Anatomy of the Nervous System

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Central Nervous System

Fundamental Subdivisions of Brain

The same idea like the git system

Forebrain (prosencephalon) المصطلحات الي بين القوسين لها علاقة بالاجنين وبداية تكوين الاعضاء

Two parts

Telencephalon: Two lateral extensions, each of which looks like half of a sphere, known as cerebral hemisphere. They overhang the diencephalon (thalamus) form both sides and together form a sphere known as **cerebrum**. The surface (gross) anatomy

These 2 hemispheres Separated by main longitudinal fissure

تخيل معي انو الtelencephalon هو الجزء المعلق فوق ال diencephalin

Diencephalon: Central midline part, it forms different components of thalamus. To see the diencephalon we should open the two hemisphere

Midbrain (mesencephalon) Proximal to the pons

It is shortest and simplest out of the three components of brain.

Hindbrain (rhombencephalon)

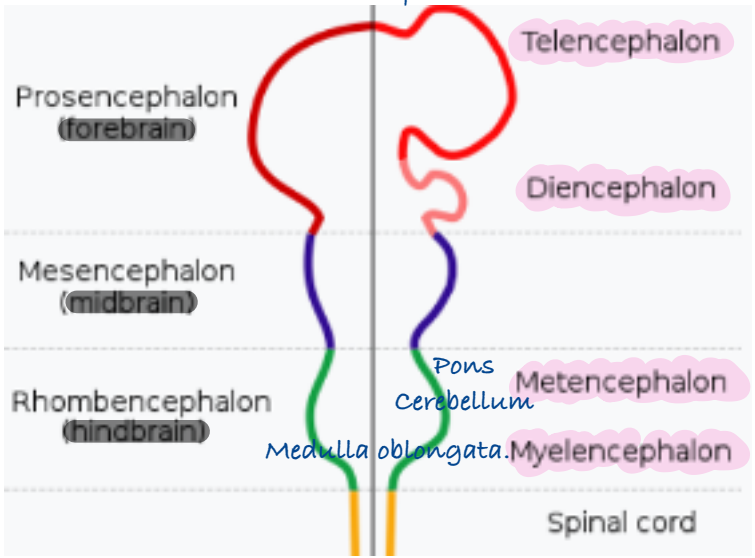
It is subdivided into:

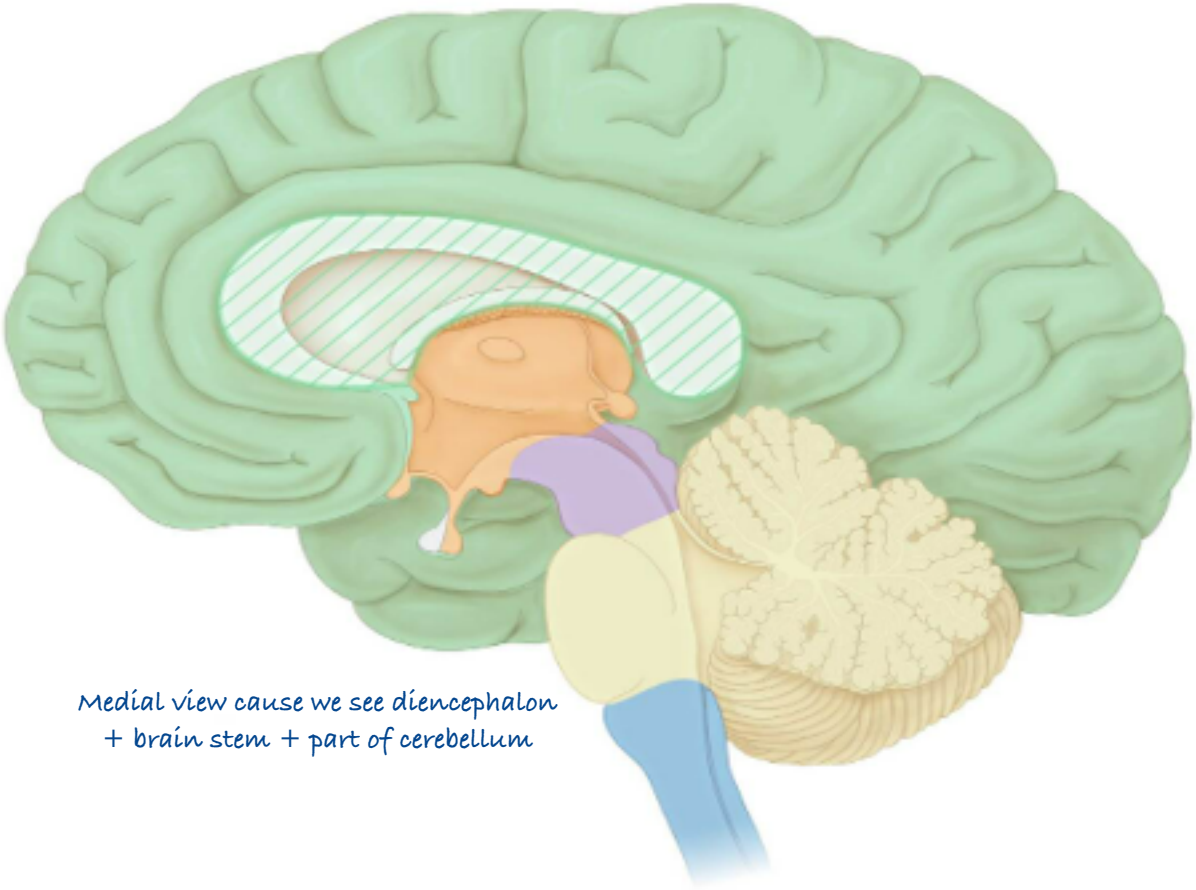
Proximal (Metencephalon): Which is further subdivided into two parts: 1. Ventral: Pons 2. Dorsal: Cerebellum

Part of brain stem

Distal (Myelencephalon): 3. *Medulla oblongata*

Last part of brain stem





Medial view cause we see diencephalon + brain stem + part of cerebellum

Telencephalon (cerebrum)

Corpus callosum

Diencephalon

Thalamus related structure

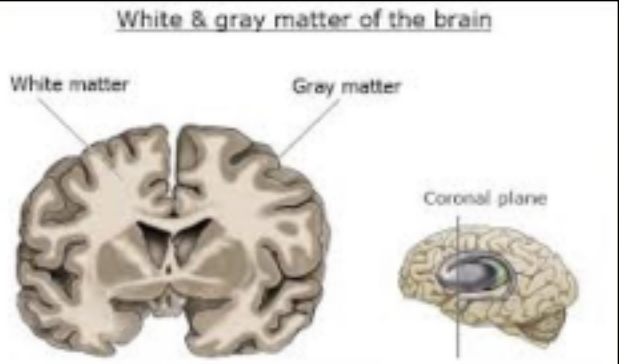
Mesencephalon (midbrain)

Metencephalon (pons and cerebellum)

Myelencephalon (medulla oblongata)

Cerebrum

الفكرة هان انو بشكل عام اي مكان لتجمع الcell bodeis تعود الneorons الي هيا الخلية العصبية وهادة النيورون اله cell body بتوصل الاشارة من fibres لآخر
هسا الفكرة انو تجمع الخلايا تاعت الneurons بتعمل الgray matter.
اما الfibres بغض النظر عن نوعها لو كانت uni or bi polar بتعمل الwhite matter.



- **Outer gray matter and inner white matter**: (The gray overlying the white; Cortex; Medulla)

superficial part of cerebrum is made up of grayish colored neuronal cell bodies which forms **gray matter**. This constitutes **cerebral cortex**. Deep inner or central core is made up of process of neurons which are whitish myelinated nerve fibers. This component of cerebrum is called **white matter** or **medullary substance**

- The cerebral cortex receives its convoluted appearance from a network of **gyri** (rounded ridges on the surface of the cortex) and **sulci** (furrows separating the gyri).

التعرجات تاعت المخ
نفس فكرة الfissure يعني الفواصل الي بين الأجزاء المتعرجة

- The **longitudinal fissure** divides the brain into two hemispheres. Rt + Lt

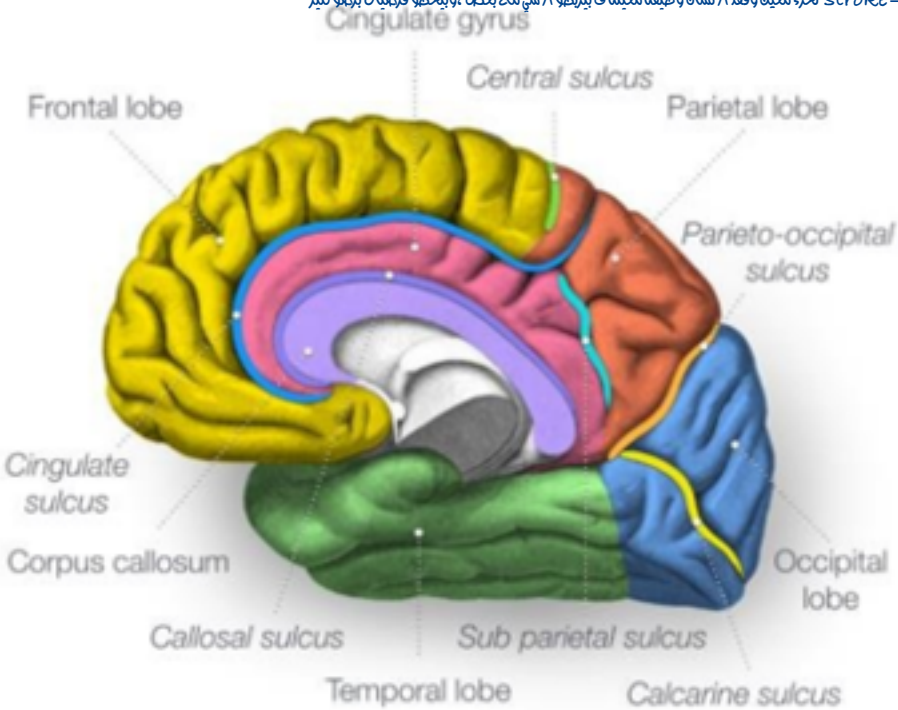
- **Deep sulci** divide each hemisphere further into a **frontal**, **temporal**, **parietal**, and **occipital lobe**. (Most ant.; Lateral; Superior; Posterso inferior)

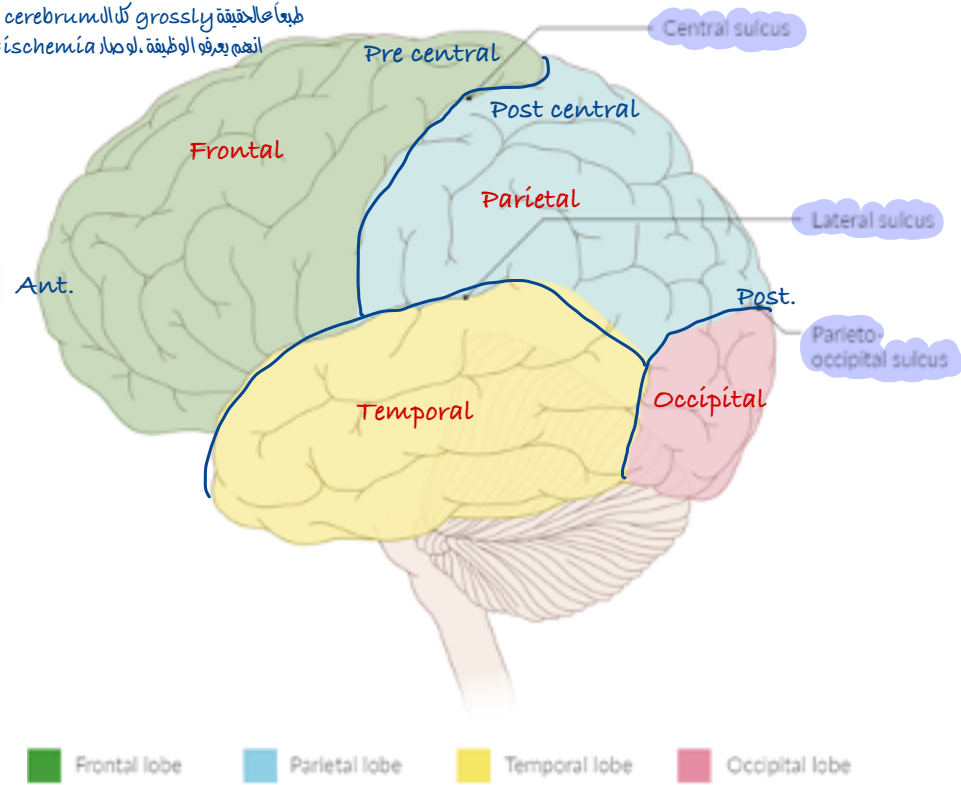
Parts or lobes of the cerebrum.

5th lobe: Insular lobe
بيكون مختفي تحت الfrontal+frontoparitel+temporal
خنحكي عنه كمان كم سلايد

بيكون مختفي تحت اللوهدول ب

طبعاً الحقيقة grossly كل الـcerebrumبيبين كـ نسيج واحد وما فيه اختلاف، كل فكرة التقسيم لـ أجزاء ومناطق بناءً على الوظيفة تاعت هاد الجزء، وفكرة انهم يعرفو الوظيفة، لو صار stroke=ischemia لجزء معين وفقد الانسان وظيفة معينة ف بيربطو الشي مع بعض، وبيحطو فرضيات برضو كتير



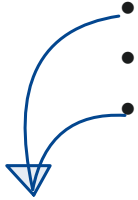


The 4 lobes of each cerebral hemisphere are separated by 3 main sulci:

–The central sulcus separates the frontal lobe from the parietal lobe.
–The lateral sulcus separates the temporal lobe from the frontal lobe and the parietal lobe.
–The parieto-occipital sulcus separates the parietal lobe from the occipital lobe.

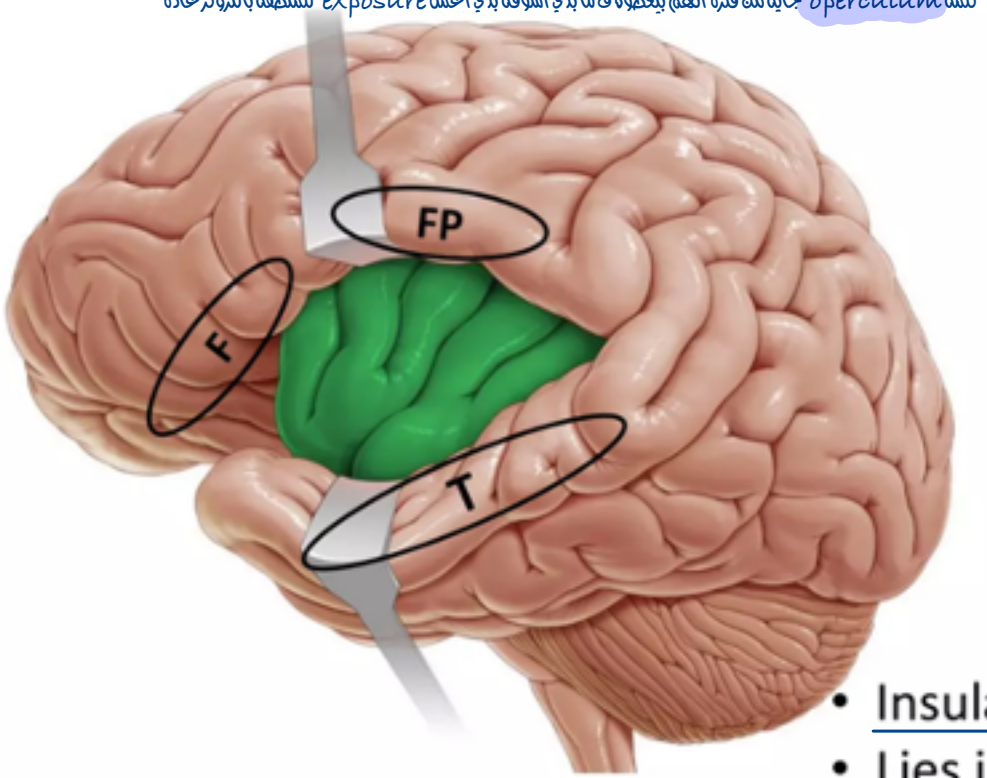
- **The main sulci**

  - **Central sulcus (of Rolando):** separates the frontal and parietal lobes
  - **Lateral sulcus (Sylvian fissure**): separates the frontal and temporal lobes anteriorly and the parietal and temporal lobes posteriorly
  - **Cingulate sulcus:** separates the cingulate gyrus from the frontal and parietal lobes
  - **Parieto-occipital sulcus:** separates the parietal and occipital lobes
  - **Calcarine sulcus**: divides the occipital lobe horizontally into the **cuneus** (superior) and **lingual** (inferior) gyrus



May be added with main sulci

كلمة operculum جاية من فكرة انهم بيغطوه ف ما بدي اشوفه بدي اعمل exposure للمنطقة بالتوكر عادة



5th lobe of cerebrum!
Insula or Insular lobe

1. Frontal operculum
2. Frontoparietal operculum
3. Temporal operculum

frontal+frontoparitel+temporal الاثنين مختفي تحت بيكون

- Insula (*hidden island*)
- Lies in the depth of lateral sulcus
- Surrounding areas which cover the insula are called as **opercula** (meaning: **lid**).

Function of the insula lobe: The main function is related to pain

The insula is important for gustatory and sensorimotor processing, risk-reward behavior, autonomics, pain pathways, and auditory and vestibular functioning. It is because of insula that people are able to perceive pain and have the awareness about their body and self.

Precentral or the frontal part called primary motor gyri
Postcentral or the parietal part called primary somato sensory gyri

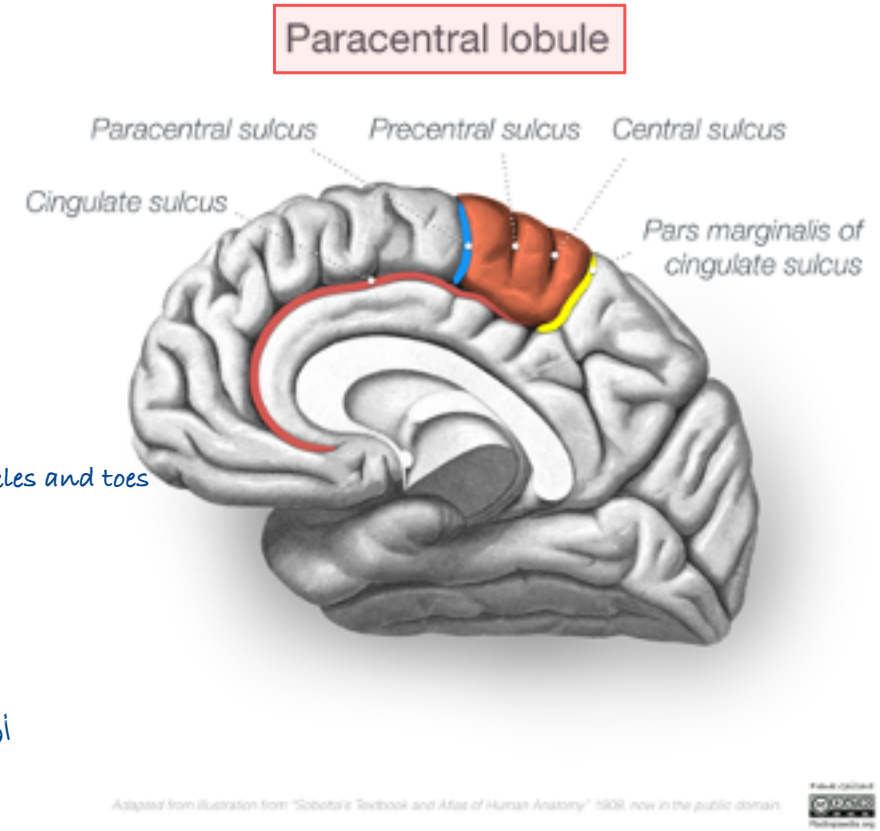
Precentral is followed to frontal
Where postcentral follow the parietal

Paracentral lobule is on the **medial** surface of the hemisphere and is the continuation of the precentral and postcentral gyri.

The paracentral lobule controls motor and sensory innervations of the contralateral lower extremity. Hip, knee, genital organs, ankles and toes

It is also responsible for control of **defecation and urination**. Micturation

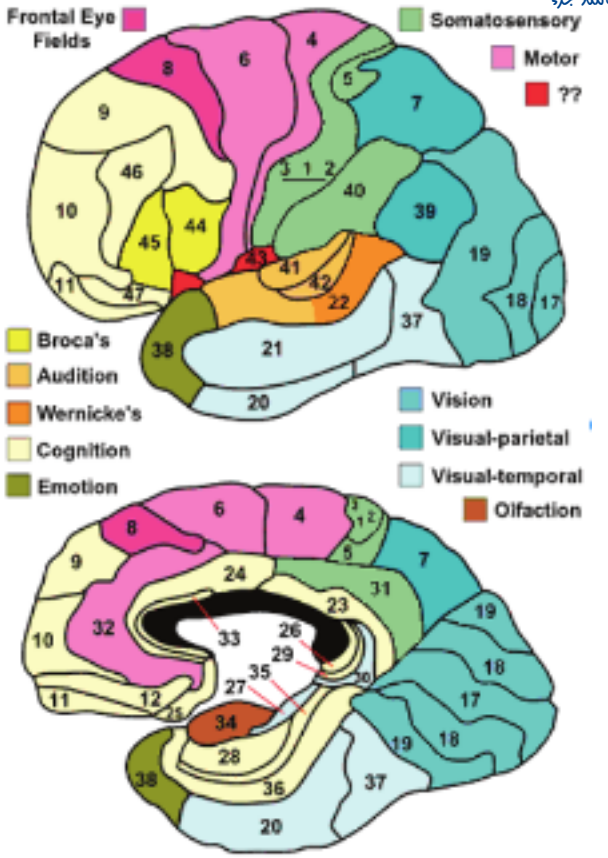
أو ع قولة صاحبنا هداك كل م ينزنق يحكي ايشه ،والله حكا عن هادي بوليشه



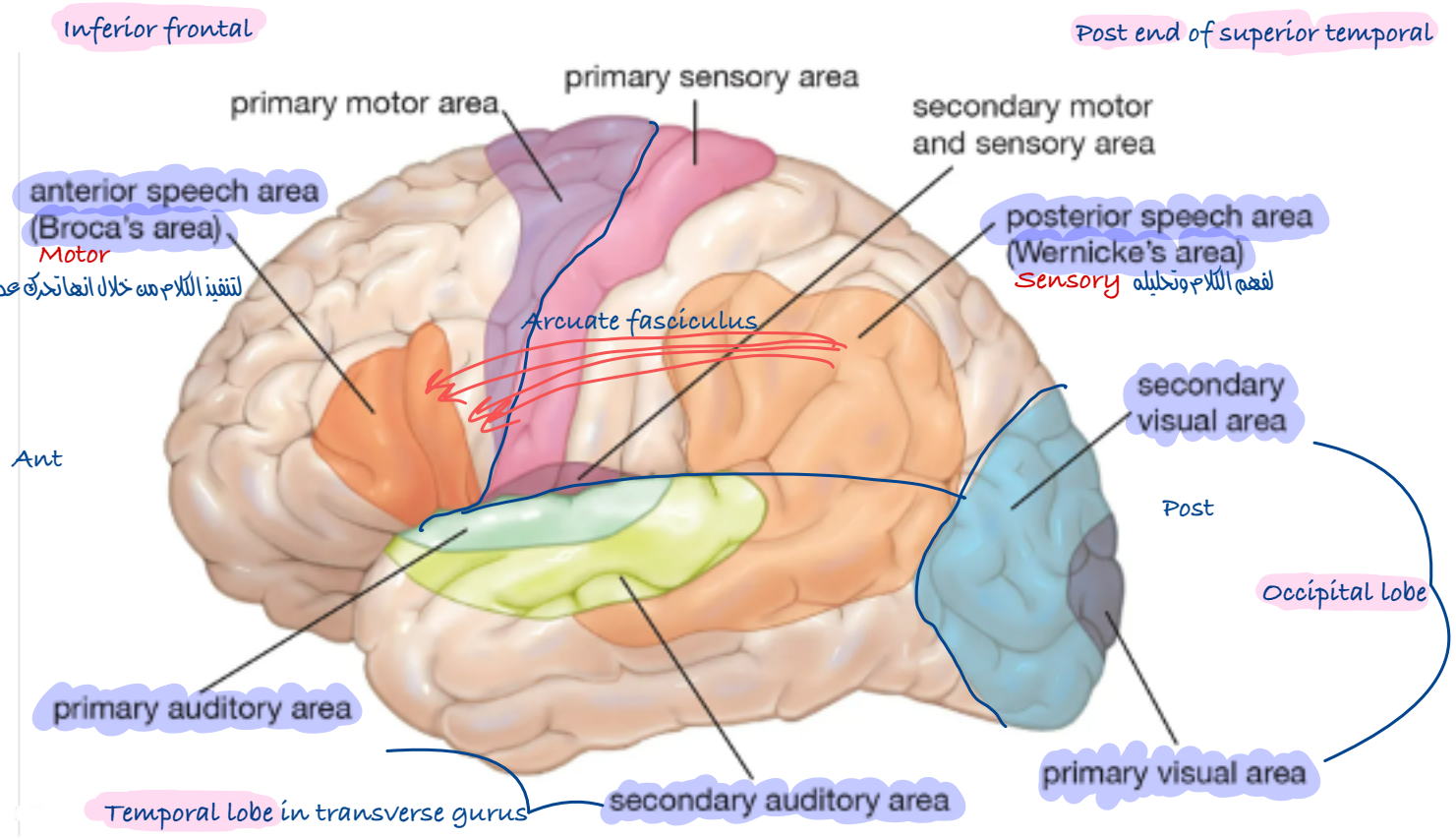
Brodmann’s functional classification

الجداول الجاية مش مطالبين فيهم هاد ممكن ناخدهم بالفسيو وبشكل مبسط كتير قال انه خطهم بالسلايد بس لو احتجنا نرجعلهم

هاد النظام نفس فكرة تقسيم segments و lobes ل lung وال segments & ل liver بس هاد الفكرة انه بيقسمه بناء على انه القروب هاد من الـ gyri بيتشاركو وظيفة معينة مع بعض ف مثلاً جزء للسمع جزء للرؤية جزء للتفكير جزء لاتخاذ قرار

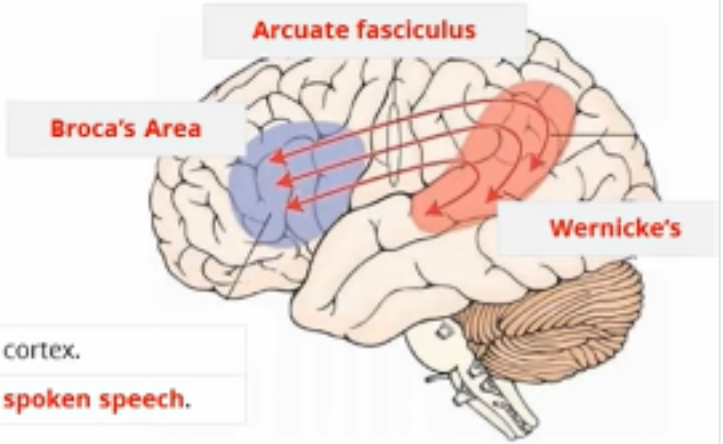


مثلاً صار مؤكد انو الـ occipital lobe يحتوي على ال primary and secondary visual cortex


Inferior frontal
Post end of superior temporal
primary motor area
primary sensory area
secondary motor
and sensory area
anterior speech area
(Broca's area)
Motor
لتنفيذ الكلام من خلال انها تحرك عضلات المسئولين عن الكلام
posterior speech area
(Wernicke's area)
Sensory
لفهم الكلام وتحليله
Arcuate fasciculus
secondary
visual area
Ant
Post
Occipital lobe
primary auditory area
secondary auditory area
primary visual area
Temporal lobe in transverse gurus

Introduction – Speech areas

Speech	An ability to understand or express oneself by spoken or written words.
Areas involved	**Broca's Area & Wernicke's area - Major.** Visual & auditory association area - Accessory areas.



Broca's Area

- Located in **inferior frontal gyrus (Area 44).** +45
- Includes 2 motor areas controlling "Spoken & Written speech".
- Function - **Center for motor part of speech & sentence formulation**
- Connections - Information received from Wernicke's area → Send to motor cortex.
- Lesions → **"Motor/Non-fluent aphasia" - Inability to express oneself by spoken speech.**

هاد الشخص بيكون قادر يستوعب الكلام ويفهم النقاش وكل حاجة بس
المسئول عن انقباض عضلات الكلام مش شغال ف مش حيقدر يتكلم

Wernicke's area

- Located in **posterior end of superior temporal gyrus.**
- Concerned with COMPREHENSION, planning of words & Integration site for 2° somatic, auditory & visual areas.
- Connections - Ultimate signals **send to Broca's area via arcuate fasciculus.**
- Disorder - Lesion results in **"Sensory/Fluent aphasia".**

هاد الشخص بيكون قادر يتكلم بس بدون فهم لانه بني الكلام بدون م يعرف ايش بيحكي او شو الكلام

Disorders of speech

Aphasia — Speech disorders resulting from lesions in brain.

Sensory aphasia

- Cause - **Lesions in Wernicke's area.**
- Intact Broca's area
- C/F - **Defect in comprehension,** fluent & nonsensical speech

Motor/non-fluent aphasia

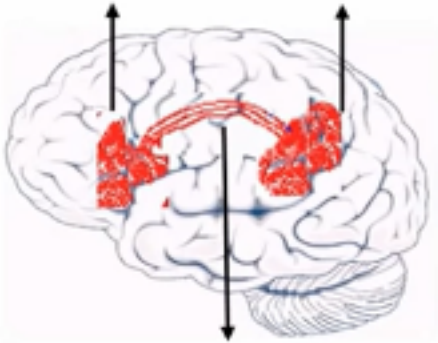
- Cause - **Lesions in Broca's area.**
- Intact Wernicke's area.
- C/F - **Defect in verbal/speech expression,** non-fluent. effortful & slow speech.

Conduction/fluent aphasia

- Cause - **Lesion in arcuate fasciculus.**
- Intact Wernicke's area & Broca's Area
- C\F - **Impaired repetition, preserved comprehension** & fluent speech.

Broca's - Motor aphasia

Sensory aphasia - Wernicke's



Arcuate fasciculus - Conduction aphasia

Areas of Frontal Lobe

Area	Location	Motor and cognitive functions	Effect of lesion

Primary motor cortex (Brodmann area 4)	• Precentral gyrus on the frontal lobe	• Initiation of voluntary movement
		• Gives rise to axons that form the corticospinal tract
		• The cortical regions responsible for processing the motor functions of the different regions of the body can be mapped using the motor homunculus
		  ◦ The individual parts of the body are arranged against the corresponding cortical regions proportionate in size to their degree of innervation (e.g., the hand is represented disproportionately larger than the foot)
		  ◦ Arranged medially to laterally as follows: toes, ankle, knee, hip, trunk, shoulder, elbow, wrist, hand, little finger to thumb, eye, facial expression, mouth, chin, tongue, swallowing
		  ◦ The primary sensory cortex is mapped in the same way using the sensory homunculus
			• Contralateral upper motor neuron dysfunction (e.g., contralateral movement paralysis)
			• Lesions in the paracentral lobule can cause urinary incontinence

Premotor cortex (Brodmann area 6)	• Anterior to the precentral gyrus on the frontal lobe	• Contributes to the corticospinal tract • Involved in control of axial and proximal muscles • Informs the primary motor cortex before execution of movements	• Apraxia
Frontal eye field (Brodmann area 8)	• Posterior part of the middle frontal gyrus	• Controls voluntary saccadic eye movements • Stimulation causes contralateral conjugate deviation of the eyes	• Transient ipsilateral conjugate deviation of the eyes

Prefrontal cortex (prefrontal association area)	• Connected to the mediodorsal nucleus of the thalamus	• Higher cognitive functions (e.g., goal-setting, decision-making)
		• Short-term memory
		• Concentration
		• Contains Brodmann areas 8–14, 24, 25, 32, and 45–47
			• Frontal lobe syndrome/ frontotemporal dementia
			  ▪ Personality changes
			  ▪ Aggressive behavior
			  ▪ Social and sexual disinhibition
			  ▪ Tremor
			  ◦ Dystonia

Broca area (Brodmann areas 44 and 45)	• Posterior part of the inferior frontal gyrus (dominant hemisphere)	• Area responsible for processing speech
		• Connected to Wernicke area via the arcuate fasciculus
			• Broca aphasia
			  ▪ Nonfluent, telegraphic, and grammatically incorrect speech
			  ▪ Intact comprehension of simple language

Parietal lobe

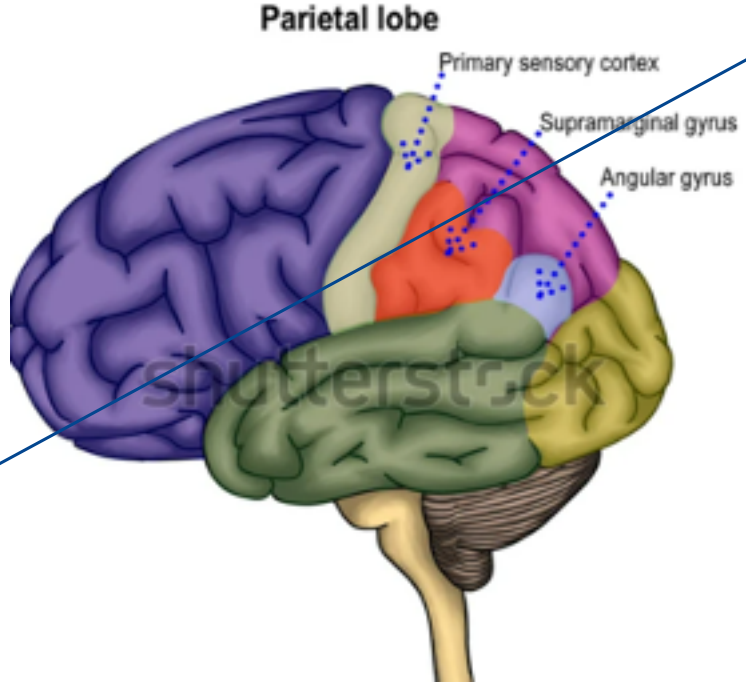
Area	Location	Characteristics (sensory functions)	Effect of lesion

Primary somatosensory cortex	• Postcentral gyrus (parietal lobes)	• Receives input from the ventral posterior nuclei of the thalamus
		• Contributes to the corticospinal tract
		• The cortical regions receiving sensory input of the different regions of the body can be mapped using the **sensory homunculus**.
		  ◦ The individual parts of the body are arranged against the corresponding cortical regions proportionate in size to their degree of innervation (e.g., the lips are represented disproportionately larger than the feet).
		  ◦ The primary motor cortex is mapped in the same way using the motor homunculus.
			• Contralateral sensory loss

Somatosensory association cortex	• Superior parietal lobule and supramarginal gyrus	• Integrates palpatory sensory information for pattern recognition	• Contralateral **astereognosis** (loss of ability to identify an object by tactile input alone)
			• Contralateral **astatognosis** (loss of ability to recognize the position of one's own body parts)
			• **Apraxia** (loss of ability to perform coordinated, purposeful, and/or learned movements when asked, even if the request is understood)
			  ◦ Most common type: **facial apraxia** (loss of ability to coordinate and execute facial movements, like whistling or winking)
			• **Conduction aphasia** (e.g., loss of ability to repeat verbal commands)
			  ◦ Due to damage of the **arcuate fasciculus** (a white matter bundle connecting the frontal, parietal, and temporal lobes that plays a major role in language processing)

Parietal lobe

Visual association cortex	• Angular gyrus	• Integrates visual sensory information for pattern recognition	• Injury to dominant hemisphere: Gerstmann syndrome
			  ◦ Inability to recognize right or left
			  ◦ Finger agnosia (loss of ability to distinguish or recognize one's own fingers or those of others)
			  ◦ Agraphia (loss of ability to write down thoughts)
			  ◦ Dyscalculia (loss of ability to do mathematical calculations)
			• Unilateral injury to the nondominant hemisphere: contralateral hemispatial neglect syndrome



Temporal lobe

Area	Location	Characteristics (hearing)	Effect of lesion

Primary auditory cortex (Brodmann areas 41 and 42)	• Transverse gyrus of the temporal lobe	• Receives input from the medial geniculate body	• One-sided primary auditory cortex lesions do not cause hearing loss because of bilateral representation of hearing on each side. I.e., a primary auditory cortex on the left receives auditory input from both sides, so does the right primary auditory cortex. Therefore, even if the primary auditory cortex on one side is damaged, the cortex on another side will be able to compensate for that.
			• Bilateral primary auditory cortex lesions may lead to cortical deafness.
			  ◦ Characterized by an inability to perceive both pure tones and complex sounds
			  ◦ The startle reflex is preserved.
			  ◦ Bilateral sensorineural hearing loss pattern is confirmed with audiogram

Wernicke area	• Posterior part of the superior temporal gyrus (superior portion of the temporal lobe)	• Part of the auditory association cortex (Brodmann area 22) • Connected to Broca area via the arcuate fasciculus	• Dominant hemisphere: Wernicke aphasia • Nondominant hemisphere: aprosodia

Occipital lobe

Area	Location	Characteristics (visual functions)	Effect of lesion
Primary visual cortex	• In the region of the calcarine sulcus (cuneus and lingual gyrus)	• Receives input from the lateral geniculate body via optic radiations (also known as visual radiations, geniculocalcarine tract) • Controls involuntary pursuit and tracking eye movements • Stimulation causes contralateral conjugate deviation of the eyes	• Difficulty tracking slow movements and/or contralateral homonymous hemianopsia
Secondary visual cortex	• Occipital lobe • Surrounds the primary visual cortex	• Integrates visual properties such as color, position in space, and illusory contours	• Visual hallucinations

Cerebrum – White matter

The part under the gray
The axons and bundles that transmit signals from cell body (neuron) to another one

يتم تقسيمهم على اختلاف منطقة التوصيل

Bundles of white matter are classified into following **three** groups: → Short in compareson to commissural or even projectional fibers

1. **Association fibers** are the fiber bundles which interconnect **different areas of same cerebral hemisphere**. But these may be restricted in one lobe or may extend from one lobe to another. So, these fibers **do not cross midline** and **do not go to any subcortical centers.** They interconnect adjacent gyri.

2. **Commissural fibers** interconnect identical areas of **two cerebral hemispheres**. So these fibers **cross the midline but do not extend to any center below cerebral cortex.**

3. **Projection fibers**, as the name suggests, project **from one cerebral hemisphere to subcortical centers of same side or opposite side.** So these fibers extend beyond cerebral cortex and may or may not cross the midline.
With sub cortical structure like basal ganglia or thalamus

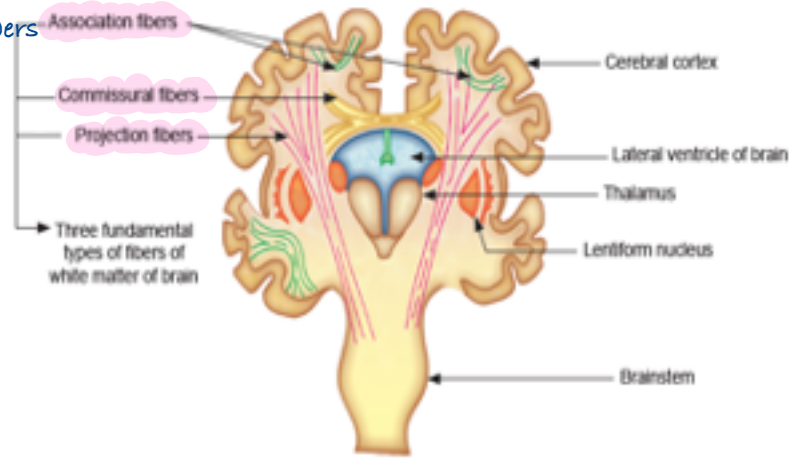


Fig. 9.1 Fundamental types of fibers of white matter of brain

Transport signals between the 2 hemisphere.

Example of commissural fibers of white matter

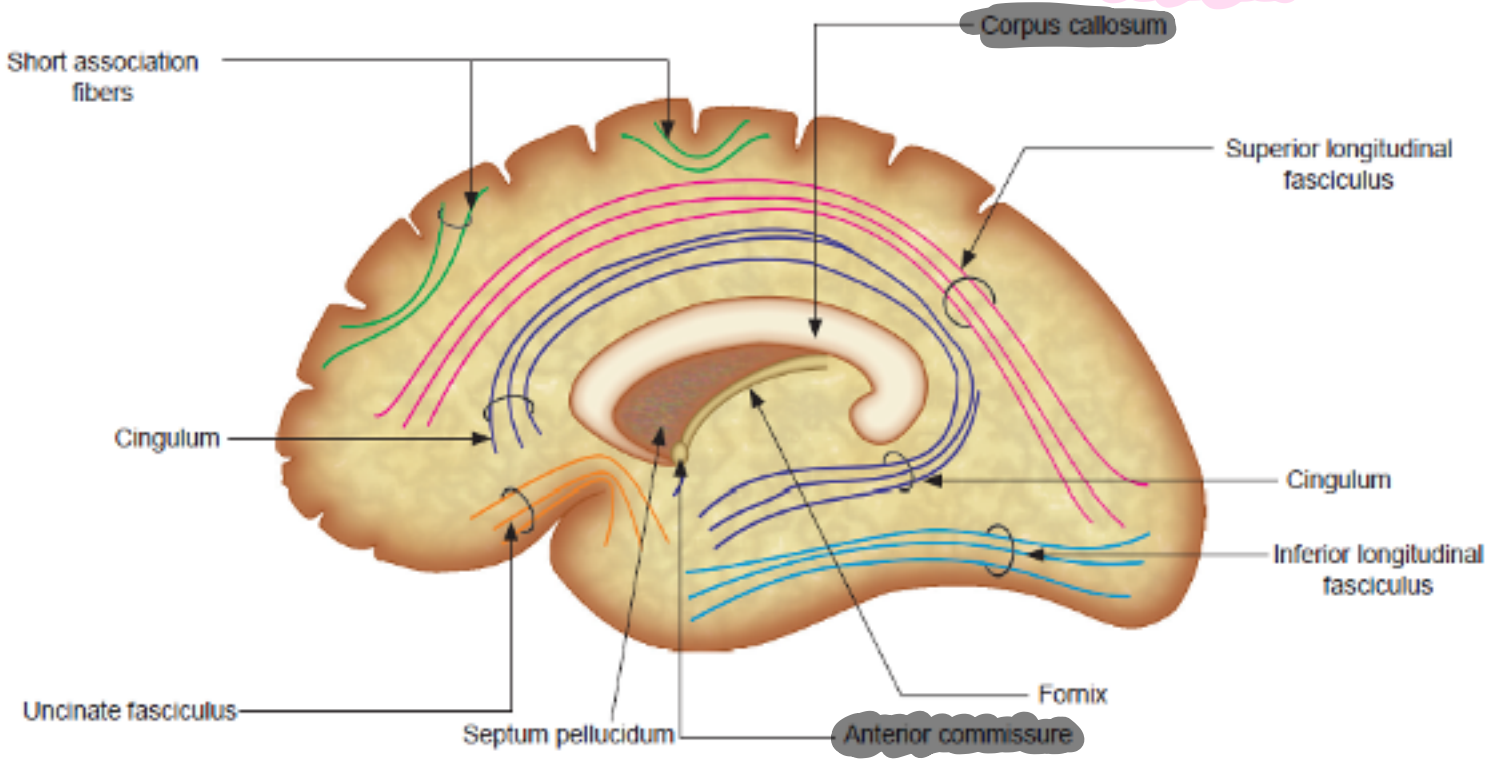


Fig. 9.2 Association fibers of white matter of cerebrum

Commissure fibers

Transport signals between the 2 hemisphere.

1. Corpse Callosum

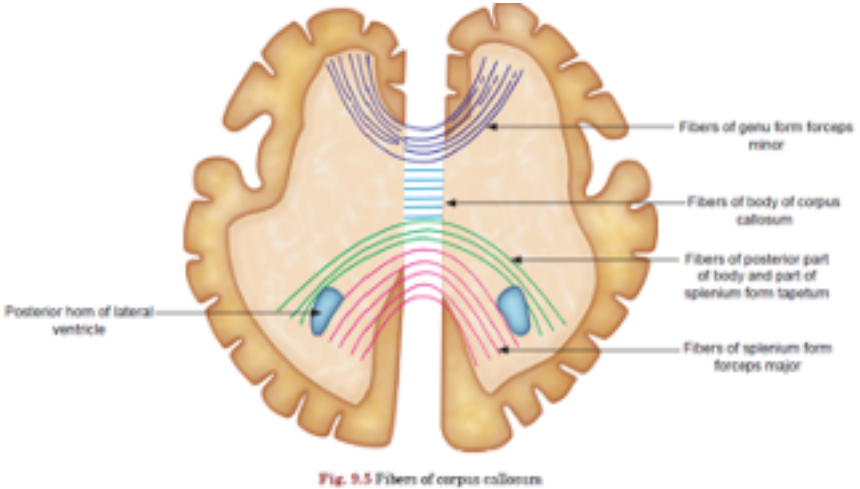
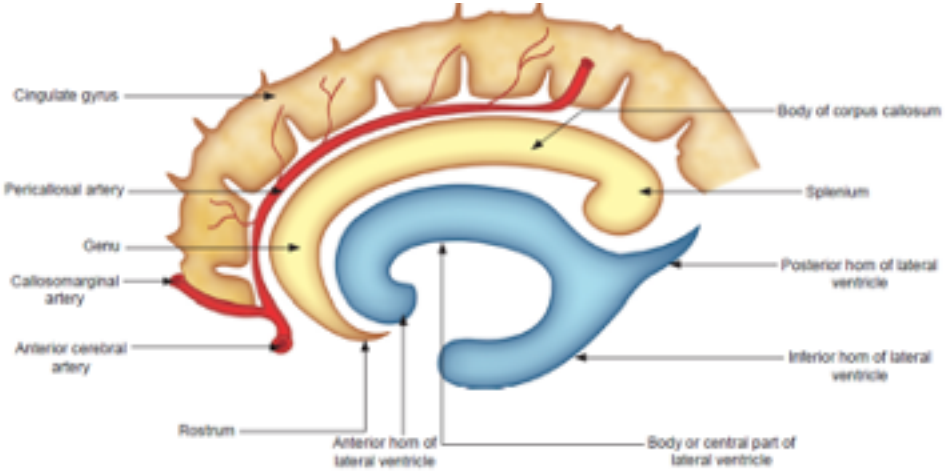
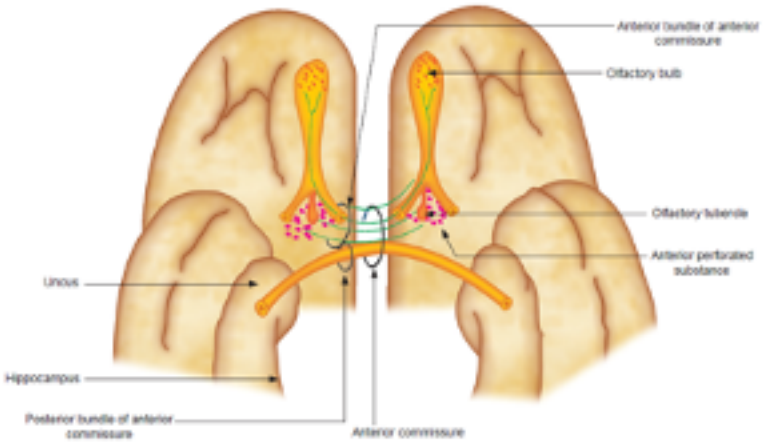


Fig. 9.5 Fibers of corpus callosum



Commissure fibers

2. **Anterior Commissure** (anterior limb & posterior limb)



Other commissures: posterior commissure, Habenular commissure, hippocampal commissure

Internal Capsule - Projection fibers

Transport the signal to the subcortical structures and its the longest fibers.

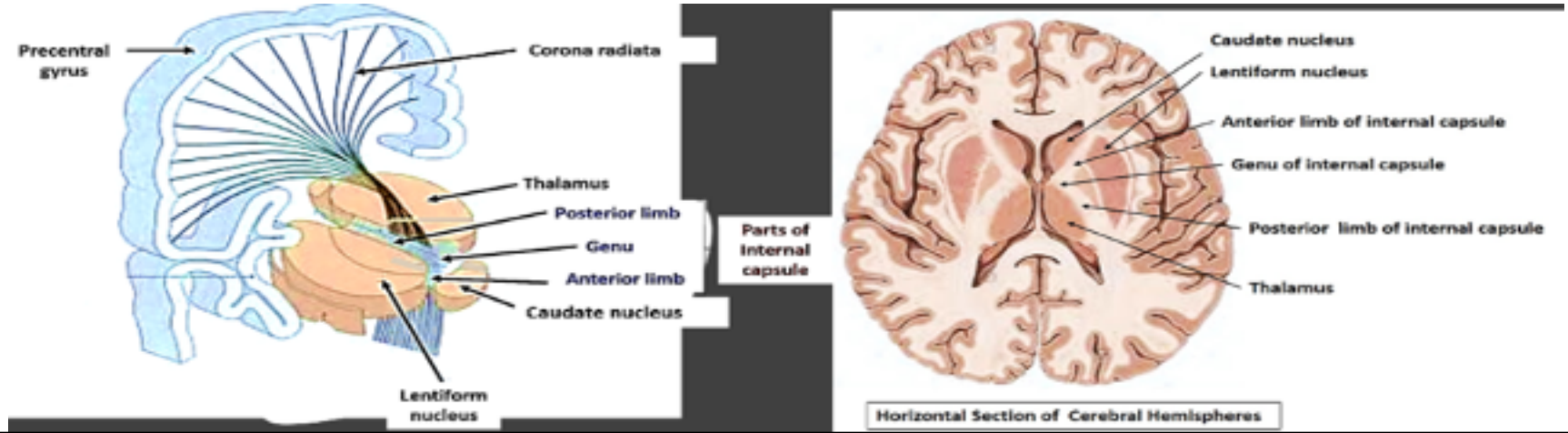
a broad and compact band of white matter in horizontal section of cerebral hemisphere

Components:

anterior limb, genu, and posterior limb

- **Anterior limb:** contains the **thalamocortical tract** Between the cortex and thalamus
- **Genu:** contains the **corticobulbar tract** Bulbar is the main parts of cranial nerves
- **Posterior limb:** contains the **corticospinal tract** and **thalamocortical** and **somatosensory** fibers

spinal cord بما انه الجزء الخلفي ف استنتج انه بيجيب اشارات وبيوديها لل



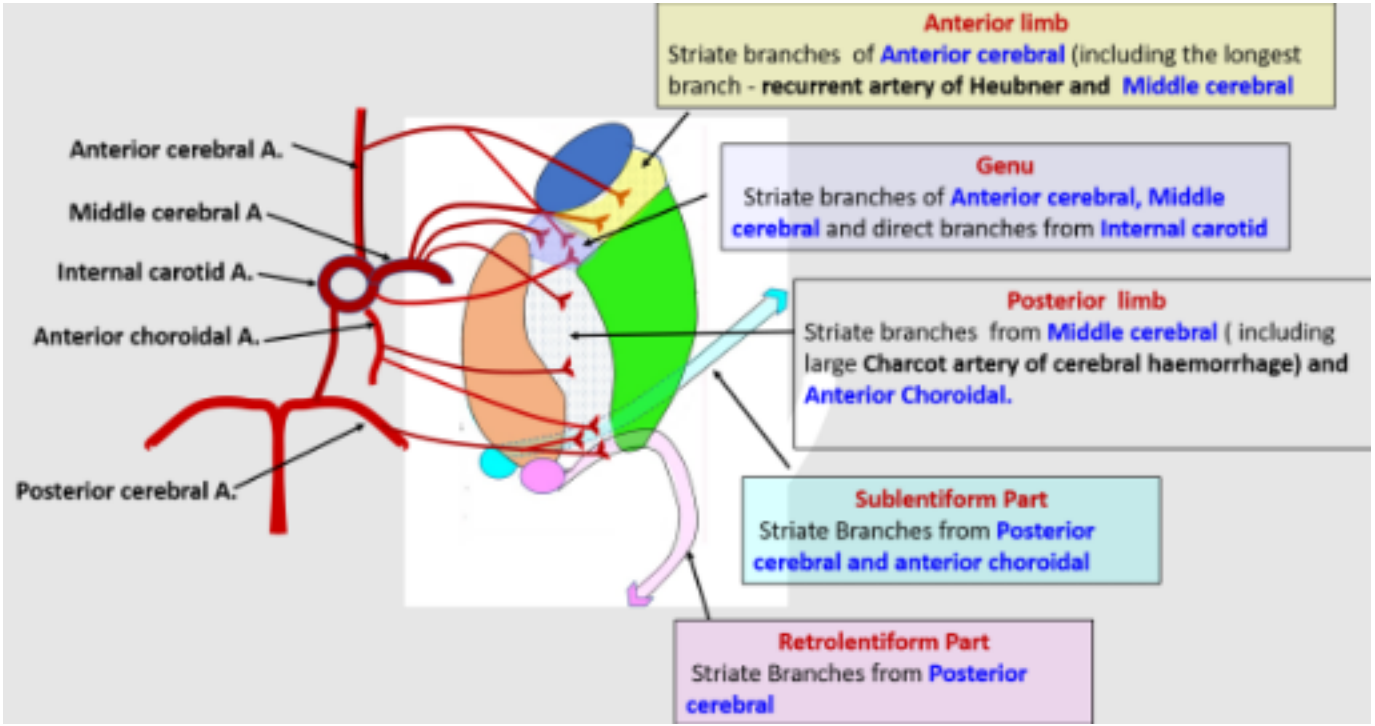
Blood supply of the brain is circle of Willis

Blood supply of the internal capsule

(Ant. + middle) cerebral

Ant. choroidal

main branches 3 الي بيهمني هان انو بيجيها تغذية من

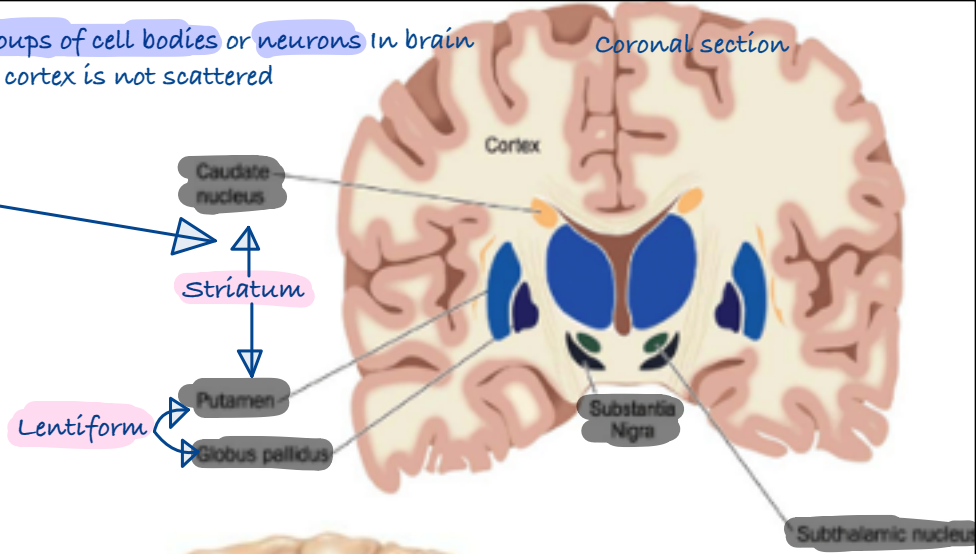


Basal Ganglia

System

Nuclei is a scattered groups of cell bodies or neurons In brain
But the cortex is not scattered

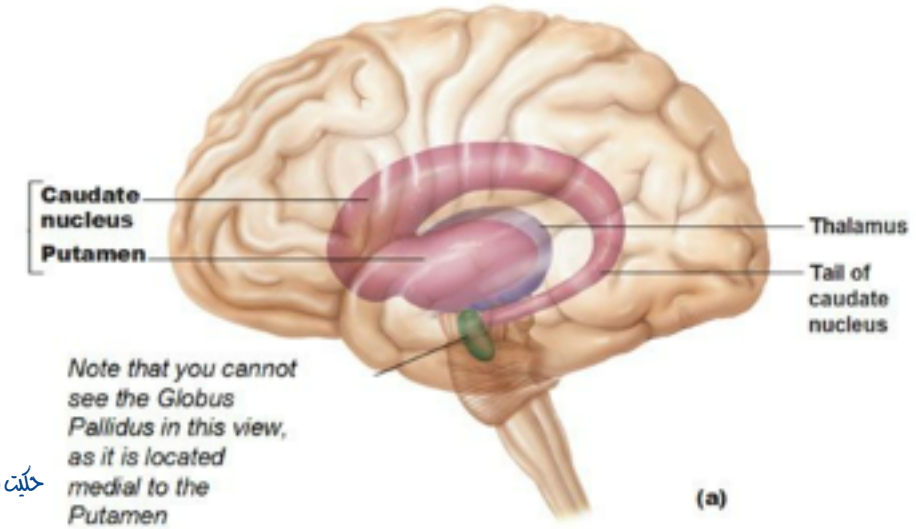
Basal ganglia		Location
Striatum	Caudate nucleus	• Telencephalon
	Putamen	
Lentiform nucleus	Globus pallidus	• Diencephalon Thalamus
	Putamen	
Subthalamic nucleus		
Substantia nigra		• Mesencephalon



Its main function is control the motor orders that come from primary motor gyrus or precentral

Function: Motor Control
person with basal ganglia dysfunction may have trouble starting, stopping, or sustaining movement + problems controlling speech, movement, and posture. This combination of symptoms is called **parkinsonism**.

carpidopa والـ levodopa حكيت للدكتور انه الدواء جيب سحب عليا وما سمعني بس احفظوهم هما الـ



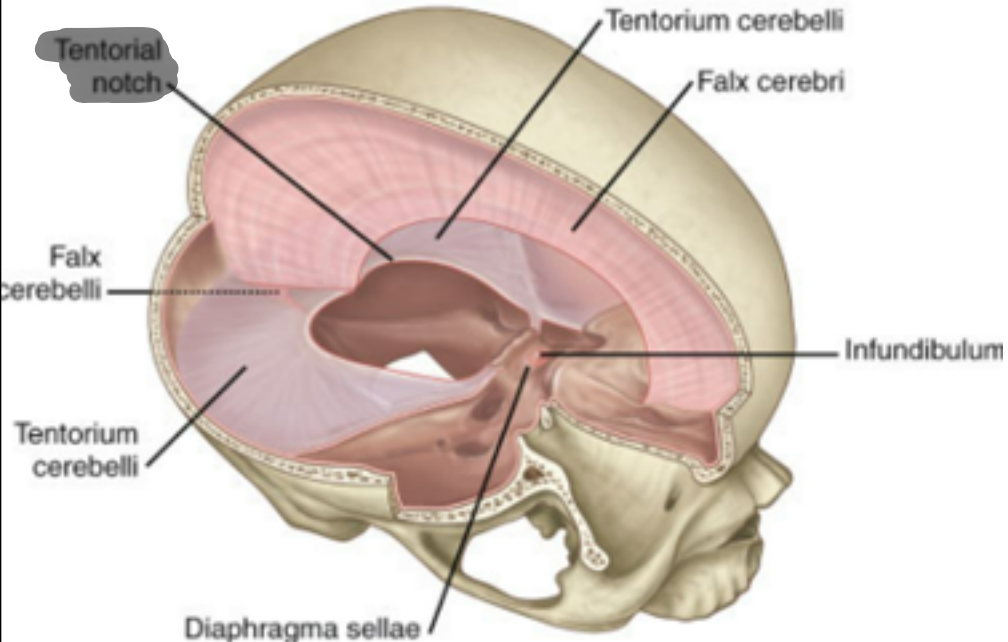
Falces of the brain

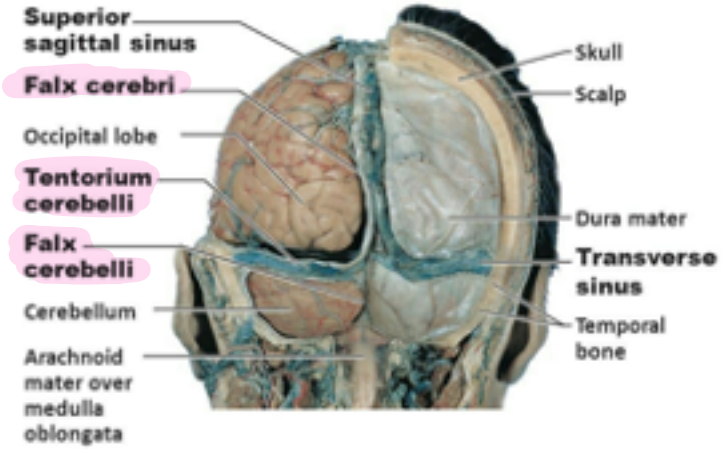
Part of connective fibrous tissue work as supportive media to the brain
وايضاً وظيفة ثانية اقل اهمية انو ال brain ما بيبجي على سطح هدول الfalces dural venous system الي بال
بيروح على ال :
falx cerebri from the cerebrum itself
Falx cerebelli in the middle of cerebelli and share the division to 2 hemisphere
Tentorium cerrbelli horizontal line perpendicular to falx cerebri

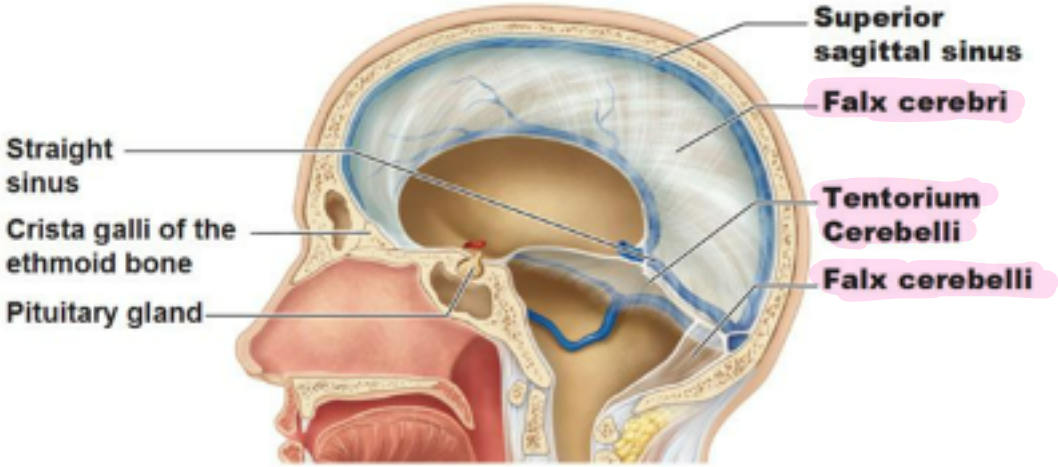
معلومة حلّاها مهمة انه ال٣ هدول مشتركين بشغلة انهم بيتصلو بال crest of occipital bone posteriorly

Tentorial notch in the middle of tentorium cerebelli to pass the brain stem through it.

Structure	Location	Characteristics	Sites of attachment	Cerebral sinuses
Falx cerebri	• Longitudinal fissure	• Separates the cerebral hemispheres	• **Crista galli** of the ethmoid bone anteriorly • Internal occipital protuberance posteriorly • Midline of the cranium superiorly • Superior surface of the tentorium cerebelli inferiorly	• The superior border contains the **superior sagittal sinus**. • The inferior border contains the **inferior sagittal sinus**. • The site of attachment to the tentorium cerebelli contains the **straight sinus**.
Falx cerebelli	• Floor of the posterior cranial fossa	• Separates the two cerebellar hemispheres	• **Tentorium cerebelli** superiorly • Posterior edge of the foramen magnum inferiorly • Internal occipital crest posteriorly • Edge that separates the cerebellum anteriorly	• Site of attachment to the internal occipital crest, which contains the **occipital sinus**
Tentorium cerebelli	• Perpendicular to the falx cerebri (in the axial plane)	• Separates the cranial cavity into infratentorial and supratentorial compartments	• Falx cerebri on the midline • Anterior clinoid processes of the sphenoid bone anteriorly ◦ Forms the lateral part of the **cavernous sinus** • Petrous part of the temporal bone bilaterally (anterolateral margins) • Posteroinferior angles of the parietal bone and transverse sulci of the occipital bone (posterolateral margins) • Internal occipital protuberance posteriorly	• The midline attachment with the falx cerebri contains the **straight sinus**. • The posterolateral attachments contain the **transverse sinus**.







(a) Midsagittal view

The Diencephalon

All structure related to thalamus

- **Location**: caudal portion of the forebrain, situated between the cerebrum and midbrain
- **Embryogenesis**: arises from prosencephalon Forebrain.
- ***Parts of diencephalon***: **five in number separated by hypothalamic sulcus**

Dorsal diencephalon (above hypothalamic sulcus)

1. The thalamus: relay center of **sensory** information between subcortical and cortical structures
2. Meta-thalamus: made up od medial & lateral geniculate bodies Semiposterior
3. Epithalamus: **(pineal gland)** involved in the regulation of the sleep-wake cycle

primary to secondary يستخدم كـ منطقة تحويل او ترحيل المعلومات من ال visual cords in the occipital lobe

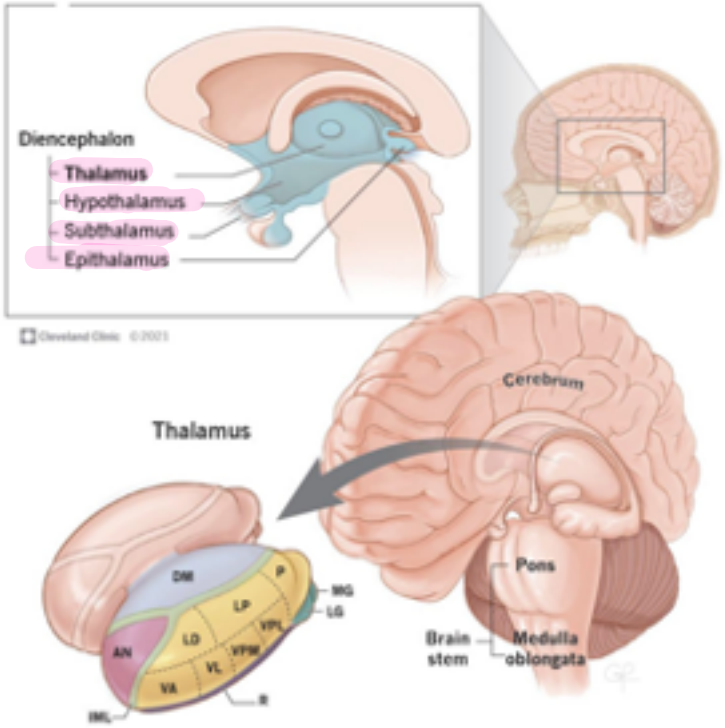
Ventral diencephalon (below hypothalamic sulcus)

4. Subthalamus: contains the subthalamic nucleus, a part of the basal ganglia
5. Hypothalamus: main center of **autonomic** function and **endocrine** system function

وتقريباً وظيفة ال thalamus كلها انه يشتغل كـ relay stage مؤقتاً قبل م توصل ال inputs للمركز تاعها بالمخ

Anatomy of the thalamus

Diencephalon and the nuclei of the thalamus



AN	Anterior nucleus
IML	Internal medullary lamina
DM	Dorsomedial nucleus
LD	Lateral dorsal nucleus
LP	Lateral posterior nucleus
P	Pulvinar nucleus
VA	Ventral anterior nucleus
VL	Ventrolateral nucleus
VPM	Ventral posteromedial nucleus
VPL	Ventral posterolateral nucleus
MG	Medial geniculate nucleus
LG	Lateral geniculate nucleus
R	Reticular nucleus

Thalamus

a group of nuclei constituting the **main relay center of ascending sensory information between subcortical and cortical centers** (except for the sense of smell)

The Two thalami are interconnected by a compact band of white matter crossing midline, called **inter-thalamic adhesion**

Type of commissural fibers

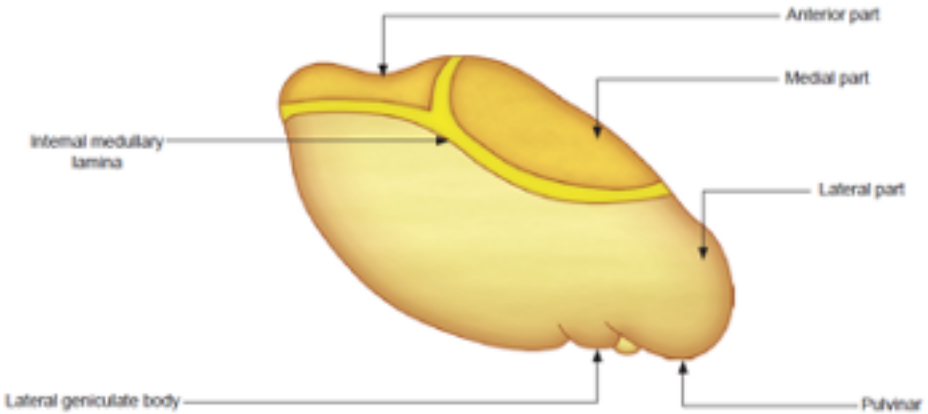
Composition

- L**ateral, anterior, medial**, and **intralaminar nuclear groups** and the metathalamic region
- Lateral, ant., and medial nuclear groups are separated by Y-shaped internal medullary lamina
- The **lateral group** can be subdivided into **posterior, dorsal, and ventral subgroups**

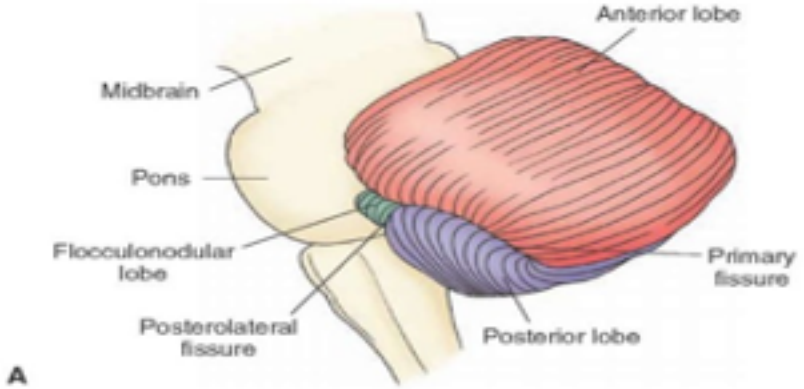
Blood supply

Mainly derived from branches of

the posterior cerebral artery

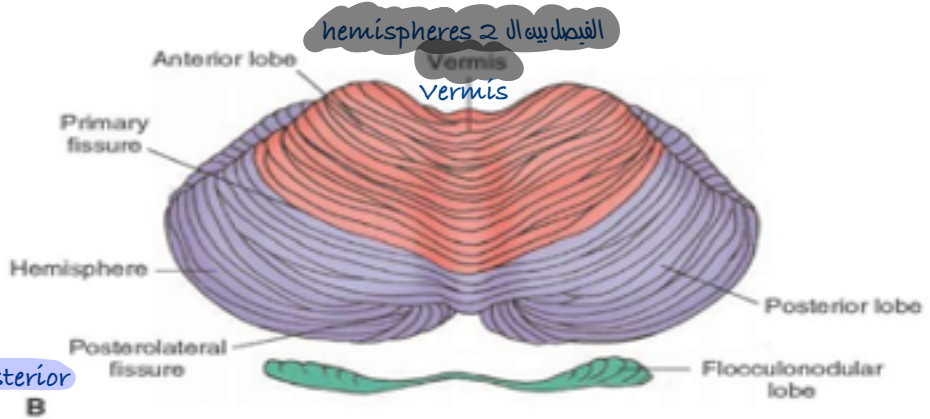


Gross Anatomy of cerebellum



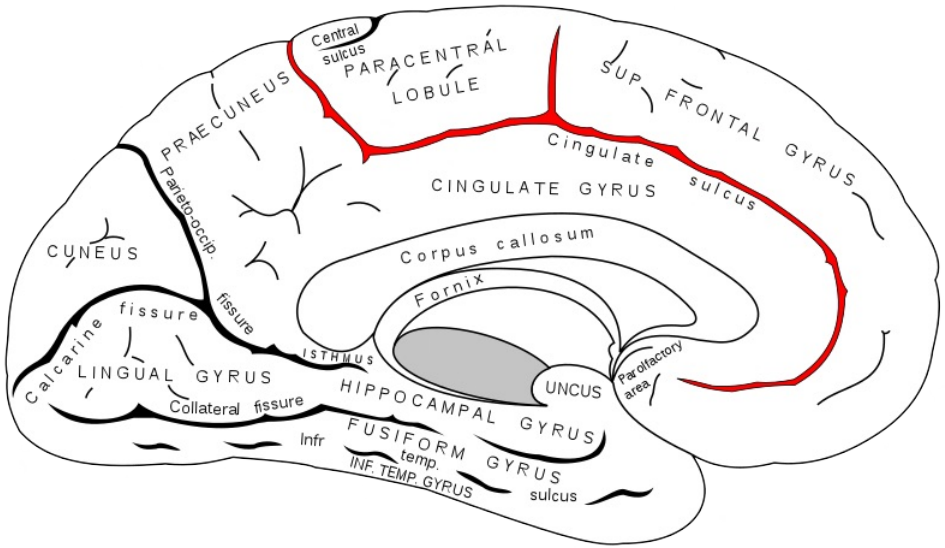
Lobes and fissures

- **Three lobes**
  - Anterior lobe under the occipital cortex
  - Posterior lobe The most dominant.
  - Flocculonodular lobe The smallest part
- **Main fissures**
  - The primary fissure separates the anterior and po Posterior
  - The posterolateral fissure separates the posterior lobe from the flocculonodular lobe.



في شوية أشياء من الmedial aspect

في حاجة اسمها cingulate gyrus هادة تابع لـ limbic system الي الها علاقة بال behaviors وبما انه cingulate gyrus اذن تابع لـ cortex وتحته حاجة اسمها corpus callosum وبيفصله عنها حاجة اسمها sulci والابيض الي تحت الاسمه corpus callosum يسمى septum



Cerebellum

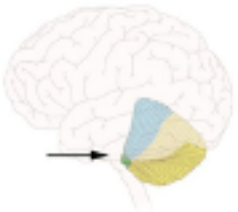
- Lies in the posterior cranial fossa
- Covered by the tentorium cerebelli (dura mater)
- Connected to brainstem via three paired cerebellar peduncles (sup, mid, inf)
- Separated from the medulla and pons by the fourth ventricle

Functionally, it is divided into **three zones**. These are the:

cerebro-cerebellum (the lateral zones), which receives **sensory** information from the cerebral cortex and is responsible for the planning of movements that are just about to occur **(motor planning);**

spino-cerebellum (the vermis and intermediate zones), which receives **proprioceptive** information from the dorsal columns of the spinal cord and is responsible for the coordination of movements **(motor execution);**

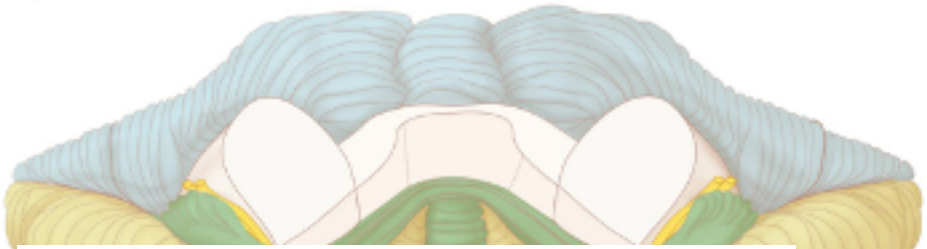
Vestibulo-cerebellum (the flocculonodular lobe), which receives information from the vestibular nuclei and visual cortex and is responsible for **balance and ocular movements**

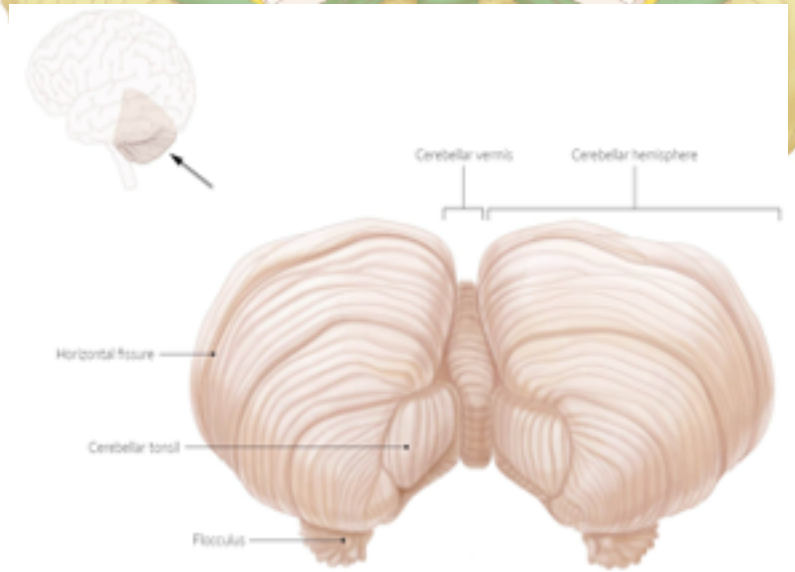


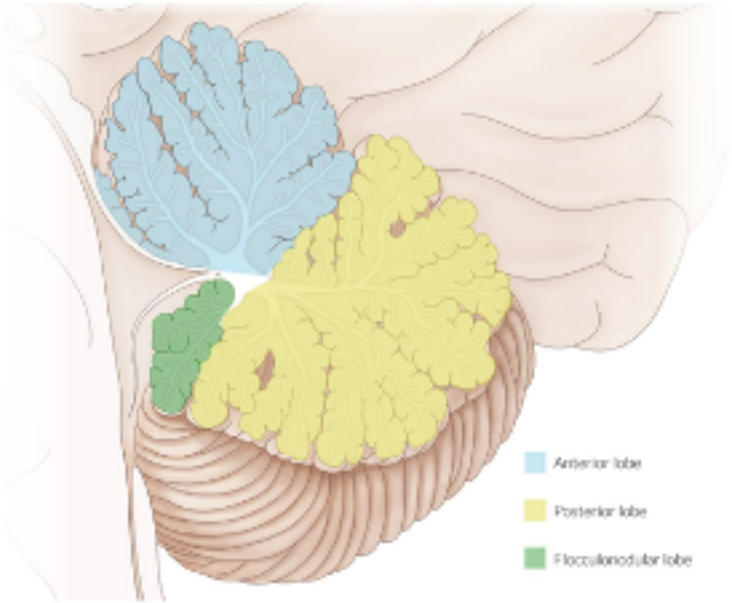
Anterior lobe of cerebellum

Posterior lobe of cerebellum

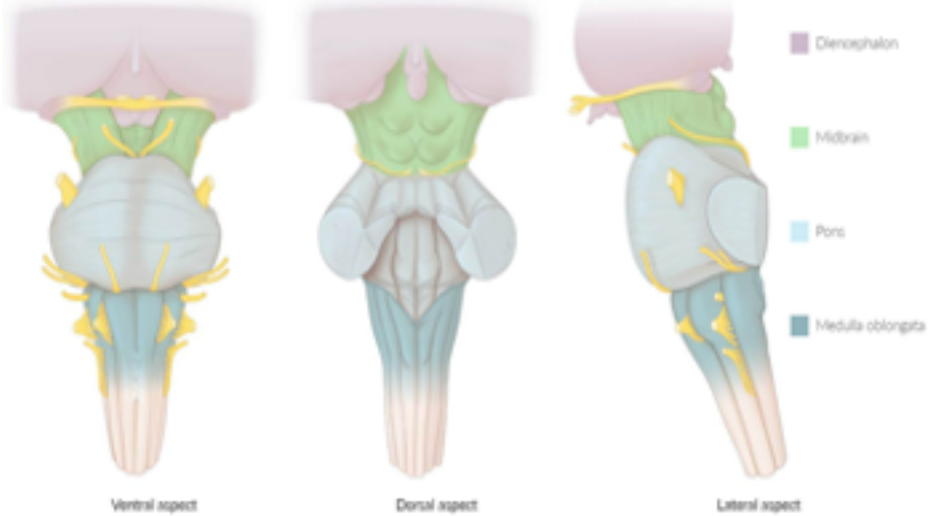
Flocculonodular lobe







The Brainstem



1- Midbrain is the smallest - 2cm in length

As it ascends, the midbrain travels through the opening in the **tentorium cerebelli.**

*It can be divided into **two main parts:***

Tectum – located posterior to the cerebral aqueduct
Paired cerebral peduncles – located anteriorly and laterally.
Internally, the cerebral peduncles are further separated by the substania nigra into the crus cerebri (anterior) and the tegmentum (posterior).

Tectum

The tectum houses four rounded prominences named colliculi (collectively the corpora quadrigemina) which sit directly inferior to the pineal gland. The colliculi are separated by the cruciform sulcus; there are two superior and two inferior colliculi.

Extending laterally from each colliculi are the quadrigeminal brachium:

Superior quadrigeminal brachium forms a pathway between the superior colliculus and the retina of the eye.
Inferior quadrigeminal brachium conveys fibres from the lateral lemniscus and inferior colliculus to the medial geniculate body.
Inferior to the colliculi, the trochlear nerve (CN IV) emerges before sweeping across to the anterior surface.

Cerebral Peduncles

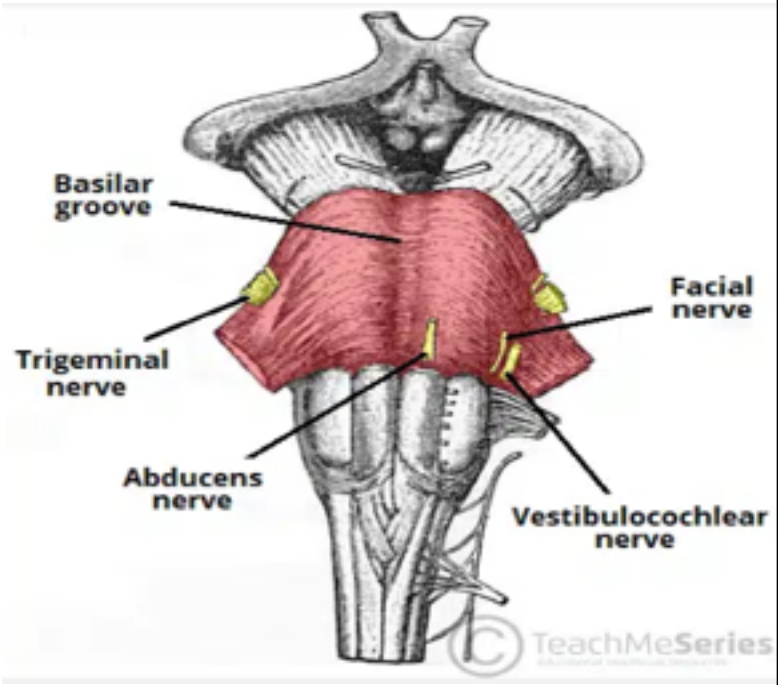
The paired cerebral peduncles extend from the cerebral hemispheres to converge as they meet the pons. They are separated anteriorly in the midline by the interpeduncular fossa, the floor of which is termed the posterior perforated substance (as many perforating blood vessels can be identified).

2) Pons is a group of nerves that function as a connection between the cerebrum and cerebellum (pons is Latin for bridge).

Anteriorly: the pons is marked by a bulging formed by the transverse pontocerebellar fibres. These fibres wrap around the otherwise vertically oriented brainstem. It measures around 2.5 cm in adults.

The **basilar groove** demarcates the midline of the ventral surface and is where the **basilar artery** is located.

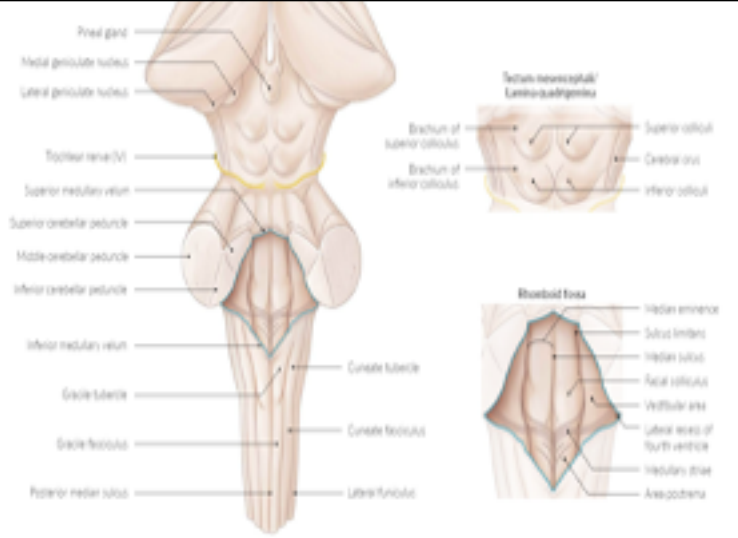
The **pontomedullary junction** is an important anatomical landmark

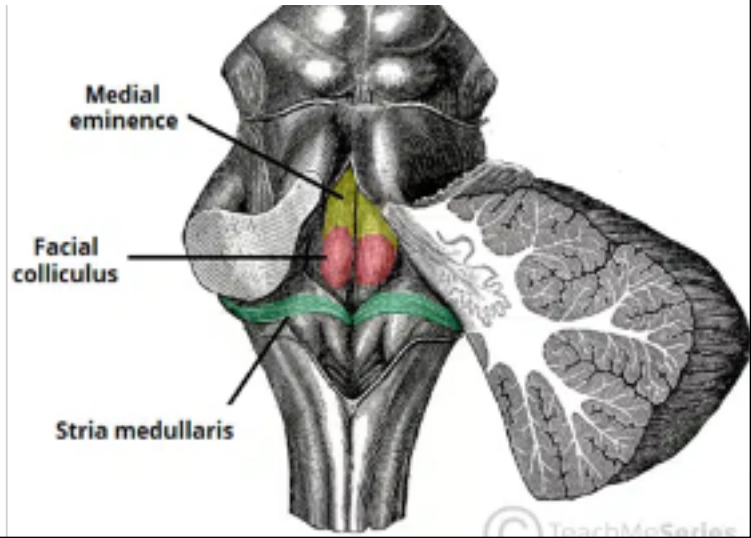


Posteriorly: The pons is intimately related to the cerebellum and is connected to it by the **middle cerebellar peduncles**. Removal of the cerebellum will reveal the underlying fourth ventricle.

The floor of the **fourth ventricle** is composed of the dorsal surface of the pons and the medulla. There are some important anatomical landmarks here:

The **medial eminence** marks the midline of the floor.
The **facial colliculus** is a bulging formed by the fibres of the facial nerve looping around the abducens nucleus.
The **stria medullaris** of the fourth ventricle is a bundle of nerve fibres crossing transversely from the lateral aspect into the midline. They mark the posterior border between the pons and the medulla.
The angle formed at the junction of the pons, medulla, and cerebellum is another anatomical landmark and is named cerebellopontine angle. Here, the cerebellar flocculus, the ventricular choroid plexus and the emerging CNs VII and VIII surround the lateral apertures of the fourth ventricle (the foramen of Luschka).





3) medulla

The superior margin of the medulla is located at the junction between the medulla and pons, while the inferior margin is marked by the origin of the first pair of cervical spinal nerves. This occurs just as the medulla exits the skull through the **foramen magnum**.

Anterior Surface: There are several structures visible on the anterior surface of the medulla – namely the three fissures/sulci, the pyramids, the olives, and five cranial nerves.

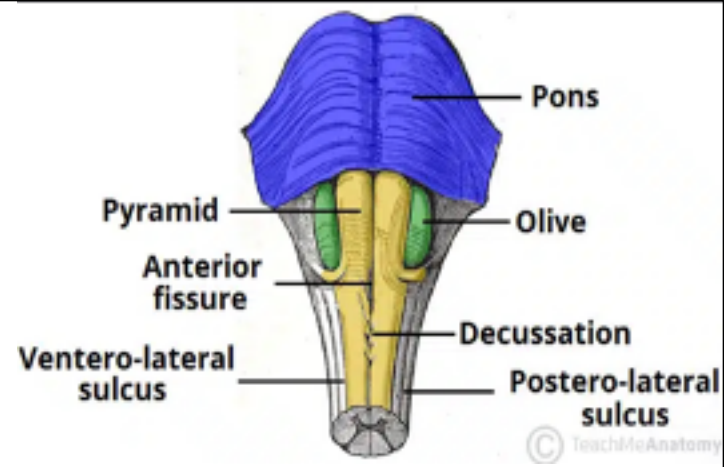
In the midline of the medulla is the anterior median fissure, which is continuous along the length of the spinal cord. However, it is interrupted temporarily by the decussation of the pyramids (see below). As we move away from the midline, two sulci are visible – the ventrolateral sulcus and the posterolateral sulcus.

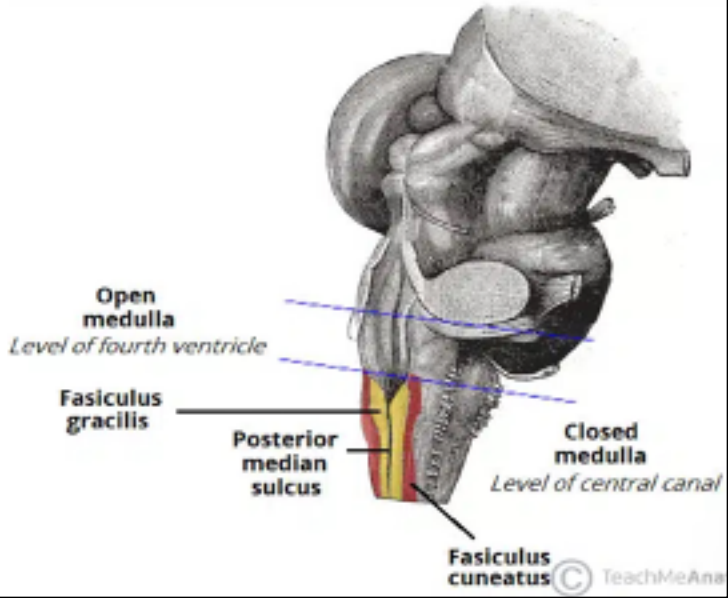
The pyramids are paired swellings found between the anterior median fissure and the ventrolateral sulcus. Information on the pyramids can be found here. **The olives** are another pair of swellings located laterally to the pyramids – between the ventrolateral and posterolateral sulci.

Posterior Surface: Unlike the anterior surface of the medulla, the posterior surface is largely obstructed from view and is relatively devoid of features. In order to appreciate the posterior surface, the cerebellum must be removed.

Similar to the anterior surface, the posterior surface has a midline structure – the posterior median sulcus – which is continuous below as the posterior median sulcus of the spinal cord. Above, the sulcus ends at the point in which the fourth ventricle develops.

As we move lateral from the midline, the fasciculus gracilis and fasciculus cuneatus are seen, separated by the posterior intermediate sulcus.





Origin of the Cranial Nerves

There are **12** cranial nerves in total.

The olfactory nerve (CN I) and optic nerve (CN II) originate from the cerebrum. Cranial nerves III – XII arise from the brainstem (Figure 1).

They can arise from a specific part of the brainstem (midbrain, pons or medulla), or from a junction between two parts:

Midbrain – the trochlear nerve (IV) comes from the posterior side of the midbrain. It has the longest intracranial length of all the cranial nerves.

Midbrain-pontine junction – oculomotor (III).

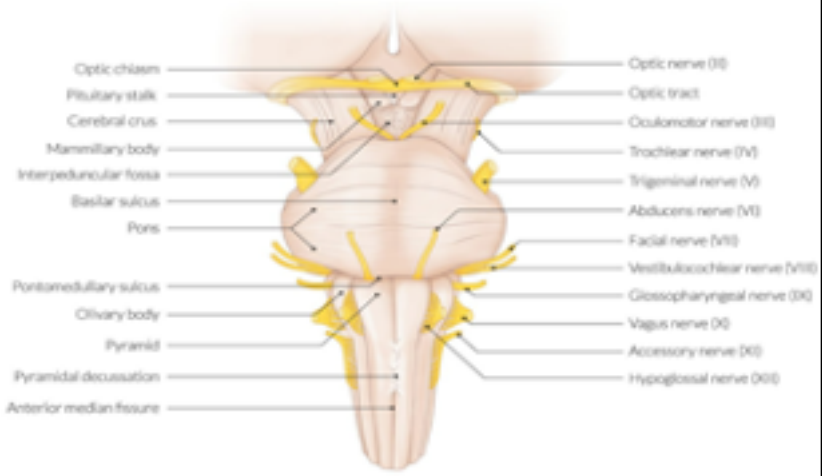
Pons – trigeminal (V).

Pontine-medulla junction – abducens, facial, vestibulocochlear (VI-VIII).

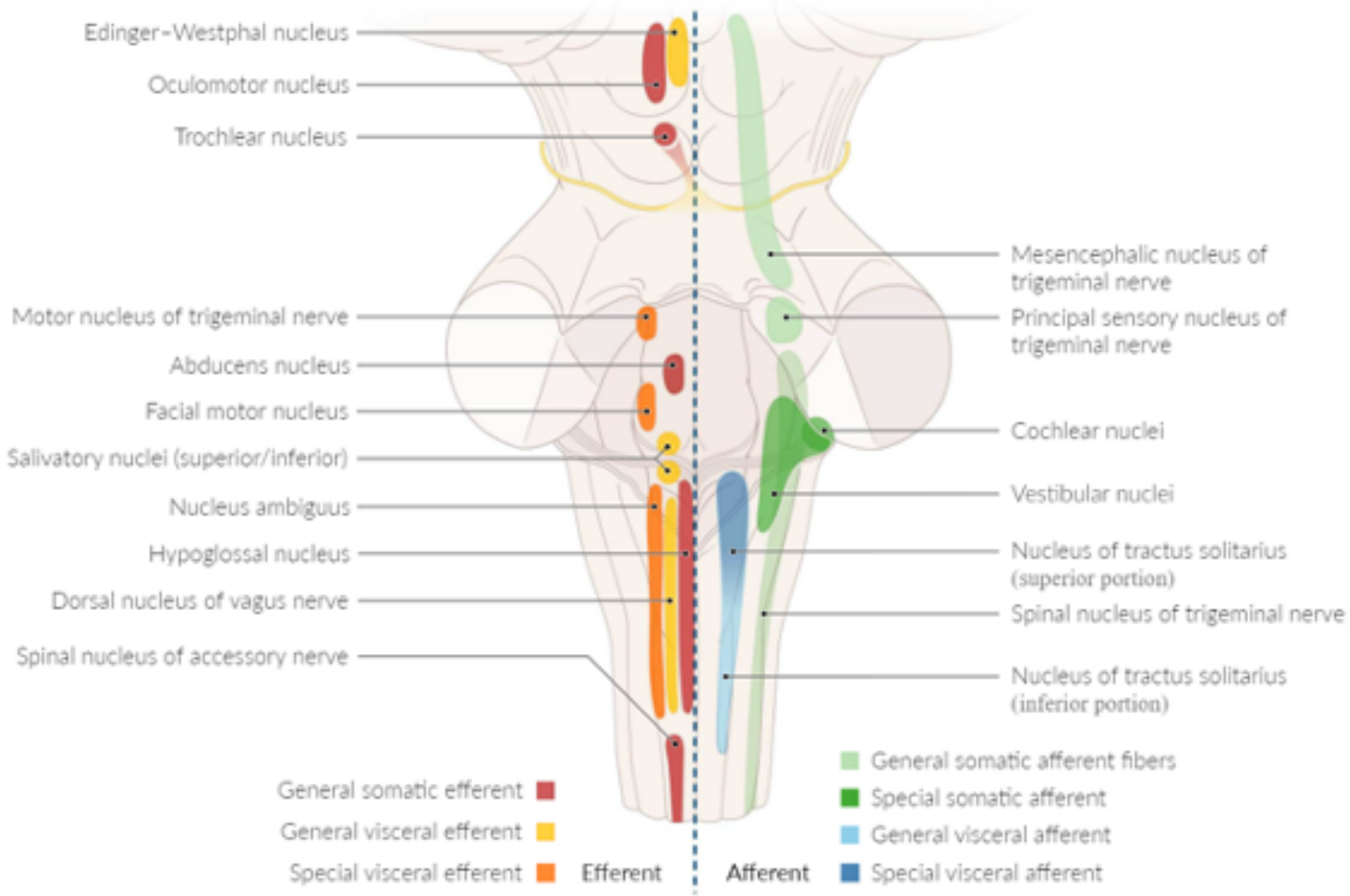
Medulla oblongata

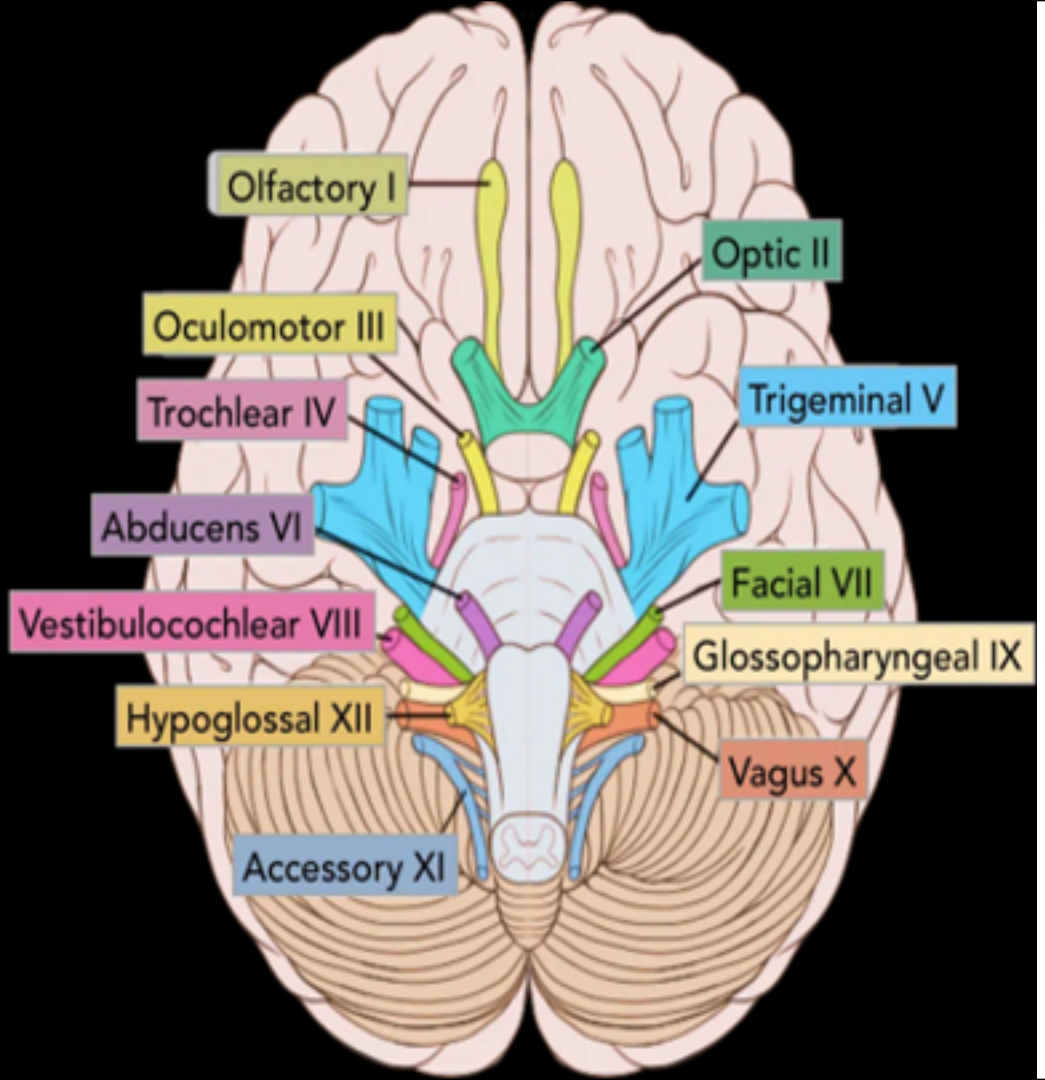
Posterior to the olive: glossopharyngeal, vagus, accessory (IX-XI).

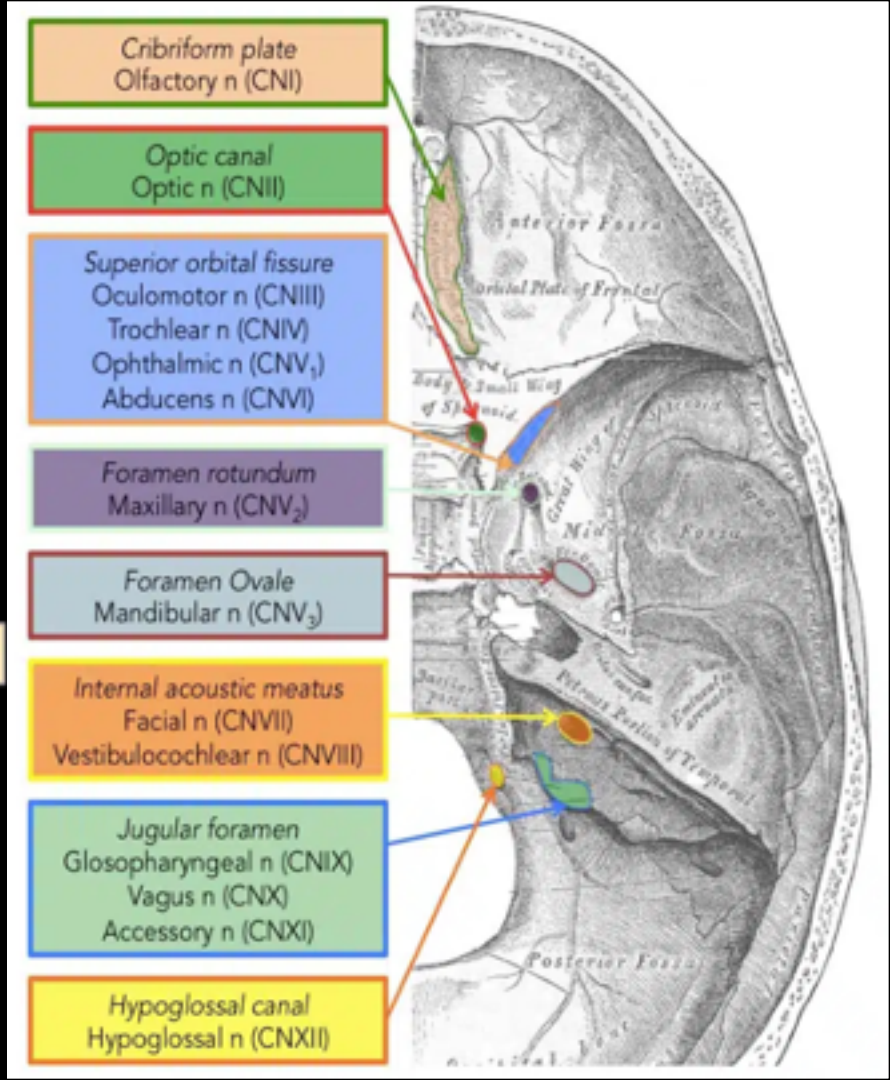
Anterior to the olive: hypoglossal (XII).



The cranial nerves are numbered by their location on the brainstem (superior to inferior, then medial to lateral) and the order of their exit from the cranium (anterior to posterior)


Edinger-Westphal nucleus
Oculomotor nucleus
Trochlear nucleus
Motor nucleus of trigeminal nerve
Abducens nucleus
Facial motor nucleus
Salivatory nuclei (superior/inferior)
Nucleus ambiguus
Hypoglossal nucleus
Dorsal nucleus of vagus nerve
Spinal nucleus of accessory nerve
Mesencephalic nucleus of trigeminal nerve
Principal sensory nucleus of trigeminal nerve
Cochlear nuclei
Vestibular nuclei
Nucleus of tractus solitarius (superior portion)
Spinal nucleus of trigeminal nerve
Nucleus of tractus solitarius (inferior portion)
General somatic efferent
General visceral efferent
Special visceral efferent
Efferent
Afferent
General somatic afferent fibers
Special somatic afferent
General visceral afferent
Special visceral afferent


Olfactory I
Optic II
Oculomotor III
Trochlear IV
Trigeminal V
Abducens VI
Facial VII
Vestibulocochlear VIII
Glossopharyngeal IX
Hypoglossal XII
Vagus X
Accessory XI


Cribriform plate
Olfactory n (CNI)
Optic canal
Optic n (CNII)
Superior orbital fissure
Oculomotor n (CNIII)
Trochlear n (CNIV)
Ophthalmic n (CNV1)
Abducens n (CNVI)
Foramen rotundum
Maxillary n (CNV2)
Foramen Ovale
Mandibular n (CNV3)
Internal acoustic meatus
Facial n (CNVII)
Vestibulocochlear n (CNVIII)
Jugular foramen
Glosopharyngeal n (CNIX)
Vagus n (CNX)
Accessory n (CNXI)
Hypoglossal canal
Hypoglossal n (CNXII)

The limbic systemic *In the medial aspect of the brain*

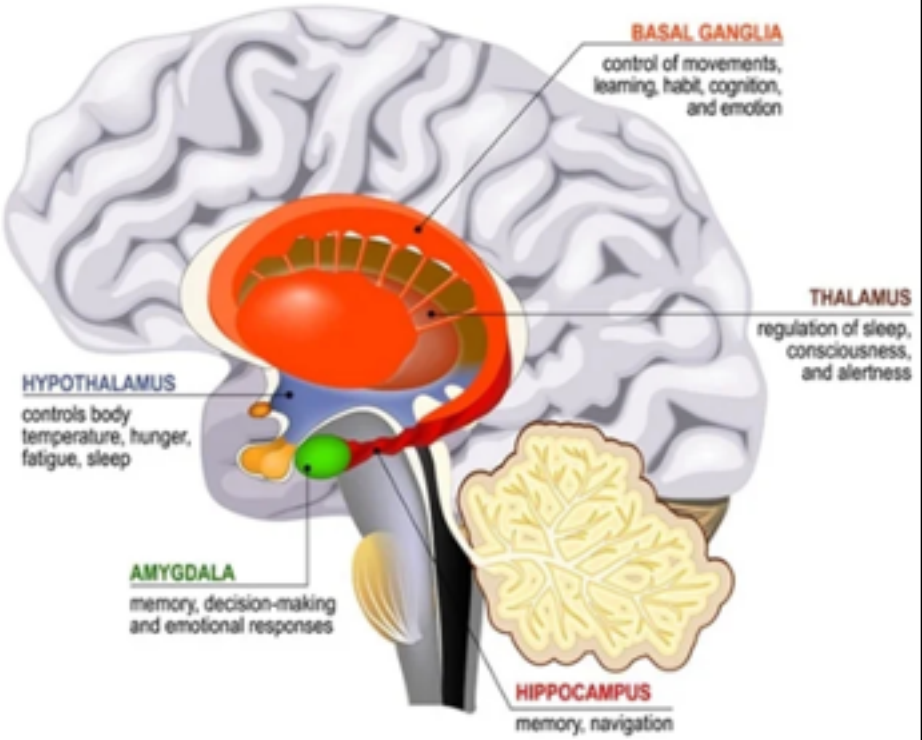
- involved in **emotional** and behavioral responses, motivation, **memory, olfaction, and autonomic nervous system function.**

- **Components**

  - **Areas of the cerebral cortex**: **hippocampal formation** (hippocampus, dentate gyrus, entorhinal cortex), **cingulate gyrus**

  - **Nuclei**: mammillary bodies, amygdala, anterior thalamic nuclei

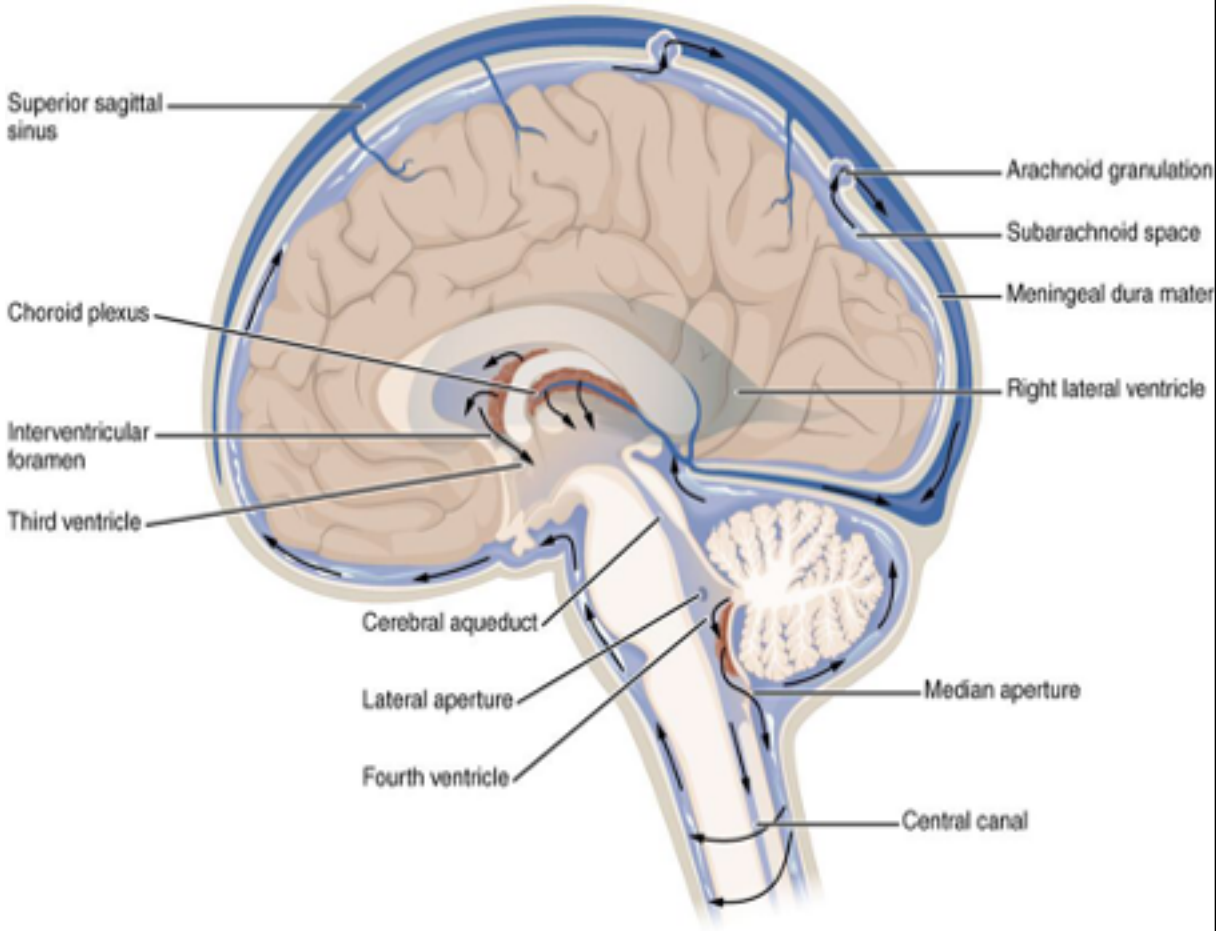
  - **Nerve fiber tracts**
    - Cerebral fornix: C-shaped nerve fiber bundle that represen the major output tract of the hippocampus
    - Cingulum: nerve fiber bundle connecting cingulate gyrus and entorhinal cortex
    - Mammillothalamic tract
    - Striae terminalis



Ventricular system

Ventricles are structures that produce CSF, and transport it around the cranial cavity. They are lined by **ependymal cells**, which form a structure called the choroid plexus. It is within the **choroid plexus** that CSF is produced.

Lateral Ventricles:
The left and right lateral ventricles are located within their respective hemispheres of the cerebrum. They have ‘horns’ which project into the frontal, occipital and temporal lobes. The volume of the lateral ventricles increases with age.



Third Ventricle

The lateral ventricles are connected to the third ventricle by the foramen of Monro. The third ventricle is situated in between the right and the left thalamus. The anterior surface of the ventricle contains two protrusions:

Supra-optic recess – located above the optic chiasm.

Infundibular recess – located above the optic stalk.

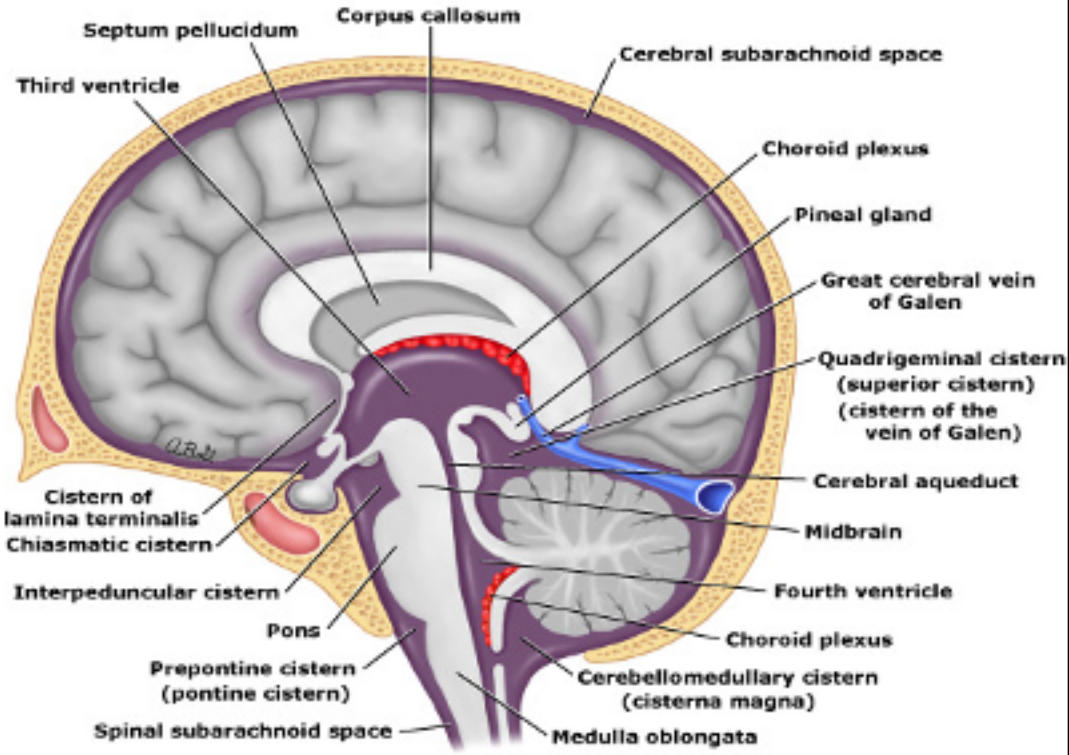
Fourth Ventricle

The fourth ventricle is the last in the system – it receives CSF from the third ventricle via the cerebral aqueduct. It lies within the brainstem, at the junction between the pons and medulla oblongata.

From the 4th ventricle, the fluid drains into two places:

Spinal canal – bathes the spinal cord

Subarachnoid cisterns – bathes the brain, between arachnoid mater and pia mater. Here it's reabsorbed by the arachnoid villi into the dural venous sys..



The median aperture (foramen of Magendie) opens on midline into a subarachnoid space inferior to the cerebellum called the cisterna magna and into the quadrigeminal cistern in the region of the tectum of the midbrain. Two lateral apertures (foramen of Luschka) also open into the cisterna magna.

Spinal cord

The spinal cord arises cranially as a continuation of the medulla oblongata.

It then travels inferiorly within the vertebral canal, surrounded by the spinal meninges containing cerebrospinal fluid.

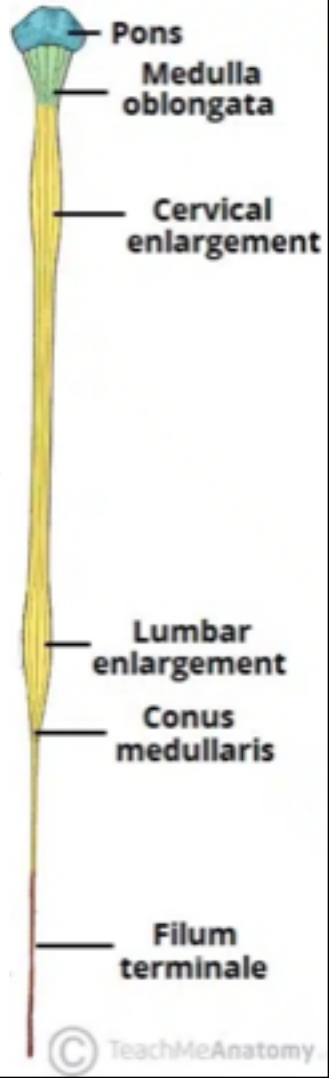
At the L2 vertebral level the spinal cord tapers off, forming the **conus medullaris** (L3 vertebra in neonates).

As a result of the termination of the spinal cord at L2, it occupies around two thirds of the vertebral canal. The spinal nerves that arise from the end of the spinal cord are bundled together, forming a structure known as the **cauda equina "horse tail"** (it's comprised of L2-S5 nerves + the coccygeal nerve - 10 nerve pairs).

During the course of the spinal cord, there are two points of enlargement. The cervical enlargement is located proximally, at the C4-T1 level. It represents the origin of the brachial plexus. Between T11 and L1 is the lumbar enlargement, representing the origin of the lumbar and sacral plexi.

The spinal cord is marked by two depressions on its surface. The anterior median fissure is a deep groove extending the length of the anterior surface of the spinal cord. On the posterior aspect there is a slightly shallower depression – the posterior median sulcus.

The pia mater that surrounds the spinal cord continues downwards all the way to the coccyx as a thin filament known as the **filum terminale**. This provides for a tight connection between the medullary cone and the back of the coccyx and, thereby, stabilizing the entire spinal cord



Formation of the Spinal Nerves (31 pairs through the 33 vertebrae)

The spinal nerves are mixed nerves that originate from the spinal cord, forming the peripheral nervous system.

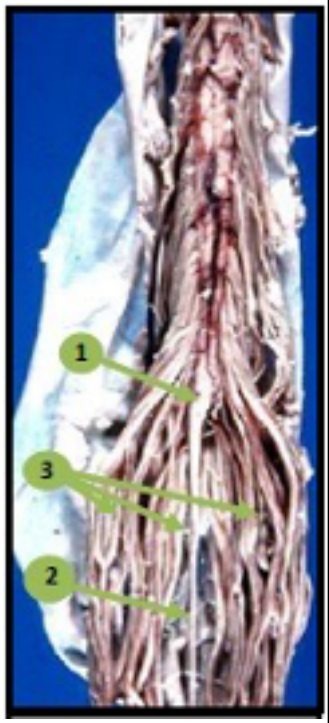
Each spinal nerve begins as an anterior (motor) and a posterior (sensory) nerve root. These roots arise from the spinal cord, and unite at the **intervertebral foramina**, forming a single spinal nerve.

The spinal nerve then leaves the vertebral canal via the intervertebral foramina, and then divides into two:

Posterior rami – supplies nerve fibres to the synovial joints of the vertebral column, deep muscles of the back, and the overlying skin.

Anterior rami – supplies nerve fibres to much of the remaining area of the body, both motor and sensory.

The nerve roots L2-S5 arise from the distal end of the spinal cord, forming a bundle of nerves known as the cauda equina.



Inside, the spinal cord consists of grey matter and white matter.

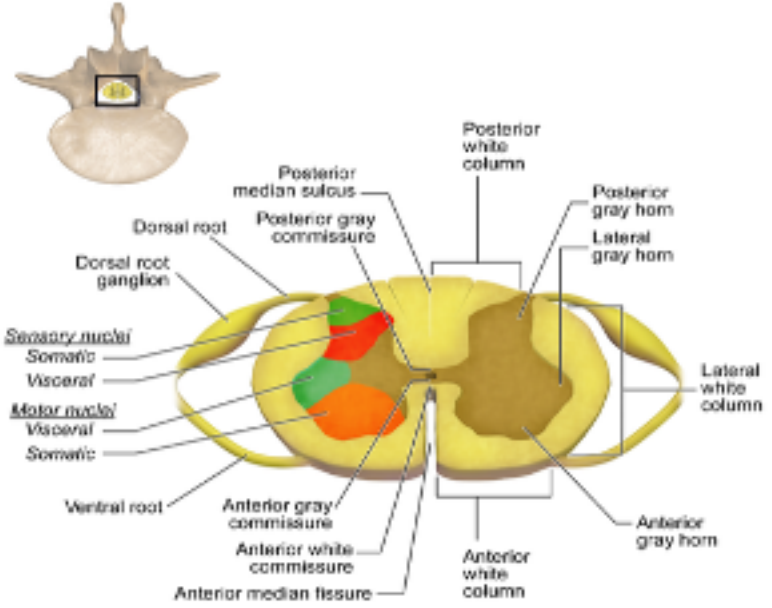
The **grey matter** takes on the shape of a butterfly, with four 'wings' called horns: The horns in the front contain motor neurons; the horns in the back contain sensory neurons which carry sensory information.

The spinal cord grey matter is surrounded by a column of **white matter**, containing axons that allow different parts of the spinal cord to communicate smoothly, with signals passing upwards and downwards conveying eg sensation and motor signals.

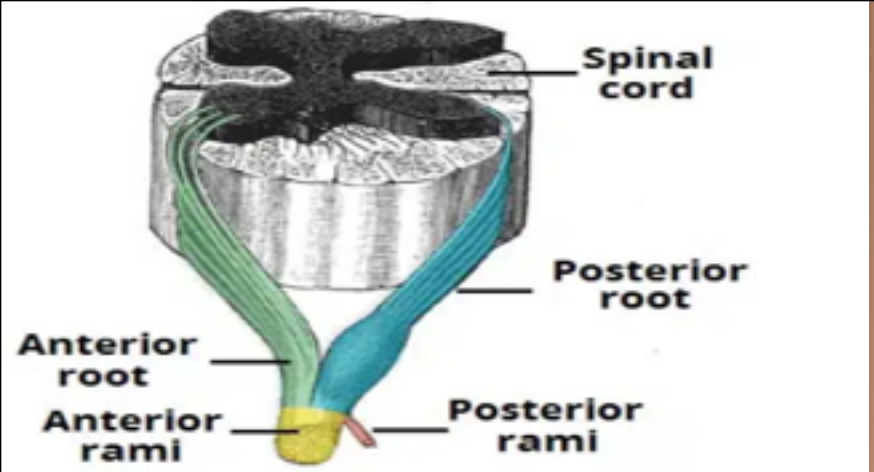
Entry and Exit

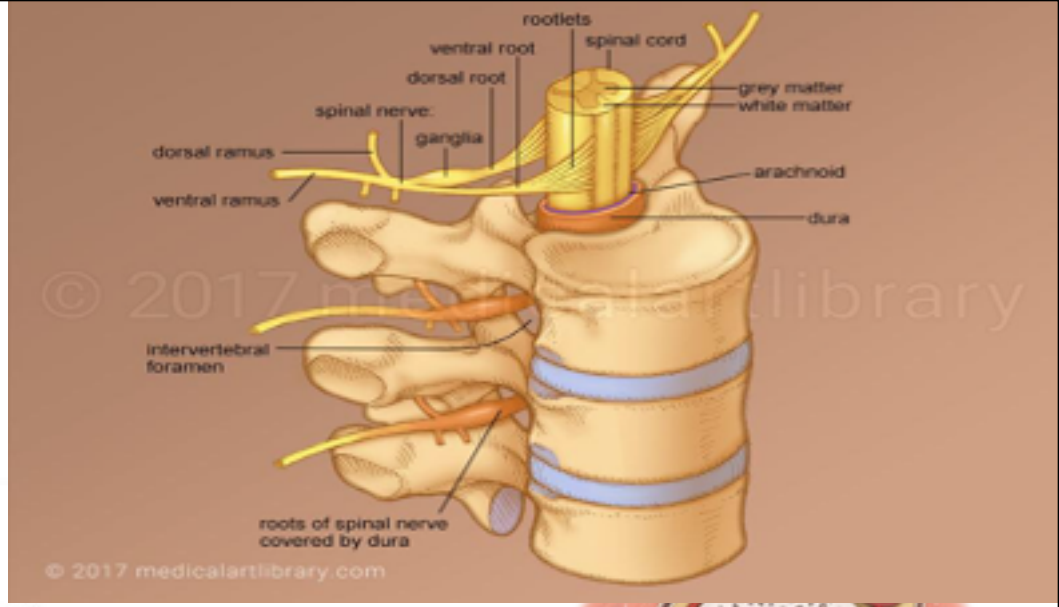
Sensory Nerve Fibres enter the Spinal Cord via the Posterior (Dorsal) Root. The cell bodies for these neurons are situated in the Dorsal Root Ganglia.

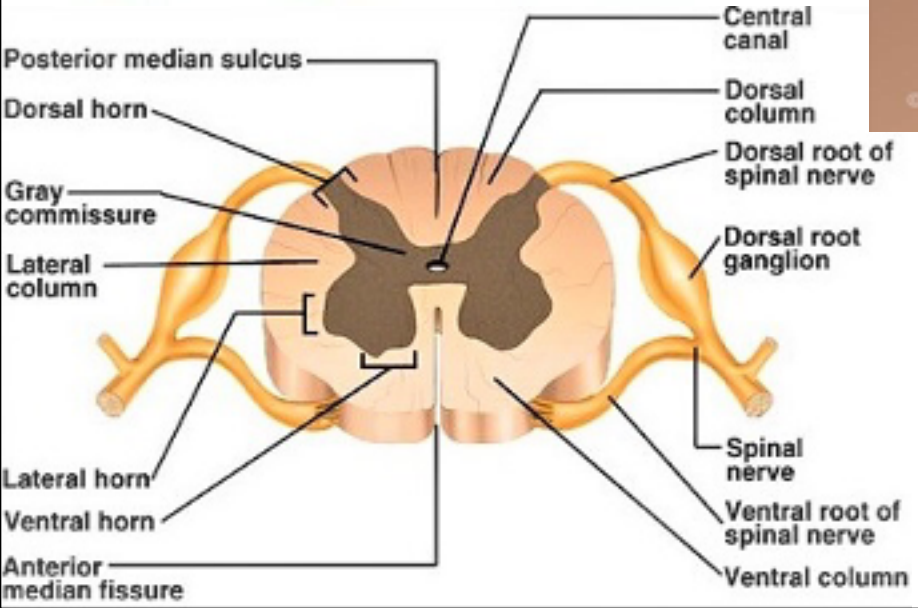
Motor and Preganglionic Autonomic Fibres exit via the Anterior (Ventral) Root.



Sectional Organization of the Spinal Cord



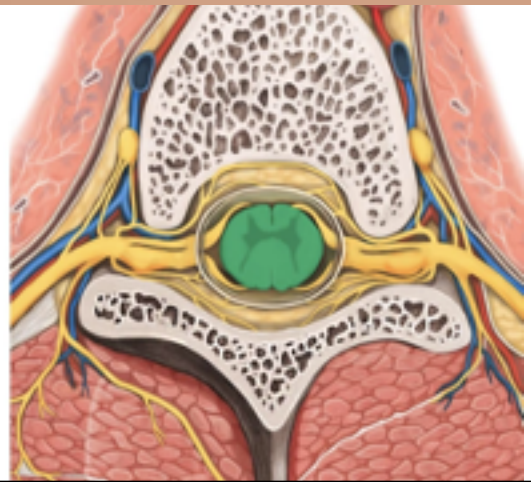




Spinal cord

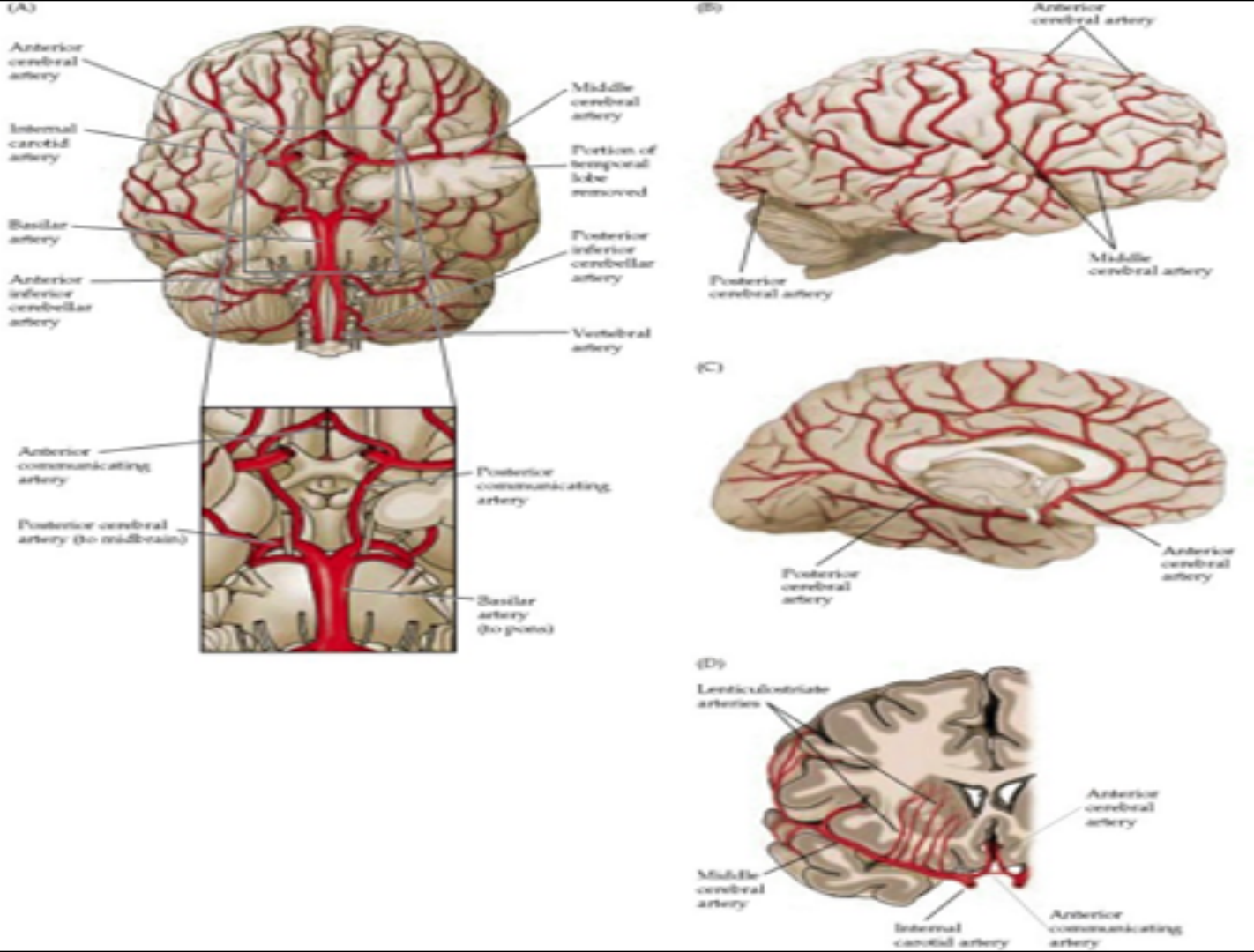
Gray matter:
cell bodies and glia.

White matter:
ascending or the descending fiber pathways.

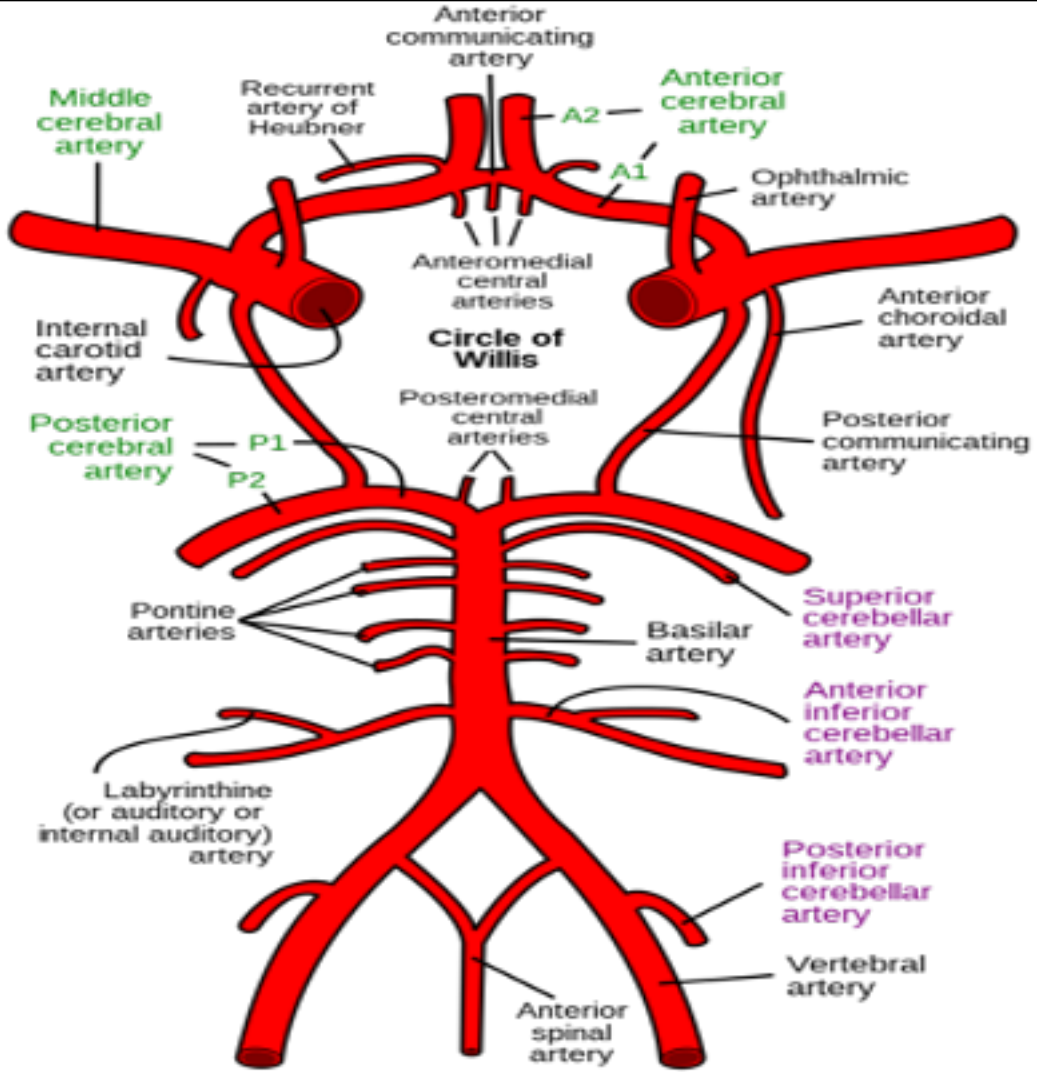


Brain Blood Supply

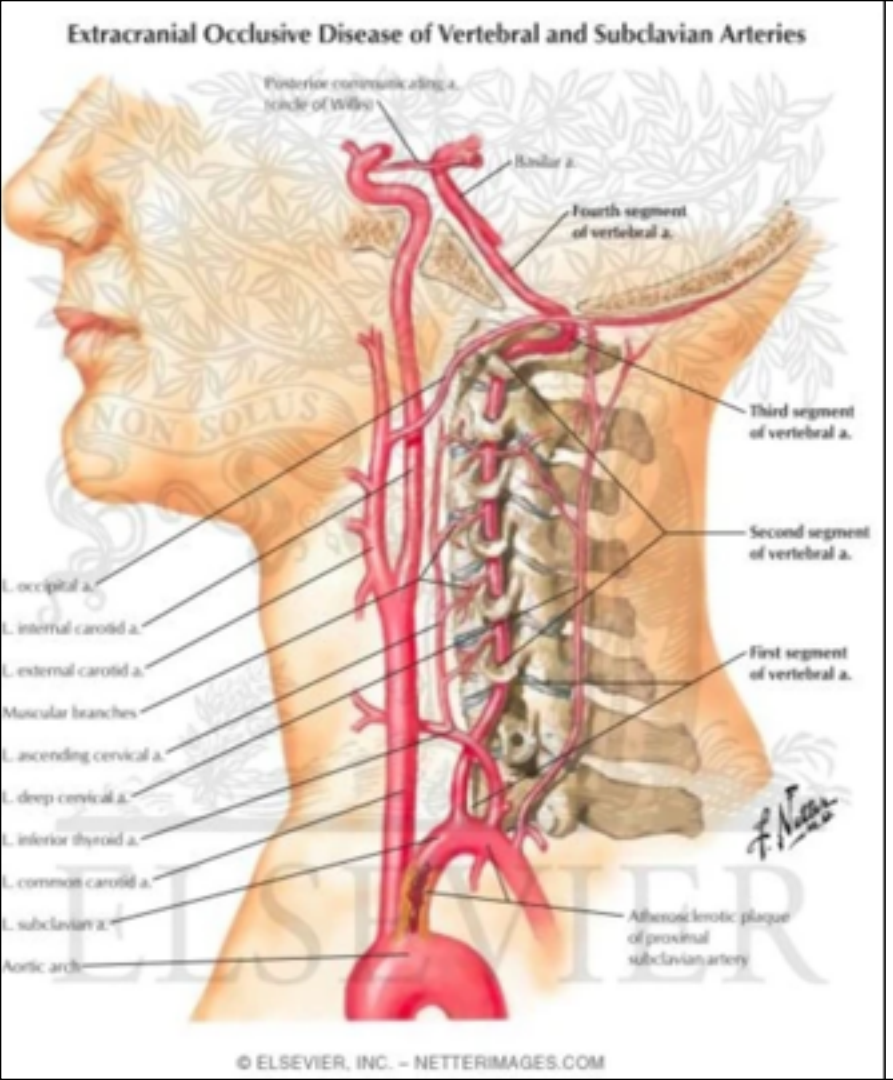
The brain receives blood from two sources: the **internal carotid arteries 80%**, which arise at the point in the neck where the common carotid arteries bifurcate, and the **vertebral arteries 20%**. The internal carotid arteries branch to form two major cerebral arteries, the anterior and middle cerebral arteries. The right and left vertebral arteries come together at the level of the pons on the ventral surface of the brainstem to form the midline basilar artery. The basilar artery joins the blood supply from the internal carotids in an arterial ring at the base of the brain (in the vicinity of the hypothalamus and cerebral peduncles) called the circle of Willis. The posterior cerebral arteries arise at this confluence, as do two small bridging arteries, the anterior and posterior communicating arteries. Conjoining the two major sources of cerebral vascular supply via the circle of Willis presumably improves the chances of any region of the brain continuing to receive blood if one of the major arteries becomes occluded


(A)
Anterior cerebral artery
Internal carotid artery
Basilar artery
Anterior inferior cerebellar artery
Middle cerebral artery
Portion of temporal lobe removed
Posterior inferior cerebellar artery
Vertebral artery
Anterior communicating artery
Posterior cerebral artery (to midbrain)
Posterior communicating artery
Basilar artery (to pons)
(B)
Anterior cerebral artery
Posterior cerebral artery
Middle cerebral artery
(C)
Posterior cerebral artery
Anterior cerebral artery
(D)
Lenticulostriate arteries
Middle cerebral artery
Anterior cerebral artery
Internal carotid artery
Anterior communicating artery

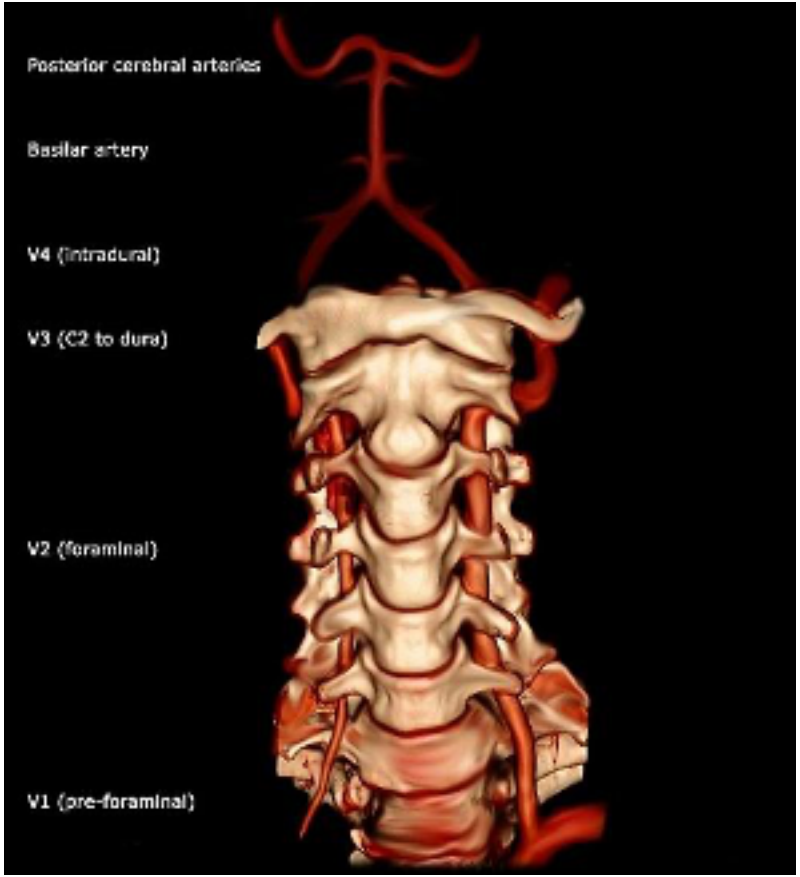
The major branches that arise from the **internal carotid artery**—the **anterior and middle cerebral arteries**—form the anterior circulation that supplies the forebrain. These arteries also originate from the **circle of Willis**. Each gives rise to branches that supply the cortex and branches that penetrate the basal surface of the brain, supplying deep structures such as the basal ganglia, thalamus, and internal capsule. Particularly prominent are the **lenticulostriate arteries** that branch from the middle cerebral artery. These arteries supply the basal ganglia and thalamus. The posterior circulation of the brain supplies the posterior cortex, the midbrain, and the brainstem; it comprises arterial branches arising from the **posterior cerebral, basilar, and vertebral arteries**. The pattern of arterial distribution is similar for all the subdivisions of the brainstem: Midline arteries supply medial structures, lateral arteries supply the lateral brainstem, and dorsal-lateral arteries supply dorsal-lateral brainstem structures and the cerebellum. Among the most important dorsal-lateral arteries (also called long circumferential arteries) are the posterior inferior cerebellar artery (**PICA**) and the anterior inferior cerebellar artery (**AICA**), which supply distinct regions of the medulla and pons. These arteries, as well as branches of the basilar artery that penetrate the brainstem from its ventral and lateral surfaces (called **paramedian and short circumferential arteries**), are especially common sites of occlusion and result in specific functional deficits of cranial nerve, somatic sensory, and motor function


Anterior communicating artery
Middle cerebral artery
Recurrent artery of Heubner
A2
Anterior cerebral artery
A1
Ophthalmic artery
Anteromedial central arteries
Internal carotid artery
Circle of Willis
Anterior choroidal artery
Posteromedial central arteries
Posterior cerebral artery
P1
P2
Posterior communicating artery
Pontine arteries
Basilar artery
Superior cerebellar artery
Anterior inferior cerebellar artery
Labyrinthine (or auditory or internal auditory) artery
Posterior inferior cerebellar artery
Vertebral artery
Anterior spinal artery

The physiological demands served by the blood supply of the brain are particularly significant because neurons are more sensitive to oxygen deprivation than other kinds of cells with lower rates of metabolism. In addition, the brain is at risk from circulating toxins, and is specifically protected in this respect by the **blood-brain barrier**. As a result of the high metabolic rate of neurons, brain tissue deprived of oxygen and glucose as a result of compromised blood supply is likely to sustain transient or permanent damage. Brief loss of blood supply (referred to as ischemia) can cause cellular changes, which, if not quickly reversed, can lead to cell death. Sustained loss of blood supply leads much more directly to death and degeneration of the deprived cells. **Strokes**—a term that refers to the death or dysfunction of brain tissue due to vascular disease—often follow the occlusion of (or hemorrhage from) the brain's arteries. Historically, studies of the functional consequences of strokes, and their relation to vascular territories in the brain and spinal cord, provided information about the location of various brain functions. The location of the major language functions in the left hemisphere, for instance, was discovered in this way in the latter part of the nineteenth century. Now, noninvasive functional imaging techniques based on blood flow have largely supplanted the correlation of clinical signs and symptoms with the location of tissue damage observed at autopsy.



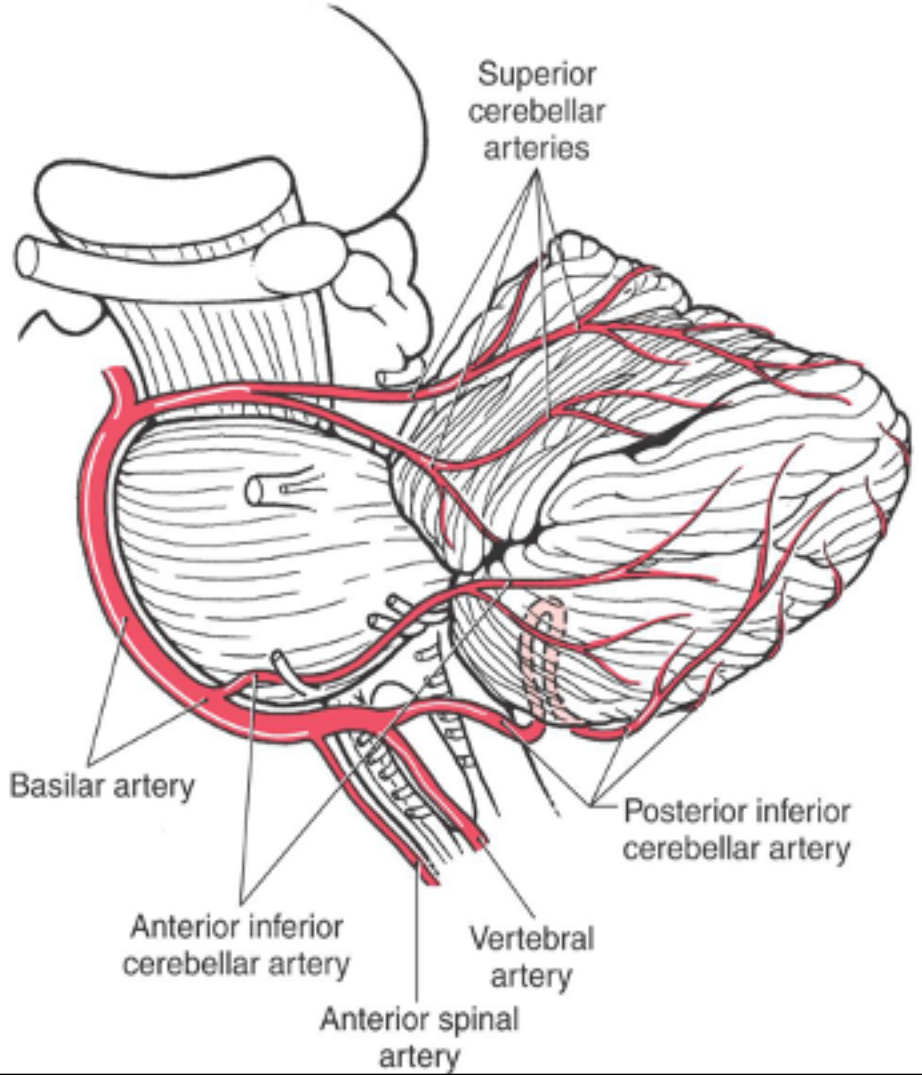
Vertebral Artery

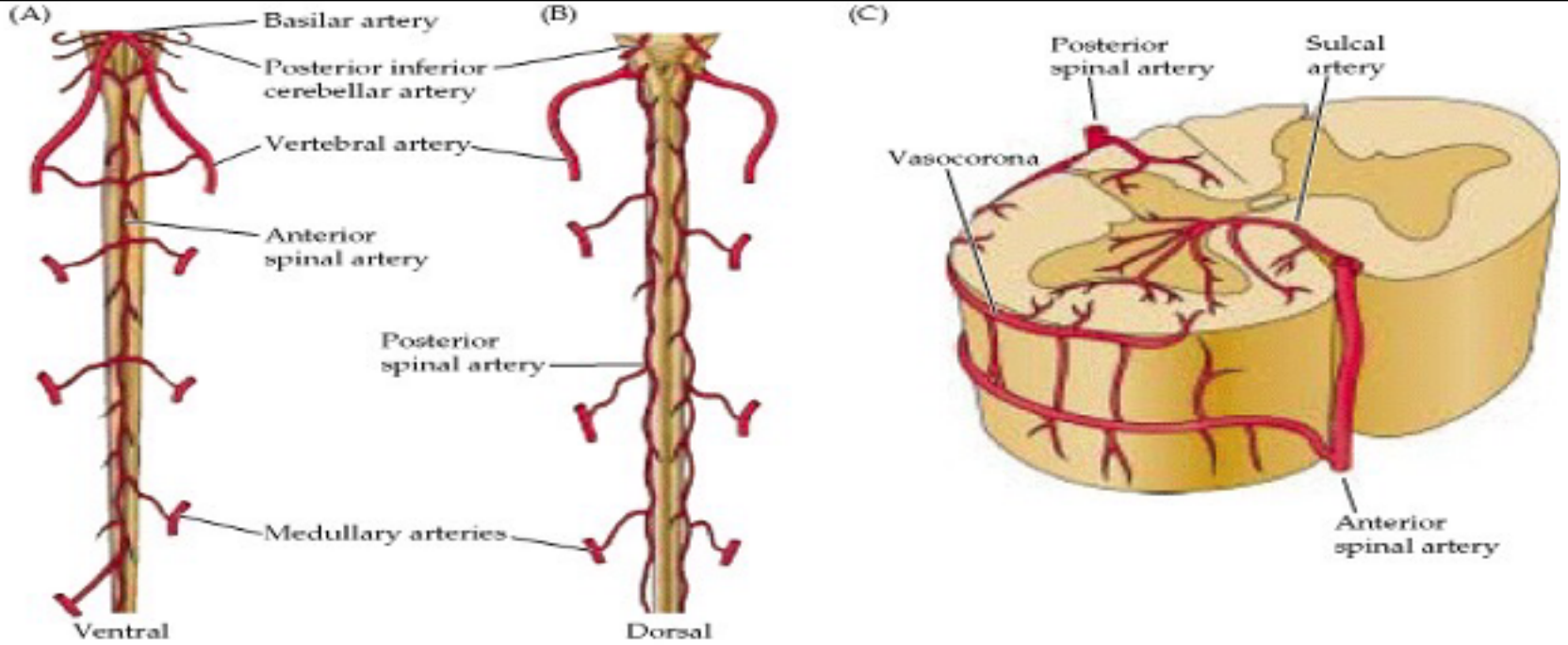


There are four segments of the vertebral artery, following its way through the neck; preforaminal, foraminal, extradural (atlantic), and intradural (intracranial) parts.

Cerebellum blood supply

The cerebellum is supplied by three bilateral arteries from the vertebrobasilar system: superior cerebellar artery (SCA): branch of the distal basilar artery. anterior inferior cerebellar (AICA): branch of the proximal basilar artery. posterior inferior cerebellar (PICA): branch of the distal vertebral arteries.





Blood supply of the spinal cord. (A) View of the ventral (anterior) surface of the spinal cord. At the level of the medulla, the vertebral arteries give off branches that merge to form the anterior spinal artery. Approximately 10 to 12 segmental arteries (which arise from various branches of the aorta) join the anterior spinal artery along its course. These segmental arteries are known as medullary arteries. (B) The vertebral arteries (or the posterior inferior cerebellar artery) give rise to paired posterior spinal arteries that run along the dorsal (posterior) surface of the spinal cord. (C) Cross section through the spinal cord, illustrating the distribution of the anterior and posterior spinal arteries. The anterior spinal arteries give rise to numerous sulcal branches that supply the anterior two-thirds of the spinal cord. The posterior spinal arteries supply much of the dorsal horn and the dorsal columns. A network of vessels known as the **vasocorona** connects these two sources of supply and sends branches into the white matter around the margin of the spinal cord.

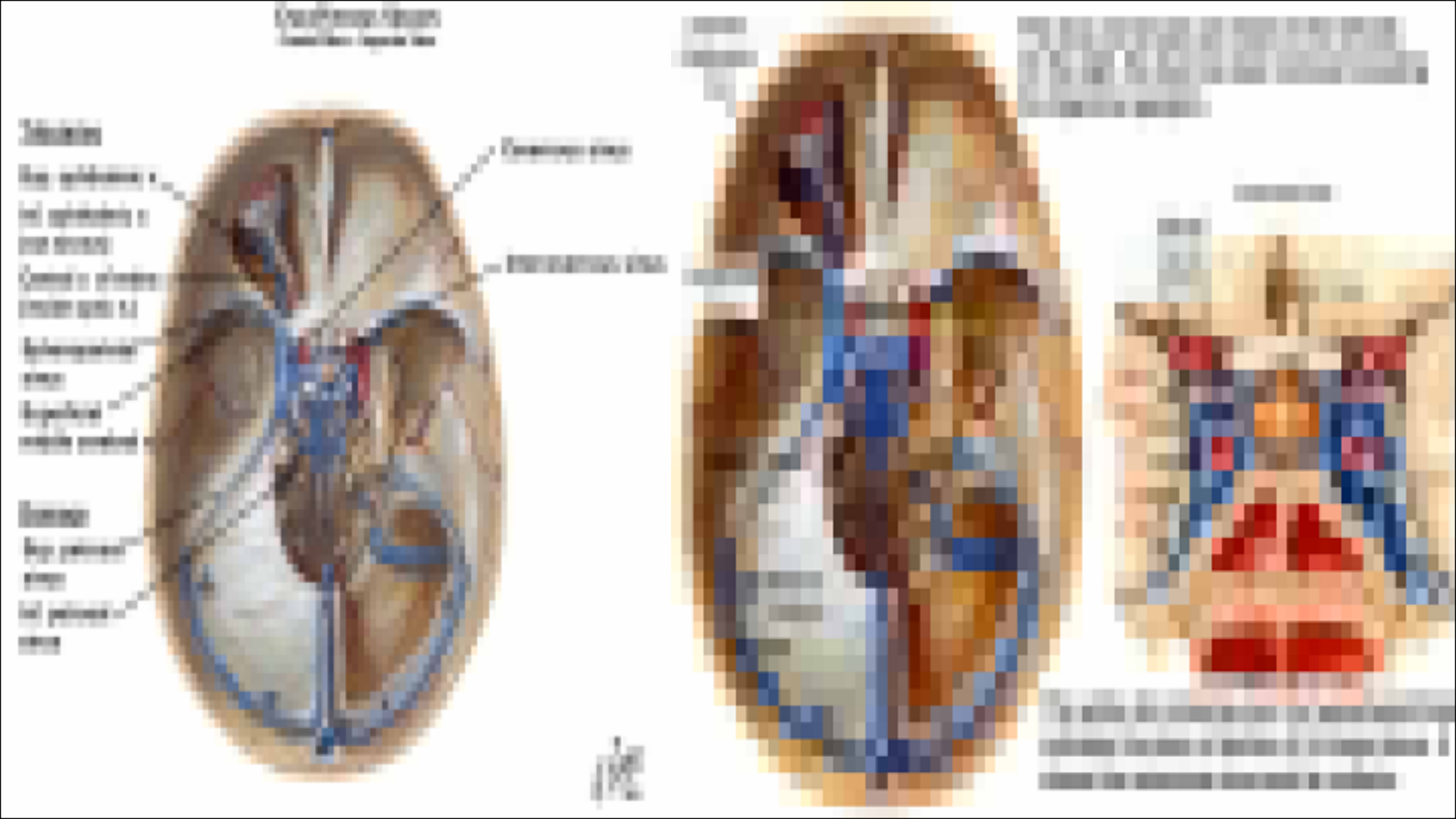
Cerebral venous drainage

Dural Venous Sinuses
The dural venous sinuses lie between the periosteal and meningeal layers of the dura mater. They are best thought of as collecting pools of blood, which drain the central nervous system, the face, and the scalp. All the dural venous sinuses ultimately drain into the internal jugular vein. Unlike most veins of the body, the dural venous sinuses do not have valves.

There are eleven venous sinuses in total. The straight, superior, and inferior sagittal sinuses are found in the falx cerebri of the dura mater. They converge at the confluence of sinuses (overlying the internal occipital protuberance). The straight sinus is a continuation of the great cerebral vein and the inferior sagittal sinus.

From the confluence, the transverse sinus continues bi-laterally and curves into the sigmoid sinus to meet the opening of the internal jugular vein.

The cavernous sinus drains the ophthalmic veins and can be found on either side of the sella turcica. From here, the blood returns to the internal jugular vein via the superior or inferior petrosal sinuses.



Veins of the Cerebrum

The veins of cerebrum are responsible for carrying blood from the brain tissue, and depositing it in the dural venous sinuses.

They can be divided into superficial and deep groups, which are flamboyantly arranged around the gyri and sulci of the brain. Upon exiting the cerebral parenchyma, the veins run in the subarachnoid space and pierce the meninges to drain into the dural venous sinuses.

Superficial System

The superficial system of veins is largely responsible for draining the cerebral cortex:

Superior cerebral veins: Drain the superior surface, carrying blood to the superior sagittal sinus.

Superficial middle cerebral vein: Drains the lateral surface of each hemisphere, carrying blood to the cavernous or sphenopalatine sinuses.

Inferior cerebral veins: Drain the inferior aspect of each cerebral hemisphere, depositing blood into cavernous and transverse sinuses.

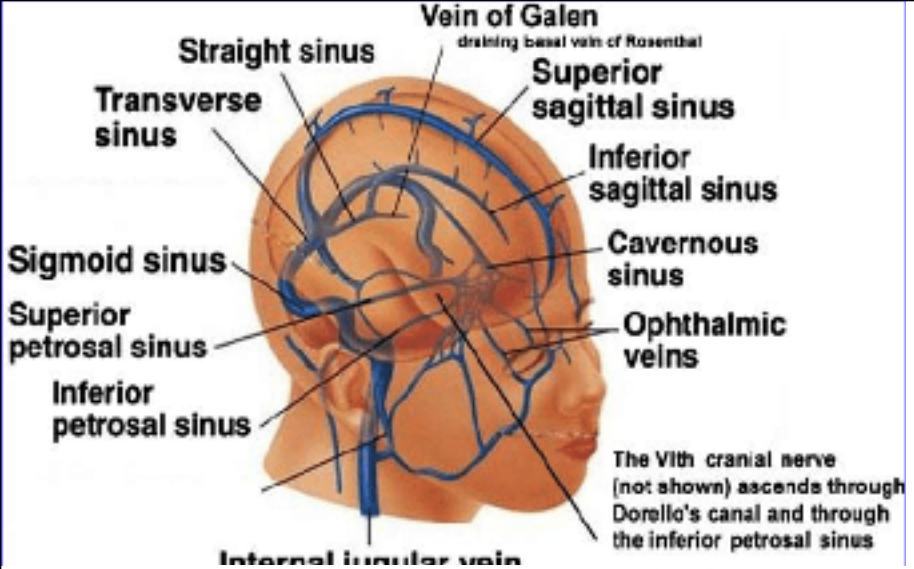
Superior anastamotic vein (Trolard): Connects the superficial middle cerebral vein to the superior sagittal sinus.

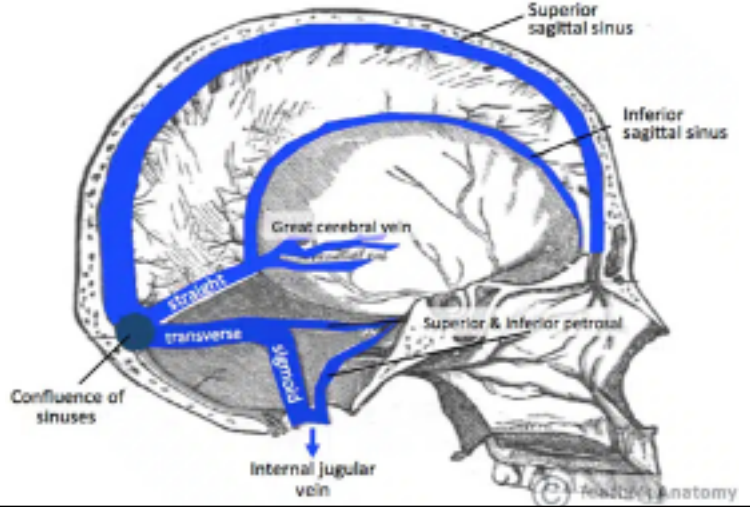
Inferior anastamotic vein (Labbé): Connects the superficial middle cerebral vein to the transverse sinus.

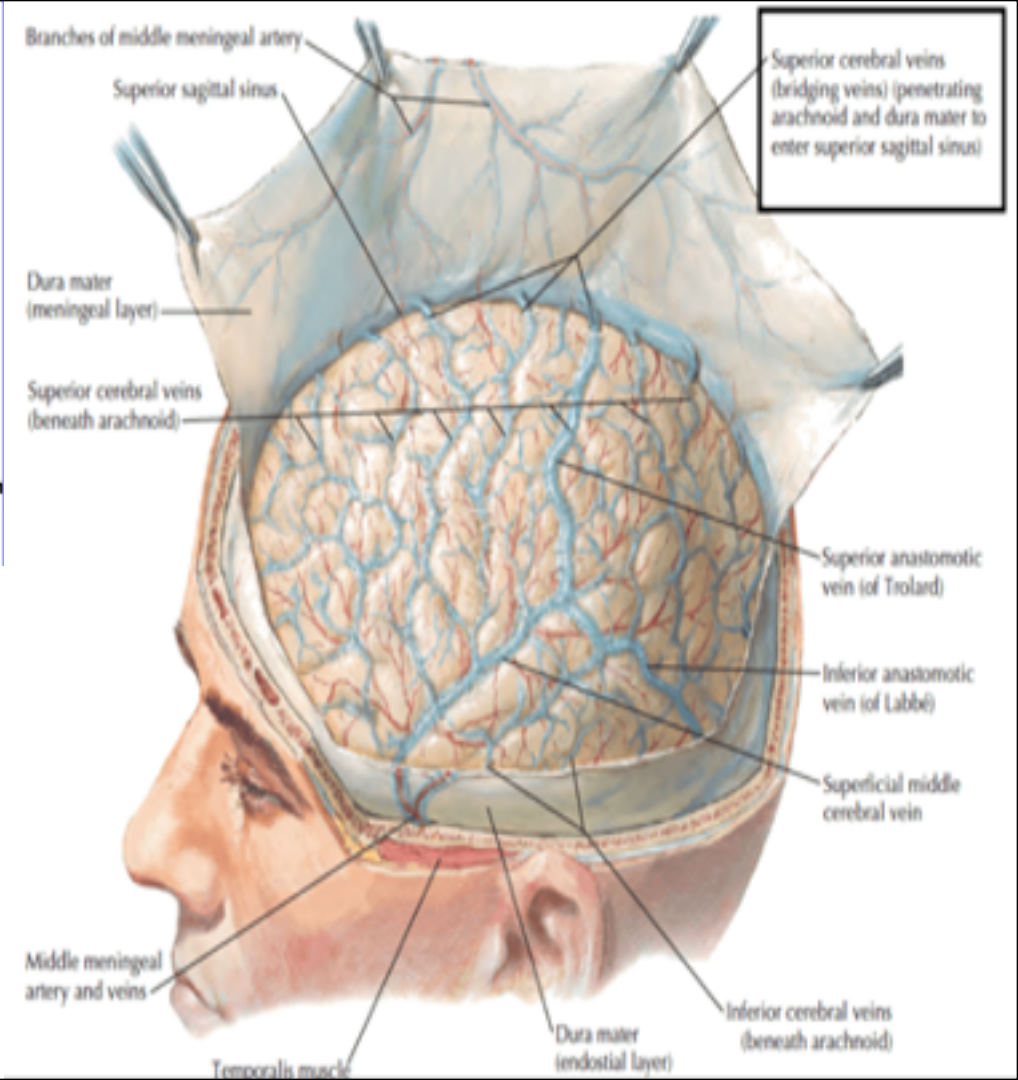
Deep System

Subependymal veins – There are numerous subependymal veins, which will not be described here in detail. These receive blood from the medullary veins and carry it to the dural venous sinuses. The great cerebral vein (vein of Galen) is worthy of a mention; it is formed by the union of two of the deep veins, and drains into the straight sinus.

Medullary veins: Originate 1-2cm below the cortical grey matter, and drain into subependymal veins. These drain the deep areas of the brain.


Vein of Galen
draining basal vein of Rosenthal
Straight sinus
Transverse sinus
Superior sagittal sinus
Inferior sagittal sinus
Sigmoid sinus
Cavernous sinus
Superior petrosal sinus
Ophthalmic veins
Inferior petrosal sinus
The VIth cranial nerve (not shown) ascends through Dorello's canal and through the inferior petrosal sinus
Internal jugular vein


Superior sagittal sinus
Inferior sagittal sinus
Great cerebral vein
straight
transverse
sigmoid
Superior & Inferior petrosal
Confluence of sinuses
Internal jugular vein


Branches of middle meningeal artery
Superior sagittal sinus
Superior cerebral veins (bridging veins) (penetrating arachnoid and dura mater to enter superior sagittal sinus)
Dura mater (meningeal layer)
Superior cerebral veins (beneath arachnoid)
Superior anastomotic vein (of Trolard)
Inferior anastomotic vein (of Labbé)
Superficial middle cerebral vein
Middle meningeal artery and veins
Inferior cerebral veins (beneath arachnoid)
Temporalis muscle
Dura mater (endostial layer)

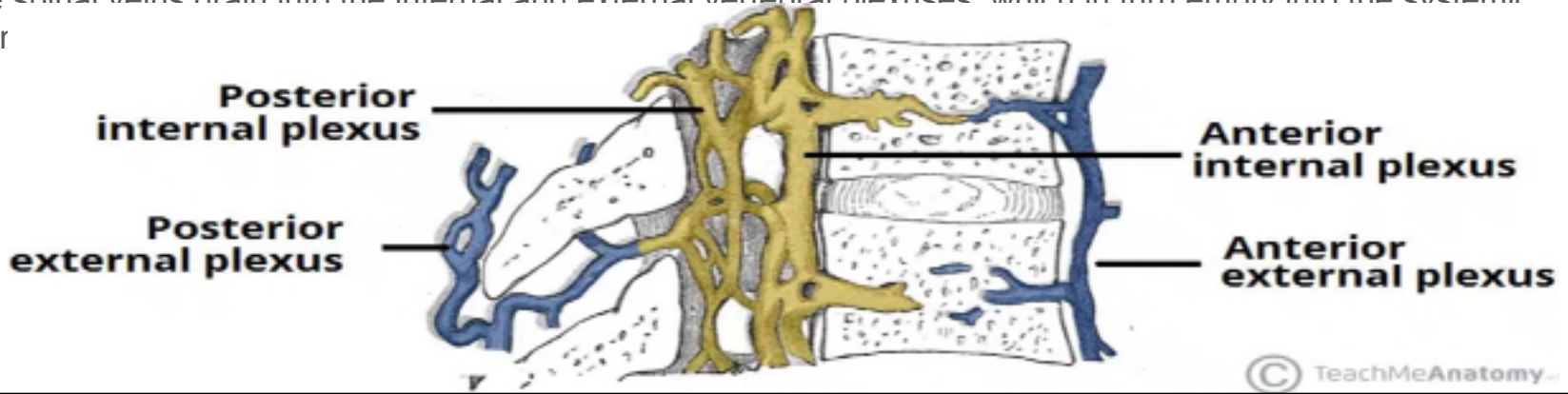
Cerebellum

There are two main veins responsible for the venous drainage of the cerebellum – the superior and inferior cerebellar veins. They empty into the superior petrosal, transverse and straight dural venous sinuses.

Brainstem

Venous drainage of the brainstem is carried out by numerous vessels – many of which are beyond the scope of this article. Examples of veins that drain the brainstem include the transverse pontine vein, anteromedian medullary vein, and the anterior and posterior spinal veins.

Spinal Cord

The spinal cord is supplied by three anterior and three posterior spinal veins. These veins are valveless, and form an anastamotic network along the surface of the spinal cord. They also receive venous blood from the radicular veins.

The spinal veins drain into the internal and external vertebral plexuses, which in turn empty into the systemic segr