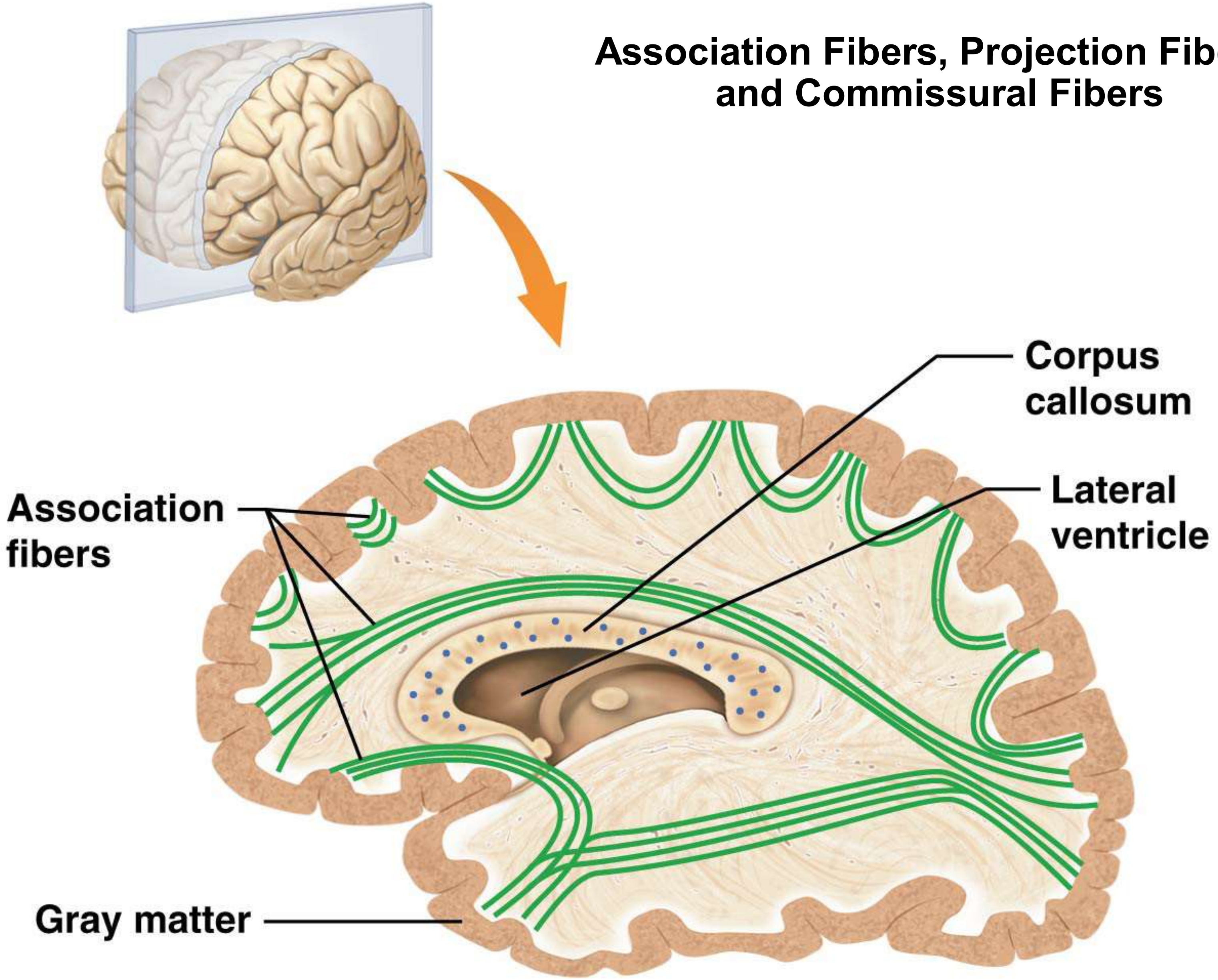
(c) Frontal section of brain and spinal cord

Association Fibers, Projection Fibers, and Commissural Fibers



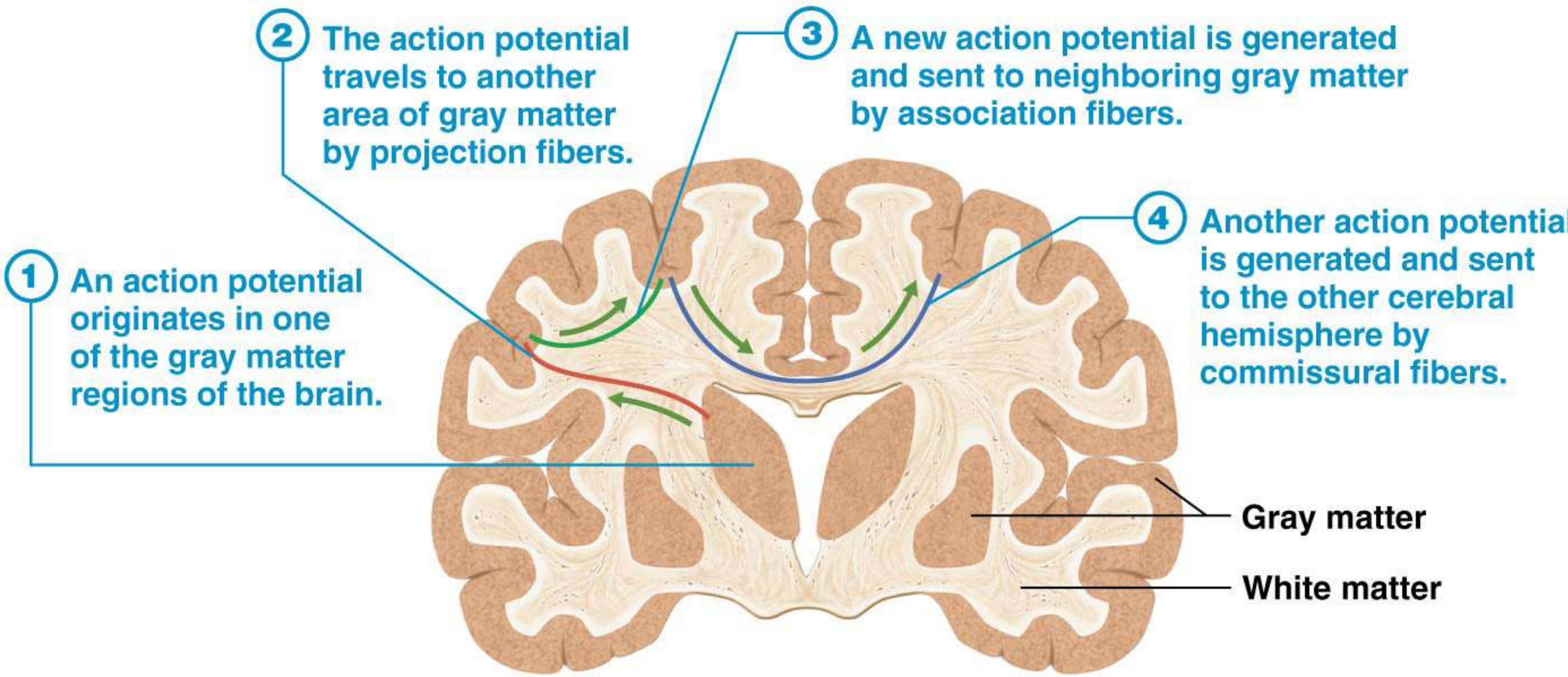
(a) Frontal section

Association Fibers, Projection Fibers, and Commissural Fibers

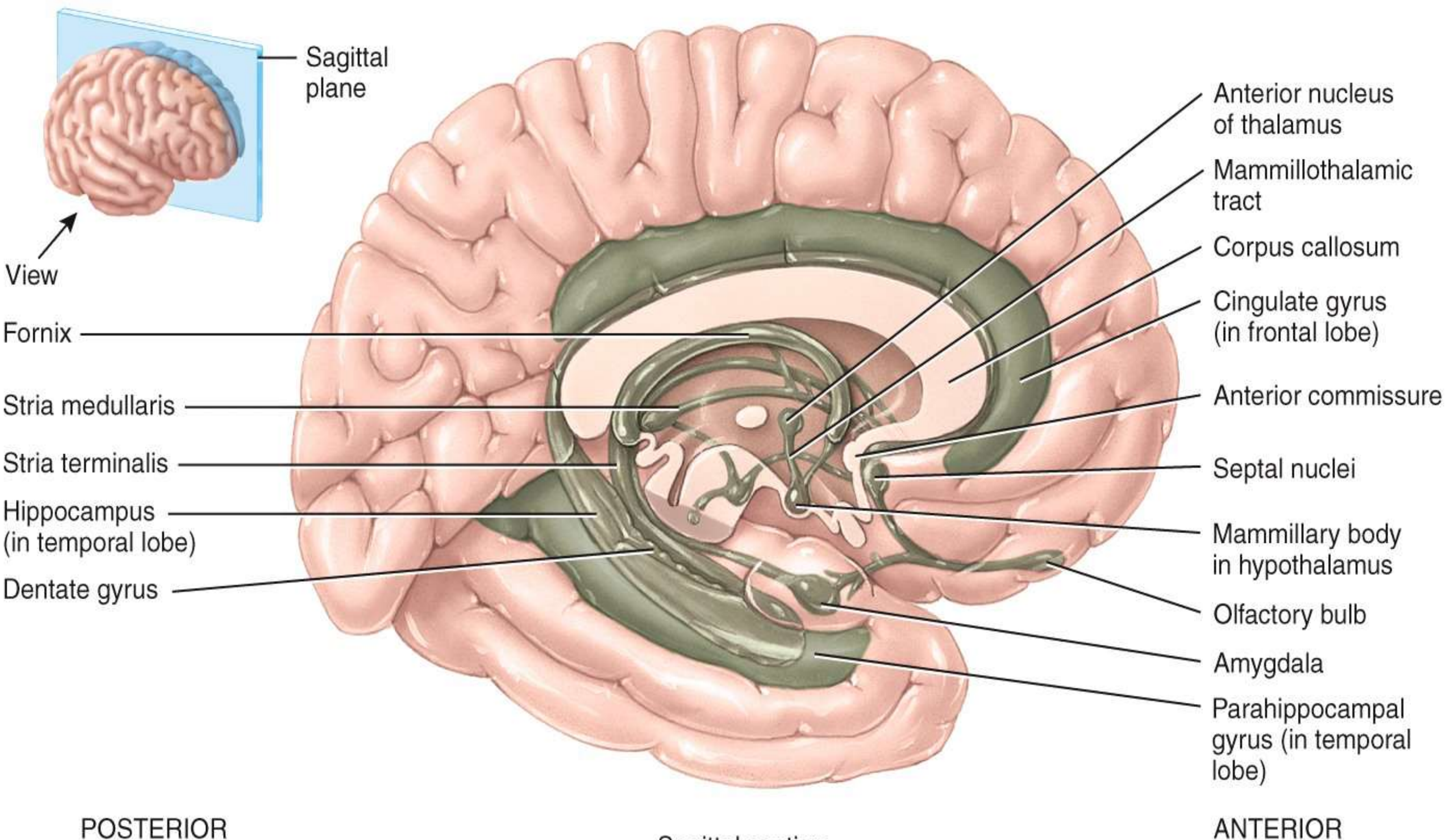


(b) Parasagittal section

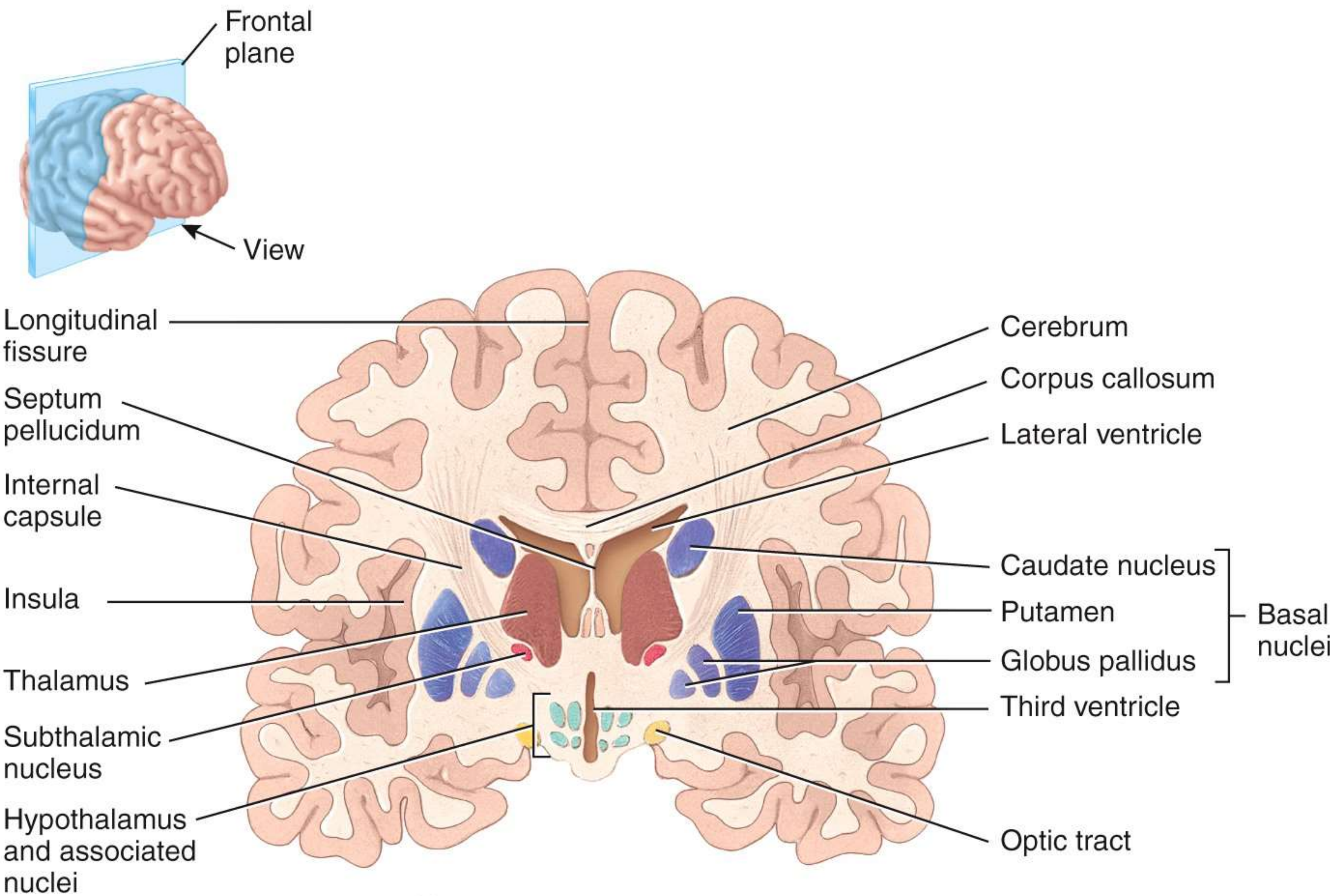
A possible pathway for conduction of an action potential in the brain.



The Limbic System

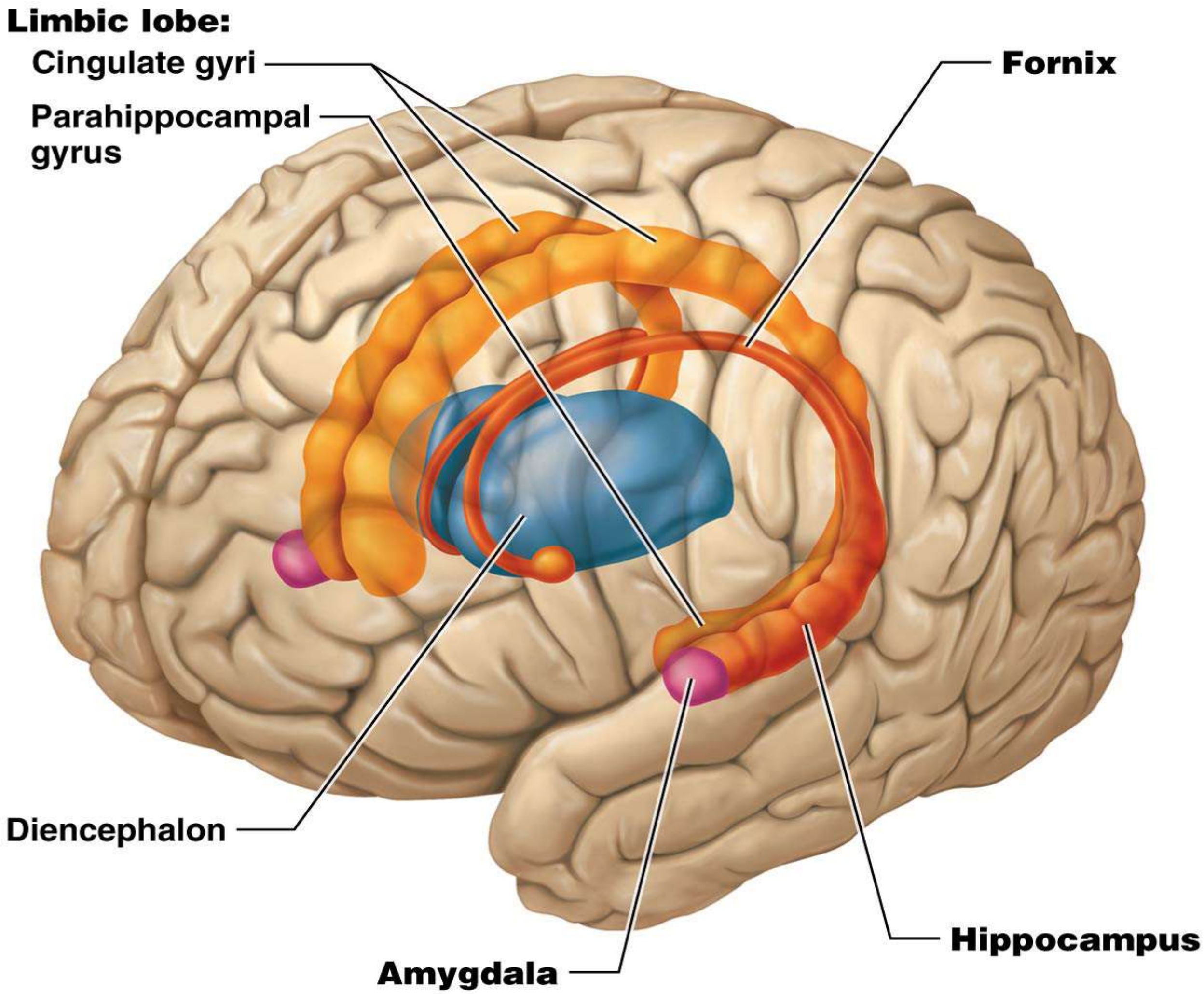


Sagittal section

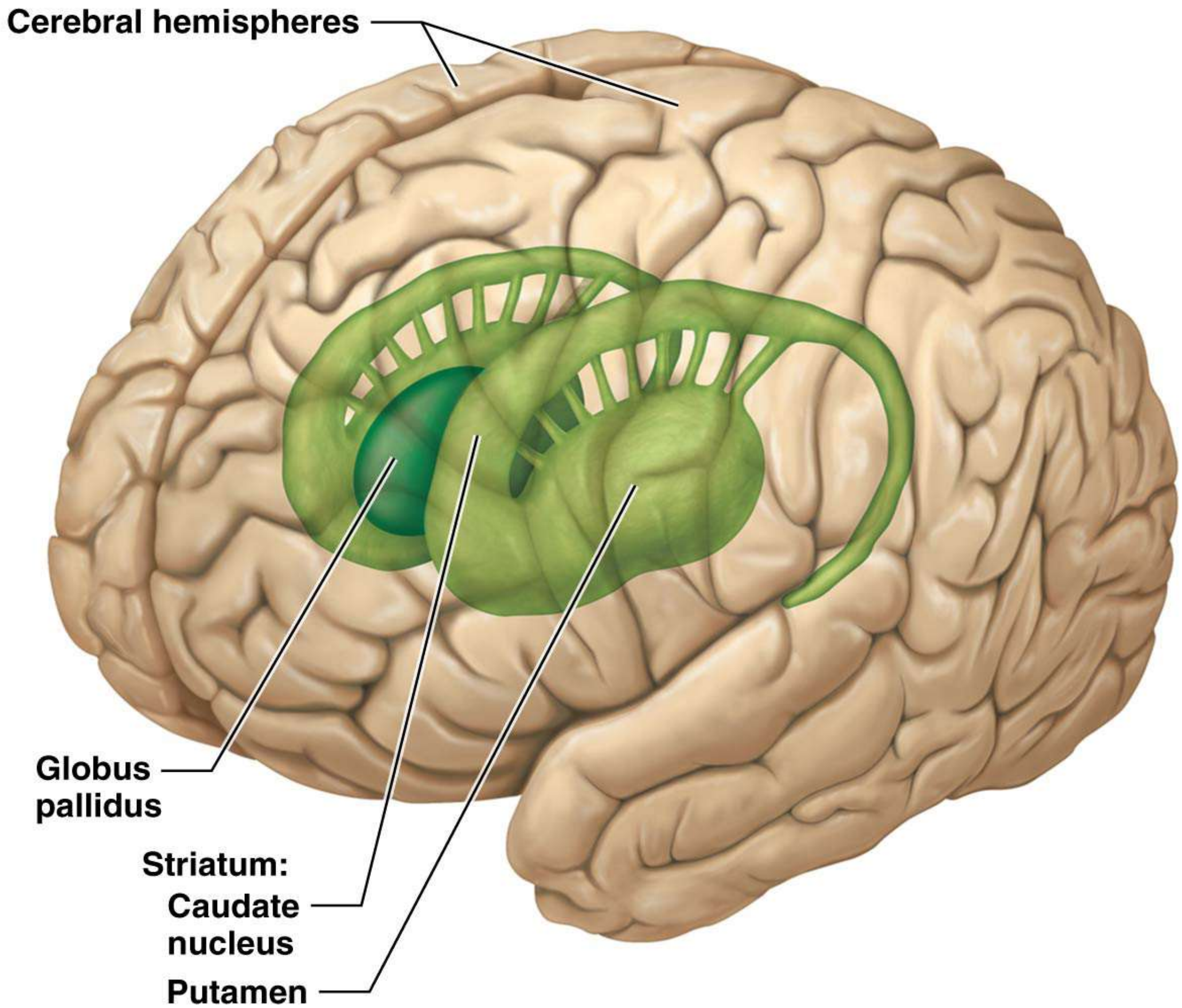


(b) Anterior view of frontal section

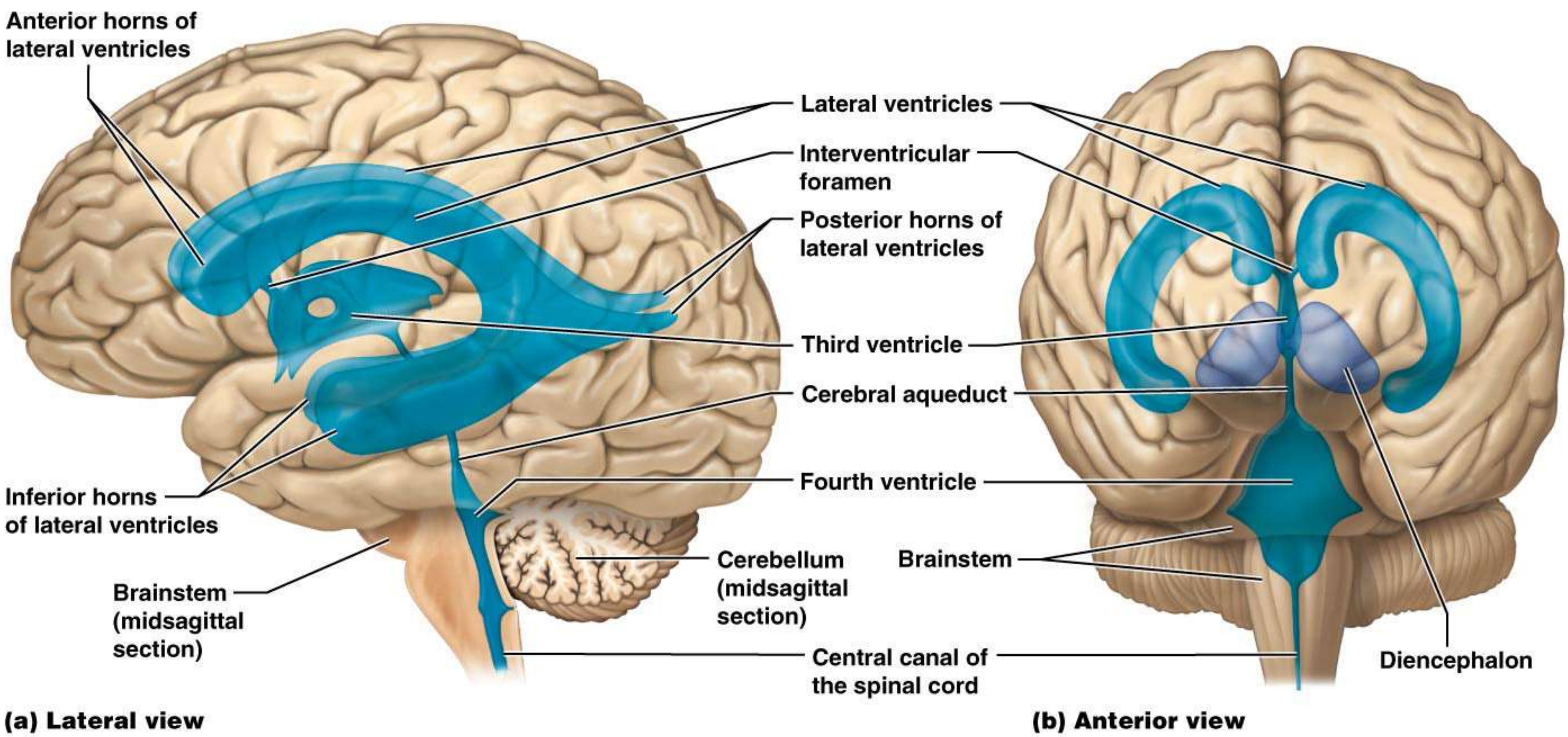
Limbic System Structues (incomplete)

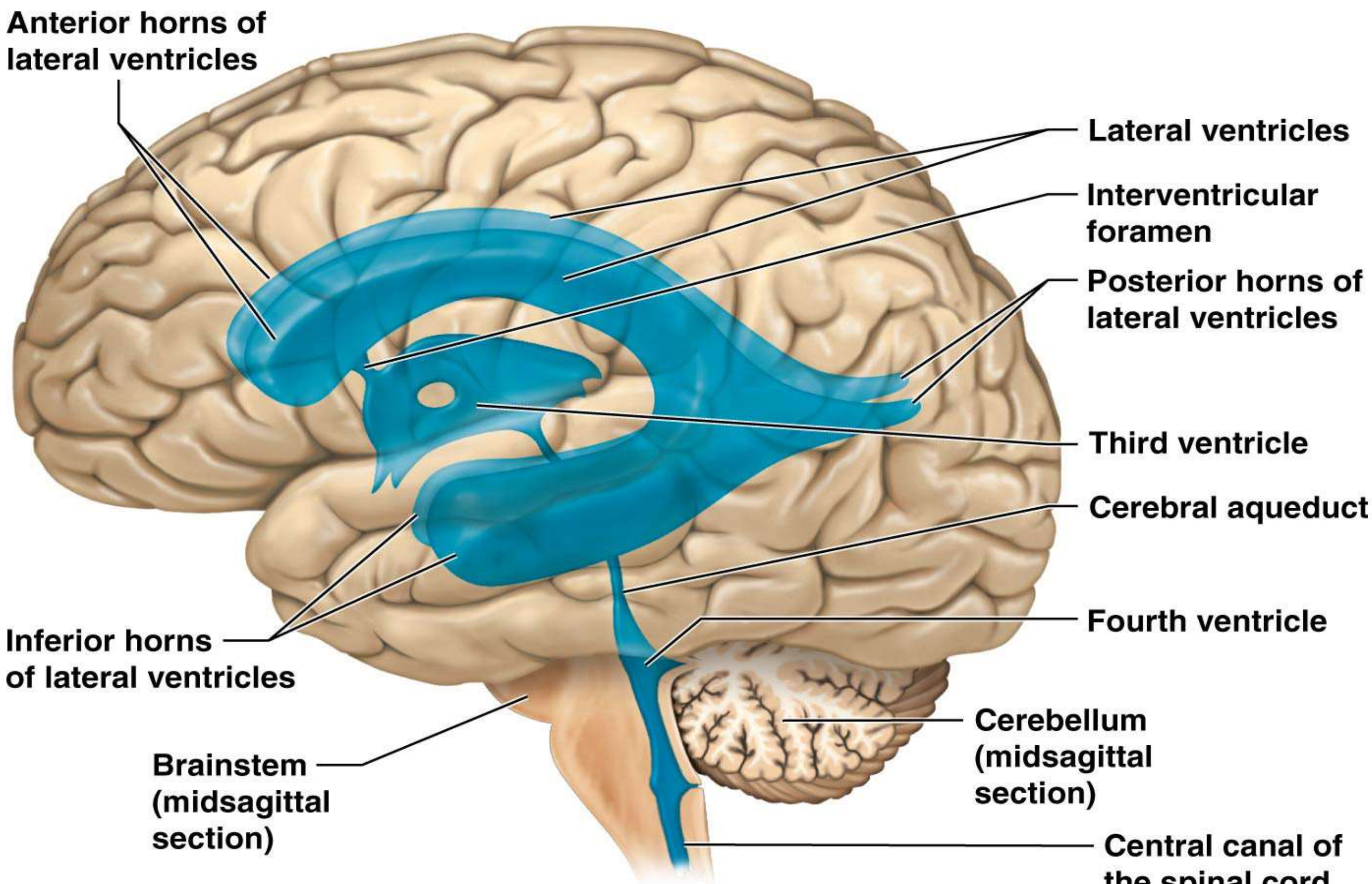


Structure of the basal nuclei.
(anterolateral view)

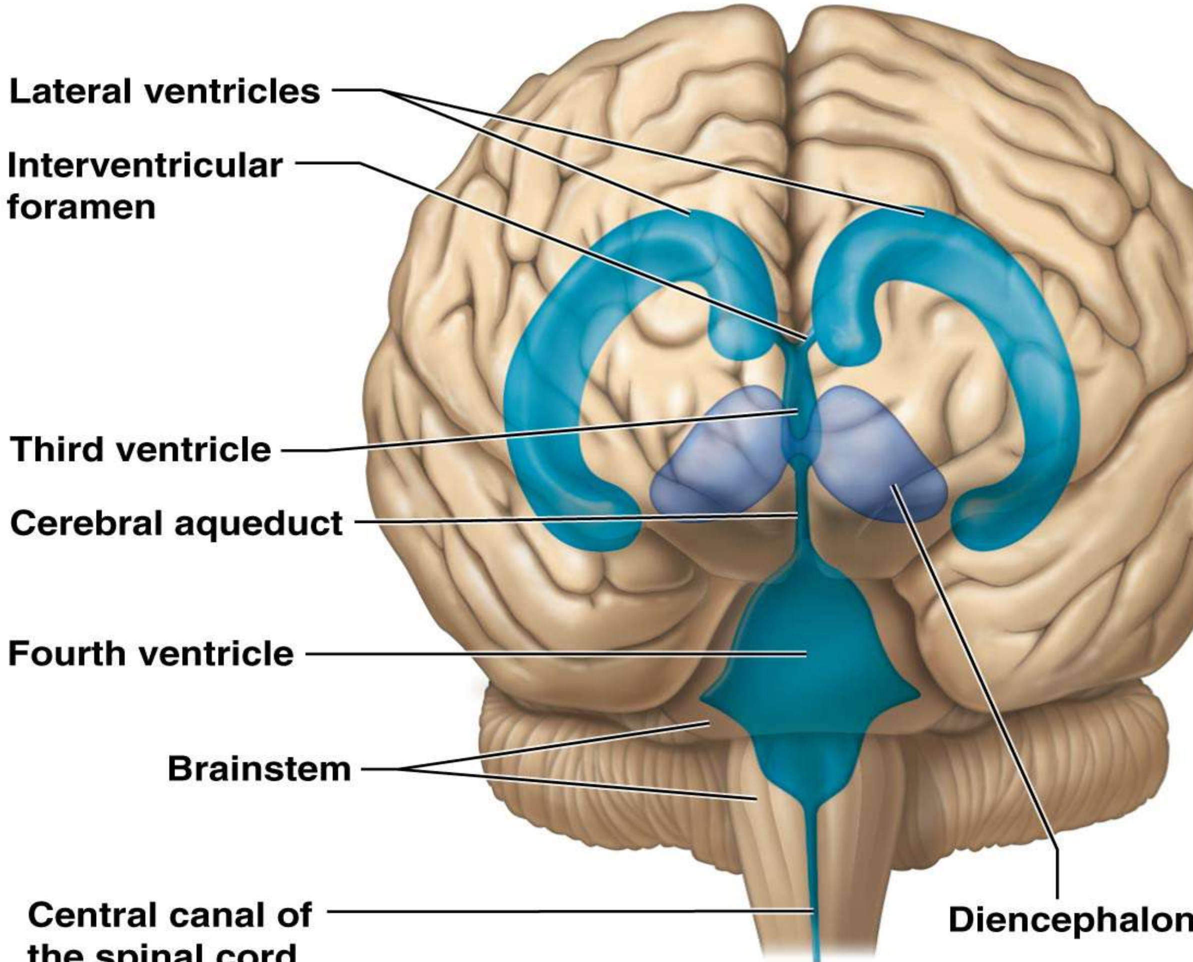


Ventricles of the brain.



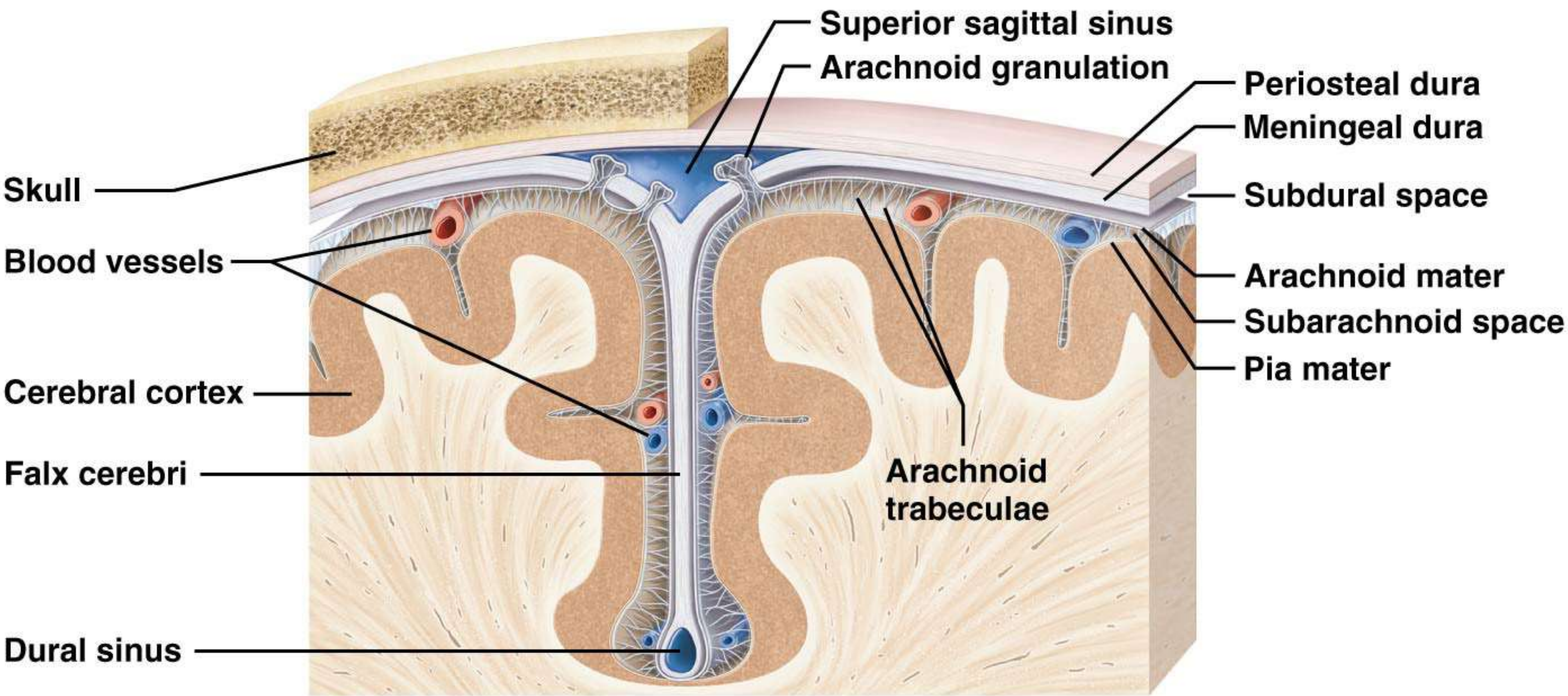


(a) Lateral view



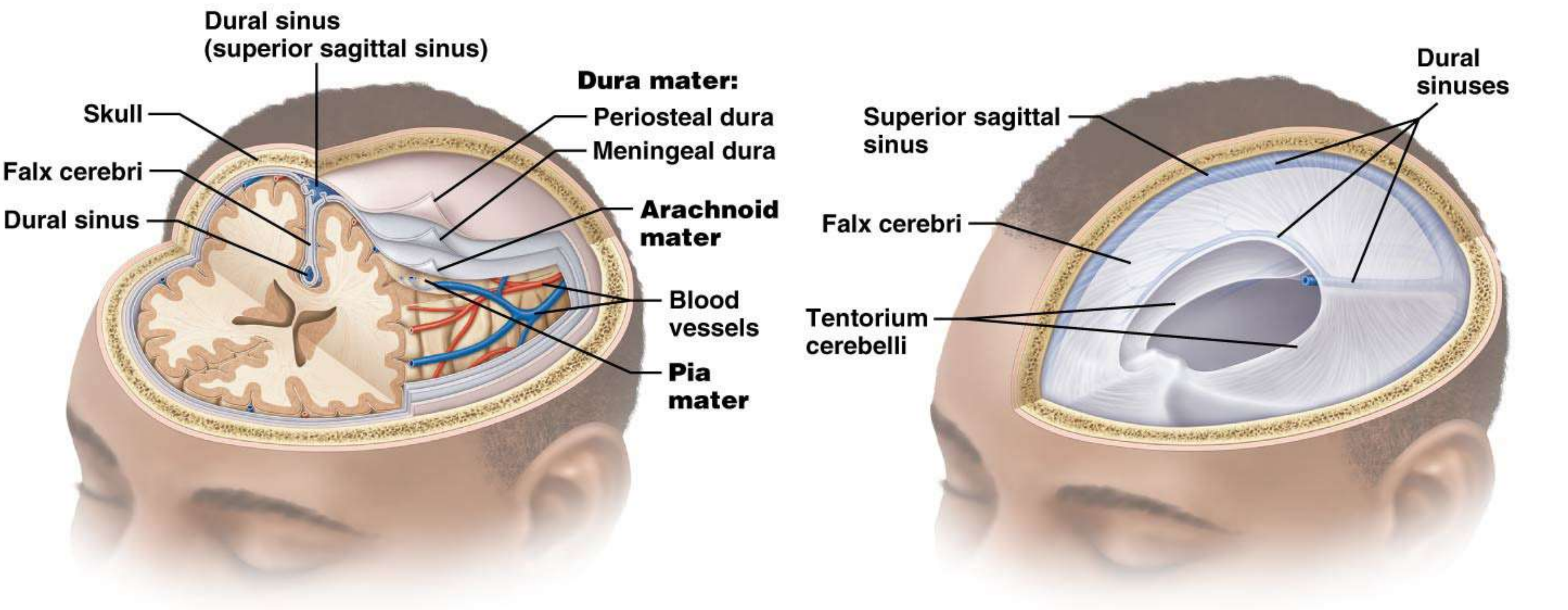
(b) Anterior view

Structure of the cranial meninges and dural sinuses.



(c) Cranial meninges, frontal section

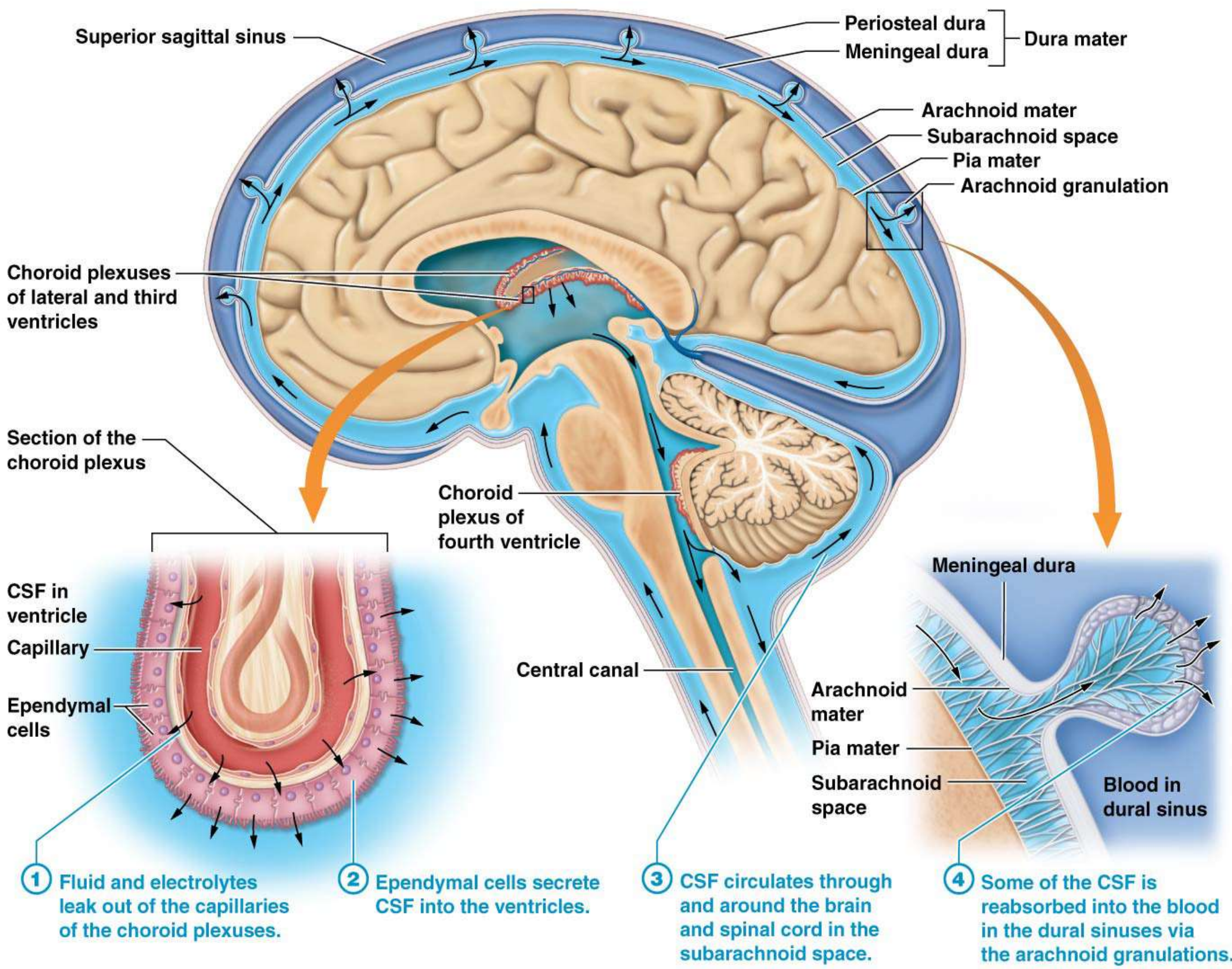
Structure of the cranial meninges and dural sinuses.



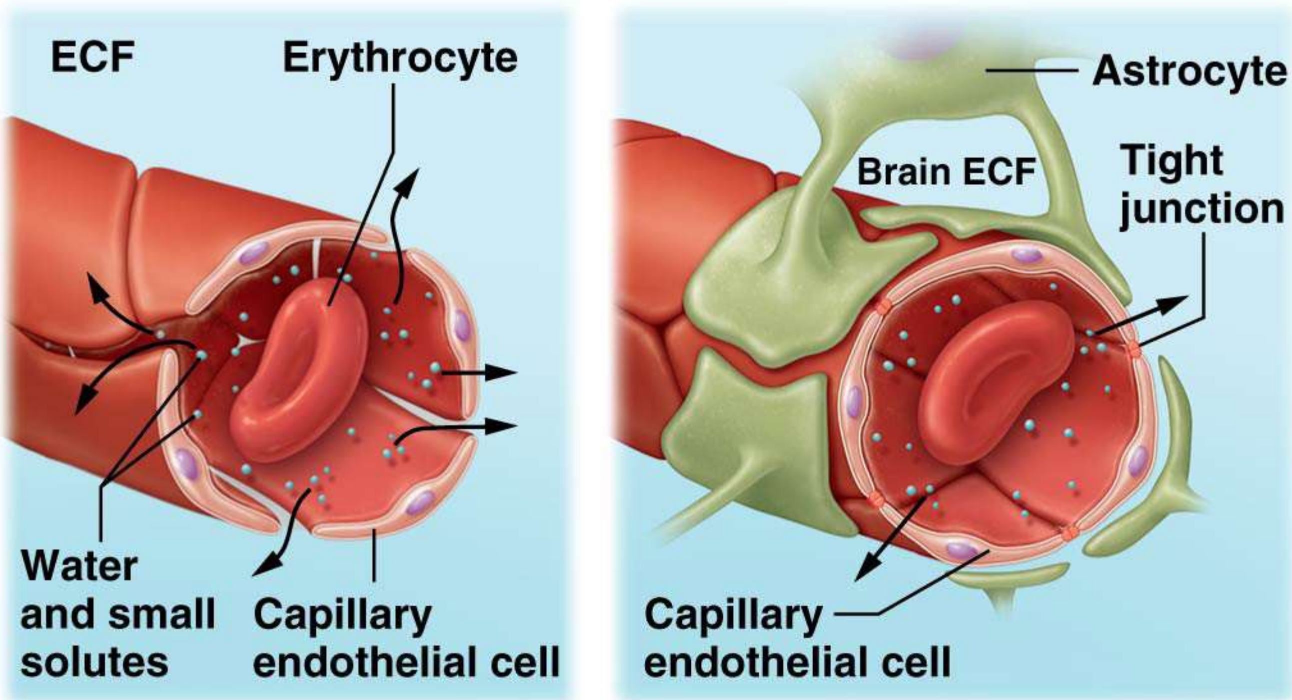
(a) Cranial meninges

(b) Dural folds and dural sinuses

Formation and flow of cerebrospinal fluid (CSF).



The blood-brain barrier.



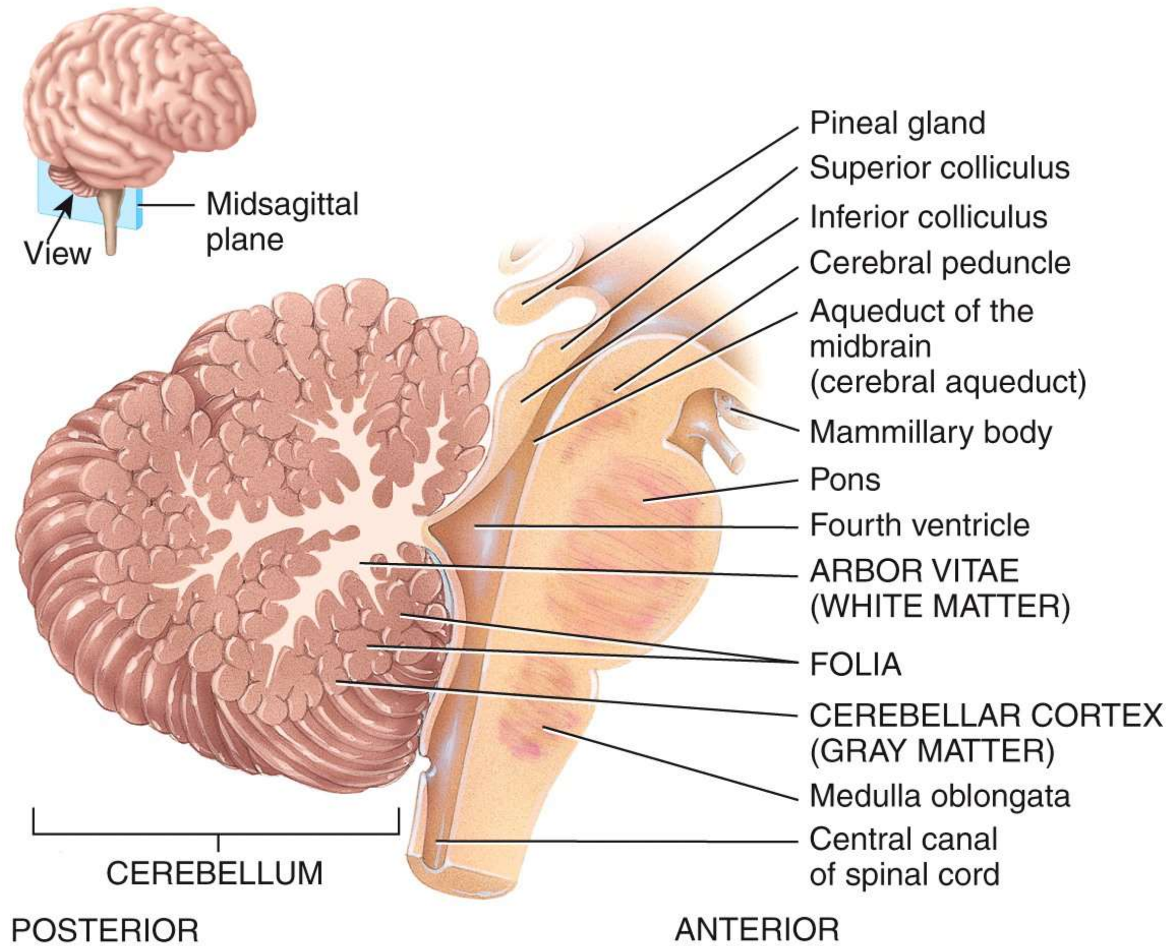
A typical capillary allows water and small solutes to move from the blood to the ECF.

Astrocytes and tight junctions in brain capillaries limit the solutes that enter the brain ECF.

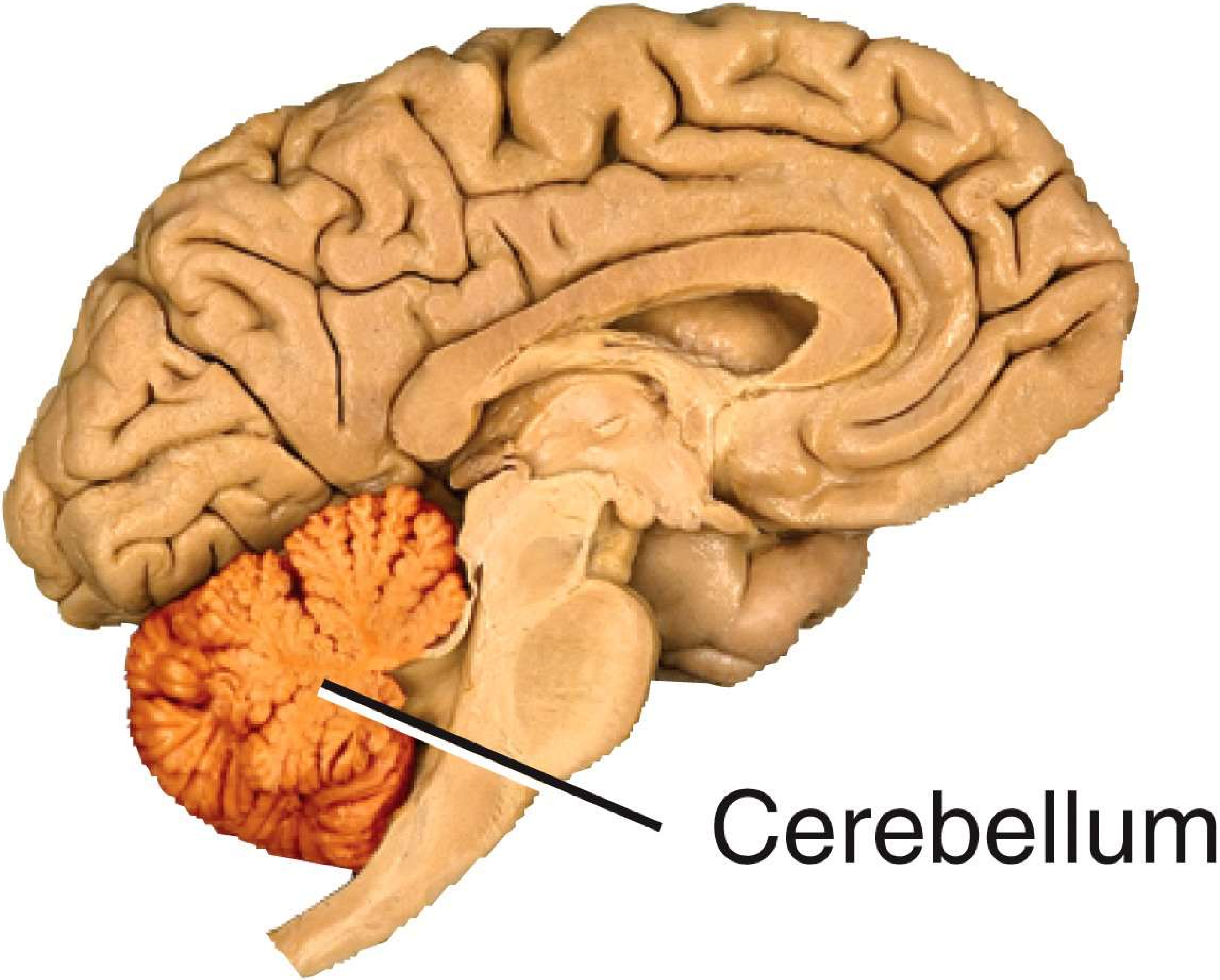
Note: There is also a blood-cerbrofluid barrier but no cerbrofluid-brain interstitial barrier.

Cerebellum

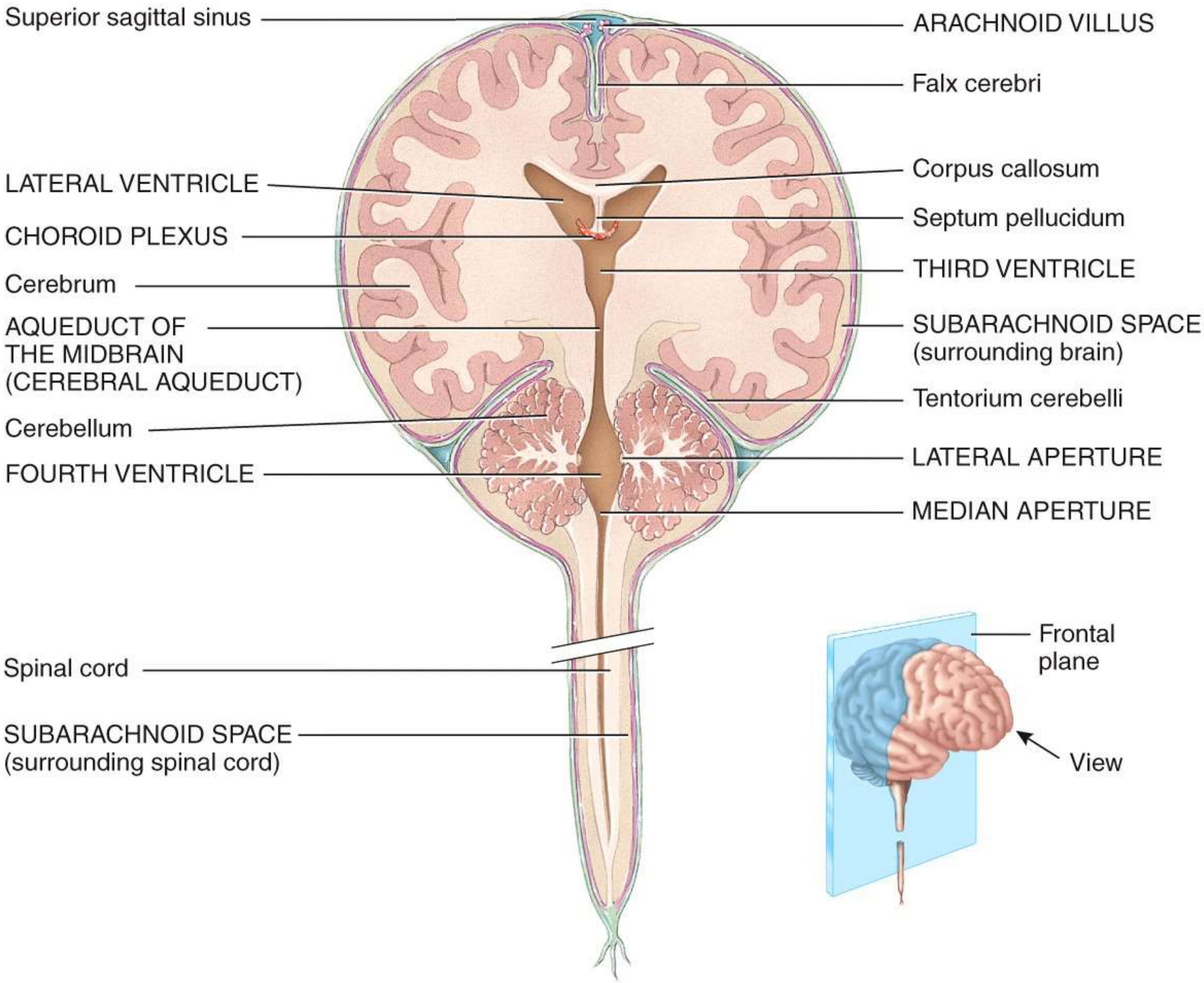
- occupies <u>posterior cranial fossa</u>
- marked by gyri, sulci, and fissures
- about 10% of brain volume
- contains over 50% of brain neurons



(c) Midsagittal section of cerebellum and brain stem

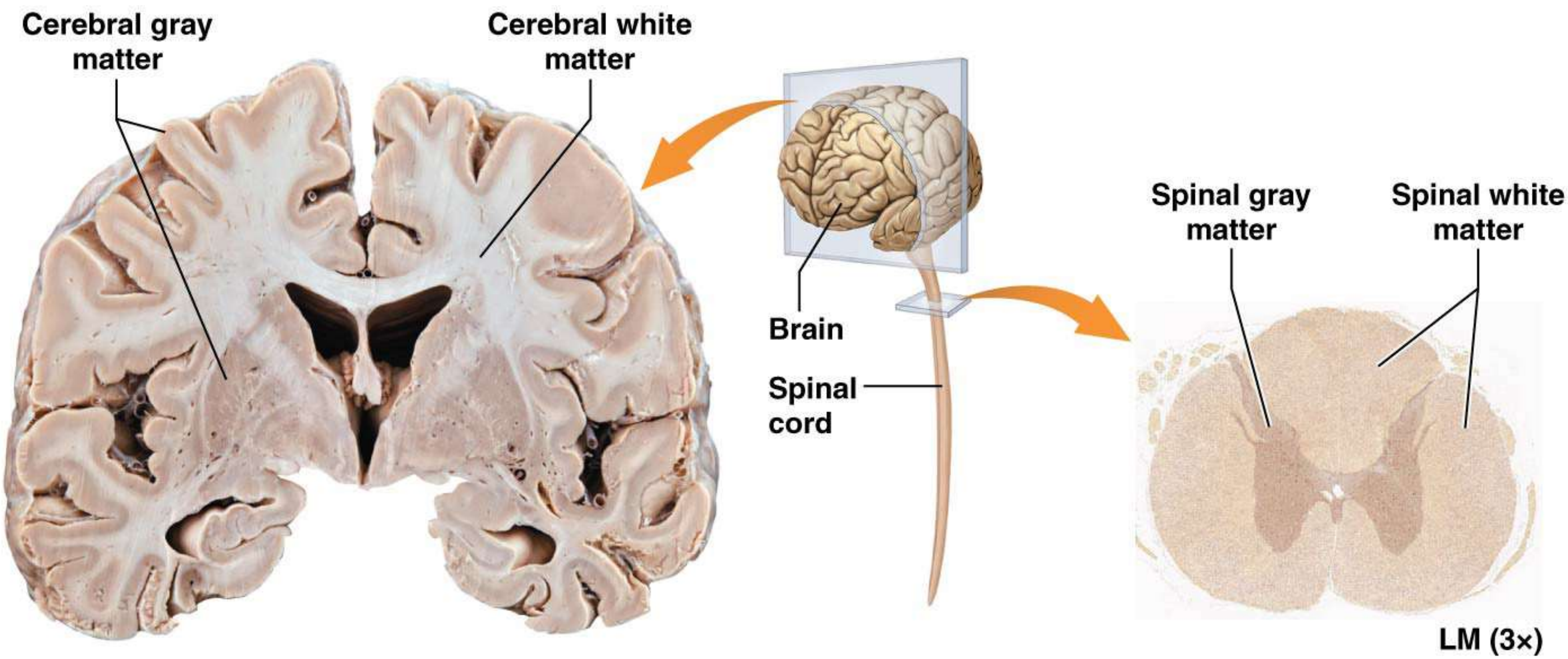


Dissection Shawn Miller, Photograph Mark Nielsen



(c) Frontal section of brain and spinal cord

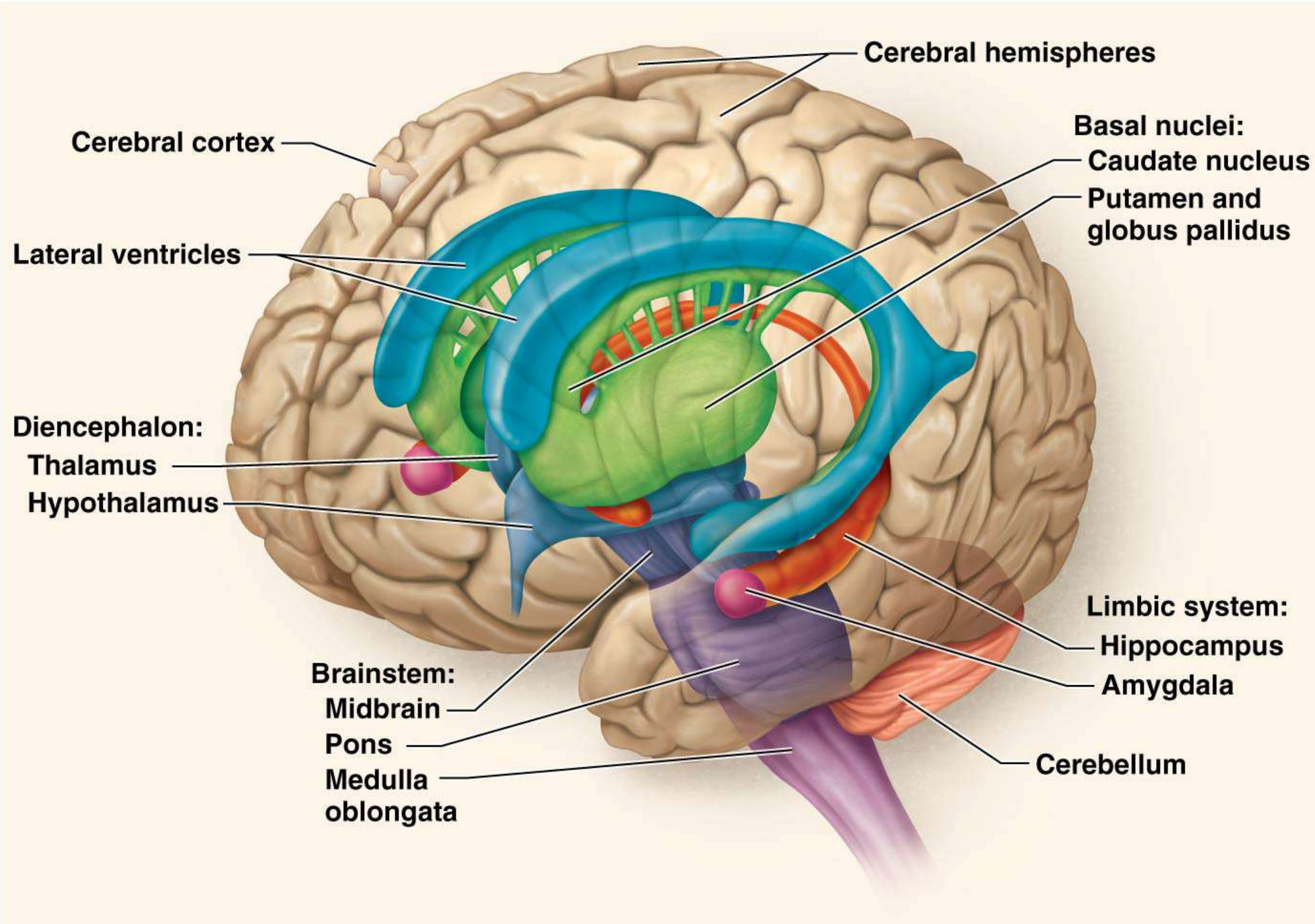
How white and gray matter in the CNS is organized in the brain and spinal cord.



(a) Brain, frontal section

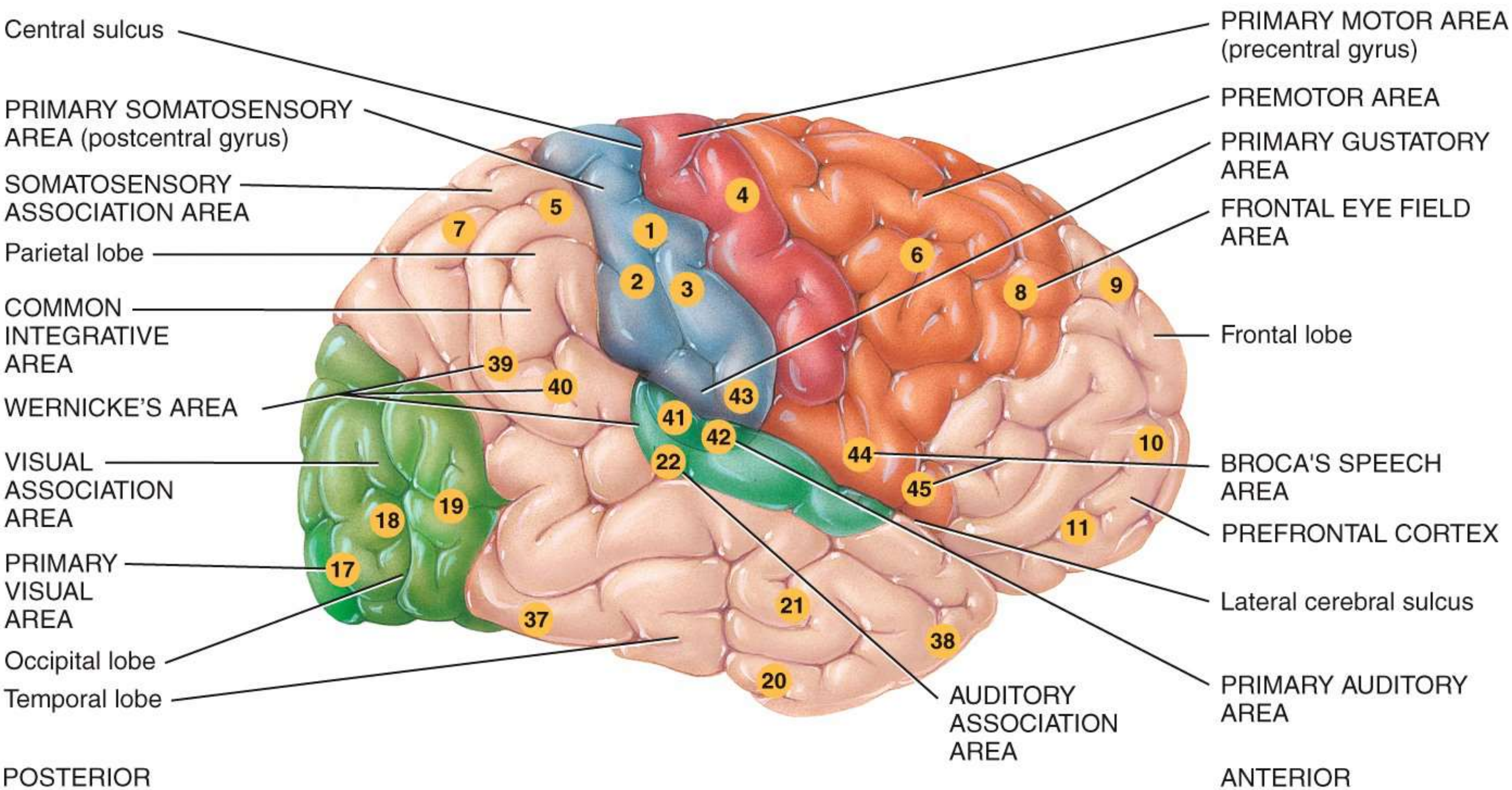
(b) Spinal cord, transverse section

The Big Picture of Brain Anatomy.



Introduction to Brain Function

(Structure VS Function)



Lateral view of right cerebral hemisphere

Strange Factoids About Brain Function

Structurally, we have one brain, however. Functionally, we have many brains with different “types of memories” and different “states of awareness” (i.e. unconscious, subconscious, and conscious). This brings into questions how we reach decisions and form opinions and why!   So how would you explain the following........

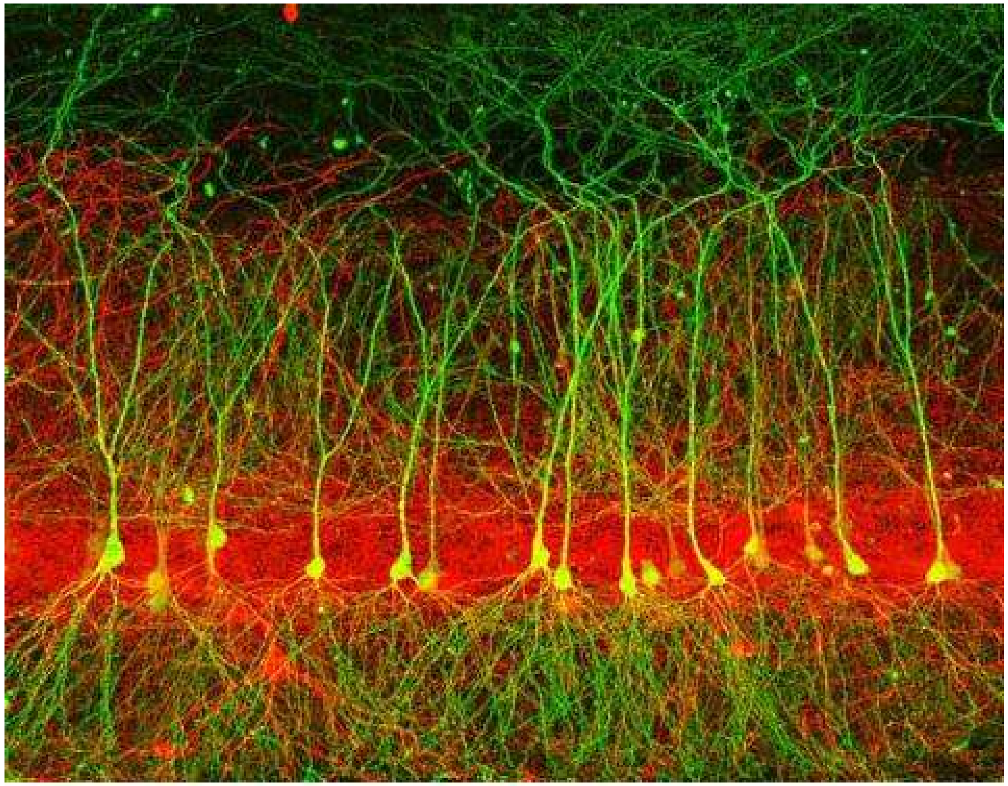
If there is a “foul smell” in the room then you are more likely to make a “harsh decision”.

If you sit near a container of “hand sanitizer cleaner” then your political opinions shift more toward the “political right”.

If you hold a cup of “hot coffee” then you will have a “more pleasant feeling about your mother”.

If a woman's iris is dilated then men find her more “desirable”.

Colored three-dimensional magnetic resonance imaging (MRI) scan showing molecules with many hydrogens (water and fatty acids). The fatty acids show the tracts (white matter pathways of the brain). Lateral view.



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The key to understanding how our brains work lies in determining how each nerve cell or neuron continuously integrates the information it receives from other neurons via connections called synapses. For example, each pyramidal neuron (colored green) can receive tens of thousands of synapses from neurons belonging to several different brain regions. Interneurons (colored red) form local connections onto pyramidal neurons to form specific microcircuits. By using a combination of approaches including electrophysiology, microscopy, molecular biology and computer modeling, scientists are able to approach the complex puzzle of understanding how the 100 billion neurons in our brains make us who we are.

Technical Details:
The image was produced using array tomography. This technique involves collecting thousands of ultrathin serial sections of brain tissue that was fixed and stained, imaging them with a fluorescent microscope, and aligning all of them into a 3D reconstruction using a computer. The resulting image enables the detailed patterns of connectivity to be mapped between fluorescently-labeled neurons.

Credit:
Erik Bloss, PhD and Nelson Spruston, PhD., HHMI, Janelia Research Campus