Physiology of Motor Tracts

Dr. Salah Elmalik

Learning objectives:

At the end of this lecture the student should :

- Appreciate what is upper motor neuron and lower motor neuron .
- Explain the origin , course and functions of the following motor tracts:

  - ➢ Pyramidal tracts:
    - ✓ (corticospinal & corticobulbar tracts)
  - ➢ Extrapyramidal tracts as:
    - ✓ Rubrospinal .
    - ✓ Vestibulospinal .
    - ✓ Reticulospinal .
    - ✓ Olivospinal .
    - ✓ Tectospinal

For performance of voluntary movements two levels of neurons are essential:

-Upper motor neurons (UMN)

These are the motor neurons whose cell bodies lie in the higher motor centers, and their axons pass to brain stem and spinal cord to activate the cranial (brain stem neurons) and spinal motor nuclei .

-Lower motor neurons: (LMN)

These are the motor neurons of the spinal cord (AHCs) and brain stem motor nuclei of the cranial nerves that innervates skeletal muscle directly.

Classification of descending motor systems

- The descending motor pathways have commonly been divided into ***"pyramidal"*** and ***"extrapyramidal"*** tracts.
- This classification is based on the finding that the motor tract which originates from the cerebral cortex and descends to the spinal cord (the corticospinal tract) passes through the pyramids of the medulla, and therefore has been called the ***"the pyramidal tract".***
- The rest of the descending motor pathways do not travel through the medullary pyramids, and are therefore collectively gathered under the heading: ***"the extrapyramidal tracts".***

❑ *The following are the important sets of descending motor tracts, named according to the origin of their cell bodies and their final destination:*

1) **Corticospinal tract,**
2) **Corticobulbar tract.**

(= Pyramidal tract)

1) **Rubrospinal tract,**
2) **Reticulospinal tracts,**
3) **Vestibulospinal tracts,**
4) **Tectospinal tract, and**
5) **Olivspinal tract .**

Extrapyramidal tracts

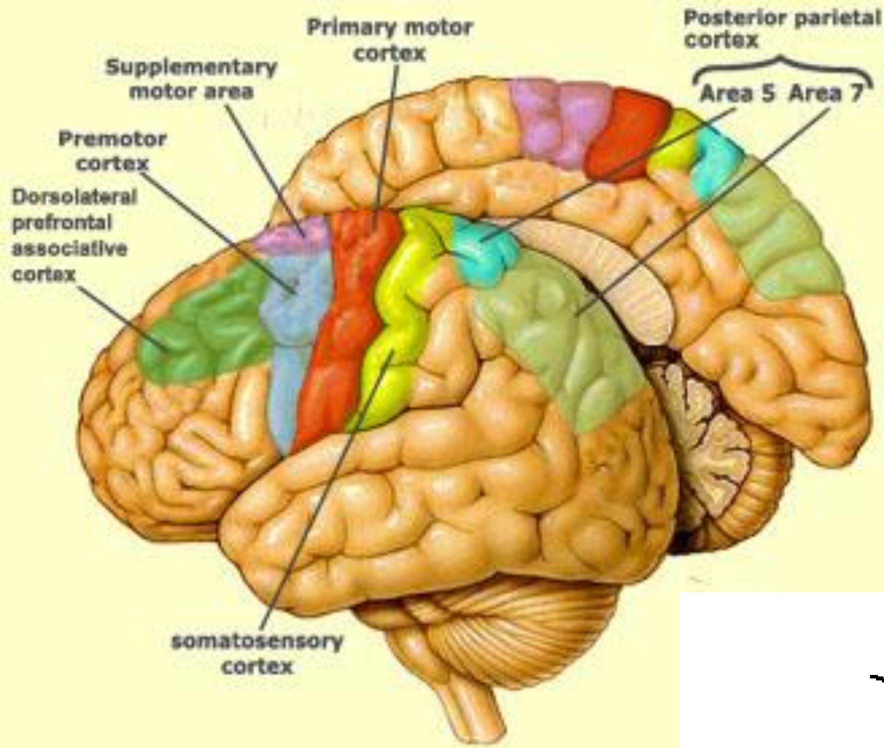
Pyramidal Tracts

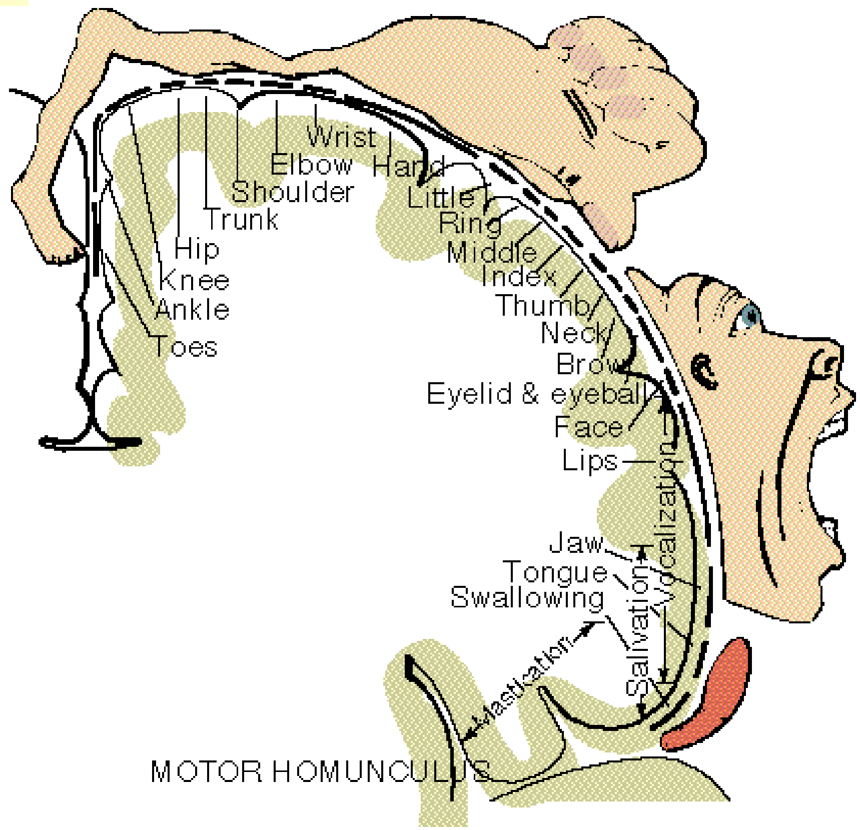
Motor Areas

- (1) The primary motor area (M1 . Motor area 4)

occupies the precentral gyrus & contains large , highly excitable Betz cells.

- MI of one side controls skeletal muscles of the opposite side of the body
- Area of representation is proportional with the complexity of function done by the muscle. So, muscles of hands and speech occupies 50% of this area
- The neurons of this area arranged in vertical Columns.
- Each column has six distinct layers of cells, The pyramidal cells that give rise to the to the corticospinal fibers all lie in the fifth layer of cortical surface
- Each column of cells functions as a unit, operate as an integrative - processing system, using information from multiple inputs to determine the output response from the column.


Primary motor cortex
Supplementary motor area
Premotor cortex
Dorsolateral prefrontal associative cortex
Posterior parietal cortex
Area 5
Area 7
somatosensory cortex


Wrist
Elbow
Hand
Shoulder
Little
Trunk
Ring
Middle
Hip
Index
Knee
Thumb
Ankle
Neck
Toes
Brow
Eyelid & eyeball
Face
Lips
Vocalization
Jaw
Tongue
Swallowing
Salivation
Mastication
MOTOR HOMUNCULUS

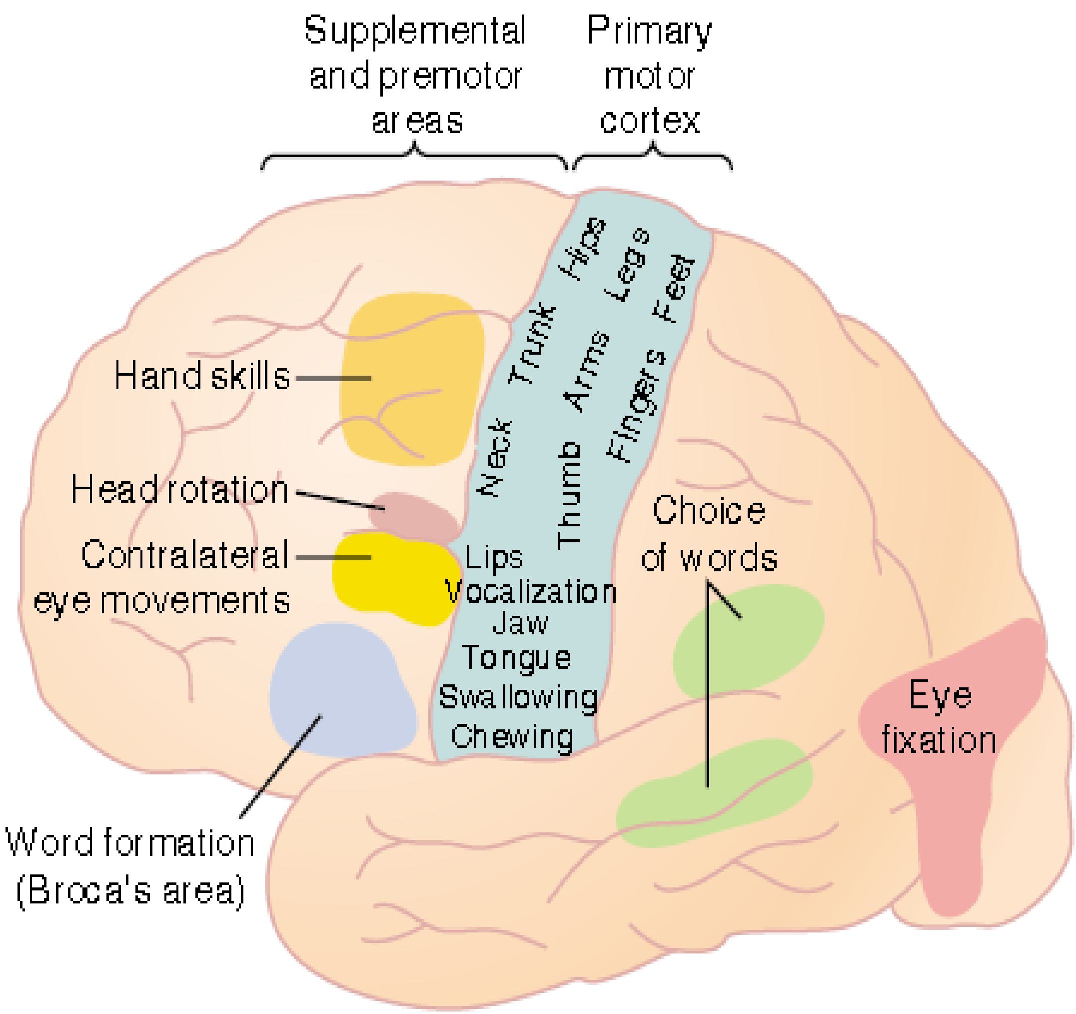
(2) Premotor Area

- lies infront of the primary motor area & below supplementary motor area.
- Stimulation of the premotor area produces complex coordinated movements, such as setting the body in a certain posture to perform a specific task.
- It works in association with the supplemental motor area, establishing the motor programs necessary for execution of complex movements

- (3) The Supplementary Motor Area
- Lies in front of area 4 and above the premotor area
- Stimulation of this area leads to bilateral grasping movements of both hands simultaneously.

- This area make motor programs for axial muscles. It provides background adjustment for finer motor control of the arms and the hands by the premotor area and primary motor cortex

- A few highly specialized motor centers have been found in the premotor areas of the human cerebral cortex:
- **Broca's Area for Speech**
- **The Frontal Eye Movements Area:**
  - ✓ located above Broca's area in the frontal lobe
  - ✓ controls voluntary movements of the eyes toward different objects in the visual field.
- **Head Rotation Area:**
  - ✓ located just above the eye movement area in the motor cortex .
  - ✓ directing the head toward different visual objects .
- **Area for Hand Skills**


Supplemental and premotor areas
Primary motor cortex
Hips
Legs
Feet
Trunk
Arms
Fingers
Neck
Thumb
Hand skills
Head rotation
Contralateral eye movements
Lips
Vocalization
Jaw
Tongue
Swallowing
Chewing
Choice of words
Eye fixation
Word formation (Broca's area)

Corticospinal (Pyramidal) Tracts

- **Cells of origin :**

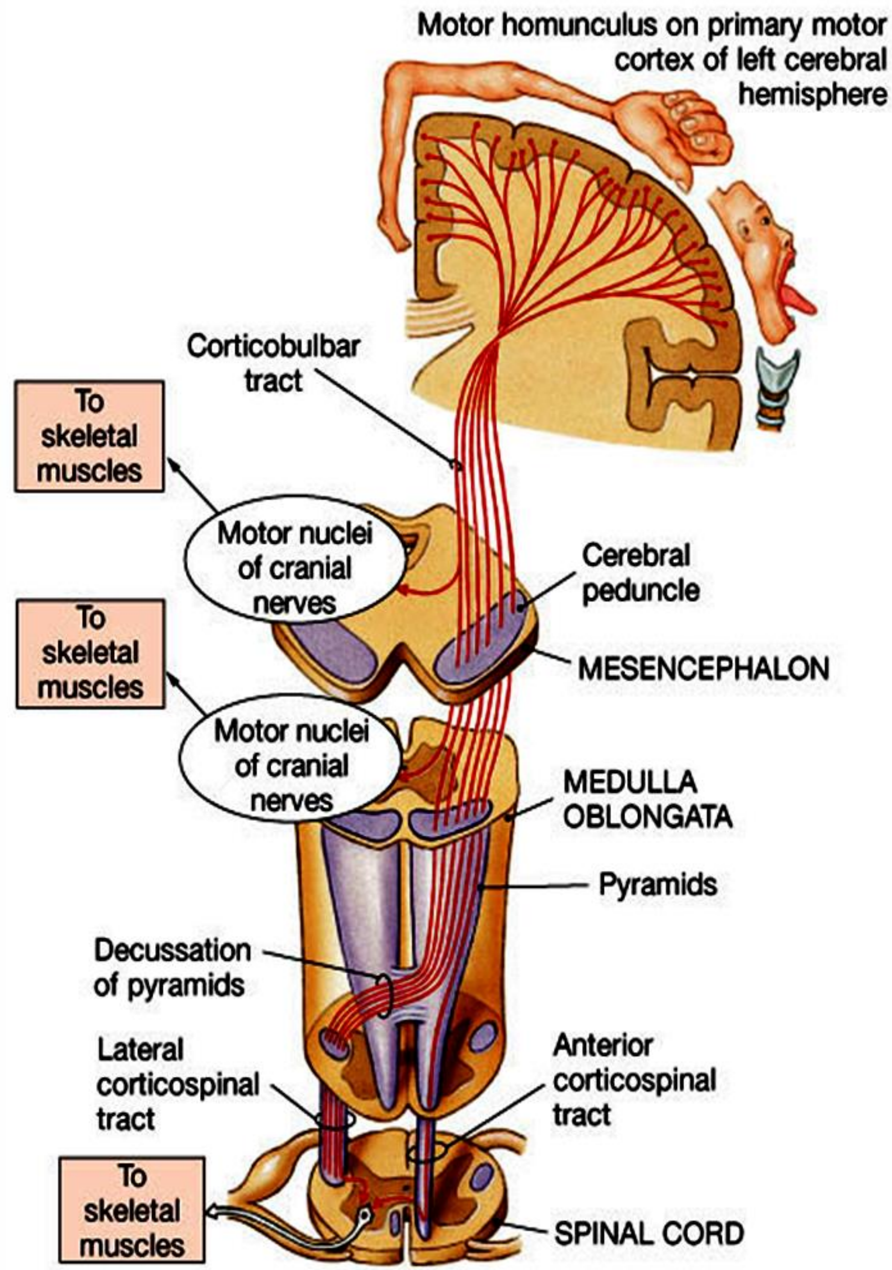
30% originate from the primary motor area,

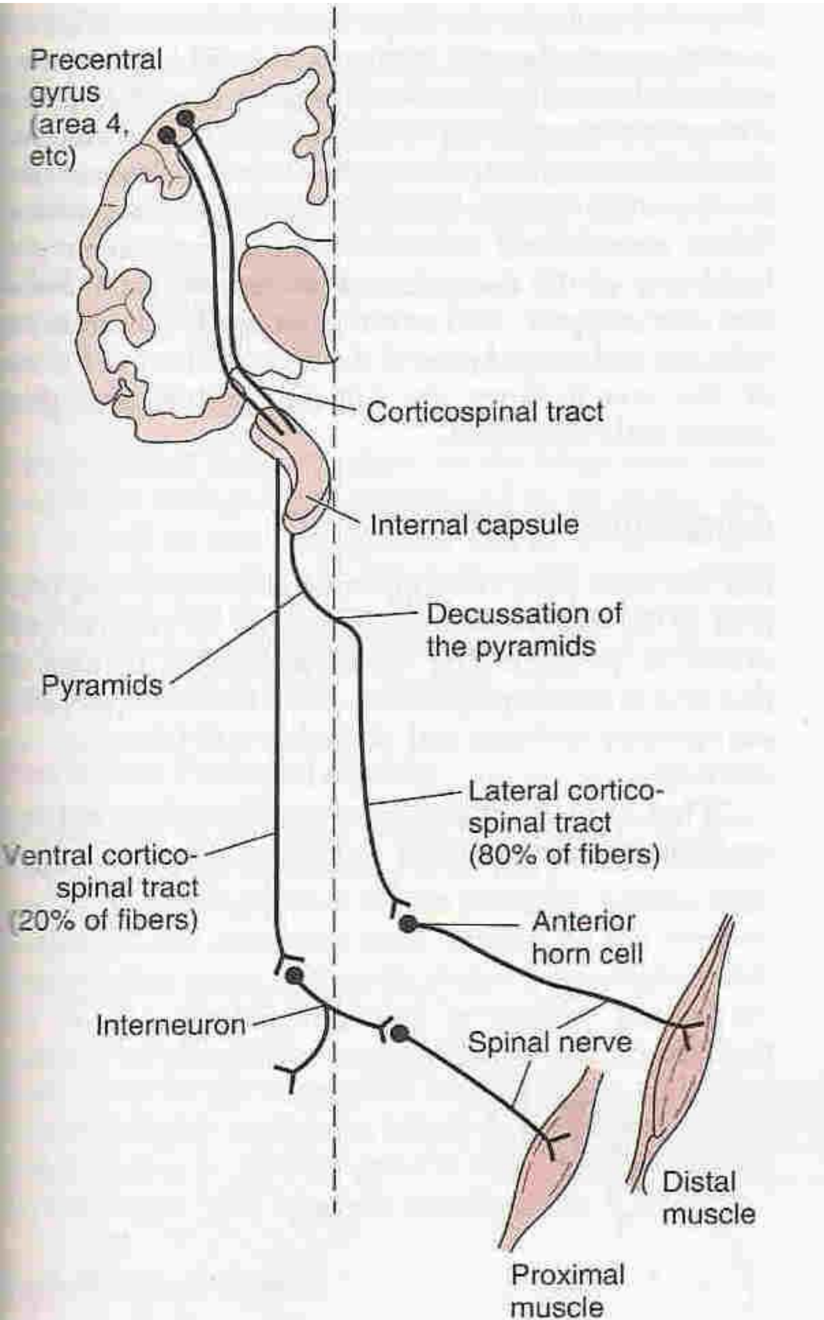
30% from the premotor area , and supplementary motor area

40% from the somatic sensory areas posterior to the central sulcus.

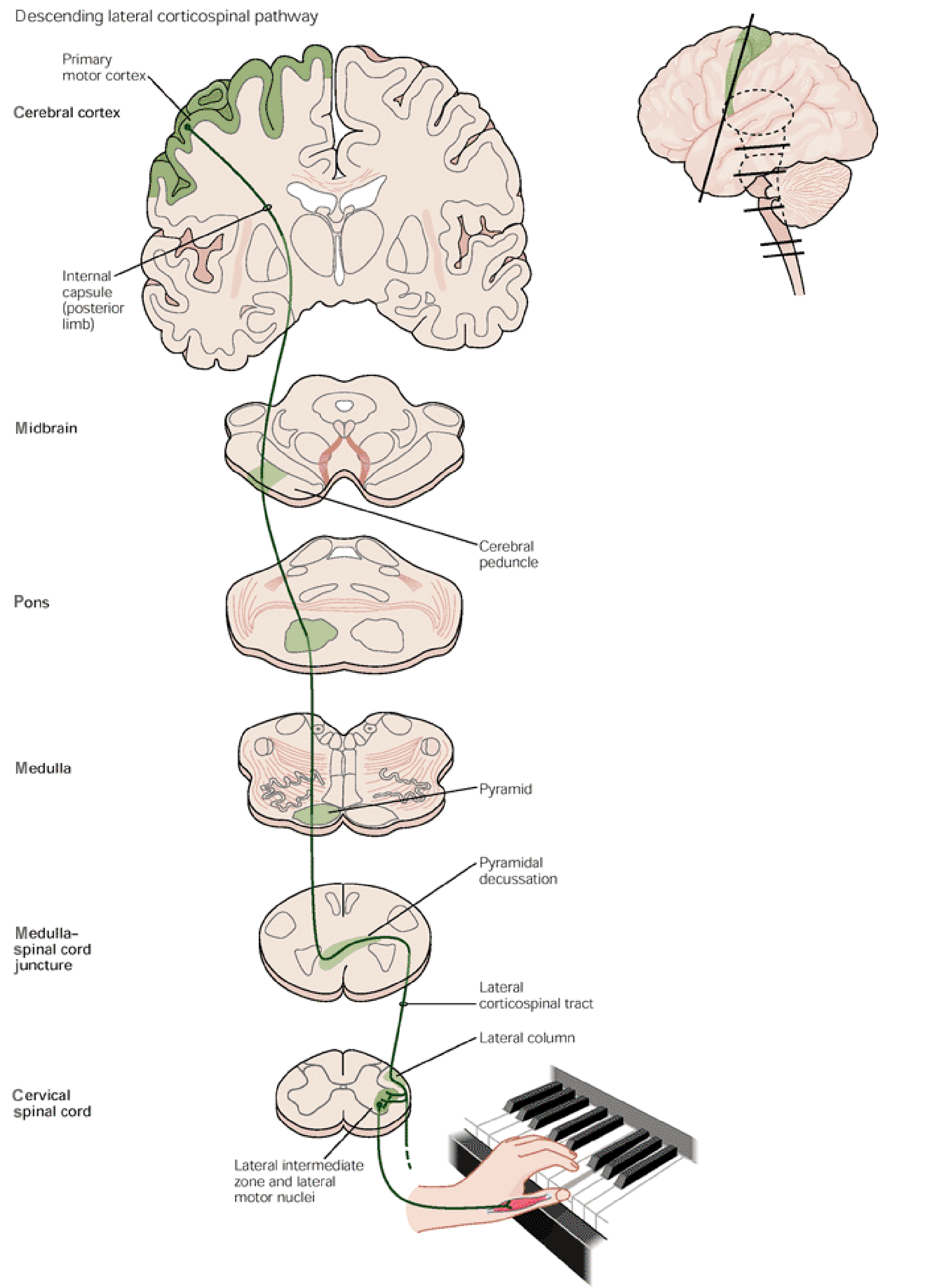
- 3% of the fibres are large myelinated fibres, derived from the large , highly excitable pyramidal Betz cells of MI . These fibers form monosynaptic connections with motor neurons of the spinal cord.
- But most of pyramidal fibers are unmyelinated
- Fibers from the cerebral cortex descend in corona radiata to reach the posterior limb of internal capsule (between caudate and putamen nuclei of the basal ganglia)

- Then descend through the midbrain and pons.
- ✓ Some fibers cross in brainstem to supply contralateral cranial nerve nuclei constitute the Corticobulbar tract .
- In the lower medulla around 80% of the fibres cross to the opposite side, and descend in the lateral column of spinal cord as the <u>Lateral Corticospinal Tract</u> .
- They synapse on the contralateral spinal motor neurons , or on interneurons
- <u>These fibers controls and initiates fine discrete skilled movement of fingers and hands.</u>



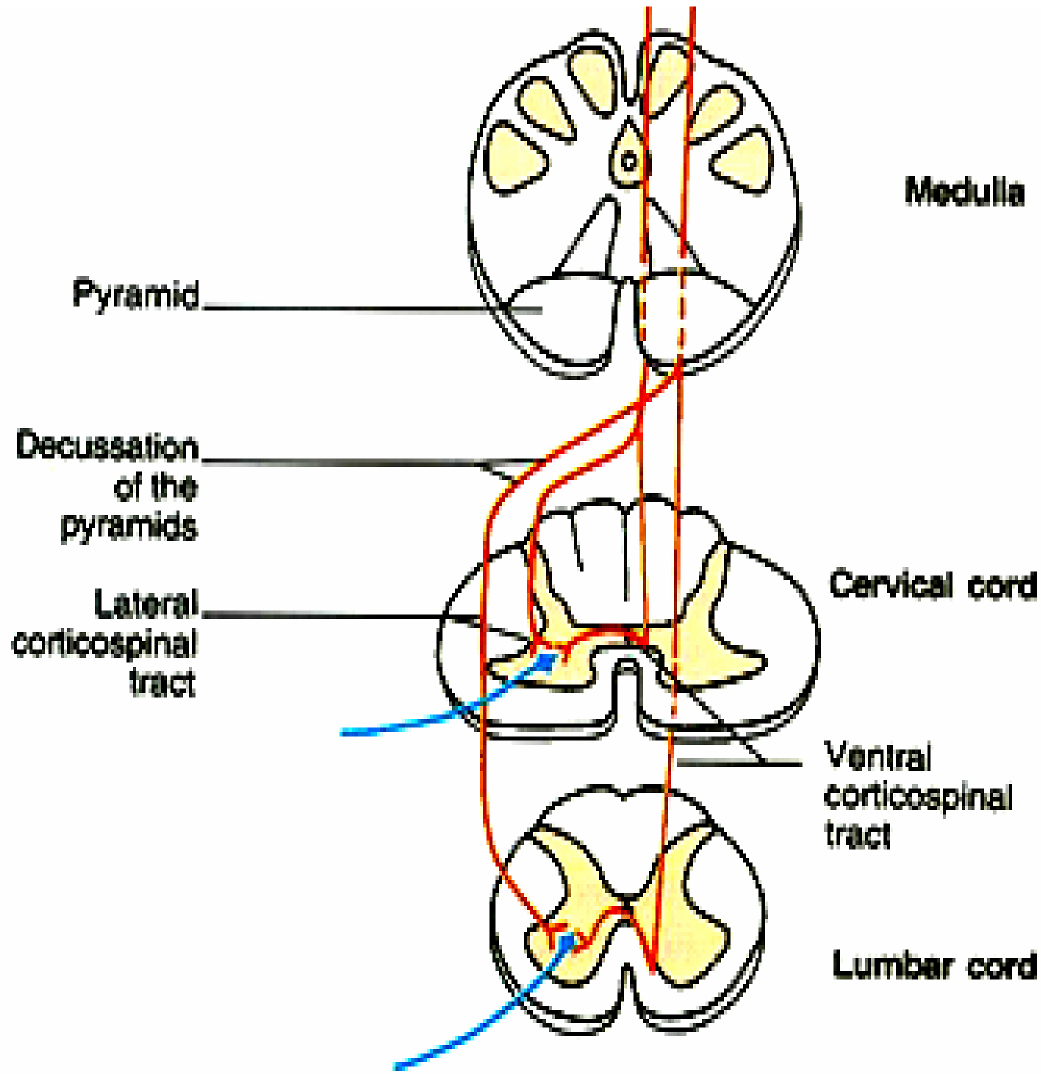


Precentral gyrus (area 4, etc)
Corticospinal tract
Internal capsule
Decussation of the pyramids
Pyramids
Lateral cortico-spinal tract (80% of fibers)
Ventral cortico-spinal tract (20% of fibers)
Anterior horn cell
Interneuron
Spinal nerve
Distal muscle
Proximal muscle



Descending lateral corticospinal pathway
Primary motor cortex
Cerebral cortex
Internal capsule (posterior limb)
Midbrain
Cerebral peduncle
Pons
Medulla
Pyramid
Pyramidal decussation
Medulla–spinal cord juncture
Lateral corticospinal tract
Lateral column
Cervical spinal cord
Lateral intermediate zone and lateral motor nuclei

- The remaining 20 % of corticospinal fibers do not decussate in the medulla .
- They descend ipsilaterally in the ventral column of the spinal cord white matter , Constituting the <u>Ventral (Antrior) Corticospinal Tract .</u>
- Finally they decussate (cross to the opposite side) & synapse on the contralateral spinal motor neurons
- <u>These fibers control the axial and proximal limbs muscles so it concern with control of posture.</u>



Course and Termination

fibers of the Corticospinal tract descend from the cerebral cortex

↓

collect together and descend through the posterior limb of the internal capsule

↓

through the middle portion of the cerebral peduncles of the midbrain

↓

The fibers are separated by transverse pontine fibres in the pons

↓

In the upper medulla oblongata where they form the pyramids of the medulla

↓

In the lower region of the medulla, most of the fibers cross to the opposite site forming the "medullary decussation"

About 80% % cross to the opposite side of the spinal cord (contralaterally) and continue as the "lateral corticospinal tract".

fibers which do not decussate in medulla (about 20%) descend on the same side of the spinal cord (ipsilaterally) as the "ventral corticospinal tract".

FUNCTIONS OF PYRAMIDAL SYSTEM

1) Initiation of voluntary movements in the contralateral side of the body
2) The lateral corticospinal tract fibers that descend in the spinal cord for control of muscles of the distal parts of the limbs, especially the hand and digits muscles, which subserve fine skilled movements used in manipulation by hand and fingers, and other accurate motor actions done by the limbs .
3) The ventral corticospinal tracts control posture of axial and proximal muscles for balance , climbing and walking.
4) Facilitation of muscle tone through gamma motor neurons
5) those fibers originate from parietal lobe are for sensory-motor coordination
6) Corticobulbar tracts /control face & neck muscles & facilitate their tone, and are involved in facial expression, mastication, swallowing

Removal of the Primary Motor Cortex (Area Pyramidalis)

- Removal of a the area that contains the giant Betz pyramidal cells **(Area Pyramidalis) causes varying degrees of paralysis of the represented muscles.**

- If the caudate nucleus and adjacent premotor and supplementary motor areas are not damaged, gross postural and limb "fixation" movements can still occur, *but* *there is a loss of voluntary control of discrete movements of the distal segments of the limbs especially of the hands and fingers.*
- So area pyramidalis is essential for voluntary initiation of finely controlled movements, especially of the hands and fingers

Effects of Lesions in the Motor Cortex or in the Corticospinal Pathway(The stroke)

- The motor control system can be damaged by the "stroke -the result is loss of blood supply to the cortex or to the corticospinal tract where it passes through the internal capsule.
- **Muscle Spasticity Caused by Lesions That Damage Large Areas Adjacent . to the Motor Cortex**
- The primary motor cortex normally exerts a continual tonic stimulatory effect on the motor neurons of the spinal cord; when this stimulatory effect is removed, hypotonia results.
- Most lesions of the motor cortex, especially those caused by a stroke, involve the primary motor cortex & adjacent parts of the brain such as the basal ganglia. In these instances, muscle spasm occurs in the muscles on the opposite side of the body .

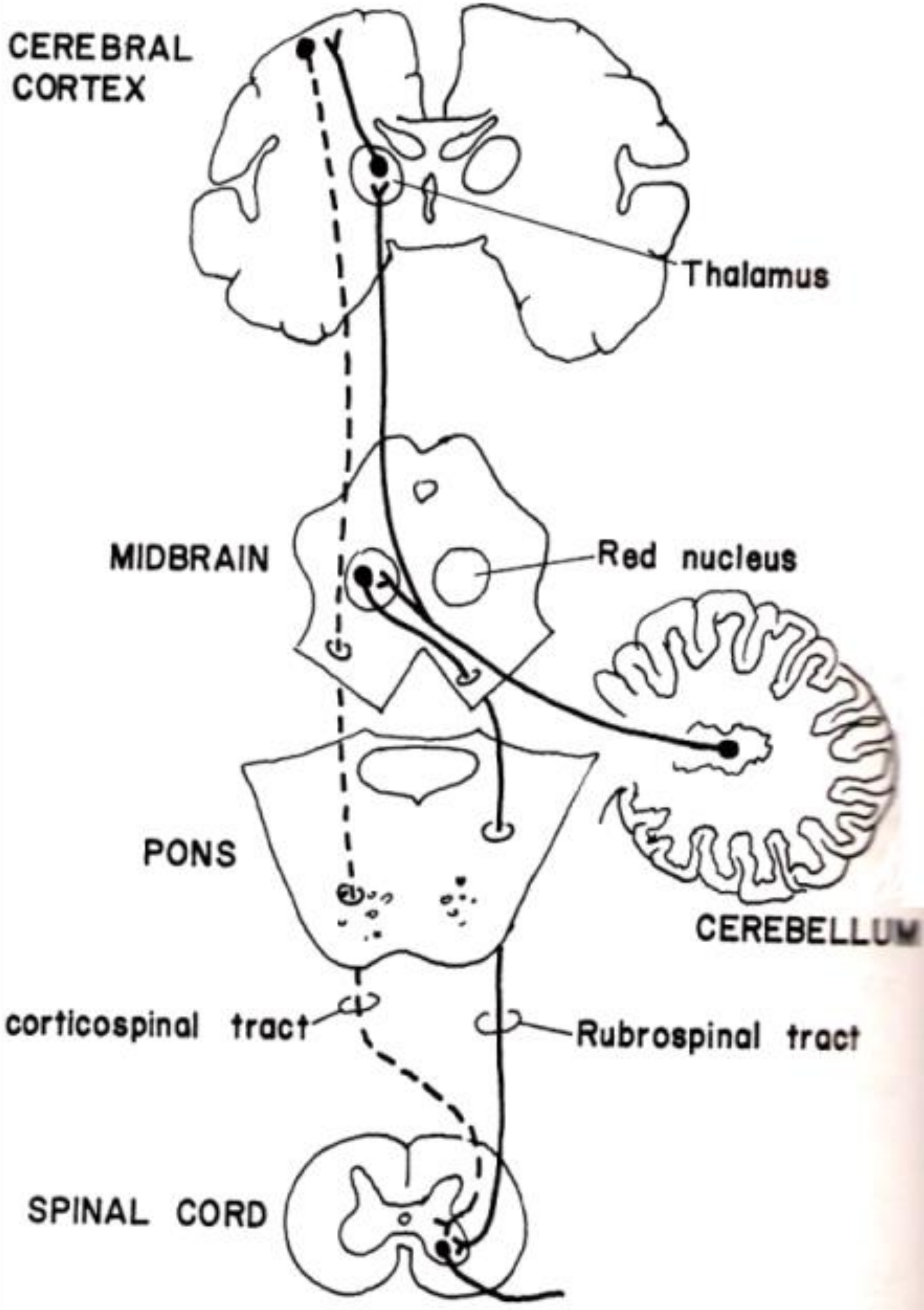
Extrapyramidal Tracts

Rubrospinal Tracts

After emerging from Red Nucleus in midbrain , fibers decussate at same level of red nucleus
It receives afferent connections from:
•Ipsilateral cortical motor area (corticobulbar pathway)
•Contralateral side of cerebellum
•Basal ganglia

Descend with the lateral corticospinal tract

In spinal cord tract occupies the lat. white column , & fibers synapse on the contralateral interneurons of spinal cord grey matter or directly on AHCs



Functions of rubrospina tract

1) an additional pathway for transmission of cerebral cortical motor commands to the lower motor neurons similar to those of the corticospinal tract.

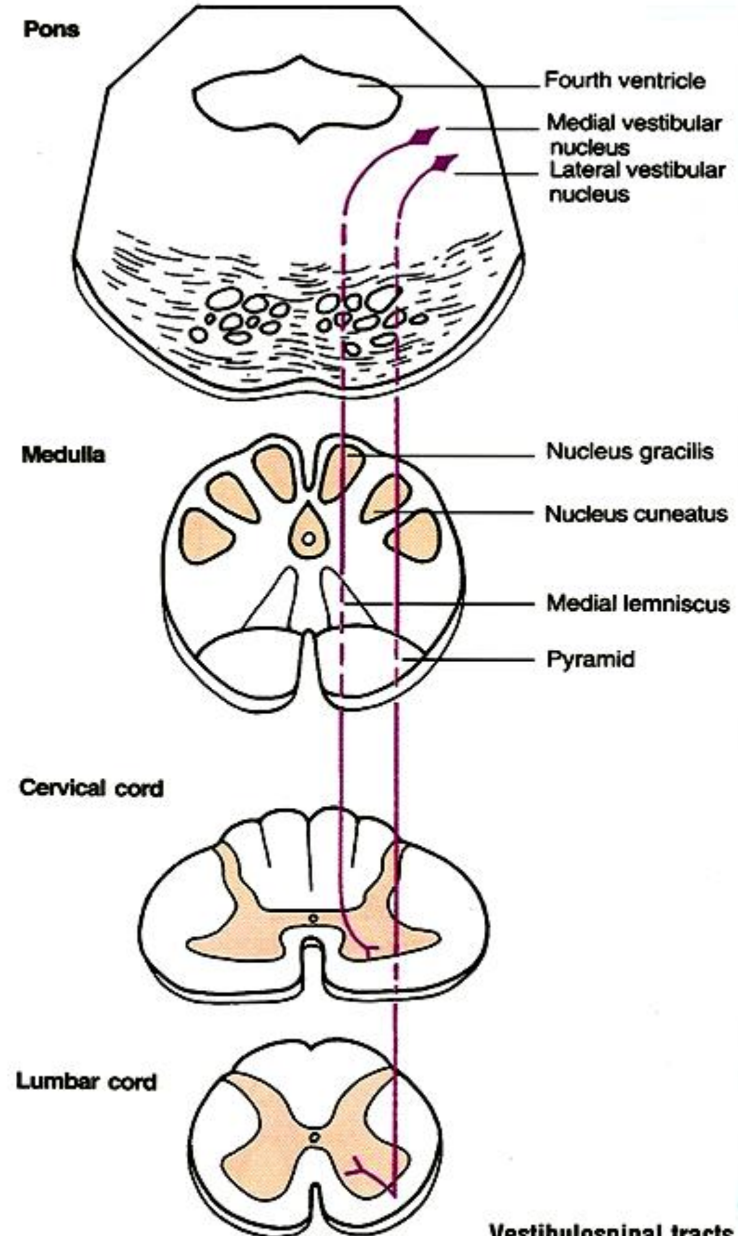
2) facilitatory to the α- and γ-MNs of the distal flexor muscles, but they are inhibitory to extensor muscles.

- ✓ Rubrospinal tract lies in the lateral columns of the spinal cord, along with the corticospinal tract, and terminates on the interneurons and motor neurons that control the more distal muscles of the limbs.
- ✓ Therefore, corticospinal & rubrospinal tracts together are called the lateral system of the cord, in contradistinction to a vestibulo-reticulospinal system which lies mainly medially in the cord and is called **the medial motor system of the cord**

Vestibulospinal Tracts

✓Vestibular Apparatus detects changes head position) → sends fibers to Vestibular Nuclei in Pons + to Cerebellum → correction Of body position + moves eyes to help in correction (correction consciously by vision)

✓ Vestibular nuclei tracts are always excitatory to Gamma Efferents (whereas Red nucleus is always inhibitory)



Vestibulospinal tracts.

Vestibulospinal Tracts

- The lateral vestibulospinal
- Cells of origin : Lateral Vestibular Nucleus
- Axons descend in the ipsilateral ventral white column of spinal cord .
- ***This tract mediates excitatory influences upon extensor motor neurons to maintain posture***
- **The medial vestibulospinal tract :**
- Cells of origin : Medial Vestibular Nucleus
- As its axons descend ipsilaterally in the ventral white column of spinal cord , they form part of the Medial Longitudinal Fasciculus
- The medial longitudinal fasciculus consists of both ascending & descending fibers that link vestibular nuclei to nuclei supplying the extraocular muscles for coordination of head and eye movements

The Reticulospinal Tracts

Divisions: *1) Medial reticulospinal tract.* *2) Lateral reticulospinal tract.*

Medial reticulospinal tract	*Lateral reticulospinal tract*
➢arises from neurons of the "pontine reticular formation"	➢arises from neurons in the "medullary reticular formation"
➢descends to all levels of the spinal cord	➢its fibers descend to all levels of the spinal cord
➢Terminate mainly on interneurons in the spinal gray matter which excite the medially situated α- and γ-MNs innervating the antigravity muscles, that is, the muscles of the vertebral column and the extensor muscles of the lower limbs.	➢synapse with interneurons that inhibit the α- and γ-MNs of antigravity and extensor muscles , but they facilitate the α- and γ-MNs of flexor muscles.

Medial reticulospinal tract	Lateral reticulospinal tract
➢ ***Functions:*** the medial (or pontine) reticulospinal tract exerts *a strong facilitatory effect on the motor neurons of the antigravity and extensor muscles* to support the body posture against gravity .	➢ ***Functions:*** activate the medullary inhibitory system, which can thus counter-balance the facilitatory effect of the pontine reticular formation on the antigravity muscles.

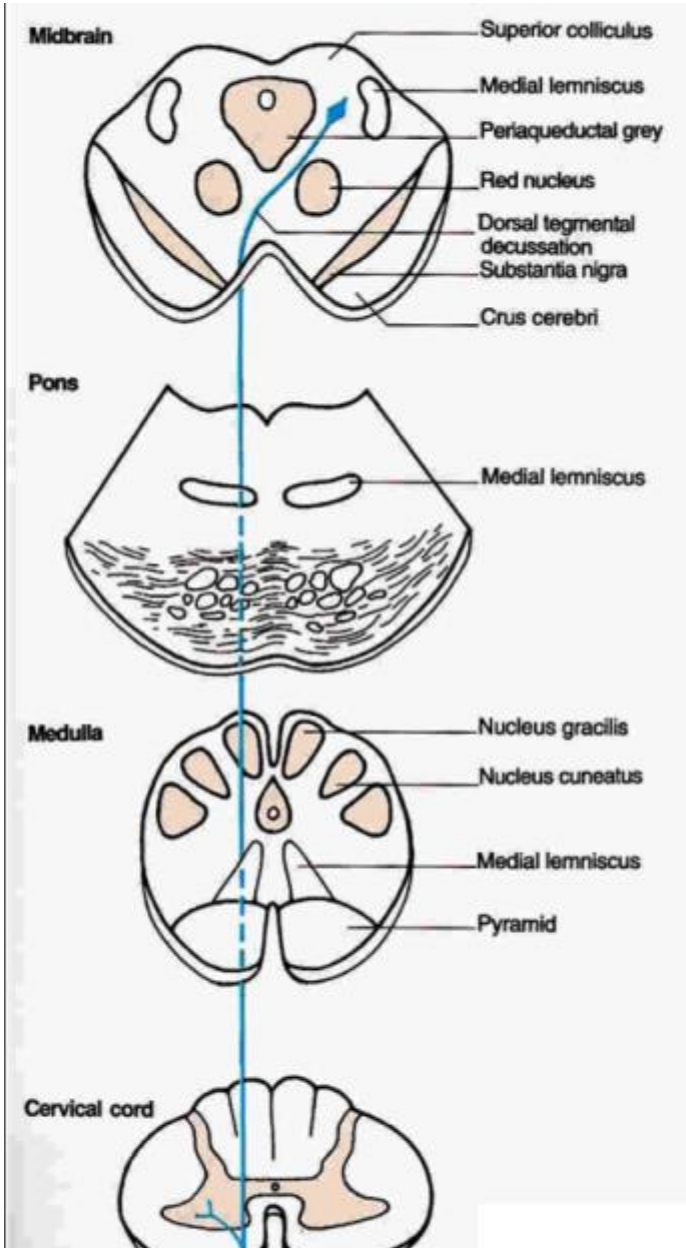
Tectospinal Tract

Originates in Superior Colliculus in midbrain) → then decussate in the dorsal tegmentum

Axons descend in ventral white column of spinal cord

And terminate on Contralateral cervical AHCs

Function :This tract produces reflex turning of the head and neck (in response to visual stimuli) → toward the direction of the stimulus

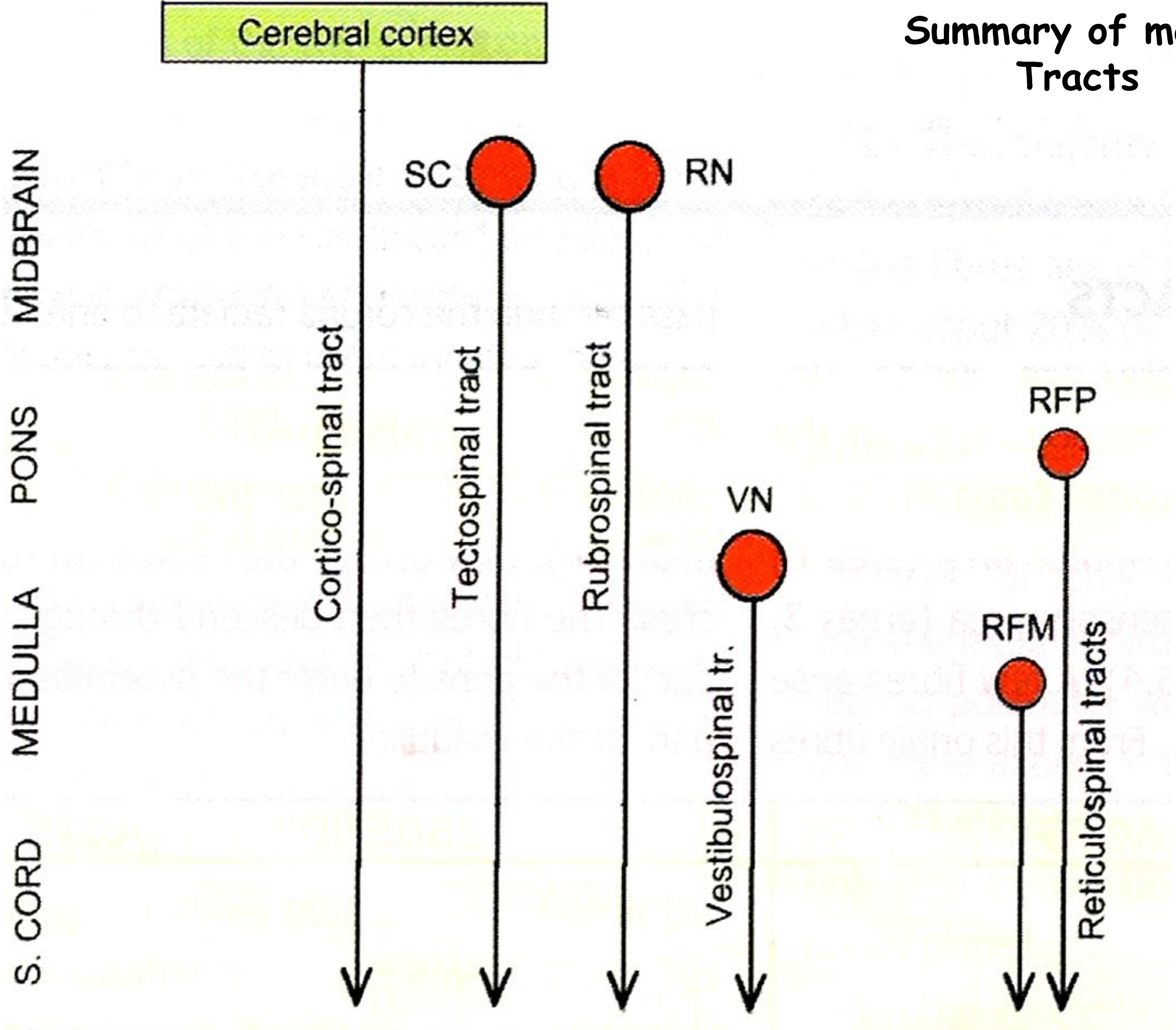


Tectospinal tract.

Olivospinal Tract

- Originates in Inferior Olivary Nucleus of the medulla is found only in the cervical region of the spinal cord.
- Function is uncertain, but thought to facilitate muscle tone

Summary of motor Tracts



- Thank you