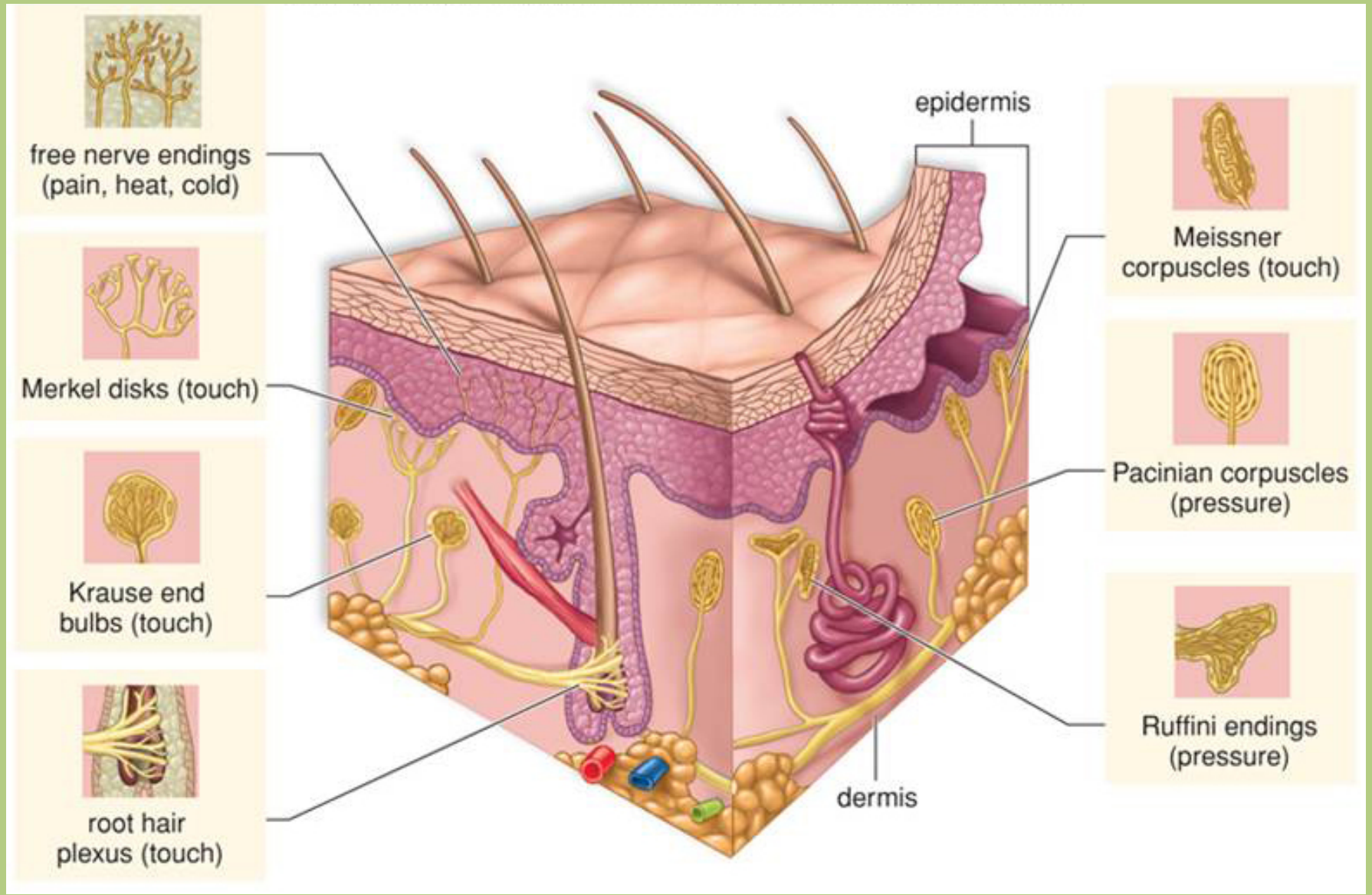
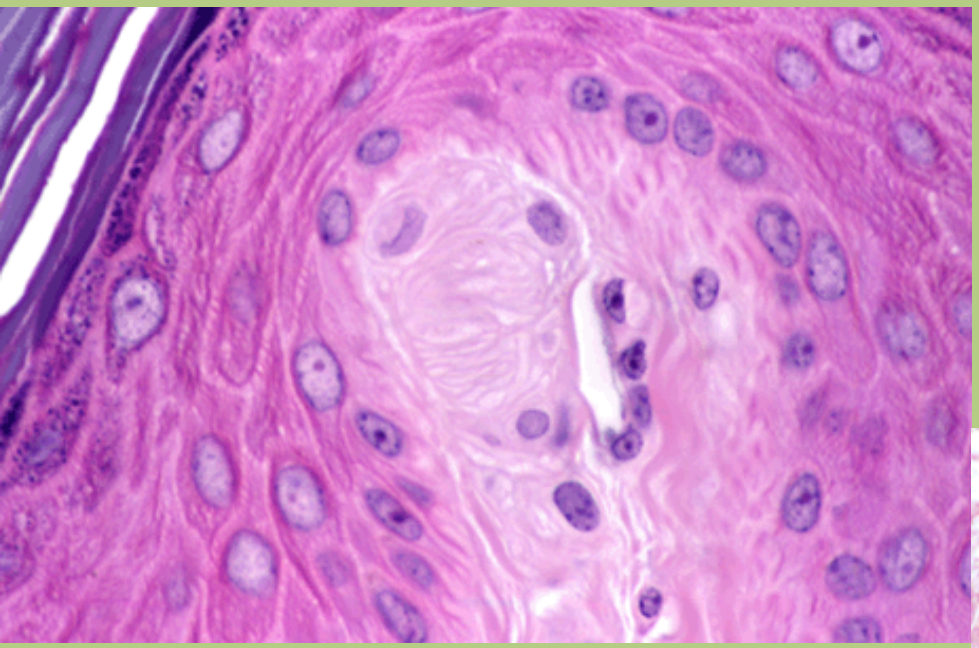
# Sensory and motor pathways

Sándor Katz M.D., Ph.D.

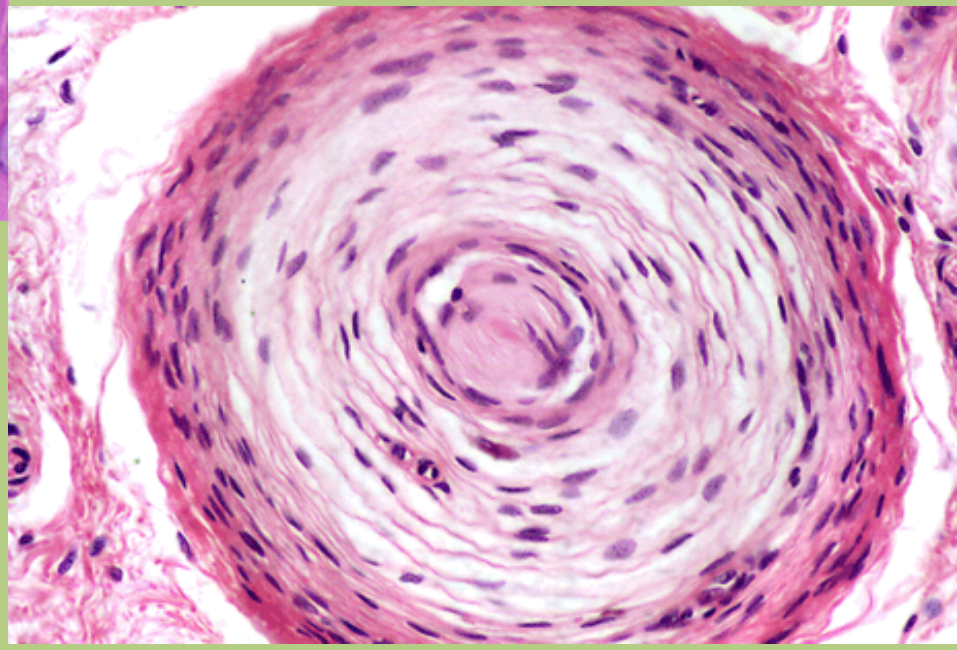
# Sensory pathways - receptors



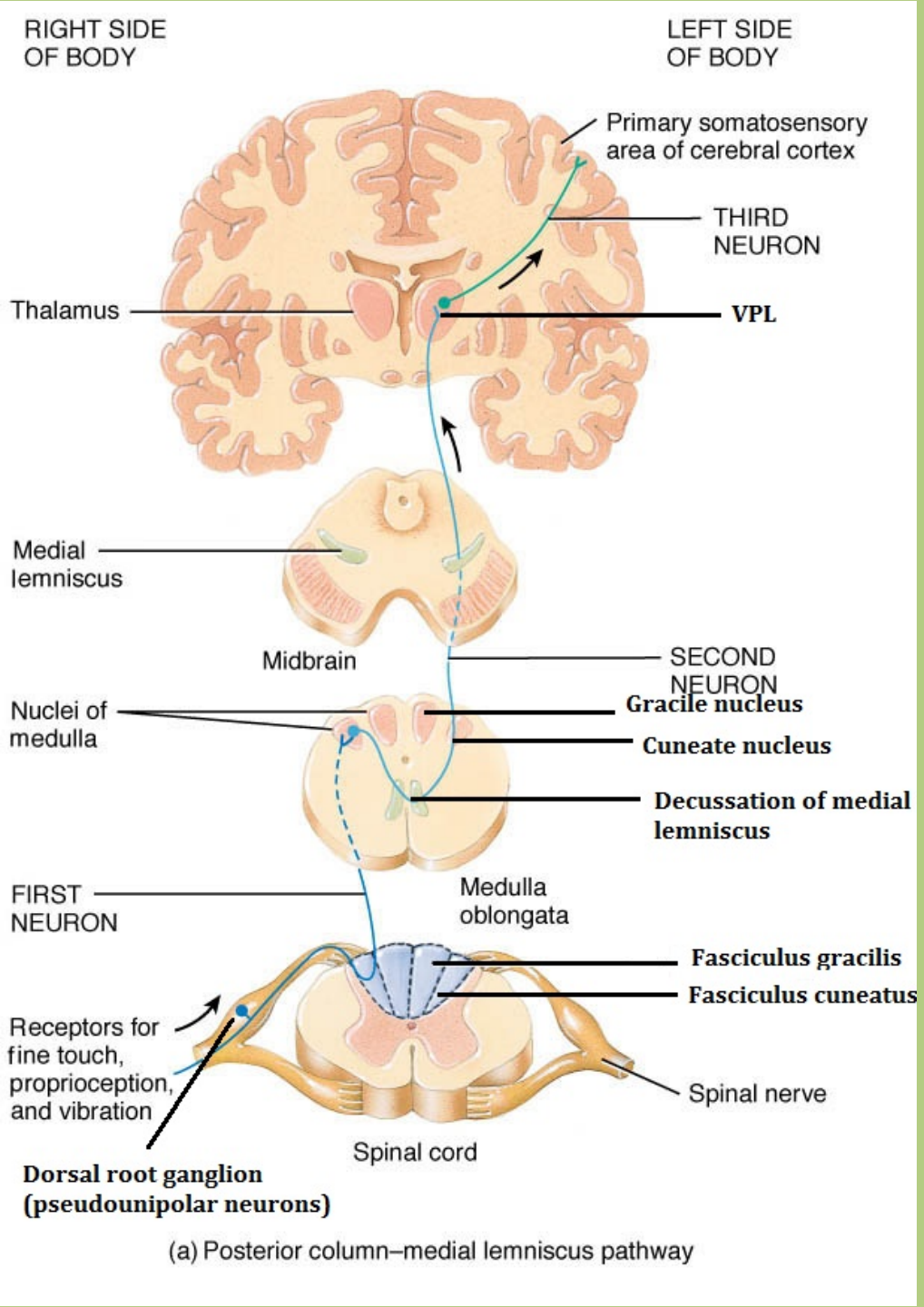
# Sensory pathways - receptors



Meissner's corpuscle



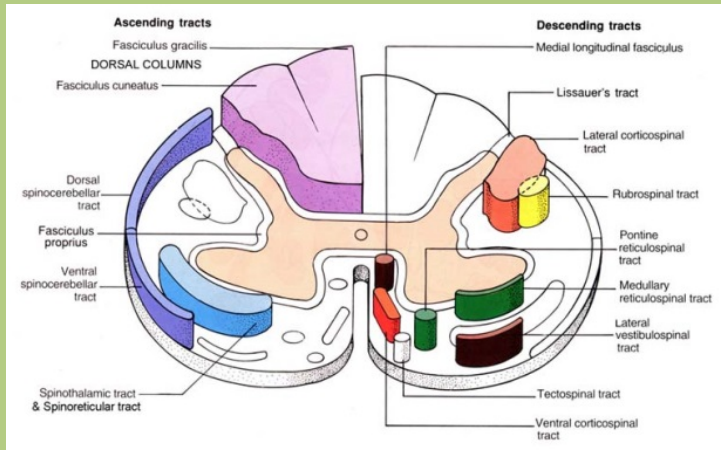
Pacinian corpuscle

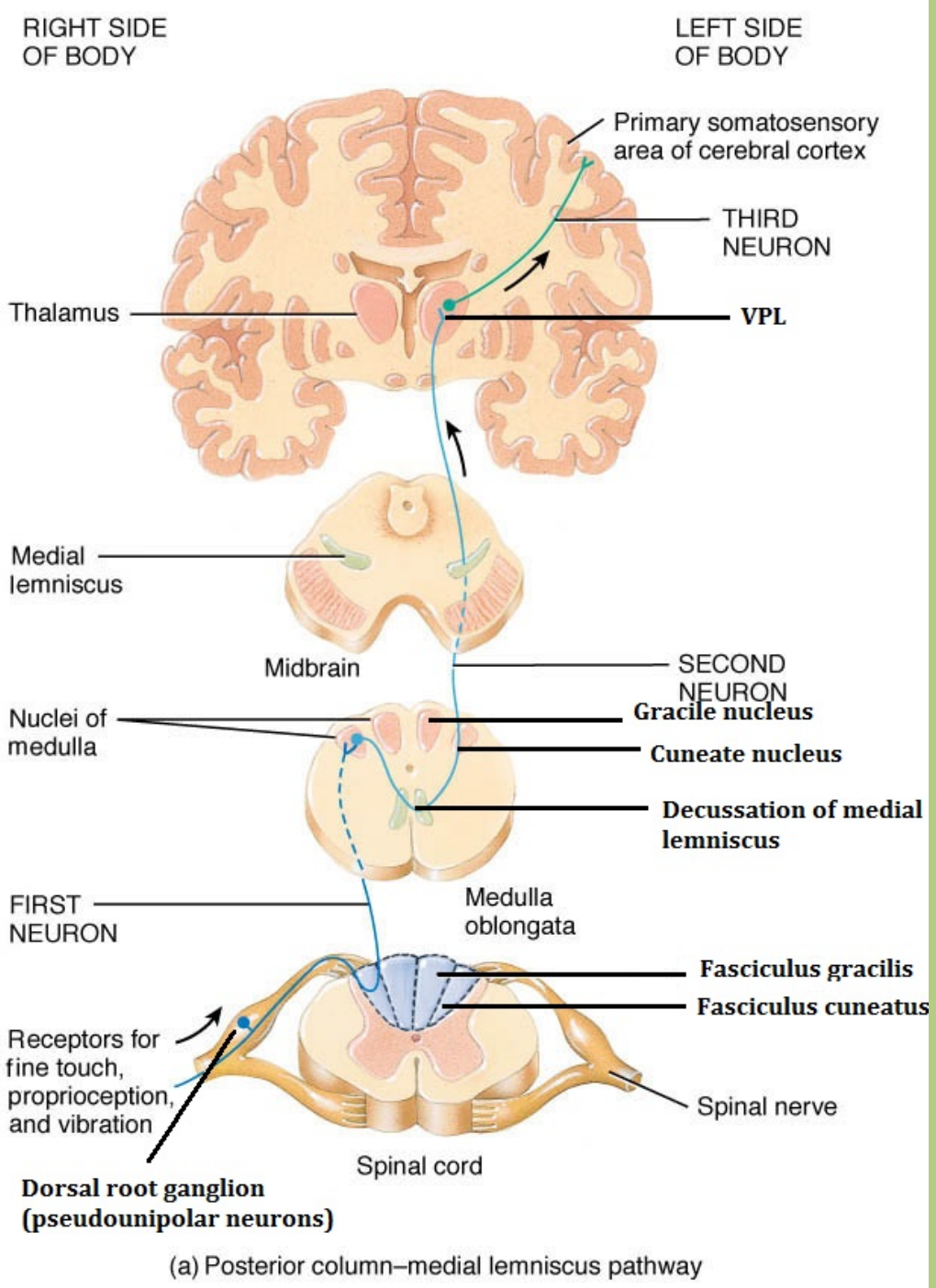



(a) Posterior column–medial lemniscus pathway

# Sensory pathways (ascending tracts)- Fasciculus gracilis (Goll's) and cuneatus (Burdach's)

- Both tracts convey fibers for **position sense** (conscious proprioception) and **fine cutaneous sensation** (touch, vibration, fine pressure sense, two-point discrimination) =**EPICRITIC SENSATION**.
- The **fasciculus gracilis** carries fibers only from the ***lower limbs***, while the **fasciculus cuneatus** carries fibers only from the ***upper limbs*****,** therefore it is not presented in the spinal cord below the T3-(6) level.

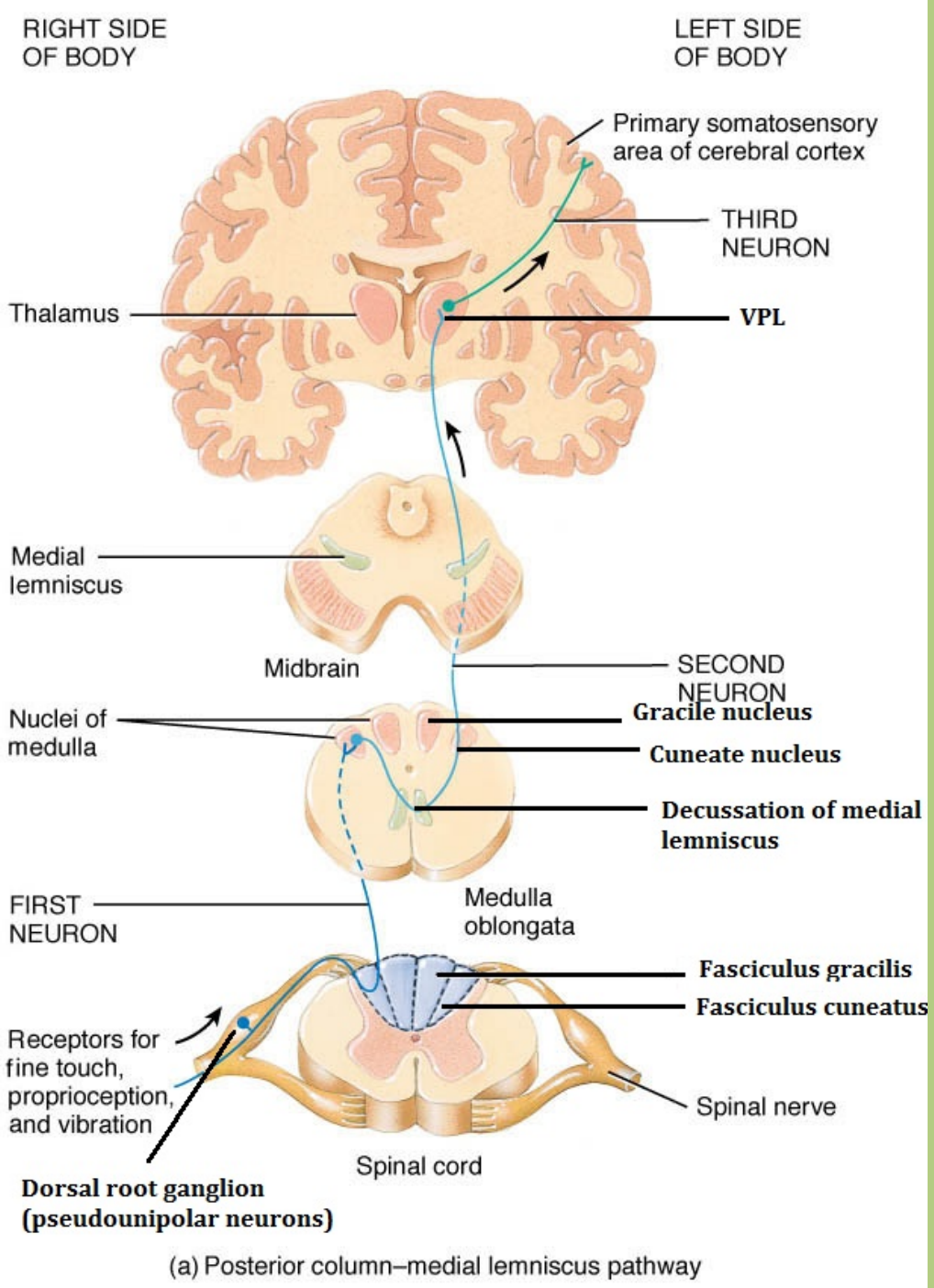





(a) Posterior column–medial lemniscus pathway

# Sensory pathways (ascending tracts)- Fasciculus gracilis and cuneatus

- **Receptors:** tactile corpuscles. Muscle spindles and tendon organs for the conscious proprioception.
- **1st neuron**: pseudounipolar neurons in the *dorsal root ganglion*.
- Many of the fibers travel ipsilaterally in the posterior funiculi to the *gracile and cuneate nuclei* (**2nd neuron**) in the medulla oblongata.

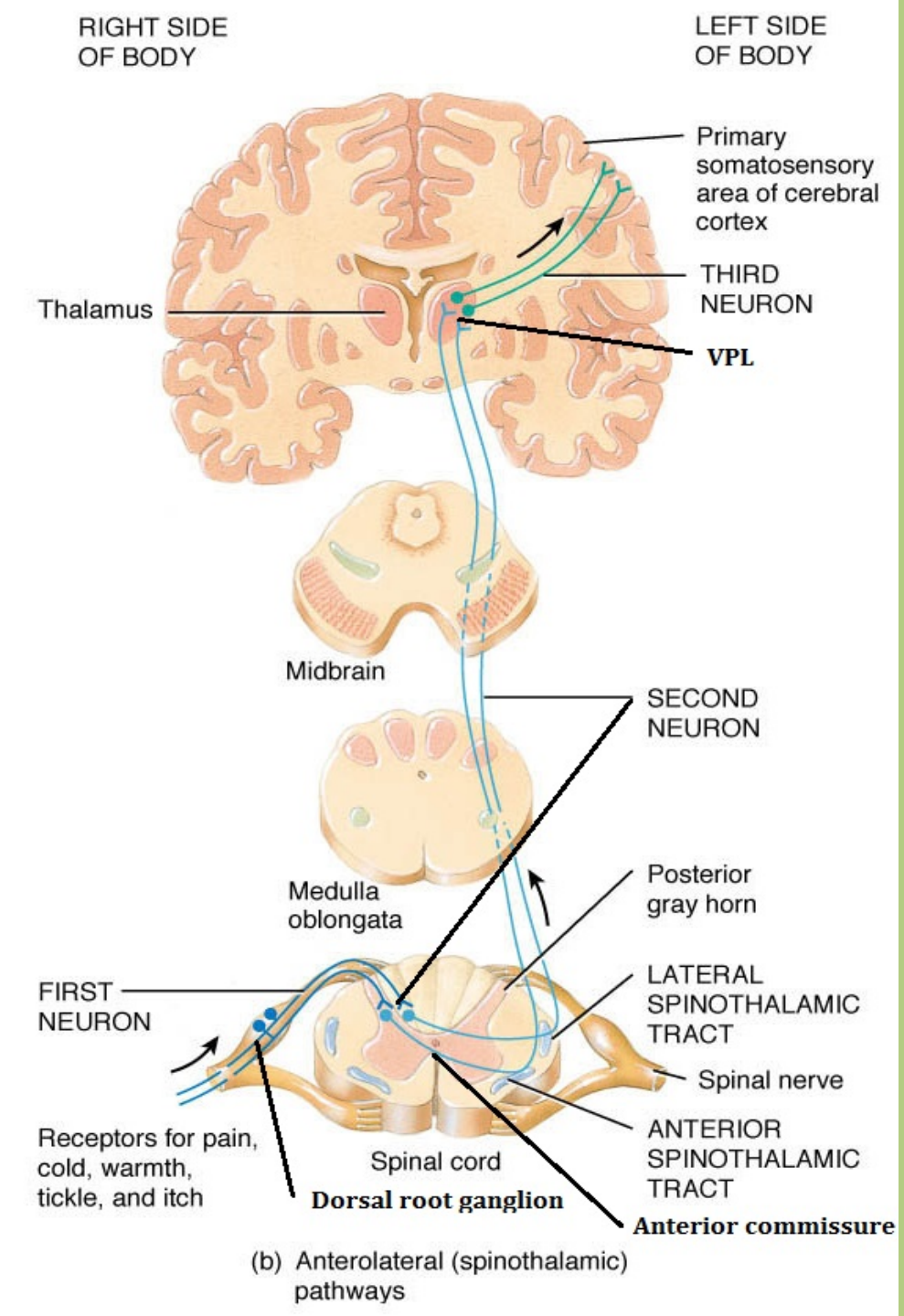



(a) Posterior column–medial lemniscus pathway

# Sensory pathways (ascending tracts)- Fasciculus gracilis and cuneatus

- The axons cross in the medulla oblongata and travel as a single bundle ***(medial lemniscus)*** to the *VPL* of thalamus (**3rd neuron**).

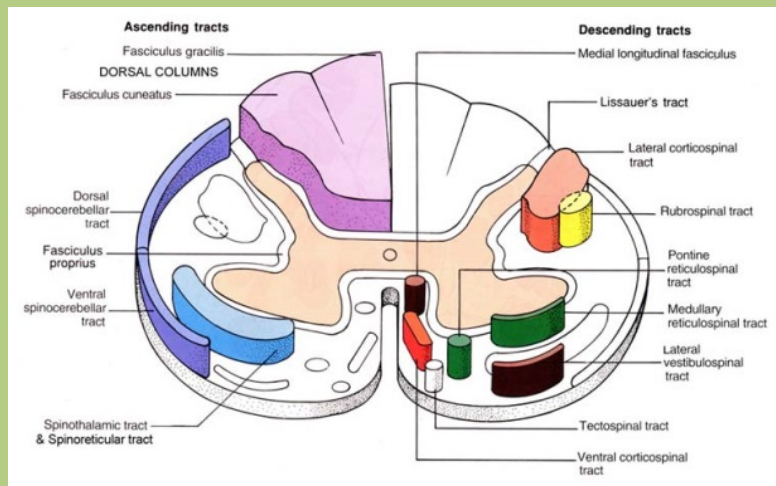
- The axons of the third neurons terminate in the *primary somatosensory cortex*, located in the postcentral gyrus.



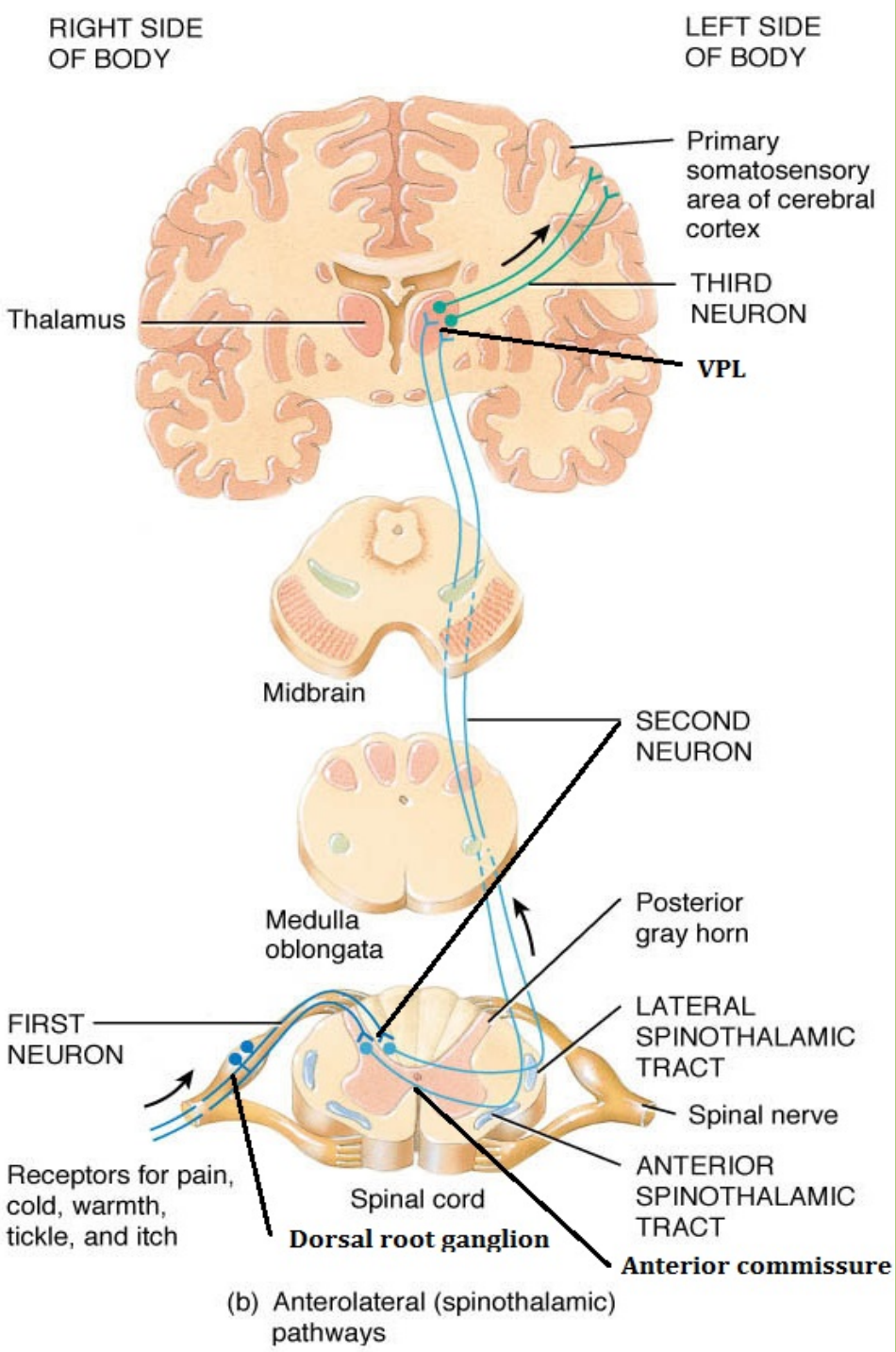

(b) Anterolateral (spinothalamic) pathways

# Sensory pathways (ascending tracts)- Spinothalamic tracts

- The **anterior spinothalamic tract** is the pathway for ***crude touch and pressure sensation***, while the **lateral spinothalamic tract** conveys ***pain, temperature, tickle, itch and sexual sensation*** = ***PROTOPATHIC SENSATION*.**



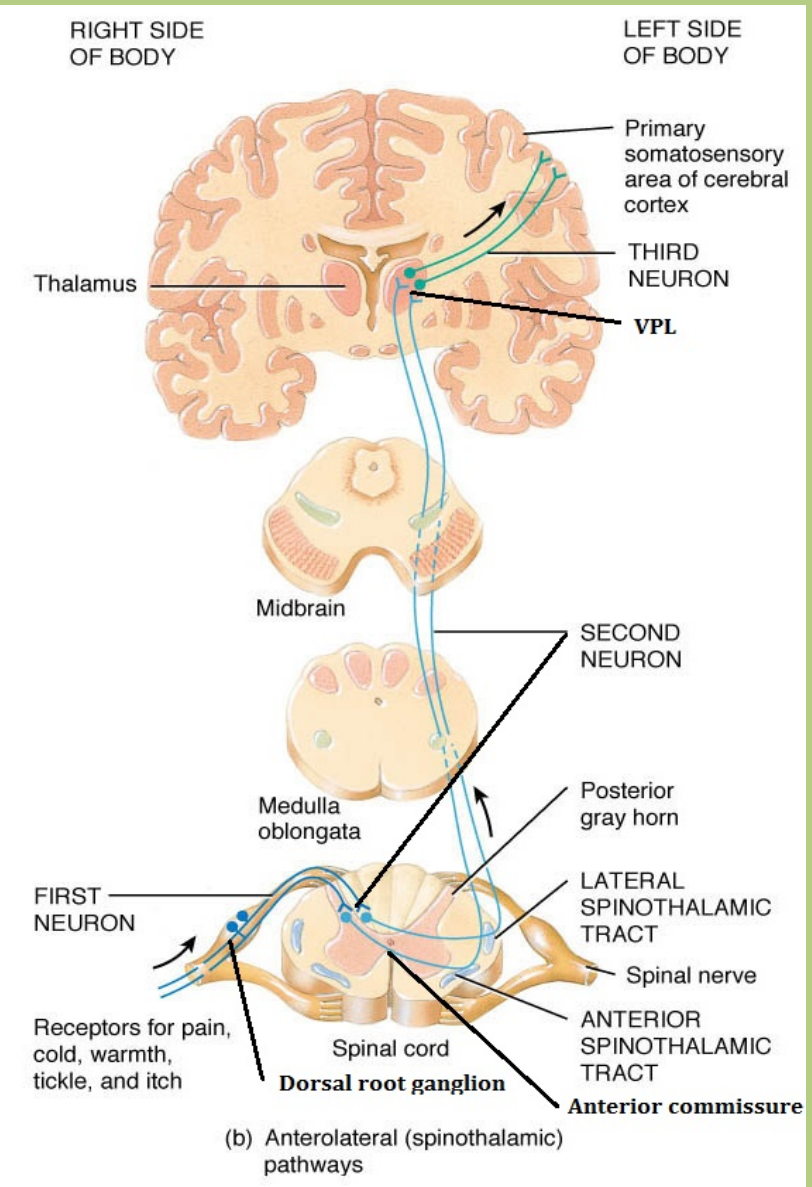
# Sensory pathways (ascending tracts)- Lateral spinothalamic tract




(b) Anterolateral (spinothalamic) pathways

- **Receptors:** Free nerve endings in the skin for **pain and temperature sensation**.
- The pain impulses are transmitted to the spinal cord in fast-conducting delta A-type fibers *(initial sharp pain)* and slow-conducting C-type fibers *(prolonged burning, aching pain)*.
- The cell bodies of these nerve endings are located in the *dorsal root ganglion* (**1st neuron**).
- The central processes of first neurons pass through the dorsal root into the white matter of the spinal cord and divide into descending and ascending branches (*dorsolateral tract of Lissauer*), then they terminate on *secondary sensory neurons* in the posterior horn (including cells of the substantia gelatinosa) (**2nd neuron**).
- The axons of second neurons *cross in the anterior white commissure* in the corresponding spinal segment and ascend in the anterolateral funiculus on the opposite (contralateral) side.

# Sensory pathways (ascending tracts)- Lateral spinothalamic tract




- Many of the fibers of lateral spinothalamic tract terminate in the *VPL* of thalamus (**3rd neuron**).
- The axons of third neurons radiate to the *primary somatosensory cortex* in the postcentral gyrus.

# Pain control in the CNS

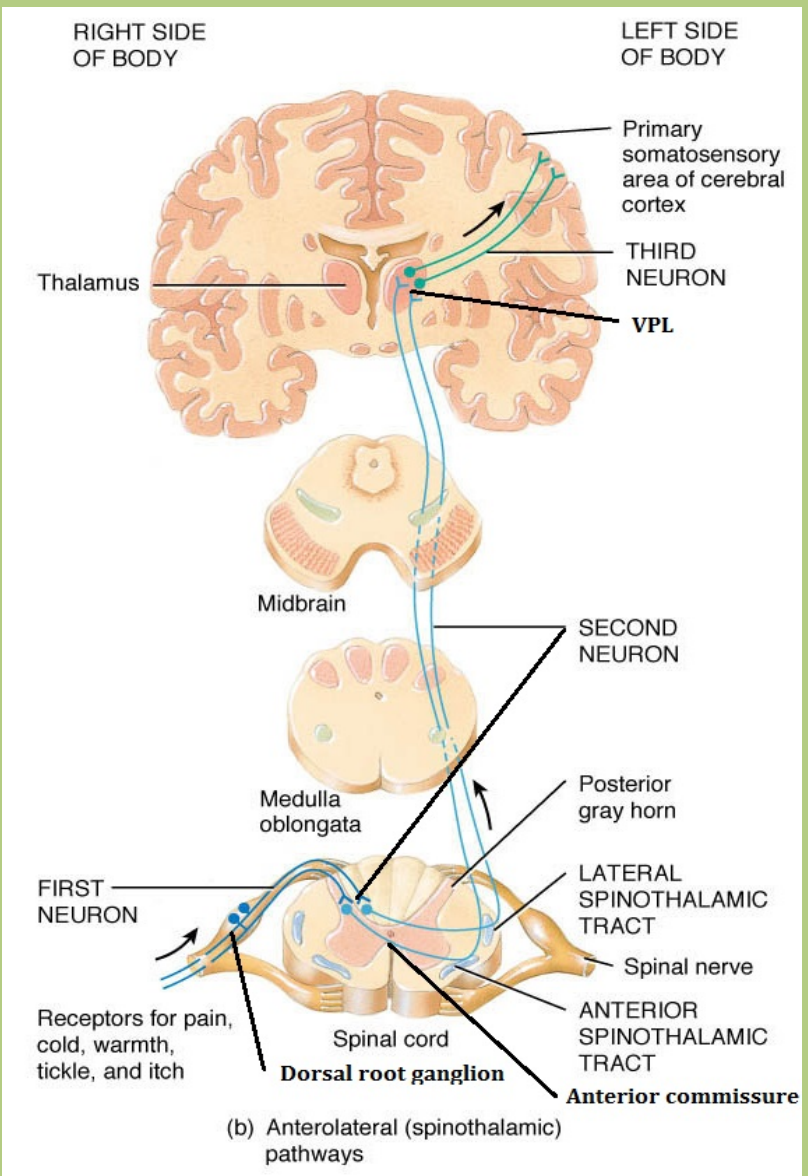
**Gate Control Theory**

***Massage, acupuncture and low frequency electrical stimulation can relieve pain.***
Although the *precise mechanism for these phenomena is not understood*, the theory was proposed in 1965 by Ronald Melzack and Patrick Wall.
It was suggested that at the side ***where the pain fibers enter the CNS, inhibition could occur*** by means of connector neurons excited by large, myelinated afferent fibers carrying information of non painful touch and pressure.

**The Analgesia System**

***Stimulation of certain areas of the brainstem can reduce or block sensations of pain.***
These areas include the *periventricular area of the diencephalon, the periaqueductal gray matter of the midbrain, and midline nuclei of the brainstem*. It is believed that fibers of the reticulospinal tract pass down to the spinal cord and synapse on cells concerned with pain sensation in the posterior gray column. The analgesic system can suppress both sharp pricking pain and burning pain sensations.
(Related neurotransmitters are *enkephalins, endorphins and serotonin*, inhibiting the release of substance P in the posterior gray column.)

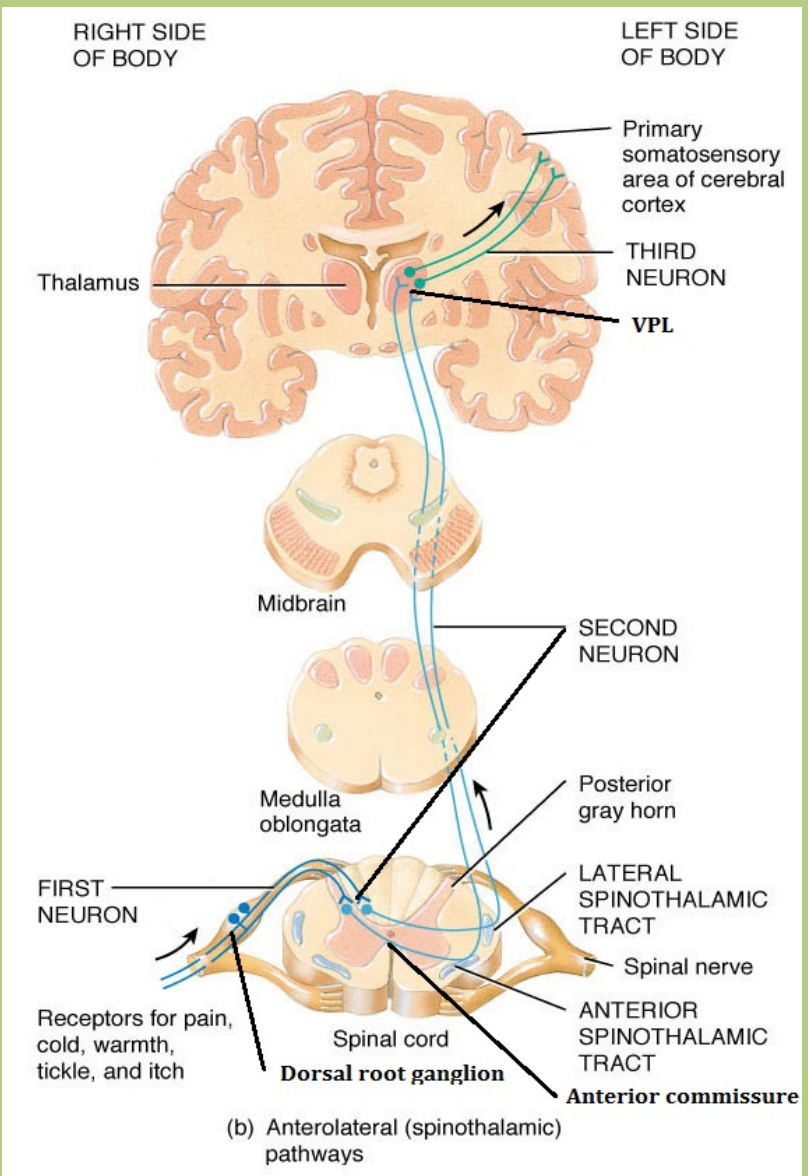
# Sensory pathways (ascending tracts)- Anterior spinothalamic tract



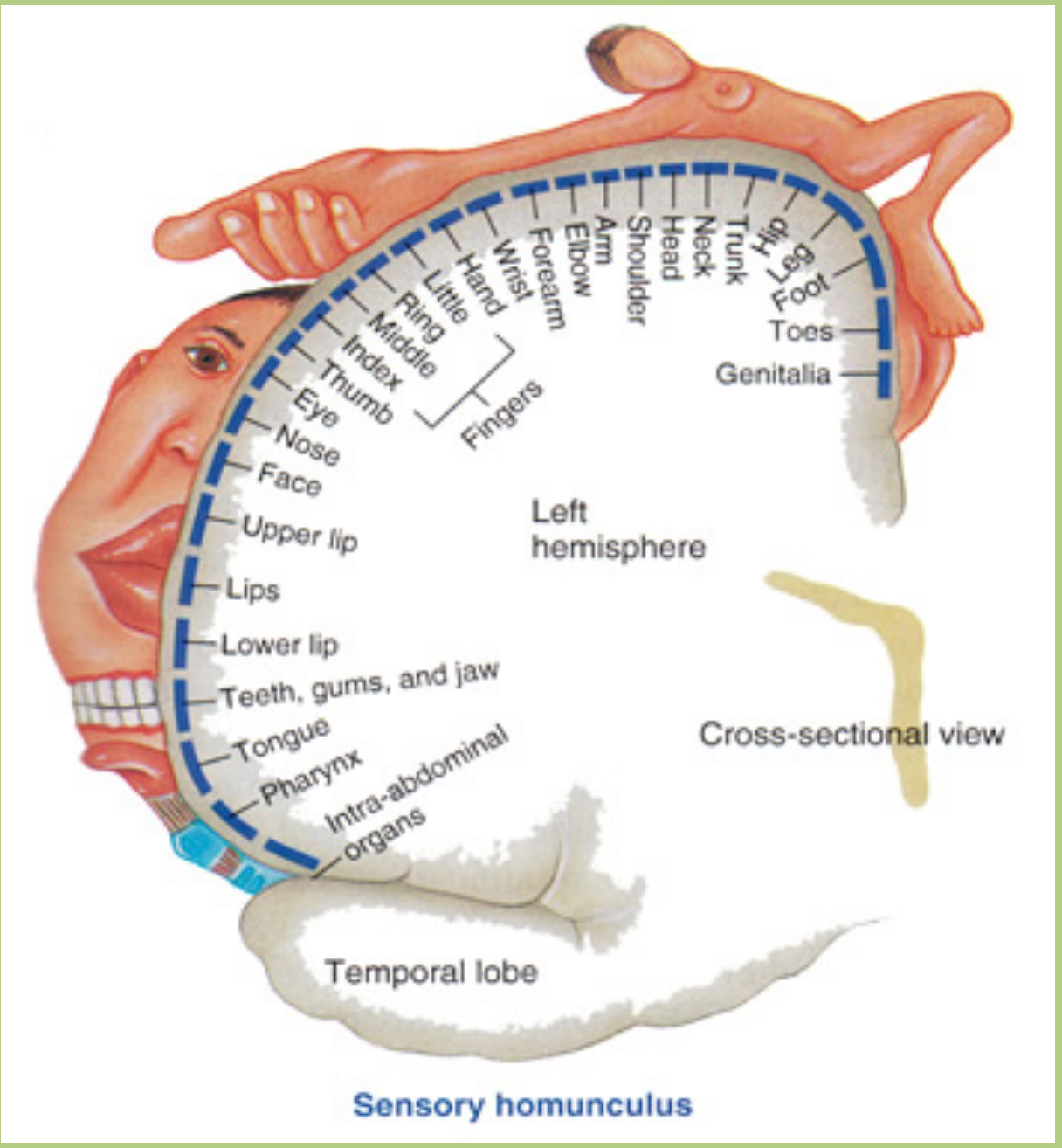
(b) Anterolateral (spinothalamic) pathways

- **Receptors:** Impulses from tactile corpuscules and from receptors about the hair follicles.
- **1st neuron**: pseudounipolar neurons in the *dorsal root ganglion*.
- The central processes of first neurons pass through the dorsal root into the white matter and divide into descending and ascending branches (*dorsolateral tract of Lissauer*), then they terminate on *secondary sensory neurons* in the posterior horn (including cells of the substantia gelatinosa) -**2nd neuron**.

# Sensory pathways (ascending tracts)- Anterior spinothalamic tract



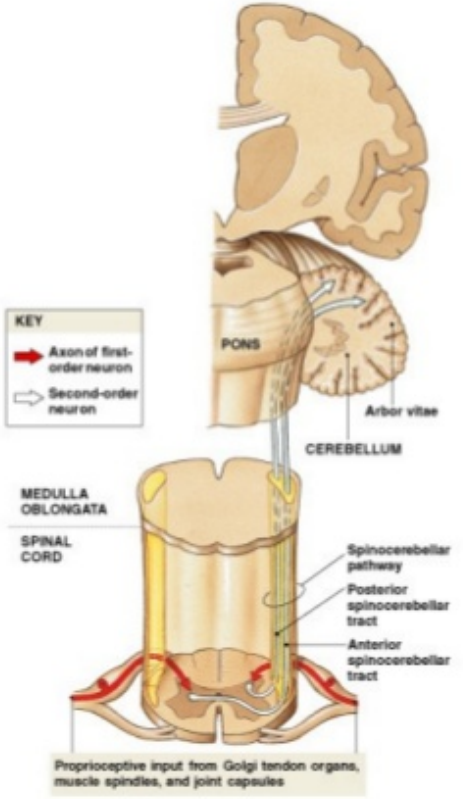

- The axons of second neurons *cross in the anterior white commissure* within several spinal segments and ascend in the anterolateral funiculus on the opposite (contralateral) side.
- The axons terminate in the *VPL* of the thalamus (**3rd neuron**).
- The axons of third neurons radiate to the *primary somatosensory cortex* in the postcentral gyrus.




The contralateral half of the body is represented as inverted, with the hand and mouth situated inferiorly and the leg situated superiorly, and with the foot and anogenital region on the medial surface of the hemisphere.

# Sensory pathways (ascending tracts)- Spinocerebellar tracts

## The Spinocerebellar Pathway

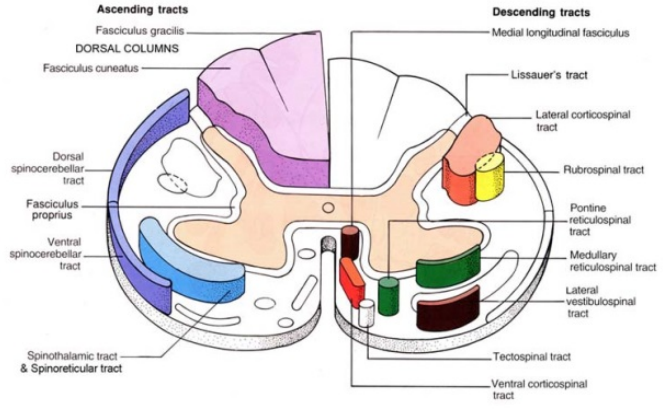



- Proprioceptive information about position of skeletal muscles, tendons, and joints sent to cerebellum

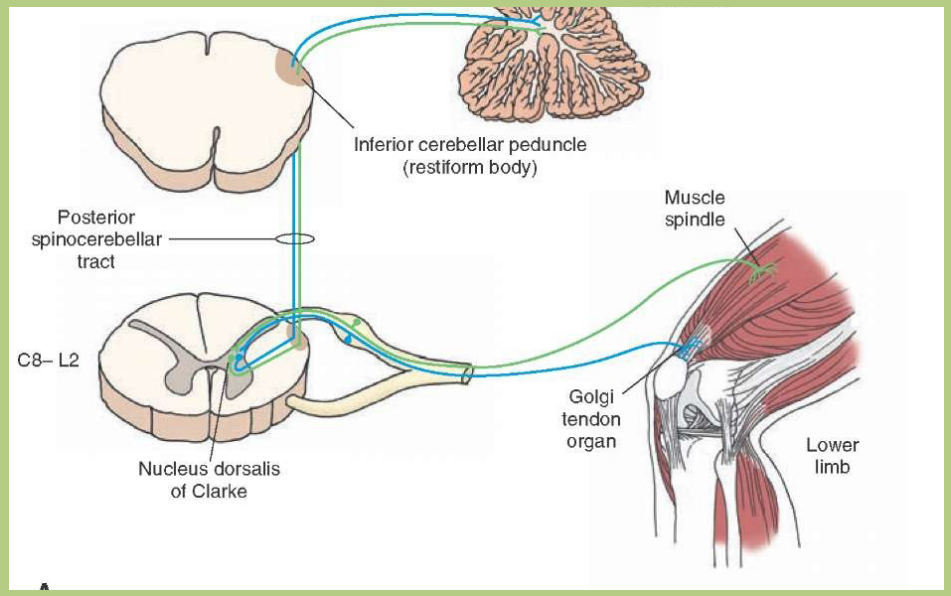
**posterior** spinocerebellar tracts **do not cross**

**Anterior** spinocerebellar tracts **do cross**

**Receptors:** muscle spindles, tendon organs and joint receptors.

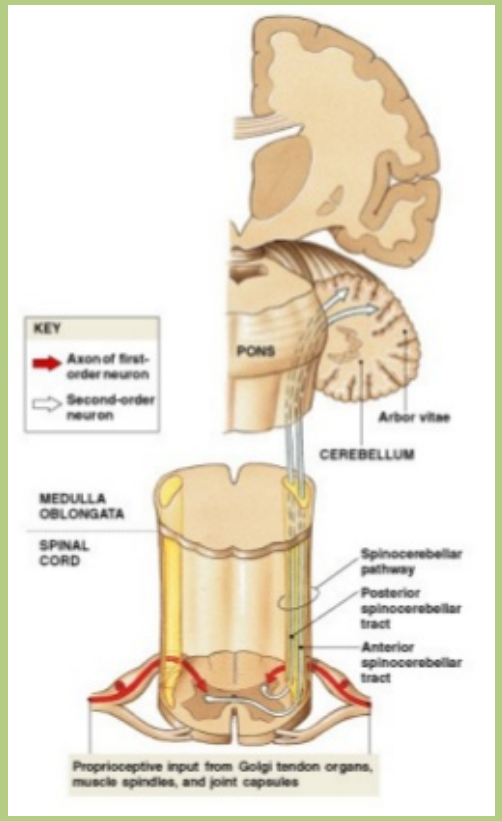


# Sensory pathways (ascending tracts)- Posterior spinocerebellar tract



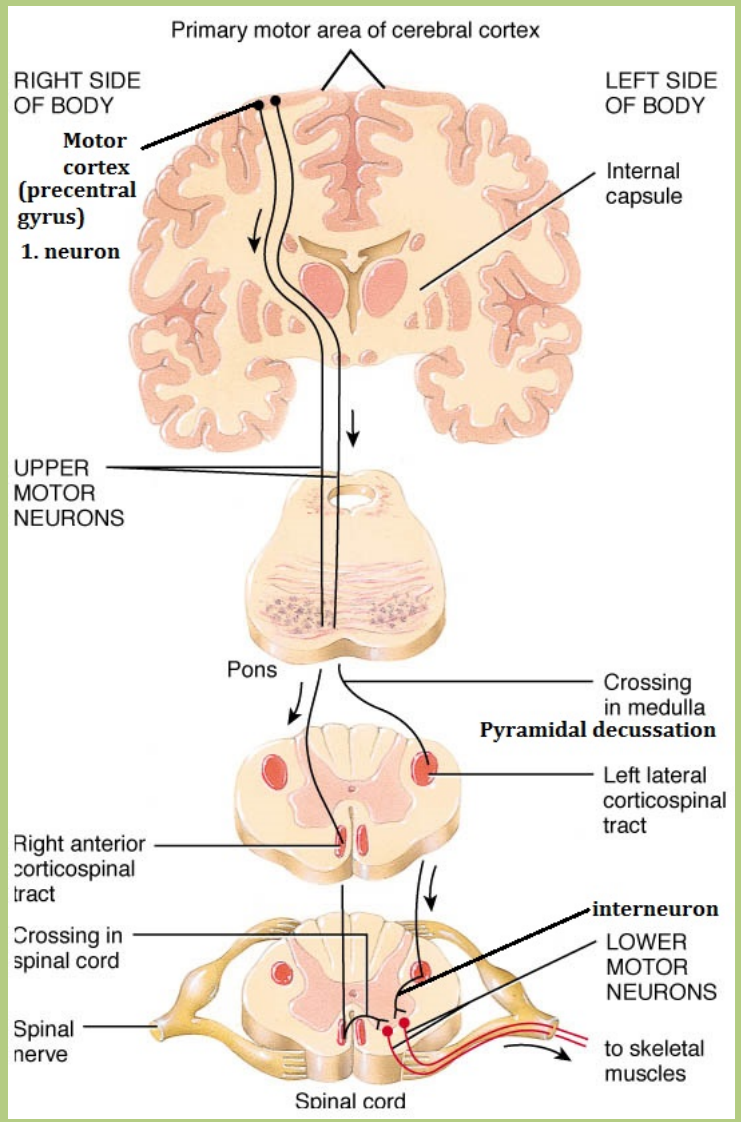

- Muscle spindles and tendon receptors convey proprioceptive information from **lower body part** to pseudounipolar neurons in the *dorsal root ganglion* (**1st neuron**).
- The axons terminate at the dorsal nucleus (*Clark's*) of gray matter (**2nd neuron**), which spans spinal cord segments C8 to L3.
- The axons of the second neurons ascend ipsilaterally to the cerebellum, entering through the inferior cerebellar peduncle.
- The axons terminate with *mossy fibers in the stratum granulosum* of cerebellar cortex.

# Sensory pathways (ascending tracts)- Anterior spinocerebellar tract

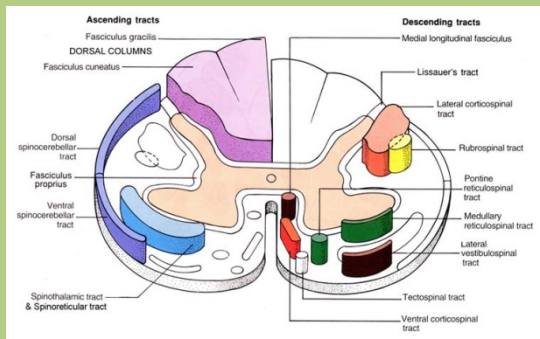



- Muscle spindles and tendon receptors convey proprioceptive information from **lower body part** to pseudounipolar neurons in the *dorsal root ganglion* (**1st neuron**).
- The axons terminate at the *dorsal gray horn* (**2nd neuron**), which spans spinal cord segments L4 to S3.
- The majority of the axons of second neurons crosses in the anterior commissure and ascends contralaterally to the cerebellum, entering through the superior cerebellar peduncle.
- The axons terminate with *mossy fibers in the stratum granulosum* of cerebellar cortex.
- *(It is believed that those fibers that crossed over to the opposite side in the spinal cord cross back within the cerebellum.)*

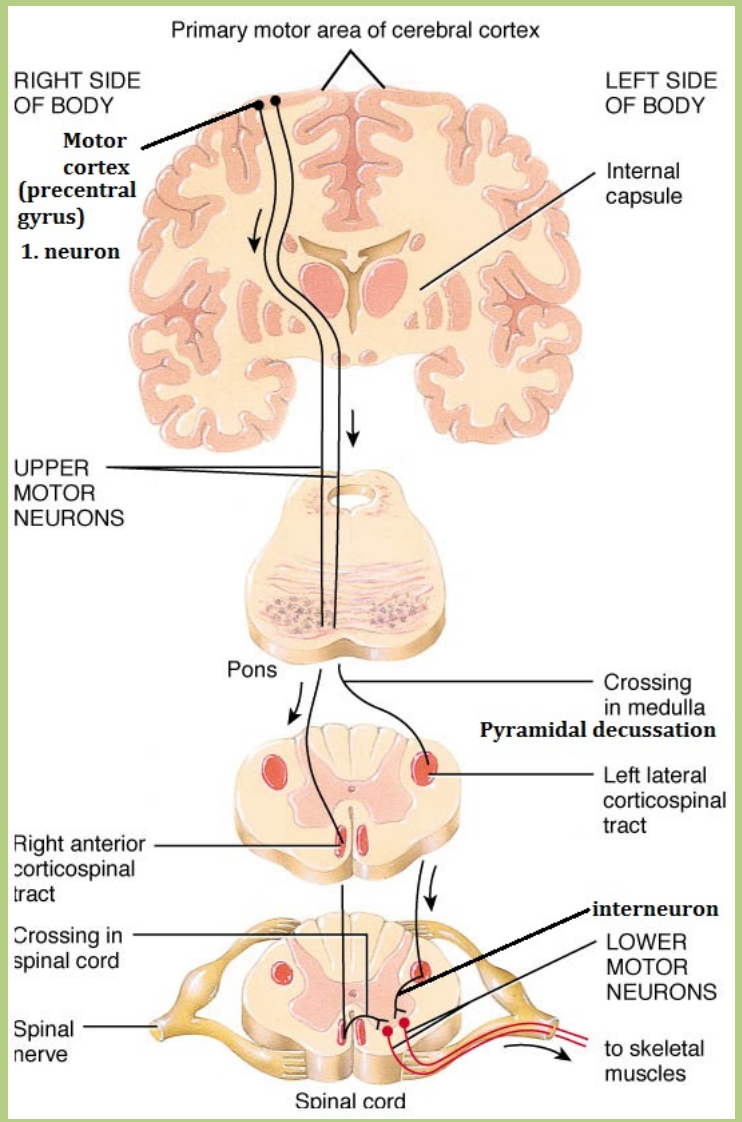
# Motor pathways(descending tracts)- Pyramidal tracts




- The most important pathway for voluntary motor function.
- Some of its axons, the **corticonuclear** fibers terminate at the cranial nerve nuclei.
- Others, the **corticospinal** fibers terminate on the motor neurons in anterior horn of gray matter.
- A third group, the **corticoreticular** fibers are distributed to nuclei of reticular formation.

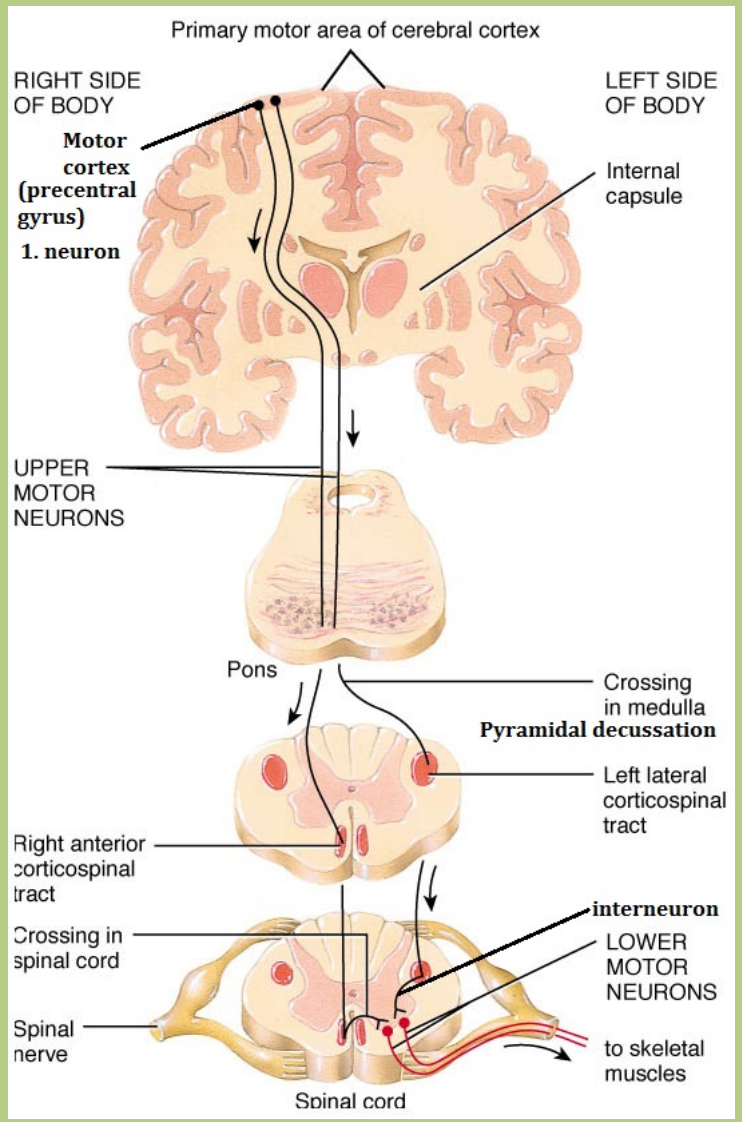


# Motor pathways(descending tracts)- Pyramidal (corticospinal) tracts



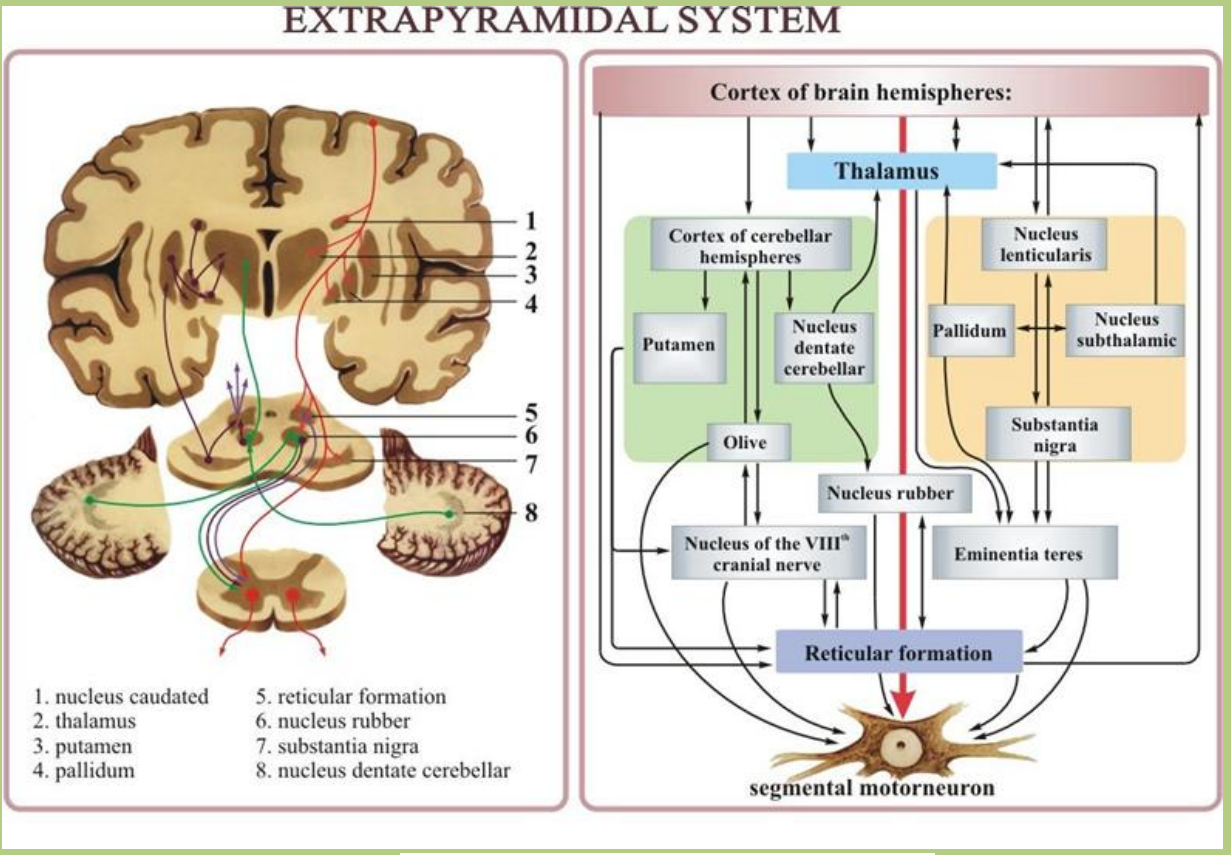

- The tracts originate in the motor cortex at the *pyramidal cells* (**1st neuron**).
- The corticospinal fibers pass through the internal capsule, continuing into the brainstem and spinal cord.
- The fibers descend to the ***pyramidal decussation*** in the medulla oblongata, where approximately 80% of them cross to the opposite side. The fibers continue into the spinal cord where they form the **lateral corticospinal tract**, which has somatotopic organization: the fibers for the sacral cord are the most lateral, while the fibers for the cervical cord are the most medial.

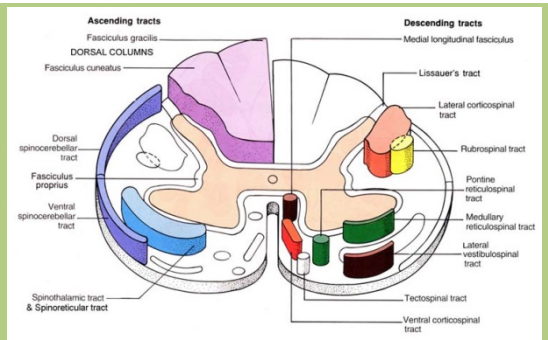
# Motor pathways(descending tracts)- Pyramidal (corticospinal) tracts




- The remaining 20% of corticospinal fibers continue to descend ***without crossing***, forming the **anterior corticospinal tract**, which borders the ventral median fissure.
- The anterior corticospinal tract is particularly well developed in the cervical cord, but is not present in the lower thoracic, lumbar or sacral cords.
- The axons of the pyramidal cells terminate via intercalated cells on alpha and gamma motor neurons, Renshaw cells and interneurons (**2nd neuron**).
- Most fibers of ant. corticospinal tract cross at the segmental level to terminate on the same *motor neurons* (**3rd neuron**) as the lateral corticospinal tract.

# Motor pathways(descending tracts)- Extrapyramidal tracts



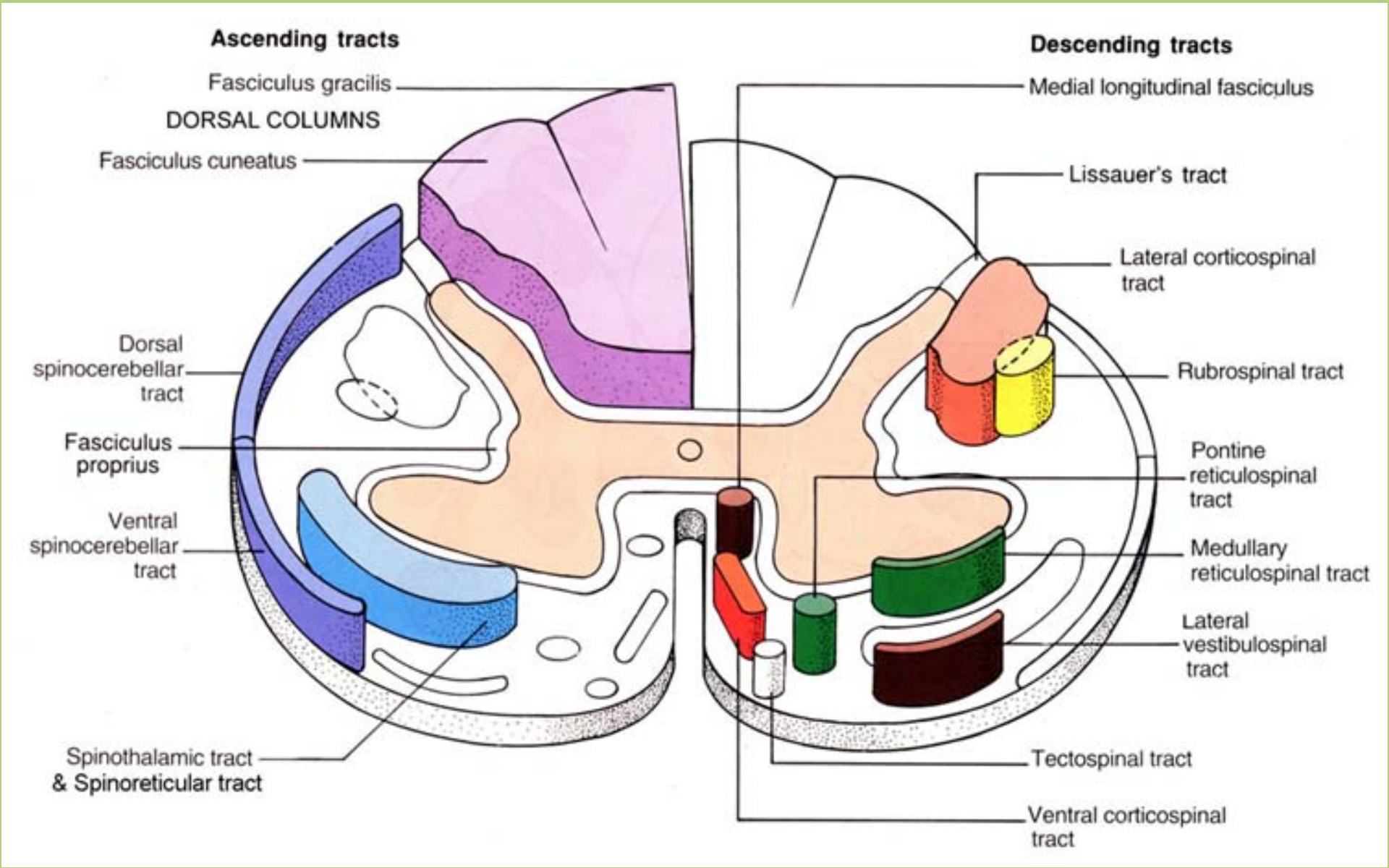




- Unlike the pyramidal tract, which controls conscious, voluntary motor activities, the **extrapyramidal motor system (cerebellum, basal ganglia and motor nuclei of the brainstem) is necessary for autonomic and learned motor processes (e.g., walking, running, cycling).**

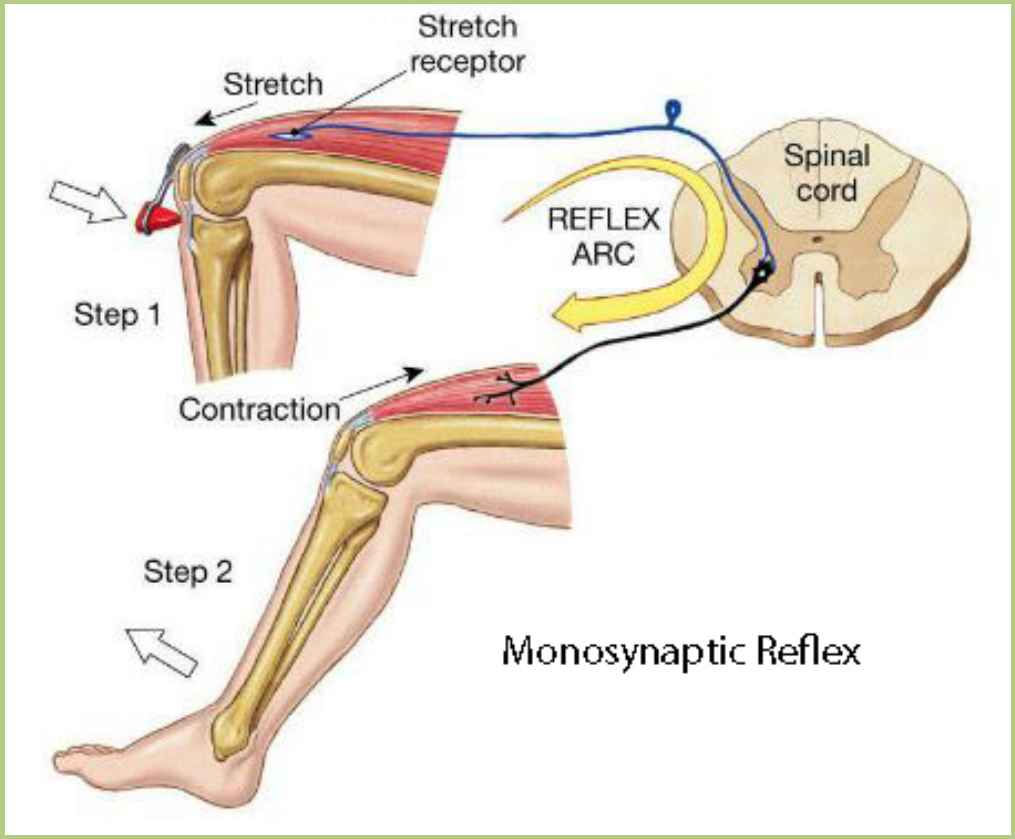
Some important tracts:

- **Tectospinal tract**: coordinates head and eye movements.
- **Rubrospinal tract**: mediation of voluntary movements.

# Ascending and descending tracts - overview

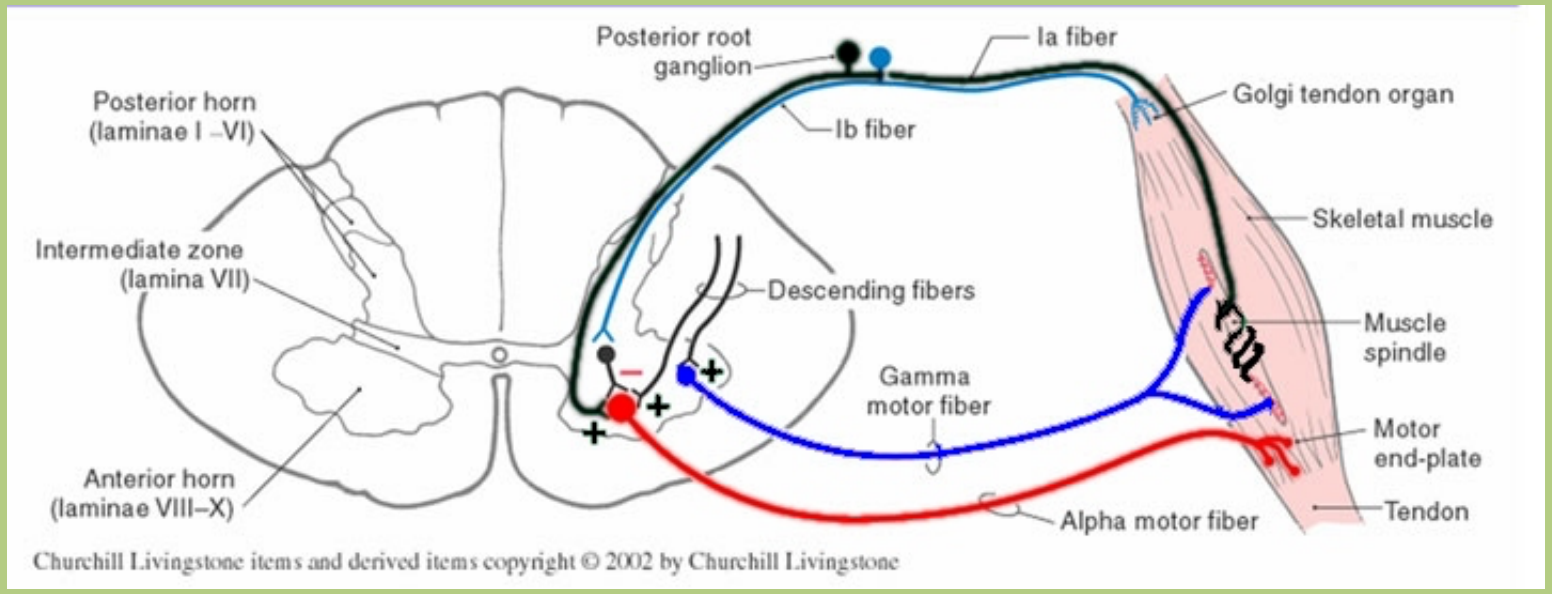


# Monosynaptic reflex arc - stretch reflex




The ***muscle is briefly stretched*** by a tap on its tendon. ***Stretch receptors*** (muscle spindles) in the muscle ***transmit signals to alpha motor neurons via pseudounipolar neurons*** whose cell bodies are in the dorsal root ganglion. These afferent neurons release excitatory transmitters which cause the alpha motors neurons to ***stimulate muscle contraction***.

# Gamma loop




The term gamma loop was introduced by Granit to refer to the ***activation of alpha motoneurones indirectly*** through the effect of gamma efferent drive to the muscle spindles.

# Thank you for your attention.


References:
McGraw-Hill Company's pictures
Nature Reviews
Pearson Education
Thieme: Atlas of Anatomy, Head, Neck, and Neuroanatomy