Systemic Module

CNS1

“Anatomy”

Sensory Tracts

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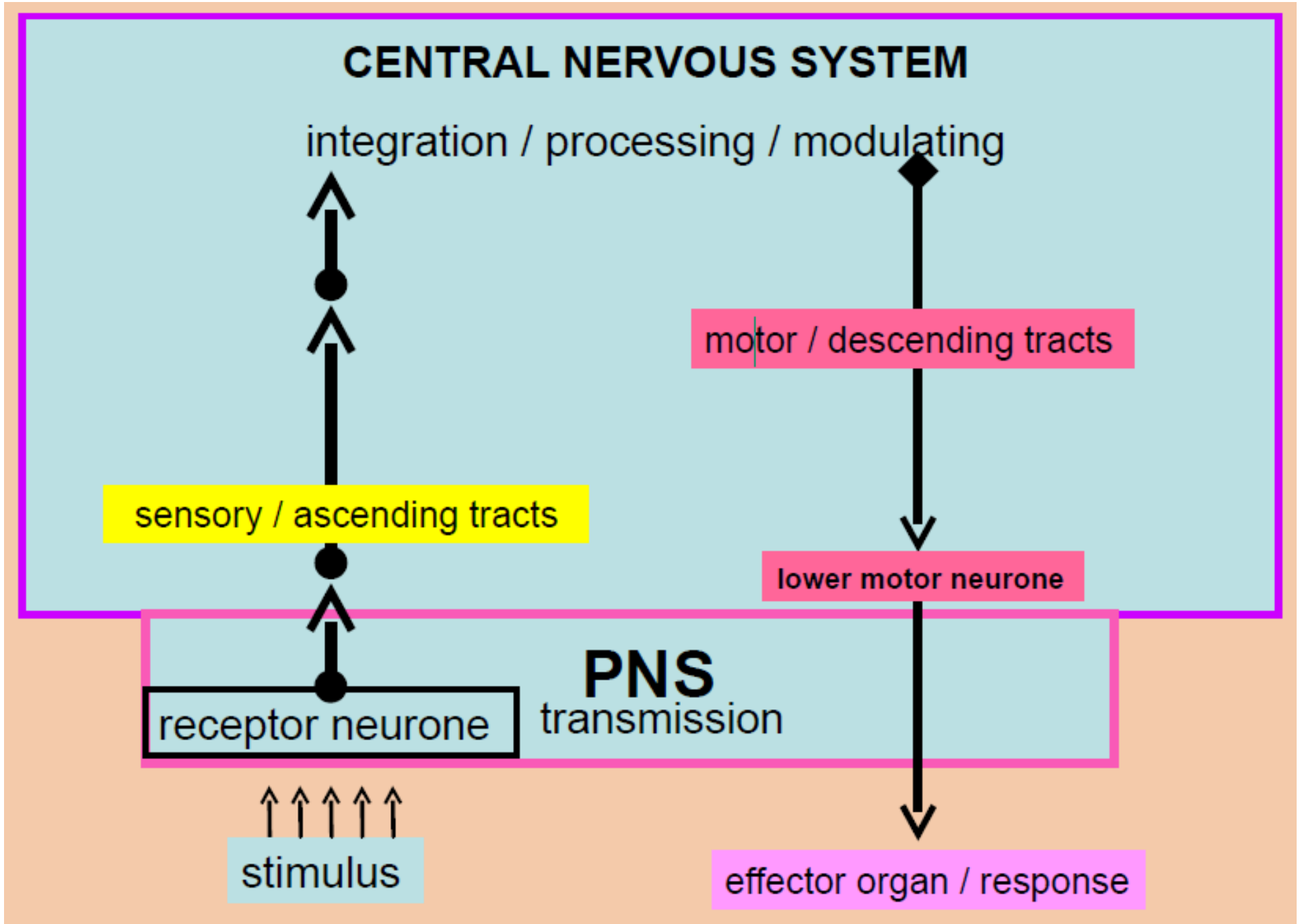
Sensory and Motor Tracts

- The white matter of spinal cord on each side is divided **dorsal column**, **lateral column** and **ventral column**.
- Within these column, the fibers with common origin, function and termination site are arranged into bundle called **spinal tract**.
- Each spinal tract occupies specific part of the white matter.
- The spinal tracts are either **sensory** or **motor :**
  - **The sensory (ascending) tracts** *carry sensations up to the brain*.
  - **The motor (descending) tracts** *carry motor signals from the brain to the spinal cord*.


CENTRAL NERVOUS SYSTEM
integration / processing / modulating
motor / descending tracts
sensory / ascending tracts
lower motor neurone
PNS
transmission
receptor neurone
stimulus
effector organ / response

Sensory Tracts

Sensory Pathways from Limbs and Trunk

- The sensory pathways from the limb and trunk carry general sensations such as **proprioception**, **touch**, **pain**, **temperature** and **pain.**

- Any sensation can be consciously felt and well appreciated only if it reach the cortex.

- All of the conscious sensations (except olfaction) pass through the thalamus in their way to the cerebral cortex.

Sensory Tracts

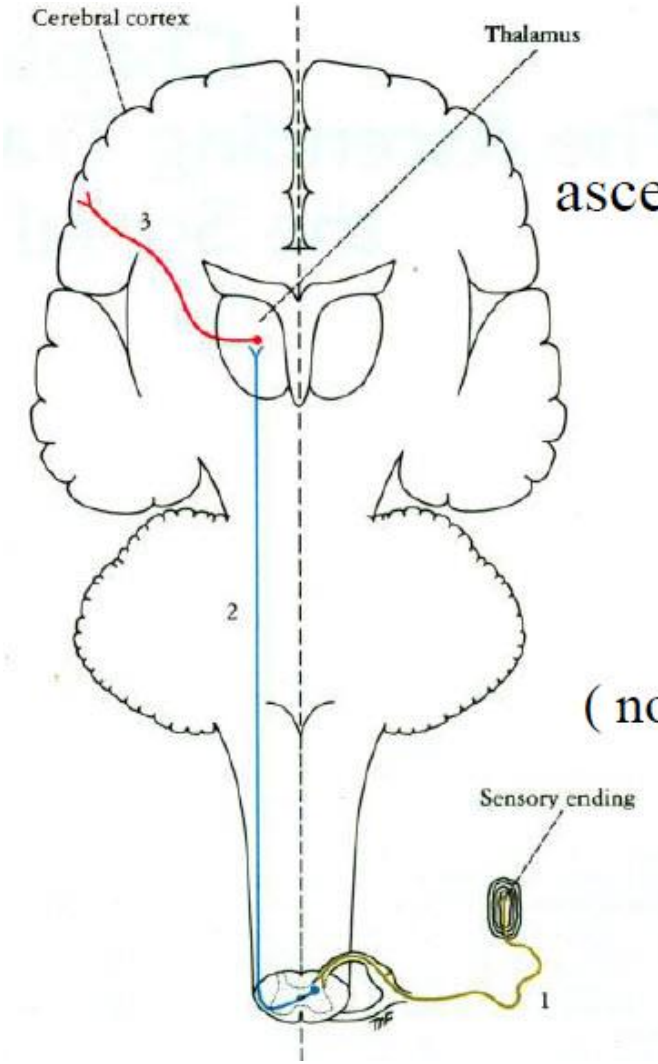
- The general sensations from the limbs and trunk are carried by three major sensory tracts:

1. **The posterior column tracts**
2. **The spinothalamic tracts**
3. **The spinocerebellar tracts**

Sensory Tracts

- They are crossed pathways: cross the midline.
- They are formed of three order neurons.

1. **First-order neuron**
2. **Second-order neuron**
3. **Third-order neuron**



ascending sensory pathway

(in general form)

from sensory endings

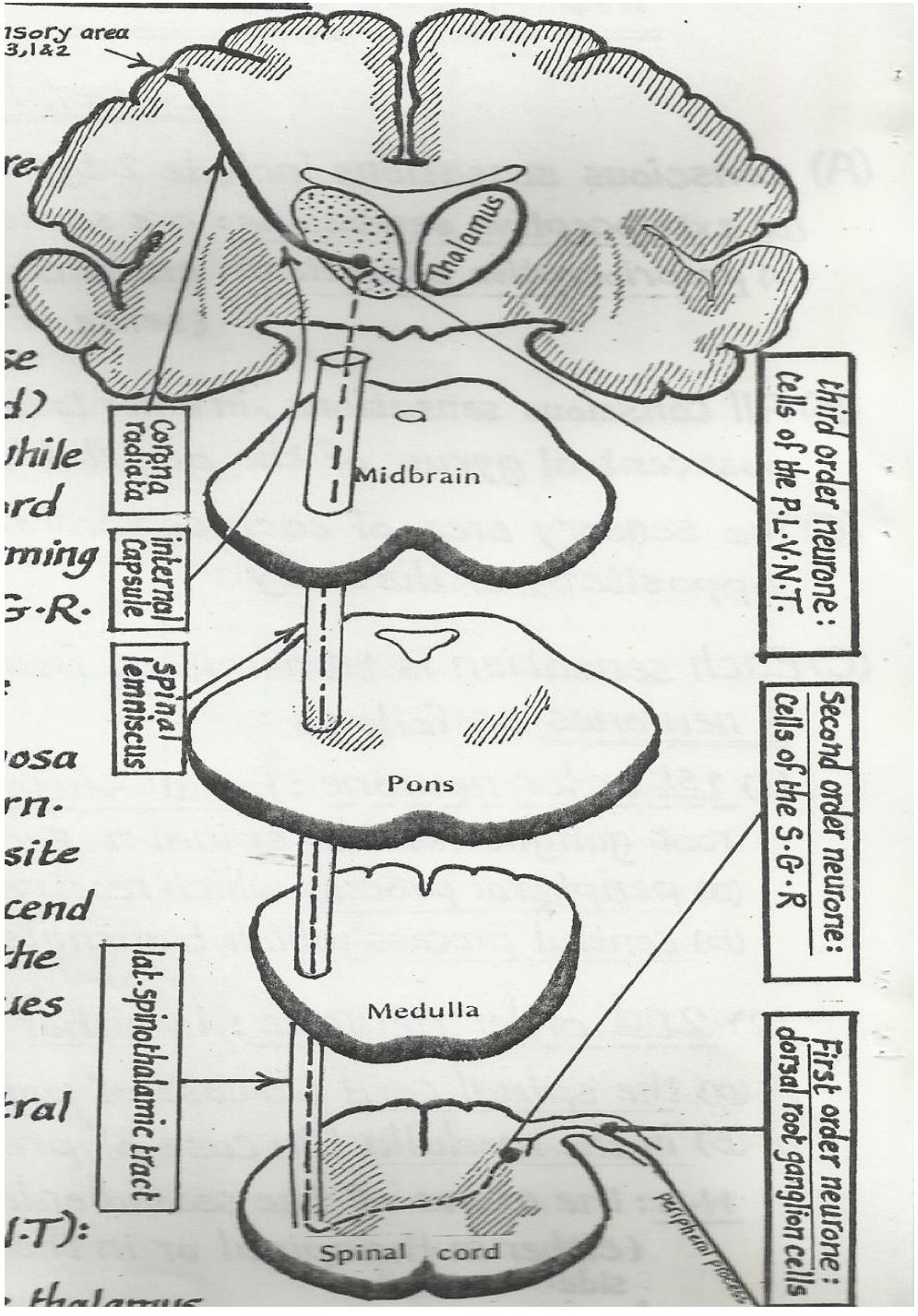
to

cerebral cortex

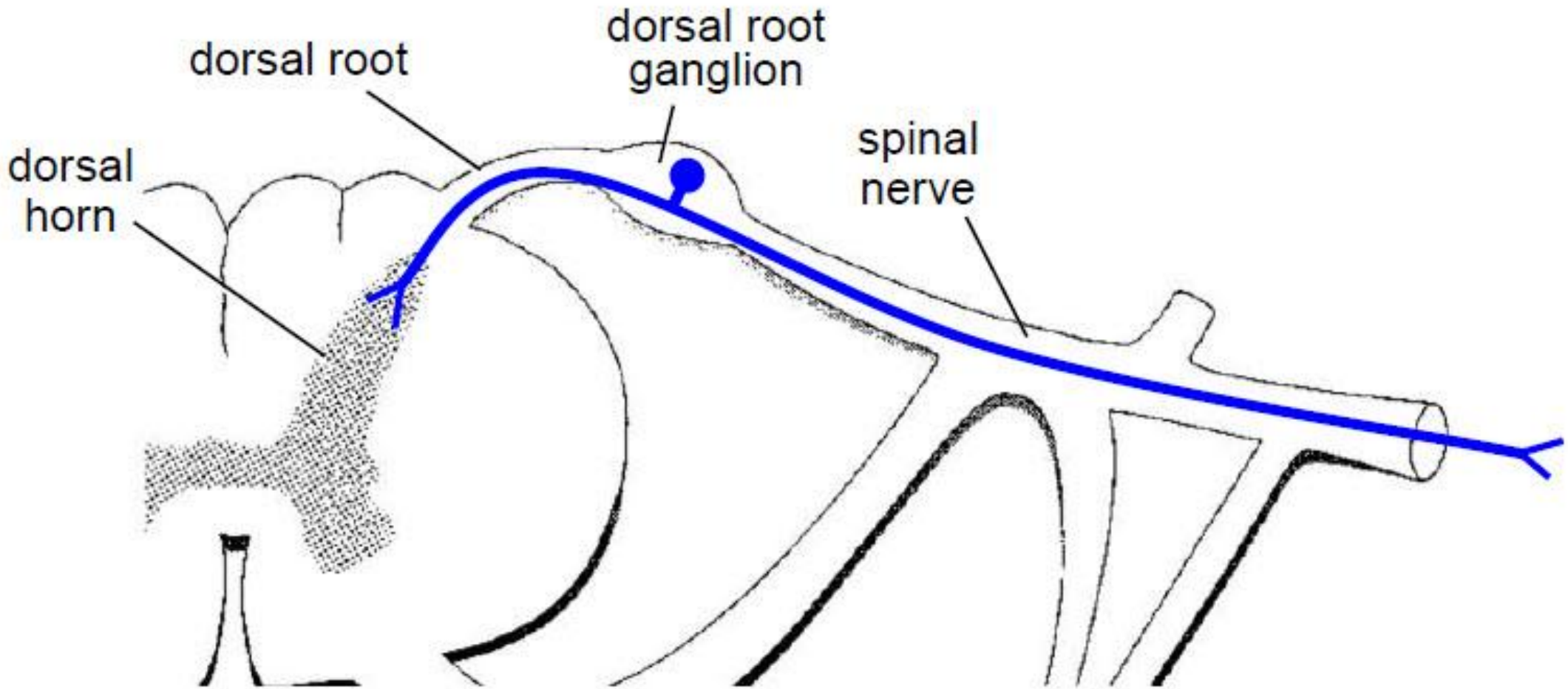
(note the three neurons chain)

First-order Neuron

- Delivers sensations to the CNS
- They are always a pseudounipolar cells whose cell bodies reside in the posterior (dorsal) root ganglion.
- They carry sensation by their peripheral process from receptors and conveys this sensation by their central processes to the dorsal root to the spinal cord.



FIRST ORDER NEURON

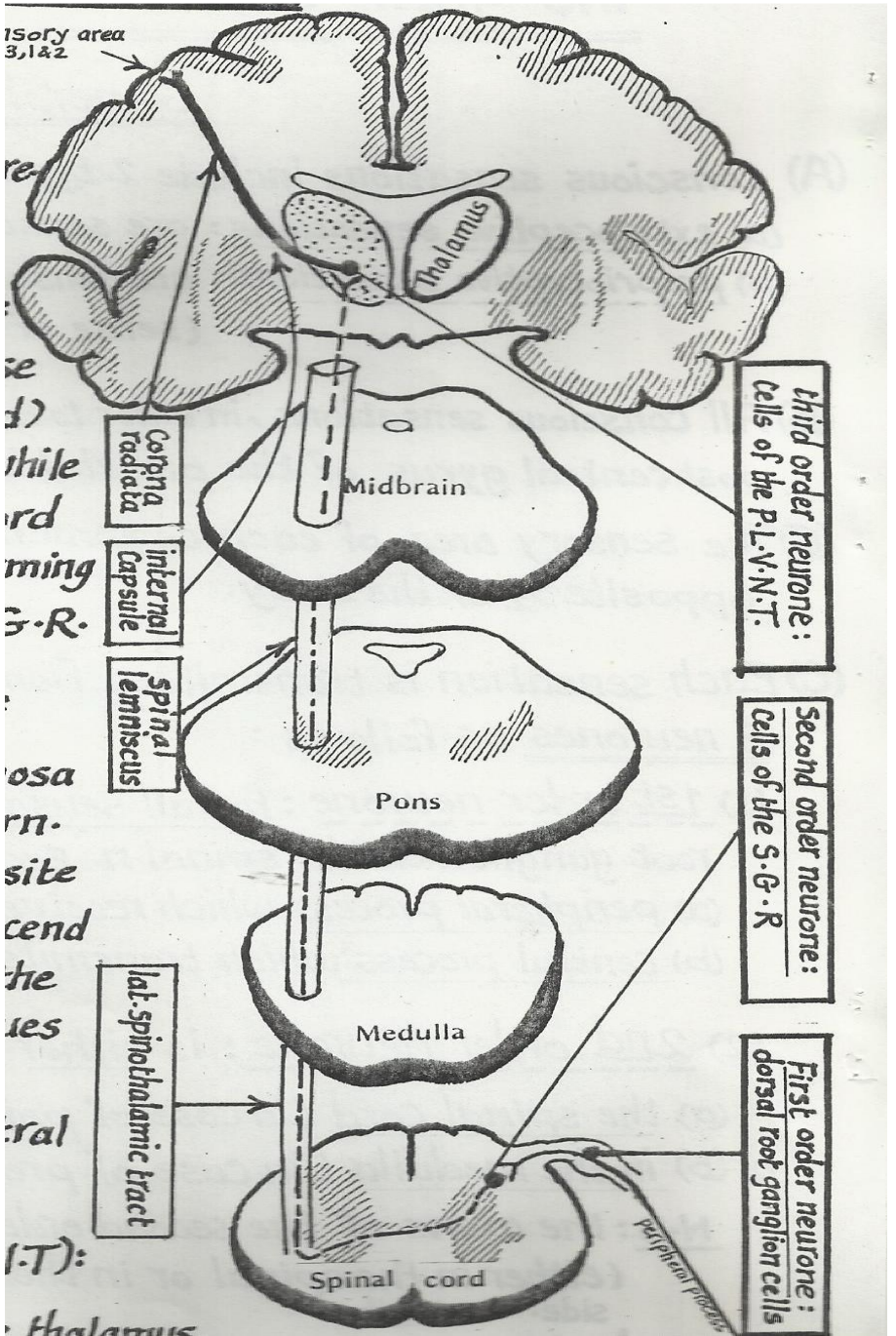


Second-order Neuron

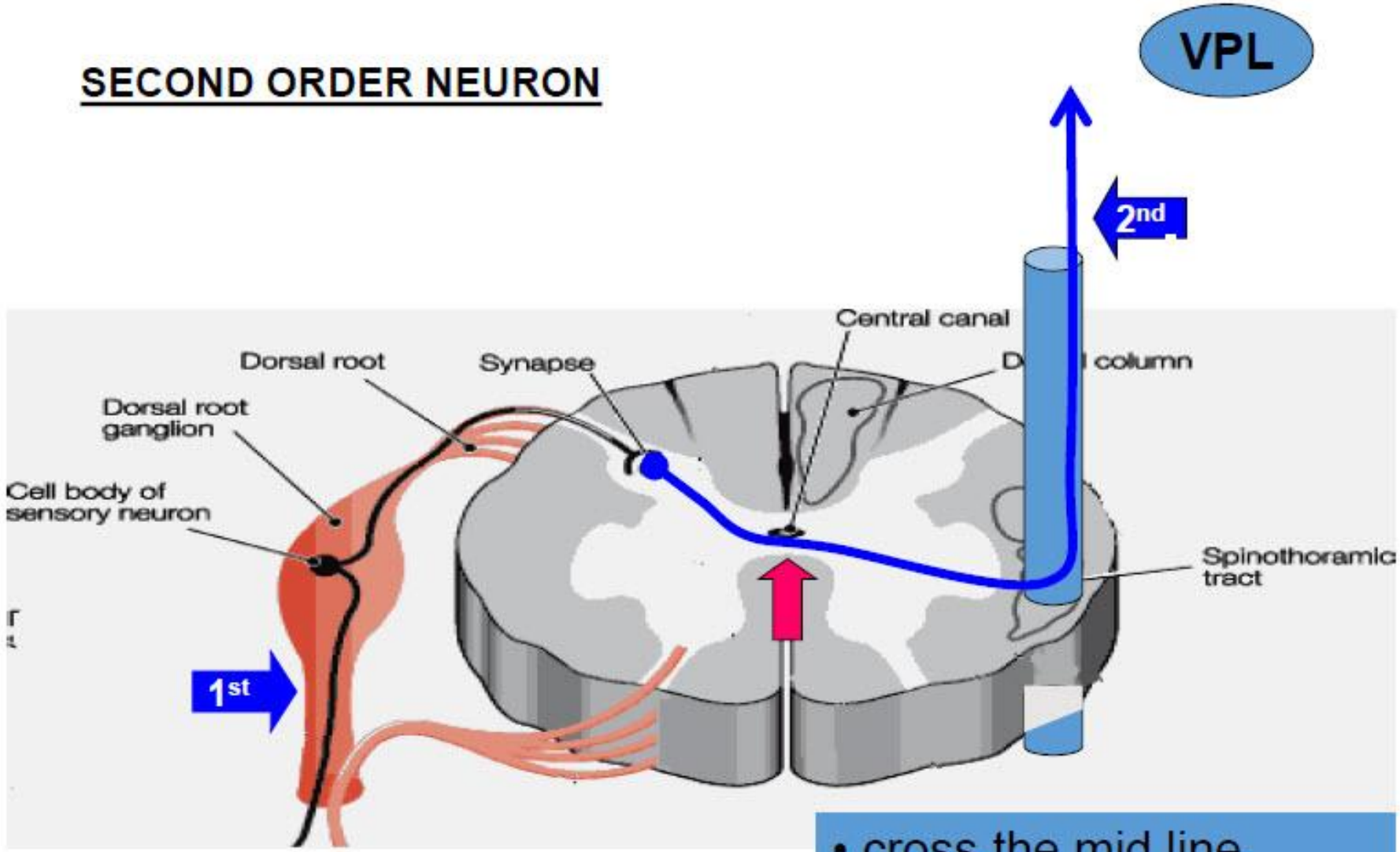
- They are always a cells in the CNS (spinal cord or medulla oblongata).
- Their axons always decussate to the opposite side and ascends in the brainstem as lemniscus to end in the thalamus.

Third-order Neuron

- Transmits information from the thalamus to the cerebral cortex.
- Their cell bodies are in the ventral postero-lateral nucleus of thalamus (VPLN).
- Their axons pass through posterior limb of internal capsule, then through corona radiata to reach sensory area of cerebral cortex.



SECOND ORDER NEURON



- cross the mid line
- in front of central canal

Posterior Column Tracts

(Pathway of Conscious Proprioception and Fine Touch)

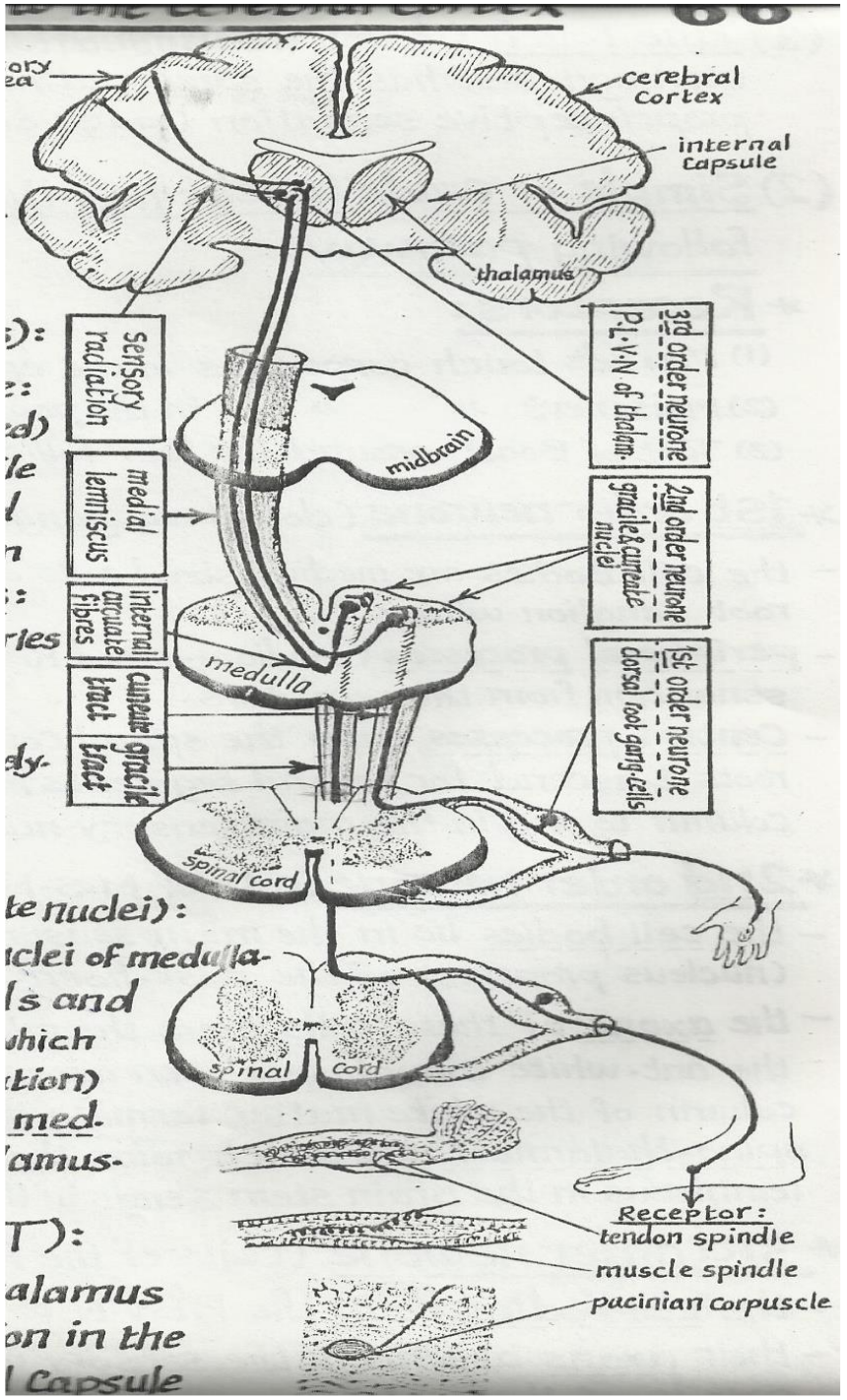
(Gracile and Cuneate tracts)

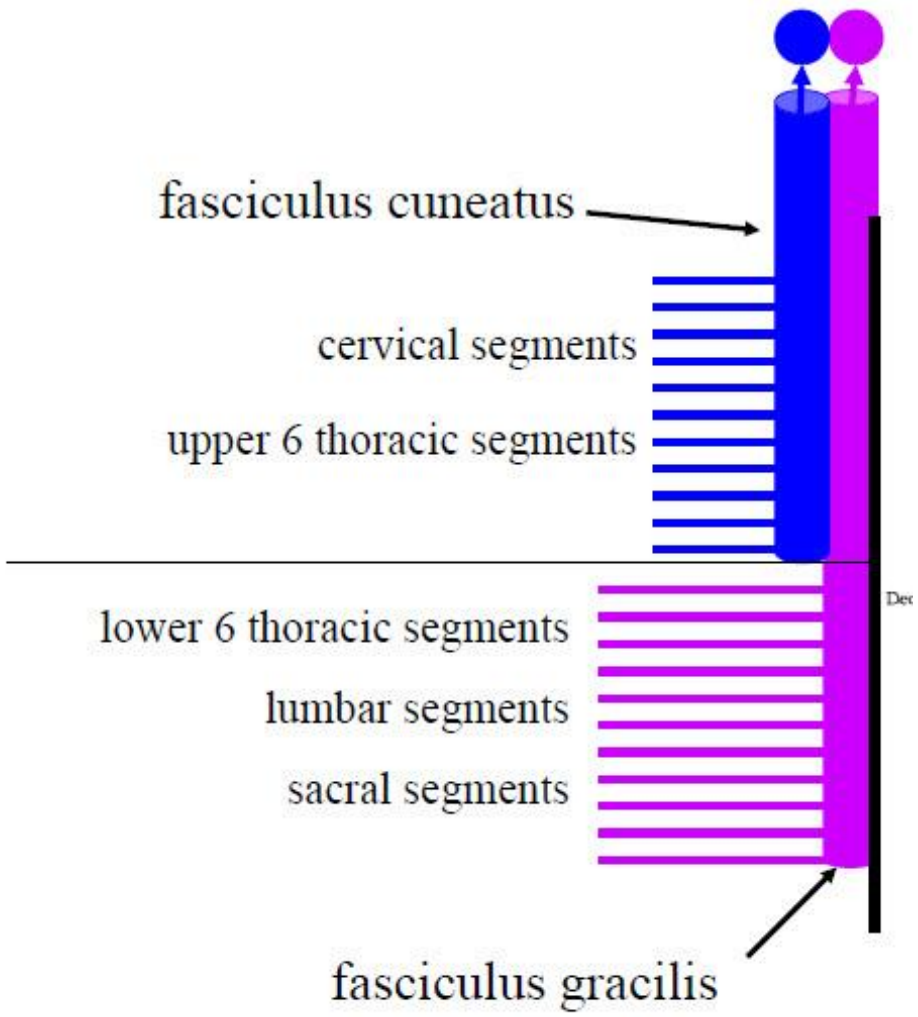
- **Proprioception (deep sensations):**
  - Sense of position.
  - Sense of movement.
  - Sense of vibration.

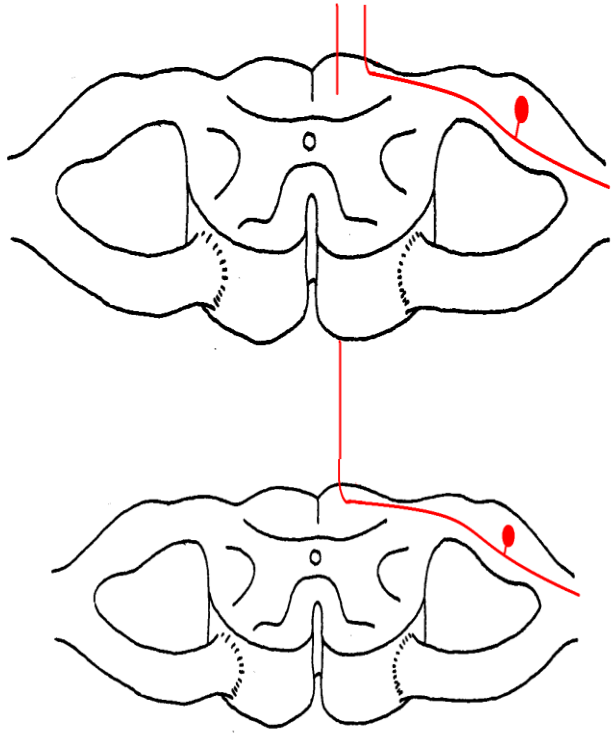
- **Fine touch (complex touch):**
  - Tactile discrimination.
  - Tactile localization.
  - Stereognosis

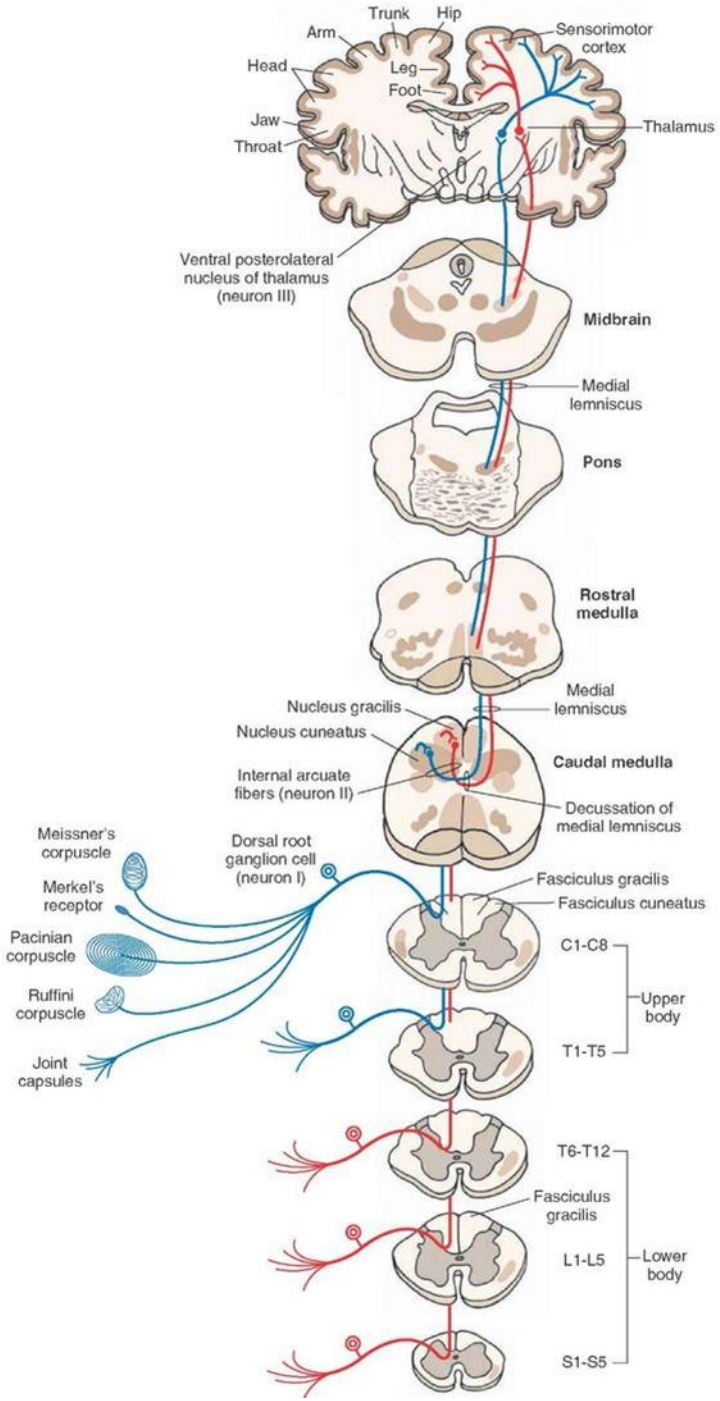
- **1st Neuron:** the cell bodies of these neurons are in in Dorsal Root Ganglion, they are pseudounipolar.

  - Their peripheral processes carry sensations from receptors (in skin, muscles, tendons and joints).
  - Their central processes pass to the spinal cord via the dorsal root.
  - Fibers from the lower part of the body (**below T6 spinal segmen**t) ascend medially in the dorsal column forming the **gracile tract**.
  - Fibers from the upper part of the body (**above T6 spinal segment**) ascend laterally in the dorsal Column forming the **cuneate tract**.
  - Fibers of gracile and cuneate tracts ascend without synapsing where they terminate upon 2nd order neurons in **gracile nucleus** and **cuneate nucleus,** in the medulla obolngata.

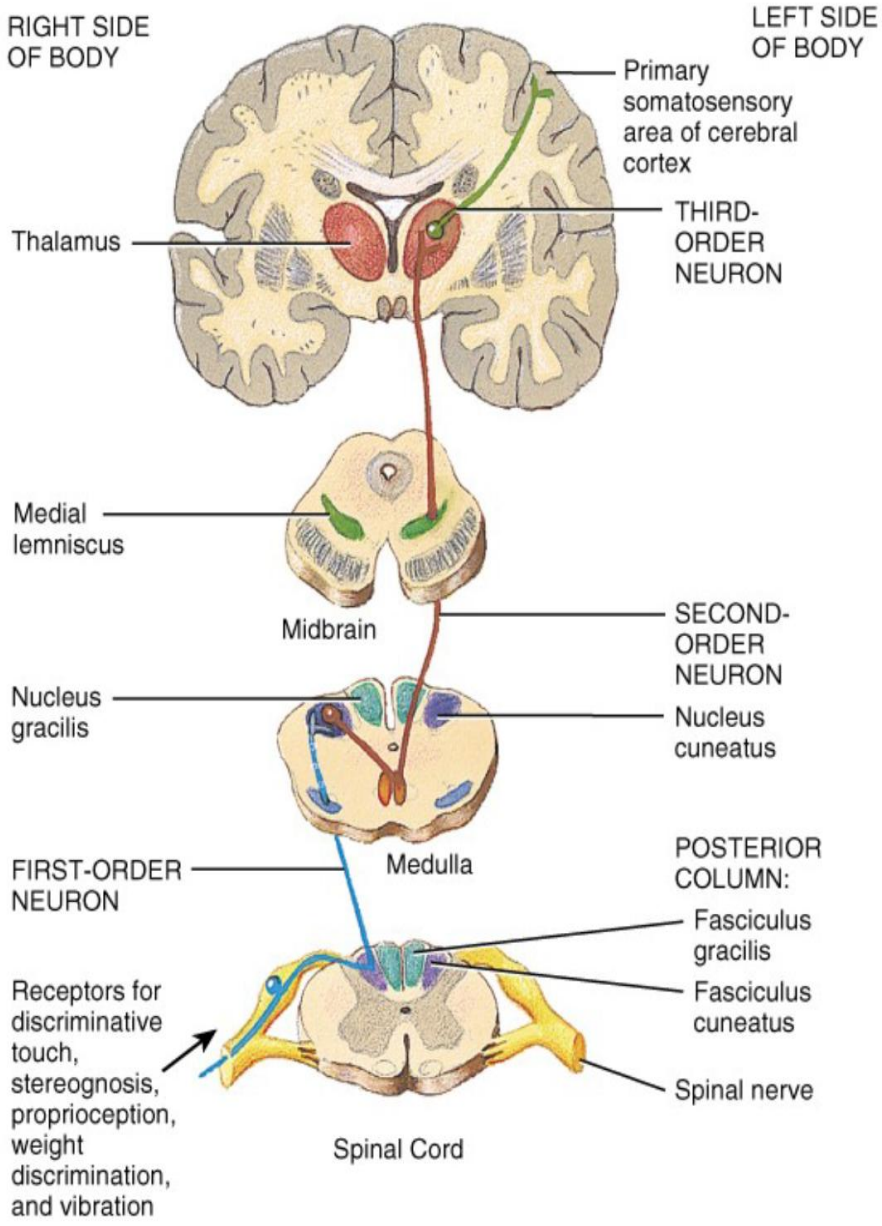



fasciculus cuneatus
cervical segments
upper 6 thoracic segments
lower 6 thoracic segments
lumbar segments
sacral segments
fasciculus gracilis

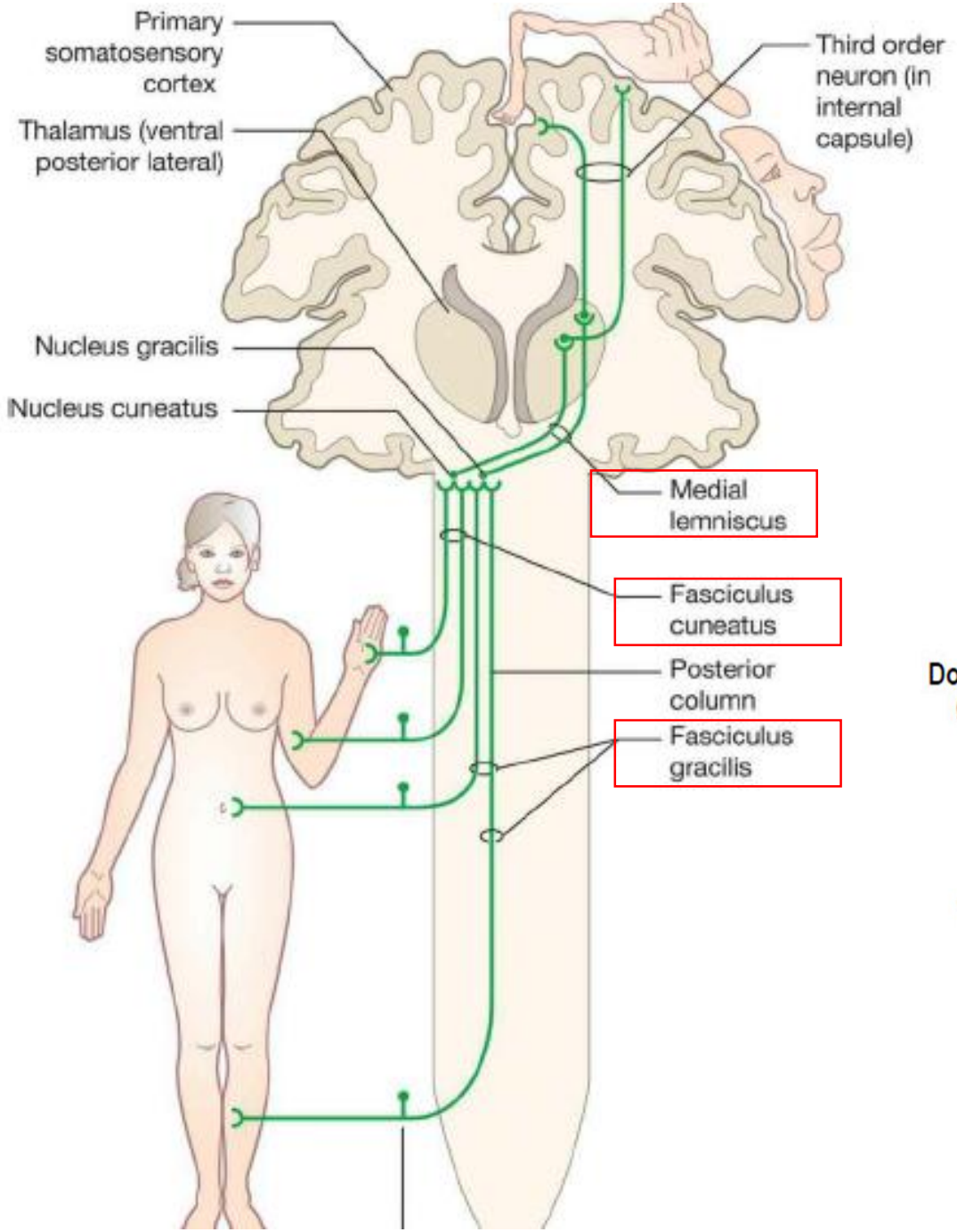


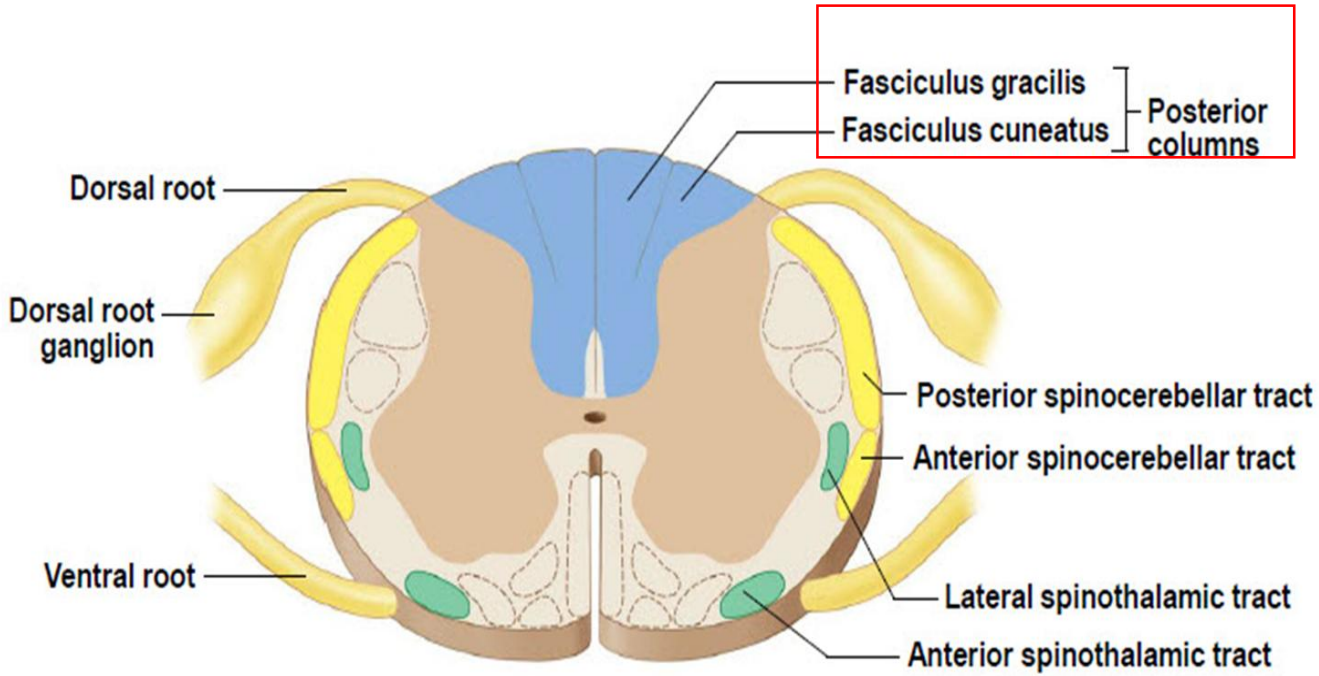

Trunk
Hip
Arm
Sensorimotor cortex
Head
Leg
Foot
Jaw
Thalamus
Throat
Ventral posterolateral nucleus of thalamus (neuron III)
Midbrain
Medial lemniscus
Pons
Rostral medulla
Medial lemniscus
Nucleus gracilis
Nucleus cuneatus
Caudal medulla
Internal arcuate fibers (neuron II)
Decussation of medial lemniscus
Meissner's corpuscle
Dorsal root ganglion cell (neuron I)
Fasciculus gracilis
Merkel's receptor
Fasciculus cuneatus
Pacinian corpuscle
C1-C8
Upper body
Ruffini corpuscle
T1-T5
Joint capsules
T6-T12
Fasciculus gracilis
L1-L5
Lower body
S1-S5

- **2nd Neuron:** The cell bodies of these neurons are located in the gracile and cuneate nuclei in the medulla.
  - Their axons cross the midline forming the **internal arcuate fibers** (sensory decussation) and ascend in brain stem as the **medial lemniscus** to terminate in the **ventral posterolateral (VPL) nucleus** in the thalamus.
- **3rd Neuron:** The cell bodies of these neurons are located in the Ventral Posterolateral Nucleus (VPLN) of thalamus.
  - Axons of these cells pass through **posterior limb of internal capsule**, then through corona radiata to reach sensory area of cerebral cortex.



Dorsal Column Tract





Clinical Application

Lesion in Posterior Column Tract

- Lesion in the pathway of discriminative touch and proprioception at any level produce the following :

    1. **Loss of tactile discrimination: astereognosis and agraphesthesia**
    2. **Sensory ataxia***

- The body part affected by the lesion in these pathways depend on the site and the side of the lesion:

    1. Lesion in the medial lemniscus or internal capsule (after sensory decussation) causes loss of sensation on the opposite side of the body

    2. Lesion in the dorsal column of the spinal cord (before sensory decussation) causes loss of sensation on the same side of the body from the level of the lesion and below.

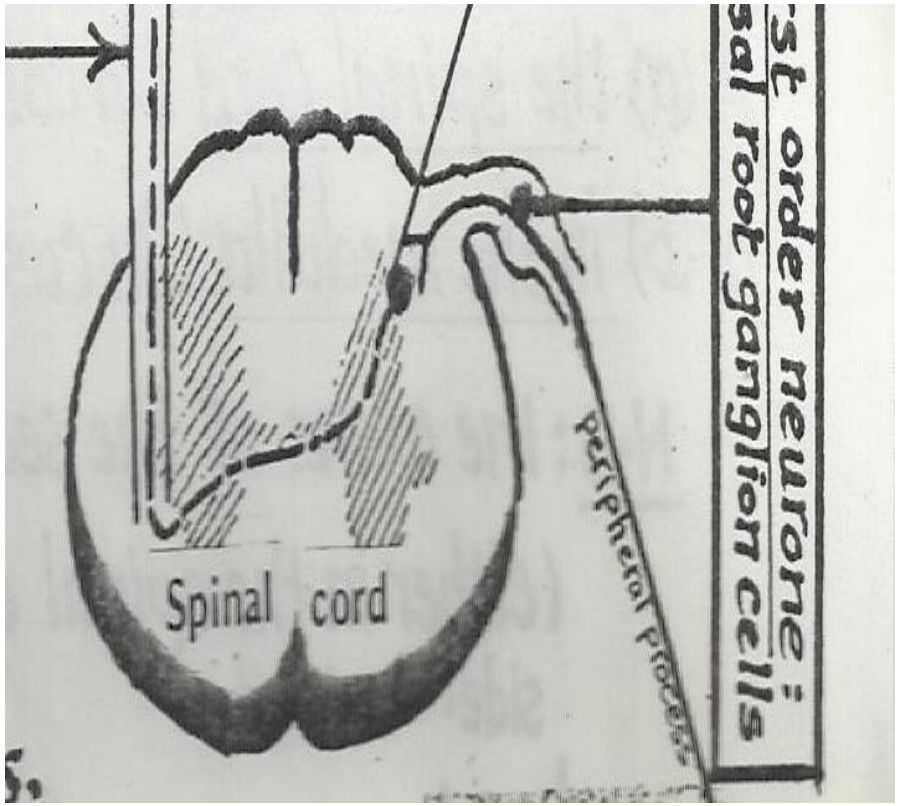
Sensory Ataxia

- loss of movement coordination caused by the **loss of proprioception**.
  - To avoid falling, **the patient stands and walk on a wide base**, and usually watch his lower limb to see where they are.
  - His body sways from side to side when standing with feet close together and eyes closed (**positive Romberg's sign**). The body swaying improve when the eye are opened because the vision help the patient to recognize the position of his feet.
  - The patient has also **stamping gait**, in taking a step the patient lift the advancing leg suddenly and too high and then bring down his leg strongly on the floor.
- The sensory ataxia can be tested by **Romberg test**, the **finger to nose test**, and the **heel to knee test**. Patient with sensory ataxia perform these tests better with his eyes opened.

Lateral Spinothalamic Tract

(Pathway for Pain and Temperature from Body)

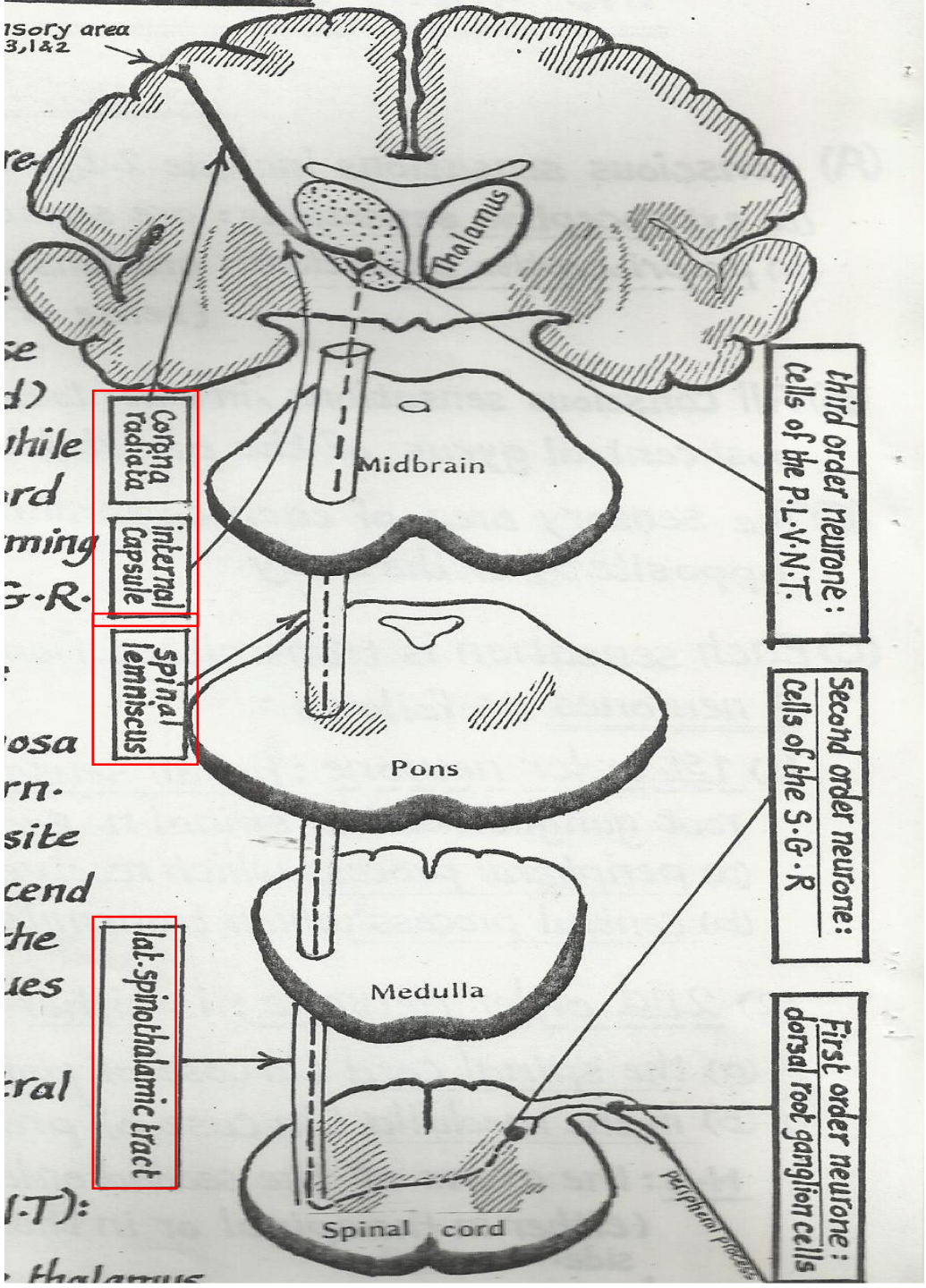
1st neuron: Dorsal root ganglion cells (pseudounipolar).



- Their peripheral processes carry pain and temperature sensations from the receptors (free nerve endings in skin)

- Their central processes enter the spinal cord ascend in the dorsolateral (**Lissauer's)** tract for one or two segments before entering the dorsal horn. They end on neurons in many Laminae of the grey matter of the spinal cord mainly Lamina II & III (**Substantia gelatinosa of Rolandi**).

- **2nd Neuron:** Cell body of second order neuron is present in substantia gelatinosa of dorsal horn.
  - Their axons cross the midline in the ventral white commissure and ascend in the lateral white column as **lateral spinothalamic tract**.
  - The tract ascends in the brain stem as the **spinal lemniscus**. It reaches the thalamus where it ends on VPL nucleus of thalamus.
- **3rd Neuron:** ascend through the internal capsule then through corona radiata to reach to the postcentral gyrus of the cortex, bringing pain and temperature sensations from specific anatomical regions of the skin.

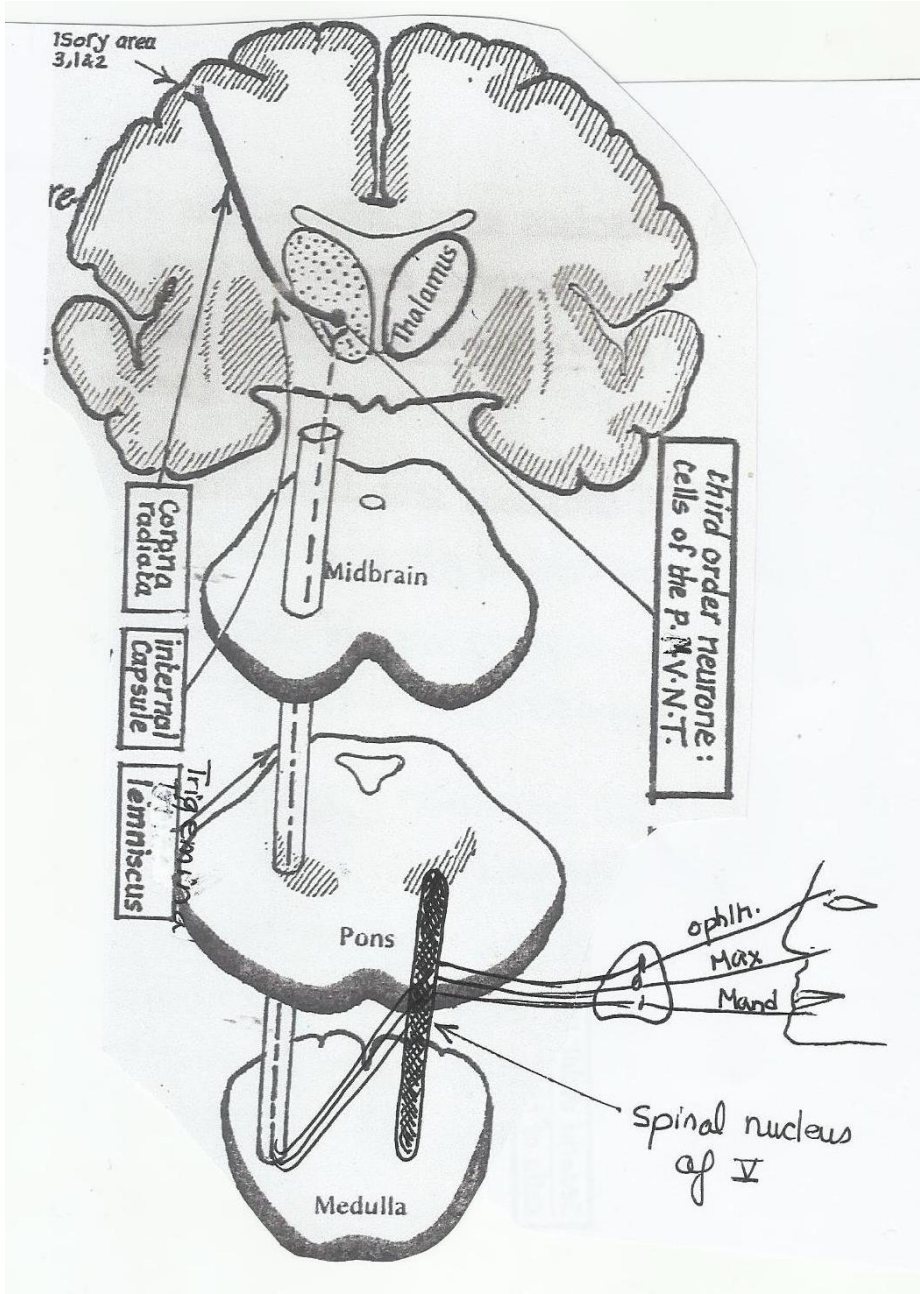


Note: Pain and temperature from the face and head are carried by the **trigeminal nerve.**

- **First Neuron:** is Trigeminal Ganglion (formed of pseudounipolar cells as DRG).

- **Second Neuron:** is Spinal Nucleus of Trigeminal. Its axons cross to opposite side forming **trigemino-thalamic tract (lemniscus)** which ascends to end on the ventral posteromedial nucleus (VPMN) of thalamus.

- **Third Neuron:** is VPMN of thalamus whose axons pass in internal capsule, then the corona radiata to reach sensory area of face in cerebral cortex.



Clinical Application

Lesion in Lateral Spinothalamic Tract

- Lesion in this pathway at any level lead to **loss of pain and temperature**.

- The body part affected by the lesion in these pathways depend on the site and the side of the lesion:

1. Damage of this pathway in the internal capsule or the brain stem cause loss of pain and temperature in all dermatomes contralateral to the lesion.

2. Damage of the lateral spinothalamic tract in the spinal cord cause loss of pain and temperature in the contralateral side, starting from one or two segments below the level of the lesion and below.

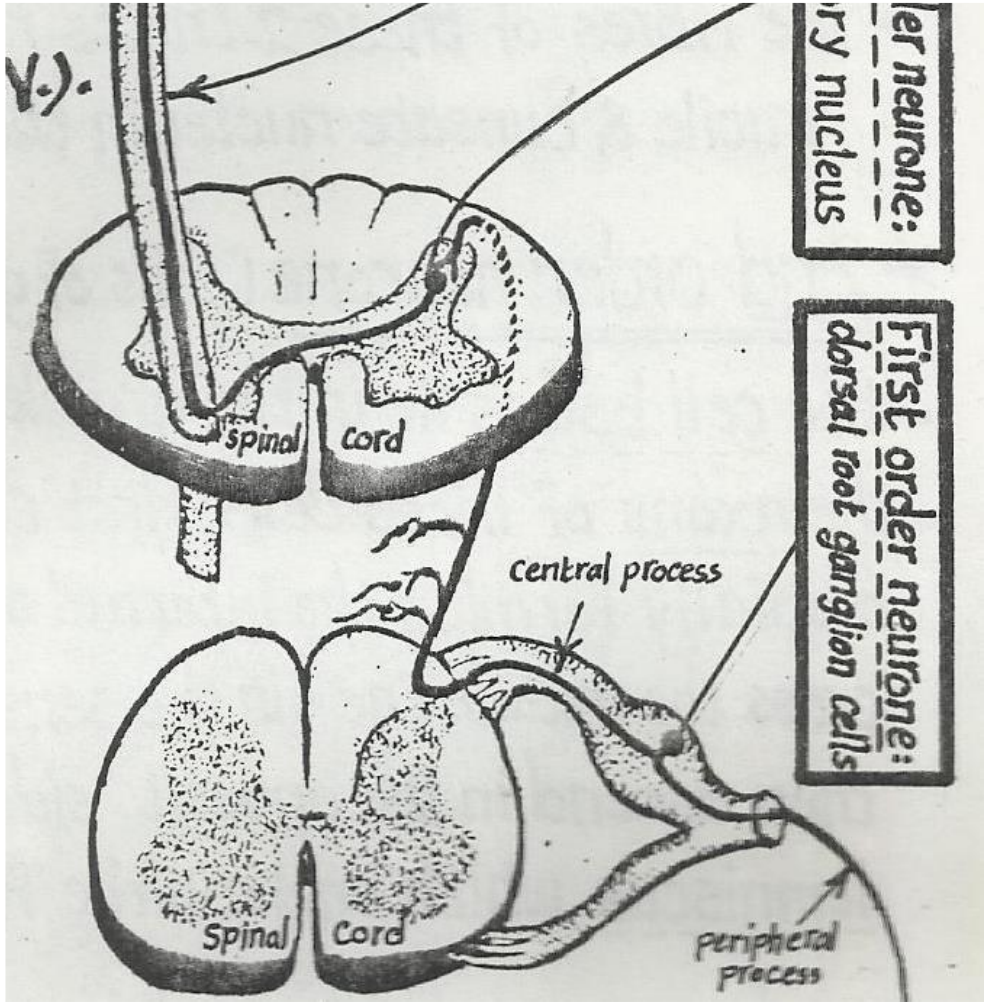
3. Damage of the pain and temperature fibers in the anterior white commissure causes loss of pain and temperature in the right and left dermatomes, one or two segments below the level of the lesion **only**.

Ventral Spinothalamic Tract

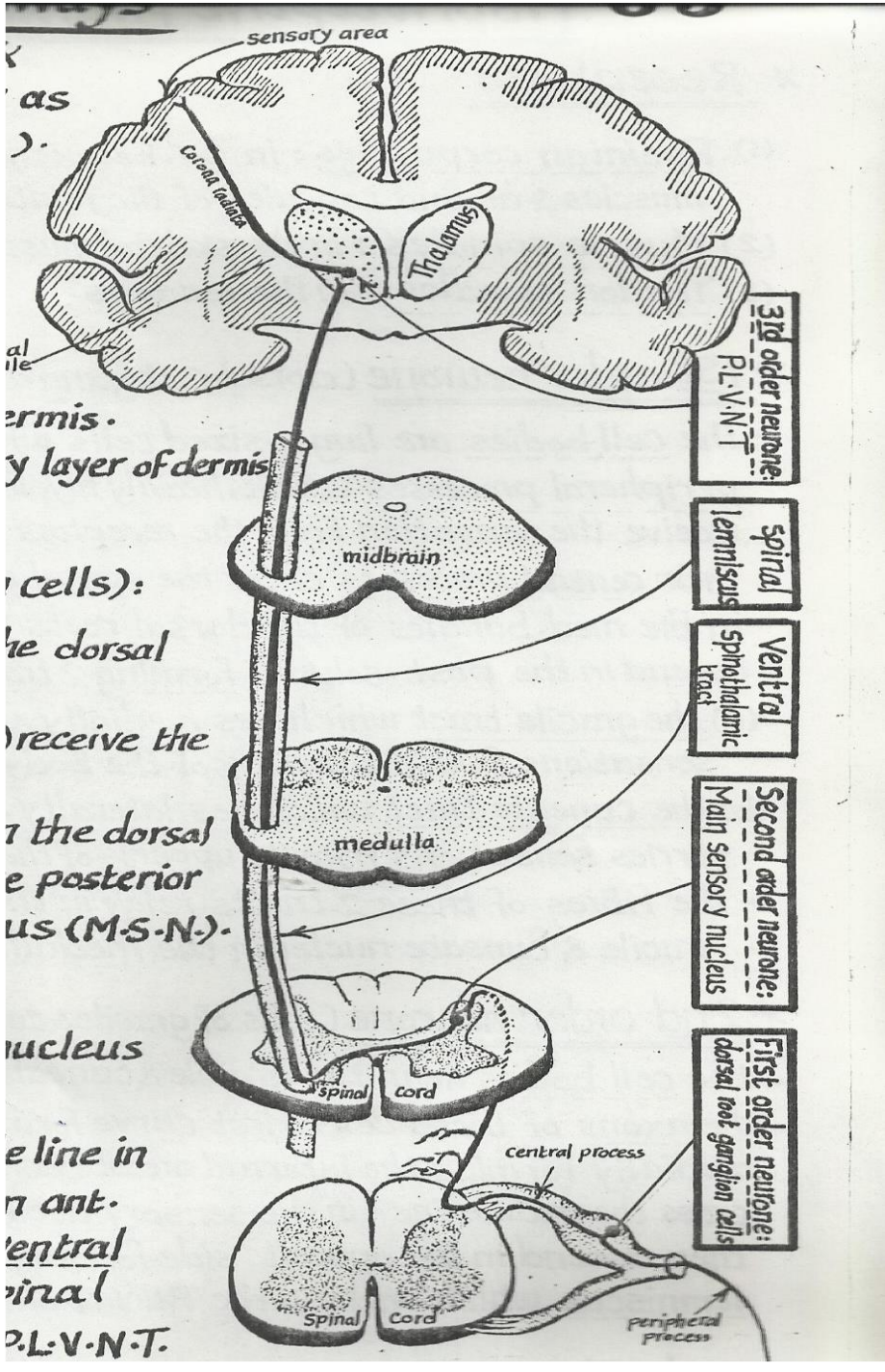
(Pathway for Crude Touch and Pressure)

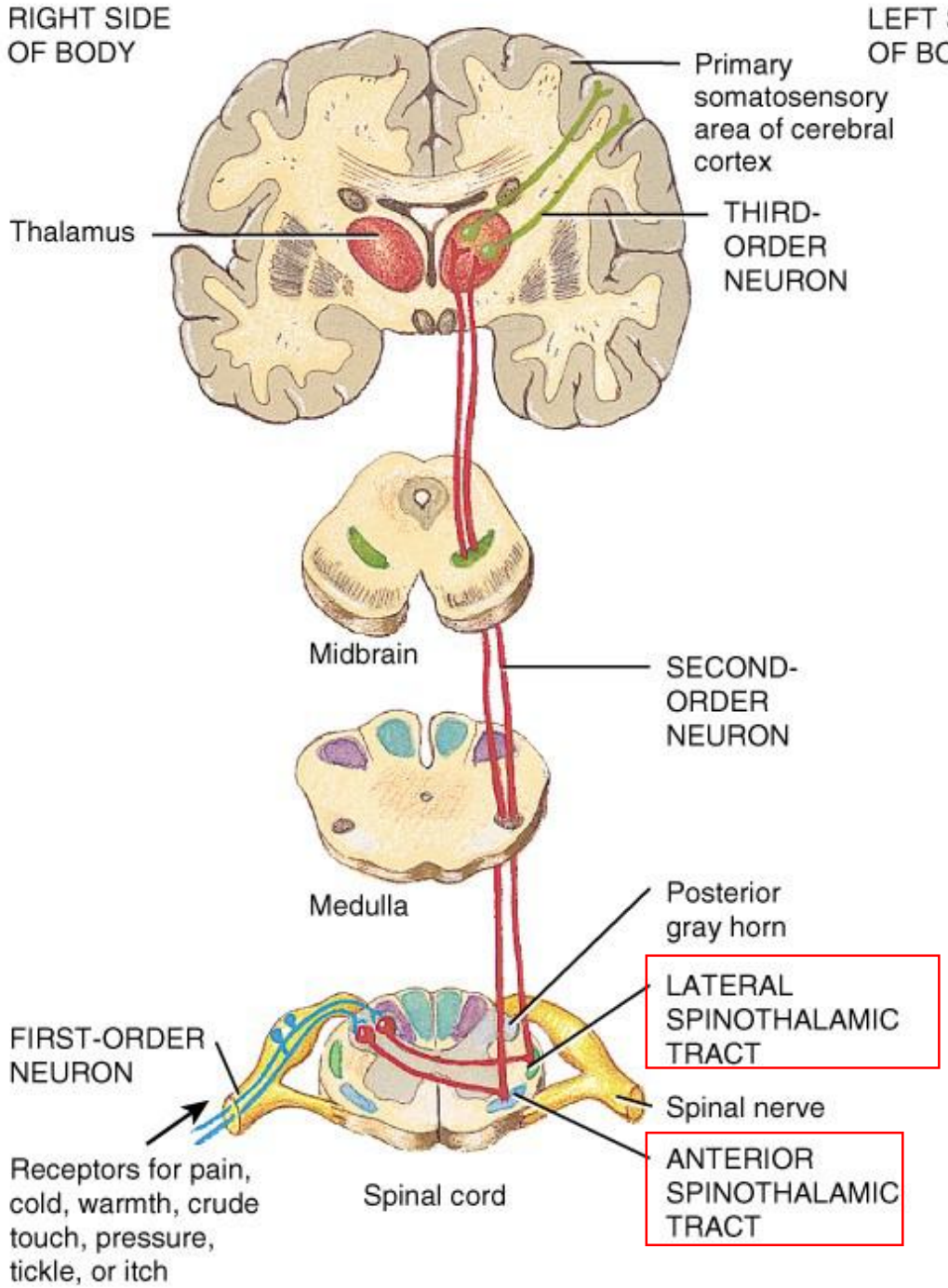
1st neuron: Dorsal root ganglion cells (pseudounipolar).

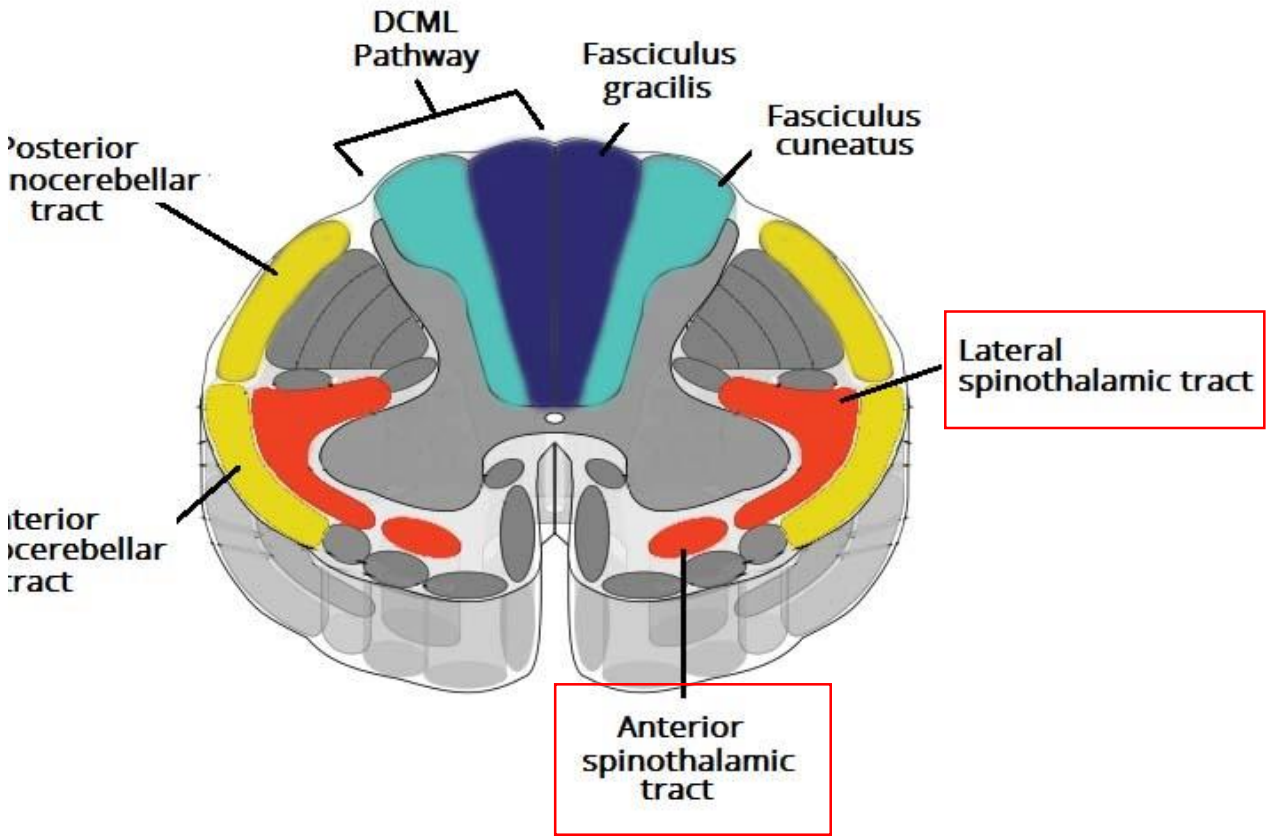
- Their peripheral processes carry crude touch and pressure from the receptors.
- Their central processes enter the spinal cord and may ascend for few segments before making synapses with second order neurons in the dorsal horn (Laminae IV –VII).



- **2nd Neuron:** Cell body of second order neuron is present in laminae IV -VII. of dorsal horn.
  - Their axons cross the midline in the ventral white commissure to reach the opposite ventral white column and ascend as the **ventral spinothalamic tract.**
  - The tract ascends in the brain stem where it joins the **spinal lemniscus** and reaches the thalamus where it ends on VPL nucleus of thalamus.
- **3rd Neuron:** ascend through the internal capsule then through corona radiata to reach to the postcentral gyrus of the cortex, bringing pain and temperature sensations from specific anatomical regions of the skin.




RIGHT SIDE OF BODY
LEFT SIDE OF BODY
Primary somatosensory area of cerebral cortex
Thalamus
THIRD-ORDER NEURON
Midbrain
SECOND-ORDER NEURON
Medulla
Posterior gray horn
LATERAL SPINOTHALAMIC TRACT
FIRST-ORDER NEURON
Spinal nerve
ANTERIOR SPINOTHALAMIC TRACT
Receptors for pain, cold, warmth, crude touch, pressure, tickle, or itch
Spinal cord


DCML Pathway
Fasciculus gracilis
Fasciculus cuneatus
Lateral spinothalamic tract
Anterior spinothalamic tract

Spinocerebellar Tracts

(Pathways for Unconscious Proprioception)

- Two tracts: Anterior and Posterior

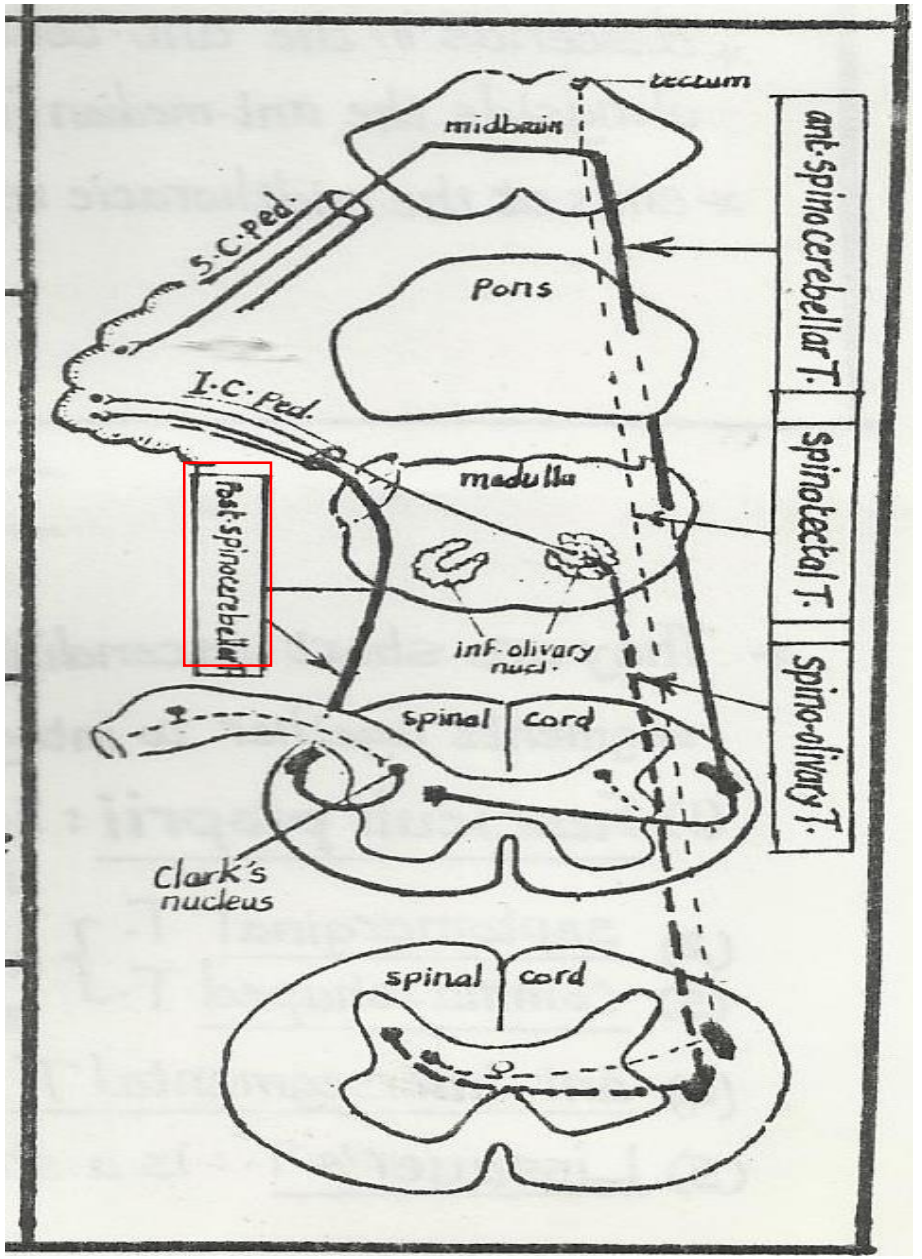
- These pathways provide **unconscious proprioceptive information** to the **ipsilateral cerebellum.**

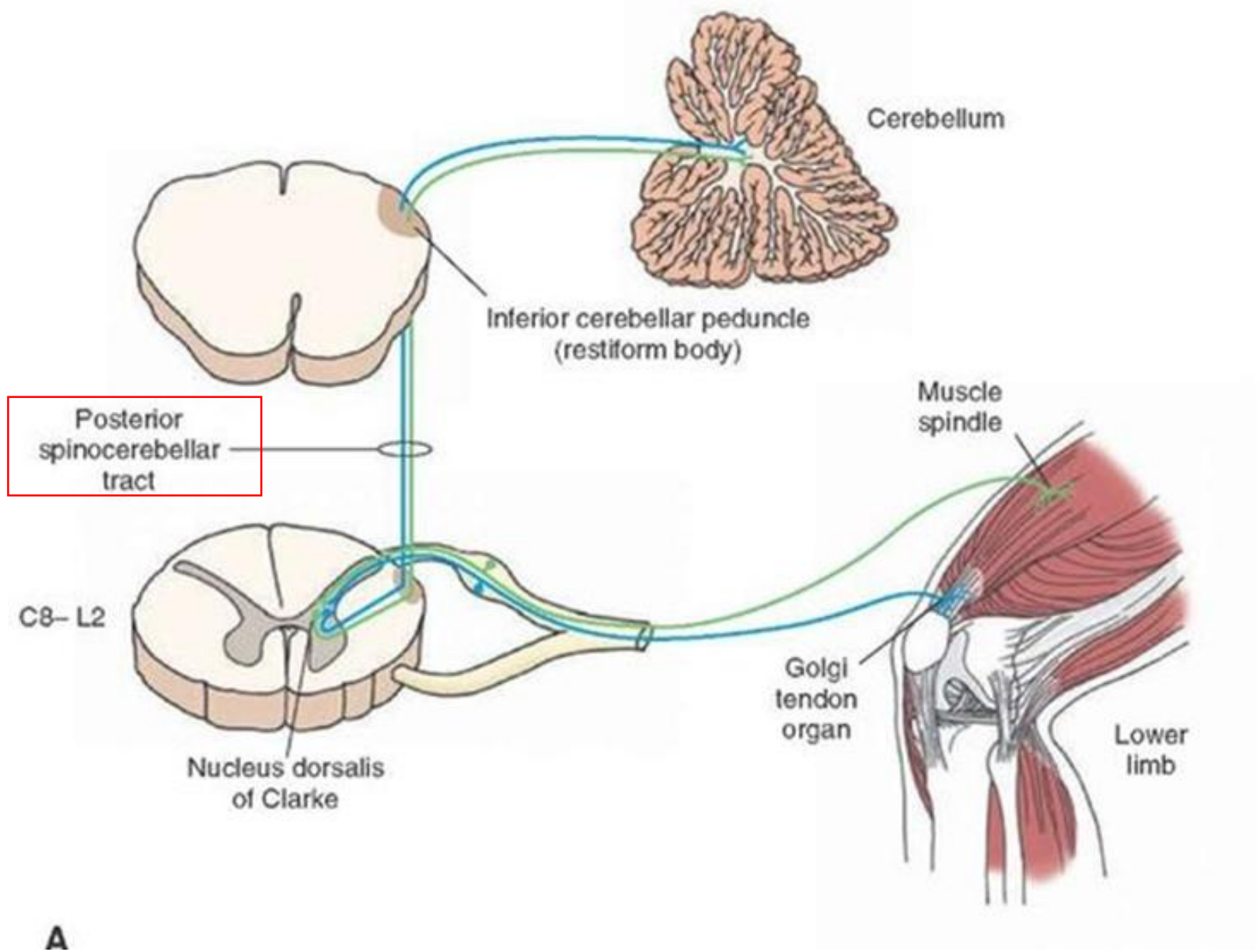
- These pathways consist of a chain of **only** two neurons.

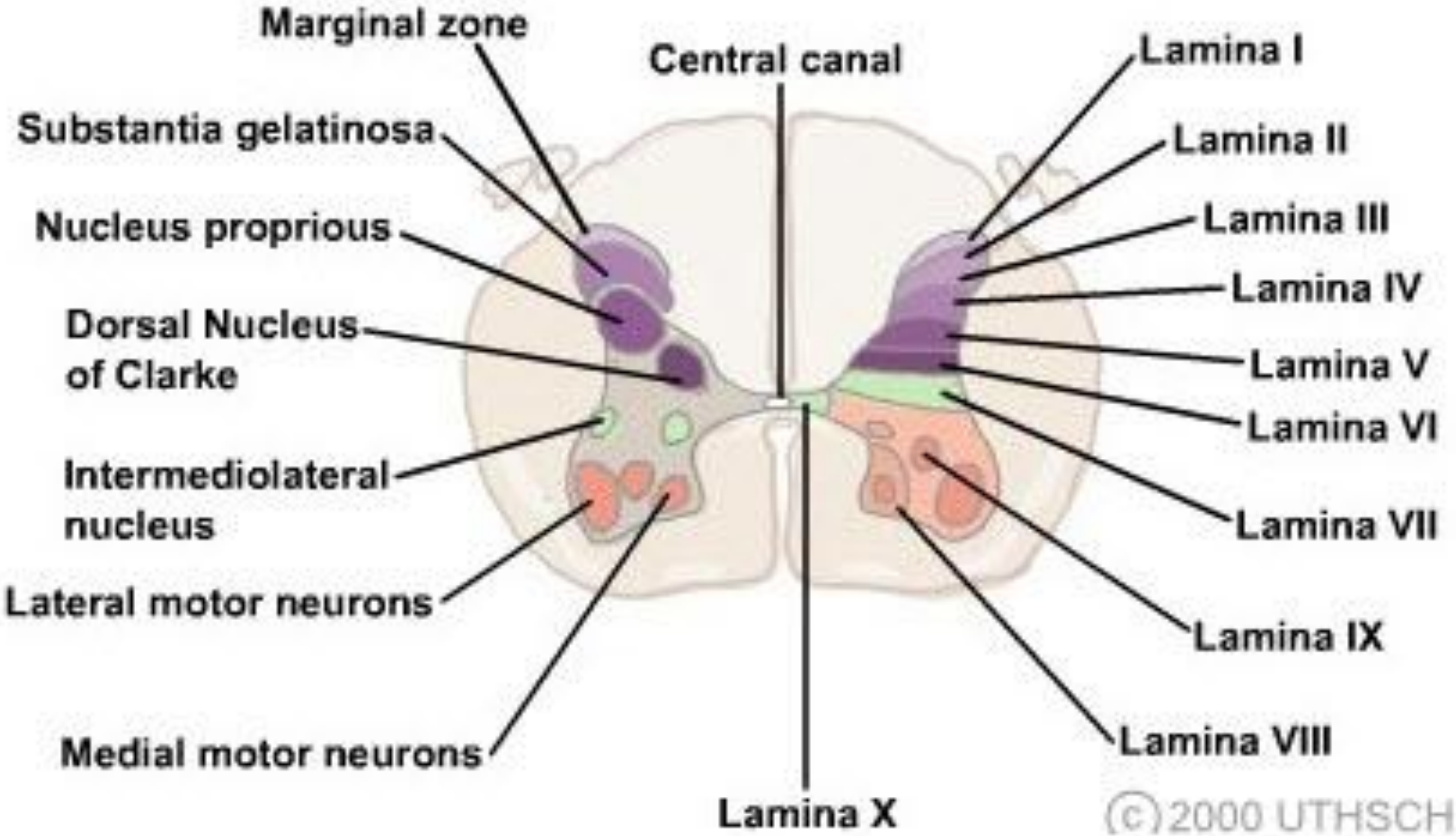
- The cerebellum depend on this unconscious proprioception **for the control of posture and coordination of movements** (detect any error in the voluntary muscles activities and to act as the main center for voluntary muscles coordination)

Posterior Spinocerebellar Tract

- The posterior spinocerebellar stays originally uncrossed.
- Carries unconscious proprioception from the lower limb & trunk (fibers of C8-L2 spinal nerves).
- The central processes of 1st neurons in DRG cells enter the spinal cord to make synapse on 2nd neurons in ipsilateral **Clarke's nucleus** in dorsal horn.
- The tract ascends ipsilaterally in the lateral white column, posterior to the anterior spinocerebellar tract and enters the ipsilateral cerebellum via the **inferior cerebellar peduncle (ICP).**




Cerebellum
Inferior cerebellar peduncle
(restiform body)
Posterior
spinocerebellar
tract
Muscle
spindle
C8– L2
Golgi
tendon
organ
Lower
limb
Nucleus dorsalis
of Clarke
A


Marginal zone
Central canal
Lamina I
Substantia gelatinosa
Lamina II
Nucleus proprious
Lamina III
Lamina IV
Dorsal Nucleus
of Clarke
Lamina V
Lamina VI
Intermediolateral
nucleus
Lamina VII
Lateral motor neurons
Lamina IX
Lamina VIII
Medial motor neurons
Lamina X
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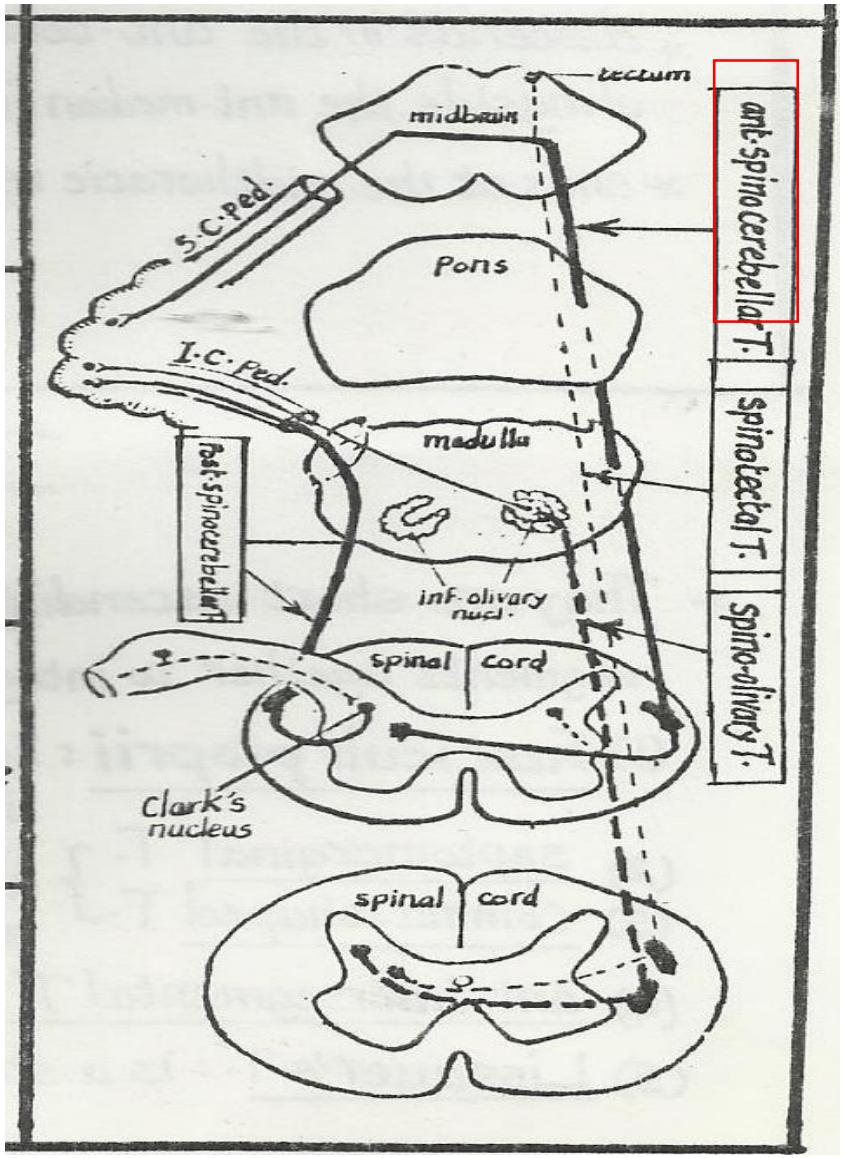
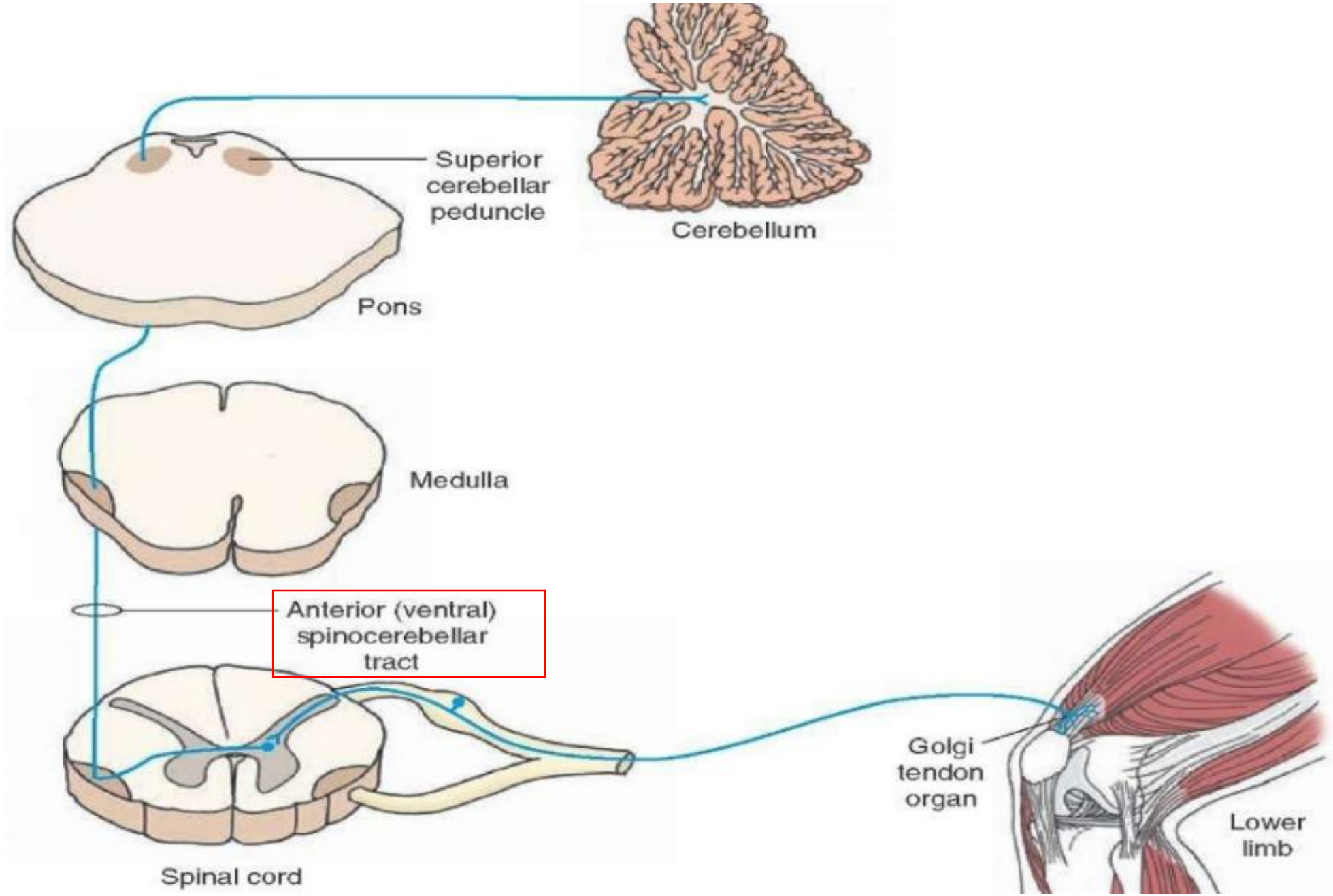
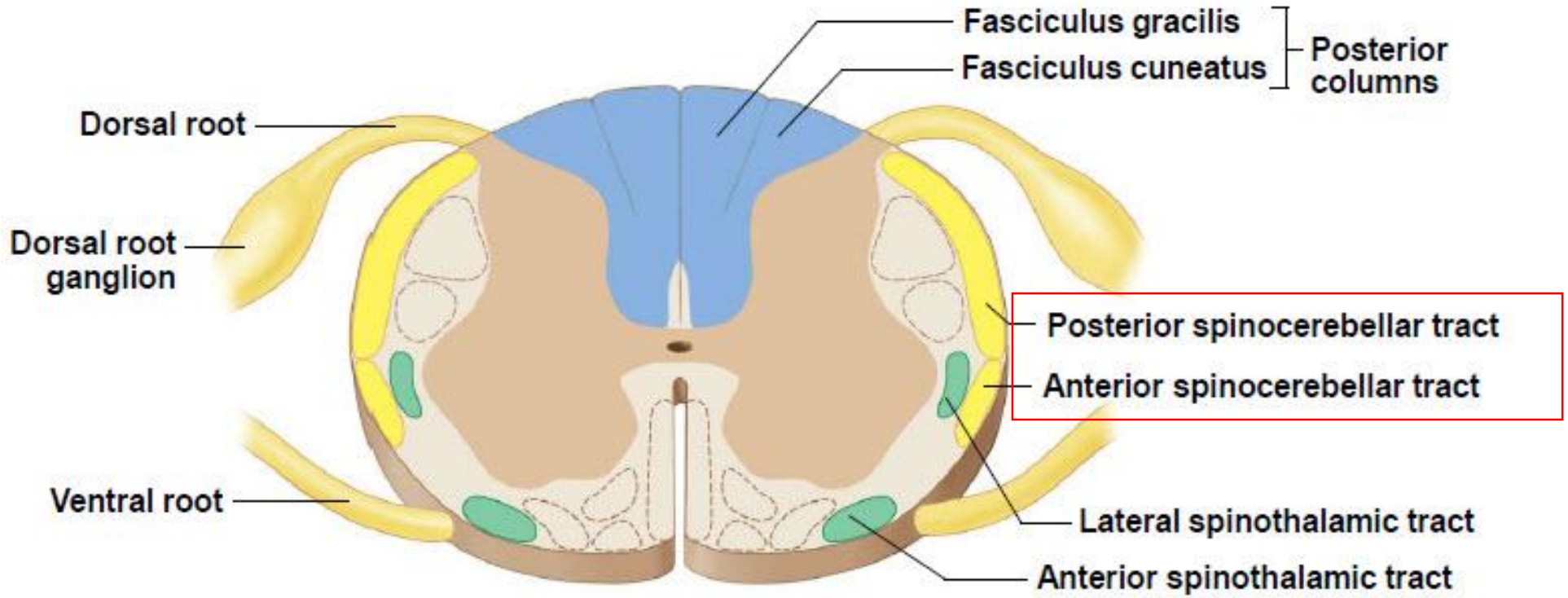
Anterior Spinocerebellar Tract

- Crosses twice, so eventually ends same side.
- Carries most of the unconscious proprioception from the lower limb.
- The central processes of 1st neurons from the lower part of the body make synapse on 2nd neurons in in laminae V through VII in cord segments L1 and below.
- Axons forming the tract mostly decussate in the ventral white commissure and ascend in the lateral white column.
- They enter the cerebellum via the **superior cerebellar peduncle** (SCP) after crossing again to reach the ipsilateral cerebellum.




Superior cerebellar peduncle
Cerebellum
Pons
Medulla
Anterior (ventral) spinocerebellar tract
Spinal cord
Golgi tendon organ
Lower limb

Spinocerebellar Tracts



Clinical Application

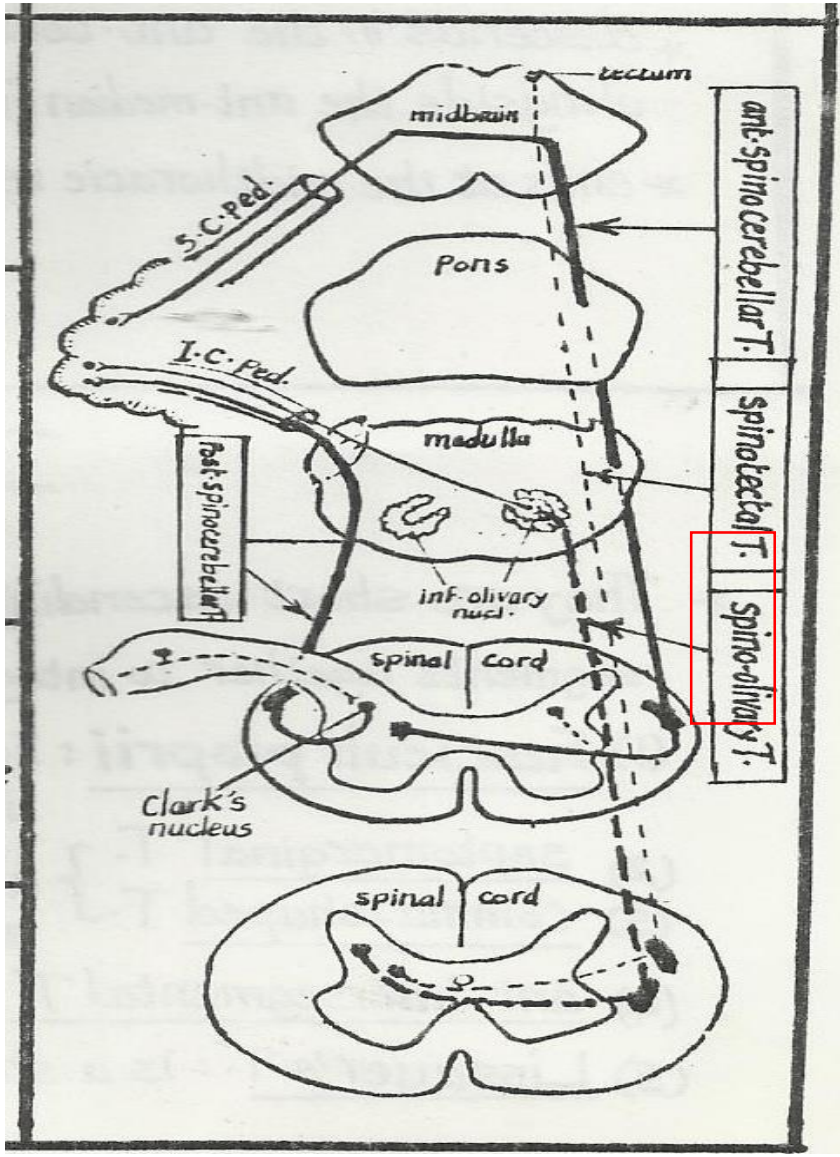
Lesion in Posterior and Anterior Spinocerebellar Tracts

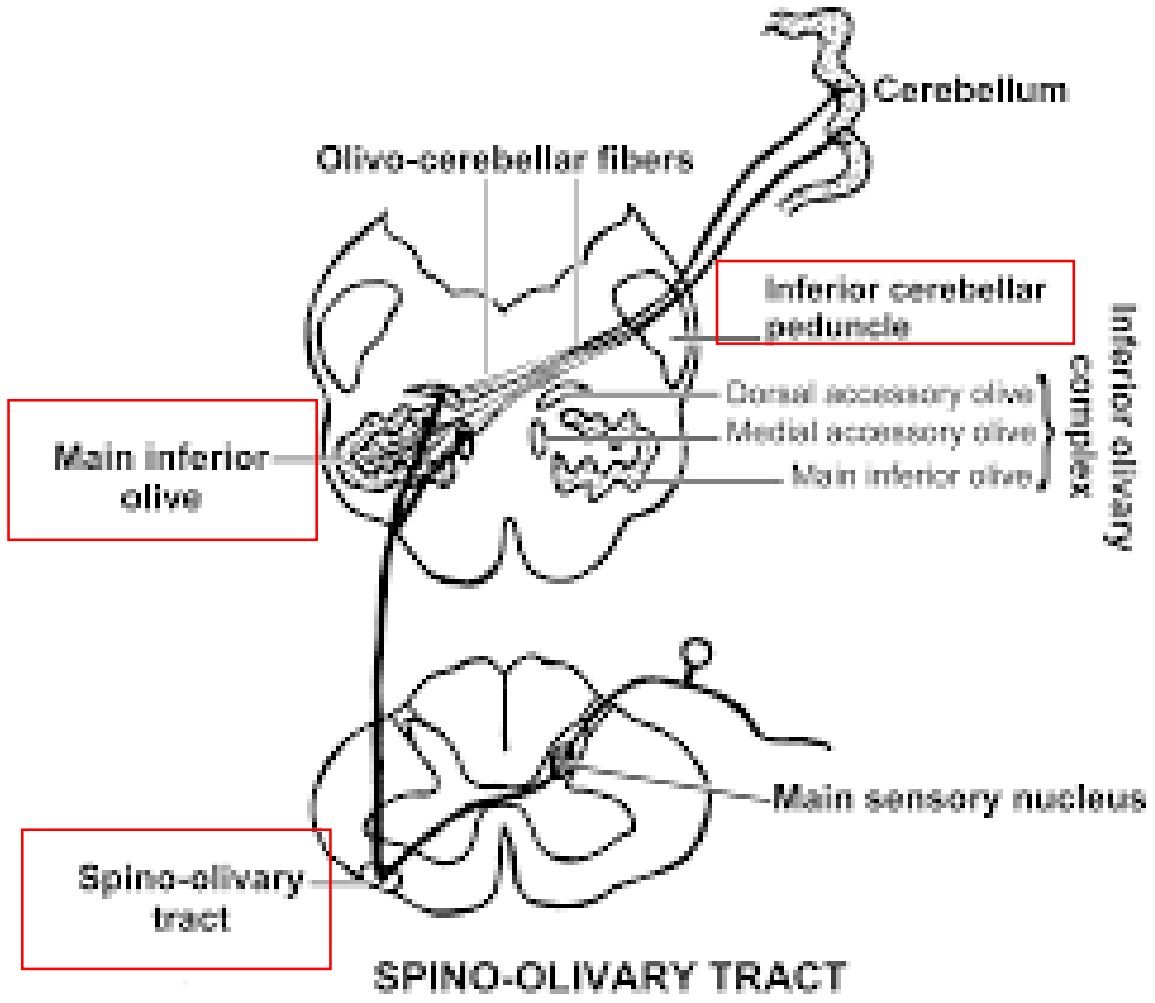
- Lesion in pathways for unconscious proprioception causes disturbance in balance and movement coordination (**Cerebellar Ataxia**).

Other Ascending Tracts

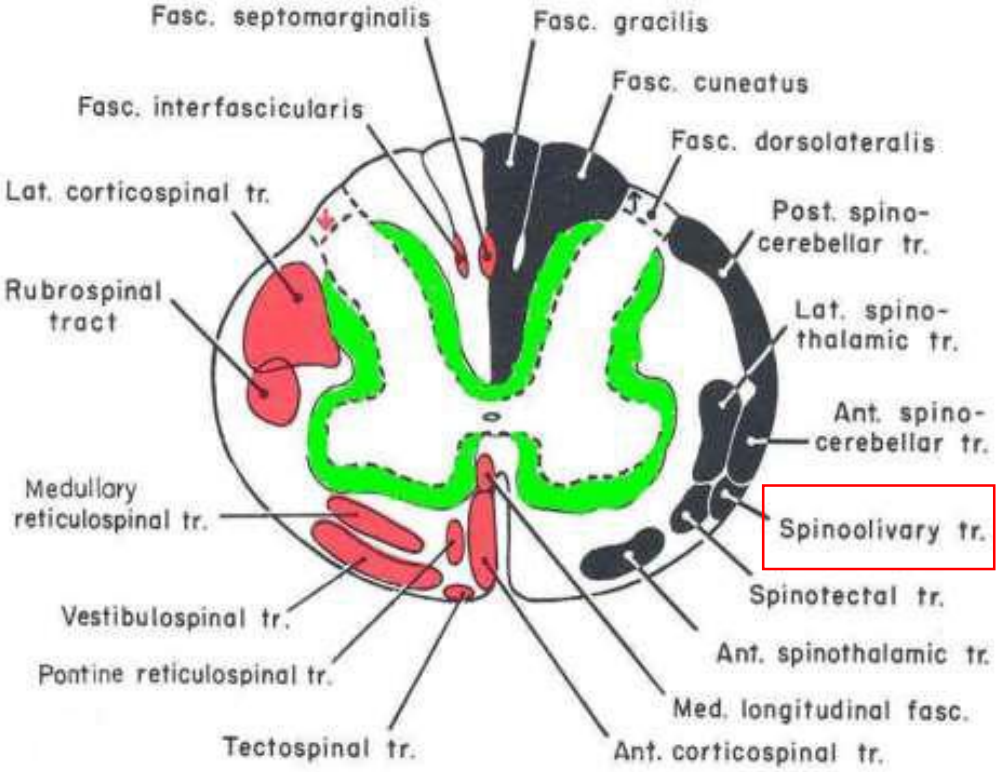
1- Spino-olivary Tract

- **Indirect spinocerebellar pathway** (spino-olivocerebellar).
- Fibers arise at all level of the spinal cord.
- It carries **unconscious proprioception** from both upper and lower limbs to reach the ipsilateral cerebellum.
- Its fibers cross & ascend at the junction of lateral and ventral white columns to end on the contralateral inferior olivary nucleus in medulla.
- Olivocerebellar fibers cross & pass via the **ICP** to reach the ipsilateral cerebellum.





SPINO-OLIVARY TRACT

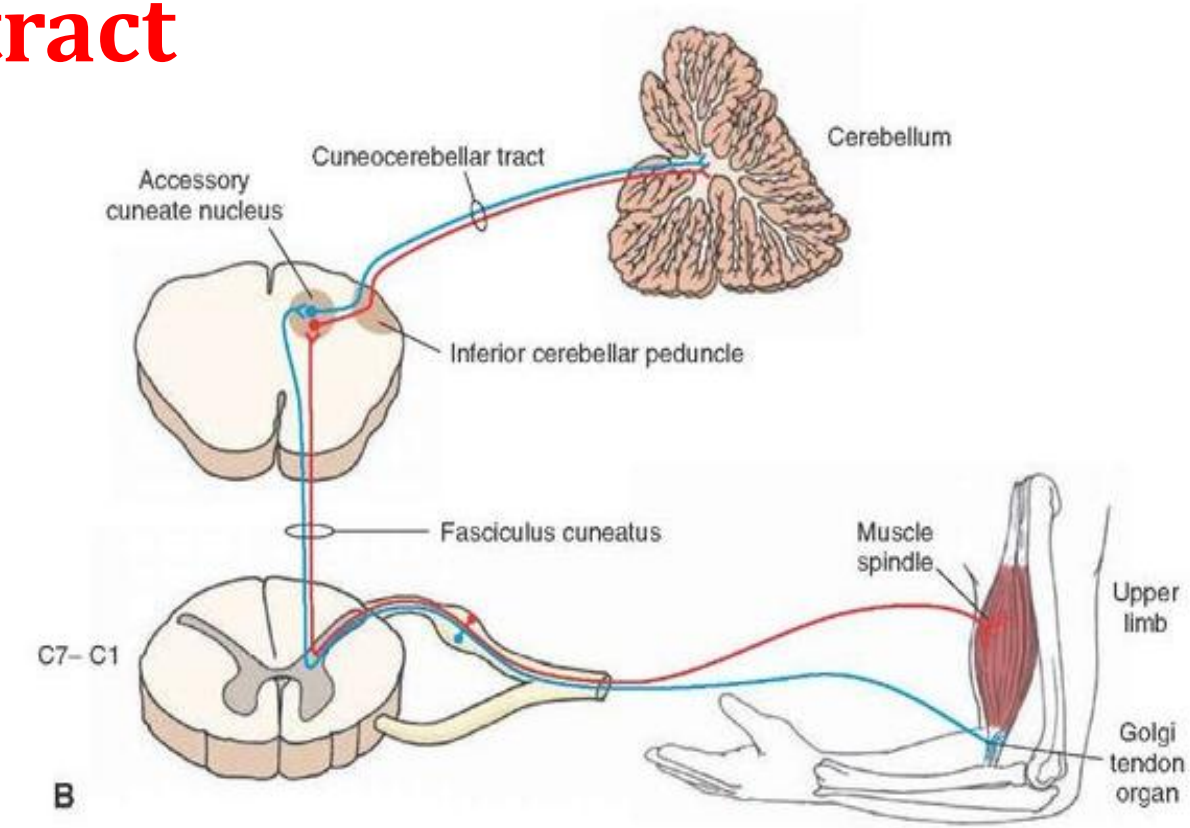


Other Ascending Tracts

2- Collaterals from cuneate tract

- This tracts carries **unconscious proprioception** from the upper limb to the accessory cuneate nucleus of the medulla.

- Axons of the accessory cuneate nucleus form the **external arcuate fibers** (Cuneocerebellar tract) which reach the ipsilateral cerebellum via the ICP.

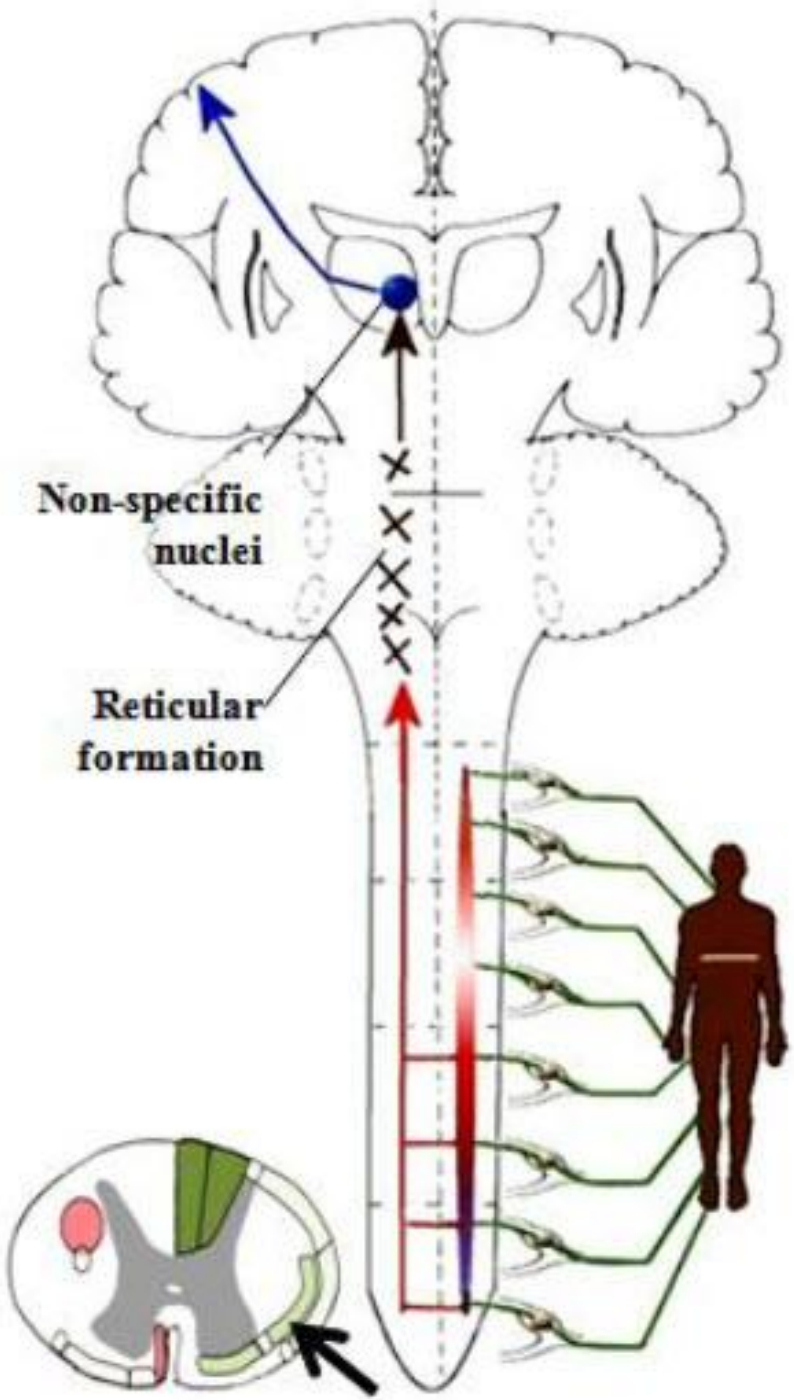


Other Ascending Tracts

3- Spino-reticular Tract

- Its fibers ascend in the lateral & ventral white columns where it is intermingled with the spinothalamic tracts.
- Most fibers **cross** to the opposite side and ascend to end on neurons of the ponto-medullary reticular formation.
- A spino-reticulo–thalamo-cortical pathway was suggested as a route for **slow dull-aching pain sensation**.

Spino-reticular tract

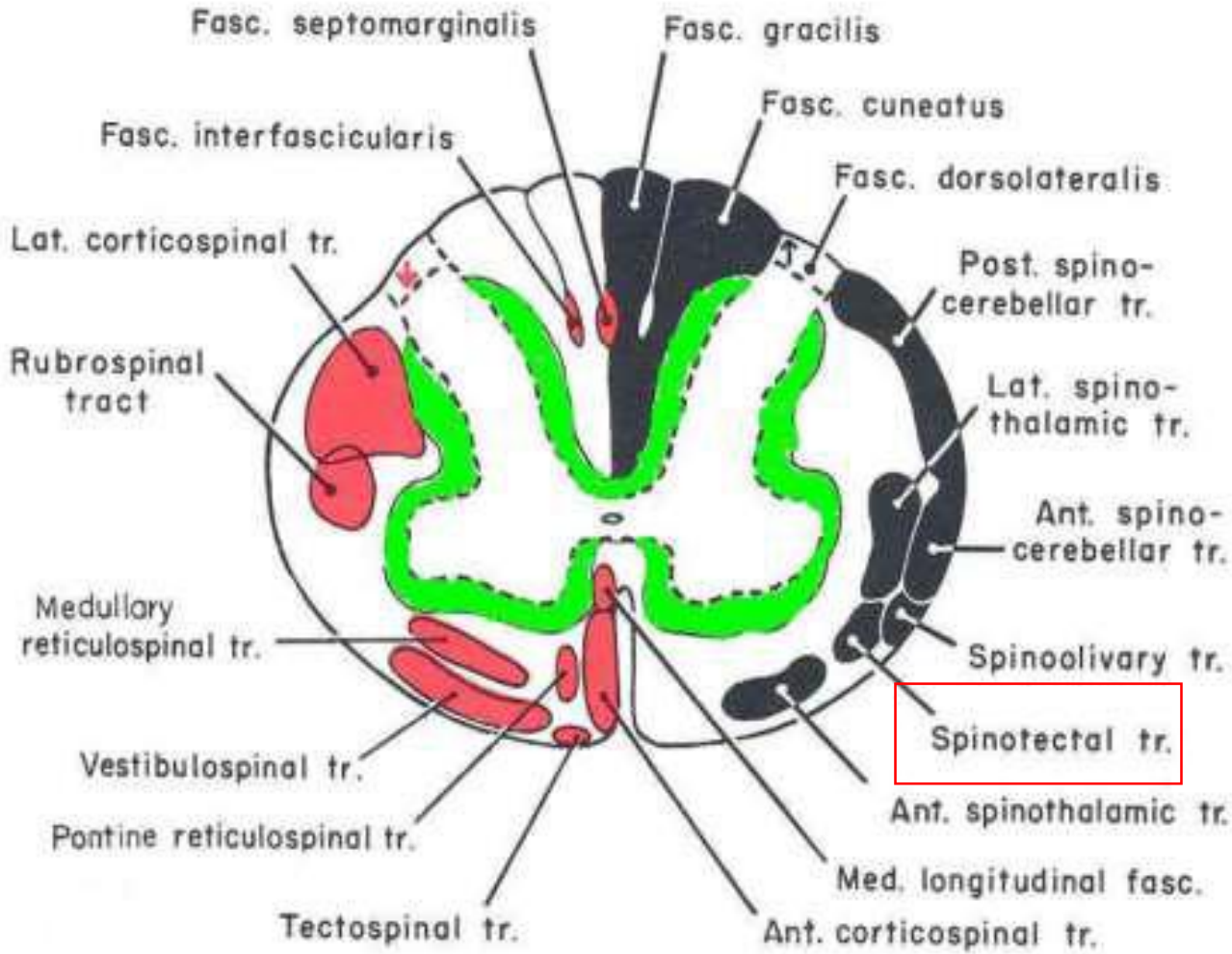


Other Ascending Tracts

4- Spino-tectal Tract

- Most fibers **cross** to the opposite side and ascend in the lateral white column to end in the **superior colliculi of the midbrain**.

- The spino-tectal tract is concerned with **spino-visual reflexes** (head turning towards source of cutaneous stimulus).


Fasc. septomarginalis
Fasc. gracilis
Fasc. cuneatus
Fasc. interfascicularis
Fasc. dorsolateralis
Lat. corticospinal tr.
Post. spino-cerebellar tr.
Rubrospinal tract
Lat. spino-thalamic tr.
Ant. spino-cerebellar tr.
Medullary reticulospinal tr.
Spinoolivary tr.
Spinotectal tr.
Vestibulospinal tr.
Ant. spinothalamic tr.
Pontine reticulospinal tr.
Med. longitudinal fasc.
Tectospinal tr.
Ant. corticospinal tr.

Thank you

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