Neuroanatomy 6: Cerebellum

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Location, relations & external features:

The cerebellum is the second biggest part of the brain after the cerebrum. It is the dorsal part of the hindbrain that occupies most of the posterior cranial fossa. The cerebellum has a major role in maintaining skeletal muscle tone, planning & execution of fine movements, & maintaining posture & balance.

Morphologically, the cerebellum is made of a narrow median mass, the **vermis**, & 2 much larger lateral **cerebellar hemispheres**. The vermis is separated from the hemispheres by the **paramedian sulci**. Anteriorly, the cerebellum is connected to the brainstem on each side by 3 large bundles of nerve fibers: the superior, middle, & inferior **cerebellar peduncles** that are attached to the midbrain, pons, & medulla oblongata, respectively.

The cerebellum has a flat, slightly concave **superior surface** that slopes inferolaterally. The paramedian sulci are shallow in the superior surface. At the junction between the anterior 1/3rd & posterior 2/3rd of the superior surface, lies the **primary fissure**, separating the **anterior** & **posterior lobes** of the cerebellum. A third **flocculonodular lobe** exists antero-inferiorly & is separated from the rest of the cortex by the posterolateral fissure. The superior cerebellar surface is related to the tentorium cerebelli, with the superior vermis lying parallel to the straight venous sinus. The **inferior cerebellar surface** is convex & fills the concavity of the posterior cranial fossa. Here, the paramedian sulci are deep, & the hemispheres bulge beyond the vermis, leaving a median space between them, the **vallecula**, in which the **falx cerebelli** lies. A long deep **horizontal fissure** separates the superior & inferior surfaces of the cerebellum. The anterior surface of the cerebellum is irregular, it receives the cerebellar peduncles, & overlies the roof of the 4th ventricle. Laterally, the anterior cerebellar surface is related to the petrous part of temporal bone. The outer surface of the cerebellar vermis & hemispheres is a made by gray matter cortex that shows large number of curved, horizontally placed grooves (sulci) & **folia** (gyri). The cerebellar cortex is divided into 9 zones arranged supero-inferiorly, each zone consists of a segment in the vermis & 2 lateral lobules in the hemispheres. The cerebellar zones are arranged as follows:

No.	**Vermal segment**	**Hemisphere segment**	**Lobe**	**Fissure**
1	Lingula	Wing of lingula		
2	Central lobule	Ala of central lobule	Anterior	
3	Culmen	Anterior quadrangular lobule		Primary
4	Simple (declive)	Posterior quadrangular lobule		
5	Folium	Superior semilunar lobule	Posterior	Horizontal
6	Tuber	Superior semilunar lobule		
7	Pyramis (pyramid)	Biventral lobule		Secondary
8	Uvula	Tonsil		Posterolateral
9	Nodule	Flocculus	Flocculonodular	

Note the following:

- The **cerebellar tonsils** are rounded bulges seen on the inferomedial aspect of the hemispheres, separated from the biventral lobules by the secondary fissure. They are just superior to the foramen magnum, & can "herniate" through it when the intracranial pressure increases.
- The **nodule** is the most caudal part of the vermis. it is attached to 2 long lateral extensions (the **flocculus**) to form the flocculonodular lobe, separated from the tonsils by the posterolateral fissure.

Cerebellar Peduncles:

Cerebellar peduncles are 6 thick bundles, 3 on each side, of afferent & efferent fibers connecting the cerebellum to the rest of the brain. The peduncles are continuous with the white matter of the cerebellum.

I- **Superior cerebellar peduncle**: this is the smallest & most medial peduncle, connecting the cerebellum to the posteroinferior aspect of the midbrain. The 2 superior peduncles, as they exit the cerebellum, pass anterosuperiorly & converge towards the midline before joining the midbrain. The space between the superior cerebellar peduncles is closed by a thin pia mater sheet, the superior medullary vellum, that forms the upper half of the roof of the 4th ventricle. The superior cerebellar peduncles is mainly efferent, with most of its fibers emerging from the deep cerebellar nuclei to the red nucleus of the midbrain & the thalamus.

II- **Middle cerebellar peduncle**: this is the largest & most lateral peduncle, connecting the cerebellum to the ventral pons. The middle peduncle is made by the pontocerebellar fibers, emerging from the contralateral pontine nuclei, crossing the midline, & passing posterolaterally to the cerebellum. So, the middle cerebellar peduncles is purely afferent.

III- **Inferior cerebellar peduncle**: this peduncle passes from the posterosuperior aspect of the medulla oblongata to enter the cerebellum between the superior & middle peduncles. It is mainly afferent, consisting mainly of the posterior spinocerebellar & olivocerebellar tracts. The space between the inferior cerebellar peduncles is closed by a thin pia mater sheet, the inferior medullary vellum, that forms the lower half of the roof of the 4^{th} ventricle.

For the specific tracts present in each peduncle, see the table in the last page.

Internal Structure:

Gray Matter:

A. Cerebellar Cortex: Cerebellar gray matter includes the cerebellar cortex & the deep cerebellar nuclei.

The cerebellar cortex is made of 3 layers: **molecular** (externally), **Purkinje cells** (in the middle), & **granular** (internally). The cerebellar cortex receives almost all of the afferent tracts entering the cerebellum. Afferent fibers that reach & synapse in the molecular layer are called climbing fibers, while those which reach & synapse in the granular layer are called Mossy fibers. Efferent fibers of the of the cerebellar cortex are the axons of Purkinje cells. They terminate almost exclusively on the deep cerebellar nuclei, except for those from the flocculonodular lobe which leave the cerebellum as the cerebellovestibular tract.

Functionally, the cerebellar cortex is divided into 3 divisions:

1. **Spinocerebellum**: this includes the vermis & the paravermal (intermediate) zone of cerebellar hemispheres. The vermis controls muscle tone, posture, & controls the movements of the axial body, neck, shoulders, and hips. The paravermal zone is concerned with controlling muscle contractions in the distal portions of the upper and lower limbs, especially the hands and fingers and feet and toes.
2. **Cerebrocerebellum**: this includes the lateral parts of the cerebellar hemispheres. These areas are extensively connected with the cerebral cortex (especially the premotor areas & the somatosensory areas). The cerebrocerebellum functions to plan the sequential movements of the entire body and is involved with the conscious assessment of movement errors.
3. **Vestibulocerebellum**: this includes the flocculonodular lobe of cerebellum. It is concerned with balance & posture maintenance, & the coordination of the head & eye movement with the body position.

B. Deep Cerebellar Nuclei: the cerebellum contains 4 gray matter nuclei embeded in its white matter on each side. These are (from lateral to medial): dentate, emboliform, globose, & fastigial nuclei.

1. **Dentate nucleus** is the largest one, it is a hollow oval corrugated mass of gray matter with its opening (hilum) facing medially, via which its efferent fibers exit as the dentorubrothalamic tract.
2. **Emboliform nucleus** is ovoid and is situated medial to the dentate nucleus, partially covering its hilum.
3. **Globose nucleus** consists of one or more rounded cell groups that lie medial to the emboliform nucleus
4. **Fastigial nucleus** lies near the midline in the vermis, close to the roof of the fourth ventricle; it is larger than the globose nucleus.
   The deep cerebellar nuclei receive afferent fibers from the cerebellar cortex. Their axons represent the efferent fibers of the cerebellum. See the table in the last page to know their main connections.

White Matter:

There is a small amount of white matter in the vermis; and a large amount of white matter in each cerebellar hemisphere. The white matter is made up of three groups of fibers: (1) intrinsic, (2) afferent, and (3) efferent.

The **intrinsic fibers** do not leave the cerebellum but connect its different regions. The majority of those fibers are the axons of the cortical Purkinje cells that terminate on the deep cerebellar nuclei. Some interconnect folia of the cerebellar cortex and vermis on the same side.

The **afferent fibers** form the greater part of the white matter and proceed to the cerebellar cortex. They enter the cerebellum mainly through the inferior and middle cerebellar peduncles & end in the cortex (as climbing & Mossy fibers) &/or the deep cerebellar nuclei.

The **efferent fibers** constitute the output of the cerebellum and commence as the axons of the Purkinje cells of the cerebellar cortex. The great majority of the Purkinje cell axons pass to and synapse with the neurons of the cerebellar nuclei (fastigial, globose, emboliform, and dentate). The axons of the neurons then leave the cerebellum. A few Purkinje cell axons in the flocculonodular lobe and in parts of the vermis bypass the cerebellar nuclei and leave the cerebellum without synapsing. Fibers from the dentate, emboliform, and globose nuclei leave the cerebellum through the superior cerebellar peduncle. Fibers from the fastigial nucleus leave through the inferior cerebellar peduncle.

Clinical Considerations:

- *Each cerebellar hemisphere is connected by nervous pathways principally with the same side of the body; thus, a lesion in one cerebellar hemisphere gives rise to signs and symptoms that are limited to the same side of the body.*
- *The essential function of the cerebellum is to coordinate, by synergistic action, all reflex and voluntary muscular activity. Thus, it graduates and harmonizes muscle tone and maintains normal body posture. It permits voluntary movements, such as walking, to take place smoothly with precision and economy of effort. It must be understood that although the cerebellum plays an important role in skeletal muscle activity, it is not able to initiate muscle movement.*

Signs and Symptoms of Cerebellar Disease

Hypotonia: *The muscles lose resilience to palpation. There is diminished resistance to passive movements of joints. Shaking the limb produces excessive movements at the terminal joints. The condition is attributable to loss of cerebellar influence on the simple stretch reflex.*

Postural Changes and Alteration of Gait: *The head is often rotated and flexed, and the shoulder on the side of the lesion is lower than on the normal side. The patient assumes a wide base when he stands and is often stiff legged to compensate for loss of muscle tone. When the individual walks, he lurches and staggers toward the affected side.*

Disturbances of Voluntary Movement (Ataxia): *The muscles contract irregularly and weakly. Tremor occurs when fine movements, such as buttoning clothes, writing, and shaving, are attempted. Muscle groups fail to work harmoniously, and there is decomposition of movement. When the patient is asked to touch the tip of the nose with the index finger, the movements are not properly coordinated, and the finger either passes the nose (past-pointing) or hits the nose.*

Disturbances of Reflexes: *Movement produced by tendon reflexes tends to continue for a longer period of time than normal.*

Disturbances of Ocular Movement: *Nystagmus, which is essentially an ataxia of the ocular muscles, is a rhythmical oscillation of the eyes. The movement of nystagmus may be confined to one plane and may be horizontal or vertical, or it may be in many planes when it is referred to as rotatory nystagmus.*

Disorders of Speech: *Dysarthria occurs in cerebellar disease because of ataxia of the muscles of the larynx. Articulation is jerky, and the syllables often are separated from one another. Speech tends to be explosive, and the syllables often are slurred.*

Note: In cerebellar lesions, paralysis and sensory changes are not present. Even though the muscular contractions may be weak and the patient may be easily fatigued, there is no atrophy.

END

Peduncle	Direction	Tract / Fibers	Origin	Destination	Function
Superior	Afferent	Anterior spinocerebellar	Nucleus dorsalis (of Clarke) in the spinal cord (of both sides)	Via mossy fibers to cerebellar cortex	Conveys information from muscles and joints
	Efferent	Dentorubrothalamic	Dentate nucleus of cerebellum	Contralateral red nucleus (dentorubral fibers) & ventral lateral (VL) nucleus of thalamus (dentothalamic fibers)	Influences ipsilateral motor activity
		Globose-emboliform-rubral	Globose & emboliform cerebellar nuclei	Contralateral red nucleus	Influences ipsilateral motor activity
Middle	Afferent	Pontocerebellar	Contralateral pontine nuclei	Via mossy fibers to cerebellar cortex	Conveys control from cerebral cortex
Inferior	Afferent	Posterior spinocerebellar	Nucleus dorsalis (of Clarke) in the spinal cord (of the same side)	Via mossy fibers to cerebellar cortex	Conveys information from muscles and joints
		Olivocerebellar	Contralateral olivary nuclei of the medulla	Via climbing fibers to cerebellar cortex	Conveys control from cerebral cortex
		Vestibulocerebellar	Ipsilateral vestibular nuclei (& vestibular ganglion)	Via mossy fibers to cortex of flocculonodular lobe	Conveys information of head position and movement
		Cuneocerebellar	Ipsilateral cuneate nucleus of the medulla	Via mossy fibers to cerebellar cortex	Conveys information from muscles and joints of upper limb
		Reticulocerebellar	Reticular formation of the medulla	Via mossy fibers to cerebellar cortex	Conveys control from cerebral cortex
	Efferent	Cerebellovestibular	Purkinje cells in the cortex of flocculonodular lobe	Vestibular nuclei	Affects the vestibular pathway
		Fastigiovestibular	Ipsilateral fastigial nucleus of cerebellum	Vestibular nuclei	Affects the vestibular pathway
		Fastigioreticular	Ipsilateral fastigial nucleus of cerebellum	Reticular formation in the pons & medulla	Influences ipsilateral muscle tone