Physiology Team 439

MED439
KING SAUD UNIVERSITY

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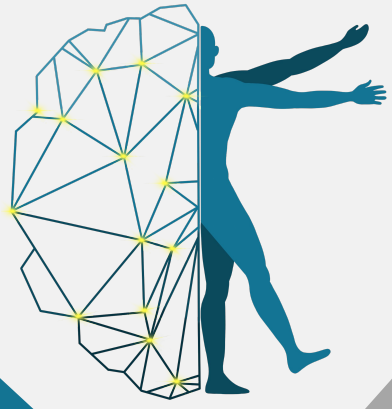


Physiology of Cerebellum

Objectives:

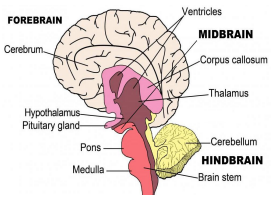
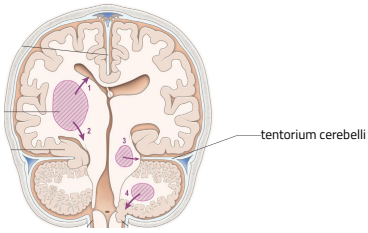
- Describe the functional divisions of the cerebellum; vestibulocerebellum, spinocerebellum and cerebrocerebellum.
- Define the physiological roles of the cerebellum in regulation of movement.
- Explain the abnormalities associated with cerebellar disease: e.g. Cerebellar nystagmus, changes in muscle tone, ataxia, drunken gait, scanning speech, dysmetria (past-pointing), intention tremors, rebound phenomenon and adiadochokinesia.

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

Editing File

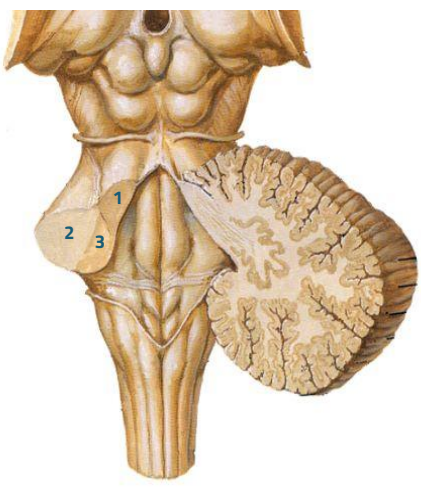
Cerebellum

Overview	- Cerebellum is derived from a Latin word means "little brain."* Cerebellum is the largest part of the hindbrain, lies behind the pons and medulla Oblongata.* - It occupies a prominent position beside the main sensory and motor systems in the brain stem.*	
Location	Posterior cranial fossa.*	
Shape	Oval, the largest part of hindbrain with an approximate weight 150 gm.*	
Relations	**Anteriorly**: 4th ventricle, pons, and medulla oblongata*	
	Superiorily: Covered by tentorium cerebelli* extension of the dura mater that lying between the cerebellum and the occipital lobes of the cerebrum and encircling the midbrain.	
	Posterio-inferiorly: Squamous occipital* part of occipital bone	

Cerebellar Peduncles:

It is connected to the brain stem by three cerebellar peduncles:
(**A**fferent fiber:input fiber to cerebellum and **E**fferent fiber:output fiber from cerebellum)

1. **Superior Cerebellar Peduncle**
   Inputs to the Cerebellum from the cerebrum*
2. **Middle Cerebellar Peduncle**
   Inputs to the Cerebellum from the Pons*
3. **Inferior Cerebellar Peduncle**
   Inputs to the Cerebellum from the Medulla Oblongata*



Cerebellar Divisions

- The anterior & posterior lobes on each side constitute **2 large cerebellar hemispheres**, which are separated by a narrow band called the **vermis.***
- **Guyton:** The flocculonodular lobe is the oldest of all portions of the cerebellum; it developed along with (and functions with) the vestibular system in controlling body equilibrium.

male slide only

Anatomically	Physiological	Functional
Anterior lobe	Paleocerebellum	Spinocerebellum
Posterior lobe	Neocerebellum	Cerebrocerebellum
Flocculonodular lobe	Archicerebellum	Vestibulocerebellum

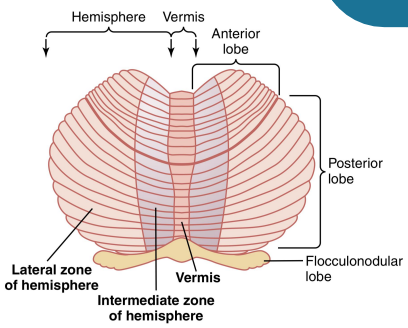
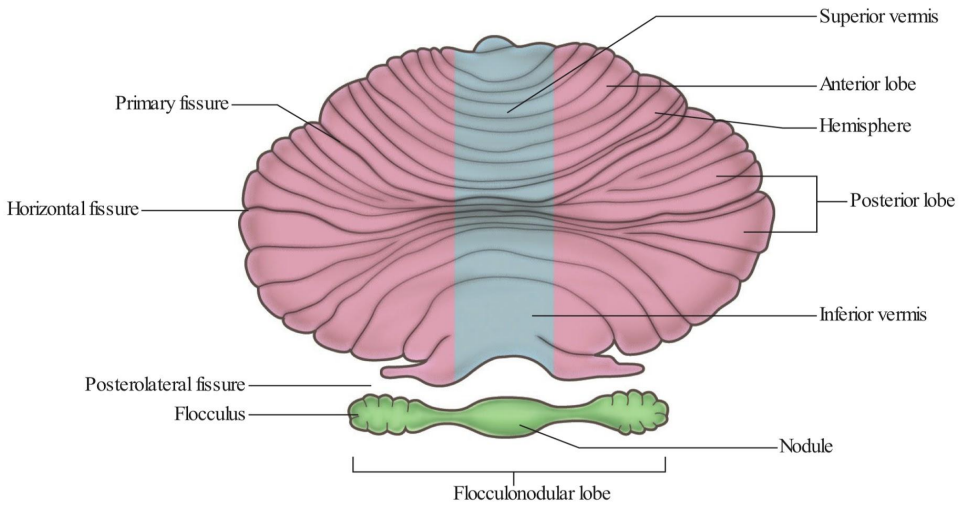


Figure 56-2 Functional parts of the cerebellum as seen from the posteroinferior view, with the inferiormost portion of the cerebellum rolled outward to flatten the surface.



Functional Divisions: Extra : Explanation for images in slides

- **Spinocerebellum**: Regulation of **muscle tone, coordination of skilled voluntary movement**. Receives proprioceptive input and copy of the motor plan from the motor cortex and sends impulse to medial and lateral descending system for motor execution. **Guyton:** This consists of most of the vermis of the posterior and anterior cerebellum plus the adjacent intermediate zones on both sides of the vermis.

- **Cerebrocerebellum**, **planning and initiation of voluntary activity.** Interacts with motor and premotor cortices. **Guyton:** This consists of the large lateral zones of the cerebellar hemispheres, lateral to the intermediate zones.

- **Vestibulocerebellum**: **Maintenance of balance, control of eye movement.** Connects with vestibular nuclei. **Guyton:** This consists principally of the small flocculonodular cerebellar lobes that lie under the posterior cerebellum and adjacent portions of the vermis.

Structure and Connections of the cerebellum

Cells

Cortex nuclei

1. Purkinje cell.
2. Granule cell.
3. Basket cell.
4. Golgi cell.
5. Stellate cell.

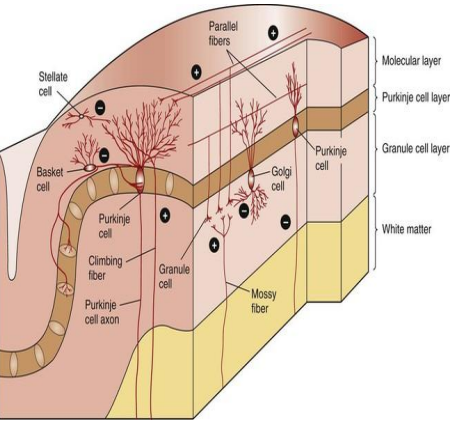
Fibers

1. Climbing fiber.
2. Mossy fiber.
3. Parallel fiber.

Nuclei

1. Inferior olivary nucleus.
2. Deep cerebellar nuclei.

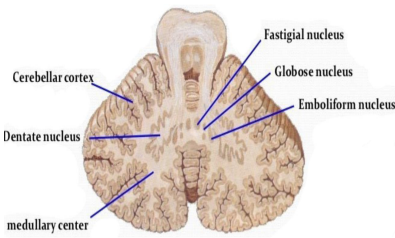
- The cortex is deeply infolded, giving a large surface area, and it contains five different cell types.*
- The cerebellum has an external cerebellar cortex (gray matter) separated by inner white matter =medulla from the deep cerebellar nuclei as follows:



cerebellar cortex		
Layer*	**Cells**	**Action**
Molecular Layer	Stellate cells (inhibitory Interneuron)	Release Taurine*, GABA (**Inhibition**)
	Basket cells (inhibitory Interneuron)	Release GABA (**Inhibition**)
Purkinje Cell Layer	Purkinje cells (**output cells**) inhibit the deep nuclear cells(DNCs). (its axons take feedback from cortex to deep nuclei, then deep nuclei give the efferents)	
Granular Layer	Golgi cells (inhibitory Interneuron)	
	Granular cells has $GABA_A$ receptors	Release Glutamate (**Excitation**)

Cerebellar nuclei (Deep nuclei in white matter):

- **D**entate Nucleus in cerebrocerebellum
- Interpositus nucleus in spinocerebellum
  - **E**mboliform Nucleus
  - **G**lobose Nucleus
- **F**astigial Nucleus in the spinocerebellum and vestibulocerebellum



From lateral to medial
"**D**on't **E**at **G**reasy **F**ood "

- All afferent fibers (have specific target cell) relay first at the deep nuclei and the cerebellar cortex, then the latter discharges to the deep nuclei, from which the efferent fibers originate and leave the CB.*

Afferent (input) pathway*

- The CB **receives both sensory** and **motor information** through a rich afferent nerve supply.
- This arises from : 1-Other areas of the brain 2-Peripheral receptors.

and **enters the CB via the 3 cerebellar peduncles.**

Types of Afferent Fibers

Climbing fibers	Mossy fibers
From the Inferior olivary nucleus	From all other afferents that enter the cerebellum + some fibers coming from the inferior olivary nucleus (So they are greater than climbing fibers)
It learns the cerebellum to **perform new patterns of movements precisely** movement skills لتعلم اي	**Help the precise execution** (التنفيذ الدقيق) **of the voluntary movements** (concerning their initiation, duration and termination), which occurs by controlling the turn on and turn off output signals from the cerebellum to the muscles.
They synapses with only one Purkinje cell.	They synapses with Granule cells, which in turn affect many Purkinje cells.
They both give of afferent fibers to to deep cerebellar nuclei, which are excitatory.	

PRINCIPAL AFFERENT TRACTS TO THE CEREBELLUM*

AFFERENT TRACTS	TRANSMITS
Vestibulocerebellar	Vestibular impulses from labyrinths, direct & via vestibular nuclei
Dorsal Spinocerebellar	Prorioceptive & exteroceptive impulses from the body
Ventral Spinocerebellar	Prorioceptive & exteroceptive impulses from the body
Cuneocerebellar	Prorioceptive impulses, especially from the head and neck
Tectocerebellar	Auditory & visual impulses via inferior and superior colliculi
Pontocerebellar	Impulses from motor and other parts of cerebral cortex via pontine nuclei
Olivocerebellar	Proprioceptive input from whole body via relay in inferior olive

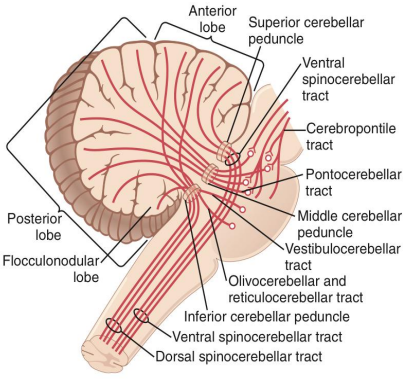


Figure 57-4. Principal *afferent* tracts to the cerebellum.

Efferent (output) pathway*

- There are 3 main efferent pathways from the 3 parts of the CB .
- the axons of the 3 deep nuclei, Leave the CB through the **superior and inferior** peduncles (only two)

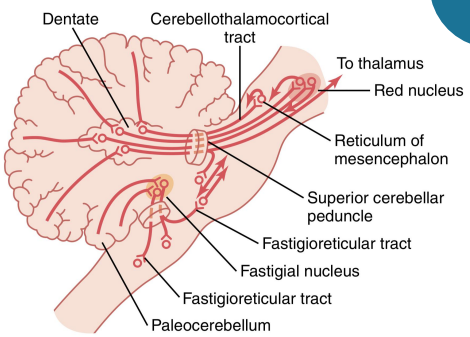


Figure 56-6 Principal *efferent* tracts from the cerebellum.

The Rule of 3*

3 lobes:	Floculonodular Lobe	Anterior lobe	Posterior lobe
3 Cortical Layers:	Molecular layer	Purkinje cell layer	Granular layer
3 purkinje's cells afferent paths:	Mossy fibers	Climbing fibers	Aminergic fibers
3 pairs of deep nuclei:	Fastigial	Interposed (globose & emboliform)	Dentate
3 pairs of peduncles:	Superior (pri.output)	Middle (pri.Input)	Inferior (pri.Input)
3 functional division:	Vestibulocerebellum	Spinocerebellum	Cerebrocerebellum

Functions of the cerebellum*

- **1.Maintenance of equilibrium.**
- **3. Coordination of the half-automatic movement** (like swinging of arms during walking) of walking and posture maintenance.
- **5. Motor Learning – Motor Skills.**
- **2. Balance, posture, eye movement** such as vestibulo ocular reflex**.**
- **4. Adjustment of muscle tone.**

- 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 :

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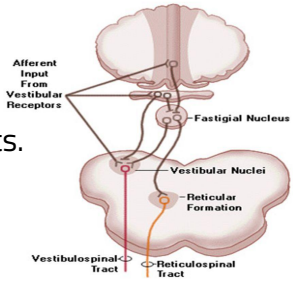
A Control of equilibrium & postural movements:

The function of the vestibulocerebellum.

1. It receives information from the **vestibular apparatus.**
2. Through the **fastigial nucleus** it discharges to the brain stem 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

- e.g Due to a tumor called **medulloblastoma**. (commonly in children)
- Leads to **trunk ataxia** which is characterized by **Equilibrium disturbances**: the patient sways on standing, cannot maintain the erect posture, needs support, and walks by a staggering or drunken gait and have nystagmus (tremor of eyeball).

Cont. FUNCTIONS OF THE CEREBELLUM*

B Control of the Stretch Reflex:

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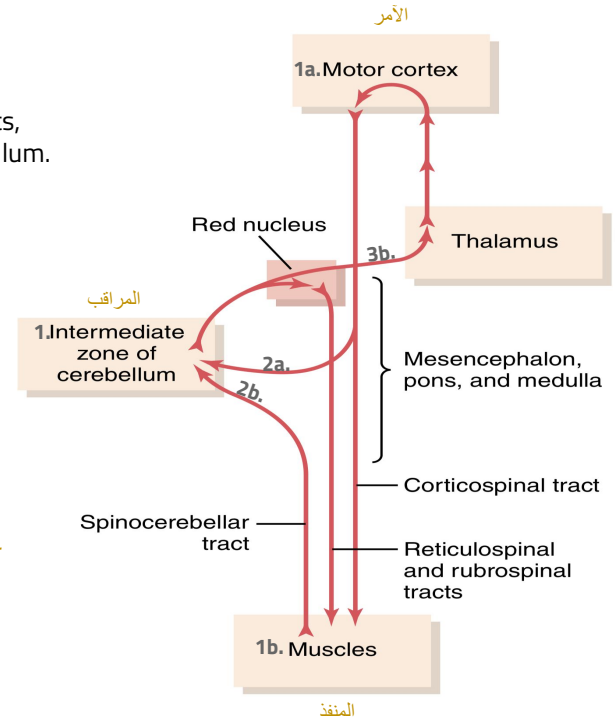
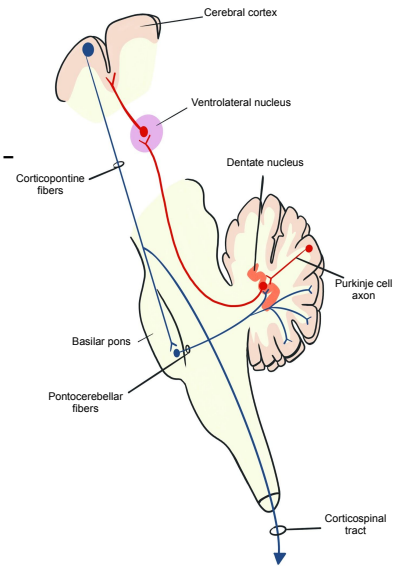
- The **cerebrocerebellum** exerts a **facilitatory** effect on the stretch reflex and increases the muscle tone.
- The **spinocerebellum** probably exerts an **inhibitory** effect.
- **Normally the facilitatory effect predominates** (so cerebellar diseases often result in hypotonia).

C Control of voluntary movements:

- Cerebral and cerebellar control of voluntary movements, involving especially the intermediate zone of the cerebellum.



1. The intermediate zone of cerebellum/ spinocerebellum connected with:
   - **1a**. with the **motor cortex** which is the origin of the motor order.
   - **1b**. the **muscles** to perform the voluntary movement
2. The descending tracts or the corticospinal tracts going down to the muscle give **branch to the spinocerebellum (2a) to copy the order**, also the **muscle send a copy (2b) of its preforms.**
3. Then the spinocerebellum compare between the order and the performance:
   - **3a**. If everything is ok, the discharge will remain the same to the red nucleus and muscle work will not change.
   - **3b**. If the performance is low it will increase the discharge through the thalamus and vice versa.



- Each cerebellar hemisphere is connected by efferent and afferent pathways to the **contralateral cerebral cortex** (the cortico –ponto-crebello-dentato- thalamo- cortical circuit).*

The **cerebellum exerts its effects on the samenside** of the body:

1. **The vermis** controls muscle movements of the **axial** body, neck, shoulders and hips.
2. **The intermediate zones** controls muscle contractions in the distal portions of both the upper and lower limbs (especially the hands, fingers, feet and toes).
3. **The lateral zones** help in the planning of sequential movements.

Summary: FUNCTIONS OF THE CEREBELLUM*

Cerebellum lobe	Paleocerebellum (Spinocerebellum)	Neocerebellum (Cerebrocerebellum)	Archicerebellum (Vestibulocerebellum)
Nuclei	Interposed; Fastigial	Dentate	Fastigial
Cortex	Vermis & Medial portions of Cerebellar hemispheres (paravemis)	Lateral portions of Cerebellar Hemisphere	Flocculonodular
Input	Spinal and brainstem paths	Corticopontine/pontocerebellar	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 & skilledhand movements	Balance, equilibrium

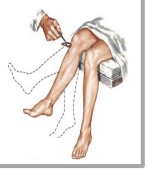
Defects produced by cerebellar lesions in humans*

1-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 (ipsilateral) i.e. a lesion of the left cerebellar hemisphere produces its effects on the left side of the body.
- Bilateral dysfunction of the cerebellum is caused by alcoholic intoxication, hypothyroidism, inherited cerebellar degeneration (ataxia), multiple sclerosis or non metastatic disease.
- **Manifestations**:

1

Hypotonia:
(Decreased muscle tone*)
Due to loss of the facilitatory effect of the cerebellum on the stretch reflex, and it is associated with **pendular knee jerk.**



2

Asthenia (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.

3

Motor ataxia:
Incoordination of the voluntary movements, specially the rapid movements (becoming abnormal in rate, range, force and direction).

Posture Gait – Ataxia Tremor

The Neocerebellar patient will have Ataxic gait.

Left cerebellar tumor

Ataxic gait and position:

- Sways (يتأرجح) to the left in standing position.
- Steady on the right leg.
- Unsteady on the left leg.
- Ataxic gait.

cont. Defects produced by cerebellar lesions in humans*

2- Ataxia:

- ❖ This is incoordination of voluntary movements. (especially rapid movement, will not be precise)
- ❖ It is either sensory or motor (or mixed).
- ❖ Reeling, wide-based gait.*

Motor ataxia: Is due to defect in the coordination of the voluntary movements. It commonly occur in lesions of The cerebellum or spinocerebellar tracts.

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.

2

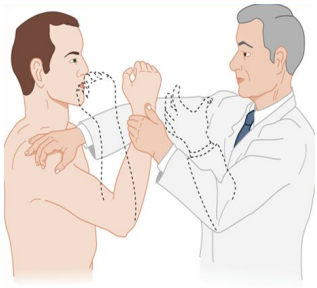
Kinetic (intension, action or terminal) tremors:

- It appears on performing a voluntary movement (especially at its end) but is absent at rest.
- Demonstrated by the **finger nose test.**
- It is secondary to **dysmetria**.

3

Rebound Phenomenon:

Overshooting 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- **Adiadokokinesia (dysdiadokokinesia):** Inability to perform alternate (opposite) movements successively at a rapid rate, 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.

Cont. Manifestations of Motor ataxia*

6

Dysartheria:

This is difficulty in producing clear speech. It is due to incoordination of the speech muscles secondary to loss of the predictive functions of the CB. The syllables may be too long or too short, loud or weak and speech may be 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 vestibulocerebellar damage**). Nystagmus is a very common feature of multiple sclerosis.

8

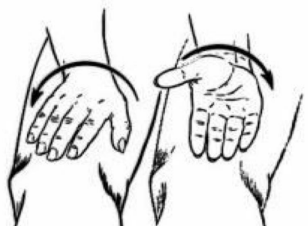
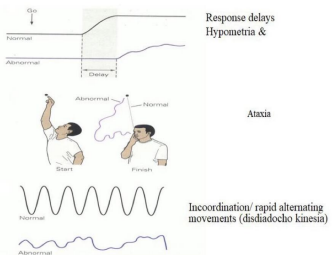
Staggering (drunken) gait:

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 vestibulocerebellar damage.

Abnormalities associated with cerebellar disease*

Disorder	Description
Ataxia	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
Tremors	Rhythmic, alternating, oscillatory movement of a limb as it approaches a target (intention tremor) or of proximal musculature when fixed posture or weight bearing is attempted (postural tremor)

TESTS RELATED TO CEREBELLUM*

Test	Description	Image
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.**	 Finger-to-nose test. Patient cannot direct finger accurately with eyes closed
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	Dysdiadochokinesis: Inability to perform rapidly alternating movements. Is called dysdiadochokinesia. It is usually caused by **multiple sclerosis in adults** and **cerebellar tumors in children**. Patients with other movement disorders (e.g. Parkinson's disease) may have abnormal rapid alternating movement testing secondary to akinesia or rigidity, thus creating a false impression of dysdiadochokinesia.	
Cerbellar signs	- Response delays Hypometria. - Ataxia. - Incoordination/ rapid alternating movements (disdiadocho kinesia).	

MCQ & SAQ:

Q1: What is the origin of climbing fiber ?

A. Vestibular nucleus.
B. Inferior olivary nucleus.
C. Red nucleus.
D. Trigeminal nucleus.

Q2: all the following are inhibitory cells except ?

A. Granule cells.
B. Purkinje cells.
C. Golgi Cells.
D. basket Cells.

Q3: The cerebellum receives afferent pathway via middle peduncle from ?

A. cerebrum.
B. Pons.
C. Medulla oblongata.
D. Spinal cord.

Q4: Control of equilibrium & postural movements is done by vestibulocerebellum through which nucleus?

A. Dentate nucleus.
B. Fastigal nucleus.
C. Interpositous nuclei.
D. Emboliform nucleus.

Q5: Which of the following is NOT one of the manifestations of neocerebellar syndrome:

A. Motor ataxia.
B. Asthenia.
C. Hypotonia.
D. Sensory ataxia.

Q6: Inability to perform rapid alternating movements?

A. Tremor.
B. Ataxia.
C. Dysdiadochokinesia.
D. Dysarthria.

answer key:
1: B
2: A
3: B
4: B
5: D
6: C

1. **What are the functions of cerebellum ?**
2. **List the functional divisions of the cerebellum and explain the function for each one of them?**
3. **List three manifestations of motor ataxia.**
4. **What are the functions of The vestibulocerebellum.**

A1: Page 8.

A2: Page 4.

A3: Page 12+13.

A4: Page 4.

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- Yara Alomar.
- Yara Alzahrani.
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