

ORGANIZATION OF THE CNS

- SPINAL CORD -

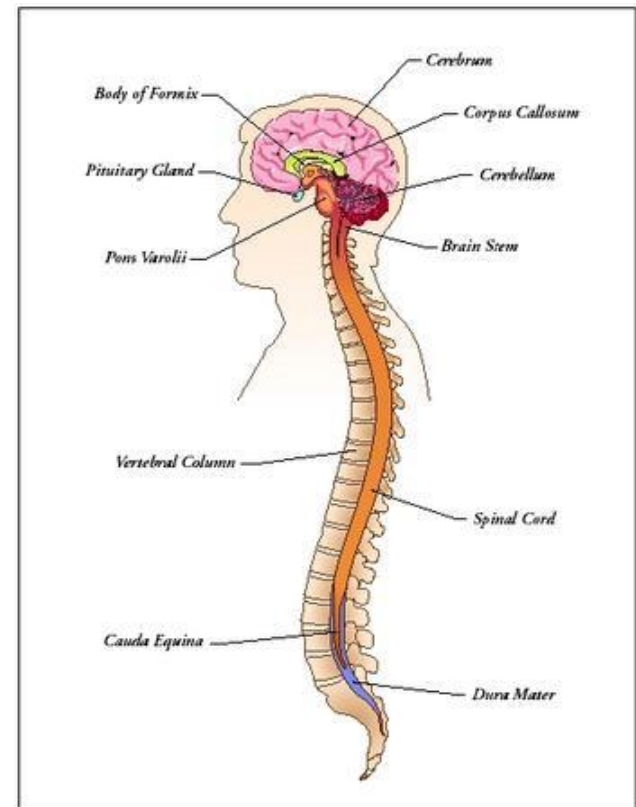


Ivana Pavlinac Dodig, M.D., Ph.D.

Organization of the CNS

- Spinal cord -

1. Organization of the CNS
2. Spinal cord
3. Pathways of the spinal cord
 1. Long ascending tracts
 2. Long descending tracts
4. Spinal cord in cross sections



Organization of the CNS

Grey and White Matter

Grey Matter = Cell Body



White Matter = Myelinated axon

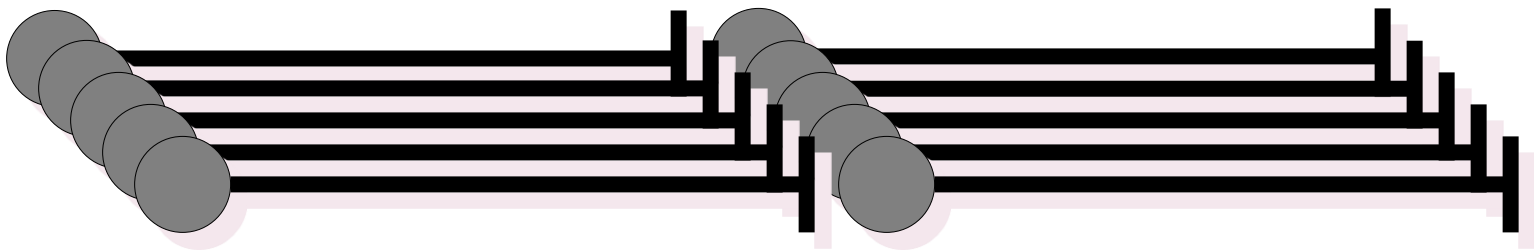
Grey Matter

- Cortex
- Nucleus (CNS)
- Ganglion (PNS); exception: Basal Ganglia



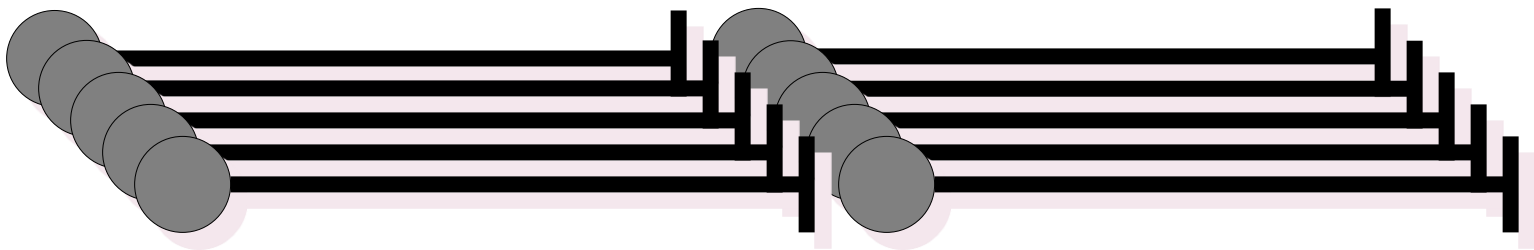
White Matter

- Nerve (PNS)
- Tract (CNS)
- Fasciculus/Funiculus = group of fibers with common origin and destination
- Lemniscus = ribbon-like fiber tract
- Peduncle = massive group of fibers (usually several tracts)

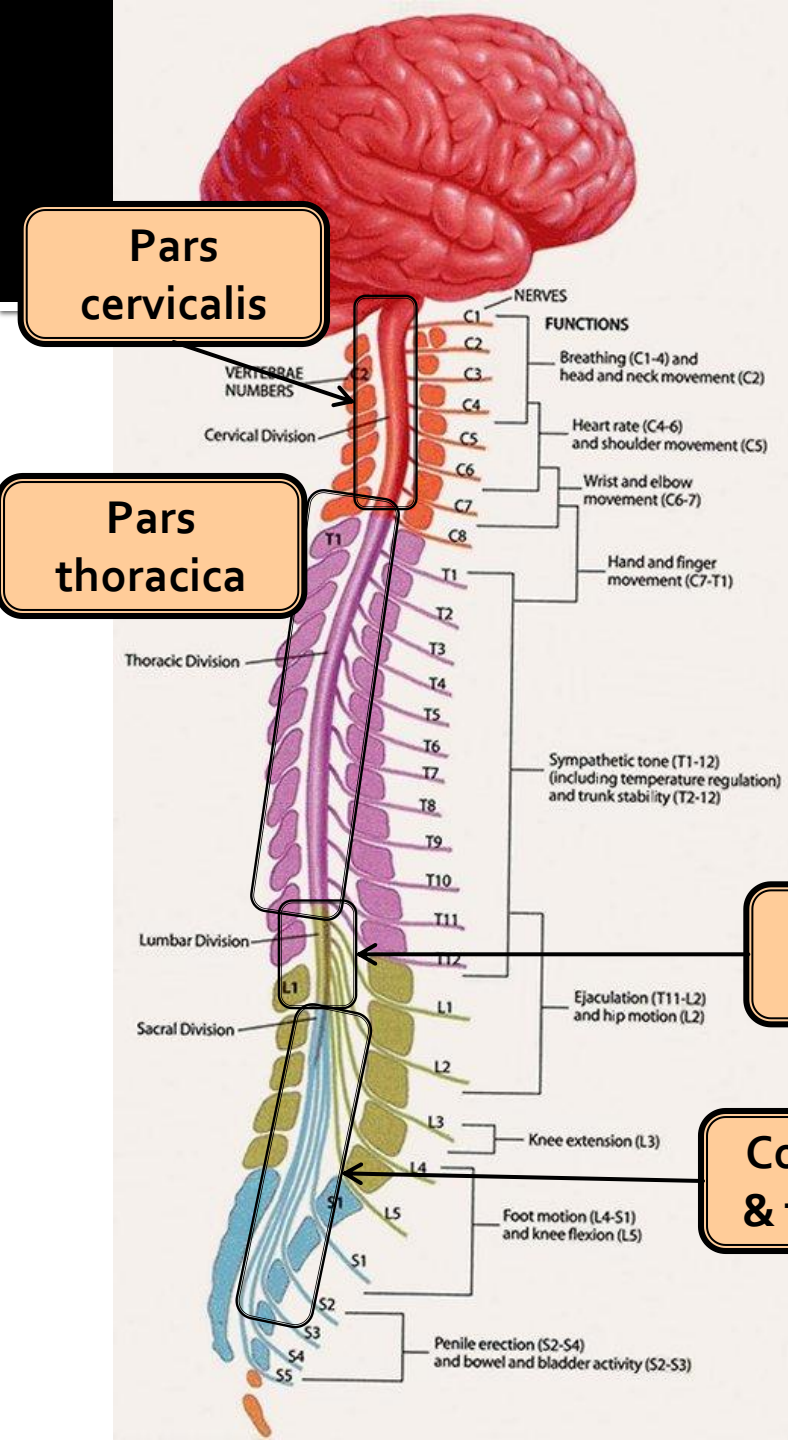


Grey and White Matter

- Tracts are named with origin first, then destination
 - Corticobulbar tract
 - Corticospinal tract
 - Spinocerebellar tract
 - Mammillothalamic tract



Spinal cord



Pars cervicalis

Pars thoracica

Pars lumbalis

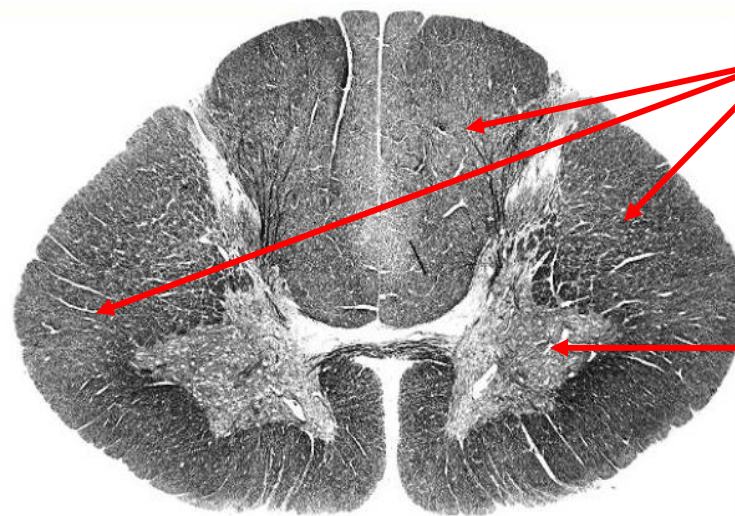
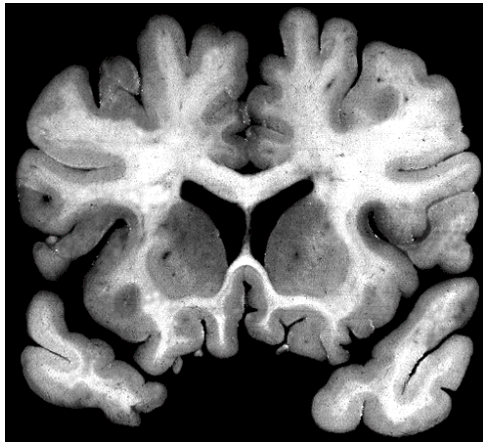
Conus medullaris & filum terminale

- Spinal cord is **SMALL!**
 - 40-45 cm long
 - 1 cm wide at widest point
 - Does not extend all the way to the bottom of the spinal column
 - From foramen magnum to intervertebral disc (L1-L2); continues as filum terminale (to sacral canal)

- Upper 2/3 of the vertebral column

Spinal cord - General Organization

- Pattern of grey/white matter is reversed in the cord
 - White matter tracts on outside
 - Grey matter on the inside
 - Staining reverses this!!!



White matter
(tracts of axons)

Grey matter
(cell bodies)

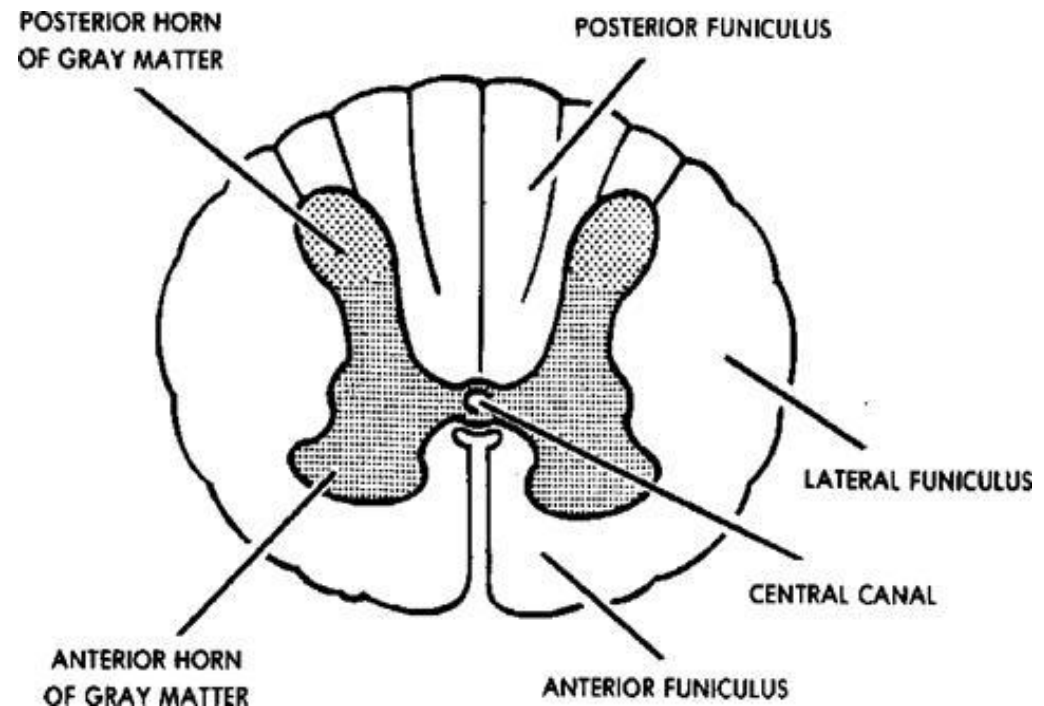
Internal structure of spinal cord

White matter - funiculi:

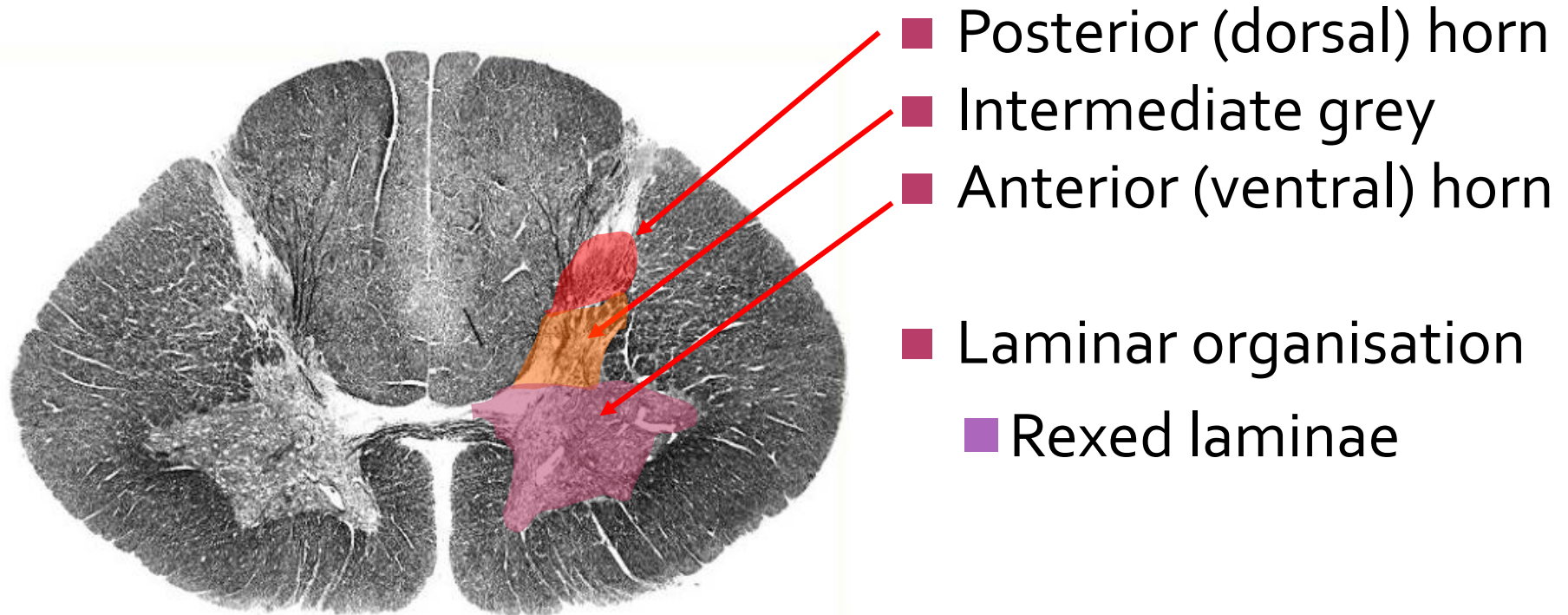
- Dorsal (posterior)
- Lateral
- Ventral (anterior)

Gray matter – butterfly shaped – horns:

- Anterior
- Posterior
- Intermediolateral cell column (IML)

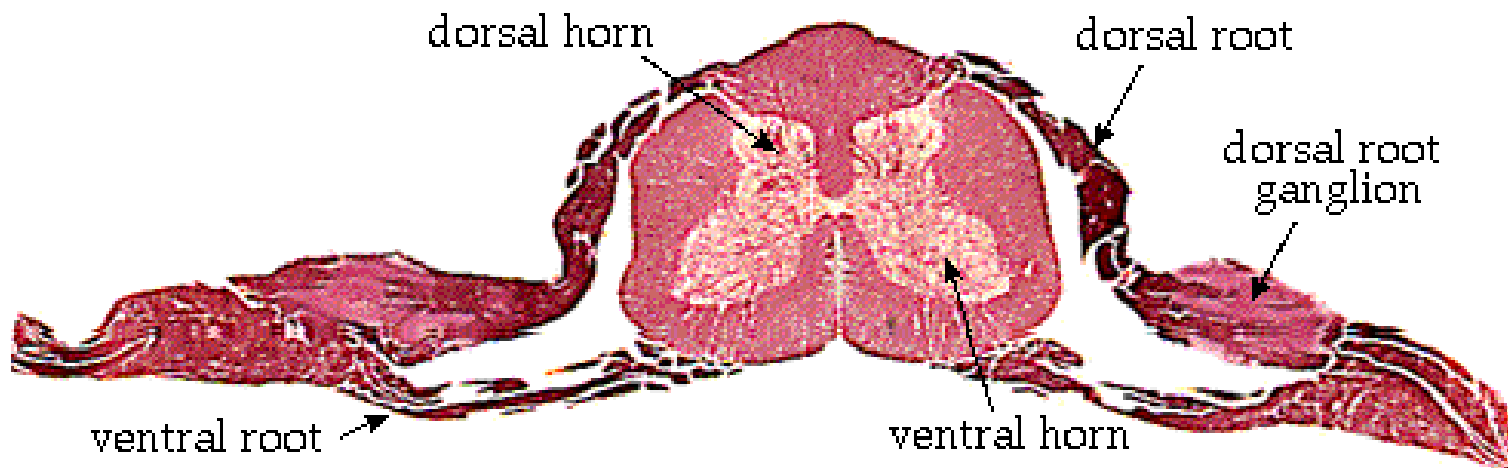


Grey Matter



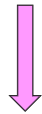
Spinal cord - general organization

- Spinal cord is segmented anatomically
- Input and output occurs in groups of rootlets arranged in a series longitudinally along the cord
 - Dorsal rootlets = Input (carry sensory information)
 - Ventral rootlets = Output (motor neurons)

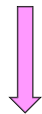


Spinal cord to spinal nerves

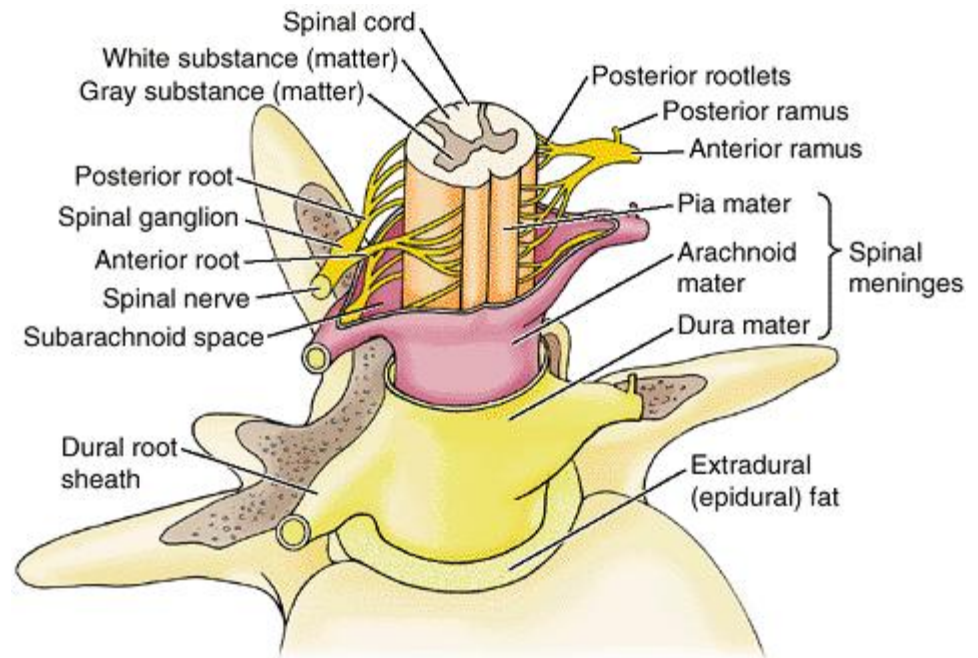
Dorsal and ventral roots

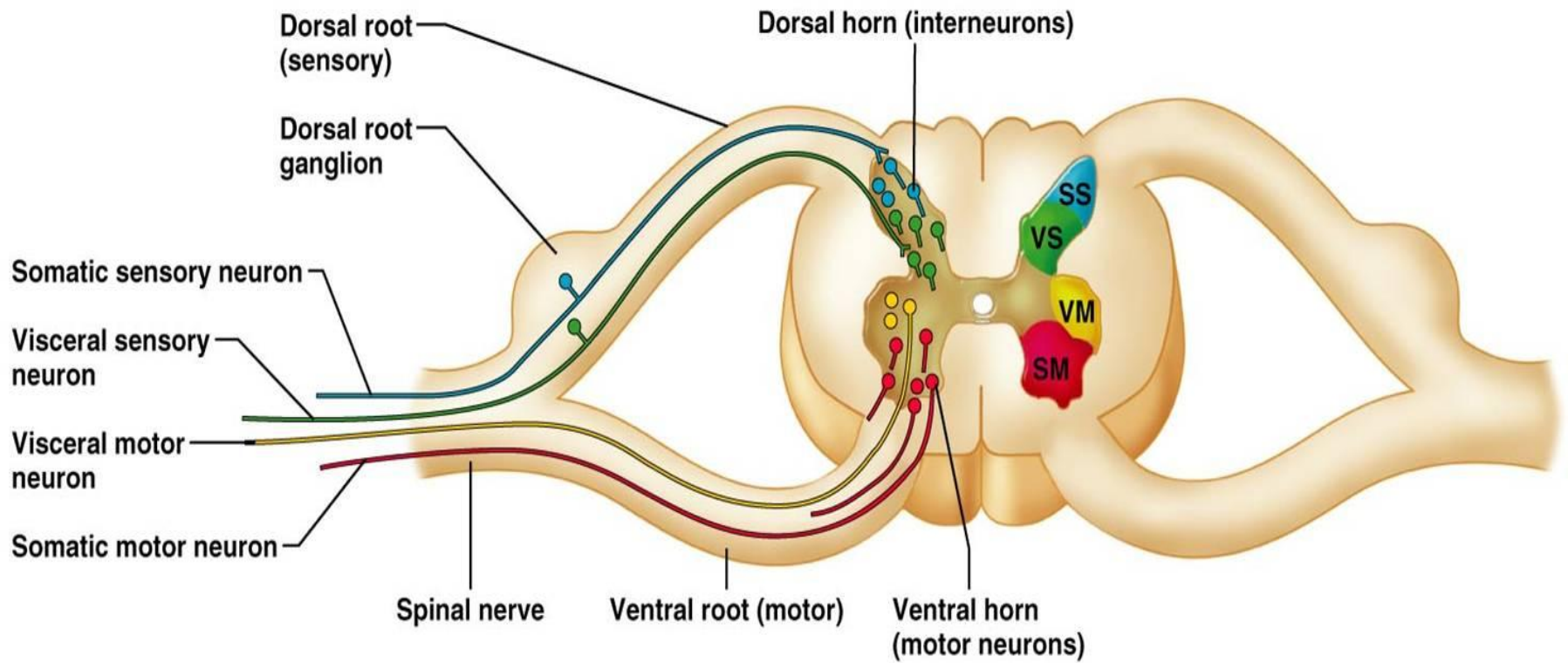


Common spinal nerve trunk
(1-2 mm)



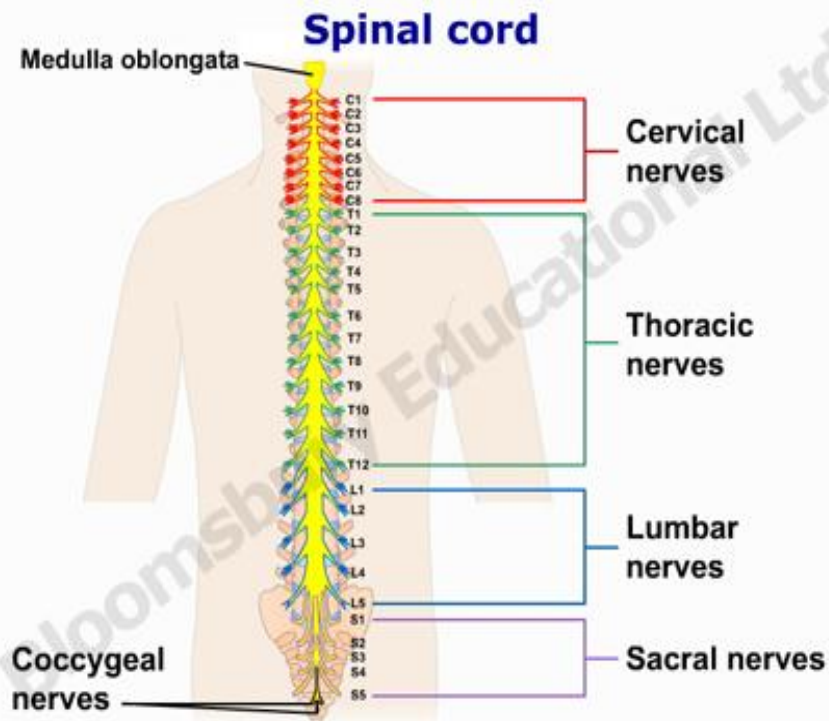
Dorsal and ventral ramus





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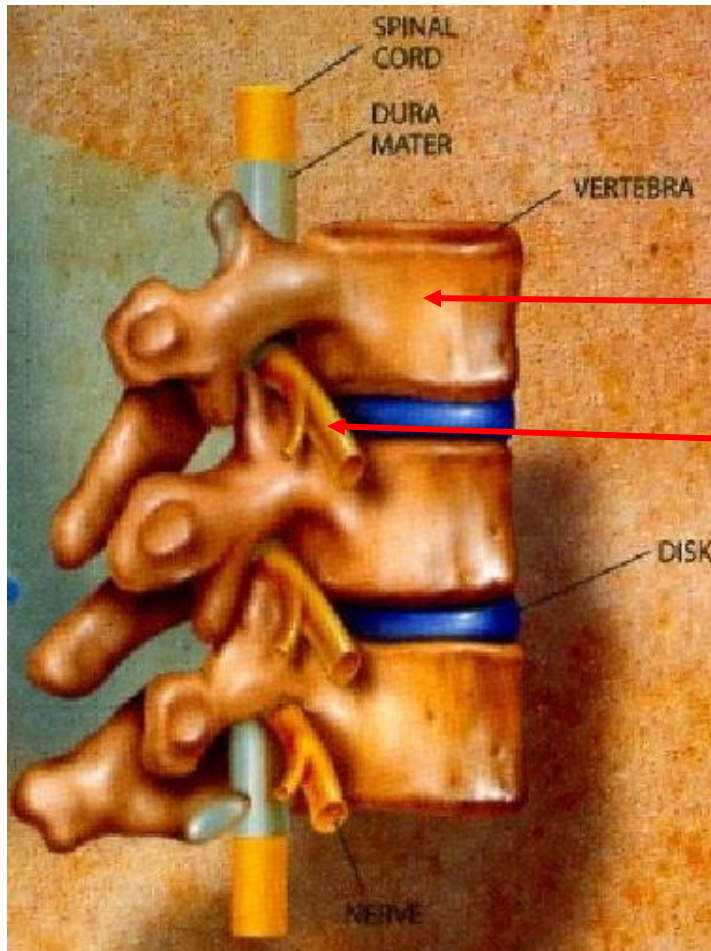
Spinal cord



- 31 pair of spinal nerves
 - 8 cervical (C₁ - C₈)
 - 12 Thoracic (T₁ - T₁₂)
 - 5 Lumbar (L₁ - L₅)
 - 5 Sacral (S₁ - S₅)
 - 1 Coccygeal

Pascalis Spyrou

Spinal cord



- The spinal cord is housed within the vertebral column
- Each cord segment has a corresponding vertebra of the same name (e.g., C₃)
- Spinal nerves enter/exit underneath their corresponding vertebral segment

Spinal cord

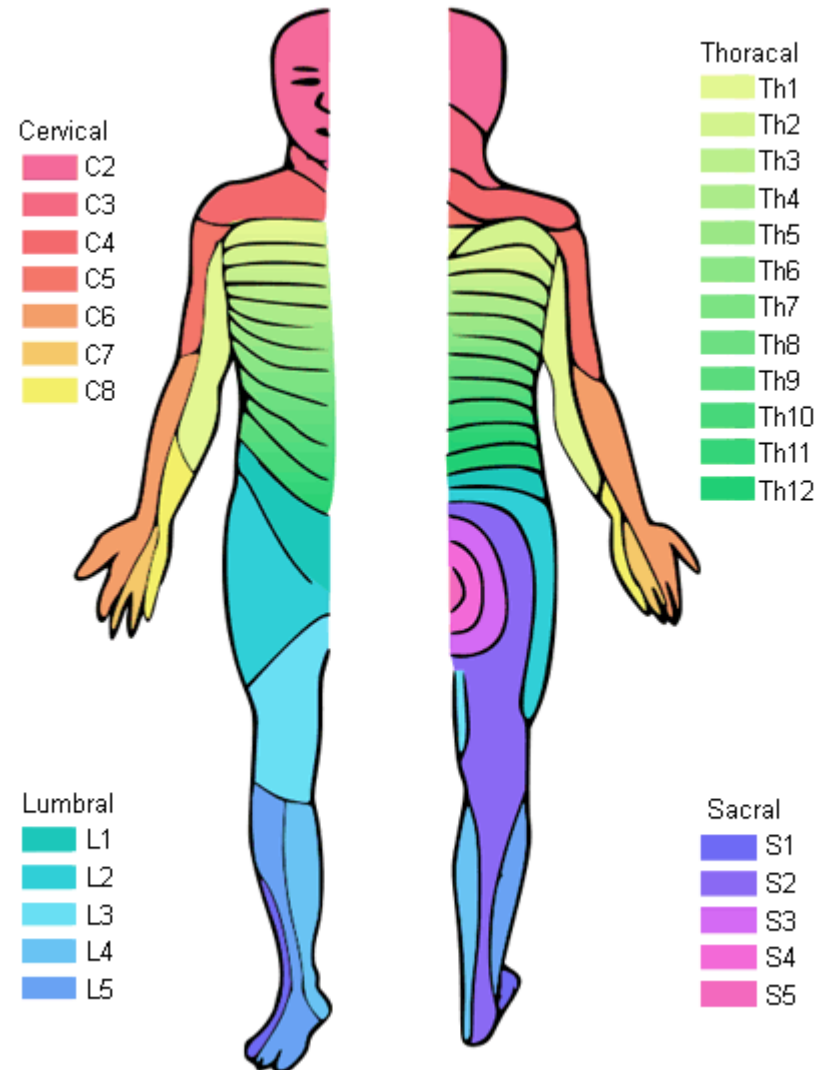
- But wait! Something doesn't add up!
 - How can spinal nerves exit below their corresponding vertebral segment if the cord is only 40cm-45cm long?
 - Answer: Spinal nerves extend down to the appropriate vertebral segment forming the **cauda equina**
- This means cord segments and vertebral segments don't line up

Dermatomes

Each set of rootlets forms a spinal nerve that innervates a corresponding segment of the body

Area of the skin supplied by the right and left dorsal roots of a single spinal segment.

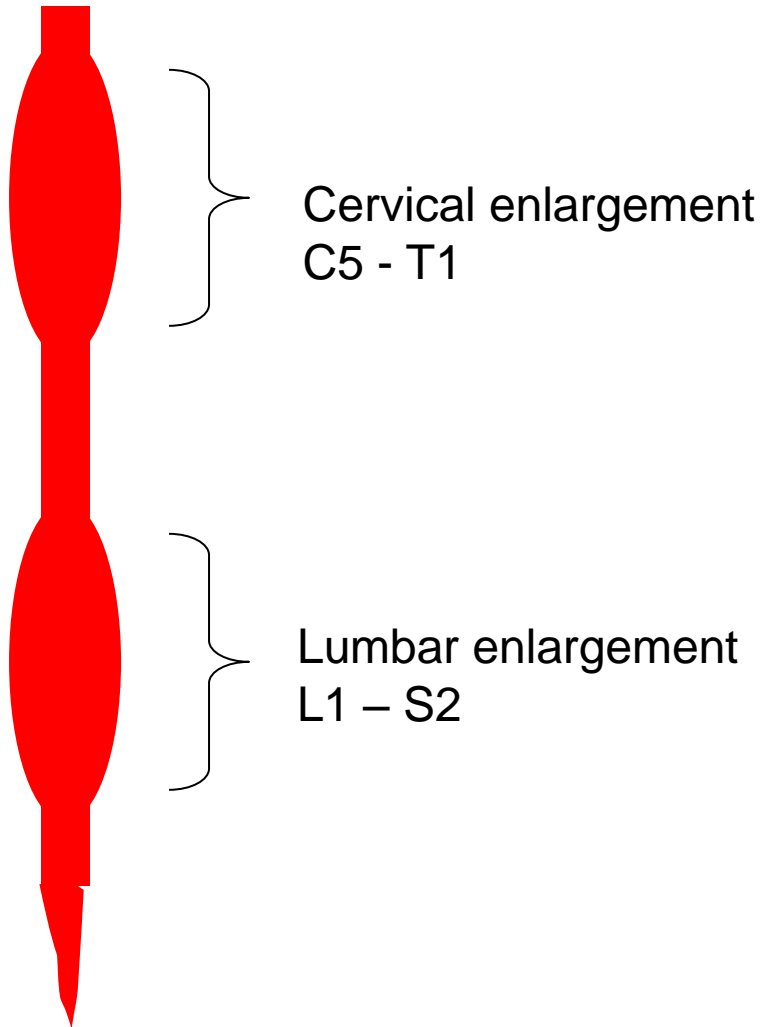
Overlapping areas!



Spinal cord

- Cord is not of uniform thickness throughout its length. Why not?
- Answer:
 - Segments of the cord innervate parts of the body that differ in complexity
 - There are fewer white matter tracts lower in the cord.

Spinal cord enlargements

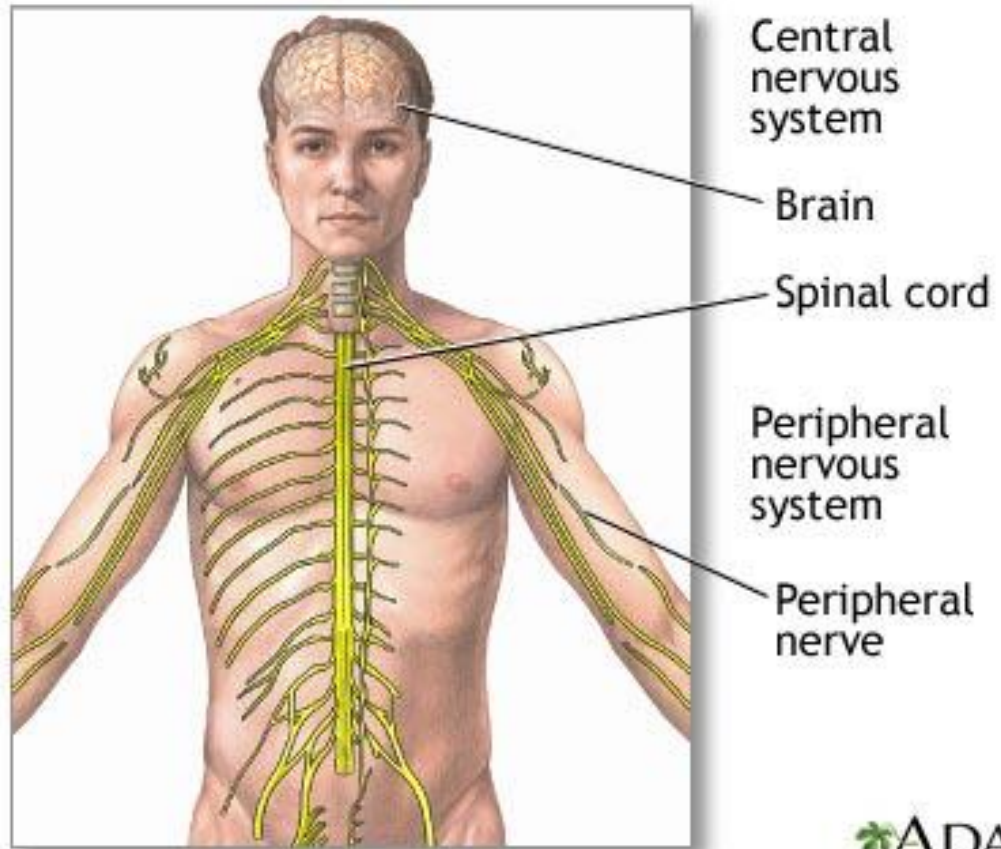


2 enlargements:

- Cervical (C₅-T₁)
 - Lumbar (L₁-S₂)
-
- C₁-C₄ = plexus cervicalis
 - C₅-T₁ = plexus brachialis
 - L₁-L₄ = plexus lumbalis
 - L₄-S₂ = plexus sacralis

Pathways of the spinal cord:

- Association
- Projection
- Commissural



ADAM.

General senses:

- ***Exteroceptive (from surface):*** touch, vibration, pain, temperature, localization
- ***Proprioceptive (deep, protopathic):*** locomotor system (periost, tendon and muscle spindles, joints); mostly nonconscious!
- ***Interoceptive:*** from visceral system; mostly nonconscious! Base for proper function of the autonomic reflexes, homeostasis, neuroendocrine system

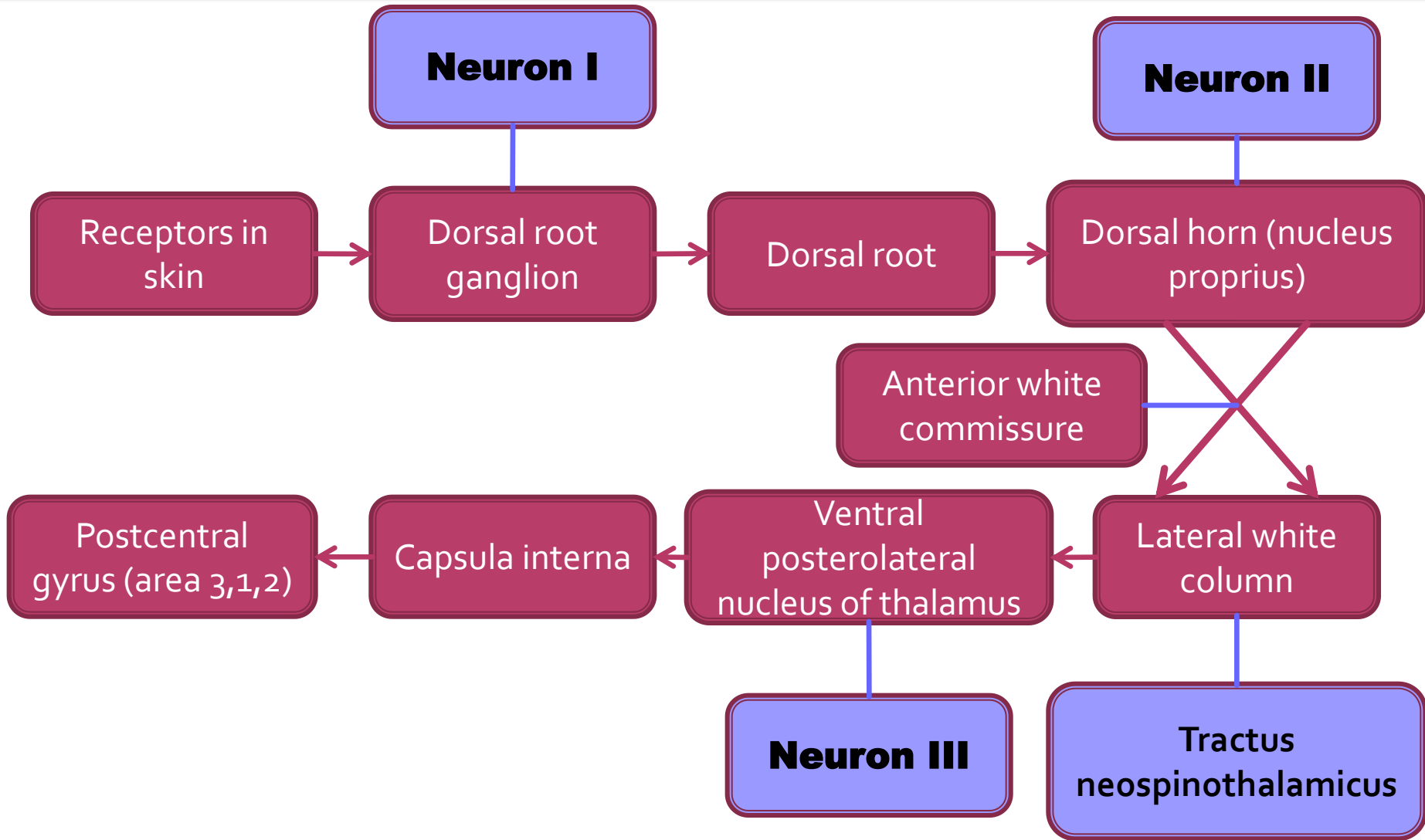
Long ascending tracts (projections):

- Tractus spinothalamicus
- Tractus spinocerebellaris
- Fasciculus gracilis and cuneatus

Tractus spinothalamicus

- 1. *Direct pathway*** (pain, temperature, simple tactile sensations)
 - Neospinothalamic tract
- 2. *Indirect pathways*** (affective, autonomic, endocrine, motor, and arousal components of pain, and simple tactile sensations)
 - Paleospinothalamic
 - Spinoreticular
 - Spinomesencephalic tracts

Neospinothalamic tract



Paleospinothalamic tract

- Neurons located in the dorsal horn and intermediate gray matter
- Ascend contralaterally and ipsilaterally
- Synapses in ***reticular formation***
- Project in ***midline*** and ***intralaminar thalamic*** nuclei – diffuse projections to the cortex and ***limbic regions*** (cingulate gyrus)

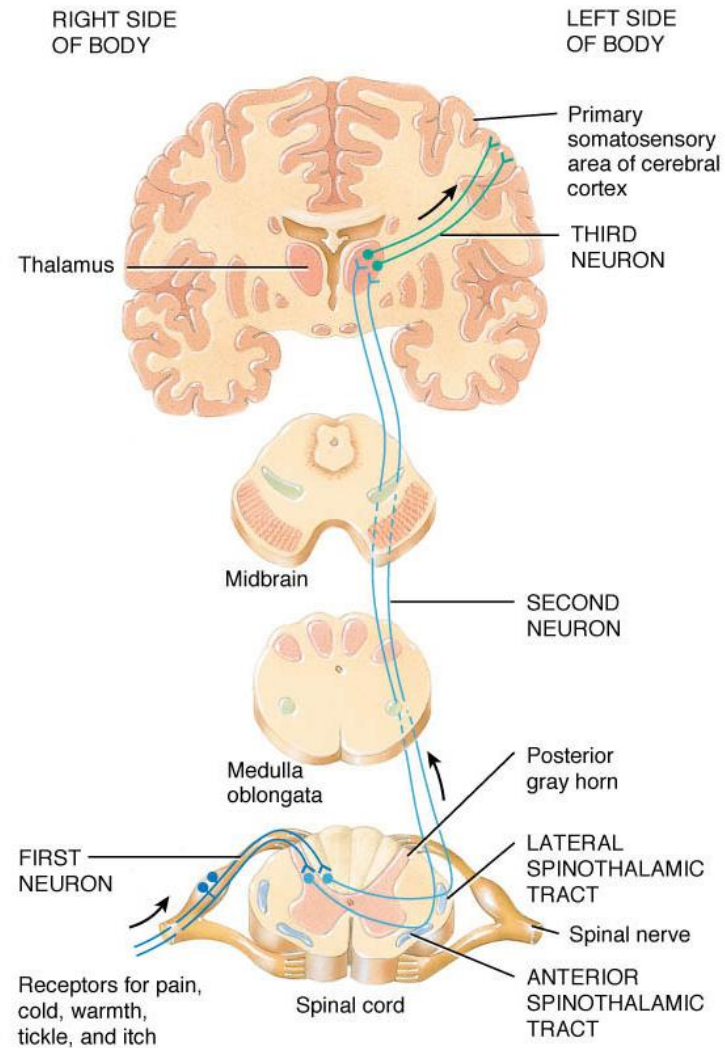
Spinoreticular tract

- Neurons located in the dorsal horn and intermediate gray matter
- Ascend contralaterally and ipsilaterally
- Synapses in medullary and pontine ***reticular formation***
- Project in ***midline*** and ***intralaminar thalamic nuclei*** – diffuse projections to the cerebral ***cortex***

Spinomesencephalic tract

- Neurons located in the dorsal horn and intermediate gray matter
- Ascend to the *midbrain (PAG)*
 - Descending projections to the spinal cord to *inhibit pain sensations*
- Transmission to the amygdala via parabrachial nuclei?

Neospinothalamic tract



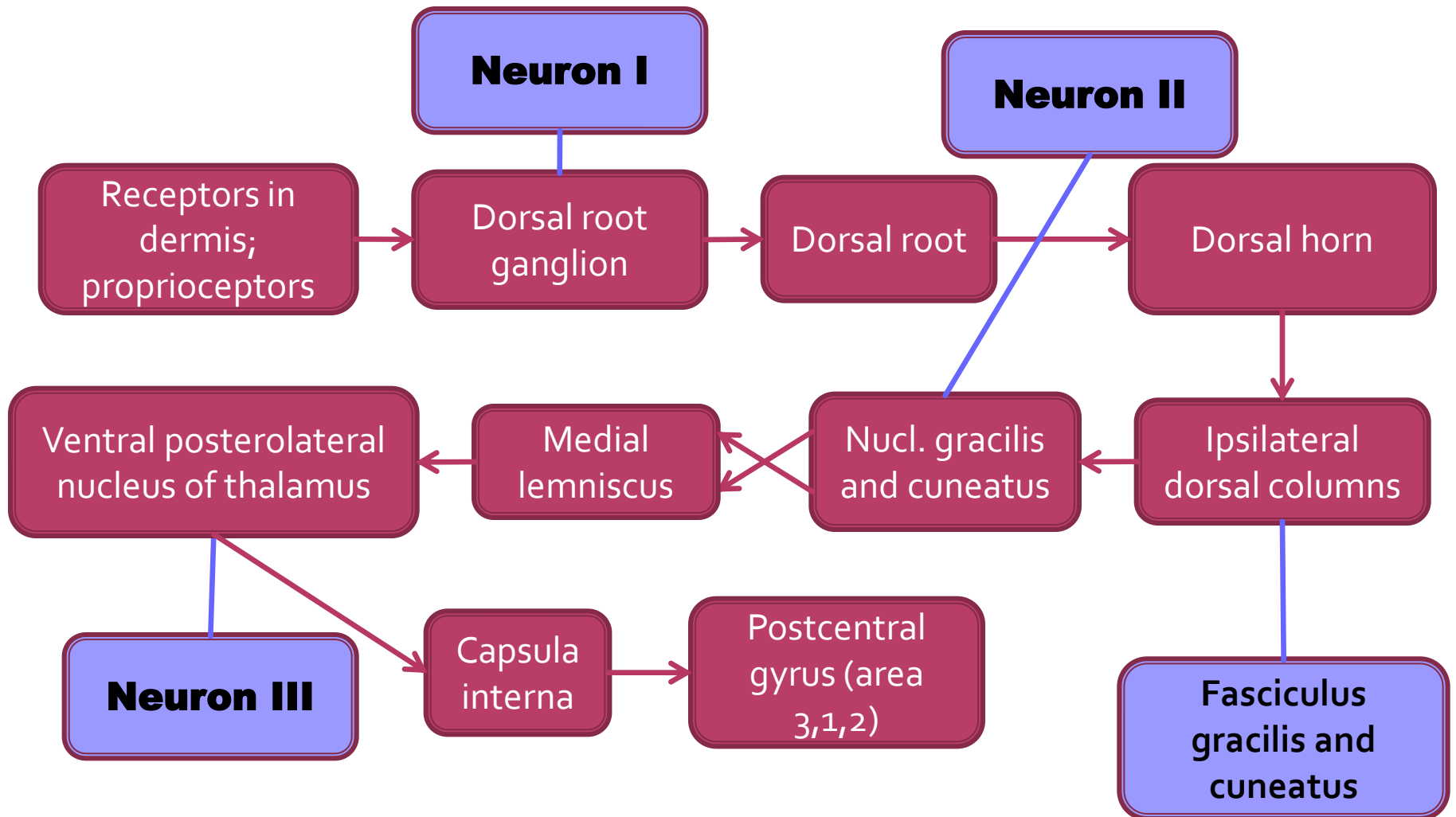
Clinical importance...

- *Neospinothalamic tract* – anesthesia, thermoanesthesia, loss of simple tactile sensations
- *Sacral sparing* – damage to the neospinothalamic tract leaves intact the pain, temperature, and simple tactile sensations in sacral dermatomes (lesion in the gray matter first affects thoracic and cervical fibers due to somatotopic organization of the tract)

Tactile and kinesthetic sense – fasciculus gracilis et cuneatus

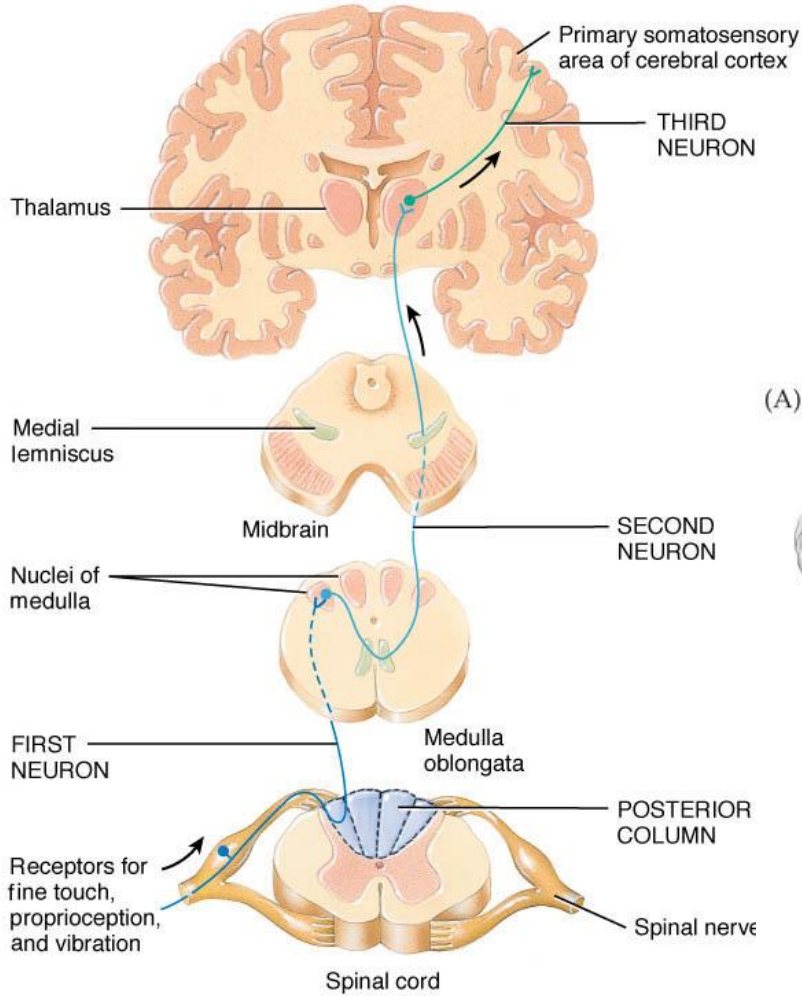
- Tactile sense: vibration, deep touch, two-point discrimination
- Kinesthetic sense: position and movement
- Sacral and lumbar part = medial
→ *fasciculus gracilis (Goll's fascicle)*
- Toracal and cervical part = lateral
→ *fasciculus cuneatus (Burdach's fascicle)*

Discriminative touch and kinesthesia – fasciculus gracilis and cuneatus

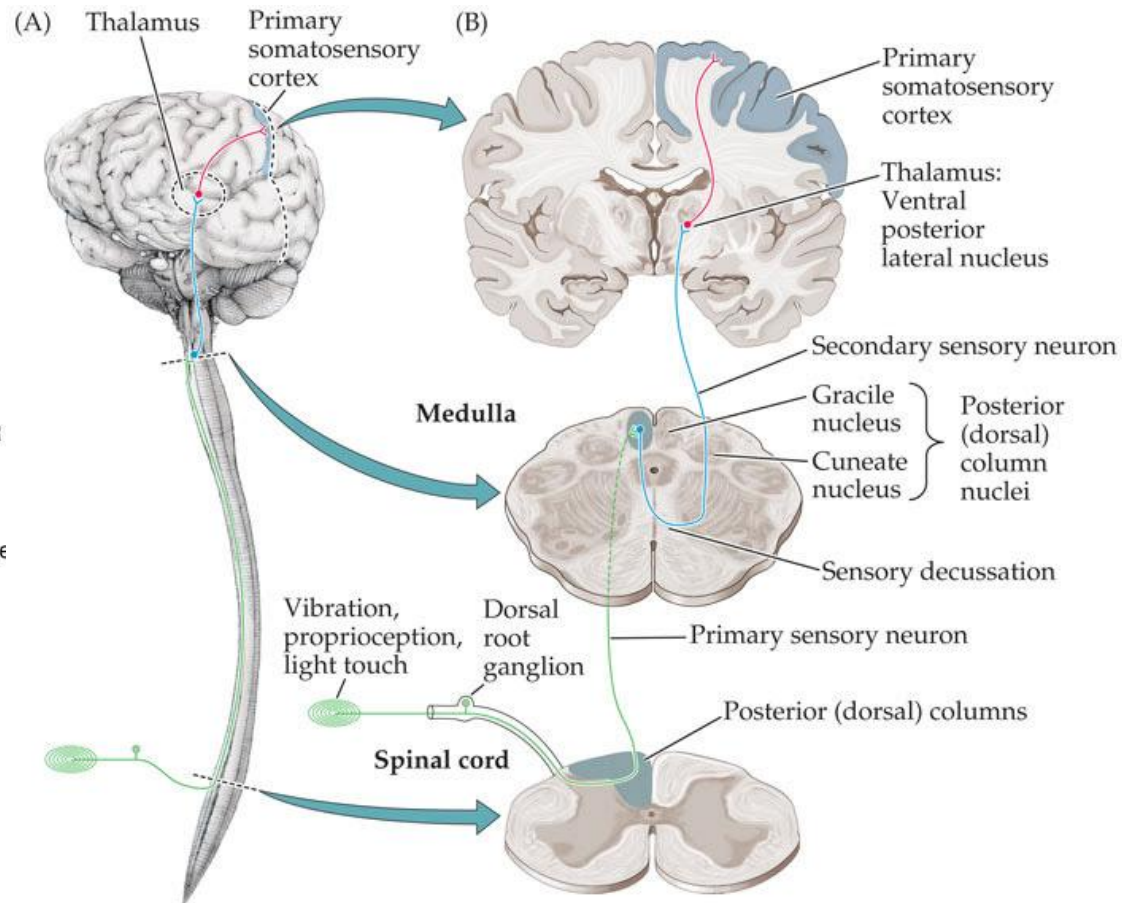


RIGHT SIDE
OF BODY

LEFT SIDE
OF BODY



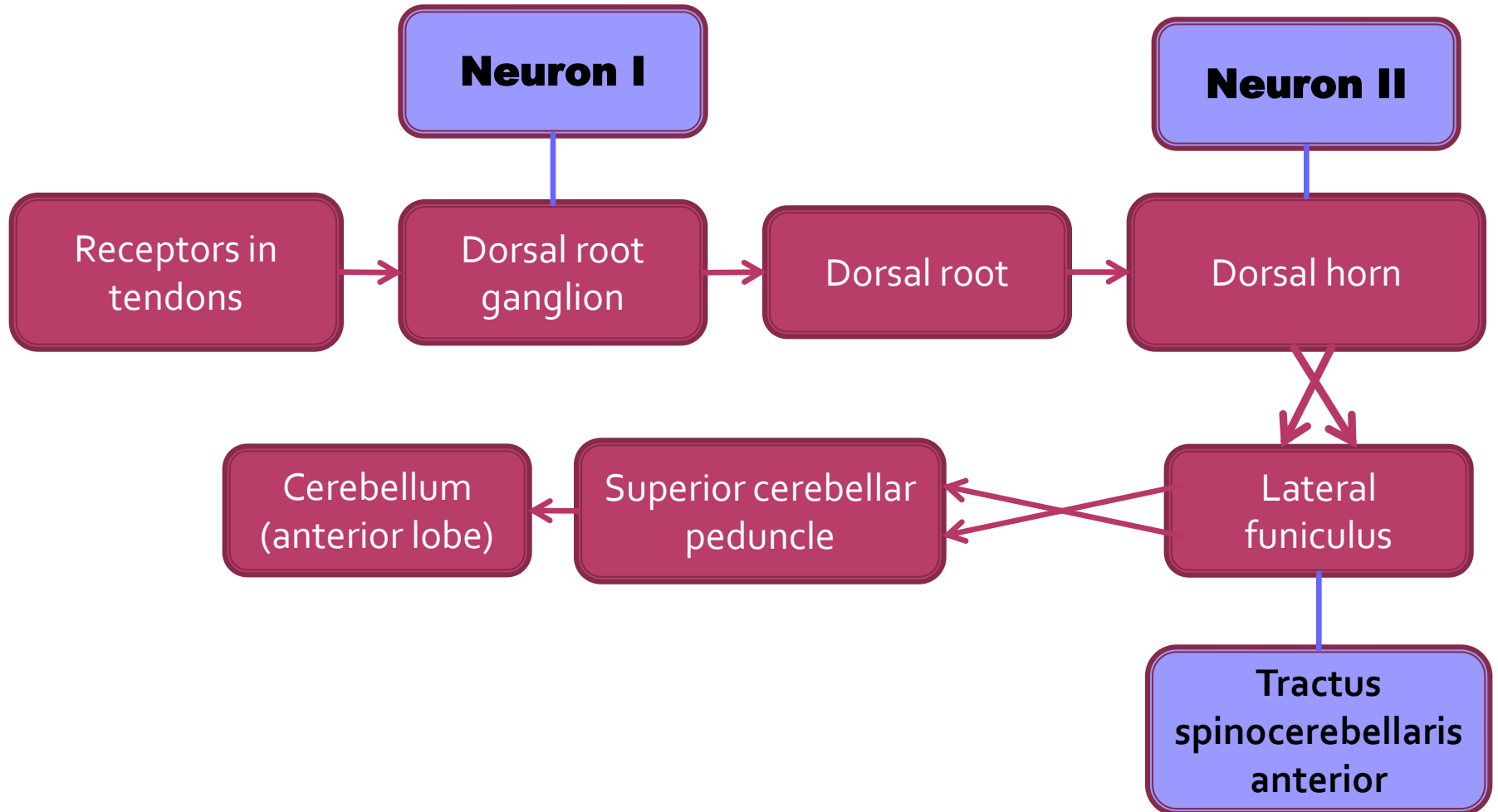
Dorsal (posterior) columns



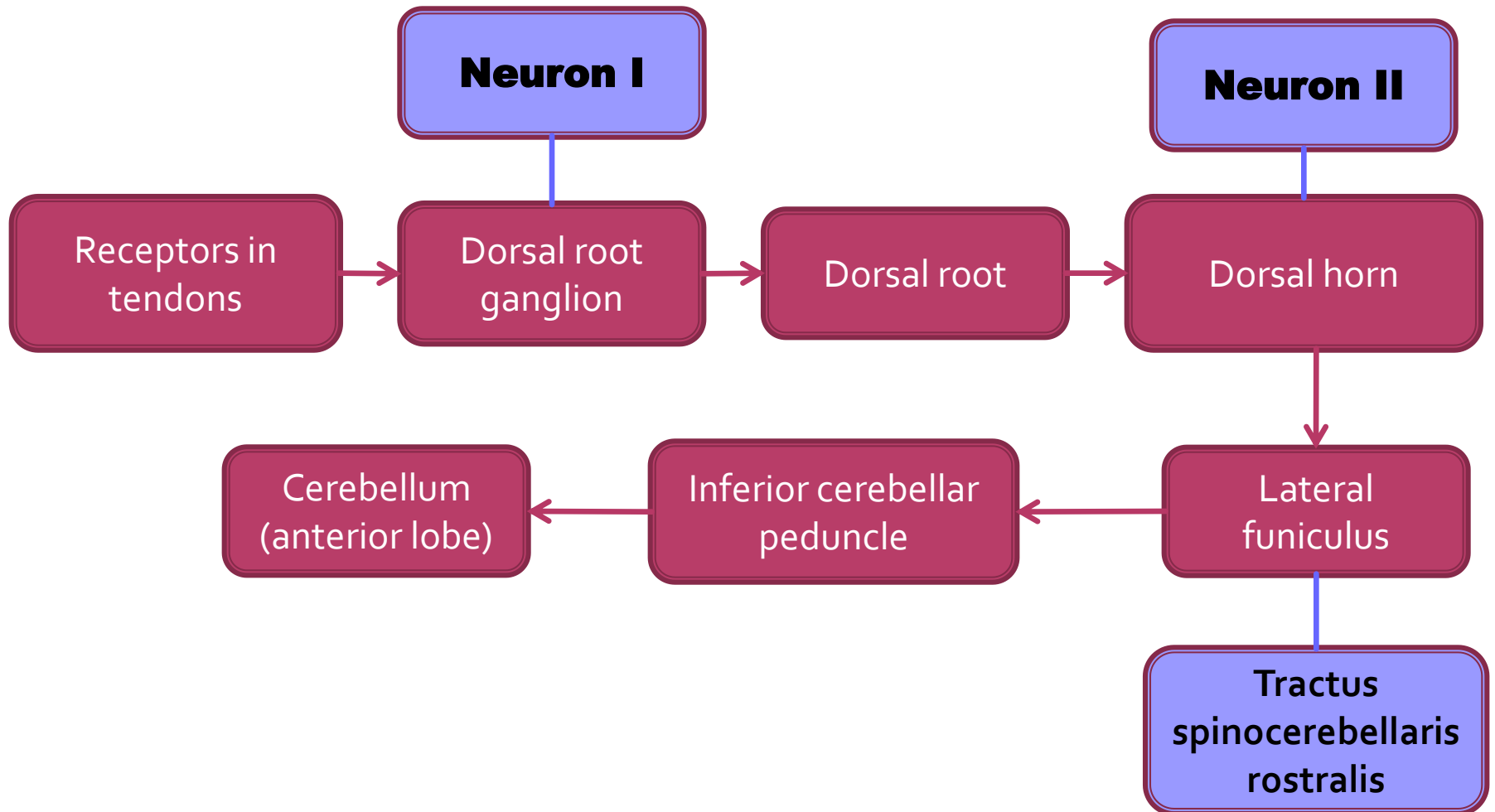
Tractus spinocerebellaris

- ***Tractus spinocerebellaris anterior*** – information about whole limb movement and postural adjustments (lower limb)
- ***Tractus spinocerebellaris rostralis*** – upper limb
- ***Tractus spinocerebellaris posterior*** – status of individual muscles and groups of muscles + ***tractus cuneocerebellaris***
- ***All enter cerebellum ipsilaterally!!!***

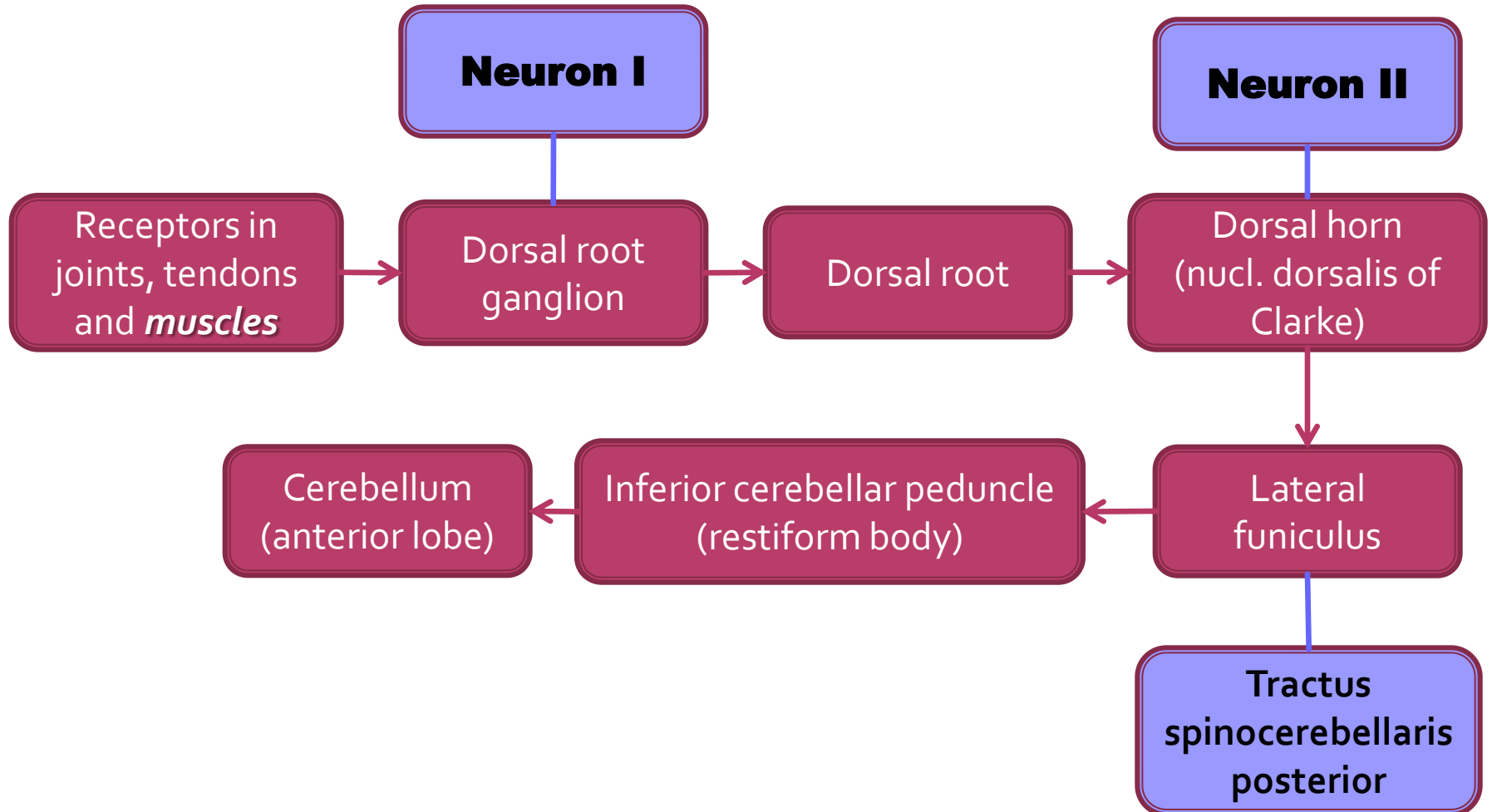
Nonconscious proprioception – tractus spinocerebellaris anterior: lower limb



Nonconscious proprioception – tractus spinocerebellaris rostralis: upper limb



Nonconscious proprioception – tractus spinocerebellaris posterior: lower limb



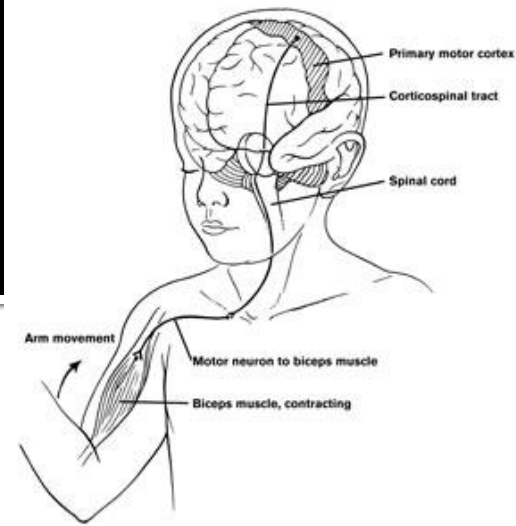
Tractus cuneocerebellaris

- Nonconscious proprioception of upper limb
- Rostral to C8 (no nucl. dors. of Clarke)
- Ipsilaterally in the fasciculus cuneatus
- Neuron II = accessory cuneate nucleus

Long ascending tracts

| | Tractus neospinothalamicus | Tractus spinocerebellaris | Fasciculus gracilis et cuneatus |
|-------------------|--------------------------------|-------------------------------------|---|
| Neuron I | Dorsal root ganglion | | |
| Neuron II | Dorsal horn (nucleus proprius) | Dorsal horn (nucl. dorsalis Clarke) | Nucl. gracilis et cuneatus |
| Neuron III | thalamus | | thalamus |
| Function | <i>Pain and temperature</i> | <i>Nonconscious proprioception</i> | <i>Discriminative touch and kinesthesia</i> |

Long descending tracts:



- Corticospinal tract
- Rubrospinal tract

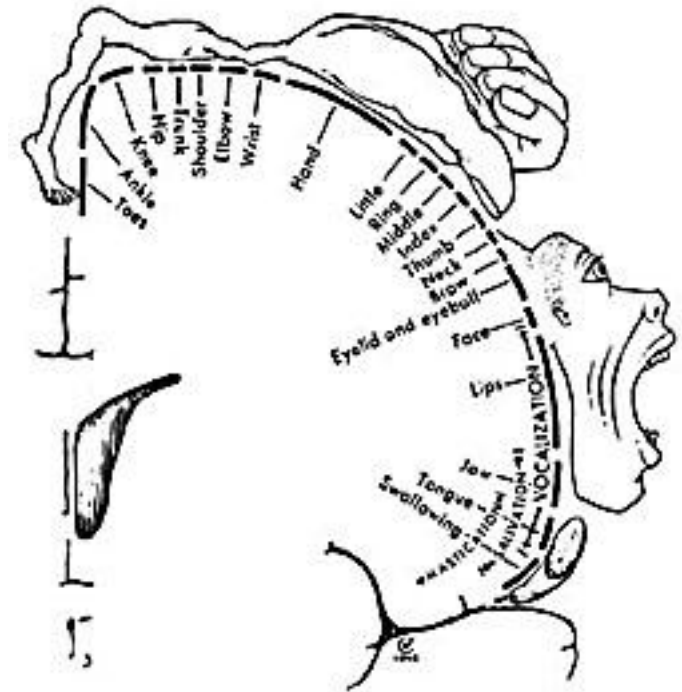
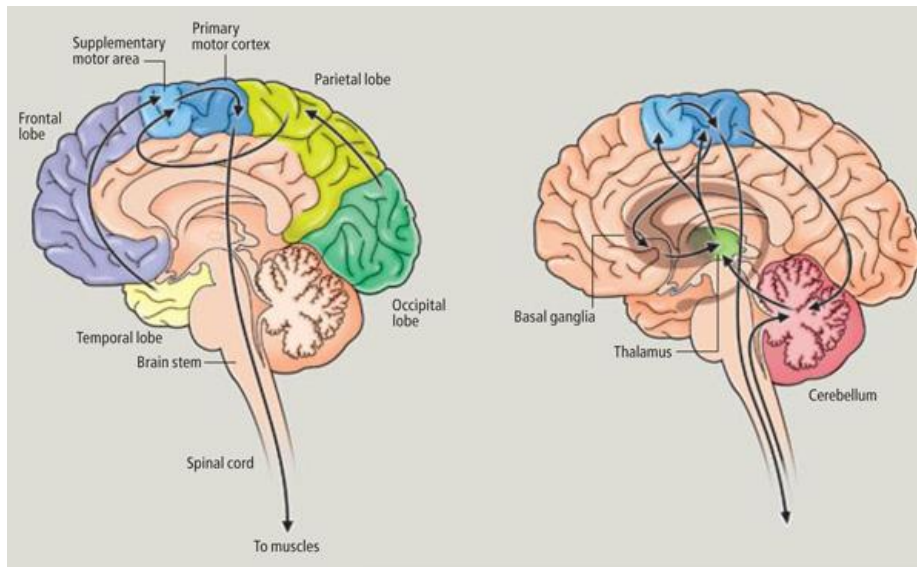
Flexor motor system, fine movements of the limbs

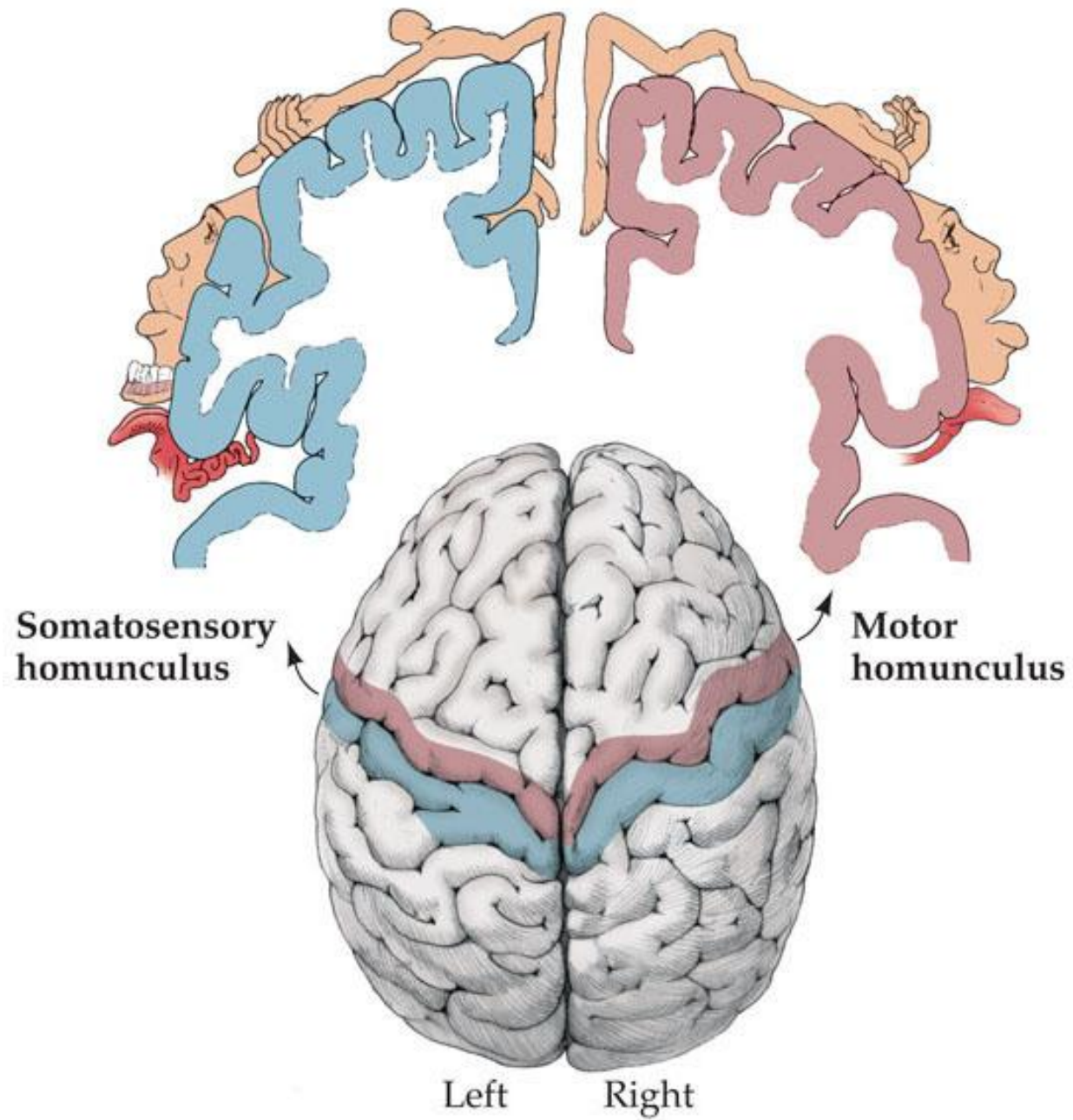
- Tectospinal tract
- Vestibulospinal tract
- Reticulospinal tract

Antigravity muscles, posture, and balance

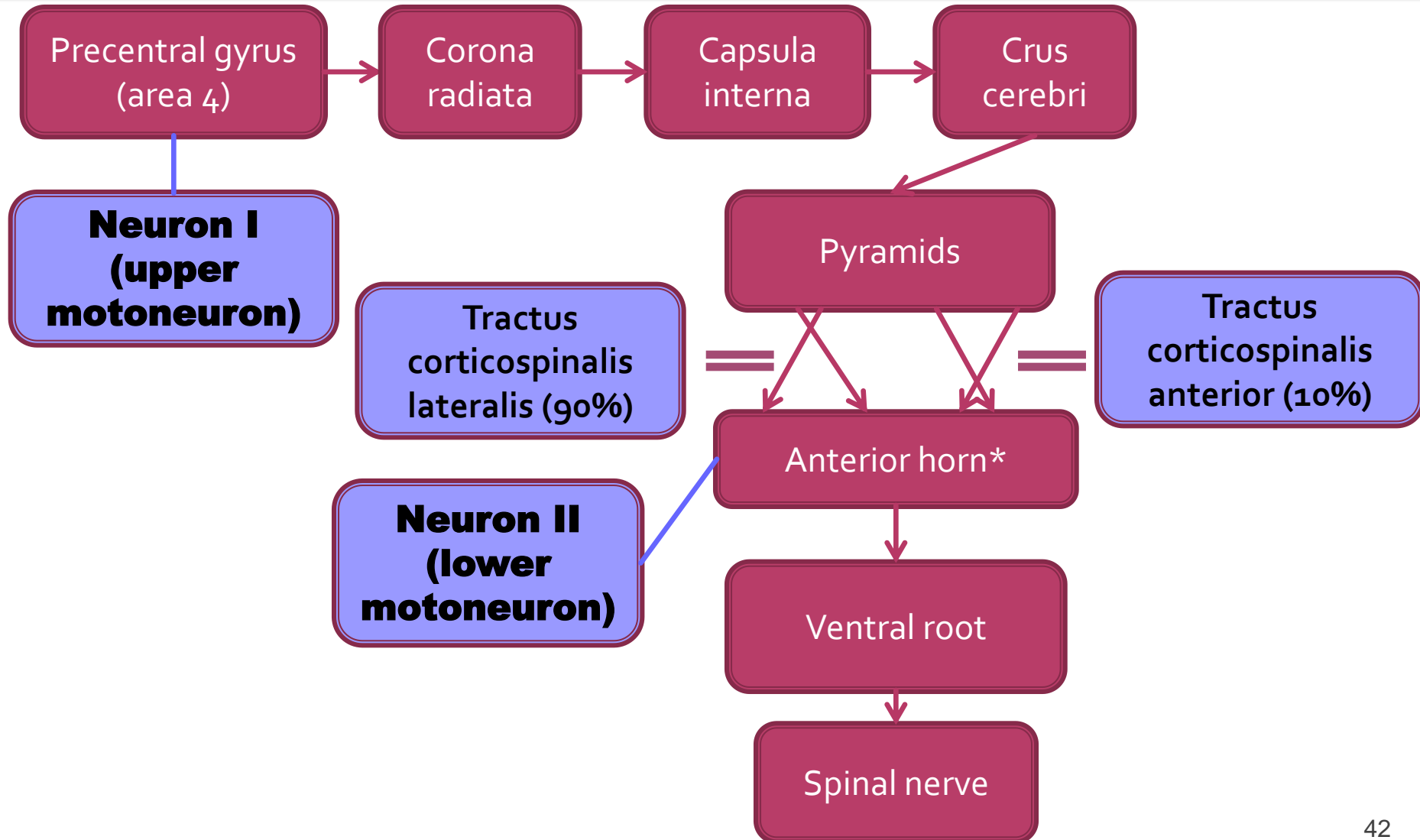
Tractus corticospinalis

- Homunculus – precentral gyrus
- Primary motor cortex



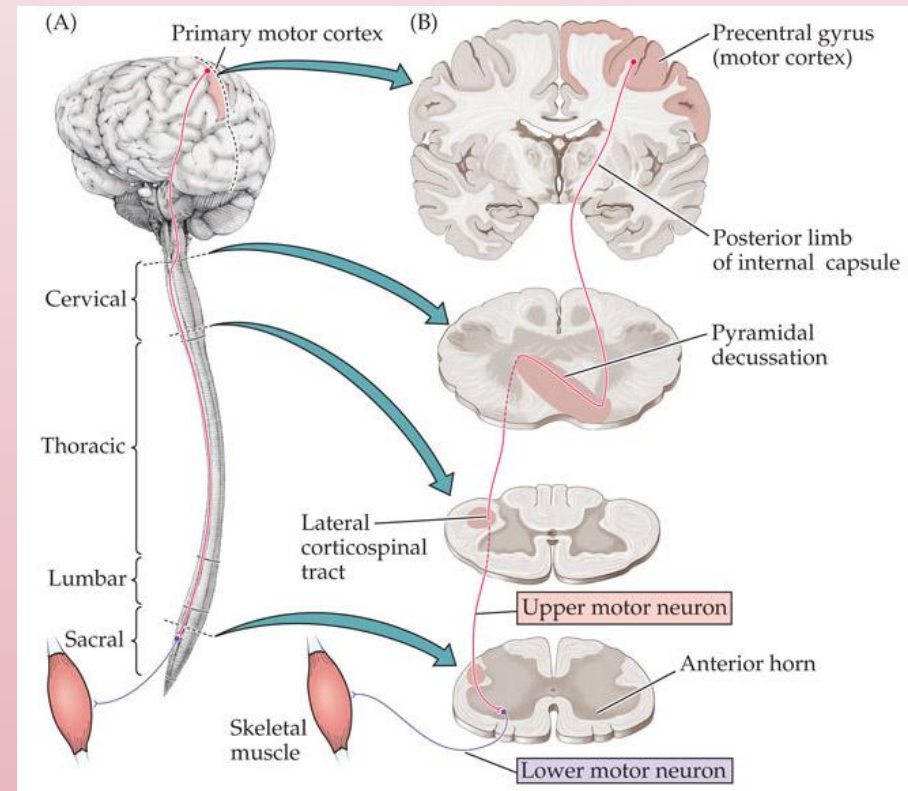


Tractus corticospinalis



Corticospinal tract

- 90% fibers cross at pyramidal decussation → lateral funicle (**tractus corticospinalis lateralis**): limb muscles



- 10% fibers descend ipsilaterally (**tractus corticospinalis anterior**) and cross at the level of lower motoneuron: axial muscles

Damage to corticospinal tract

Lower motor neuron paralysis:

- loss of voluntary movement,
- flaccid paralysis,
- loss of muscle tone,
- atrophy of muscles,
- loss of all reflexes

Upper motor neuron paralysis:

- loss of voluntary movement,
- spasticity,
- increased deep tendon reflexes,
- loss of superficial reflexes,
- Babinski sign

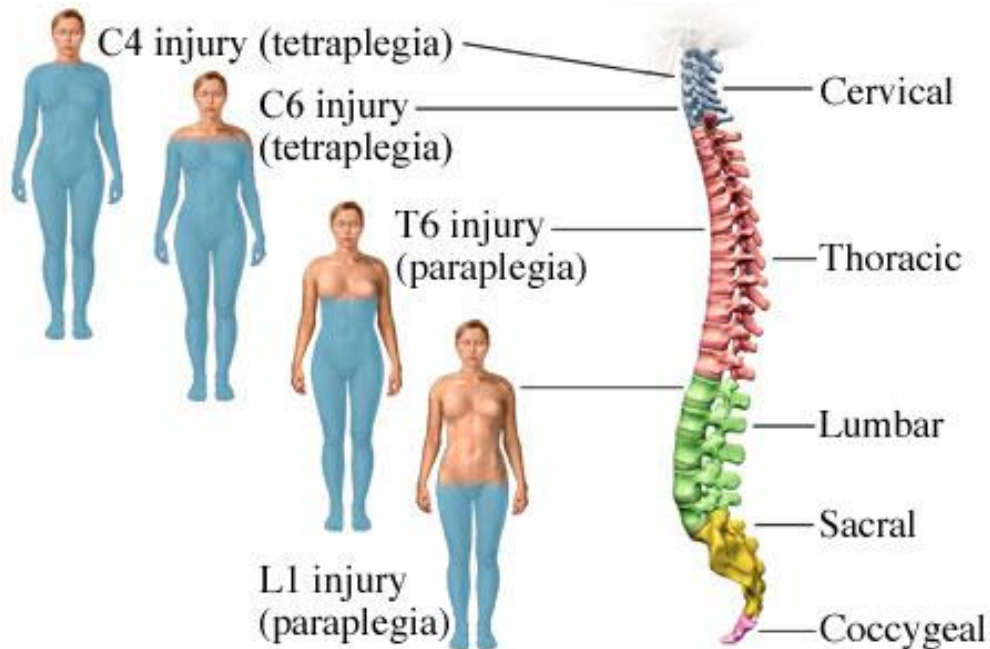
Normal toe flexion



Positive Babinski's reflex



Damage to corticospinal tract



- monoplegia
- hemiplegia
- diplegia
- paraplegia
- quadriplegia (tetraplegia)

Tractus corticospinalis

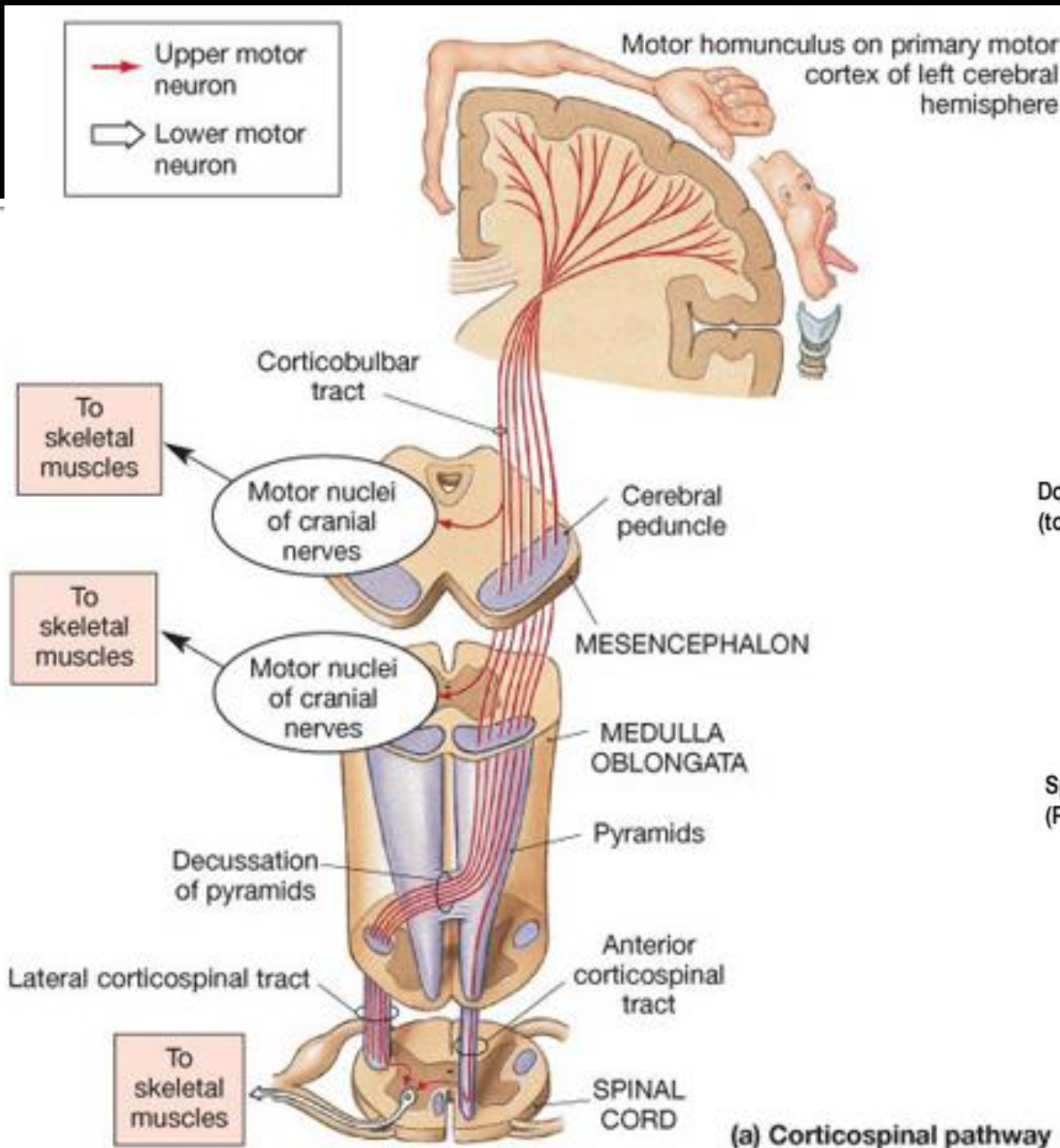
**Neuron I
(upper motoneuron)**

Precentral gyrus (area 4)

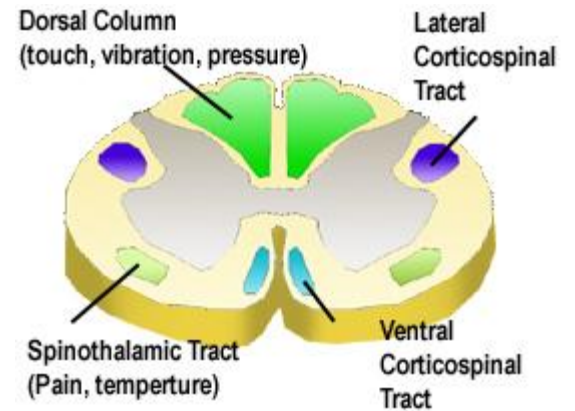
**Neuron II
(lower motoneuron)**

Spinal cord: anterior horn

*Plexus brachialis: C5-Th1
Plexus lumbosacralis: L1-S5

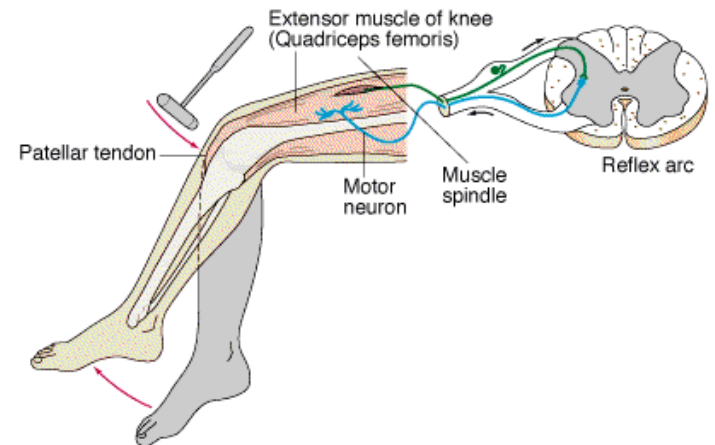


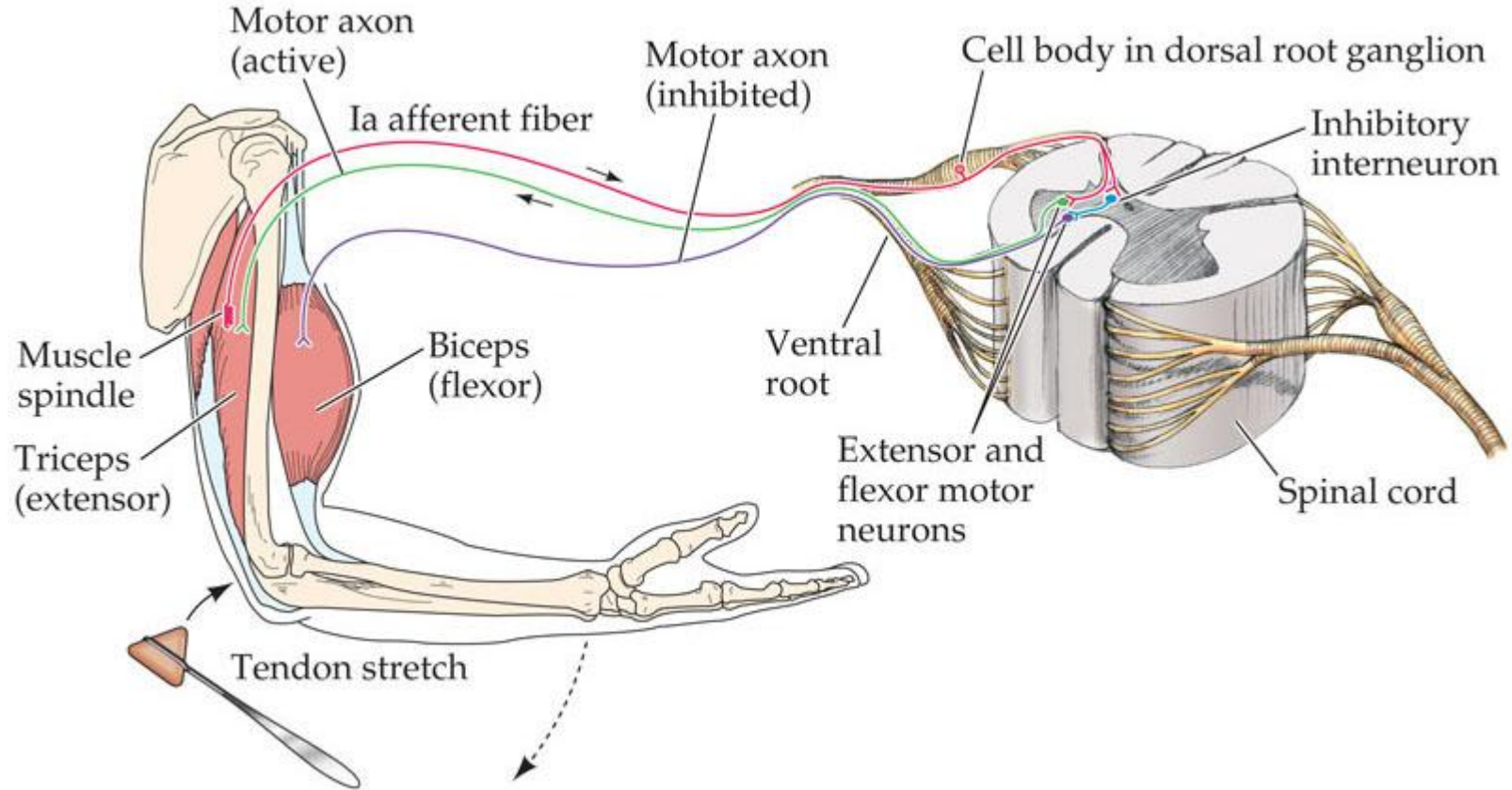
(a) Corticospinal pathway



Spinal reflexes

- Motor responses to afferent stimulation
- *Automatic reactions* – fast response to pain and noxious stimuli
- *Reflex arc – spinal segment:*
 - Afferent neuron
 - Interneuron = *Renshaw's cell*
 - Efferent neuron
 - Effector (muscle)

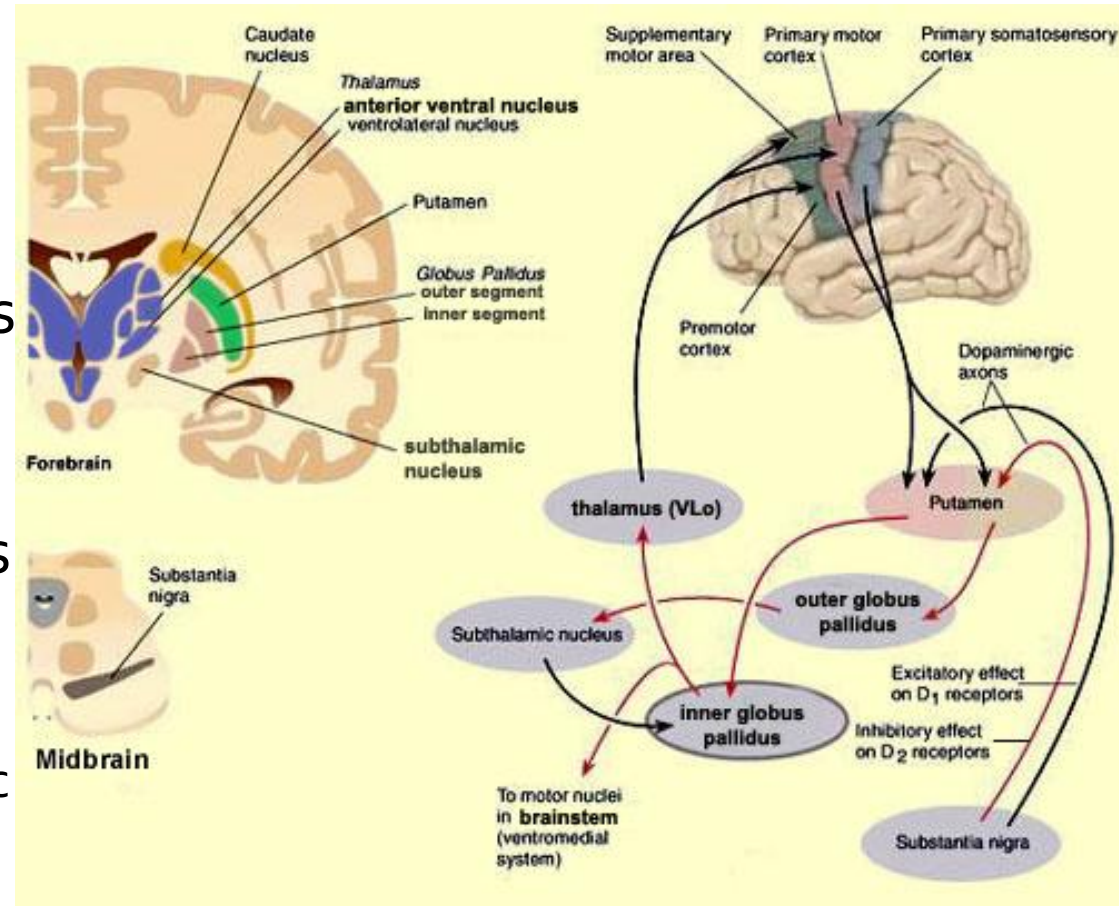




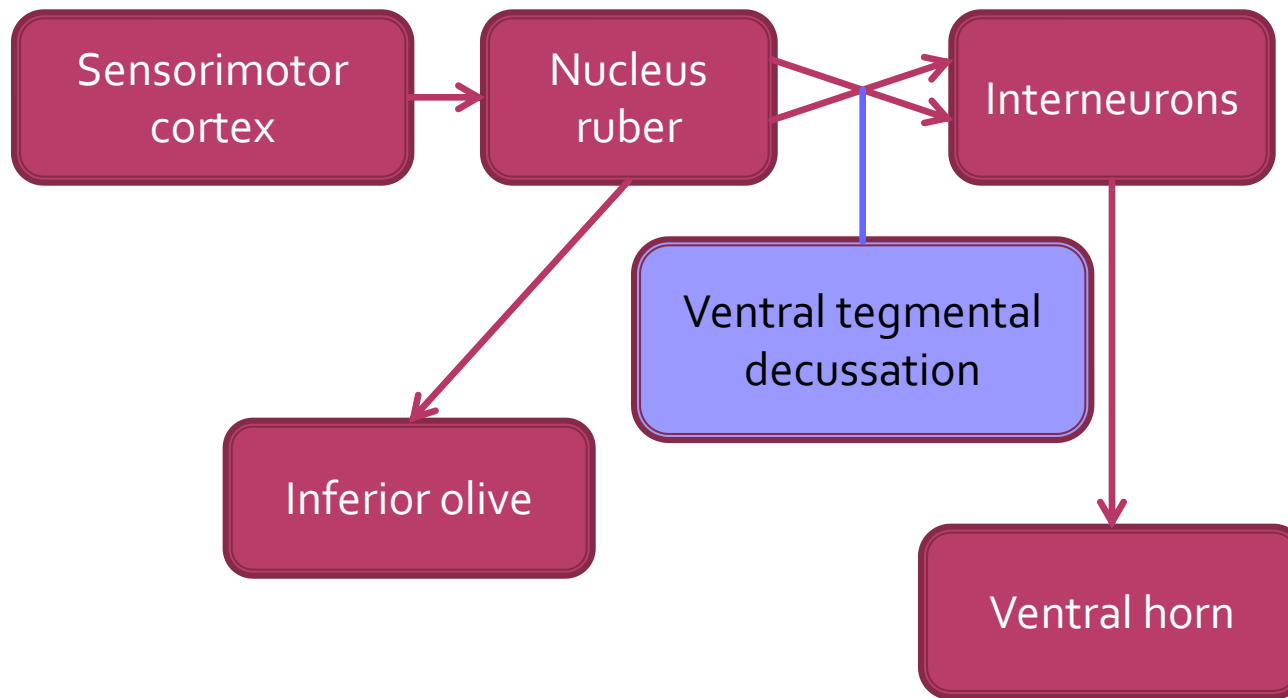
Triceps muscle stretch elicited by tapping the tendon causes agonists (triceps) to contract and antagonists (biceps) to relax.

Extrapyramidal motor pathways

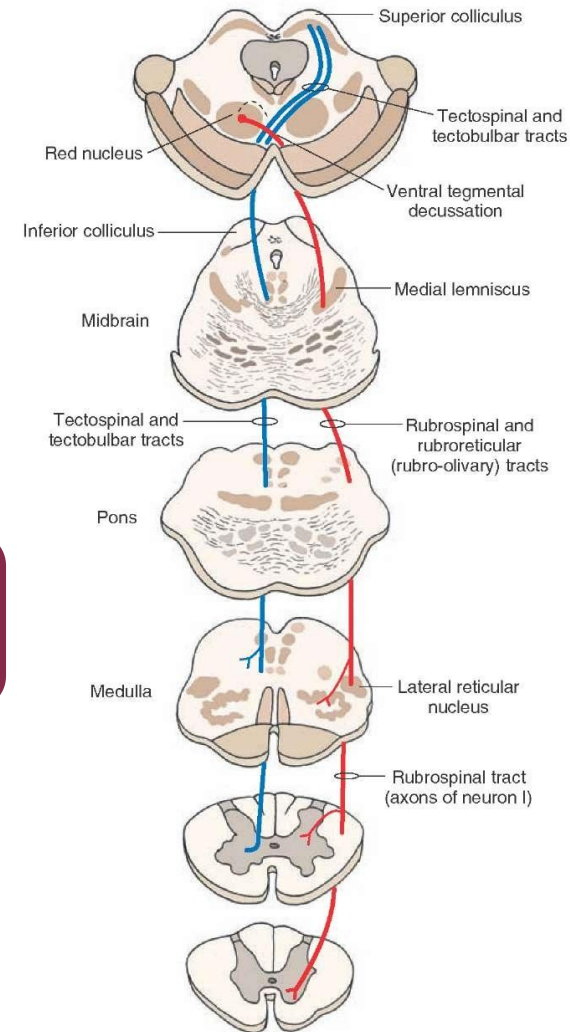
- Tractus rubrospinalis
- Tractus tectospinalis
- Tractus vestibulospinalis (medialis and lateralis)
- Tractus reticulospinalis
- Fasciculus longitudinalis medialis
- Fasciculi proprii – intrinsic reflex mechanisms of the spinal cord



Tractus rubrospinalis



- **Facilitation of flexor motor neurons**
- Inhibition of extensor motor neurons



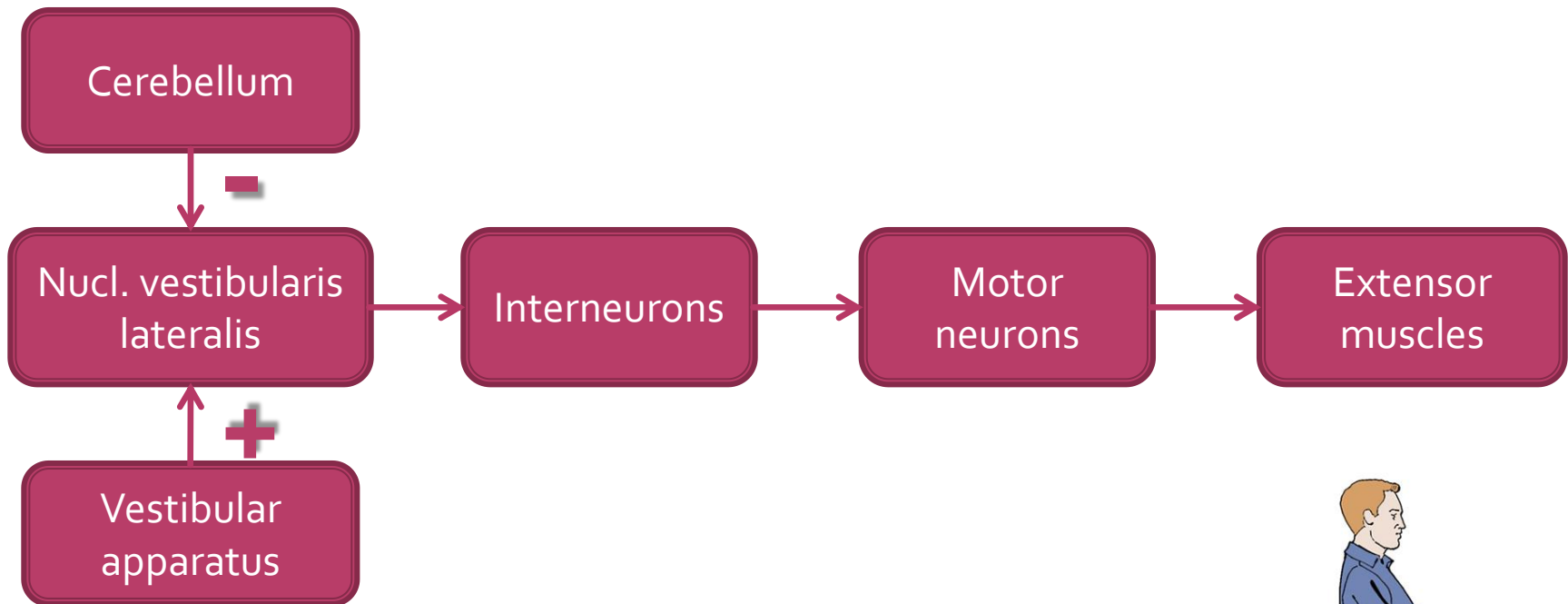
Tractus tectospinalis



- Aid in directing head movements in response to auditory and visual stimuli



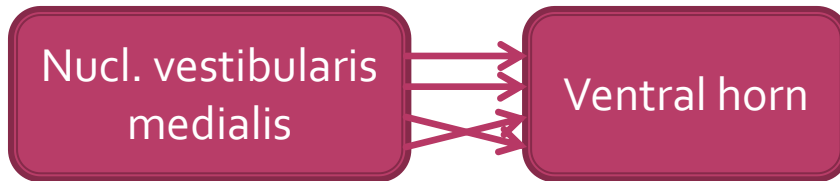
Tractus vestibulospinalis lateralis



- **Facilitation of ipsilateral extensor muscles**
- Maintaining upright posture and balance



Tractus vestibulospinalis medialis



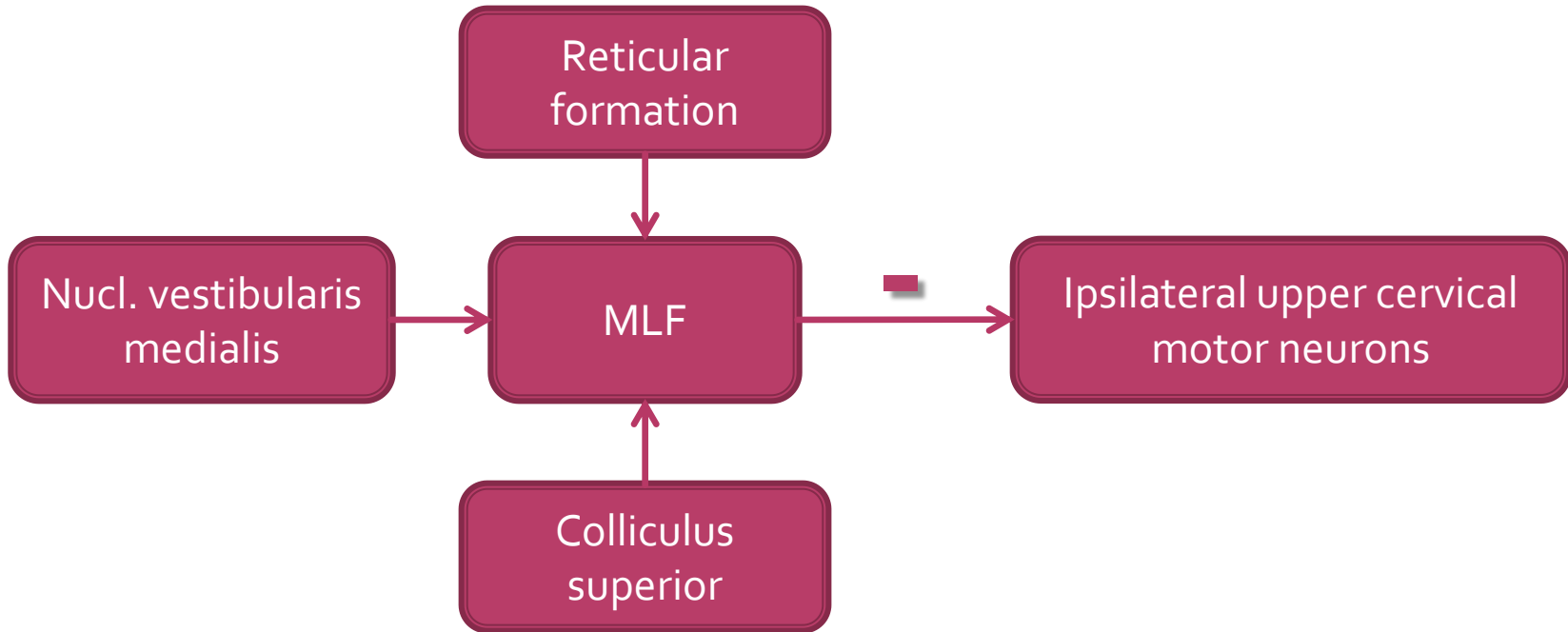
- Adjustment of head position in response to changes in posture (i.e. while walking)



Tractus reticulospinalis

- ***Motor functions***
 - Medullary (lateral) reticulospinal tract – suppresses extensor spinal reflexes
 - **Pontine (medial) reticulospinal tract – facilitates extensor spinal reflexes**
- ***Autonomic functions*** (ventrolateral medulla – IML of thoracolumbar cord)
- ***Modulation of pain*** (enkephalinergic)
 - Midbrain PAG → nucl. raphe magnus → dorsal horn interneurons → spinothalamic system

Fasciculus longitudinalis medialis (MLF)



- Mainly ascending fibers!!!
- Head position control in response to excitation by the labyrinth

The Spinal Cord in Cross Section

Cross Sectional Organization

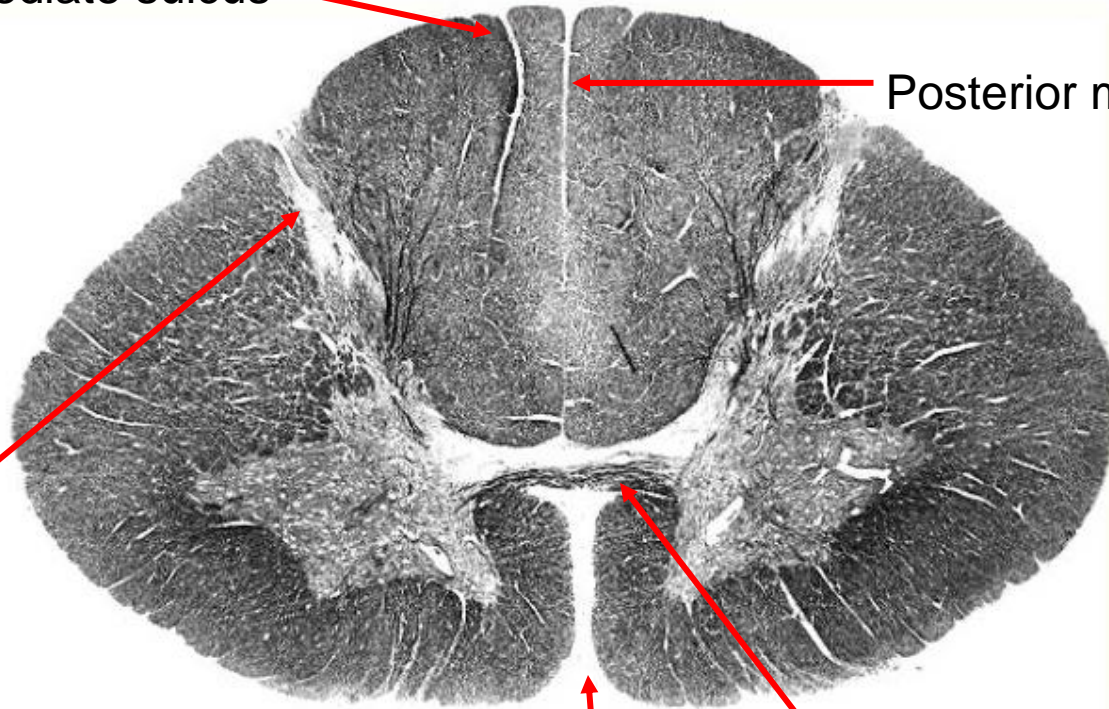
Posterior intermediate sulcus

Posterior median sulcus

Tract of Lissauer

Anterior white commissure

Anterior median fissure



Cord Sections

- Segments of the spinal cord have a similar organization, but vary in appearance.
- Always know where you are in the cord (i.e., cervical, thoracic, lumbar, sacral)

Cord Sections -- Cervical



- Cervical cord is wide, flat, almost oval in appearance.

Cord Sections -- Cervical Enlargement



Cervical

- *What's different about the cervical enlargement?*



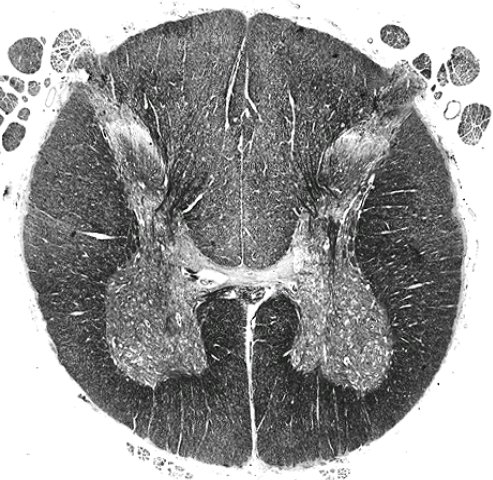
Cervical Enlargement

Cord Section -- Thoracic



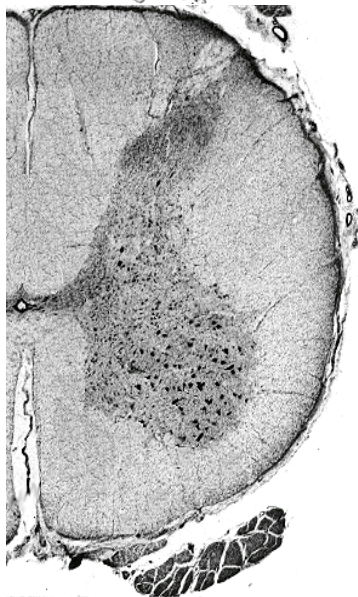
- Less white matter than cervical
- Rounder appearance
- Less prominent ventral horns than cervical enlargement

Cord Section -- Lumbar



Lumbar

- Less white matter than thoracic
- Rounder appearance
- Larger ventral horns, especially in lumbar enlargement



Lumbar Enlargement

Cord Section -- Sacral



- Not much white matter
- Mostly grey, although not much of that either

Cross sections:

- IML = T1-L2
- Clarke's nucleus = C8-L3
- Fasciculus cuneatus = above T6

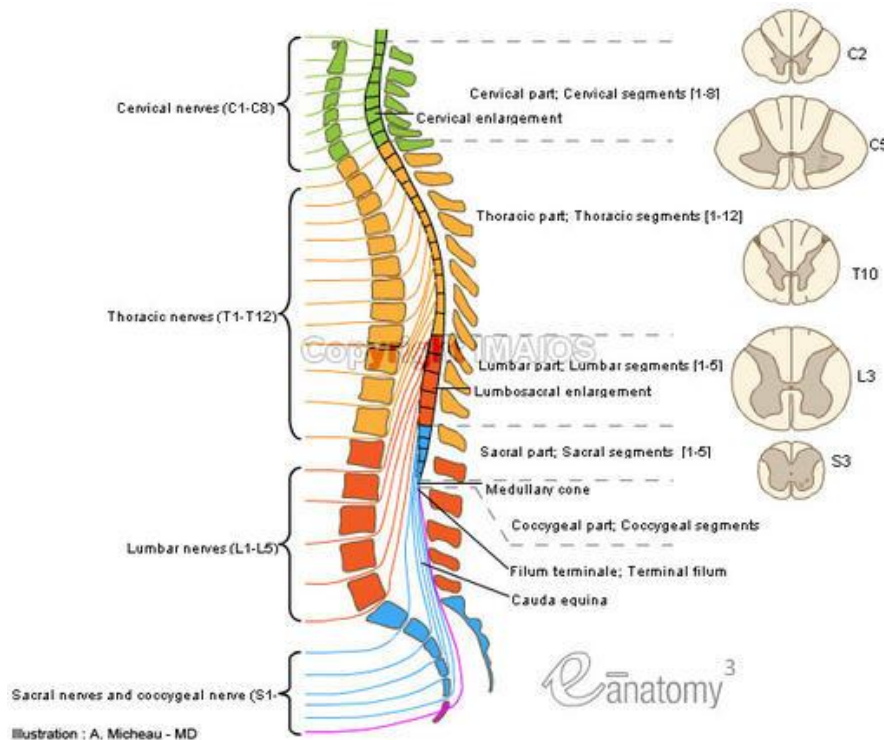
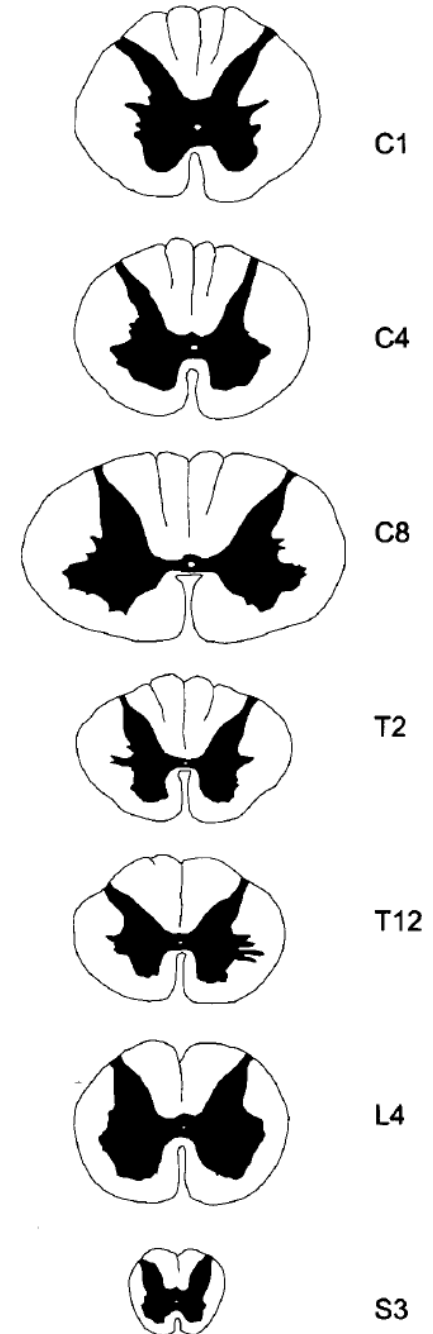
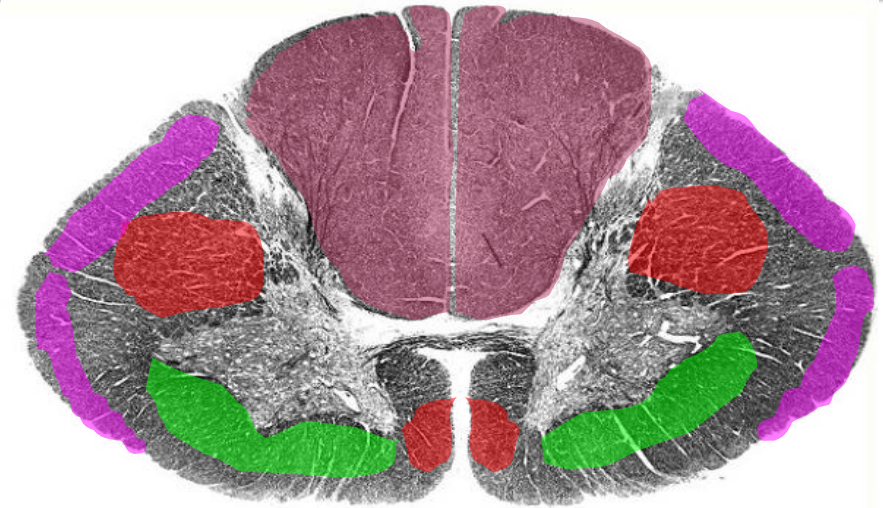


Illustration : A. Micheau - MD



The Big Four

- Corticospinal tract
 - Voluntary movement
- Dorsal columns
 - Discriminative touch
 - Conscious proprioception
- Spinocerebellar tract (dorsal and ventral)
 - Unconscious proprioception
- Spinothalamic tract
 - Pain/temperature



- Corticospinal tracts
- Dorsal Columns
- Spinothalamic tracts
- Spinocerebellar tracts

Questions?

