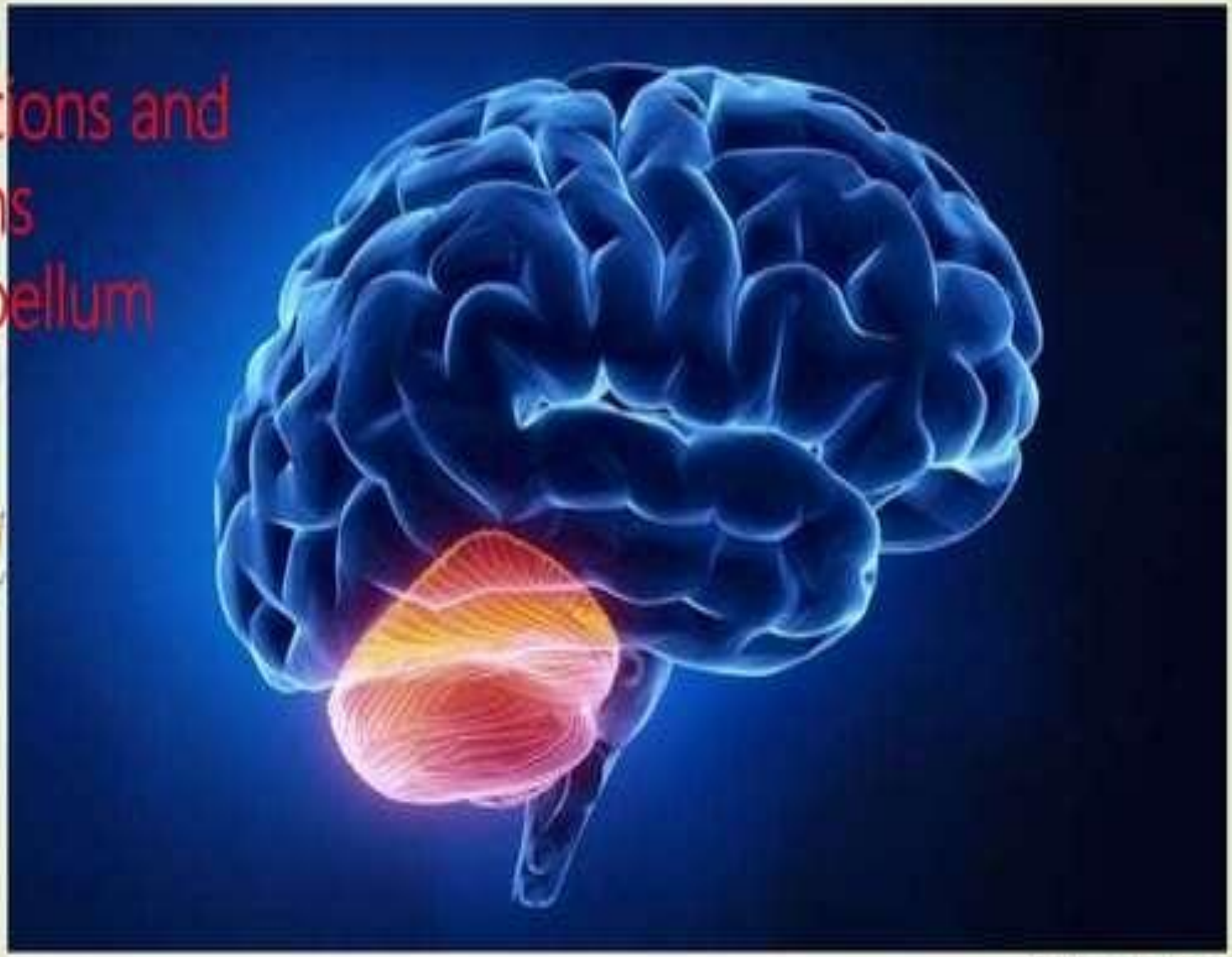
Connections and Functions of Cerebellum



Dr. Ranadhi Das

Cerebellum

- Introduction
- Division of Cerebellum
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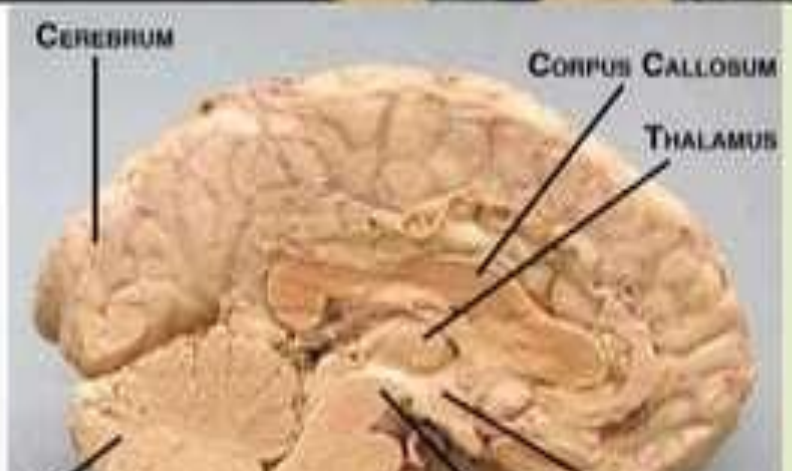
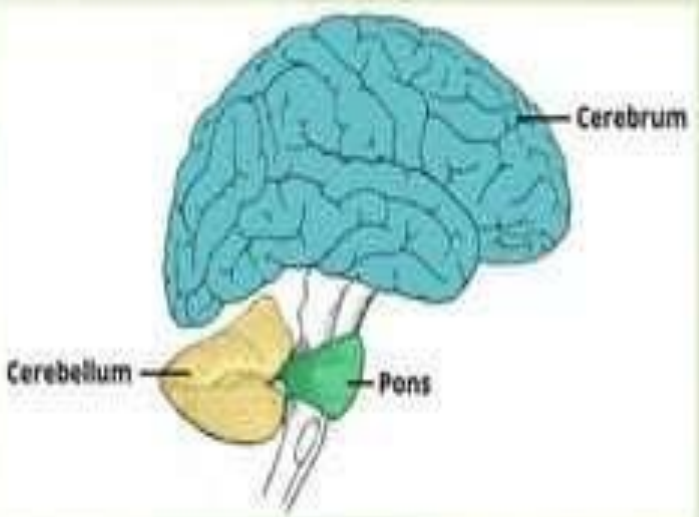
  - Phylogenetic
  - Functional
- Histology Of Cerebellum
- Cerebellar Nuclei
- Intrinsic Cerebellar Circuit
- Afferent pathway to the cerebellum
- Efferent output from cerebellum
- Functions of cerebellum

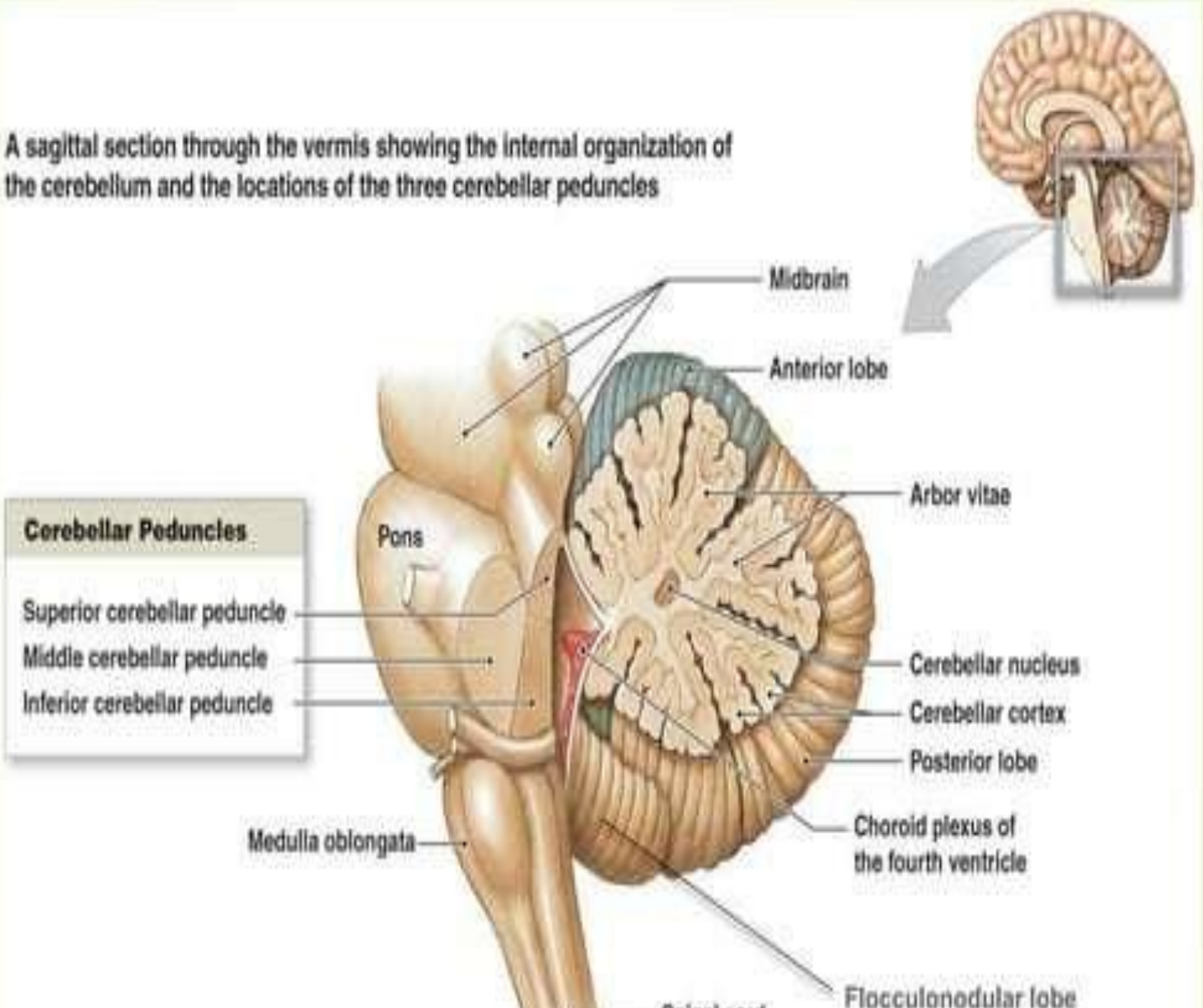


Introduction



- Largest part of hind brain.
- Called " silent area/Little Brain "
- Weight- 150 gms.
- Cerebellar cortex is a large folded sheet, each fold is called Folium.
- Connected to brain stem by 3 pairs of peduncles- Superior (Brachium conjunctiva), Middle (Brachium Pontis) & Inferior (Restiform body) peduncle.
- David Marr (in 1969) proposed that the cerebellum is a device for learning to associate elemental movements encoded by climbing fibers with mossy fiber inputs that encode the sensory context.
- James Albus (in 1971) proposed that a cerebellar Purkinje cell functions as a abstract learning device.

A sagittal section through the vermis showing the internal organization of the cerebellum and the locations of the three cerebellar peduncles



Anatomical Divisions

1.Anterior lobe

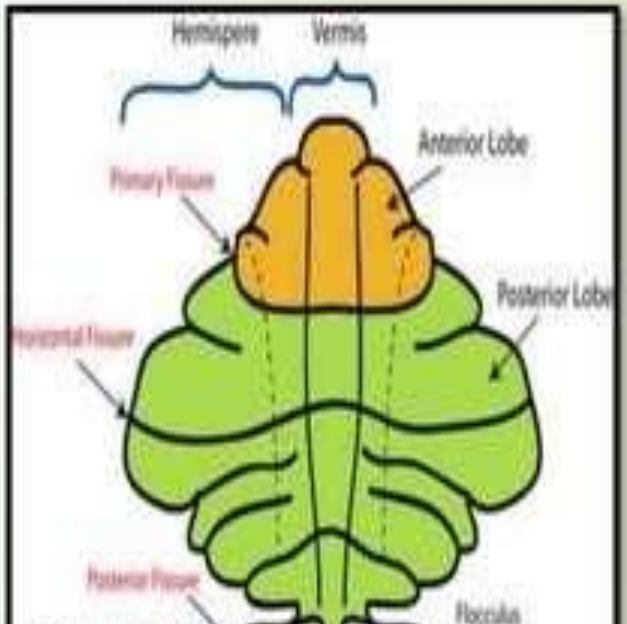
- Lingula
- Centralis
- Culmen

2.Posterior lobe

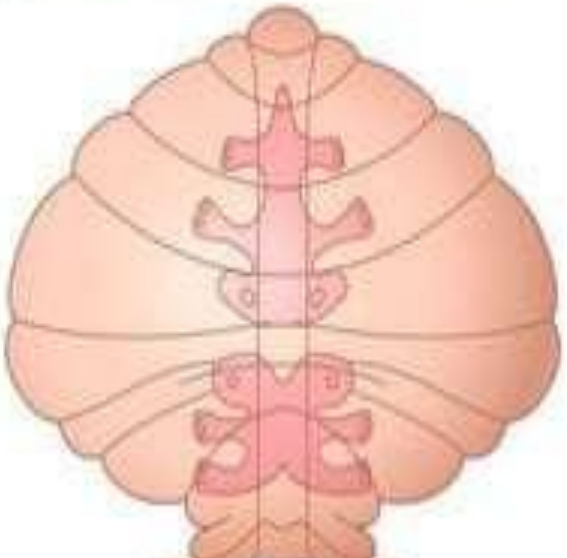
- Simplex
- Declive
- Folium
- Tuber
- Ansiform lobe

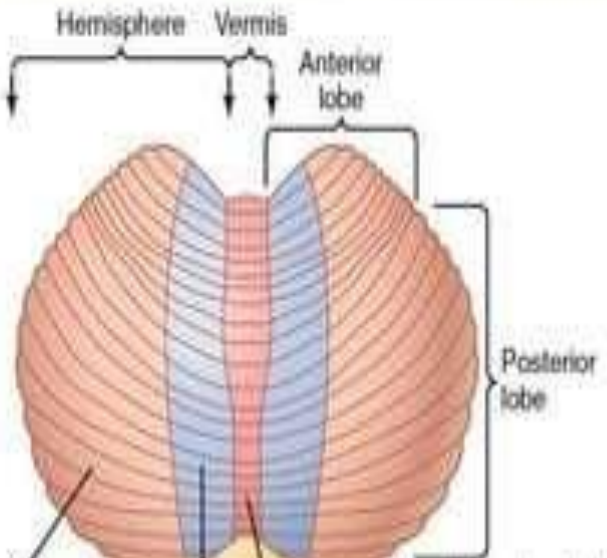
3.Flocculonodular lobe-

- Pyramis
- Uvula
- Nodule
- Flocullus.



- A narrow band down the center of the cerebellum called Vermis.
- It controls most of the cerebellar functions.
- The axial portion of the body is topographically represented in the vermis.



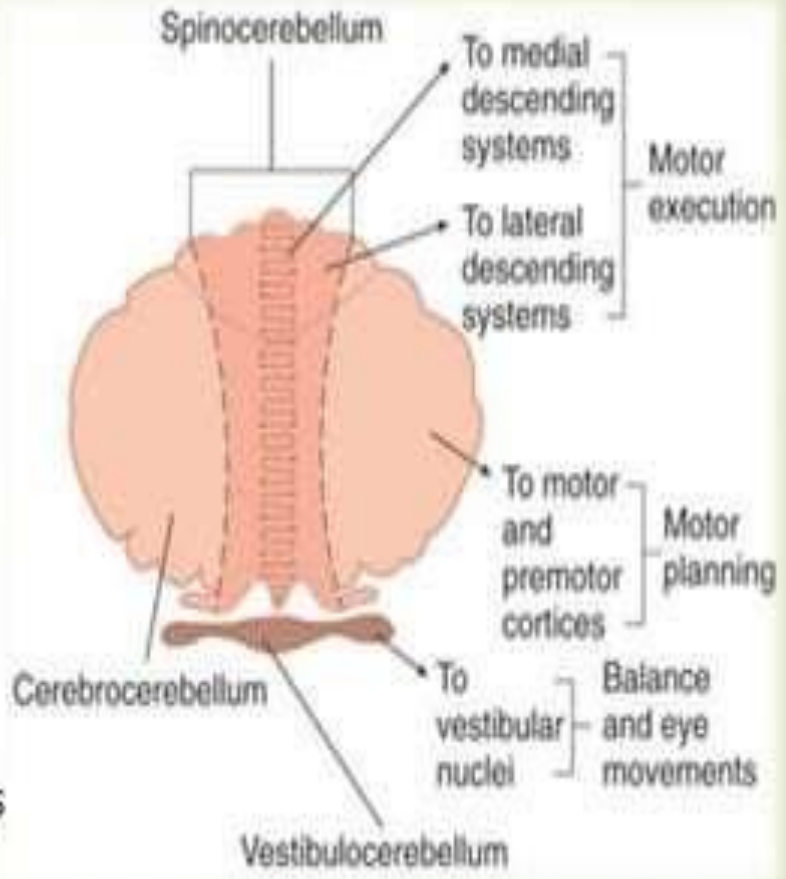


Phylogenetic Divisions

- Archicerebellum
  - Flocculonodular lobe
- Palaeocerebellum
  - Anterior lobe- Lingula, Centralis, Culmen, Simplex
  - Posterior lobe – pyramis, uvula & paraflocculus.
- Neocerebellum
  - Whole posterior lobe- Declive, Folium, Tuber, Ansiform lobe, Paramedian lobe.

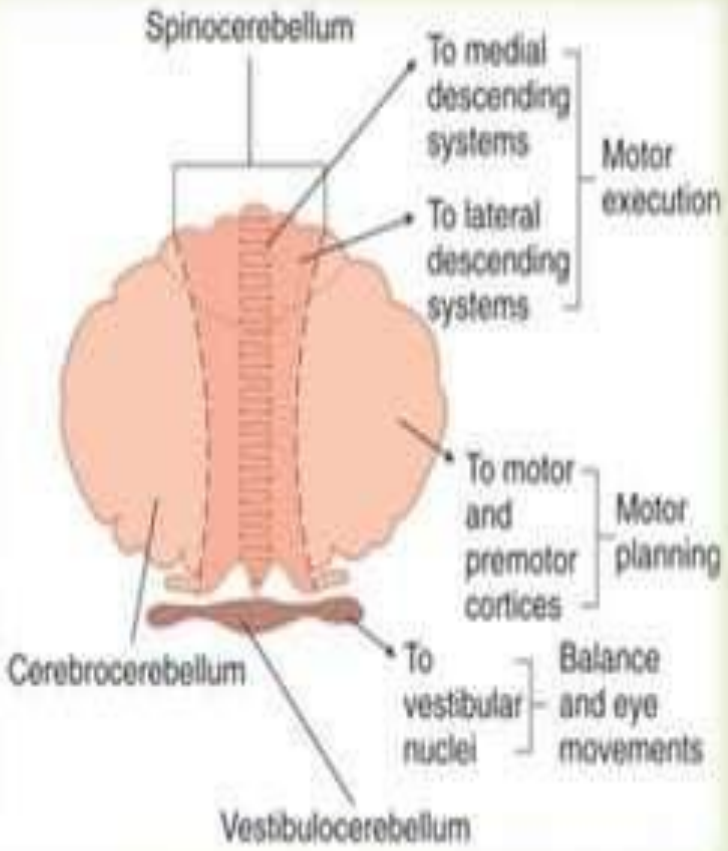
Functional Divisions

- Vestibulo-cerebellum.
  - Consists of Flocculonodular lobe, adjacent part of vermis, Lingula
  - Oldest part
  - Has Vestibular connections
  - N. fastigial – effector N.
  - Control body **posture, equilibrium & eye movements**
  - Control **axial and proximal limbs.**



- Spino-cerebellum.
  - Consists of most of the vermis and adjacent intermediate zone on both side of vermis.
  - N. Interpositus (N.Globose & N. Emboliformis) – effector N.

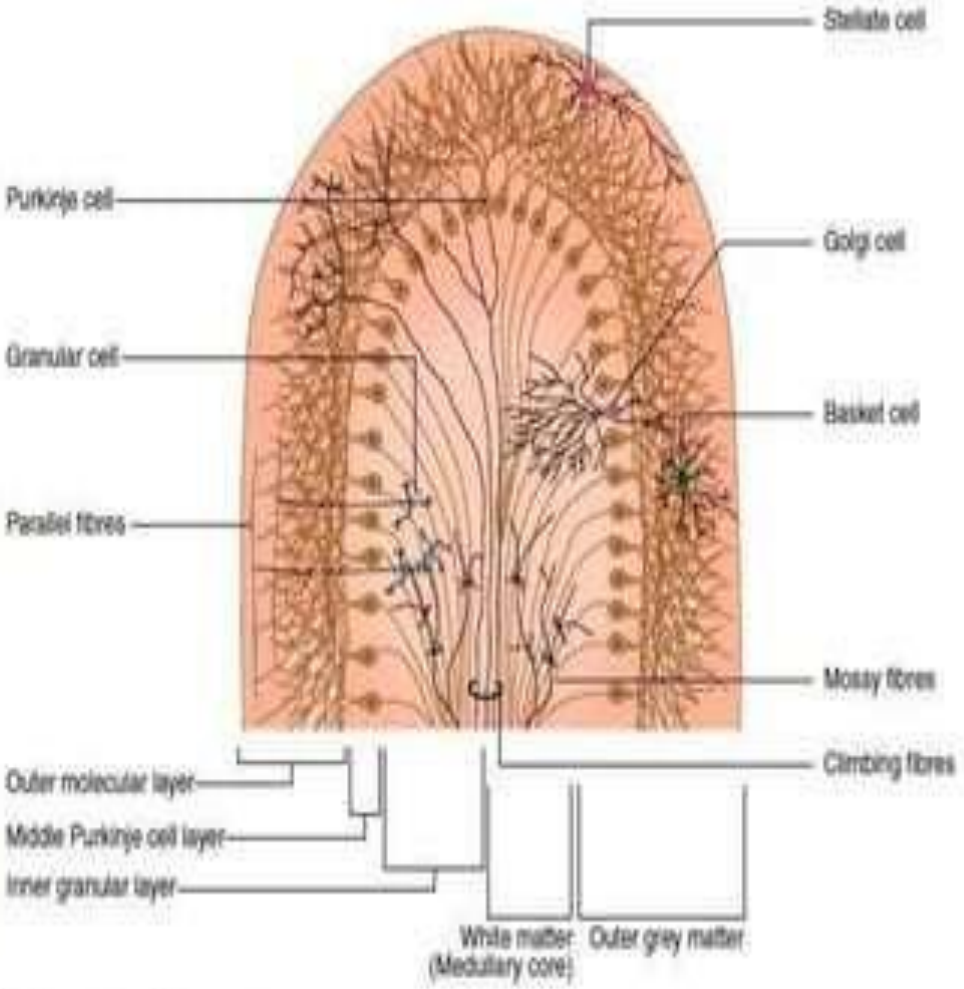
- Vermis projects to brainstem area-
- Concerned with control of **axial & proximal limb muscles**. (Medial brain stem pathway)
- Cerebellar hemisphere project to brainstem area-
- Concerned with **distal limb movements** (Lateral brain stem pathway)



- Cortico-cerebellum.
  - Consist of lateral zone of cerebellar hemisphere.
  - Newest from phylogenic point of view.
  - Greatest development in humans.
  - **Dentate N.**- effector nucleus.
  - Receives input from cerebral motor cortex, premotor cortex, somatosensory cortices of the cerebrum.

Histology Of Cerebellum

- External Cortex (Grey Matter)
- Cortex has 3 layers
  - Outer molecular layer
  - Middle Purkinje cell layer
  - Inner granular layer
- Functional unit-
  - Single layer of Purkinje cell
  - Corresponding deep nuclei
- It has about **30 million** functional units and 30 million neuronal circuit of the functional unit
- Output from function unit- deep nuclear cells

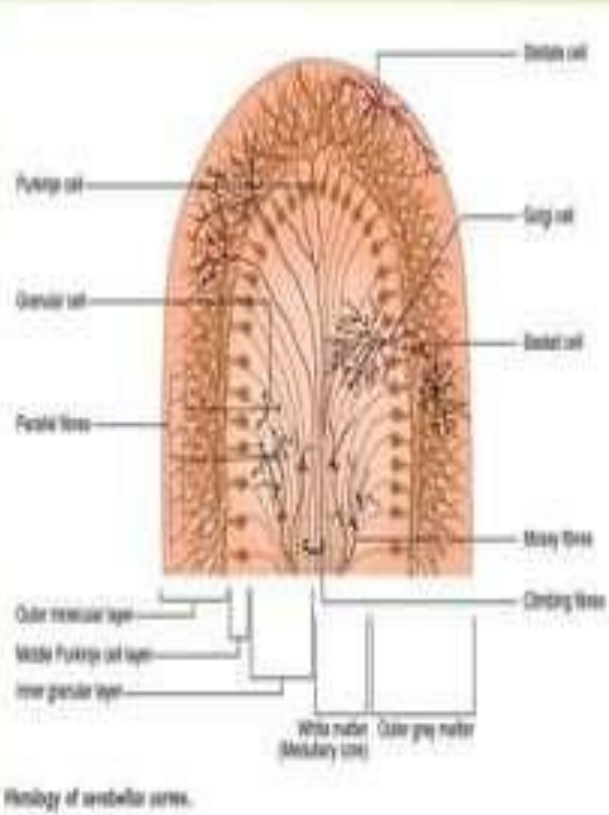


Afferent Fibers

Mossy fibers	Climbing fibers
All except Olivo-cerebellar tract	Only Olivo-cerebellar tract
Weakly excitatory	Strongly excitatory
Action potential- simple	Complex
Action potential- Na+ dependent	Ca+ dependent
Effects short lasting	Long lasting
Action potential- Small amplitude	Large amplitude
Action potential- graded	Follows all or none law
Neurotransmitter- not known	Aspartate

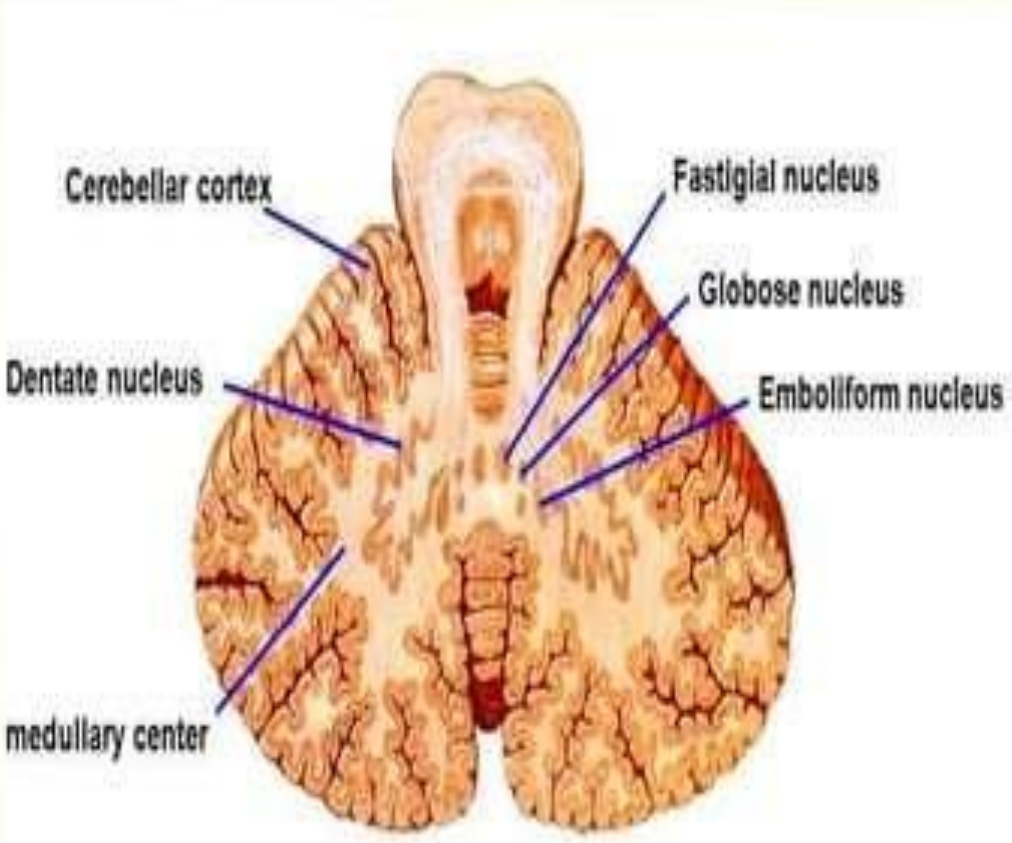
Histology Of Cerebellum (Contd.)

- **Molecular layer-**
  - Dendrites of Purkinje cells
  - Axons of Granules cells
  - Afferent fibers (climbing fibers) which form synapses with dendrites of Purkinje cells
  - Basket cells, stellate cells.
- **Purkinje cells layer-**
  - Biggest cells in CNS
  - Project to deep cerebellar nuclei where they form inhibitory synapses.
  - Basket cells axons form a basket around the cell body & axon hillock of Purkinje cells.
- **Granular cell layer-**
  - Cell bodies of the Granular cell.
  - Receive excitatory input from Mossy fibers.
  - Each Granular cell sends an axon to the molecular layer where it bifurcates to form parallel



Cerebellar Nuclei-

- The Purkinje cells are only output of cerebellar cortex.
- They project to deep cerebellar nuclei –
  - Dentate nucleus
  - Interpositus nucleus (Globose and Emboliform)
  - Fastigial nucleus
- Neurotransmitter is GABA



Intrinsic Cerebellar Circuit

Feed forward inhibition of Purkinje cells

- The basket and stellate cells are excited by granule cells via their parallel fibers.
- The basket and stellate cells, in turn, inhibit the Purkinje cells
- Purkinje cell and basket cell are excited by the same excitatory input, this arrangement is called feed forward inhibition.
- This helps to limit the duration of excitation produced by given afferent impulses

- **Feed forward inhibition of granule cells**
- Mossy fibers stimulate the granule cells.
- The mossy fiber also excites Golgi cell which inhibits the granule cell.
- Since the granule cell and Golgi cells are excited by the same excitatory input (from mossy fibers)
- This arrangement is said to produce feed forward inhibition o

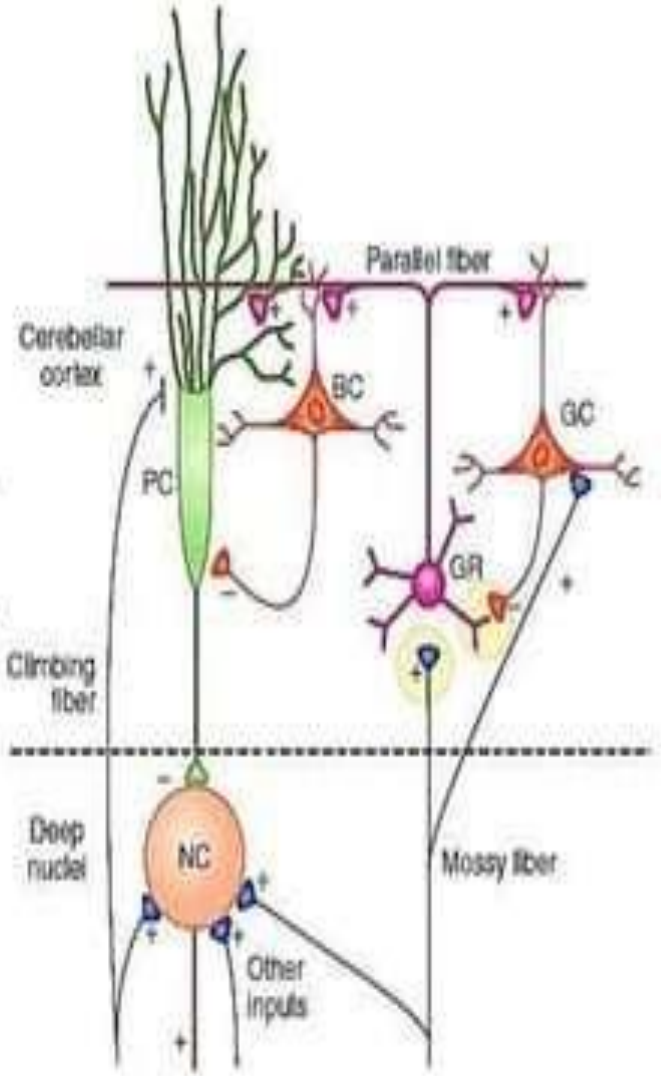


Diagram of neural connections in the cerebellum. Plus (+) and minus (–) signs indicate whether endings are excitatory or inhibitory. BC, basket cell; GC, Golgi cell; GR, granule

- **Feedback inhibition of granule cells**
- the granule cell is excited by the mossy fibers.
- The axon of granule cell excites the Golgi cell dendrites, whose axon inhibits the granule cell.
- Excitation of the granule cell is rapidly stopped by a negative feedback loop.
- Called feedback inhibition of granule cells.

- **The Reverberating circuit**
- The granule cells and Purkinje cells form a reverberating (echoing) circuit.
- Function is to revive and strengthen the non-synapses, when two neurons discharge by repeatedly and synchronously.
- This principle was developed by Hebb

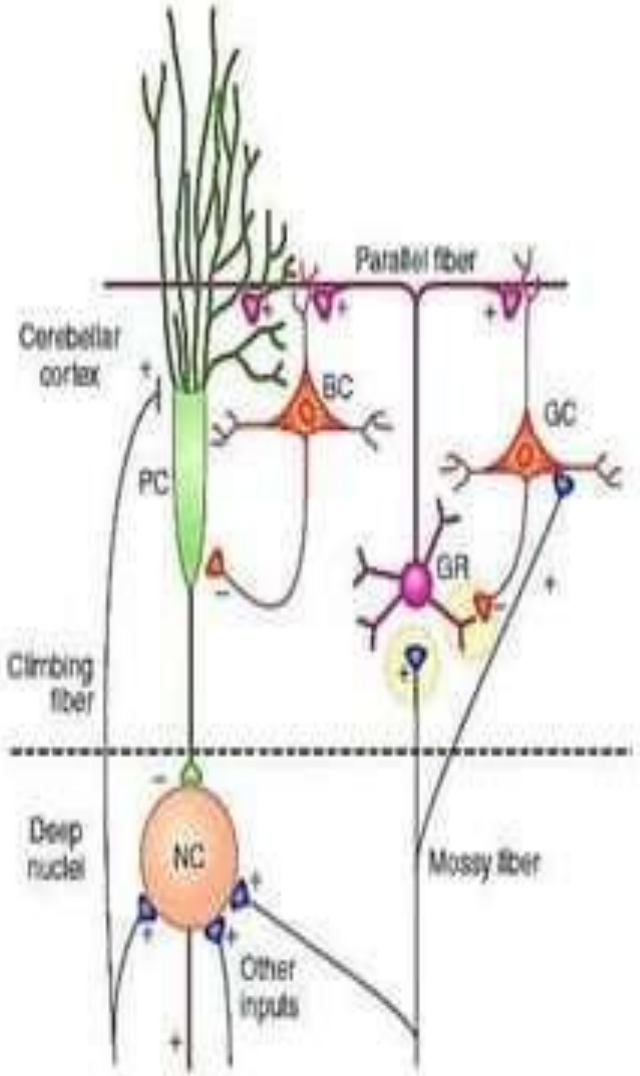


Diagram of neural connections in the cerebellum. Plus (+) and minus (-) signs indicate whether endings are excitatory or inhibitory. BC, basket cell; GC, Golgi cell; GR, granule

Afferent Pathway To The Cerebellum

1.Cortico-ponto-cerebellar pathway-

- **Origin**- Cerebral motor cortex, premotor cortex, somatosensory cortex
- Passes by **Pontine nu**.
- Ponto-cerebellar tract enter through **Middle cerebellar peduncle** (Opposite side)
- Distributed mainly to **lateral zone** of cerebellar hemisphere.

2.Olivo-cerebellar tract-

- Passes from **inferior Olivary complex** in medulla.
- Enters through **Inferior cerebellar peduncle**(Opposite side)
- Relay all over the cerebellum.
- Receive proprioceptive input from whole body.
- **The inferior Olivary complex is stimulated by-**
  - Cerebral motor cortex
  - Basal ganglia
  - Reticular formation

3.Vestibulo-cerebellar tract-

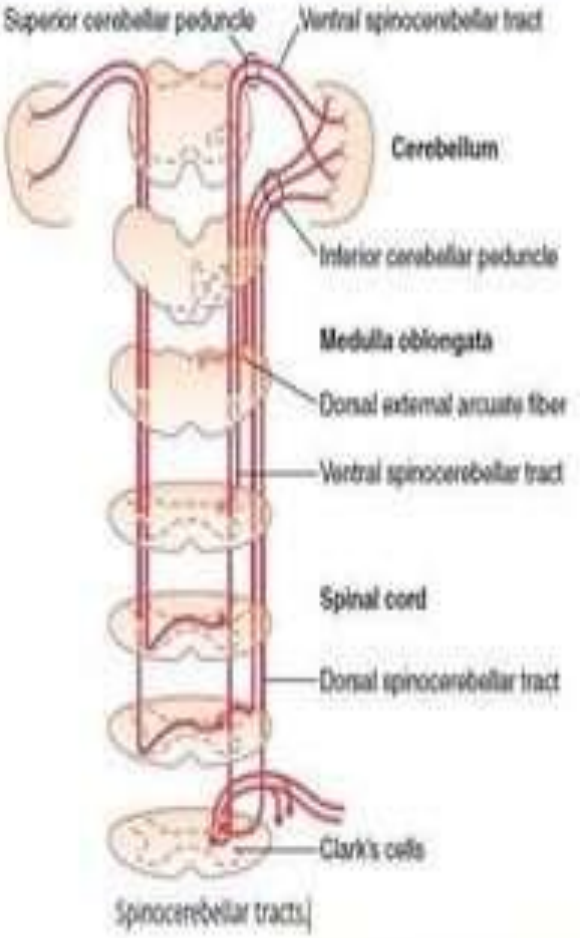
- Origin- Vestibular apparatus & brainstem vestibular nuclei
- Enters through inferior cerebellar peduncle
- Terminates in Fastigial nu. In floculonodular lobe
- Helps in balance, equilibrium, posture and eye movement.

4. Reticulo-cerebellar tract-

- Origin- Brainstem reticular formation
- Enters through inferior cerebellar peduncle
- Terminates in Vermis.

5. Dorsal/Posterior spino-cerebellar tract-

- Enters through inferior cerebellar peduncle (same side)
- Terminates in vermis & intermediate zone of cerebellum
- Receive signals from muscle spindle, Golgi tendon organs, large tactile receptors of skin, joints



6. Ventral/Anterior spino-cerebellar tract-

- Enters through **superior cerebellar peduncle** (same side)
- Terminates on both side of the cerebellum
- Receive signals from anterior horn cell of spinal cord
- Receive **proprioceptive** and **exteroceptive** (touch, pressure) signals.
- Convey information about length and tension of muscle fibers (**unconscious proprioceptive sensation**)
- **Most rapid** conduction pathway.

7. Cuneocerebellar tract-

- Carries proprioceptive impulse from head and neck.

8. Tecto-cerebellar tract-

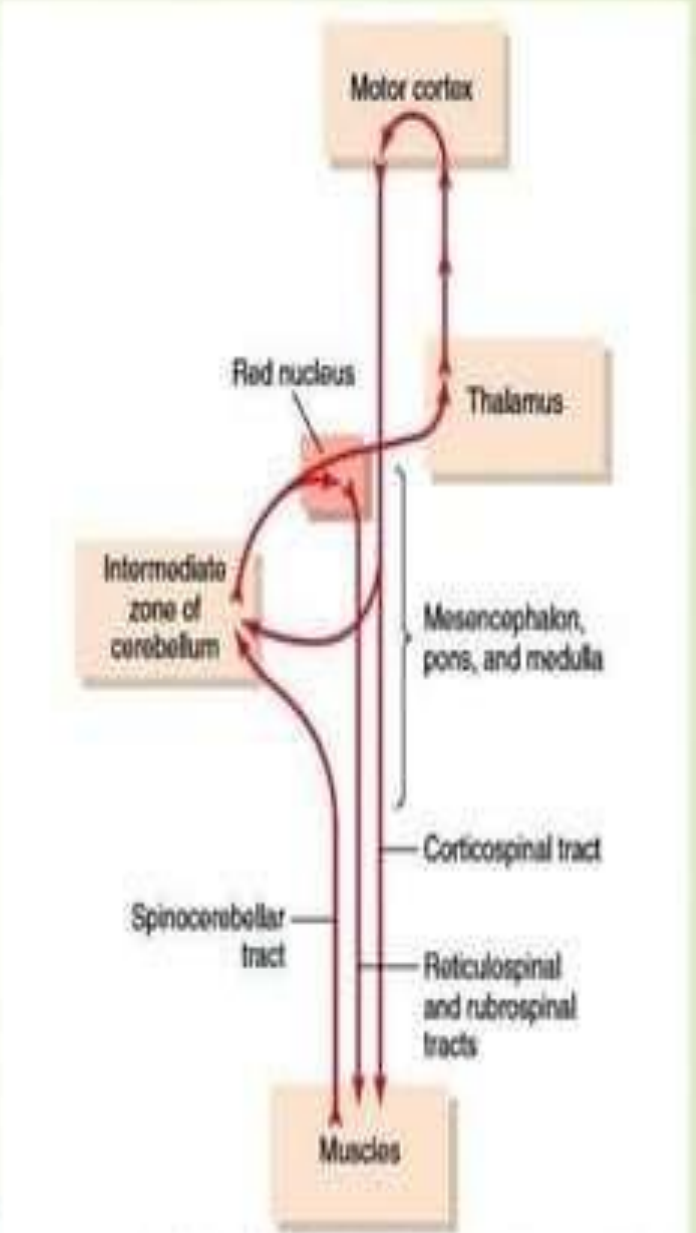
- Carries auditory and visual impulse via inferior and superior colliculi.

Efferent Output From Cerebellum

- Cerebello-vestibular pathway-
  - **Origin-** Fastigial nu. At floculonodular lobe of cerebellum.
  - Passes through **Inferior cerebellar** peduncle.
  - Signal goes to brainstem **reticular formation** and **vestibular nu**. by reticulo-spinal tract and vestibulo-spinal tract
  - To axial and proximal muscles.
  - Maintain the **posture, tone, equilibrium, balance and eye movements.**

- Cerebello-rubro-thalamo-cortical pathway-
  - **Origin-** Interpositus nu. Of Intermediate zone of cerebellar hemisphere
  - Passes through **superior cerebellar** peduncle
  - Signals goes to **thalamus, cerebral cortex, basal ganglia, red nucleus, reticular formation.**
  - Helps to **co-ordinate** reciprocal contraction of agonist & antagonist muscles in the distal muscles, **compare** them.

- Cerebello-thalamo-cortical pathway-
  - Origin- Dentate nu.
  - Passes through **superior cerebellar** peduncle
  - Goes to **thalamus**(ventro-lateral, ventro-anterior), **cerebral cortex, premotor area.**
  - Via **cortico-spinal** tract it affect the distal muscles.
  - Help to **co-ordinate sequential motor activities** and **Plan, program, motor learning.**



Functions of Cerebellum

- It helps to control the tone of the muscles on the same side of the body.
- Control the rate, range, force & direction of movement.(Synergia)
- Control rapid muscular movements, like running, typing, talking. Cerebellum helps in co-ordination of these activities, sequencing them & correcting them.
- It received continuously update information on the desired programme of muscular contractions.
- It has a comparator function.
- It helps in planning the next sequential movement in advance while the present movement is going on.
- It helps in timing of the movement, controls ballistic and saccadic movements.
- Helps in predicting from a changing visual scene, how fast he is approaching an object.
- Helps in applying brakes where necessary.
- Helps in smooth coordinated movements by virtue of efference copy.
- Helps in speech.

Thank You