Cerebellum

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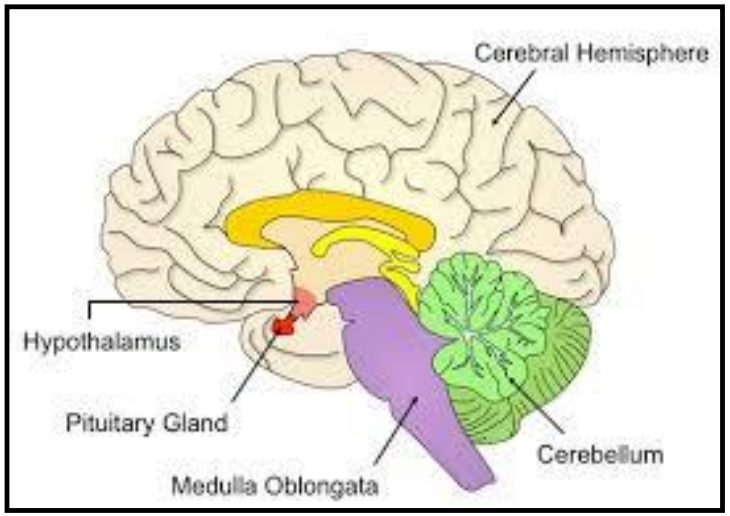
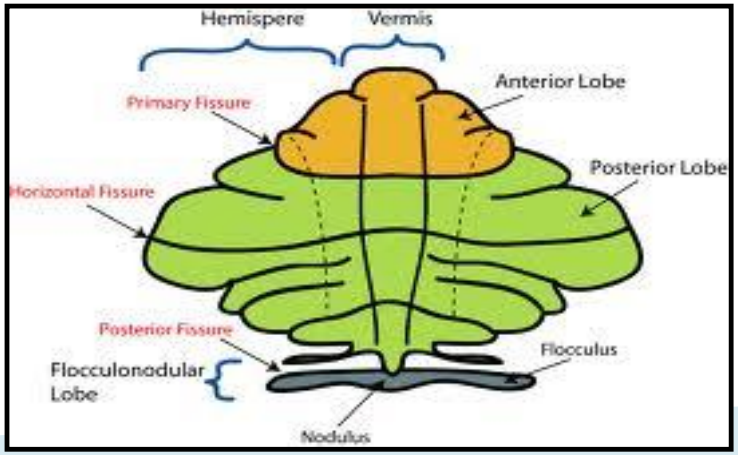


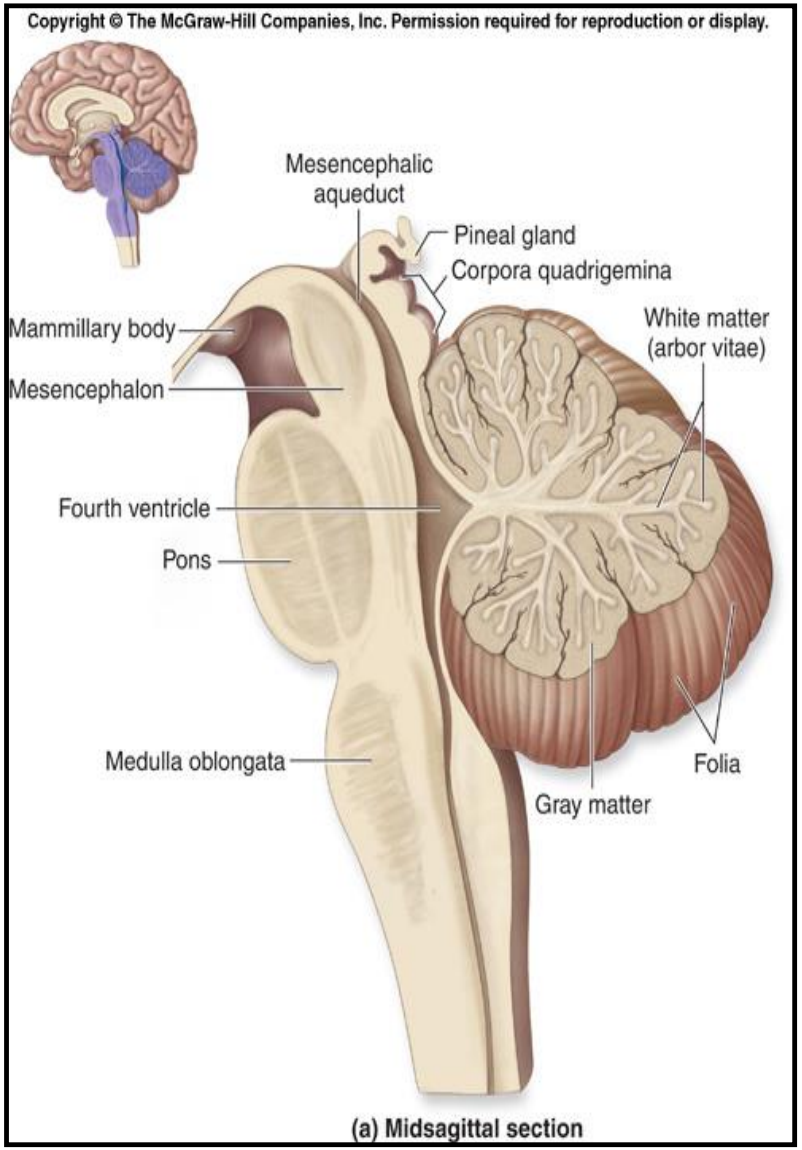


Objectives

- At the end of this lecture you will be able to:-
- 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: Cerebellar nystagmus, changes in muscle tone, ataxia, drunken gait, scanning speech , dysmetria (past-pointing), intention tremors, rebound phenomenon and adiadochokinesia.

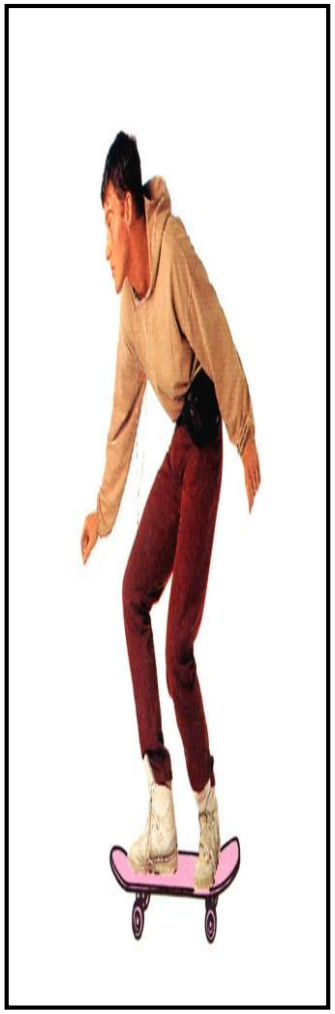
Cerebellum

- 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

- **Maintenance of equilibrium**
  - *balance, posture, eye movement*
- **Coordination of half-automatic movement** of walking and posture maintenance
- **Adjustment of muscle tone**
- **Motor Learning – Motor Skills**



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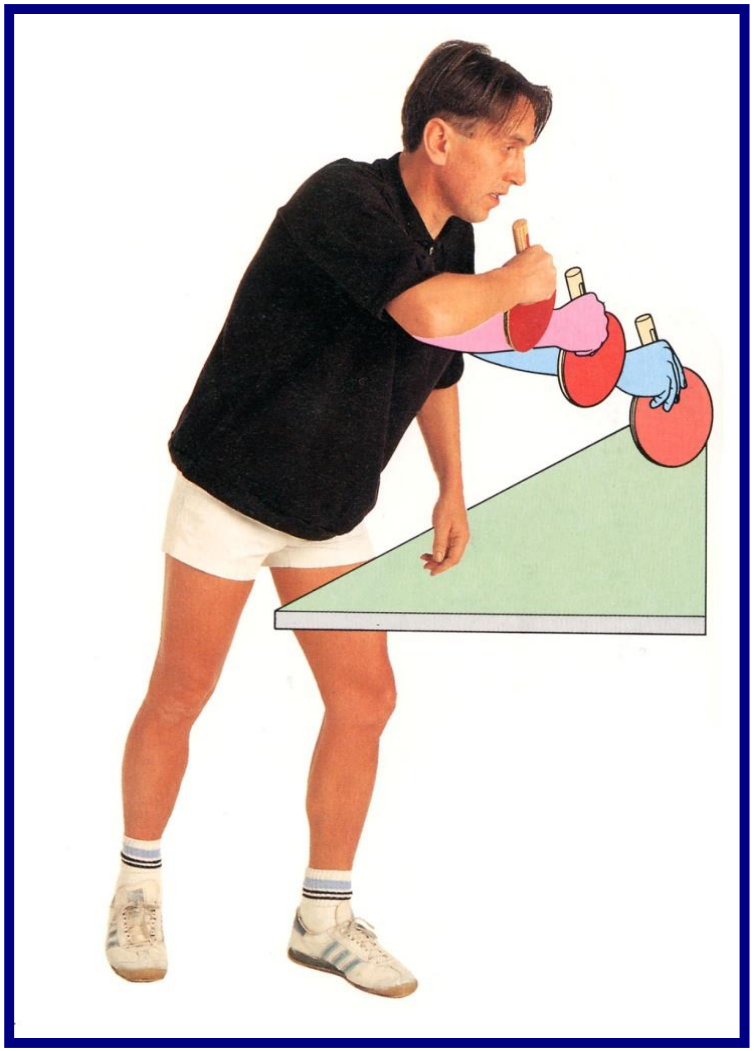
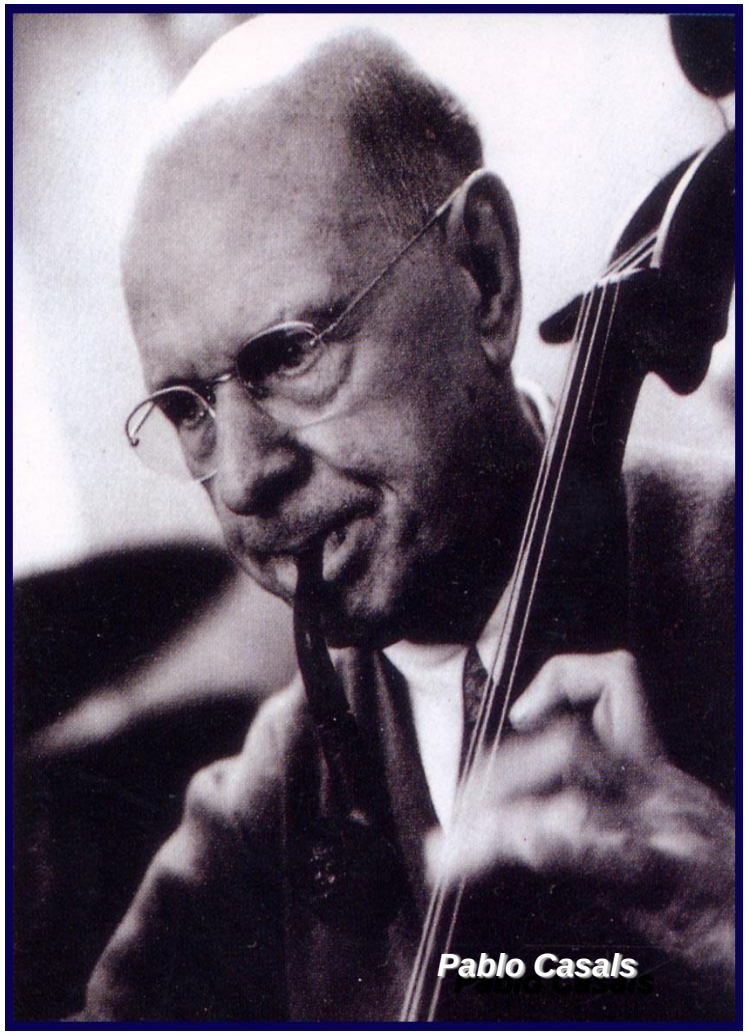
Motor learning and motor skill





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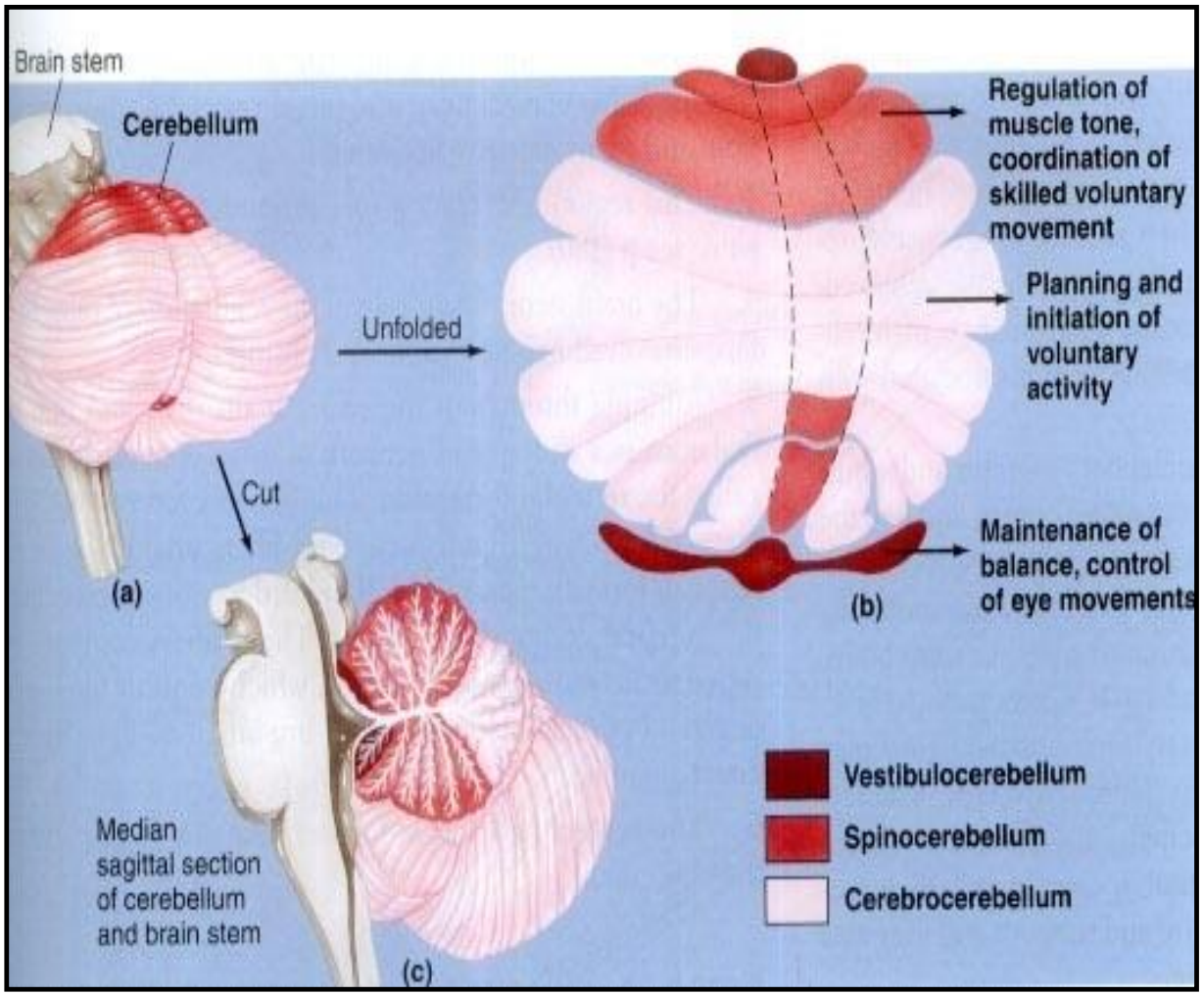
Anatomical & Functional divisions of cerebellum

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



Functional divisions of cerebellum

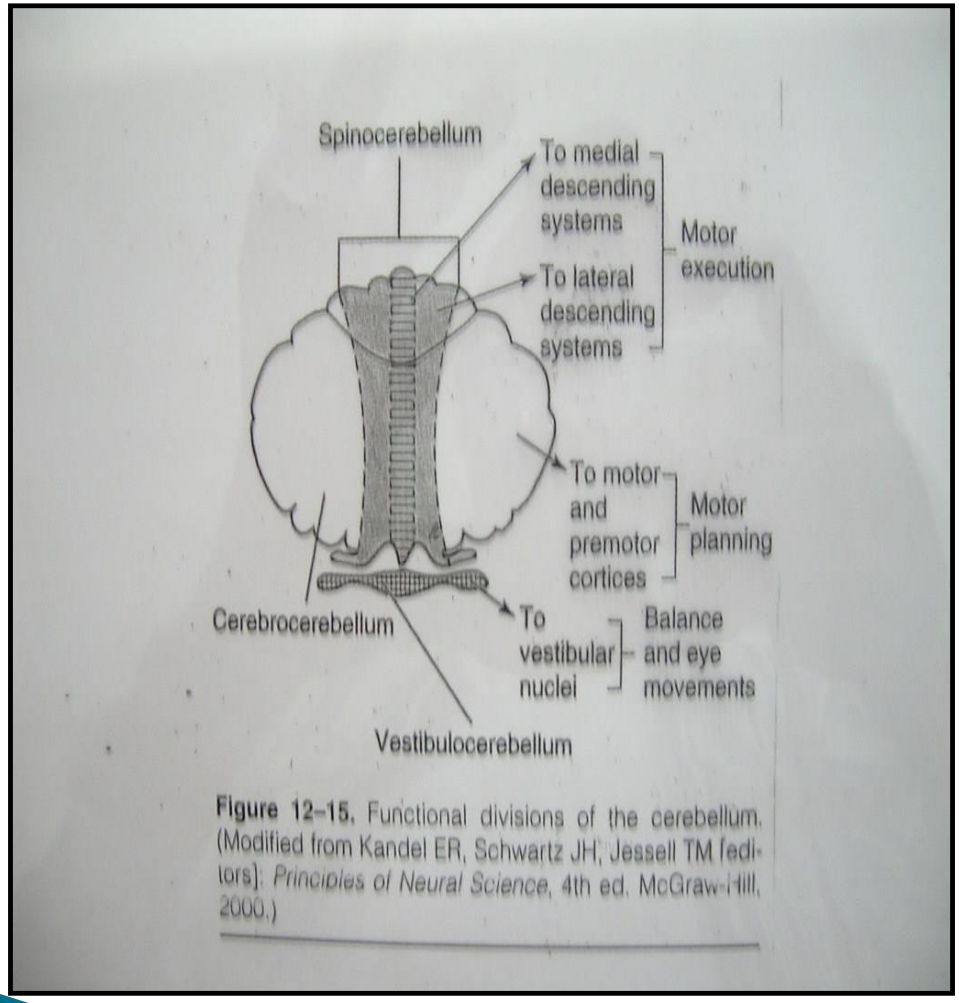
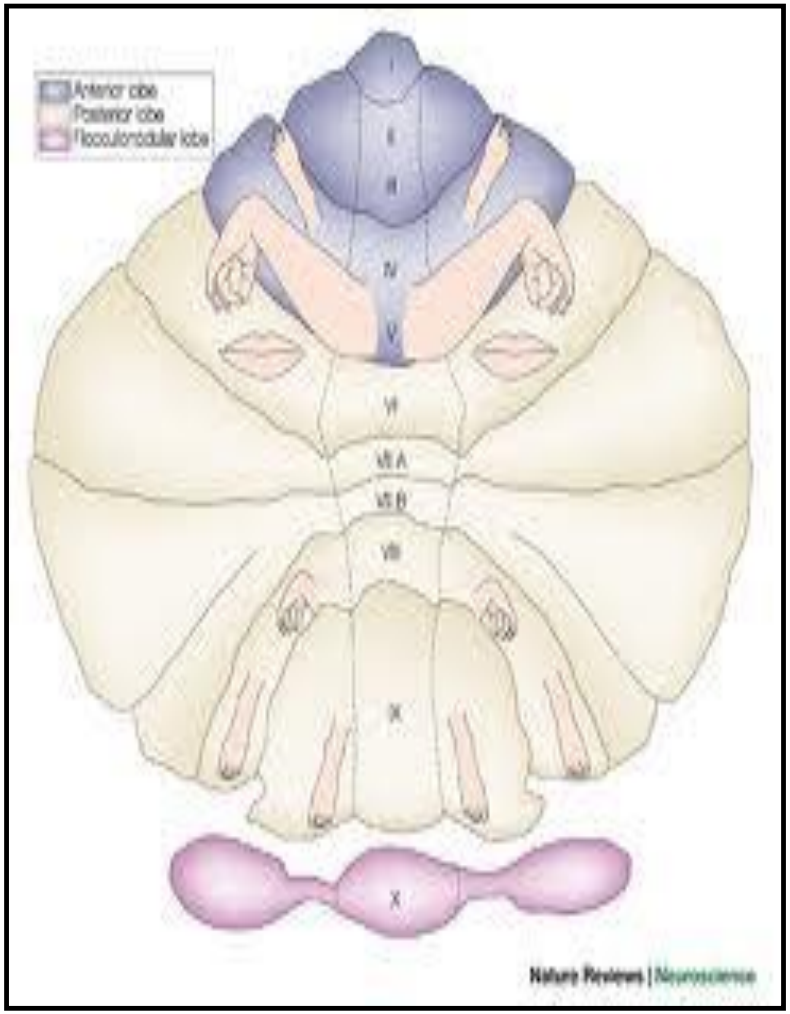
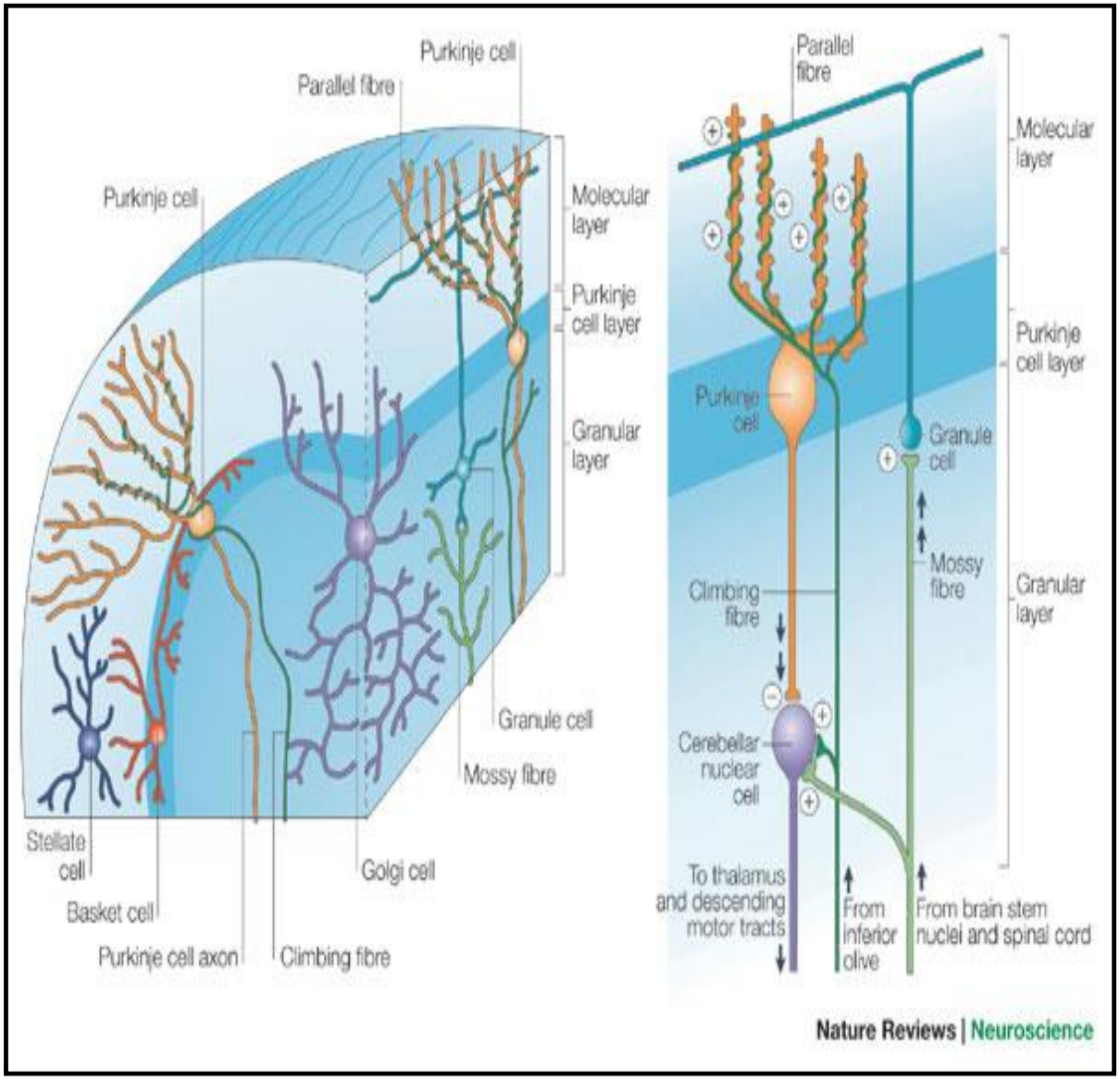


Figure 12–15. Functional divisions of the cerebellum. (Modified from Kandel ER, Schwartz JH, Jessell TM [editors]: *Principles of Neural Science*, 4th ed. McGraw-Hill, 2000.)



Structure and 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



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Cont…Structure and connections of the 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**,
- **The *granule cells***, which are **excitatory**
- The ***purkinje 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)

The white matter contain 3 deep nuclei

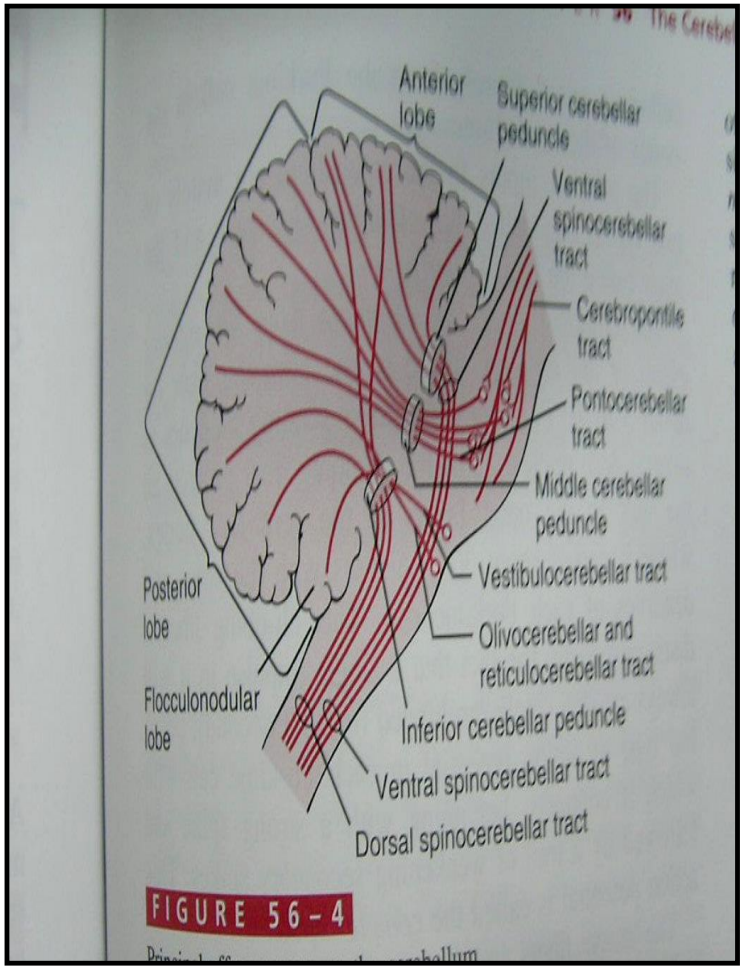
- 1- ***Dentate***
- 2- ***Fastigial***
- 3- ***Interpositous*** (formed of globose and emboliform nuclei)
- **All afferent fibers** relay first at the deep nuclei and the cerebellar cortex, then the latter discharges to the deep nuclei, from which the efferent fibers originate and leave the CB.

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.



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.

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

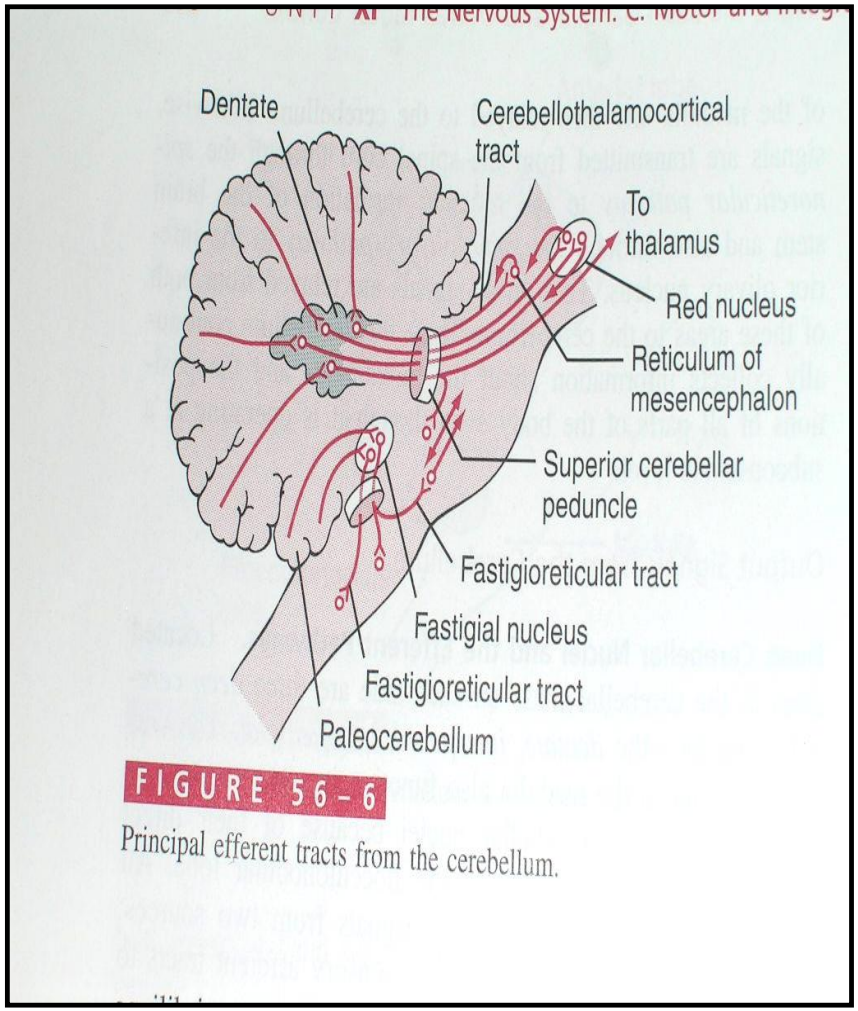


FIGURE 56–6

Principal efferent tracts from the cerebellum.

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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

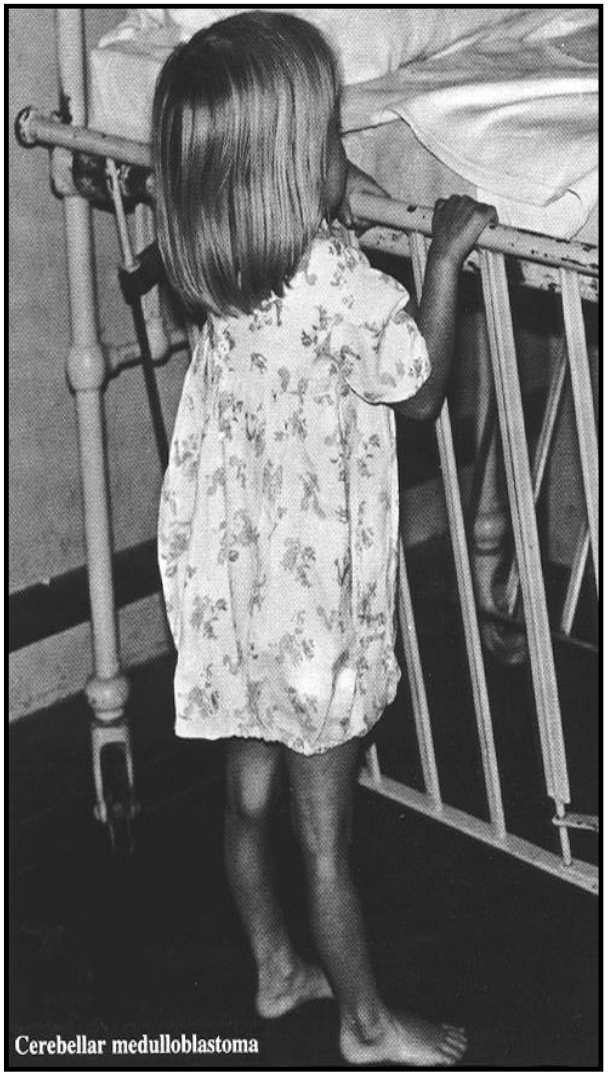
-then through the fastigal nucleus, it discharges to the brain stem, and through the vestibulospinal and reticulospinal tracts. It controls equilibrium & postural movements by affecting the activity of the axial muscles (trunk & girdle muscles).

Lesions of the vestibulocerebellum

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 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 diseases often result in ***hypotonia***).

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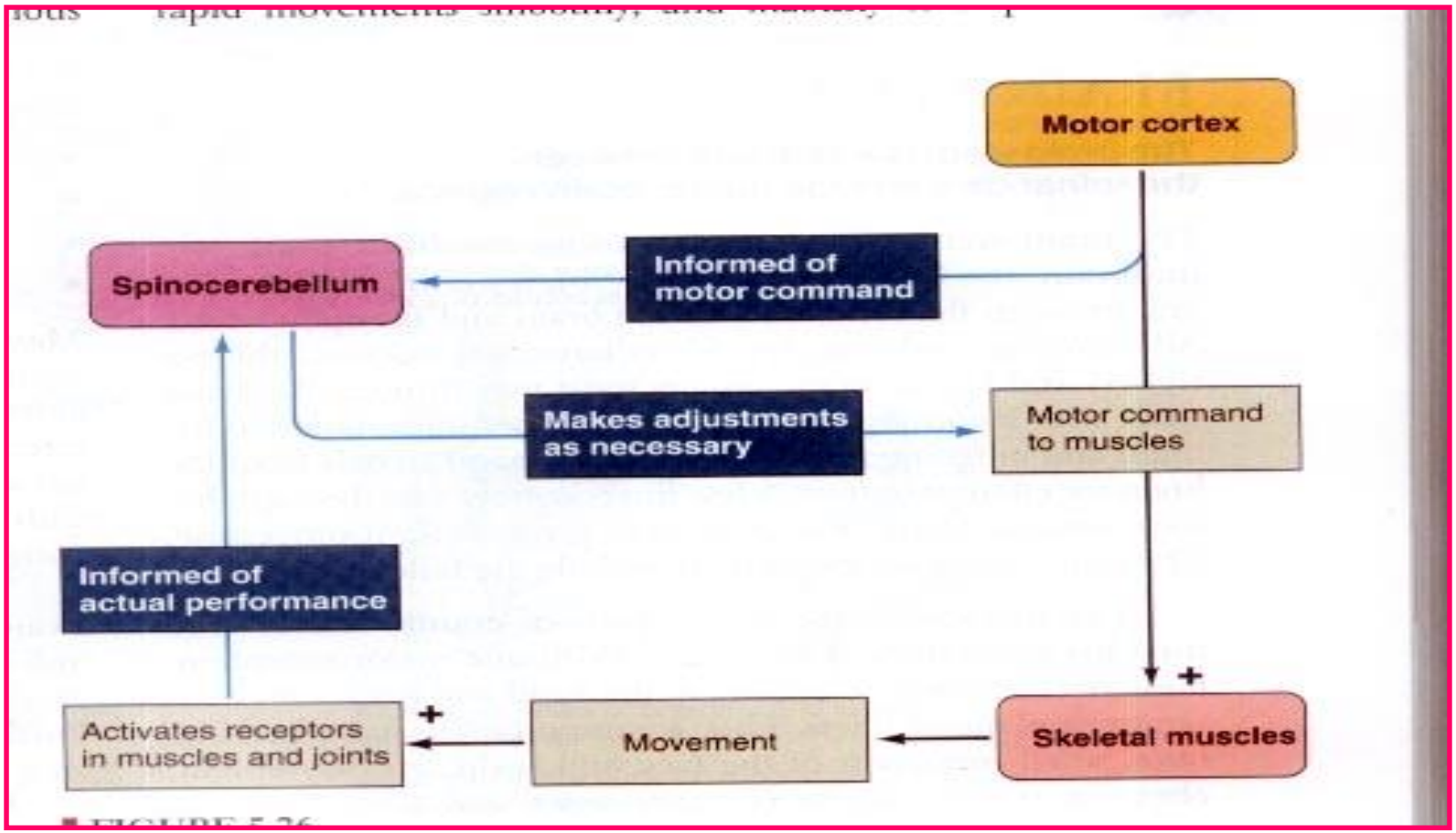
C-Control of voluntary movements by the cerebellum



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.

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

Neocerebellar syndrome

Video

http://www.dailymotion.com/video/x1j0an_cerebellar-disease_family

https://www.youtube.com/watch?v=R6KBVCkurM0

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 either

a- the cerebellum or spinocerebellar tracts

b- the labyrinth (vestibular apparatus)

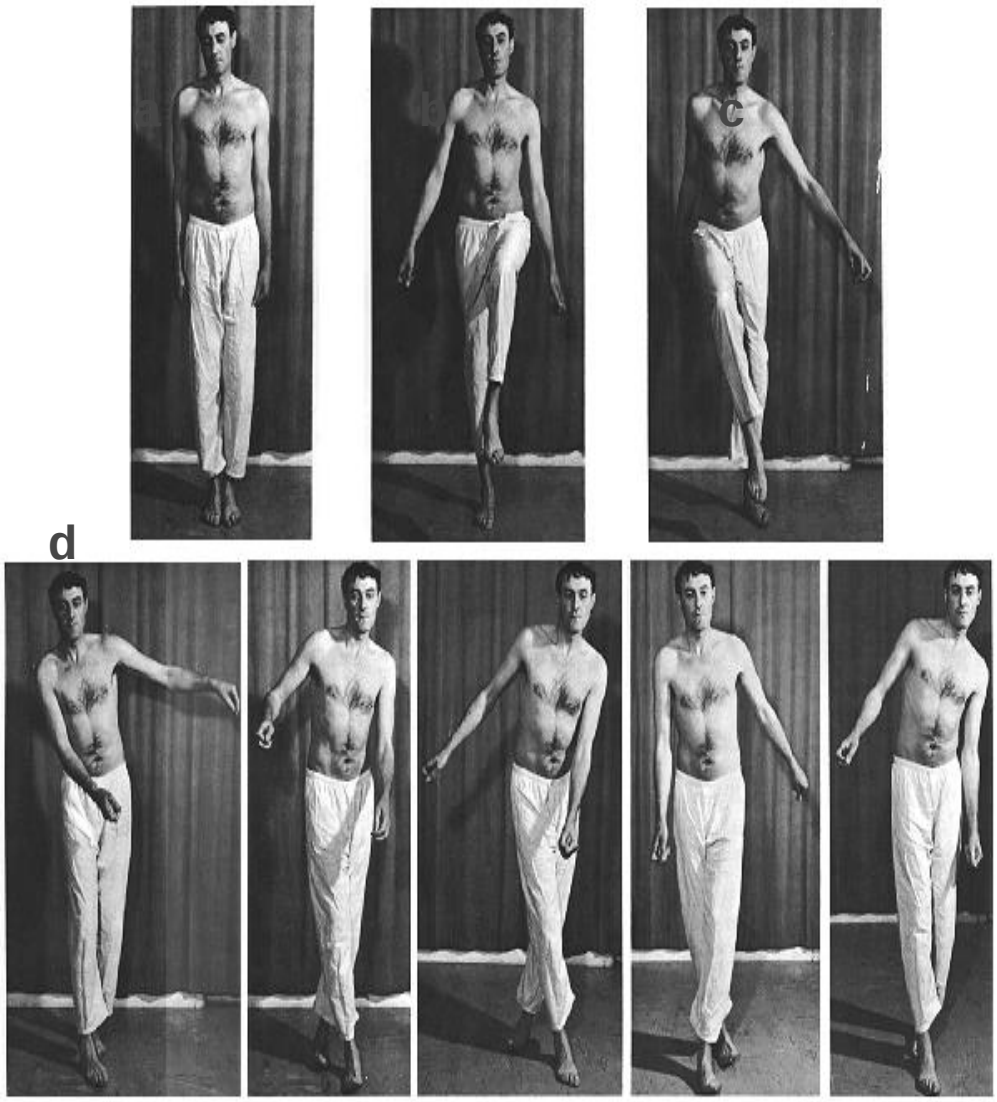
c- the cortical motor areas.

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

Posture
Gait – Ataxia
Tremor

Cerebellar Ataxia



Left cerebellar tumor

Ataxic gait and position:

a. Sways to the right in standing position

b. Steady on the right leg

c. Unsteady on the left leg

d. ataxic gait

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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.

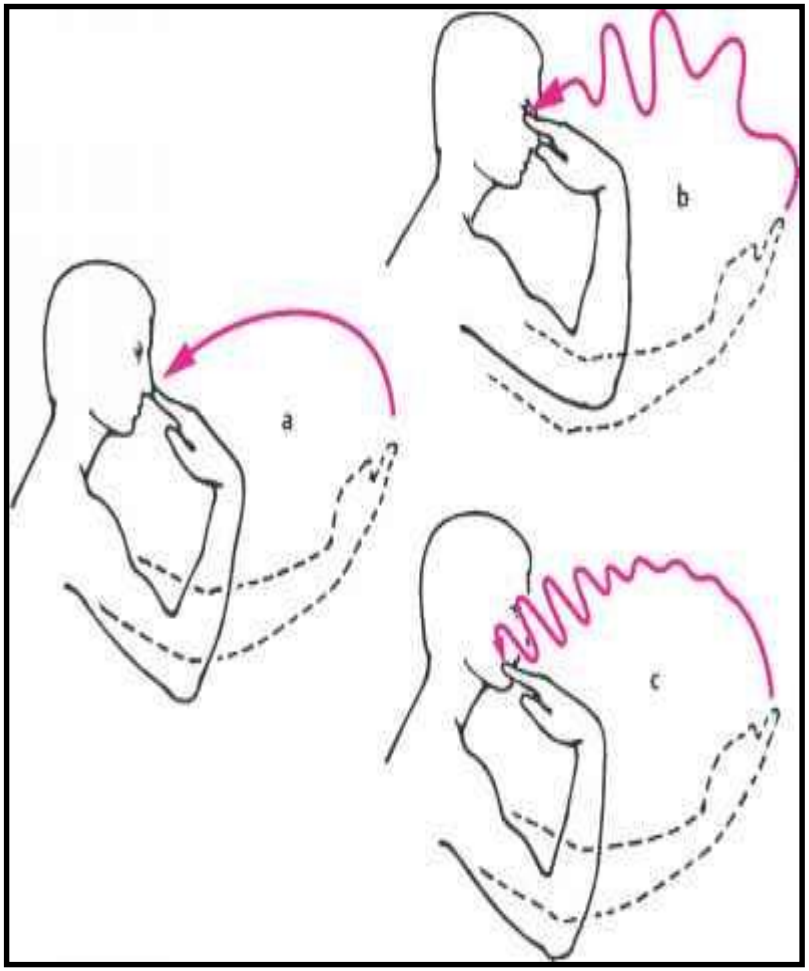
2-Kinetic (intension, action or terminal) tremors:

This an oscillatory movement that appears on performing a voluntary movement (especially at its end) but is absent at rest.

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 overshoot followed by overshoot of the correcting movements.

Finger to finger & finger to nose test



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 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 archicerebellar damage.

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