神經解剖學
NEUROANATOMY
MOTOR SYSTEM

盧家鋒 助理教授

臺北醫學大學醫學系 解剖學暨細胞生物學科

臺北醫學大學醫學院 轉譯影像研究中心

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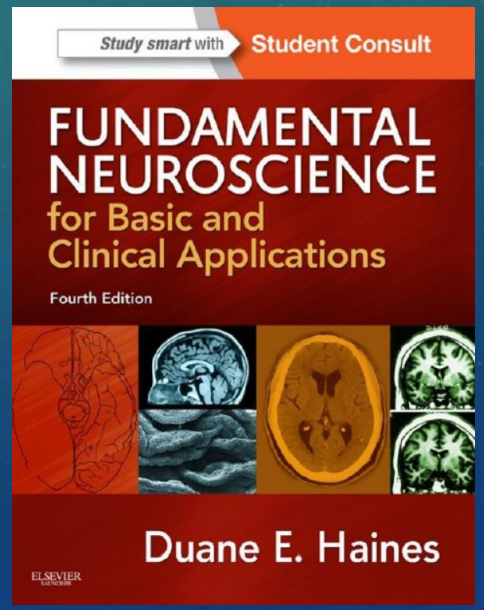
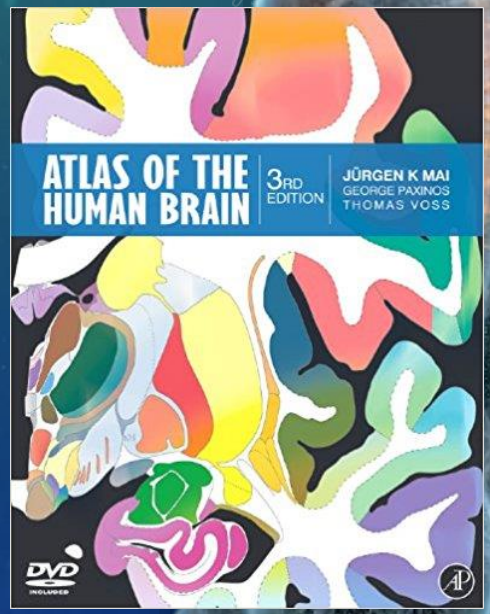
OUTLINE

- Corticofugal Systems
- Motor Cortex and the Control of Movement

- **Fundamental Neuroscience (4th edition)**
  - Chapter 25: Motor System II
- **Atlas of the Human Brain (3rd edition)**





USEFUL ONLINE MATERIALS

- **Neuroanatomy online** (University of Texas):
  - http://nba.uth.tmc.edu/neuroanatomy/index.html
- **BrainInfo** (University of Washington):
  - http://braininfo.rprc.washington.edu/Default.aspx

CORTICOFUGAL SYSTEMS

CORTICOFUGAL SYSTEMS

- **Corticospinal fibers**
  - cerebral cortex → spinal cord
- **Corticonuclear/Corticobulbar fibers**
  - cerebral cortex → medulla and pons (nuclei of cranial nerves)
- **Corticorubral fibers**
  - cerebral cortex → red nucleus of the midbrain
- **Corticoreticular fibers**
  - cerebral cortex → reticular formation of the brainstem
- **Corticopontine fibers**
  - cerebral cortex → pons

CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- Layer V cells of the cerebral cortex
  - Contain a small number of **Betz cells** (large pyramidal neurons, with somata that may reach 100 µm or more)
- Cortical locations
  - **Precentral gyrus** and **anterior paracentral gyrus** (BA 4) – 30% (aka **primary motor cortex, MI**)
  - Premotor and supplementary motor cortices (BA 6) – 29%
  - Postcentral gyrus (BA 3, 1, 2), superior parietal lobule (BA 5 and 7), and portions of the cingulate gyrus – 40%

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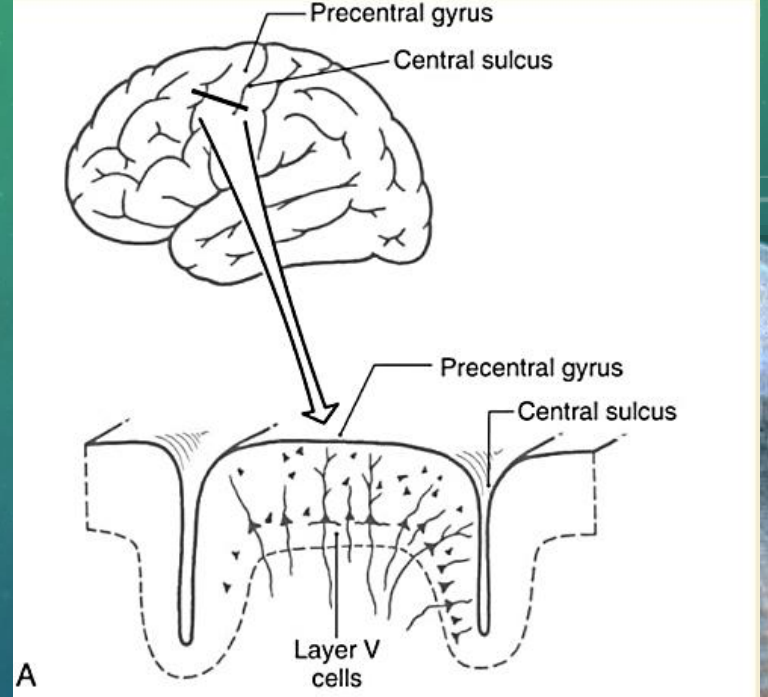
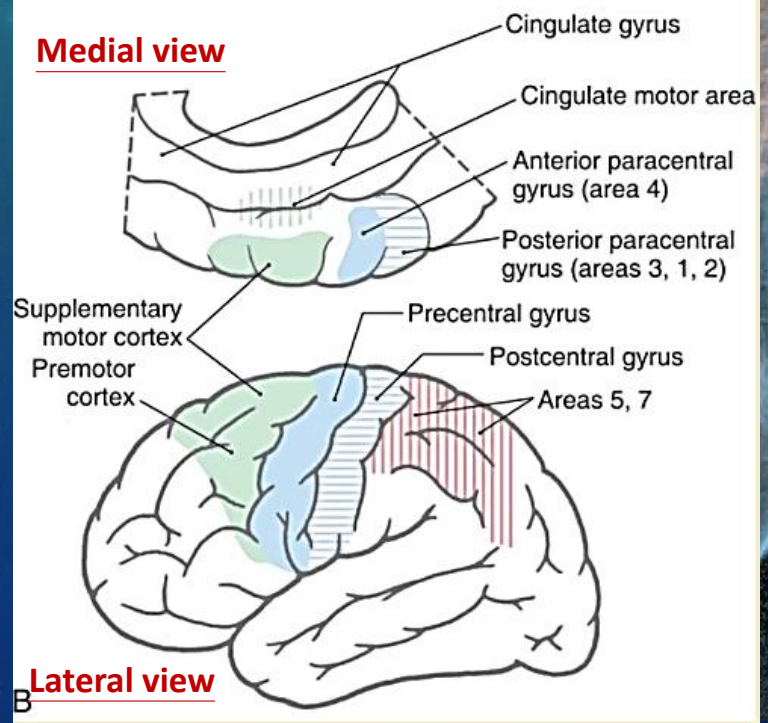
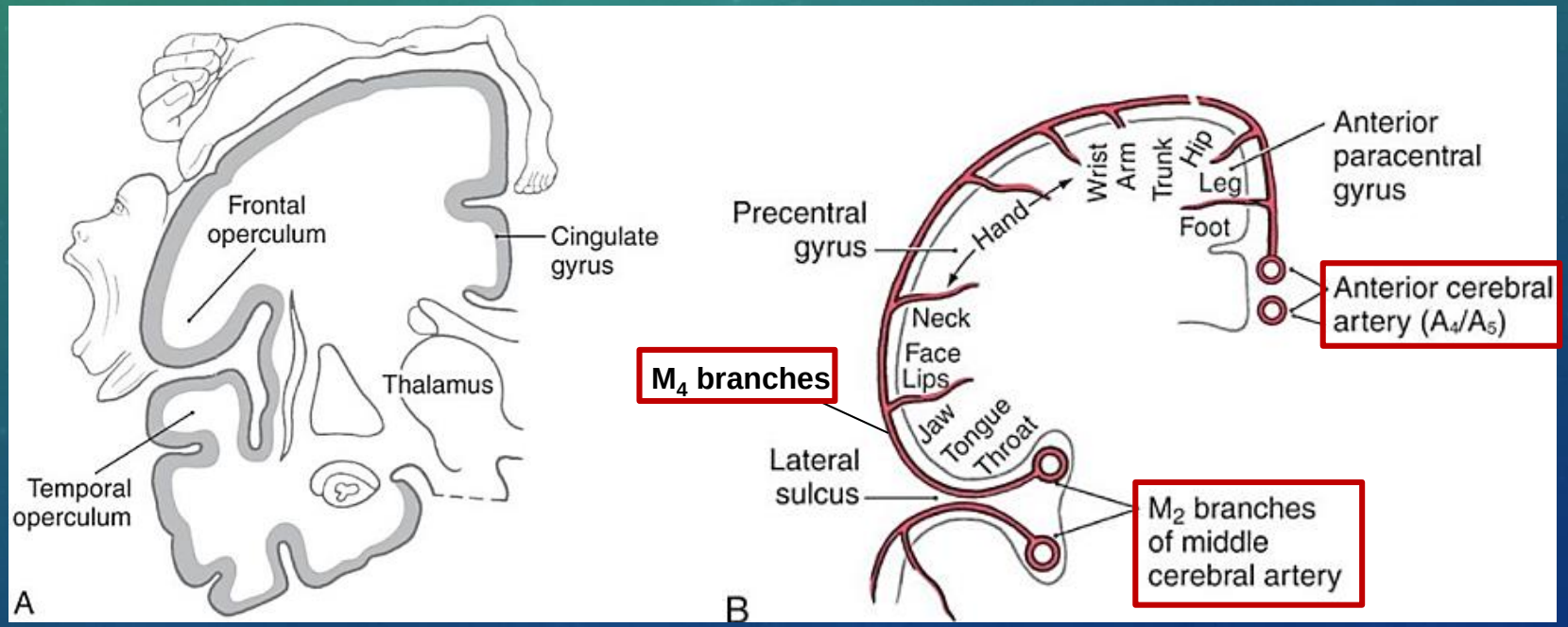




CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- Within MI, corticospinal neurons are somatotopically organized.

Motor Homunculus



CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- The largest axons in the corticospinal tract are myelinated.
  - range from 12 to 15 µm in diameter
  - have conduction velocities up to 70 m/s
  - less than 10% of the total corticospinal population
- Corticospinal fibers pass through the **corona radiata** and converge to enter **the posterior limb of the internal capsule.**

F: face
UE: upper extremity
T: trunk
LE: lower extremity

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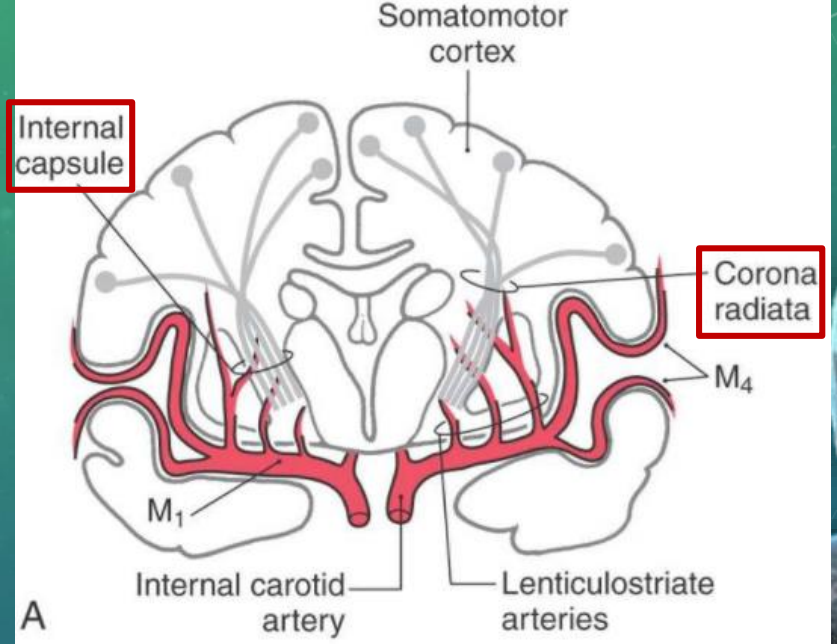

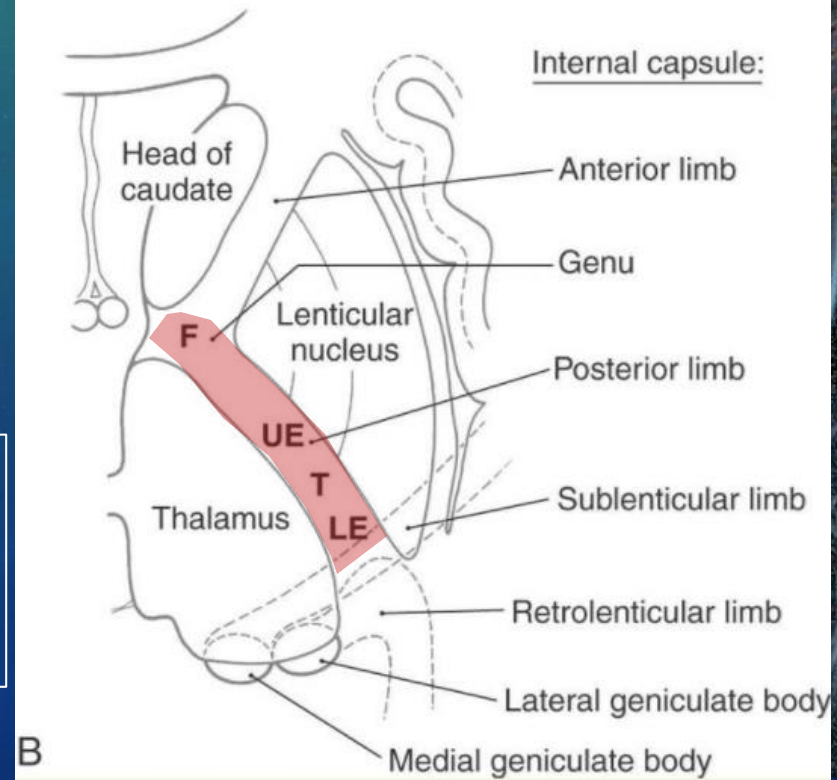

CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- In the midbrain, they coalesce to form the middle third of the cerebral peduncle (crus cerebri).
- Corticospinal fibers continue into the basilar pons, forming the basilar pontine nuclei.
- In the medulla, corticospinal fibers aggregate on the anterior surface of the brainstem, where they course within the medullary pyramids.

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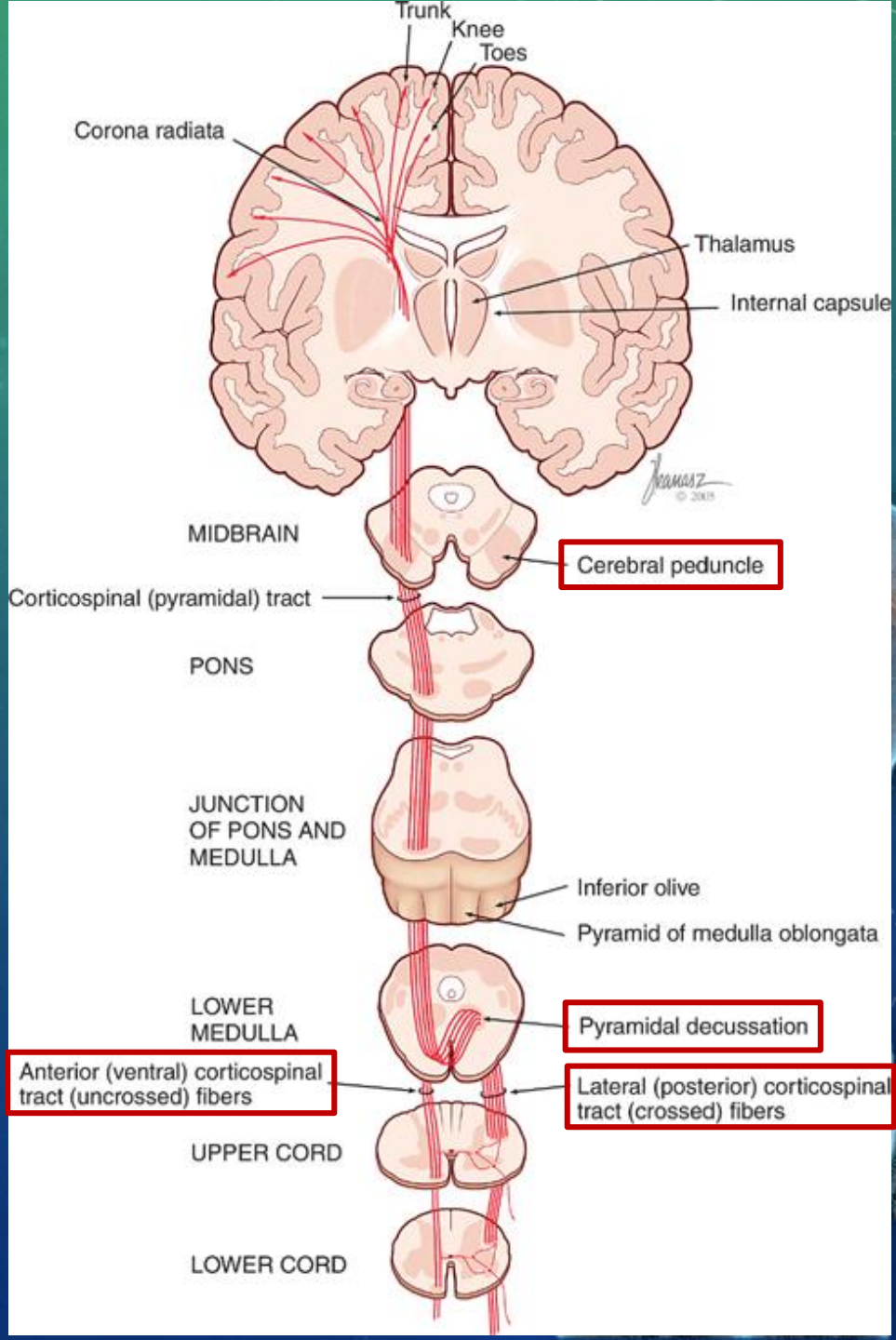

https://neupsykey.com/motor-system/

CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- Fibers from forearm-hand (upper extremity) areas of MI are located medially, whereas those from leg-foot (lower extremity) areas are located laterally.
- At the medullospinal junction, 85% to 90% of the corticospinal fibers cross the midline as the **motor (pyramidal) decussation**.

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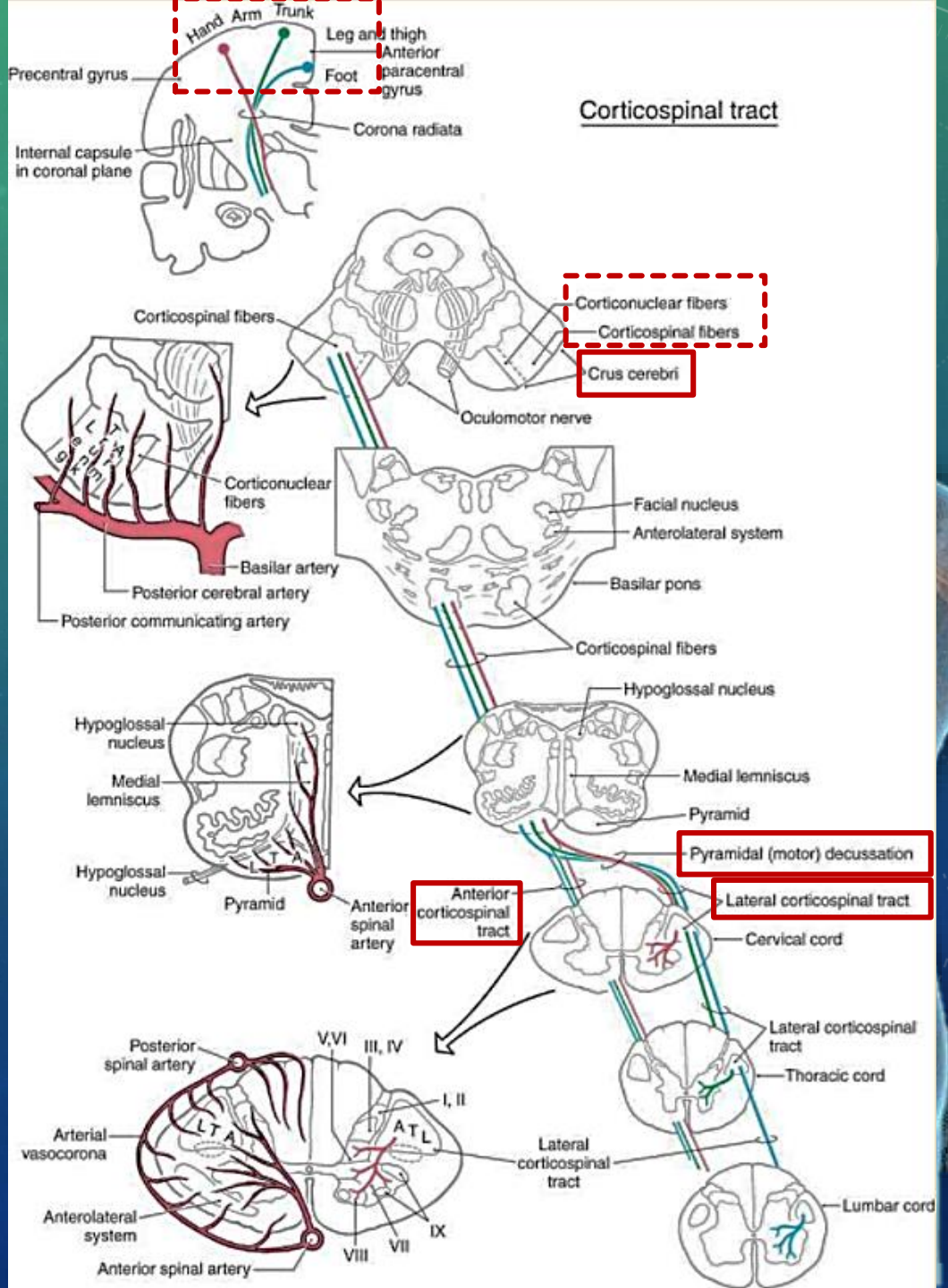
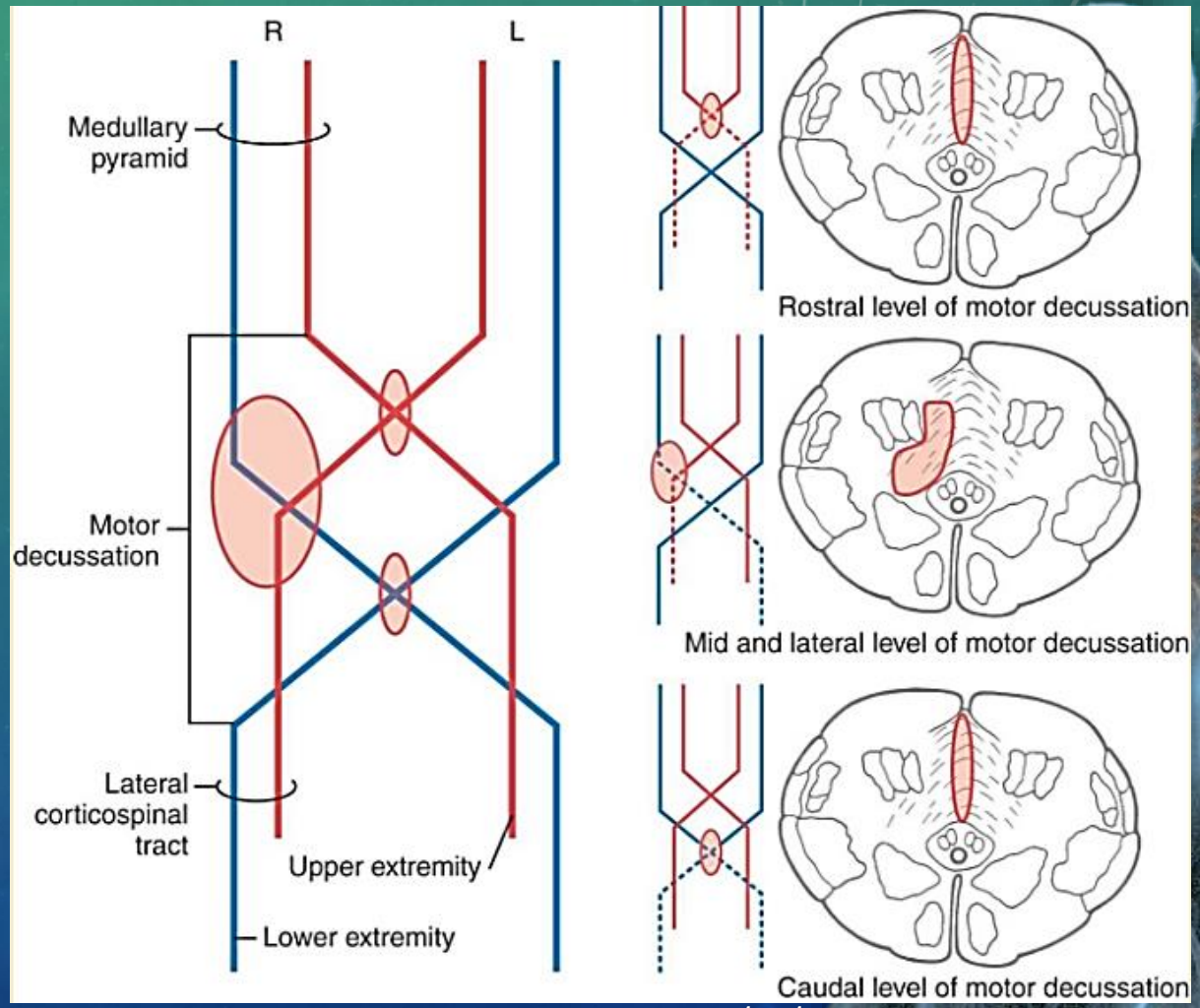


CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- Fibers that originate in the upper extremity portion of the MI cortex cross in rostral portions of the decussation and preferentially terminate in cervical cord levels.
- Fibers that arise in the lower extremity portion of MI cross in the caudal parts of the decussation and terminate primarily in lumbosacral cord levels.



CORTICOSPINAL FIBERS
ORIGIN → COURSE → TERMINATION

- Axons terminating in cervical cord levels are most medial in the lateral corticospinal tract, whereas those distributing to lumbosacral levels are most lateral.
- Termination locations
  - Cervical enlargement (55%)
  - Lumbosacral enlargement (25%)
  - Thoracic level (20%)

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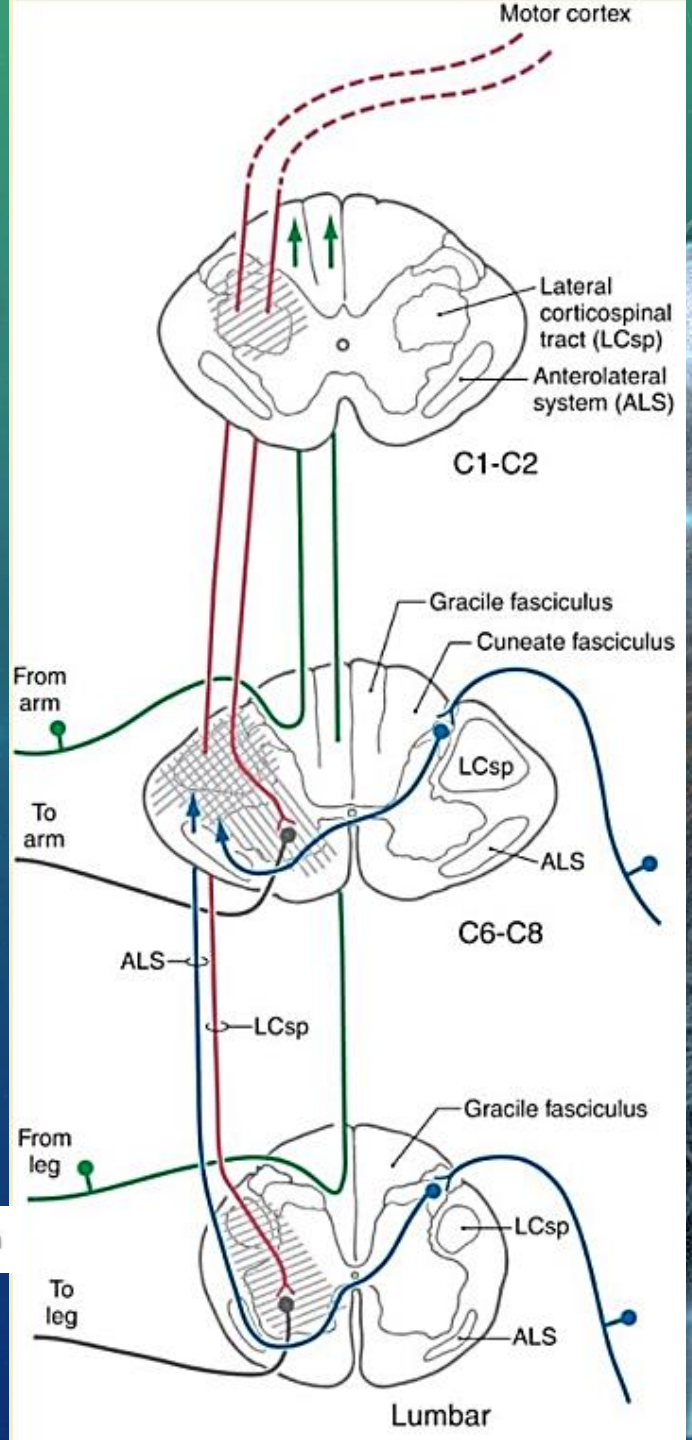
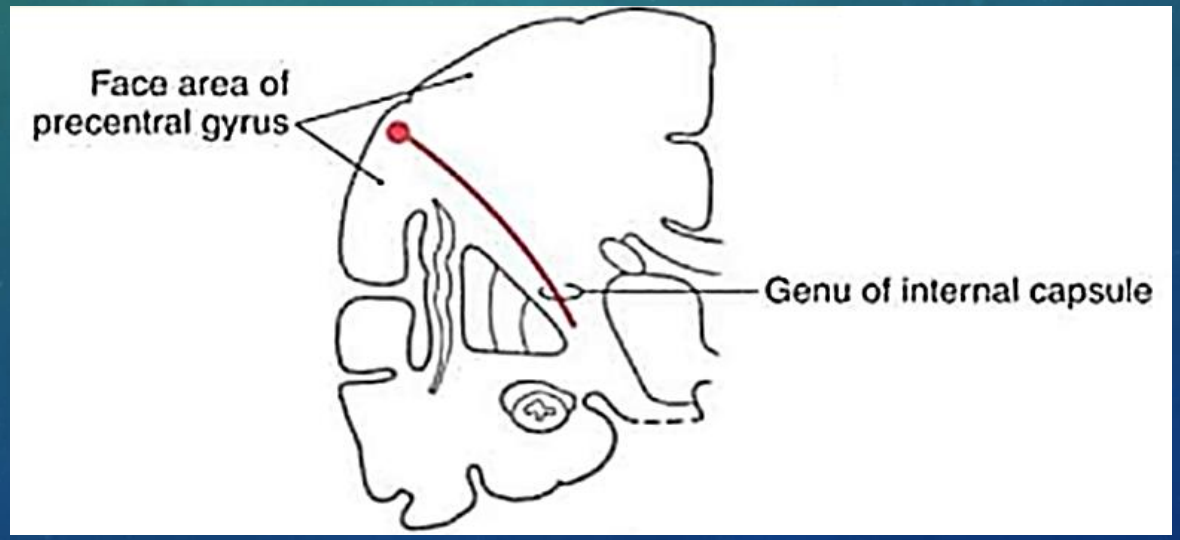


CORTICONUCLEAR/CORTICOBULBAR FIBERS
ORIGIN → COURSE → TERMINATION

- The corticonuclear system originates for the most part from the **face and head area (layer V)** of the precentral gyrus.
- Because most of the musculature innervated by cranial nerves is located in the facial region, this area of MI is typically called **face motor cortex**.



CORTICONUCLEAR/CORTICOBULBAR FIBERS
ORIGIN → COURSE → TERMINATION

- Organized in parallel with the corticospinal fibers.
- Corticonuclear fibers continue into the crus cerebri, where they are located medial to corticospinal fibers traveling to cervical cord levels.

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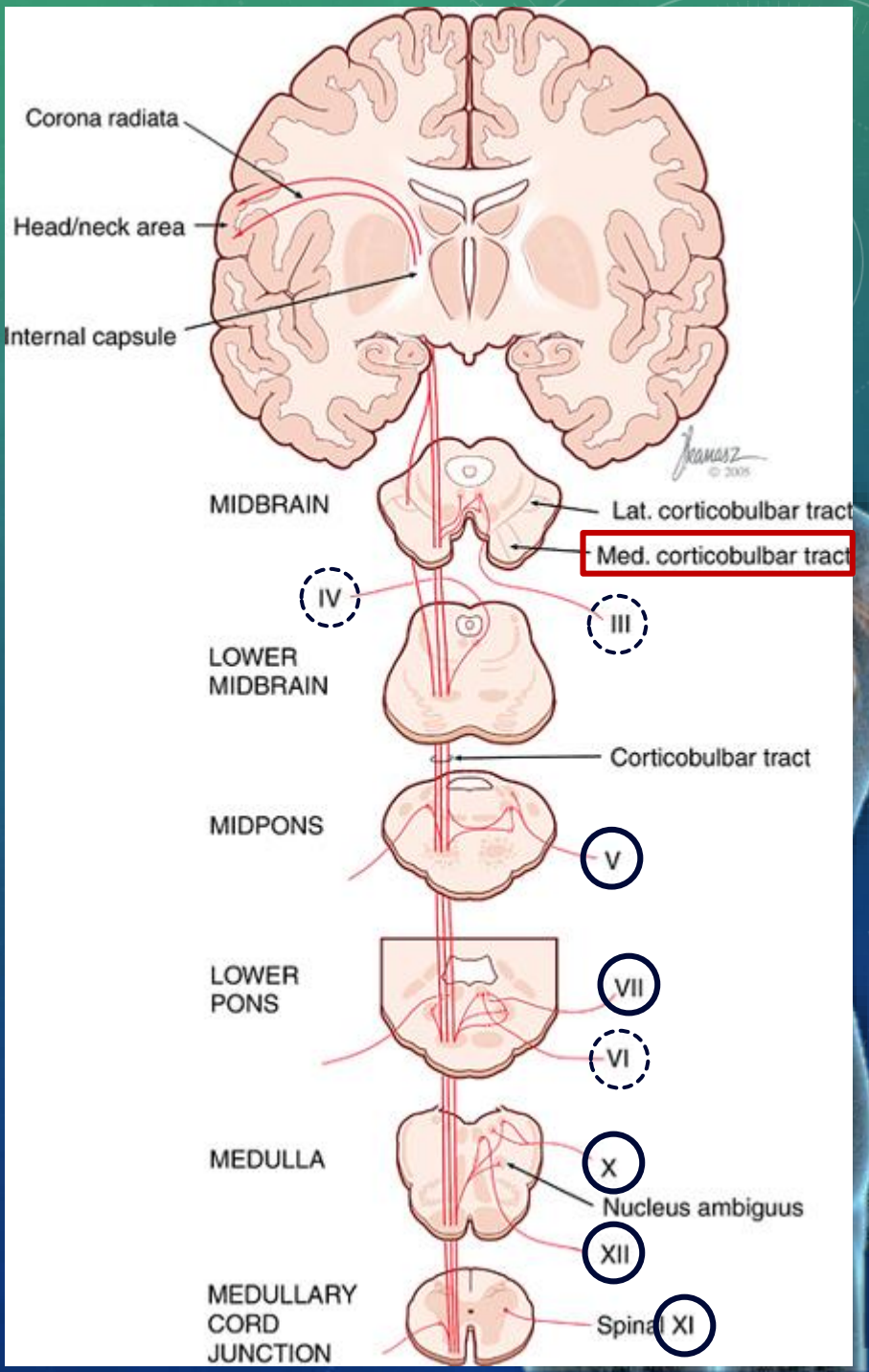
https://neupsykey.com/motor-system/



CORTICONUCLEAR/CORTICOBULBAR FIBERS

ORIGIN → COURSE → TERMINATION

Excluding CN III, IV, VI for eye movement.

Cranial Nerves	Origin/Target	Function
CN V: Trigeminal	Pons	Innervates the muscles of mastication.
CN VII: Facial	Pons	Provides motor innervation to the muscles of facial expression, posterior belly of the digastric muscle, stylohyoid muscle, and stapedius muscle.
CN XII: Hypoglossal	Medulla	Provides motor innervation to the muscles of the tongue and other glossal muscles.
CN IX: Glossopharyngeal	Medulla	Provides motor innervation to the stylopharyngeus.
CN X: Vagus	Medulla	Supplies branchiomotor innervation to most laryngeal and pharyngeal muscles.
CN XI: Accessory	Medullary cord junction	Controls the sternocleidomastoid and trapezius muscles.

https://en.wikipedia.org/wiki/Table_of_cranial_nerves

CORTICONUCLEAR/CORTICOBULBAR FIBERS

ORIGIN → COURSE → TERMINATION

- Compare this figure with the previous table to figure out the termination/innervation of corticonuclear fibers on cranial nerves.
- The majority of the cranial nerve nuclei are innervated by **both crossed and uncrossed fibers**. Therefore, when one fiber is injured, innervation from the uninjured side (either crossed or uncrossed) still exists, and a deficit may not be observed.

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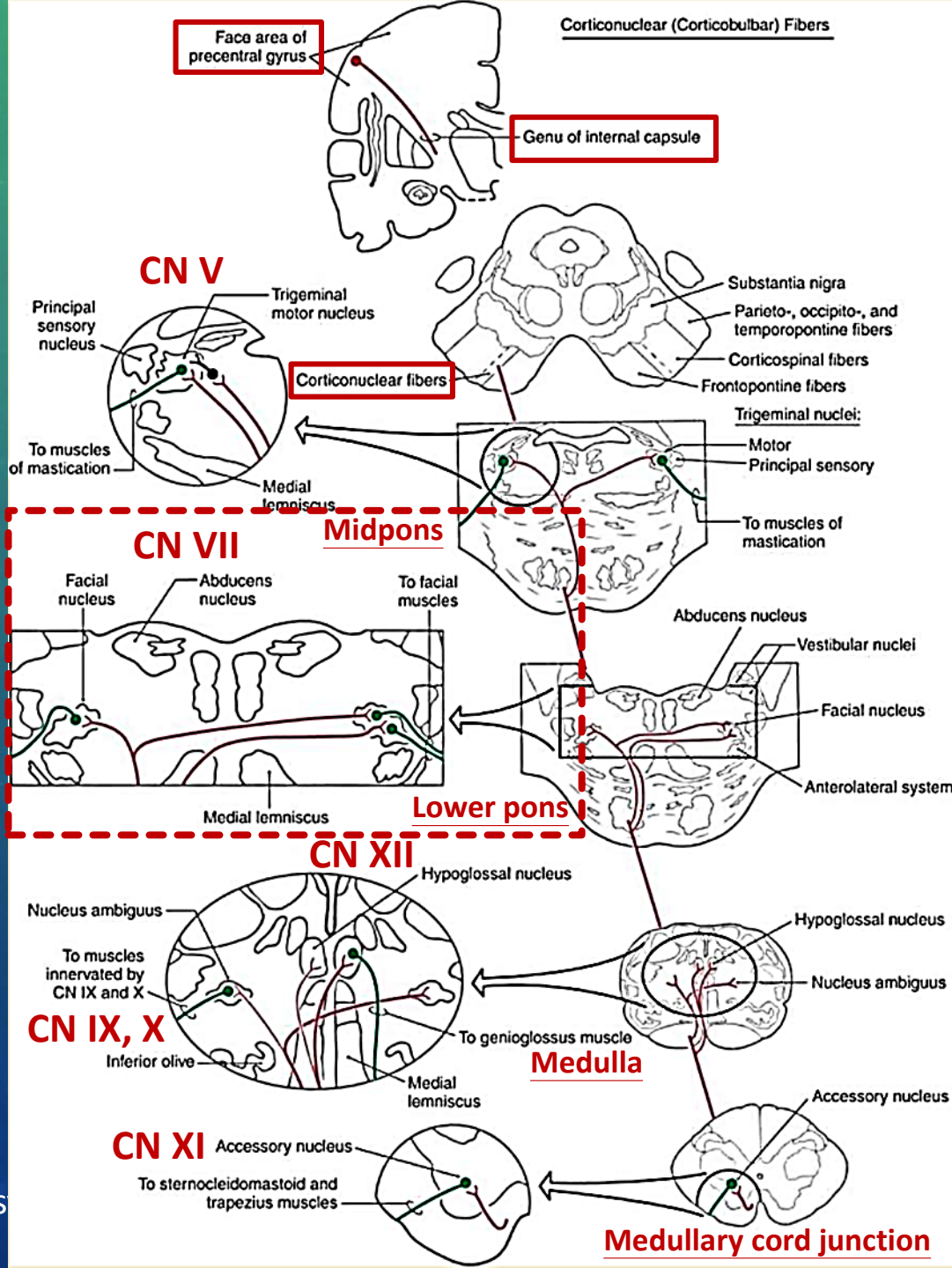
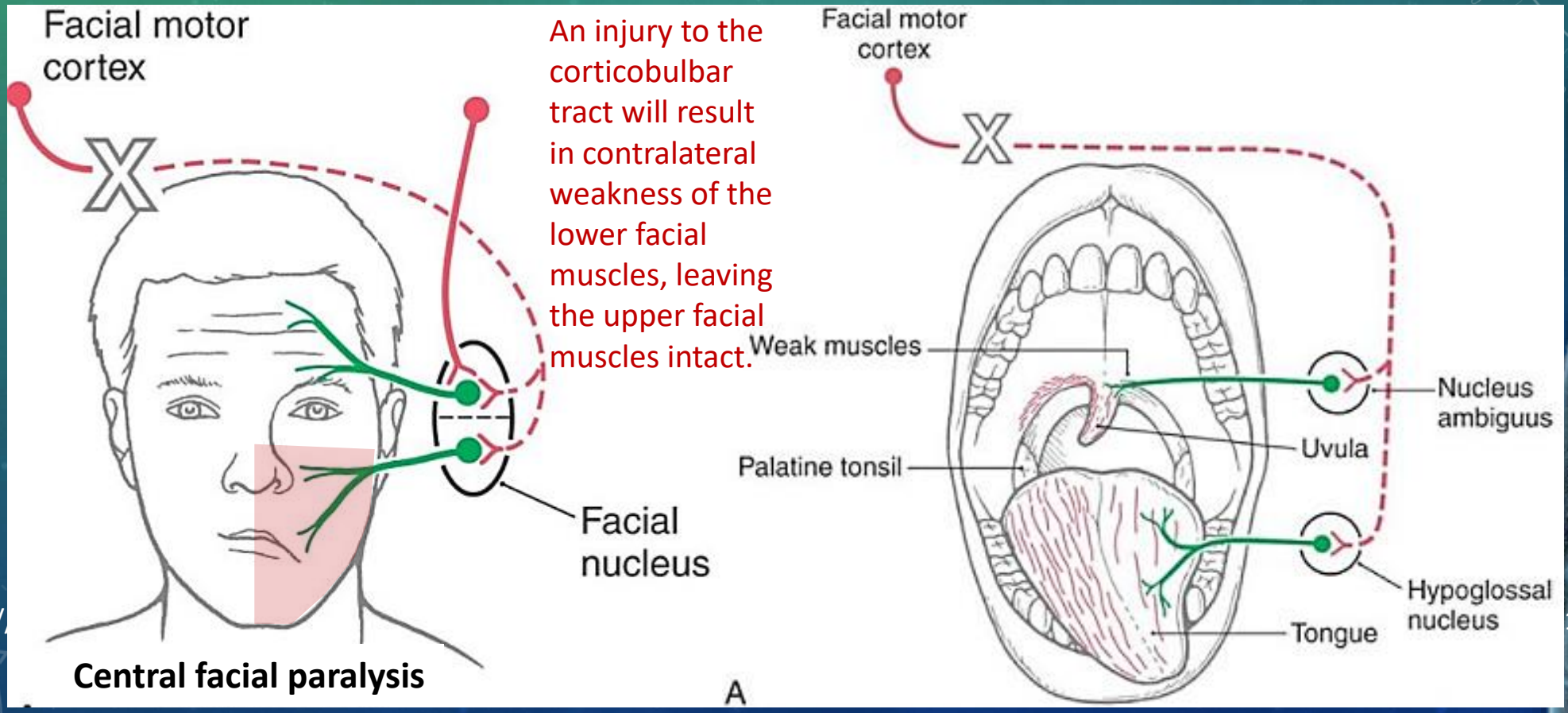
https://neupsykey.com/motor-s



LESIONS OF CORTICONUCLEAR FIBERS

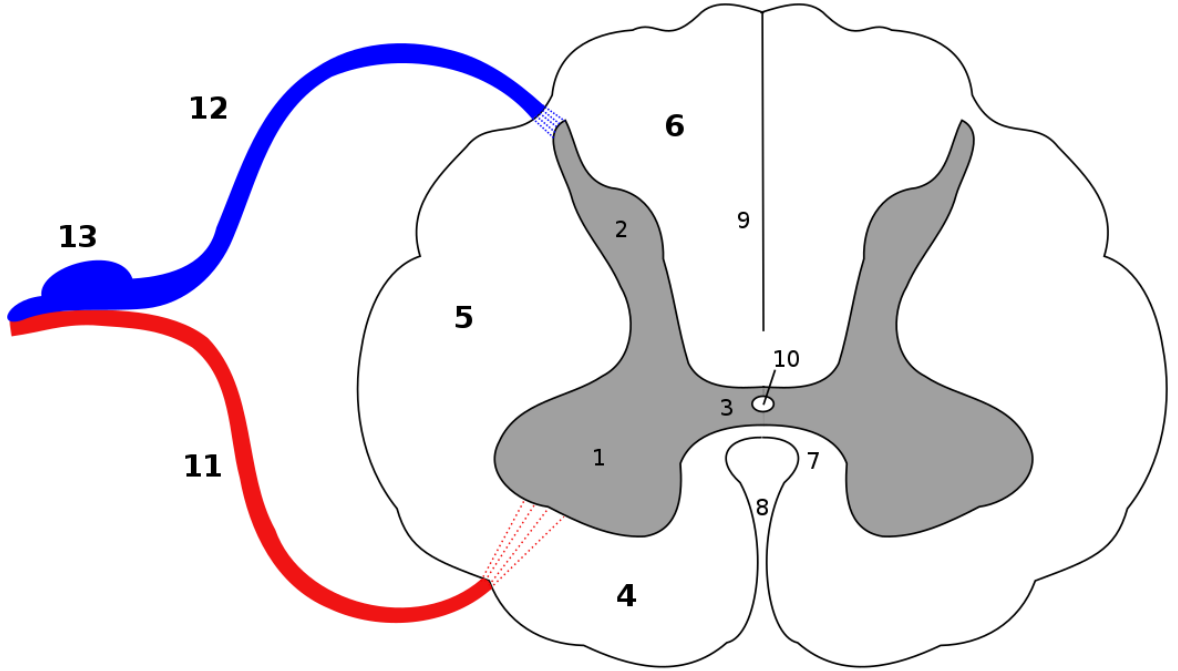
An important exception to this is the **facial nucleus**.

- The facial nucleus that innervates the lower facial muscles is supplied by crossed upper motor neuron fibers only.
- The facial nucleus that subserves the upper facial muscles receive both crossed and uncrossed fibers.



QUICK REVIEW OF SPINAL CORD

- Anterior horn (anterior grey column)
  - contains motor neurons that affect the skeletal muscles.
- Posterior horn (posterior grey column)
  - receives information regarding touch and sensation.



Gray matter

1. Anterior horn
2. Posterior horn
3. Gray commisure

White matter

4. Anterior funiculus
5. Lateral funiculus
6. Posterior funiculus
7. Anterior commisure
8. Anterior median fissure
9. Posterior median sulcus
10. Central canal
11. Anterior root
12. Posterior root
13. Dorsal root ganglion

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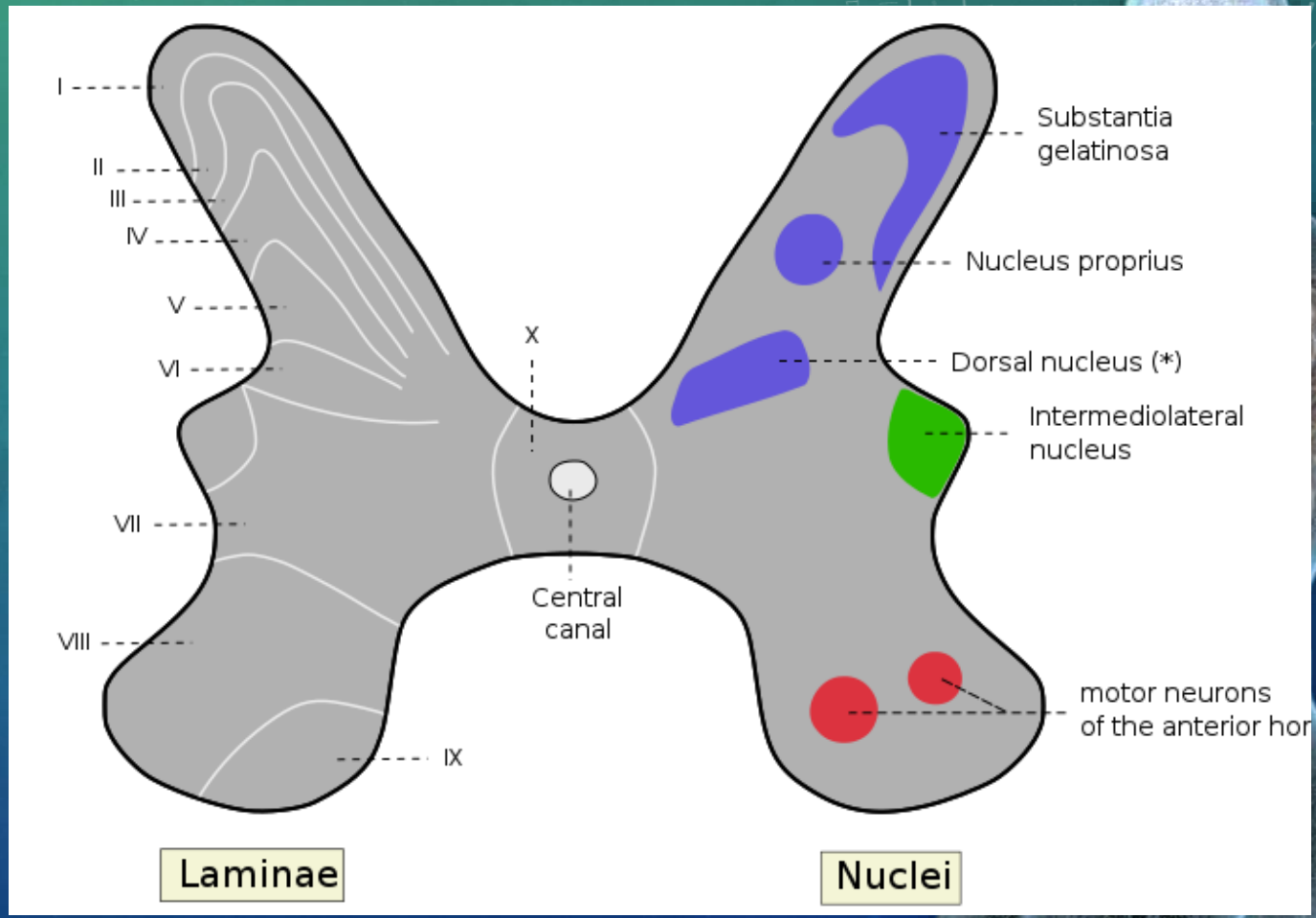
https://en.wikipedia.org/wiki/Anterior_grey_column

MOTOR NEURONS OF SPINAL CORD

- Alpha motor neurons
  - locate in lamina IX
  - innervate **extrafusal muscle** for initiating their contraction.
- Beta motor neurons
  - innervate **intrafusal fibers** of muscle spindles.
- gamma motor neurons
  - keep muscle spindles taut, thereby allowing the continued firing of alpha neurons, leading to muscle contraction.

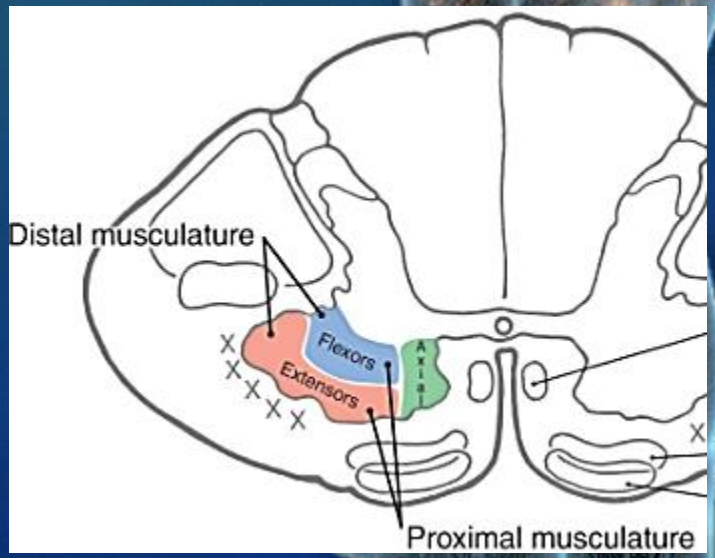


https://en.wikipedia.org/wiki/Alpha_motor_neuron

GENERAL FEATURES OF MOTOR NEURONS

- Upper motor neurons
  - Primary motor cortex
  - Corticospinal cell bodies and their axons
  - Corticonuclear cell bodies and their axons
- Lower motor neurons
  - Anterior horn motor neurons
  - Cranial nerve motor neurons

Final common path that links the central nervous system with skeletal muscles.



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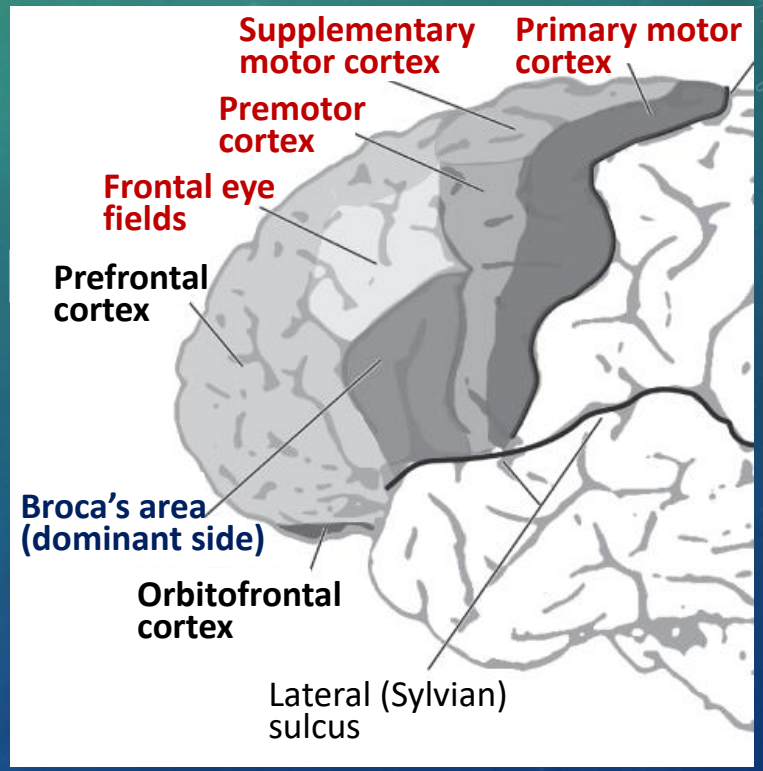
GENERAL FEATURES OF MOTOR DEFICITS

Upper motor neuron signs	Lower motor neuron signs
Muscles are **initially weak** and **flaccid** but eventually become **spastic.**	**Flaccid paralysis** followed eventually by **atrophy.**
Exhibit increased muscle tone (**hypertonia**), seen as an increase in resistance to passive movement of an extremity.	**Fibrillations** or **fasciculations** (involuntary contractions of one motor unit or a group of motor units).
Show an increase in muscle stretch reflexes (**hyperreflexia**).	**Hypotonia** (decreased muscle tone).
Usually **affect groups of muscles.**	Weakening or absence of muscle stretch reflexes (**hyporeflexia, areflexia**).

MOTOR CORTEX AND THE CONTROL OF MOVEMENT

THE CONTROL OF MOVEMENT

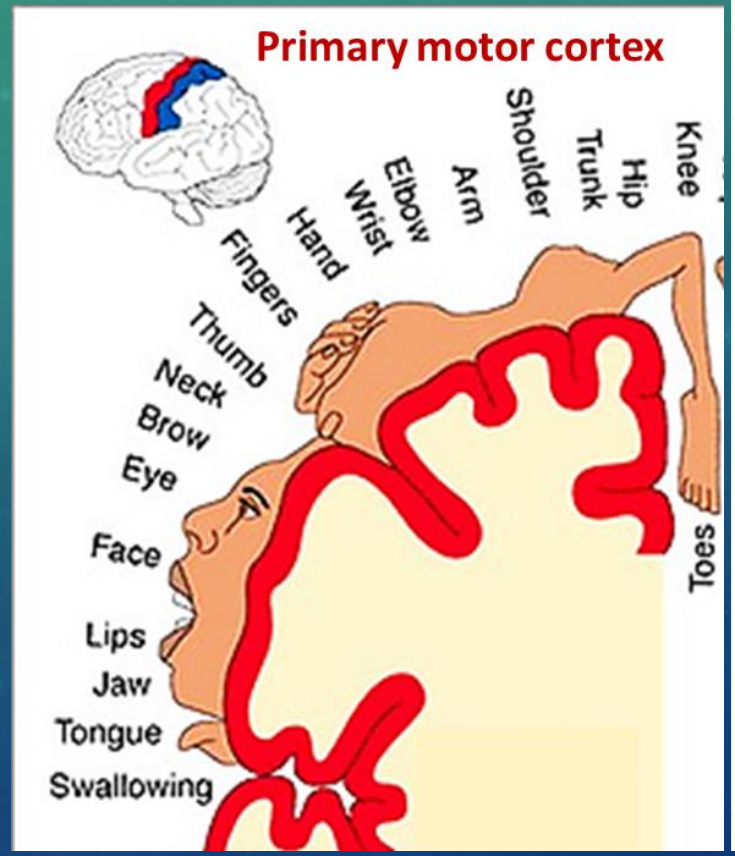
- Primary Motor Cortex (MI)
- Supplementary Motor Cortex (SMC)
- Premotor Cortex (PMC)
- Posterior Parietal Cortex (PPC)
- Cingulate Motor Cortex
- Cerebellar and Pallidal Influences

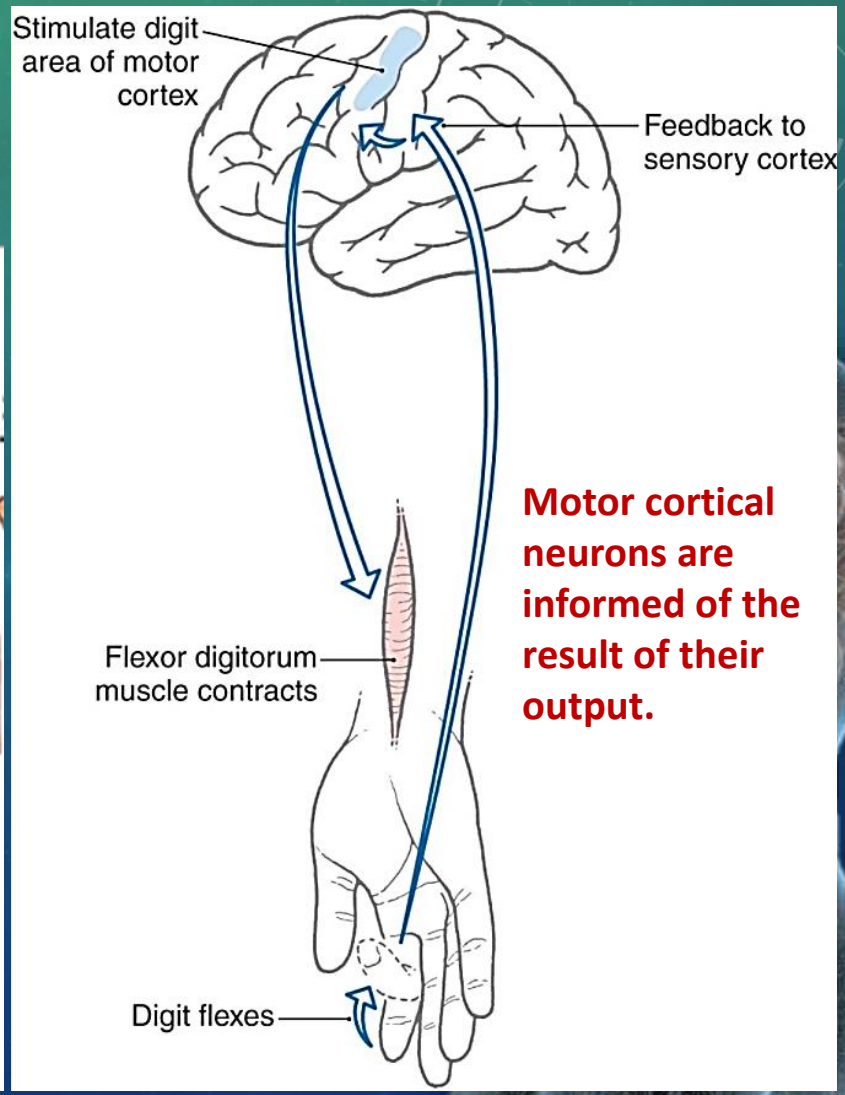


PRIMARY MOTOR CORTEX (MI)

- MI is organized into a series of modules or **vertical columns**.
- Microstimulation of specific vertical columns in MI can result in movements of individual muscles.

May be oversimplified!



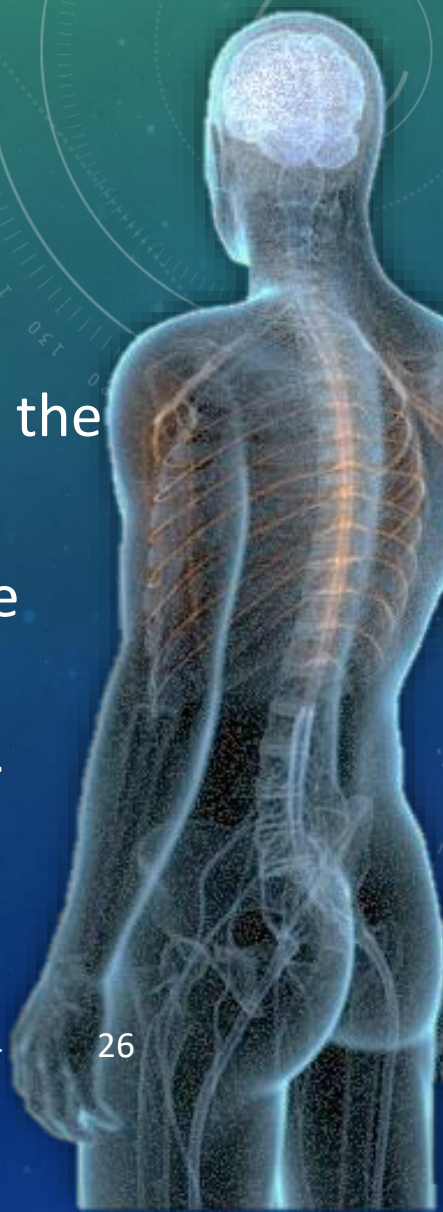


PRIMARY MOTOR CORTEX (MI)

- Motor Functions
  - Induce flexion or extension.
  - Determine the amount of force required to make the movement.
  - Encode the movement direction.

SUPPLEMENTARY MOTOR CORTEX (SMC)

- It contains a map of the body musculature that is complete although **less precisely organized** than that of MI.
- It receives **input from the parietal lobe** and projects to MI and directly to the reticular formation and spinal cord.
- These movements involve **sequences or groups of muscles** and orient the body or limbs in space.
- **Stimuli of higher intensities** are required to activate supplemental motor cortex.



SUPPLEMENTARY MOTOR CORTEX

- Random movements made without prior planning and in no particular order → activation of MI (A).
- When the movement is planned and executed in a specific sequence → activations of MI and SMC (B).
- When the movement is mentally planned but never executed → activations of SMC (C).

Organizing or **planning** the sequence of muscle activation.

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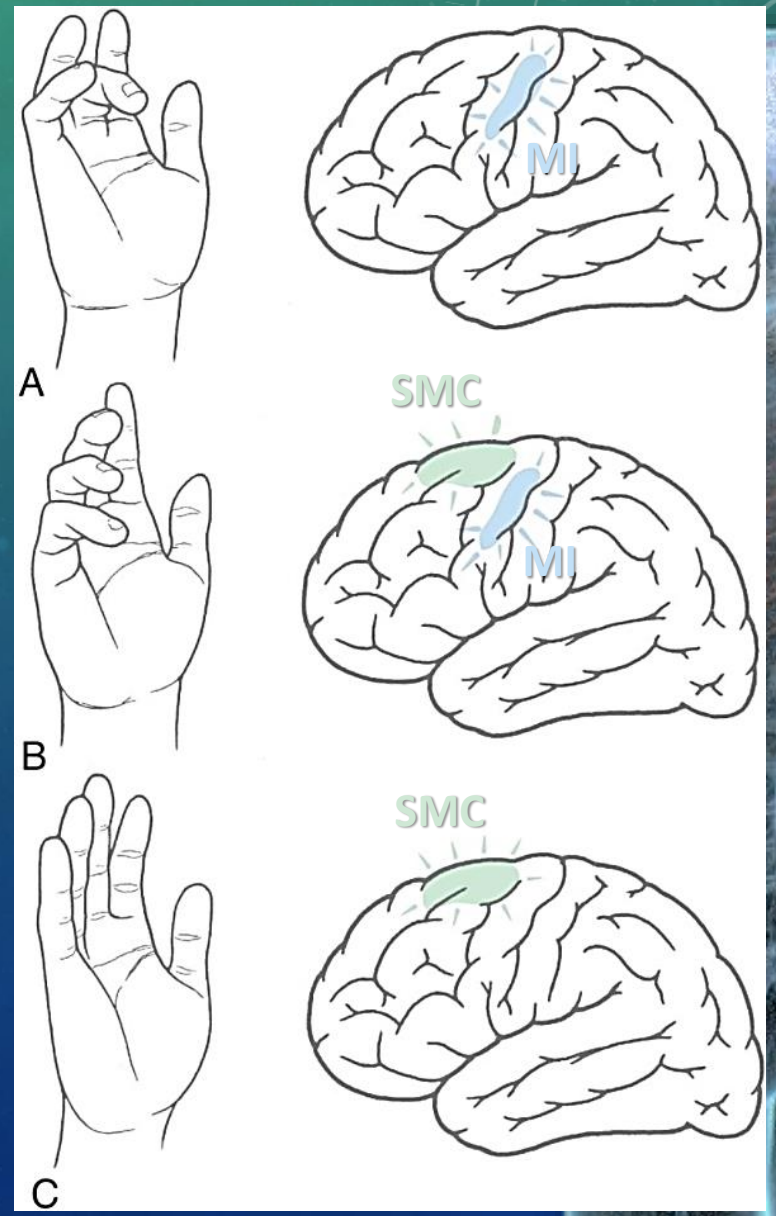


PREMOTOR CORTEX (PMC)

- It contains a map of the body musculature that is complete although **less precisely organized** than that of MI.
- PMC is involved in the **preparation to move**.
- It organizes those **postural adjustments** that are required to make a movement.
- PMC is most active in directing the control of proximal limb muscles that are used to position the arm for movement tasks or, more generally, to orient the body for movement.

POSTERIOR PARIETAL CORTEX (PPC)

- These areas carry out some of the “background computations” necessary to make movements in space.
- it is necessary to integrate input from a variety of sensory systems to create a map of space and to compute a trajectory by which a body part can reach its target.
  - BA 5 ← somatosensory cortex and vestibular system.
  - BA 7 ← visual information.

CINGULATE MOTOR CORTEX

- Little is known about the functional role of these areas, other than that stimulation in either area produces motor effects.

- these motor neurons may be involved in movements that have an **intense motivational or emotional component**.

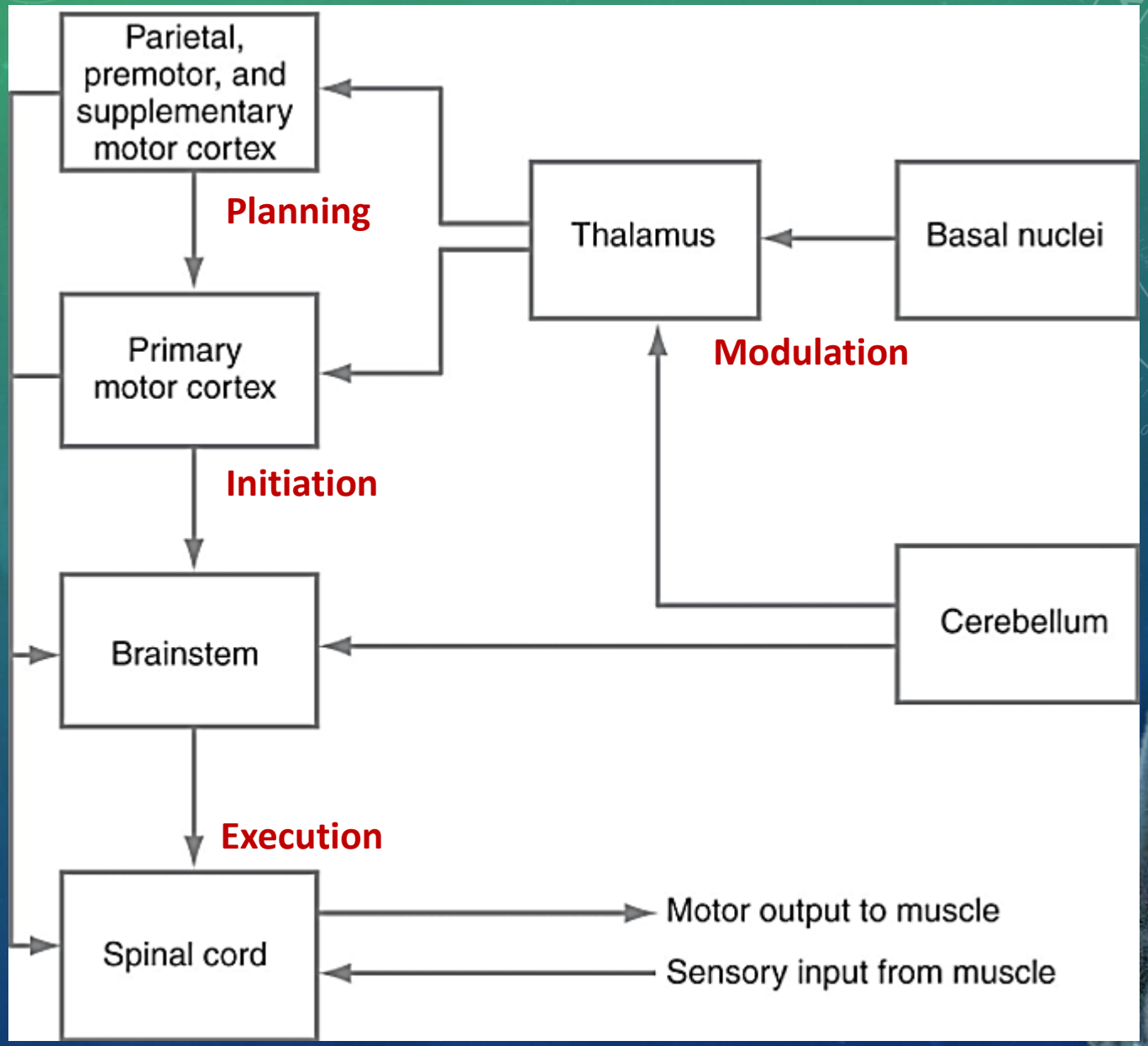
CEREBELLAR AND PALLIDAL INFLUENCES

- The cerebellar nuclei and the globus pallidus each project primarily to their own spatially segregated regions in the ventral anterior, ventral lateral, and oral parts of the ventral posterolateral nuclei of the dorsal thalamus.

- Globus pallidus → thalamic nuclei → supplementary motor cortex.
- Cerebellum → thalamic nuclei → MI.

Modulation of movments.

MOTOR SYSTEM HIERARCHY



THE END

ALVIN4016@TMU.EDU.TW (TMU EXT. 3273)