

Brainstem: Midbrain

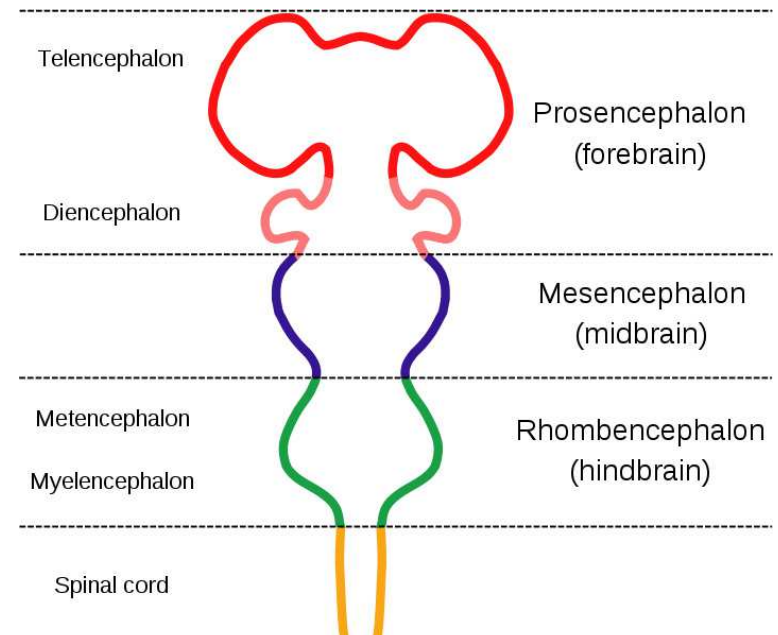
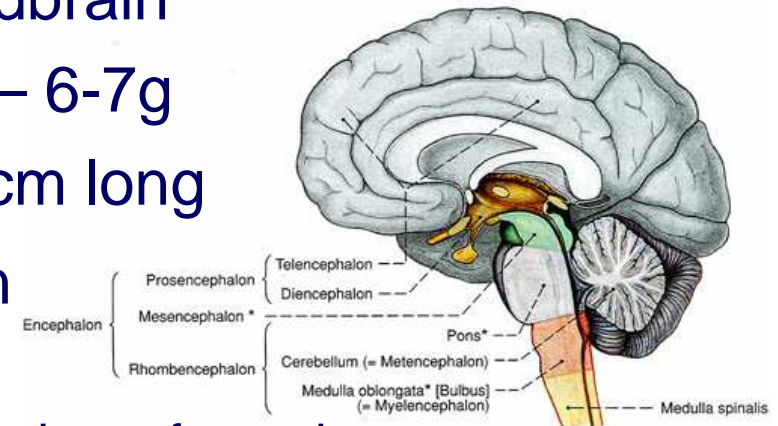
1. Midbrain – gross external anatomy
2. Internal structure of the midbrain:
 - cerebral peduncles
 - tegmentum
 - tectum (quadrigeminal plate)





Midbrain – general features

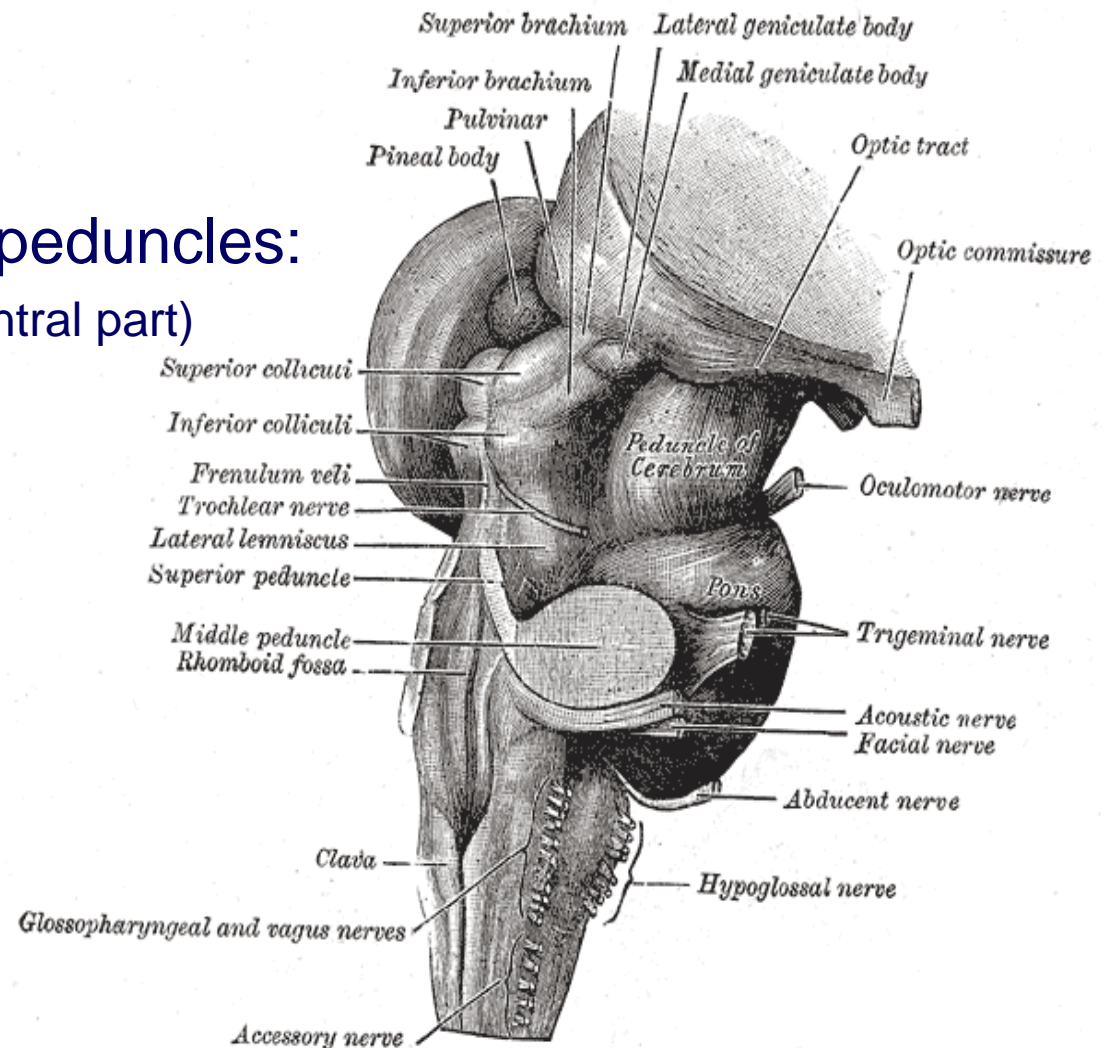
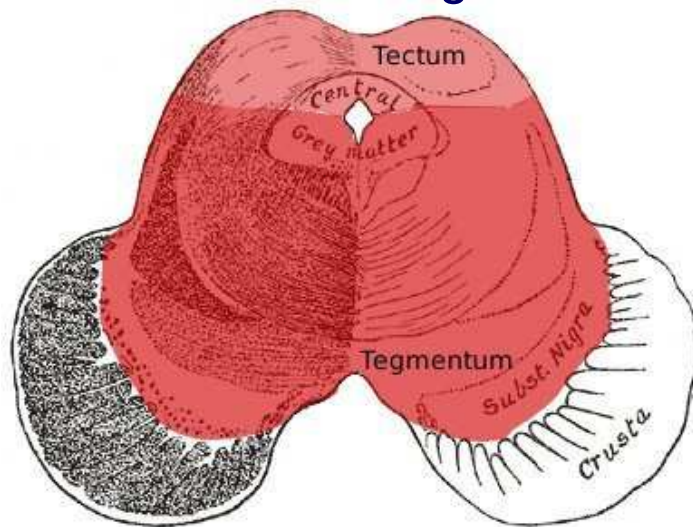
- location – between forebrain and hindbrain
- the smallest region of the brainstem – 6-7g
- the shortest brainstem segment ~ 2 cm long
- least differentiated brainstem division
- human midbrain is archipallian – shared general architecture with the most ancient of vertebrates
- embryonic origin – mesencephalon
- main functions:
 - ✓ a sort of relay station for sound and visual information
 - ✓ serves as a nerve pathway of the cerebral hemispheres
 - ✓ controls the eye movement
 - ✓ involved in control of body movement





Midbrain – gross anatomy

- dorsal part – *tectum* (quadrigeminal plate):
 - ✓ superior colliculi
 - ✓ inferior colliculi
 - ⇒ cerebral aqueduct
- ventral part – cerebral peduncles:
 - ✓ dorsal – tegmentum (central part)
 - ✓ ventral – cerebral crus
 - ⇒ substantia nigra





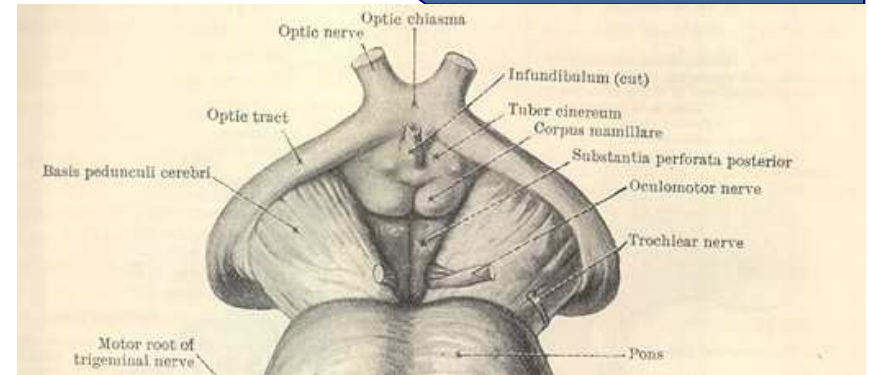
Cerebral crus – internal structure

- Cerebral peduncle:

- ✓ *crus cerebri*

- ✓ *tegmentum mesencephali*

- ✓ *substantia nigra*



- two thick semilunar white matter bundles

- composition – somatotopically arranged motor tracts:

- ✓ corticospinal } pyramidal tracts – medial $\frac{2}{3}$

- ✓ corticobulbar

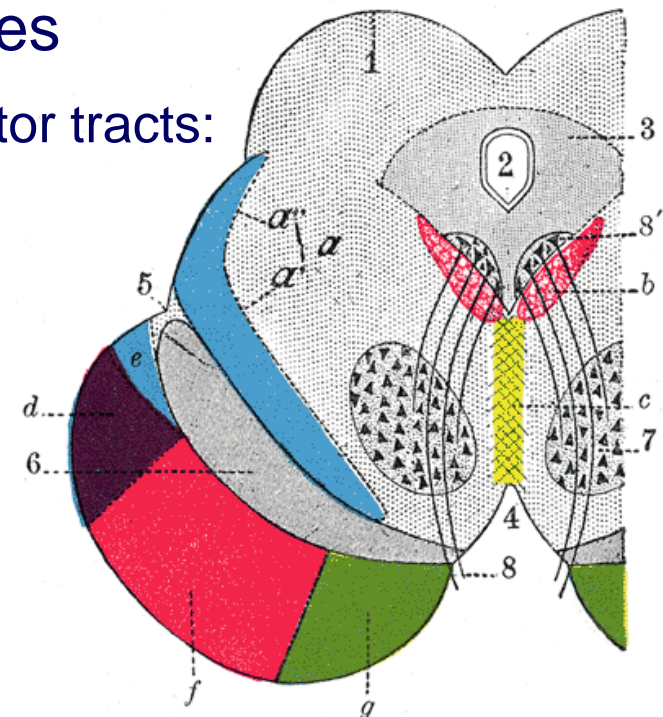
- ✓ corticopontine fibers:

- frontopontine tracts – medially

- temporopontine tracts – laterally

- interpeduncular fossa (of *Tarin*)

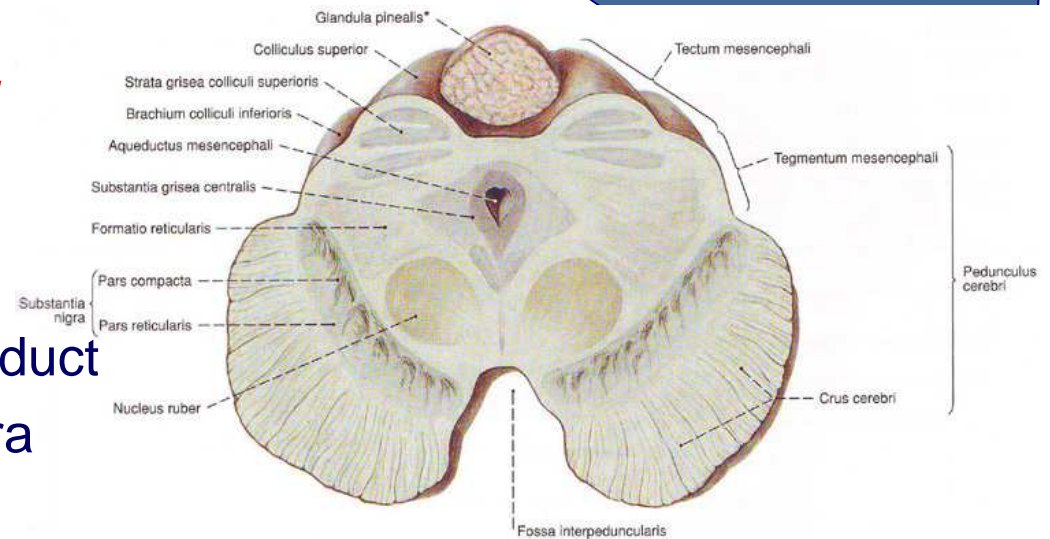
- ✓ posterior perforated substance



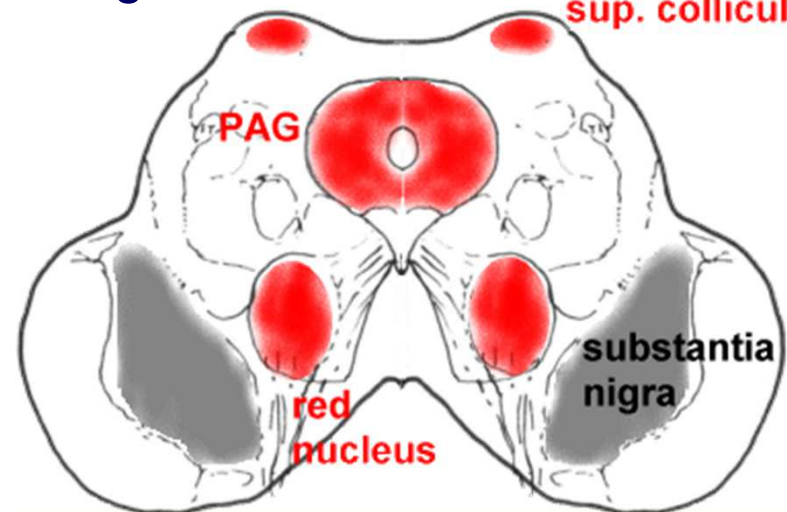


Midbrain tegmentum – internal structure

- ✓ *crus cerebri*
- ✓ *tegmentum mesencephali*
- ✓ *substantia nigra*
- location:
 - ✓ ventral to the cerebral aqueduct
 - ✓ dorsal to the substantia nigra
- grey matter content:
 - ✓ periaqueductal grey matter
 - ✓ nuclei of cranial nerves III & IV
 - ✓ midbrain reticular formation
 - ✓ red nucleus, *nucleus ruber*:
 - parvocellular part – rostral third
 - magnocellular part – caudal portion
 - ✓ ventral tegmental area



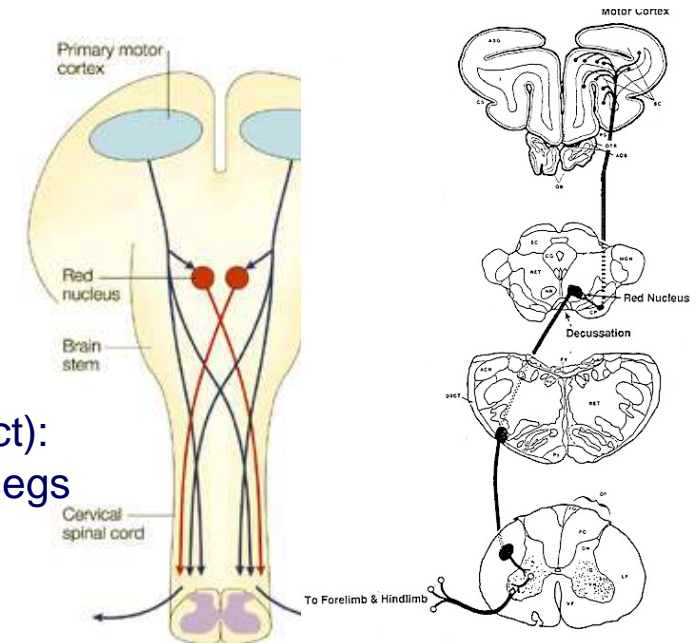
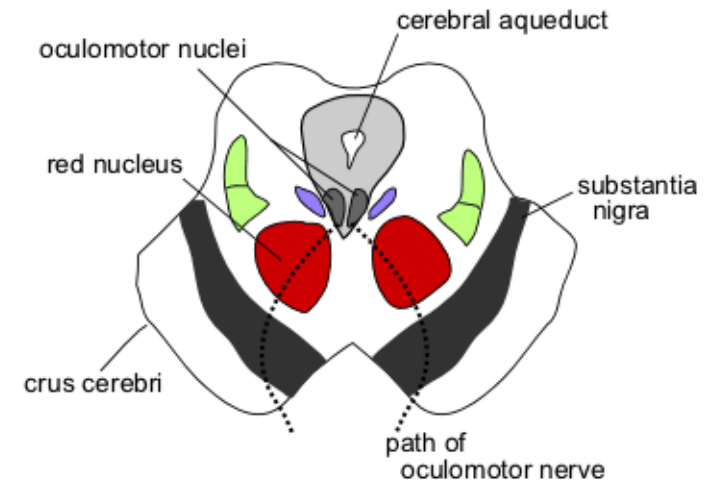
NB: *tegmentum* is Latin for *covering* **sup. colliculus**





Red nucleus, *nucleus ruber*

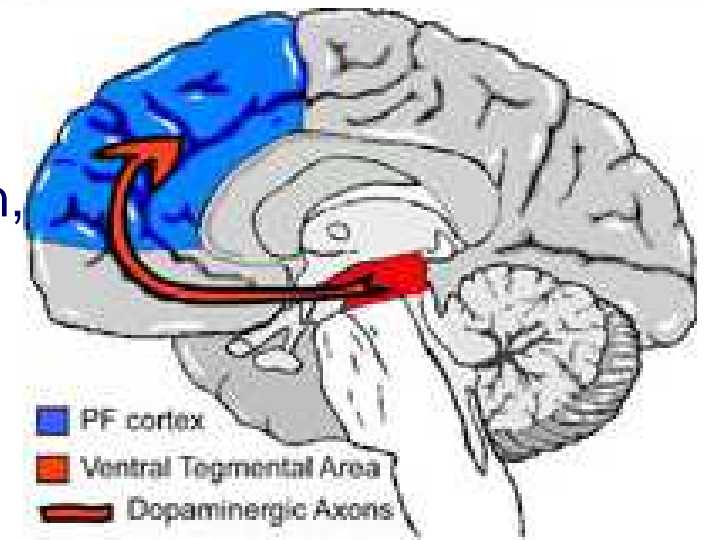
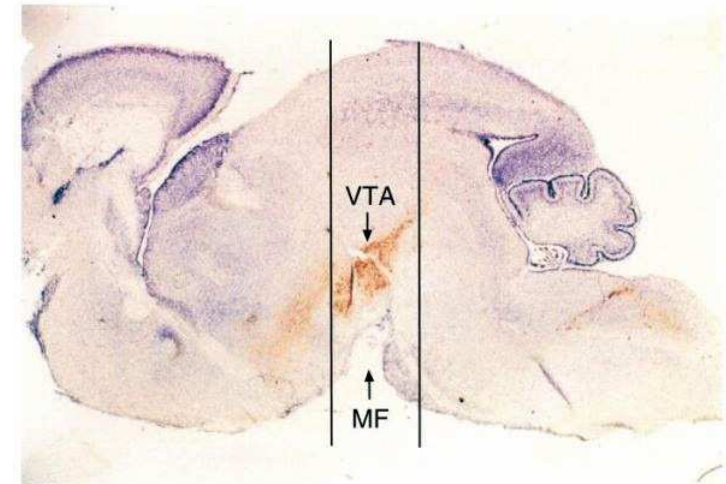
- Red nucleus:
 - ✓ ovoid mass ~ 5 mm in diameter
 - ✓ pinkish-yellow in color – iron-containing pigment
- Rubral inputs:
 - ✓ contralateral cerebellum – cerebellorubral tract
 - ✓ ipsilateral motor cortex – corticorubral tract
- Rubral outputs – rubrospinal projections (tract of *Monakow*) to:
 - ✓ contralateral side (crossed in ventral tegmental decussation of *Forel*) of:
 - rhombencephalic reticular formation
 - spinal cord
- Functions – extrapyramidal system:
 - ✓ controls the muscles of the shoulder&upper arm
 - ✓ in humans – vestigial (dominated by corticospinal tract):
 - large muscle movement such as that for arms and legs
 - arm-swinging in normal walking
 - crawling of babies





Ventral tegmental area

- a group of neurons located close to the midline on the floor of the midbrain
 - ✓ dorsomedial to the substantia nigra
 - ✓ ventral to the red nucleus
- rich in dopaminergic (50-60% of all neurons) and serotonergic neurons
- comprises the mesocorticolimbic dopamine system (A10)
- important projection to nucleus accumbens
- Functions:
 - ✓ implicated in the reward system, motivation, cognition, drug addiction
 - ✓ process various types of emotion output from the amygdala
 - ✓ role in avoidance and fear-conditioning

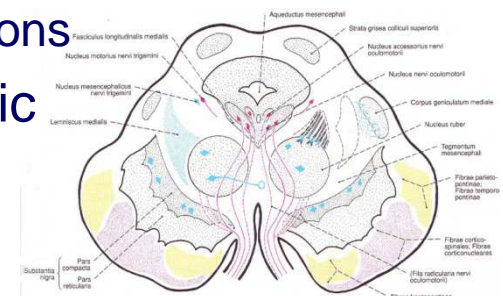
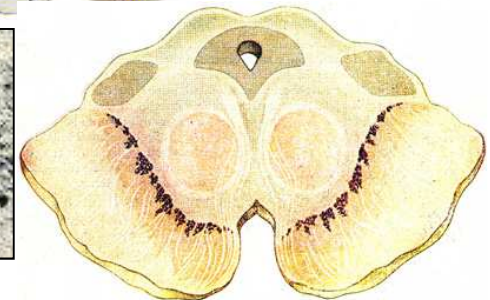
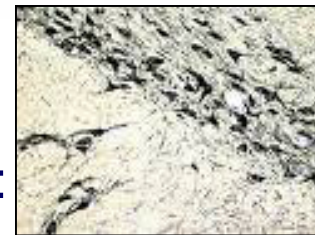
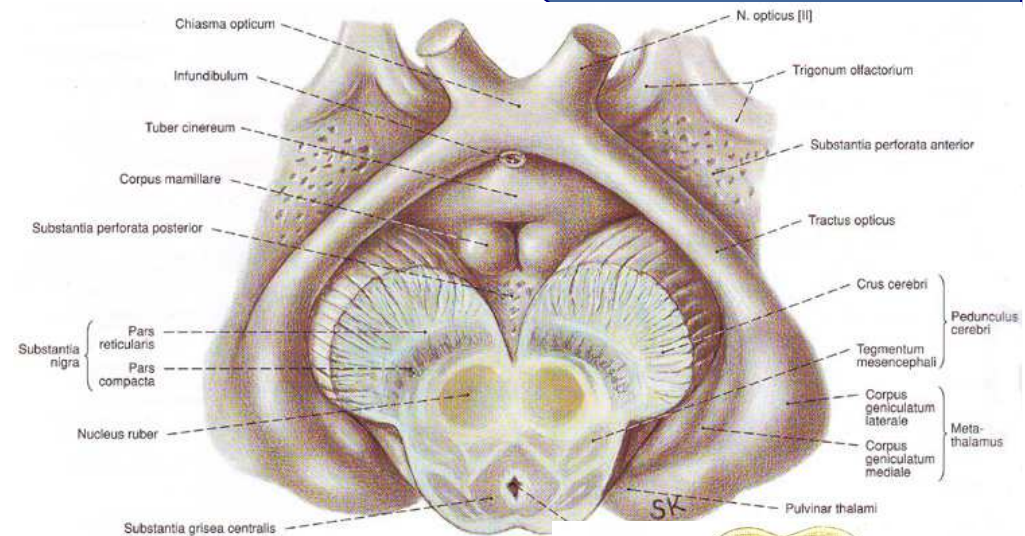




Substantia nigra

- ✓ *crus cerebri*
- ✓ *tegmentum mesencephali*
- ✓ *substantia nigra*

- pigmented grey matter (also called “**Black Matter**” though it is **not entirely black!**)
⇒ neuromelanin and dopamine: nigrostriatal pathway
- part of the basal ganglia
- subdivisions – two entirely different parts:
 - ✓ *pars compacta*: dorsal cell-rich zone of numerous medium-sized neuromelanin-containing dopaminergic neurons
 - ✓ *pars reticularis*: ventral cell-poor zone of dopaminergic and nonpigmented GABAergic neurons intermingled with nerve fibers





Substantia nigra: efferent connections

- *pars compacta* – input to the basal ganglia:

- ✓ nigrostriatal projection – dopamine

- *pars reticulata* – output conveying signals from the basal ganglia to numerous other brain structures:

- ✓ thalamus – nigrothalamic pathway (GABA)

- ✓ superior colliculus

- ✓ reticular formation

- Functions:

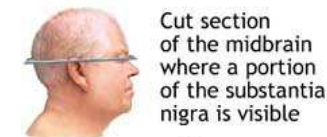
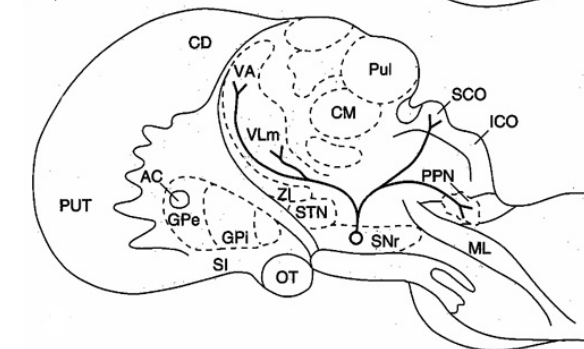
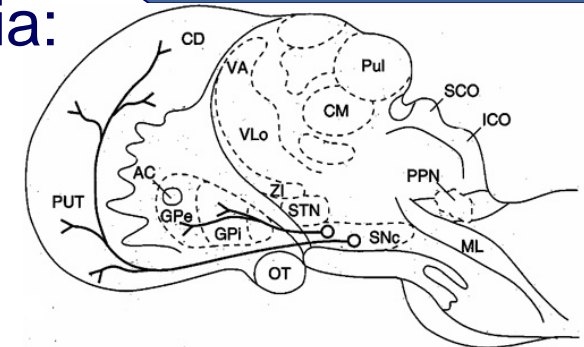
- ✓ *pars compacta*: motor control

- Parkinson's disease

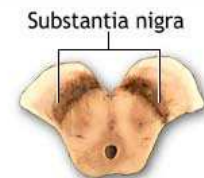
- learned responses to stimuli

- "spatial learning"

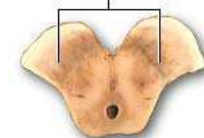
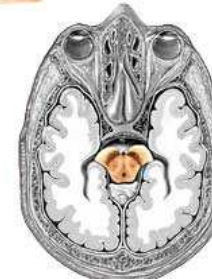
- ✓ *pars reticulata*: important processing center



Cut section of the midbrain where a portion of the substantia nigra is visible



Diminished substantia nigra as seen in Parkinson's disease



ADAM



Tectum, quadrigeminal plate

✓ *superior colliculi* (Latin, higher hills)

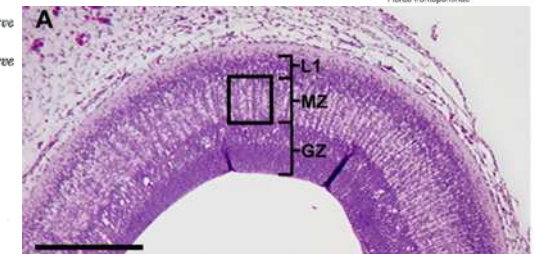
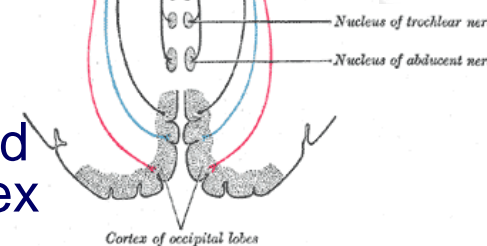
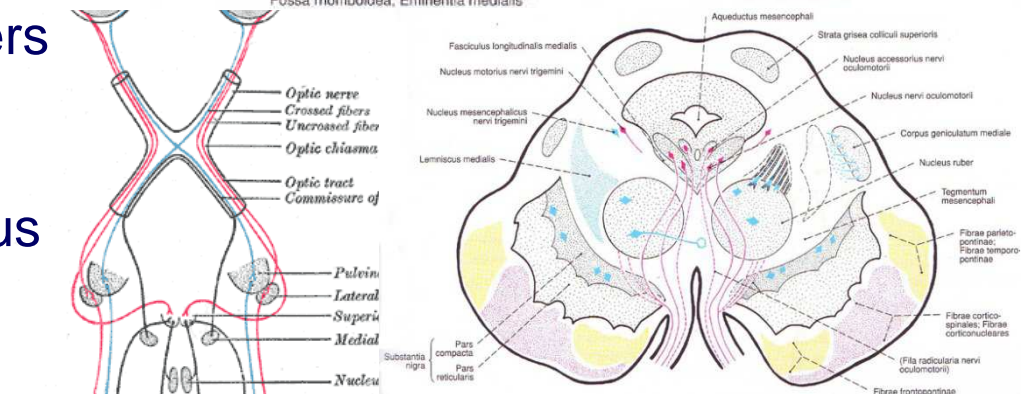
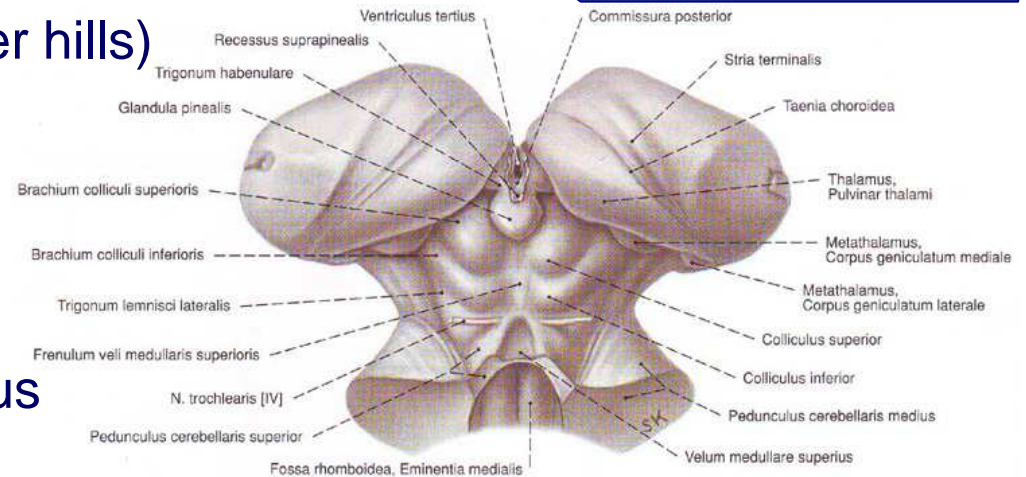
✓ *inferior colliculi* (lower hills)

Location:

- ✓ rostral half of the tectum, beneath the thalamus
- ✓ brachium of superior colliculus ⇒ lateral geniculate body
- ✓ alternate grey and white layers
- ✓ superior colliculus nucleus
- ✓ oculomotor nucleus
- ✓ accessory oculomotor nucleus (of *Edinger-Westphal*)

Functions:

- ✓ primary integrating center for visual responses
- ✓ visual coordination of eye and head movements – start reflex





Tectum, quadrigeminal plate

✓ *superior colliculi*

✓ *inferior colliculi*

■ **Location:**

✓ caudal to the superior colliculus, above the trochlear nerve

✓ inferior brachium ⇒ medial geniculate body

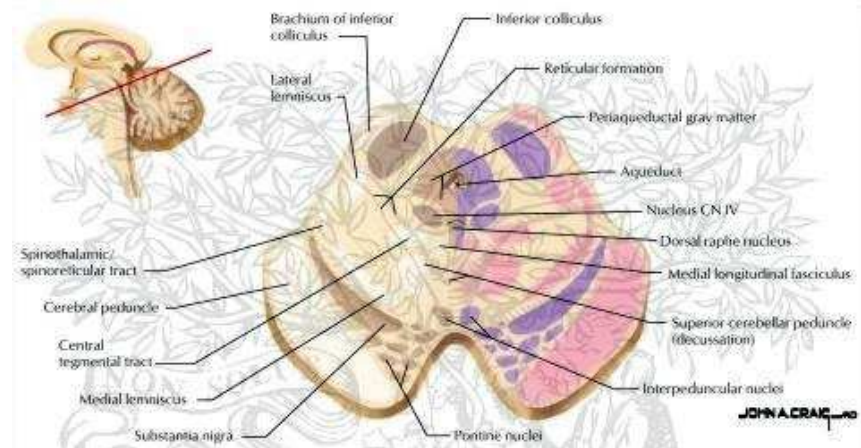
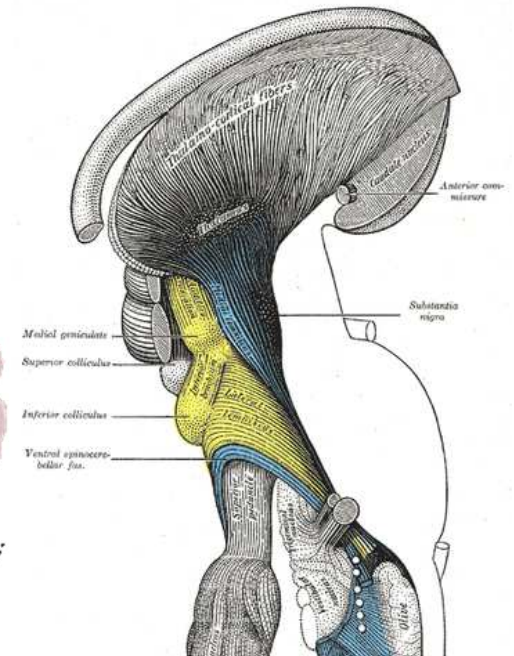
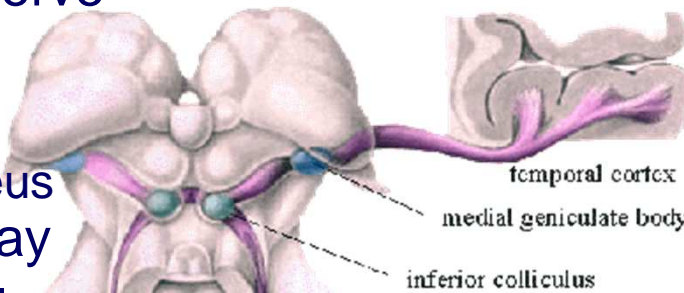
✓ principal midbrain nucleus of the auditory pathway

✓ inferior colliculus nucleus ⇐ lateral lemniscus

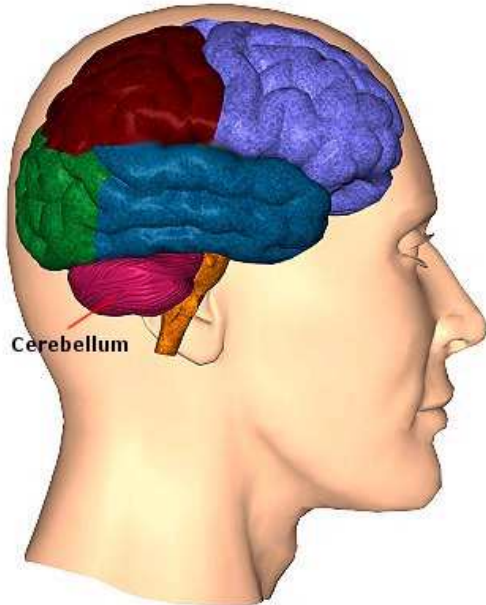
✓ trochlear nucleus – trochlear decussation

■ **Function:**

✓ principal way station for ascending sound information







Cerebellum (“little brain”)

1. General and regional organization
2. Internal structure of the cerebellum:
 - ✓ grey matter – cerebellar cortex & deep cerebellar nuclei
 - ✓ white matter – “*arbor vitae*”
3. Afferent and efferent cerebellar connections
4. Cerebellar functions and dysfunctions



Cerebellum – gross anatomy

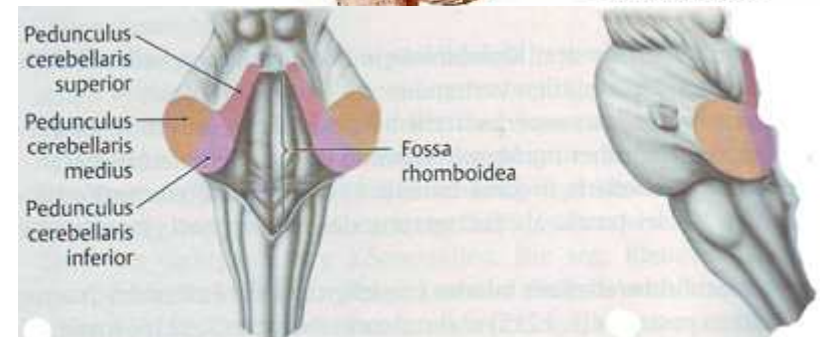
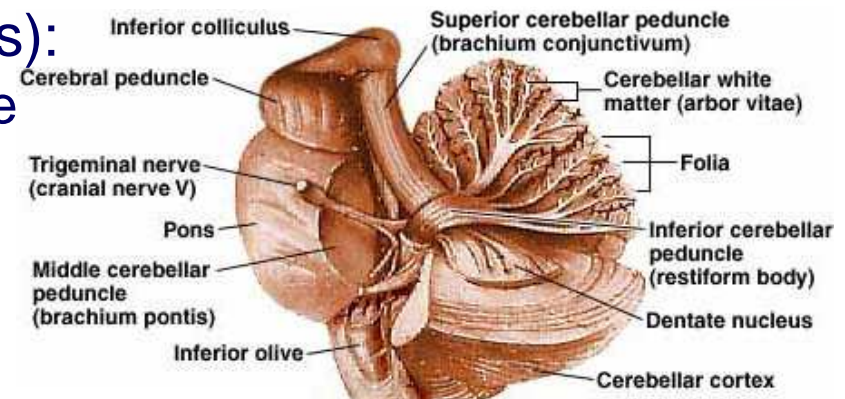
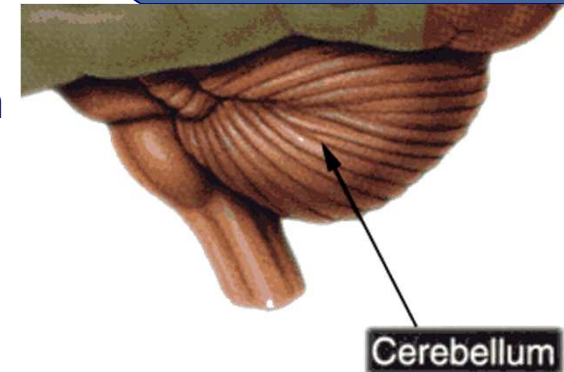
Regional location:

- ✓ posterior cranial fossa, covered by cerebellar tentorium
- ✓ beneath the occipital lobes of cerebral hemispheres
- ✓ behind the pons and medulla oblongata
- ✓ roof of the fourth ventricle

Connections with brainstem structures (three paired fiber bundles – peduncles):

- ✓ midbrain – superior cerebellar peduncle (*brachium conjunctivum*)
- ✓ pons – middle cerebellar peduncle (*brachium pontis*)
- ✓ medulla – inferior cerebellar peduncle (*restiform body*)

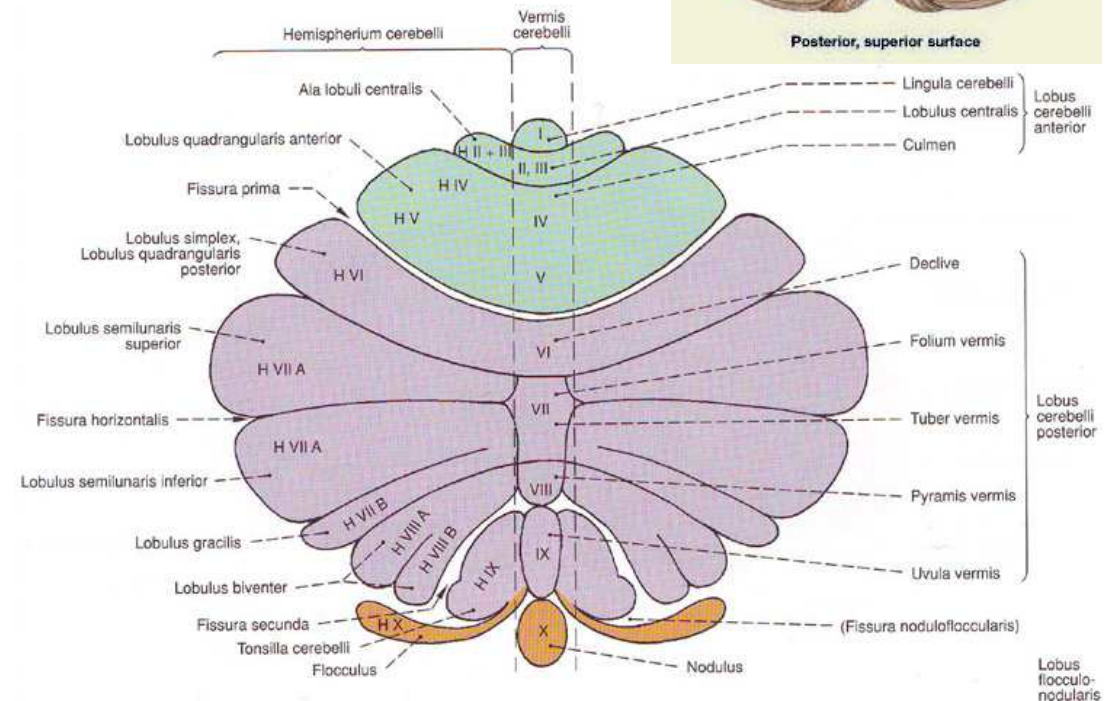
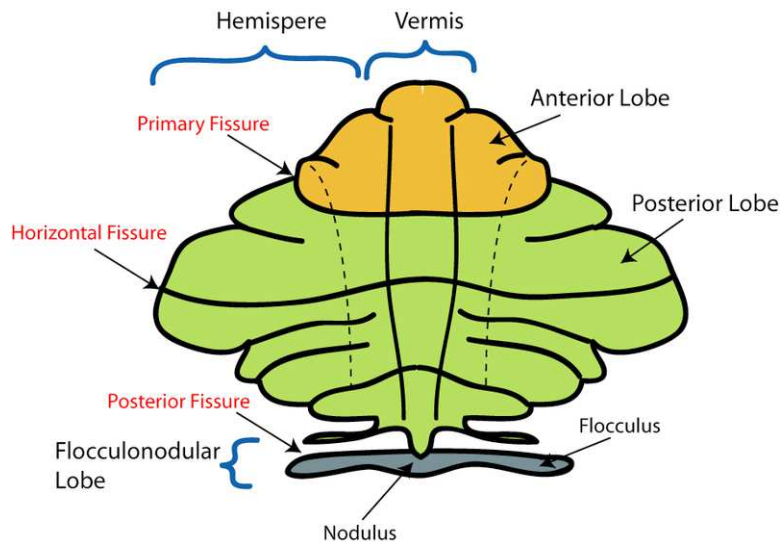
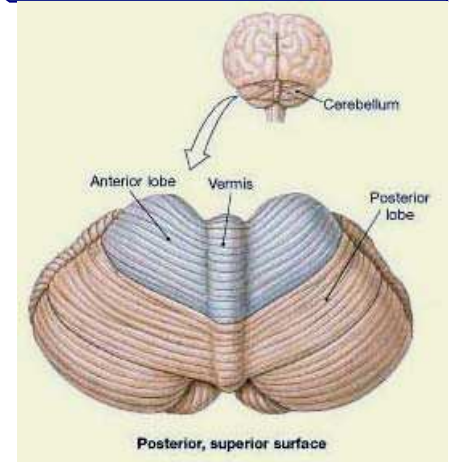
- average weight ~130 g (10% of the total brain volume)
- cerebellum:cerebrum = 1:8 (adult); 1:20 (infant)
- more than 50% of all neurons in the brain
- origin: embryonic hindbrain (rhombencephalon)
- major integrative center for the coordination of muscular activity





Cerebellum – divisions

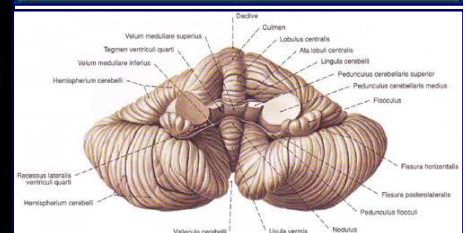
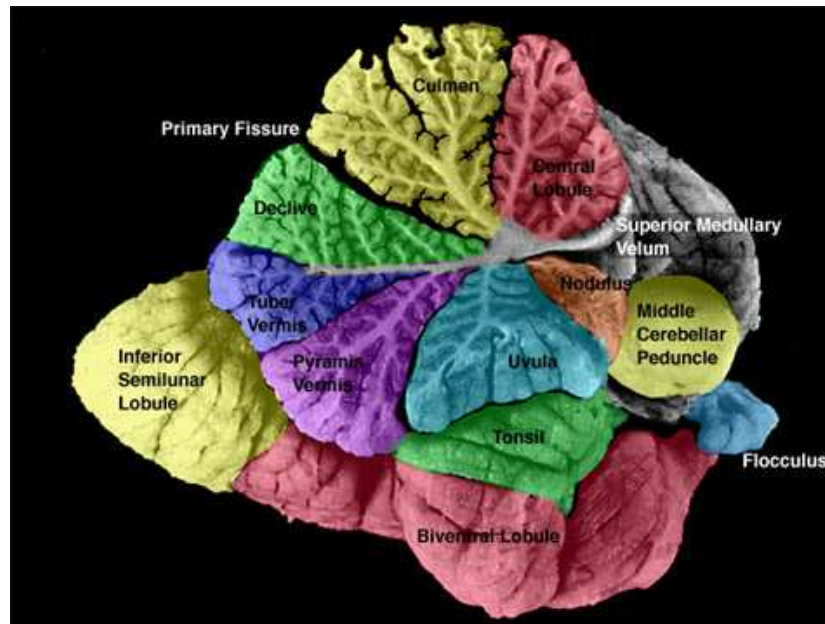
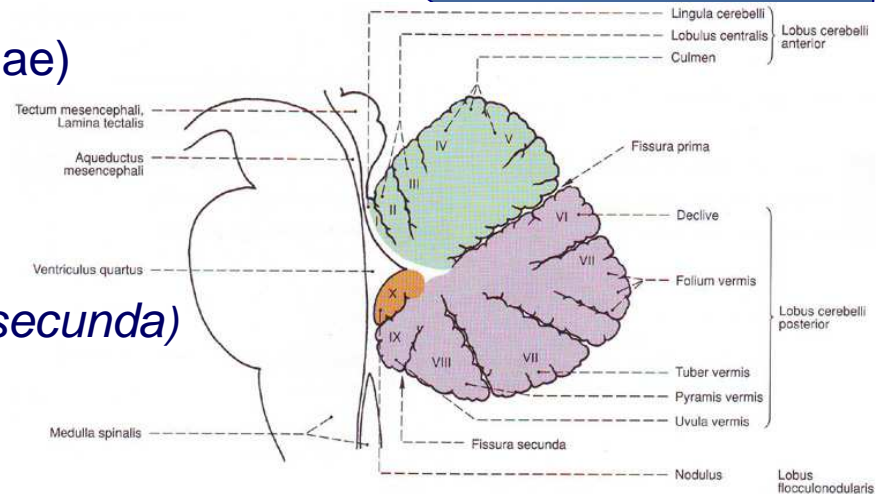
- three sagittal subdivisions:
 - ✓ median portion, cerebellar vermis
 - ✓ two lateral parts, cerebellar hemispheres
- three transverse subdivisions (lobes):
 - ✓ anterior lobe
 - ✓ posterior lobe
 - ✓ flocculonodular lobe





Cerebellum – surface topography

- Foliar pattern:
 - ✓ *folia cerebelli* (transverse leaf-like laminae)
- Cerebellar fissures:
 - ✓ *fissura prima* – V-shaped
 - ✓ horizontal fissure
 - ✓ pre- and postpyramidal fissure (*fissura secunda*)
 - ✓ posterolateral fissure
- Vermis lobules:
 - ✓ superior surface:
 - *lingula*
 - *central lobule*
 - *monticulus*:
 - *culmen*
 - *declive*
 - *folium vermis*
 - ✓ inferior surface:
 - *tuber vermis*
 - *pyramid*
 - *uvula*
 - *nodule*





Cerebellum – surface topography

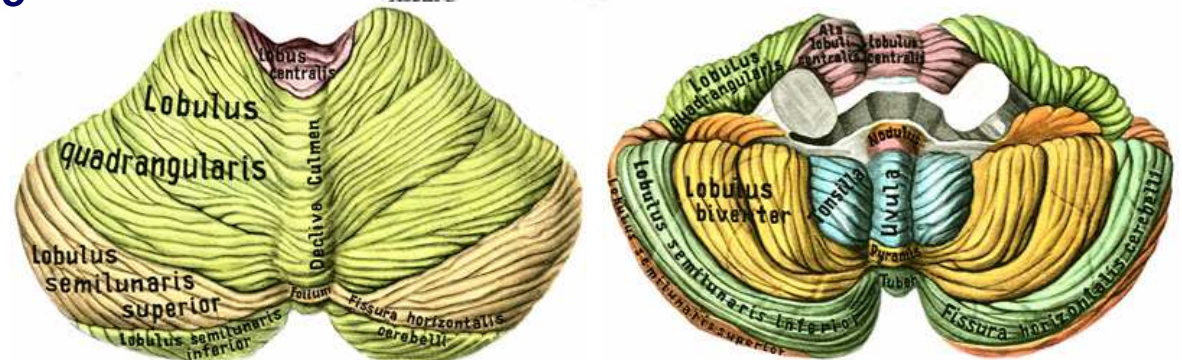
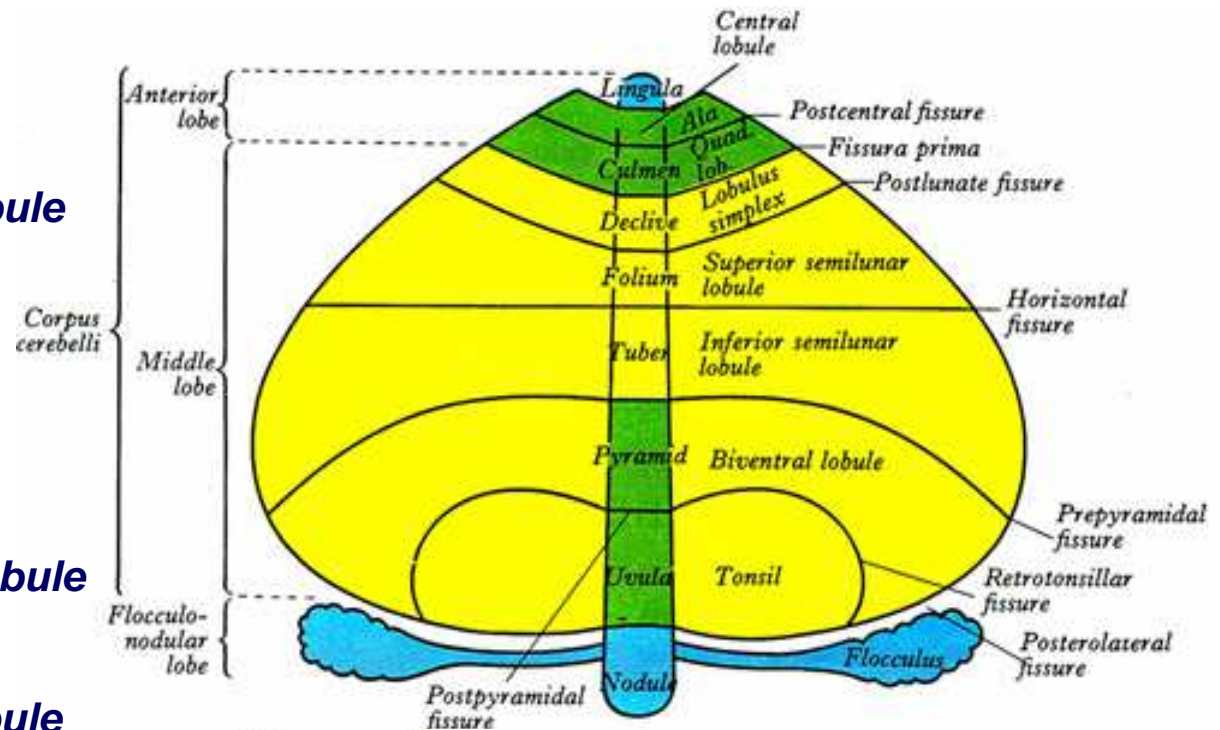
- Hemisphere lobules:

- ✓ superior surface:

- (*vinculum lingulae*)
 - *alae of the central lobule*
 - *anterior quadrangular lobule*
 - *lobulus simplex (posterior quadrangular lobule)*
 - *superior semilunar lobule*

- ✓ inferior surface:

- *inferior semilunar lobule*
 - *gracile lobule (paramedianus)*
 - *biventral lobule*
 - *tonsil*
 - *flocculus*





Phylogenetic and functional divisions

■ Archicerebellum:

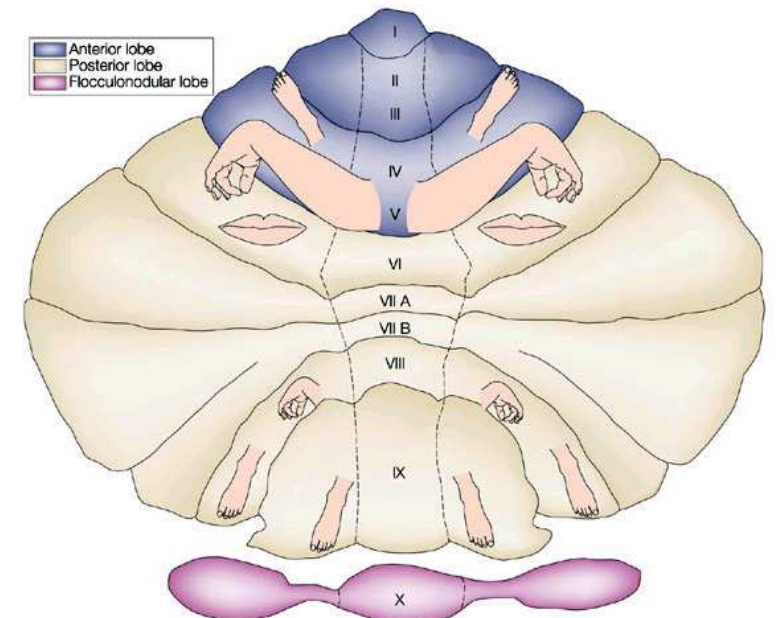
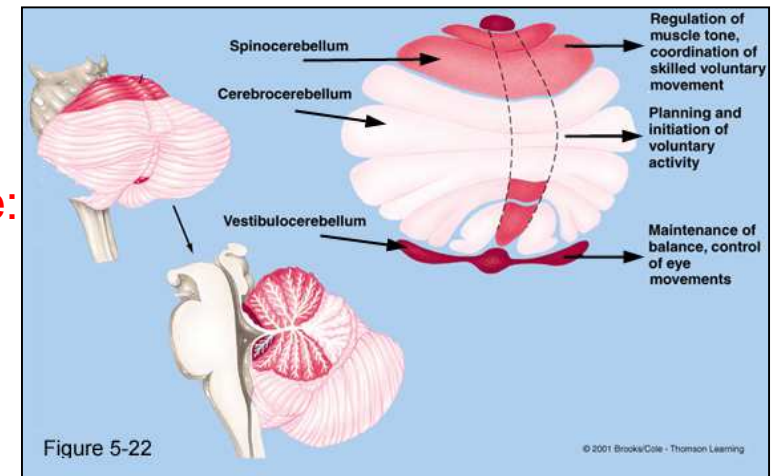
- ✓ flocculonodular lobe = *flocculus* + *nodulus* (+ part of *uvula*)
- ✓ functionally related to maintenance of balance: *vestibulocerebellum*

■ Paleocerebellum:

- ✓ anterior lobe = *lingula*, *central lobule*, *culmen*, *pyramid*, *uvula* (of vermis) + *quadrangular lobules* (of cerebellar hemispheres)
- ✓ regulates body and limb movements, involved in control of muscle tone via the spinal cord: *spinocerebellum*

■ Neocerebellum:

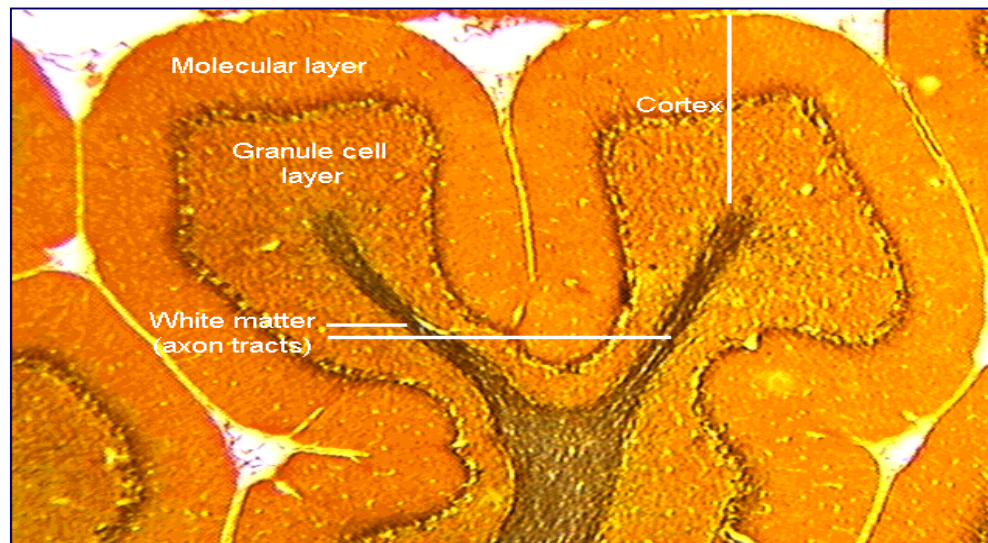
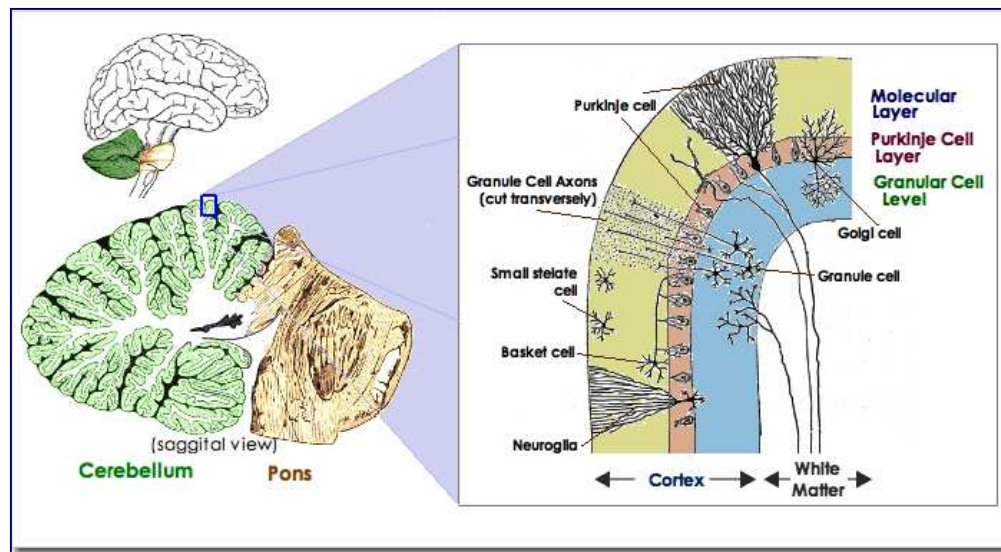
- ✓ posterior lobe = the rest of cerebellum
- ✓ most concerned with planning movement and coordination of somatic motor function: *cerebrocerebellum* (*pontocerebellum*)





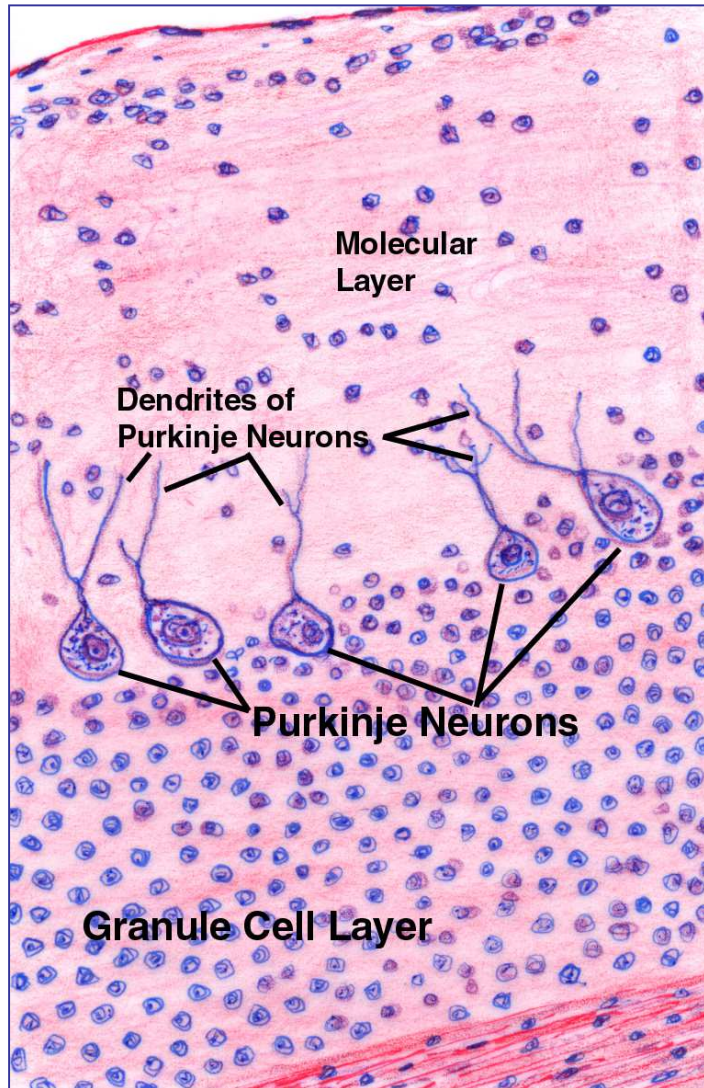
Cerebellum – internal structure

- grey matter:
 - ✓ cerebellar cortex, *cortex cerebelli*
 - ✓ intracerebellar (deep) nuclei, *nuclei cerebelli*
- white matter, medullary substance (*corpus medullare*):
 - ✓ primary laminae – “*arbor vitae*” (tree of life)
 - ✓ intrinsic fibers, *fibrae propriae*
 - ✓ projection fibers
 - ✓ myelinated axons of the Purkinje cells
 - ✓ afferent fibers – ‘climbing’ and ‘mossy’

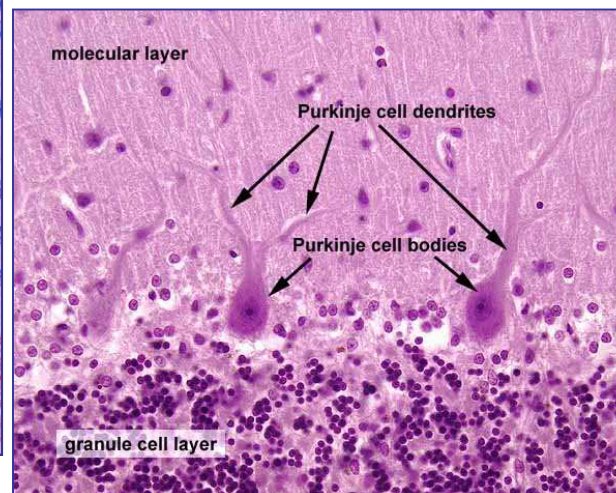
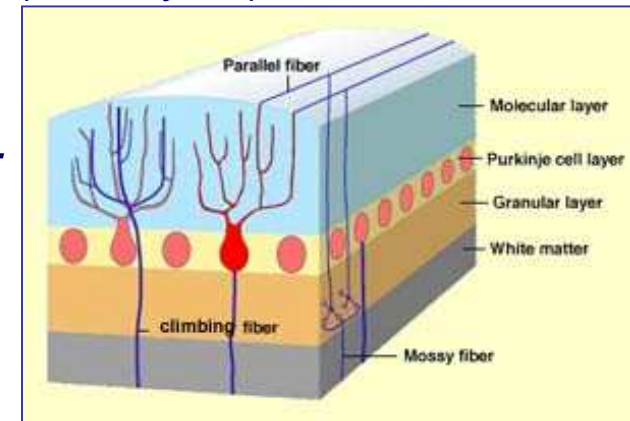




Cerebellar cortex



- Molecular layer, *stratum moleculare* – 300-400 μm :
 - ✓ outer stellate neurons and basket cells (GABA)
 - ✓ *Fañanás* glial cells (astrocytes) – feather-like
- Purkinje cell layer, *stratum purkinjense*:
 - ✓ *Purkinje* cells
 - ✓ *Bergmann* glial cells



- Granular layer, *stratum granulosum* – 100 μm :
 - ✓ granule cells – 10^{11} (Glu)
 - ✓ *Golgi* type II cells (GABA)

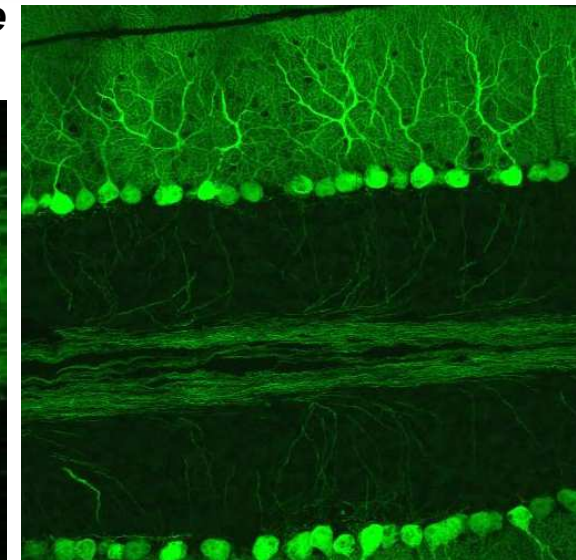
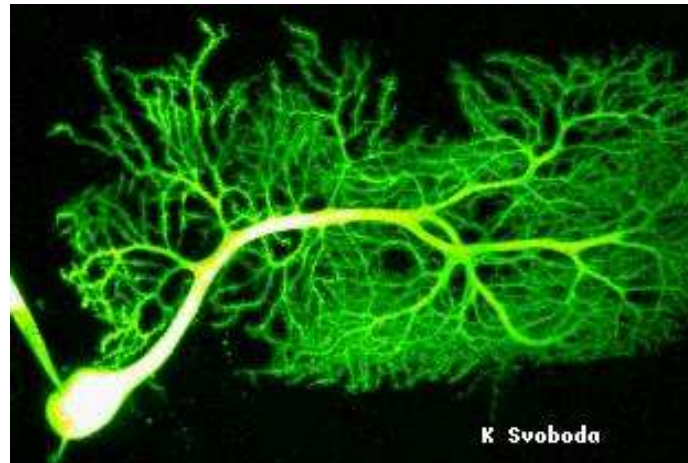
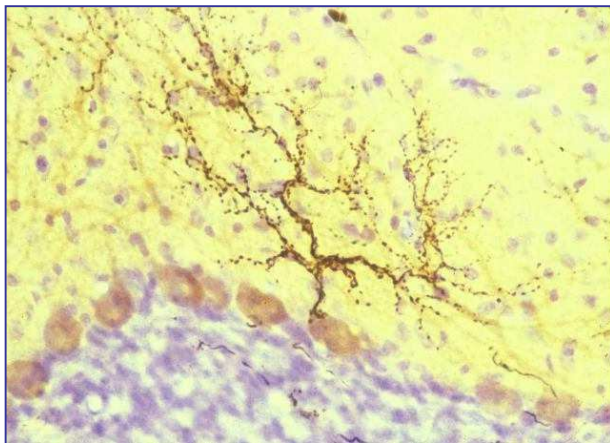
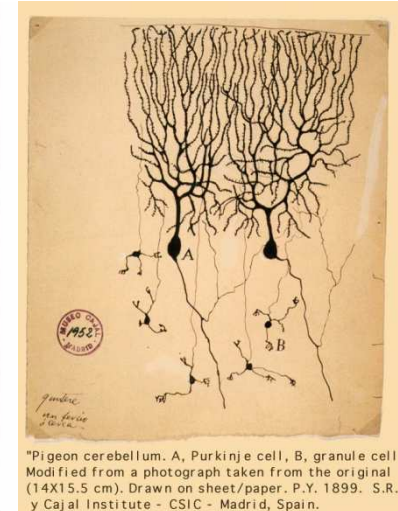


Purkinje cells

- ✓ large flask-shaped – 50-80 μm in diameter
- ✓ most numerous (15×10^6) neurons in CNS
- ✓ large number of dendritic spines (170000/cell)
- ✓ dendritic tree arborizations in the transverse plan to the long axis of the folium
- ✓ Purkinje cell axons – inhibitory synaptic contacts with deep cerebellar nuclei
- ✓ GABAergic inhibitory neurons



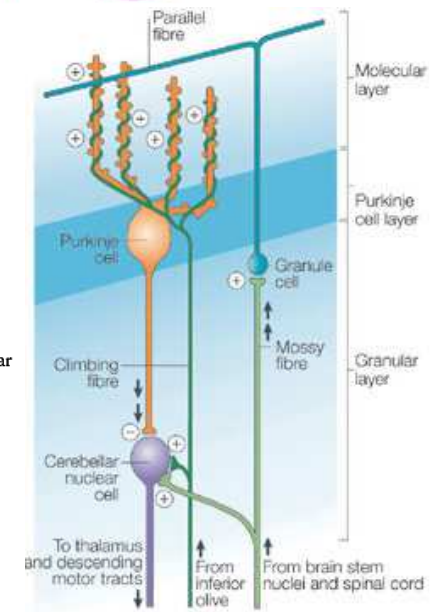
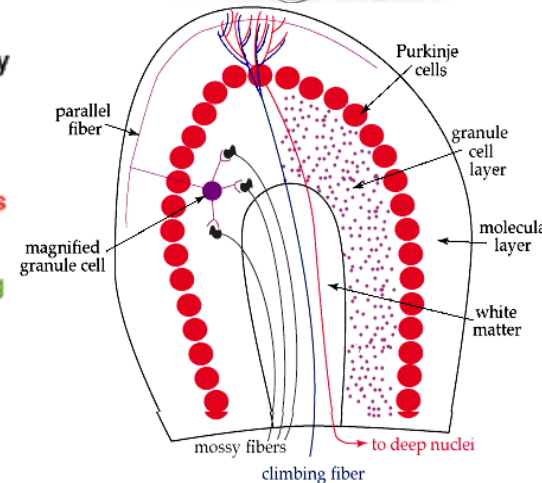
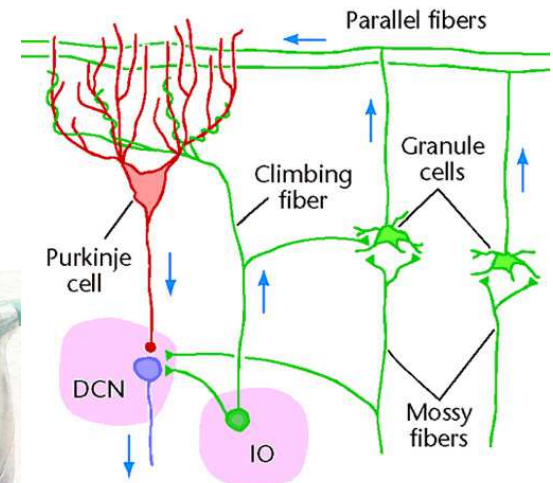
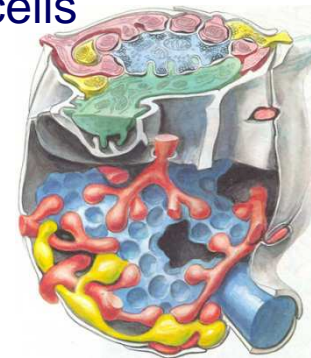
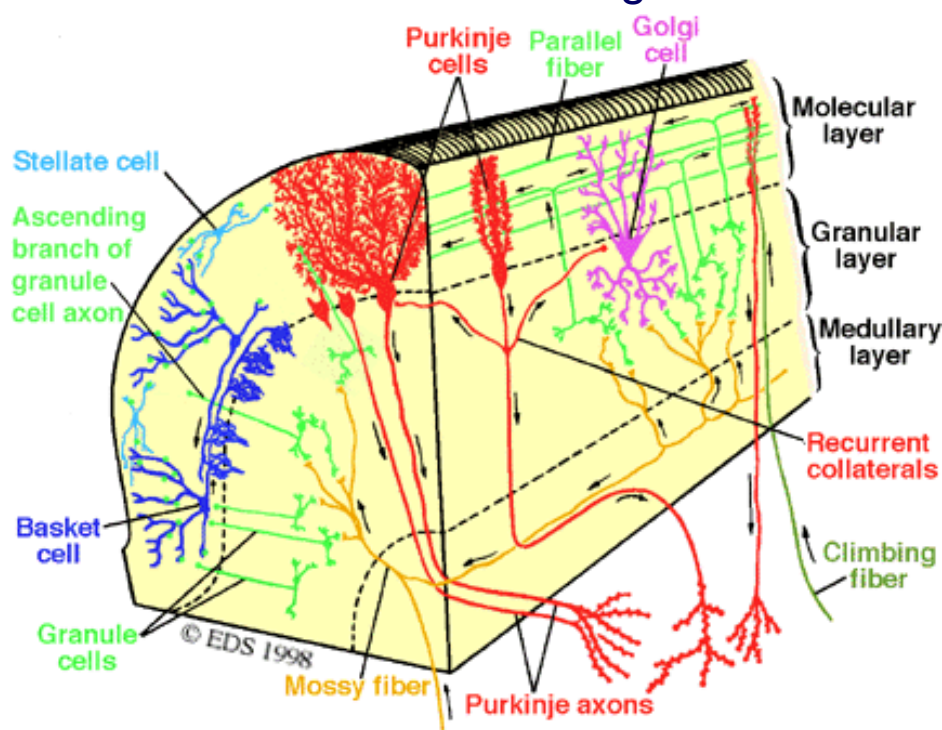
J.E. Purkinje
(1787-1869)





Cortical inputs – afferent fibers

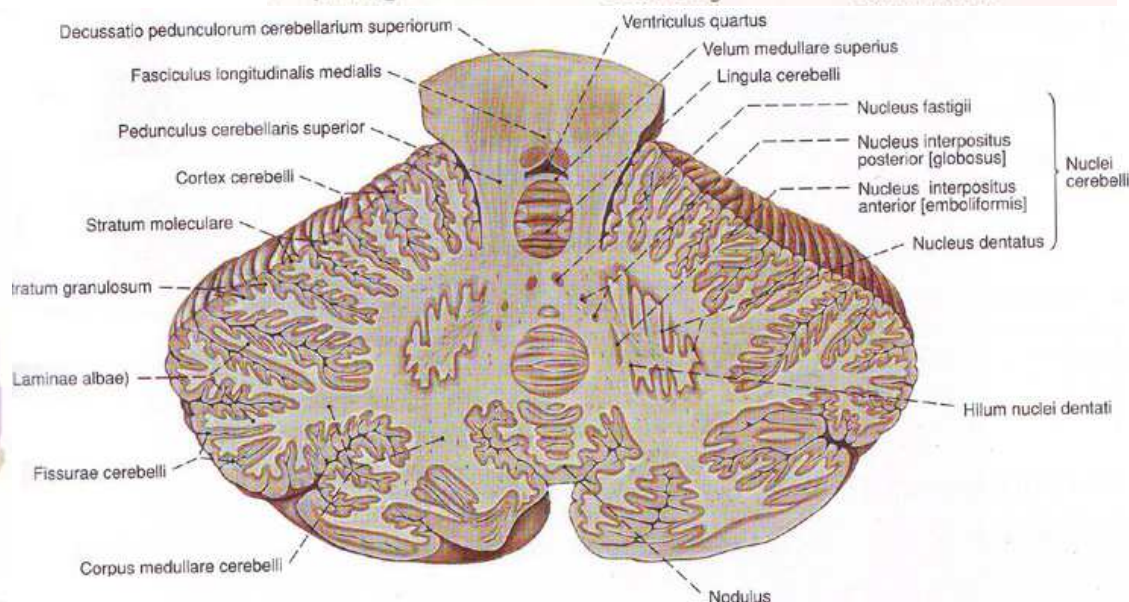
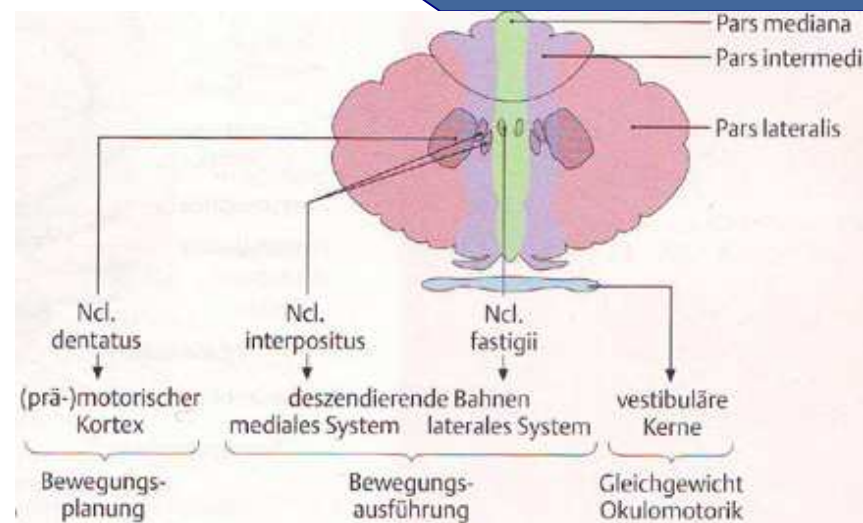
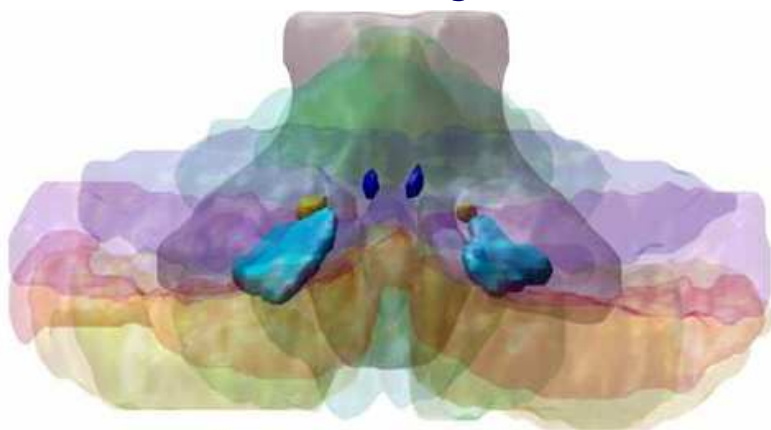
- ✓ climbing fibers:
 - originate from the inferior olivary nucleus
 - direct excitatory contacts with Purkinje cells
- ✓ mossy fibers:
 - excitatory synaptic contacts with granule cells
 - rosettes ⇒ cerebellar glomerulus





Deep cerebellar nuclei

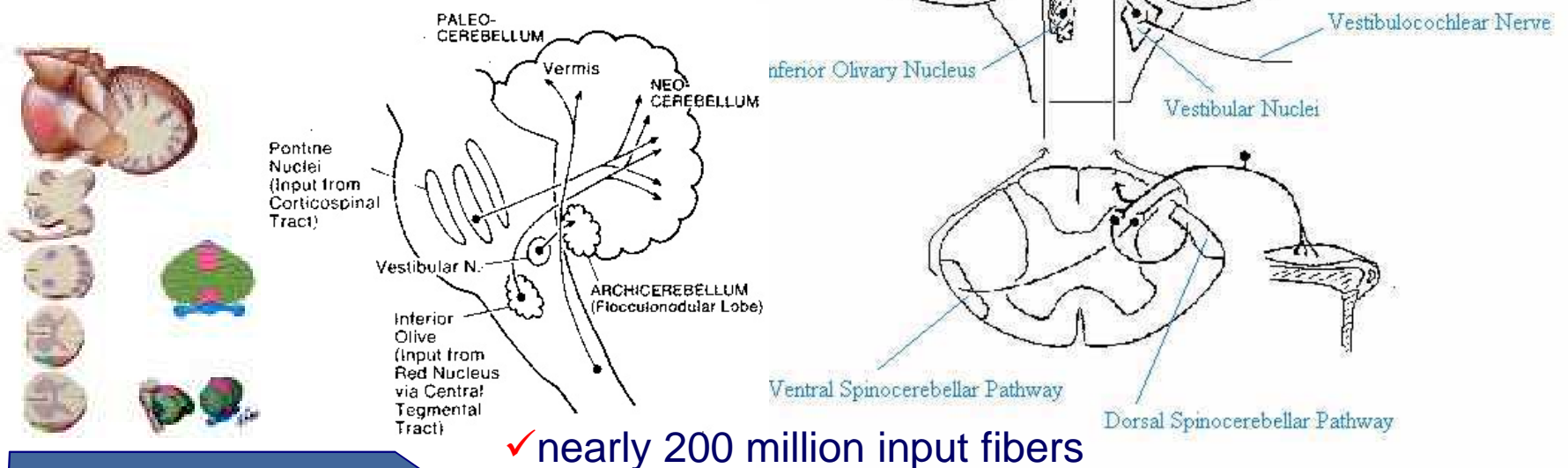
- Dentate nucleus, *nucleus dentatus*
- Interpositus nucleus:
 - ✓ emboliform nucleus, *nucleus emboliformis*
 - ✓ globose nucleus, *nucleus globosus*
- Fastigial nucleus, *nucleus fastigii*





Cerebellar input: afferent pathways

- *pedunculus cerebellaris inferior:* → *archicerebellum, paleocerebellum*
 - ✓ *tractus spinocerebellaris posterior*
 - ✓ *tractus bulbocerebellaris*
 - ✓ *tractus vestibulocerebellaris*
 - ✓ *tractus olivocerebellaris*
- *pedunculus cerebellaris medius:* → *neocerebellum*
- *pedunculus cerebellaris superior:* → *paleocerebellum*
 - ✓ *tractus pontocerebellaris*
 - ✓ *tractus spinocerebellaris anterior*
 - ✓ *tractus reticulocerebellaris*



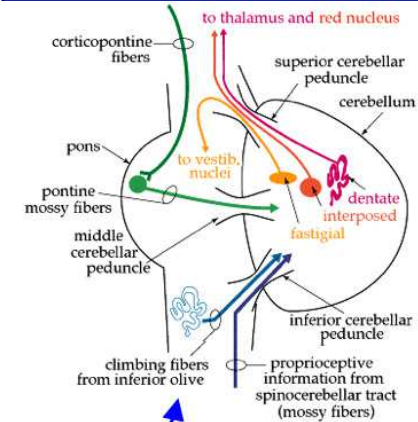
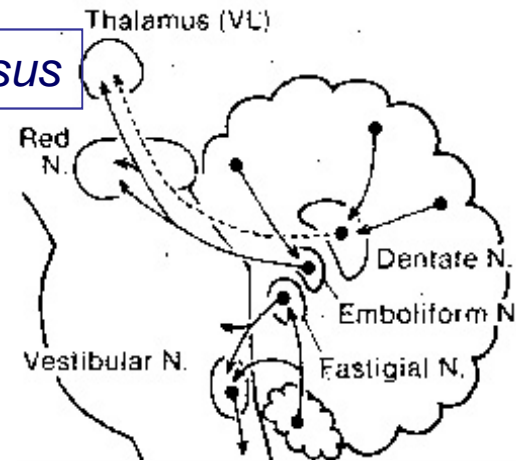


Cerebellar output: efferent pathways

nucleus dentatus, emboliformis et globosus



- *pedunculus cerebellaris superior:*
 - ✓ *tractus cerebellorubralis*
 - ✓ *tractus cerebellothalamicus*
 - ✓ *tractus cerebelloreticularis*

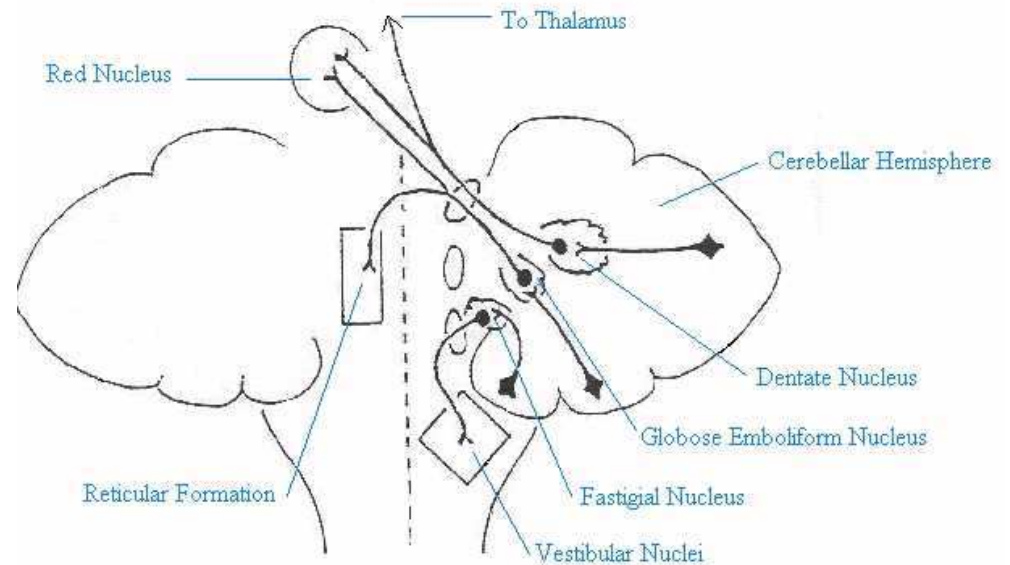


information

nucleus fastigii



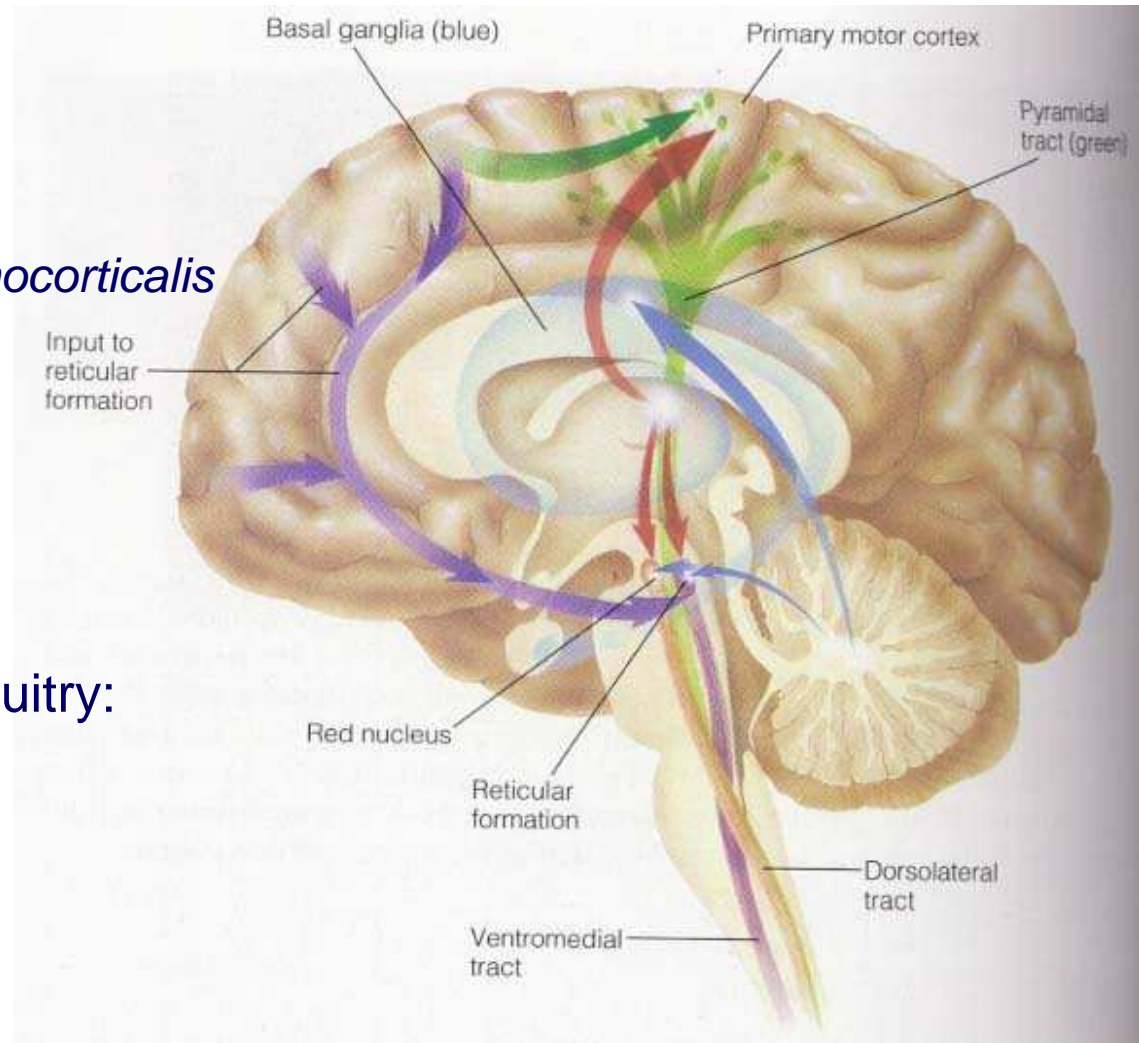
- *pedunculus cerebellaris inferior:*
 - ✓ *tractus cerebelloolivaris*
 - ✓ *tractus cerebellovestibularis*





Cerebellar circuits

- Cortico-cerebellar circuitry:
 - ✓ *tractus corticopontini*
 - ✓ *tractus pontocerebellaris*
 - ✓ *tractus dentato-rubro-thalamocorticalis*
- Trunco-cerebellar circuitry:
 - ✓ *tractus rubroolivaris*
 - ✓ *tractus olivocerebellaris*
 - ✓ *tractus cerebellorubralis*
- Vestibulo-archicerebellar circuitry:
 - ✓ *tractus vestibulocerebellaris*
 - ✓ *tractus cerebellovestibularis*





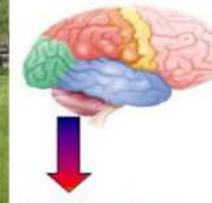
Cerebellar dysfunctions

Neocerebellar disturbances:

- ✓ hypotonia (decreased muscle tone)
- ✓ asynergia (diminished capacity for smooth, cooperative, sequential action between a series of muscle groups)
- ✓ cerebellar ataxia (disequilibrium & incoordination of willed movements)
- ✓ intention tremor (wide tremor during voluntary movements)
- ✓ nystagmus (inability to fixate an object with the eyes)



The Cerebellum and Exercise



Functions:

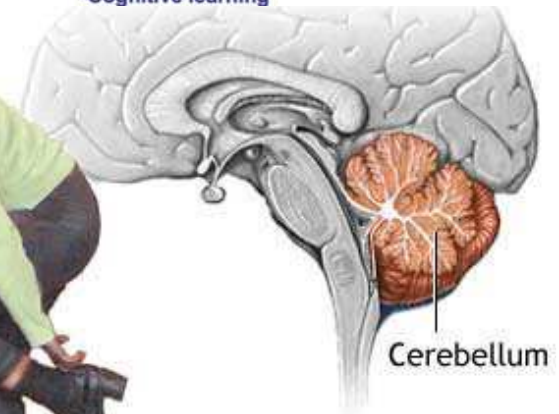
- Coordinated movement
- Balance
- Muscle timing
- Proper postural alignment
- Cognitive learning

Archicerebellar disturbances:

- ✓ trunk (truncal) ataxia
- ✓ vertigo
(dizziness: a whirling or spinning movement)

Paleocerebellar disturbances:

- ✓ hypotonia
- ✓ dyskinesia (presence of involuntary movements)

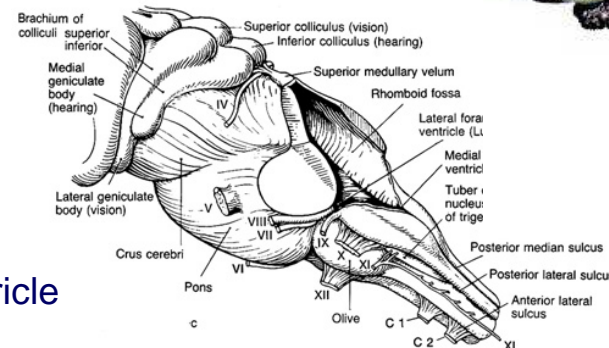
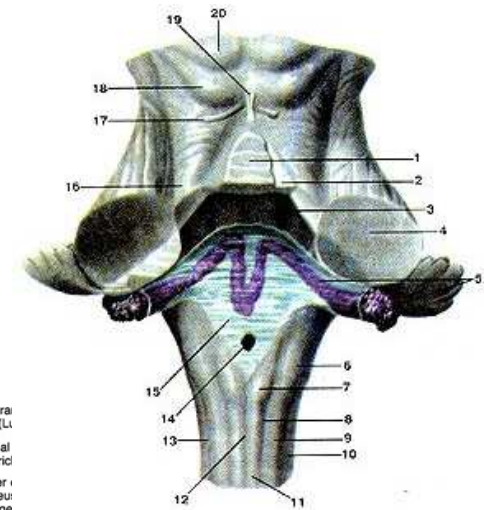
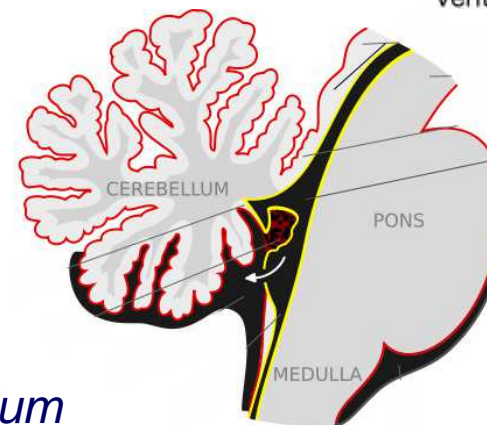
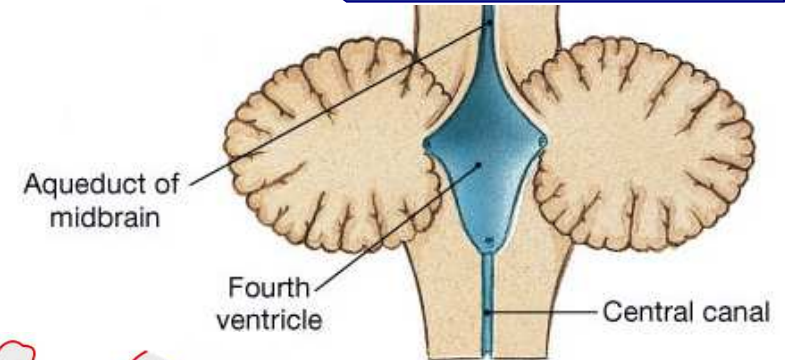


Cerebellum helps provide smooth, coordinated body movement



Fourth ventricle

- embryonic origin – *rhombencephalon*
- formation – tentorial space between:
 - ✓ dorsal pons & upper medulla oblongata
 - ✓ cerebellum
- lateral boundaries:
 - ✓ caudal part:
 - gracile & cuneate tubercles
 - fasciculus cuneatus
 - inferior cerebellar peduncle
 - ✓ cranial part:
 - superior cerebellar peduncle
- roof (dorsal wall):
 - ✓ cranial portion:
 - superior cerebellar peduncle
 - superior medullary velum
 - ✓ caudal portion:
 - inferior medullary velum
 - tela choroidea ⇒ choroid plexuses
- ventral floor – rhomboid fossa
- communication openings:
 - ✓ median aperture (of Magendie) ⇒ central canal
 - ✓ lateral apertures (of Luschka)
 - ✓ cerebral aqueduct (of Sylvius) ⇒ IIIrd ventricle





Thank you...

