SOMATOSENSORY PATHWAYS

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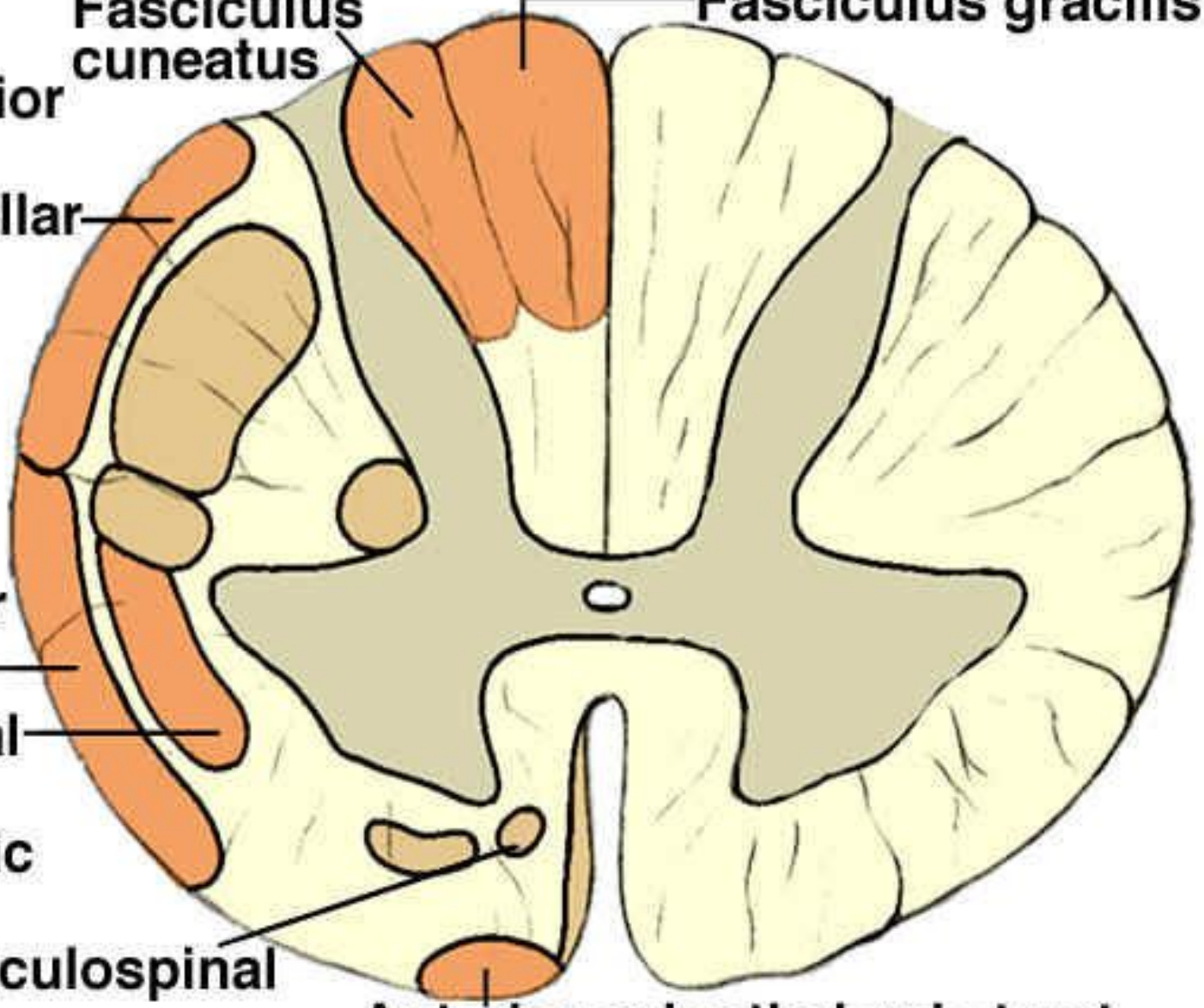
- **FOR CONSCIOUS PERCEPTION:**

1. Anterolateral system
2. Dorsal Column Medial Lemniscus system

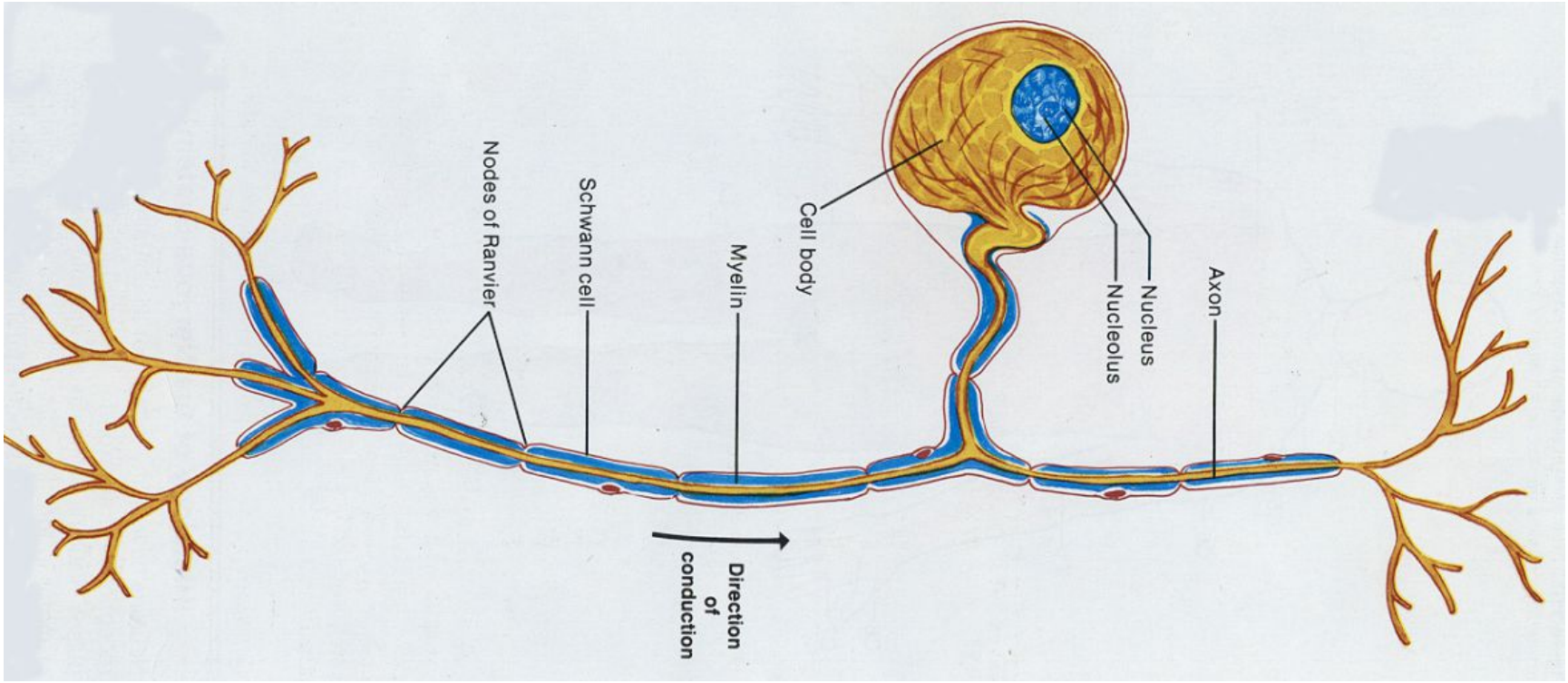
- **FOR UNCONSCIOUS PERCEPTION:**

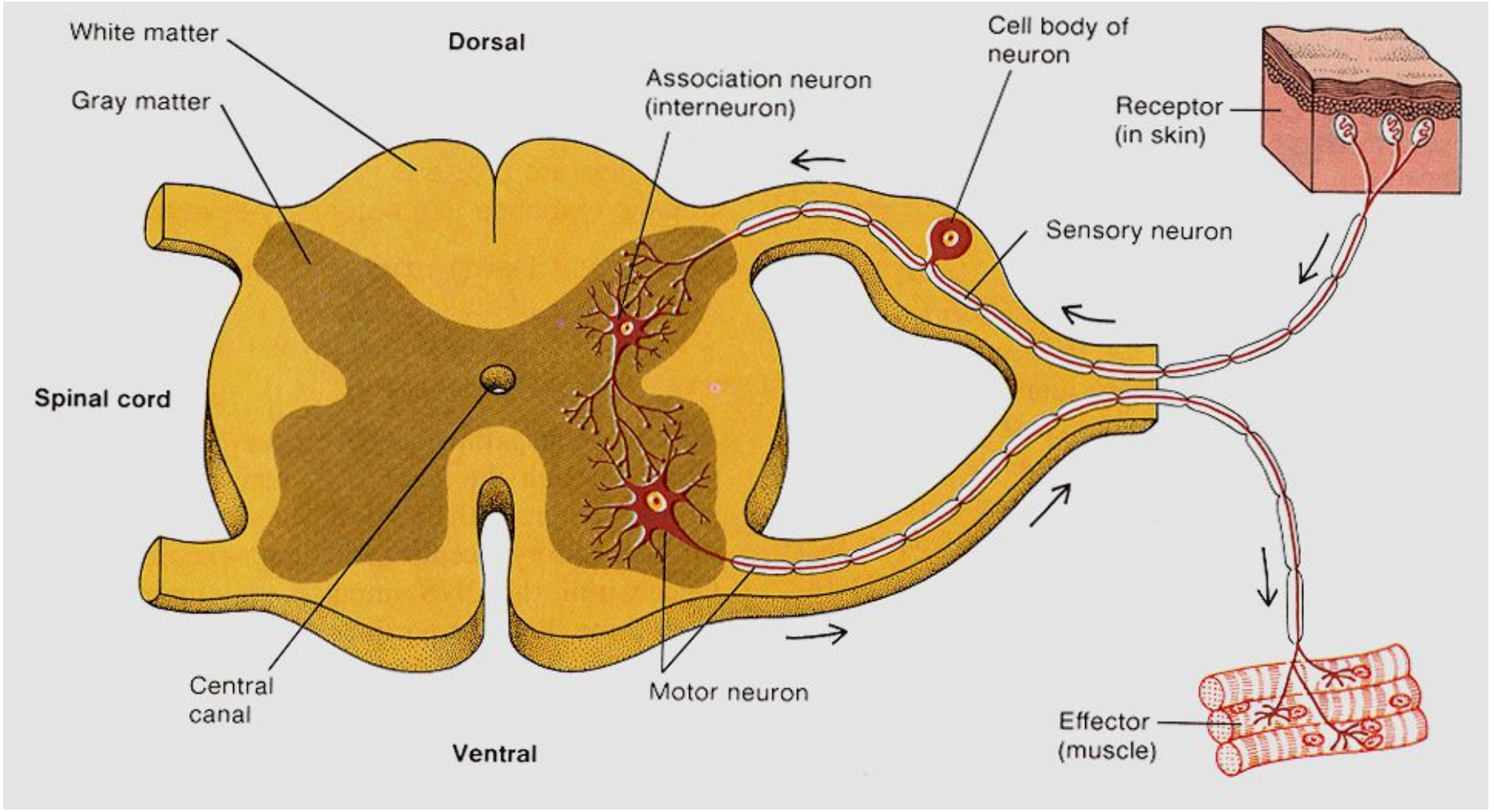
1. Spinocerebellar
2. Spino-olivary
3. Spinotectal
4. Spinoreticular

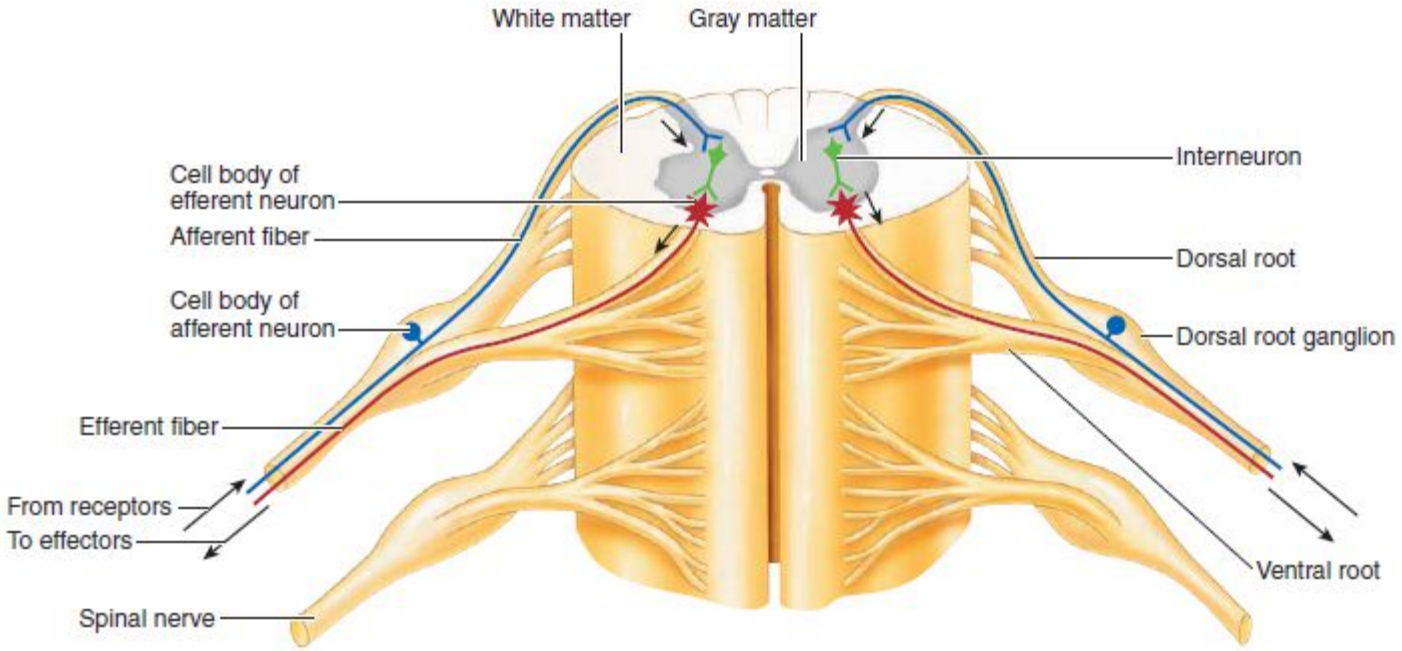
Spinal Cord—Ascending Nerve Tracts



A Sensory Neuron

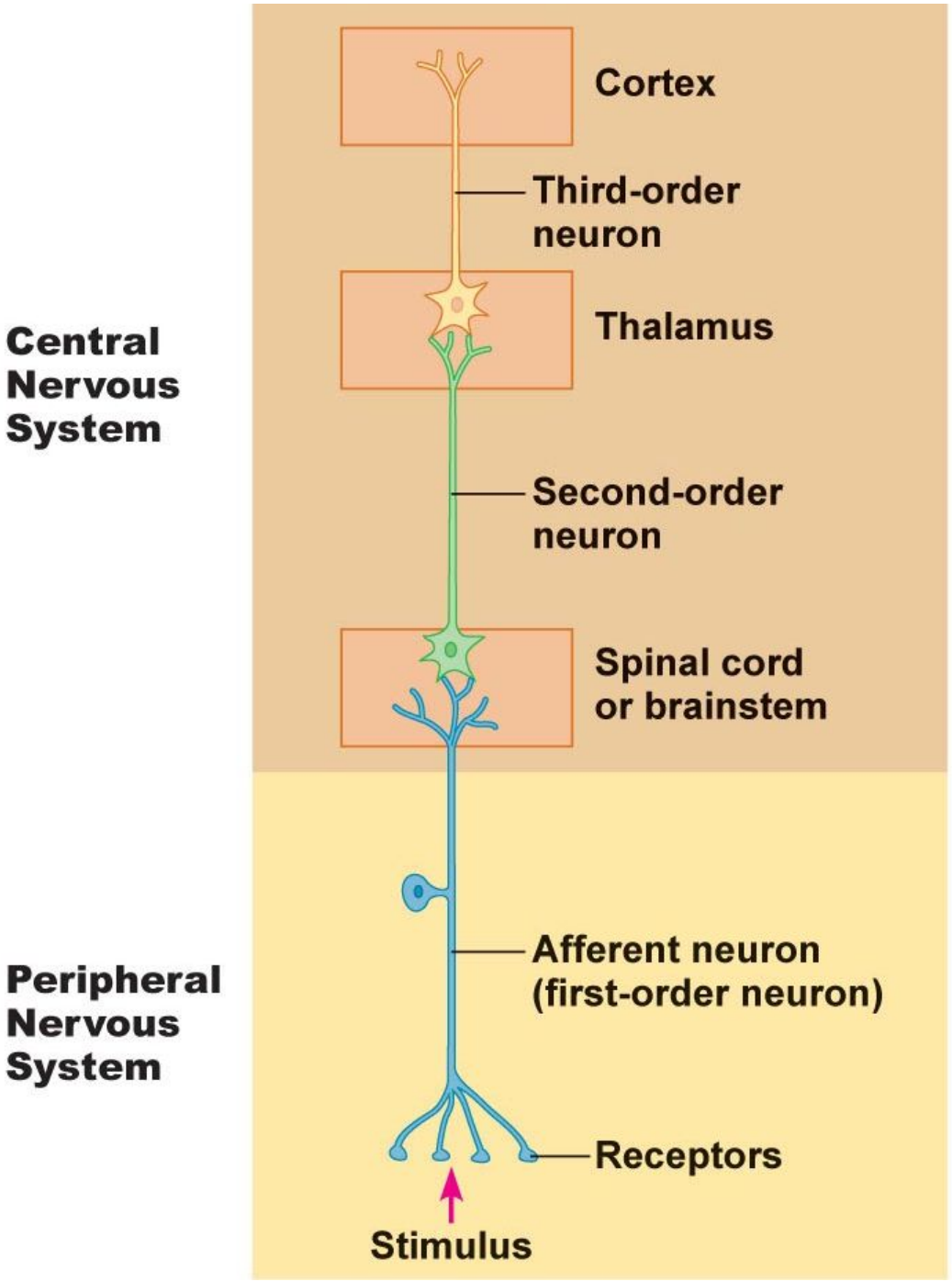



White matter
Gray matter
Dorsal
Association neuron
(interneuron)
Cell body of
neuron
Receptor
(in skin)
Sensory neuron
Spinal cord
Central
canal
Motor neuron
Ventral
Effector
(muscle)



● **FIGURE 5-26 Spinal cord in cross section.** The afferent fibers enter through the dorsal root, and the efferent fibers exit through the ventral root. Afferent and efferent fibers are enclosed together within a spinal nerve.

What do you understand by First, Second & Third Order neurons?


Central Nervous System
Peripheral Nervous System
Cortex
Third-order neuron
Thalamus
Second-order neuron
Spinal cord or brainstem
Afferent neuron (first-order neuron)
Receptors
Stimulus

The pathways have to cross over at some time because the cerebral cortex works on a contralateral basis.

THE FIBERS OF THE SENSORY PATHWAYS SYNAPSE AND THEN CROSS!

(The crossing occurs at different levels for different pathways.)

DCML is a **crossed** sensory system, which conveys information for discriminative touch, proprioception and vibration sense from the body to the sensory cortex.

THE DORSAL COLUMN-MEDIAL LEMNISCUS SYSTEM (DCML)

- **Also called:**

The dorsal column-medial lemniscal system, as its name implies, is present mainly in the *dorsal columns* of the cord. Its is also called by the following names:

  - Dorsal white column system
  - The Lemniscal system

- **Constituted** of 2 tracts called:
  - Fasciculus Gracilis (Tract of GOLL)
  - Fasciculus Cuneatus (Tract of BURDACH)
- **Neurons:**
  - A-alpha fibers
  - A-Beta fibers

FUNCTIONS:

It carries the following sensations:

- Fine touch, tap, flutter (Meissner's)
- Tactile localization & discrimination (Meissner's,)
- Vibration & pressure (Pacinian Corpuscle, Ruffini's endings)
- Kinesthetic sense e.g. Joint and muscle position sense (Muscle Spindle & Golgi Tendon organs)
- Stereognosis (It is the ability to recognize an object by touch only with eyes closed)- It is the function of the various mechanoreceptors working together.

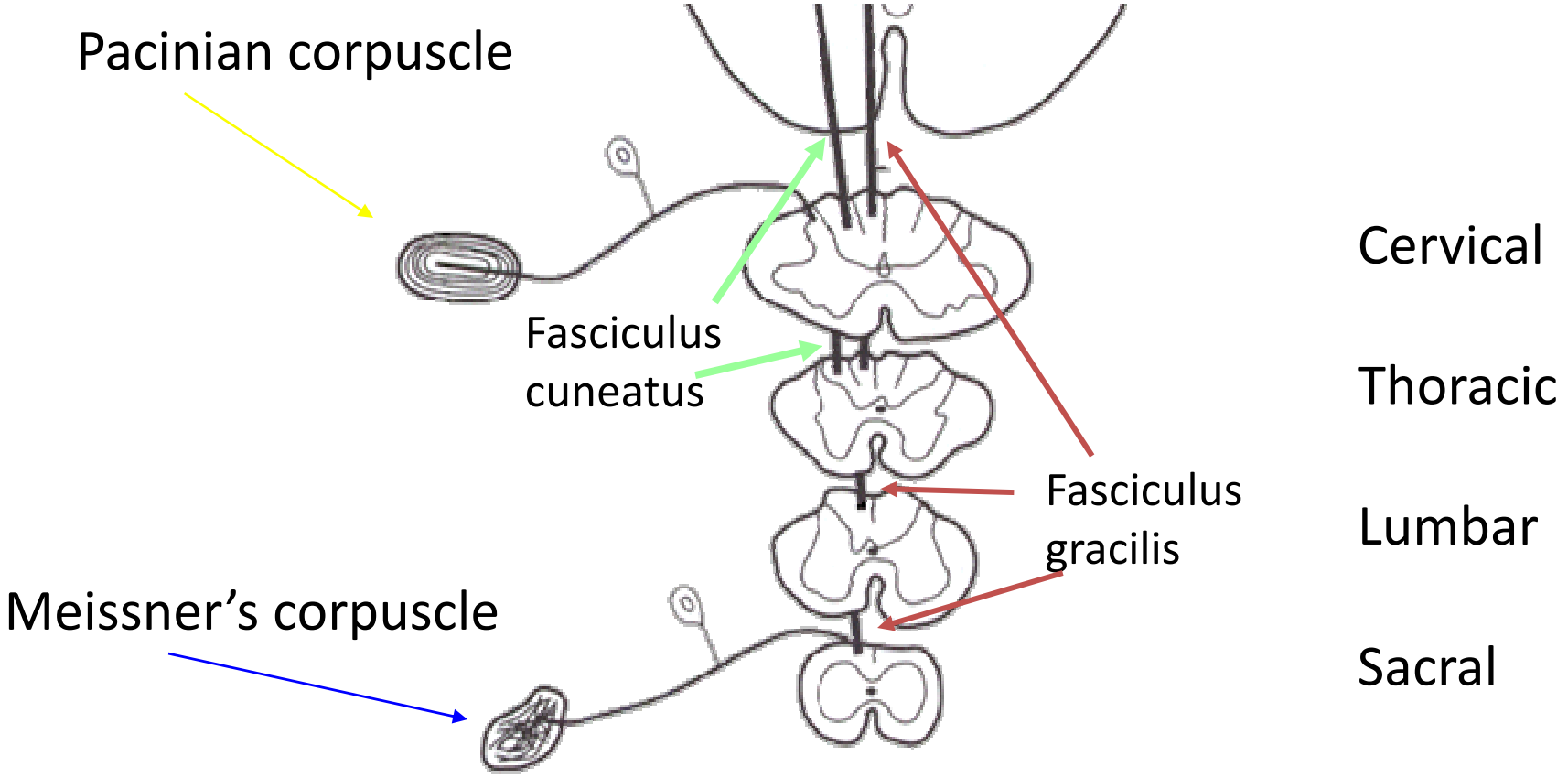
Fasciculus Gracilis

- Cells of origin: Dorsal root ganglia BELOW T6 (sacral, lumbar, lower thoracic segments).
- A- Alpha and A-Beta fibers.
- Axons ascend ipsilaterally and synapse in NUCLEUS GRACILE.

Fasciculus Cuneatus

- Cells of origin: Dorsal root ganglia T6 and above (Upper thoracic and cervical segments).
- A-alpha and A-beta fibers.
- Axons ascend ipsilaterally and synapse in NUCLEUS CUEATUS.

FASCICULUS GRACILIS & CUNEATUS



Fasciculus Gracilis + Cuneatus

↓**FIRST ORDER NEURON**

Ascend in the Spinal cord

(Dorsal column same side)

↓

Synapse with the Cuneate and Gracile Nuclei in the Medulla Oblongata

↓**SECOND ORDER NEURONS**

INTERNAL ARCUATE FIBERS arise & cross over to form the SENSORY DECUSSATION

↓

Ascends as the MEDIAL LEMNISCUS through the pons & midbrain on the <u>contralateral side</u>

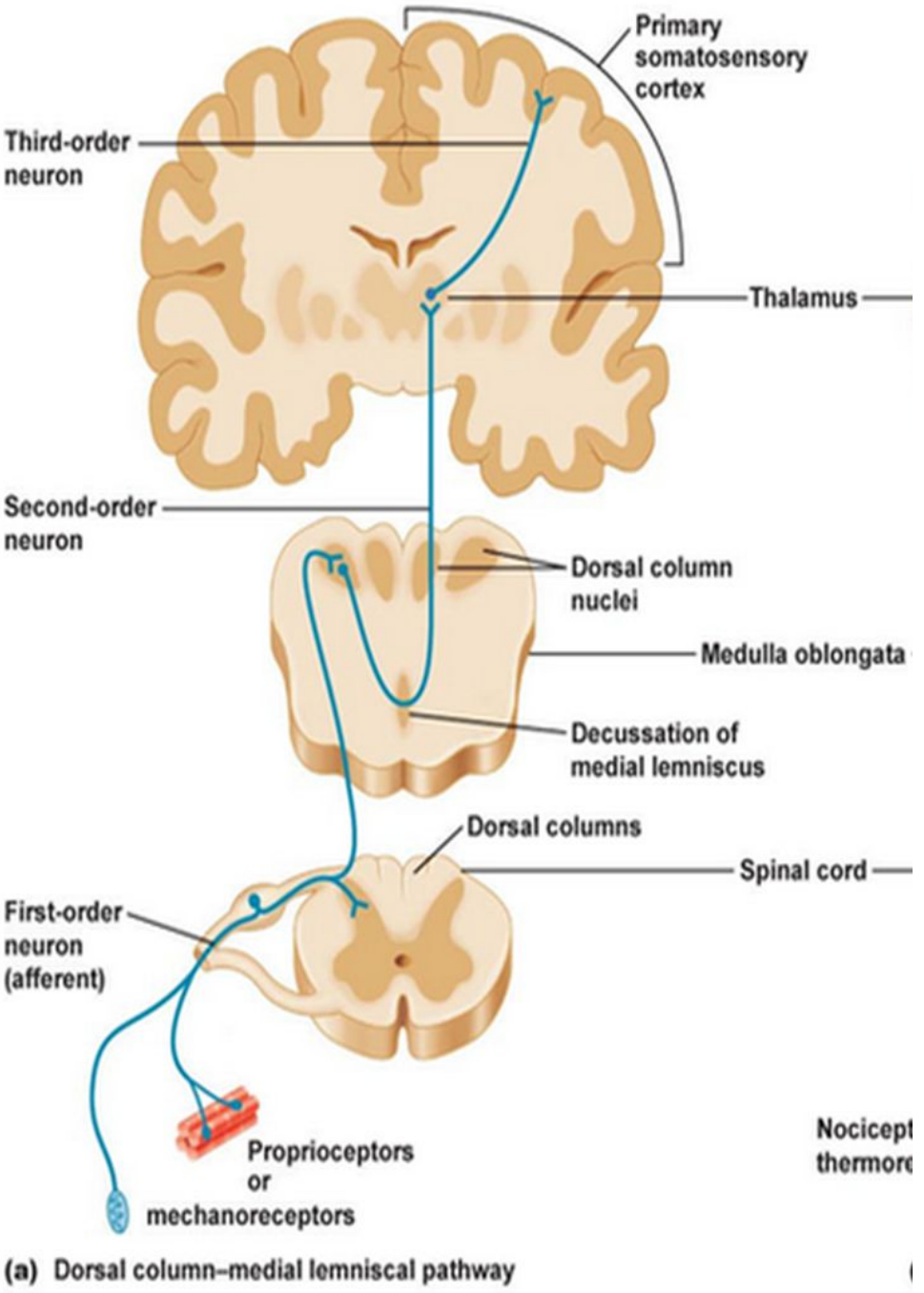
↓

Synapse on the Ventral Posterolateral (VPL) nucleus of THALAMUS

↓**THIRD ORDER NEURONS**

Cerebral cortex

(Primary Somatosensory Cortex in the Post central Gyrus)



(a) Dorsal column–medial lemniscal pathway

Some fibers carry information from the Muscle spindle and the Golgi tendon organs.

↓

They carry the sensation of Proprioception from the joints and tendons.

↓

Instead of entering into the
INTERNAL ARCUATE FIBRES,
these fibers form the DORSAL & VENTRAL EXTERNAL ARCUATE FIBERS

↓

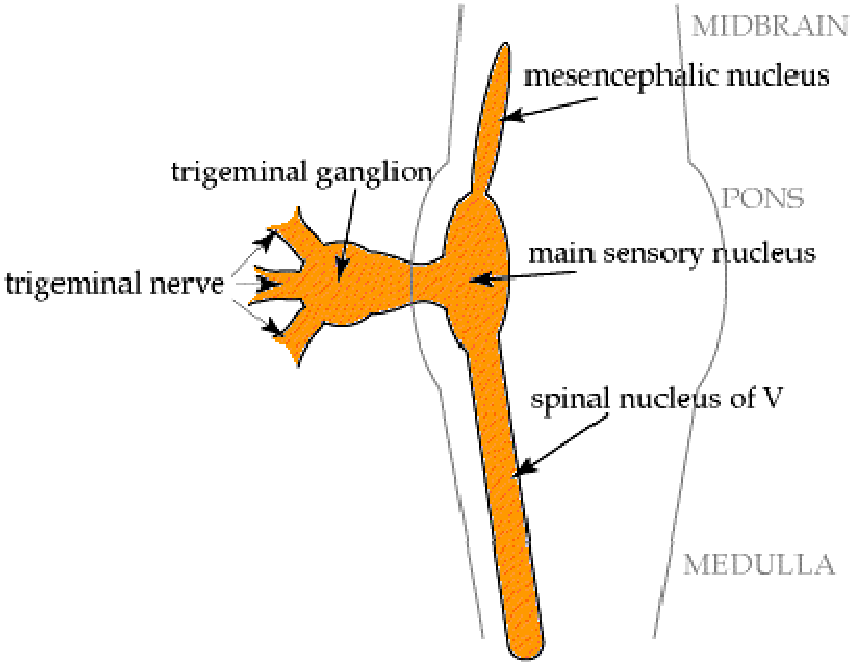
Ascend through the same side

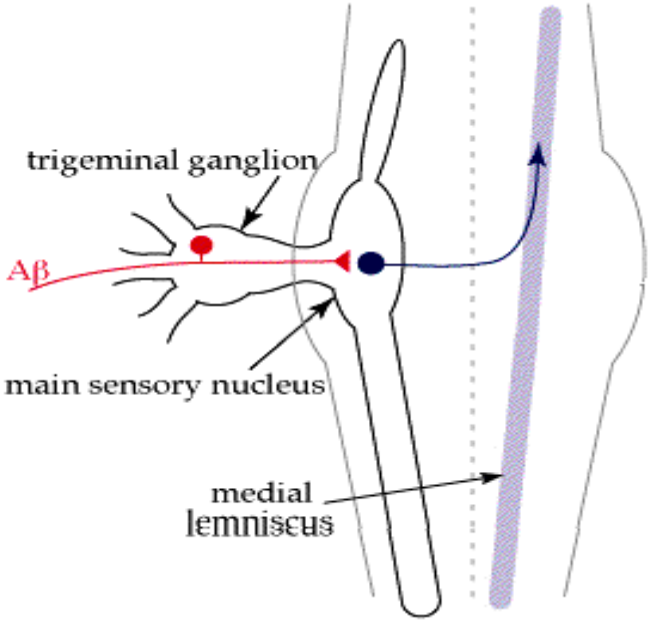
↓

Enter into the CEREBELLUM
(Spinocerebellar Pathway)

SENSORY INPUT FROM FACE?

- The sensory input from the face does not enter the spinal cord.
- Touch and proprioception from the head are relayed mostly via the main sensory and mesencepahlic nuclei of the **Trigeminal Nerve** directly into the BRAINSTEM.
- They then cross and join the medial lemniscus on its way to the thalamus.





What happens when there is a lesion of the DCML system?

Effects produced by lesion depends on the level of the lesion:

The lesion produces the following effects:

1. Loss of tactile localization and two-point discrimination.
2. Loss of vibratory and pressure sense.
3. Astereognosis (loss of appreciation of difference in weight and inability to identify objects placed in hand by feeling them, with eyes closed).
4. Loss of position and movement sense leading to impairment in the performance of voluntary motor functions.
5. Romberg's Test is positive.

(The effect produced will be seen either on the IPSILATERAL or CONTRALATERAL side depending on the level of the lesion.)

ROMBURG'S TEST

The test is carried out as follows:

Subject stands erect with feet together and eyes open. The examiner observes him for 30 seconds- 1 minute.

Now the patient closes the eyes and the examiner observes the patient for a full minute.

The essential feature is that the patient becomes more unsteady with eyes closed.

Romberg's test is positive if the patient sways or falls while the patient's eyes are closed.

Patients with a positive result are said to demonstrate Romberg's sign or *Rombergism*. They can also be described as *Romberg's positive*.

Patient stands feet together, eyes open and then closes both eyes for 20 to 30 sec without support; positive test with eyes open suggestive of cerebellar ataxia; with eyes closed suggestive of impaired proprioception (e.g. from pathology of dorsal columns).

A Quick Review to see if you know the basics of DCML!

Lesion of the DCML at the level of T8 on the left side causes what kind of impairment?

It causes absence of light touch, vibration and position sensation in the left leg and lower left trunk. It is because only Fasciculus Gracilis exists below T6 and the tract has not decussated/crossed over as yet. So the impairment is on the same side as the lesion.

Lesion of the DCML at the level of C3 on the left side produces what kind of impairment?

It causes absence of light touch, vibration and position sense in the lower and upper trunk and upper limb and chest below the level of the lesion on the left side. This is because both gracilis and cuneatus are present at this level but decussation has not occurred.

Lesion of the right medial lemniscus produces what impairment?

It causes absence of light touch, vibration and position on the entire left side, because crossing over has taken place in the sensory decussation and the medial lemniscus now consists of fibers from the opposite side of the body.

Lesion of the right somatosensory cortex produces what impairment?

Absence of all sensations including the face on the entire left side.

Where would the sensory loss be if you cut the Left Gracile fasciculus?

The left leg and lower trunk.

Where would the sensory loss be if both dorsal columns are cut?

The entire body below the level of the cut

(if below T6, then leg and if above T6, then trunk and leg with arms).

ANTEROLATERAL SYSTEM

It is a **crossed sensory system** that carries the sensation of pain, temperature, crude touch, itch and tickle.

Anterolateral System

FUNCTIONS:

- Pain- (Fast and Slow Pain) (Free nerve endings)
- Temperature- (cold & warmth) (Free nerve endings and Krause's End bulb)
- Crude touch (Merkel's discs)
- Pressure (Pacinian Corpuscle)
- Tickle & Itch (Free nerve endings)

NEURONS:

- A-delta fibers
- C unmyelinated fibers

TRACTS: There are 2 tracts in the Anterolateral System.

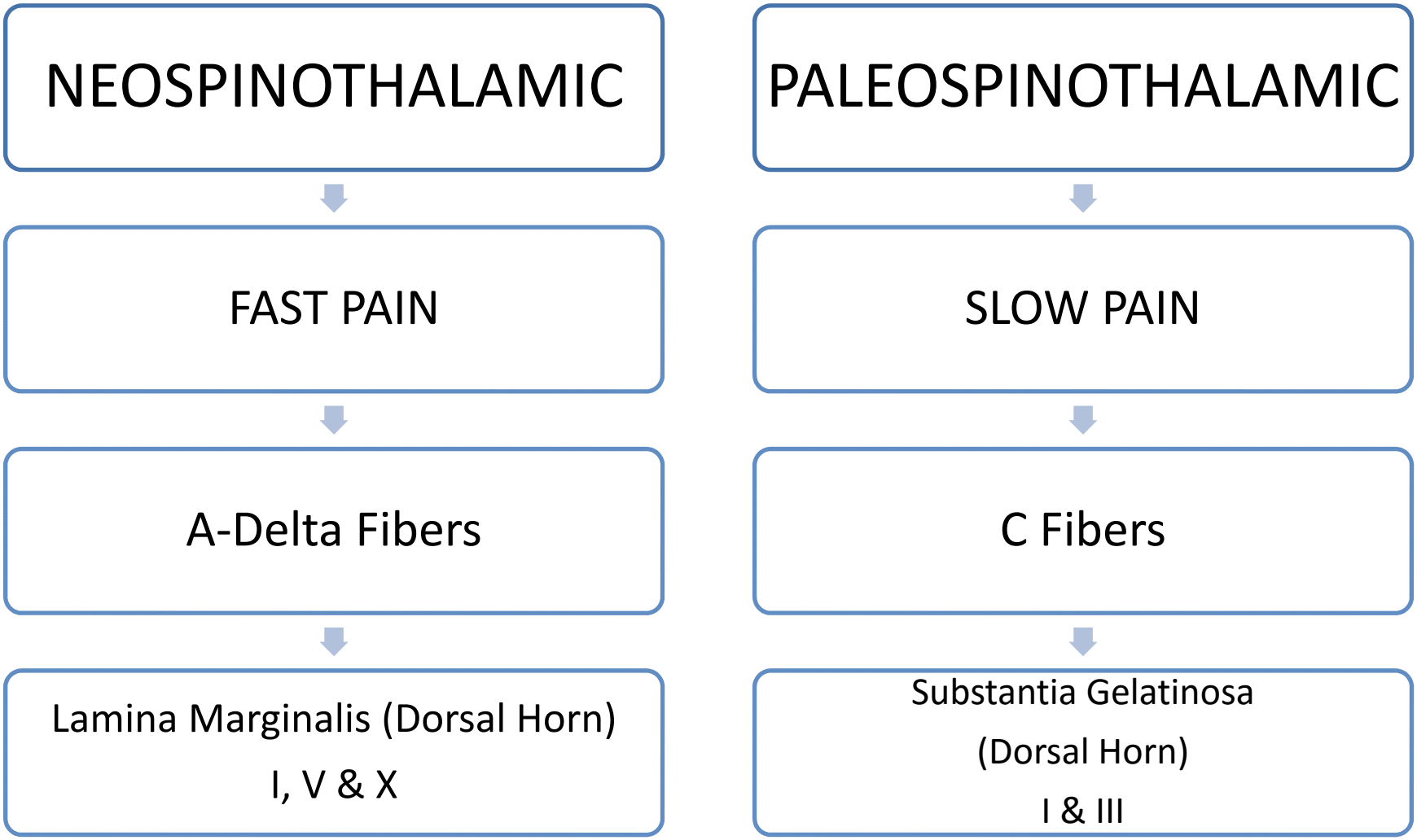
  - Anterior Spinothalamic Tract: carries fibers for crude touch, tickle, itch and pressure.
  - Lateral Spinothalamic Tract: carries fibers for pain and temperature.

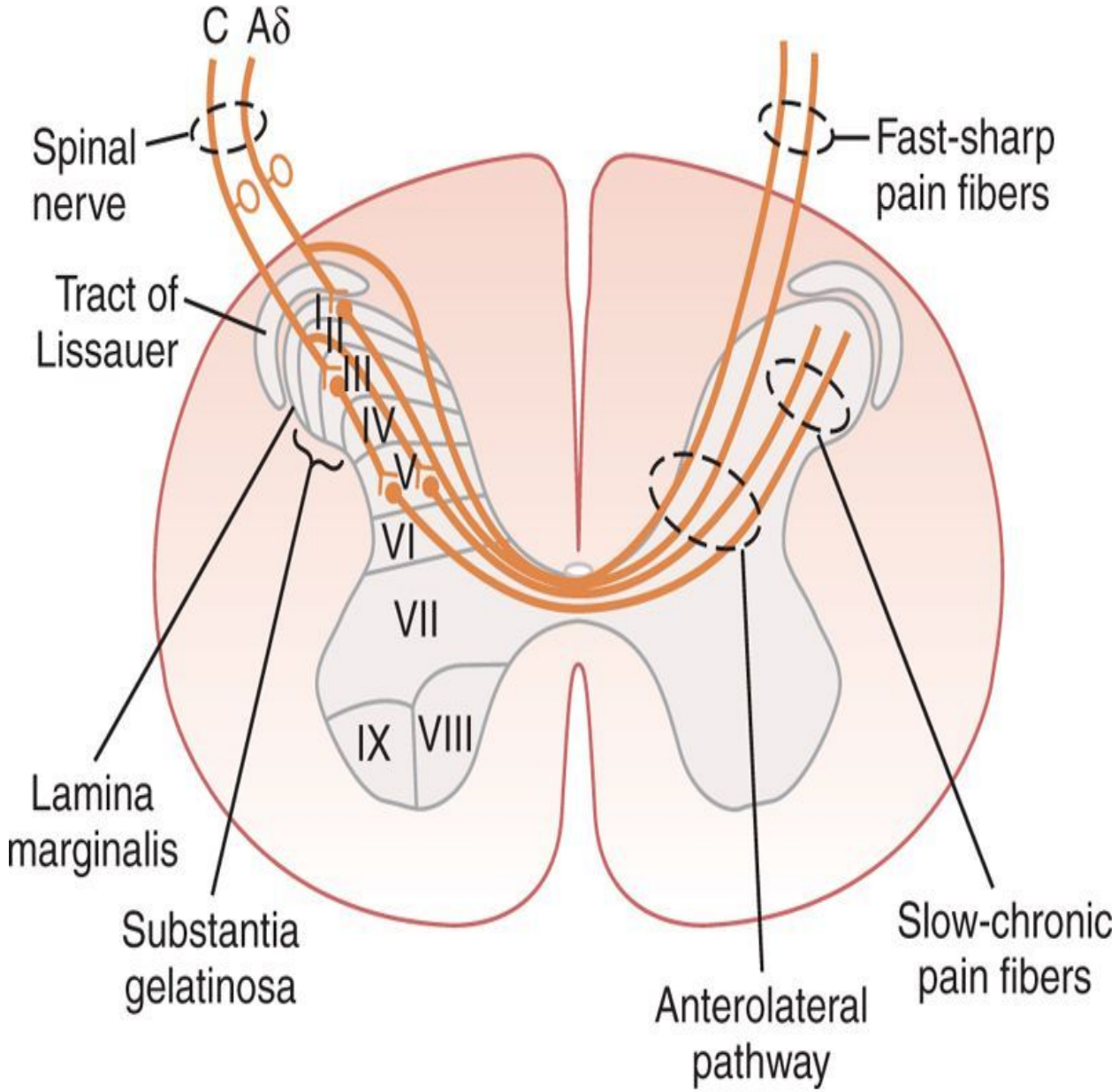
- There is a double system of pain innervation in the **Lateral Spinothalamic tract:**

1. NEOSPINOTHALAMIC PATHWAY: For **FAST** pain carried by A-delta fibers
2. PALEOSPINOTHALAMIC PATHWAY: For **Slow** pain carried by C fibers.

Because of this double system of pain innervation, a sudden painful stimulus often gives a "double" pain sensation: a fast-sharp (also called First pain) that is transmitted to the brain by the Aδ fibers, followed a second or so later by a slow (Second pain) that is transmitted by the C fibers.

Even though all pain receptors are free nerve endings, these endings use two separate pathways for transmitting pain signals into the central nervous system. The two pathways mainly correspond to the two types of pain-a *fast-sharp pain pathway* and a *slow-chronic pain pathway.*


NEOSPINOTHALAMIC
FAST PAIN
A-Delta Fibers
Lamina Marginalis (Dorsal Horn)
I, V & X
PALEOSPINOTHALAMIC
SLOW PAIN
C Fibers
Substantia Gelatinosa
(Dorsal Horn)
I & III



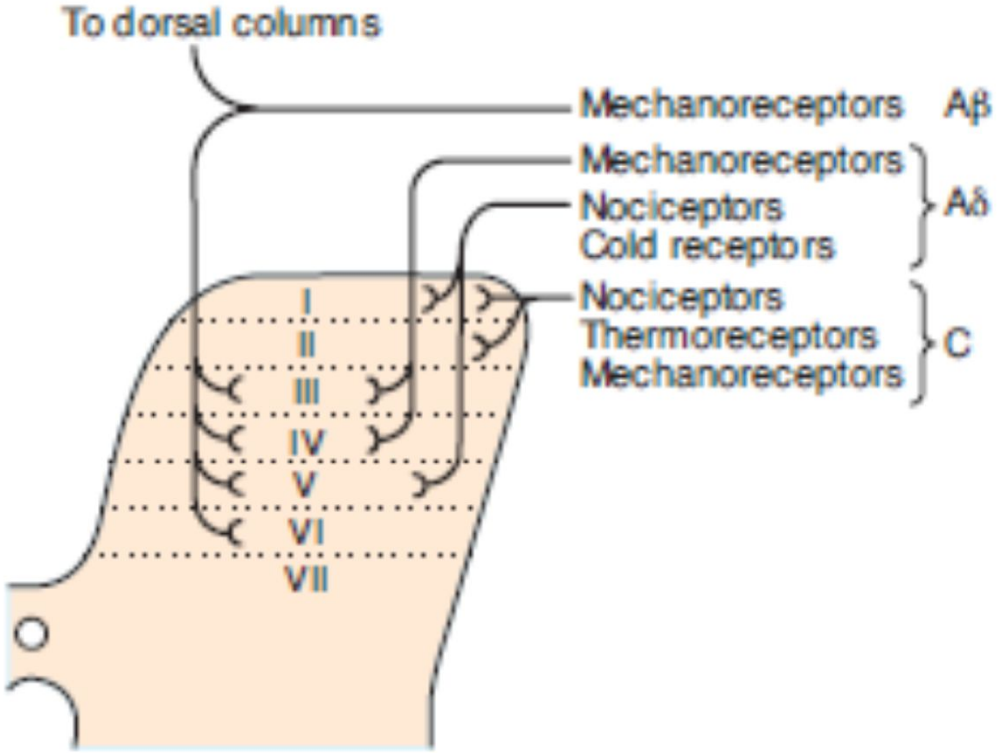


FIGURE 11–1 **Schematic representation of the terminations of the three types of primary afferent neurons in the various layers of the dorsal horn of the spinal cord.**

Receptors (Mechanoreceptors, Thermal & Pain receptors)

↓

- **Fast** Pain carried by A-delta fibers (6-30 m/sec)
- **Slow** Pain carried by Type C fibers (0.5-2 m/sec)

↓

First Order Neuron

↓

Posterior root ganglion (Cell bodies)

↓

Fibers ascend or descend 1-2 spinal cord segments where they are called the **Tracts of Lissaeur**

↓

On entering the spinal cord, the pain signals take one of the two pathways after synapsing:

Neospinothalamic pathway

Lamina I of dorsal horn

(Lamina marginalis)

↓

Second order neurons

↓

Paleospinothalamic pathway

Lamina II & III of dorsal horn

(Substantia Gelatinosa)

↓

Second order neurons

↓

Decussate immediately through the anterior commissure & then ascend in the anterior & lateral columns of the opposite side of the spinal cord.

Ascend through the brainstem (medulla, pons & midbrain)

as the **Spinal Lemniscus**

(where fibers of Anterior & Lateral Spinothalamic tract ascend together in the lower part of medulla)

↓

Thalamus (VPL nucleus)

Some fibers carrying the slow pain also relay to the Reticular area and Tectal area and Periacquiductal gray region giving rise to **SPINOTECTAL** and **SPINORETICULAR** tract

↓

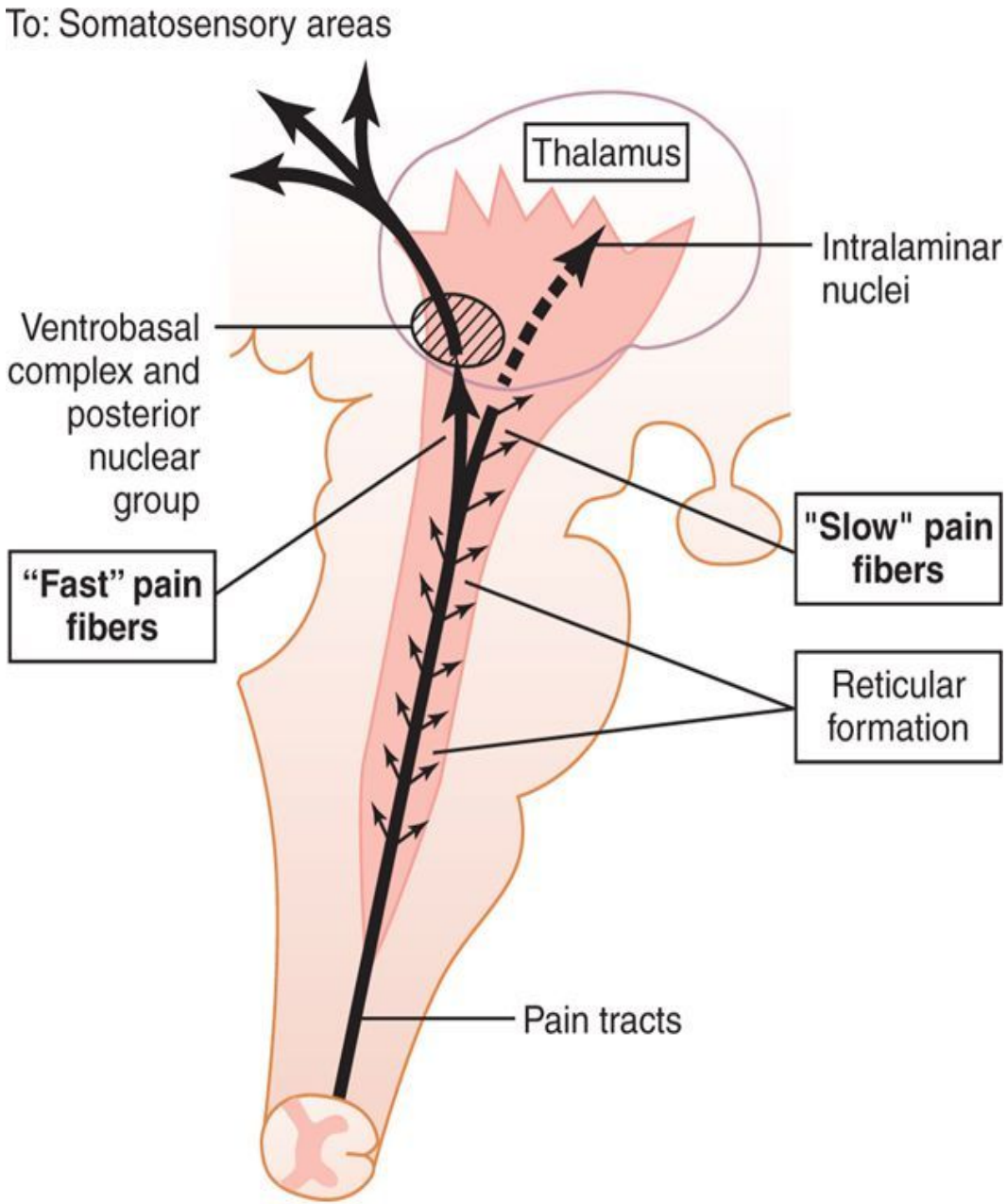
Third Order neurons

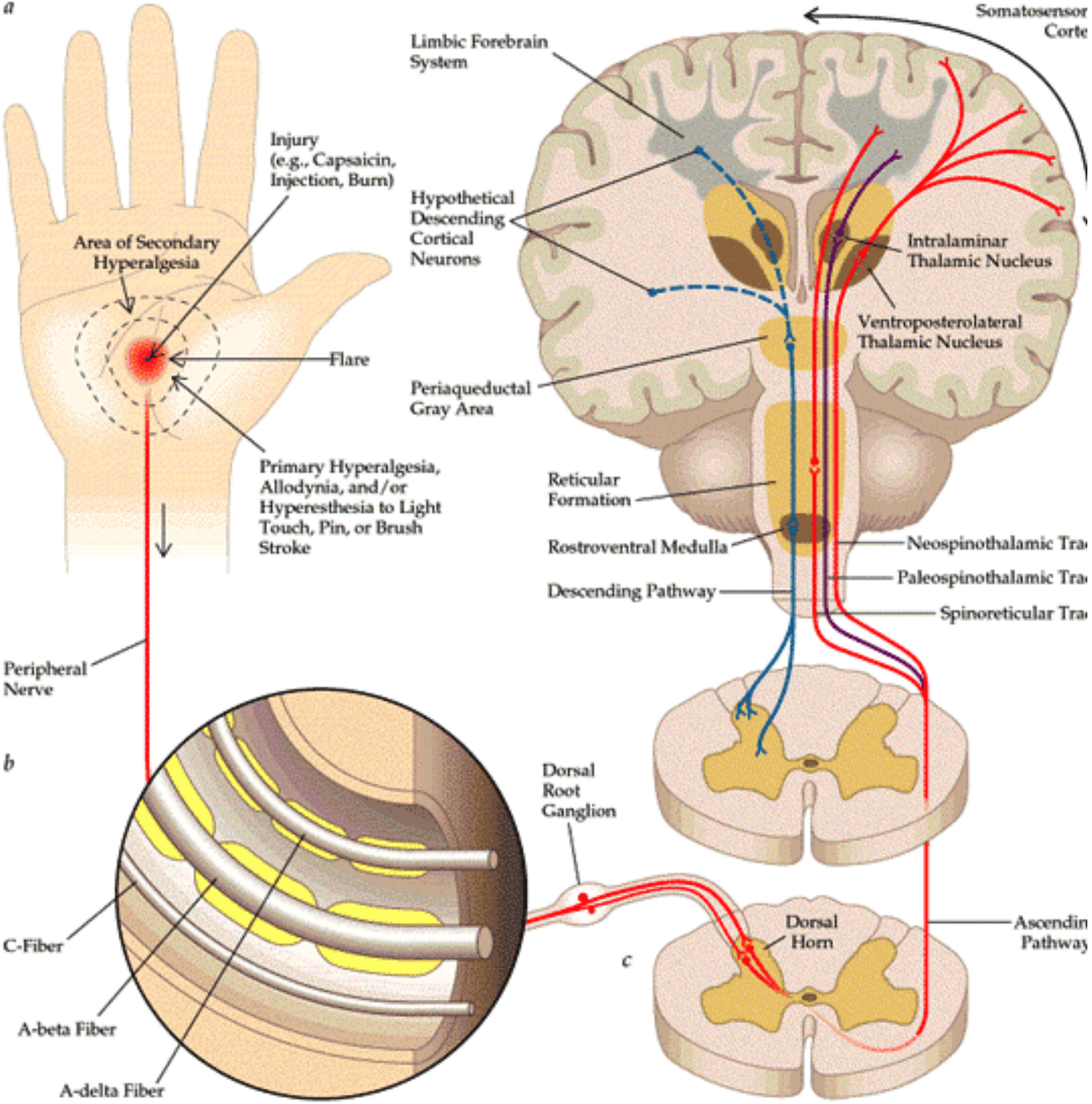
↓

Somatosensory Cortex

(Some fibers carrying the fibers for slow pain also terminate in the hypothalamus)

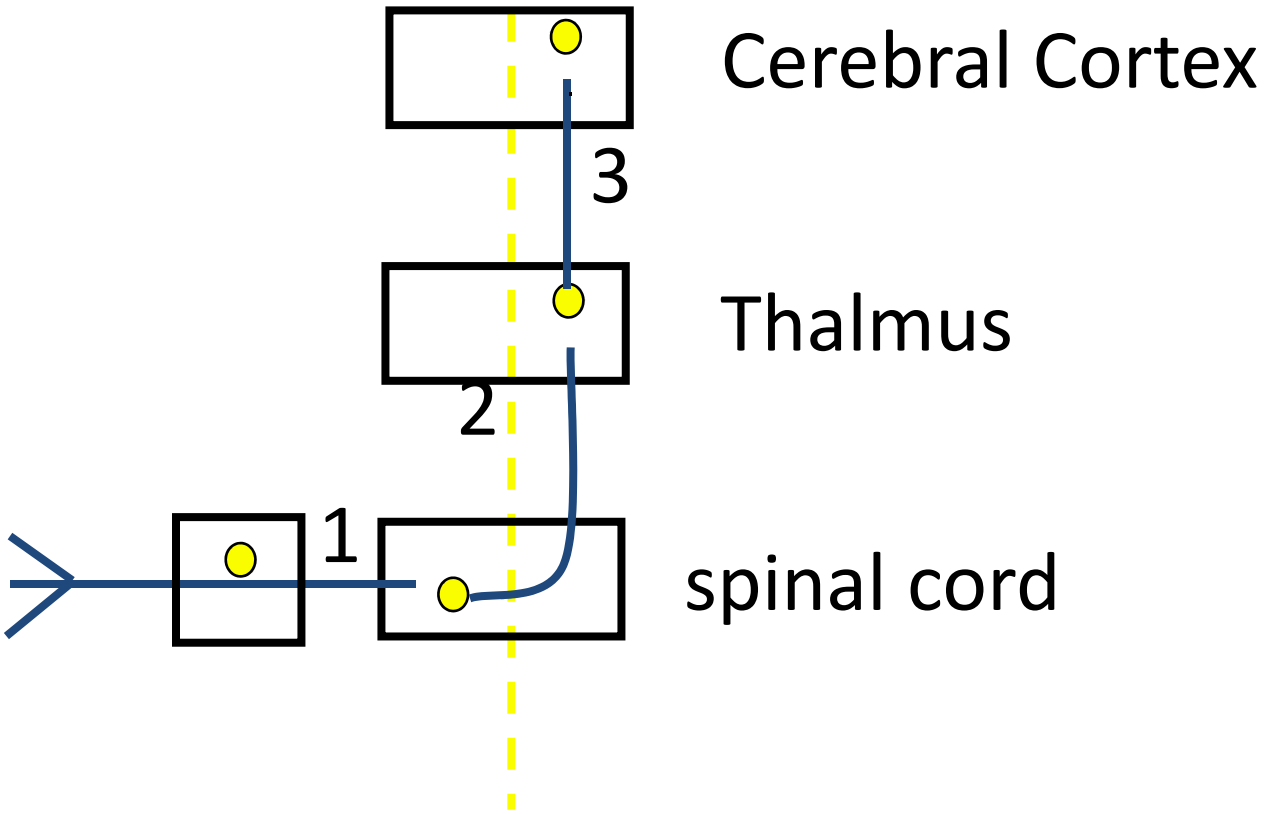
Spinothalamic: synapse in the **thalamus**
Spinoreticular: synapse in the **reticular formation**
Spinotectal: synapse in the **tectum (colliculus)**




a
Injury
(e.g., Capsaicin,
Injection, Burn)
Area of Secondary
Hyperalgesia
Flare
Primary Hyperalgesia,
Allodynia, and/or
Hyperesthesia to Light
Touch, Pin, or Brush
Stroke
Peripheral
Nerve
Limbic Forebrain
System
Hypothetical
Descending
Cortical
Neurons
Periaqueductal
Gray Area
Somatosensor
Corte
Intralaminar
Thalamic Nucleus
Ventroposterolateral
Thalamic Nucleus
Reticular
Formation
Rostroventral Medulla
Descending Pathway
Neospinothalamic Tra
Paleospinothalamic Tra
Spinoreticular Tra
b
C-Fiber
A-beta Fiber
A-delta Fiber
Dorsal
Root
Ganglion
c
Dorsal
Horn
Ascendin
Pathway

Pain and Temperature

- Anterolateral System



Effect of Lesion

Anterior Spinothalamic Tract:

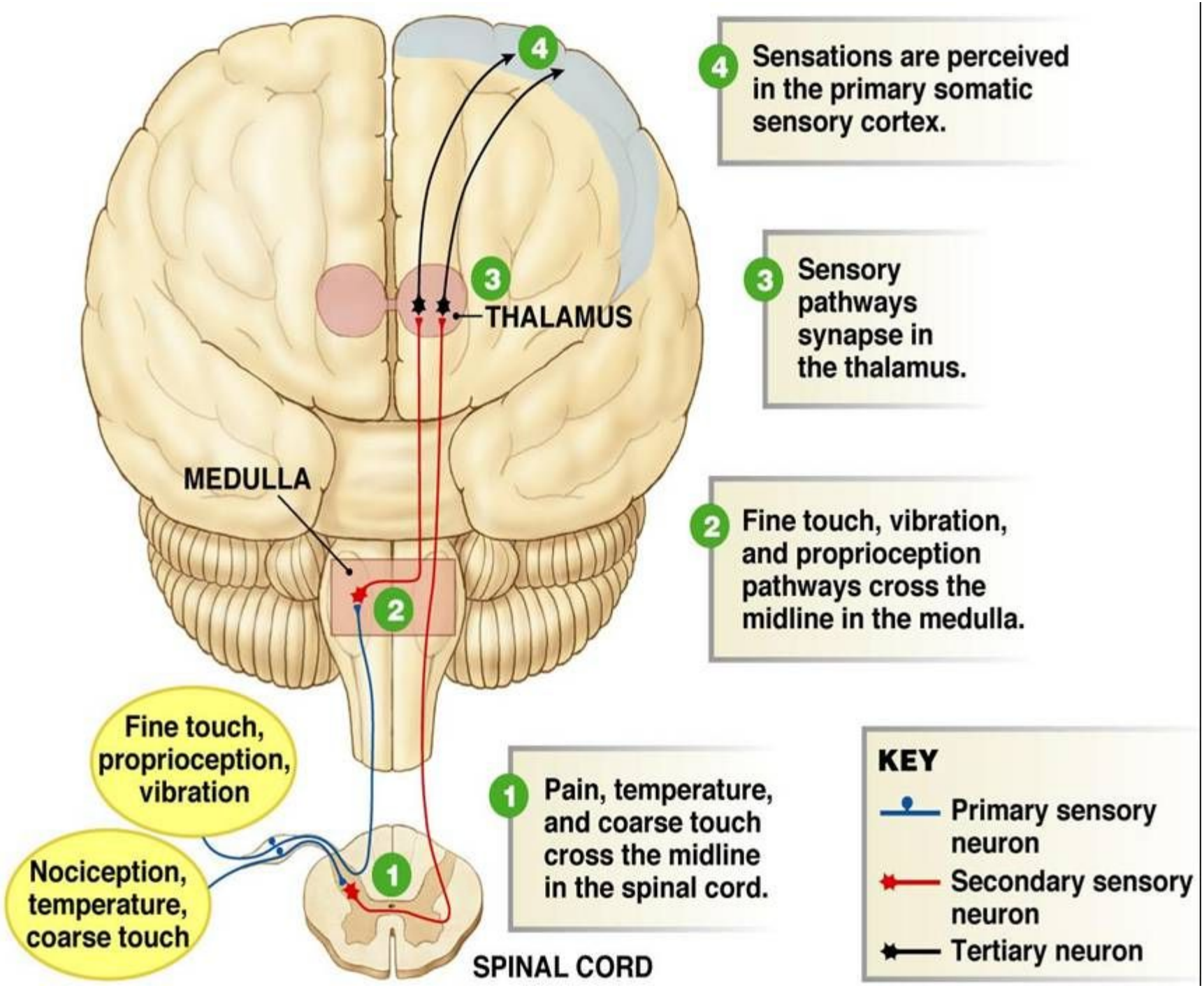
- The destruction of this tract produces little if any tactile disturbances as touch is also carried in DCML.
- Bilateral lesion of this tract leads to loss of sensations of crude touch, itch and tickle below the lesion.
- The unilateral lesion of the tract causes loss of sensation below the level of the lesion on the opposite side.

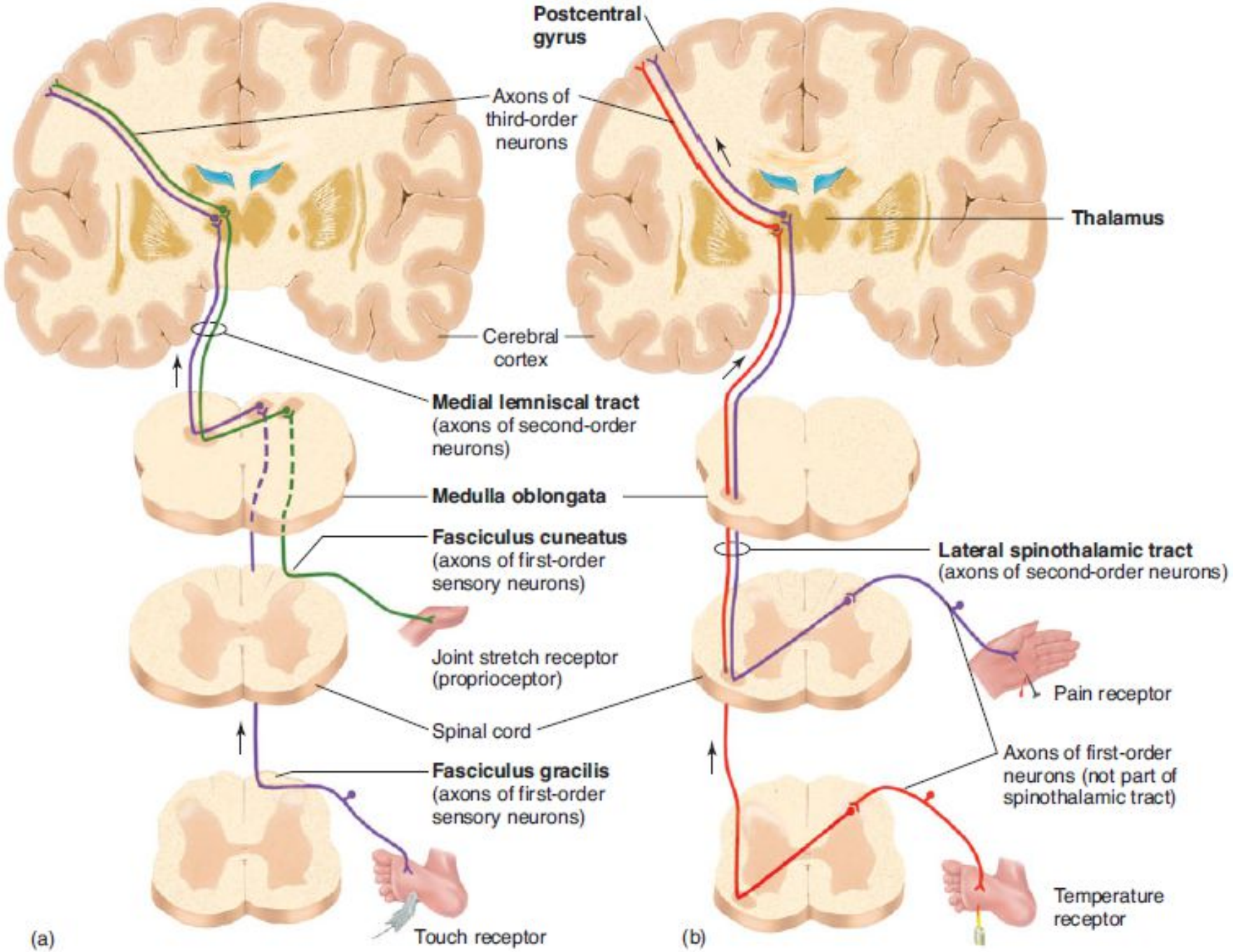
Lateral Spinothalamic Tract:

- The bilateral section of the tract leads to total loss of pain and temperature sensations on both sides below the lesion.
- The unilateral lesion causes loss of pain (analgesia) and temperature (thermoanesthesia) below the level of the lesion on the opposite side.
- This contralateral sensory loss extends to a level one segment below that lesion.
- At some point there may be some return of pain & Temperature.

What are the differences between DCML & Anterolateral System?

- Differ in their names.
- Differ in the kind of information that they carry.
- Differ in where they travel up the cord.
- Differ in whether or not they cross the spinal cord.


4
Sensations are perceived in the primary somatic sensory cortex.
3
THALAMUS
Sensory pathways synapse in the thalamus.
MEDULLA
2
Fine touch, vibration, and proprioception pathways cross the midline in the medulla.
Fine touch, proprioception, vibration
Nociception, temperature, coarse touch
1
Pain, temperature, and coarse touch cross the midline in the spinal cord.
SPINAL CORD
KEY
Primary sensory neuron
Secondary sensory neuron
Tertiary neuron


Postcentral gyrus
Axons of third-order neurons
Thalamus
Cerebral cortex
Medial lemniscal tract (axons of second-order neurons)
Medulla oblongata
Fasciculus cuneatus (axons of first-order sensory neurons)
Lateral spinothalamic tract (axons of second-order neurons)
Joint stretch receptor (proprioceptor)
Pain receptor
Spinal cord
Axons of first-order neurons (not part of spinothalamic tract)
Fasciculus gracilis (axons of first-order sensory neurons)
Temperature receptor
Touch receptor
(a)
(b)

DIFFERENCES B/W DCML & ANTEROLATERAL SYSTEM

DCML

1. Large, myelinated fibers
2. Mechanoreceptors & Proprioceptors
3. High velocity: upto 70 meters/ sec.
4. Spatial orientation is highly developed. High degree of localization.
5. Travel in the Dorsal Column.
6. Comprises of Gracile & Cuneate Fasciculus.
7. Level of Crossing: SENSORY DECUSSATION (Medulla Oblongata)
8. Ascends as MEDIAL LEMNISCUS
9. Terminates in Cerebral Cortex.
10. Transmits the sensations:

- Tactile localization & Two-point discrimination
- Pressure & Vibration
- Stereognosis
- Proprioception

ANTEROLATERAL SYSTEM

1. Small diameter, myelinated as well as unmyelinated fibers.
2. Free nerve endings & Mechnoreceptors
3. Low velocity: 1-15 m/sec
4. Poor spatial orientation. Low degree of localization.
5. Travel in the Anterior & Lateral Column.
6. Comprises of Spinotectal, Spinoreticular & Spinothalamic Tracts
7. Level of Crossing: ANTERIOR COMMISSURE (Spinal Cord)
8. Ascends as SPINAL LEMNISCUS
9. Terminates in Tectal Area, Reticular Area and Cerebral Cortex.
10. Transmits the sensations:

- Pain & Temperature
- Itch & Tickle
- Crude touch & pressure

The fibers of this pathway convey proprioceptive impulses to the cerebellum. It has 2 divisions:

1. Anterior Spinocerebellar Tract
2. Posterior Spinocerebellar Tract

THE SPINOCEREBELLAR TRACT

SPINOCEREBELLAR TRACTS

Anterior Spinocerebellar Tract

- Proprioceptive information from the entire lower limb.
- Fibers cross over but then cross back again in the cerebellar peduncles. This is called “Double Cross”.
- Terminate in the cerebellum.

Posterior Spinocerebellar Tract

- Proprioceptive information and somatosensory information from cutaneous receptors of the trunk and lower limb.
- Ascends ipsilaterally to terminate in the cerebellum of the same side.

REVIEW THE ASCENDING PATHWAYS AGAIN.

Spinal Cord—Ascending Nerve Tracts