Cerebellum

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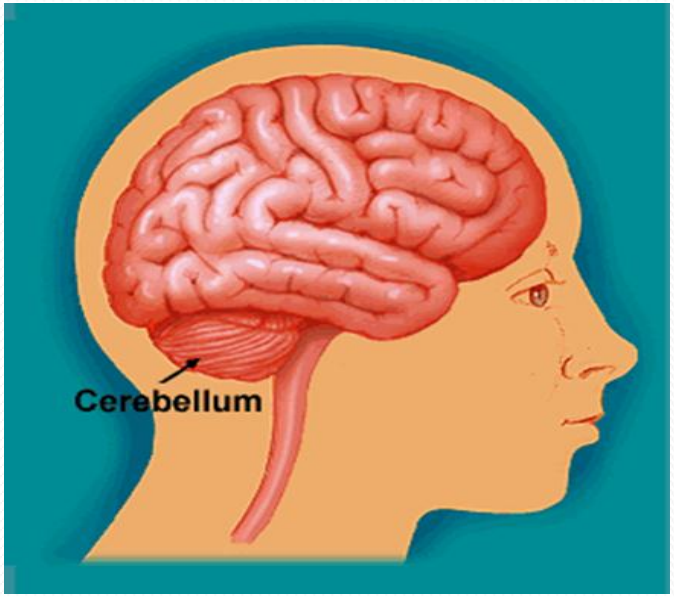
Learning Objectives

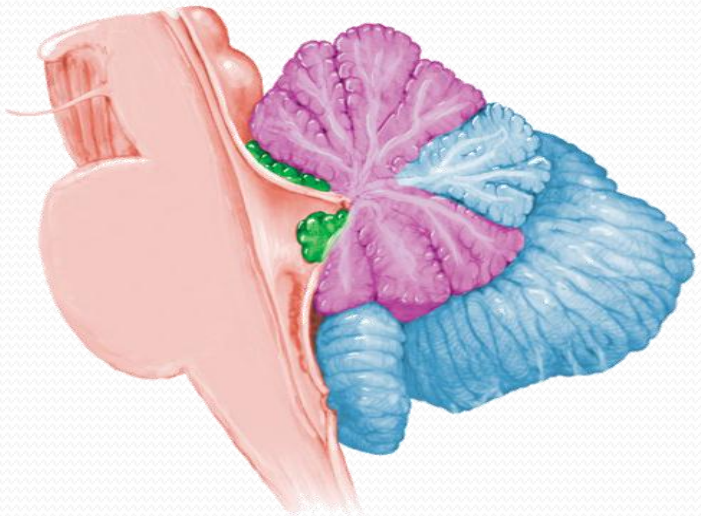
Upon completion of this lecture, students should be able to:

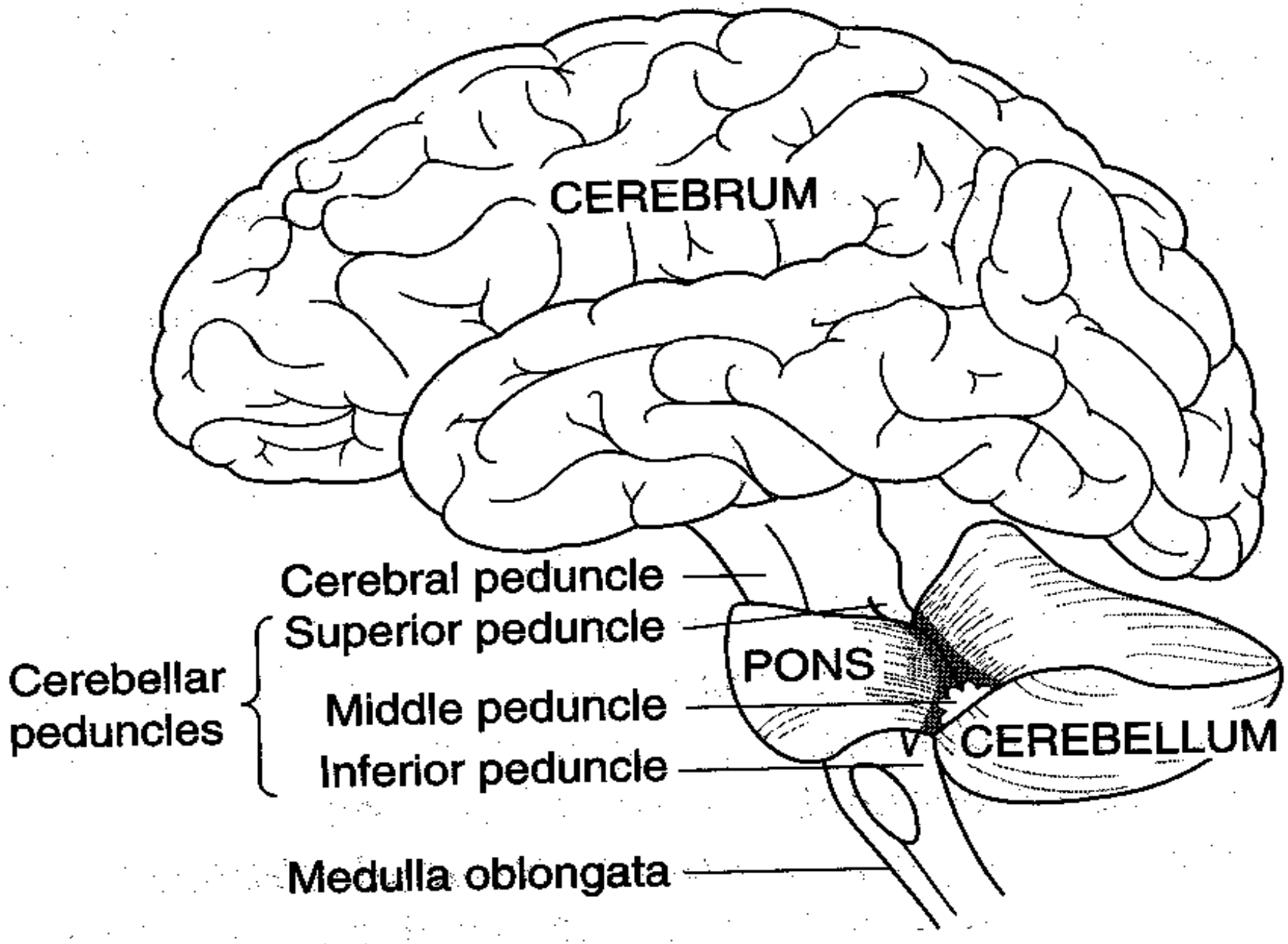
- Describe the functional divisions of the cerebellum (vestibulocerebellum, spinocerebellum and cerebrocerebellum).
- Understand cell types / nuclei of the cerebellum
- Understand the functions of cerebellum in regulation of movement, tone and balance.
- Understand the abnormalities associated with cerebellar disease

Cerebellum (CB)

- Cerebellum is a **highly folded** part of the brain, lies underneath the occipital lobe of the cortex
- It is attached to the brain stem on each side by 3 cerebellar peduncles 1) superior 2) middle 3) inferior
- It consists of two connected hemispheres (cerebellar hemispheres connected by <u>vermis)</u>
- Each hemisphere controls the same side (ipsilateral) of the body (unlike the cerebral cortex)



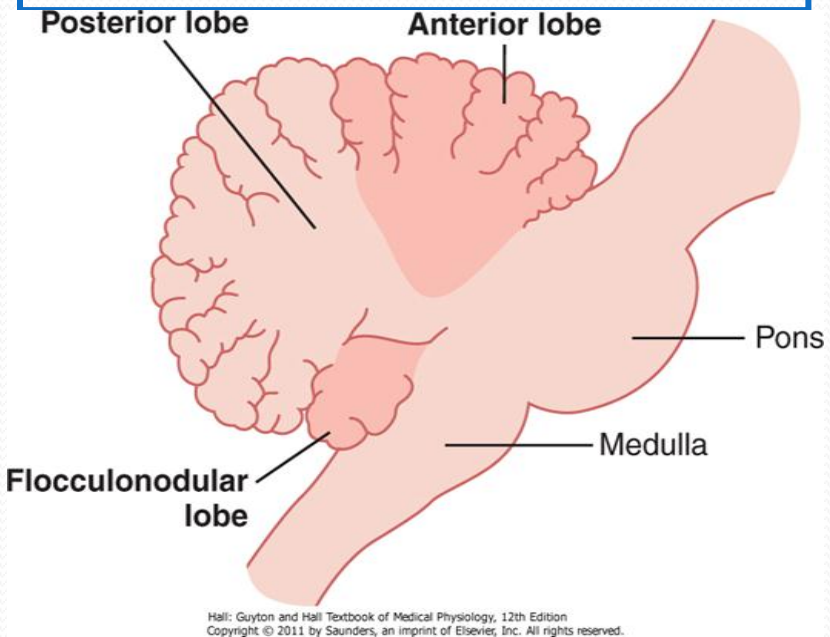


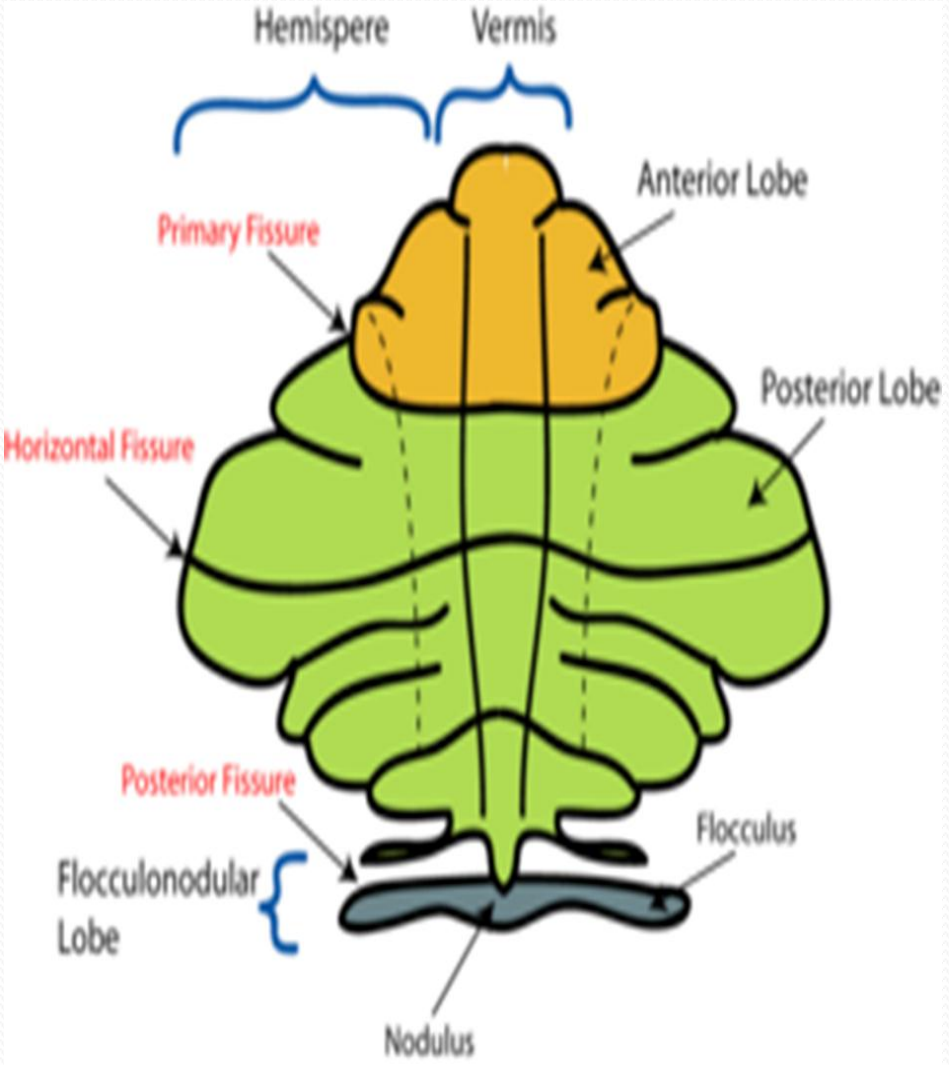

CEREBRUM
Cerebral peduncle
Superior peduncle
Cerebellar peduncles
Middle peduncle
Inferior peduncle
PONS
CEREBELLUM
Medulla oblongata

Anatomical Lobes of CB

Anatomically, the CB is divided into 3 lobes:

- the anterior lobe,
- the posterior lobe,
- the flocculo-nodular lobe





Functionally speaking , the Cerebellum is divided into 3 parts : Neocerebellum , Spinocerebellum , & Vestibulocerebellum

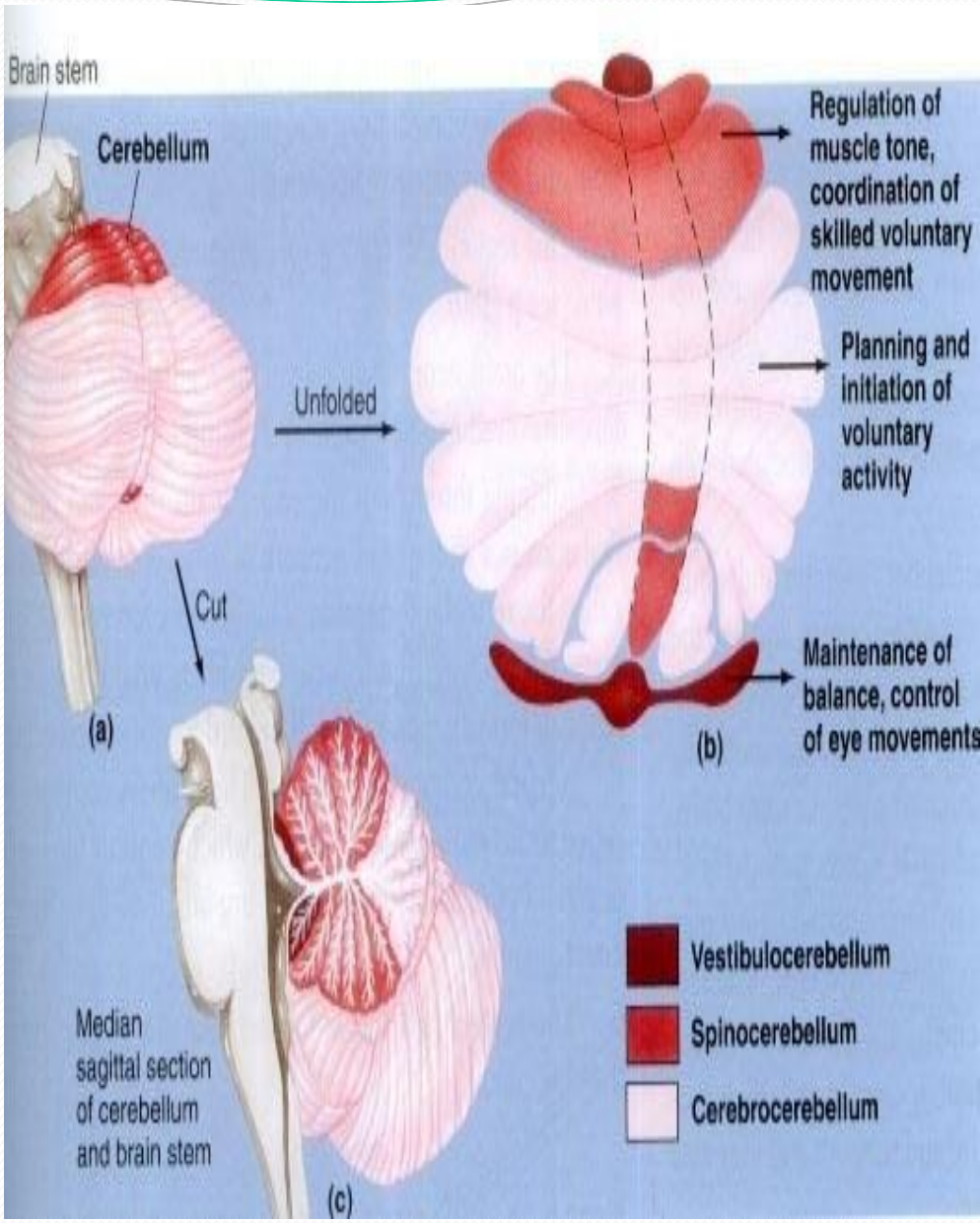
(A) Neocerebellum (cerebrocerebellum)

- ✓ Consists of the lateral parts of cerebellar hemispheres.
- ✓ It receives inputs from the cortex via Pontine Nuclei (Cortico-ponto-cerebellar fibers)

The Neocerebellum is involved in →

- ✓ **(1) planning and**
- ✓ **(2) initiation of motor function**
- ✓ (particularly skilled movements)

e.g.→ distal limb muscles , such as hand manipulative , skilled movements .



(B) Spinocerebellum

- Includes vermis & adjacent part of cerebellar hemispheres.
- It receives proprioceptive impulses from the body (via the spinocerebellar tracts)
- It also receives a copy of 'motor plan' from motor cortex.

- **It is concerned with regulation of muscle tone .**

(C) Vestibulocerebellum

- It is connected to vestibular nuclei
- Phylogenetically oldest part of cerebellum
- Includes flocculo-nodular lobe & part of vermis.
- It sends impulses to eye and body muscles

Function:

Maintain balance, equilibrium & control eye movements

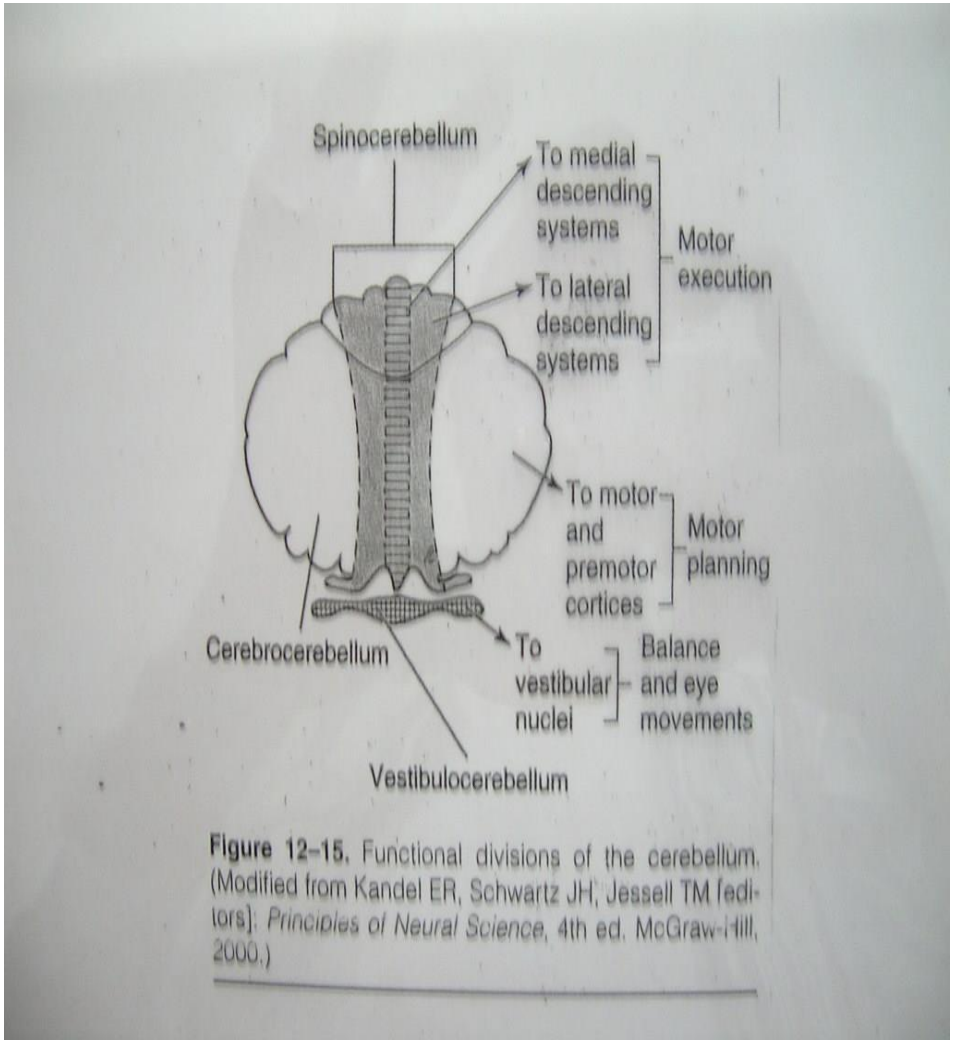
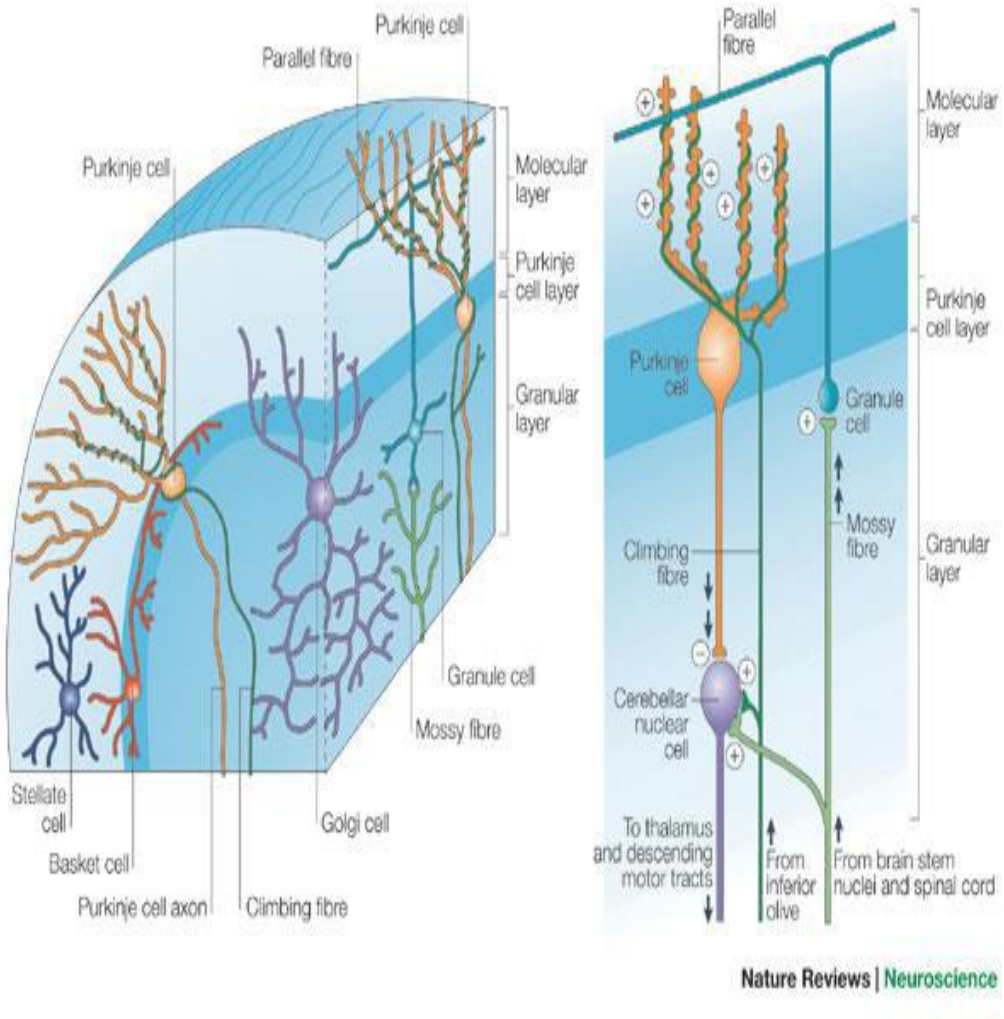


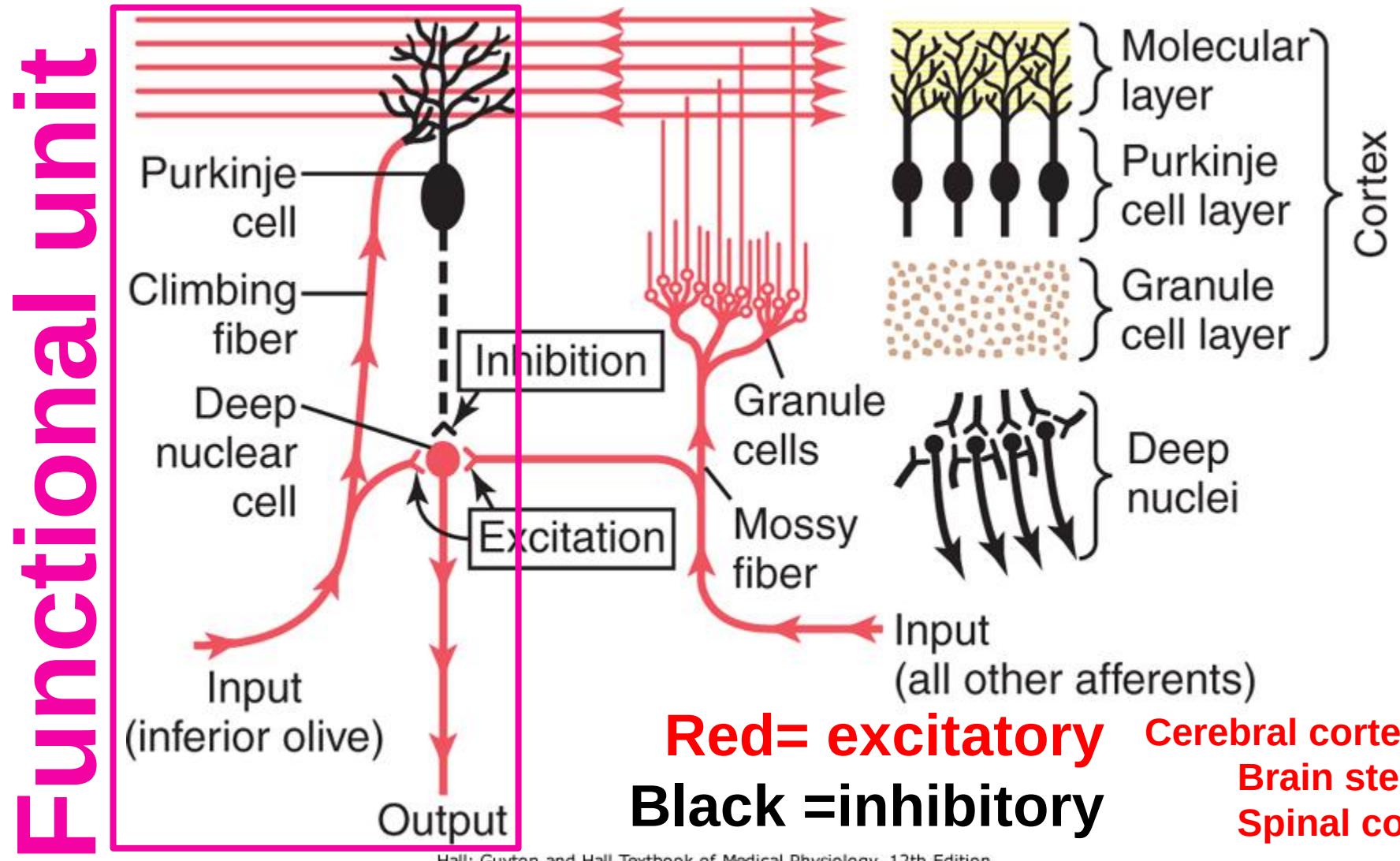
Figure 12–15. Functional divisions of the cerebellum. (Modified from Kandel ER, Schwartz JH, Jessell TM [editors]: *Principles of Neural Science*, 4th ed. McGraw-Hill, 2000.)

Structure & connections of 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



Functional Unit of the Cerebellar Cortex-the Purkinje Cell and the Deep Nuclear Cell



Red= excitatory

Black =inhibitory

- **Cerebral cortex,**
- **Brain stem,**
- **Spinal cord**

Structure & connections of Cerebellum cont.

- **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 inhibitoryneurons in the CB release GABA(e.gstellate, basket, Golgi, PC)**
- **The excitatoryneurons release glutamate(e.g. granule cells, that also has GABA A receptors)**

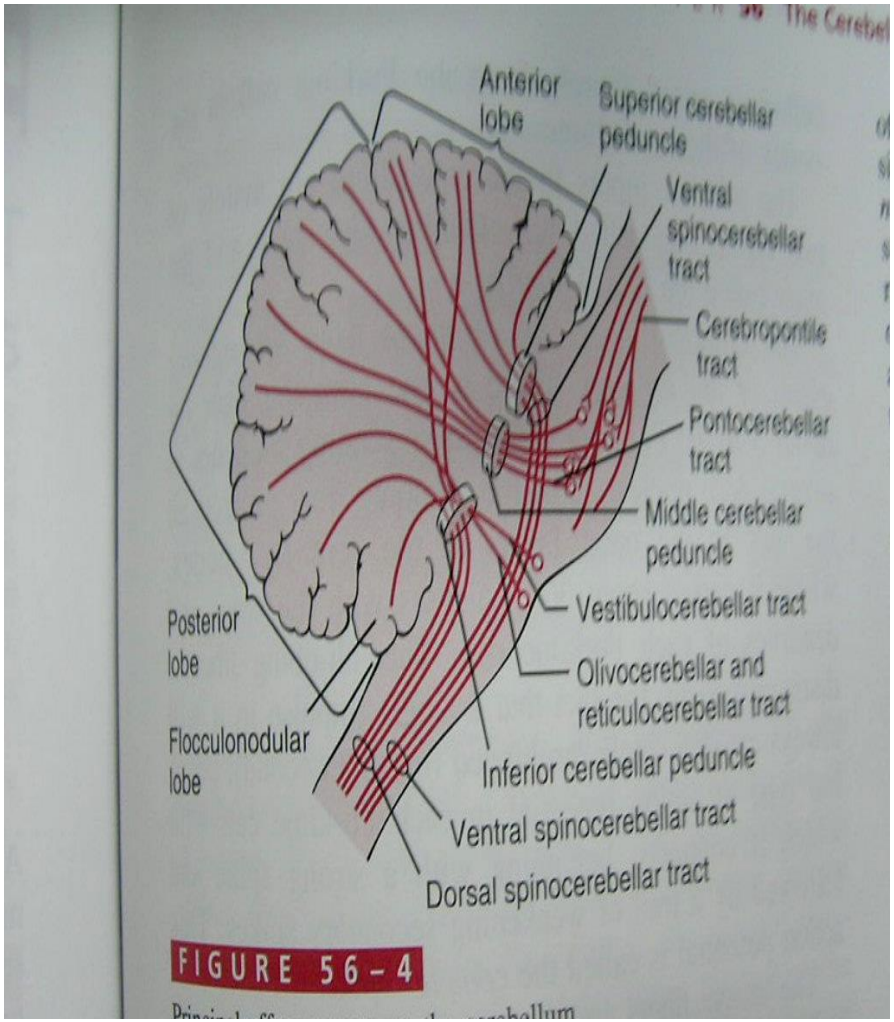
- The white matter contains 3 deep nuclei:
- 1-**Dentate**
- 2-**Fastigial**
- 3-**Interpositous**(formed of globose and emboliform nuclei)
- **All afferent fibers relay first at the deep nuclei and the cerebellar cortex, then the latter discharges to the deep nuclei, from which the efferent fibers originate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

Afferent (Input) pathway

- 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.



Afferent (Input) pathway Cont.

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) Fibers

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 **cerebellar peduncles**

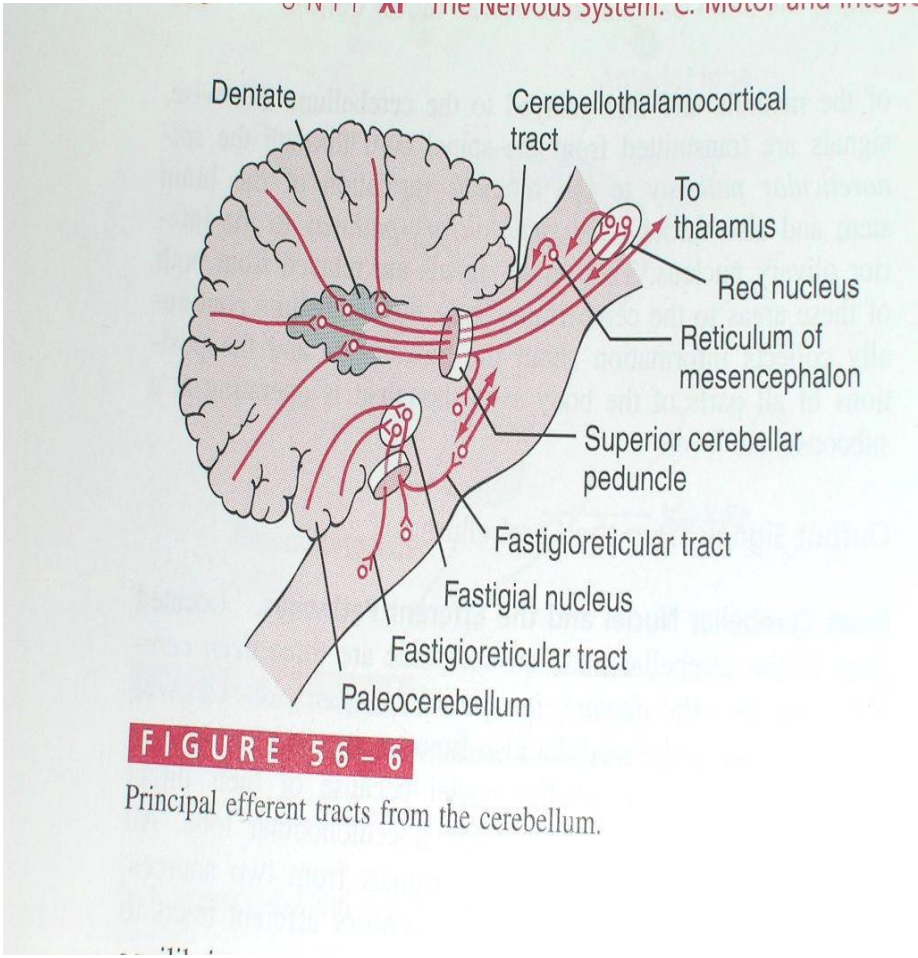


FIGURE 56–6

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 *in coordination 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 :***

Functions of The Cerebellum Cont.

A. Control of equilibrium & postural movements:

- The function of the vestibulocerebellum

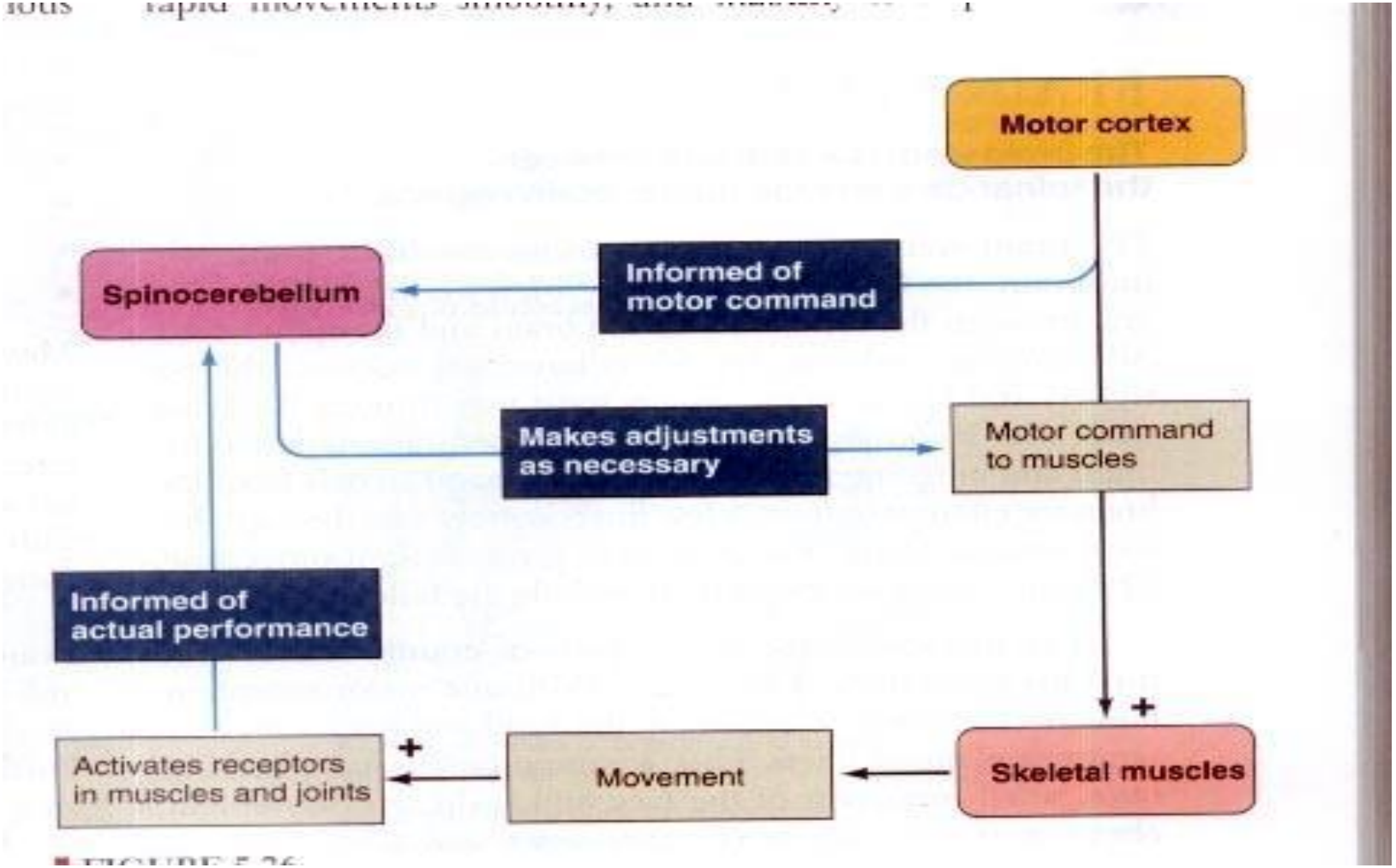
- It receives information from the vestibular apparatus

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

Functions of The Cerebellum Cont.

- **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).

C. Control of voluntary movement by the cerebellum.



Functions of The Cerebellum Cont.

- 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 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 overshoot.

Summary of Connections & Functions

	Cortex	Inputs	Outputs	Function
Neo-cerebellum	Lateral portions of Cerebellar Hemisphere	Corticopontine/ pontocerebellar	to thalamus (& therough its connections → to the cerebral cortex).	Planning and executive of voluntary & skilledhand movements
Spino-cerebellum	Vermis & Medial portions of Cerebellar hemispheres	Spinal and brainstem paths	to Red Nucleus & to RF	Muscle tone , posture & coordination of movements
Vestibulo-cerebellum	Flocculonodular	Vestibular nuclei	Vestibular nuclei & RF	Balance ,&equilibrium

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Clinical Abnormalities of the Cerebellum

- Lesions of cerebellar hemispheres show no abnormalities when person is **at rest**,
- Most abnormalities are apparent only during movement
- No paralysis or loss of sensations.
- Generally motor disorders due to lesions of medial regions are more apparent in proximal parts of limbs.
- While lesions of lateral parts cause abnormalities in distal muscles of limbs.

All movements are characterized by '<u>Ataxia</u>' (incoordination)

Cerebellar Lesions (The neocerebellar syndrome)

- Damadge of the deep cerebellar nuclei as well as cerebellar cortex.
- The manifestation occurs on the same side of the lesion
- The manefestations include:

1. **Dysmetria & ataxia**:

Movements usually over shoot their intended mark,(past pointing) , which result in incoordination of movement (ataxia).

2. Failure of progression of voluntary movement:

This results in:

-Dysdiadochkinesia:

Inability to perform rapidly alternating opposite movements such as repeated pronation and supination of the hands .

-Dysarthria- (Scanning speech)

3. Kinetic or Intention tremor

- 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

. Nystagmus: Tremor of the eye ball which occurs when the subject attempt to fix his gaze on an object to the side of his head.

5. Rebound phenomen 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

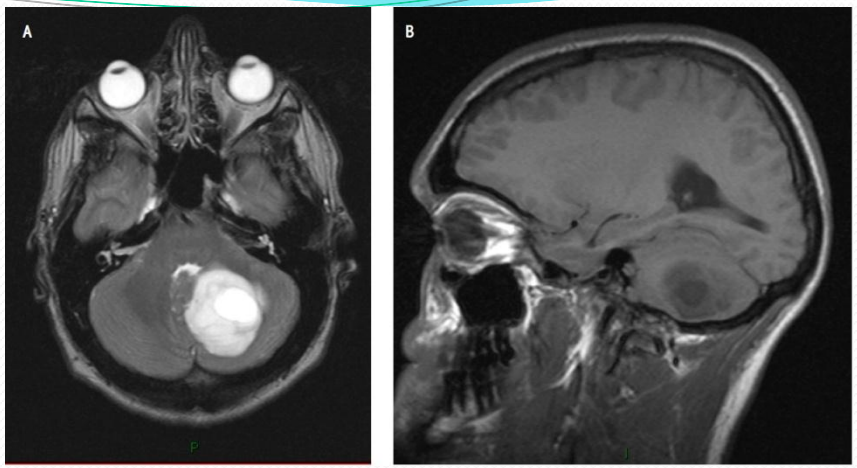
6. Hypotonia ; due to loss of the facillitatory effect of the CB on the stretch reflex, and I ti sassociated with ***pendular knee jerk***

7. Decomposition of movement Inability to perform actions involving simultaneous movements at more than one joint.
8. Rough movement. i.e. threading a needle or buttoning of a shirt become very difficult.

9. Disturbance of posture and gait. The head tilted to one side and patient walk in with a wide base in drunken fashion

Flocculonodular Lobe Lesion

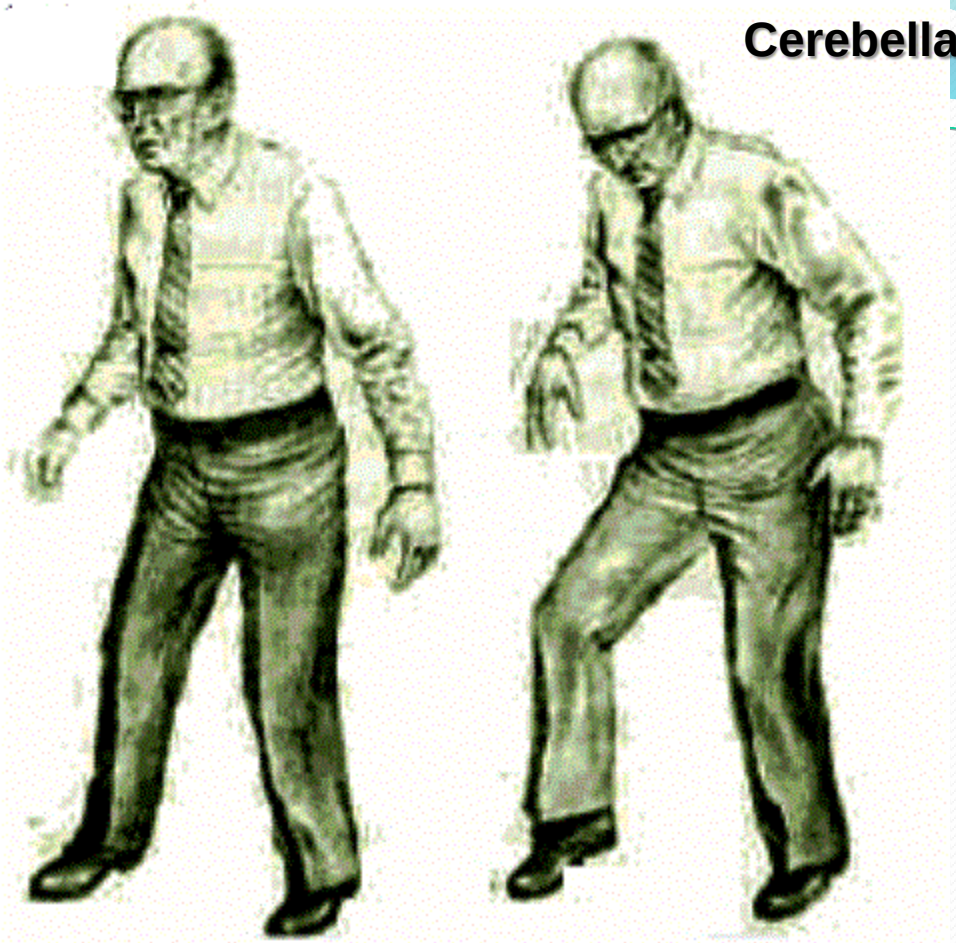
- Midline cerebellar tumors in children involving the Flocculonodular lobe makes the child to walk in an unsteady and staggering fashion
- Such a child is afraid & reluctant to stand erect and move without support .
- This is because if he tries to walk , he does so in a staggering fashion → staggering gait on a broad base, & tends to fall .
- Moreover , selective Flocculonodular lobe lesions may cause vertigo.

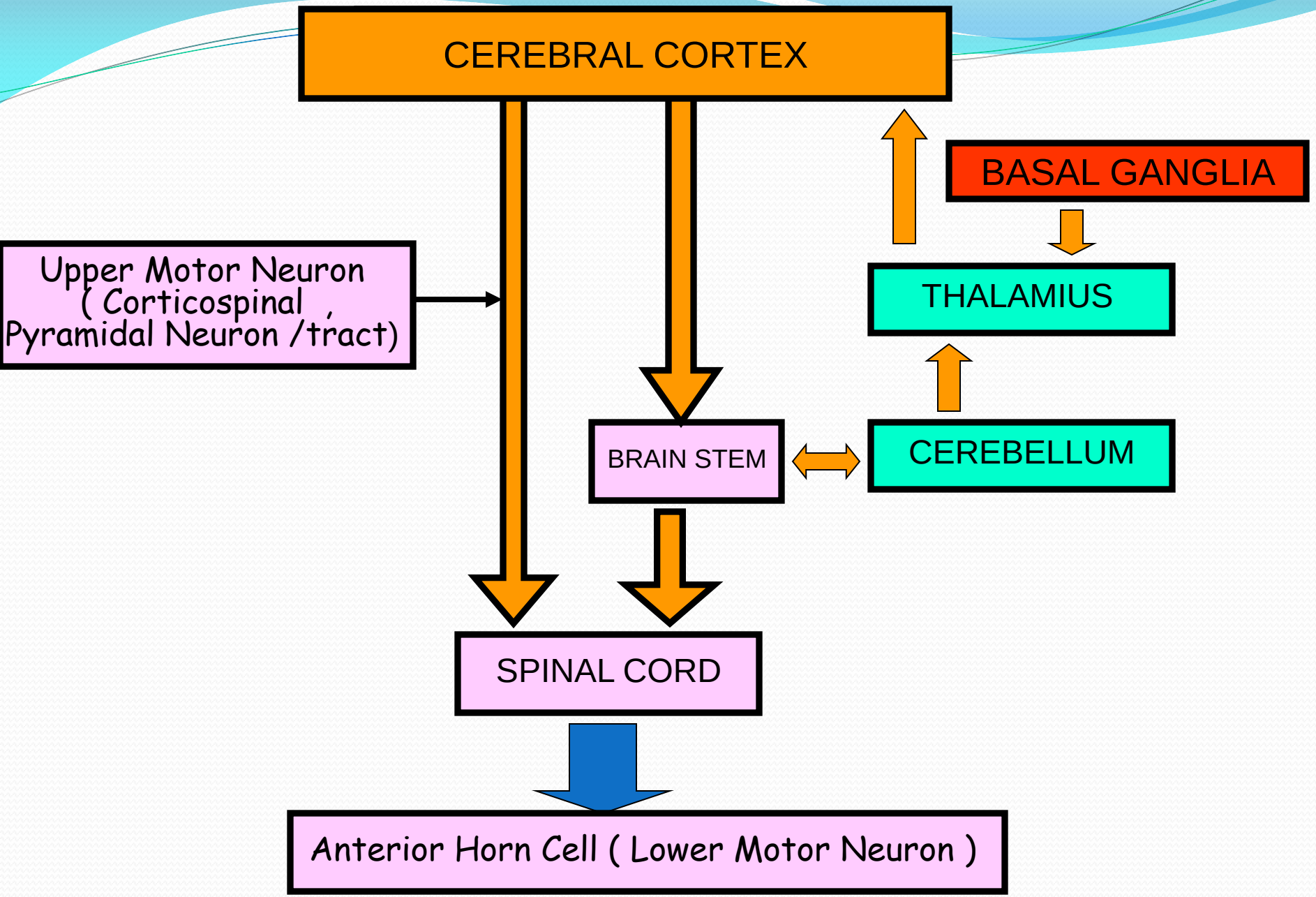


Cerebellar Ataxia

Ataxia is incoordination of muscle movememt leading to imbalance.

Cerebellar Ataxia




CEREBRAL CORTEX
BASAL GANGLIA
Upper Motor Neuron
(Corticospinal ,
Pyramidal Neuron /tract)
THALAMIUS
BRAIN STEM
CEREBELLUM
SPINAL CORD
Anterior Horn Cell (Lower Motor Neuron)