Physiology of Motor Tracts

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Objectives:

upon completion of this lecture, students should be able to describe :

- the upper and lower motor neurons
- the pathway of pyramidal tracts (corticospinal & corticobulbar tracts)
- the lateral and ventral corticospinal tracts.
- functional role of corticospinal & corticobulbar tracts
- the extrapyramidal tracts as rubrospinal , vestibulospinal ,reticulospinal and Tectspinal Tracts.

Upper & lower motor neurons

1-Upper motor neurons (UMN):-

- Neurons of motor cortex & their axons that pass to brain stem and spinal cord to activate (brain stem neurons) cranial & spinal motor neurons

-**There are two UMN Systems :**

1- Pyramidal system (corticospinal tracts).

2- Extrapyramidal system

2- lower motorv neurons(LMN)

Spinal motor neurons (AHCs)in the spinal cord & cranial motor neurons in the brain stem that innervate muscles directly

Descending Tracts

- 1-Corticospinal (Pyramidal tracts)& corticobulbar tracts;-

-Origin/

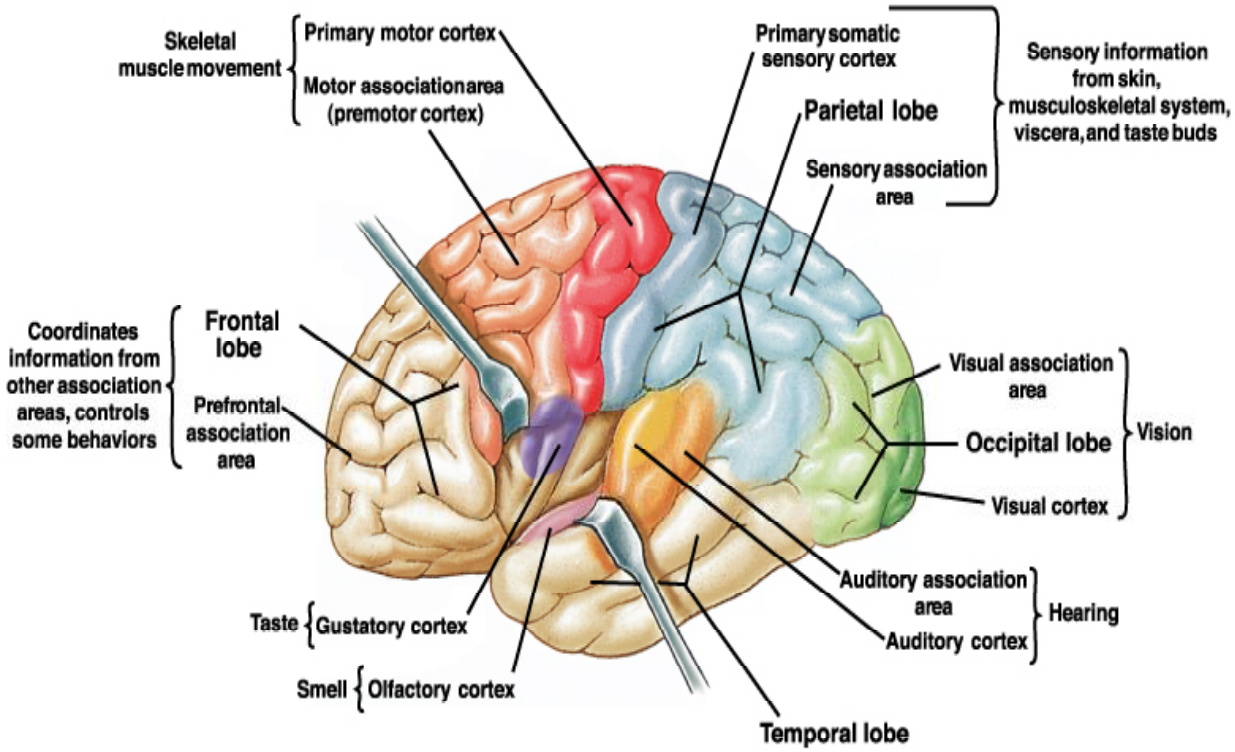
1- 30% motor area 4 (the primary motor area) (M1) . Occupies the precentral gyrus.

2- 30% from the premotor areas & supplemetary cortex

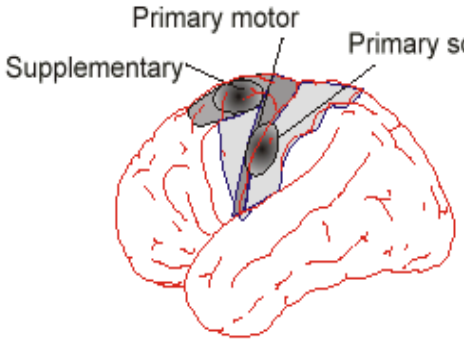
- Premotor area:- (motor association area) lies in front of the primary motor area & below supplementary motor area. Its stimulation produces complex coordinated movements, such as setting the body in a certain posture to perform a specific task.

- Supplemetary cortex is a small area 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.
• This area projects mainly to M1 and is concerned with planning and programming motor sequences.•

3- 40% parietal cortex (somatic sensory area 3,1,2)


Skeletal muscle movement
Primary motor cortex
Motor association area (premotor cortex)
Primary somatic sensory cortex
Parietal lobe
Sensory association area
Sensory information from skin, musculoskeletal system, viscera, and taste buds
Coordinates information from other association areas, controls some behaviors
Frontal lobe
Prefrontal association area
Visual association area
Occipital lobe
Visual cortex
Vision
Taste
Gustatory cortex
Smell
Olfactory cortex
Auditory association area
Auditory cortex
Hearing
Temporal lobe

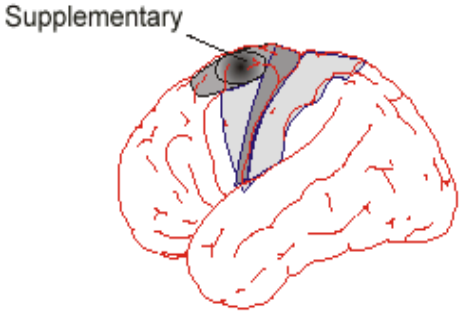
b) When the subject makes a complex finger movement sequence, such as opposing thumb with each finger in turn, activity is seen in the finger area of the primary motor cortex, the primary somatic sensory cortex, and the supplementary motor area.



Supplementary activity seen when making a sequence with either hand (as apposed to primary motor activity which is always contra lateral).

This bilateral activity is useful in movements that require both hands eg tying one's shoe laces.

c) When the subject imagines the complex finger movement sequence, activity is seen only in the supplementary motor area.



CONT//

- **3% of the pyramidal fibres are large myelinated, derived from the large ,giant, highly excitable pyramidal Betz cells in motor area 4.**
  - -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 any signals from the brain to the cord.
  - - The axons from the giant Betz cells send short collaterals back to the cortex itself to inhibit adjacent regions of the cortex when the Betz cells discharge, thereby "sharpening" the excitatory signal.
- **- Fibers from the cerebral cortex descend in >>>>CORONA RADIATA to >>>>INTERNAL CAPSULE genu and the anterior two-third of the posterior limb then to >>>>>>BRAIN STEM (midbrain,pons,medulla oblongata)**

CONT//-

-In the brain stem midbrain, pons & medulla oblongata -

1-Corticobulbar tract terminates on LMNs -

(AHCs = cranial nerve nuclei of opposite side) -

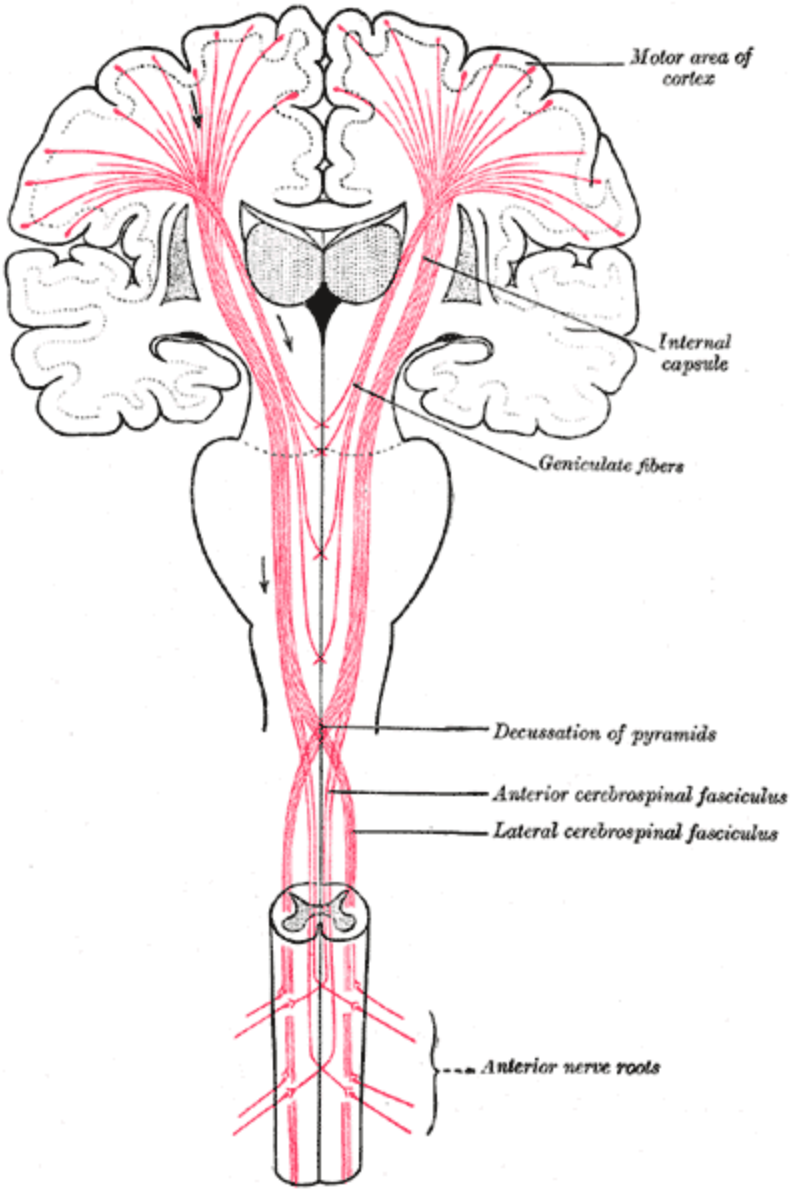
(decussating just before they reach their target nuclei .)-

-The corticobulbar tract carries information to motor neurons of the cranial nerve nuclei

(These nuclei that are bilaterally innervated a slightly stronger connection contralaterally than ipsilaterally. -
The corticobulbar tract directly innervates the nuclei for cranial nerves V, VII, XI, and XII.-
It does not innervate nuclei for nerves III, IV, and VI because these are mediated by the MLF(medial longitudinal fasciculus)-

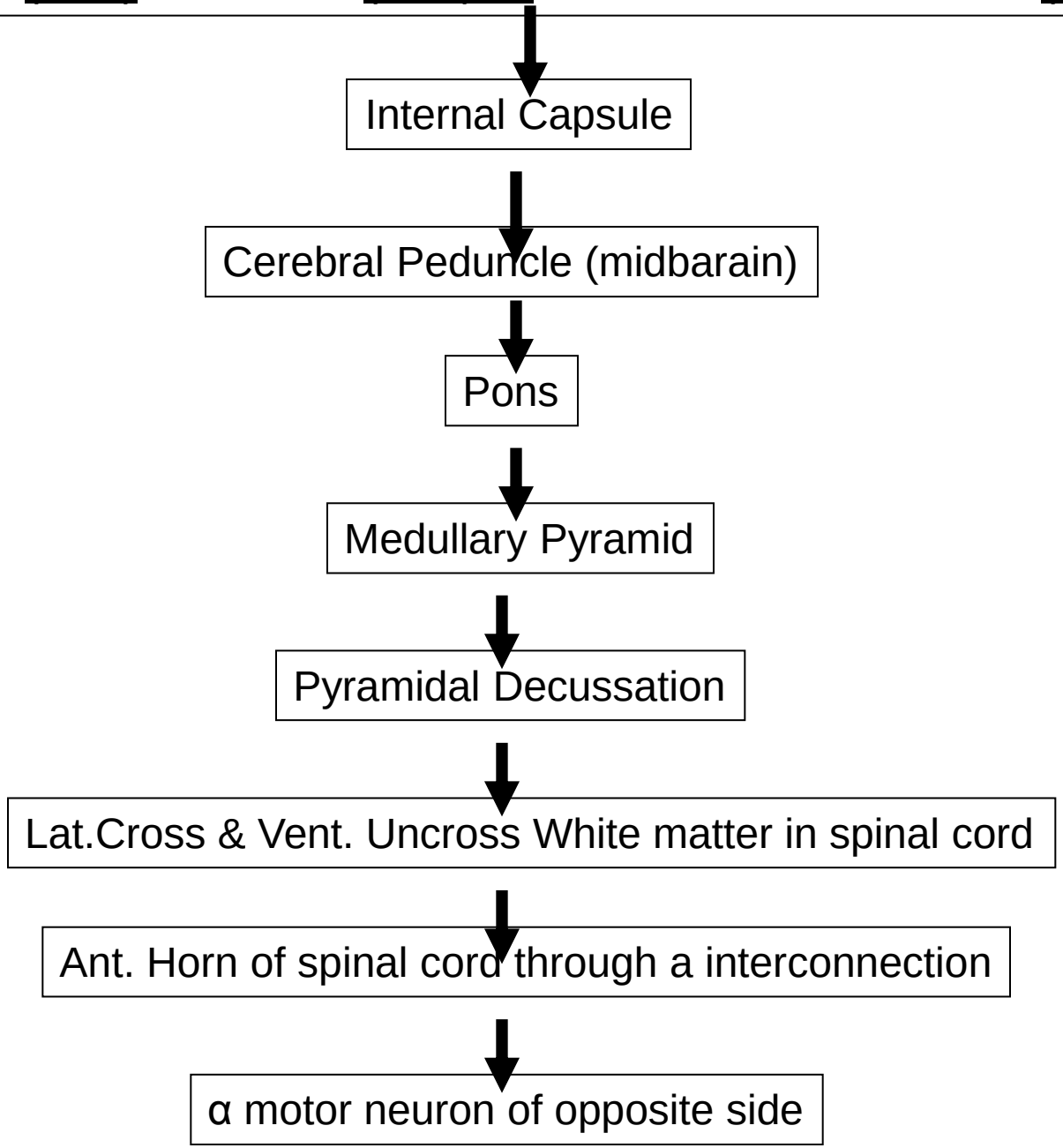
2- Corticospinal tracts (pyramidal) descends through the midbrain and pons.•

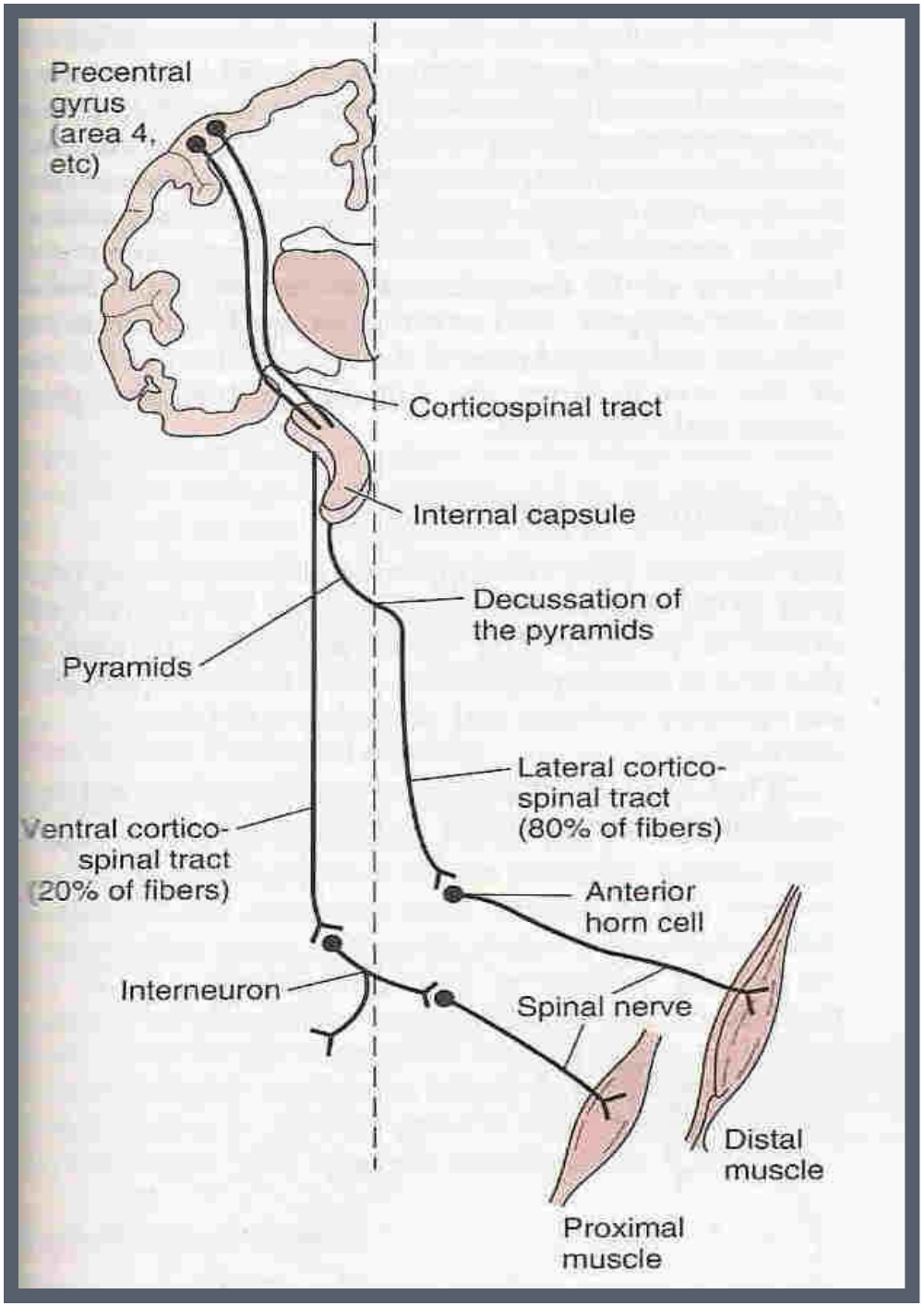
- Then in the lower medulla oblongata the fibers form pyramids so called pyramidal tract which divide into:-


Motor area of cortex
Internal capsule
Geniculate fibers
Decussation of pyramids
Anterior cerebrospinal fasciculus
Lateral cerebrospinal fasciculus
Anterior nerve roots

Origin – Sensory cortex, primary Motor Cortex, premotor & supplementary cortex

(40%) (30%) (30%)




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

A-CORTICOSPINAL TRACTS DIVIDES INTO:

1- LATERAL CORTICOSPINAL TRACTS :-

- 80% OF FIBERS CROSS MIDLINE IN PYRAMIDS
- PASS LATERALLY IN SPINAL CORD WHITE MATTER
- ENDS DIRECTLY (NOT VIA INTERNEURONS = MONOSYNAPTIC CONNECTIONS) ON MOTOR NEURONS (AHCS) OF THE OPPOSITE SIDE . HERE THE LOWER MOTOR NEURONS (LMN) OF THE CORTICOSPINAL CORD ARE LOCATED.

N.B/-THE FIBERS OF THE CORTICOSPINAL TRACT TERMINATE AT DIFFERENT LEVELS IN INTERNEURONS OF THE GREY MATTER &SOME ENDS AT SENSORY NEURONS OF DORSAL HORN & A VERY FEW TERMINATE DIRECTLY ON THE ANTERIOR MOTOR NEURONS THAT CAUSE MUSCLE CONTRACTION.

-THEN PERIPHERAL MOTOR NERVES CARRY THE MOTOR IMPULSES FROM THE ANTERIOR HORN TO THE VOLUNTARY MUSCLES

- AS THE FIBERS PASS LATERALLY IN SPINAL CORD WHITE MATTER, SO THEY CONTROL DISTAL LIMB MUSCLES

FUNCTION//- CONTROLS AND INITIATES FINE DISCRETE SKILLED MOVEMENTS OF FINGERS AND TOES.

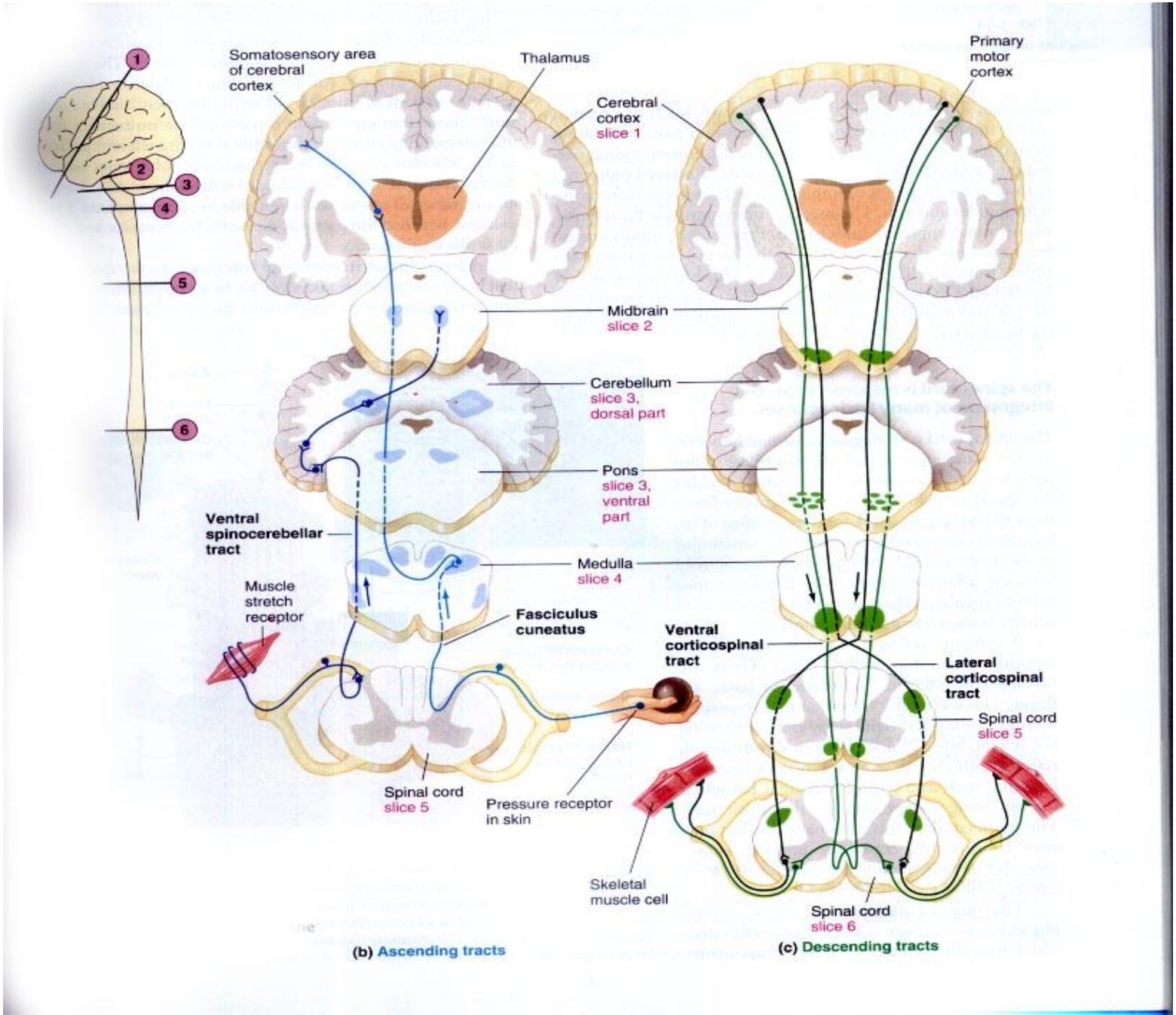
2- VENTRAL (ANTERIOR) CORTICOSPINAL TRACTS :-

- **- Remaining 20% fibers does not cross midline**
  - Cross at level of termination to synapse with interneurons , that synapse with motor neurons (AHCs) of opposite side specially in in the neck or in the upper thoracic region.

-Pass medially in ventral horn so control axial & proximal limb muscles

NB/ So corticospinal tract(ANT& LAT) supply skeletal muscles of the opposite side

N.B/ These fibers may be concerned with control of bilateral postural movements by the supplementary motor cortex(which share in origin of these tracts)


1
2
3
4
5
6
Somatosensory area of cerebral cortex
Thalamus
Cerebral cortex slice 1
Primary motor cortex
Midbrain slice 2
Cerebellum slice 3, dorsal part
Pons slice 3, ventral part
Ventral spinocerebellar tract
Medulla slice 4
Muscle stretch receptor
Fasciculus cuneatus
Ventral corticospinal tract
Lateral corticospinal tract
Spinal cord slice 5
Spinal cord slice 5
Pressure receptor in skin
Skeletal muscle cell
Spinal cord slice 6
(b) Ascending tracts
(c) Descending tracts

Functions of corticospinal tracts:-

1-initiation of fine ,discrete, skilled voluntary movements .(on which 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) e.g Painting ,writing, picking up of a small object etc.

3- Ventral corticospinal tracts control posture of axial & proximal muscle for balance, climbing, walking

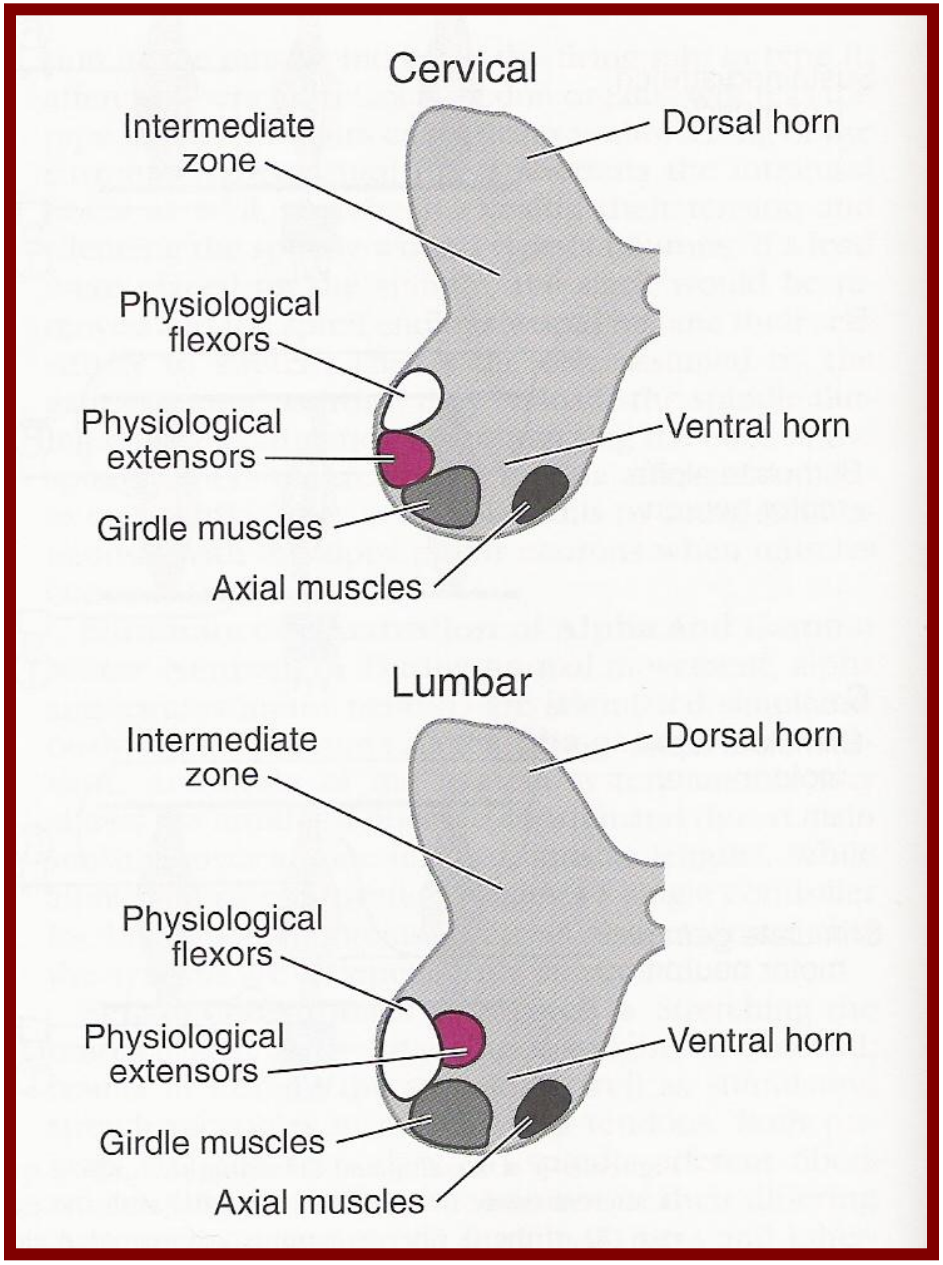
4- Effect on stretch reflex:-

- Faccilitate 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 & faccilitate their tone, and are involved in facial expression, mastication, swallowing.

-NB/ In the cervical enlargement of the cord where the hands and fingers are represented, large numbers of corticospinal and rubrospinal fibers terminate directly on the anterior motor neurons to activate muscle contraction.


Cervical
Intermediate zone
Dorsal horn
Physiological flexors
Physiological extensors
Ventral horn
Girdle muscles
Axial muscles
Lumbar
Intermediate zone
Dorsal horn
Physiological flexors
Physiological extensors
Ventral horn
Girdle muscles
Axial muscles

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..

-Each column has six distinct layers of cells, The pyramidal cells that give rise to the corticospinal fibers all lie in the fifth layer of from the cortical surface.

-Function of Each Column of Neurons.

-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.

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

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Dynamic and Static Signals Are Transmitted by the Pyramidal Neurons.

If a strong signal is sent to a muscle to cause initial rapid contraction, then a much weaker continuing signal can maintain the contraction for long periods thereafter.

-To do this, each column of cells excites two types of pyramidal cell neurons

***1*-The dynamic neurons** are excited at a high rate for a short period at the beginning of a contraction, causing the initial rapid *development of force*.

***2*- The static neurons** 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.

-The neurons of the red nucleus have similar dynamic and static characteristics,

- Greater percentage of dynamic neurons is in the red nucleus and a greater percentage of static neurons is in the primary motor cortex.

why/?

This may be related to the fact that the red nucleus is closely allied with the cerebellum, and the cerebellum plays an important role in rapid initiation of muscle contraction

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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 *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; rather, the *ability to control the fine movements is gone)*.

-So area pyramidalis is essential for voluntary initiation of finely controlled movements, especially of the hands and fingers

Effect of Lesions in the Motor Cortex or in the Corticospinal Pathway—The "Stroke"

The motor control system can be damaged by the "stroke." This is caused by hemorrhages by thrombosis of one of the major arteries supplying the brain.

-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 (because the motor pathways cross to the opposite side).

-This spasm results mainly from damage to accessory pathways from the nonpyramidal portions of the motor cortex which normally inhibit the vestibular and reticular brain stem motor nuclei.

-When these nuclei cease their state of inhibition (become are "disinhibited"), they become spontaneously active and cause excessive spastic tone in the involved muscles. (as in stroke)

-EXTRAPYRAMIDAL TRACTS :-

TRACTS OTHER THAN CORTICOSPINAL TRACT & ARE OUTSIDE PYRAMIDS

ORIGIN/ MOTOR AREA 4, PREMOTOR AREA 6, 4 SUPPRESSOR >>>>CORONA RADIATA TO>>>>INTERNAL CAPSULE TO>>>>BASAL GANGLA TO >>BRAIN STEM >>>BULBOSPINAL TRACTS DESCEND TO SPINAL CORD AS :-

A- RUBROSPINAL TRACT.

B- VESTIBULOSPINAL TRACT.

C- RETICULOSPINAL TRACT

D- TECTSPINAL TRACT.

E- OLIVOSPINAL TRACT

EXTRAPYRAMIDAL SYSTEM :

(1) SETS THE POSTURAL BACKGROUND NEEDED FOR PERFORMANCE OF SKILLED MOVEMENTS

(2) CONTROLS SUBCONSCIOUS GROSS MOVEMENTS

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1-RUBROSPINAL TRACTS:-

- THE *RED NUCLEUS* LOCATED IN THE MESENCEPHALON
-IT RECEIVES DIRECT FIBERS FROM THE PRIMARY MOTOR CORTEX THROUGH THE *CORTICORUBRAL TRACT & SOME* BRANCHING FIBERS FROM THE CORTICOSPINAL TRACT AS IT PASSES THROUGH THE MESENCEPHALON.
-THESE FIBERS SYNAPSE IN THE LOWER PORTION OF THE RED NUCLEUS, THE ***MAGNOCELLULAR PORTION***
- CONTAINS LARGE NEURONS GIVE RISE TO THE *RUBROSPINAL TRACT,* WHICH CROSSES TO THE OPPOSITE SIDE IN THE LOWER BRAIN STEM INTO THE LATERAL COLUMNS OF THE SPINAL CORD.
- 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, -

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Function of the Corticorubrospinal System.

- Stimulation of a single point in the magnocellular portion of the red nucleus causes contraction of either a single muscle or a small group of muscles.
-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..
- 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, the corticospinal and rubrospinal tracts 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 TRACTS:-

-FROM VESTIBULAR NUCLEUS. FIBERS ORIGINATE IN VESTIBULAR NUCLEI IN PONS (WHICH RECEIVE INPUTS FROM INNER EAR ,VESTIBULARAPPARATUS AND CEREBELLUM)

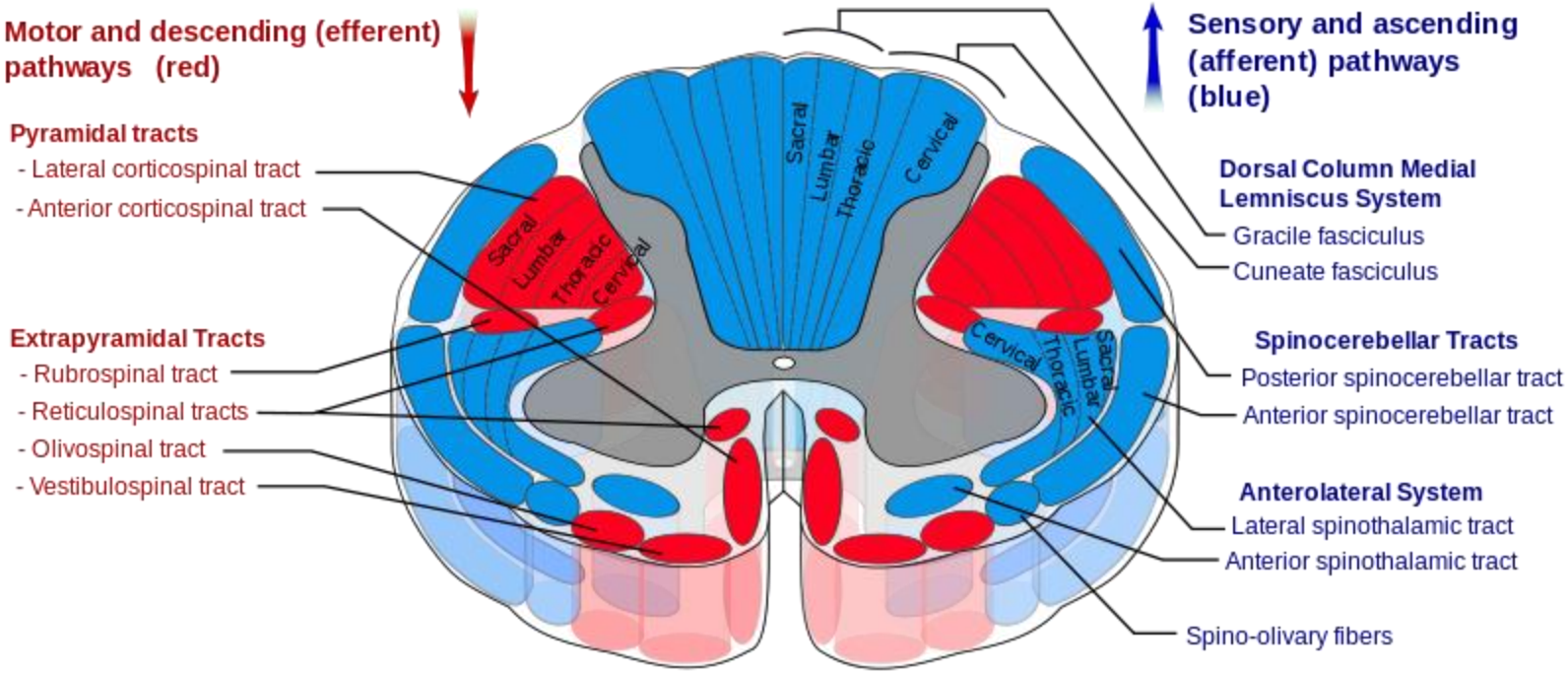
-AXONS DESCEND IN THE IPSILATERAL VENTRAL WHITE COLUMN OF SPINAL CORD

-FUNCTIONS:-

1- CONTROLS POSTURAL & RIGHTING REFLEXES.

2-EXCITATORY TO IPSILATERAL SPINAL MOTOR NEURONS-THAT SUPPLY AXIAL & POSTURAL MUSCLES

3- CONTROL EYE MOVEMENTS


Motor and descending (efferent) pathways (red)
Pyramidal tracts
- Lateral corticospinal tract
- Anterior corticospinal tract
Extrapyramidal Tracts
- Rubrospinal tract
- Reticulospinal tracts
- Olivospinal tract
- Vestibulospinal tract
Sacral
Lumbar
Thoracic
Cervical
Sensory and ascending (afferent) pathways (blue)
Dorsal Column Medial Lemniscus System
Gracile fasciculus
Cuneate fasciculus
Spinocerebellar Tracts
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Anterolateral System
Lateral spinothalamic tract
Anterior spinothalamic tract
Spino-olivary fibers

Functions of Vestibulospinal Tracts

- **The lateral vestibulospinal**

- Cells of origin : Lateral Vestibular Nucleus
- Axons descend in the ventral white column of spinal cord
- This tract mediates **excitatory** influences upon extensor motor neurones to maintain **posture**

- **The medial vestibulospinal tract** :

- Cells of origin : Medial Vestibular Nucleus
- As its axons decsend in the ventral white column of spinal cord to end at the cervical segments of the spinal cord, some fibers form part of the **Medial Longitudinal Fasciculus fibers in brain stem** that link vestibular nuclei to nuclei supplying the extra-ocular muscles.

Function//**for coordination of head and eye movements**

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Role of the Vestibular Nuclei to Excite the Antigravity Muscles

The *vestibular nuclei*, function in association with the pontine reticular nuclei to control the antigravity muscles.

- The vestibular nuclei transmit excitatory signals to the antigravity muscles by way of the *lateral* and *medial vestibulospinal tracts*

-Without this support of the vestibular nuclei, the pontine reticular system would lose much of its excitation of the axial antigravity muscles.

3- Tectospinat tracts:-

-from superior colliculi (VISUAL) & inferior colliculi (AUDITORY) of midbrain

- Ends on **Contralateral cervical motor neurons**

Function: Mediate/facilitate turning of the head in response to visual or Auditory stimuli

4- Reticulospinal Tract :-

-The reticular formation makes up a central core of the brainstem. It contains many different neuronal groups.

-Pontine and medullary nuclei projects to the AHCs of the spinal cord via Reticulospinal Tract

Functions:

1-Influence motor functions as voluntary & reflex movement

2-Excitatory or inhibitory to muscle tone

Types of reticulospinal tracts:-

(1) Pontine (Medial) Reticulospinal Tract:

- Cells of origin: Pontine Reticular Formation which has high excitability & In addition, they receive strong excitatory signals from the vestibular nuclei .
- Axons descend in anterior(ventral)white column of spinal cord
- Pontine Reticulospinal Tract increases Gamma efferent activity (excitatory to axial & antigravity, extensor muscles of the body= increases muscle tone)

-- when the pontine reticular excitatory system is unopposed by the medullary reticular system, it causes powerful excitation of antigravity muscles

(2) Medullary (Lateral) Reticulospinal Tract:

- Cells of origin: Medullary Reticular Formation
- Axons descend in lateral white column of spinal cord on both sides

-It receive strong input from (1) the corticospinal tract, (2) the rubrospinal tract, and (3) other motor pathways. These activate the medullary reticular inhibitory system to counterbalance the excitatory signals from the pontine reticular system, so under normal conditions the body muscles are not abnormally tense.

- Medullary Reticulospinal Tract, inhibits Gamma efferent activity (transmit *inhibitory*

signals to antigrav ity extensor muscles= decreases muscle tone) •

-

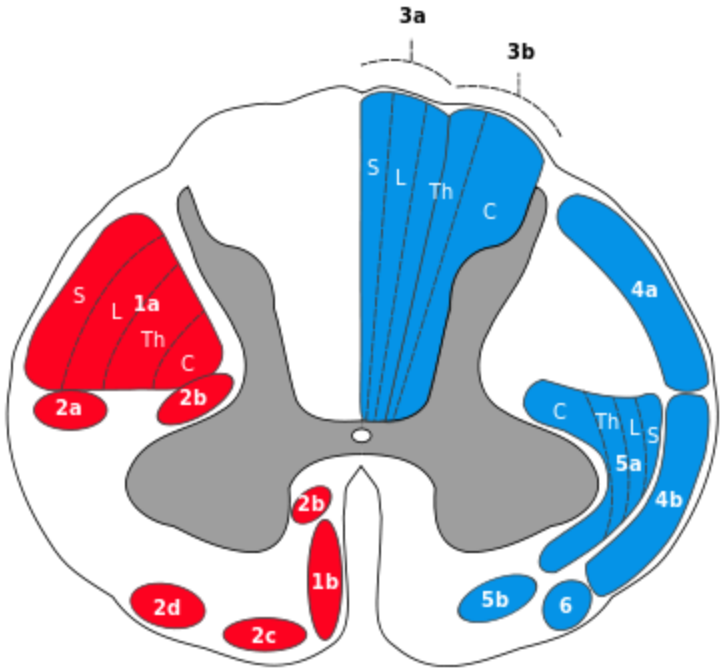
- SOME SIGNALS FROM HIGHER AREAS OF THE BRAIN CAN "DISINHIBIT" THE MEDULLARY SYSTEM WHEN THE BRAIN WISHES TO EXCITE THE PONTINE SYSTEM TO CAUSE STANDING.

- EXCITATION OF THE MEDULLARY RETICULAR SYSTEM CAN INHIBIT ANTIGRAVITY MUSCLES IN CERTAIN PORTIONS OF THE BODY TO ALLOW THOSE PORTIONS TO PERFORM SPECIAL MOTOR ACTIVITIES.

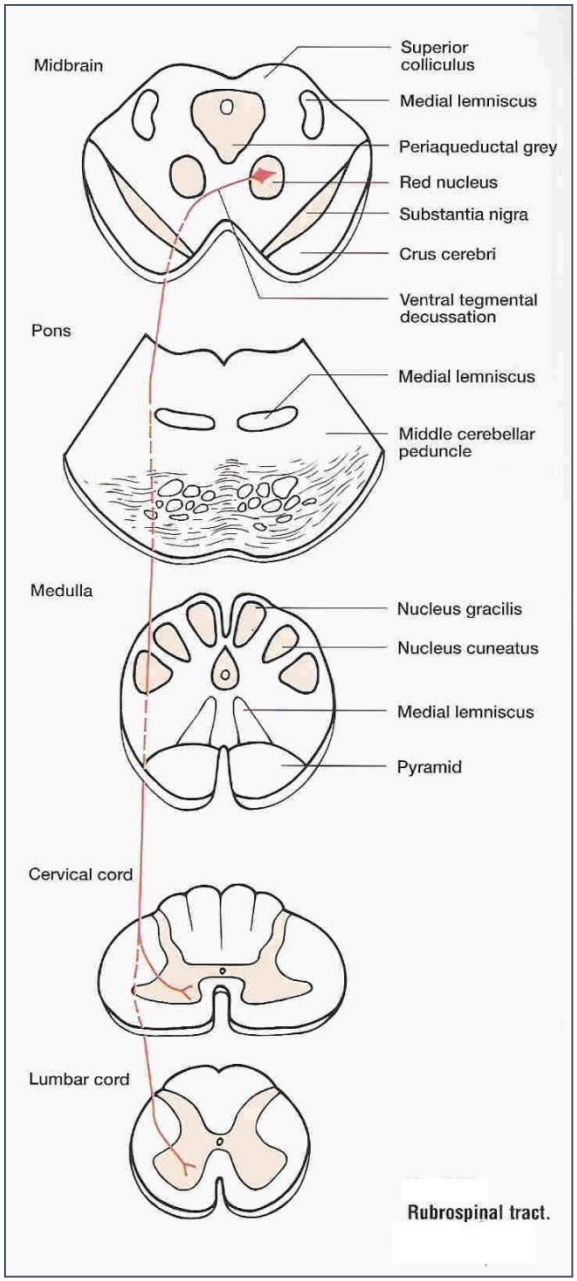
- THE EXCITATORY AND INHIBITORY RETICULAR NUCLEI CONSTITUTE A CONTROLLABLE SYSTEM THAT IS MANIPULATED BY THE CEREBRAL CORTEX TO PROVIDE NECESSARY BACKGROUND MUSCLE CONTRACTIONS FOR STANDING AGAINST GRAVITY

5-Olivospinal Tract :- It arises from inferior olivary N of the medulla & is found only in the cervical region of the spinal cord (supply neck muscles) of unknown function

– secondary *olivocerebellar fibers* transmit signals to multiple areas of the cerebellum.



Motor and decending (efferent) pathways (left, red)	**Sensory and ascending (afferent) pathways (right, blue)**
1. Pyramidal Tracts	**3. Dorsal Column Medial Lemniscus System**
1a. Lateral corticospinal tract	3a. Gracile fasciculus
1b. Anterior corticospinal tract	3b. Cuneate fasciculus
2. Extrapyramidal Tracts	**4. Spinocerebellar Tracts**
2a. Rubrospinal tract	4a. Posterior spinocerebellar tract
2b. Reticulospinal tract	4b. Anterior spinocerebellar tract
2c. Vestibulospinal tract	**5. Anterolateral System**
2d. Olivospinal tract	5a. Lateral spinothalamic tract
	5b. Anterior spinothalamic tract
Somatotopy Abbreviations:	
S: Sacral, **L: Lumbar**	6. Spino-olivary fibers
Th: Thoracic, **C: Cervical**	



Red Nucleus in Midbrain

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Decussation at the level of red nucleus

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Pass down through Pons & Medulla

↓

Ends in ant. Horn of spinal cord

↓

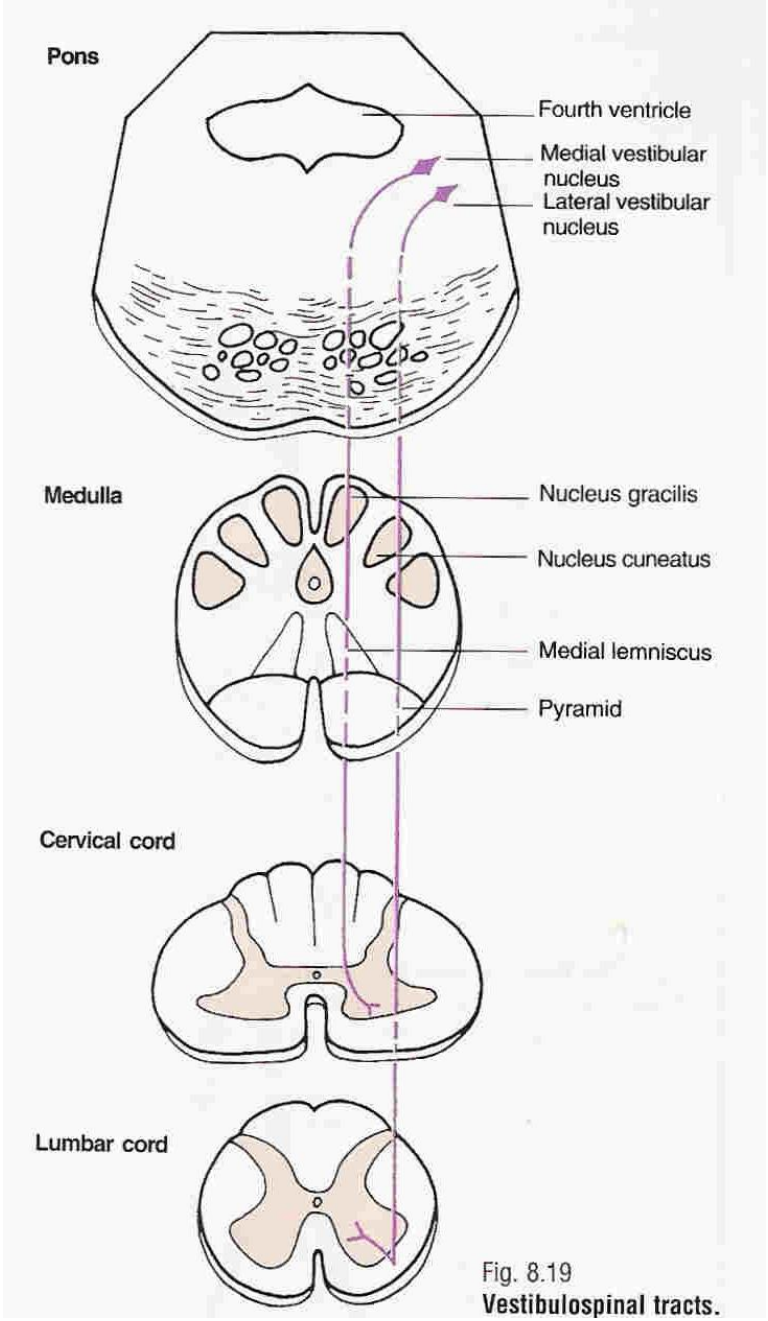

Fig. 8.19
Vestibulospinal tracts.

Afferent from cerebellum, vestibular apparatus & vestibular nuclei

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Spinal motor neuron

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Innervating axial & postural muscles

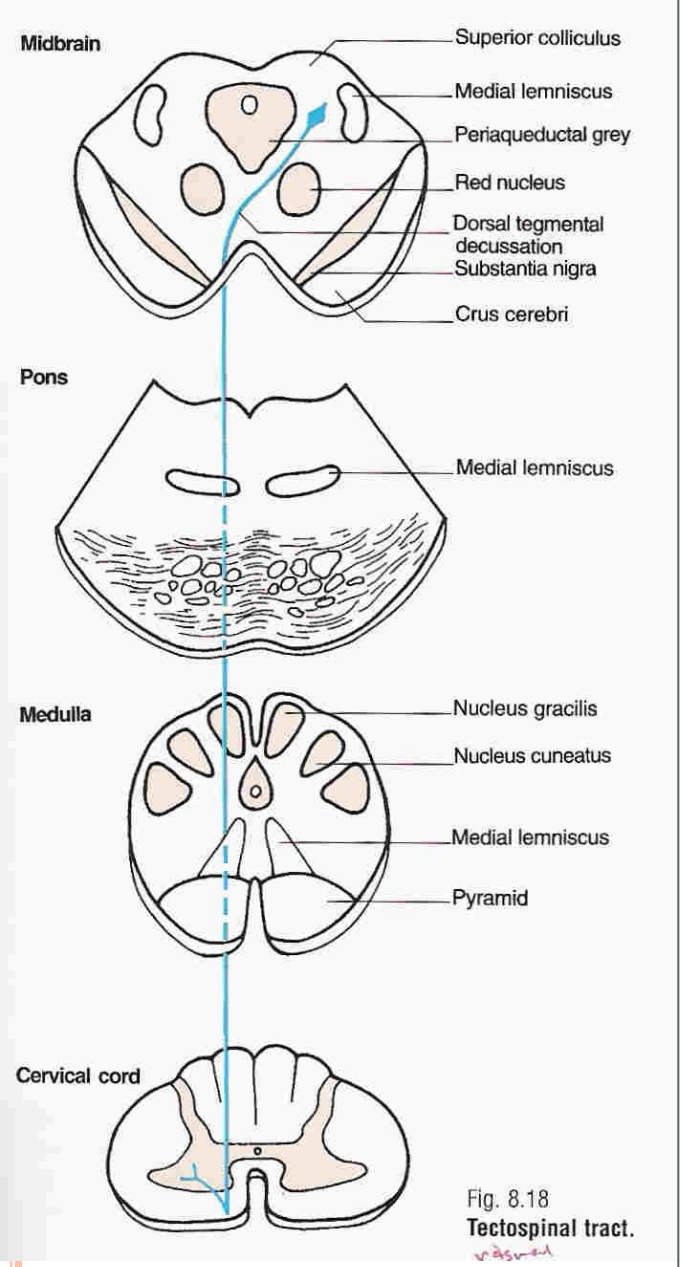

Fig. 8.18
Tectospinal tract.

Superior & Inferior collicili in midbrain>>>>>

Near Medial longitudinal fasiculus>>>>

Cervical spinal motor neuron of anterior horn