6. Control of movements, posture & motor function (cerebellum and brain)

By

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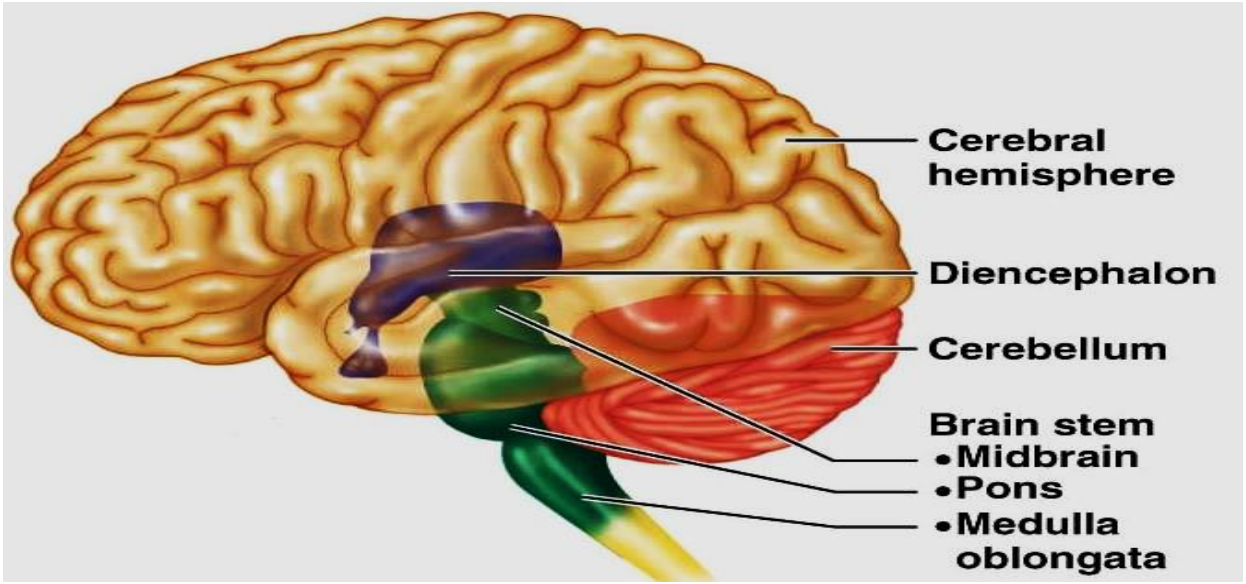
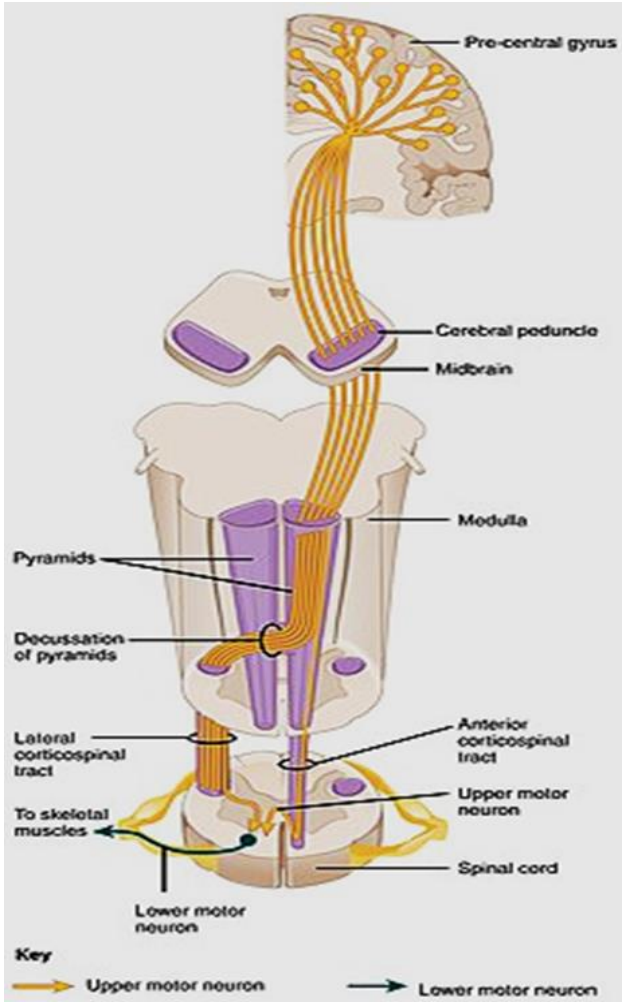

Cerebral hemisphere
Diencephalon
Cerebellum
Brain stem
•Midbrain
•Pons
•Medulla oblongata


Pre-central gyrus
Cerebral peduncle
Midbrain
Medulla
Pyramids
Decussation of pyramids
Lateral corticospinal tract
Anterior corticospinal tract
Upper motor neuron
To skeletal muscles
Spinal cord
Lower motor neuron
Key
Upper motor neuron
Lower motor neuron

The descending tracts

-**Voluntary movements** to be done accurately in our bodies, many higher and lower nerve centers must cooperate for this performance.

-The order of the movement is developed in the **motor association areas** in the frontal lobe of the cerebral cortex. Then the program of these movements is also developed in the **basal ganglia** and the **cerebellum**, which through the whole movement they modulate and modify the performance of the muscle secondary to **afferent impulses** that arise from these muscles. Finally the motor area **(4)** and the pre-motor area **(6)** in the frontal lobe send the excitatory impulses to the skeletal muscles to carry on the movements.

-The skeletal muscle contractions are of **two** types :-

1-Reflex contractions like in withdrawal reflex. A group of "neurons" must be intact which are called the **"lower motor neurons**, they are found in the AHC in the spinal cord for limbs and trunk muscles and in the brain stem for muscles of the head and neck.

2-Voluntary contractions like in writing or doing skilled movements. Another group of neurons must be intact in addition to the lower motor neurons. These neurons are present in the motor and pre-motor areas in the cerebral cortex and other brain stem centers, and they are called the "**upper motor neurons** **(U.M.N**).

-The **descending** tracts are classified into two groups:

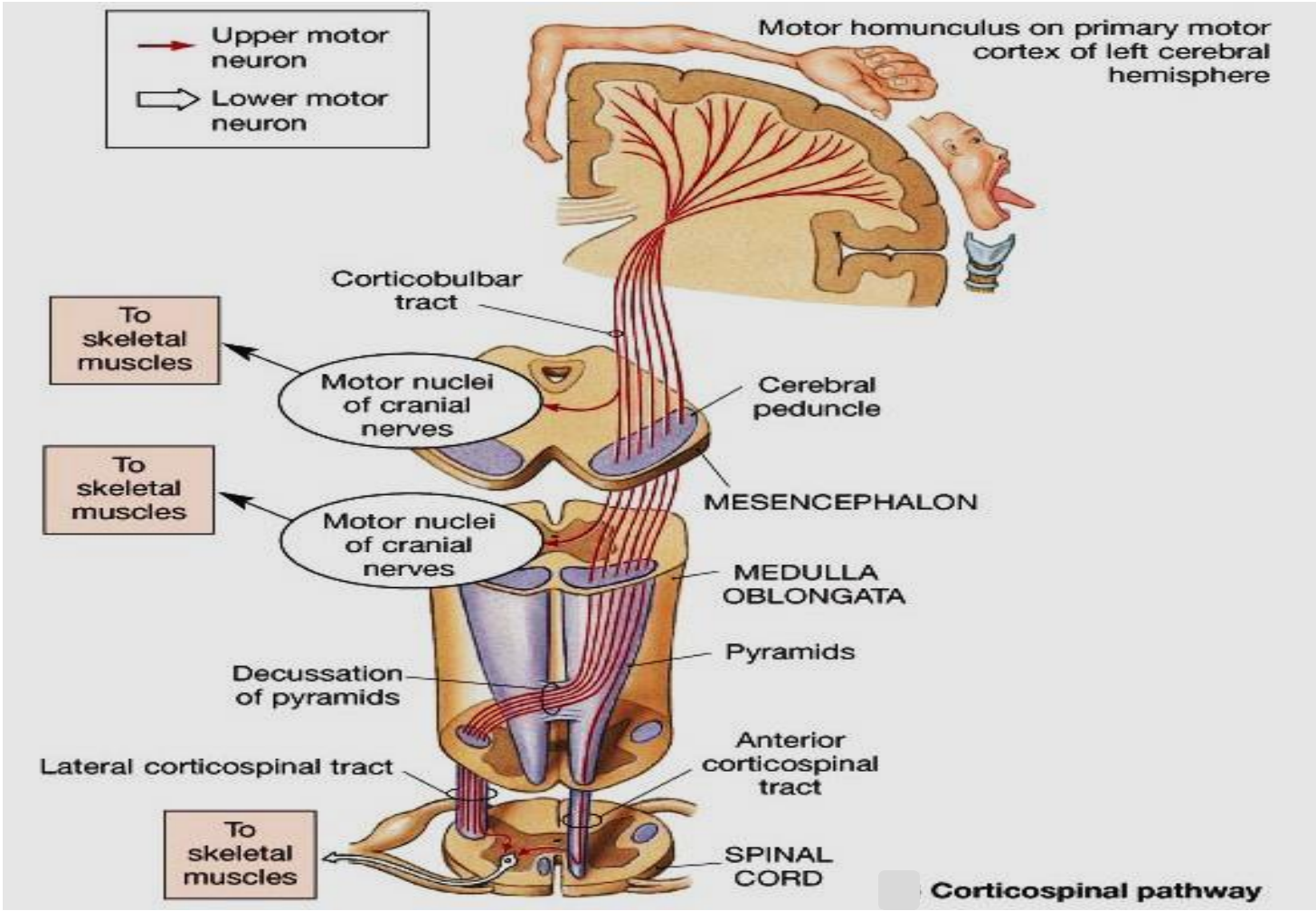
A-Pyramidal tract. B-Extra-pyramidal tracts .

A- Pyramidal tracts

-The pyramidal tract is **one way**, **direct** connection between **UMN and AHC**. It contains about one million fibers only **60 %** of them are **myelinated** and this myelination becomes complete one year after birth

-About **30 %** of it's fibers arise from the primary motor area "4" and **30 %** from the pre-motor area "6" and the remaining **40 %** from somatic sensory area (areas 3,1, 2 and area 5,7).

-It is called "pyramidal" because it is the only tract which contains the axons of certain cells called "the Pyramidal" or "**Betz** "cells which are found in the 5^{th} layer in the motor area "4". These cells are never found in any other area except in area (4).


Upper motor neuron
Lower motor neuron
Motor homunculus on primary motor cortex of left cerebral hemisphere
Corticobulbar tract
To skeletal muscles
Motor nuclei of cranial nerves
Cerebral peduncle
To skeletal muscles
Motor nuclei of cranial nerves
MESENCEPHALON
MEDULLA OBLONGATA
Pyramids
Decussation of pyramids
Lateral corticospinal tract
Anterior corticospinal tract
To skeletal muscles
SPINAL CORD
Corticospinal pathway

-The axons of the tract form in the cortical area what is called the "**corona radiata**" which occupies the anterior 2/3 of the posterior limb of the **internal capsule**. In the **midbrain** the fibers of the tract are grouped in bundles and it from 3/5 of **basis pedunculi** and descends to the **pons** in the **basis pontis** and finally reaches the **medulla** where they from specific elevations called the " pyramid ".

-In the medulla oblongata , **80%** of fibers **cross to the opposite side** forming **motor decussation** then descend in the cord forming the **lateral cortico-spinal tract** and ends around interneurons and A.H.C at different levels of the spinal cord segments.

-About **20%** of fibers descends in **same side** forming direct or **ventral cortico- spinal tract** but these fibers **re-cross** to the opposite side in different levels in cervical and thoracic regions to end around A.H.C.

-1% of fibers descend directly without crossing forming **Ipsilateral cortico-spinal tract** to the same side AHC.

- **The cortico-bulbar tract:** is part of the pyramidal system which originates mainly from lower parts of area " **4** " and **" 6** " in the cerebral cortex and terminates on motor nuclei of **cranial nerves** that supply muscles and glands of **head & neck**, cranial nerves number (**V,VII, IX, X, XI and XII**). Large part of fibers cross in the brain stem to opposite side but many fibers innervate same side which explains little affection of the face in internal capsule lesion. **All hypoglossal nucleus** and **lower 1/2 of facial nucleus** are innervated only from **opposite** pyramidal tract.

- **Cortico-nuclear tract:-** is that part of pyramidal tract which innervate the nuclei of **III, IV , and VI** which supplies the **extra-occular muscles**. The tract originates form specific area called " **frontal eye field** " or area **" 8 "** and supplies the specific cranial nuclei of **both sides** (medial longitudinal bundle). The tract performs conjugated deviation of both eyes to opposite side and the accommodation to near and far vision. **Thus**:- the **Pyramida**l tract includes:
- 1- The **cortico-spinal** tract 2- The **cortico- bulbar** tract 3- the **cortico-nuclear** tract.

Functions of the pyramidal tract:-

1-It initiates and facilitates isolated skilled voluntary movements, specially those which need training and educations as writing, threading a needle, typing .

2- It increase muscle tone and other deep reflexes.

3- It inhibits the primitive withdrawal reflex (Babiniski's sign).

-Lesions of the pyramidal tract:- Most probably vascular (thrombosis or hemorrhage) or may be due to tumors or traumatic causes, most common site in **internal capsule or medulla**.

It causes :- 1- Loss of skilled voluntary movements (paralysis) in **opposite side**.

2-Pure pyramidal lesion without other extra-pyramidal lesions -causes **hypotonia**.

3- Appearance of Babiniski's sign (dorsiflexion of big toe).

B. The extra-pyramidal tract

-Any descending tract other than pyramidal is called extra-pyramidal tract.

-They are group of " **multi-stations** " descending fibers originating from more wider areas in the cerebral cortex including area " **4** " area " **6** " in the frontal lobe, **basal ganglia** and other many brain stem centers (reticular formation, tectum of mid brain, red nucleus, olivary nuclei and vestibular nucleus), where they terminate finally around **gamma cells** (mainly) and **anterior horn cells** in different levels of the spinal cord.

-Some of these tracts descend **directly** without crossing while others **cross** to opposite side, a third type may innervate **both sides**.

-In the **Extrapyramidal** system, the brain stem centers (as reticular formation, red nucleus and vestibular nuclei) receive many impulses form **higher cortical areas** as pre-motor area, basal ganglia, cerebellum and motor area and the activity of these brain stem centers are greatly controlled by these connections.

-The most important extrapyramidal tracts are :-

A) Reticulo-spinal tracts:- which arise from reticular formation in the brain stem and then divides into :-

1- Medial reticulo-spinal tract: arises from pontine reticular formation and descends without crossing (direct), this tract is **facilitatory** to muscle tone.

2- Lateral reticulo-spinal tract: arises from medullary reticular formation and crosses to opposite side, this tract is **inhibitory** to muscle tone and end mainly around A.H.C.

B) Vestibulo-spinal tract: arises from vestibular nucleus to A.H. cells. This tract carries the pathways of postural reflexes arising from the labyrinth. It divides into **lateral** and **medial**, no crossing (direct), it is **facilitatory** to muscle tone specially extensors (antigravity muscles). It ends at different levels of the spinal cord.

C) Rubro-spinal tract: - from red nucleus in mid brain which receives many impulses from higher cortical area, basal ganglia and cerebellum. The tract **crosses** rapidly in midbrain to the opposite side.

The rubro-spinal tract is mainly **inhibitory** to muscle tone (interneuron) beside it controls many muscle activities through special tract called " cortico-rubro-spinal system".

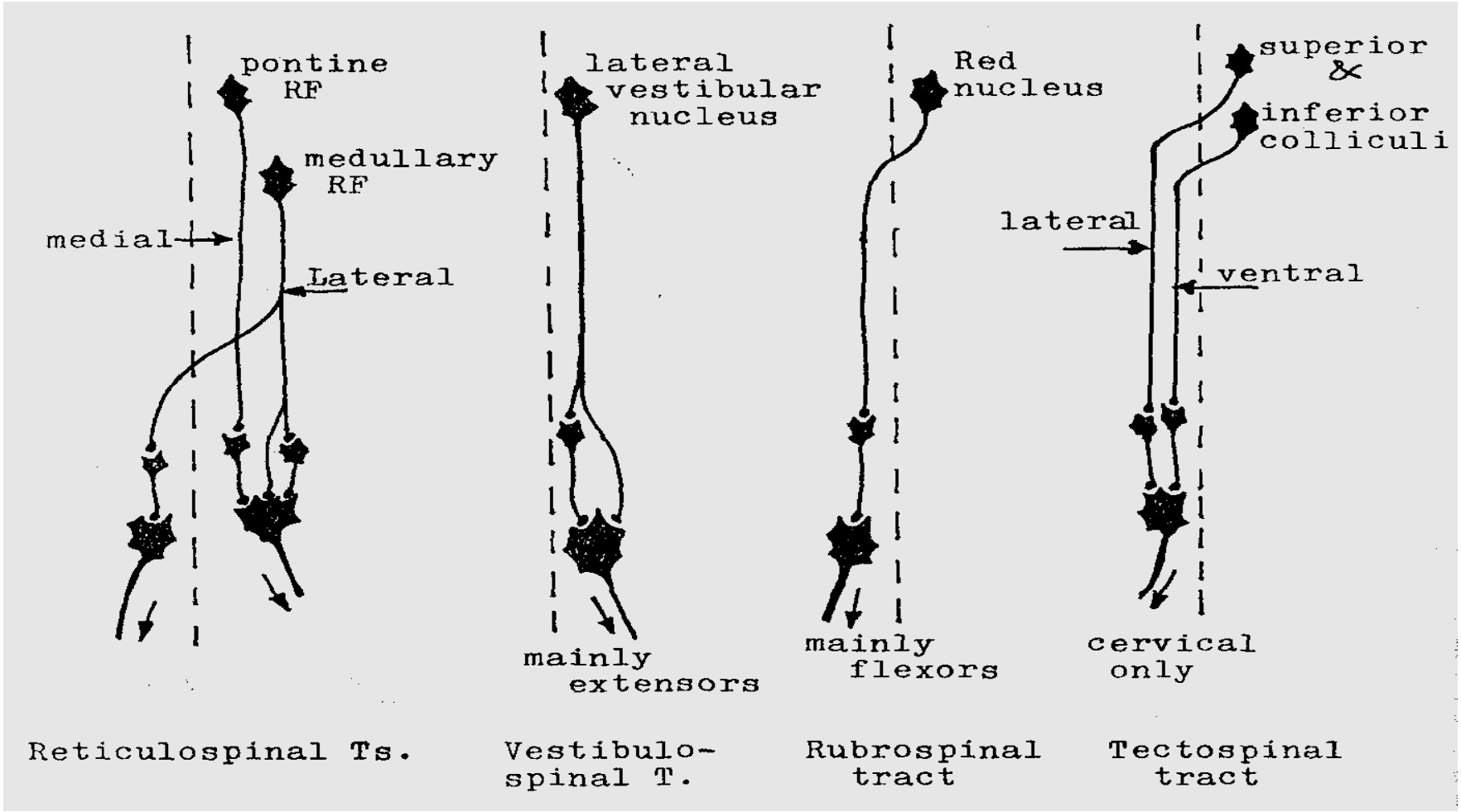
D) Olivo-spinal tract: - is relatively short tract ends around A.H.C till the **cervical region** only. It arises from the **inferior olivary nuclei** in the medulla and descends without crossing (direct), causing **facilitation** to muscle tone. Olivary nuclei receive impulses from basal ganglia.

E) Tecto-spinal tracts :-

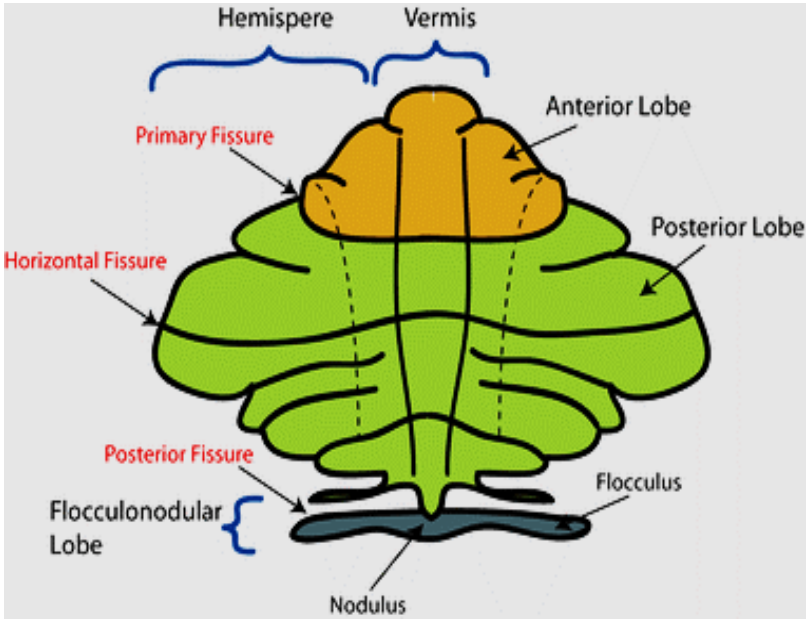
1- **Lateral**, from **superior colliculus** of the mid brain. 2-**Medial**, from **inferior colliculus** of the mid brain.

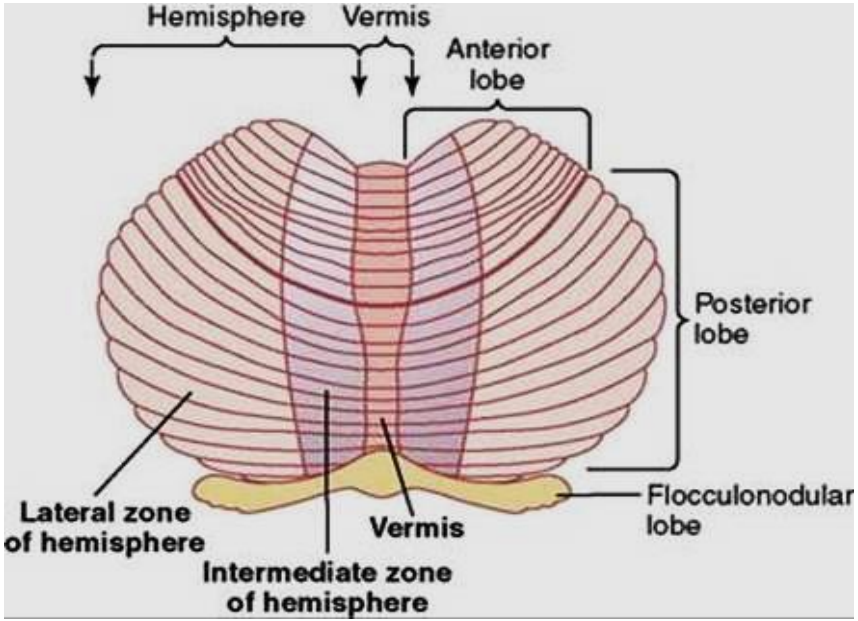
-After **crossing**, both tracts end around A.H Cells in cervical region of the spinal cord which controls movement of the neck muscles, also some movements like raising the arms in front of eyes. The tecto-spinal tracts coordinate, what is called "**visual and auditory spinal protective reflexes",** like reflex turning of the head either away or towards visual or auditory stimuli .

Note that- The extrapyramidal fibers which originate from premotor area during their descend to brain stem nuclei, they mix with pyramidal fibers in the **corona radiata** and **internal capsule** (anterior limb), before reaching to the basal ganglia.


pontine RF
medullary RF
medial
Lateral
lateral vestibular nucleus
mainly extensors
Red nucleus
mainly flexors
superior &
inferior colliculi
lateral
ventral
cervical only
Reticulospinal Ts.
Vestibulo-spinal T.
Rubrospinal tract
Tectospinal tract

Crebellum


Hemispere
Vermis
Anterior Lobe
Primary Fissure
Posterior Lobe
Horizontal Fissure
Posterior Fissure
Flocculus
Flocculonodular
Lobe
Nodulus


Hemisphere
Vermis
Anterior
lobe
Posterior
lobe
Flocculonodular
lobe
Lateral zone
of hemisphere
Vermis
Intermediate zone
of hemisphere

Cerebellum

Functions of the cerebellum:

1.Control of equilibrium (mainly performed by the **flocculo-nodular lobe**) which is assisted by it's connection to the labyrinth through the vestibular nuclei.

2.Regulation of the muscle tone; the **paleo-cerebellum** is inhibitory to the muscle tone while the **neo-cerebellum** is excitatory to it.

3.Regulation of the gross involuntary movements: through it's connection with basal ganglia, motor areas and other extra pyramidal system.

4. Role of cerebellum in ballistic movement:

Most rapid movements of the body such as the movements of the fingers in typing and the saccadic movements of the eyes.

5.Control of voluntary movements

Mainly the function of **neo-cerebellum**, controlling the timing and the progression from one movement to another rather than initiation of these movements through the following functions:

A-Servo-comparator function: Any movement to be done by the muscles of the body the following steps are carried out one by one:

1.The motor associated areas in the frontal lobe of the cerebral cortex **put the program** of this movement and **inform** both the cerebellum and the basal ganglia by this program even before information of motor area

2. The **motor area "4"** starts to excite the specific muscles through the pyramidal and the extra pyramidal tracts and at the same time it **inform the cerebellum** by these orders through the closed feed back circuit between them (cortico - ponto - dentato - thalame cortical circuit).

3.When the muscles and joints begin to carry out the movements, the **performance of this muscle is transmitted** to the cerebellum by the very rapid spino - cerebellar tracts (dorsal and ventral).

4. The cerebellum now **compares** between: a- **The program** of the movement from the frontal associated areas.

b- The **intention** (orders) to the muscles from motor area "4". c- The **performance** of the muscles to the movements.

-Any error or imbalance between these 3 items is immediately detected by the cerebellum, then calculated and at once corrected through: a- Correction of impulses from motor area to the muscles either by "**braking**" impulses to slow down or by **enhancing it** to increase its power of contraction. This is done through "**dentato- thalamo- cortical** connection".

b- Through the wide connection of the cerebellum to the **extra-pyramidal system** it can increase tone in certain muscle, inhibits it in other muscles thus it can adjust any movement to accurate performance preventing overshooting of the muscles.

B-Damping function of the cerebellum:

-Damping function means "**preventing oscillation**" of the movements, the cerebellum makes movements starts smoothly or easily and also ends abruptly (without overshooting).

-Any muscle has a "mass" and to move easily it must overcome it's "**inertia**", the cerebellum enables muscle to start contraction and to overcome this inertia (through facilitating tone).

-Also when a group of muscle move, they will have momentum. This momentum does not enable the moving limb to stop abruptly and cause overshooting. The cerebellum also overcomes this momentum and prevents overshooting by initiating **braking** impulses which stops limb at the point of intention this is done by stimulating antagonistic muscles.

C- Predictive function:

The cerebellum could expect next movement by the limbs, thus making it performed easily by affecting muscle tone.

D- Programmer function:

It makes the voluntary movement **smooth**, **rapid**, **less** of **energy** consumption, **less of errors** and **purposeful**, through it's connection to the frontal motor association areas

-**Lesions in cerebellum:** due to atherosclerosis or degeneration in the deep nuclei, vascular lesions as thrombosis or hemorrhage, tumors or traumatic lesions are also common causes. **Manifested by:**

1. Archi-cerebellar syndrome:

It affects mainly **folucculo-nodular lobe** with disturbances in equilibrium with a characteristic gait called "**drunken gait**", patient walks swinging from side to side like a drunken person.

2. Paleo- cerebellum Syndrome:
In which there is **hypertonia** but the equilibrium and voluntary movements are more or less normal.

3. Neo- Cerebellar syndrome (Ataxia): Which affect the **neo-cerebellum** and is characterized by:

a-Athenia: severe muscle **weakness** but not paralysis in the same side of lesion.

b-Hypotonia: because neo-cerebellum facilitates the muscle tone. The tendon jerk takes the characteristic "**Pendular knee jerk".**

c- Cerebellar ataxia:

Ataxia is loss of coordination of voluntary motor activity. This mean that the muscles are not paralyzed but it cannot perform accurate movements.

Cerebellar (motor ataxia) are characterized by:

1. **Dysmeteria:** "dys" means disturbed while "meteria" means distance i.e patient cannot adjust the distance of the movements and either Hypermeteria or Hypometeria occur. It is well diagnosed by "finger nose test".

2. **Dys-diadocokinesia:** inability to perform rapid alternative antagonizing movements as flexion of right hand and extension of the left hand at the same time. The hand on diseased side follow that on intact side.

3. **Stacatto speech :** inability to speak correctly , the word is broken to many letters, due to tremors of speech muscles.

4. **Kinetic (intention) tremors :** at the beginning the moving part shows involuntary rhythmic oscillations which disappear during rest and sleep. These tremors are due to loss of damping action , it increases at end of motion due to failure of cortical correction.

5. **Cerebellar Nystagmus:** movements of the both eyes from side to side during fixation of eye on an object. This is attributed to tremors that occurs in Extra- occular muscles.

6. **Rebound phenomenon :** inability to stop suddenly a rapidly moving limb due to failure of braking mechanism.

7. **Abnormal gait, Zigzag gait**, : In unilateral lesion the muscles on that side are weak due to hypotonia and if the patient walk on a straight line he will deviate towards the weak side . In bilateral lesions the patient swings from side to side giving zigzag gait.

8. **Decomposition of movements:** inability to perform complex movements easily , due to loss of programmer function.

Thank You