14

Physiology of cerebellum

PHYSIOLOGY
CNS BLOCK
TEAM 443

MED 443
King Saud University

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Color Index:

- Main text
- Important
- Girls Slides
- Boys Slides
- Notes
- Extra

Editing File

Objectives:

- Describe the divisions of the cerebellum
- Describe **the functional divisions** of the cerebellum; (vestibulocerebellum, spinocerebellum and cerebrocerebellum).
- Understand the cell types/ nuclei of the cerebellum
- Understand the functions of cerebellum in regulation of movement, tone and balance.
- 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.

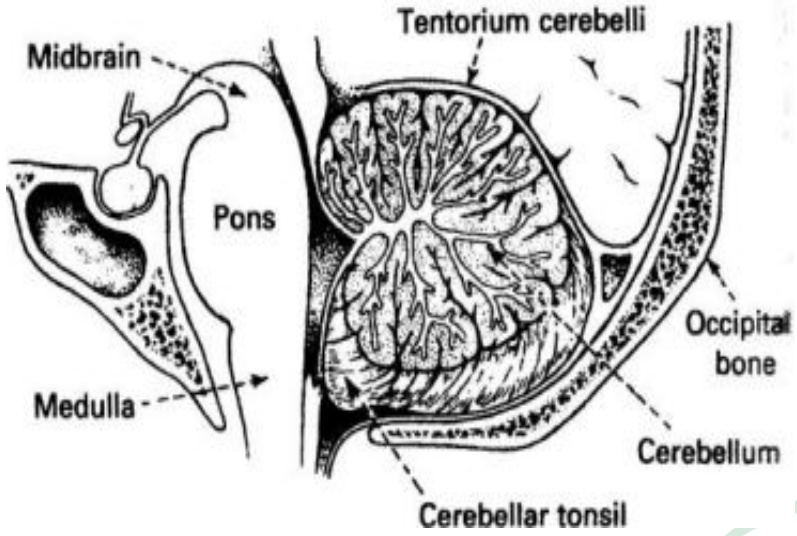
helpful video

Very recommended video
you should also study the anatomy before studying this lecture

Cerebellum

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.

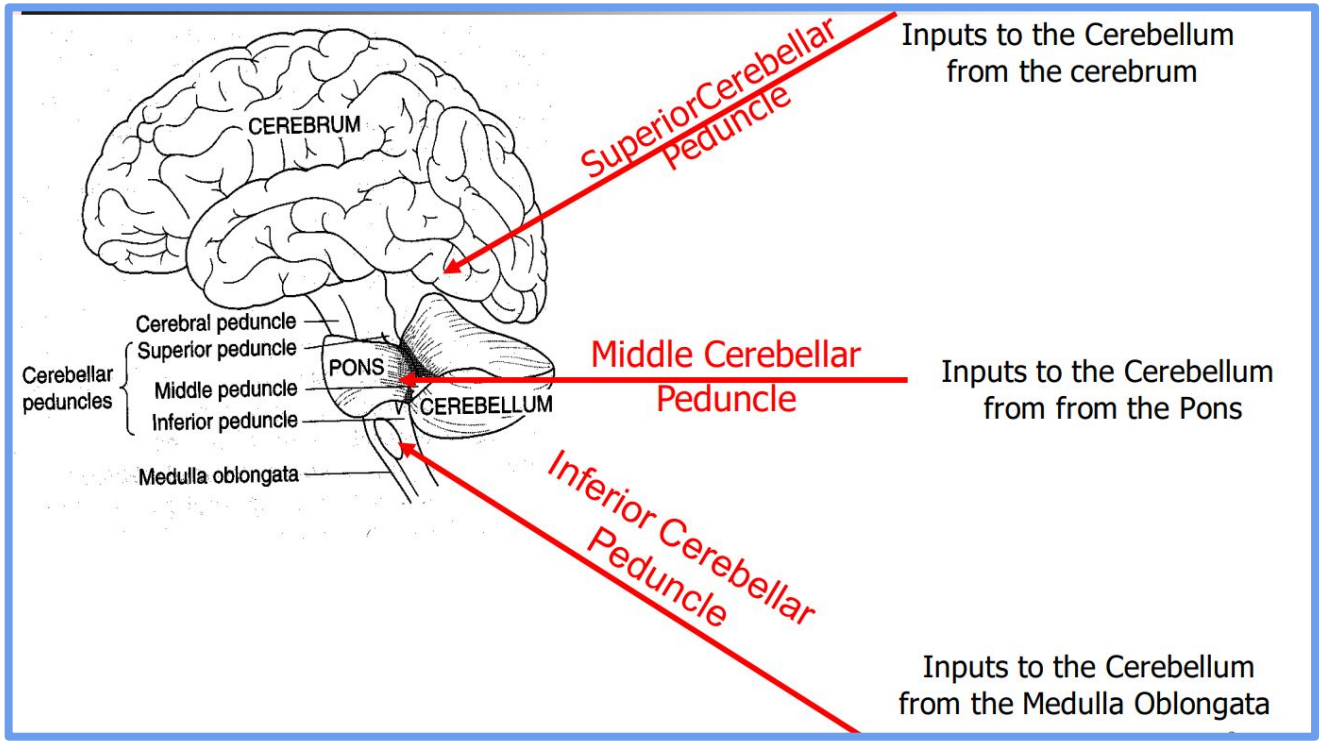
Shape	Oval shaped, weighs approximately 150g	
Location	Situated in the posterior cranial fossa	
Relations	Anteriorly	4th ventricle, pons, and medulla oblongata
	Superiorly	Covered by tentorium cerebelli (Extension of the dura mater)
	Posterio-inferiorly	Squamous occipital (part of occipital bone)



Cerebellar peduncles

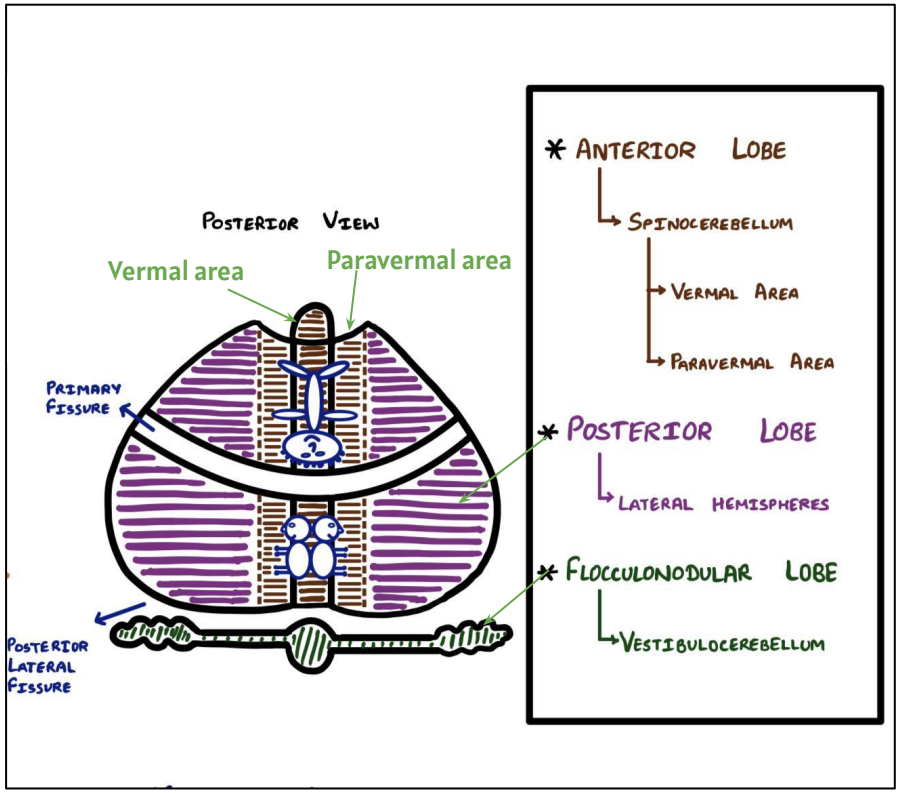
- It is connected to the brainstem by three cerebellar peduncles:
(bundle of fibers that connects the cerebellum to different areas)
- Various fibers enter and leave the cerebellum through these peduncles

1. Superior Cerebellar Peduncle
2. Middle Cerebellar Peduncle
3. Inferior Cerebellar Peduncle



Extra:functional anatomy

- Vermal area receives sensory information from the trunk, neck and most of the head
- Paravermal area receives sensory information from the limbs and the lateral head
- Contains the interposed nuclei : Globose nucleus,Emboliform nucleus
- Controls muscle tone and posture
- Spinocerebellum/Paleocerebellum



Cerebrocerebellum/Neocerebellum

- Found in the lateral hemispheres of the cerebellum
- Contains the dentate nucleus
- Co-ordinates muscles and plans future movements

Vestibulocerebellum/Archicerebellum

- Found in the floculonodular lobe
- Contains the fastigial nucleus
- Maintains balance

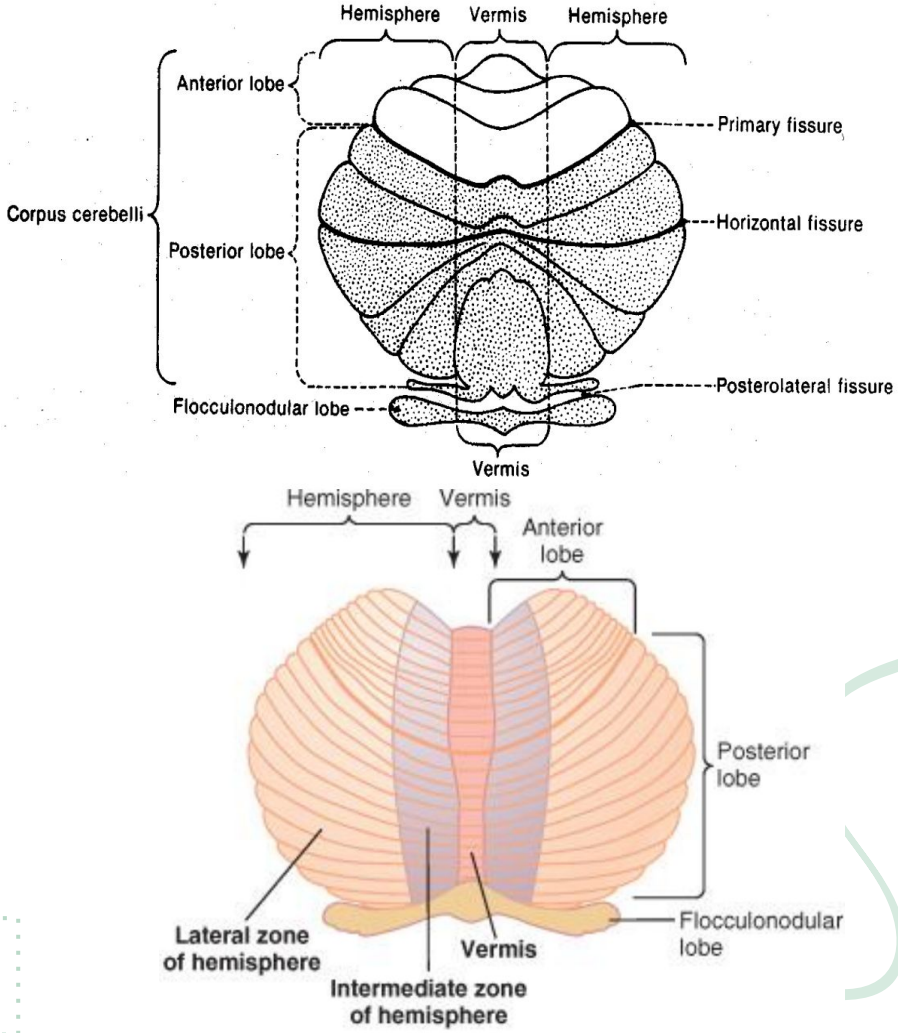
Cerebellar Divisions

The cerebellum is anatomically and physiologically divided into three parts:

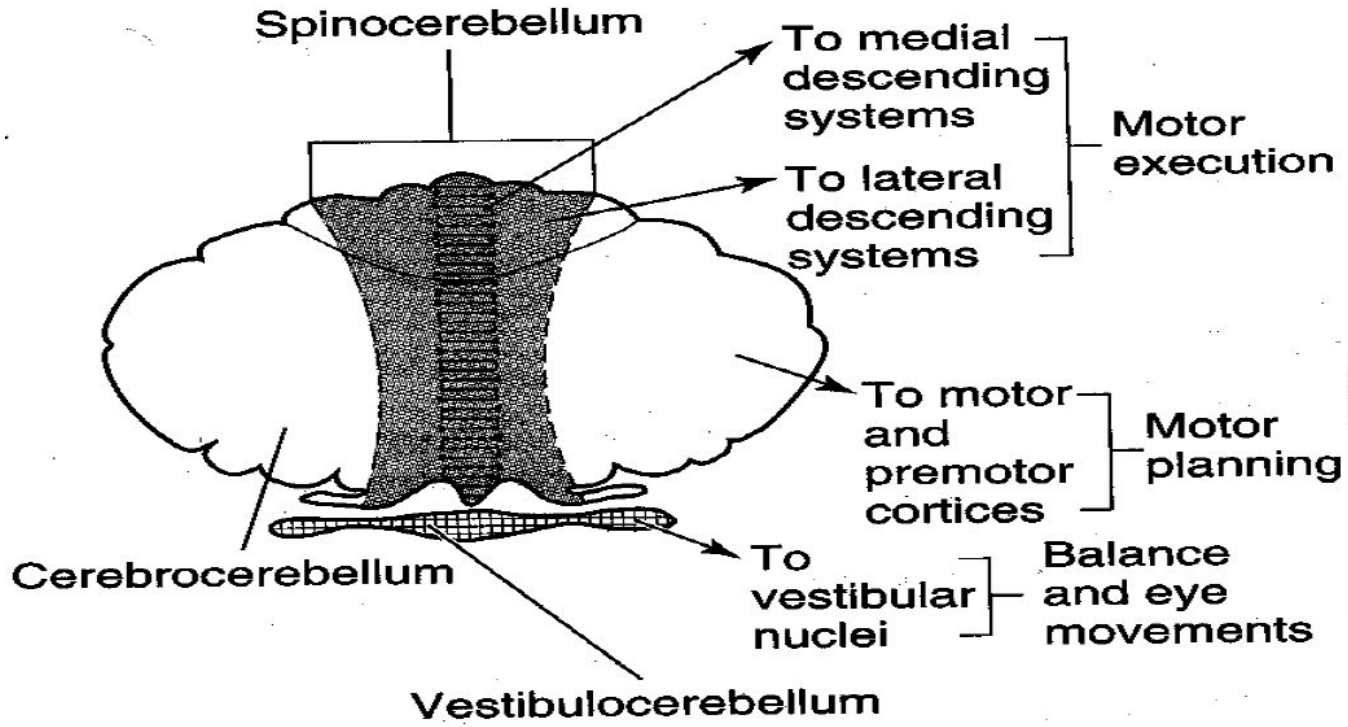
	Anatomical	Physiological	Functional
1	Anterior lobe	Paleocerebellum	Spinocerebellum. It makes the movements smooth and coordinated
2	Posterior lobe	Neocerebellum	Cerebrocerebellum. It interacts with motor cortex in planning & programming of movements.
3	Flocculonodular lobe	Archicerebellum	Vestibulocerebellum for Maintenance of balance, control of eye movements

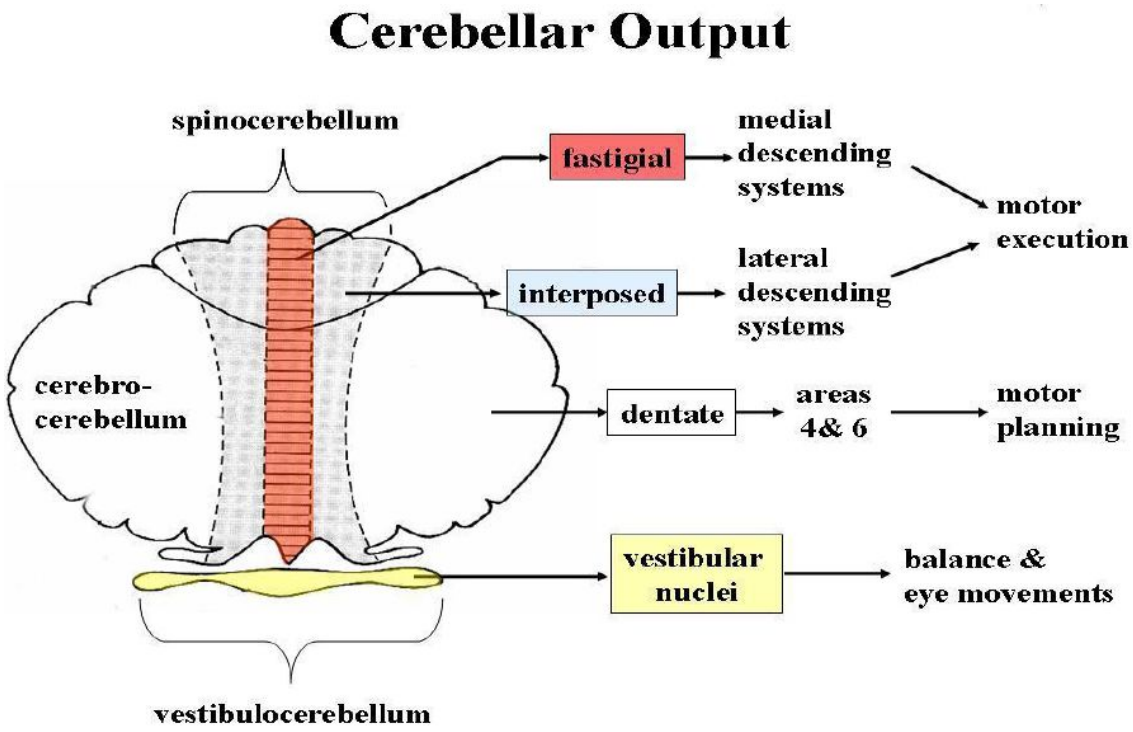
- The anterior & posterior lobes on each side constitute **the large right and left cerebellar hemispheres**, which are separated by a narrow band called the **vermis.**

Each part has 3 names



Functional divisions of the cerebellum



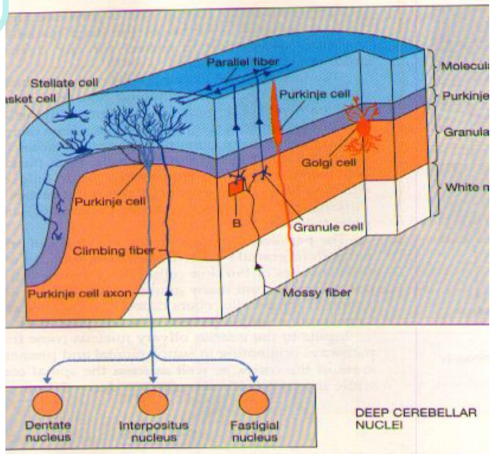


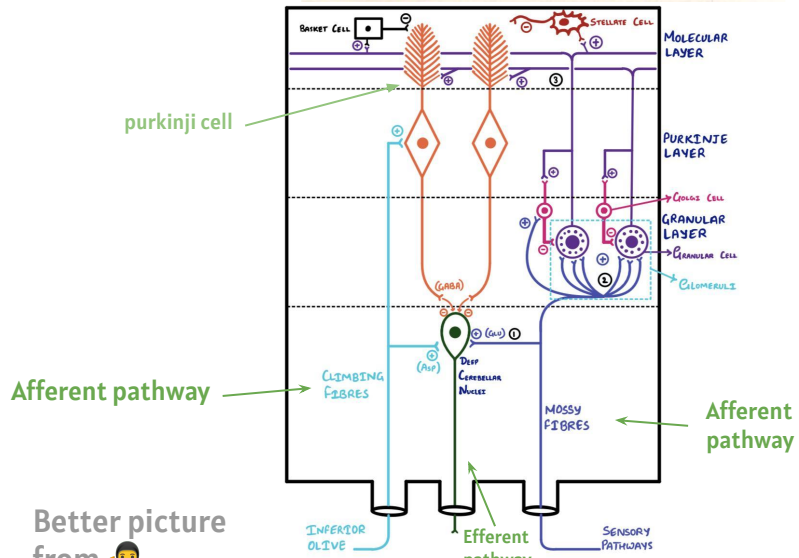
Important

Cerebellar cortex

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

Cortex Layers	Cells	Action
Molecular Layer	**Stellate cells (inhibitory interneuron)** (Inhibit Purkinje cells)	Release GABA, Taurine (inhibition)
	Basket cells (inhibitory interneuron) (Inhibit Purkinje cells)	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 (excitatory interneuron) Excites purkinji cells	Release Glutamate (Excitation)





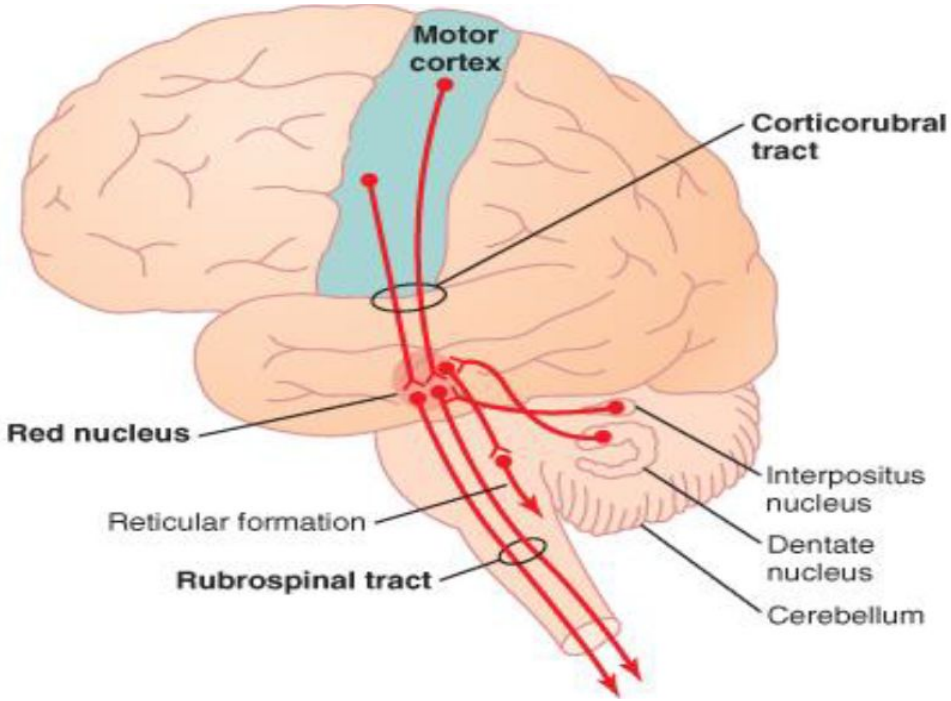
Better picture from

Figure 3 Layers of the cerebellar cortex and its regulatory pathways

Cerebellar nuclei (deep nuclei in white matter)

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

1. **Dentate Nucleus**
   in cerebrocerebellum
2. **Interpositus nucleus**
   in spinocerebellum
   - Emboliform Nucleus
   - Globose Nucleus
3. **Fastigial Nuclei**
   in the vermis



Afferent (input) pathway

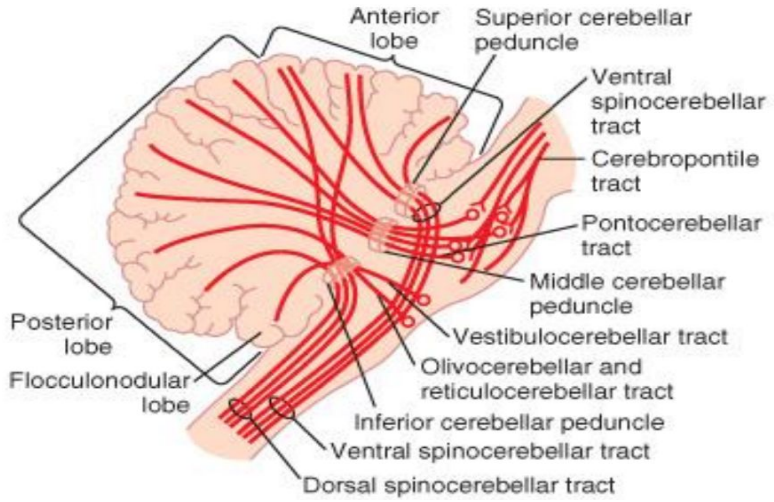
- The CB receives both **sensory** and **motor information** through a rich afferent nerve supply.
- This arises from: -Other areas of the brain and brain stem
  -Peripheral receptors.

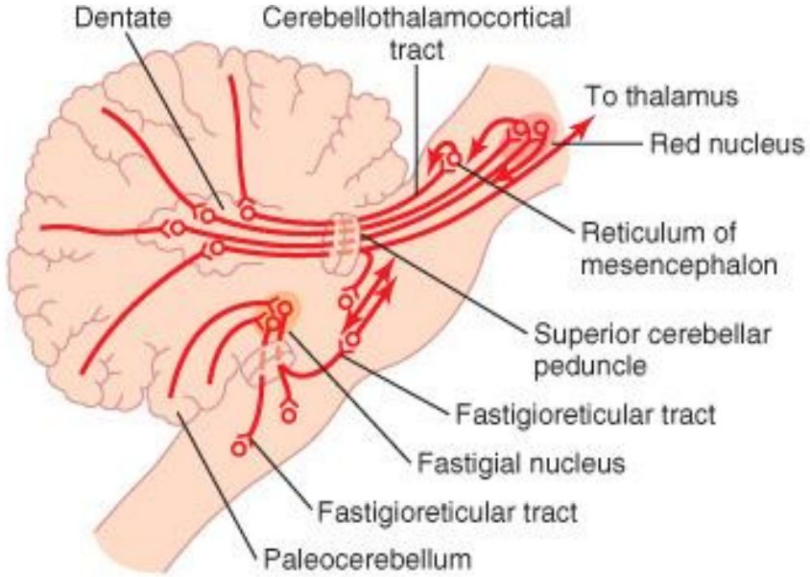
  and **enters the CB via the 3 cerebellar peduncles.**

Types of Afferent Fibers	
Climbing fibers	**Mossy fibers**
Originate from the Inferior olivary nucleus. It ends on the soma and dendrites of the Purkinje cells	From all the 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 (motor learning and motor skills). This occurs through modifying the inhibitory discharge from the PC on the deep nuclei.	Help the precise execution of the voluntary movements (concerning their initiation, duration and termination), which occurs by controlling the turn on and turn off output signals from the cerebral cortex to the muscles.
They both give of afferent fibers to deep cerebellar nuclei, which are excitatory.	

PRINCIPAL AFFERENT TRACTS TO THE CEREBELLUM

Afferent tract	Transmits
Vestibulocerebellar	Vestibular impulses from labyrinths, direct & via vestibular nuclei
Dorsal Spinocerebellar	Proprioceptive & exteroceptive impulses from the body.
Ventral Spinocerebellar	Proprioceptive & exteroceptive impulses from the body.
Cuneocerebellar	Proprioceptive 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.





Effrent (output) pathway

The axons of the 3 cerebellar nuclei are the main efferent pathways from the cerebellum

They leave the cerebellum through the **superior and inferior peduncles only.**

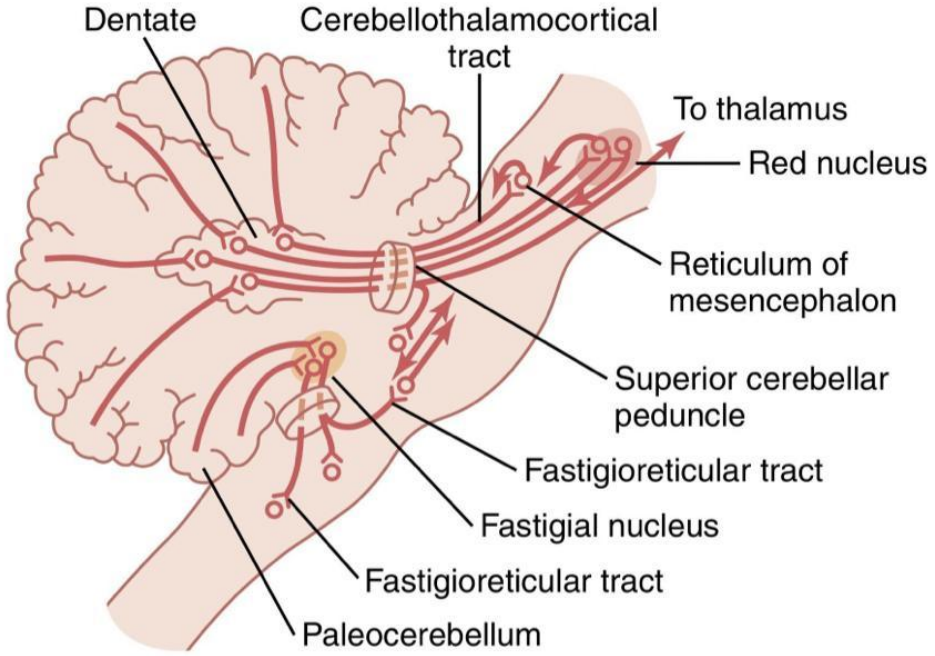


Figure 56-6 Principal *efferent* tracts from the cerebellum.

Rule of three

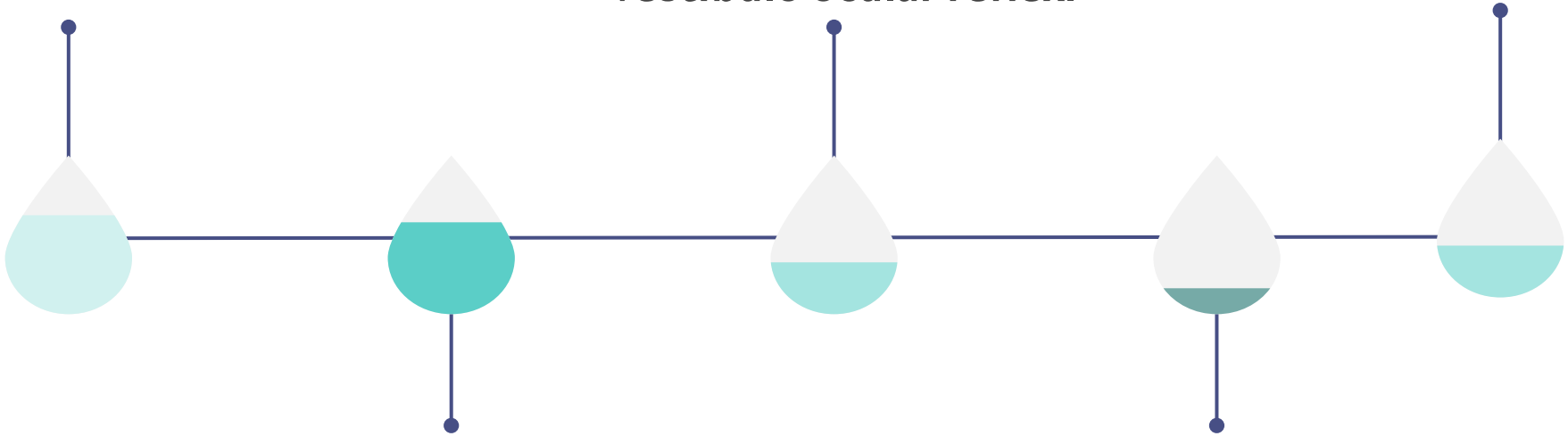
3 lobes	I-Floculonodular Lobe, 2-Anterior lobe, 3-Posterior lobe
3 Cortical Layers	I-Molecular layer, 2-Purkinje cell layer, 3-Granular layer
3 purkinje's cells afferent paths	I-Mossy fibers, 2-Climbing fibers 3-Aminergic fibers
3 pairs of deep nuclei	I-Fastigial, 2-Interposed(globose & emboliform) 3-Dentate
3 pairs of peduncles	I-Superior (pri.output), 2-Middle (pri.Input), 3-Inferior (pri.Input)
3 functional division	I-Vestibulocerebellum, 2-spinocerebellum, 3-Cerebrocerebellum

Functions of the cerebellum (intro)

Maintenance of equilibrium.

Balance, posture, eye movement such as vestibulo ocular reflex.

Motor Learning – Motor Skills.



Coordination of the half-automatic movement (like swinging of arms during walking) of walking and posture maintenance.

Adjustment of muscle tone.

Functions of the 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 especially the rapid movements e.g typing, piano playing, speaking, etc..
- 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 :

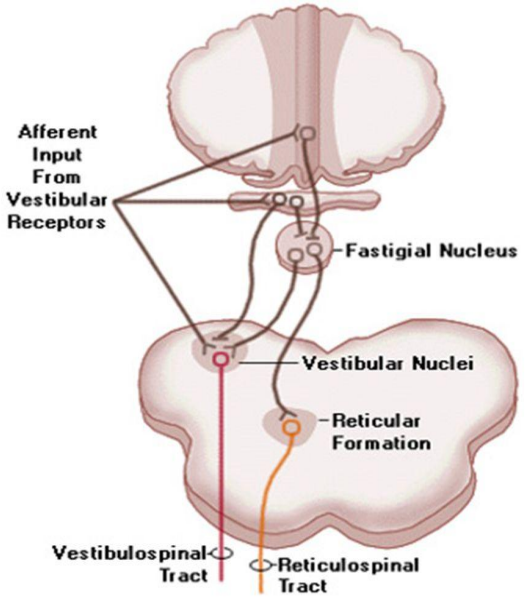
Cont.. Functions of the Cerebellum

A Control of equilibrium and 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 (reticular formation and vestibular nuclei) which send impulses through the vestibulospinal and reticulospinal tracts.

It controls equilibrium & postural movements by affecting the activity of the **axial muscles** (shoulder, trunk & pelvic girdle muscles).

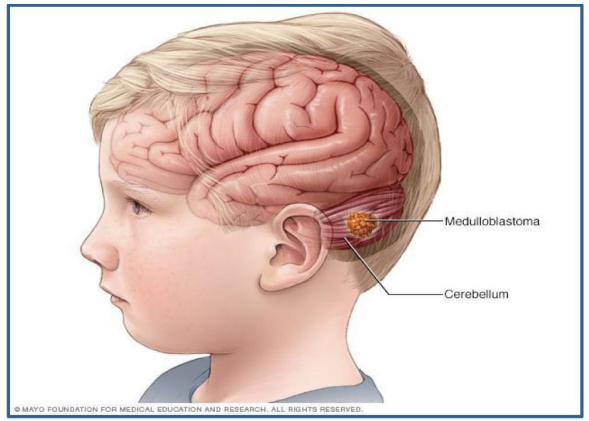


Cont.. Functions of the Cerebellum

Lesions of the vestibulocerebellum

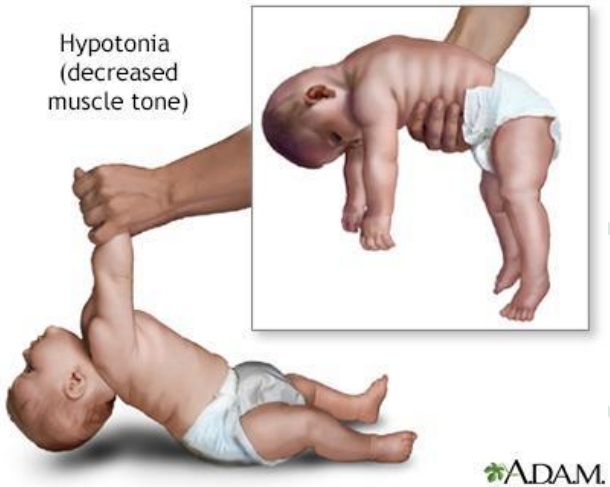
- e.g Due to a tumor called **medulloblastoma**. (commonly in children)

- 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).



B Control of the stretch reflex

- 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).



Cont.. Functions of the Cerebellum

C Control of voluntary movements:

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

The **cerebellum exerts its effects on the same side** of the body:

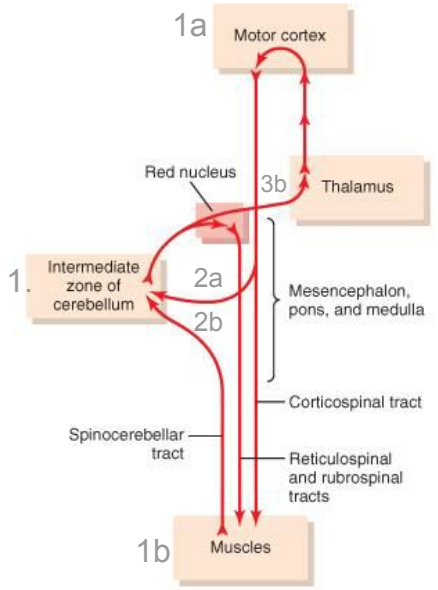
1. **The vermis** controls muscle movements of the **axial** body, neck, shoulders and hips.
2. **The intermediate zones** controls muscle contractions in the distal portions of both the upper and lower limbs (especially the hands, fingers, feet and toes).
3. **The lateral zones** help in the planning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

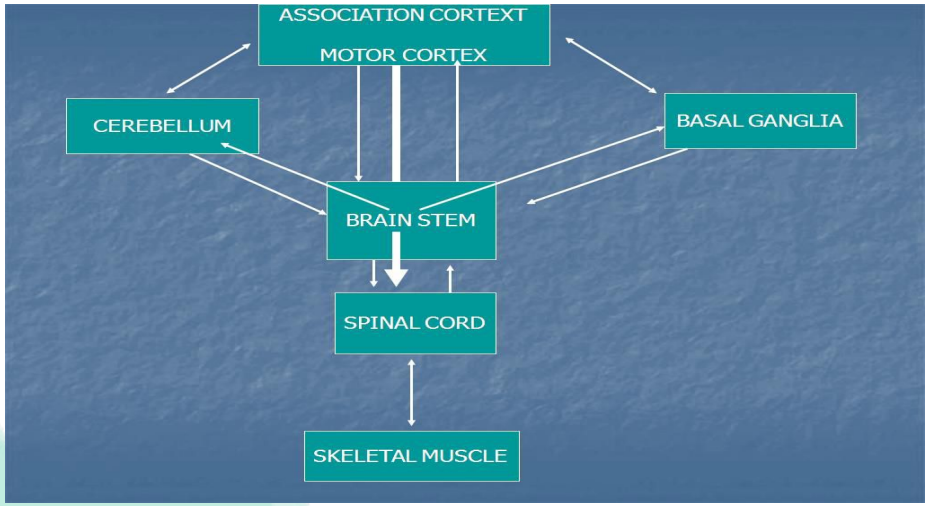
Comparator function of the cerebellum

The cerebellum especially the intermediate/paravermal zone compares the actual muscle movements with the movements intended by the motor system (planned by the motor cortex)

If the two do not compare favorably, then instantaneous subconscious corrective signals are transmitted back into the motor system to increase or decrease the levels of activation of specific muscles.

Example for cerebellar involvement: if you were walking while using your phone then stopped suddenly to not bump into a wall that's the work of the cerebellum





44I:
I. The intermediate zone of cerebellum/ spinocerebellum connected with:
Ia. with the motor cortex which is the origin of the motor order.
Ib. 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.

Summary: functions of the cerebellum

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

Defects of the cerebellum

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 (spinning of eye)
Scanning speech	Slow enunciation with a tendency to hesitate at the beginning of a word or syllable (تأتأة)
Tremor	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)

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**: 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).

Defects produced by cerebellar lesions in humans

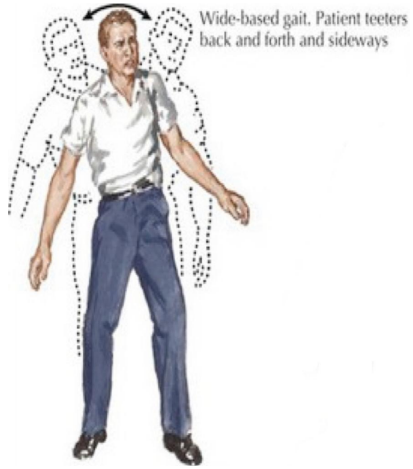
Posture Gait – Ataxia Tremor

The Neocerebellar patient will have Ataxic gait.

Left cerebellar tumor

Ataxic gait and position:

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



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.**

In parkinson's disease we will see a resting tremor (a tremor at rest and less to no tremor with movement)

Manifestations of Motor ataxia:

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- **Adiadochokinesia (dysdiadochokinesia):** 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 .

Manifestations of Motor ataxia:

6

Dysarthria:

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:

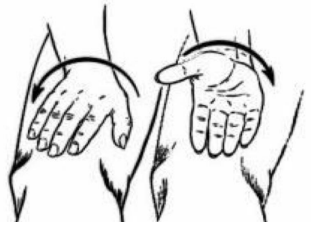
The patient walks unsteady – on a wide base (zigzag-like gait) in a drunken (swaying) manner, and tends to fall on the diseased side. Such gait is more apparent with vestibulocerebellar damage.

Tests related to the cerebellum

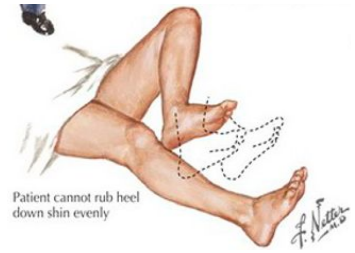
Finger nose test: While the examiner holds his finger at arm's length from the patient, Patient touches her nose and then touches the examiner's finger. After several sequences, the patient is asked to repeat the exercise with her closed eyes A patient with a cerebellar disorder tends to miss the target

Finger-to-nose test. Patient cannot direct finger accurately with eyes closed

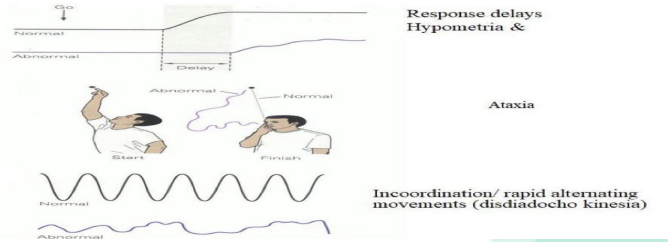
Dysdiadochokinesis: Inability to perform rapidly alternating movements Is called dysdiadochokinesia It is usually caused by multiple sclerosis in adults and cerebellar tumors in children. Patients with other movement disorders (e g Parkinson's disease) may have abnormal rapid alternating movement testing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



Heel to shin: 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


Patient cannot rub heel down shin evenly

Cerebellar lesion signs: 1-Response delays Hypometria
2-ataxia
3-Incoordination/rapid alternating movements (dysdiadochokinesia)



TEST YOURSELF !

all the following are inhibitory cells except ?

A)Granule cells.

B)Purkinje cells.

C)Golgi Cells.

D)basket Cells.

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

A)Dentate nucleus.

B)Fastigal nucleus

C)Interpositous nuclei.

D)Emboliform nucleus.

Inability to perform rapid alternating movements?

A)Tremor

B)Ataxia

C)Dysdiadochokinesia

D)Dysarthria

What is the origin of climbing fiber

A)Vestibular nucleus.

B)Inferior olivary nucleus.

C)Red nucleus.

D)Trigeminal nucleus.

A, B, C, B

SAQ

List the three deep nuclei of the cerebellum?

Page 9

What are the 2 types of afferent fibres?

Page 10

List three functions of the cerebellum ?

Page 14

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Omar Alamri
sultan almishrafi
Mohammad Alzahrani
Khalid Alanezi
sami Mandoorah
Abdullah alzamil
Mohammed Alqutub
Mohammed Bin Manee

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Special Thanks to Physiology **Team441**
Team logo and design was done by **Rafan Alhazzani**
Thanks to **ALEEN ALKULYAH** for Helping with the design!

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