NERVOUS SYSTEM
BLOCK

19th Lecture

Physiology of cerebellum

PHYSIOLOGY TEAM – 430

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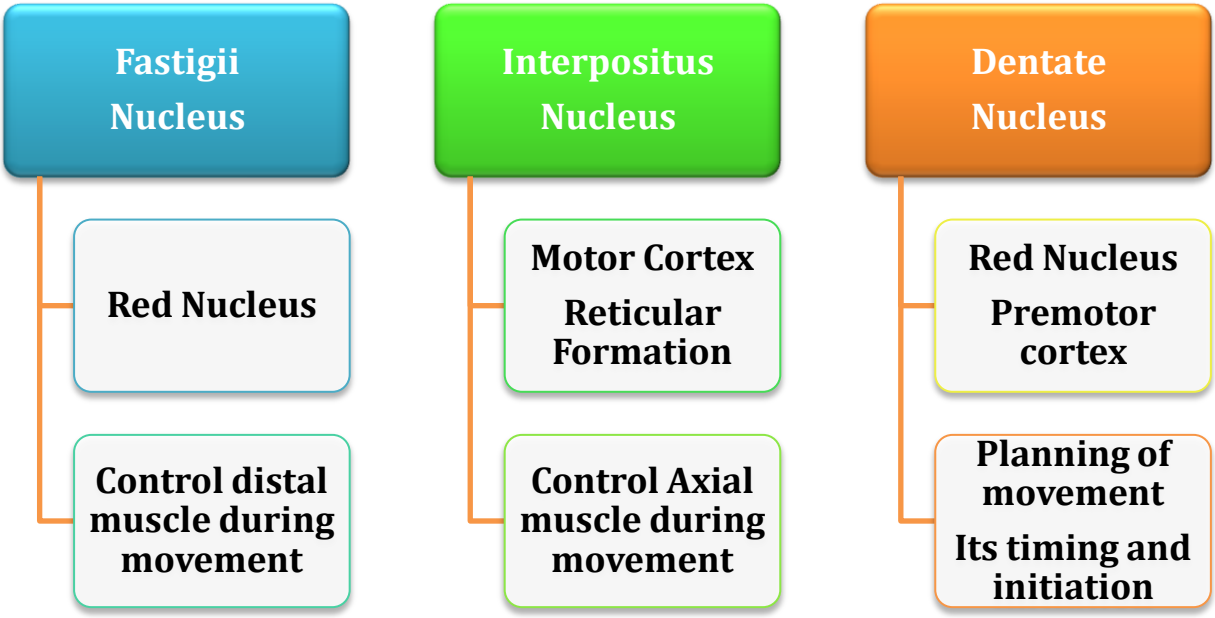
The physiology of Cerebellum

- **The Deep Cerebellar Nuclei are:**

1. **Fastigial** nucleus
2. Interposed (**Globosenucleus** and **Emboliformnucleus**)
3. **Dentate** nucleus

- **Output of deep cerebellar nuclei :**



Axial muscle: Any of the skeletal muscles of the trunk or head.

Distal muscle: Any of the skeletal muscles of the lower part of both of the limbs.

- **Vestibulocochlear (8th) nerve**

Conducts hearing (audition) and balance (vestibular).

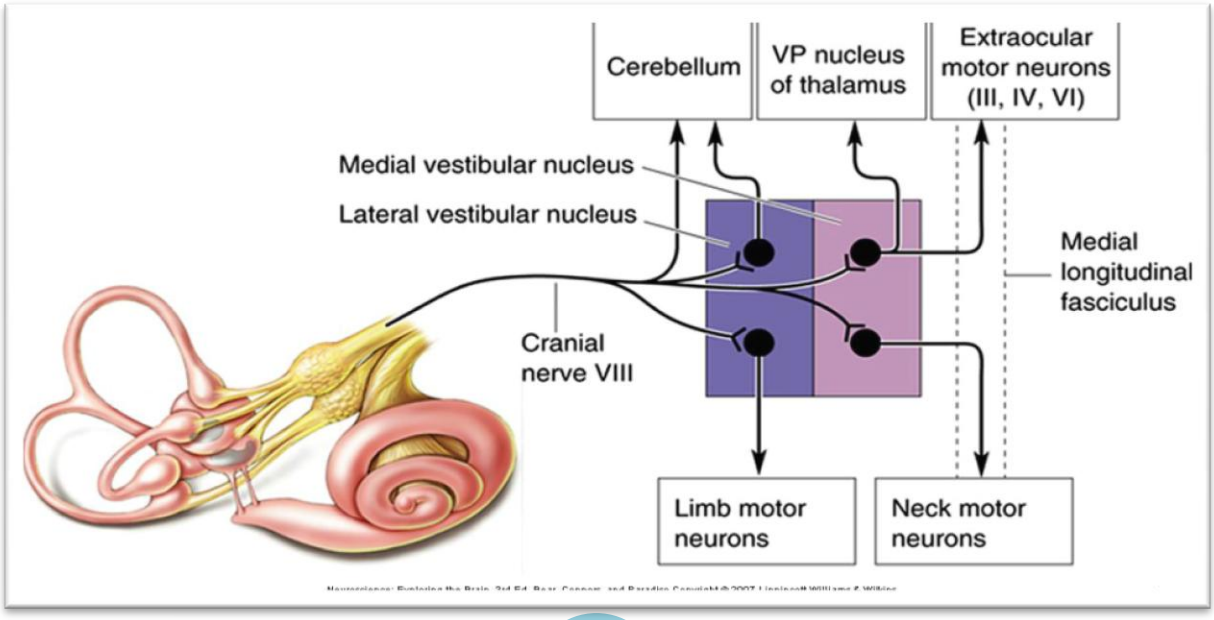
The receptor cells are located in the membranous labyrinth.

Two specialized organs in the bony labyrinth:
1- cochlea 2- vestibular apparatus.

The vestibular apparatus senses head position changes relative to gravity.

– Movement causes fluid vibration resulting in hair cell displacement that activates the vestibular part of the eighth nerve.

The receptor cells are located in the membranous labyrinth which is embedded in the petrous part of the temporal bone.



Vestibular nuclei establish connections with other regions for:

- The control of **posture**
- Maintenance of **equilibrium**
- Coordination of the **head & eye movements** and the awareness of the vestibular stimulation.
- Fibers from the vestibular nuclei contribute to the **Medial & lateral vestibulospinal tracts.**
- **Vestibulospinal fibers** influence the activity of the **spinal motor neurons** concerned with the **control of body posture and balance**.
- Control of **head and eye movements**.
- Some fibers from the vestibular nuclei pass through the **ICP** to the **folliculonodularlobe** which is concerned with **equilibrium**.
- Other fibers project to **thalamus** then to the **cortical regions** responsible for conscious awareness of **vestibular sensations**.

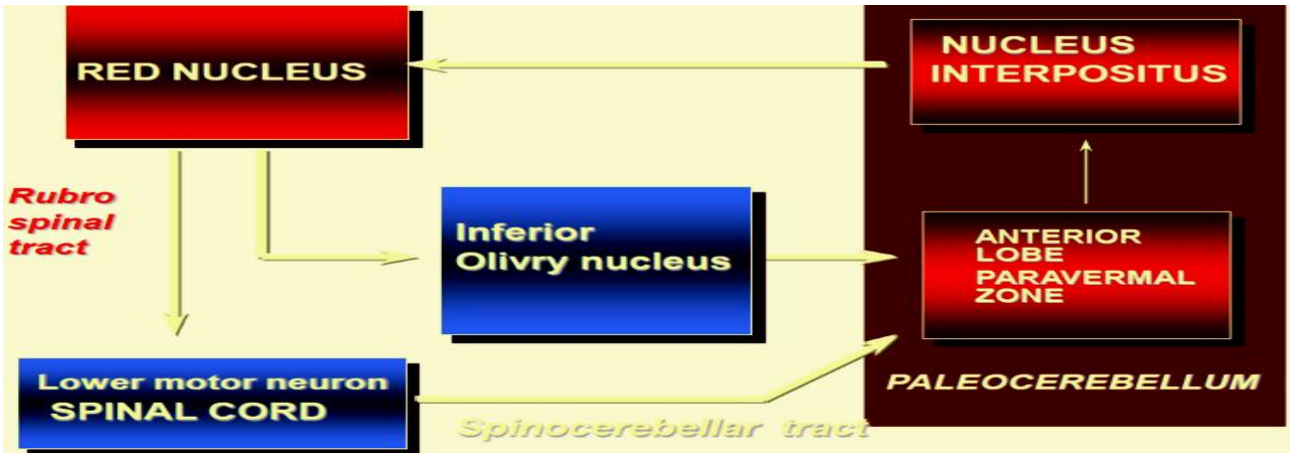
Acoustic Neuroma:

- **Benign tumour** of 8thCN leads to compression of it & adjacent structures.
- **Attacks of Dizziness** accompanied by profound deafness.
- **Ataxia,** paralysis of the cranial nerves V-VII and limbs.
- It occurs either **unilaterally or bilaterally** in an **inherited disease** called **neurofibromatosis**

Functions of Cerebellum:

- The CB is called the **silent area**, because its stimulation does not give rise to any sensation and cause almost no motor movements.
- It is important in the precise execution of rapid muscular movements. Damage to the CB cause almost total incoordination of muscular movements, although the muscles are not paralyzed.
- The cerebellum is concerned only with subconscious control of motor activity, and its functions as well as the involved part include the following:

1. Main Connections of the Paleocerebellum :



- **Functions** of The anterior lobe: Paleocerebellum [Spinocerebellum] :

– It's concerned with **regulation of muscle tone**

– **How it works?**

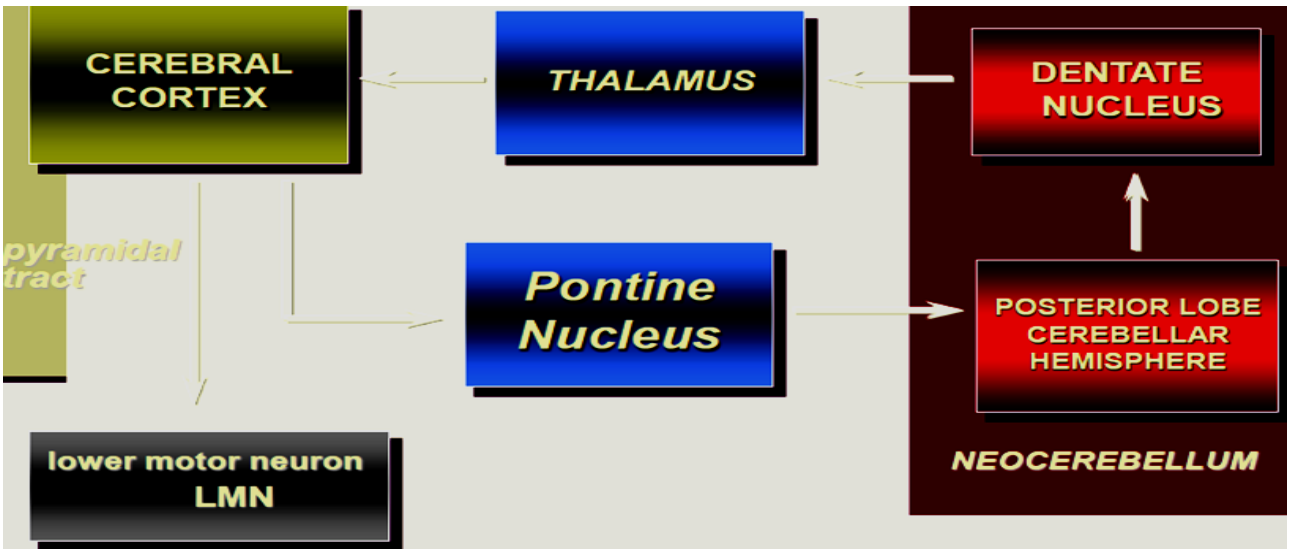
It receives inputs from muscle stretch receptors via a distinctive structure in the medulla known as the inferior olive.
The inferior olive also receives inputs from a number of midbrain nuclei such as superior colliculus and the red nucleus.
The inferior olive sends outputs to the cerebellum through the inferior cerebellar peduncle.

It also receives a copy of the "Motor Plan" from the motor cortex, therefore by comparing plan with performance, it acts as a "comparator" and sends impulses back to the cortex to correct movement thereby it coordinates & smoothes ongoing body movements.

2. Control of stretch reflex:

– The **cerebrocerebellum** exerts a **facilitatory effect on the stretch reflex** & **increases** the muscle tone, while;
– The **spinocerebellum** probably exerts **an inhibitory effect**.
– However, **normally the facilitatory effect predominates**(so cerebellar disease often results in **hypotonia**).

3. MAIN CONNECTIONS OF THE NEOCEREBELLUM



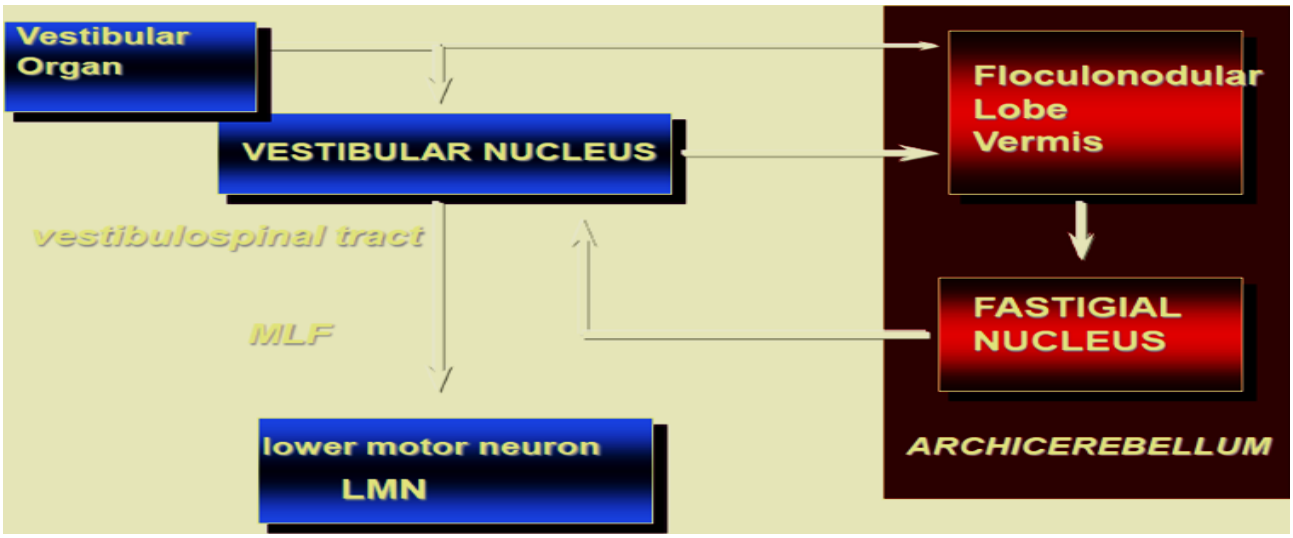
- **Functions** (The posterior lobe / Neocerebellum [Cerebrocerebellum]):
  - It coordinates movements particularly of **the distal limb muscles (hand)** which are employed in skilful movement.
  - **How it works?**

It receives inputs from the cerebral cortex via the pontine nuclei in the base of the pon.
Axons from the pontine nuclei enter the cerebellum through the middle cerebellar peduncles.
The major output tract of the cerebellum is the superior cerebellar peduncle, which primarily sends signals to the motor cortex and the supplementary motor area.
The Neocerebellum is involved in conjucation of the cerebral cortex on planning and execution of voluntary body movements.

N.B:

- Each cerebellar hemisphere **is connected by efferent and afferent pathways to the contra lateral cerebral cortex(the cortico–ponto-crebello-dentato-thalamo-cortical circuit).**
- The cerebellum exerts its effects on the **same side** of the body.
- **The vermis controls muscle movements of the axial body, neck, shoulders and hips.**
- **The intermediate zones controls muscle contractions in the distal portions of both the upper and lower limbs** (especially the hands, fingers, feet and toes).
- **The lateral zones help in the planning of sequential movements.**

4. MAIN CONNECTIONS OF THE VESTBULOCEREBELLUM

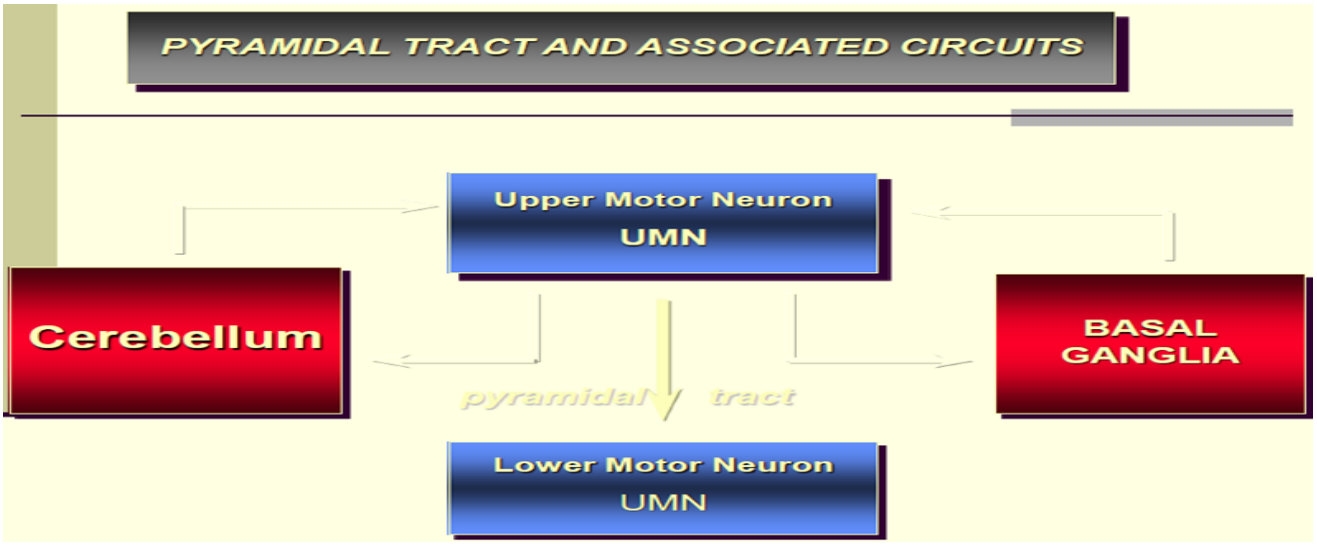


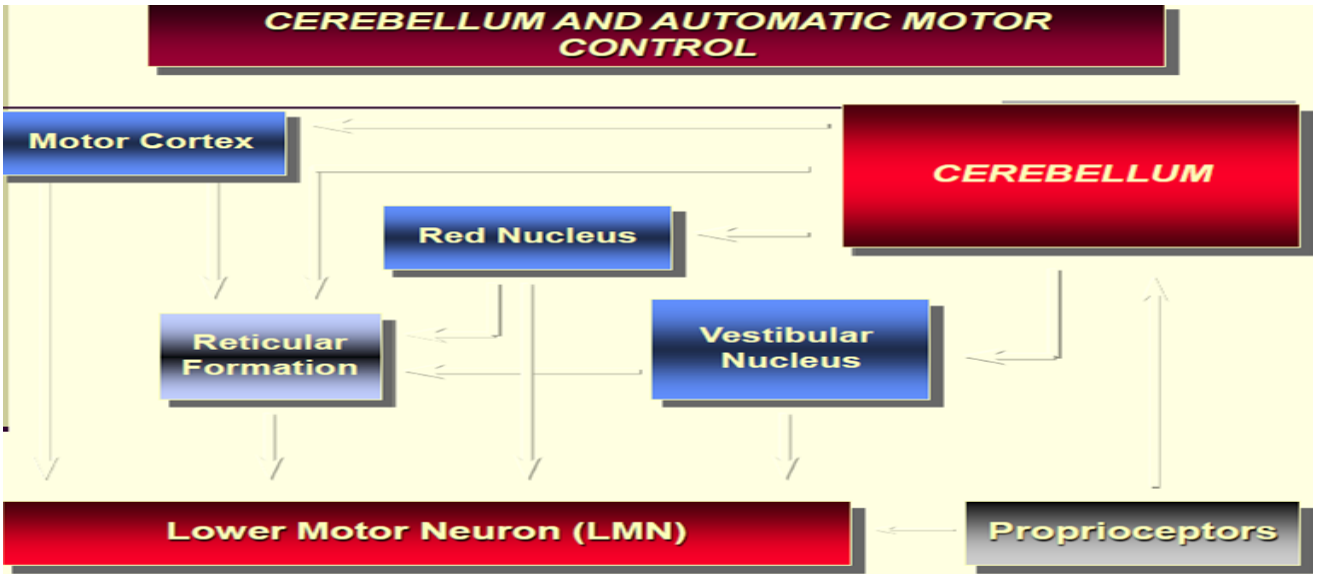
- **Function**
  (Floculonodularlobe/Archicerebellum [Vestibulocerebellum]) :

The archicerebellum is the oldest part of the cerebellum from an evolutionary point of view.

– It has connections to the vestibular nuclei and it is part of the vestibular system concerned with balance and equilibrium.
– **Control of equilibrium & postural movements**
– **How it works?**

It receives information from the vestibular apparatus then through the fastigal nucleus, it discharges to the brain stem, and through the vestibulospinal and reticulospinal tracts.
It controls equilibrium & postural movements by affecting the activity of the axial muscles (trunk & girdle muscles).





Lesions of the Vestibulocerebellum:

***Due to a tumor called <u>"Medulloblastoma"</u>**

Cause "Trunk Ataxia" which is characterized by:

- **<u>Equilibrium disturbances</u>**:
  the patient sways on standing,can not maintain the erect posture, needs support, and walks by a staggering or drunken gait.

- Lesions of the vestibulocerebellumal so **clearly illustrate the role of the cerebellum in learning normally the vestibulococular reflex results in the eye moving in the opposite direction to rotation of the head.**

- Patients with vestibulocerebellar lesions, however, **are unable to adapt to the input and the original reflex is maintained,** even though it is now inappropriate and they have Nystagmus.

5. Cerebellum controls voluntary functions through:

- **The braking and damping function of the cerebellum :**
  To not by pass the intended point, the CB must act to inhibit the motor cortex at the appropriate time after the muscles have begun to move. Thus brakes are applied to stop the movement at the precise intended point and prevent overshooting (by contraction of the antagonistic muscles).
- **The control of ballistic movements:**
  Movements of the fingers in typing, piano playing, movement of the eyes while reading.

6. The planning, predictive and timing function of the cerebellum:

The 2 way connection between the cerebral cortex and the cerebrocerebellum enables the latter to display the plan of the next move ment at the same time to present movement is occurring. It predicts how far the movement will go in a given time,and provides appropriate timing for each succeeding movement….Such function determine when the next movement should begin.

Such predictive function is necessary for:
A-smooth transition from one movement to the next
B-Joining of sequential movements (which prevent decomposition of movements).

7. Other functions of the cerebellum:

The CB co-ordinates involuntary postural movements initiated by extra-pyramidal system by acting as a comparator (in the same way as involuntary movement) and correcting errors so movements do not over shoot.

Defects produced by cerebellar lesions in humans:

(The neocerebellar syndrome)

This is due to **damage** of the **deep cerebellar nuclei** as well as **the cerebellar cortex;**

The **manifestations** occur **on the same side of the lesion (ipsilatteral)** i.e a lesion of the left cerebellar hemisphere produces its effects on the left side of the body .,etc.

Bilateral dysfunction of the cerebellum is caused by Alcoholic intoxication, hypothyroidism, inherited cerebellar degeneration (ataxia), multiple sclerosis or non-metastatic disease.

Ataxia

This is incoordination of voluntary movements. It is either sensory or motor (or mixed).
Motor ataxia: This is due to defect in the coordination of the voluntary movements.
It commonly occur in lesions of either:
a-The cerebellum or spinocerebellartracts

b-The labyrinth (vestibular apparatus)

c-The cortical motor areas.

Manifestations of Neocerebellar syndrome:

A) **Hypotonia:** due to loss of the facillitatory effect of the CB on the stretch reflex, and it is associated with pendular knee jerk.

b) **Athenia:** (muscle weakness): This is due to difficulty in initiation and maintenance of muscle contraction secondary to loss of the potentiating signals by the mossy fiber circuit.

c) **Motor ataxia:** This is incoordination of the voluntary movements, specially the rapid movements (becoming abnormal in rate, range, force and direction).

Manifestations of motor ataxia:

1-Dysmetria: Inability to control the distance of the motor act, which may either overshoot the intended point (=hypermetria or past pointing) or stop before it. It is due to lack of the damping, prediction and timing functions of the cerebellum.

2-Kinetic (intension, action or terminal) tremors

*This an oscillatory movement that appears on performing a voluntary movement (especially at its end) but is absent at rest, and it can be demonstrated by the finger nose test. It occurs secondary to dysmetria and is due to a series of subconscious correction of the over shoot followed by over shoot of the correcting movements.

3-Rebound phenomenon: This is over shooting of a limb when a resistance to its movement is suddenly removed. (loss of the braking function of the CB),(the arm pulling or flexion)test

4-Asynergia: This is loss of the harmony between the three groups of muscles involved in performance of voluntary movement the agonists, protagonists, and antagonists).

5-Failure of progression of movements: manifested by:

a-Adidokokinesia(=dysdiadokokinesia)
Inability to perform alternate (opposite)movements successively at a rapidrate e.g pronation and supination of the forearm or upward and downward movement the hand.
b-Decomposition (fragmentation of movements): inability to perform actions involving simultaneous movements at more than one joint.

***6-Dysartheria*:**
This is difficulty inproducing clear speech. It is due to incoordination of the speech muscles secondary to loss of the predictive functions of the CB. The syllables maybe

too long or too short ,loud or weak and speech maybe also staccato or scanning i.e cut off into separate syllables.

7-Nystagmus:
This is tremor of the eyeballs that occurs on looking to an object placed at one side of the head. (mainly in archicerebellar damage) Nystagmusis a very common feature of multiple sclerosis).

8-Staggering (drunken) gait:
The patient walks unsteady –on a wide base (*zigzag-like gait*) in a *drunken* (swaying) manner, and tends to fall on the diseased side. Such gait is more apparent with archicerebellar damage.

SUMMARY: FUNCTIONS OF CEREBELLUM

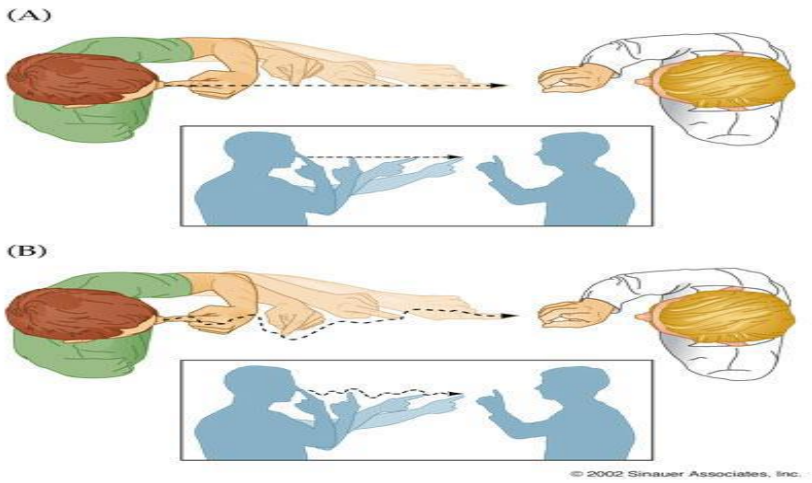
Cerebellum Lobe	**Paleocerebellum**	**Neocerebellum**	**Archicerebellum**
Deep Nuclei	Archicerebellum	Dentate	Fastigial
Cortex	Vermis & Medial portions of Cerebellar hemispheres	Lateral portions of Cerebellar Hemisphere	Corticopontine/pontocerebellar
Inputs	Spinal and brainstem paths	Flocculonodular	Vestibular nuclei
Outputs	SCP to Red Nucleus; Fastigial to RF	SCP	Vestibular nuclei; RF
Function	Muscle tone, posture & coordination of movements	Planning and executive of voluntary & skilled hand movements	Balance, equilibrium & VOR

CLINICAL FEATURES / TESTS RELATED TO CEREBELLUM

	Reeling, wide-based gait
Decomposition of Movement	Inability to correctly sequence fine, coordinated acts
Dysarthria	Inability to articulate words correctly, with slurring and inappropriate phrasing
Dysdiadochokinesia	Inability to perform rapid alternating movements
Dysmetria	Inability to control range of movement
Hypotonia	Decreased muscle tone
Nystagmus	Involuntary, rapid oscillation of the eyeballs in a horizontal, vertical, or rotary direction, with the fast component maximal toward the side of the cerebellar lesion
Scanning speech	Slow enunciation with a tendency to hesitate at the beginning of a word or syllable
Tremor	1- Rhythmic, alternating, oscillatory movement of a limb as it approaches a target (intention tremor). 2- Proximal musculature when fixed posture or weight bearing is attempted (postural tremor)

- **Finger-Nose Test:**

  While the examiner holds his finger at arm's length from the patient. Patient touches her nose and then touches the examiner's finger. After several sequences, the patient is asked to repeat the exercise with her closed eyes. A patient with a cerebellar disorder tends to miss the target.



- **Heel-To-Shin Test:**
  The heel to shin test is a measure of coordination and may be abnormal if there is loss of motor strength, proprioception or a cerebellar lesion.
  If motor and sensory systems are intact, an abnormal, asymmetric heel to shin test is highly suggestive of an ipsilateral cerebellar lesion

- **Dysdiadochokinesis:**
  Inability to perform rapidly alternating movements.
  It is usually caused by multiple sclerosis in adults and cerebellar tumors in children. Patients with other movement disorders (e.g. Parkinson'sdisease) may have abnormal rapid alternating movement testing secondary to akinesia or rigidity, thus creating a false impression of dysdiadochokinesia.