physiology team 429

CEREBELLUM

Done By :
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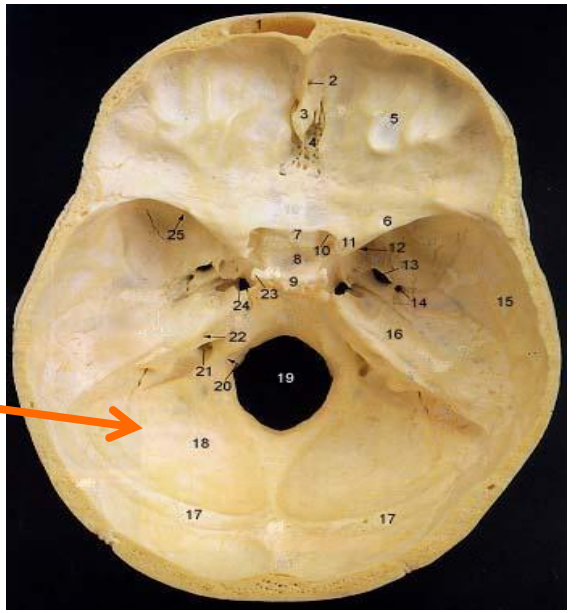
CEREBELLUM INTRODUCTION:



- Position:

- Cerebellum is situated in the posterior cranial fossa.

-beside the main sensory and motor systems in the brain stem.

- various fibers inter and leave the cerebellum through three cerebellar peduncles: superior, middle and inferior which connects the cerebellum to the brain stem .

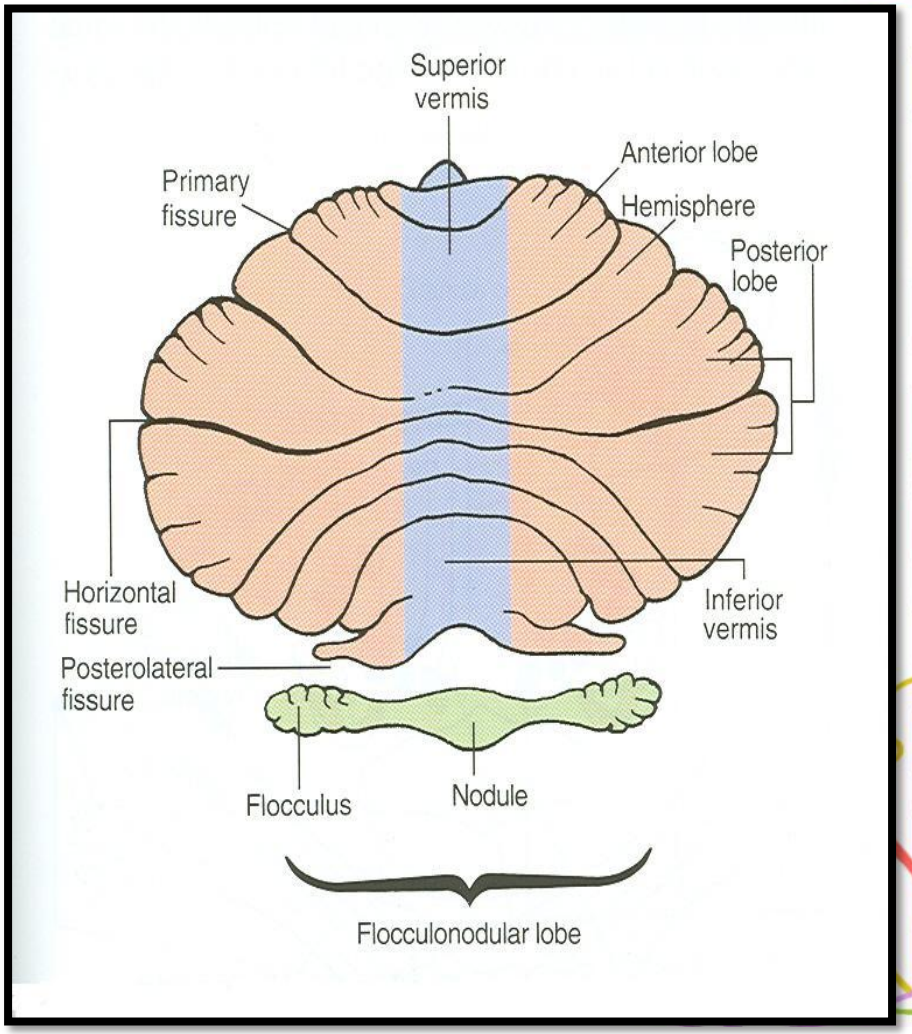
Function of cerebellum (generally):

1. Maintenance of Equilibrium (*balance*, *posture*, *eye movement).*
2. Coordination of half-automatic movement of walking and posture maintenance (*posture*, *gait).*
3. Adjustment of Muscle Tone.
4. Motor Leaning – Motor Skills.
5. Cognitive Function.

ANATOMICAL SUBDIVISION:

1. ***Anterior lobe****:* in front of primary fissure
2. ***Posterior (middle) lobe****:* behind primary fissure
3. ***Flocculonodular lobe***.

* 2 large cerebellar hemispheres, which are separated by a narrow band called the vermis.



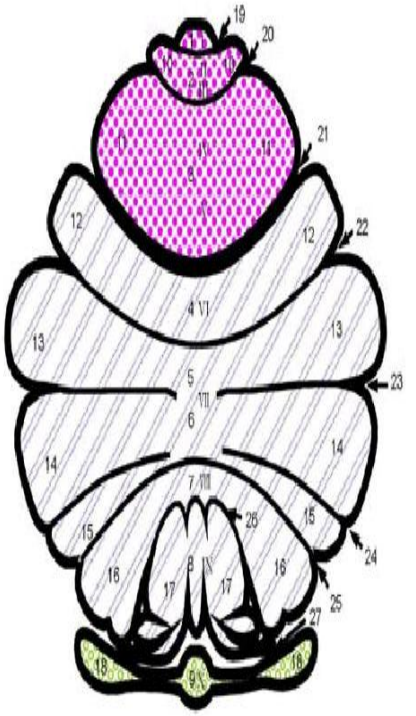
FUNCTIONAL (PHYSIOLOGICAL) DIVISIONS OF CEREBELLUM:

1) Vestibulocerebellum (archicrebellum):

- ✓ The oldest part of the CB.
- ✓ Its consist of the flocculonodular lobe & the adjacent portions of the vermis.
- ✓ It's responsible for:
  - a) *equilibrium.*
  - *b) learning induced changes in vestibulo-ocular reflex (VOR)*

2) Spinocerebellum (paleocrebellum): (anterior lobe) :

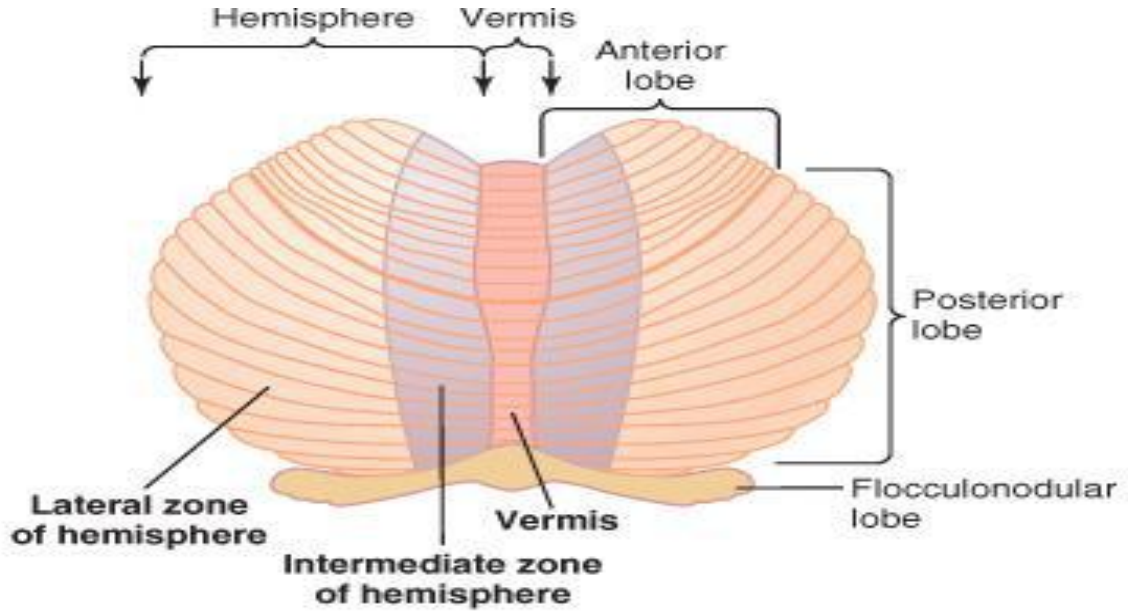
- ✓ The intermediate (or paravermal) zones of the 2 hemispheres & most of the vermis of the anterior and posterior lobes.
- ✓ It plays a role in:
  - *a) regulation of muscle tone* and *posture.*
  - *b) It smoothes and coordinates movements that are going.*



* ***Spinocerebellum.***
* ***Crebrocerebellum.***
* ***Vestibulocerebellum.***

3) Crebrocerebellum (neocerebellum): (posterior lobe):

- ✓ The newest part of the CB.
- ✓ It's consist of the large lateral zones of the 2hemispheres.
- ✓ It's function:
  - interact with the motor cortex in planning & programming of movements.



FUNCTIONAL DIVISIONS OF CEREBELLUM:

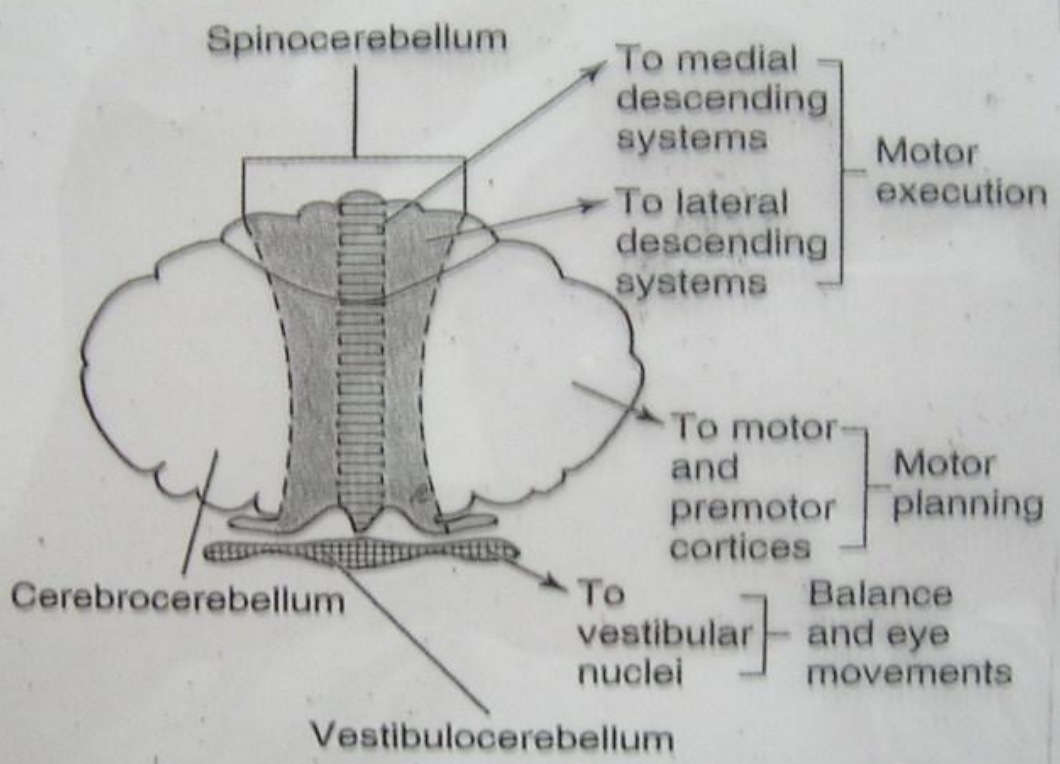
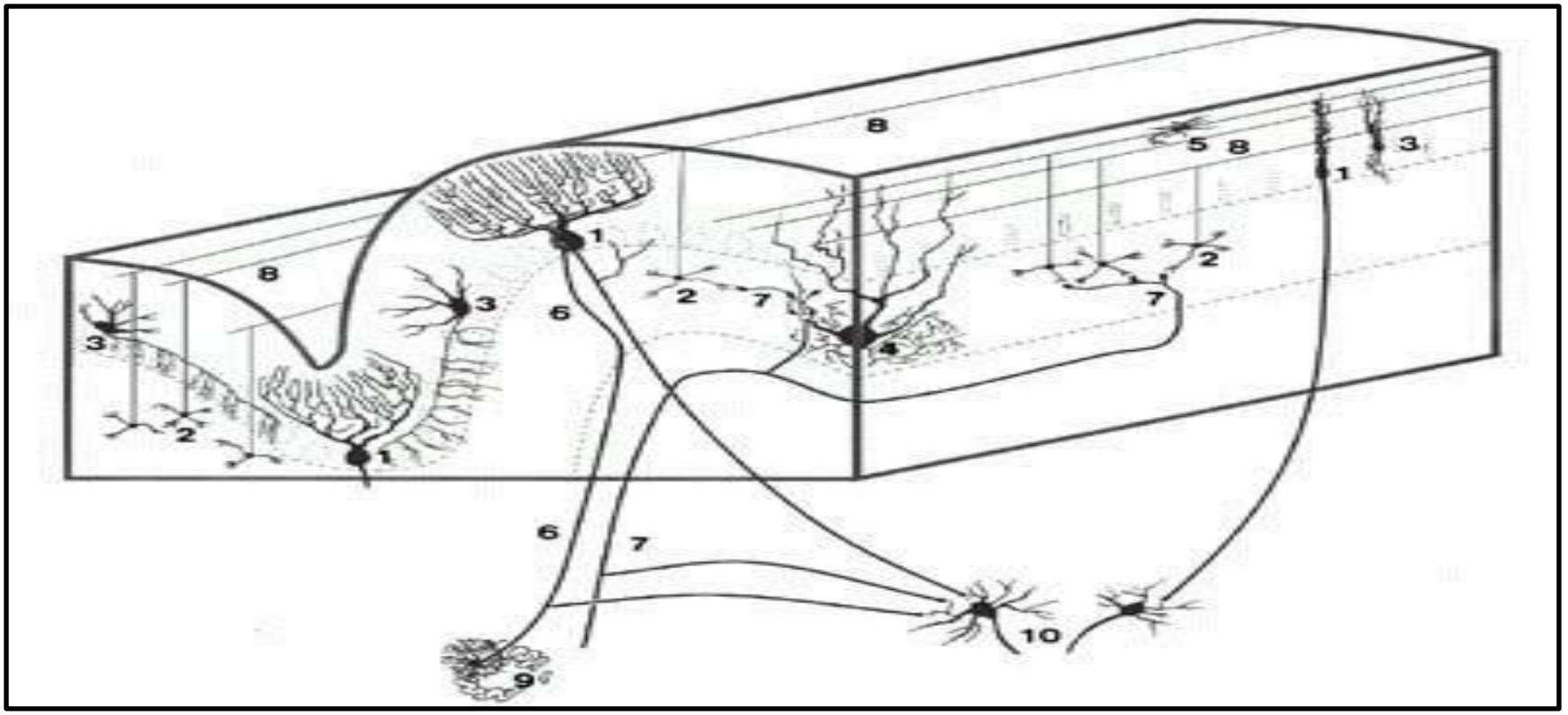


Figure 12–15. Functional divisions of the cerebellum. (Modified from Kandel ER, Schwartz JH, Jessell TM [editors]: *Principles of Neural Science*, 4th ed. McGraw-Hill, 2000.)

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.

STRUCTURE OF THE CEREBELLUM:

- The CB has an external layer of gray matter **(cerebellar cortex),** and an inner white matter **(cerebellar medulla).**

Cells of gray matter (cerebellar cortex)	**nuclei of white matter "deep nuclei" (cerebellar medulla)**
1. *The Golgi cells.* 2. *The Basket cells.* 3. *The Stellate cells.* 4. The *granule cells.* 5. The *purkinje cells.*	1. *Fastigial.* 2. *Interpositous (Globose and Emboliform nuclei).* 3. *Dentate.*

THE CEREBELLAR CORTEX & ITS NEURONAL CIRCUITS:

formed by 3 layers:

- **The Molecular layer :**

  the outer layer, contains dense short parallel interconnecting fibers.

- **The purkinje cell layer:**

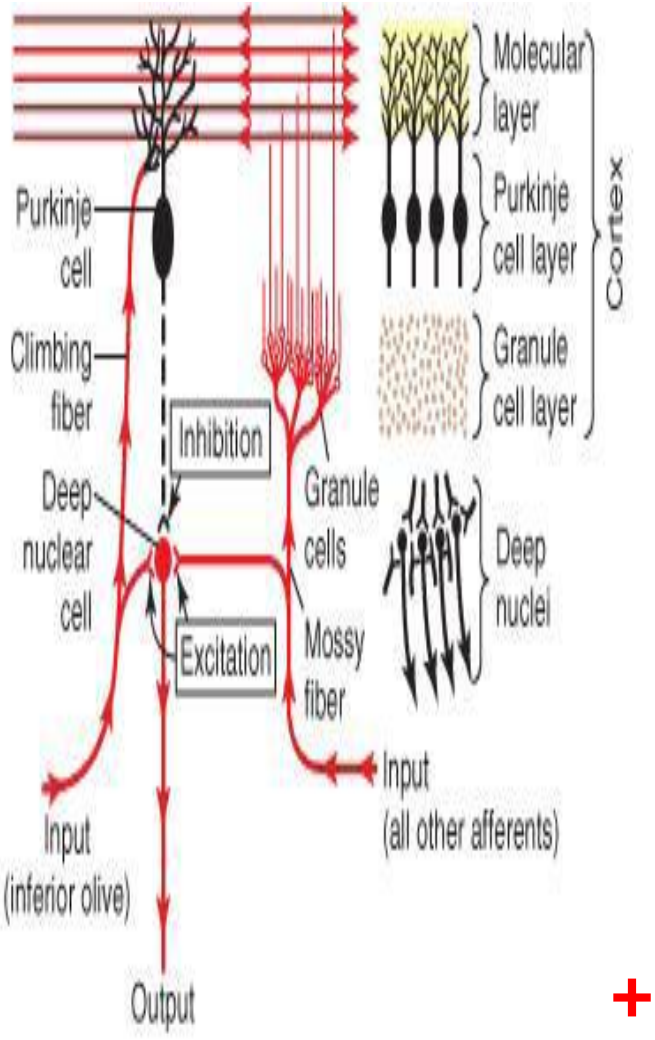
  the middle layer, contain large purkinje cells (PCs) that:

  a) their axons are the only fibers that leave the cerebellar cortex

  b) inhibit the deep nuclear cells (DNCs).

- **The granule cell layer:**

  It is the inner layer, it contains the granule cells.



CEREBELLAR CORTEX:

1) Molecular Layer:

- ***StellateCell :*** *taurine (inhibitory)*
  - afferent: *parallel fiber.*
  - efferent: Purkinje cell dendrite.
- ***Basket Cell :*** *GABA (inhibitory)*
  - afferent: *parallel fiber.*
  - efferent: Purkinje cell soma.

2) Purkinje Cell Layer:

- ***Purkinje Cell:*** GABA (inhibitory)
  - afferent: *parallel fiber , climbing fiber,* stellate cell, basket cell.
  - efferent: deep cortical nuclei.
  - Are the main output neurons.

CONT…

3) Granular Layer :

- ***Granular Cell :*** glutamate (excitatory)
  - afferent: *mossy fiber*.
  - efferent: *Purkinje cell dendrite*, basket cell, stellatecell, Golgi cell.

- ***Golgi Cell:*** GABA (inhibitory)
  - afferent: parallel fiber, mossy fiber rosette.
  - efferent: granule cell dendrite.

Afferent Fibers:

- 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.

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

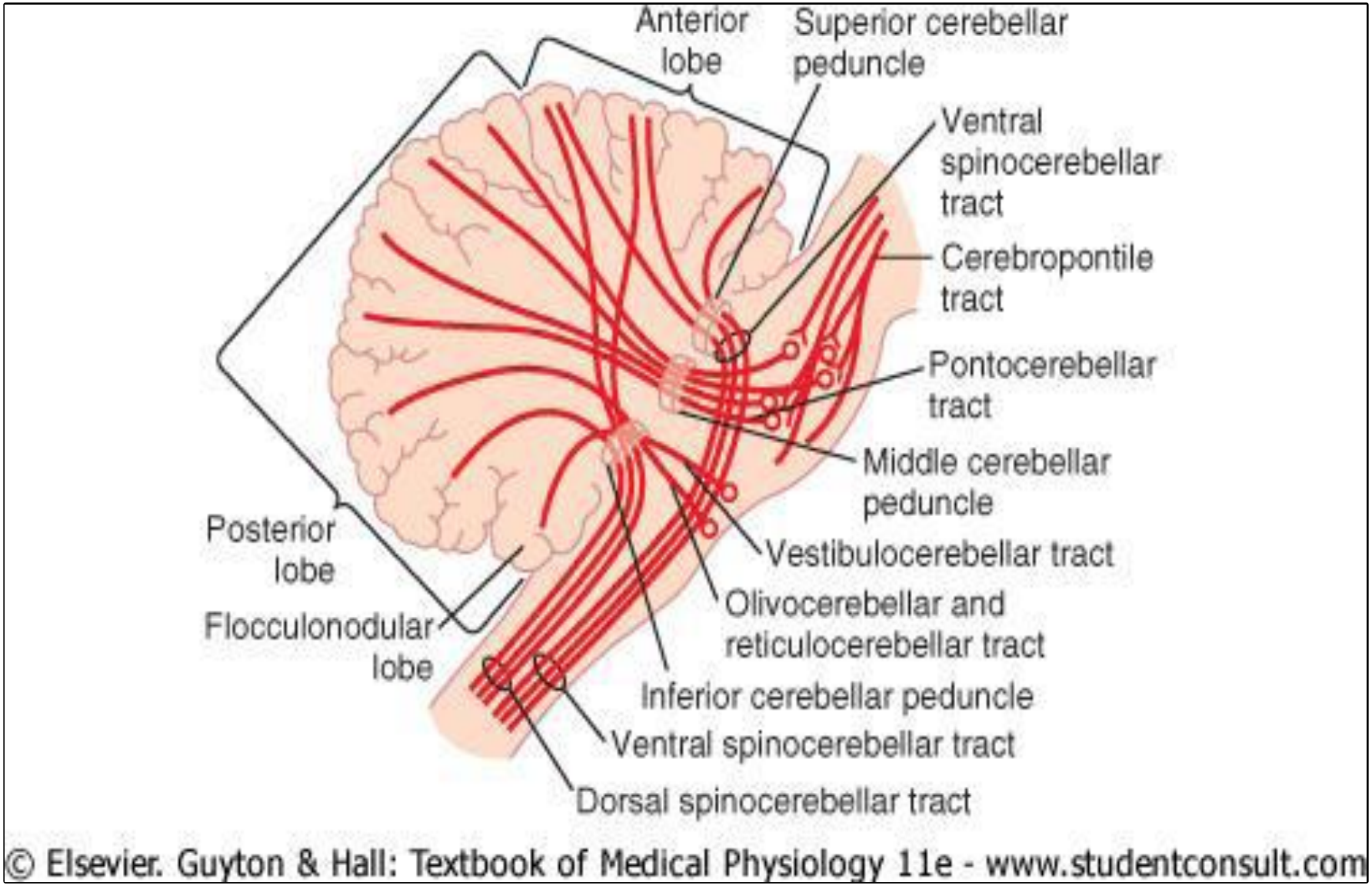
This arises **from:**

a) other areas of the brain.

b) peripheral receptors.

and enters the CB via the 3 cerebellar peduncles.

Cont… Afferent (input) connections of cerebellum:



EFFERENT (OUT PUT) PATHWAYS:

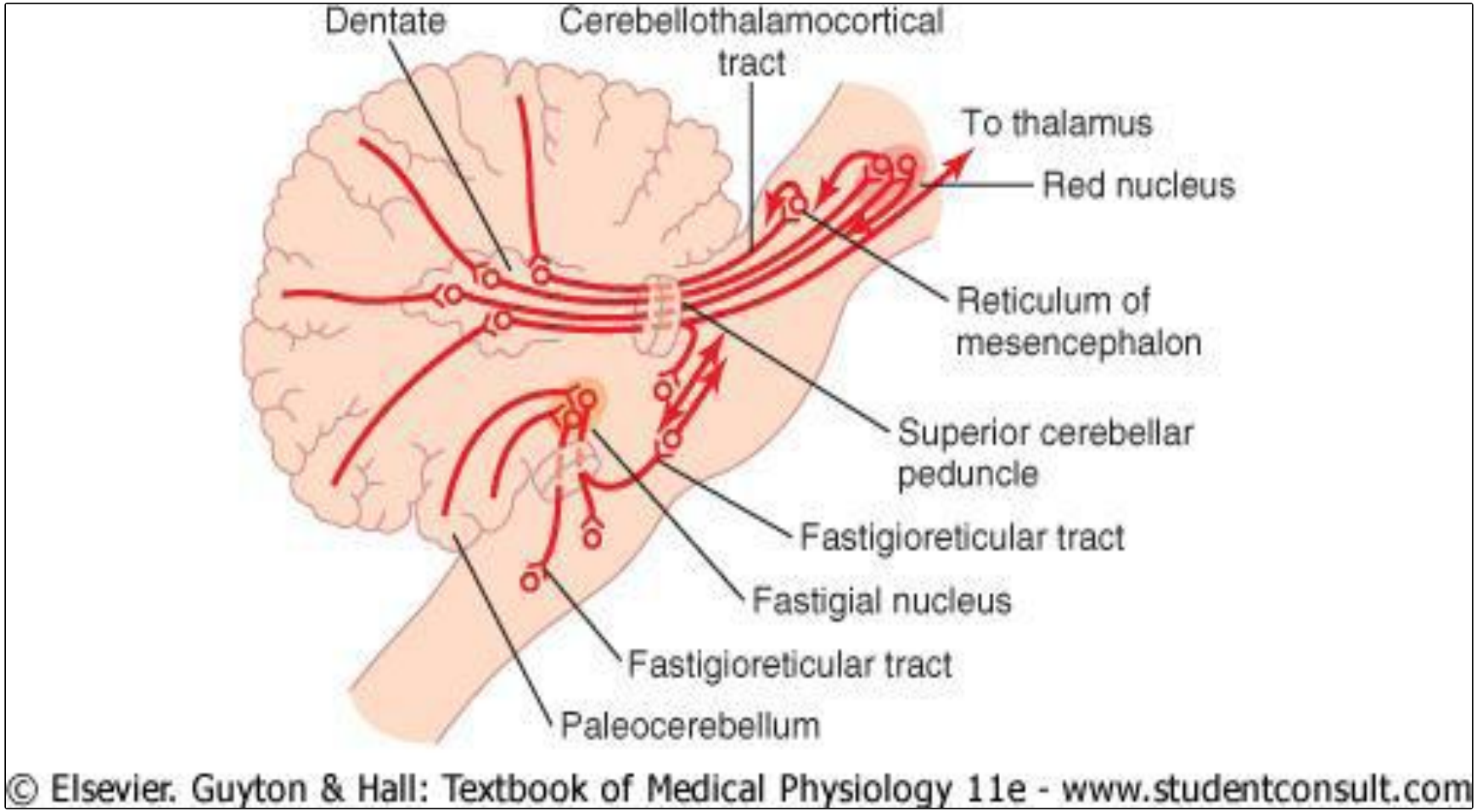
- There are 3 main efferent pathways from the 3 parts of the CB.
- Are the axons of the 3 deep nuclei.
- Leave the CB through the **superior** and **inferior** peduncles.

N.B:

Efferent pathways mainly are:

1) Vestibulospinal , Reticulospinal tracts.
2) Rubrospinal tracts.
3) Corticospinal (Pyramidal) tracts.

Efferent (out put) connections of the cerebellum:



CEREBELLUM: THE RULE OF 3 :

3 Lobes	•FloculonodularLobe •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

CEREBELLUM:

1. The CB is called the ***silent area***, because its stimulation does **not give** rise to any **sensation** and cause almost **no motor movements.** (important)

2. 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.

3. The cerebellum is concerned ***only with subconscious control of motor activity*** .

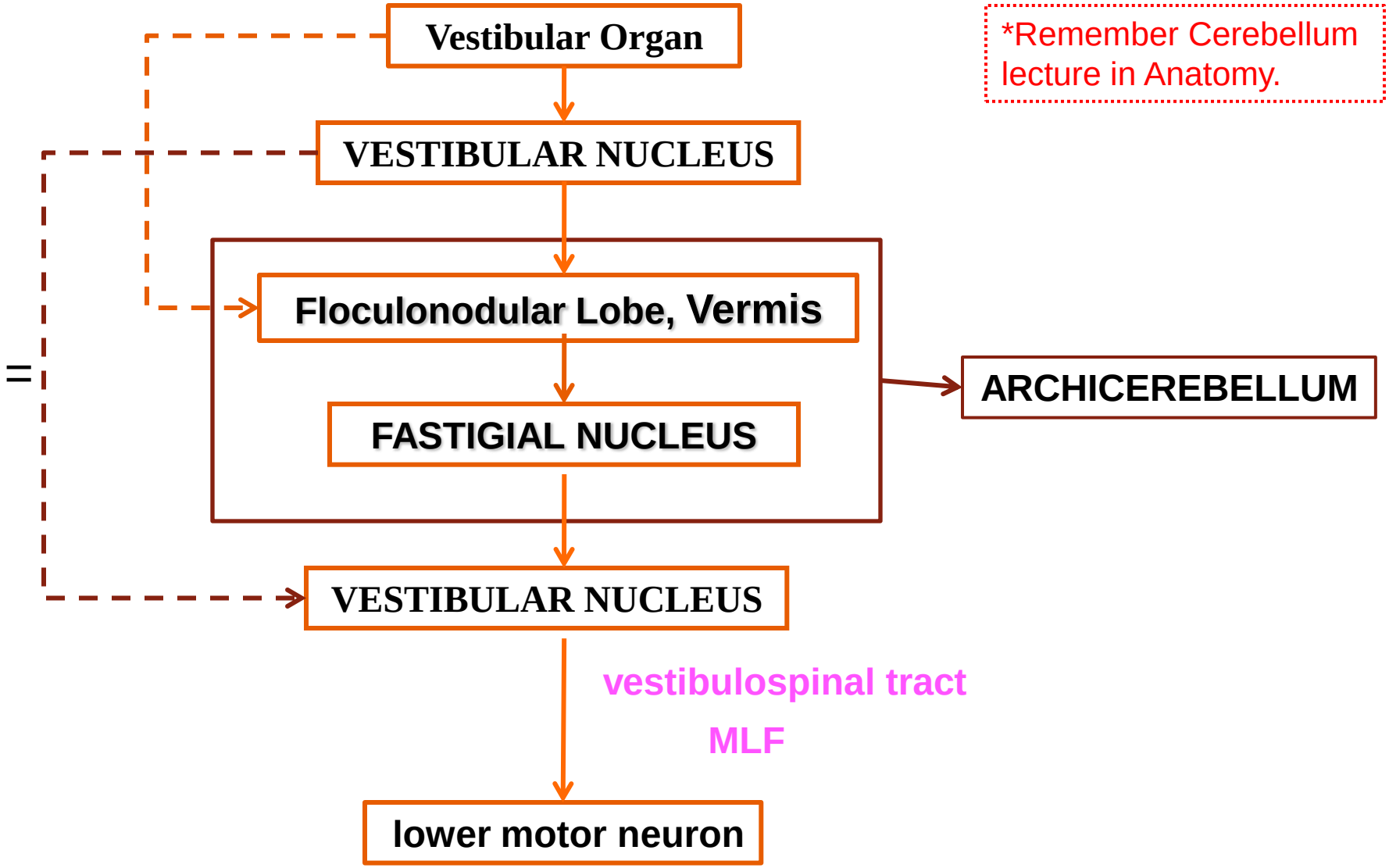
FUNCTIONS OF CEREBELLUM:

a) CONTROL OF EQUILIBRIUM & POSTURAL MOVEMENTS.

b) CONTROL OF THE STRETCH REFLEX.

c) CONTROL OF VOLUNTRY MOVEMENTS.

A)CONTROL OF EQUILIBRIUM & POSTURAL MOVEMENTS:
The role of the Vestibulocerebellum



*Remember Cerebellum lecture in Anatomy.

CONT……CONTROL OF EQUILIBRIUM & POSTURAL MOVEMENTS

Final step through the **vestibulospinal** and **reticulospinal tracts**

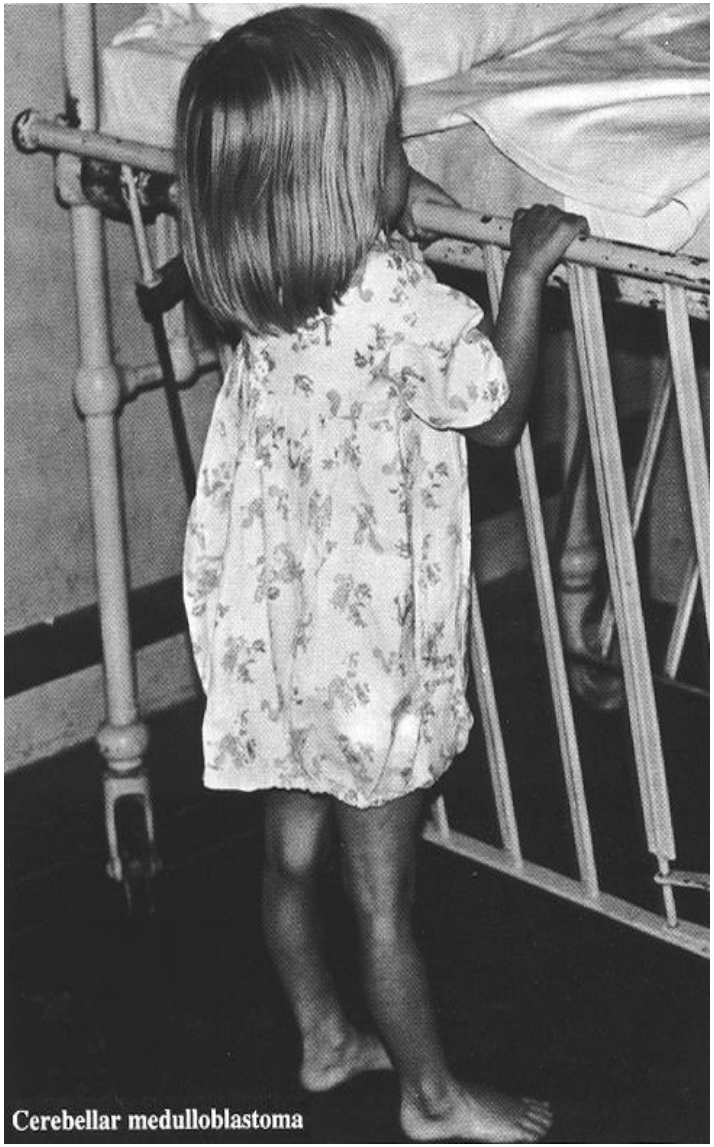
it controls equilibrium& postural movements by affecting the activity of the axial muscles (trunk & girdle muscles).

CONT….

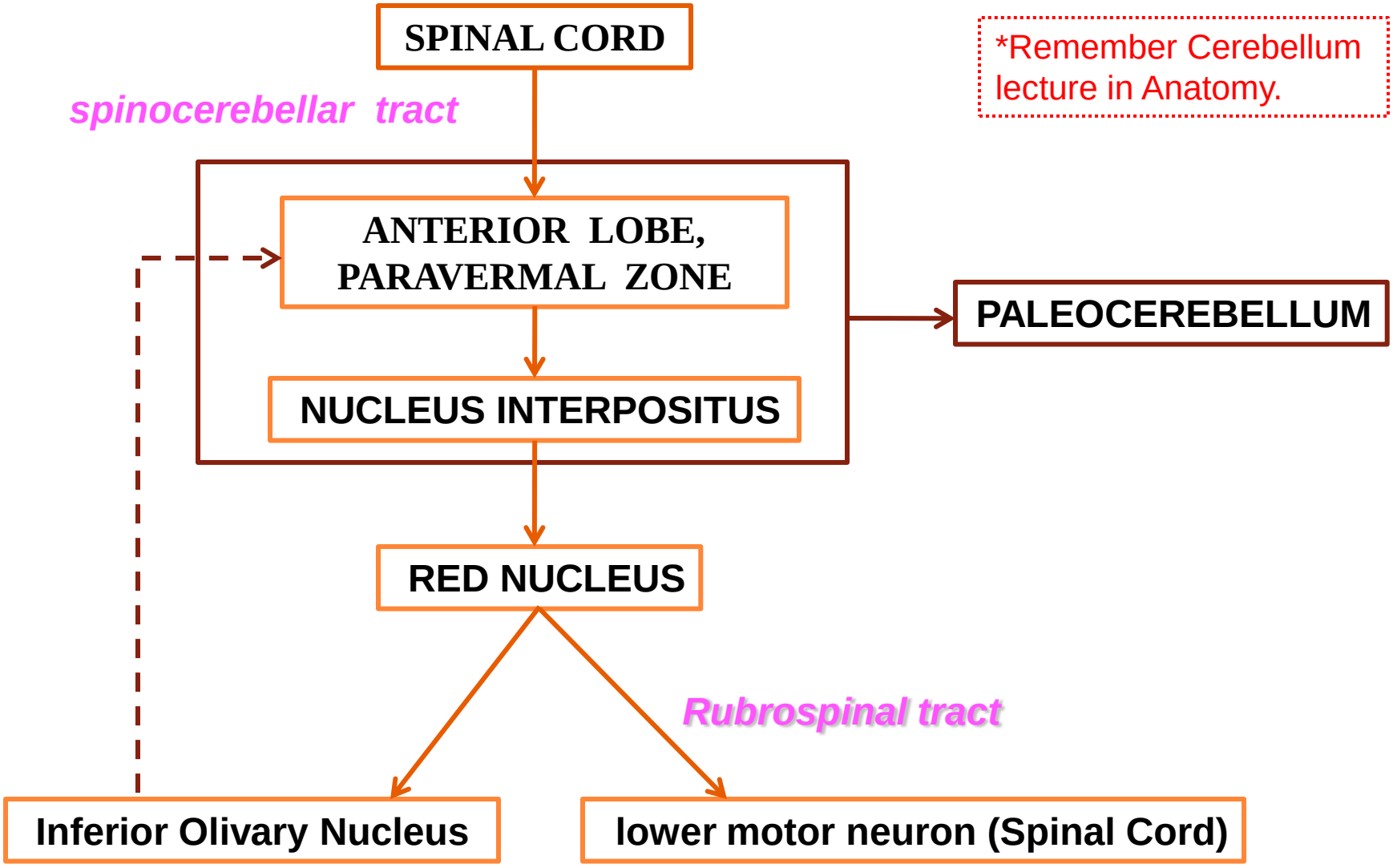
Lesions of the vestibulocerebellum:

- e.g due to a tumor called medulloblastoma.
- lead to trunk ataxia which is characterized by:

1. **Equilibrium disturbances:**
   the patient needs support or falls on the affected side, and walks by a staggering or drunken gait.
2. Eye moving in the opposite direction to rotation of the head (impairment in the vestibulo-ocular reflex).
3. Patients are unable to adapt to the input and the original reflex is maintained, even though it is now inappropriate and they have Nystagmus.


Cerebellar medulloblastoma

B)CONTROL OF THE STRETCH REFLEX:



CONT…..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 disease often results in ***hypotonia***).

For you to remember:

*** Increase Muscle Tone:**

1. Corticospinal tracts.
2. Lateral Vestibulospinal tracts.
3. Medial (Pontine) Reticulospinal tracts.
4. Cerebrocerebellum (neocerebellum).

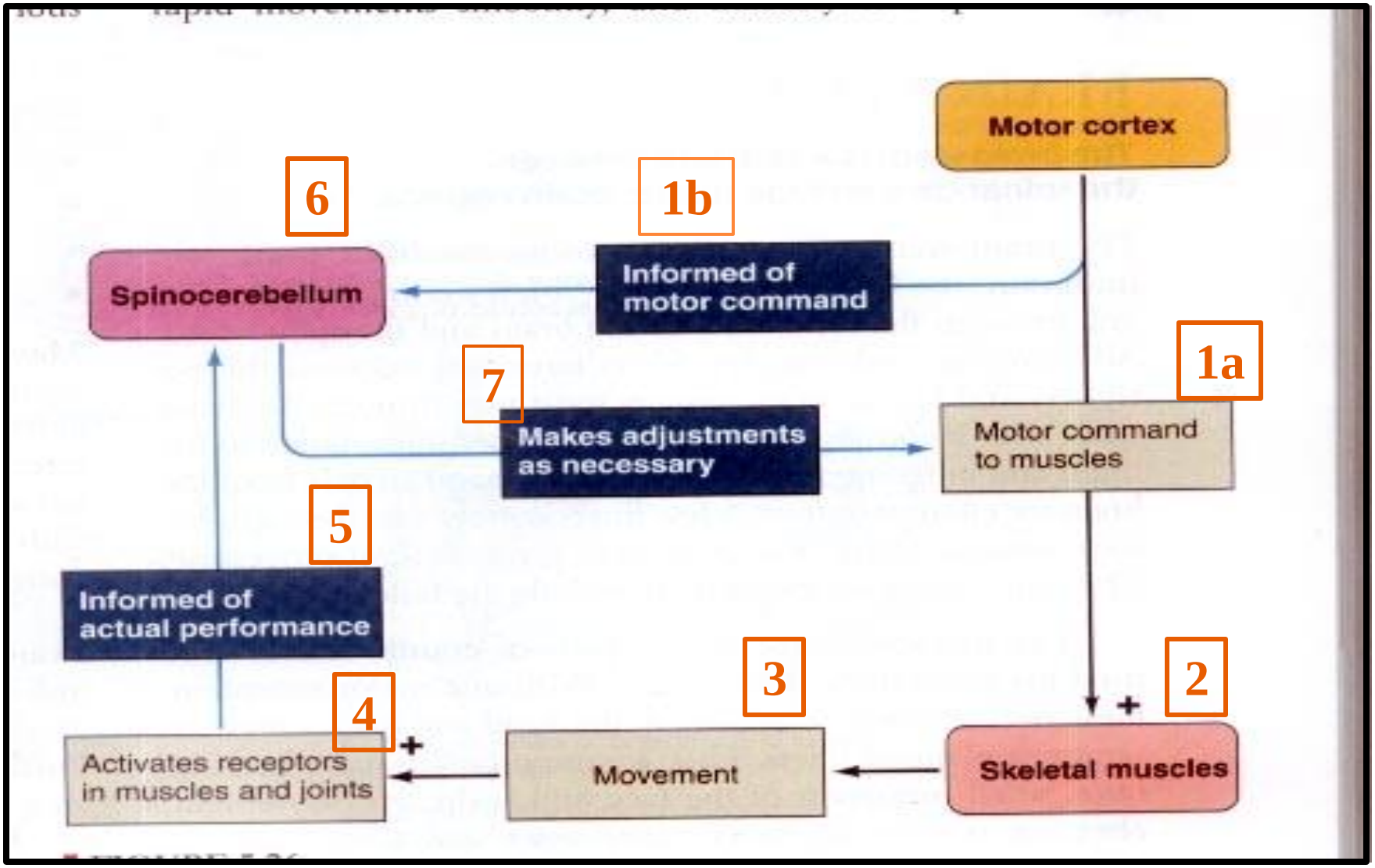
***Decrease Muscle Tone:**

1. Inverse Strech Reflex (Golgi tendon organe reflex).
2. Rubrospinal tracts.
3. Lateral (Medullary) Reticulospinal tracts.
4. Spinocerebellum (Paleocerebellum).

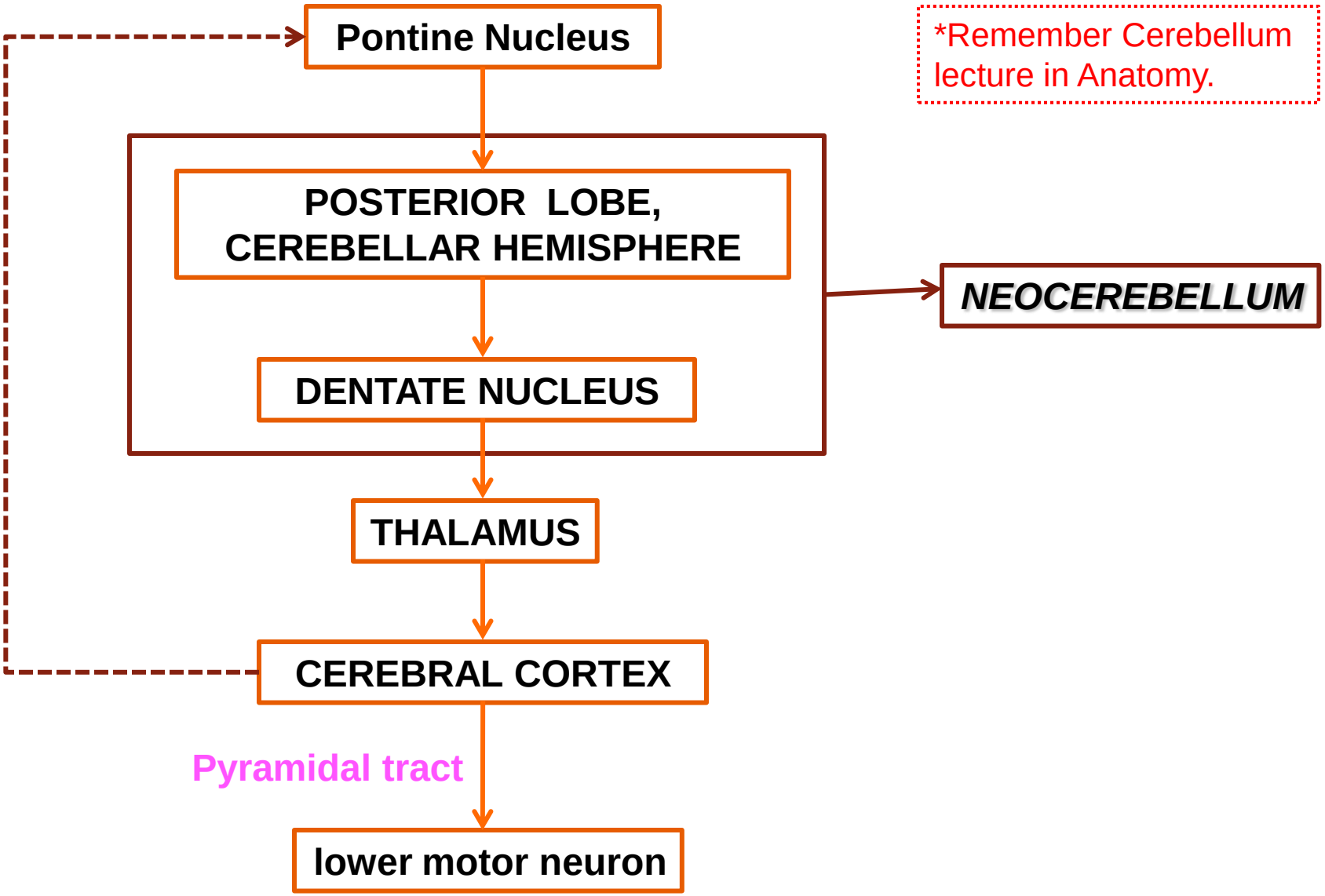
SPINOCEREBELLAR LESION:

- Lesion results in dysmetria.
- Past pointing: The movement goes beyond the point of intention.
- Reflexes are pendulardue to reduction of facilitation of gamma motor efferent.

C-CONTROL OF VOLUNTARY MOVEMENTS BY THE CEREBELLU:



C-Control of voluntary movements by the cerebellum (Cerebrocerebellum):

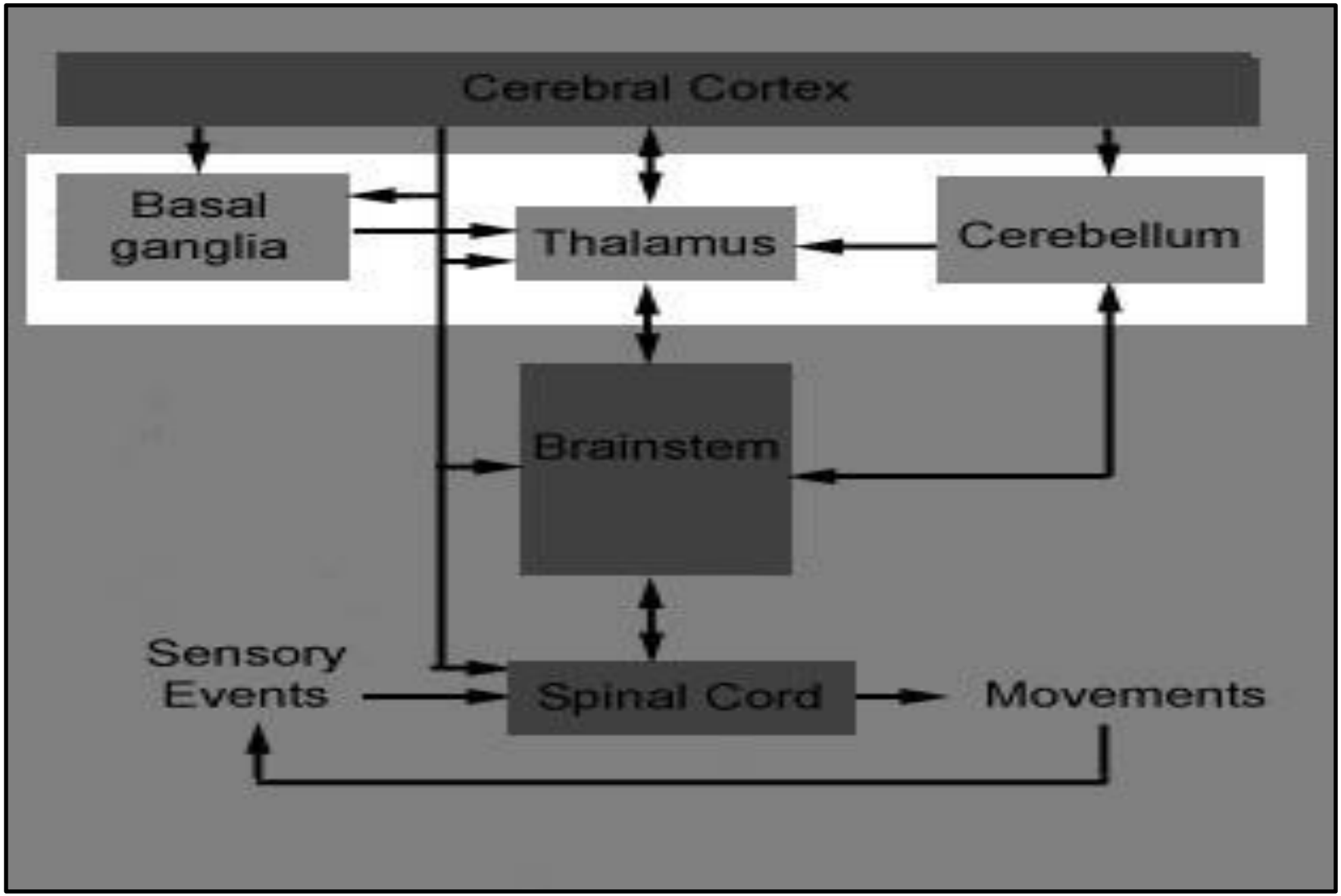


N.B:

- 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.*** (important)

  - ***The vermis*** controls muscle movements of the axial & proximal muscular movement " 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.

CONNECTIONS OF THE CEREBELLUM:



CEREBELLUM CONTROLS VOLUNTARY MOTOR FUNCTION THROUGH:

1) The braking effect of the cerebellum.
2) The damping function of the cerebellum.
3) The control of ballistic movements by the cerebellum.
4) The planning and timing function of the cerebellum.
5) predictive function of the CB.

THE BRAKING EFFECT OF THE CEREBELLUM:

In every day life , especially during rapid movements, the motor cortex transmits far more impulses than are needed to perform each intended movement.

To not bypass 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.

THE DAMPING FUNCTION OF THE CEREBELLUM:

- Almost all movements of the body are pendular due to momentum., so they have tendency to over shoot.

- To overcome this, the CB sends appropriate signals which stop the movement at the required point and prevent overshooting (by contraction of the antagonistic muscles).
- **If the CB is damaged**, overshooting occurs and the cerebral cortex will try to correct this overshoot but the arm will oscillate beyond the point of intention several times before it settles on the intended point.
- This forms the basis of the kinetic or intension ***tremors of the neocerebellar syndrome.***

THE CONTROL OF BALLISTIC MOVEMENTS BY THE CEREBELLUM:

BALLISTIC MOVEMENTS : rapid movements that are planned to travel to a specific distance and stop precisely at the point of intension.

e.g: 1- movements of the fingers in typing

2- piano playing

3- movement of the eyes while reading.

- the cerebellum, first send ***excitatory signals*** to the motor areas initiating the motor movements so as to ***reinforce the onset*** of ballistic movements.
- then follows by ***inhibitory signals***, which stop the ballistic movements by ***the braking effect***..

- This function allows the smooth progression of movements for the performance of rapid movements

TIMING FUNCTION OF THE CEREBELLUM:

- Another important function of the lateral cerebellar hemisphere is to provide appropriate timing for each movement . 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.

- Absence of the timing function of the CB causes the succeeding movement to begin too early or, more likely, too late resulting in incoordination of the complex rapid movements (e.g writing, running, and talking), and also failure of their smooth progression.

PREDICTIVE FUNCTION OF THE CB:

- The 2 way connection between the cerebral cortex and the cerebrocerebellum enables the latter to ***display the plan of the next movement at the same time the present movement is occurring.***
- thus the CB is not involved with what is happening at a given moment but with what will occur subsequently.

- 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).

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:

(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.*

- { if there is an anterior lobe lesion ,There is significant gait ataxia like drunken gait and Head tremor, Seen mostly in chronic alcoholics}.

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.

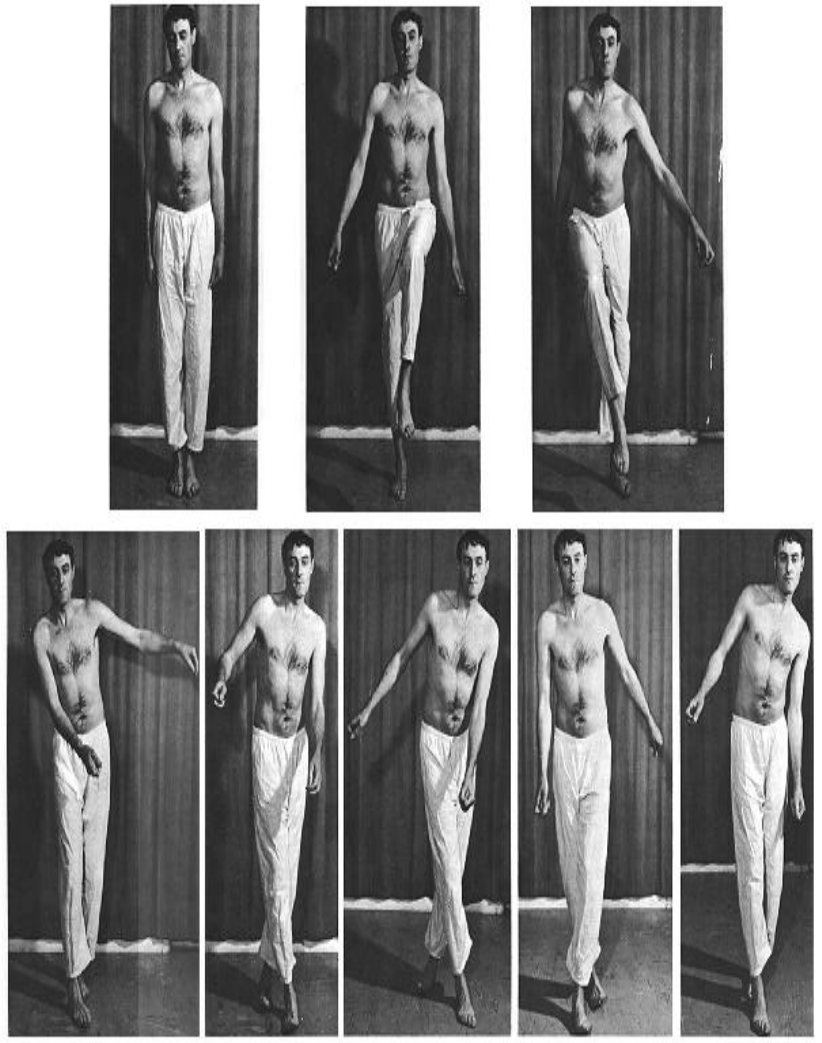
c) Motor ataxia:

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

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:**

a- the cerebellum or spinocerebellar tracts.

b- the labyrinth(vestibular apparatus).

c- the cortical motor areas.

MANIFESTATIONS OF MOTOR ATAXIA:

1-Dysmetria:

Inability to control the distance of the motor act, which may either overshoot the intended point (=hypermetria or pastpointing) 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 overshoot followed by overshoot of the correcting movements.

- alternating, oscillatory movement of a limb as it approaches a target (intention tremor).
- alternating of proximal musculature when fixed posture or weight bearing is attempted (postural tremor).

CONT….

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.

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 archicerebellar 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.

TEST OF COORDINATION IN UPPER LIMB:

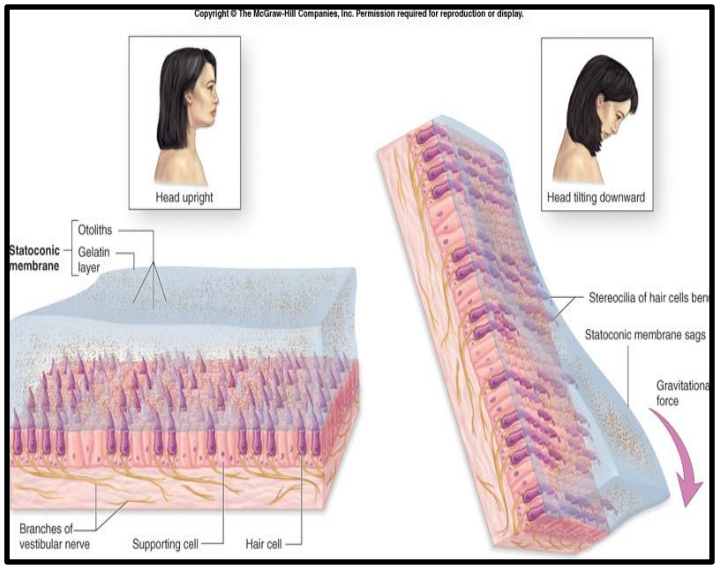
- Intention tremor.
- Finger Nose Test.
- Dysmetria.
- Rebound phenomenon.
- Dysdiadochokinesia.

TEST OF COORDINATION IN LOWER LIMB

- Unsteadiness while walking on a straight line.
- Tandom gait.
- Heel on Shin test.
- The gait can be drunken, reeling or broad base

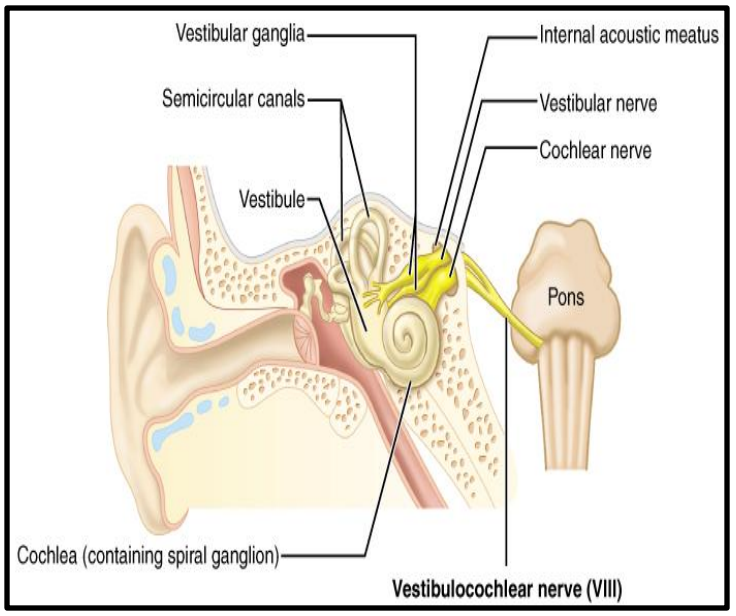
THE VESTIBULAR APPARATUS:

*is the organ that 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.



CN VIII: Vestibulocochlear Nerve:

*conducts two special senses: hearing (audition) and balance (vestibular).
*enters the brain stem at the junction of the pons and medulla lateral to the facial nerve.
*The vestibular part of the eight nerve ***ends in the vestibular nuclear*** complex located in the floor of the fourth ventricle
*The receptor cells are located in the membranous labyrinth.



- **Vestibulospinal fibres influence the activity of the spinal motor neurons concerned with the:**

1) Control of ***body posture and balance***.
2) Control of ***head and eye movements***.
3) Some fibres from the vestibular nuclei pass through the ICP to the folliculonodular lobe which is concerned with ***equilibrium***.
4) Other fibres project to ***thalamus*** then to the cortical regions responsible for conscious awareness of vestibular sensations.

- *Fibres from the vestibular nuclei contribute to the Medial &lateral vestibulospinal tracts.

ACOUSTIC NEUROMA

- Benign tumour of 8th CN 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,