Physiology of Motor Tracts

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OBJECTIVES

At the end of this lecture the student should be able to:

(A) Appreciate what is upper motor neuron and lower motor neuron .

(B) List the main differences between the pyramidal and extrapyramidal systems .

(C) explain the origin , course and functions of the following motor tracts :

- **(1) corticospinal.**
- **(2) tectospinal .**
- **(3) rubrospinal .**
- **(4) vestibulospinal .**
- **(5) reticulospinaql .**
- **(6) olivospinal .**

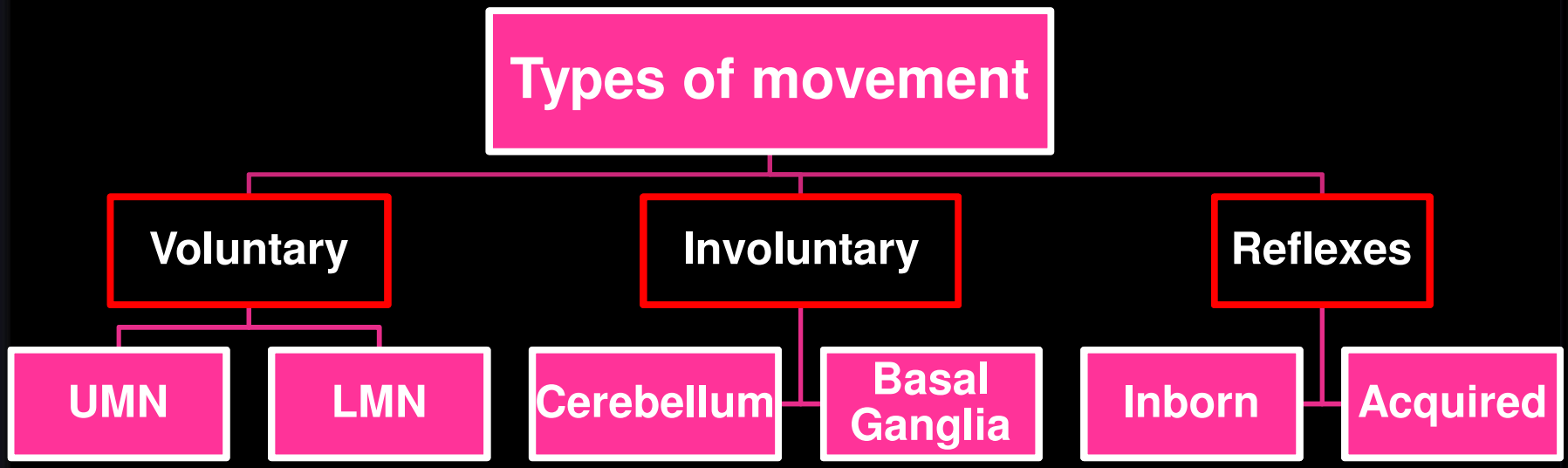
MOTOR SYSTEM LAYOUT

Motor = movement

For movement we need nervous system and muscles.

Components of motor system are:

- Motor cortex
- Upper and lower motor neurons
- Cerebellum
- Basal ganglia
- Spinal cord
- Muscles



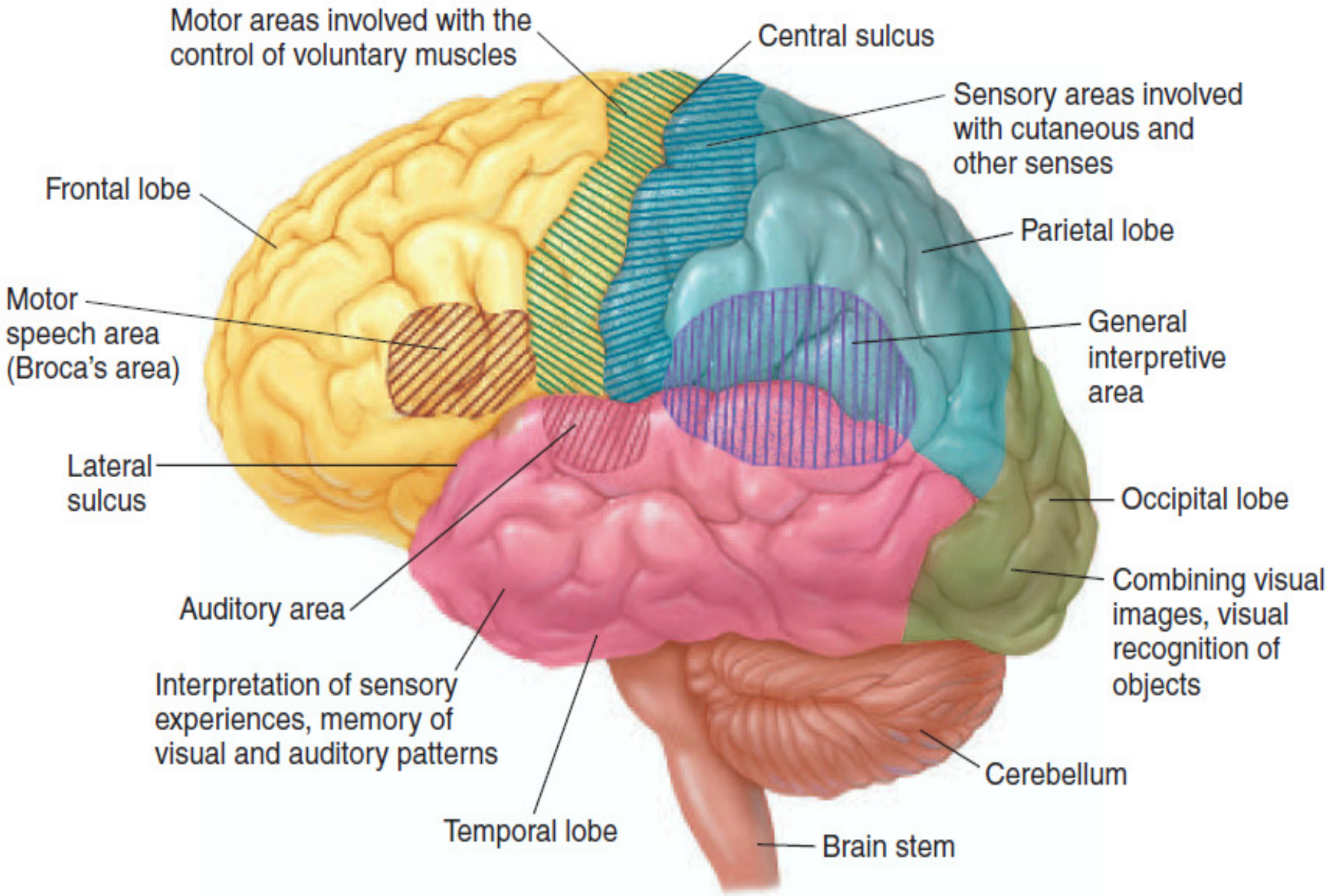
INITIATOR OF MOTOR ACTIVITY

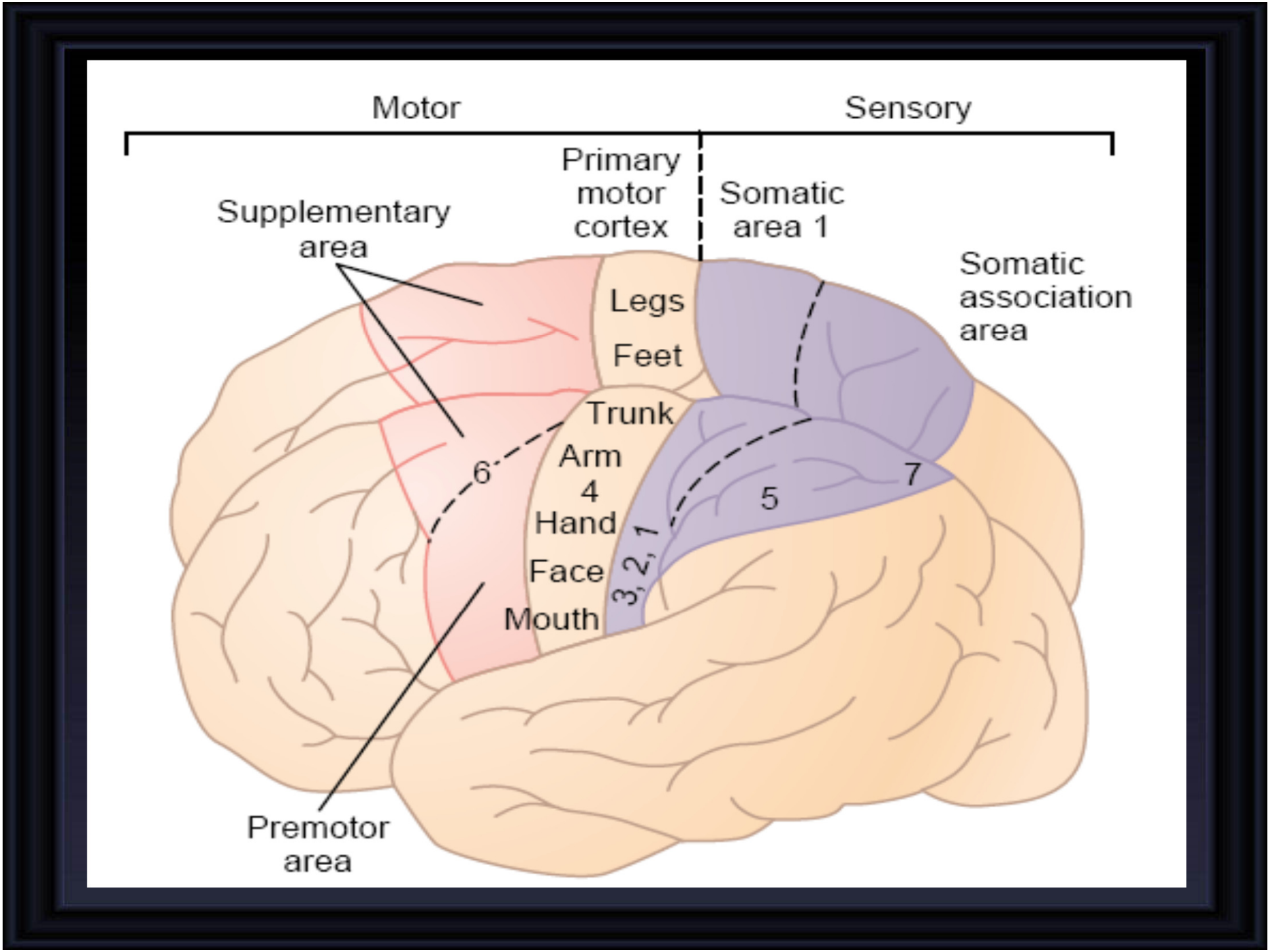
Corticospinal tract (Pyramidal tract)

REGULATOR OF MOTOR ACTIVITY

Extrapyramidal tracts & Cerebellum

CEREBRAL CORTEX AREAS & FUNCTIONS




Motor
Sensory
Primary motor cortex
Somatic area 1
Supplementary area
Somatic association area
Legs
Feet
Trunk
Arm
4
Hand
Face
Mouth
6
5
7
3, 2, 1
Premotor area

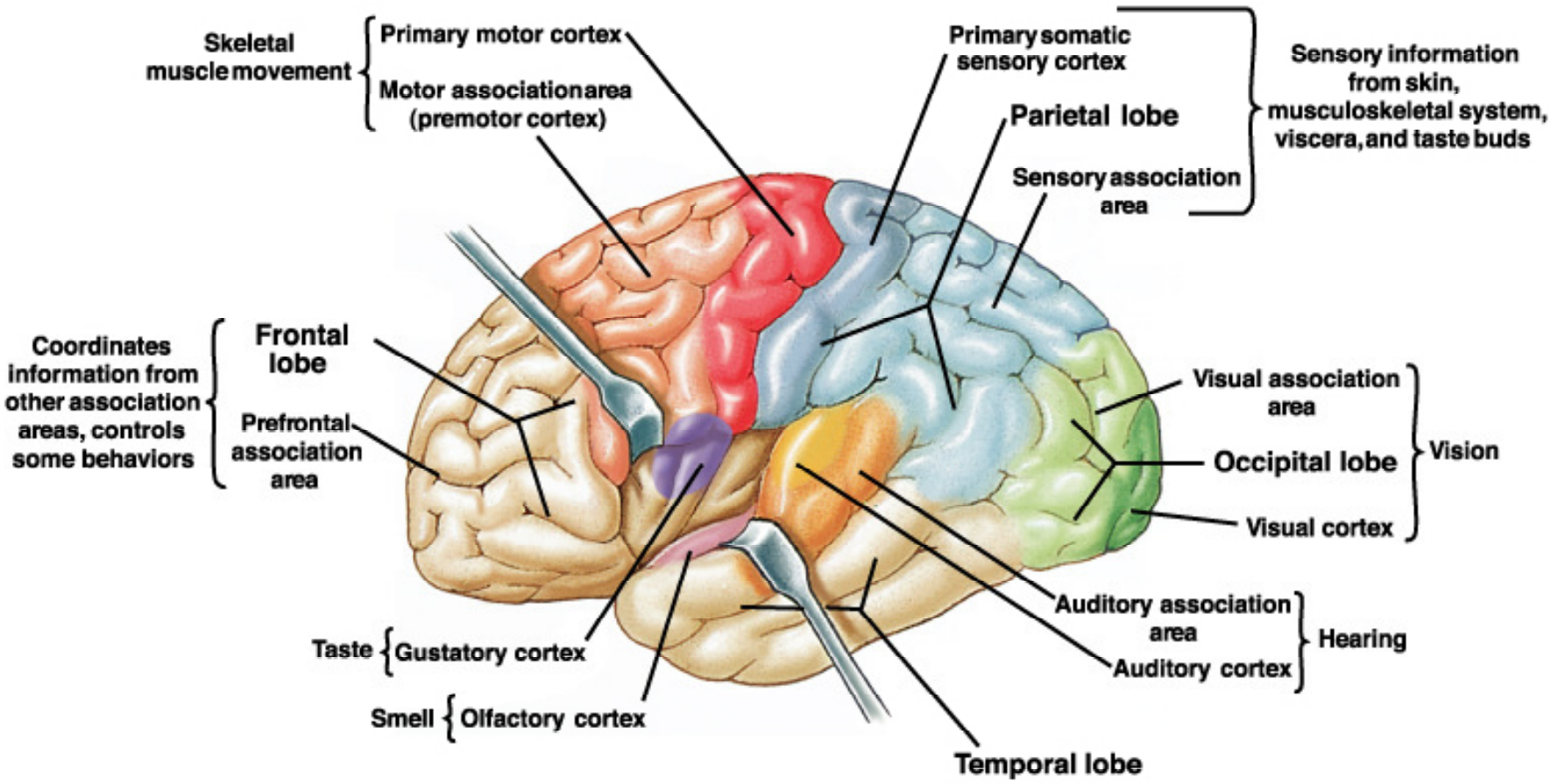
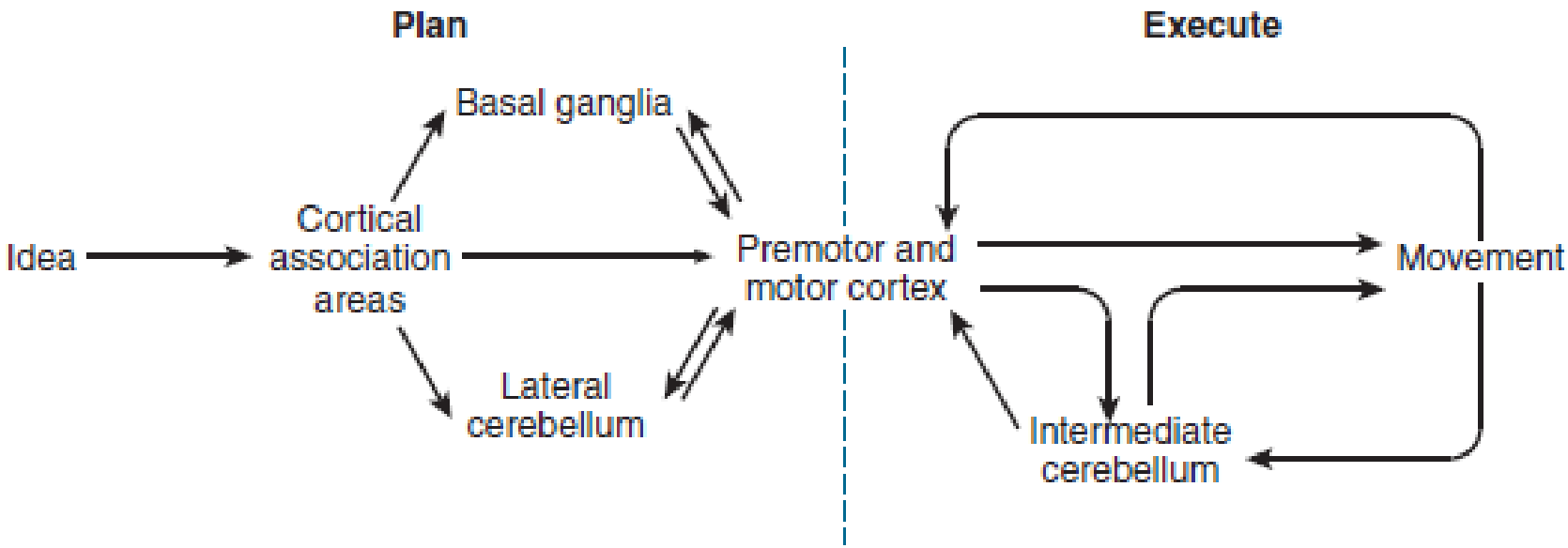
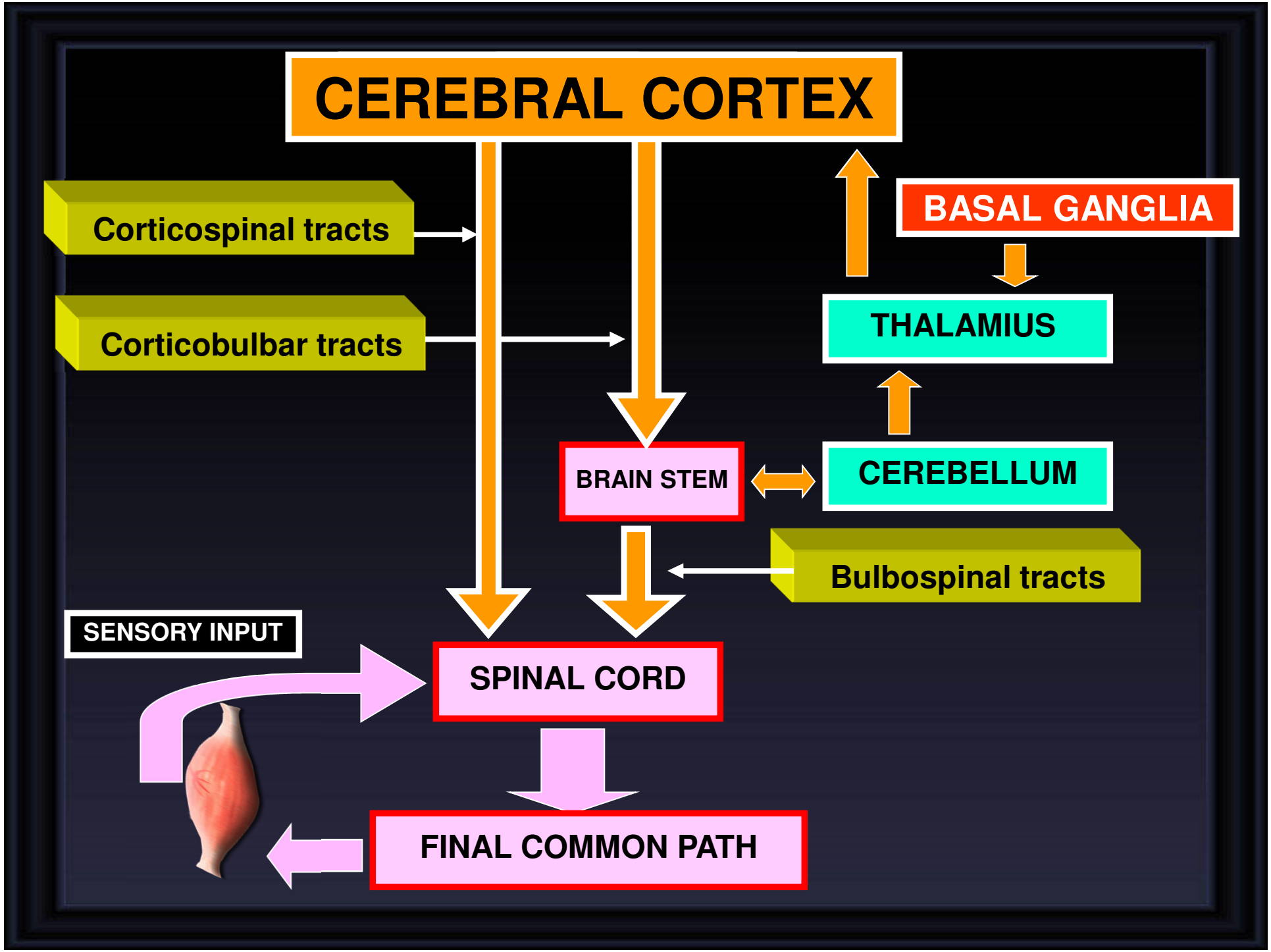
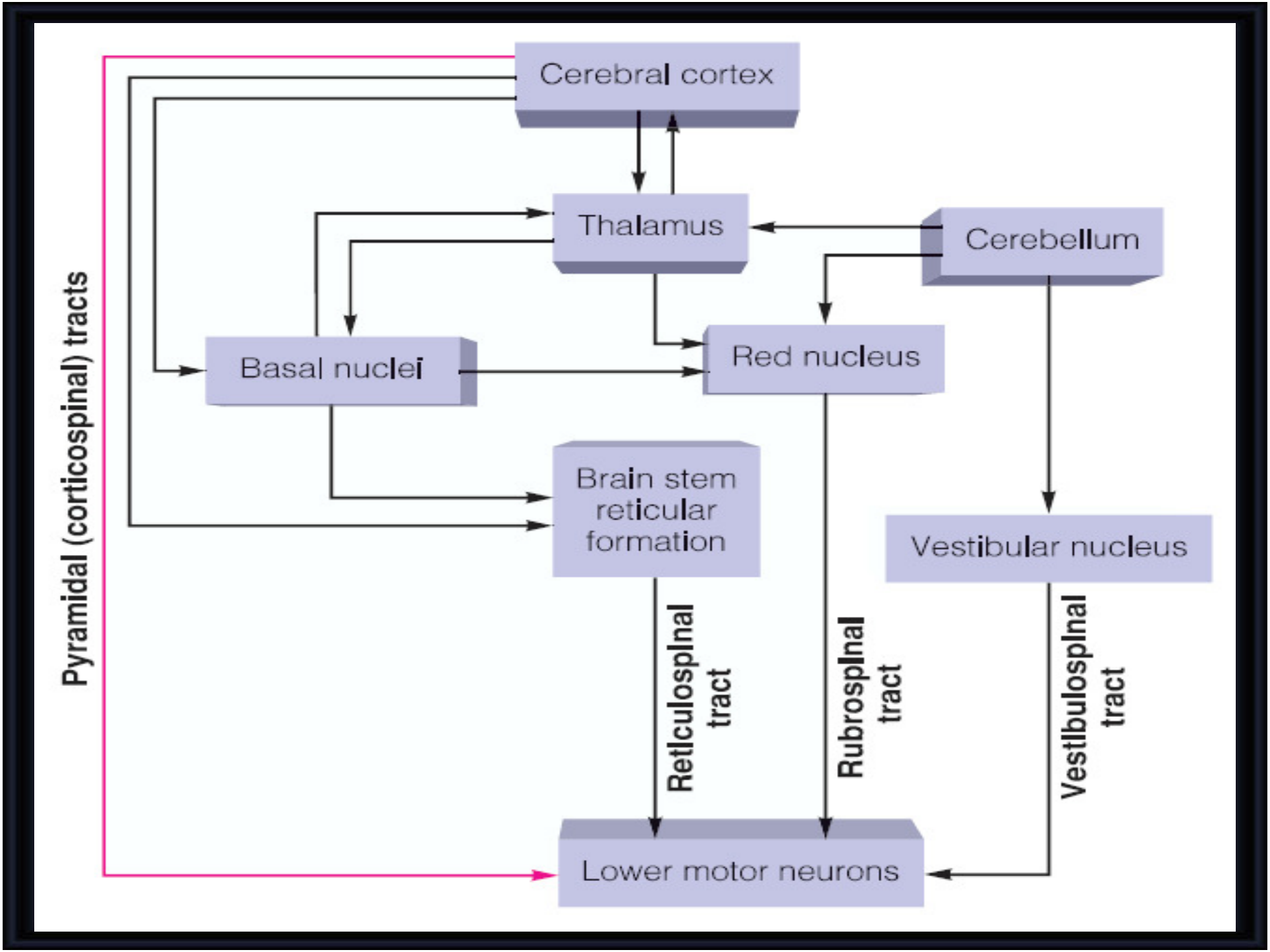

Skeletal muscle movement
Primary motor cortex
Motor association area (premotor cortex)
Primary somatic sensory cortex
Parietal lobe
Sensory association area
Sensory information from skin, musculoskeletal system, viscera, and taste buds
Coordinates information from other association areas, controls some 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

FIGURE 12.7 Control of voluntary movement. Commands for voluntary movement originate in cortical association areas. The cortex, basal ganglia, and cerebellum work cooperatively to plan movements. Movement executed by the cortex is relayed via the corticospinal tracts and corticobulbar tracts to motor neurons. The cerebellum provides feedback to adjust and smooth movement.




CEREBRAL CORTEX
Corticospinal tracts
Corticobulbar tracts
BASAL GANGLIA
THALAMIUS
CEREBELLUM
BRAIN STEM
Bulbospinal tracts
SENSORY INPUT
SPINAL CORD
FINAL COMMON PATH


Cerebral cortex
Thalamus
Cerebellum
Basal nuclei
Red nucleus
Brain stem reticular formation
Vestibular nucleus
Lower motor neurons
Pyramidal (corticospinal) tracts
Retículospinal tract
Rubrospinal tract
Vestibulospinal tract

DESCENDING TRACTS

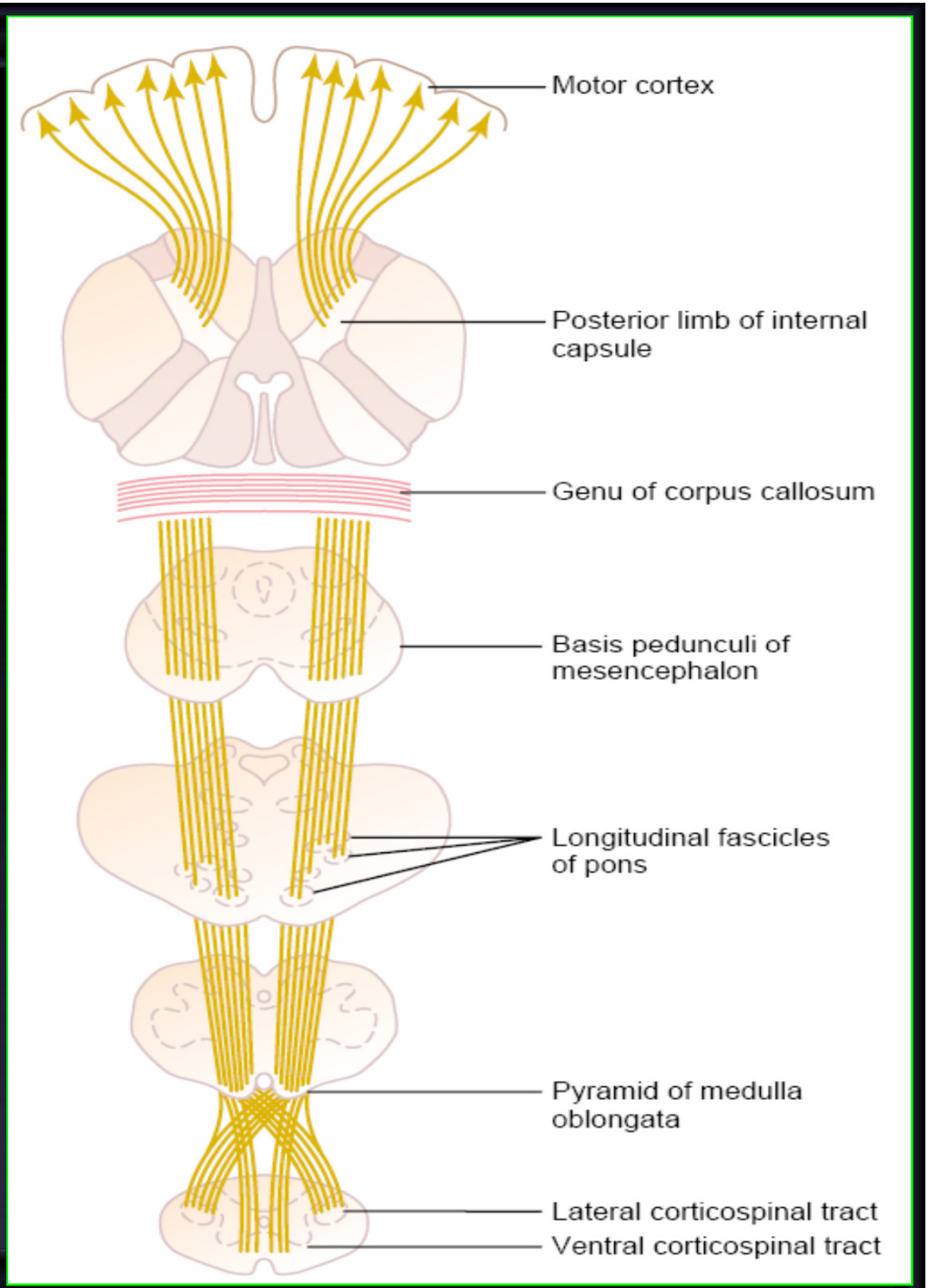
TWO MAJOR GROUPS

1. CORTICOSPINAL OR PYRAMIDAL TRACTS
2. EXTRAPYRAMIDAL TRACTS

PYRAMIDAL TRACTS

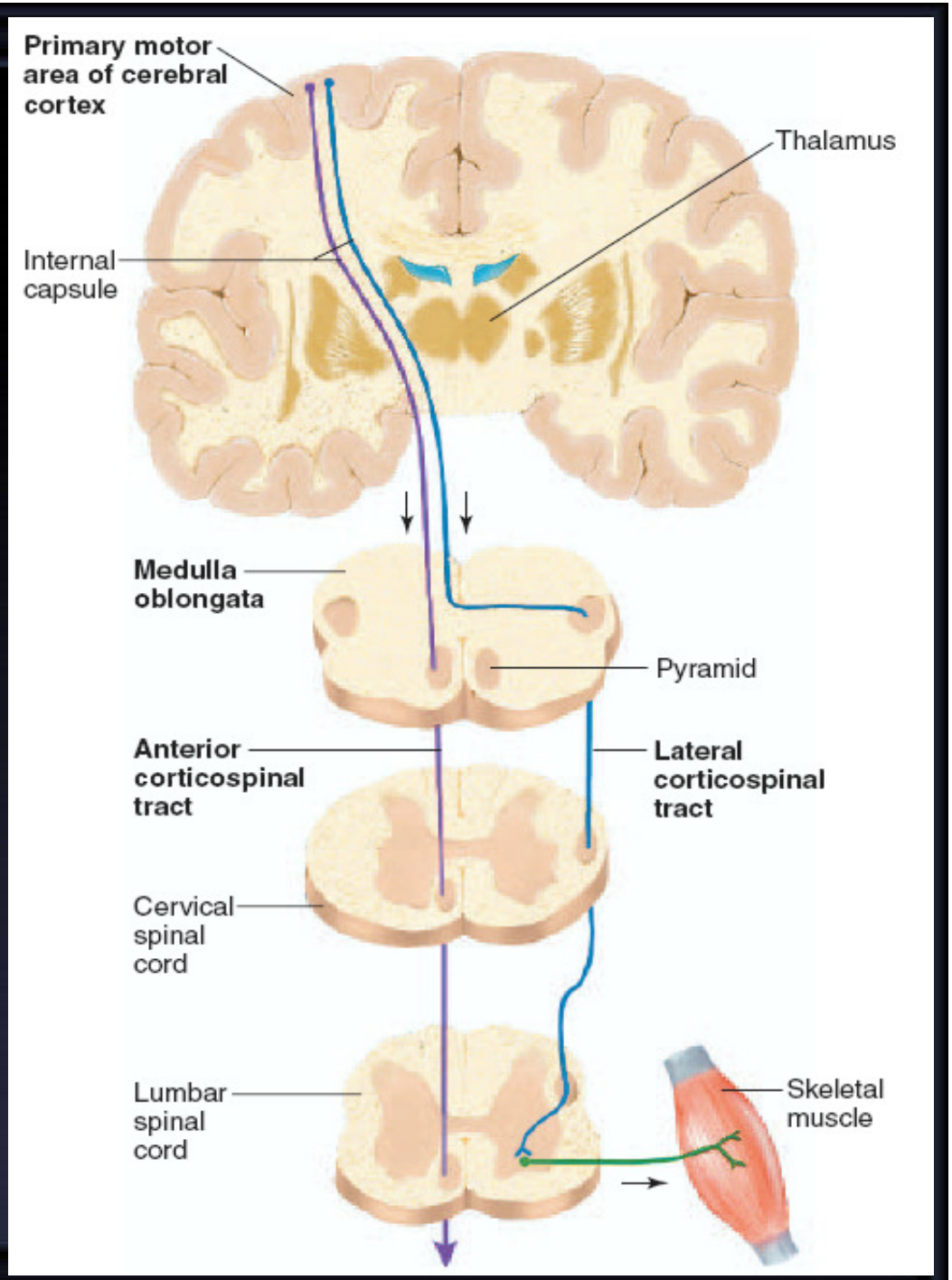
Corticospinal tract originates from:

- 30% from primary motor cortex (Motor Area 4)
- 30% from premotor & supplementary motor areas
- 40% from somatosensory areas(somatic sensory area 3,1,2)



PYRAMIDAL TRACTS

- Originating Cells: Giant pyramidal cells
- 80% to 90% of the pyramidal fibers then cross in medulla to the opposite side and descend into the lateral corticospinal tracts
- Anterior or ventral corticospinal tract is formed by uncrossed fibers are primarily concerned with the control of fine movements that require dexterity.



COMPONENTS OF MOTOR NEURONS

Upper motor neuron (corticospinal & corticobulbar).

Starts from motor cortex and ends in

1. Cranial nerve nucleus (corticobulbar).
2. Anterior horn of spinal cord in opposite side(corticospinal tracts).

Lower Motor Neuron

Starts from anterior horn of spinal cord and & cranial motor neurons in the brain stem that innervate muscles directly ends in appropriate muscle of the same side.

LATERAL AND VENTRAL CORTICOSPINAL TRACTS

- The majority of the pyramidal fibers (80-90%) then cross in the lower medulla to the opposite side and descend into the lateral corticospinal tracts and ends……
  - directly on motor neurons (AHC) of the opposite side
  - interneurons of the grey matter
  - some ends at sensory neurons of dorsal horn
- Functions: Controls distal limb muscles for skilled voluntary movements (Fingers & Toes)

- Anterior or ventral corticospinal tract is formed by uncrossed fibers and many of these cross at level of termination to synapse with interneurons, specially in in the neck or in the upper thoracic region.
- Functions: These fibers may be concerned with control of bilateral postural movements by the supplementary motor cortex. Pass medially in ventral horn so control axial & proximal limb muscles in coordination with tectspinal, reticulospinal and vestibulospinal 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

3- Ventral corticospinal tracts control posture

4- Effect on stretch reflex:-

- Facilitate muscle tone through gamma motor neurons

5- 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.

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

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

-Removal of the Primary Motor Cortex (Area Pyramidalis)

- 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.**
- Area pyramidalis is essential for what??

essential for voluntary initiation of finely controlled movements, especially of the hands and fingers

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 not only the primary motor cortex but also adjacent parts of the brain such as the basal ganglia. In these instances, *muscle spasticity* almost invariably occurs in the afflicted muscle areas on the o*pposite side* of the body.

This spasm results mainly from damage to accessory nonpyramidal pathways. These pathways 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 MOTOR TRACTS

Originate in the midbrain and brain stem regions

If the pyramidal tracts of an experimental animal are cut, electrical stimulation of the cerebral cortex, cerebellum, and basal nuclei can still produce movements.

The term extrapyramidal motor system is widely used in clinical circles to denote **all those portions of the brain and brain stem that contribute to motor control** but are not part of the direct corticospinal-pyramidal system.

Components of extrapyramidal system

1. Basal Ganglia
2. Midbrain giving rise to following bulbospinal tracts.
   A. Rubrospinal tract.
   B. Vestibulospinal Tract.
   C. Reticulospinal Tract
   D. Tectspinal Tract.
   E. Olivospinal Tract.

(1) sets the postural background needed for performance of skilled movements
(2) controls subconscious gross movements

Excitation of the Spinal Cord Motor Control Areas by the Primary Motor Cortex and Red Nucleus (Dynamic and Static signals)

- Cells of the motor cortex are organized in vertical columns with thousands of neurons in each column
- Each column has 6 distinct layers and Pyramidal cells originate from Layer 5
- Each Column of neurons operate as an integrative processing and amplifying system (50-100 Pyramidal cells), using information from multiple input sources to determine the output response from the column for purposeful activities.
- Each column of cells excites two populations of pyramidal cell neurons, one called *dynamic neurons* and the other *static neurons.*

Excitation of the Spinal Cord Motor Control Areas by the Primary Motor Cortex and Red Nucleus (Dynamic and Static signals) Cont.

- The dynamic neurons are excessively excited for a **short period at the beginning of a contraction**, causing the initial rapid *development of force.* Then the static neurons fire at a much slower rate, but they continue firing at this slow rate to ***maintain the force*** **of contraction** as long as the contraction is required.

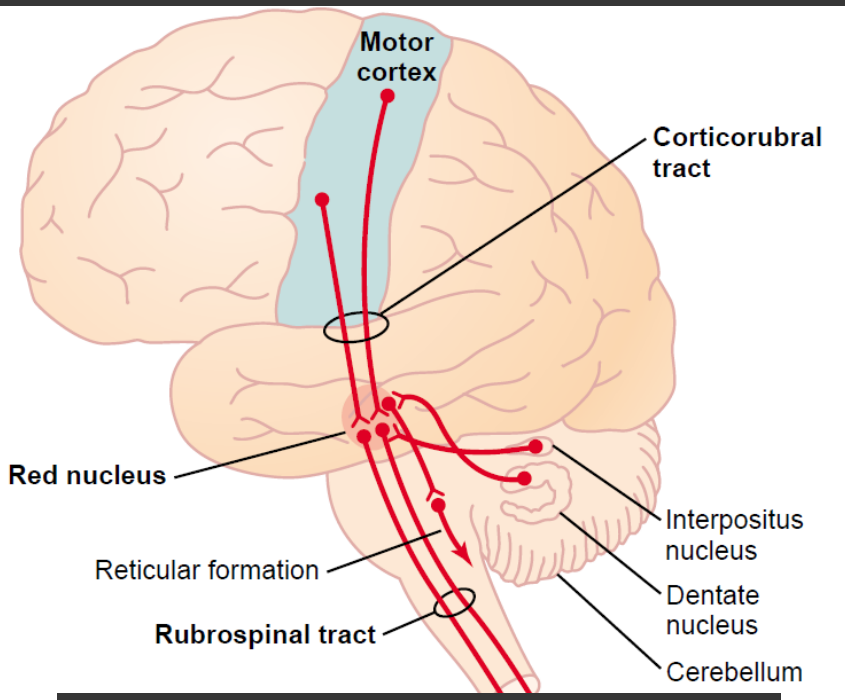
- Greater percentage of dynamic neurons is in the red nucleus and a greater percentage of static neurons is in the primary motor cortex

Red Nucleus Serves as an Alternative Pathway for Transmitting Cortical Signals to the Spinal Cord

- **RUBROSPINAL TRACTS**
- **Red Nucleus receives large number of 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 *magnocellular portion,* containing large neurons like betz cells and give origin to Rubrospinal tract.**
- **The red nucleus also has close connections with the cerebellum**

- ***LATERAL MOTOR SYSTEM :*** the corticospinal and rubrospinal tracts together
- ***MEDIAL MOTOR SYSTEM:*** vestibuloreticulospinal system, lies mainly medially in the cord

The corticorubrospinal pathway serves as an accessory route for transmission of relatively discrete signals from the motor cortex to the spinal cord.



Corticorubrospinal pathway for motor control, showing also the relation of this pathway to the cerebellum.

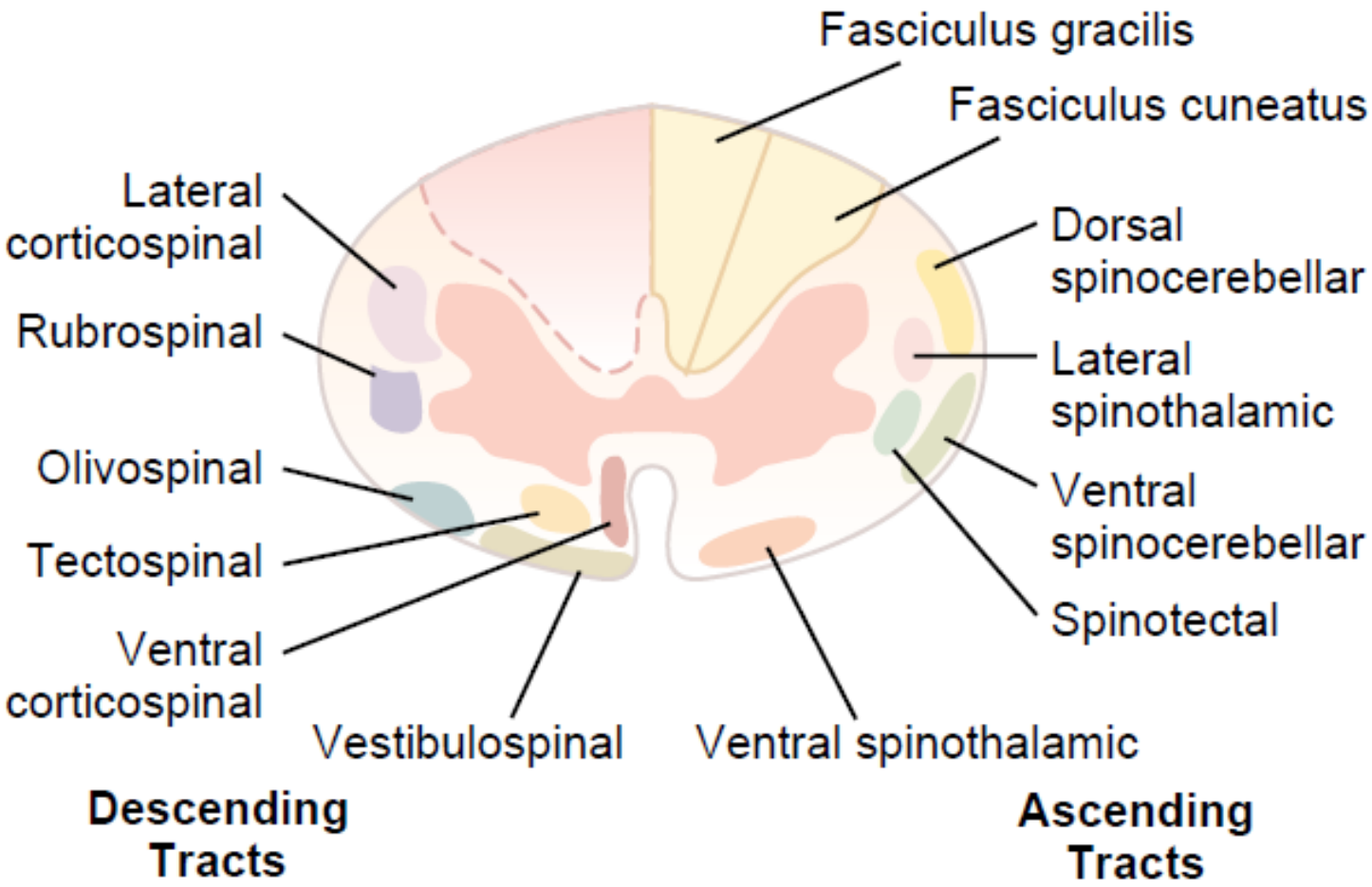
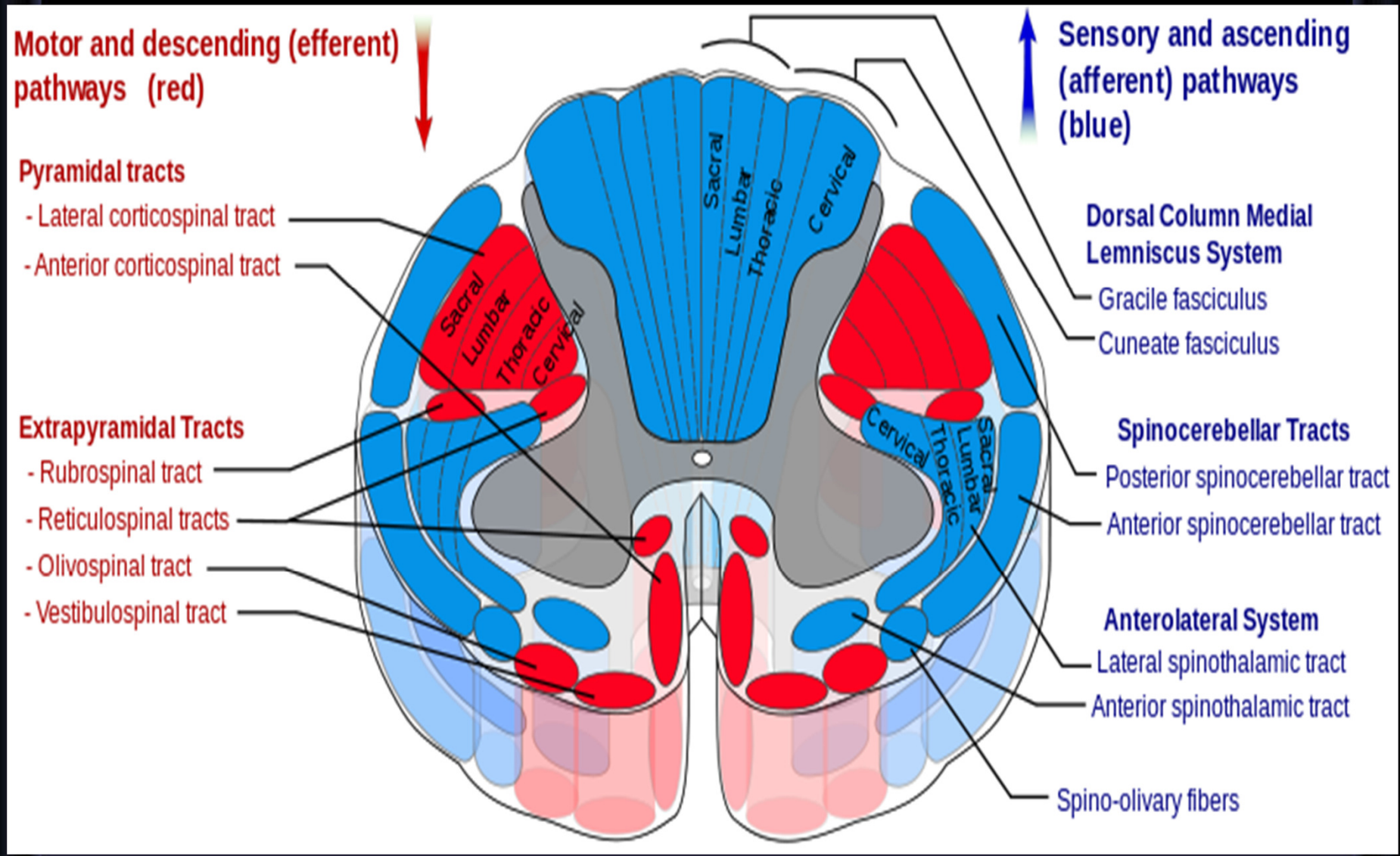
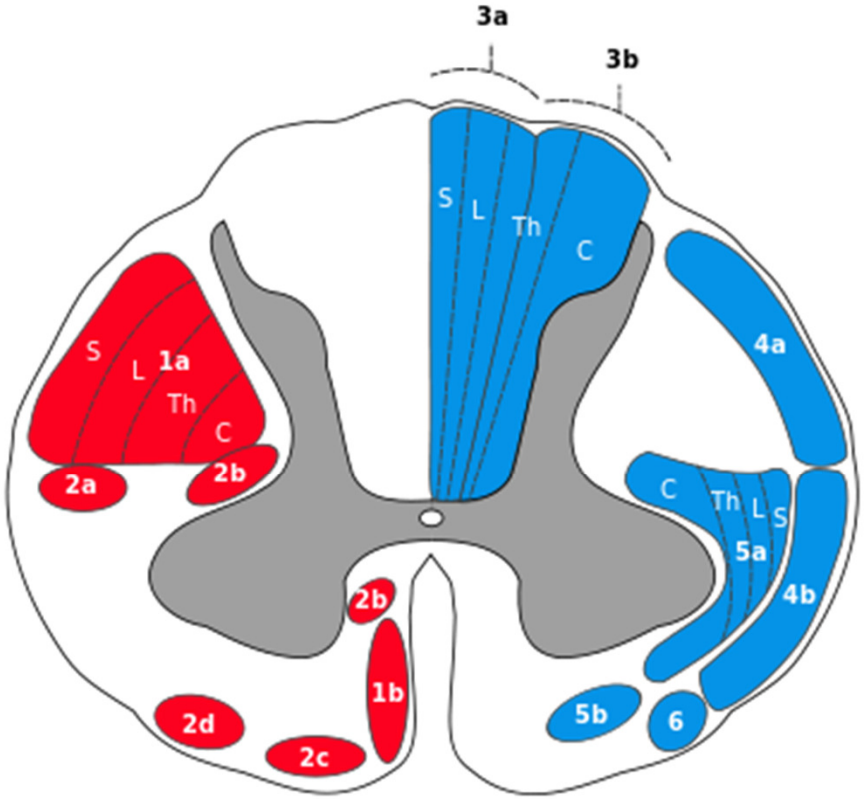


Figure 48–8

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


Motor and descending (efferent) pathways (red)
Pyramidal tracts
- Lateral corticospinal tract
- Anterior corticospinal tract
Extrapyramidal Tracts
- Rubrospinal tract
- Reticulospinal tracts
- Olivospinal tract
- Vestibulospinal tract
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
Sacral
Lumbar
Thoracic
Cervical



Motor and decending (efferent) pathways (left, red)

1. Pyramidal Tracts
1a. Lateral corticospinal tract
1b. Anterior corticospinal tract

2. Extrapyramidal Tracts
2a. Rubrospinal tract
2b. Reticulospinal tract
2c. Vestibulospinal tract
2d. Olivospinal tract

Somatotopy Abbreviations:
S: Sacral, **L: Lumbar**
Th: Thoracic, **C: Cervical**

Sensory and ascending (afferent) pathways (right, blue)

3. Dorsal Column Medial Lemniscus System
3a. Gracile fasciculus
3b. Cuneate fasciculus

4. Spinocerebellar Tracts
4a. Posterior spinocerebellar tract
4b. Anterior spinocerebellar tract

5. Anterolateral System
5a. Lateral spinothalamic tract
5b. Anterior spinothalamic tract

6. Spino-olivary fibers

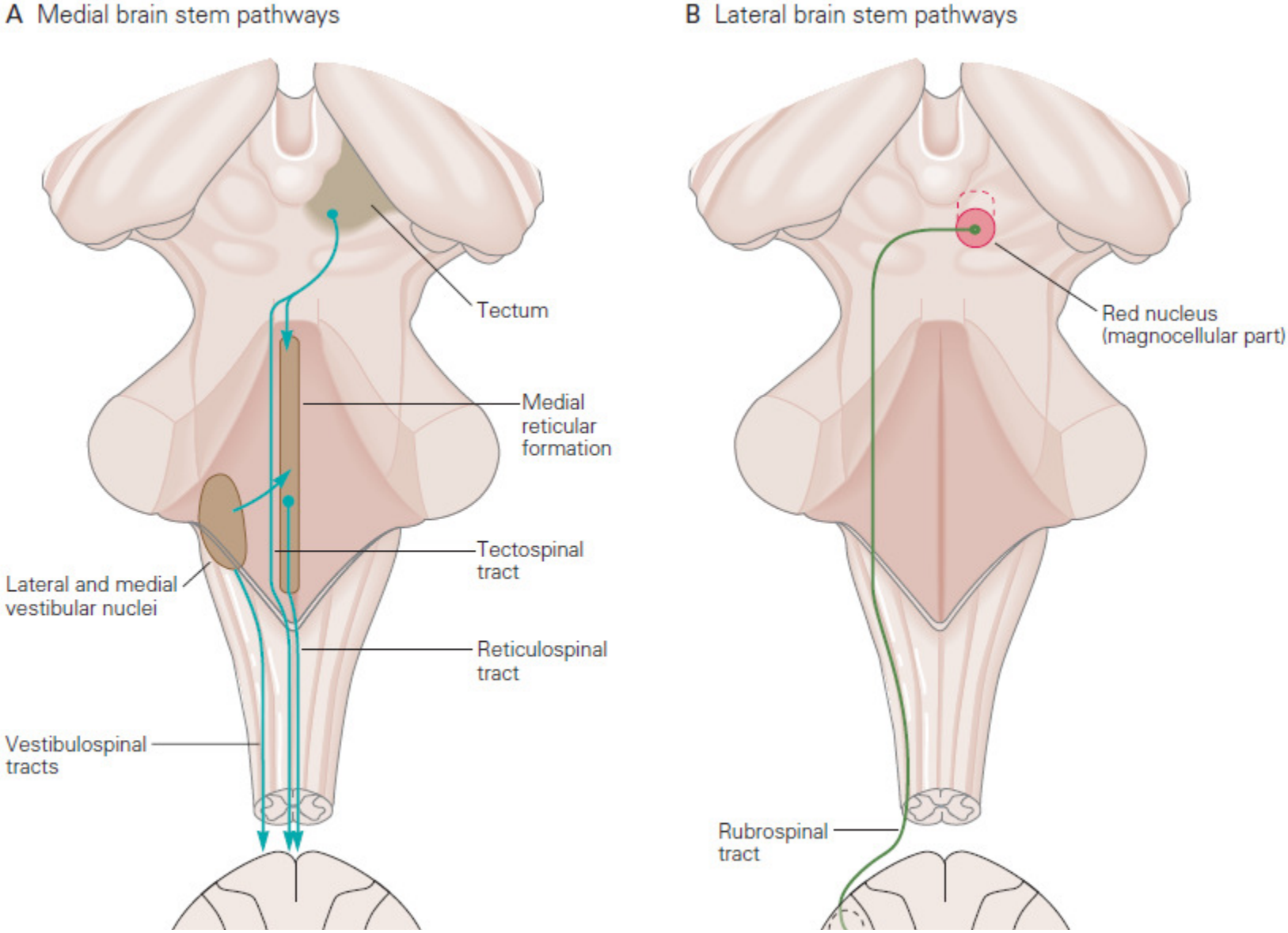
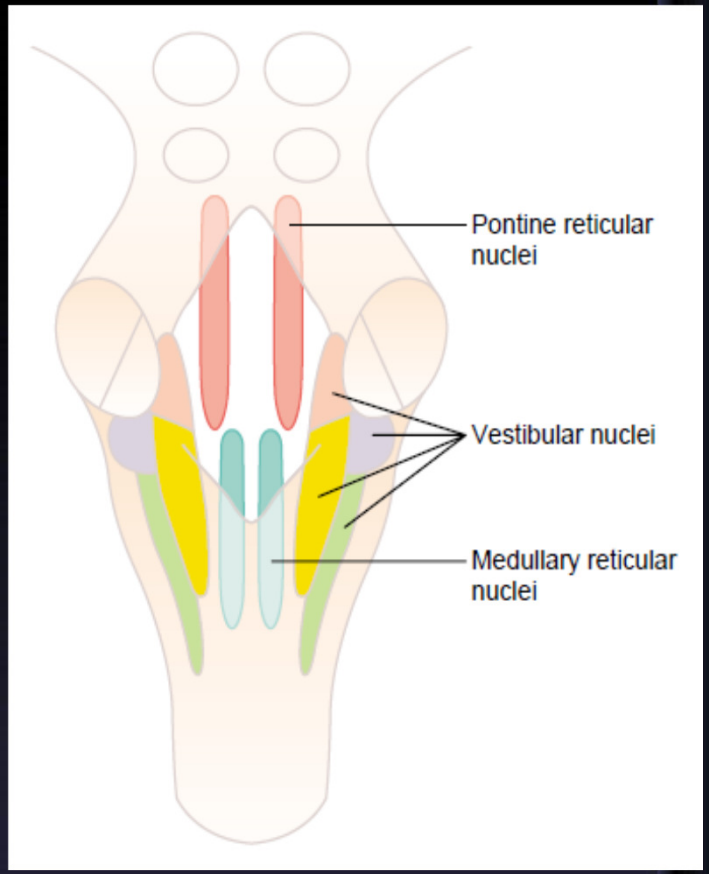


FIGURE 12–11 Medial and lateral descending brain stem pathways involved in motor control. A) Medial pathways (reticulospinal, vestibulospinal, and tectospinal) terminate in ventromedial area of spinal gray matter and control axial and proximal muscles. **B)** Lateral pathway (rubrospinal) terminates in dorsolateral area of spinal gray matter and controls distal muscles. (From Kandel ER, Schwartz JH, Jessell TM [editors]: *Principles of Neural Science*, 4th ed. McGraw-Hill, 2000.)

Vestibulospinal tracts

-Originates from vestibular nucleus in pons (which receive inputs from inner ear ,Vestibular Apparatus 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 head & eye movements

Functions of Vestibulospinal Tracts

The lateral vestibulospinal tract

- Cells of origin : Lateral Vestibular Nucleus
- Axons descend in the ventral white column of spinal cord .

Functions: It activates motor neurons to antigravity muscles (eg, proximal limb extensors) to control posture and balance.

The medial vestibulospinal tract

- Cells of origin : Medial and inferior Vestibular Nuclei
- As its axons descend 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 fibres in brain stem that link vestibular nuclei to nuclei supplying the extra-ocular muscles.

Functions: Coordination of head and eye movements

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

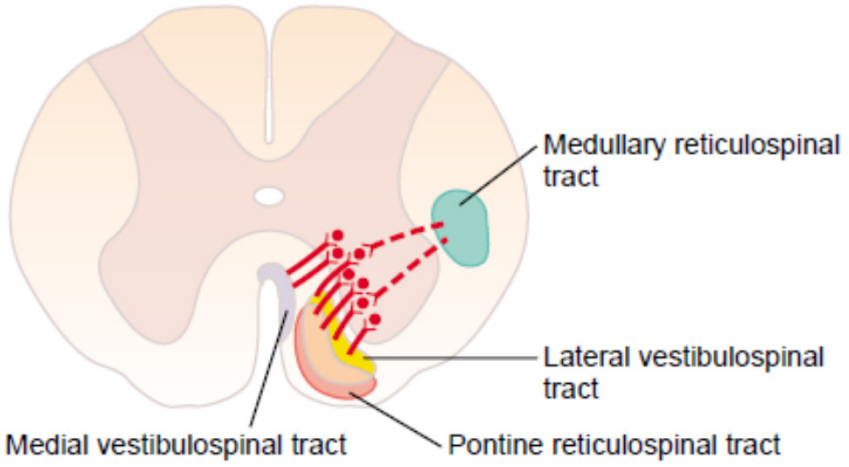


Figure 55–8

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.

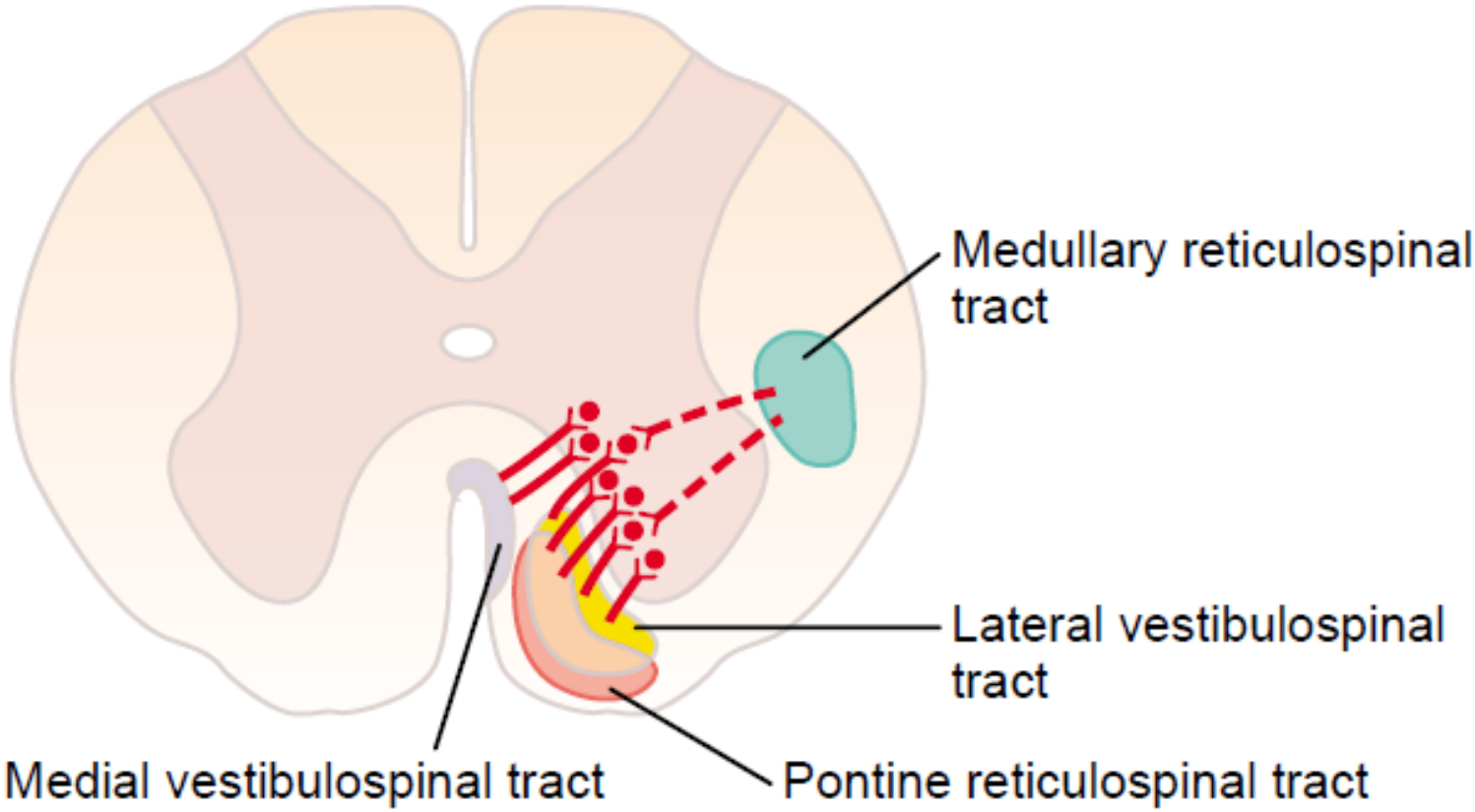


Figure 55–8

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.

Two types of reticulospinal tracts

(1)Pontine (Medial) Reticulospinal Tract(anterior column of spinal cord)

- Transmit excitatory signals downward into the cord→medial anterior motor neurons that excite the axial muscles of the body, which support the body against gravity. In addition, they receive strong excitatory signals from the vestibular nuclei & from deep nuclei of the cerebellum.
- Axons descend in anterior(ventral)white column of spinal cord
- Functions: Excite the antigravity muscles of the body and increases Gamma efferent activity

(2)Medullary (Lateral) Reticulospinal Tract:

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→ activate the medullary reticular inhibitory system to counterbalance the excitatory signals from the pontine reticular system

- Functions: counterbalance the excitatory signals from the pontine reticular system and inhibits Gamma efferent activity

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

Tectospinal tracts

It arises from superior (VISUAL) & inferior colliculi (AUDITORY) of midbrain and Ends on Contralateral cervical motor neurons

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

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

Functions: Exact function is not known but it is belived to be invoved in reflex movements arising from proprioceptors.

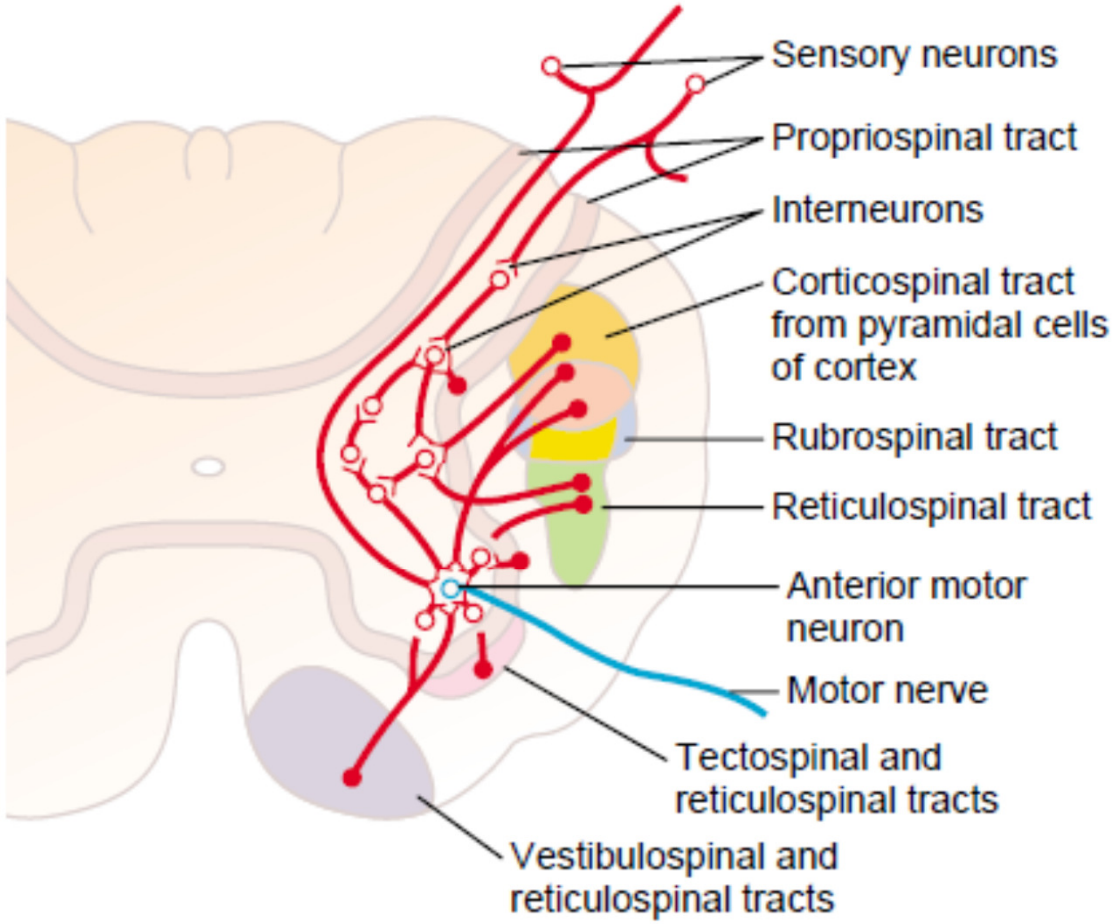


Figure 55–6

Convergence of different motor control pathways on the anterior motor neurons.