Neuroanatomy Lecture
TUCOM
B. Puder, Ph.D.

Organization of the Central Nervous System: Brain, Meninges, & Cranium
Objectives

1. Define all the terms used to describe anatomical relationships.
2. Describe the anatomical relationships of the tentorium cerebelli, falx, and venous sinuses.
3. List/name the 12 cranial nerves.
4. Describe the anatomical relationships of the incisura (tentorial notch) and foramen magnum.
5. Describe the basic location and the relationships of various structures to the following portions of the ventricular system:
    - anterior horn
    - body
    - posterior horn
    - inferior horn
    - interventricular foramen of Monro
    - third ventricle
    - cerebral aquaduct of Sylvius
    - fourth ventricle
    - medial and lateral aperatures (Majendie and Luschka)
6. Describe the location of the following cisterns:
    - cerebello-medullary cistern (cisterna magna)
    - pontine cistern
    - quadrigeminal cistern (superior or cisterna ambiens)
    - interpeduncular cistern
7. Describe the location of the choroid plexus.
8. Describe the source, flow, and elimination of cerebrospinal fluid (CSF).
9. Describe the relationship of the meninges to the central nervous system.
10. Identify brain lobes and describe their general function.
11. Identify specific cortical gyri and describe their function.
12. Identify the 4 major diencephalic structures and describe the function of each structure.
13. List and identify the components of the Basal nuclei and describe their general function.
14. Identify major brainstem regions and structures and describe their function.
15. Identify the cerebellum and state its function.
16. Explain the clinical importance of the supra and infratentorial compartments and describe how volume or pressure changes impact the structures in each compartment.

Organization of the Central Nervous System: Brain, Meninges, & Cranium Outline

I. General Information
    A. Major divisions
        1. Central nervous system (CNS)
        2. Peripheral nervous system (PNS)
    B. Functions of the nervous system
        1. Motor
        2. Sensory (general)
        3. Sensory (special)
        4. Associational areas
    C. CNS intracranial relationships

II. Orientation and Terminology

III. Gross relationships of the CNS
    A. Cerebrum
        3 major divisions
        1. Cerebral Cortex
        2. Subcortical white matter
        3. Basal nuclei
    B. Major brain lobes
        4 major lobes
        1. Frontal lobe
            a. Precentral gyrus
            b. Premotor cortex
                i. Superior Frontal gyrus
                ii. Middle Frontal gyrus
                iii. Inferior Frontal gyrus
                    a. Broca's motor speech area
        2. Parietal lobe
            a. Postcentral gyrus
            b. Superior parietal lobule
            c. Inferior parietal lobule
                i. Supramarginal gyrus
                ii. Angular gyrus
        3. Temporal lobe
            a. Superior temporal gyrus
            b. Middle temporal gyrus
            c. Inferior temporal gyrus
            d. Heschl's gyrus
        4. Occipital lobe
            a. Cuneus gyrus
            b. Lingual gyrus

C. Gyri and structures on medial aspect of brain
    1. Precuneus gyrus
    2. Paracentral gyrus
    3. Cingulate gyrus
    4. Corpus callosum
        a. Rostrum
        b. Genu
        c. Body
        d. Splenuim
D. Ventral (inferior) surface of brain
    1. Gyrus rectus
    2. Olfactory bulb and tract
    3. Occipitotemporal gyrus
    4. Parahippocampal gyrus
        a. Uncus
        b. Amygdala
        c. Hippocampus
E. Deep cortical structures
    1. Basal nuclei (ganglia)
        a. Caudate
        b. Putamen
        c. Globus Pallidua
        d. Subthalamic nucleus
        e. Substantia nigra
F. Diencephalon
    1. Dorsal thalamus
    2. Subthalamus
    3. Hypothalamus
    4. Epithalamus
    5. Other structures in area
        a. Anterior commissure
        b. Posterior commissure
        c. Fornix
G. Brainstem
    1. Midbrain
    2. Pons
    3. Medulla
H. Cerebellum
I. Spinal cord
J. Gross bumps on brainstem
    1. Midbrain
        a.Cerebral peduncles
        b. Superior colliculus
        c. Inferior colliculus
        d. Cranial nerves III & IV

2. Pons
    a. Superior Cerebellar peduncle
    b. Middle cerebellar peduncle
    c. Inferior cerebellar peduncle
    d. Superior medullary velum
    e. Facial colliculus
    f. Cranial nerves V, VI, VII, VIII
3. Medulla
    a. Pyramids
    b. Olives
    c. Gracile tubercles
    d. Cuneate tubercles
    e. Cranial nerves IX, X, XI, XII

K. Ventricles and Ventricular system
    1. Cerebrospinal fluid

L. Meninges
    1. Dura Mater
    2. Arachnoid
    3. Pia Mater

M. Cisterns
    1. Pontine
    2. Interpeduncular
    3. Chiasmatic
    4. Superior
    5. Cerebellomedullary
    6. Lumbar

N. Dura, Dural venous sinuses, and supra and infratentorial compartments
    1. Falx cerebri
    2. Tentorium cerebelli

O. Intracranial compartments
    1. Supratentorial
    2. Infratentorial

P. Pressure relationships
    1. Uncal herniation
    2. Cerebellar tonsil herniation

Q. Cranial nerves

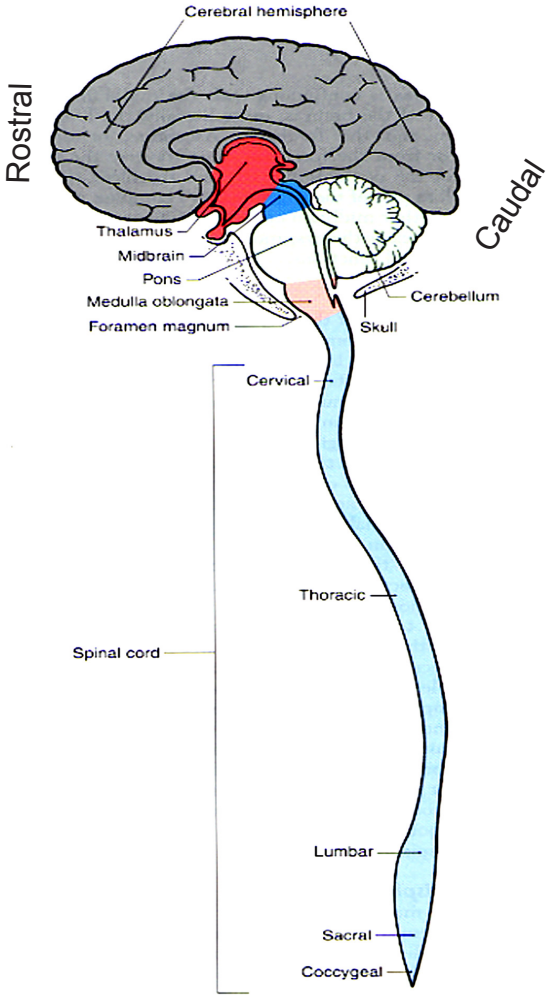
S. Relationships of ventricles to neighboring structures

Organization of the Central Nervous System

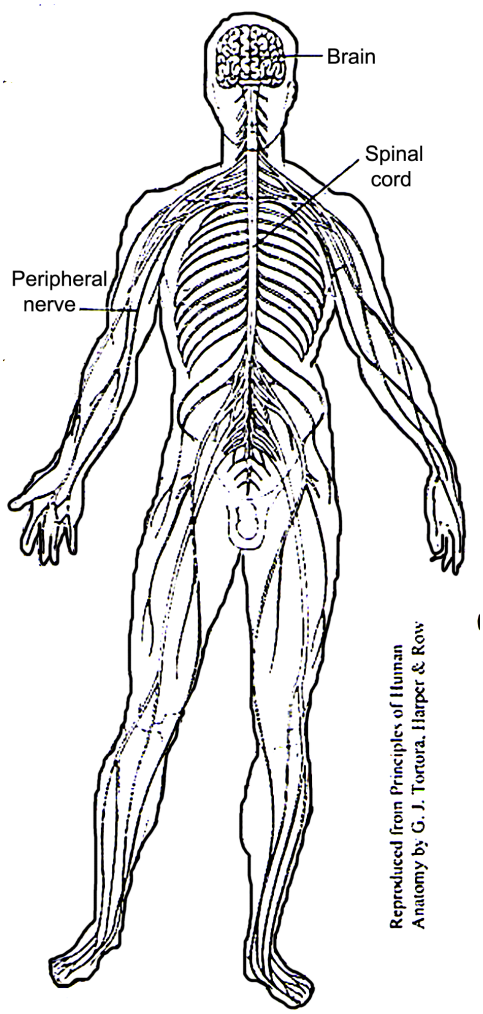
I. General Information

A. The Nervous system is composed of 2 major divisions:

1. Central nervous system (CNS) = brain and spinal cord
2. Peripheral nervous system (PNS) = all nerves that connect brain and spinal cord with peripheral structures



Sagittal view of CNS



Human Nervous System

B. Functions of nervous system

1. Motor - for stimulating movement of skeletal muscles
2. Sensory (general) - for reception and interpretation of sensory input (pain, touch, pressure)
3. Sensory (special) - for reception and interpretation of visual, auditory,olfactory, and taste cues
4. Associational areas - for interpreting sensory input to the brain and combining input from different systems and associating it for eventual output

C. Central nervous system and its intracranial relationships

Basic Information

-The brain is contained in a bony compartment = skull or cranium

-The brain and spinal cord are the consistency of jello (right before it is set)

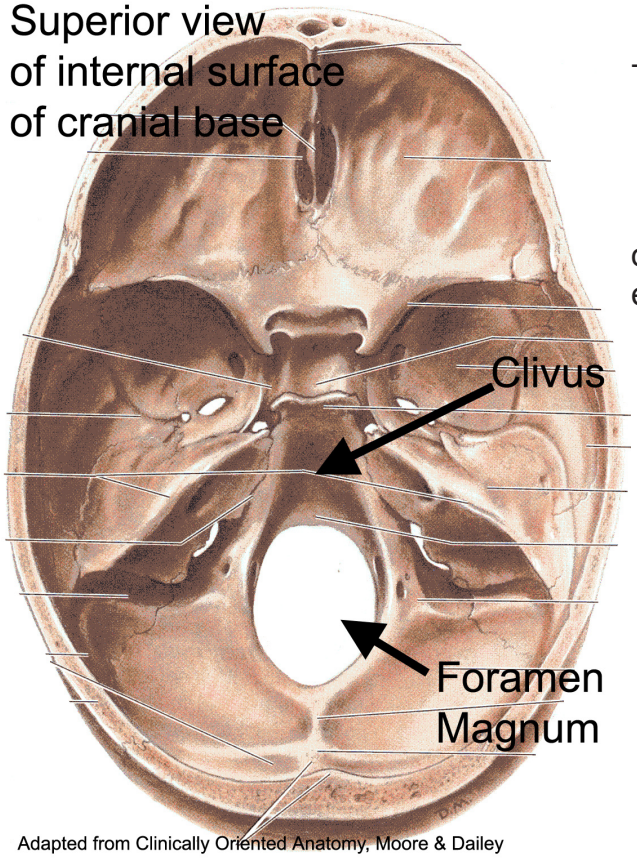
-The brain and spinal cord float in cerebrospinal fluid (CSF)

-The brain and spinal cord are suspended by a tough connective tissue membrane (dura mater)

-The brain and spinal cord are soft tissue that is rigidly suspended so that abrupt head trauma can tear connections and damage nervous tissue.

- The cranium is hard bone so that any space occupying lesions (eg. tumors, blood hemorrhages) will increase pressure on the brain and cause damage.

- It is **important to consider relationships between nervous system structures** because when lesions occur in one area, they may affect the surrounding structures as well.

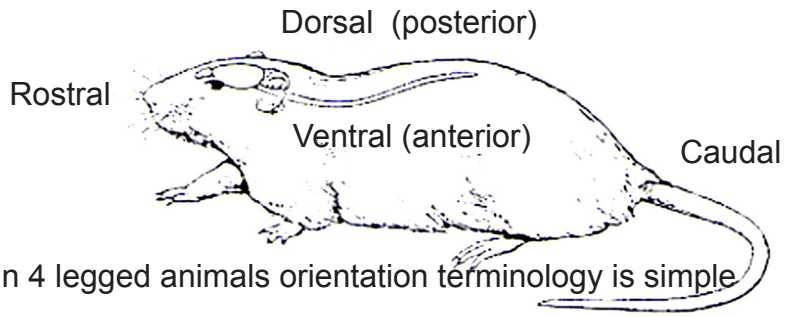


Adapted from Clinically Oriented Anatomy, Moore & Dailey

- The foramen magnum (means big hole) is a major opening in the cranium. The medulla of the brainstem is located at this opening. If pressure builds in the brain it is going to push structures out any open space that it can which can cause life ending consequences.

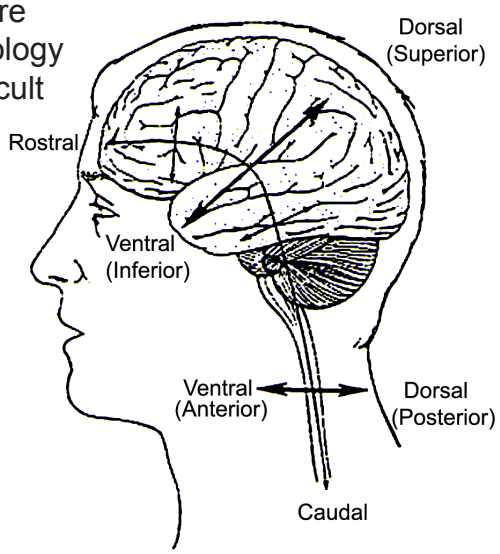
- Skull fractures can impinge on nervous tissue or major arteries that supply the brain. The clivus is a bone at the base of the skull which, if cracked can damage a major artery (Basilar artery) of the brainstem. A blow to the side of the head can damage the middle meningeal artery.

II. Orientation andTerminology



In 4 legged animals orientation terminology is simple

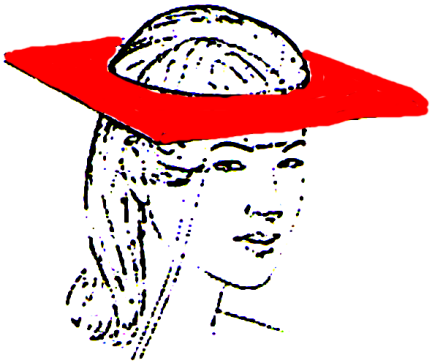
Because humans are upright, this terminology becomes more difficult



Adapted from Fundamental Neuroscience for Basic and Clinicla Applications, D.E.

Adapted from Neuroanatomy Text and Atlas by J.H. Martin, Appleton & Lange

Horizontal section



Coronal section

Sagittal section

Important Terms

Anterior (ventral) - Front of the body

Posterior (dorsal) - Back of the body

Superior (cephalad or craniad) - Toward the head or the upper part of a structure

Inferior (caudad) - Away form the head or toward the lower part of a structure

Medial - Nearer to the midline of the body or structure

Lateral - Farther away from the midline of the body or structure

Intermediate - Between 2 structures in which one is medial and one is lateral

Proximal - Nearer to the attachment of an extremity to the trunk or a structure, nearer to the point of origin

Distal - Farther from the attachment of an extremity to the trunk or structure, farther away from the point of origin

Superficial - Toward or on the surface of the body

Deep - Away form the surface of the body

Parietal - Pertaining to the outer wall of a body cavity

Visceral - Pertaining to the covering of an organ (viscus)

Ipsilateral - On the same side of the body

Contralateral - On the opposite side of the body

Commissure - A group of nerve fibers that connect one side of the brain with the other

Decussation - The actual crossing of the nerve fibers from one side to the other

White matter - The axon portion of the neuron appears white due to the myelin that surrounds the axon

Gray matter - The cell body part of a neuron

Afferent - axons **A**rriving at a structure

Efferent - axons **E**xiting a structure

Functional system - neurons linked together to convey a particular type of information or task (systems/pathways definition may overlap)

Region - specific anatomical place (systems/pathways transverse many regions)

Depressions and Openings

Fissure - A narrow cleftlike opening between adjacent parts of the brain through which blood vessels or nerves pass

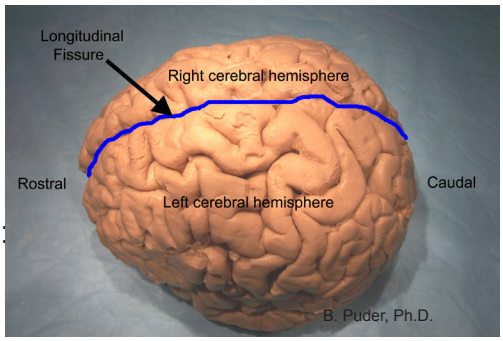
Foramen (hole) - An opening through which blood vessels, nerves, or ligaments pass

Meatus (canal) - A tubelike passageway running within bone

Groove or sulcus (sulcus = a ditchlike groove) - A furrow or depression that accomodates a soft structure such as a blood vessel, nerve, or tendon

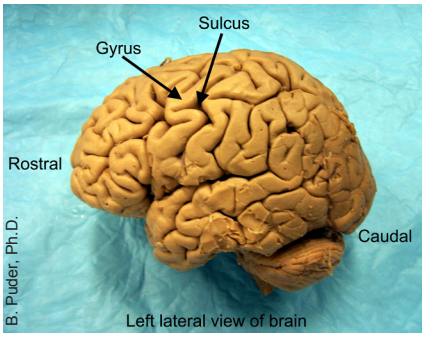
Fossa (fossa = basinlike depression) - A depression in or on a bone

III. Gross relationships of the CNS

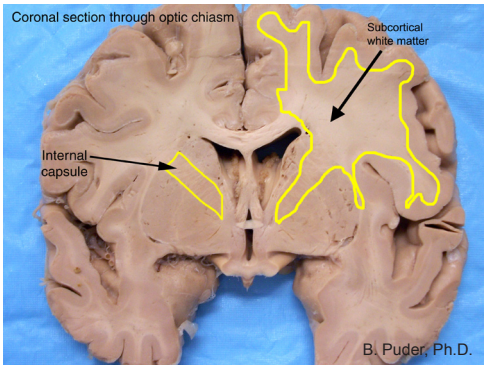


A. Cerebrum (telencephalon)

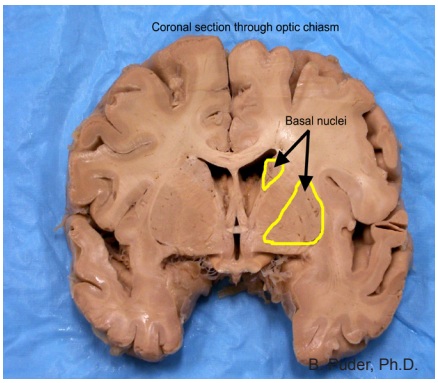
Has 2 hemispheres
Divided by the longitudinal fissure
Each hemisphere has 3 major divisions:



1. Cerebral cortex
-cell bodies (gray matter) .5cm thick
-thrown into folds = gyri (singular fold = gyrus)
-creases between gyri = sulci (singular = sulcus)
-contains sensory and motor gyri and association (for analysis of cognitive thought)



2. Subcortical white matter
-myelinated axons carry information to and from cortex
-largest and most organized structure is the internal capsule



3. Prominent group of cell bodies = basal nuclei (ganglia)
- involved in motor function

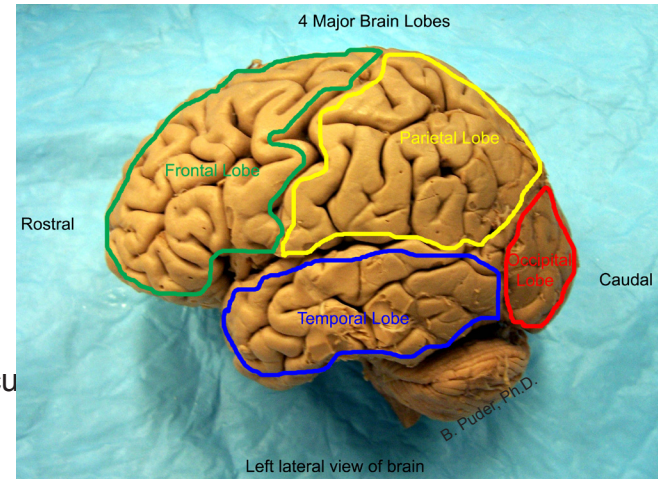
B. Major Brain Lobes

The cerebrum can be divided into 4 major brain lobes:

1. Frontal lobe
2. Parietal lobe
3. Temporal lobe
4. Occipital lobe

(there is a 5th lobe = limbic lobe that we will talk about later)

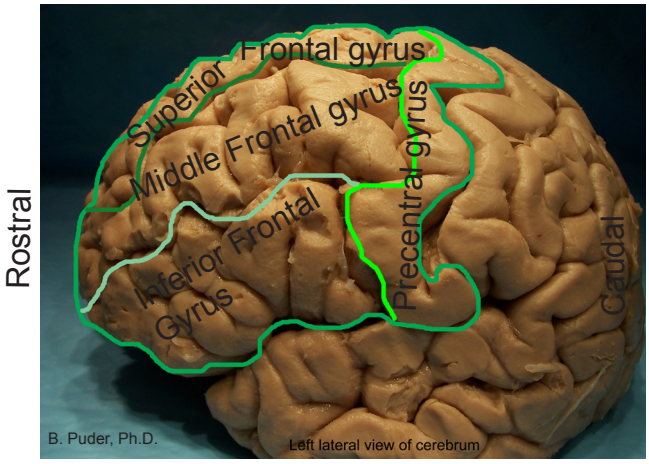
Lobes are divided in part by the **Central sulcus** and **Lateral sulcus**

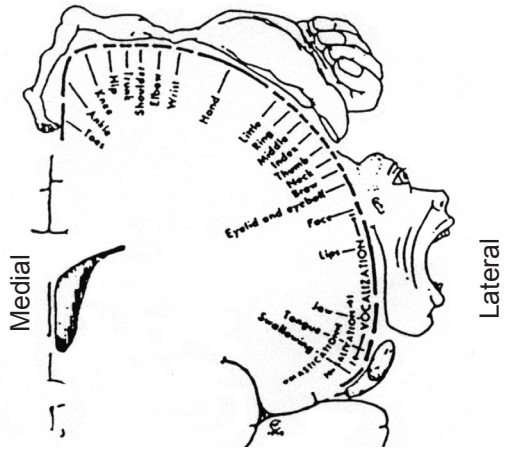


1. Frontal lobe

Rostral section of cerebrum
Ends at central sulcus and lateral sulcu
Functions include motor and limbic

a. Frontal lobe gyri
   i. **Precentral gyrus**
      Integrates motor functions
      Primary notor cortex to control voluntary movements
      Somatotopically organized
         Homunculus = "little man"
            depicts relative sizes of populations of neurons associated with specific body parts
   ii. Premotor cortex
      Includes:
         Superior, middle, and inferior frontal gyri
      supplementary motor cortex - initiates and sequences movements
      Inferior frontal gyrus contains **Broca's motor speech area**





Coronal section through the precentral gyrus depicting the motor homunculus

2. Parietal Lobe

Rostal boundary is central sulcus, inferior boundary is lateral sulcus,
medial boundary is parieto-occipital sulcus
Involved in **somatosensory processing**

a. Parietal lobe gyri

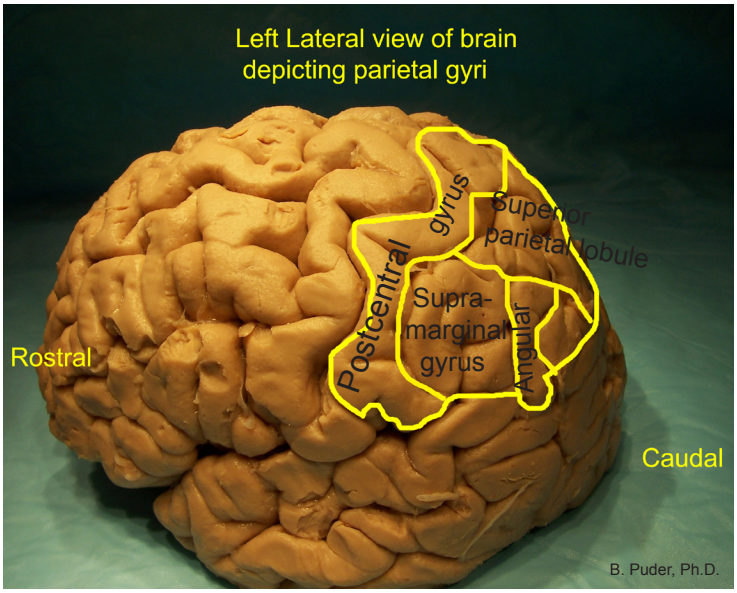
i. **Postcentral gyrus**

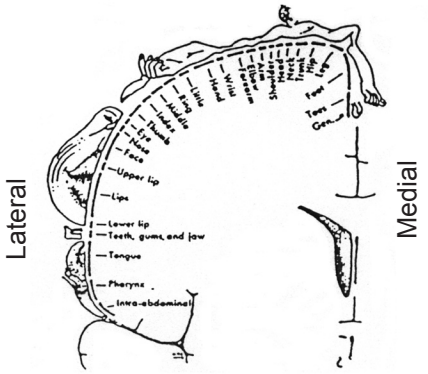
receives somesthetic (tactile) information
sensory homunculus is represented here

ii. Superior parietal lobule

iii. Inferior parietal lobule

contains **Supramarginal** and **Angular** gyri
A portion of Wernicke's area (speech/language association area) is represented here
receive from auditory and visual areas and discriminate and integrate info





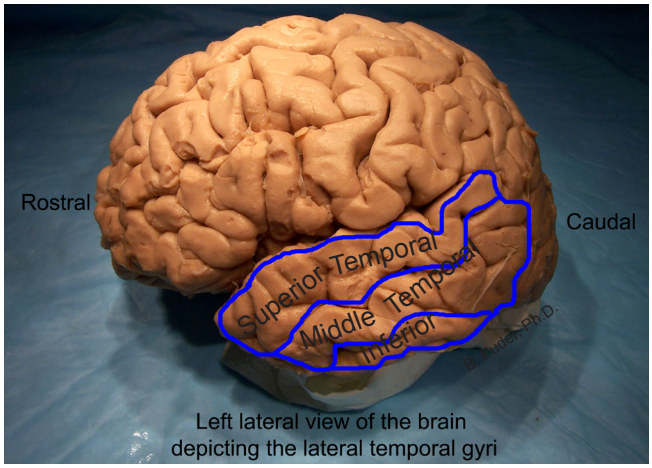
Coronal section through postcentral gyrus
depicting the sensory Homunculus

3. Temporal lobe

Superior boundary is lateral sulcus
Looks like the thumb part of a boxing glove
Involved in auditory processing
deeper structures are involved in learning and memory (hippocampus)

i. Temporal lobe gyri
3 lateral temporal lobe gyri include:
1. **superior**
2. **middle**
3. **inferior temporal gyri**

1 deep lateral gyri = **Heschl's gyrus**
located superior and medial to
superior temporal gyrus
(primary auditory area)



Left lateral view of the brain
depicting the lateral temporal gyri

4. Occipital lobe

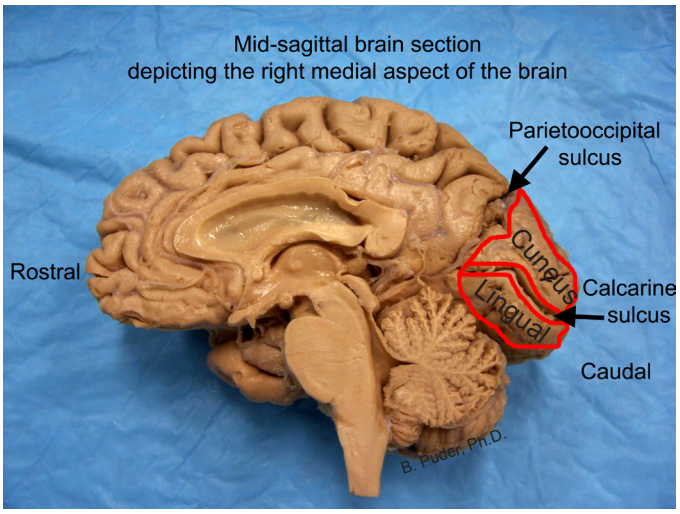
Located in caudal area of cerebrum

Boundaries (easier to see on medial aspect of brain) include parieto-occipital sulcus and calcarine sulcus

involved in visual processing occipital gyri include:

cuneus (wedge) gyrus

lingual (tongue) gyrus



C. Other gyri and structures on the medial aspect of the brain

Precuneus gyrus - **visual associational** gyri

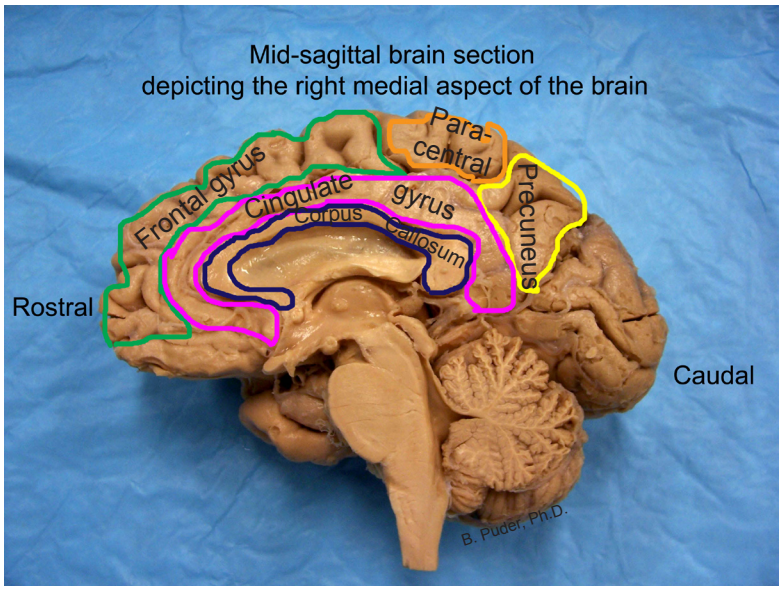
Paracentral gyrus - part of the **motor homunculus representing the foot and lower extremity** and **sensory homunculus representing the genitalia, foot, and lower extremity**

Cingulate gyrus - part of the 5th lobe known as the limbic lobe. Many other structures are **part of the limbic system** that controls mood, emotions, behaviors, learning, and visceral processes.

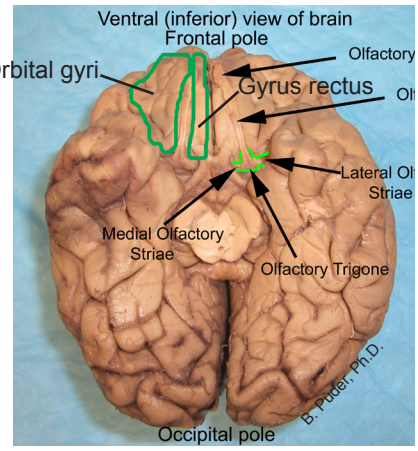
Corpus callosum - huge **axonal fiber bundle** that **relays information** to and from **right** and **left hemispheres**

4 parts to the corpus callosum:

1. **rostrum**
2. **genu**
3. **body**
4. **splenium**

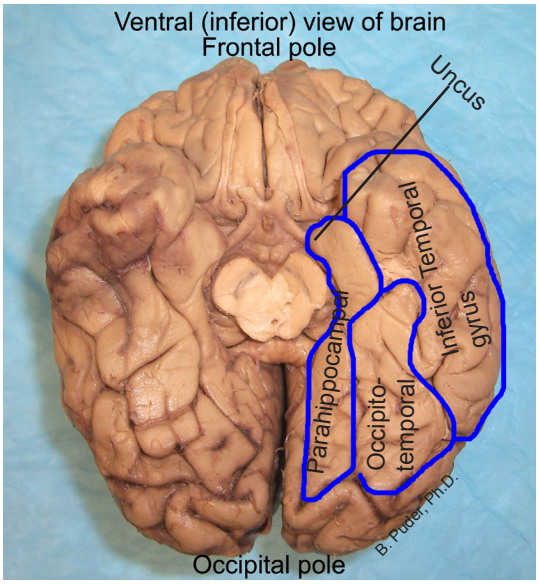


D. Vental (inferior) surface of brain



1. Frontal lobe

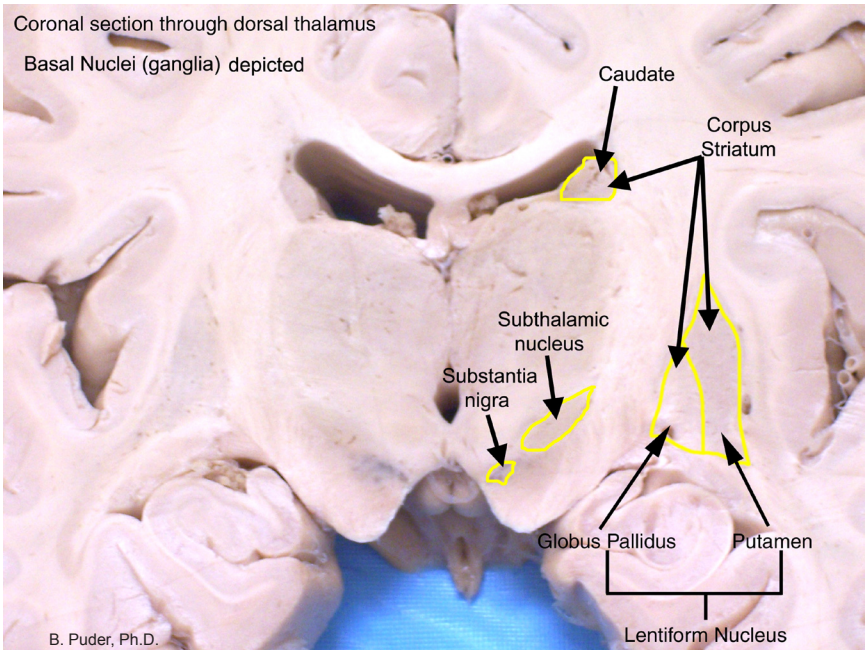
Gyrus rectus (straight gyrus) - most medial gyrus
Orbital gyri are lateral to gyrus rectus
Olfactory bulb and tract is located between orbital and straight gyri



2. Temporal lobe

Occipitotemporal gyrus
Parahippocampal gyrus
Rostral part = **uncus**
Amygdala and Hippocampus are structures deep in parahippocampal gyrus which are part of the limbic system

E. Deep cortical structures



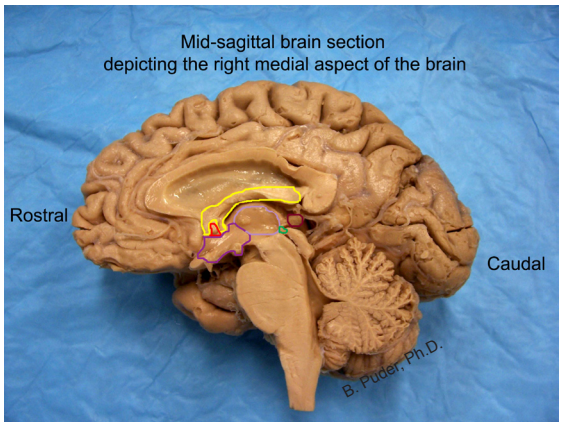
Basal nuclei (ganglia) involved in motor integration
structures that are part of the basal nuclei include:
Caudate
Putamen
Globus Pallidus
Subthalamus - part of the diencephalon
Substantia nigra - part of the midbrain of the brainstem

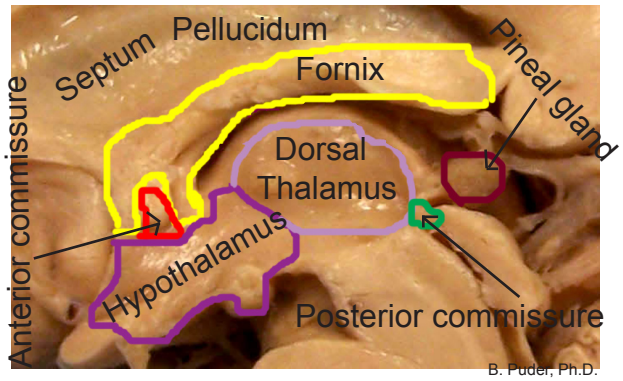
F. Diencephalon

located inferior to the telencephalon and superior to the brainstem

consists of 4 major areas:

1. **dorsal thalamus**
2. **subthalamus (ventral thalamus)**
3. **hypothalamus**
4. **epithalamus**





1. **Dorsal thalamus** - **integrates and relays sensory and motor information**
2. **Subthalamus** - **motor integration**
3. **Hypothalamus** - regulates **autonomic and visceral functions, synthesizes hormones**
4. **Epithalamus** - **Pineal gland is a major structure** of the epithalamus which **converts serotonin to melatonin**

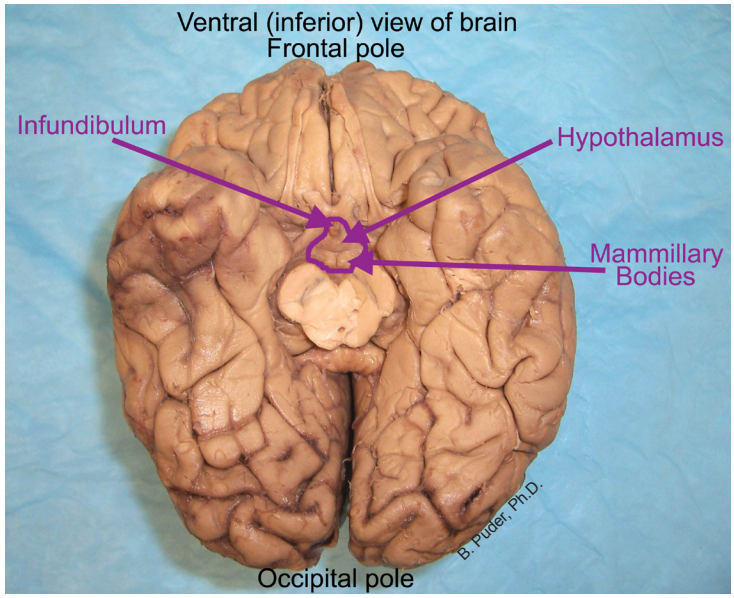
Other structures in this area include:

Anterior commissure - Axonal fibers that **relay information** to and from the **temporal lobes**

Posterior commissure- Axonal fibers that are part of the the **visual system**

Fornix - axonal fibers that **leave the hippocampus and project to the hypothalamus** or **septal areas**

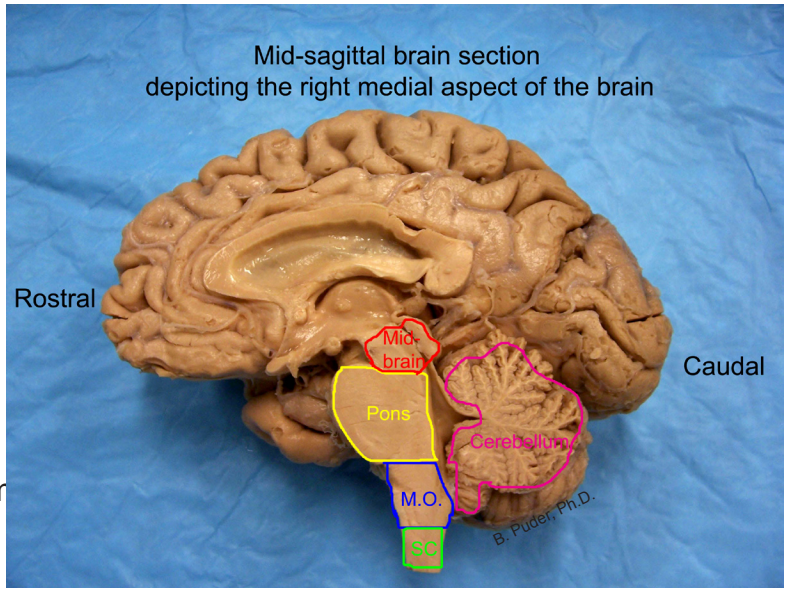
Septum pellucidum - tissue layer that separates the 2 lateral ventricles



G. Brainstem

Located inferior to Diencephalon
Relays information to and from cortex via axons
and also contains nuclei that are involved in auditory and visual processing, autonomic responses such as heart rate and respiration, and sensory and motor functions of the face
3 major areas:

1. **Midbrain**
2. **Pons**
3. **Medulla Oblongata**

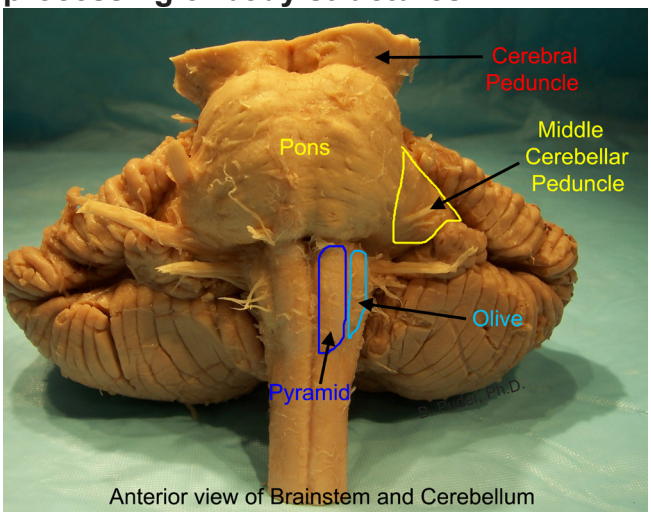


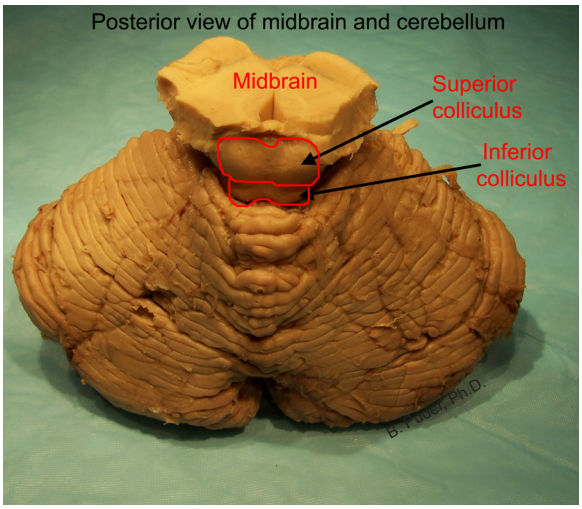
H. Cerebellum

means "little brain" in Latin
Functions to monitor and **coordinate muscle activity**

I. Spinal cord

Relays information to and from cortex
Also contains nuclei that are **involved in sensory and motor processing of body structures**





J. Big gross bumps of the brainstem

1. Midbrain

Tentorial notch (incisura) of meninges surrounds midbrain

<u>Anterior area</u>

Cerebral peduncles - consists of descending axons involved in motor functions (eg. corticospinal tract)
Cranial nerve III (occulomotor nerve) - nerve fibers project out at anterior midline

<u>Posterior area</u>

Superior colliculus - Visual processing
Inferior colliculus - Auditory processing
Cranial nerve IV (trochlear nerve) - nerve fibers project out posteriorly at midline

2. Pons (means "bridge")

Anterior area

Relays information to cerebellum and descending motor tracts

Cranial nerve V, VI, VII, VIII project from pons

Posterior area

3 pairs of cerebellar peduncles

1. **Superior cerebellar peduncle**
2. **Middle cerebellar peduncle**
3. **Inferior cerebellar peduncle**

→ Efferent and afferent axons associated with the cerebellum

Superior medullary velum - makes the roof of the 4th ventricle

Facial colliculus - Cell bodies of Cranial nerve VI and axons of cranial nerve VII located here

Clinical Correlation:

The cerebellar pontine angle is located posterolaterally where the pons, cerebellum and medulla meet. Tumors called **vestibular schwannomas** or **acoustic neuromas** can form here and impinge on **cranial nerve VIII** and **eventually VII** causing specific deficits.

3. Medulla

Foramen magnum of cranium is at level of lower medulla

Anterior area

Pyramids - contain descending motor fibers

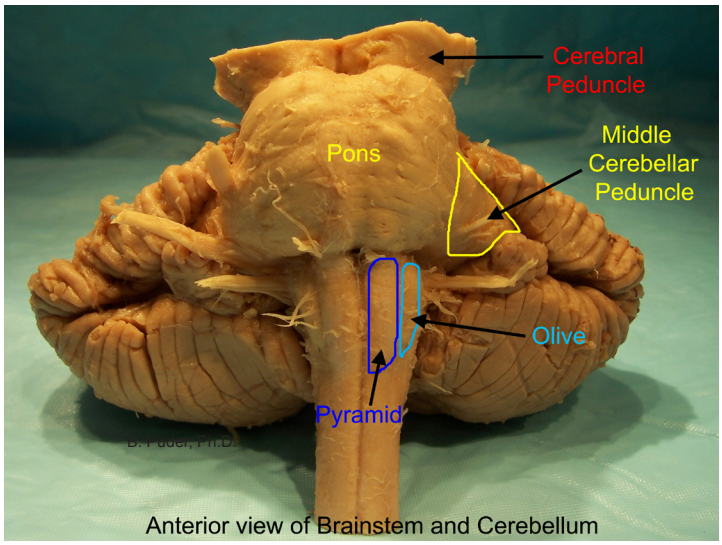
Olives - cell bodies of neurons in the auditory pathway

Cranial nerves IX, X, XI, XII

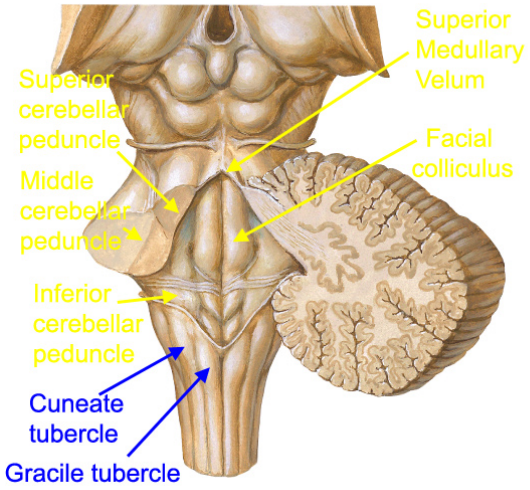
Posterior area

Gracile tubercles - medial bumps, contain cell bodies that are part of a somatosensory pathway (Posterior columns/Medial Lemniscus)

Cuneate tubercles - lateral bumps, contain cell bodies of the above mentioned pathway



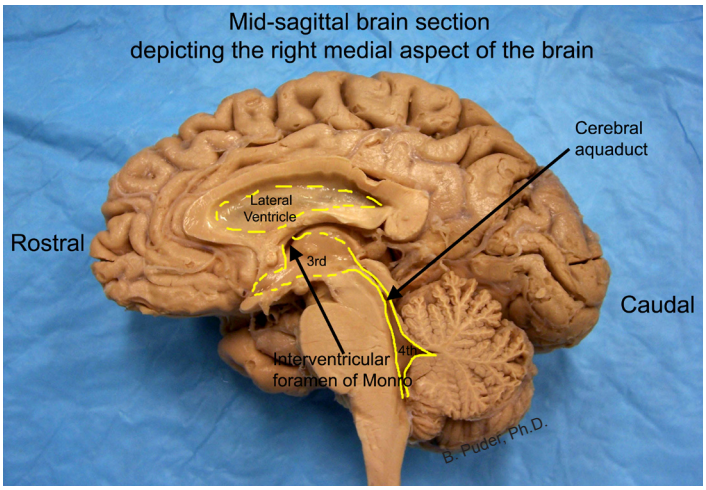
Anterior view of Brainstem and Cerebellum

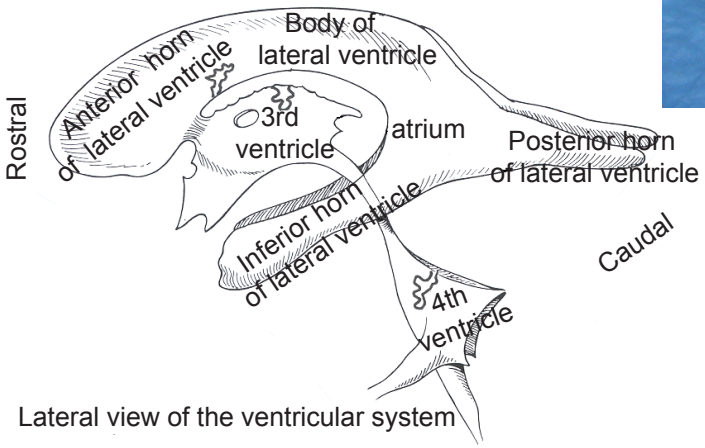


Posterior view of brainstem with part of cerebellum removed

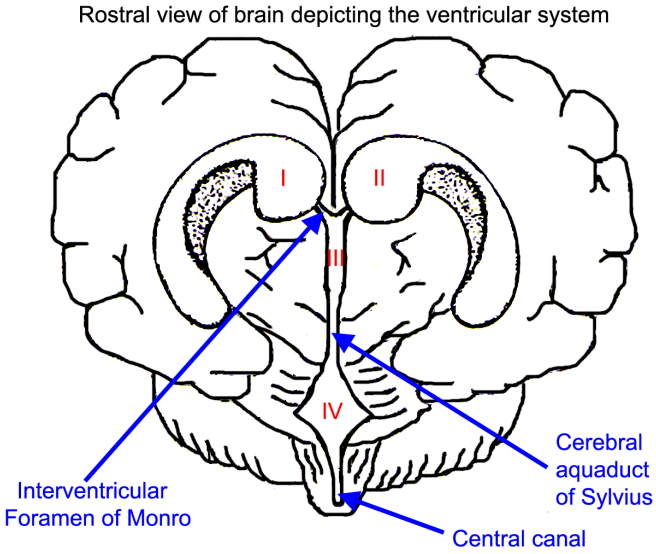
K. Ventricles and Ventricular system

- Series of cavities within the brain where cerebral spinal fluid (CSF) is produced (in the choroid plexus) and circulated
- Lined by ependymal cells which convert plasma to CSF
- Ventricular system consists of :
  - 2 lateral ventricles
    interventricluar foramen (of Monro)
  - 3rd ventricle
  - cerebral aquaduct
  - 4th ventricle
  - 2 lateral foramina of Luschka
  - 1 medial foramen of Majendie





Lateral view of the ventricular system



CSF leaves 4th ventricle via 3 foramina and enters subarachnoid space of meninges

CSF
- Plasma is converted by ependymal cells of the choroid plexus
-CSFcontains
  1-5 cells/cc (mainly lymphocytes)
  Water
  Ions - Na,K ,Cl,Ca, Mg (source of electrolytes)
  a little glucose
  500ml produced daily, 135-150ml in circulation (so there is constant production and resorption

-CSF helps suspend the brain and cushions the brain against injury, trauma,movement

(weight of brain in air = 1400g, in fluid = 45g)

- CSF moves along pressure gradient from high pressure arterioles to venous system, and via pulsations of arteries in subarachnoid space

L. Relationship of ventricles to neighboring structures

Lateral ventricles

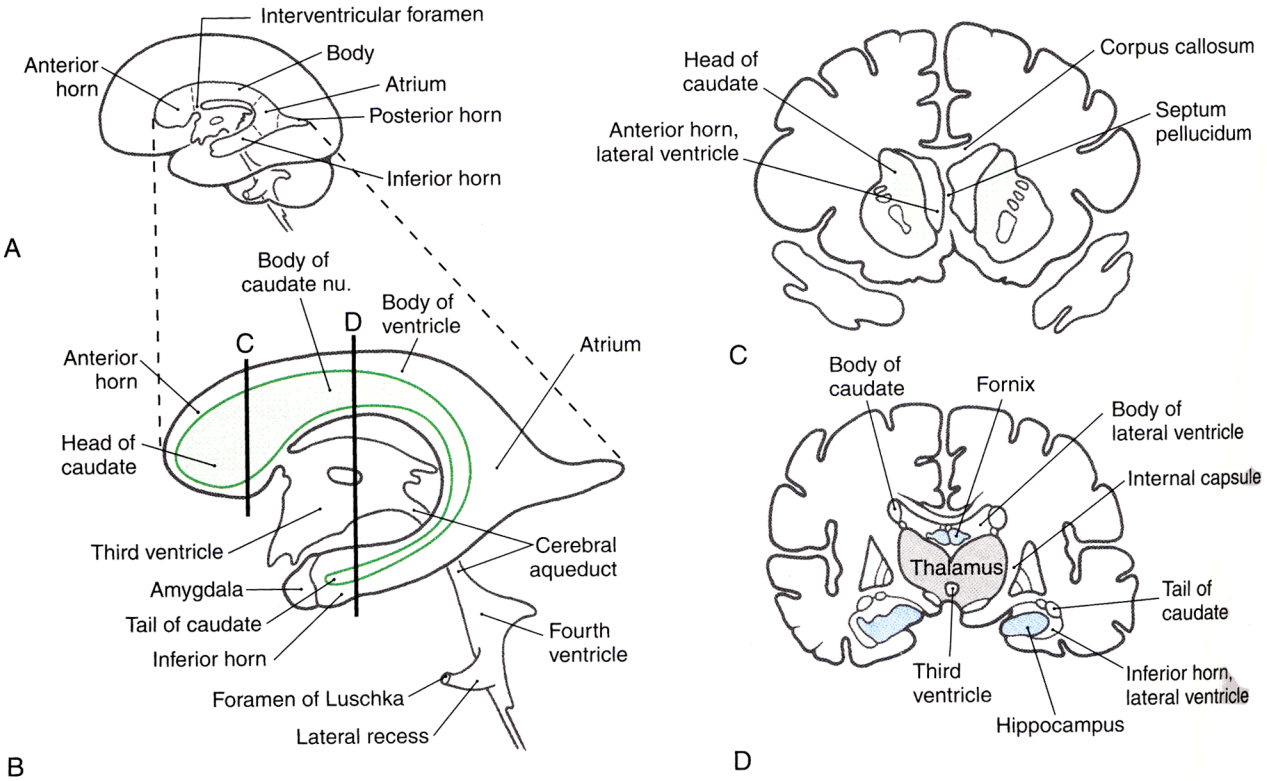
- anterior horn and body
  - medial boundary = septum pellucidum and fornix
  - superior boundary = corpus callosum
  - lateral boundary = caudate nucleus (head and body)
- body
  - floor = thalamus
  - lateral boundary = caudate nucleus body
- inferior horn of lateral ventricle
  - medial boundary = hippocampal formation
  - lateral boundary = caudate nucleus (tail)
  - rostral boundary= amygdaloid complex

third ventricle

- boundaries include thalamus and hypothalamus

fourth ventricle

- boundaries include cerebellum, pons and medulla



Adapted from Fundamental Neuroscience for Basic and Clinical Applications, D.E. Haines

Always remember that relationships are important!!!

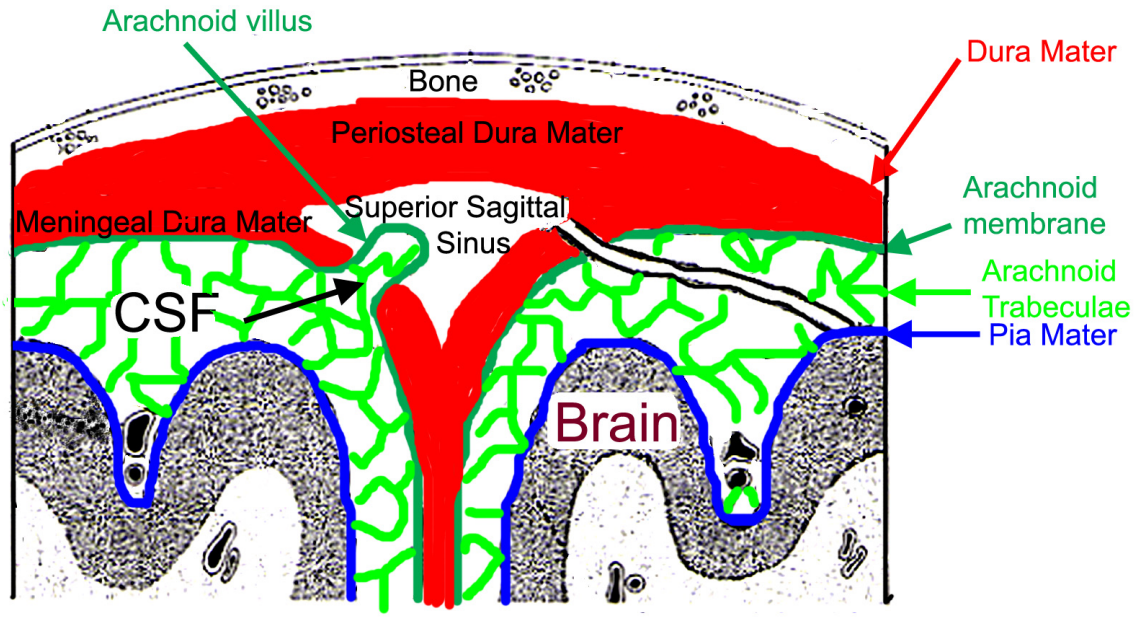
M. Meninges

Deep to the cranium (calvarium or bone) is a tough thick memebrane called the meninges
The meninges consist of 3 layers:

1. Dura Mater - outermost layer, very thick, contains venous sinuses
2. Arachnoid membrane - below the dura mater, contains processes that project from the arachnoid membrane to the innermost meningeal layer (pia mater). These processes give it a spider web appearance (arachnoid = spider).

The space between the arachnoid membrane and the pia mater that contains the arachnoid projections is the subarachnoid space.
This space also contains cerebrospinal fluid (CSF).

3. Pia Mater - innermost meningeal layer

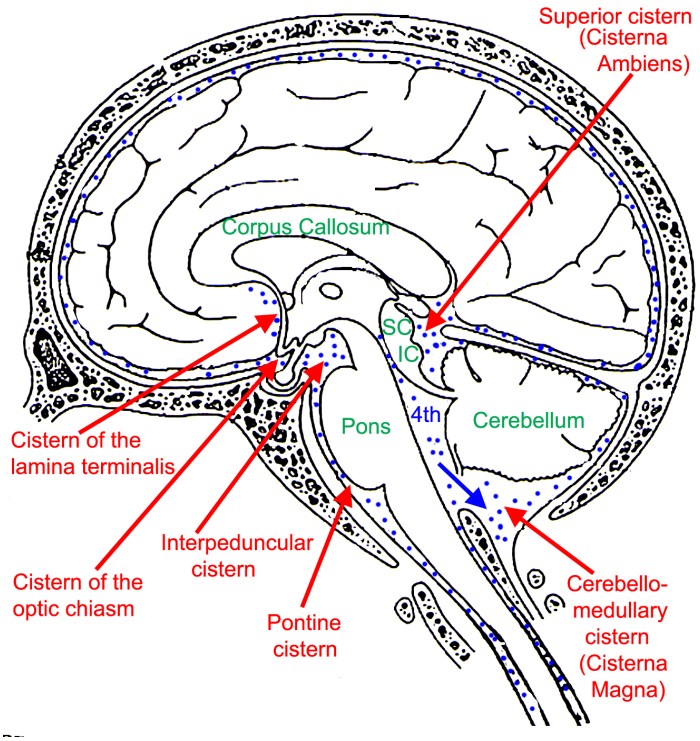


N. Cisterns

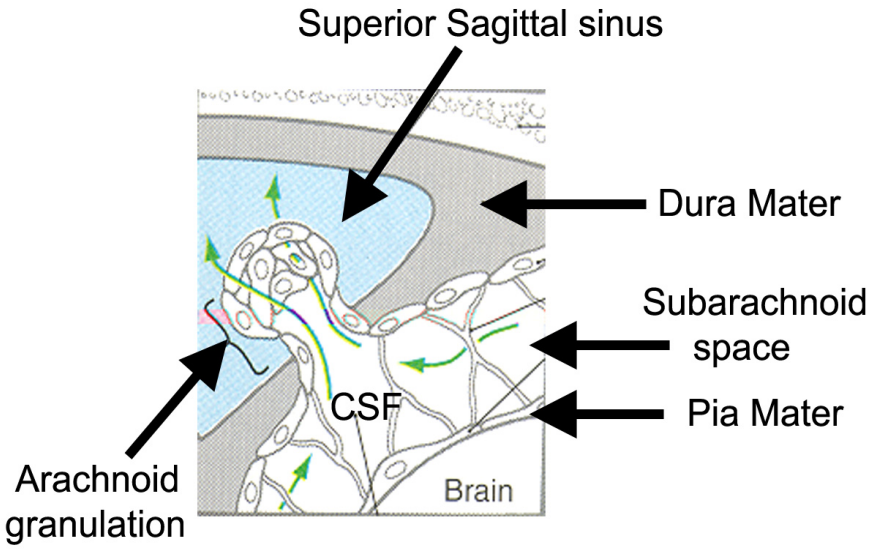
cistern are areas where the subarachnoid space expands

Major cisterns include:

Pontine
Interpeduncular
Chiasmatic
Superior
Cerebellomedullary
Lumbar



CSF is eliminated via arachnoid granulations which protrude into the superior sagittal sinus



Clinical Correlation:

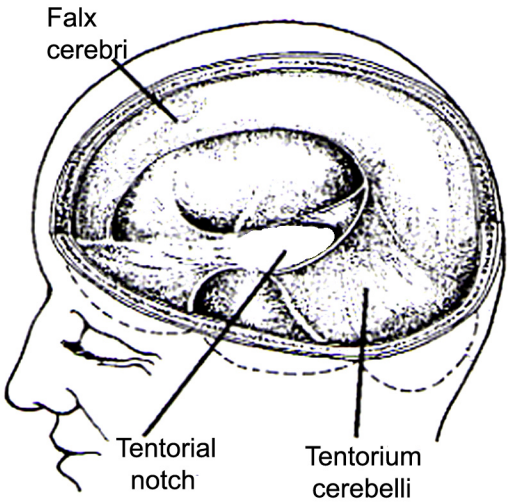
Hydrocephalus is a condition that occurs when **CSF flow is obstructed**.

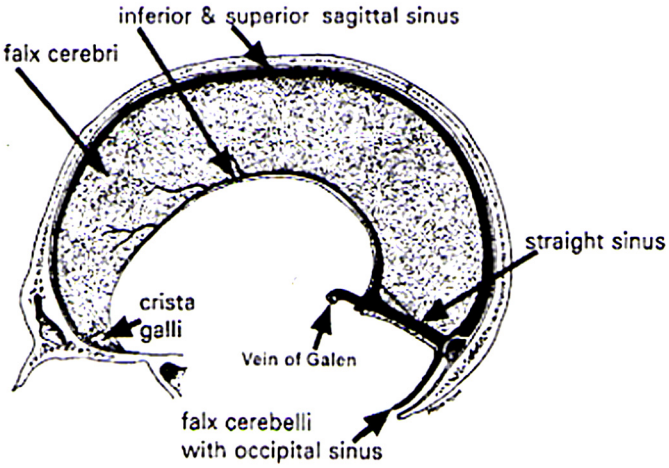
O. Dura, Dural venous sinuses, and Supra- and Infratentorial compartments

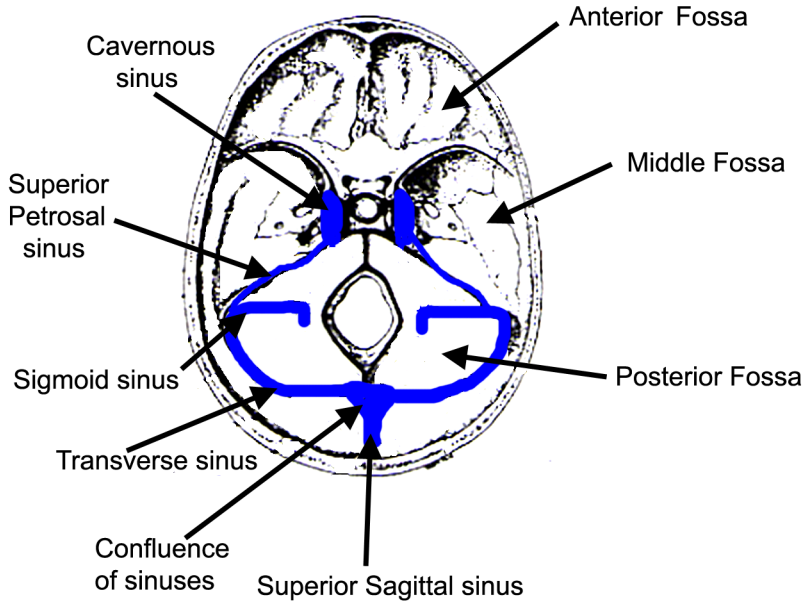
In the cranium, the dura becomes folded on itself to form supports for the brain and spaces in which venous blood can flow and drain. These are called dural reflections and dural venous sinuses.

There are 2 major reflections:
1. Falx cerebri - between the 2 cerebral hemispheres
2. Tentorium cerebelli - between the cerebrum and the cerebellum, makes a tent over the cerebellum

Venous sinuses run in the free margin of some of these reflections

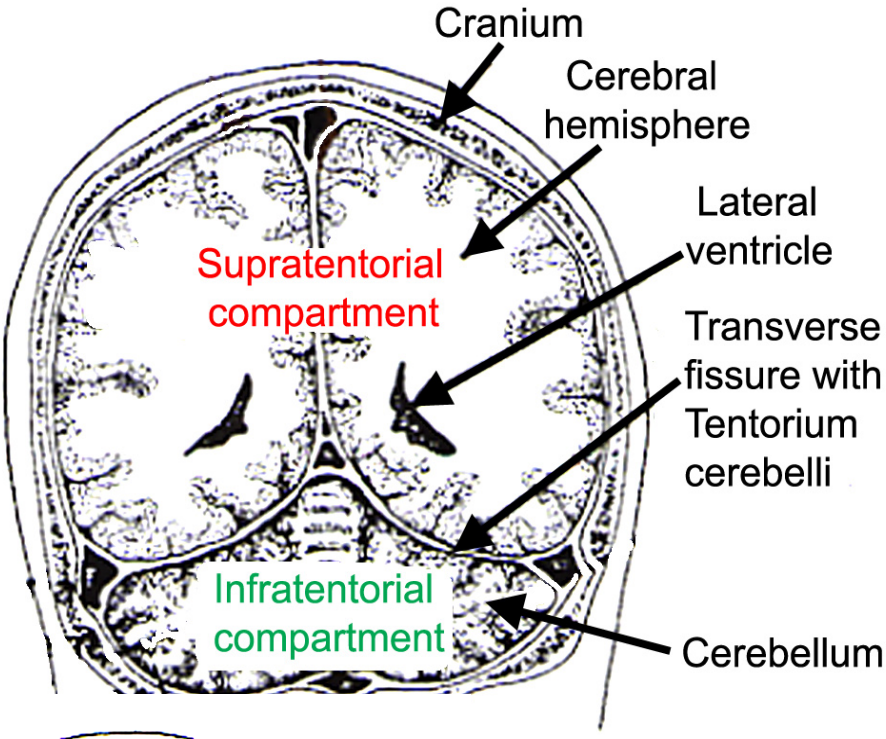


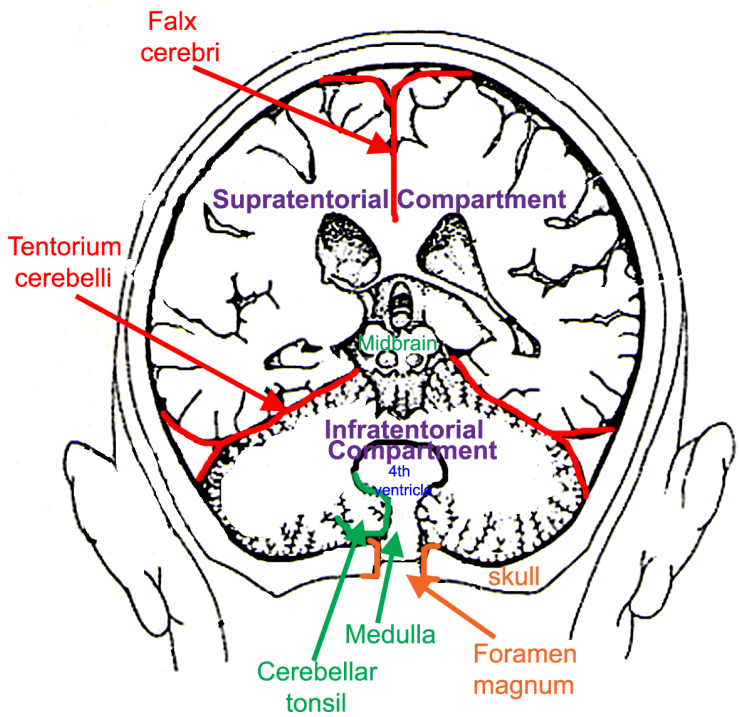




P. Dural reflections create intracranial compartments that have clinical significance

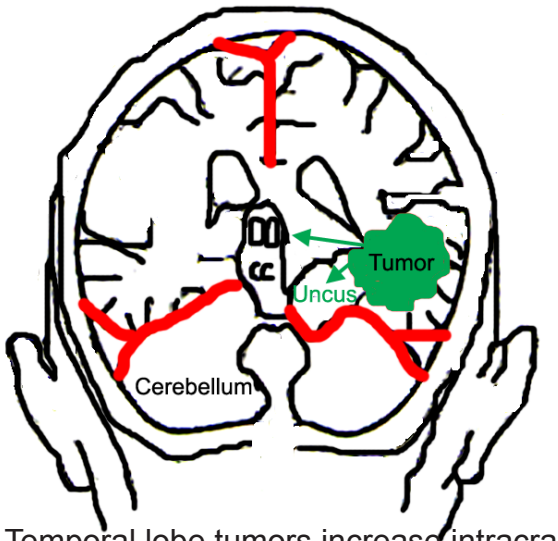
The tentorium cerebelli creates supratentorium and infratentorium compartments.
The infratentorial compartment is essentially the posterior cranial fossa.
When there is a infratentorial condition, it affects the brainstem or cerebellum.
Supratentorial pressure can shift brain parts from the supra to the infratentorial compartments.
Therefore any increase in pressure is bad.

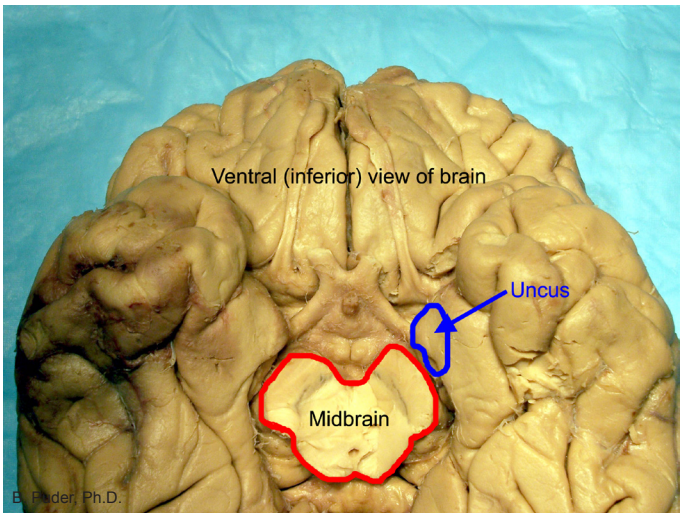




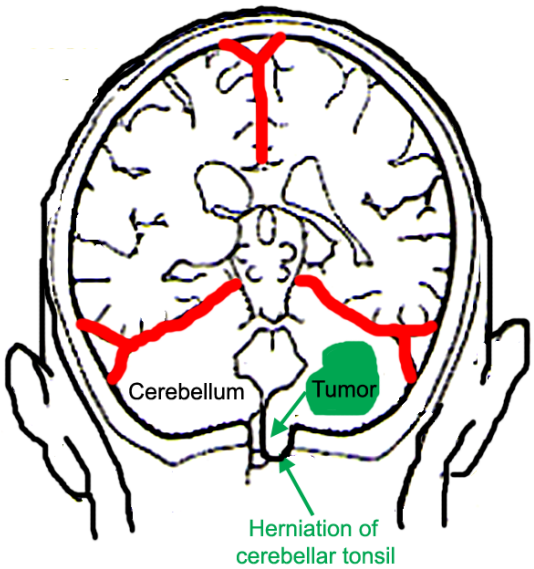
Q. Pressure relationships, meninges, and herniations (uncus and cerebellar tonsils)

Changes in intracranial pressure can alter the normal relationship between soft and hard tissue.
The soft tissues give way.
Pressure changes can occur by head trauma leading to intracranial bleeding, by the growth of tumors.
These can lead to changes in the compartments and on structures.
2 structures in the brain commonly involved are the uncus and the cerebellar tonsils.





Temporal lobe tumors increase intracranial pressure in the supratentorial compartment.
The uncus will herniate into the tentorial notch (incisura) and impinge on the midbrain



A cerebellar tumor increases intracranial pressure in the infratentorial compartment and pushes tonsil into the foramen magnum which will compress the medulla which conains cardiovascular and respiratory centers and reticular formation (coma).

R. Cranial Nerves