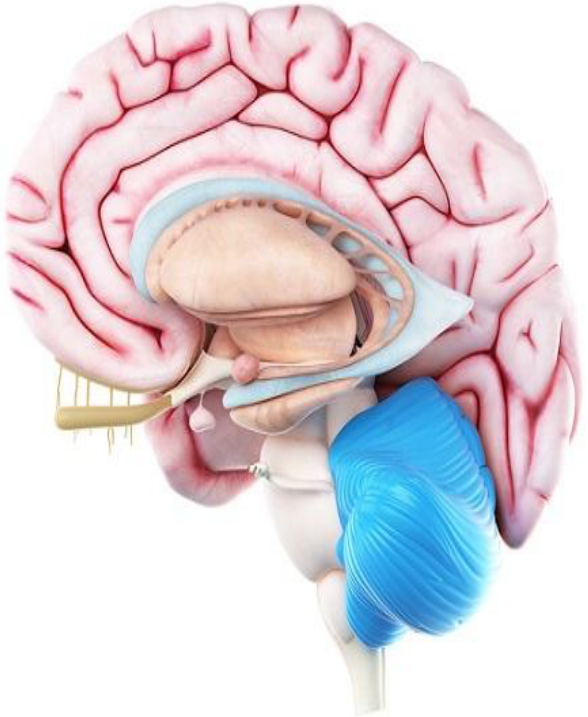
Physiology of Cerebellum



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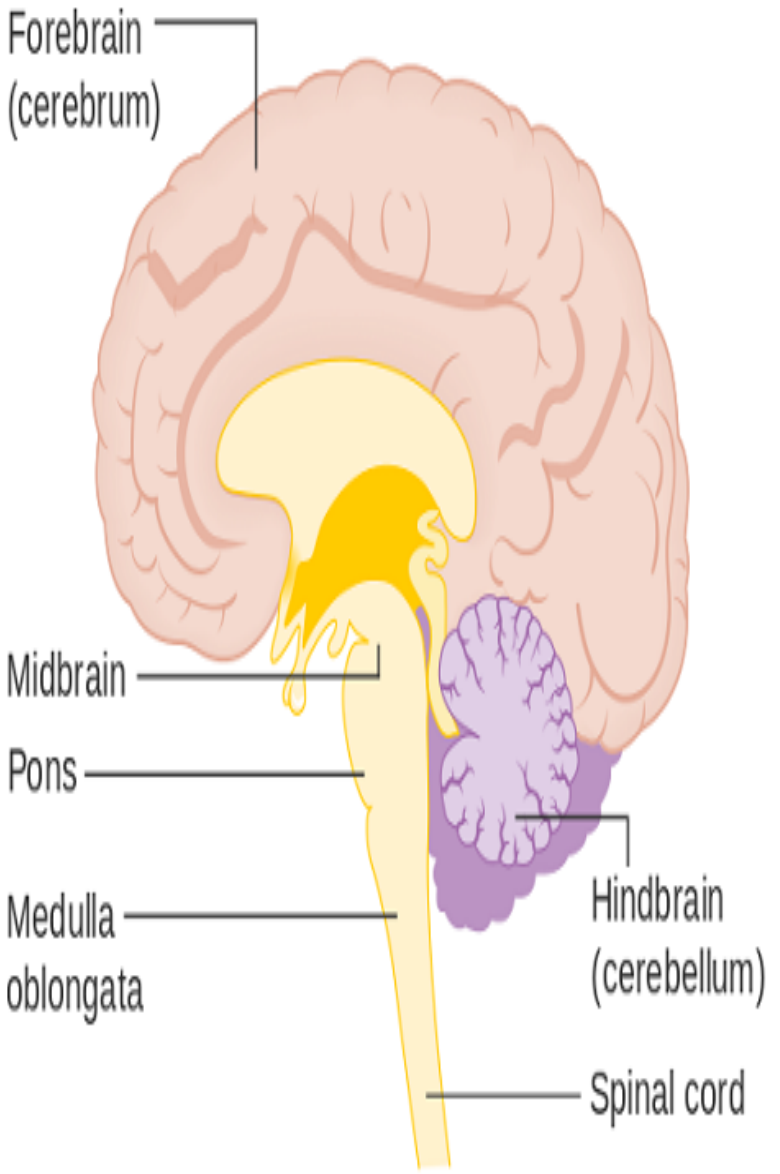
Objectives

At the end of this lecture you will be able to:-

1. Describe the functional divisions of the cerebellum; vestibulocerebellum, spinocerebellum and cerebrocerebellum
2. Define the physiological roles of the cerebellum in regulation of movement.
3. 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.

Cerebellum

- Occupies a prominent position beside the main sensory and motor systems in the brain stem.
- It is connected to the brain stem by **three cerebellar peduncles**: ***superior***, ***middle*** and ***inferior.***
- Various fibers inter and leave the cerebellum through these peduncles.



Functions of cerebellum

1. **Maintenance of equilibrium**
2. **Balance, posture, eye movement.**
3. **Coordination of the half-automatic movement** of walking and posture maintenance.
4. **Adjustment of muscle tone.**
5. **Motor Learning – Motor Skills.**

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Motor learning and motor skill

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Anatomical & Functional divisions of cerebellum

The anterior & posterior lobes on each side constitute 2 **large cerebellar hemispheres,** which are separated by a narrow band called the **vermis.**

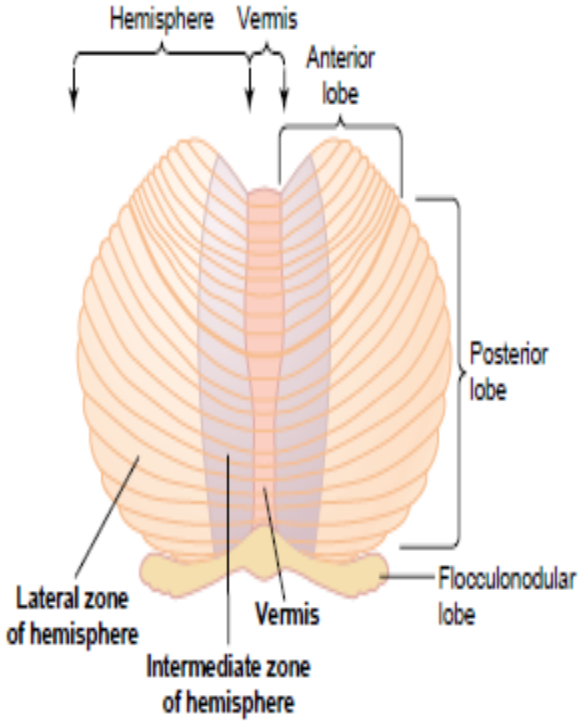


Figure 56–2

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

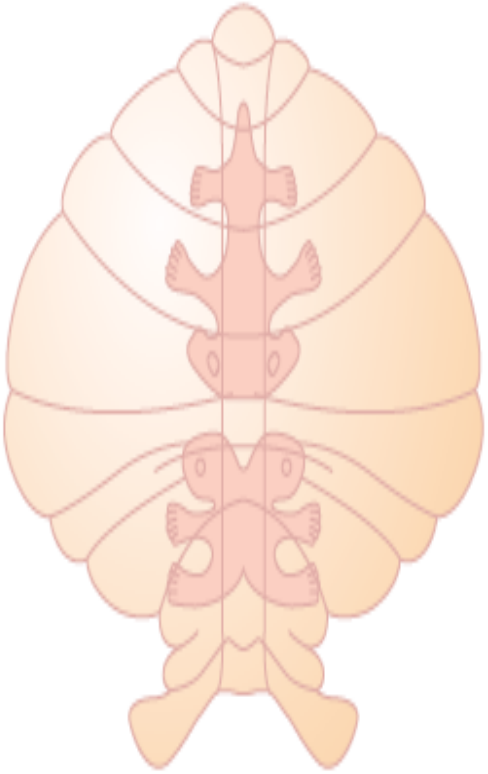


Figure 56–3

Somatosensory projection areas in the cerebellar cortex.

Functional divisions of cerebellum

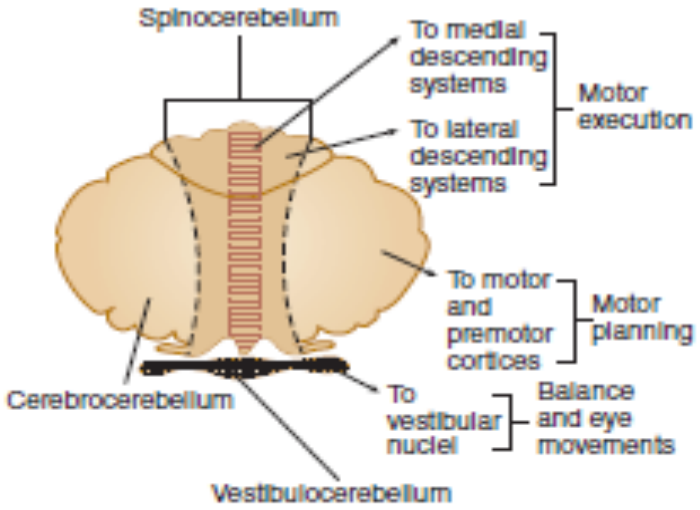
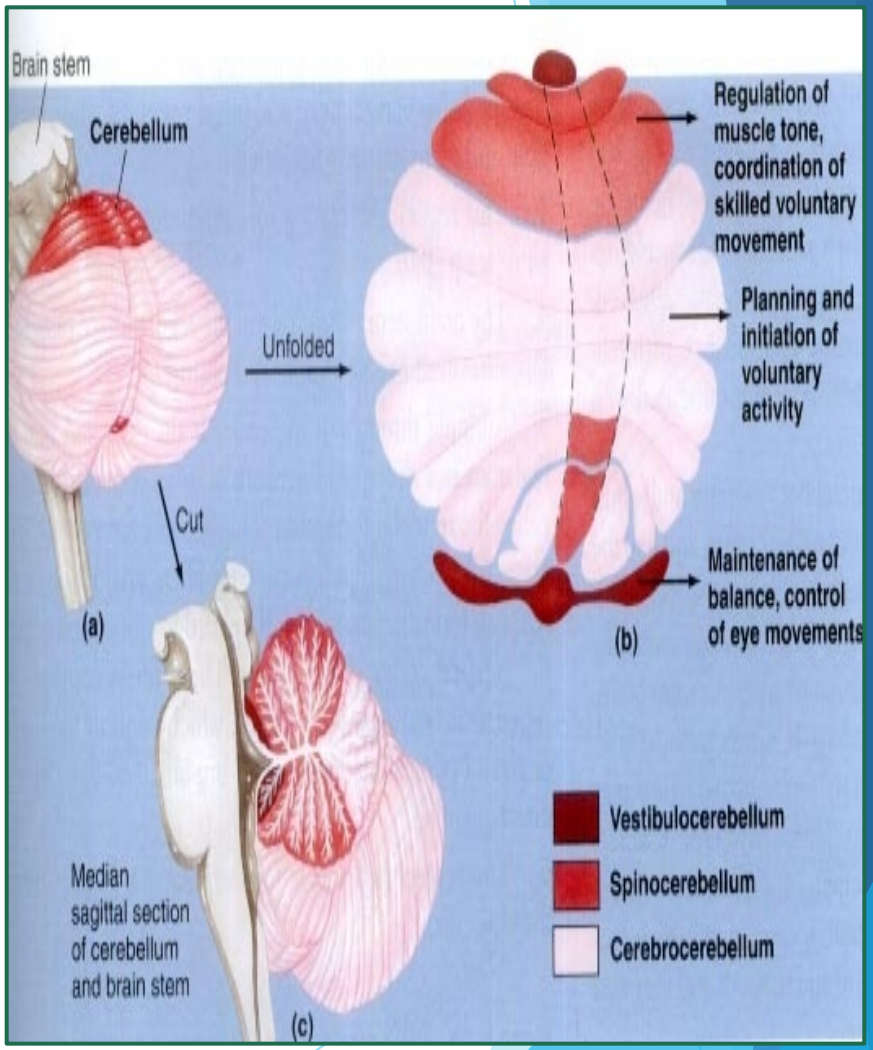


FIGURE 12–19 **Three functional divisions of the cerebellum.** The nodulus in the vermis and the flanking flocculus in the hemisphere on each side form the vestibulocerebellum which has vestibular connections and is concerned with equilibrium and eye movements. The rest of the vermis and the adjacent medial portions of the hemispheres form the spinocerebellum, the region that receives proprioceptive input from the body as well as a copy of the "motor plan" from the motor cortex. The lateral portions of the cerebellar hemispheres are called the cerebrocerebellum which interacts with the motor cortex in planning and programming movements. (Modified with permission from Kandel ER, Schwartz JH, Jessell TM (eds): *Principles of Neural Science*, 4th ed. New York, NY: McGraw-Hill; 2000.)



Structure & connections of the cerebellum

1. Purkinje cell
2. Granule cell
3. Basket cell
4. Golgi cell
5. Stellate cell
6. Climbing fiber
7. Mossy fiber
8. Parallel fiber
9. Inferior olivary nucleus
10. Deep cerebellar nuclei

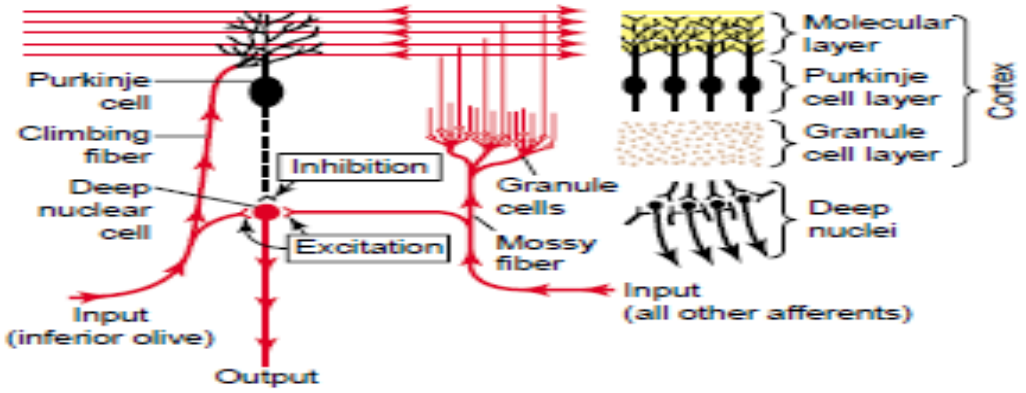
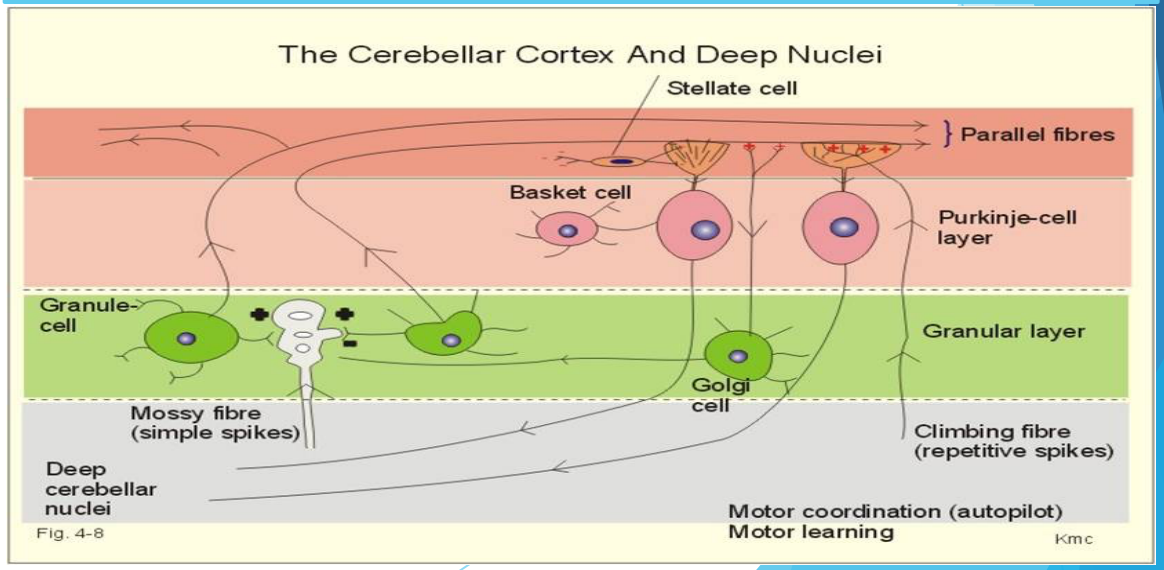


Figure 56–7

The left side of this figure shows the basic neuronal circuit of the cerebellum, with excitatory neurons shown in red and the Purkinje cell (an inhibitory neuron) shown in black. To the right is shown the physical relationship of the deep cerebellar nuclei to the cerebellar cortex with its three layers.



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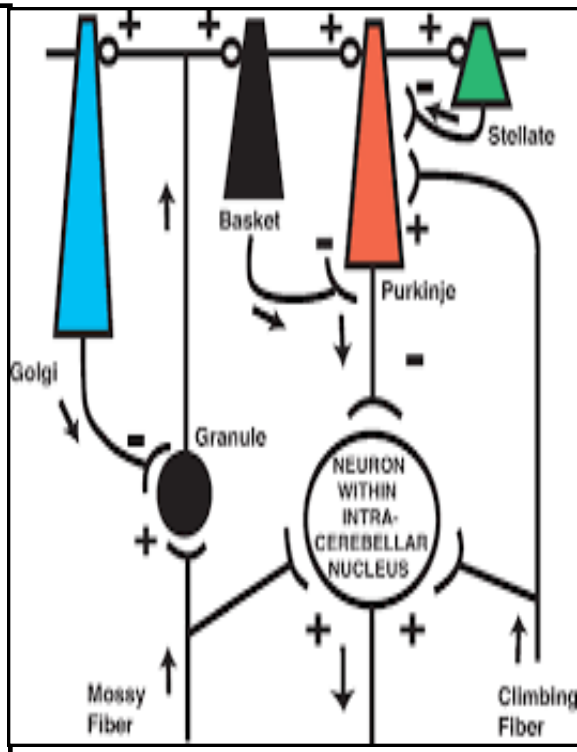
Cont…Structure and connections of cerebellum

- The CB has an external layer of ***gray matter*** (cerebellar cortex), and an inner **white matter**.
- The cortex is deeply infolded, giving a large surface area , and it contains **five different cell types,**
- ***Golgi, basket, stellate*** which are **inhibitory interneurons**,
- ***Granule cells***, which are **excitatory**
- P***urkinje cells*** which are **the output cells,** inhibit the deep nuclear cells (DNCs).
- The **inhibitory** neurons in the CB release GABA (e.g stellate, basket, Golgi, PC)
- The **excitatory** neurons release glutamate (e.g. granule cells, that also has $GABA_A$ receptors)



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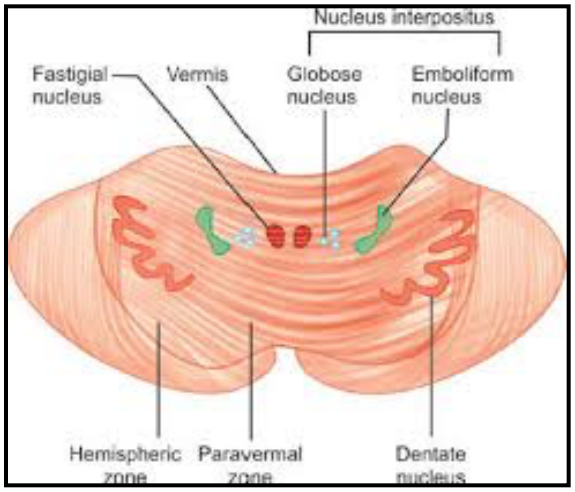
The white matter contain 3 deep nuclei

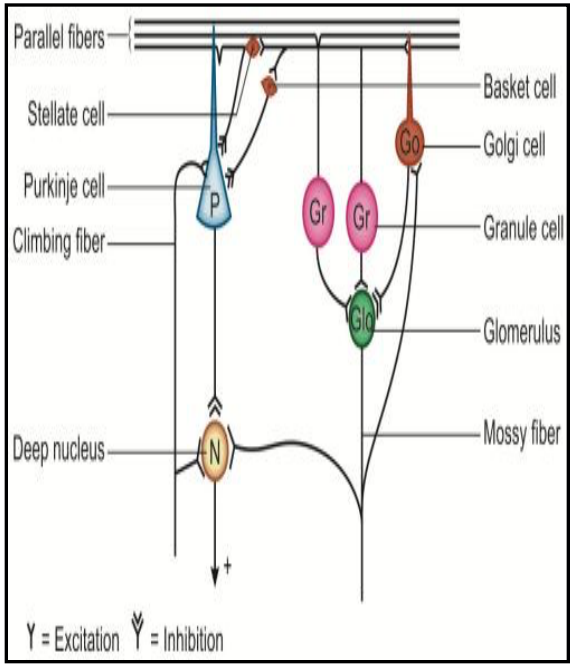
1- ***Dentate***

2- ***Fastigial***

3- ***Interpositous*** (formed of globose and emboliform nuclei)



All afferent fibers 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.



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Afferent (input) pathways

- The CB receives both **sensory** and **motor information** through a rich afferent nerve supply.

This arises from

- **Other areas of the brain**.
- **Peripheral receptors**,

and enters the CB via the 3 cerebellar peduncles.

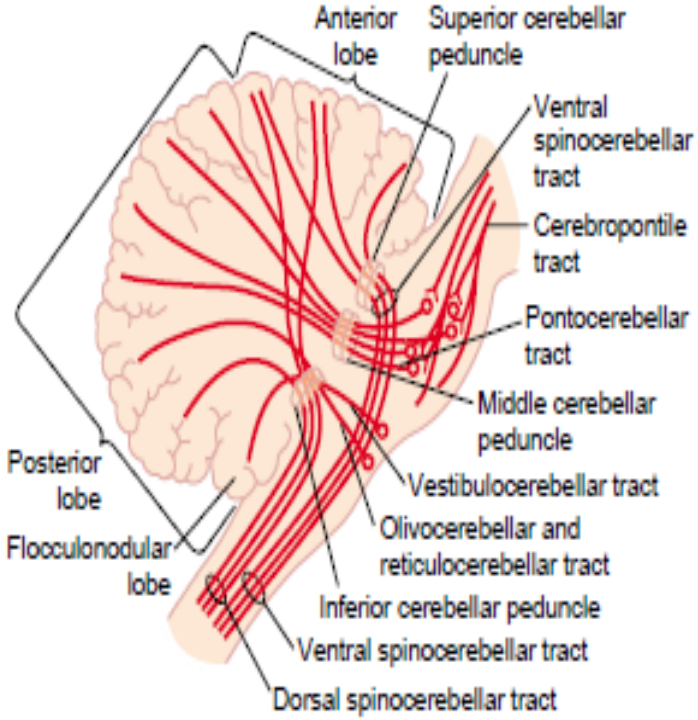


Figure 56–4

Principal *afferent* tracts to the cerebellum.

Cont.. Afferent fibers of CB

1-The climbing fibers:

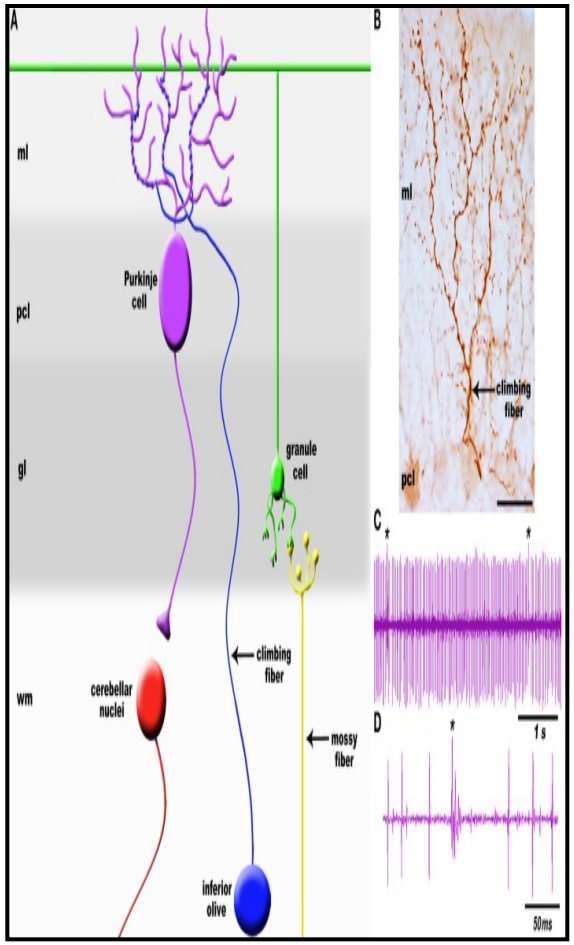
From the inferior olivary nucleus.

It learns the cerebellum to perform new patterns of movements precisely.

2-The mossy fibers:

From all other afferent fibers that enter the cerebellum + some fibers coming from the inferior olivary nucleus (so they are greater than the climbing fibers).

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 cerebellum to the muscles.



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Efferent (out put) pathways

There are 3 main efferent pathways from the 3 parts of the CB:-

- Are the axons of the 3 deep nuclei,
- Leave the CB through the **superior** and **inferior** peduncles

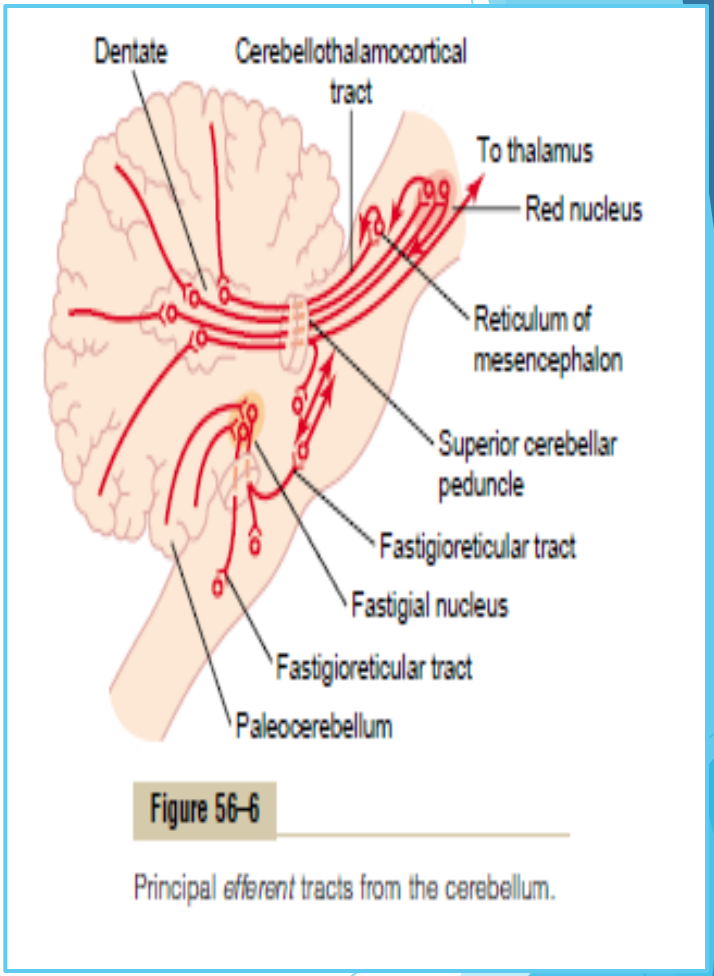


Figure 56–6

Principal *efferent* tracts from the cerebellum.

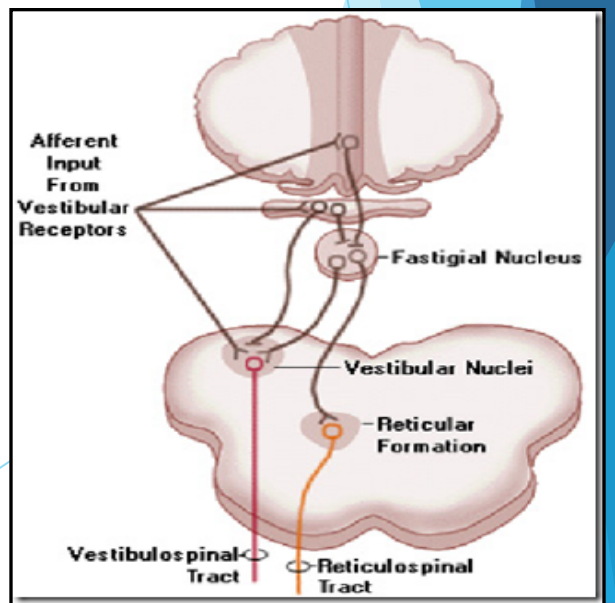
FUNCTIONS OF THE CEREBELLUM

- 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*.
- 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 cerebellum

(A) Control of equilibrium & postural movements:

- ✓The function of the vestibulocerebellum.
- ✓It receives information from the vestibular apparatus.
- ✓ 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).

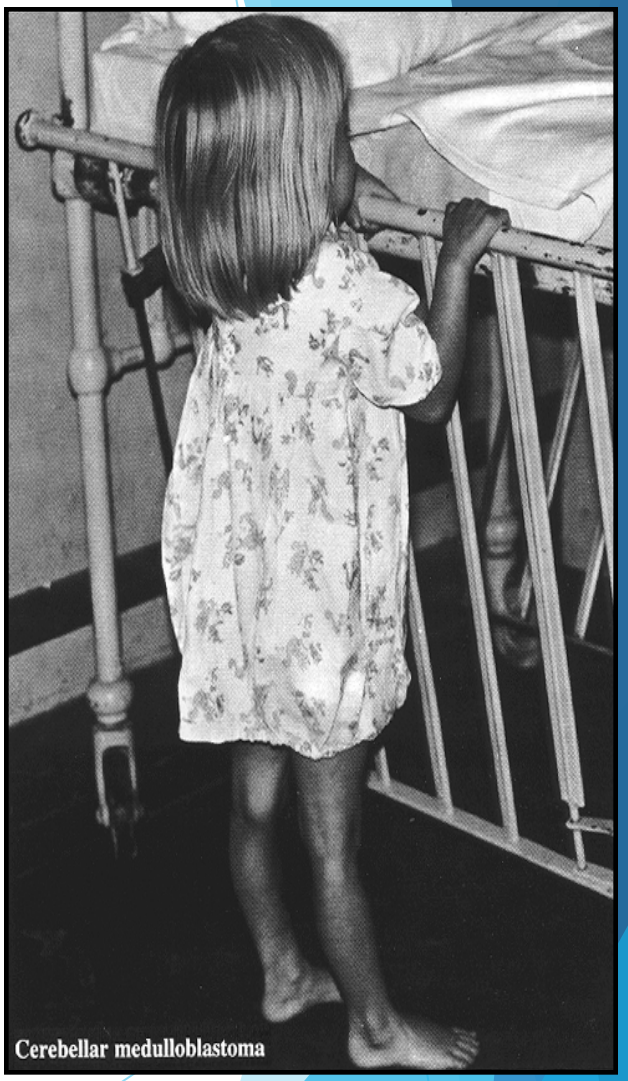


Lesions of the vestibulocerebellum

e.g Due to a tumor called **medulloblastoma**

- **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.


Cerebellar medulloblastoma

Cont… function of cerebellum

(B) Control of the Stretch Reflex

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

C- Control of voluntary movements

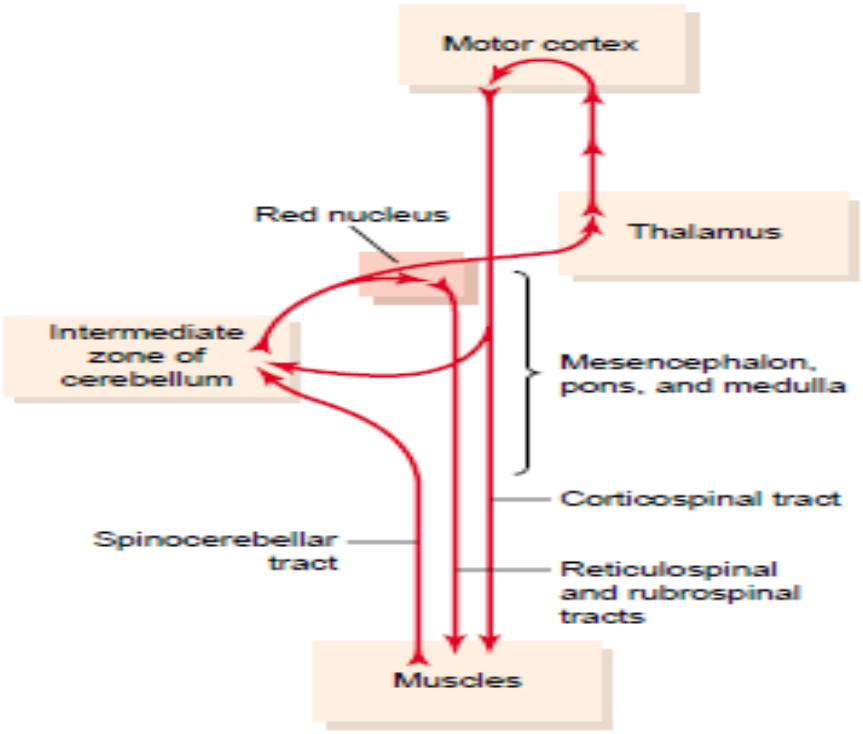
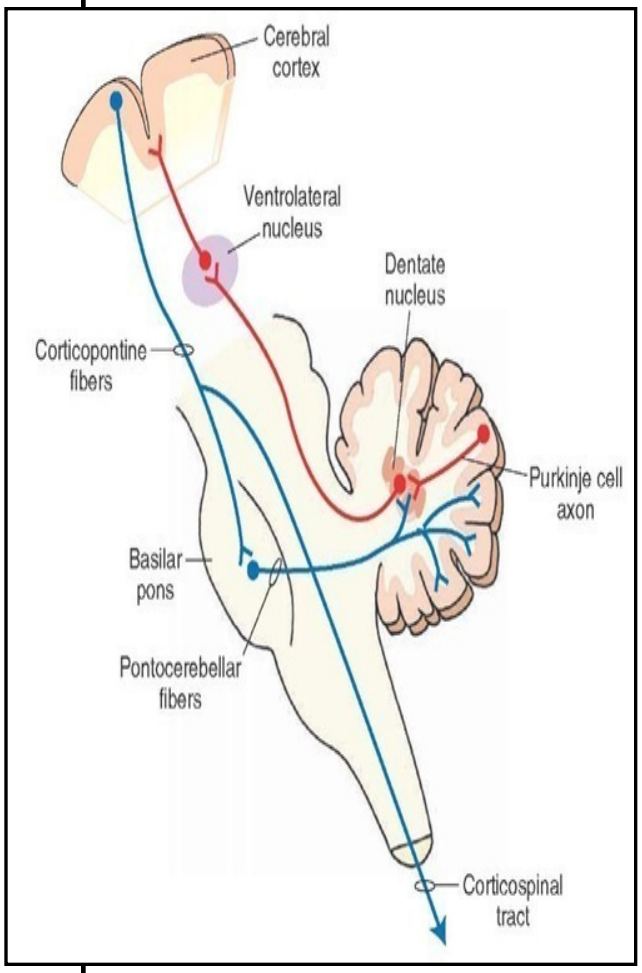


Figure 56–8

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

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.



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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.

Neocerebellar syndrome

- Video
- https://www.youtube.com/watch?v=R6KBVCkurM0
- https://youtu.be/lrerPzLtnY8

Ataxia

- ***This is incoordination of voluntary movements.***
- ***It is either sensory or motor (or mixed).***

Motor ataxia: Is due to defect in the coordination of the voluntary movements.

It commonly occur in lesions of

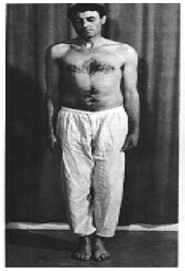
The cerebellum or spinocerebellar tracts

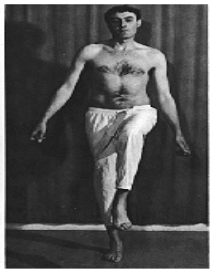
Manifestations of neocerebellar syndrome

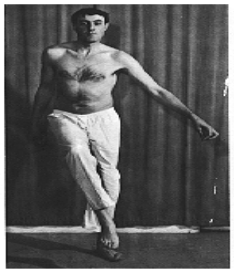
A) Hypotonia: Due to loss of the facillitatory effect of the CB on the stretch reflex, and it is associated with ***pendular knee jerk.***

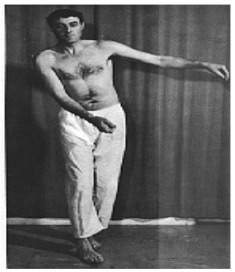
b) Asthenia*:* (muscle weakness): This is due to difficulty in initiation and maintenance of muscle contraction secondary to loss of the potentiating signals by the mossy fiber circuit.

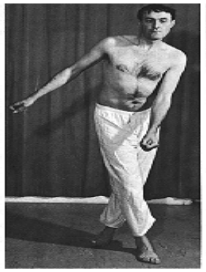
c)Motor ataxia: Incoordination of the voluntary movements, specially the rapid movements (becoming abnormal in rate, range, force and direction).

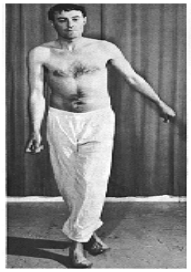












Posture
Gait – Ataxia
Tremor

Left cerebellar tumor

Ataxic gait and position:

a. Sways to the left in standing position

b. Steady on the right leg

c. Unsteady on the left leg

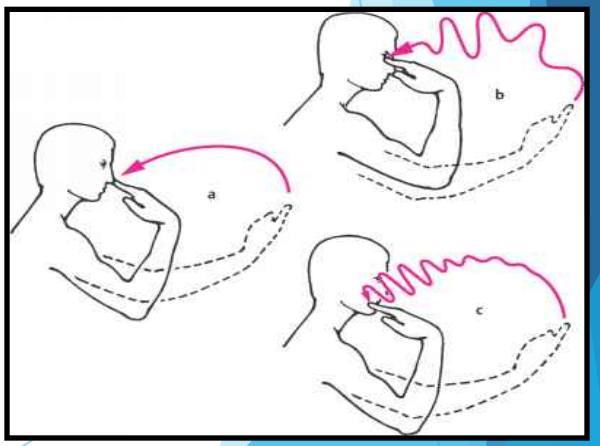
d. Ataxic gait

Manifestations of Motor ataxia

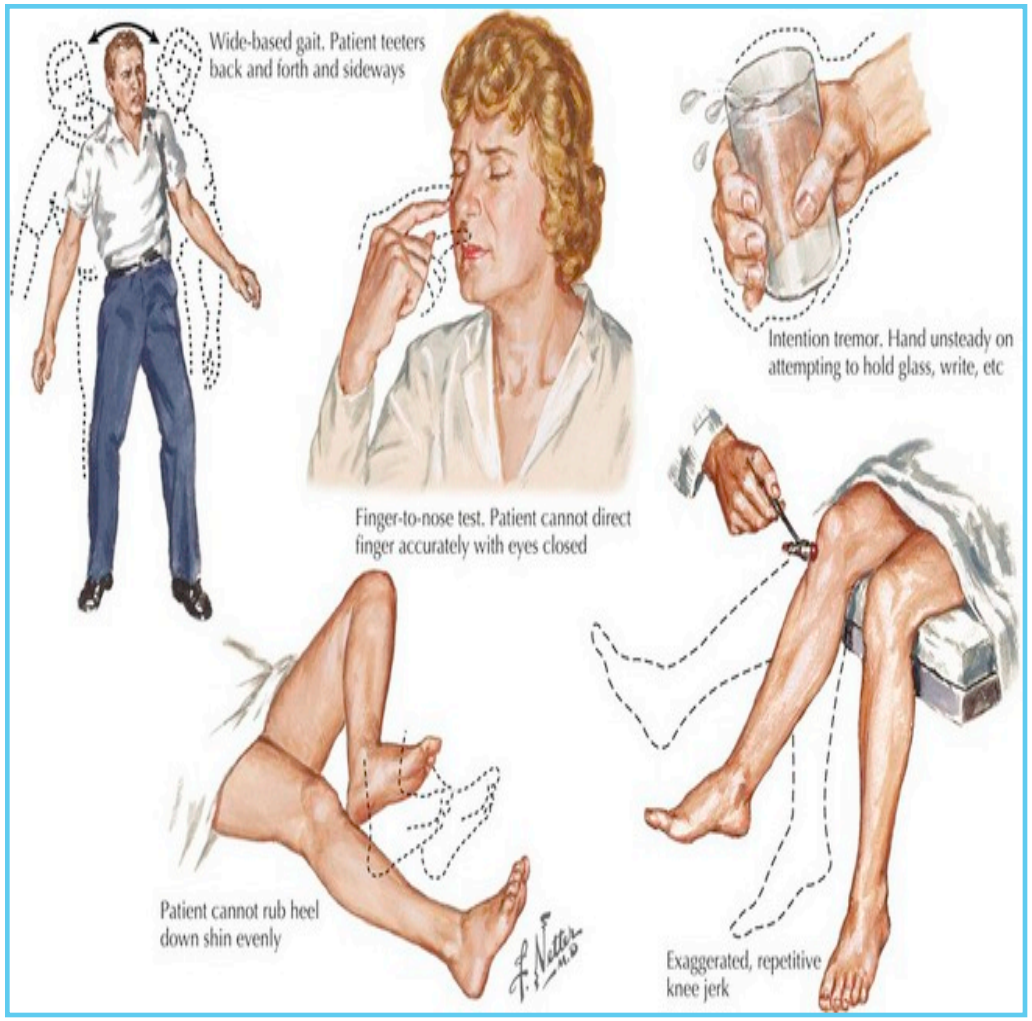
1-Dysmetria: Inability to control the distance of the motor act, which may either overshoot the intended point (=hypermetria or past pointing) or stop before it.

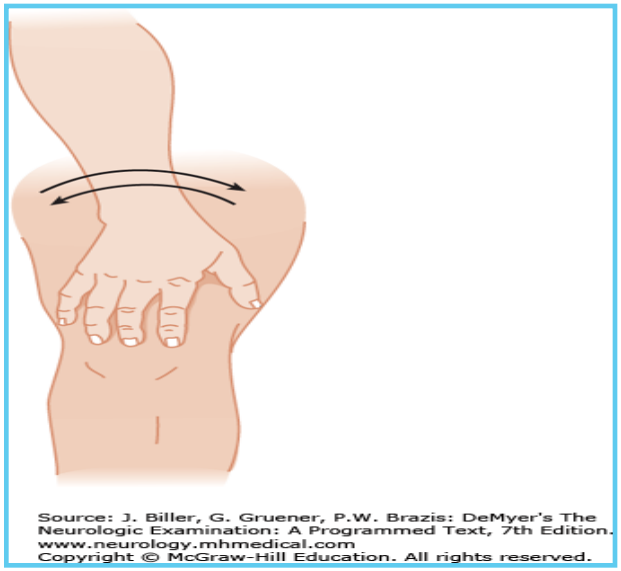
2-Kinetic (intension, action or terminal) tremors:

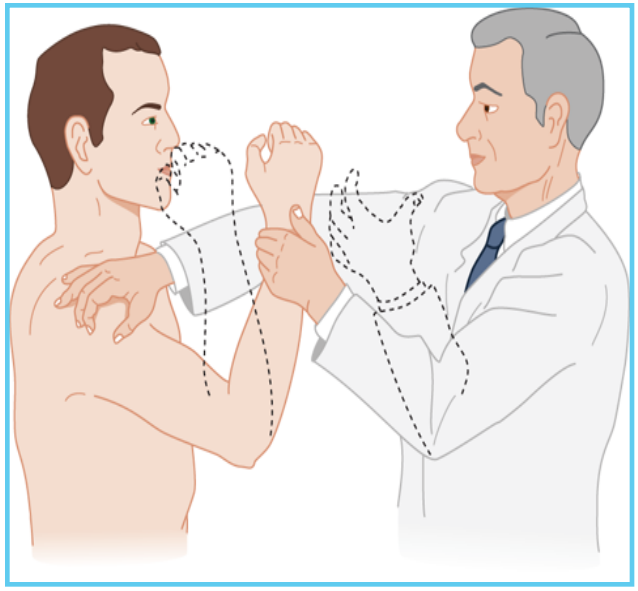
- It appears on performing a voluntary movement (especially at its end) but is absent at rest.
- Demonstrated by the finger nose test.
- It is secondary to dysmetria.



Signs of neocerebellar syndrome







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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…of 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.

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THANK YOU