Physiology Team 439

MED439
KING SAUD UNIVERSITY

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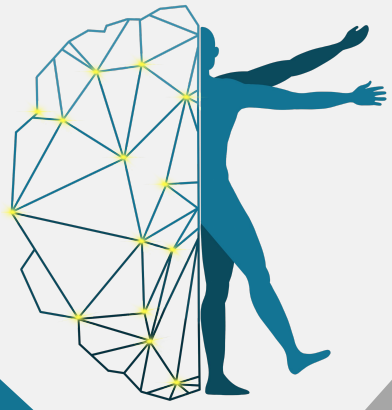


Physiology of Motor Tracts

Objectives:

- Appreciate what is upper motor neuron and lower motor neuron.
- Explain the origin , course and functions of the Pyramidal tracts & Extrapyramidal tracts.
- The pathway & functional role of the pyramidal tracts: (corticospinal & corticobulbar tracts)
- The pathway & functional role of the extrapyramidal tracts: (Rubrospinal & Vestibulospinal & Reticulospinal & Olivospinal & Tectospinal

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

Editing File

Physiology of Motor neurons

L3

In order to initiate any type of voluntary movement And for performance of motor acts we need there will be 2 levels of neurons that your body will use:

Types of Motor Neurons

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.

Upper motor neurons (UMN):

These are the motor neurons whose cell bodies lie in the motor cortex, or brainstem and they activate the lower motor neuron (LMN), highest level

Neurons of motor cortex & their axons that pass to brainstem & spinal cord to activate brainstem neurons (cranial) & spinal motor neurons.

Descending Tracts:

❖ The descending motor pathways (Upper motor neurons) have commonly been divided into **"pyramidal"** and **"extrapyramidal"** tracts. And named according to the origin of their cell bodies and their final destination

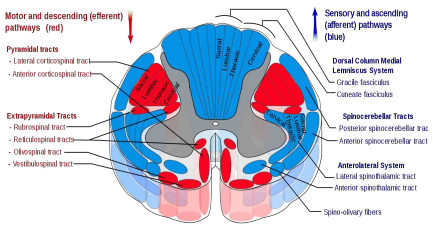
❖ This classification is based on the finding that the motor tract which originates from the cerebral cortex and descends to the spinal cord (the corticospinal tract) passes through the pyramids of the medulla, and therefore has been called the **"the pyramidal tract"**.

❖ 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"**.

Descending Motor System (UMN)

Pyramidal tract

- Corticospinal tract
- Corticobulbar tract, also called corticonuclear



Extrapyramidal tracts

- Rubrospinal tract
- Reticulospinal tracts
- Vestibulospinal tracts
- Tectospinal tract
- Olivspinal tract

Motor Areas

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1 The Primary Motor Area (M1 Motor area 4):

❖ Occupies the precentral gyrus & contains large , highly excitable Betz cells, anterior to central sulcus, Betz cells are also called pyramidal cells

❖ M1 of one side controls skeletal muscles of the opposite side of the body. Left motor area innervate right body side and vice versa

❖ Feet are at the top of the gyrus and face at the bottom , arms and the hand area in the mid portion. Inverted

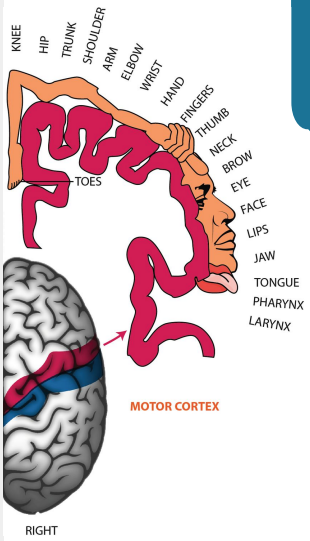
❖ Facial area is represented bilaterally, but rest of the representation is generally unilateral.

❖ Area of representation is proportional with the complexity of function done by the muscle. So, muscles of hands and speech (lips, tongue , and vocal cord) 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.

❖ The Betz cells fibers transmit nerve impulses to the spinal cord at a velocity of about 70 m/sec, the most rapid rate of transmission of signals from the brain to the cord.

❖ Betz cells axons send short collaterals back to the cortex to inhibit adjacent regions of the cortex when the Betz cells discharge, thereby "sharpening" the excitatory signal.



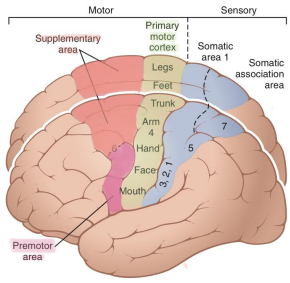


Figure 56-1. Motor and somatosensory functional areas of the cerebral cortex. The numbers *4, 5, 6,* and *7* are Brodmann's cortical areas, as explained in Chapter 48.

2 The Supplementary Motor Area (M2):

primitive type of movements.

❖ located on the lateral side of the brain in front of area 4 and above the pre-motor area & extends on medial side of the cerebral hemisphere.

❖ Concerned with planning ,programming and organizing motor sequences.

❖ Stimulation of this area leads to bilateral (bimanual)grasping movements of both hands simultaneously.Example:playing piano

❖ 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

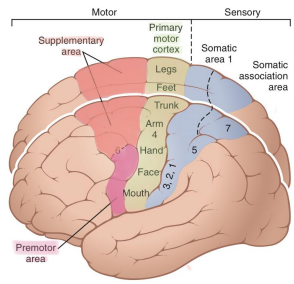


Figure 56-1. Motor and somatosensory functional areas of the cerebral cortex. The numbers *4, 5, 6,* and *7* are Brodmann's cortical areas, as explained in Chapter 48.

Motor Areas

3 The Premotor Area (M3):

skills and learned type of movements.

❖ lies in front 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. Steady position , مسؤولة عن الحركات المعقدة زي الكورشيه

❖ It works in association with the supplemental motor area, establishing the motor programs necessary for execution of complex movements.

❖ It contains mirror neurons which are important for understanding the action of other people and for learning new skills by imitation.

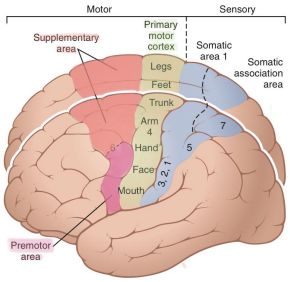


Figure 56-1. Motor and somatosensory functional areas of the cerebral cortex. The numbers *4, 5, 6,* and *7* are Brodmann's cortical areas, as explained in Chapter 48.

A few highly specialized motor centers have been found in the premotor areas of the human cerebral cortex:

Premotor Area	Location	Function
Broca's Area for Speech Damage to this area can cause Broca's aphasia (motor aphasia or aphemia)	Broca's Area	Speech
Frontal Eye Movements Area	Above Broca's area in the frontal lobe	Controls voluntary movements of the eyes toward different objects in the visual field
Head Rotation Area	Above the Eye movement area in the motor cortex	Directing the head toward different visual objects
Hand Skills Area Damage to this area causes motor apraxia (motor disorder in which the individual has difficulty with the motor planning to perform tasks or movements)راح يخسر الحركات الدقيقة	Above the Head rotation area	Hand Skills

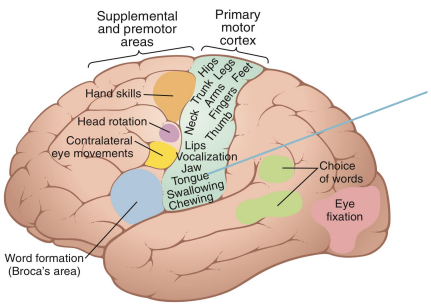


Figure 56-3. Representation of the different muscles of the body in the motor cortex and location of other cortical areas responsible for specific types of motor movements.

If we stimulate this area the patient will produce unmeaning words

Corticospinal (Pyramidal) & corticobulbar Tracts:

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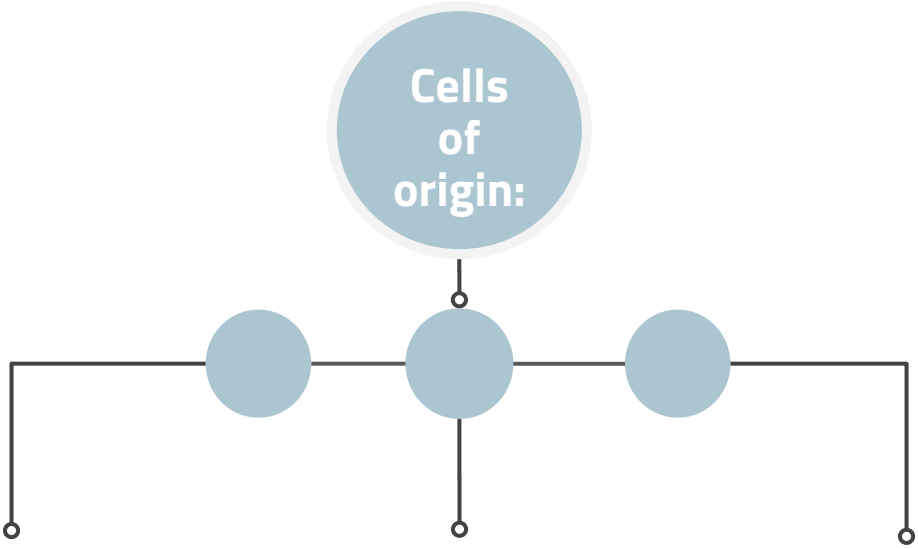


30% originate from the primary motor area (M1) / motor area 4

30% from the premotor areas, and supplementary motor areas.

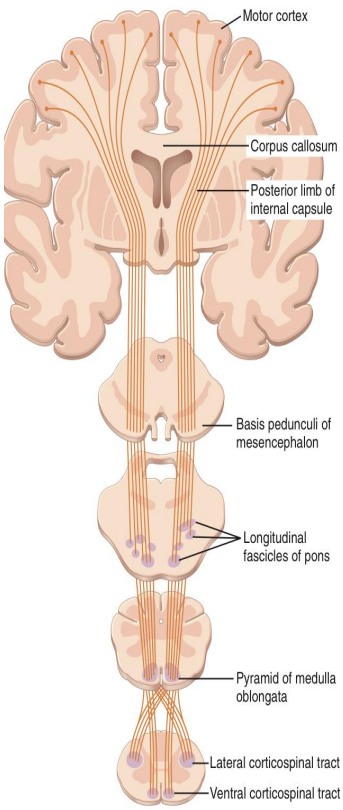
40% from the somatic sensory areas/ parietal cortex posterior to the central sulcus.In parietal lobe مسؤول عن كل الاحاسيس

General Information Of Corticospinal (Pyramidal) and corticobulbar Tracts:

- 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.

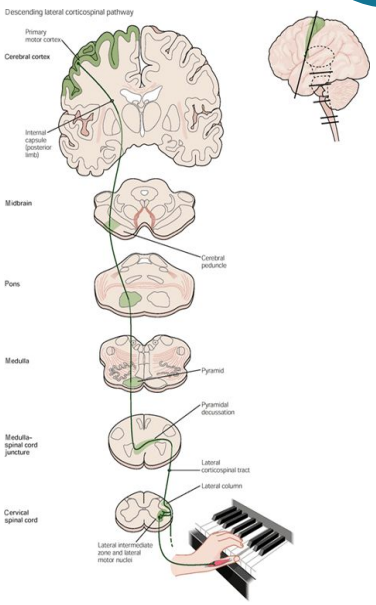
- Fibers from the cerebral cortex descend—>in corona radiata مثل شعاع الشمس, to—>reach the posterior limb of internal capsule (between caudate and putamen nuclei of the basal ganglia) and the anterior two-third of the posterior limb then to—>Brain Stem (midbrain, pons and medulla oblongata).Block in the lenticulostriate artery that supplies the internal capsule can lead to hemiplegia شلل نصفي

- In the brainstem midbrain, pons & medulla oblongata.
  1- **corticobulbar tract :** carries information to motor neurons of the cranial nerve.
  2- **corticospinal tract (pyramids) :** Descends through the midbrain and pons, then in the lower medulla oblongata the fibers form pyramids so called pyramidal tract



Corticospinal (Pyramidal) & corticobulbar Tracts cont...

Origin: Sensory Cortex, Primary Motor Cortex, Premotor and supplementary Cortex → Internal Capsule → Cerebral Peduncle (midbrain) → Pons → Medullary Pyramid → Pyramidal Decussation → Lat.Cross & Vent. Uncross White matter in spinal cord → Ant. Horn of spinal cord through a interconnection → α motor neuron of opposite side



Corticospinal Tracts (Pyramidal) Divides into:

	Lateral C.S. Tract	Ventral (anterior) C.S. Tract
Pathway of the axons	❖ 80% of fibers cross to the opposite site midline in pyramids - Pass laterally in spinal cord white matter.Crossing to opposite side after medulla ❖ Ends directly (not via interneurons = monosynaptic connections) on motor neurons (AHCs) of the opposite side here the lower motor neurons (LMNs) of the corticospinal cord are located but the majority end on interneurons in the intermediate region of the spinal cord grey matter. ❖ Some fibers cross in brainstem to supply contralateral cranial nerve nuclei constitute the corticobulbar tract ❖ Then peripheral motor nerves carry the motor impulses from the anterior horn to the voluntary muscles. ❖ The fibers pass laterally in spinal cord white matter, so they control distal limb muscles.	❖ Remaining 20% of corticospinal fibers does not cross midline and at the pyramids but pass directly untill it and do not decussate in the medulla ❖ Cross at level of their termination to synapse with interneurons, that synapse with motor neurons (AHCs) of opposite side. ❖ Pass medially in ventral horn so control axial & proximal limb muscles so control posture ❖ So corticospinal tract (ANT & LAT) supply skeletal muscles of the opposite side. ❖ They descend ipsilaterally in the ventral column of the spinal cord white matter, constituting the ventral (anterior) corticospinal tract. ❖ Finally they decussate & synapse on the contralateral spinal motor neurons
Function	These fibers controls and initiates fine discrete skilled movement of distal limb muscles (i.e. Fingers and hands)	These fibers control the axial and proximal limbs muscles so it concern with control of posture.

Corticospinal (Pyramidal) Tracts cont...

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Functions of Corticospinal (pyramidal) system :

1. Initiation of fine, discrete, skilled voluntary movements for opposite side

2. lateral corticospinal tracts (main bulk of the tract) control distal muscles of limb as fingers & thumb & toes which concerned with fine skilled movement الحركات الدقيقة e.g Painting ,writing, picking up of a small object etc. that descend in the spinal cord for control of muscles of the distal parts of the limbs, especially the hand and digits muscles, which sub serve fine skilled movements used in manipulation by hand and fingers, and other accurate motor actions done by the limbs

3. Ventral corticospinal tracts control posture of axial & proximal limb muscle for balance, climbing, walking. Upper arm , upper leg

4. Effect on stretch reflex:
Facilitate muscle tone through gamma motor neurons intrafusal fibers

5. Fibers originate from parietal lobe are for sensory-motor coordination.
Coordination between sensory and motor activity
تأخذ صورة من الأحاسيس وتعمل لها معالجة وتنظم الحركات المناسبة للأحاسيس اللي حاساها .

6. **Corticobulbar tracts** control face & neck muscles & facilitate their tone, and are involved in facial expression, mastication & swallowing.+ Extraocular muscle in eye movement

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Excitation of the Spinal Cord Motor Control Areas by the Primary Motor Cortex and Red Nucleus*

❖ Vertical Columnar Arrangement of the Neurons in the Motor Cortex.

Function of Each Column of Neurons*

❖ Each column of cells functions as a unit & as integrative processing system, using information from multiple inputs to determine the output response from the column.

❖ Each column can function as an **Amplifying system** to stimulate large **numbers of pyramidal fibers** to the same muscle or to synergistic muscles simultaneously.

Corticospinal (Pyramidal) Tracts cont...

L3

Dynamic and Static Signals Transmitted by the Pyramidal Neurons : Girls slide only

Each column of cells excites two types of pyramidal cell neurons	
The Dynamic Neurons	**The Static Neurons**
are excited at a high rate for a short period at the beginning of a contraction, causing the initial rapid development of contraction.	fire at a much slower rate, but continue firing at this slow rate to maintain the force of contraction as long as the contraction is required.
Greater percentage of dynamic neurons is in the red nucleus.	Greater percentage of static neurons is in the primary motor cortex.
The neurons of the red nucleus synergistic to pyramidal neuron have characteristics	similar dynamic and static

Removal of (Area Pyramidalis) of the Primary Motor Cortex: animal experimental

❖ Removal of the area that contains the giant Betz pyramidal cells (Area Pyramidalis) causes **loss of voluntary control of discrete movements of the distal segments of the limbs, especially of the hands and fingers** (This does not mean that the hand and finger muscles themselves cannot contract (paralysis), but the ability to control the fine movements is gone)

❖ That is because 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) : boys slides only

❖ 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.** Is a common side of stroke

❖ **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

L3

Definition

It's a tracts other than corticospinal tract & are outside pyramids .

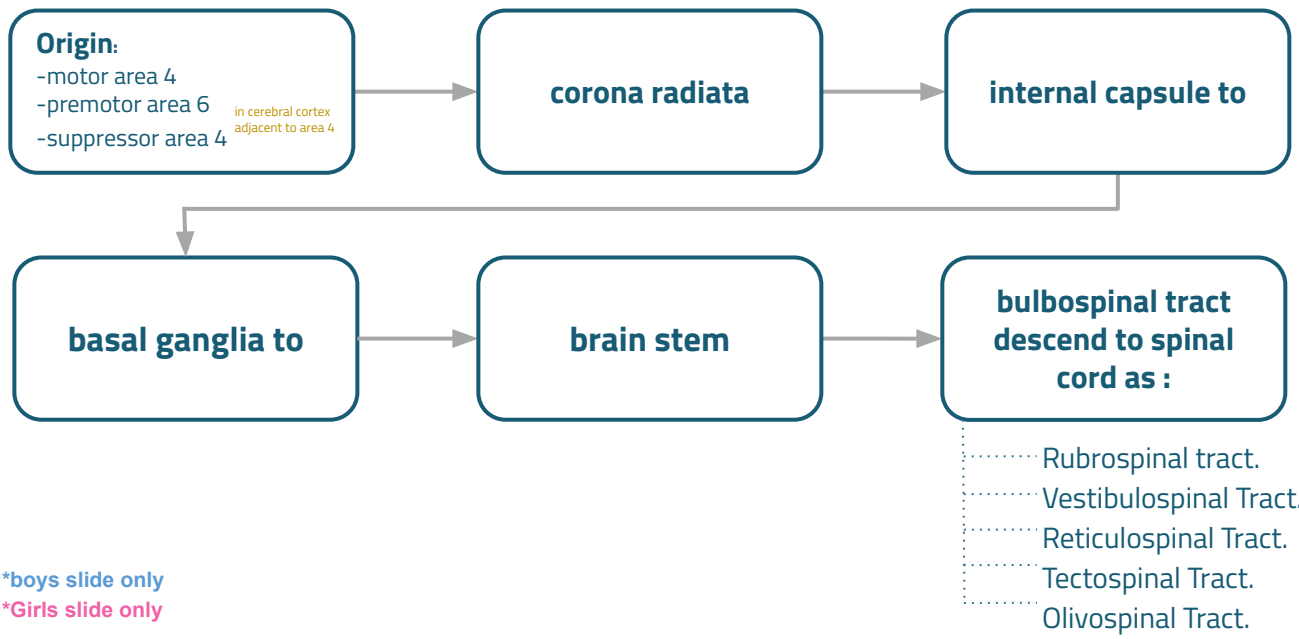
The extrapyramidal system is made up of all those part in the CNS that are concerned with motor control , other than pyramidal system. They consist of :

1- cortical motor areas, especially the premotor area and parietal cortex
2- the basal ganglia
3- The reticular formation, the red nuclei, the tectum of the brain & vestibular nuclei

Function of the Extrapyramidal Tracts:

1. Sets the postural background needed for performance of skilled movements.* Example : ballerina
2. Help pyramidal tract in initiation of voluntary movement *
3. Controls subconscious gross movements. Example : walking , buttoning clothing
4. Regulation of muscle tone *
5. Keep equilibrium and adjust body posture*
6. Share in planning and programming of voluntary movement*

Course of the Extrapyramidal Tracts:*



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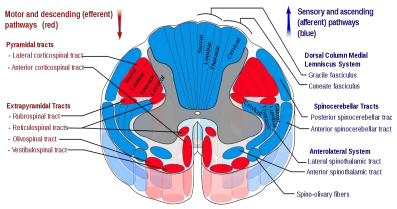
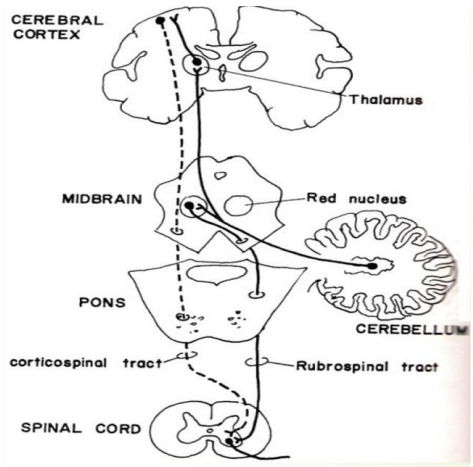
1-Rubrospinal Tract :



- After emerging from red nucleus located in the mesencephalon(midbrain),fibers decussate at same level of red nucleus.The red nucleus is not well developed in humans so it's more important in animals
- It receives **ipsilateral** fibers from the primary motor cortex through the corticorubral tract & from the corticospinal tract .
- Receive afferents from **contralateral** cerebellum & from basal ganglia .
- The rubrospinal tract crosses to the opposite side in the lower brain stem into the lateral columns of the spinal cord together with corticospinal tract.
- In spinal cord tract occupies the lateral. white column , & fibers synapse on the contralateral AHCs
- The rubrospinal fibers terminate mostly on interneurons of the cord gray matter, along with the corticospinal fibers, but some of the rubrospinal fibers terminate directly on anterior motor neurons.



Function of the Corticorubrospinal System:

1. The corticorubrospinal pathway serves as an accessory route for transmission of discrete signals from the motor cortex to the spinal cord.
When the corticospinal fibers are destroyed, discrete fine control of the fingers movements can still occur but impaired.

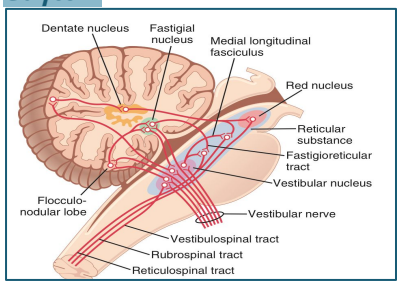
2. 1- An additional pathway for transmission of cerebral cortical motor commands to the lower motor neurons similar to those of the corticospinal tract. When the corticospinal fibers are destroyed , discrete movement can still occur but fine control of the fingers and hand is impaired
2-This tract is excitatory for flexors & inhibitory for extensors (anti-gravity muscles).

3. Rubrospinal tract lies in the lateral columns of the spinal cord, along with the corticospinal tract. Therefore, together are called **the lateral motor 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.**

2- Vestibulospinal (V.S) tracts:

- Fibers originate in vestibular nuclei in pons (which receive inputs from inner ear, Vestibular Apparatus (sensory organs for detecting sensations of equilibrium, found in the ear) and cerebellum)
- Axons descend in the ipsilateral ventral white column of spinal cord
- N.B/Vestibular nuclei tracts are always **excitatory** to Gamma Efferents (whereas Red nucleus is always inhibitory)

Guyton:



General Functions of (V.S):

1. Controls Postural & righting reflexes which correct body position.
2. Control eye movements .
3. Excitatory to ipsilateral spinal motor neurons that supply axial & postural muscles.

Component	Major component	Minor component
	Lateral V.S. Tract	Medial V.S. Tract
Cells of origin	Lateral V.S Nucleus	Medial V.S Nucleus
Pathway of the axons	Axons descend in the ventral white column of spinal cord (gets stimulated when the otolith organs signal deviations from stable balance and upright posture)	Axons descend in the ventral white column of spinal cord to the end at the cervical segments, some fibers form part of the Medial Longitudinal Fasciculus fibers (consists of both ascending & descending fibers) in the brainstem that link vestibular nuclei to nuclei supplying the extra-ocular muscles
Function	Excitatory influences upon extensor motor neurons to maintain posture & righting reflex	Coordination of head and eye movements

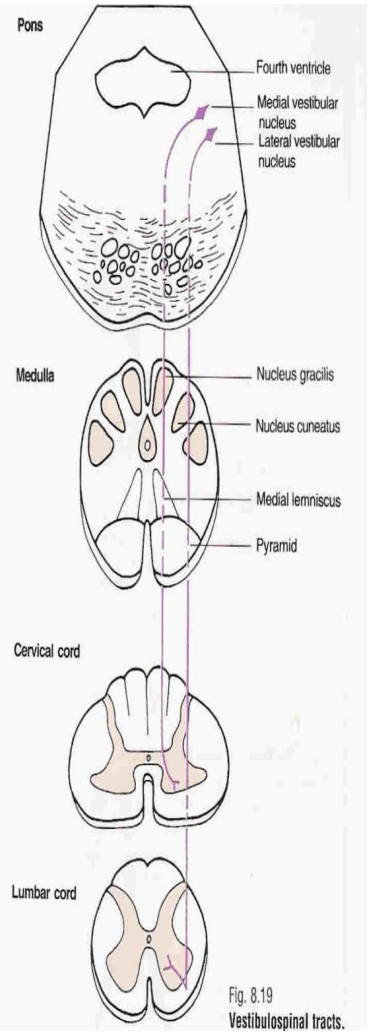


Fig. 8.19 Vestibulospinal tracts.

3- Reticulospinal tracts:

- Arises from the reticular formation of the brainstem (groups of scattered neurons along with nerve fibers present in midbrain, pons & medulla).
- Contains sensory & motor neuronal groups.
- Pontine and medullary nuclei projects to the AHCs (anterior horn cells) of the spinal cord via Reticulospinal Tract.

Guyton:

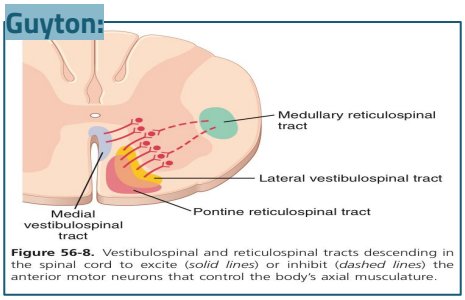


Figure 56-8. Vestibulospinal and reticulospinal tracts descending in the spinal cord to excite (*solid lines*) or inhibit (*dashed lines*) the anterior motor neurons that control the body's axial musculature.

Basically both the Vestibulospinal tracts and the Reticulospinal tracts help to maintain posture. The main differences in achieving that are:
1. The R.S tract is both excitatory and inhibitory, but the V.S is only excitatory.
2. The V.S tract maintains posture by being mainly stimulated by the vestibular apparatus.

Types	Pontine (Medial) Reticulospinal Tract	Medullary (Lateral) Reticulospinal Tract
Cells of origin	Pontine Reticular Formation which has high degree of natural excitability & they receive strong excitatory signals from the vestibular nuclei and the neocerebellum.	Medullary Reticular Formation
Pathway of the axons	Descends in anterior (ventral) white column at all levels of the spinal cord. Terminates mainly on interneurons in the spinal gray matter.	Descend in lateral white column at all levels of the spinal cord on both sides.
Function	Increases the medially situated Gamma and alpha efferent activity (excitatory to axial & antigravity, extensor muscles of the body (lower limb) & increases muscle tone) -It causes powerful excitation of antigravity muscles - It is excitatory for extensors & inhibitory for flexors (unlike rubro-spinal). Fun fact: this pontine tract is so powerful that when it's stimulated (even without higher cortical signals) in four limbed animal (like dogs) they will stand on two legs (Antigravity)!	-It receives strong input (afferent) from 1. The corticospinal tract (the premotor area of cerebral cortex) 2. The rubrospinal tract (red nucleus) 3. The paleocerebellum -These activate the medullary reticular inhibitory system to counterbalance the excitatory signals from the pontine reticular system -Synapse with interneurons that inhibits Gamma and Alpha efferent activity of antigravity and extensor muscles, but they facilitate the Gamma and Alpha of flexor muscles. -Transmit inhibitory signals to antigravity extensor muscles & decreases muscle tone. (Like rubro-spinal) Basically, since the excitation of the pontine tract is too powerful, you need inhibitory signals to counteract the severe excitation. That's why dogs don't walk around on two legs.

4- Tectospinal tracts: In tectum area (midbrain)

	Visual Reflex	Auditory Refex
Cells of origin	From **superior** colliculi in the tectum* of midbrain	From **inferior** colliculi in the tectum* of midbrain
Pathway of the axons	Decussate in the dorsal part of the tegmentum*, then descend in ventral white column of spinal cord Ends on Contralateral **cervical** motor neurons (AHCs) (does not extend to the rest of the spinal cord)	
Function	Mediate/facilitate turning of the head in response to visual stimuli	Mediate/facilitate turning of the head in response to Auditory stimuli
	قد فكرتوا كيف لما تكونون تمشون بعدين فجأة تسمعون صوت أو تشوفون شيء يتحرك، رأسكم يلف بالضبيبط للمكان اللي طلع منه الصوت وكأن عندكم خريطة 3D بعقلكم؟ هذا كله بسبب ال Tectospinal tract	

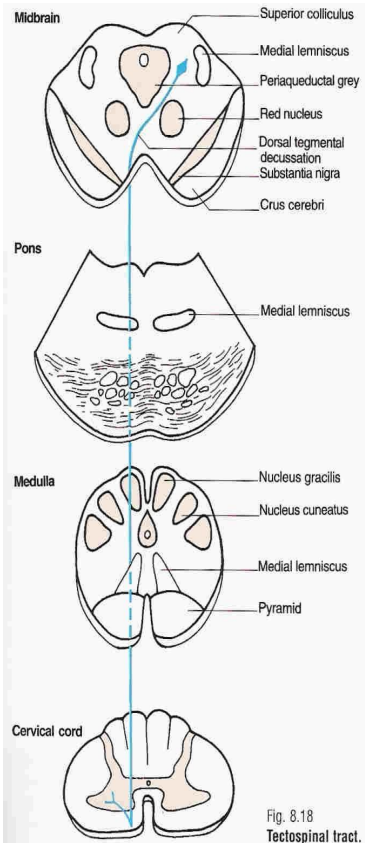
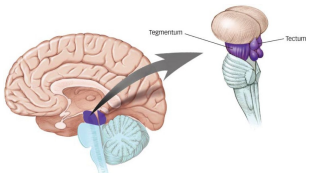


Fig. 8.18 **Tectospinal tract.**

*The midbrain has a ventral part called the tegmentum, and a dorsal part called the tectum.



5- Olivospinal tracts:

Cells of origin	It arises from inferior olivary Nucleus of the medulla
Pathway of the axons	Found only in the cervical region of the spinal cord
Function	Supply neck muscles of unknown function but thought to facilitate muscle tone. Secondary olivocerebellar fibers transmit signals to multiple areas of the cerebellum.

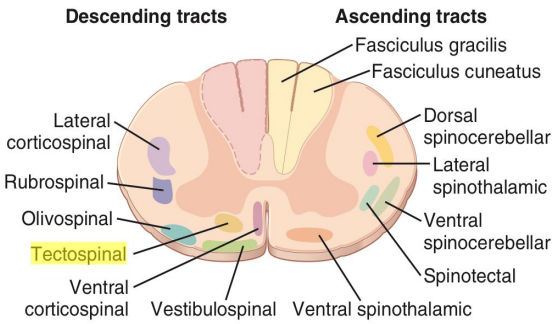


Figure 49-8. Cross section of the spinal cord, showing principal ascending tracts on the right and principal descending tracts on the left.

MCQ & SAQ:

Q1: Which one of the following tracts is a pyramidal tract?

A. Olivspinal tract
B. Rubrospinal tract
C. Corticospinal tract
D. Tectospinal tract

Q2: Stimulation of Supplementary Motor area leads to:

A. Word formation
B. Turning head to visual objects
C. Complex coordinated movements
D. bilateral grasping of hands.

Q3: The lateral motor system of the cord is formed by:

A. Rubrospinal tract
B. Corticospinal tract
C. Vestibulospinal tract
D. both A and B

Q4: Rubrospinal tract originate from :

A. Reticular formation
B. Red nucleus
C. Vestibular nucleus
D. Tectum

Q5: Which of the following tracts rises from the superior colliculi?

A.Vestibulospinal tract
B.Lateral reticulospinal
C.Olivary tract
D.Visual tectospinal

Q6: Which of the following coordinates head and eye movement?

A. Vestibulospinal tract
B. Lateral reticulospinal
C. Medial reticulospinal
D. Auditory tectospinal

answer key:
1: c
2: d
3:D
4: B
5: d
6: a

1- List the motor centers areas found in premotor area and their function.

2- Explain what will happen in case of removal of (Area Pyramidalis) of the Primary Motor Cortex.

3-List the extrapyramidal tracts.

4- List the Functions of Corticospinal Tracts.

A1: Broca's Area (Speech), Frontal Eye Movements Area (voluntary movements of the eyes toward different objects), Head Rotation Area (directing the head toward different visual objects) and Hand Skills Area (Hand Skills)

A2: loss of voluntary control of discrete movements of the distal segments of the limbs, especially of the hands and fingers.

A3: Rubrospinal tract, Vestibulospinal Tract, Reticulospinal Tract, Tectospinal Tract, and olivospinal tract.

A4: Slide 7

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