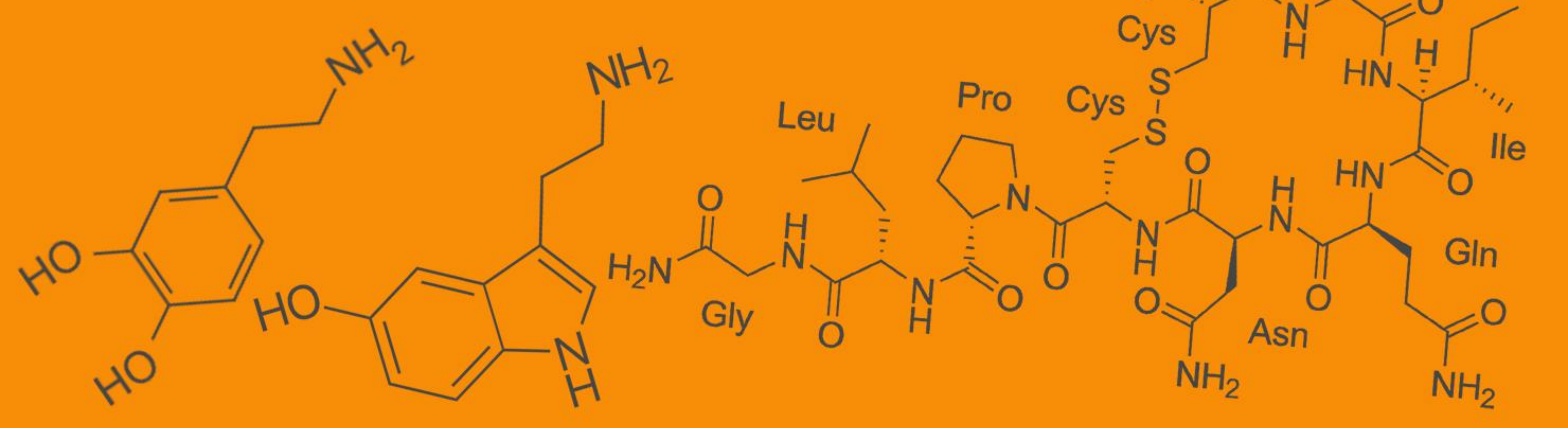


MEDICINE438's

CNS PHYSIOLOGY

Lecture XX: Cerebellum

EDITING FILE GSLIDES

IMPORTANT | MALE SLIDES | EXTRA | FEMALE SLIDES | LECTURER'S NOTES

OBJECTIVES

- Describe the divisions of the cerebellum
- 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. e.g Cerebellar nystagmus, changes in muscle tone, ataxia, drunken gait, scanning speech , dysmetria (past-pointing), intention tremors, rebound phenomenon and adiadochokinesia.

BOX 20-1: NEUROSCIENCE: EXPLORING THE BRAIN

INTRODUCTION

While the cerebellum is dwarfed by the large cerebrum, it actually has as many neurons as both cerebral hemispheres. In fact it contains more than 50% of all neurons in the CNS.

- The cerebellum is primarily a movement control center, it computes information about intended movements through cerebro-pontocerebellar fibers, and also receives information about the performed movements through spinocerebellar tract, mainly, if movements fail to meet expectations, it sends corrective impulses to the brain to maintain adequate movement and balance.
- In contrast to cerebral hemispheres, the right side of the cerebellum is concerned with movements of right side of the body, and the left side of the cerebellum is concerned with movements of left side of the body.

CEREBELLUM

Occupies a prominent position beside the main sensory and motor systems in the brain stem.

Word origin :
Derived from a Latin word means "little brain"

Shape:
Oval, the largest part of **hindbrain** with an approximate weight **150 gm**

Location: Posterior cranial fossa

Anteriorly: 4th ventricle, pons, and medulla oblongata

Superiorly: Covered by tentorium cerebelli

Posterio-inferiorly: Squamous part of occipital bone.

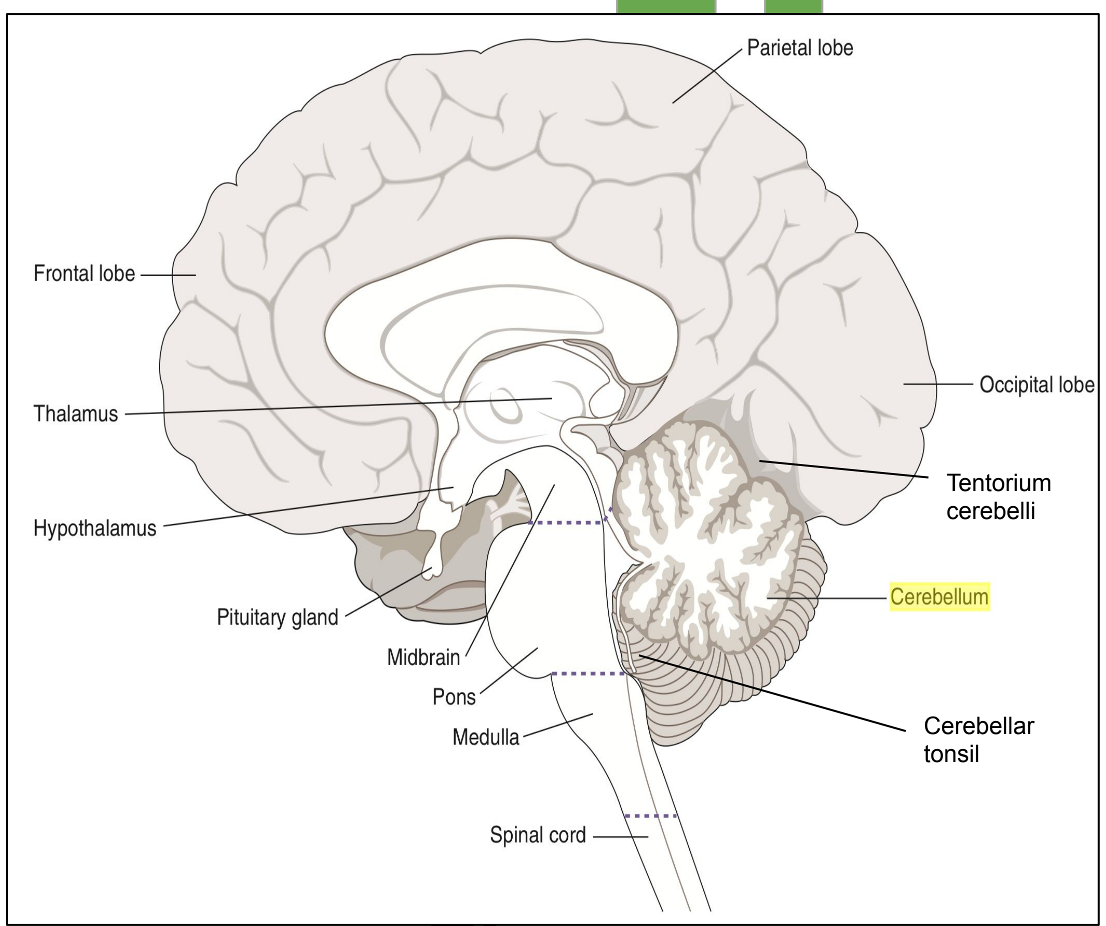


Figure 20-1

Cerebellar Peduncles[1]

Fibers enter and leave the cerebellum through these peduncles:

- **Superior**: Cerebrum → Cerebellum
- **Middle**: Pons → Cerebellum
- **Inferior**: Medulla → Cerebellum

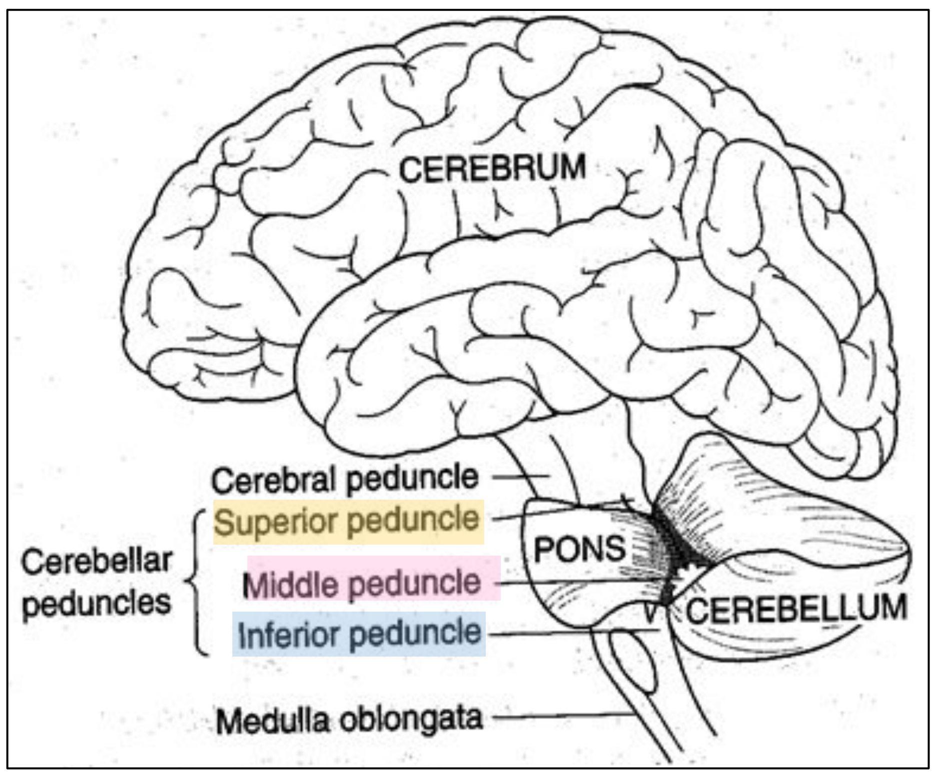


Figure 20-2

FOOTNOTES

1. Anatomically, the cerebellar peduncles are merely the axons of deep cerebellar nuclei that extend to different areas of the brain stem.

FUNCTIONS OF CEREBELLUM

1. Maintenance of equilibrium

2. Balance, posture, and eye movement.

3. Coordination of the half-automatic* movement (walking & posture maintenance.)
* involuntary but conscious movement (like swinging hand while walking)

4. Adjustment of muscle tone.

5. Motor Learning – Motor Skills. (BOX 20-1)
E.g. drawing, writing, playing piano

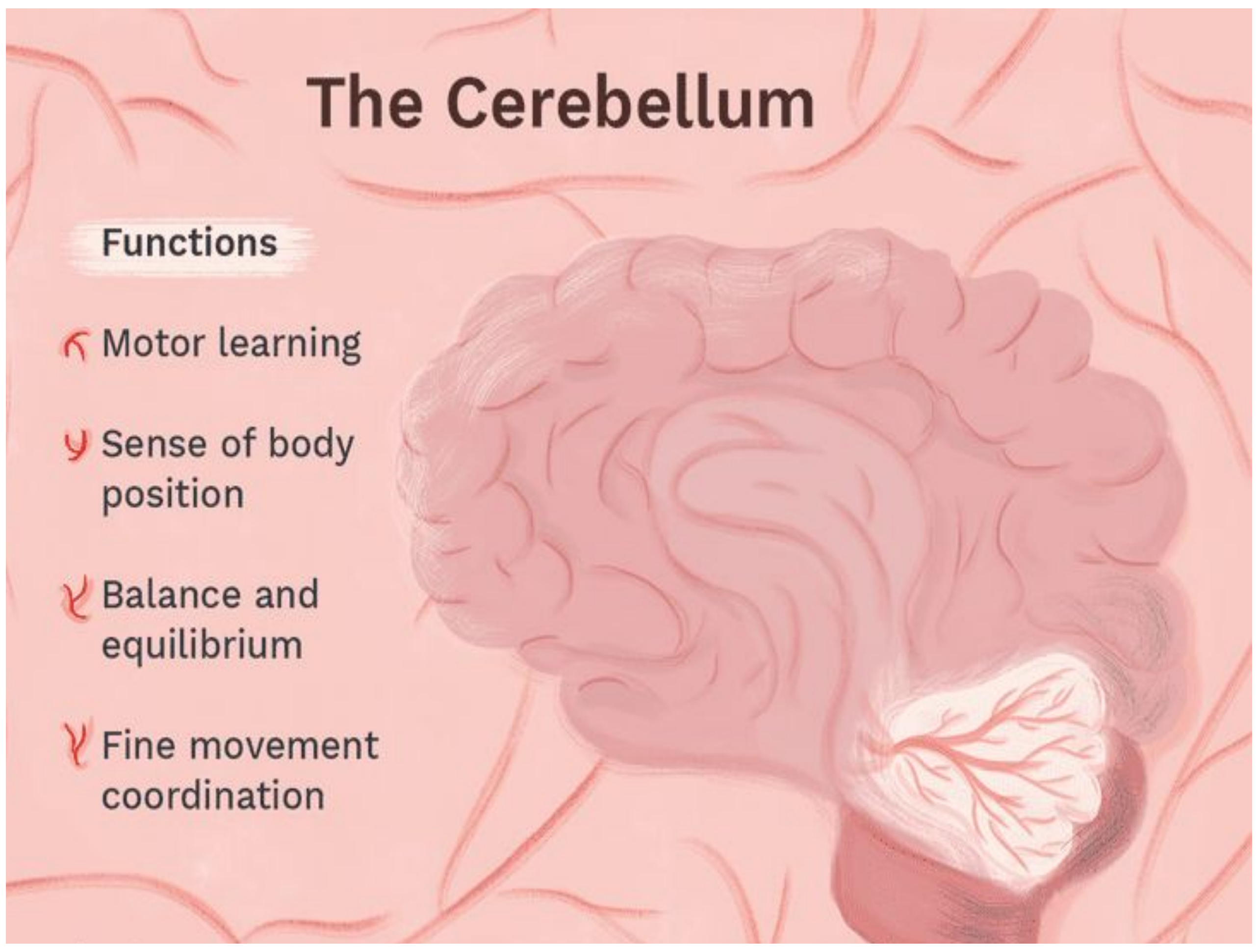


Figure 20 -3

THE RULE OF 3

3 Cortical Layers	Molecular	Purkinje cell	Granular
3 Purkinje cells afferent paths	Mossy	Climbing	Aminergic (BOX 20-2)
3 Pairs of deep nuclei	Fastigial	Interposed (globose & emboliform)	Dentate
3 Pairs of peduncles	Superior (pri.output)	Middle (pri.Input)	Inferior (pri.Input)

Table 20 -1

3 Divisions

Anatomical	Physiological	Functional
Anterior lobe	**Paleo**cerebellum	**Spino**cerebellum
Posterior lobe	**Neo**cerebellum	**Cerebro**cerebellum
Flocculonodular lobe	**Archi**cerebellum	**Vestibulo**cerebellum

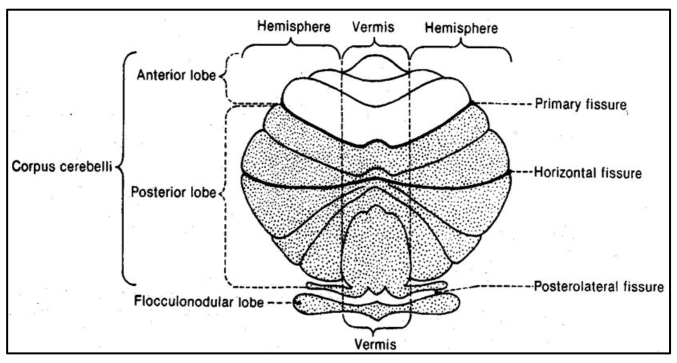


Figure 20 -4

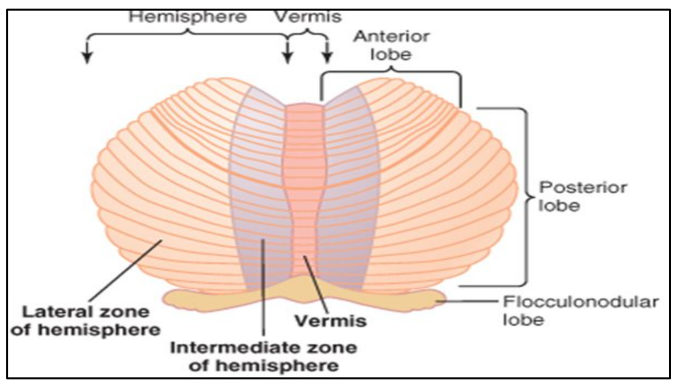


Figure 20 -5

BOX 20-2: CLINICAL NEUROANATOMY: A NERUOBEHAVIOURAL APPROACH

AMINERGIC FIBERS are the third of cerebellar afferents, these fibers likely arise from the raphe (serotonin), locus ceruleus (norepinephrine) and also the hypothalamus. These fibers terminate in the granule and molecular layers and exert inhibitory effects.

Functional Divisions of Cerebellum

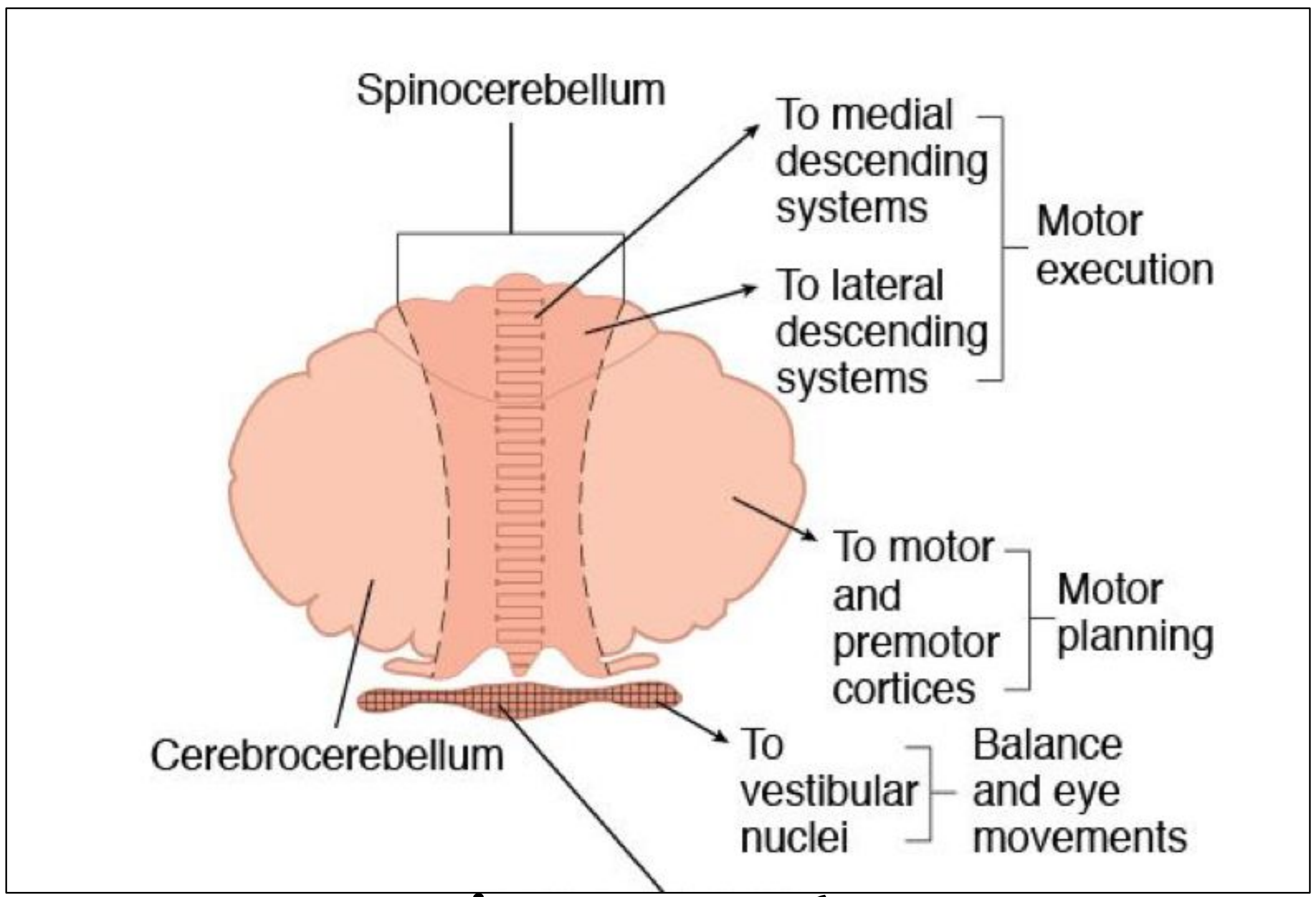


Figure 20 -6

Three functional divisions of the cerebellum: the nodules 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 movement. The rest of the vermis and adjacent medial portions of hemispheres form the spinocerebellum, the region that receives proprioceptive input from motor cortex. The lateral portions of the cerebellar hemispheres are called the cerebrocerebellum which interacts with the motor cortex in planning and programming movements.

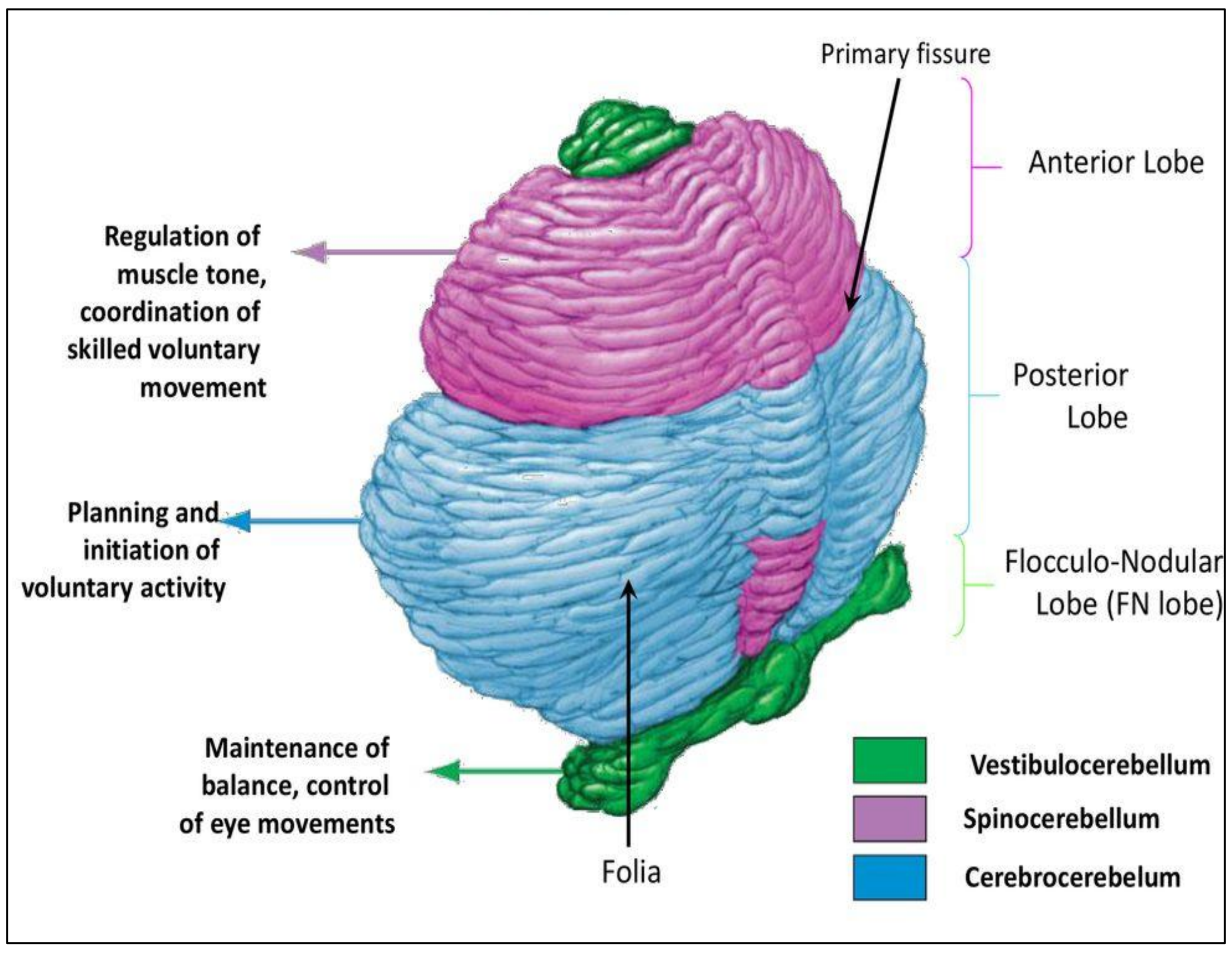
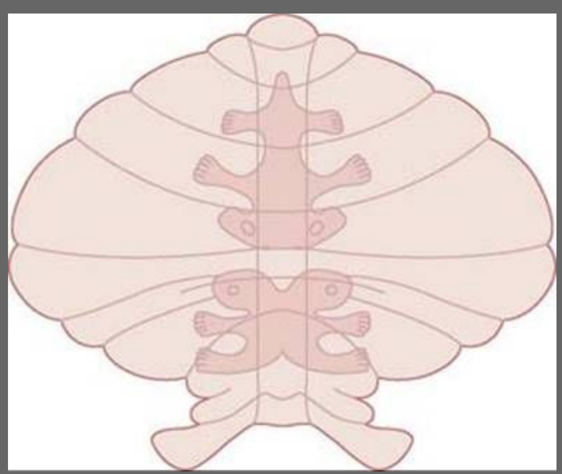


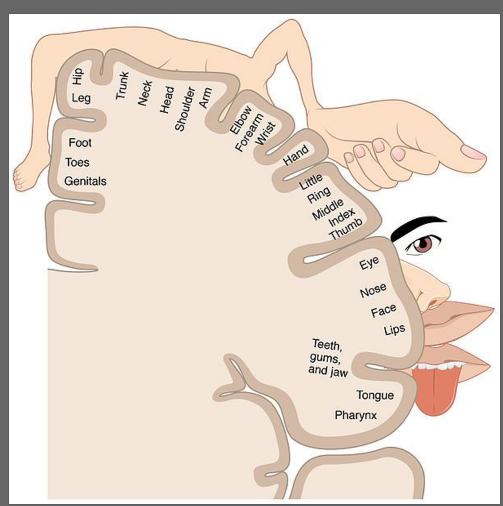
Figure 20 -7

BOX 20-3: GUYTON AND HALL

REPRESENTATION OF BODY AREAS IN CEREBELLUM



Cerebellum, illustrating the trunk in the vermis, and limbs in the intermediate zones.



Topological representation of the cerebral cortex.

In the same manner cerebral cortex, basal ganglia, red nucleus and reticular formations have topographical representations of different body parts, that is, as students know, a nucleus in the CNS corresponds to collection of cell bodies within the CNS, different cell bodies for instance in the red nucleus receive afferent fibers from different body parts, however, neurons within the nucleus send signals to specific body parts.

- As can be seen in the figure above, the axial portions of the body lie in the vermis, whereas the limbs and facial areas lie in the intermediate zones. That is, they receive signals from all over the body, but the intermediate zones and vermis send motor signals back to the same respective topographical areas of either the cortex, through ventral lateral nucleus of thalamus, or to corresponding topographical areas of reticular formations and red nucleus. The efferent and afferent fibers running to and from the brain stem constitute the cerebellar peduncles.
- Due to this reason, as we learned in lecture fourteen, midline cerebellar lesions result in truncal ataxia, whereas lesions in other areas result in limbic ataxia.
- Note that the lateral zones do not have topographic representation, these zones receive their signals almost exclusively from the cerebral cortex, to inform the cortex about intended voluntary movements, and in turn, the cerebellum send corrective signals back to the cortex.

Connections of the Cerebellum

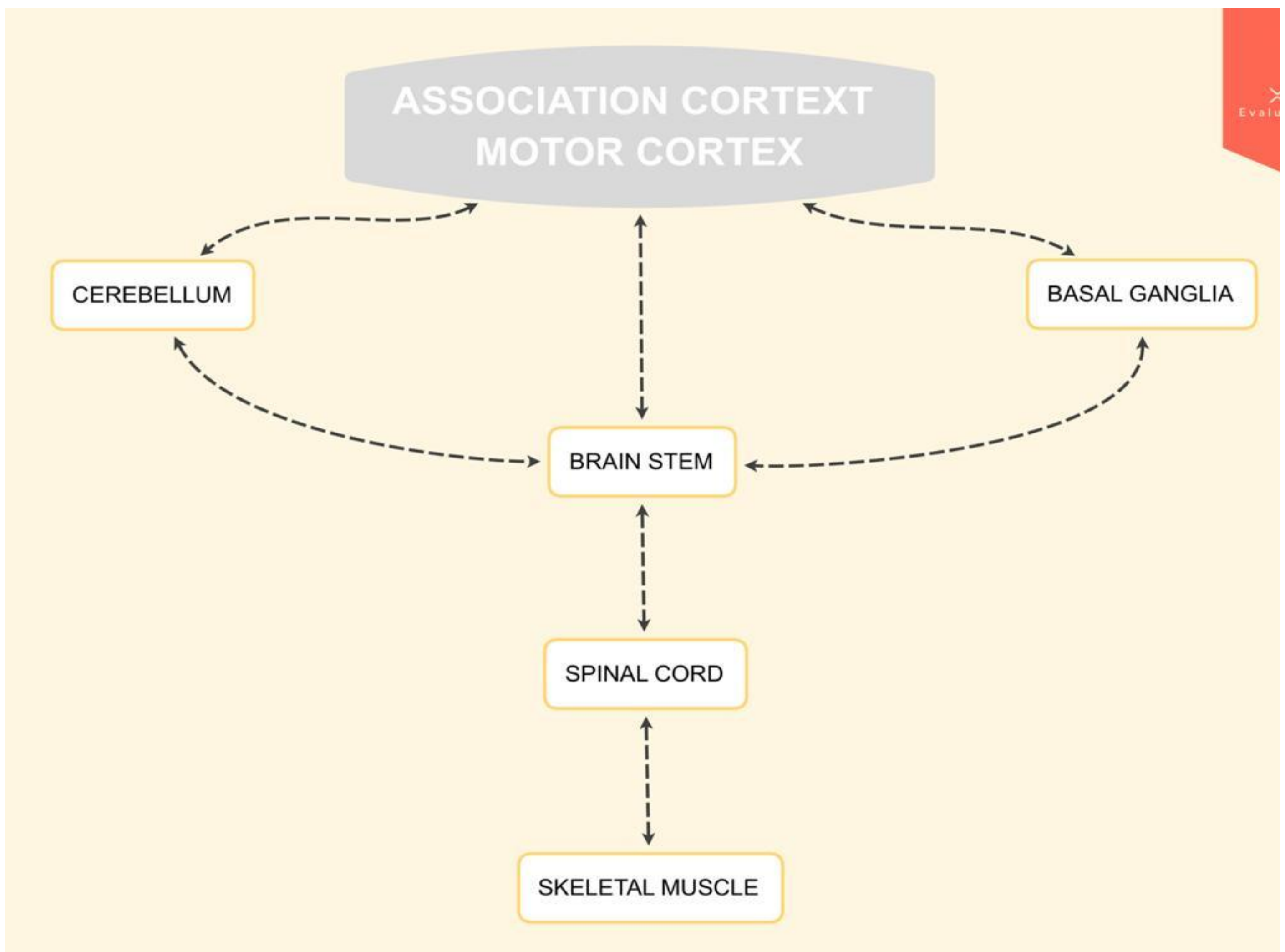


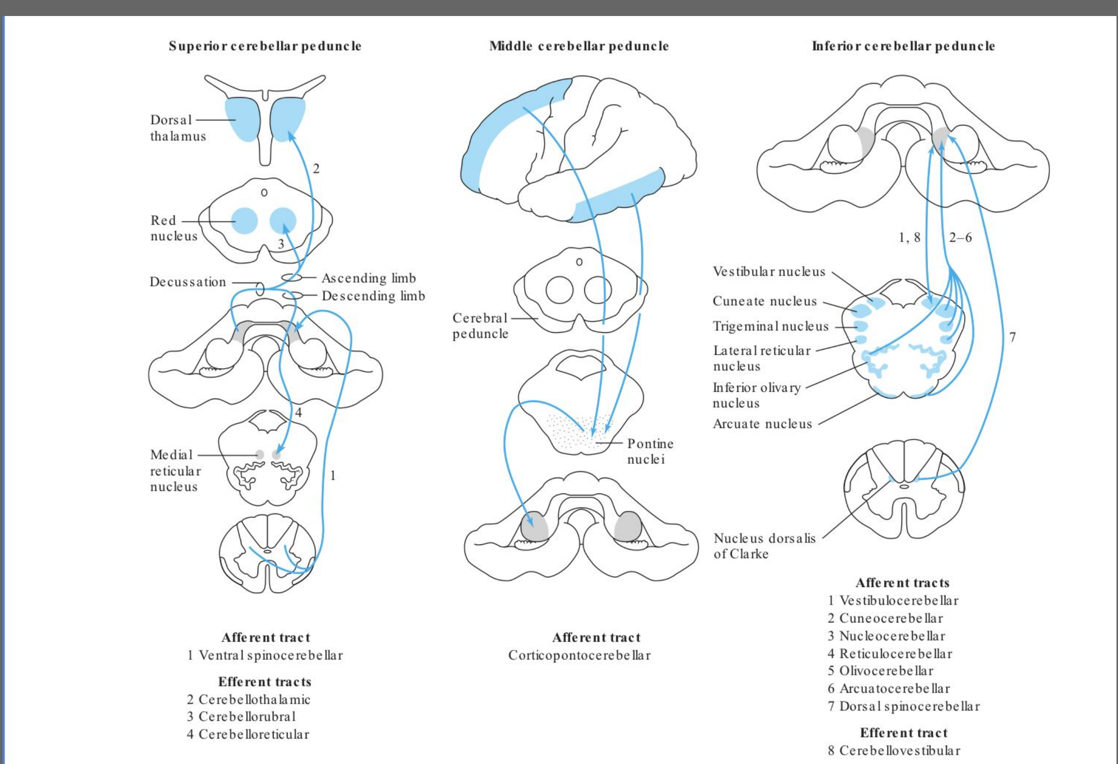
Figure 20 -8

Summary: Functions Of Cerebellum

Cerebellum lobe	Nuclei	Cortex	Input	Output	Function
Paleocerebellum	Interpositus Fastigial	Vermis & medial portions of cerebellar hemisphere	Spinal and brainstem paths	SCP to red nucleus; Fastigial to RF	Muscle tone, posture & coordinations of movement
Neocerebellum	Dentate	Lateral portions of cerebellar hemisphere	Corticopontine/pontocerebellar	SCP	Planning and portions executive of voluntary & skilled hand movements
Archicerebellum	Fastigial	Flocculonodular	Vestibular Nuclei	Vestibular nuclei; RF	Balance, equilibrium

Table 20 -2

BOX 20-4: CLINICAL NEUROLOGY AND NEUROANATOMY



Schematic of the pathways that transverse the cerebellar peduncles, remember that the peduncles are merely the fibers that run to and from the cerebellum, including the cerebellar afferents and efferents.

- The cerebellum is showed ventrally. As it is the dorsal part of the hindbrain, with the pons and medulla located ventral to it.

BOX 20-5: GUYTON AND HALL

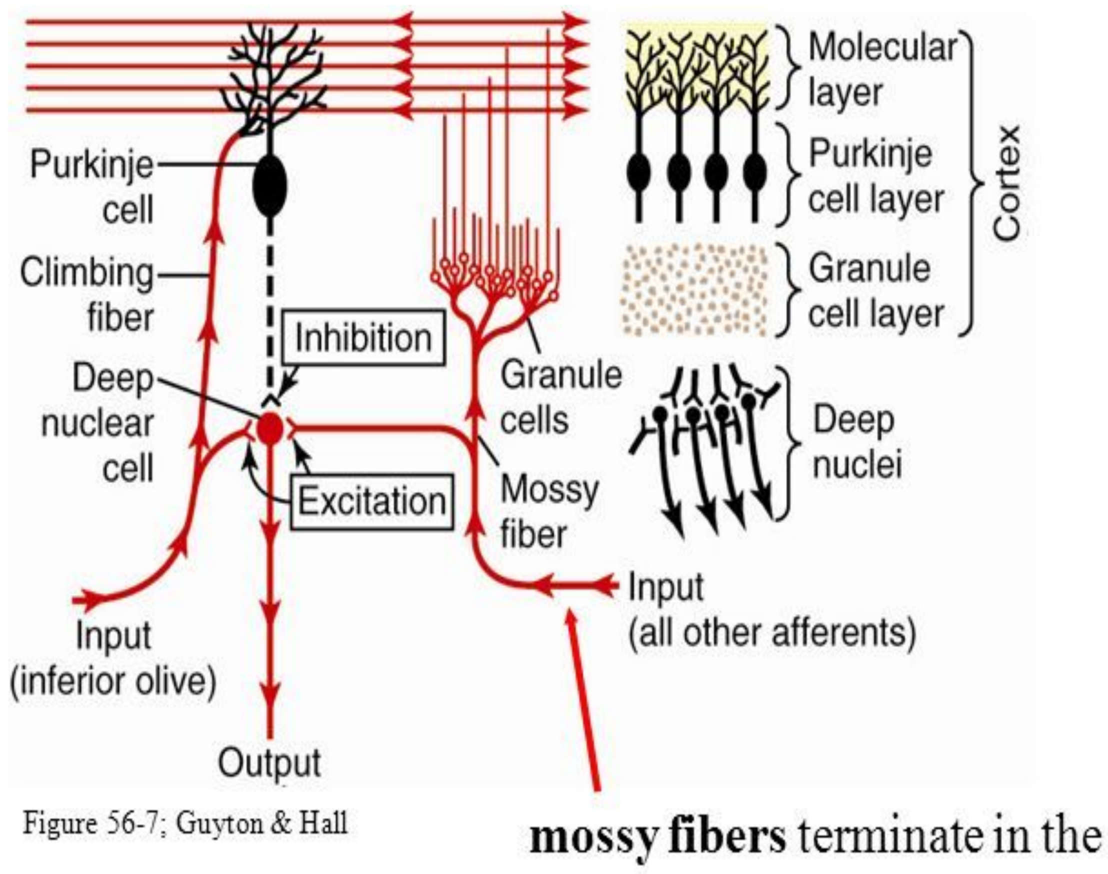
HOW THE CEREBELLUM IS EXCITED

Each time a signal enters the cerebellum itn divides and go into two directions.

1. The efferent axon sends collaterals to excite the deep cerebellar nucleus, this happens in both climbing and mossy fibers.
2. The axon itself terminates on one of the cortical layers, in case of climbing fibers they terminate directly on purkinje cells, and in case of mossy they terminate on granule cells.

Please note that the signals reaching the deep nuclei are excitatory, and acts as a turn-on signal, after the signal reaches the cortex it excites the inhibitory purkinje cells either directly or indirectly, purkinje cells then send their inhibitory fibers down to the deep cerebellar nuclei to turn them aff, after having been excited by the collaterals of ascending fibers.

- As we mentioned, mossy fibers terminate in granule cells, the most inward layer, these granule cells have very short axons and ascend to the upper molecular layer to excite the dendrites of purkinje cells. As can be seen in the figure.



mossy fibers terminate in the granular cell layer.

Figure 20 -9

The cerebellum has an external gray matter (cerebellar cortex) separated by white matter from the deep cerebellar nuclei as follows:
deeply infolded, giving a large surface area. The cerebellar cortex contains five different cell types:

Molecular Layer	Stellate cells	Taurine, GABA (Inhibition)
	Basket cells	GABA (Inhibition)
Purkinje Cell Layer	Purkinje cells (output cells) inhibit the deep nuclear cells	
Granular Layer	Golgi cells	
	Granular cells has GABA $_A$ receptors	Glutamate (Excitation)

* all cells have receptors for neurotransmitters of each other to communicate

Table 20 -3

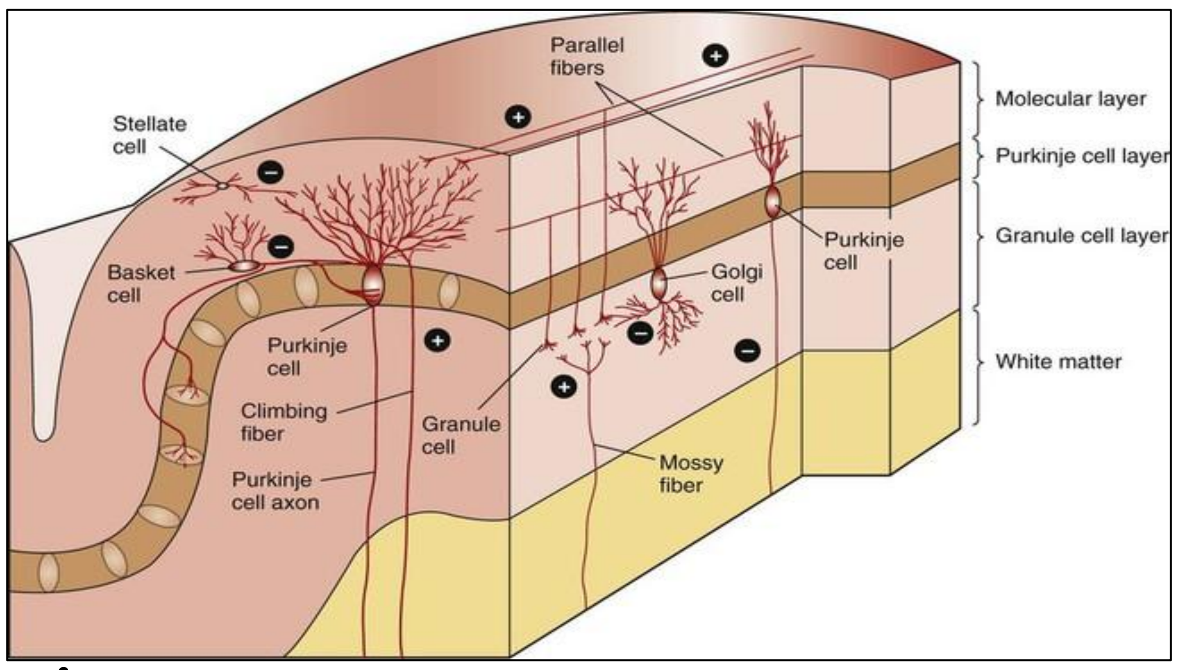


Figure 20 -10

Cerebellar nuclei

Lateral

Dentate Nucleus
Emboliform Nucleus
Globose Nucleus
Fastigial Nuclei

Medial

Emboliform + Globose: **interpositus**

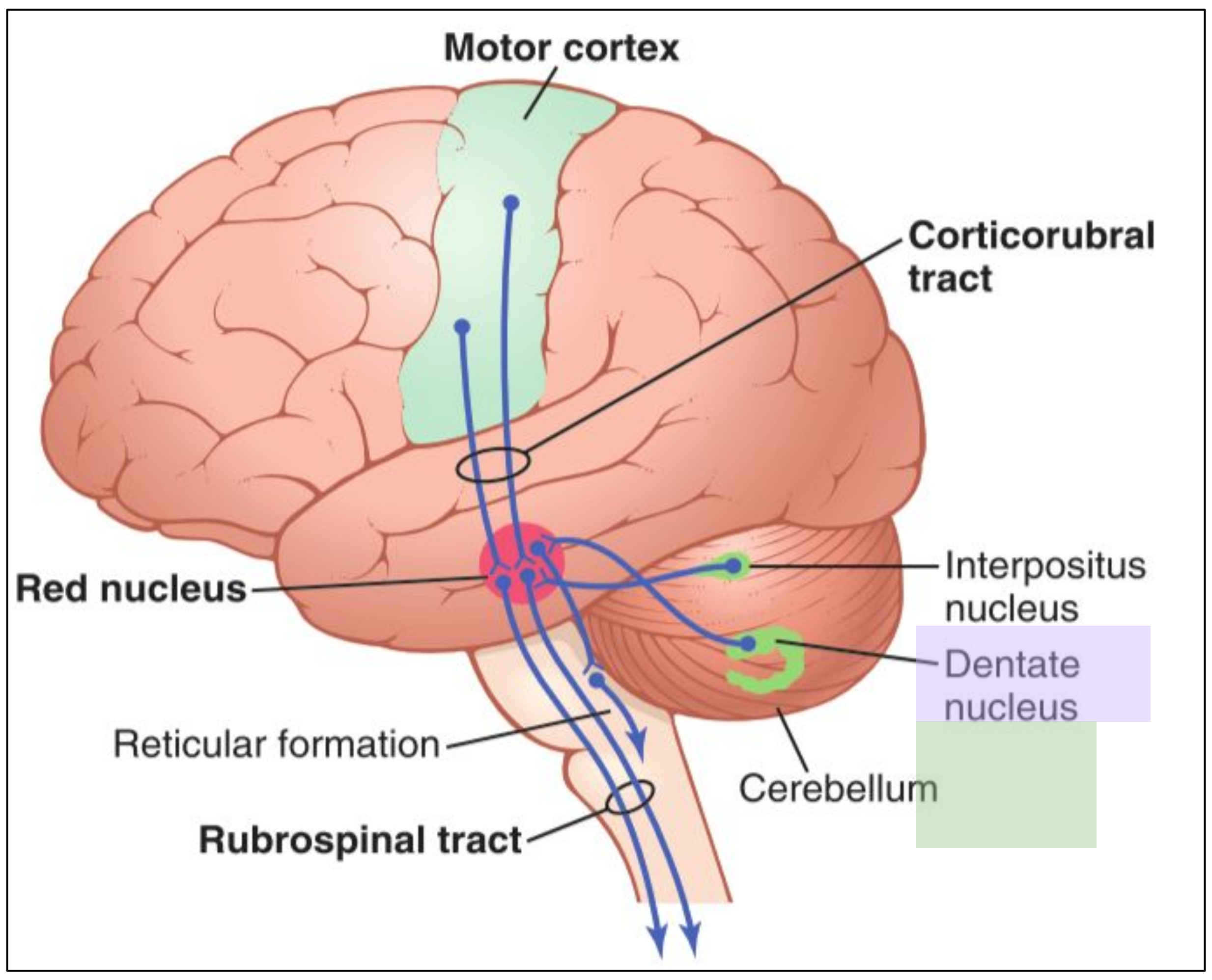


Figure 20 -11

AFFERENT FIBERS

climbing	Mossy
Inferior olivary nucleus	All other afferents + some inferior olivary (Greater than climbing)
Learns the cerebellum to perform <u>new</u> patterns of movement precisely	• Help the precise execution of the voluntary movements • For <u>already known</u> movements • Concerning the: - initiation - duration - termination occurs by controlling the turn on and turn off output signals from the cerebellum to the muscles.

Table 20 -4

Afferent pathways

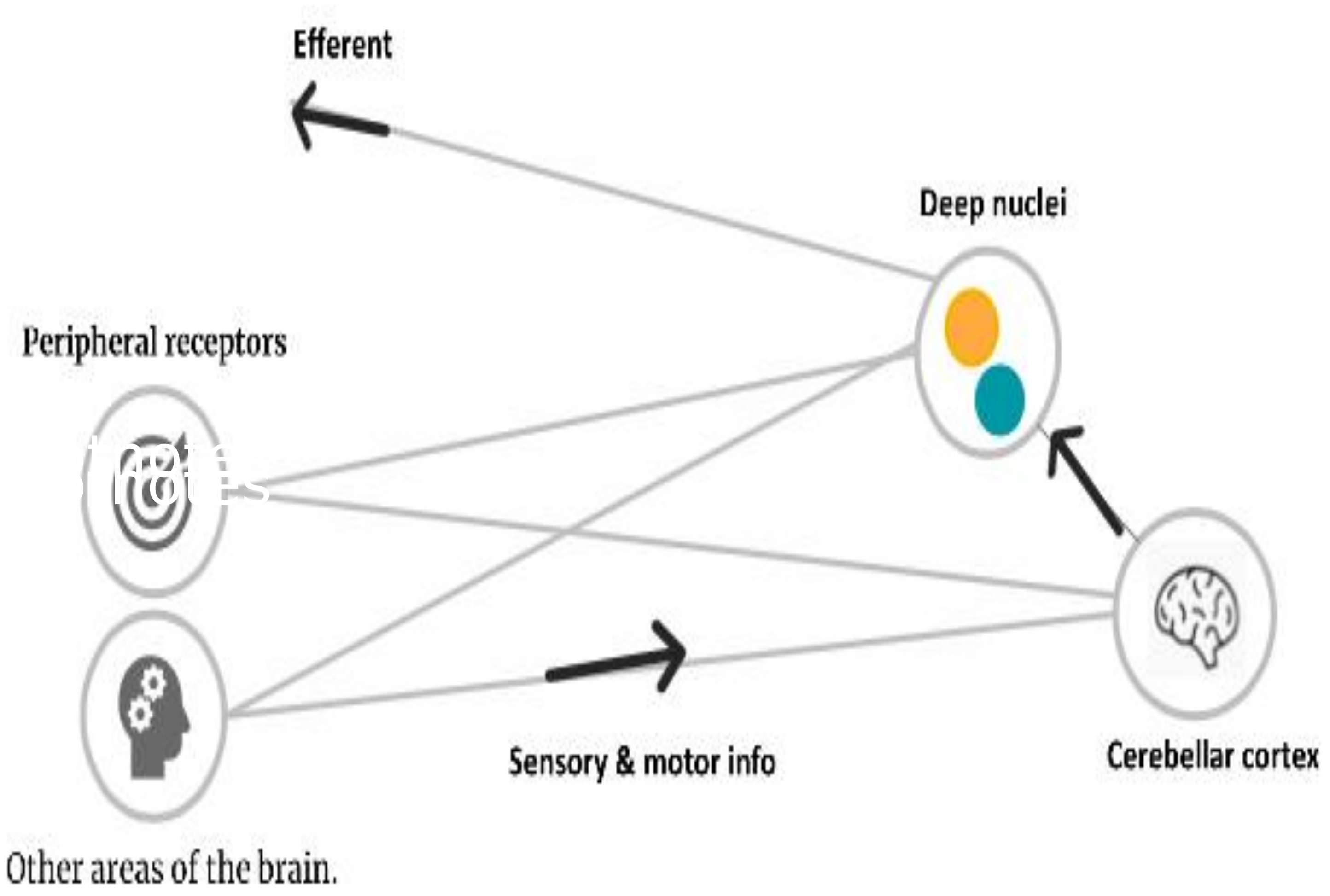
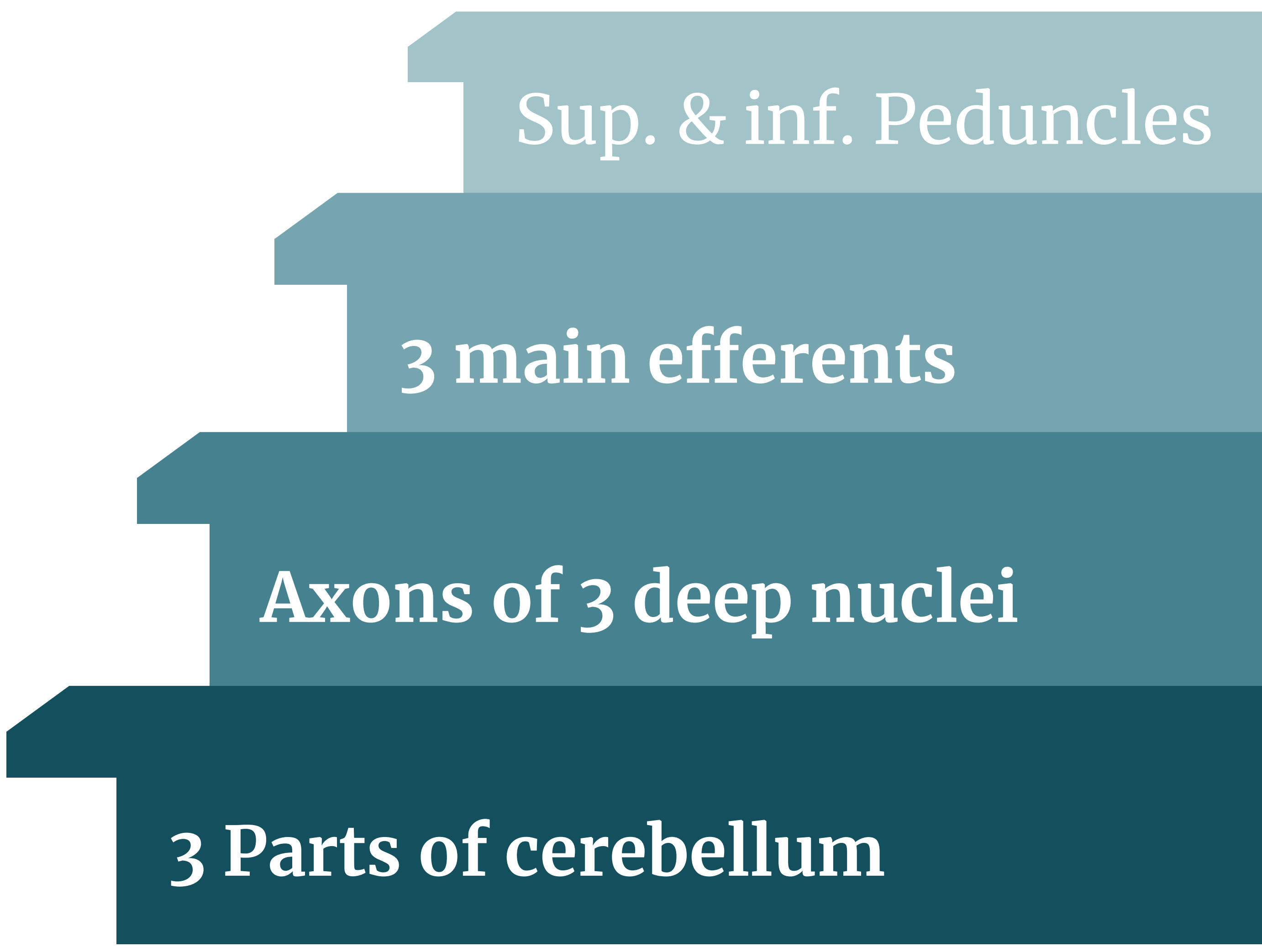


Figure 20 -12

Efferent pathways



PRINCIPAL AFFERENT TRACTS

TRACT	TRANSMITS	FROM
Vestibulocerebellar	Vestibular impulses	Labyrinths direct & via vestibular nuclei.
Dorsal Spinocerebellar	Proprioceptive & exteroceptive impulses	The body.
Ventral Spinocerebellar	Proprioceptive & exteroceptive impulses	The body.
Cuneocerebellar	Proprioceptive impulses	Head and neck.
Tectocerebellar	Auditory & visual impulses	via inferior and superior colliculi
Pontocerebellar	-	Motor and other parts of cerebral cortex via pontine nuclei
Olivocerebellar	Proprioceptive input	whole body via relay in inferior olive.

Table 20 -5

Afferent pathways

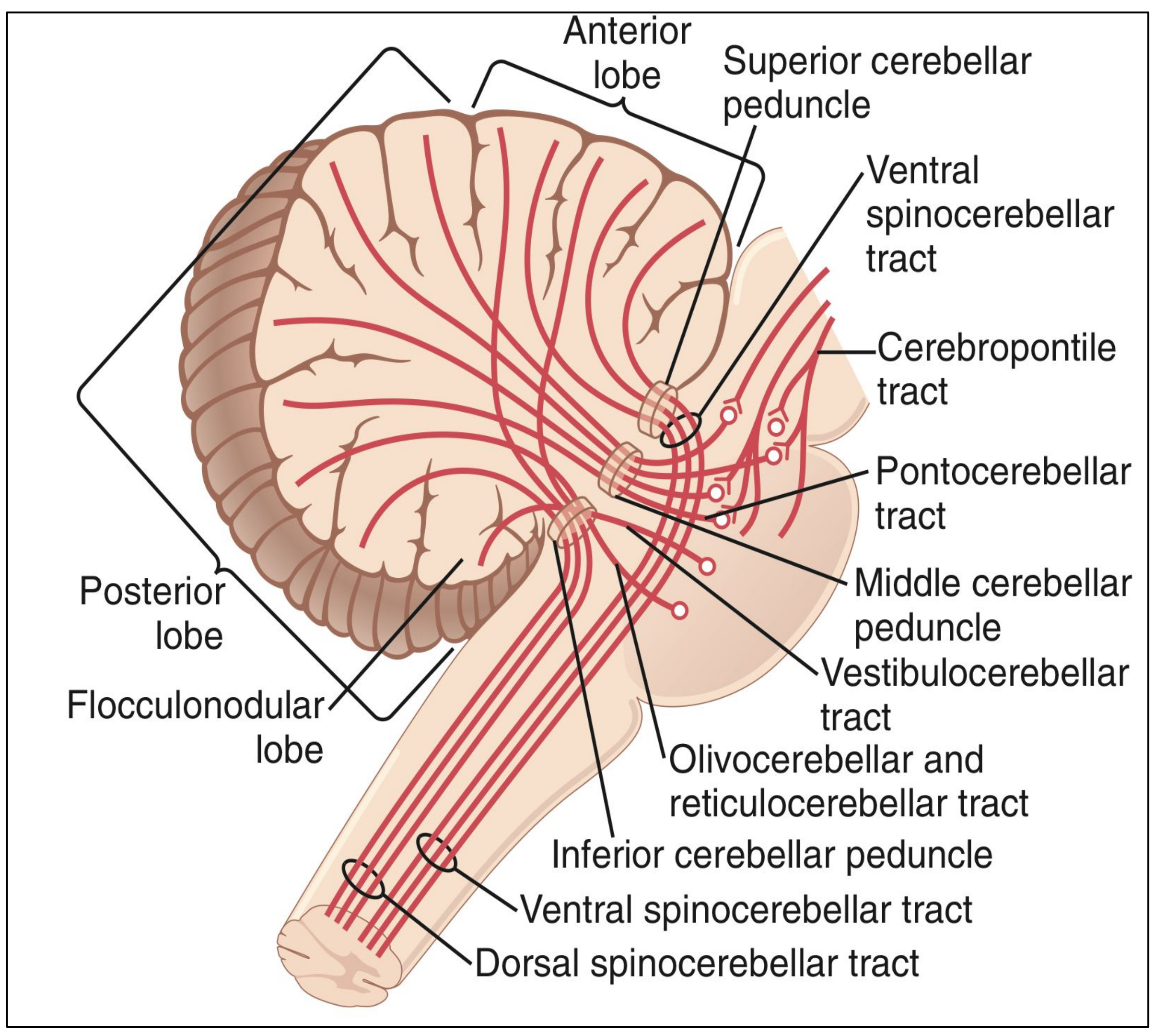


Figure 20 -13

Efferent pathways

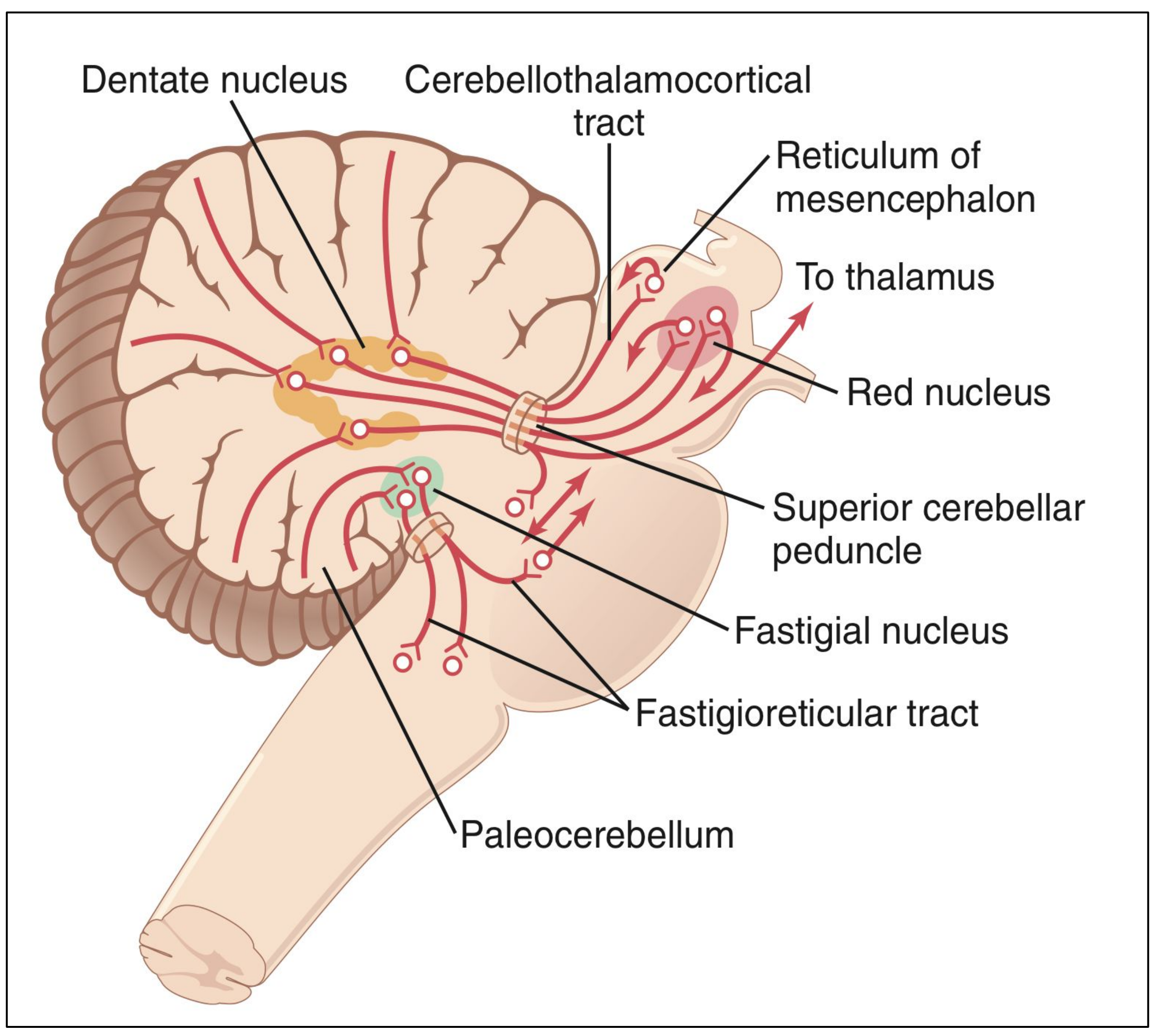


Figure 20 -14

Abnormalities associated with cerebellar disease

Disorder	Description
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 (opposite) movements
Dysmetria	Inability to control range of movement
Hypotonia	Decreased muscle tone due to loss of the facilitatory effect of the CB on the stretch reflex, and it is associated with pendular Knee jerk
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
Scanning speech	Slow enunciation with a tendency to hesitate at the beginning of a word or syllable
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)

Table 20 -6

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 following:**

Control of equilibrium & postural movements:

The function of the vestibulocerebellum:

I. It receives information from the vestibular apparatus through the fastigial nucleus
II. it discharges to the brain stem through the *vestibulospinal* and *reticulospinal* tracts
III. 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 (common in children)

Leads to trunk ataxia which is characterized by:

➔ Equilibrium disturbance: the patient sways on on standing, can't maintain the erect posture, needs support and walks by a staggering or drunken gait and have nystagmus.

Control of the strech reflex

- The **cerebrocerebellum** exerts a *facilitatory* effect on the stretch reflex and increases the muscle tone.
- The **spinocerebellum** probably exerts an *inhibitory* effect. (Cerebrocerebellum & spinocerebellum have direct connection with the muscles)
- Normally the *facilitatory* effect predominates (so cerebellar diseases often result in hypotonia).

Control of voluntary movements

N.B; Each cerebellar hemisphere is connected by efferent and afferent pathways to the contralateral cerebral cortex (the cortico –ponto-crebello-dentato- thalamo- cortical circuit).

BOX 20-6: GUYTON AND HALL

As shown in **Figure 20-14**, the intermediate zone of each cerebellar hemisphere receives two types of information when a movement is performed:
(1) information from the cerebral motor cortex and from the midbrain red nucleus, telling the cerebellum the intended sequential plan of movement for the next few fractions of a second, and (2) feedback information from the peripheral parts of the body, especially from the distal proprioceptors of the limbs, telling the cerebellum what actual movements result.
After the intermediate zone of the cerebellum has compared the intended movements with the actual movements, the deep nuclear cells of the interposed nucleus send corrective output signals (1) back to the cerebral motor cortex through relay nuclei in the thalamus and (2) to the magnocellular portion (the lower portion) of the red nucleus that gives rise to the rubrospinal tract. The rubro spinal tract in turn joins the corticospinal tract in innervating the lateralmost motor neurons in the anterior horns of the spinal cord gray matter, the neurons that control the distal parts of the limbs, particularly the hands and fingers.

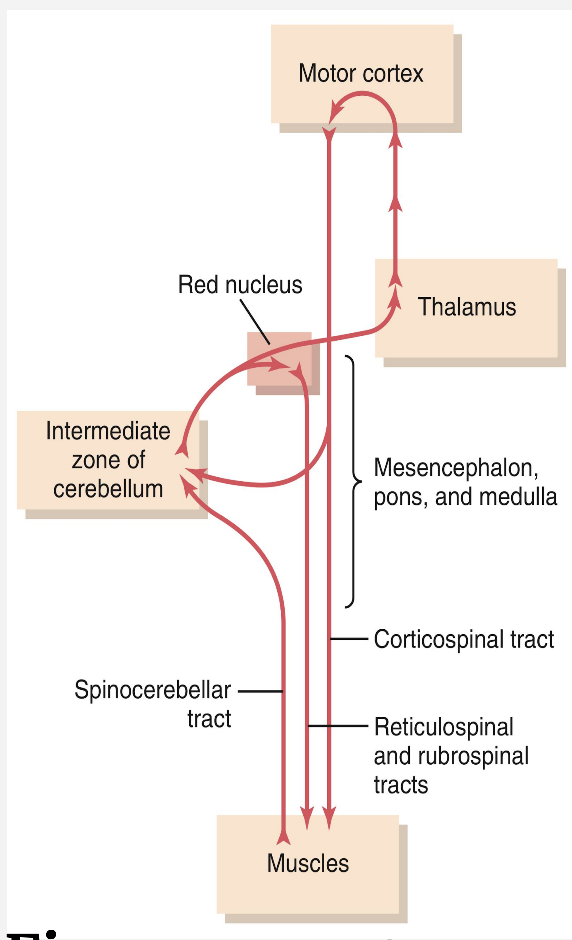


Figure 20 -15

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.

Defects produced by cerebellar lesions in humans

The Neocerebellar Syndrome

This is due to damage of the **deep cerebellar nuclei** (no efferent) 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:

I. Hypotonia:Due to loss of the facilitatory effect of the cerebellum on the stretch reflex, and it is associated with pendular knee jerk.
II. 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.
III. Motor ataxia:Incoordination of the voluntary movements, specially the rapid movements (becoming abnormal in rate, range, force and direction).

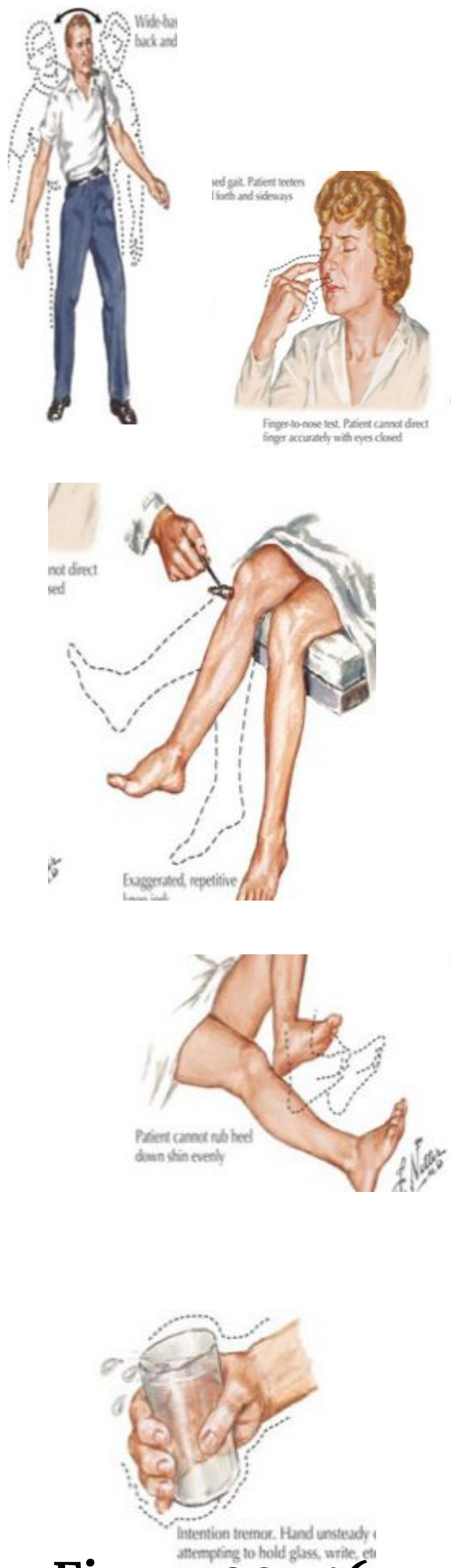


Figure 20 -16

Ataxia

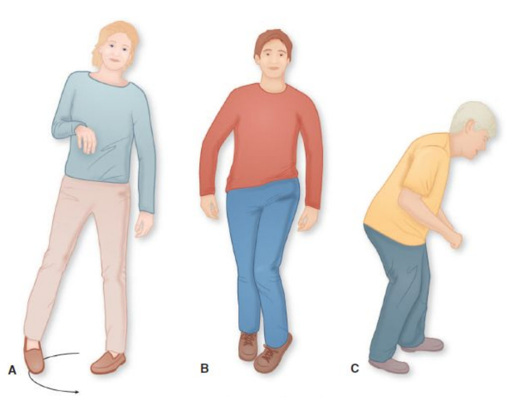


Figure 20 -17

- It is either **sensory** or **motor** or **mixed**.
- It commonly occur in lesions of the cerebellum or spinocerebellar tracts (or deep nuclei)
- **Posture Gait – Ataxia Tremor** (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

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.

3. **Rebound phenomenon:** Overshooting of a limb when a resistance to its movement is suddenly removed. (loss of the braking function of the cerebellum), (the arm pulling or flexion test).

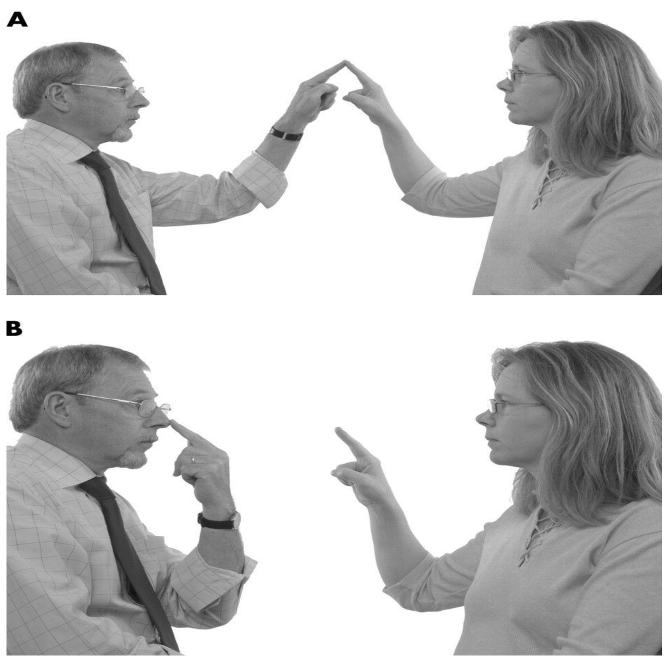
4. **Asynergia**: This is loss of the harmony between the three groups of muscles involved in performance of voluntary movement the **agonists**, **protagonists**, and **antagonists**).

5. **Failure of progression of movements manifested by:**
   - 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.
   - 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 (like in drunk people)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.



Finger nose test

Figure 20 -18

- ➢ 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.

Heel to shin test

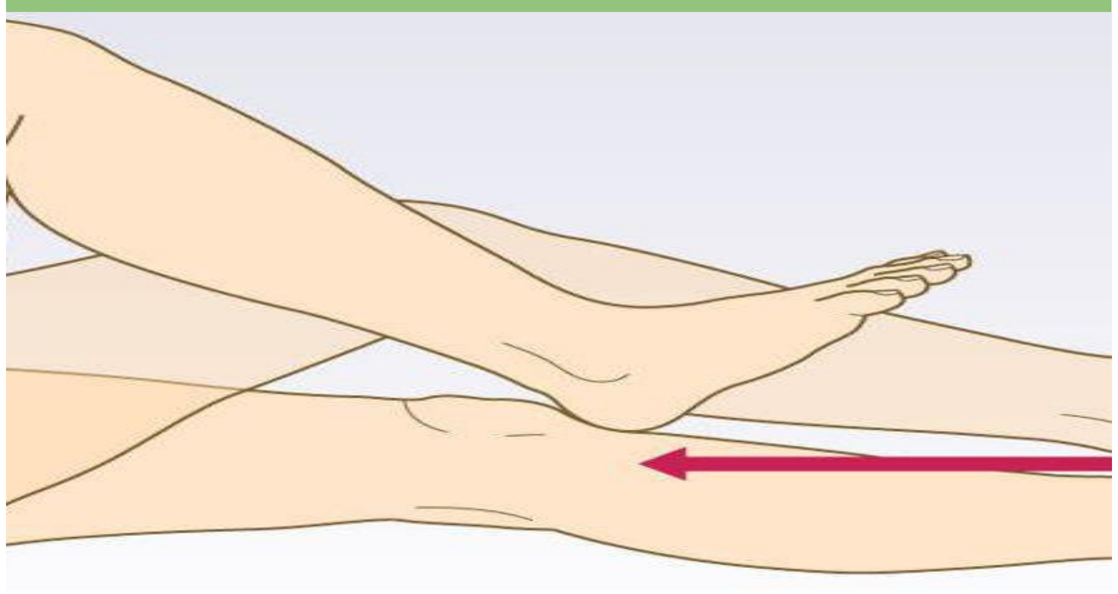


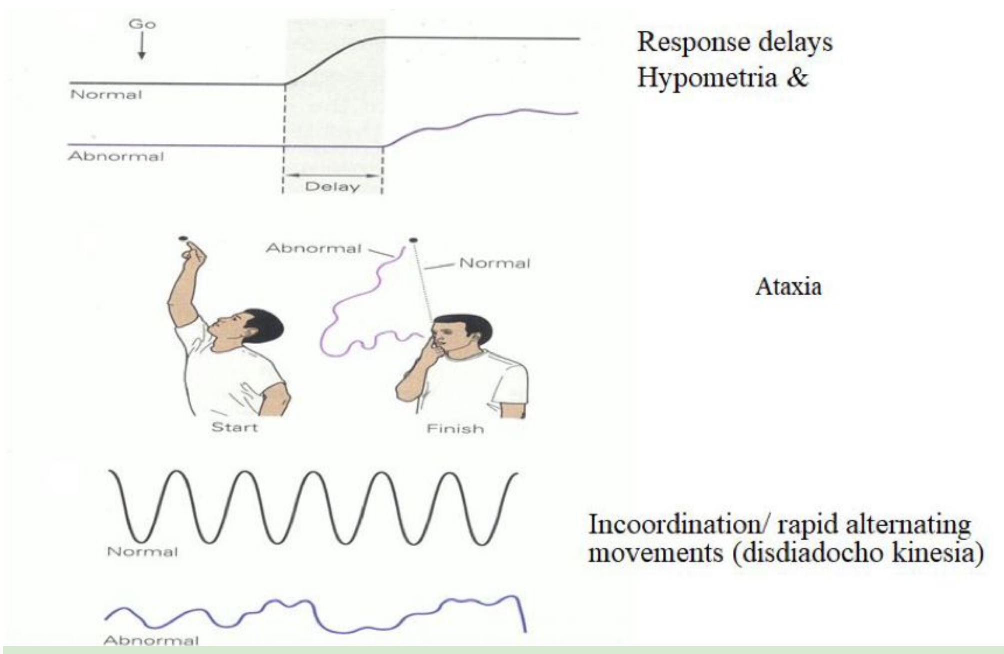
Figure 20 -19

- ➢ 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.

Dysdiadochokinesis

Figure 20 -20

- ➢ **Dysdiadochokinesia**: Inability to perform rapidly alternating movements.
- ➢ It's 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.



Cerebellar Signs

Figure 20 -21

QUIZ

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CNSPHYSIOLOGY

1. Cerebellum cortex contains five different cell types which are all inhibitory EXCEPT:
A) Purkinje cells
B) Golgi cells
C) Granular cells
D) Stellate cells

2. Control of equilibrium & postural movements is done by vestibulocerebellum through which nucleus?
A) Fastigal nucleus
B) Dentate nucleus
C) Interpositous nuclei
D) Emboliform nucleus

3. Trunk ataxia is caused by lesion of which ONE of the following:
A) Vestibulocerebellum
B) Pontocerebellarfibres

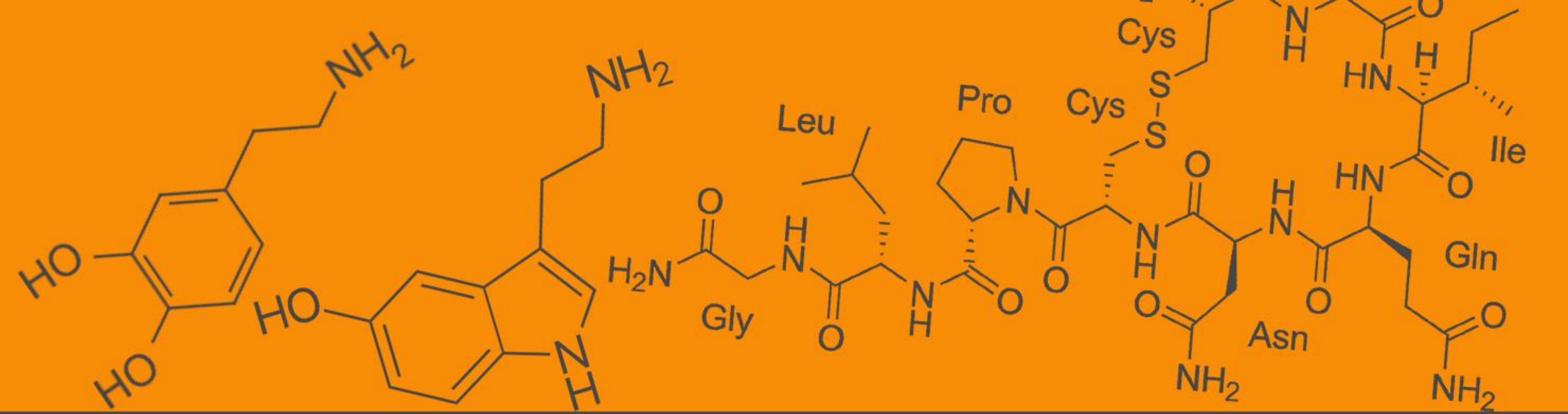
4. Which of the following is NOT one of the manifestations of neocerebellar syndrome:
A) Athenia
B) Sensory ataxia
C) Hypotonia
D) Motor ataxia

5. All the following are true about ARCHICEREBELLUM except:
A) Part of cerebellum flocculonodular lobe
B) Nuclei fastigeal
C) Afferents and Efferents from vestibular nuclei
D) Concerned with posture & muscle tone

6. Motor planning is the function of:
A) Cerebrocerebellum
B) Spinocerebellum
C) Vestibulocerebellum
D) None of the above

7. Efferent fibers originate and leave the cerebellum from the cerebellum cortex.
A) True
B) False

ANSWER KEY: C, A, A, B, D, A, B



THIS LECTURE WAS DONE BY

Noura Alturki, Deema Almaziad

FEMALE PHYSIOLOGY CO-LEADERS
Maha Alnahdi, Ghaliah Alnufaei

MALE PHYSIOLOGY CO-LEADERS
Nayef Alsaber, Hameed M. Humaid

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REFERENCES

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- Ganong's Review of Medical Physiology