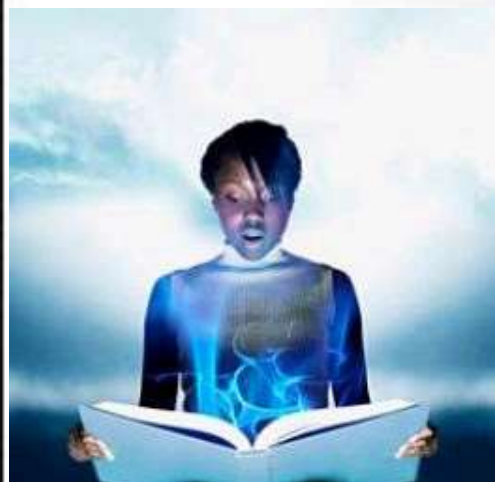


# Functional Systems in the CNS



ANDREAE VESALII  
BRUXELLENSIS. DE HVMANI CORPO-  
RIS FABRICA LIBER SEPTIMVS, CEREBRO AN-  
imalis facultatis sedis & fructuum organa delineatus, & maxime in istius omnes  
propemodum ipsius figurae, uti & duo praesens preceden-  
tes libri, commemorantur.  
PRIMA SEPTIMI LIBRI FIGVRA

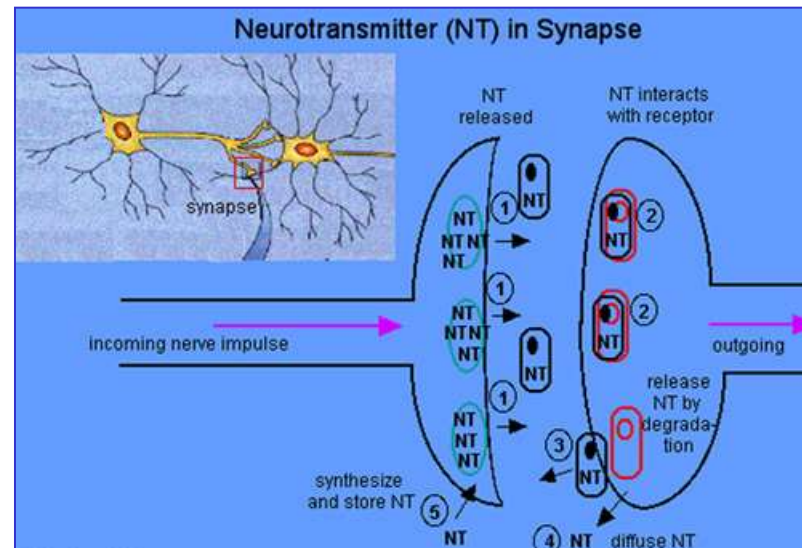
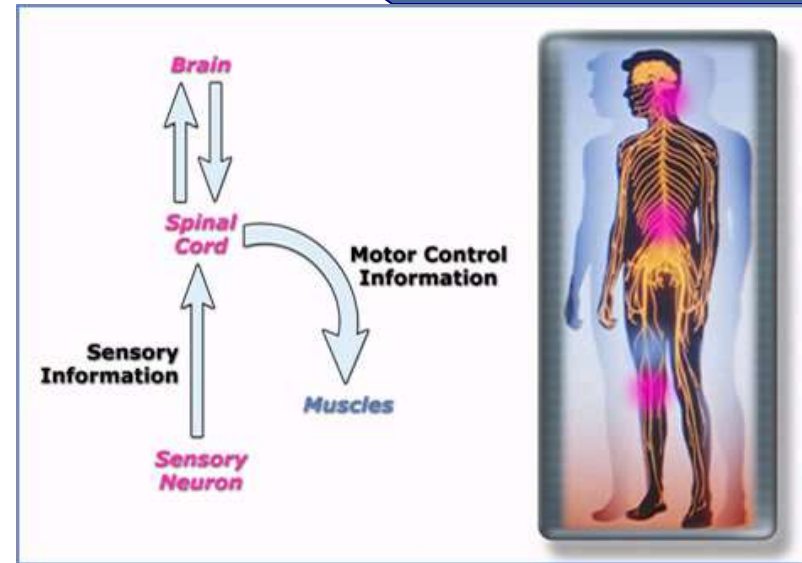


1. Afferent (sensory) pathways:
  - ✓ general sensation – superficial and deep (proprioceptive)
  - ✓ interoceptive sensation
  - ✓ special sensations – vision and hearing
2. Efferent (motor) pathways:
  - ✓ pyramidal system
  - ✓ extrapyramidal system
3. Meninges and cerebrospinal fluid
4. Blood supply of the spinal cord and the brain



# Functional systems in the CNS

- **Sensory (afferent) systems**
- **Motor (efferent) systems**
- Limbic system
- Reticular system
- Central transmitter systems:
  - ✓ cholinergic system
  - ✓ monoaminergic system
  - ✓ amino acid transmitters
  - ✓ peptidergic system
  - ✓ central neuroendocrine system





# Sensory (afferent) pathways

## Sensory (afferent) systems:

### ✓ general (somatic) sensations:

#### ➤ superficial (exteroceptive) – skin

- pain and temperature
- vibration, touch and pressure
- stereognosia

#### ➤ deep (proprioceptive)

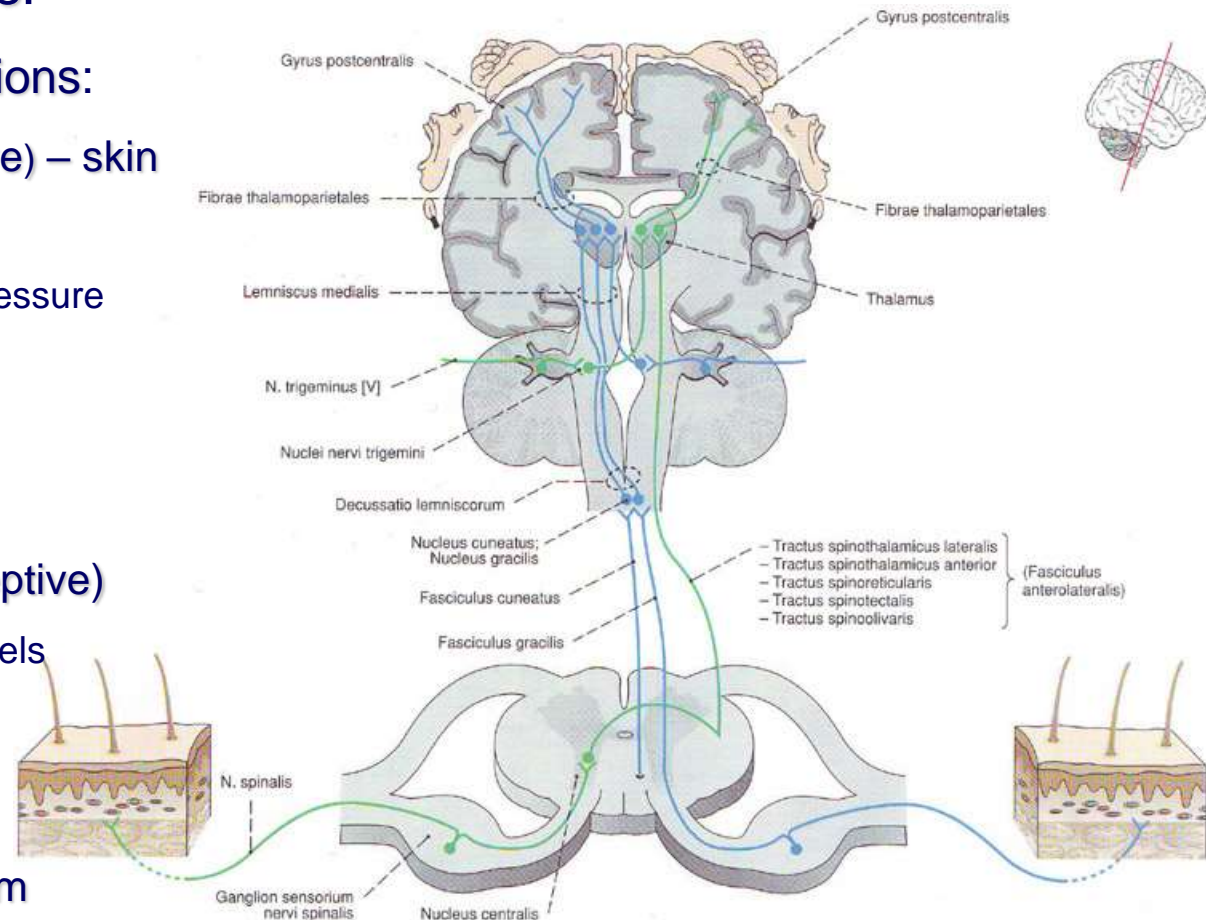
- joints and tendons

#### ➤ interoceptive (visceroceptive)

- organs and blood vessels

### ✓ special sensations:

- visual system
- vestibulocochlear system
- gustatory system
- olfactory system





# Mechanoreception system

## posterior column-medial lemniscus pathway

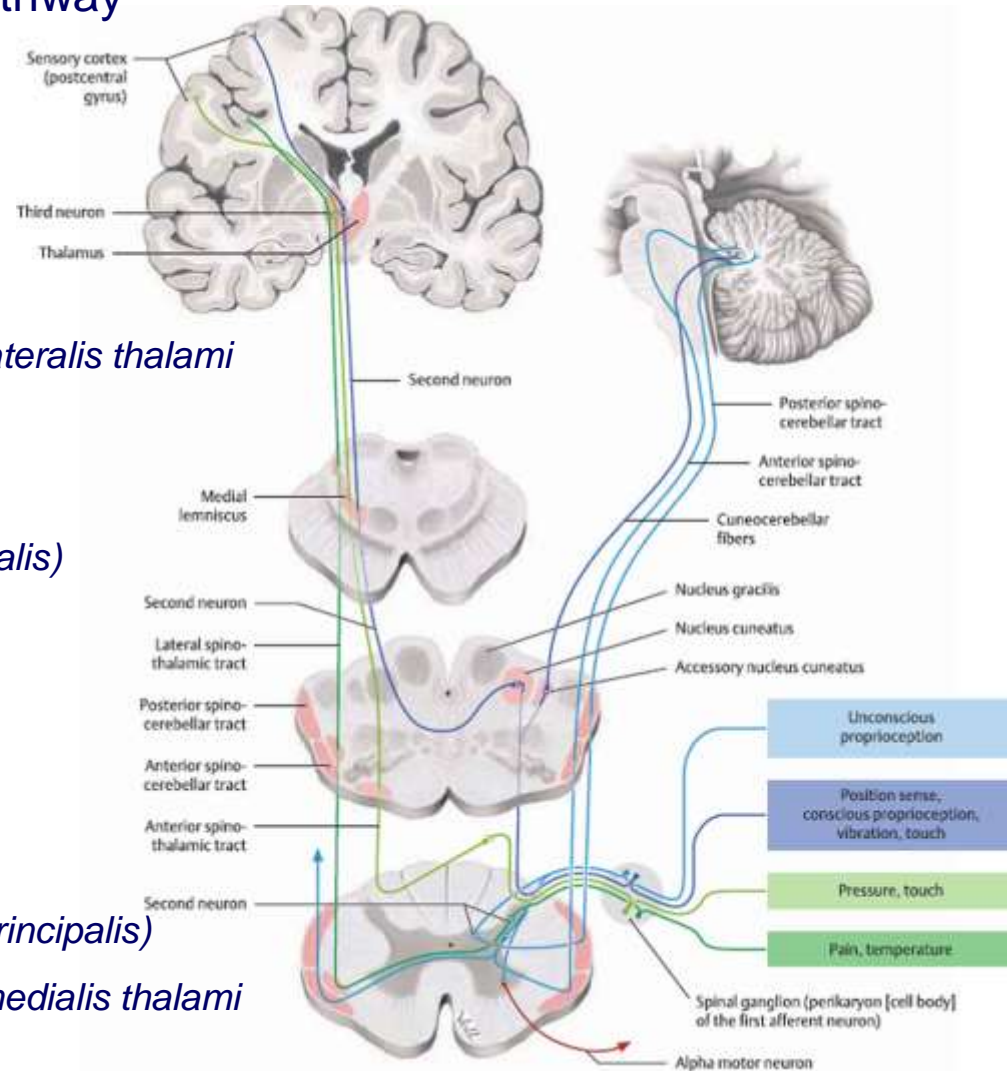
(*lemniscus medialis*):

- ✓ touch, pressure and stereognosia
  - I neuron – *ganglion spinale*
  - II neuron – *nucl. gracilis et cuneatus*
  - III neuron – *nucleus ventralis posterolateralis thalami*  
⇒ *gyrus postcentralis* (upper  $2/3$ )
- ✓ low touch and pressure
  - *tractus spinothalamicus anterior (ventralis)*

## trigeminal lemniscus

(*lemniscus trigeminalis*):

- ✓ orofacial touch and pressure
  - I neuron – *ganglion trigeminale*
  - II neuron – *nucl. pontinus (sensorius principalis)*
  - III neuron – *nucleus ventralis posteromedialis thalami*  
⇒ *gyrus postcentralis* (lower  $1/3$ )





# Pain and temperature system

## ■ Ascending nociceptive pathways (anterolateral system):

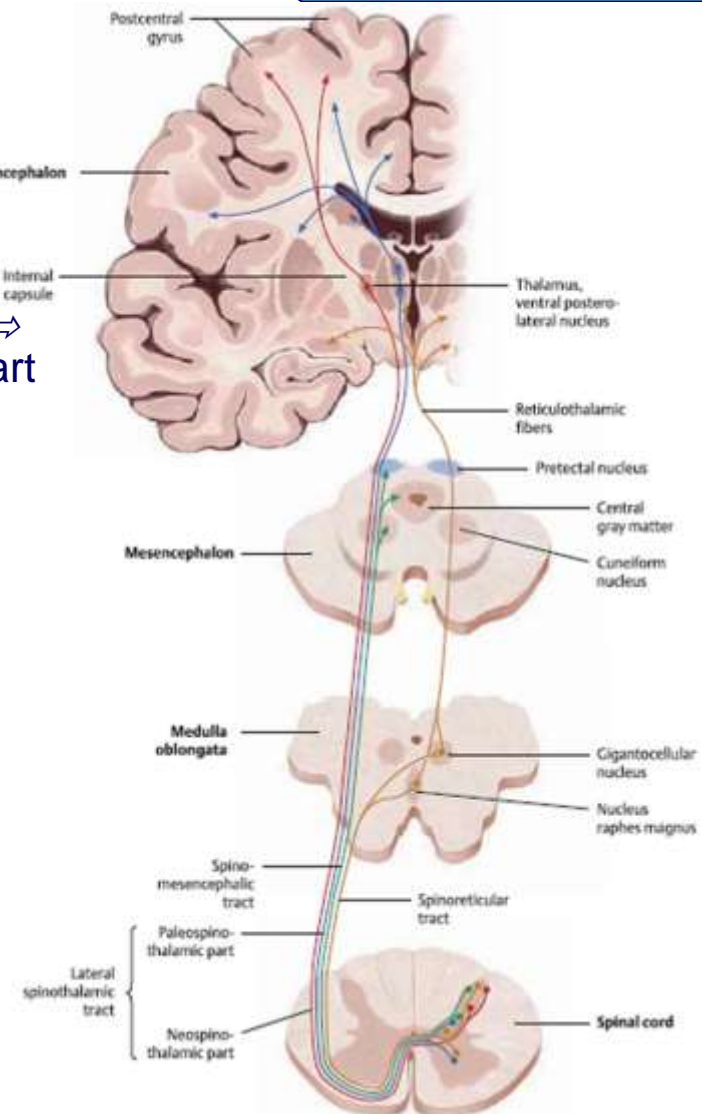
- ✓ pain (nociception) and temperature
  - I neuron – *ganglion spinale*
  - II neuron – spinal laminae I, II and V ⇒ *tractus spinothalamicus lateralis* ⇒ *lemniscus medialis*
  - III neuron – *nucleus ventralis posterolateralis thalami* ⇒ *gyrus postcentralis* (middle and upper  $\frac{1}{3}$ ), rostral part of *gyrus cinguli*, insular cortex (limbic system)

## ■ Spinal pain system:

- ✓ lateral pain system – “rapid pain” (“neospinothalamic system”)
  - *tractus spinothalamicus lateralis*
- ✓ medial pain system – “slow pain” (“paleospinoreticulothalamic system”)
  - *tractus spinoreticularis et tractus spinotectalis*
- ✓ *tractus spinotectalis* ⇒ *colliculi superiores*

## ■ Dorsolateral system: laminae III and IV, I and V

- ✓ *tractus spinocervicalis* ⇒ *nucleus cervicalis lateralis*
- ✓ *tractus spinomesencephalicus* ⇒ *substantia grisea centralis*





# Head pain and temperature system

## Head pain and temperature system:

✓ I neuron – *ganglion trigeminale*

⇒ *tractus spinalis n. trigemini*

✓ II neuron – *nucl. spinalis n. trigemini*

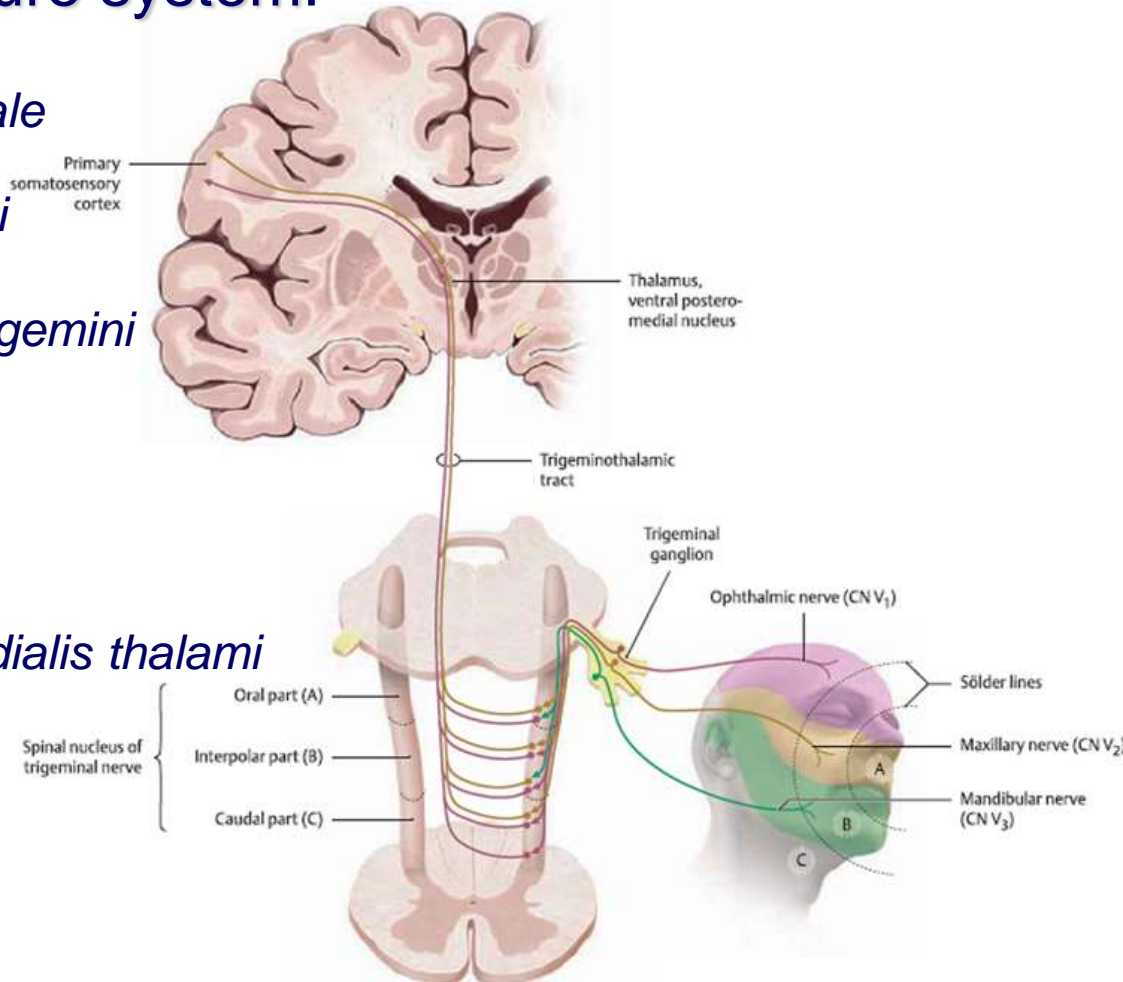
⇒ *lemniscus trigeminalis*

✓ III neuron –

*nucleus ventralis posteromedialis thalami*

⇒ *gyrus postcentralis*

(lower  $\frac{1}{3}$ )





# Proprioceptive pathways

- from the lower limb to the cerebral cortex:

- ✓ posterior column-medial lemniscus pathway:

- I neuron – *ganglion spinale*
    - II neuron – *nucleus thoracicus (Clarke-Stilling)*
    - III neuron – *nucleus Z* in the medulla
    - IV neuron – thalamus ⇒ cerebral cortex



- from the trunk to the cerebellum:

- ✓ *tractus spinocerebellaris posterior*

- I neuron – *ganglion spinale*
    - II neuron – *nucleus thoracicus (Clarke-Stilling)*  
⇒ *tractus spinocerebellaris posterior (Flechsig)* ⇒  
*cortex cerebelli*

- ✓ *tractus spinocerebellaris anterior*

- II neuron – *nucleus thoracicus (Clarke-Stilling)*  
⇒ *tractus spinocerebellaris anterior (Gowers)* ⇒  
rostral part of *cortex cerebelli*

- ✓ *tractus bulbo cerebellaris* – from the upper limb

- I neuron – *ganglion spinale*
    - II neuron – *nucleus cuneatus accessorius* ⇒  
*tractus cuneocerebellaris* ⇒ *cortex cerebelli*

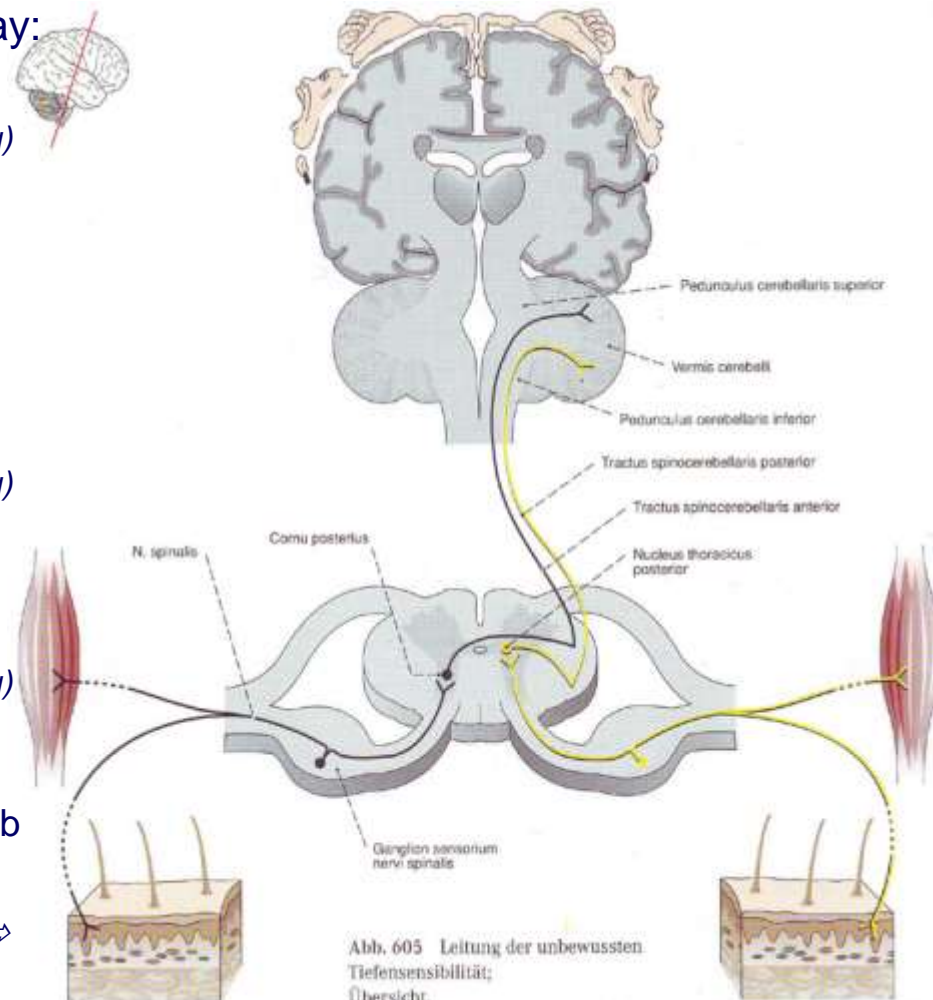


Abb. 605 Leitung der unbewussten Tiefensensibilität; Übersicht.



# Proprioceptive pathways of the head

## ■ proprioceptive pathways of the head:

### ✓ I neuron –

*nucleus mesencephalicus n. trigemini*

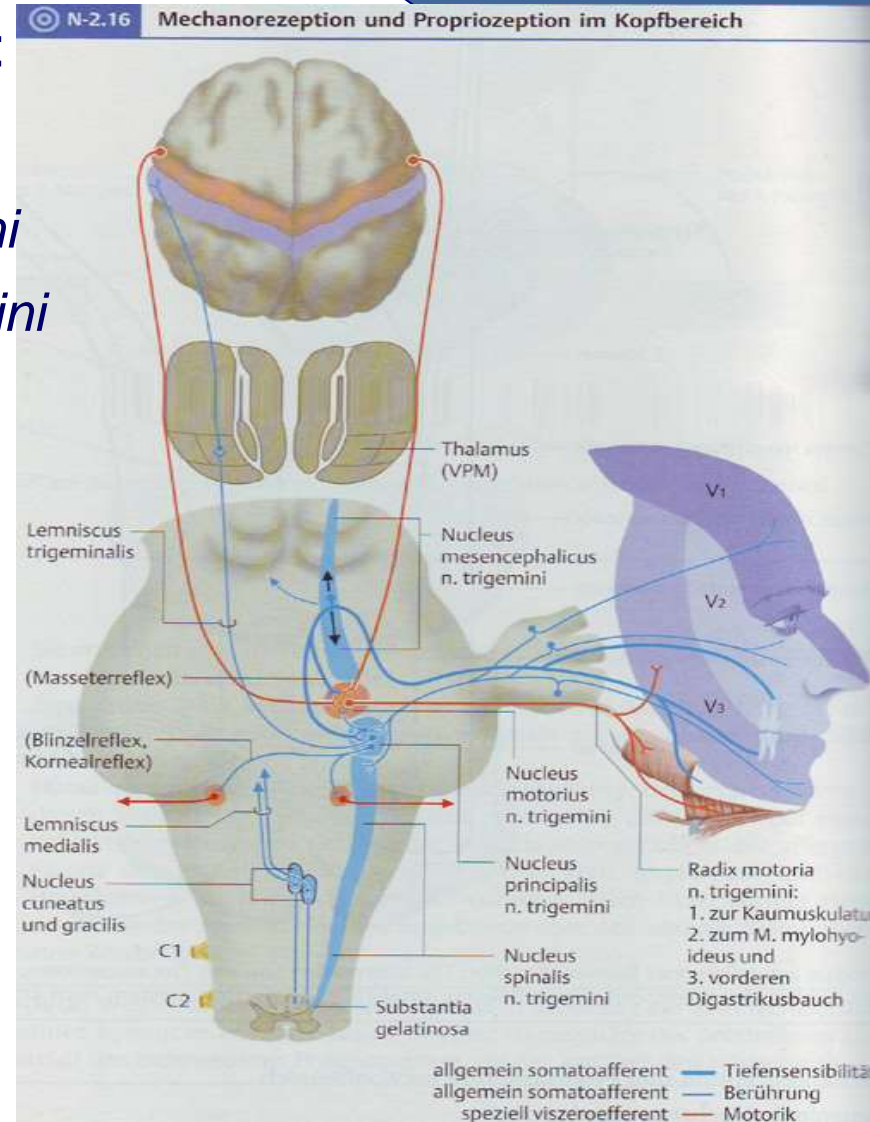
⇒ *tractus mesencephalicus n. trigemini*

⇒ *nucleus motorius n. trigemini*

### ✓ II neuron –

*nucleus ventralis posteromedialis*

⇒ *gyrus postcentralis*







# Ascending interoceptive pathways

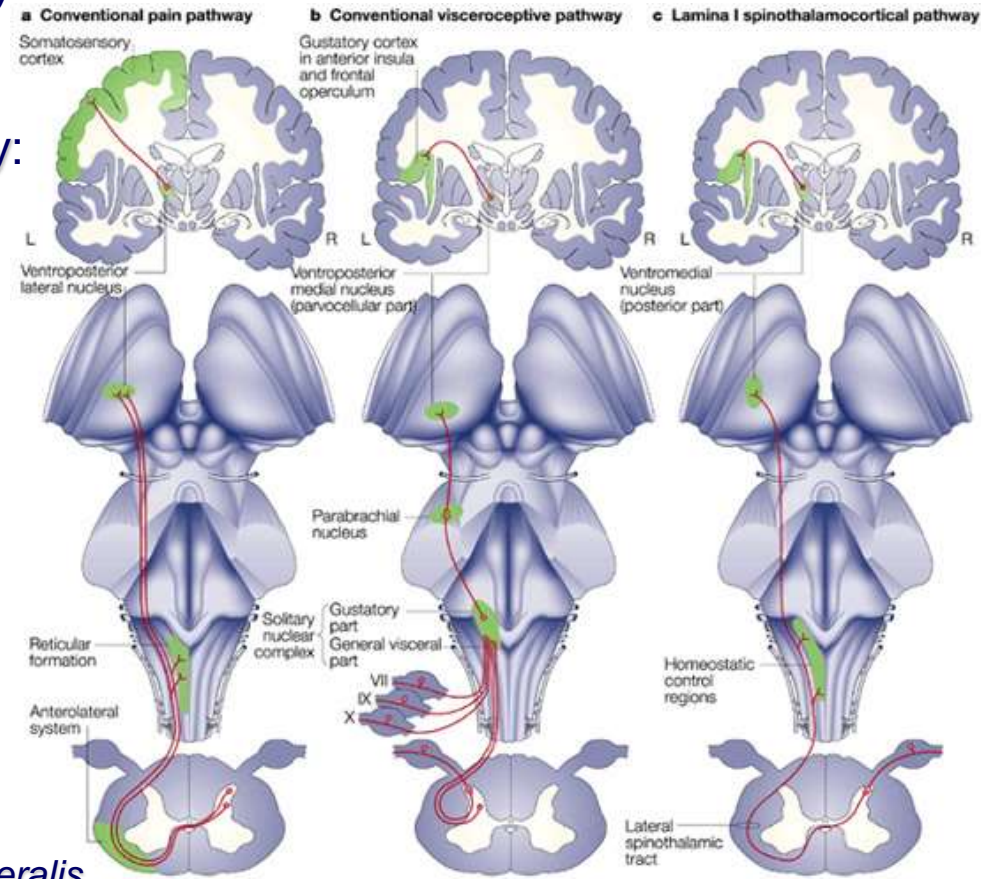
■ Sensitivity from body's viscera (organs) – predominantly nociceptive, common way with the pain and temperature pathway:

✓ conventional visceroreceptive pathway:

- I neuron – *ganglion spinale*
- II neuron – *subst. intermedia medialis*  
⇒ *tractus spinothalamicus lateralis*
- III neuron – *nucleus ventralis posterolateralis thalami* ⇒ *somatosensory cortical areas*

✓ accessory visceroreceptive pathway:

- I neuron – *nervus vagus*
- II neuron – *nucleus tractus solitarii*
- III neuron – *nucleus ventralis posterolateralis*





# Motor (efferent) pathways

## ■ Pyramidal motor system – two neuron system:

✓ *tractus corticospinalis (pyramidalis)*

✓ *tractus corticonuclearis*  
(corticonuclear system)

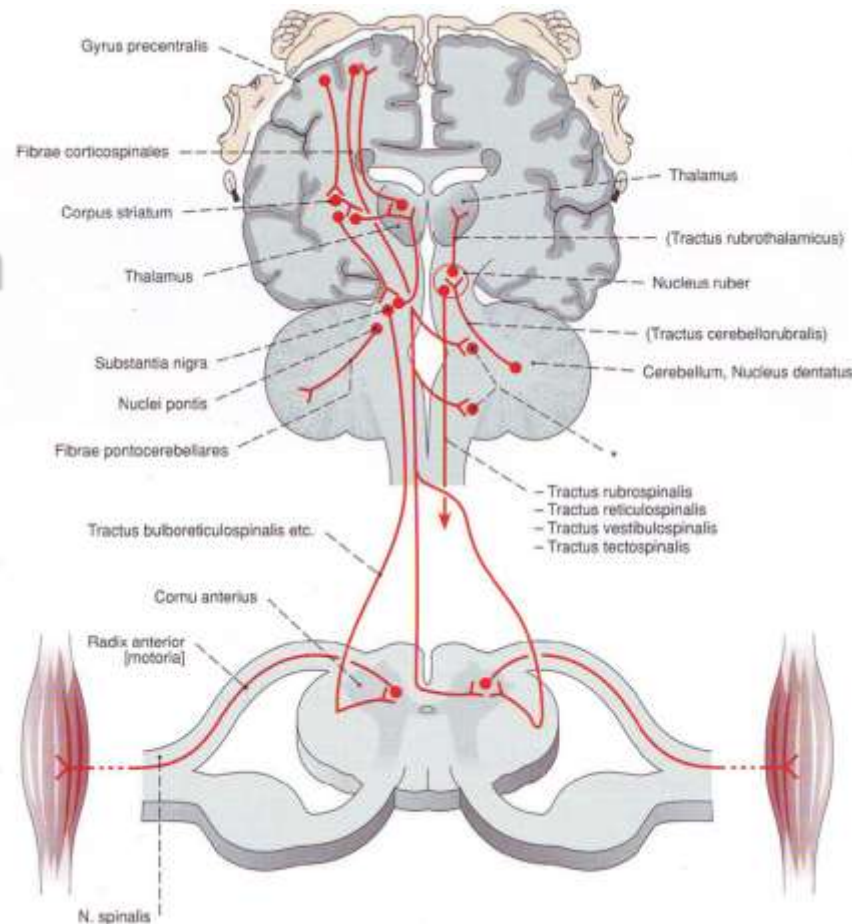
## ■ Extrapyramidal motor system (basal ganglia system)

– multineuronal and polysynaptic

## ■ Oculomotor system:

✓ frontal eye area  
(area 8, parts of 6 and 9 areas)

✓ prefrontal cortex

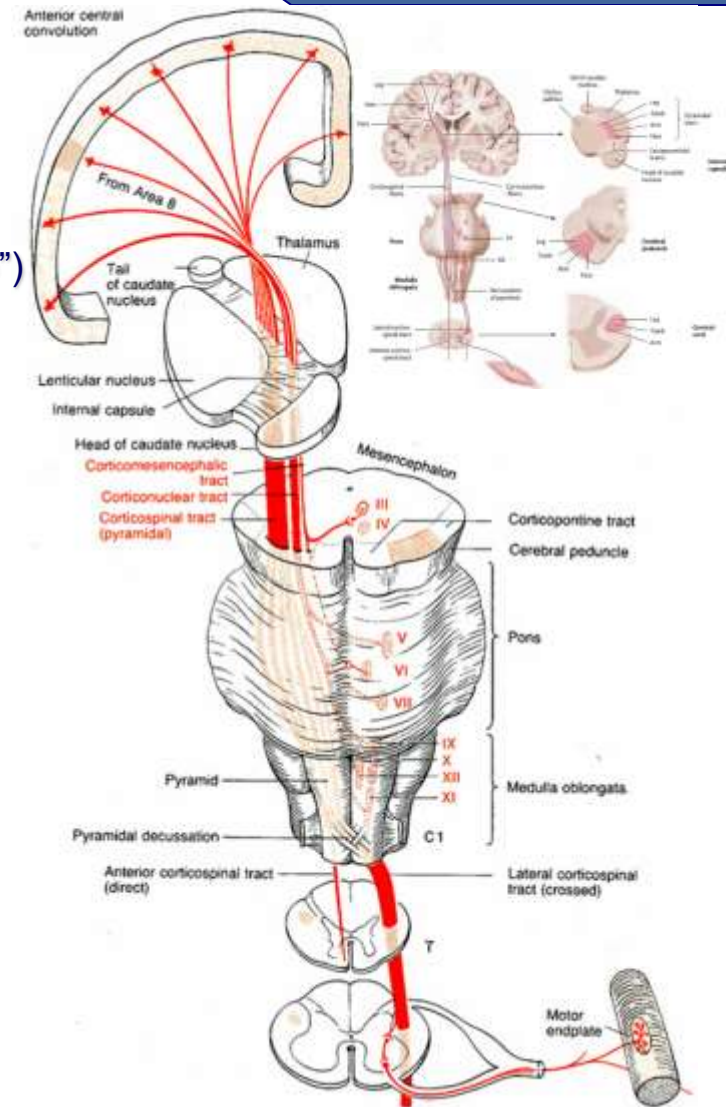




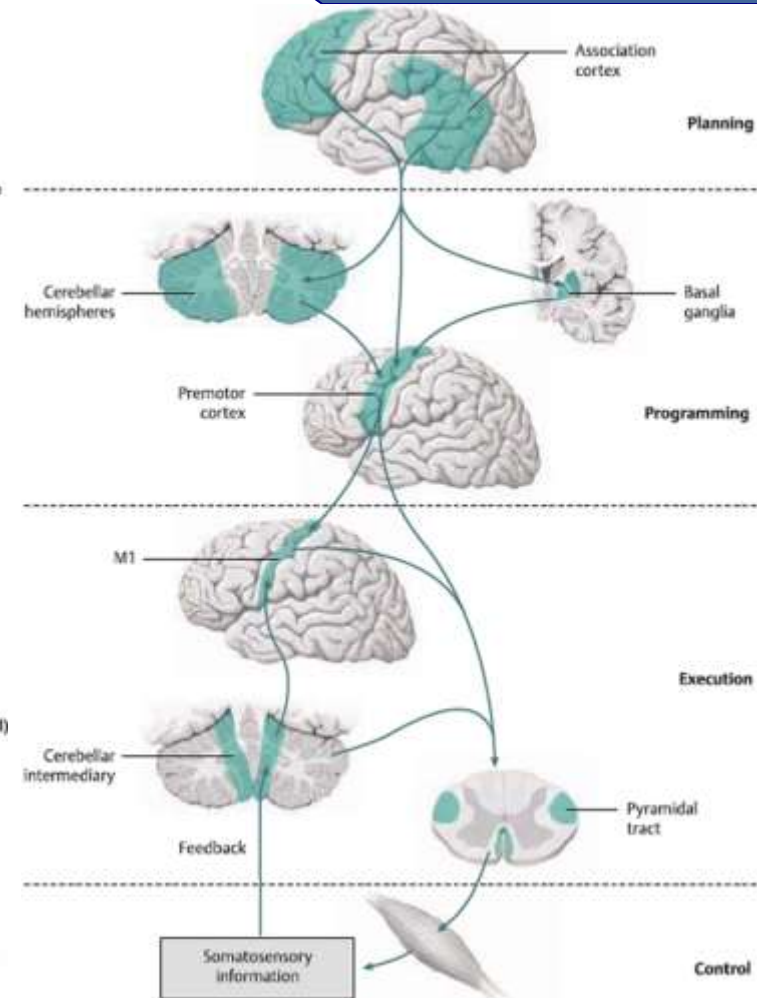
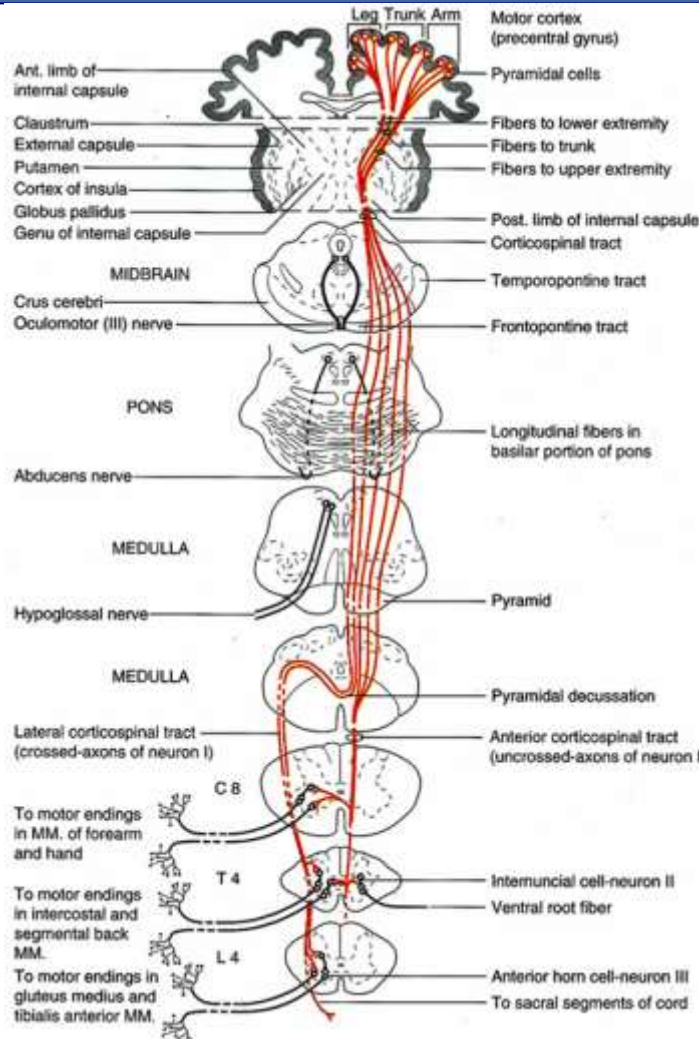
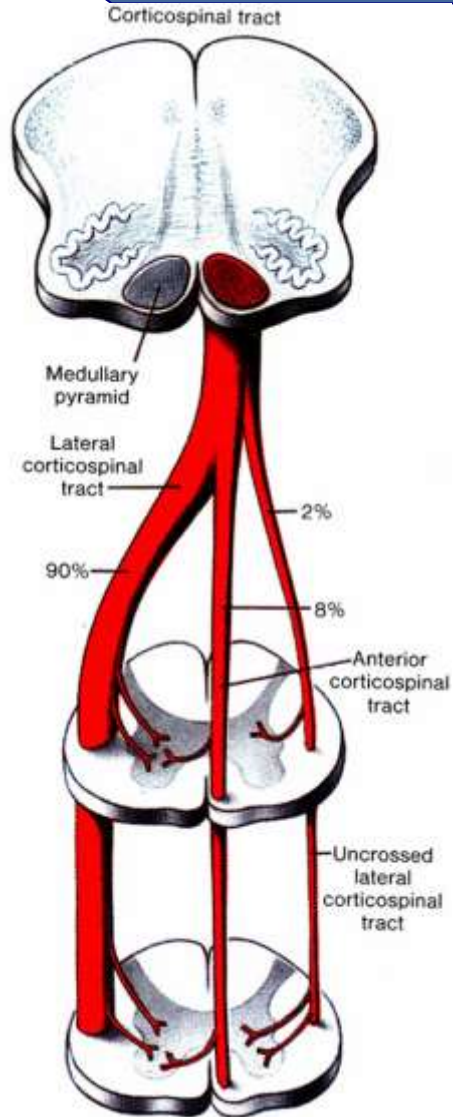
# Pyramidal motor system

■ corticospinal (pyramidal) tract – 1 million fibers:

- ✓ controls all of our voluntary movements ⇒ spastic cerebral palsy
- ✓  $\frac{1}{3}$  of the fibers from *gyrus precentralis* (“motor strip”) and *lobulus paracentralis* (Brodmann’s area 4)
- ✓  $\frac{1}{3}$  from the premotor areas (areas 6 and 8)
- ✓  $\frac{1}{3}$  from somatosensory cortex (areas 3, 1 and 2)
- ✓ posterior limb of internal capsule
- ✓ *crus cerebri* ⇒ *fibrae pontis longitudinales*
- ✓ pyramidal decussation – 85% decussate
  - lateral (crossed) corticospinal tract ⇒ to the contralateral side in the medulla oblongata
  - anterior corticospinal tract ⇒ 15% uncrossed to the ipsilateral side in the medulla oblongata



# Lateral and anterior corticospinal tracts



**NB:** The corticospinal tract terminates predominantly on interneurons, *final common pathway*, only rarely – directly on the large motoneurons!



# Pyramidal motor system

## ■ corticonuclear (corticobulbar) tract:

✓ from the lower  $\frac{1}{3}$  of *gyrus precentralis*

✓ genu of internal capsule

✓ *crus cerebri* ⇒

*pars ventralis pedunculi cerebri*

✓ corticonuclear axons innervate

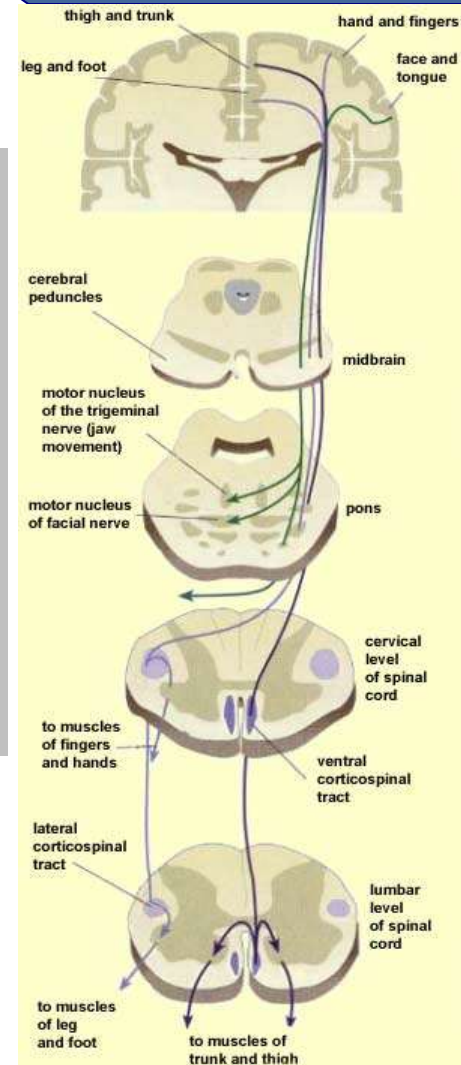
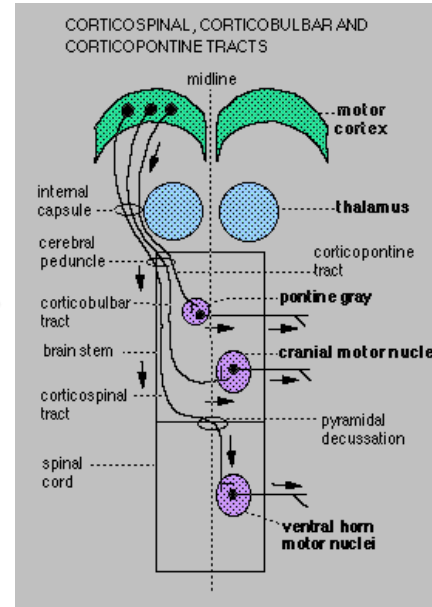
cranial motor nuclei bilaterally

✓ they directly innervate the nuclei for cranial nerves

V, VII, XI and XII

✓ indirectly innervate nuclei for nerves III, IV and VI

via interneurons



**NB:** The 'bulb' is an archaic term for the medulla oblongata.



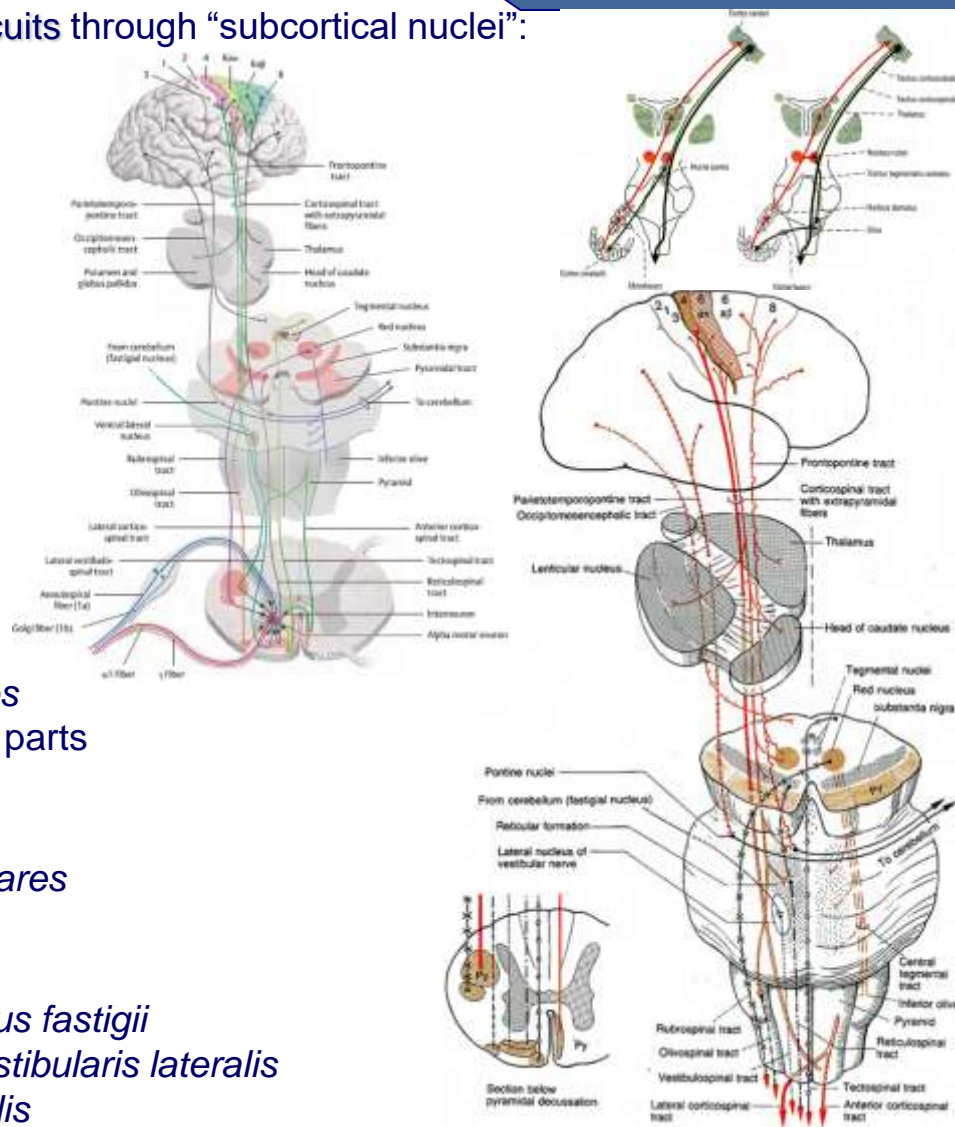
# Extrapyramidal motor pathways

- Feedback multineuronal and polysynaptic circuits through “subcortical nuclei”:

- ✓ striopallidal system
- ✓ substantia nigra
- ✓ subthalamic nucleus
- ✓ cerebellum

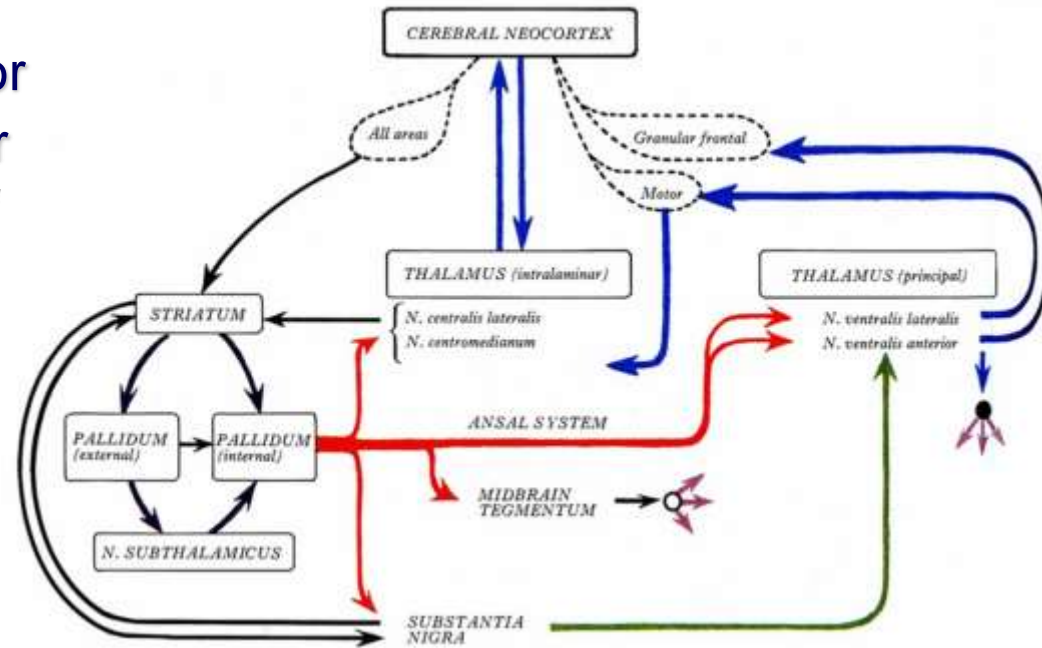
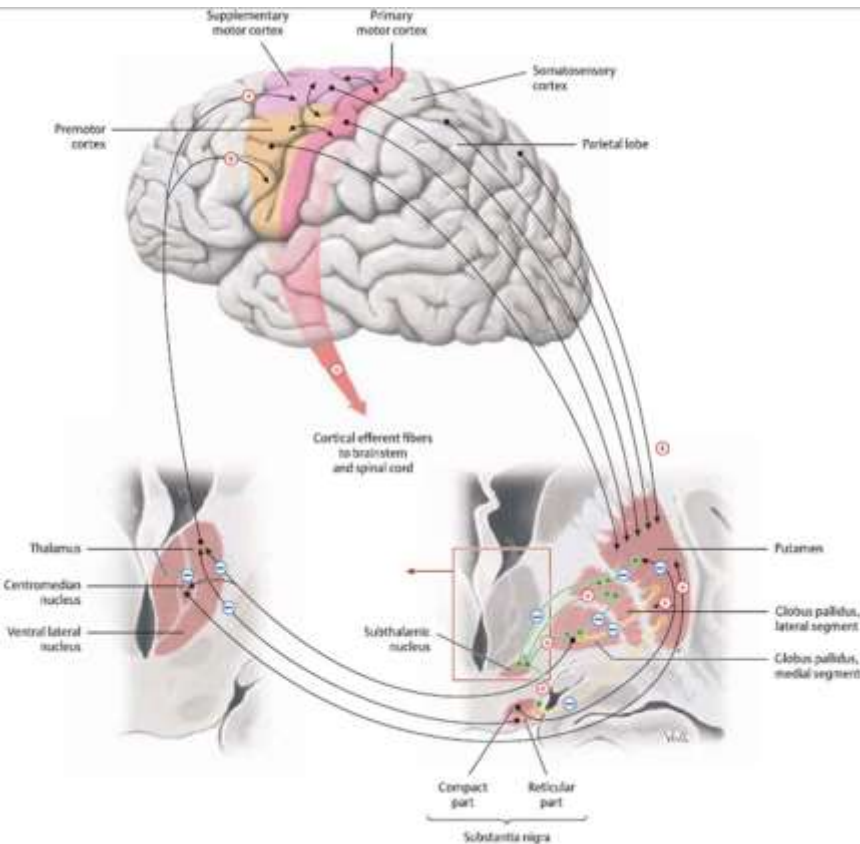
- Pathways to peripheral motoneurons:

- ✓ cortico-rubro-spinal tract – extremities:
    - *tractus frontorubralis* ⇨ *nucleus ruber*
    - *tractus rubrospinalis*
  - ✓ cerebello-rubro-spinal tract:
    - cerebellar cortex ⇨ deep cerebellar nuclei
    - *tractus cerebellorubralis* ⇨ *nucleus ruber*
    - *tractus rubrospinalis*
  - ✓ cortico-reticulo-spinal tract:
    - *fibrae corticoreticulares* ⇨ *nuclei reticulares*
    - *fibrae reticulospinales* – medial and lateral parts
  - ✓ cerebello-reticulo-spinal tract:
    - cerebellar cortex ⇨ *nucleus dentatus*
    - *tractus cerebelloreticularis* ⇨ *nuclei reticulares*
    - *tractus reticulospinalis*
  - ✓ cerebello-vestibulo-spinal tract:
    - flocculo-nodular cerebellar cortex ⇨ *nucleus fastigii*
    - *tractus cerebellovestibularis* ⇨ *nucleus vestibularis lateralis*
- tractus vestibulospinalis*



# Basal ganglia pathways

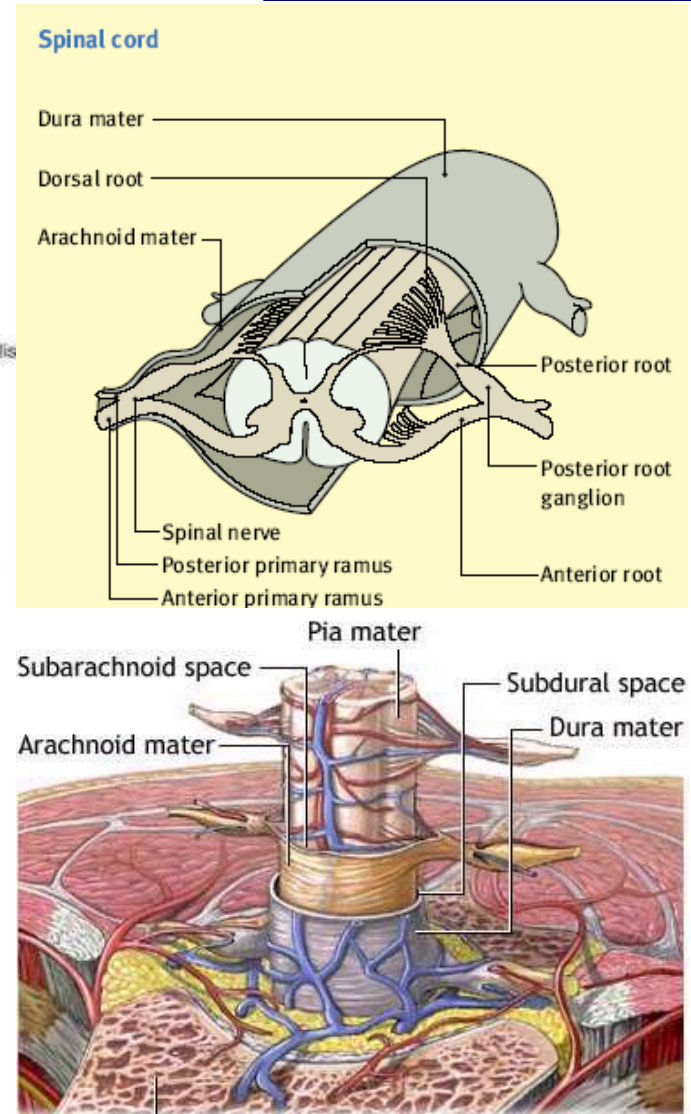
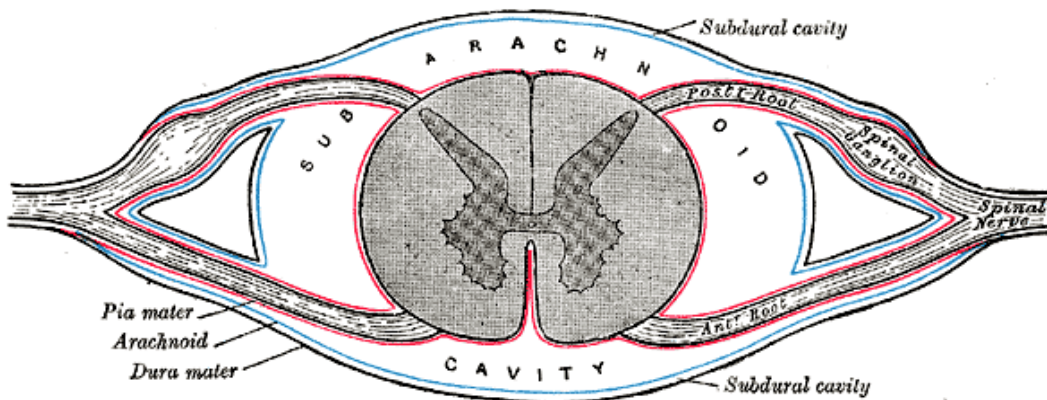
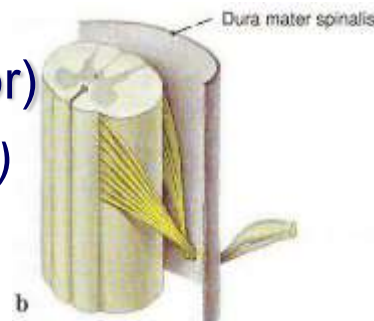
- Closed reverberating circuits of the basal ganglia:
  - ✓ striatum is the main acceptor
  - ✓ pallidum is the main effector





# Meningeal coverings of the spinal cord

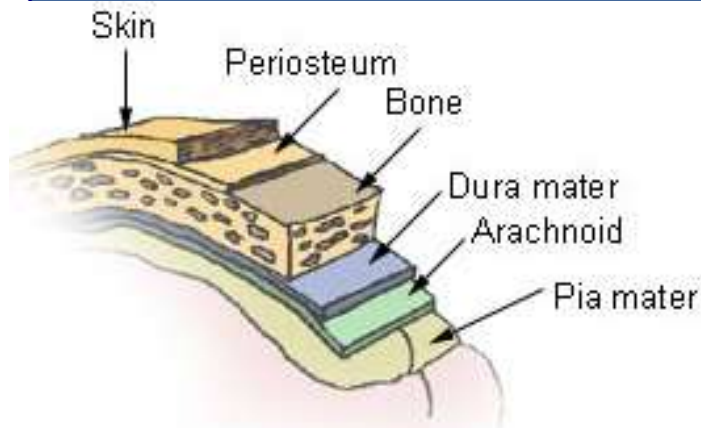
- three meninges:
  - ✓ *spinal dura mater*
    - epidural and subdural spaces
  - ✓ *arachnoid mater*
    - subarachnoid space ⇒ cerebrospinal fluid (liquor)
  - ✓ *pia mater (leptomeninges)*
    - perivascular spaces ⇒ spinal blood vessels



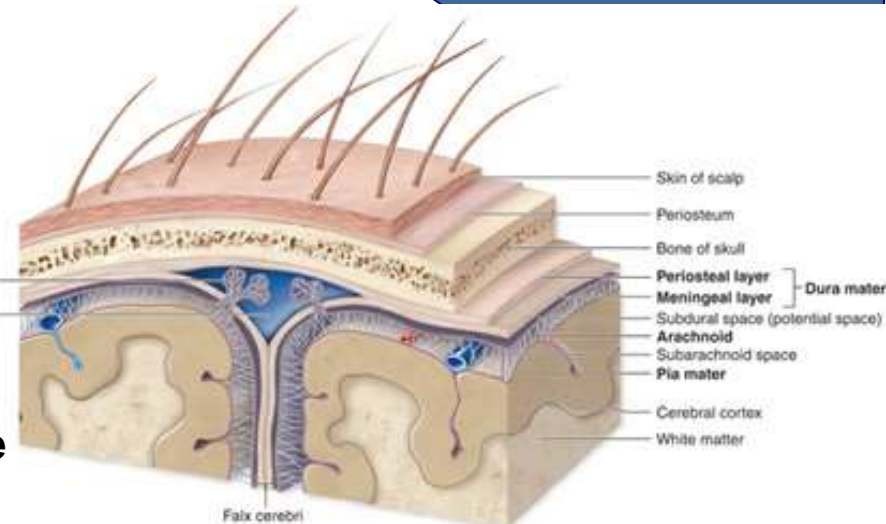




# Meninges of the brain



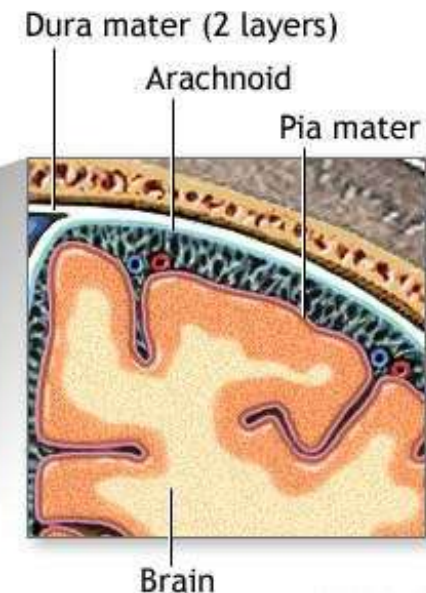
Arachnoid villus  
Superior sagittal sinus



## Meninges of the CNS - protective tissue

- Dura mater (*Pachymeninx*),  
*dura mater encephali*
- *Leptomeningx*  
(*Lepto-* from the root meaning *thin* in Greek):
  - ✓ Arachnoid mater,  
*arachnoidea mater encephali*
  - ✓ Pia mater,  
*pia mater encephali*

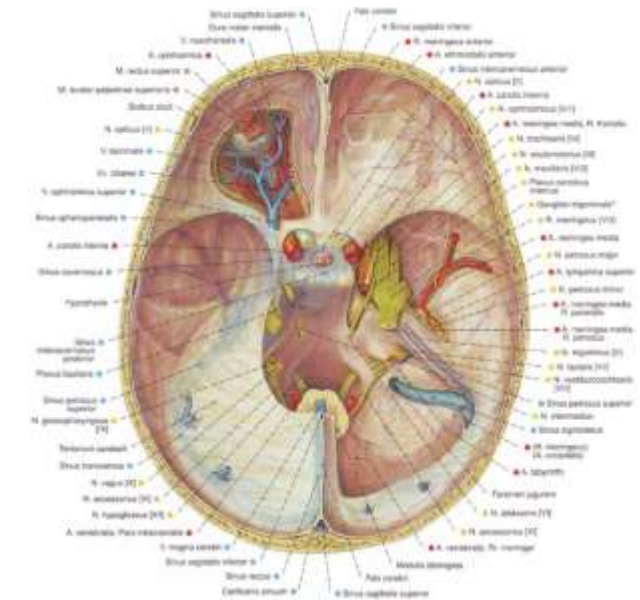
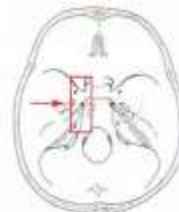
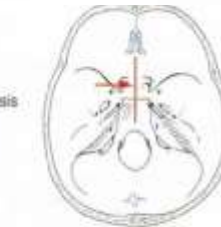
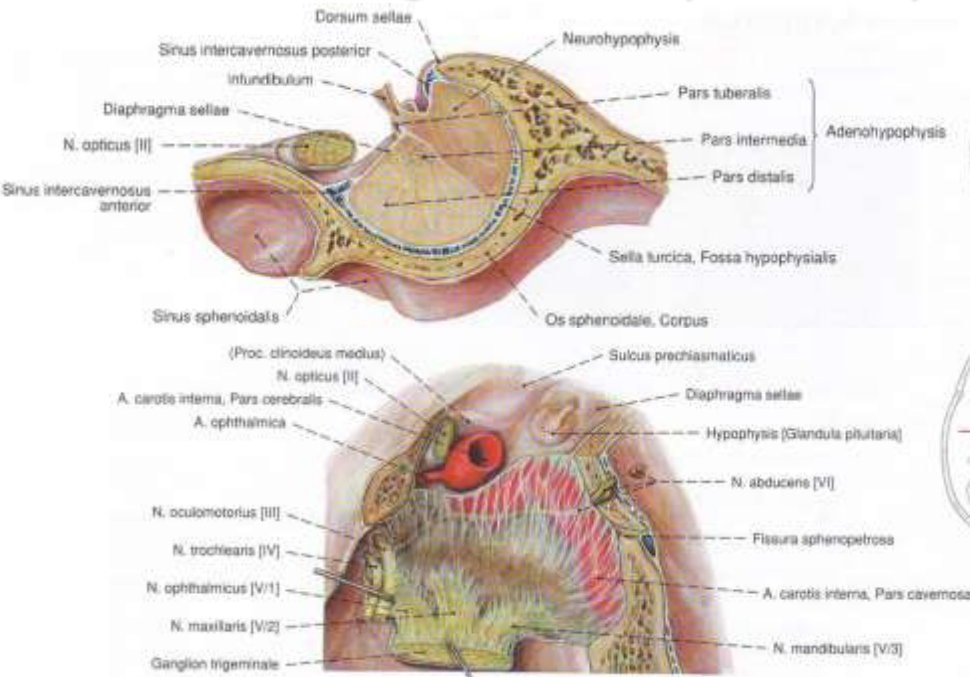
The meninges are the membranes covering the brain and spinal cord





# Cerebral dura mater structures

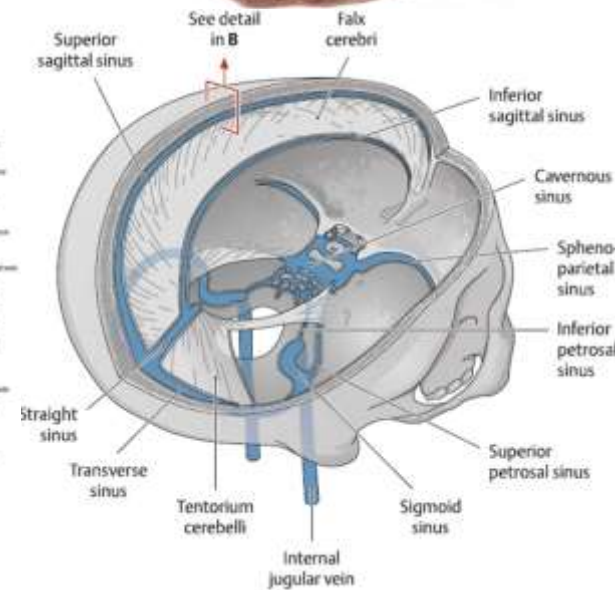
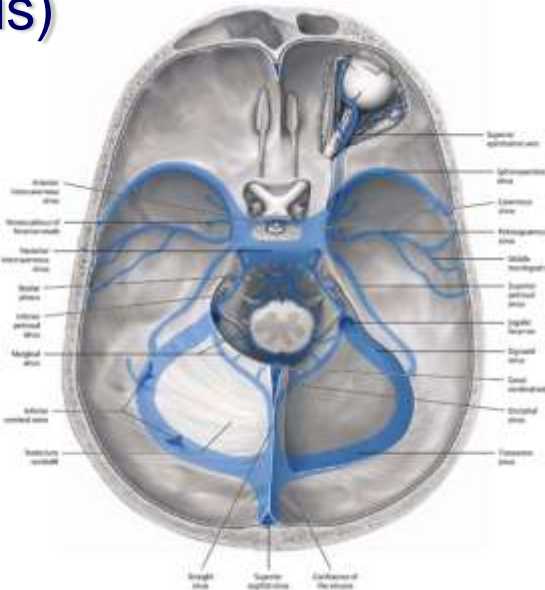
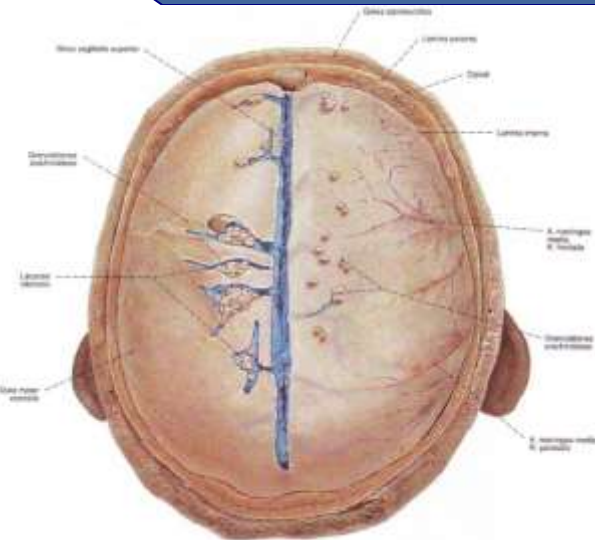
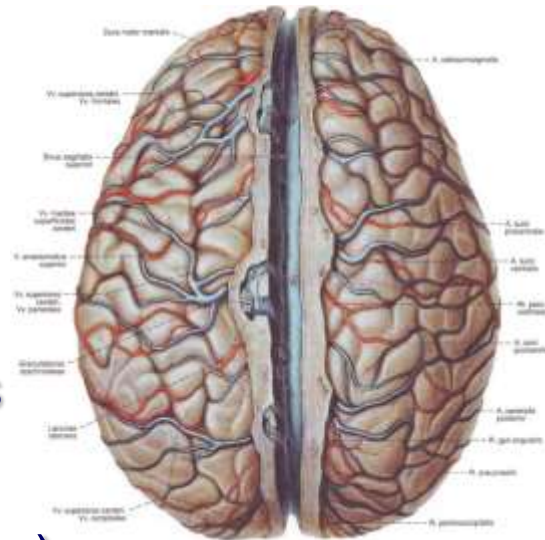
- sickle-shaped *falx cerebri*
- *tentorium cerebelli*
- *falx cerebelli*
- *diaphragma sellae*
- *cavum trigeminale (Meckeli)*





# Cranial dural venous sinuses

- ✓ superior sagittal sinus
- ✓ inferior sagittal sinus
- ✓ transverse sinuses ⇒
- ✓ sigmoid sinuses ⇒
- confluence of the sinuses
- ✓ occipital sinus
- ✓ straight sinus (sinus rectus)
- ✓ petrosquamous sinus
- ✓ superior petrosal sinuses
- ✓ inferior petrosal sinuses
- ✓ cavernous sinuses ⇒
- intercavernous sinuses,
- anterior and posterior





# Arachnoid mater

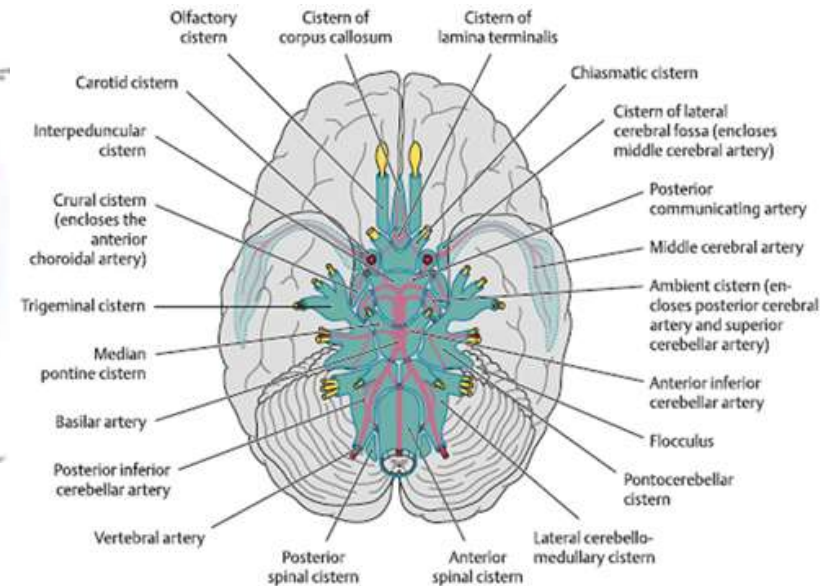
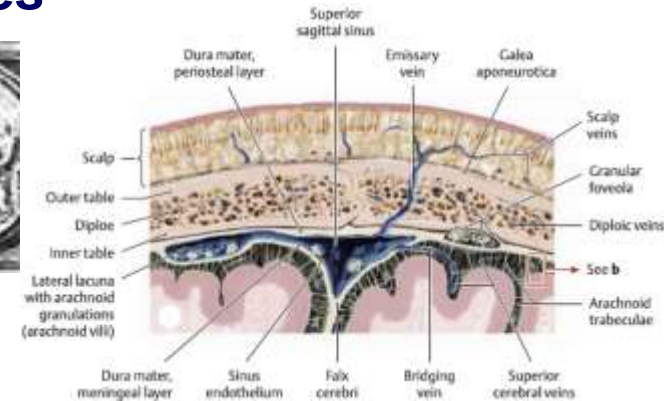
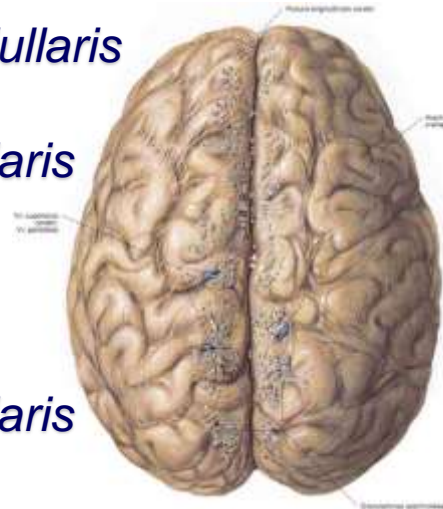
- Arachnoid granulations (or arachnoid villi) – in the sinuses  
**Pacchioni's granulations or pacchionian bodies**

**Antonio Pacchioni (1665–1726)**



- spiderweb-like layer (hence the name)
- subarachnoid space ⇒ filled with cerebrospinal fluid
- subarachnoid cisterns:

- ✓ *cisterna cerebellomedullaris posterior et lateralis*
- ✓ *cisterna pontocerebellaris*
- ✓ *cisterna ambiens*
- ✓ *cisterna trigeminalis*
- ✓ *cisterna cruralis*
- ✓ *cisterna interpeduncularis*
- ✓ *cisterna carotidis*
- ✓ *cisterna chiasmatis*
- ✓ *cisterna fossae lateralis cerebri*



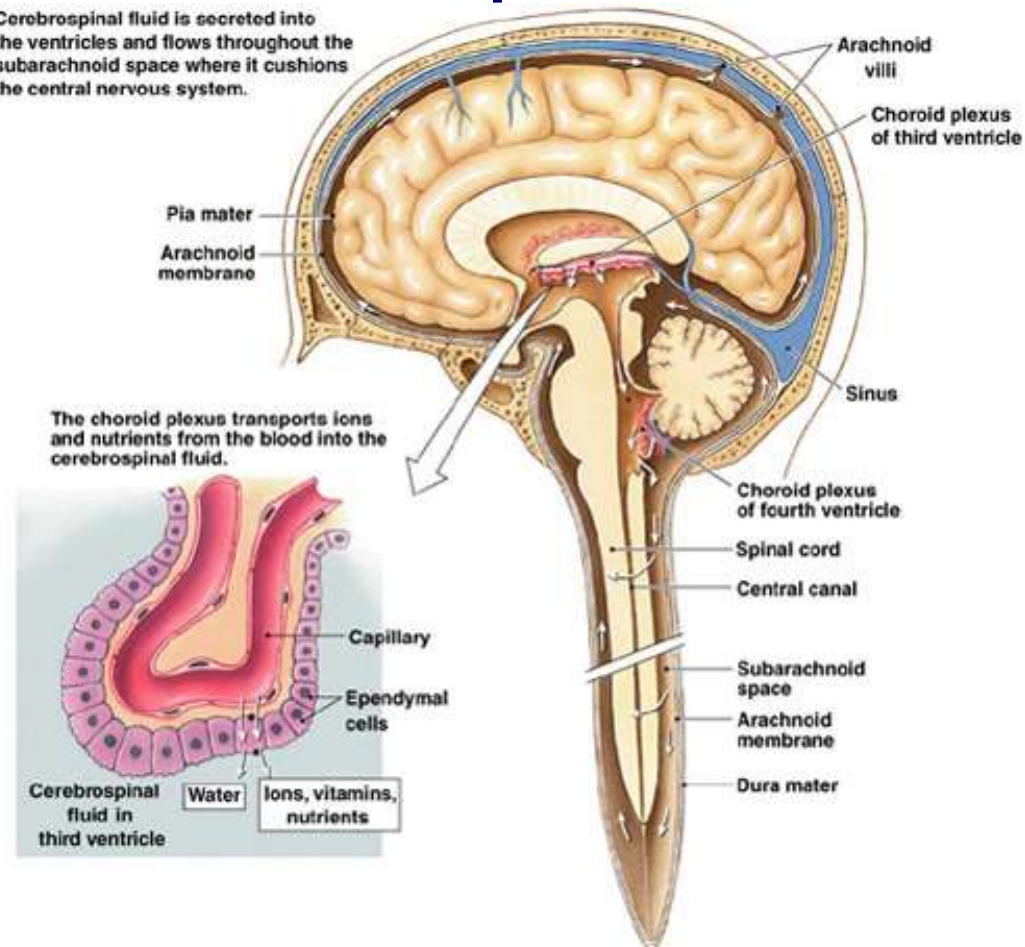


# Cerebrospinal fluid

- *liquor cerebrospinalis* – secreted by the choroid plexuses (~ 50-70%) into the ventricles and in the **subarachnoid space**:

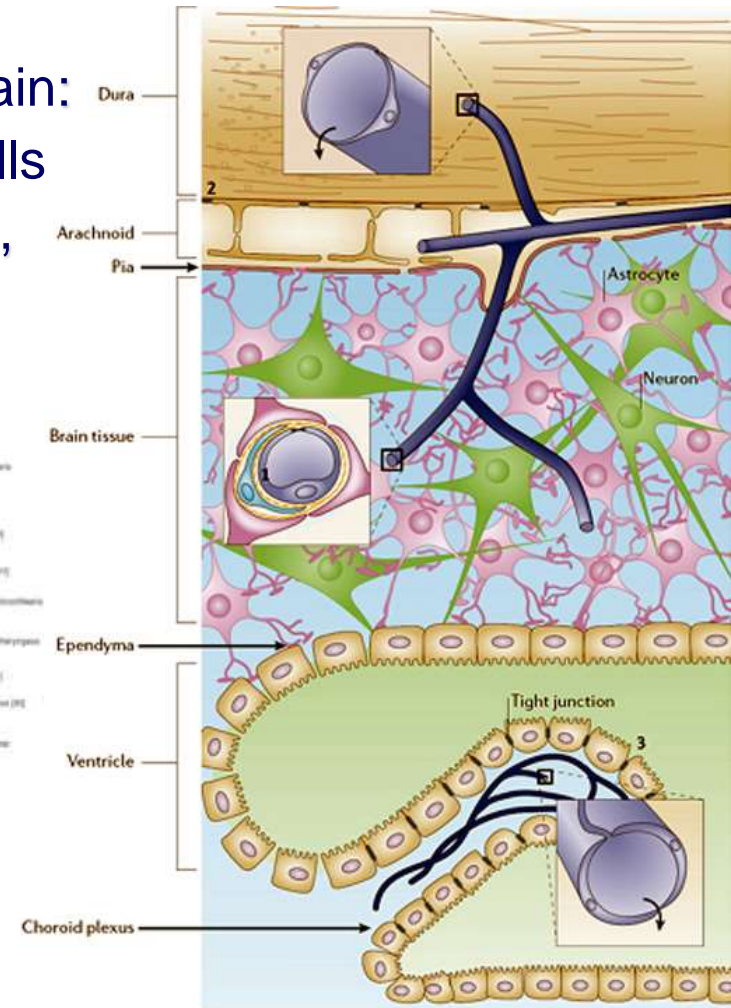
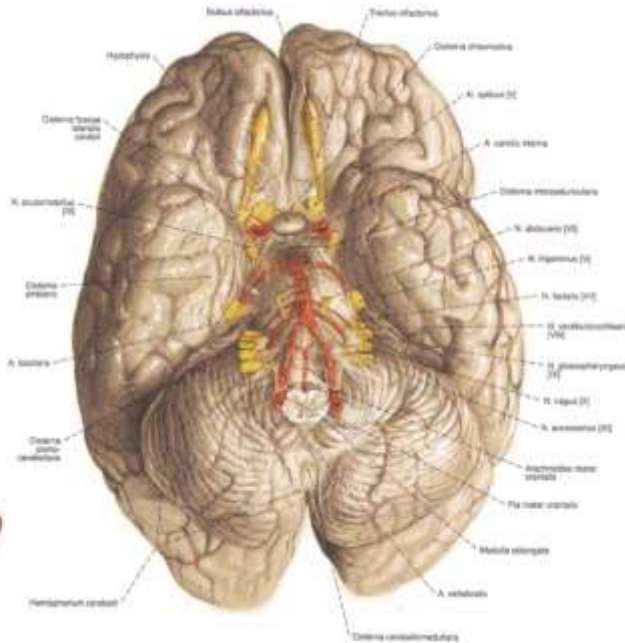
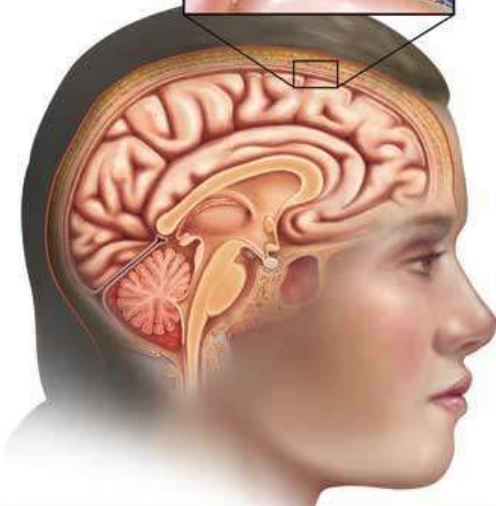
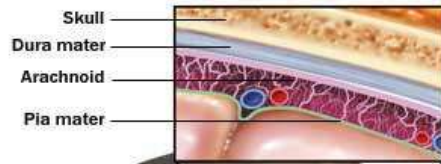
- ✓ clear, colorless liquid
- ✓ slightly alkaline
- ✓ specific gravity ~1.007
- ✓ similarly to blood plasma:
  - inorganic salts
  - traces of proteins
  - glucose
- ✓ serves to:
  - support and cushion the CNS against trauma
  - remove waste products of neuronal metabolism

Cerebrospinal fluid is secreted into the ventricles and flows throughout the subarachnoid space where it cushions the central nervous system.



# Pia mater

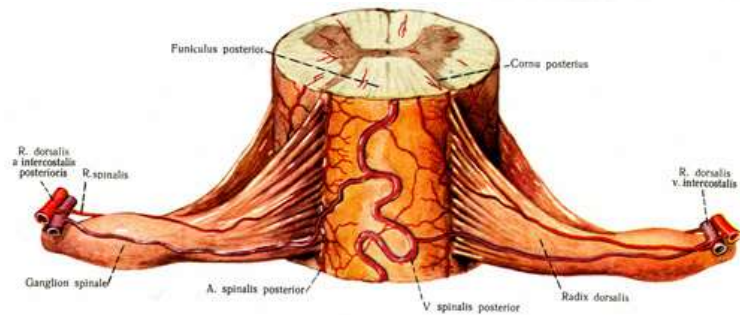
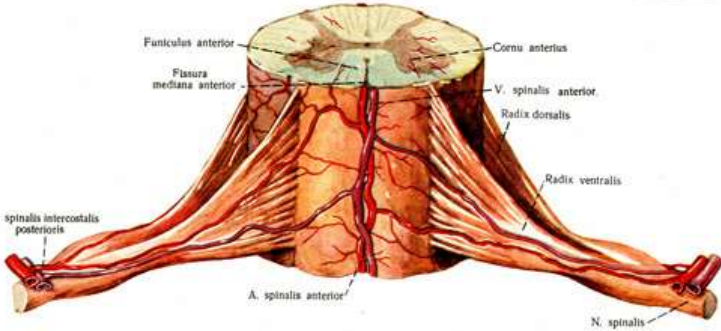
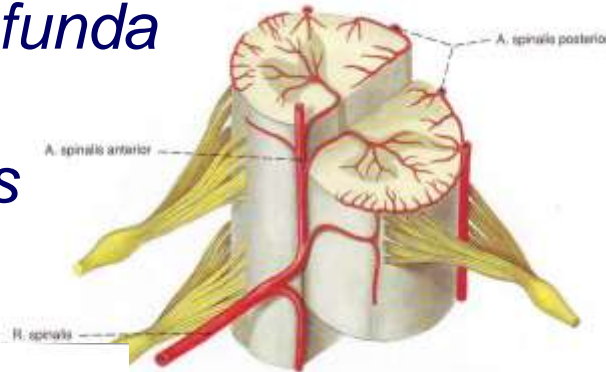
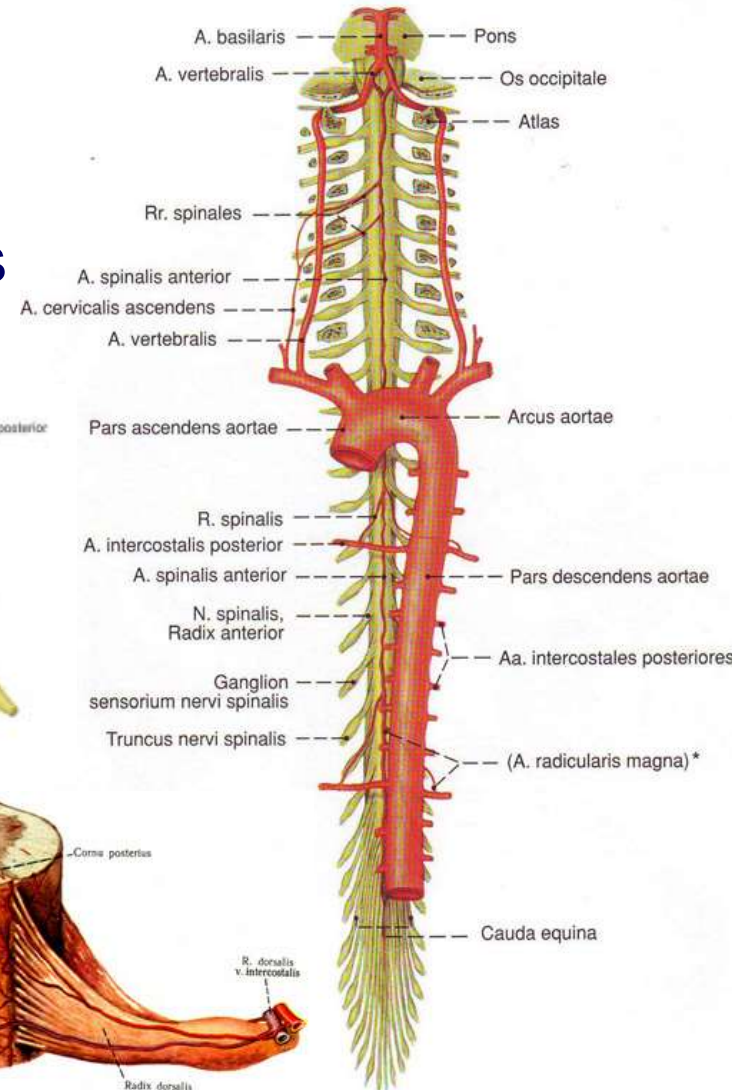
- very thin membrane, Latin "tender mother"
- neural crest derivative
- vascular membrane – nourishing the brain:
  - ✓ superficial *epipial layer* – sheet of flat cells
  - ✓ inner membranous layer – fibrous tissue, *intima pia*





# Arterial blood supply of the spinal cord

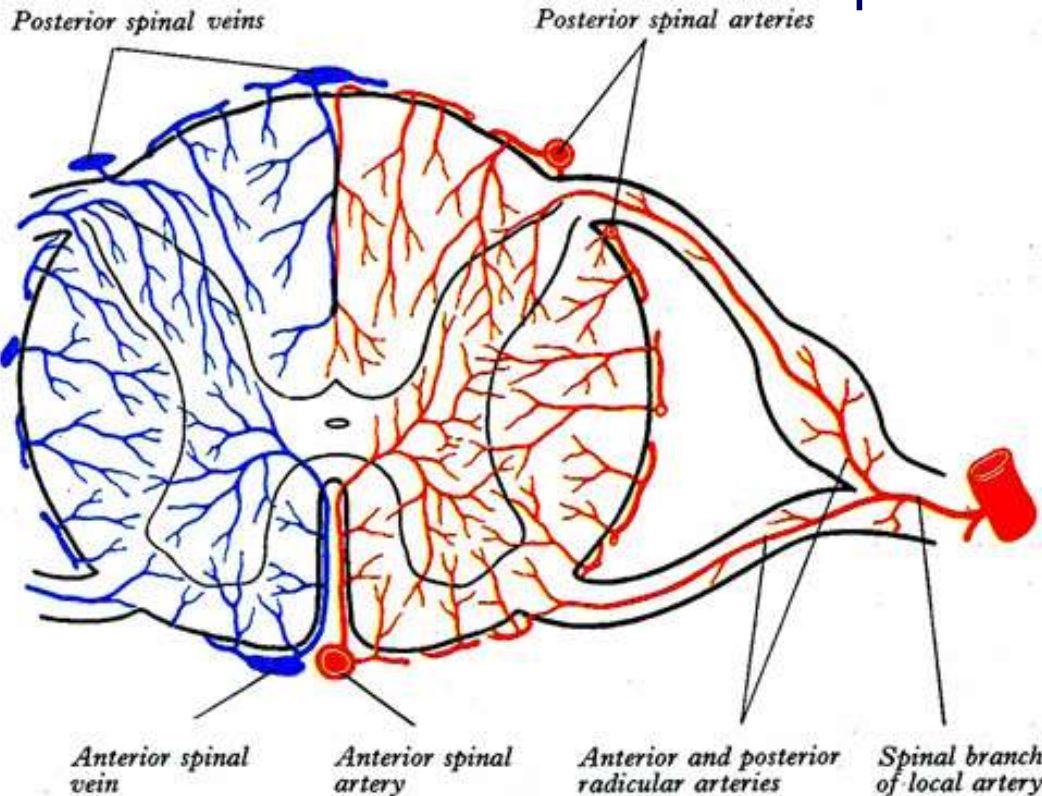
- longitudinal trunk (*a. vertebralis*):
  - ✓ unpaired *a. spinalis anterior*
  - ✓ *aa. spinales posteriores*
- segmental supply: radicular arteries
  - ✓ *a. cervicalis ascendens*
  - ✓ *a. cervicalis profunda*
  - ✓ *a. vertebralis*
  - ✓ *aa. intercostales posteriores*
  - ✓ *aa. lumbales*



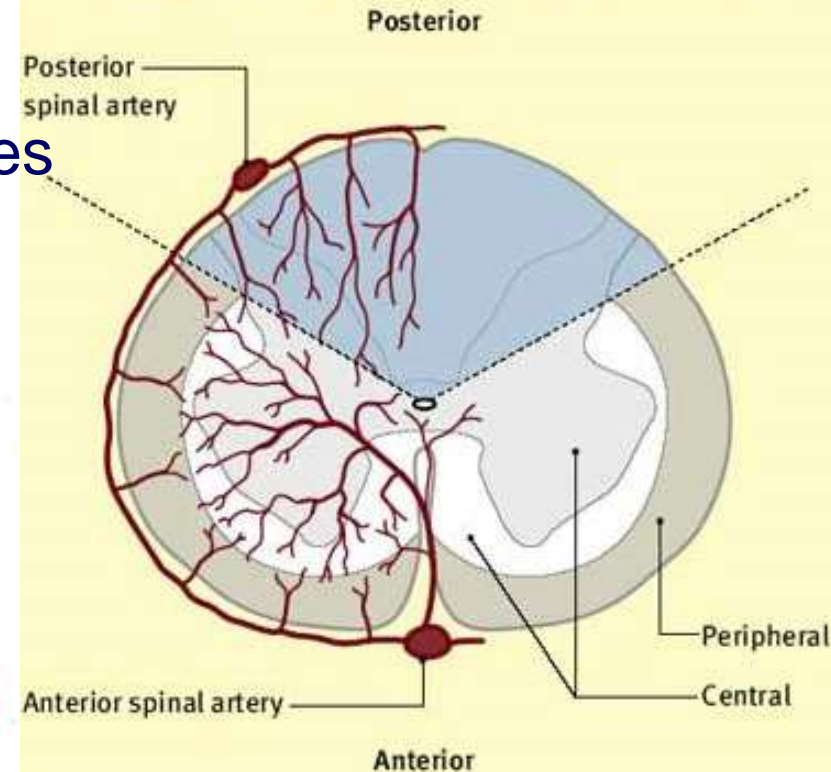


# Intrinsic blood vessels

- Venous drainage – 6 channels:
  - ✓ anterior longitudinal trunks
  - ✓ posterior longitudinal trunks
  - ✓ internal vertebral venous plexuses



Blood supply to the spinal cord: horizontal distribution



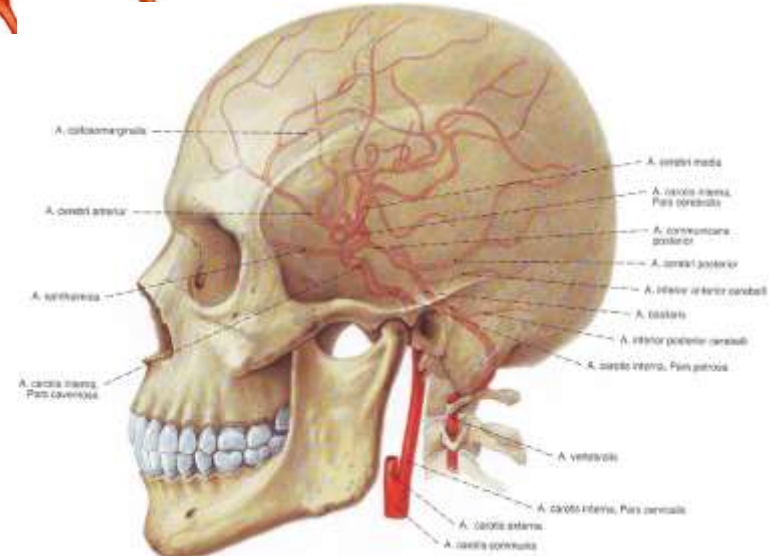
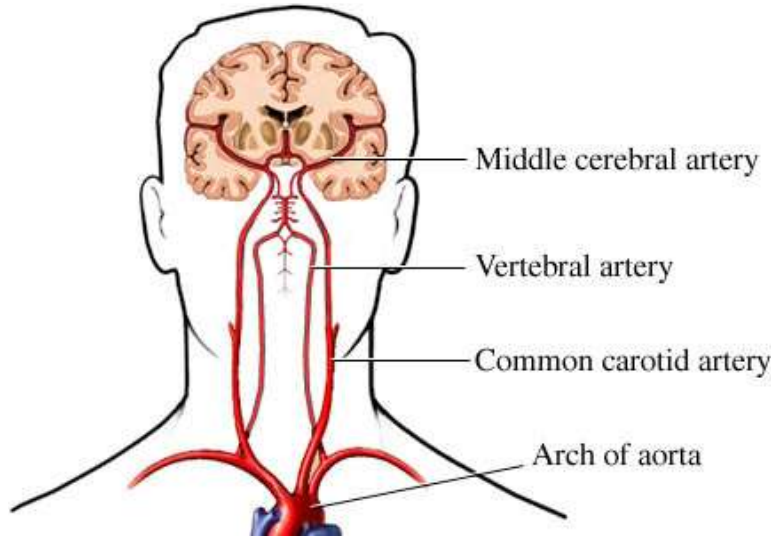
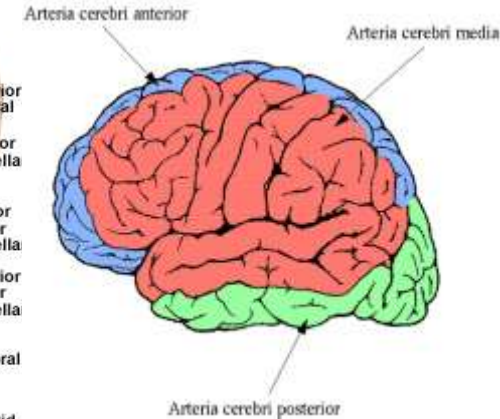
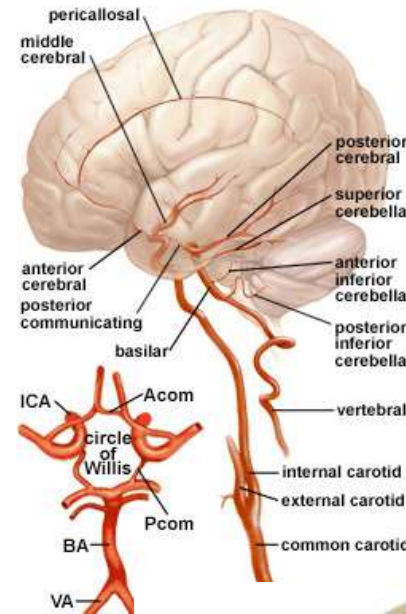
The central area supplied only by the anterior spinal artery is predominantly a motor area





# Blood supply of the brain

- **Vertebrobasilar system:**
  - ✓ *aa. vertebrales* ⇒ *a. basilaris*
- **Carotid system:**
  - ✓ *a. carotis interna*
- **Communication:**
  - ✓ *circulus arteriosus cerebri*

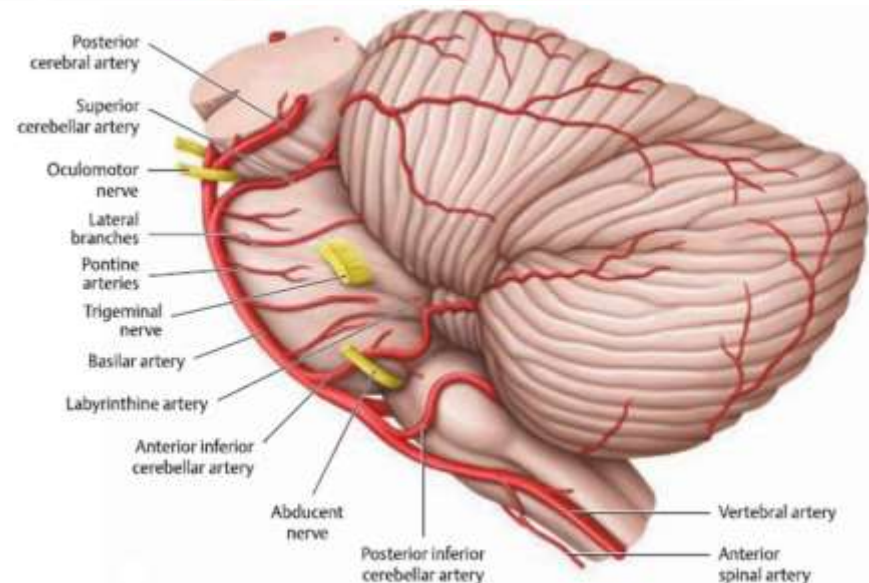
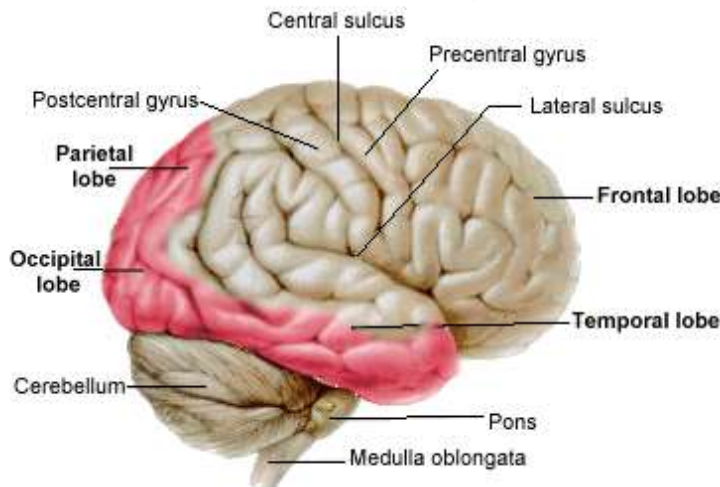
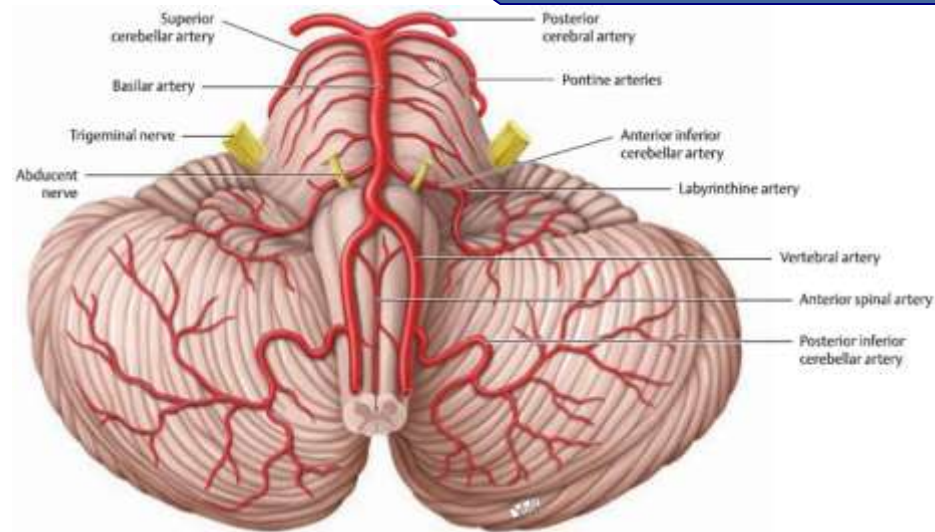




# Arterial blood supply

## Vertebrobasilar system:

- ✓ vertebral artery:
  - posterior inferior cerebellar artery
- ✓ basilar artery:
  - anterior inferior cerebellar artery
  - superior cerebellar artery
  - labyrinthine artery (internal auditive artery)
  - pontine arteries
  - posterior cerebral artery



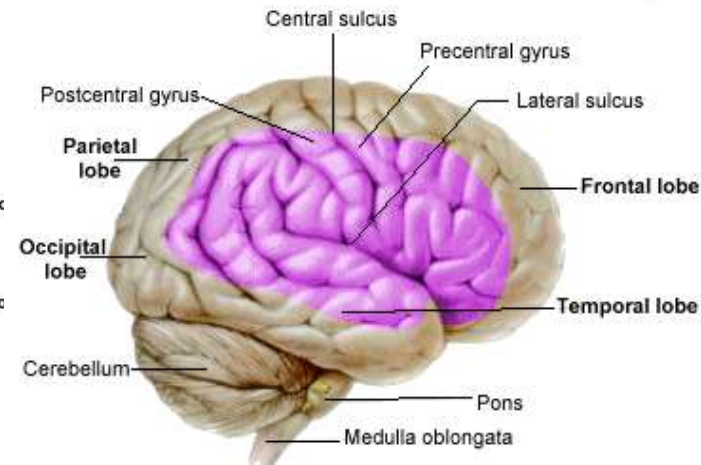
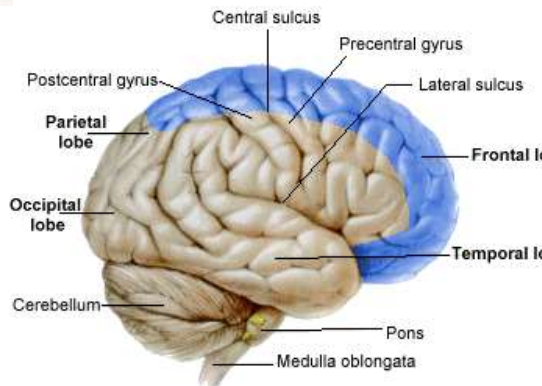
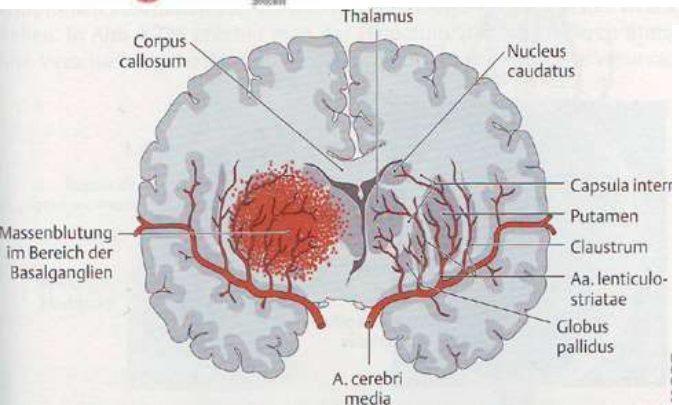
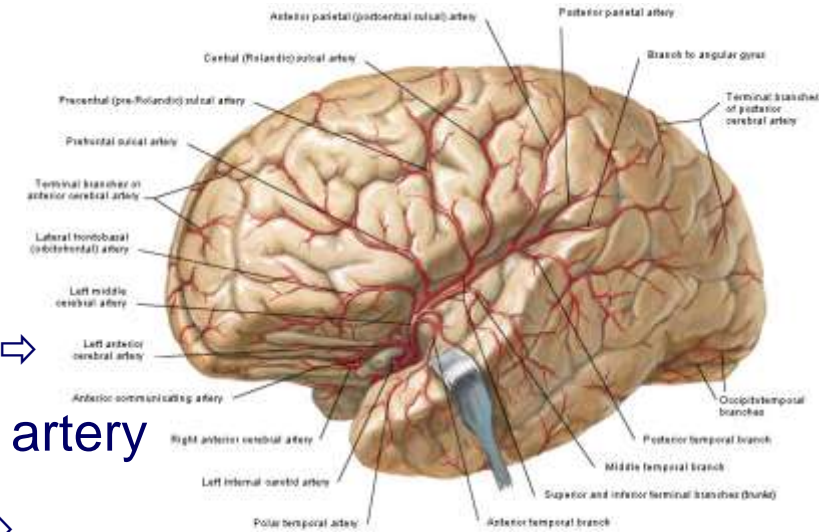
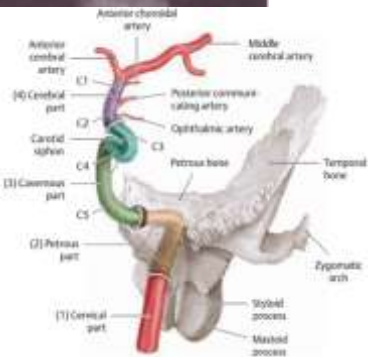


# Arterial blood supply

## Carotid system:

✓ internal carotid artery (cerebral part):

- anterior cerebral artery ⇒ anterior communicating artery
- middle cerebral artery ⇒ “a. haemorrhagica” (of Charcot)

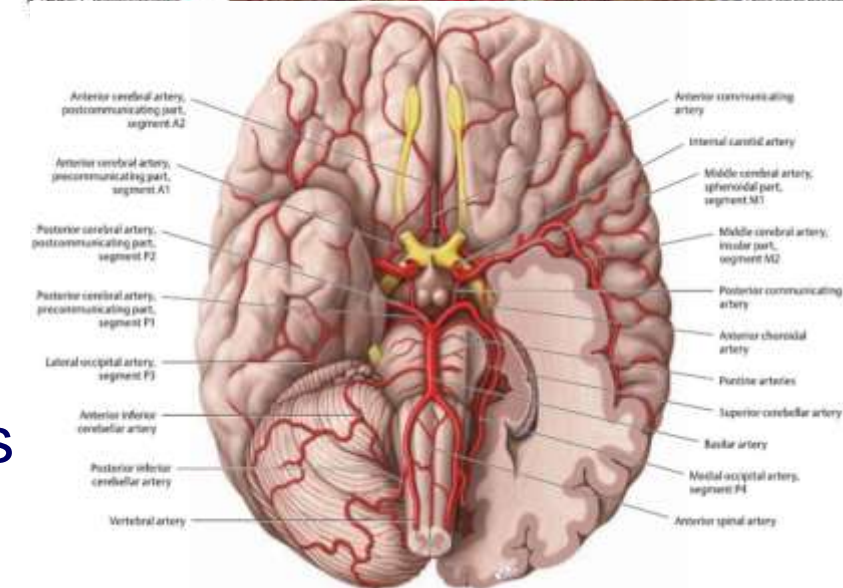
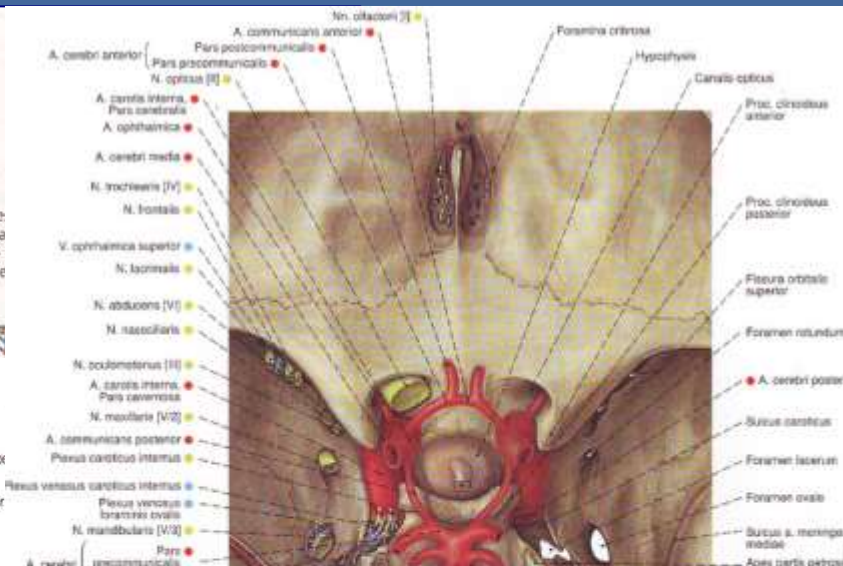
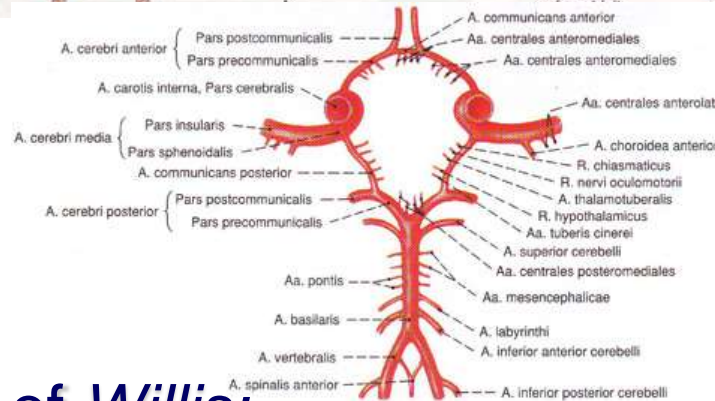
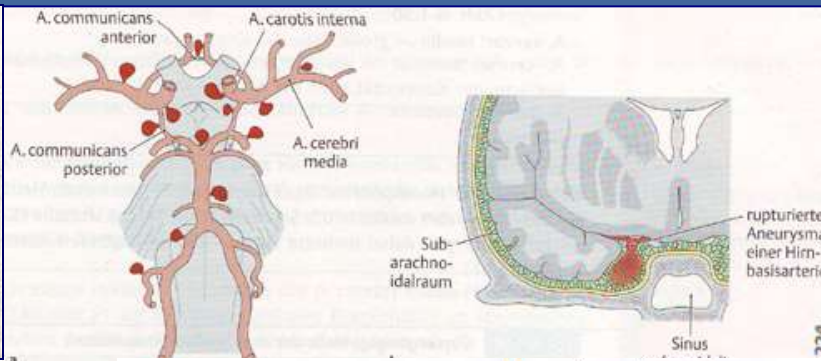




# Circulus arteriosus cerebri (circle of Willis)



**Thomas Willis (1621-1675)**



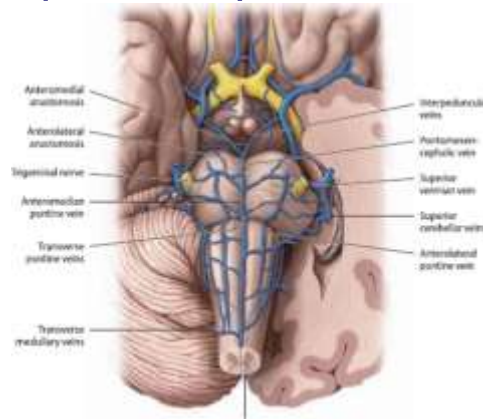
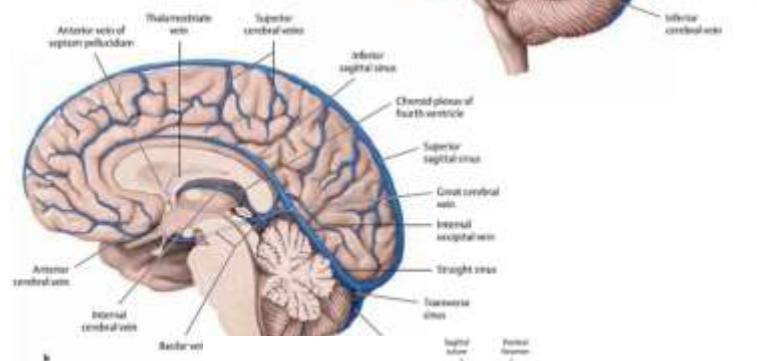
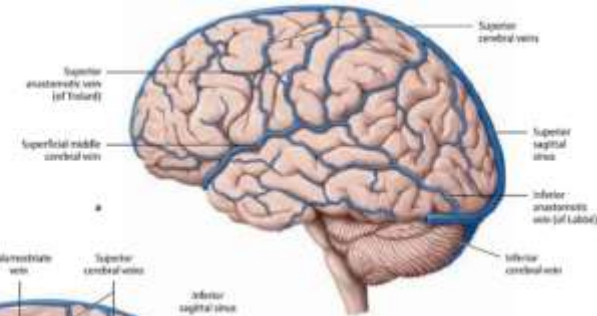
## Heptagon of Willis:

- ✓ anterior communicating artery
- ✓ anterior cerebral arteries
- ✓ posterior communicating arteries
- ✓ posterior cerebral arteries



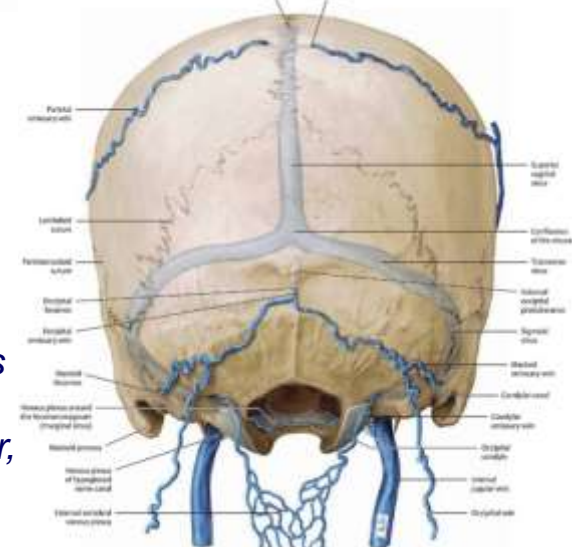
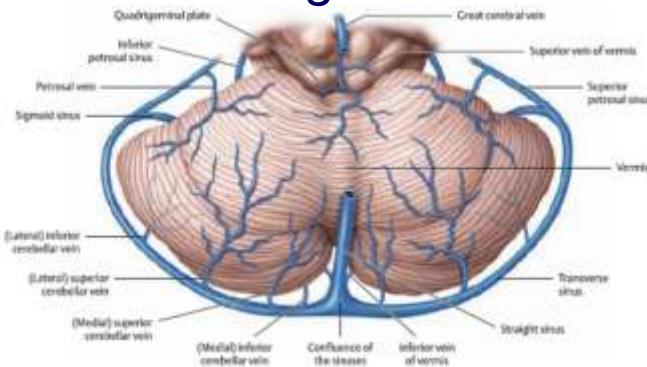
# Venous drainage of the brain

- superficial cerebral veins:
  - ✓ *vv. superficiales cerebri* ⇒ into dural venous sinuses
- deep cerebral veins:
  - ✓ *vv. profundi cerebri* ⇒ *v. magna cerebri (Galenii)*
- communication:
  - ✓ *vv. emissariae*
  - ✓ *vv. diploicae*
- cerebellar veins ⇒ *v. magna cerebri*



## ■ brainstem veins:

- ✓ medulla oblongata ⇒ *sinus occipitalis, sinus petrosus inferior, v. jugularis interna*
- ✓ pons ⇒ *sinus petrosus superior, sinus transversus*
- ✓ midbrain ⇒ *v. magna cerebri*





# Thank you...

