CEREBELLUM

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Historically, the cerebellum has been considered a motor structure, because cerebellar damage leads to impairments in motor control and posture and because the majority of the cerebellum’s outputs are to parts of the motor system.

However, motor commands are **not initiated** in the cerebellum; rather, the cerebellum **modifies** the motor commands of the descending pathways to make movements more adaptive and accurate.
The cerebellum (little brain) is a highly folded, baseball-sized part of the brain that lies underneath the occipital lobe of the cortex and is attached to the back of the upper portion of the brain stem. (The cerebellar cortex is a highly folded sheet about 17 cm wide and 120 cm long)

The cerebellum is called the SILENT AREA of the brain for 2 reasons:

1. Its stimulation does NOT cause any motor movement
2. Its simulation does NOT cause any conscious sensation.

However, damage to the Cerebellum leads to movements becoming highly abnormal.
It ensures motor activities conform to Cerebral Cortex orders

First it receives information from

Motor Cortex
Updated info about seq. of motor movements

Sensory Cortex
Updated info about status of each body part

Then, Cerebellum compares

Intended movement

Actual movement

Instantaneous subconscious corrective signals back to Motor Cortex by Cerebellum
Cerebellum Functional Anatomy
Cerebellum has three (03) major parts:

- Cerebellar Cortex
- Arbor Vitae (white matter of the cerebellum)
  - Intra Cerebellar Deep Nuclei
Internal structure

- Outer gray matter called cerebellar cortex, extensively folded forming folia
- Inner white matter, showing distinctive treelike pattern called Arbor vitae (tree of life)
- 4 pairs of nuclei within white matter, the deep cerebellar nuclei
CEREBELLAR NUCLEI

Cerebellar nuclei are masses of gray matter scattered in the white matter of cerebellum.

There are 3 main cerebellar nuclei:

1. Dentate
2. Interposed (Globose & Emboliform)
3. Fastigial
Cerebellar White Matter

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

- Midbrain
- Anterior lobe
- Arbor vitae
- Cerebellar nucleus
- Cerebellar cortex
- Posterior lobe
- Choroid plexus of the fourth ventricle

**Cerebellar Peduncles**
- Superior cerebellar peduncle
- Middle cerebellar peduncle
- Inferior cerebellar peduncle

Lateral view

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CEREBELLAR PEDUNCLES IN THE CEREBELLAR WHITE MATTER

Cerebellar peduncle connects cerebellum to the brain stem. There are 6 cerebellar peduncles in total, 3 on the left and 3 on the right. They are as follows:

- **Superior cerebellar peduncle** - connects to the Midbrain (efferent)
- **Middle cerebellar peduncle** - connects to the Pons (afferent)
- **Inferior cerebellar peduncle** - connects to the Medulla (afferent & efferent)
CEREBELLAR CORTEX
CEREBELLUM

Anatomical divisions
(horizontal divisions around 2 main fissures)

Functional divisions
(vertical divisions)

- Anterior lobe
- Posterior lobe
- Flocculonodular lobe

Vermis
Cerebrocerebellum
(lateral hemisphere)

Vestibulocerebellum

TeachMeAnatomy.ca
The cortex of the vermis influences the movements of the long axis of the body namely the neck, the shoulders, the thorax, the abdomen, and the hips.

Immediately lateral to the vermis is a so-called intermediate zone of the cerebellar hemisphere. This area has been shown to control the muscles of the distal parts of the limbs, especially the hands and feet.

The lateral zone of each cerebellar hemisphere appears to be concerned with the planning of sequential movements of the entire body and is involved with the conscious assessment of movement errors.
Which areas of the brain show topographical representation?

- Cerebral sensory cortex
- Cerebral motor cortex
  - Basal ganglia
  - Red nucleus
- Reticular formation
Vermis and intermediate zones have topographical representations of the body.

- Axial portions of the body lie in the vermis, whereas the limbs & facial regions lie in the intermediate zones.
- Receive afferent nerve signals from all parts of the body + cerebral cortex + brainstem & Send signals back to same + red nucleus + RF.

Lateral hemispheres do NOT have topographical representation.

- Receives input from the Cerebral cortex (premotor & sensory cortex) & association areas of the parietal cortex.
- This connectivity helps it play an important role in planning and coordinating the body’s rapid sequential motor activities occurring fraction of a second apart.

Figure 56-3  Somatosensory projection areas in the cerebellar cortex.
NOTE:
Cerebellum is connected to the Spinal cord of the SAME side & Cerebral Cortex of the CONTRALATERAL SIDE.
Different tracts enter and leave the Cerebellum, thus forming the afferent and efferent pathways passing through the different Cerebellar peduncles. What are the different tracts that enter and leave the cerebellum?
AFFERENT PATHWAYS FROM OTHER PARTS OF THE BRAIN

• Corticopontocerebellar Pathway (from the premotor and sensory cortex thru pons to the Lat. Hemsisphere of cerebellum on the opposite side)

• Olivocerebellar Tract (From Olive to all parts of the Cerebellum).

• Vestibulocerebellar Tract (From Vestibular apparatus & vestibular nuclei to the Flocculonodular lobe & Fastigial Nucleus)

• Reticulocerebellar fibers (From the reticular formation to the vermis).

AFFERENT PATHWAYS FROM THE PERIPHERY

• Dorsal spinocerebellar Tract (thru the Inferior cerebellar peduncle to terminate in the vermis & intermediate zone on the same side)
  - Muscle spindles – Muscle contraction
  - Golgi tendon organs (to a lesser extent) – degree of tension on the muscle tendon
  - Large tactile receptors of the skin – forces acting on the surface of the body
  - Joint receptors - position & rates of movements of the parts of the body

• Ventral spinocerebellar Tract (thru the superior cerebellar peduncle to terminate on both sides)

- EFFERENCE copy of the anterior horn motor which contains information from the:
  1. Brain thru the Corticospinal & Rubrospinal tract, and the
  2. Internal motor pattern generators

• DCML.

• Spino reticular tract &

• Spino olivary pathway.
Thus, the cerebellum continually collects information about the movements and positions of all parts of the body even though it is operating at a subconscious level.
Each time an input signal arrives in the cerebellum, it divided and goes in 2 directions:
1. Directly to one of the deep cerebellar nuclei.
2. To a corresponding area of the cerebellar cortex overlying the deep nucleus.

All input signals that enter the cerebellum eventually end in the Deep nuclei in the form of initial excitatory signals followed a fraction of a second later by inhibitory signals.
Efferent Pathways

The cerebellar **output** involves deep intra cerebellar nuclei (Dentate, Interposed, Fastigial).

1. **Vermis** → **FASTIGIAL N.** → Brainstem → Concerned with **EQUILIBRIUM** (vestibular nuclei) & **POSTURE** (Reticular Formation).

2. **Intermediate Zone of Cerebellar hemisphere** → **INTERPOSED N.** → Ventrolateral & Ventroanterior nuclei of Thalamus → Cerebral Cortex → Midline structures of Thalamus → Basal Ganglia → Red Nucleus & RF of Brainstem → Concerned with Reciprocal contraction of **AGONIST & ANTAGONIST MUSCLES** of Distal parts of the limbs, esp. hands, fingers and thumb.

3. **Lateral Zone of Cerebellar hemisphere** → **DENTATE N.** → Thalamus → Cerebral Cortex → Coordinates **SEQUENTIAL MOTOR ACTIVITIES** initiated by the Cerebral Cortex.
Functional Unit of the Cerebellar Cortex

The Cerebellar cortex has about 30 million nearly identical units. The cerebellar cortex is made up of 3 layers:

1. Outer Molecular layer
2. Intermediate Purkinje Cell layer
3. Inner Granular Cell layer
The **EXCITATORY** influences arise from direct connections with afferent fibres that enter the cerebellum from the **brain** or periphery.

The **INHIBITORY** influence arises entirely from the **Purkinje cell** in the cortex of the cerebellum.
FUNCTIONAL UNIT OF THE CEREBELLUM

The cells in the Cerebellum are:
- Basket & stellate cells in the Molecular layer
- Purkinje cells in the Purkinje cell layer
- Granule cells in the Granular cell layer

The fibers in the Cerebellum are the Mossy fibers and the Climbing fibers.
- The mossy fibers are the fibers that enter the cerebellum from multiple sources.
- The only source of climbing fibers is INFERIOR OLIVARY NUCLEUS in the medulla oblongata.
- Parallel nerve fibers of the granule cells.

The output from the functional unit is from a DEEP NUCLEAR CELL.
A Functional Unit of the Cerebellum
Excitation of the Purkinje fibres by the Climbing fibres & the Mossy fibres

• **Complex spike**
  - An initial large amplitude spike followed by a high-frequency burst of smaller amplitude action potential
  - Evoked by *climbing fibers*

• **Simple spike**
  - A brief excitatory postsynaptic potential that generates a single action potential
  - Evoked by *parallel fibers*
POINTS TO REMEMBER!

• The Purkinje cells & the Deep Nuclear cells fire continuously under normal resting conditions.

• Direct stimulation of the Deep Nuclear cells by both the climbing and mossy fibers excites them while signals arriving from the Purkinje cells inhibits them.

• The balance between the 02 effects is that under resting conditions, output from the Deep Nuclear cell remains relatively constant at a moderate level of continuous stimulation.

• Basket cells & stellate cells in the molecular layer provide sharpening of the signals by causing Lateral inhibition of Purkinje cells.
In performance of a motor movement, there is initial excitation of the deep nuclear cells followed by feedback inhibitory signals from the Purkinje cells.

Thus, first the motor movement is enhanced and then the delay-line negative feedback which provides a “damping effect”,

Otherwise, oscillation of the movements would occur.
Cerebellum, thus, plays an important role in Turn-on/Turn-off & Turn-off/Turn-on signals for the Agonist and Antagonistic muscles.

Purkinje cells and their regulation by the mossy fibres plays a very important role.
The Purkinje cells “learn” to correct motor errors- Role of the Climbing Fibers
FUNCTIONAL AREAS OF THE CEREBELLMU & their significance

There are 3 functional areas:
1. Vestibulocerebellum
2. Spinocerebellum
3. Cerebrocerebellum
Anticipatory correction of Postural Motor Signals during rapid motion, including rapidly changing direction.
Motor Cortex + Red Nucleus

Corticoponto-cerebellar tract

Corticospinal Tract

Anterior Motor Neuron in Spinal Cord (Efference Copy)

Spinocerebellar Tracts

Proprioceptive signals from Muscle spindle & the Golgi Tendon Organs

SPINOCEREBELLUM (COMPARATOR)

Purkinje + Inf. Olive

Providing the Damping System for motor control

Cerebellar Damage causes:
1. Overshoot & Intention Tremor
2. Loss of automatism of ballistic movements
1. Planning of Sequential Movements *(WHAT WILL HAPPEN?)*
   1. Timing function of the Sequential movements *(WHEN WILL IT HAPPEN?)*

Interprets & Predicts rapidly changing SPATIOTEMPORAL relations (Auditory & Visual) by providing a “time-base”
What are the functions of Cerebellum?

Cerebellum may act as a feedback control system for slow movements and a feedforward controller for fast movements.
Functions of Cerebellum

1. Regulates **tone, posture and equilibrium**.
2. **Integration & regulation** of well co-ordinated muscle movements.
3. **Damping action**: prevents exaggerated muscle activity, leading to smooth and accurate voluntary movements.
4. Control of **Ballistic movements** and their learning, such as typing, cycling, dancing etc.
5. **Timing and programming** of the various sequential movements.
6. **Correction** of any disturbance while performing the skilled movements.
7. **Comparator** function: compares the information received from the cerebral cortex and the proprioceptors and then corrects or modifies the signals to the muscles so that the movements become accurate, smooth and precise.
What will happen if the Cerebellum is damaged?

After as much as one half of the lateral cerebellar cortex on one side of the brain has been removed, if the deep cerebellar nuclei are not removed along with the cortex, the motor functions of the animal appear to be almost normal as long as the animal performs all movements slowly.

Also, Cerebellar dysfunction is characterized by a lack of movement coordination.
Patients with Cerebellar damage suffer from balance disorders, & often develop postural strategies to compensate e.g. a wide based stance.
4 signs of Cerebellar Dysfunction

- Intention Tremors
- Ataxia
- Hypotonia
- Dysmetria
• **Dysdiadochokinesia**: is the impaired ability to perform rapid, alternating movements.

• **Cerebellar Ataxia**: means clumsiness & disorderliness of movement without significant weakness.

• **Asynergia**: lack of co-ordination b/w different groups of muscles such as agonists and antagonistics.

• **Dysmetria & Past Pointing**: when arm reaches out, it overshoots (overshooting).

• **Intention tremors**: Tremors that occur while trying to do any voluntary act.

• **Dysarthria**: means difficult or unclear articulation of speech that is otherwise linguistically normal.

• **Nystagmus**: intention tremor of the eye muscles.

• **Hypotonia**: due to loss of cerebellar facilitation of the motor cortex and brainstem.
Cerebellar vs Sensory Ataxia

- **Cerebellar ataxia**: is due to disorders of the cerebellar system. Dysfunction leads to clumsiness and unsteadiness, which, if it affects walking or gait, is termed cerebellar ataxia. A person with cerebellar ataxia will walk like a drunk person would, with a wide stepping gait. This is usually due to damage to the vermis of the cerebellum.

- **Sensory ataxia**: Joint position sense is affected and thus the brain can not sense the position of the joints of the body. Thus, when the motor cortex makes an action plan, it over-compensates for the assumed joint position. When this affects walking, this is called sensory ataxia. For example, if the joint position sense from the lower limbs is affected, the motor cortex instructs the lower limbs to rise much higher than normal to clear the ground while walking, leading to a high stepping gait. The “posterior column system” subserves joint position sense and damage to this system leads to sensory ataxia.
Sensory Ataxia