Cerebellum - Structure, subdivision, nuclei

External structure

The cerebellum is located in the posterior cranial fossa and it is covered superiorly by the *tentorium cerebelli*. It is found posteriorly to the medulla, pons and 4th ventricle. The cerebellum connects to the brain stem by the superior, middle and inferior cerebellar peduncles.

It is composed of 2 hemispheres, connected by a median narrow unpaired vermis. Divided into 3 lobes:

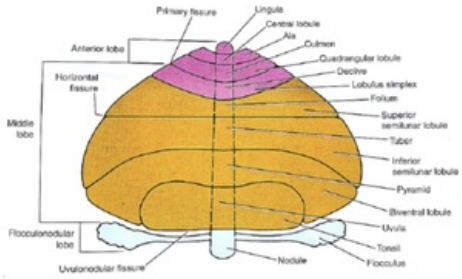
1. Anterior lobe: Seen on the superior surface of the cerebellum. It is separated by the primary fissure.
2. Middle-posterior lobe (largest part of cerebellum). It is separated by the uvulonodular fissures (posterolateral fissures)
3. Flocculonodular lobe - The superior and inferior surfaces of the cerebellum are separated by the horizontal fissure.

Subdivisions

The cerebellum and the vermis can be subdivided into lobules:

[Vermis: **Like Cats Catching Dogs For The Party Up North**]

- Lingula
- Central lobule
- Culmen
- Declive
- Folium
- Tuber
- Pyramid
- Uvula
- Nodule



Subdivisions of the cerebellum

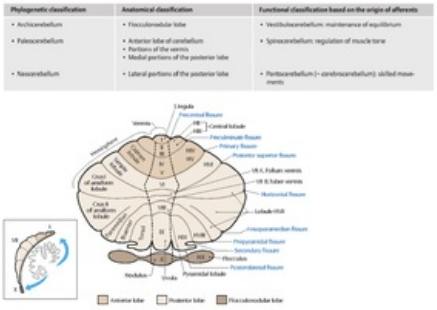
Functional organization

Vestibulocerebellum: the flocculonodular lobe and the lingula.

- Connected with the vestibular nuclei
- Controlling balance and ocular reflexes (mainly fixation on a target)

Spinocerebellum: anterior lobe (with its accompanying vermis), pyramid and uvula. It receives the proprioceptive information from the spinocerebellar tracts.

Cerebrocerebellum (largest) middle (posterior) lobe and some of the vermis.


Functional divisions of the cerebellum

- Receives afferent fibers from the cerebral cortex and pontine nuclei.
- Sends efferent fibers to: red nucleus, thalamus and inferior olivary nucleus.
- Involved with the planning of movements and motor learning, regulates coordination of muscle activation, and is important for visually guided movements

The cerebellum can also be functionally divided into 3 other parts:

Cortex of the vermis: influences movement of the trunk, shoulders, neck and hips

Intermediate zones: influences the movement of the distal limbs (especially feet and hands).

Lateral zones: involved in the conscious assessment of movement errors in the entire body.

Intracerebellar nuclei (deep cerebellar nuclei)

4 masses of gray matter (large, multipolar neurons) are found deep in the white matter (lateral to medial)

- Dentate nucleus (largest)
- Emboliform nucleus
- Globose nucleus
- Fastigial nucleus: close to the midline

These nuclei form the cerebellar outflow through the inferior and superior cerebellar peduncles.

Structure of cerebellar cortex

The cerebellar cortex is divided into 3 layers:

Molecular layer (outer): contains basket cells and stellate cells.

Purkinje cell layer: contains the purkinje cells

- Their dendritic tree passes into the molecular layer.
- Their axon gets myelinated as it passes through the white matter to synapse with the deep cerebellar nuclei.

Granular layer: contains granular cells and Golgi cells.

- The axons of the granular cells run into molecular layer, where they bifurcate in T junction form, forming parallel fibers synapse with several Purkynje trees
- The dendrites of the Golgi cells run into the molecular layer

Cerebellar glomeruli: Golgi axons, dendrites of granular cells and mossy fibers.

Mechanism of cerebellar cortex

The afferent fibers entering the cerebellar cortex are classified into:

Climbing fibers: the fibers that come from the inferior olivary complex. These fibers run into the molecular layer, where they form numerous synapses with the dendritic trees of the purkinje cells.

- Each purkinje cell synapses with a single climbing fiber, while the fiber can synapse with up to 10 purkinje cells.

Mossy fibers: afferent fibers from all the other sources. These fibers enter the granular layer and synapse with dendrites of granular cells (cerebellar glomeruli)

Excitatory fibers

Mossy fibers (Glutamate): excite the granular cells.

- Parallel fibers: excite the purkinje cells

Climbing fibers (Aspartate) excite Purkynje cells

The climbing and mossy fibers also form synapses with the deep cerebellar nuclei, causing their excitation.

The purkinje cells inhibit the neurons of the deep cerebellar nuclei, by releasing GABA.

Inhibitory interneurons:

Basket and stellate cells: inhibit the purkinje cells

Golgi cells: Inhibit the granular cells

This inhibition can limit the area of cortex excited and the ability to excite a single purkinje cell.

Thus, incoming sensory information to the cerebellum excites the deep cerebellar nuclei (via mossy and climbing fibers). These nuclei are inhibited shortly later by the purkinje cells. The efferent fibers sent from the deep cerebellar nuclei to the cerebral cortex, influence coordination and muscle tone.

Afferent connections

Cerebral cortex from the cerebellum

Corticopontocerebellar pathway: Corticopontine fibers arise from neurons cerebral cortex and run through the corona radiata and internal capsule to synapse in the pontine nuclei (in the pons). Then, the transverse pontine fibers that arise from the pontine nuclei cross the midline and run into the cerebellum (enter the contralateral cerebellar hemisphere) through the middle cerebellar peduncle.

Cerebro-olivocerebellar pathway: Cortico-olivary fibers arise from the cerebral cortex and run through the corona radiata and internal capsule to synapse in the inferior olivary nuclei bilaterally (on both sides) to the Olivocerebellar fibers cross the midline and run through the inferior cerebellar peduncle to the cerebellum, forming the climbing fibers.

Afferent pathway	origin	Destination via
Corticopontocerebellar	Frontal,parietal, temporal, occipital	Pontine nuclei & mossy fibres to cerebellar cortex
Cerebroolivocerebellar		INF olivary N & climb fibres to cerebellar cortex
Cerebroreticulocerebellar	Sensorimotor areas	Reticular formation
Ant spinocerebellar	Muscle spindles,tendons, joints	Mossy fibres to cerebellar cortex
Post spinocerebellar		
Cuneocerebellar		
Vestibular nerve	Utricle, saccule,semicircular canals	Mossy fibres to cortex of FN node
others	Red nuc, tectum	cerebellar cortex

Afferent connections

Cerebroreticulocerebellar pathway: Corticoreticular fibers arise from the cerebral cortex and run through the corona radiata and internal capsule to synapse in the reticular formation of the pons and medulla (some of the fibers cross). The reticulocerebellar fibers then enter the cerebellum via the inferior cerebellar peduncle of the same side.

Spinal cord from the cerebellum

Posterior spinocerebellar tract - uncrossed

Conveys unconscious proprioceptive information from muscle spindles, joint receptors and tendons. The information origins from the lower limb and trunk and is used by the cerebellum to maintain a steady posture, and to coordinate limb movements.

- The axons of the 1 st order neurons from the dorsal root ganglion, enter the dorsal horn to synapse with 2nd order neurons of the nucleus dorsalis (Clarke's nucleus).
- The nucleus dorsalis is only present In the C8-L3 segments of the spinal cord. Thus, 1 st order axons from lower levels ascend through the posterior white matter until they reach the nucleus dorsalis.
- The fibers ascend through the spinal cord and medulla oblongata. Then the fibers pass through the inferior cerebellar peduncle to synapse with 3 rd order neurons in the cerebellar cortex.

Anterior spinocerebellar tract

Conveys unconscious proprioceptive information (from tendons, muscle spindles and joint capsules) of the trunk, lower limb and upper limb.

- The axons of the 1 st order neurons from the dorsal root ganglion, enter the dorsal horn to synapse with 2nd order neurons in the nucleus dorsalis (CLARKE's nucleus).
- From the nucleus dorsalis:

1. Most fibers cross to the contralateral side, ascending in the anterior spinocerebellar tract.
2. Minority of fibers who didn’t cross ascend in the anterior cerebellar tract of same side.

- The fibers ascend through the spinal cord, medulla oblongata and pons. Then the fibers pass to the cerebellum via the superior cerebellar peduncle.

In the cerebellum:

- The fibers that crossed in the spinal cord, cross again to the other side of the cerebellum, synapse with 3rd order neuron of the cerebellar cortex (contralateral)
- The fibers who didn’t cross in the spinal cord synapse without crossing with 3 rd order neurons in the cerebellar cortex.

Other connections:

Cuneocerebellar pathway - uncrossed

- This tract consists of fibers that arise from the nucleus cuneatus of the medulla, enter the cerebellum uncrossed via the inferior cerebellar peduncle.
- This pathway transmits conscious proprioceptive information about the upper limb and upper thorax.

Vestibulocerebellar pathway - uncrossed

- Afferent fibers from the vestibular nerve, run directly or indirectly (after synapsing in the vestibular nuclei of the brain stem) to the flocculonodular lobe of the cerebellum.
- The fibers pass through the inferior cerebellar peduncle.

- Small bundles of afferent fibers are also received from the red nucleus and tectum.