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
- Static and dynamic signals of pyramidal 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/

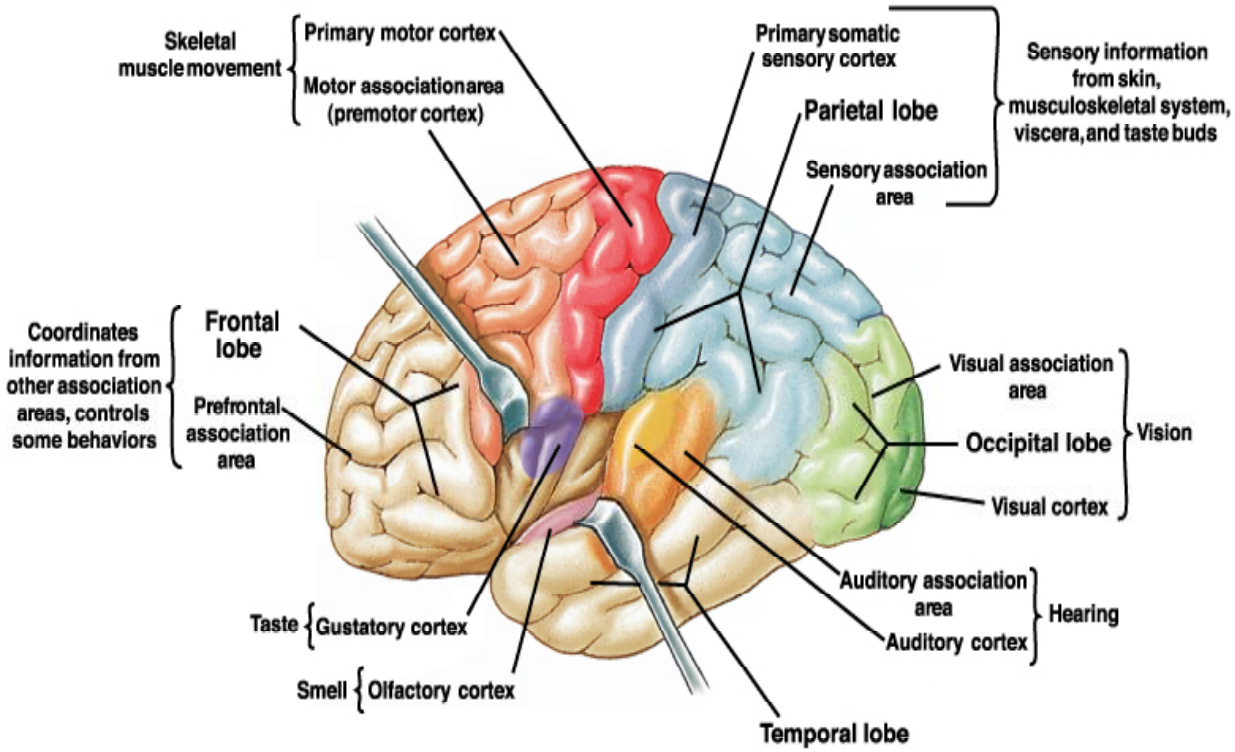
1- **30% motor area 4** (the primary motor area) (M1) . Occupies the precentral gyrus.

2- **30% from the premotor areas & supplemetary cortex**

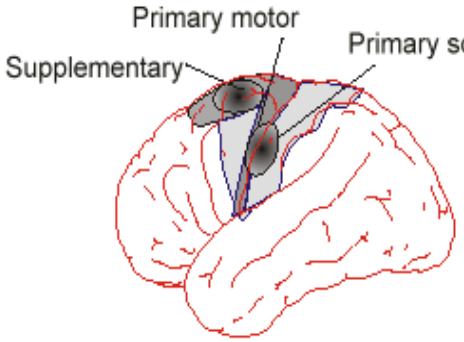
- **Premotor area:- (motor association area)** lies in front of the primary motor area & below supplementary motor area. Its stimulation produces complex coordinated movements, such as setting the body in a certain posture to perform a specific task.

- **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 , programming motor sequences& bimanual activity

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

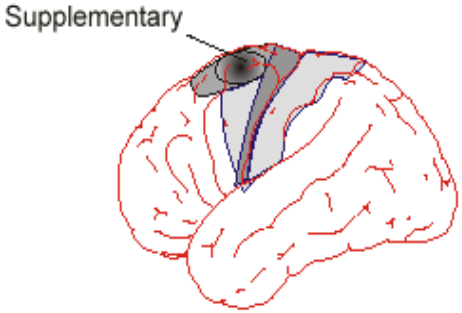
b) When the subject makes a complex finger movement sequence, such as opposing thumb with each finger in turn, activity is seen in the finger area of the primary motor cortex, the primary somatic sensory cortex, and the supplementary motor area.



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 other 97 % are mainly smaller fibers conduct tonic signals to the motor areas of 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.**

CONT//-

- • - Fibers from the cerebral cortex descend in >>>>CORONA RADIATA to >>>>INTERNAL CAPSULE genu and the anterior two-third of the posterior limb >>>>>>BRAIN STEM

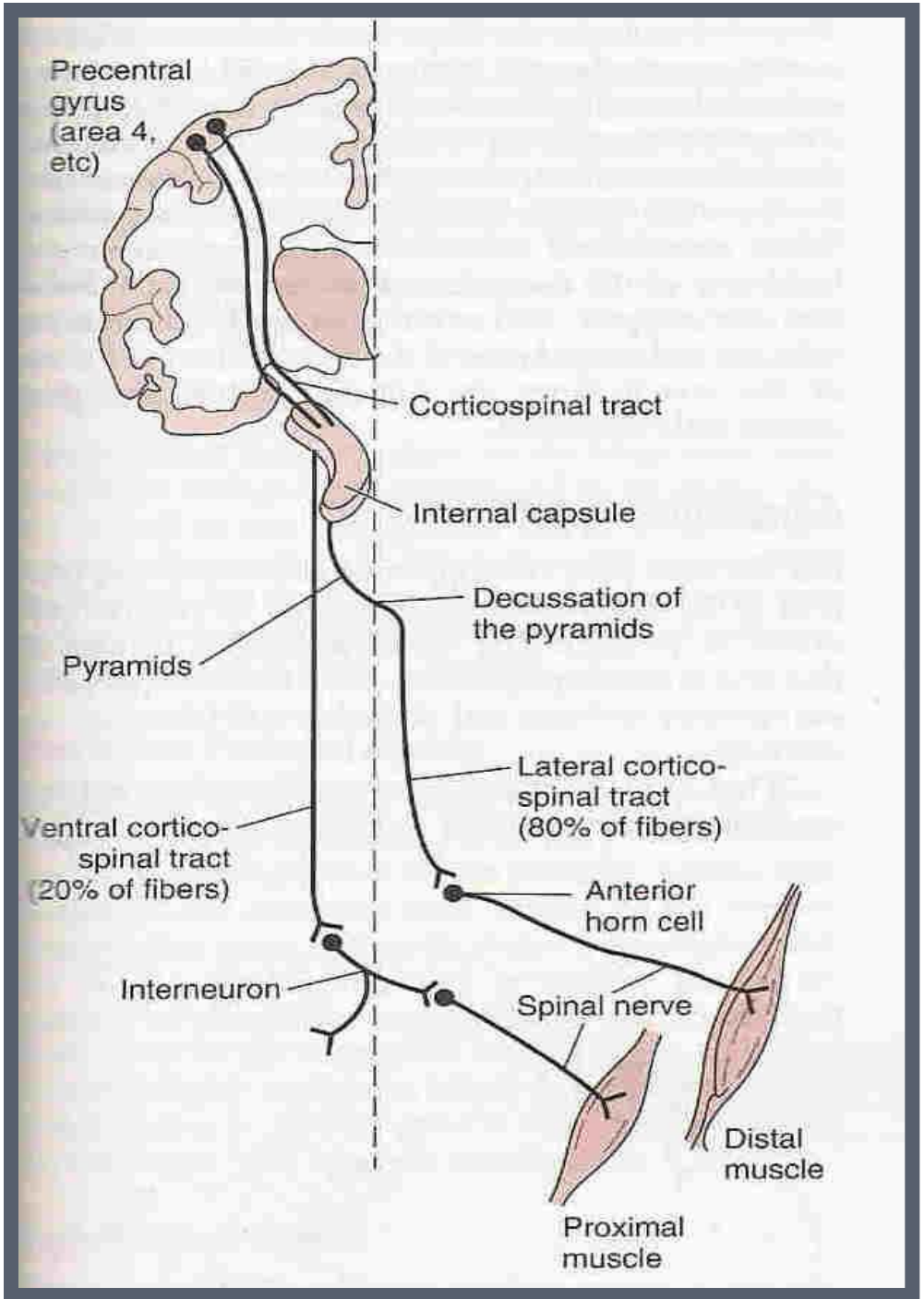
(midbrain,pons,medulla oblongata) m then divide into:-

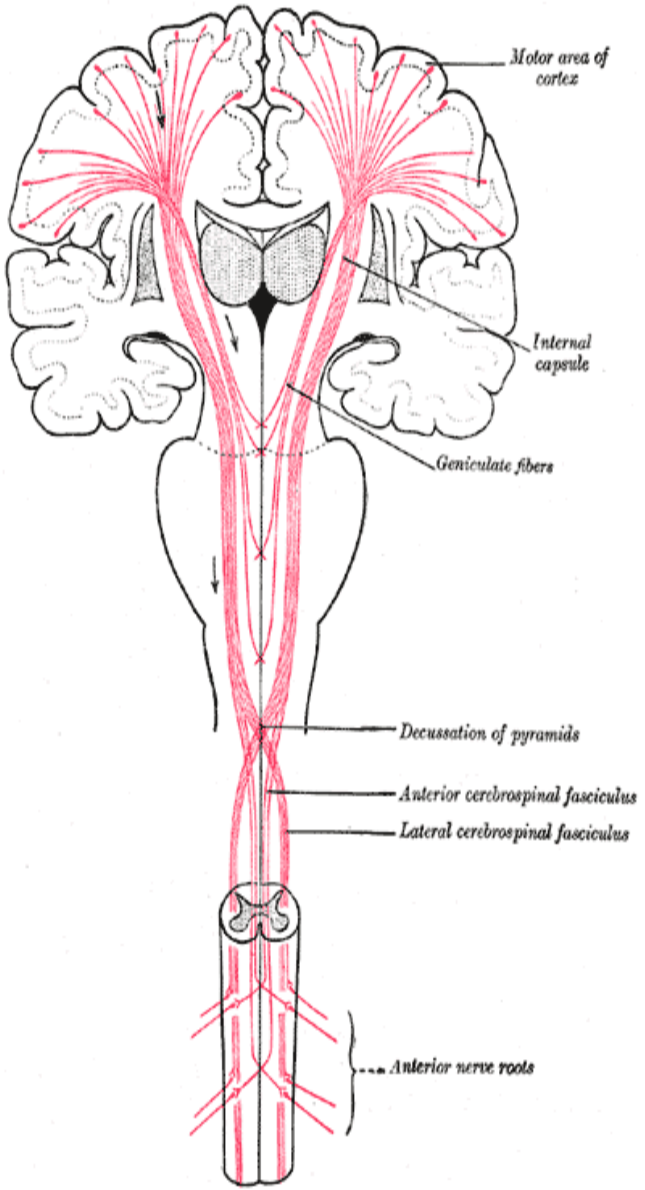
1-Corticobulbar tract terminates on LMNs (cranial nerve motor nuclei of opposite side &carries information to them)

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

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

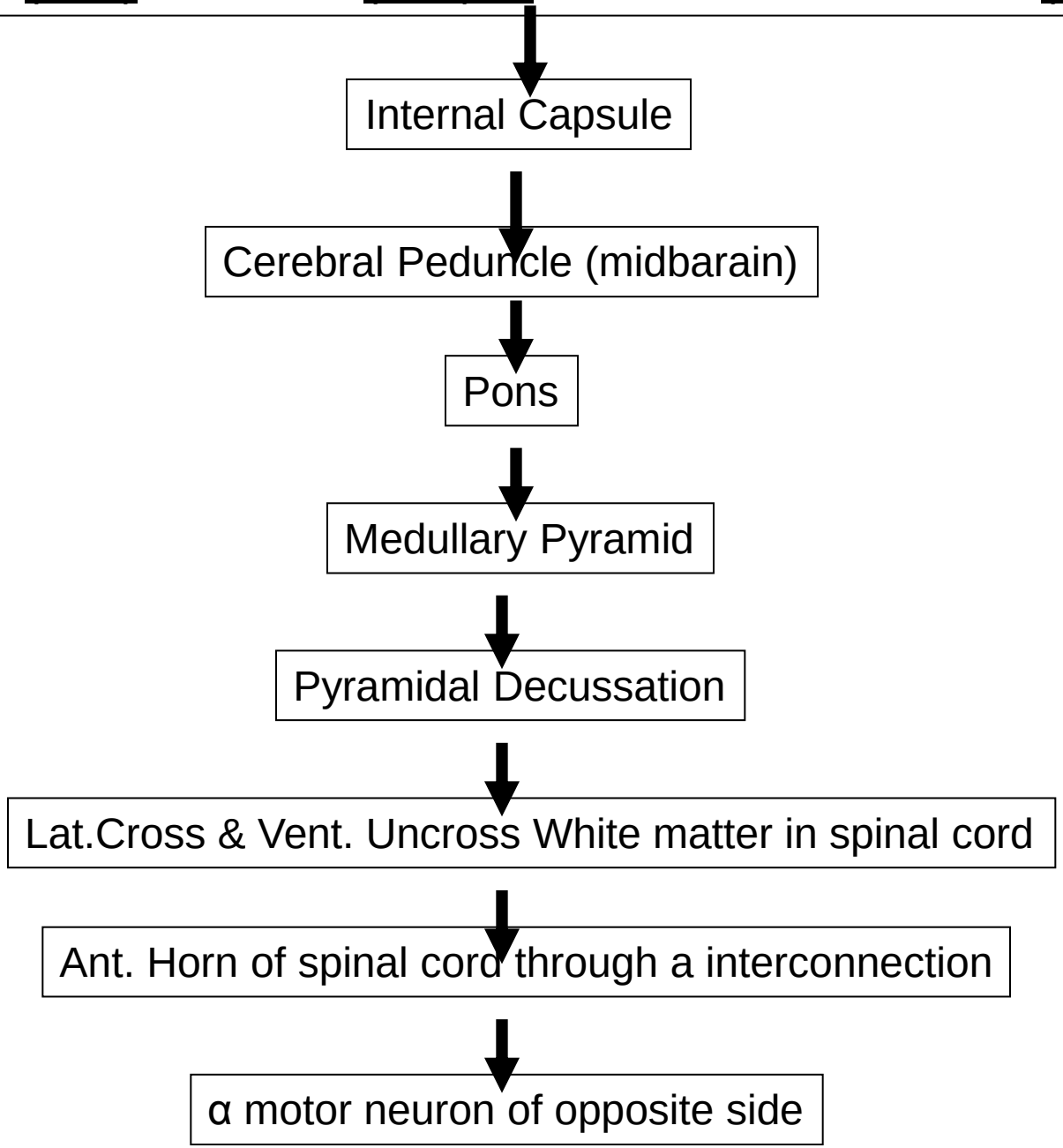
- Then in the lower medulla oblongata the fibers form pyramids so tracts originate from them are called pyramidal tract


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


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%)



- PYRAMIDAL TRACTS = CORTICOSPINAL TRACTS DIVIDES INTO:

1- LATERAL CORTICOSPINAL TRACTS :-

- THESE ARE 80% OF FIBERS THAT CROSS MIDLINE IN PYRAMIDS

-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.

. HERE THE LOWER MOTOR NEURONS (LMN) OF THE CORTICOSPINAL CORD ARE LOCATED. THEN PERIPHERAL MOTOR NERVES CARRY THE MOTOR IMPULSES FROM AHCS MOTOR NEURONS TO THE VOLUNTARY MUSCLES

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

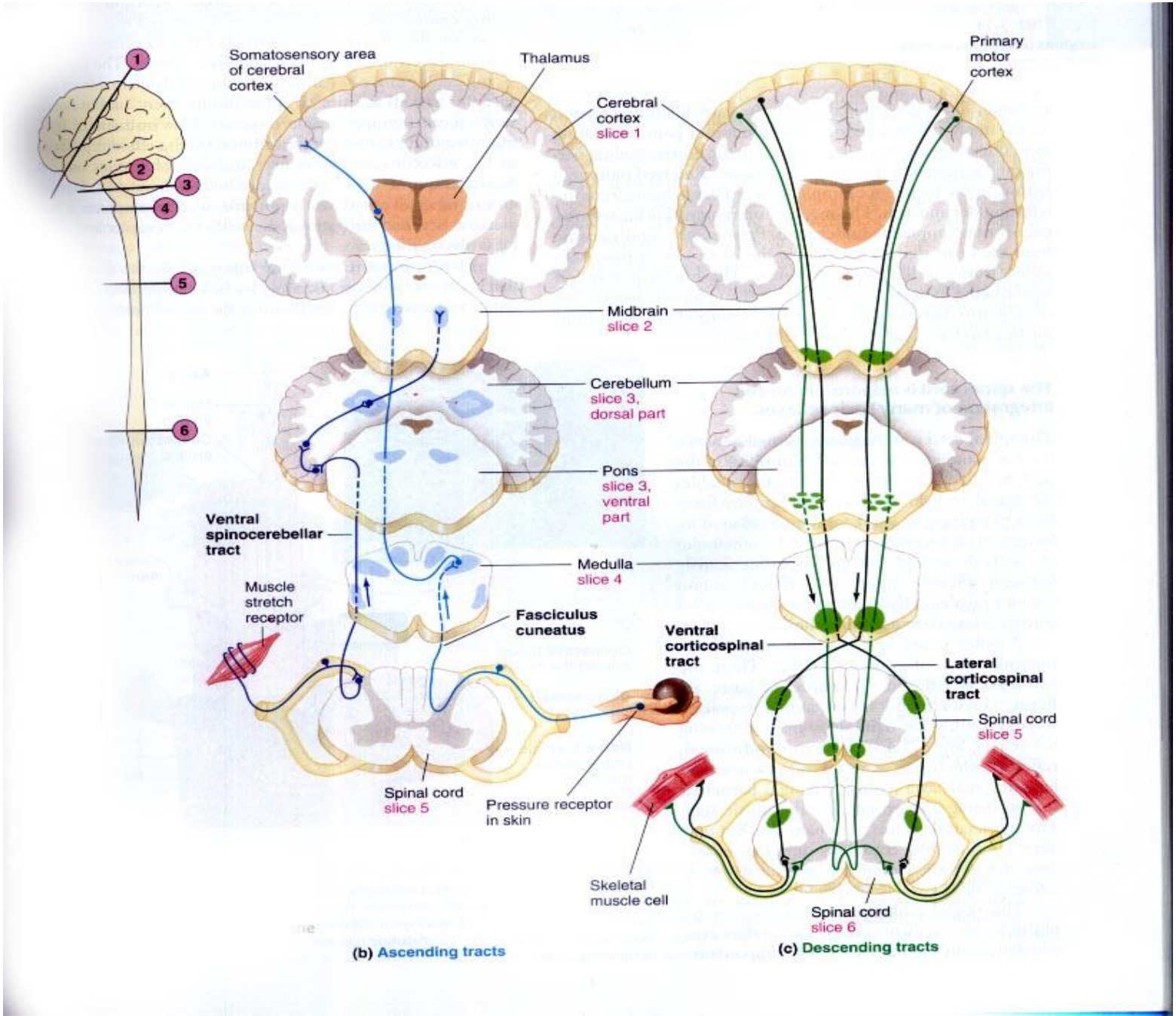
FUNCTION//- CONTROLS FINE DISCRETE SKILLED MOVEMENTS OF FINGERS AND TOES.

- **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&**may be concerned with control of bilateral postural movements

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


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
Medulla slice 4
Ventral spinocerebellar tract
Muscle stretch receptor
Fasciculus cuneatus
Spinal cord slice 5
Pressure receptor in skin
Ventral corticospinal tract
Lateral corticospinal tract
Spinal cord slice 5
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:-

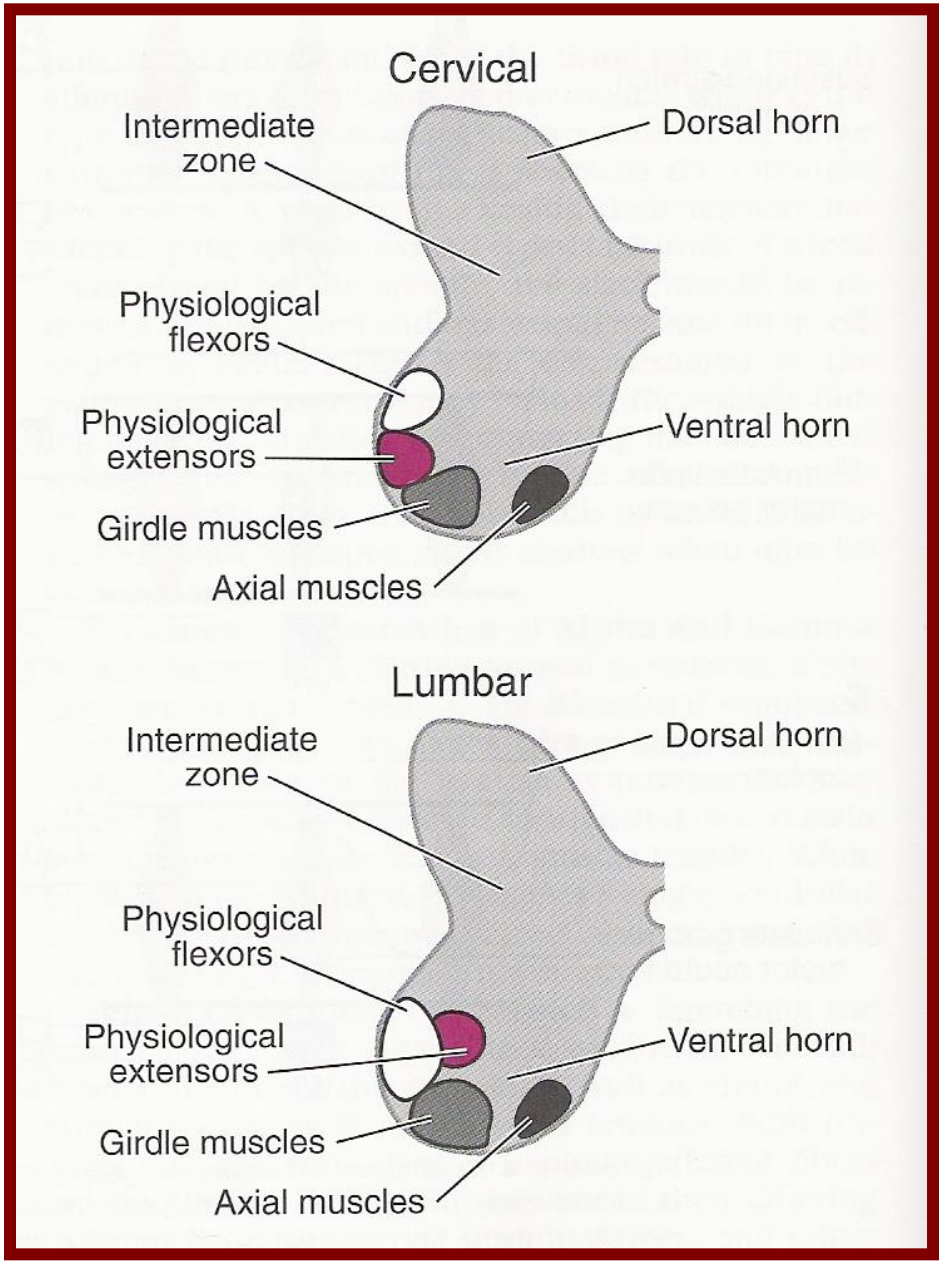
- Faccilitate muscle tone through gamma motor neurons

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 AHCs to activate direct hands and fingers muscle contraction.

This is in keeping with the fact that the primary motor cortex has an extremely high degree of representation for fine control of hand, finger, and thumb actions.


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 Areas by the Primary Motor Cortex and Red Nucleus

-Vertical Columnar Arrangement of the Neurons in the Motor Cortex with thousands of neurons in each column.

-each column has six distinct layers of cells,

-Layer 5 (from cortical surface) give origin for the pyramidal cells - that give rise to the corticospinal fibers

- the input signals enter cortex by way of layers 2 and 4. -

- sixth layer gives rise to fibers that communicate with other regions - of the cerebral cortex .

-**Function of Each Column of Neurons.**

Each column of cells functions **as an integrative processing** - **unit**& **as an amplifying system** to stimulate large numbers of pyramidal fibers to the same muscle or to synergistic muscles simultaneously.

- Use information from multiple input sources to determine the - output response

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 populations of pyramidal cell neurons:-

1-dynamic neurons.

-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- **static neurons (** greater percentage in the primary motor cortex

-They fire at a much slower rate & continue firing at this slow rate to ***maintain the force*** of contraction as long as the contraction is required.

N.B//-The neurons of the **red nucleus** have a greater percentage of dynamic and lesser static neurons,.

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

Removal of the Primary Motor Cortex (Area Pyramidalis).

Area Pyramidalis is essential for voluntary initiation of finely controlled movements, especially of the hands and fingers & contains the giant Betz pyramidal cells -

-Its removal causes varying degrees of paralysis of the represented muscles. -

-If the 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 (*the hand and finger muscles can contract; but, the *ability to control the fine movements is gone)*

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-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.

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

The motor control system can be damaged by the "stroke."

1- Heamorrhagic

2- Thrombotic

-the result is loss of blood supply to the cortex or to the corticospinal tract where it passes **spastic hemiplegia.**

Muscle Spasticity Caused by Lesions That Damage Large Areas Adjacent to the Motor Cortex.

-Most lesions of the motor cortex, especially caused by a *stroke*, involve not only the primary motor cortex but also adjacent parts of the brain such as the basal ganglia.

In these instances, *muscle spasm* almost occurs in the afflicted muscle - areas on the *opposite side* of the body .

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

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

-EXTRAPYRAMIDAL TRACTS :-

TRACTS OTHER THAN CORTICOSPINAL TRACT & ARE OUTSIDE PYRAMIDS

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

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*
-THESE FIBERS SYNAPSE IN THE LOWER PORTION OF THE RED NUCLEUS, THE ***MAGNOCELLULAR PORTION***, WHICH CONTAINS LARGE NEURONS SIMILAR IN SIZE TO THE BETZ CELLS .
-THESE LARGE NEURONS THEN GIVE RISE TO THE ***RUBROSPINAL TRACT,*** WHICH CROSSES TO THE OPPOSITE SIDE IN THE LOWER BRAIN STEM AND FOLLOWS A COURSE ADJACENT TO THE CORTICOSPINAL TRACT 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,

-THE RED NUCLEUS ALSO HAS CLOSE CONNECTIONS WITH THE CEREBELLUM
-

Function of the Corticorubrospinal System.

-The magnocellular portion of the red nucleus has **a somatographic representation** of all the muscles of the body,.
Stimulation of a single point in this 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 movements can still occur, except that the movements for fine control of the fingers and hands are considerably impaired
-Wrist movements are still functional, which is not the case when the corticorubrospinal pathway is also blocked.
-Rubrospinal tract lies in the lateral columns of the spinal cord so control the more distal muscles of the limbs.
-The corticospinal and rubrospinal tracts together are called the **lateral motor system of the cord**,
-Vestibuloreticulospinal system, which lies medially in the cord 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)

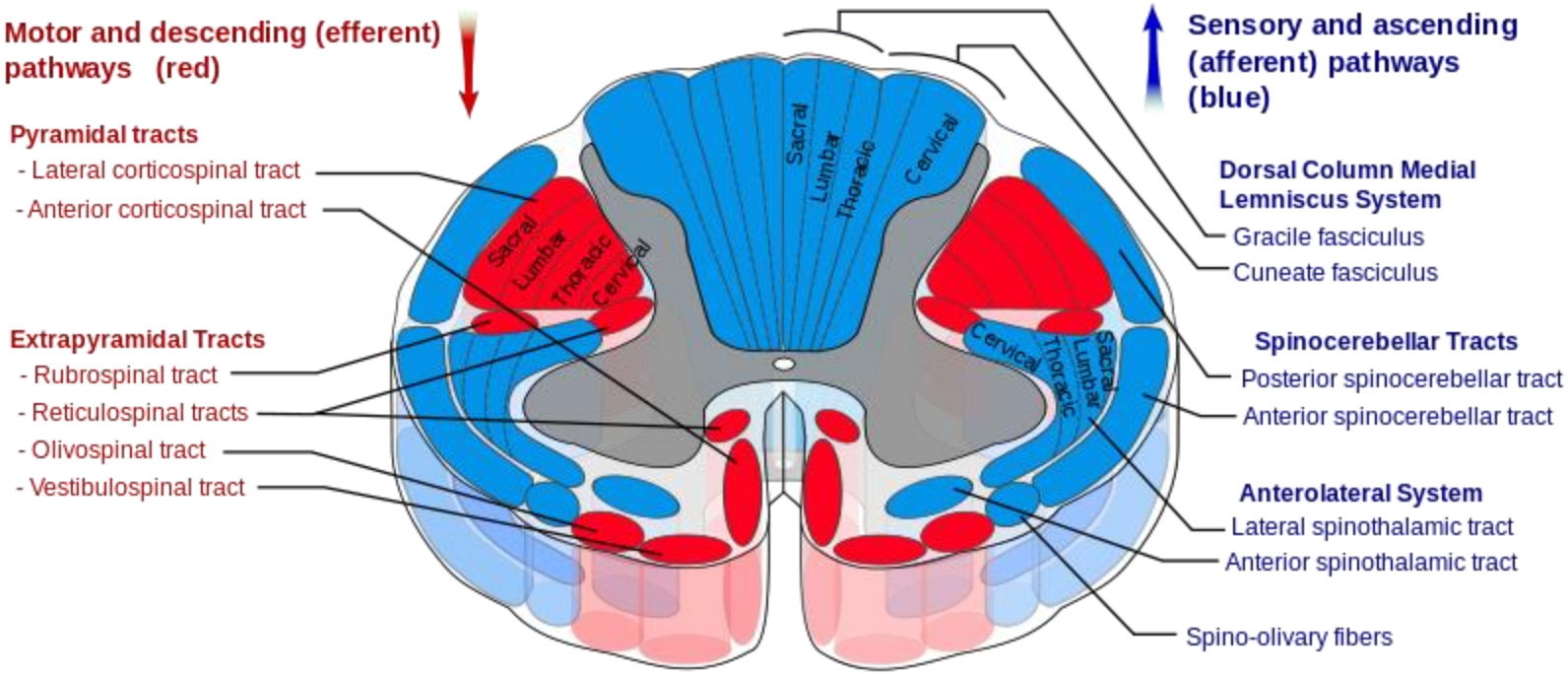
-AXONS DESCEND IN THE IPSILATERAL VENTRAL WHITE COLUMN OF SPINAL CORD

-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

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

2-The vestibular nuclei transmit strong excitatory signals to the antigravity muscles by way of the *lateral* and *medial vestibulospinal tracts* in the anterior columns of the spinal cord.

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

3-The specific role of the vestibular nuclei, however, is to *selectively* control the excitatory signals to the antigravity muscles to maintain equilibrium *in response to signals from the vestibular apparatus*.

3- Tectospinat tracts:-

-from superior (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 have a high degree of natural excitability. In addition, they receive strong exci-tatory signals from the vestibular nuclei & from deep nuclei of the cerebellum.

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

• Axons descend in anterior(ventral)white column of spinal cord

• Pontine Reticulospinal Tract increases Gamma efferent activity ,(excitatory to axial & anti-gravity, extensor muscles of the body= increases muscle tone)

(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 inputs 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) .

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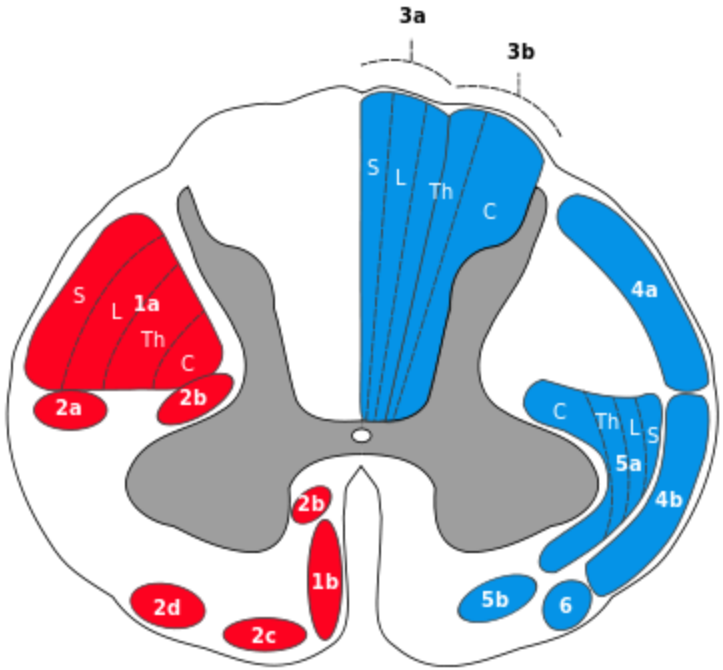
- SOME SIGNALS FROM HIGHER AREAS OF THE BRAIN CAN "DISINHIBIT" THE MEDULLARY SYSTEM WHEN THE BRAIN WISHES TO EXCITE THE PONTINE SYSTEM TO **CAUSE STANDING.**

-AT OTHER TIMES, 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.

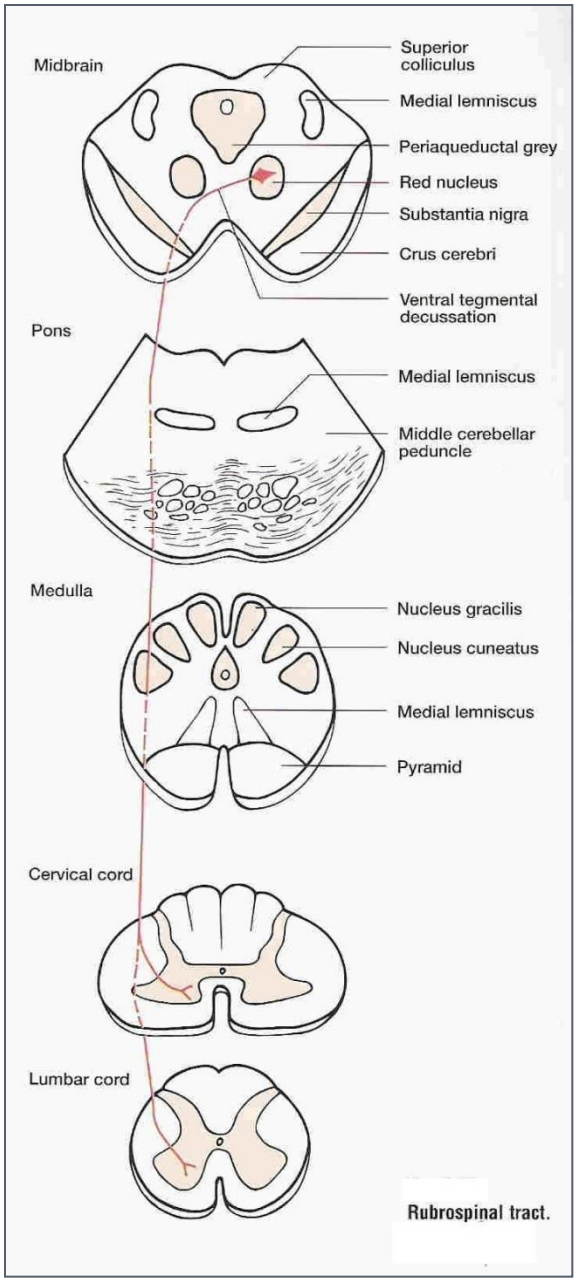
- THE **EXCITATORY AND INHIBITORY RETICULAR NUCLEI** CONSTITUTE A CONTROLLABLE SYSTEM THAT IS MANIPULATED BY MOTOR SIGNALS FROM THE CEREBRAL CORTEX TO PROVIDE NECESSARY BACKGROUND MUSCLE CONTRACTIONS FOR STANDING AGAINST GRAVITY

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

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Ends in ant. Horn of spinal cord

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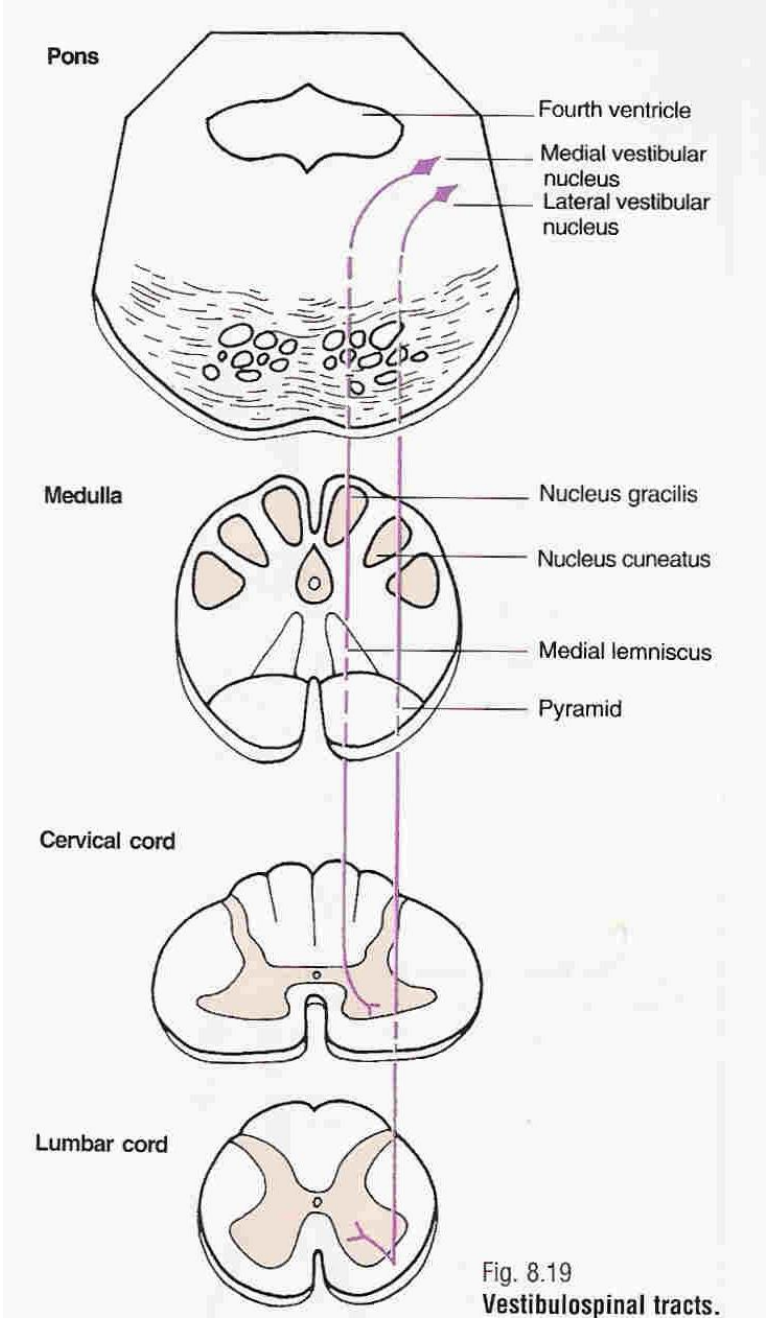

Fig. 8.19
Vestibulospinal tracts.

Afferent from cerebellum, vestibular apparatus & vestibular nuclei

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Spinal motor neuron

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Innervating axial & postural muscles

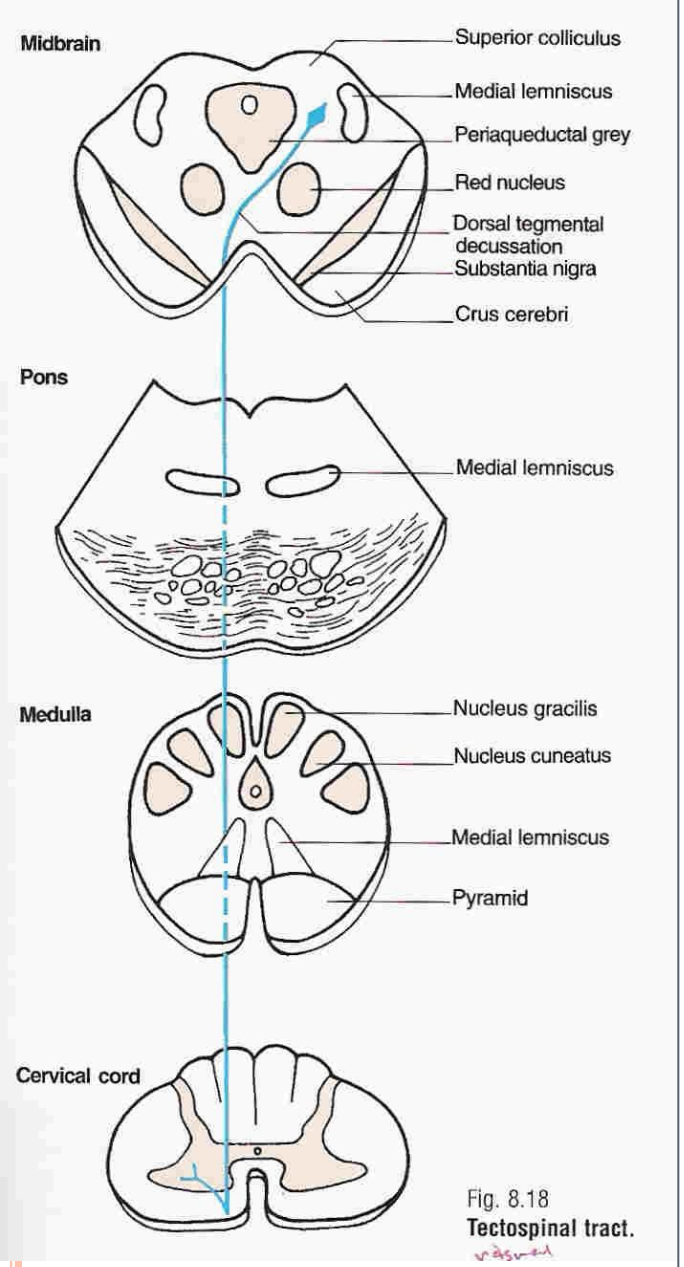

Fig. 8.18
Tectospinal tract.

Superior & Inferior collicili in midbrain>>>>>

Near Medial longitudinal fasiculus>>>>

Cervical spinal motor neuron of anterior horn