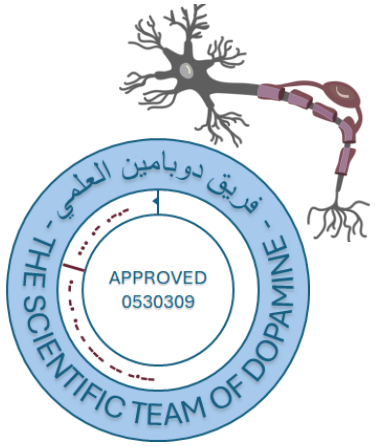


بسم الله الرحمن الرحيم

DOPAMINE SCIENTIFIC TEAM

Spinal Cord (pt.3)

MID | Lecture 4

﴿إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ ۚ مَّا مِن دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا ۚ إِنَّ رَبِّي عَلَىٰ صِرَاطٍ مُّسْتَقِيمٍ﴾

Written by: Alharith Albakkar

Reviewed by: Laith Joudeh

ANATOMY

رحلة اليقين مع سورة يس

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

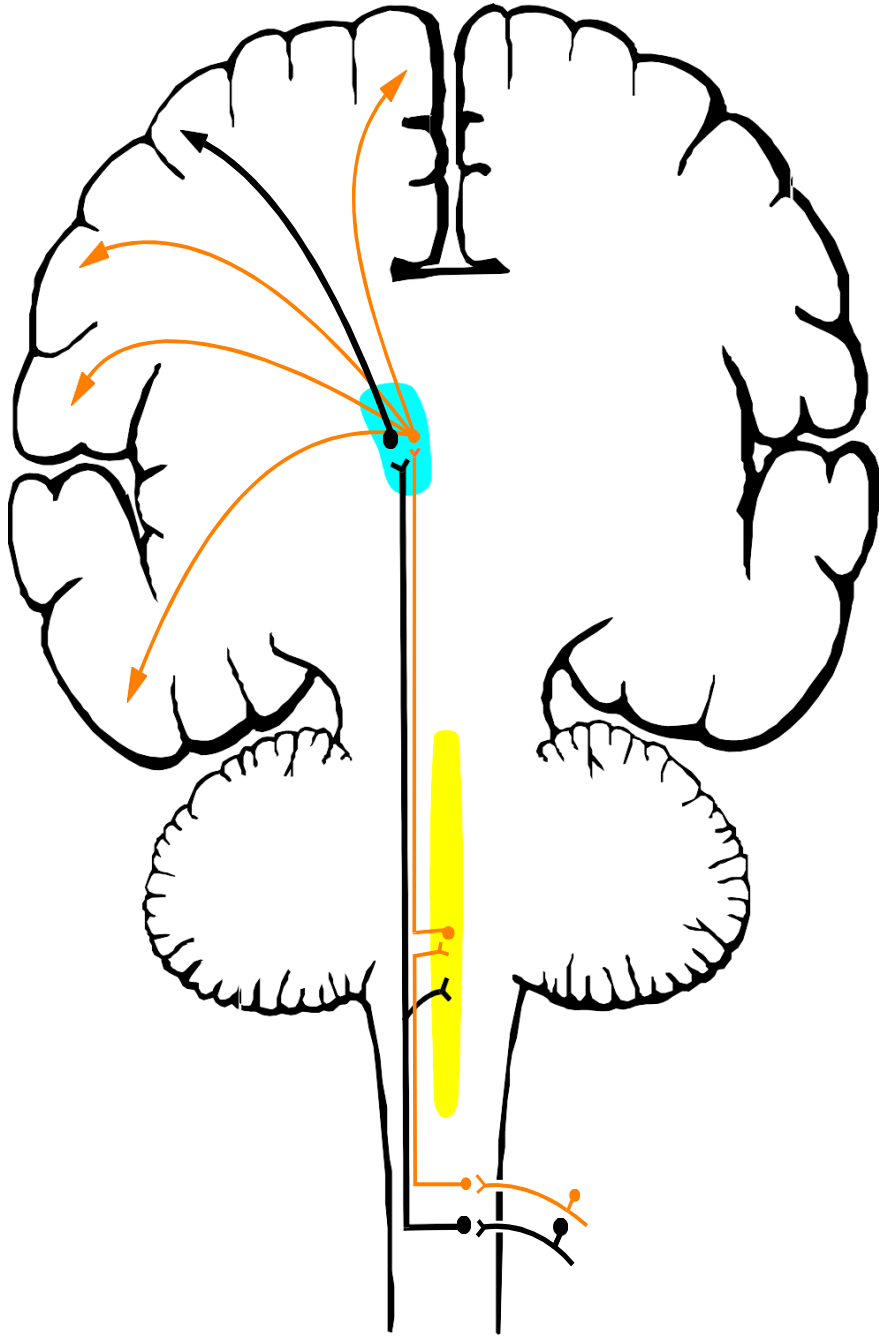
قَالُوٓاْ إِنَّا تَطَيَّرۡنَا بِكُمۡۖ لَئِن لَّمۡ تَنتَهُواْ لَنَرۡجُمَنَّكُمۡ وَلَيَمَسَّنَّكُم مِّنَّا عَذَابٌ أَلِيمٞ ١٨ قَالُواْ طَٰٓئِرُكُم مَّعَكُمۡۚ أَئِن ذُكِّرۡتُمۡۚ بَلۡ أَنتُمۡ قَوۡمٞ مُّسۡرِفُونَ ١٩

فقال أصحاب القرية لرسلهم: {إِنَّا تَطَيَّرْنَا بِكُمْ} أي: لم نر على قدومكم علينا واتصالكم بنا إلا الشر، وهذا من أعجب العجائب، أن يجعل من قدم عليهم بأجل نعمة ينعم الله بها على العباد، وأجل كرامة يكرمهم بها، وضرورتهم إليها فوق كل ضرورة، قد قدم بحالة شر، زادت على الشر الذي هم عليه، واستشأموا بها، ولكن الخذلان وعدم التوفيق، يصنع بصاحبه أعظم مما يصنع به عدوه. ثم توعدوهم فقالوا: {لَئِنْ لَمْ تَنْتَهُوا لَنَرْجُمَنَّكُمْ} أي: نقتلنكم رجما بالحجارة أشنع القتلات {وَلَيَمَسَّنَّكُمْ مِنَّا عَذَابٌ أَلِيمٌ} .

فقالت لهم رسلهم: {طَائِرُكُمْ مَعَكُمْ} وهو ما معهم من الشرك والشر، المقتضي لوقوع المكروه والنقمة، وارتفاع المحبوب والنعمة. {أَئِنْ ذُكِّرْتُمْ} أي: بسبب أنا ذكرناكم ما فيه صلاحكم وحظكم، قلتم لنا ما قلتم. {بَلْ أَنْتُمْ قَوْمٌ مُسْرِفُونَ} متجاوزون للحد، متجرهمون في قولكم، فلم يزدهم [دعاؤهم] إلا نفورا واستكبارا.

Other Terminations of the Lateral Spinothalamic Tract

- **Reticular formation**: (**majority** of the **slow** pain fibers) individual becomes aware of the pain
- **Cingulate gyrus:** Interpretation of the **emotional** aspect of pain.
- **Insular gyrus:** Concerned with the interpretation of pain stimuli from the **internal organs** of the body and brings about an **autonomic response**



Termination Sites of the Lateral Spinothalamic Tract

- As with the **dorsal column–medial lemniscus pathway**, the lateral spinothalamic tract **ultimately projects to the primary somatosensory cortex (postcentral gyrus; areas 3, 1, and 2) via the thalamus**, but due to the complex nature of pain sensation, the LST also has additional projection sites, namely the **reticular formation, cingulate gyrus, and insular cortex**.
- These structures are responsible for the **affective and emotional components of pain**; for example, chronic pain may lead to depression.

Termination Sites of the Lateral Spinothalamic Tract

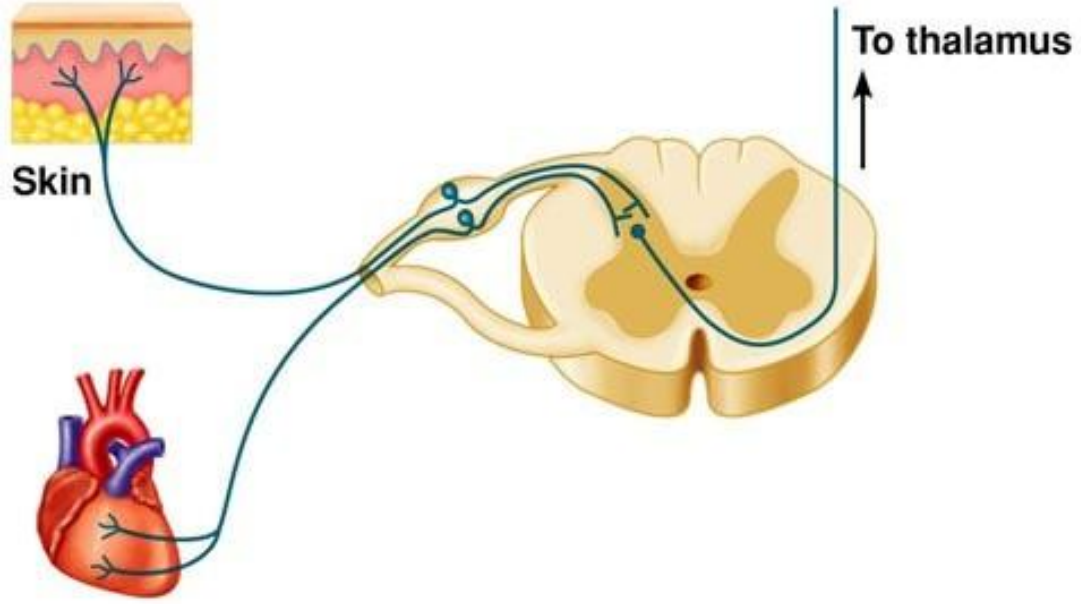
- Additional details of LST termination sites:
- **Reticular formation:** a network of neurons located in the core of the **brainstem** (**medulla oblongata, pons, and midbrain**). It also has a **motor role** via the **reticulospinal tract** and a central role in regulating the **sleep-wake cycle** (**conscious state**). It explains why a sleeping individual does not perceive **weak sensory stimuli**; in such states, the **cortex** is relatively inactive while the **reticular formation** functions as a **gating system**, whereby **low-intensity peripheral sensory input** is disregarded. In contrast, **strong sensory input** (e.g., loud sound) activates the **reticular formation**, which in turn activates the **cortex**, leading to **awakening**. It also contributes to **awareness of pain** and is connected through **collateral branches of the lateral spinothalamic tract** before **thalamic relay**.
- **Cingulate gyrus:** a **medial (deep) gyrus** within the **longitudinal fissure**, not part of the external **cerebral surface lobes**. It is a component of the **limbic system** (**emotional brain**) and participates in **emotional processing** and **recent memory** in relation to **pain**.

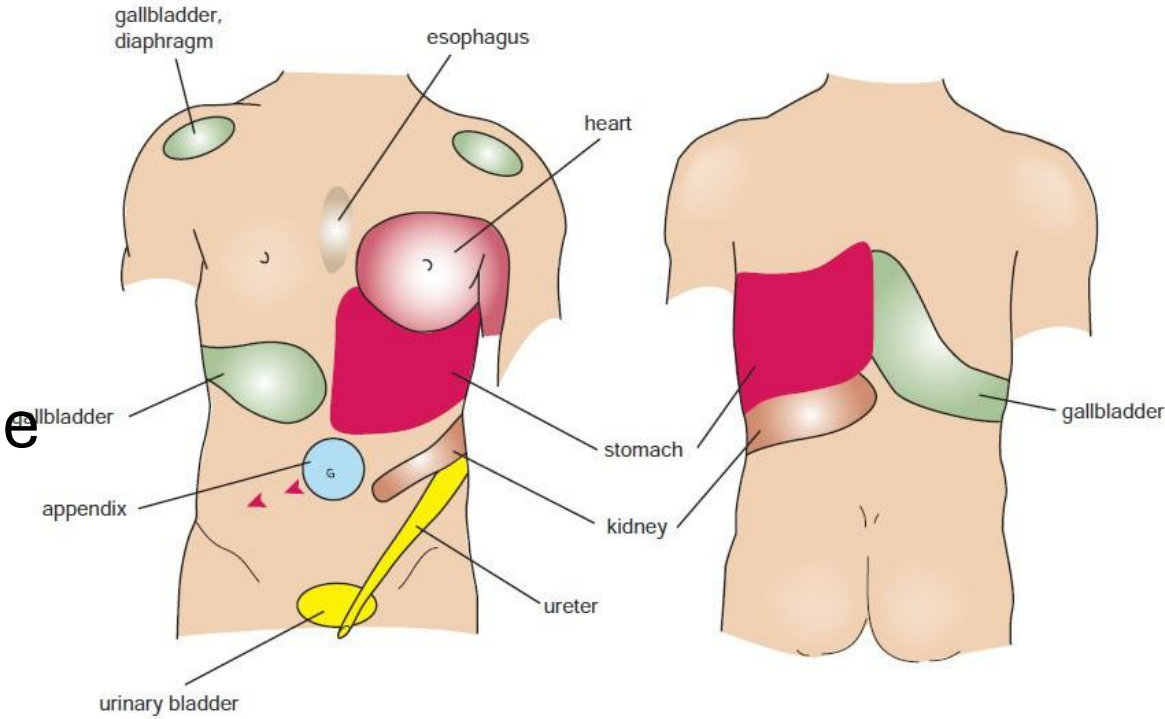
Termination Sites of the Lateral Spinothalamic Tract

- **Insular gyrus:** located deep to the **lateral (Sylvian) fissure** (which separates the **temporal lobe** (inferiorly) from the **frontal and parietal lobes** [superiorly]). It is involved in the interpretation of **visceral pain**, such as **ischemic**, **distension**, and **chemical pain**, which is **predominantly carried by C fibers**, as in **abdominal cramps** or **angina pectoris**. It also contributes to associated **autonomic responses**.

Referred Pain Mechanism: Convergence Theory

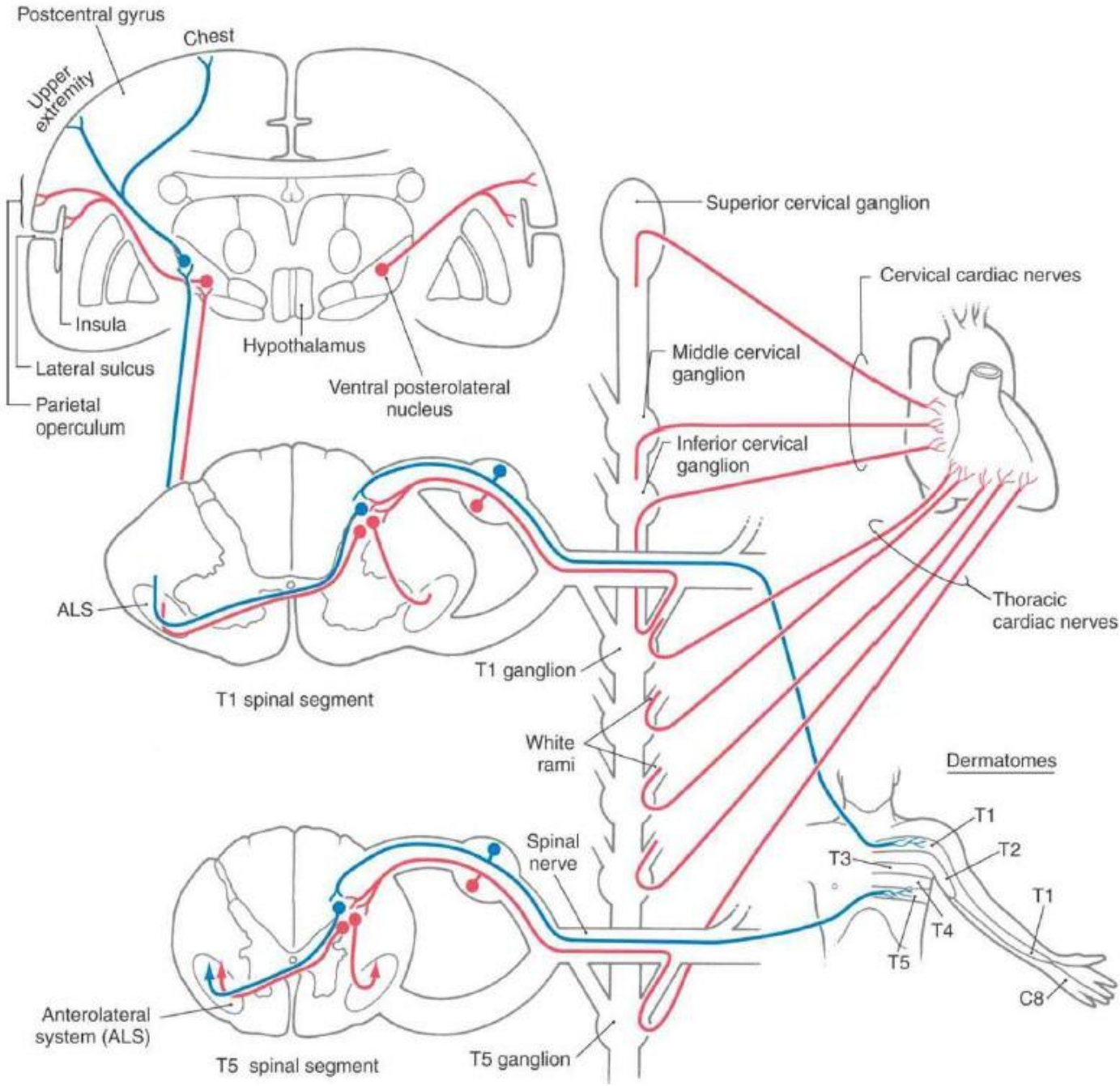
- **Referred pain** is presumed to occur because the information from multiple **nociceptor afferents** converges onto individual **spinothalamic tract neurons**.
- The **brain** therefore interprets the information coming from **visceral receptors** as having arisen from receptors on the **body surface**, since this is where **nociceptive stimuli** originate more frequently.





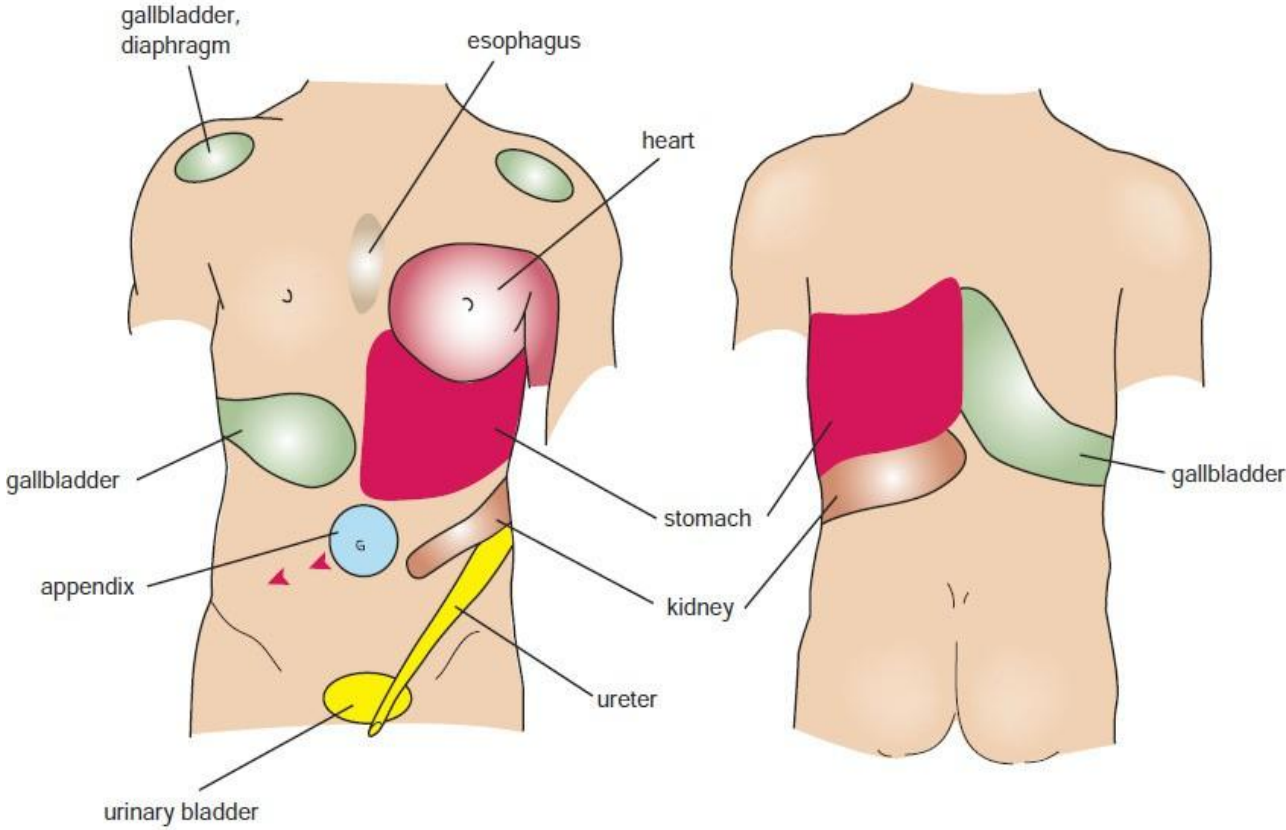
Mechanism of Cardiac Referred Pain

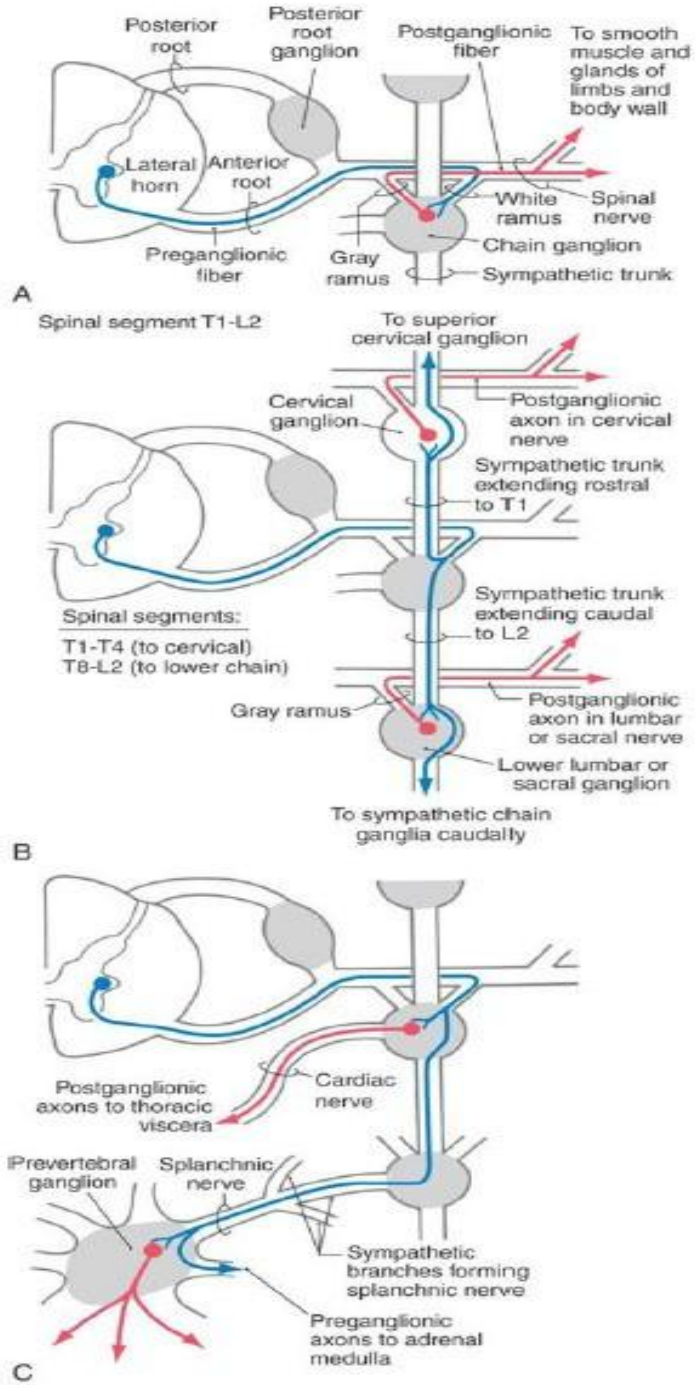
- The **heart** is supplied by **sensory C-fibers** that pass by the **sympathetic chain** without **relaying**, entering the **spinal cord** through the **dorsal root** and synapsing in the **substantia gelatinosa**, where **second-order neurons** ascend, and the pathway continues until it is related to the **insular gyrus**. Meanwhile, a **dermatomal afferent** may be in the same pathway and synapse on the same **second-order neuron**, resulting in **referred pain** in the **shoulder and neck** in some cases, in accordance with the relatively low sensory importance of **viscera** compared with **skin**, unless there is **tissue damage**.



Mechanism of Gallbladder Referred Pain

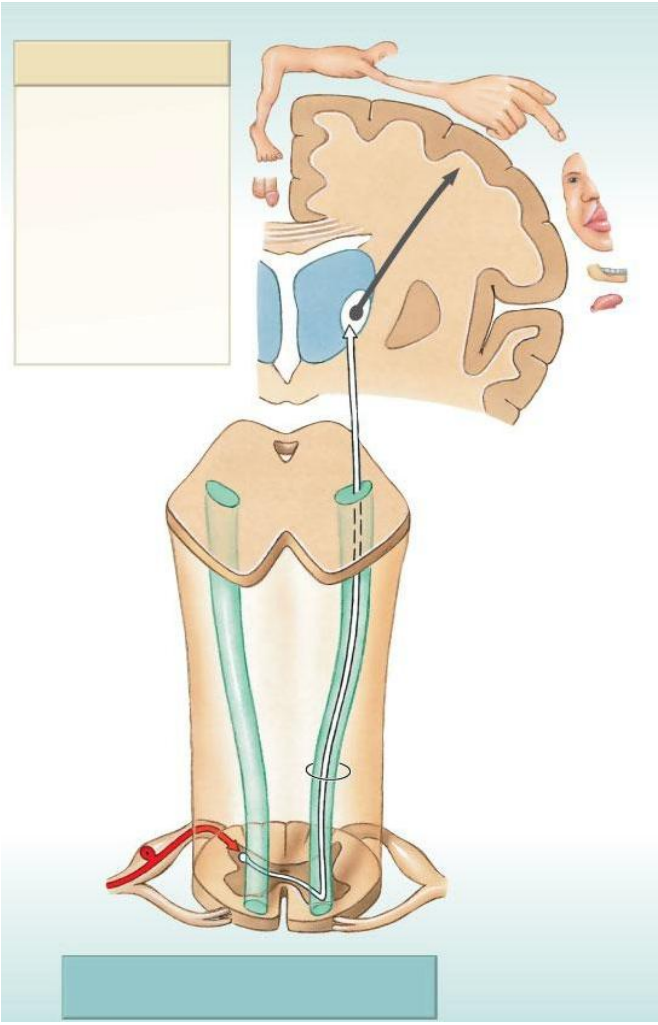
- Another example is **gallbladder referred pain**. The **gallbladder**, as part of the **abdominal viscera**, may irritate the **diaphragmatic peritoneum**, which is supplied by sensory fibers of the **phrenic nerve** (also motor to the **diaphragm** and sensory to the **fibrous pericardium** and **mediastinal pleura**). When inflammation spreads to these **phrenic nerve–supplied regions**, pain impulses are conducted to the **spinal cord segments C3–C5**. **Somatic afferents** from the **supraclavicular nerves** supplying the **shoulder dermatomes** converge on the same **second-order neurons** in these segments, resulting in **referred pain in the shoulder**.




Posterior root
Posterior root ganglion
Postganglionic fiber
To smooth muscle and glands of limbs and body wall
Lateral horn
Anterior root
White ramus
Spinal nerve
Chain ganglion
Preganglionic fiber
Gray ramus
Sympathetic trunk
A
Spinal segment T1-L2
To superior cervical ganglion
Cervical ganglion
Postganglionic axon in cervical nerve
Sympathetic trunk extending rostral to T1
Sympathetic trunk extending caudal to L2
Spinal segments:
T1-T4 (to cervical)
T8-L2 (to lower chain)
Gray ramus
Postganglionic axon in lumbar or sacral nerve
Lower lumbar or sacral ganglion
To sympathetic chain ganglia caudally
B
Postganglionic axons to thoracic viscera
Cardiac nerve
Prevertebral ganglion
Splanchnic nerve
Sympathetic branches forming splanchnic nerve
Preganglionic axons to adrenal medulla
C

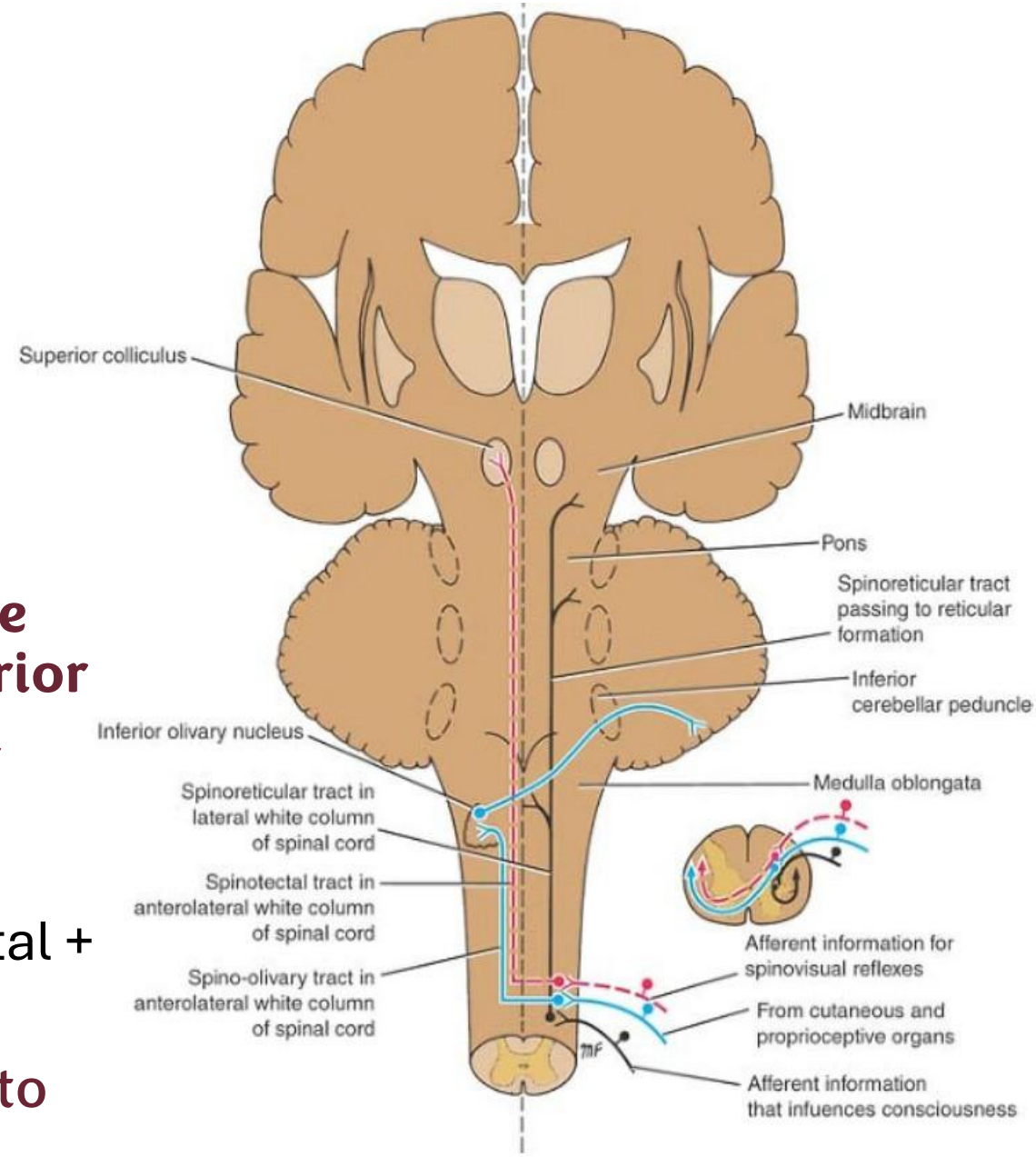
Anterior Spinothalamic Tract

- Modality: crude touch and pressure
- Receptors: free nerve endings
- 1st-order Neuron: Dorsal root ganglia
- 2nd-order Neuron: the posterior gray column (nucleus proprius) (Laminae III & IV)
- The axons of 2nd-order neurons cross obliquely to the **opposite** side in the **anterior gray and white commissures**, ascending in the **contralateral white column** as the Anterior spinothalamic tract
- **Note:** The **AST** and **lateral spinothalamic tract (LST)** ascend together in the **anterolateral system**, partially overlapping.
- 3rd-order Neuron: Thalamus (VPL) Internal Capsule —— Corona Radiata
- Termination: Primary Somesthetic Area (S I)
- The **AST** has more limited and less widespread cortical and subcortical projections than the **LST**, reflecting its role in **crude touch and pressure** rather than pain.



Spinotectal Tract

- Ascend in the anterolateral white column lying close to the lateral spinothalamic tract
- Terminate: superior colliculus
- Provides afferent information for spinovisual reflexes
- The **tectum** is the **dorsal (posterior) part of the midbrain**, consisting of the **superior and inferior colliculi**. The **superior colliculi** are involved in **visual reflex pathways**, whereas the **inferior colliculi** are related to the **auditory pathway**.
- **In Medulla**: ant spinothalamic tract + spinotectal + lateral spinothalamic = spinal leminiscus
- There is also the **medial lemniscus** projecting to the **VPL**, which we studied previously.



Spinovisual Reflex

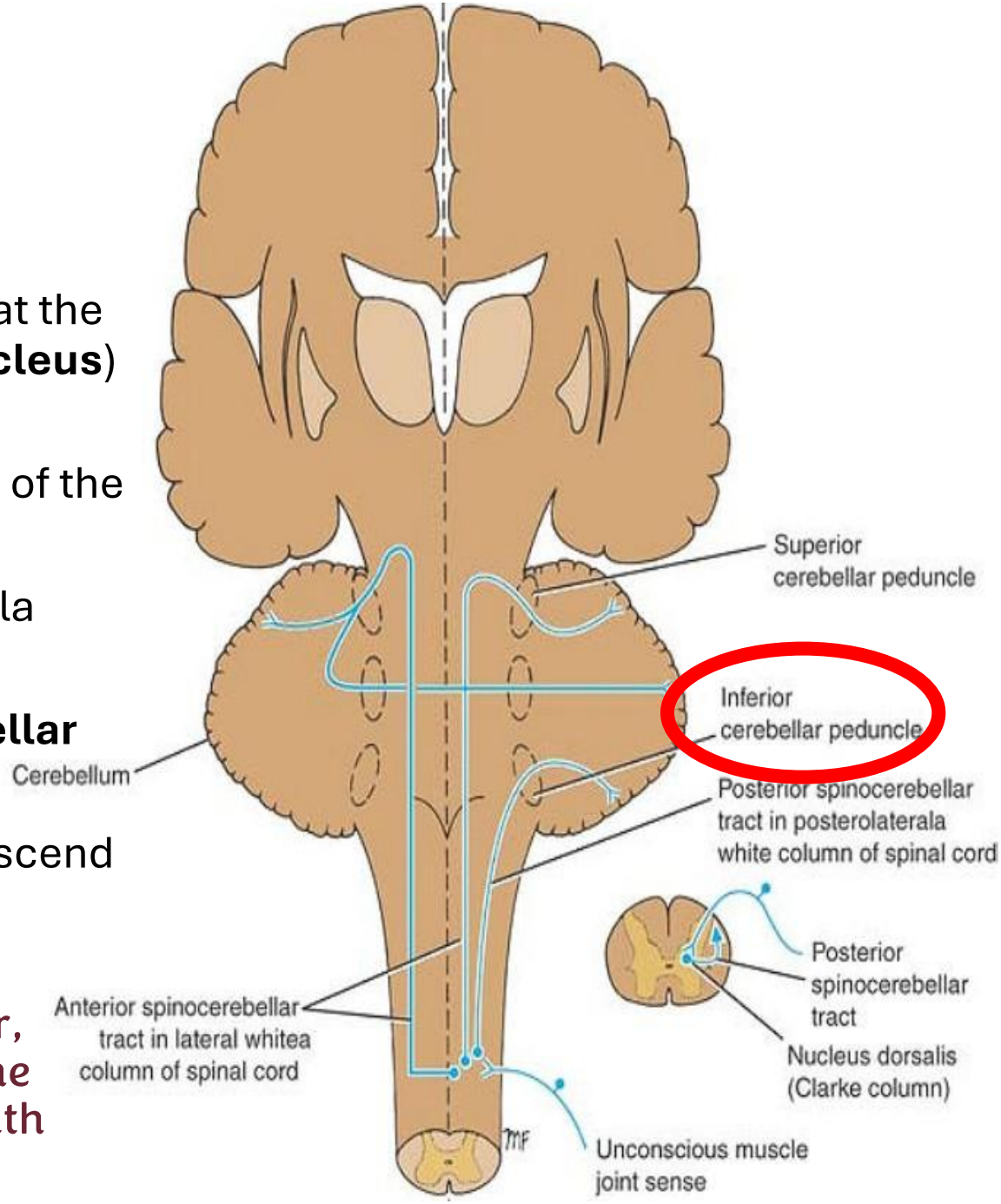
- A **reflex** consists of two **limbs**: an **afferent (sensory) limb** and an **efferent (motor) limb**. An example is the **withdrawal (flexor) reflex**, in which the body responds to a sudden **somatic pain stimulus** by withdrawing the affected part, such as when stepping on a nail.
- This reflex may be accompanied by the **spinotectal (spinovisual) reflex**, which coordinates **head, neck, and eye movements** so that a person instinctively directs the **gaze** toward the affected area after withdrawal.
- In this context, the term **"visual"** refers to changing the **visual field** by **head and eye movement (motor orientation)** rather than visual sensation itself.

Posterior Spinocerebellar

- **Muscle and joint sensation**
- 1st-order neuron axons (in dorsal root ganglia) terminate at the base of post gray column (nucleus dorsalis or **Clarks nucleus**) (part of lamina VII)
- The axons of 2nd-order neurons enter **posterolateral** part of the lateral white matter on the same side (ipsilaterally)
- Ascend as the **posterior spinocerebellar tract** to medulla Oblongata
- Terminates in **cerebellar cortex** (through **inferior cerebellar peduncle**)

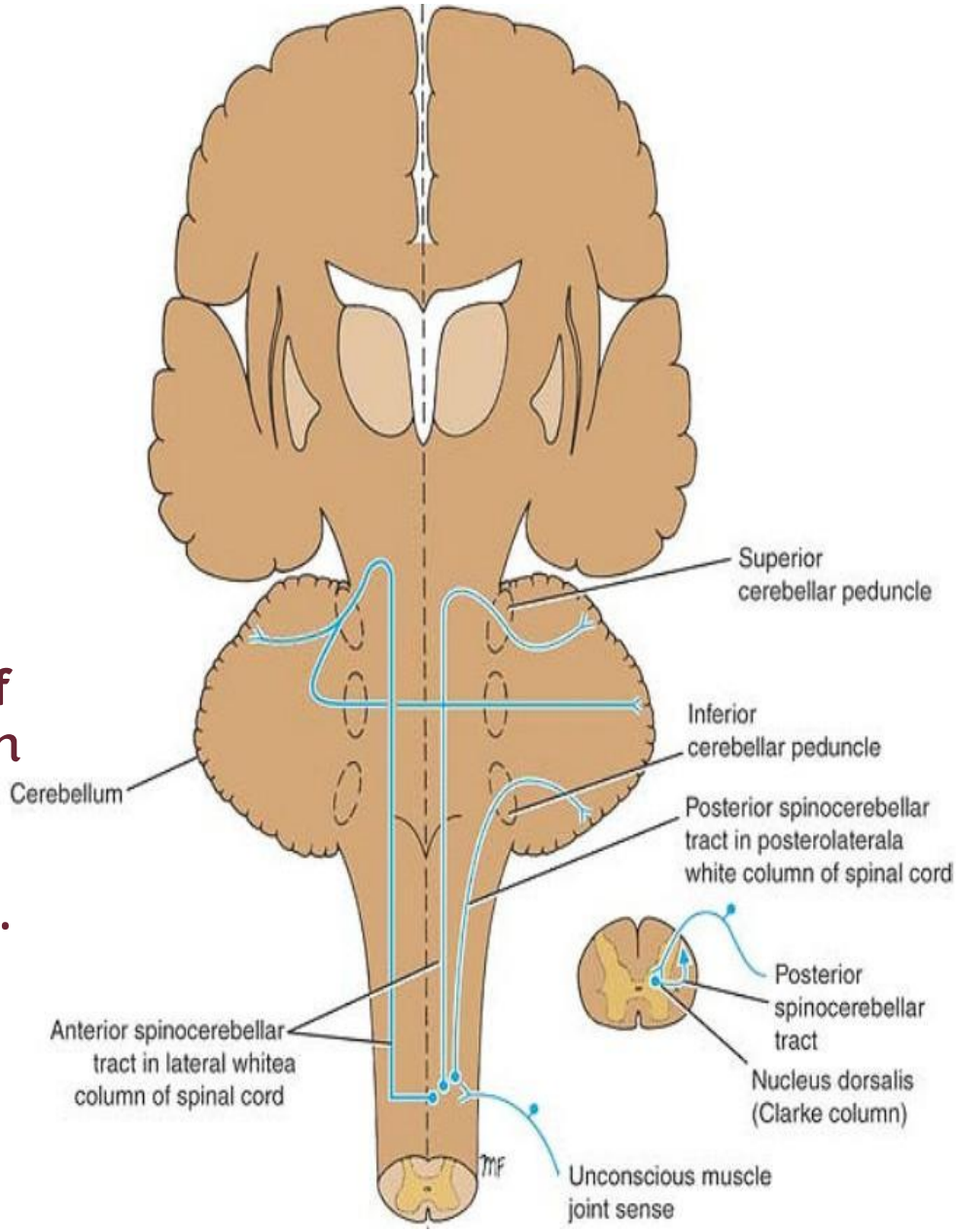
❖**Note**: Axons of **lower lumbar** and **sacral** spinal nerves ascend in the **posterior white column** until they reach **L3 or L4 segments** where they **synapse** with **nucleus dorsalis**

❖Peduncles are bands of **white** matter. There are superior, middle, and inferior cerebellar peduncles, connecting the cerebellum posteriorly to brain stem parts anteriorly, with midbrain, pons, and medulla oblongata respectively.



Posterior Spinocerebellar Tract

- The **posterior spinocerebellar tract** is responsible for **unconscious proprioception**, which constitutes a major component of **proprioceptive sensation** conducted to the **cerebellum**.
- Its **receptors** are of the same types as those of the **posterior column (dorsal column) system**.
- In the **cerebral cortex**, sensory input from one side of the body is represented in the **contralateral hemisphere (rule of decussation)**. However, the **cerebellar cortex** is an exception to this pattern, as the **right cerebellar hemisphere** coordinates the **right side of the body** and the left hemisphere coordinates the left (**ipsilateral representation**).
- Below the level of the **L3–L4 spinal segments**, the cord lacks the **nucleus dorsalis (Clarke's nucleus; lamina VII)**. Therefore, **first-order neurons** from these lower segments ascend until they reach the **L3–L4 level**, where they synapse in the **nucleus dorsalis**.



Rexed Laminae

- **Lamina 1:** relay information related to pain and temperature
- **Lamina 2:** relay information related to pain and temperature **(pain modulation)**
- **Lamina 3 and 4:** nucleus proprius; these laminae have many interneurons

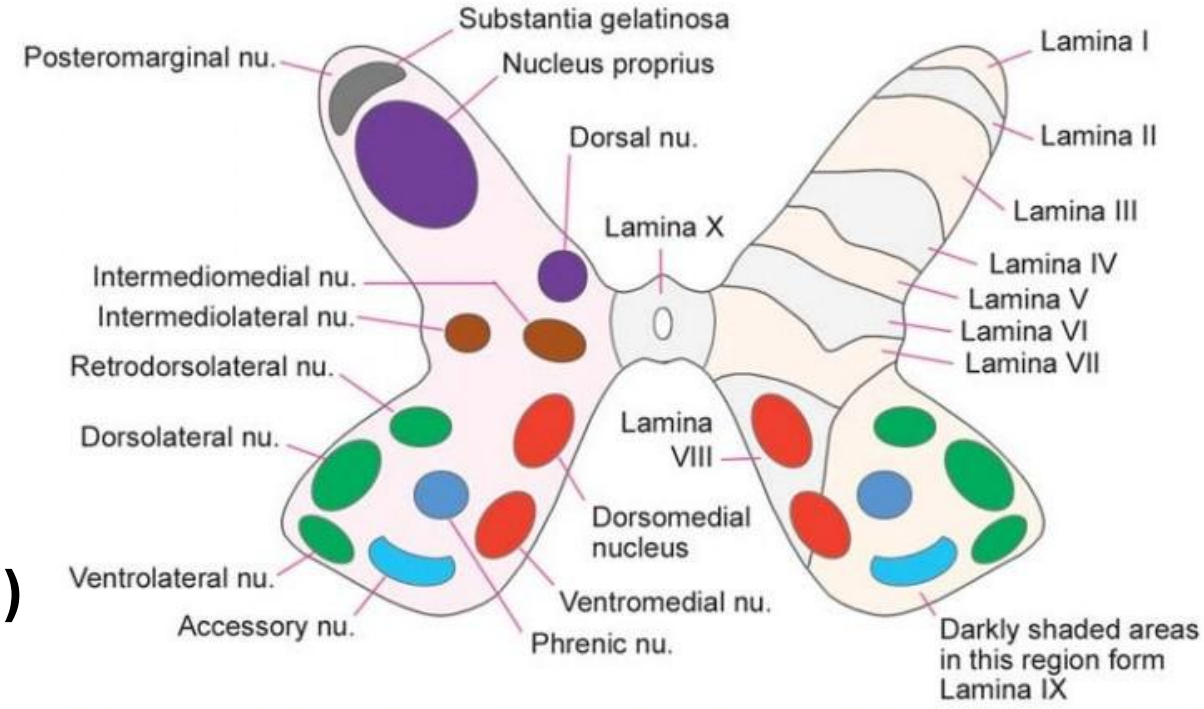
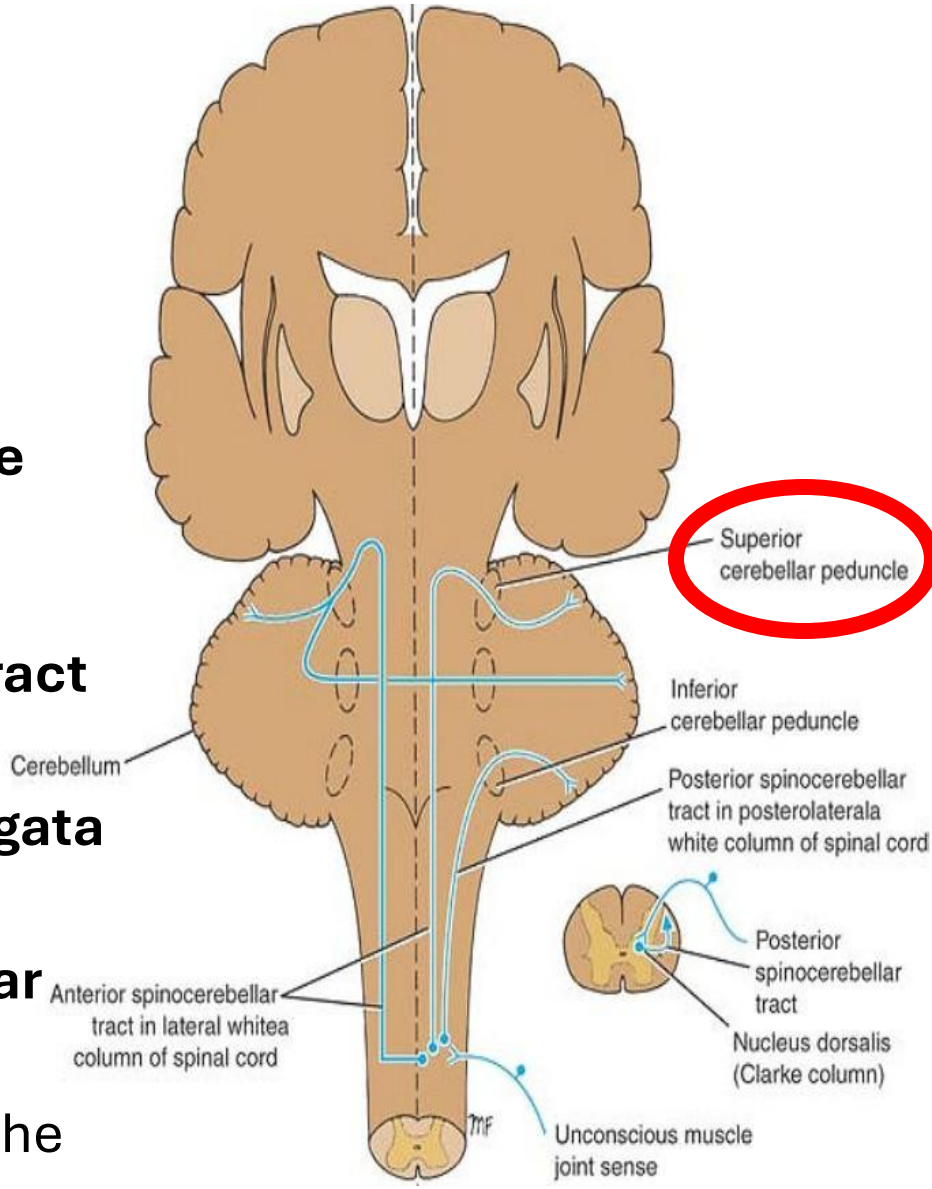


Fig. 5.2. Subdivisions of the grey matter of the spinal cord. The left half of the figure shows the cell groups usually described. The right half shows the newer concept of laminae.

- **Lamina 5:** relay information related to pain and temperature
- **Lamina 6:** presents only at the cervical and lumbar enlargements and receives proprioception
- **Lamina 7: Intermedio-lateral** nucleus, contains preganglionic fibers of sympathetic (T1-L2). **Intermedio-medial nucleus** ,all over the spinal cord, receive visceral pain. **Dorsal nucleus of Clark's** presents at (C8–L2 or T1-L4), relay center for **unconscious proprioception**

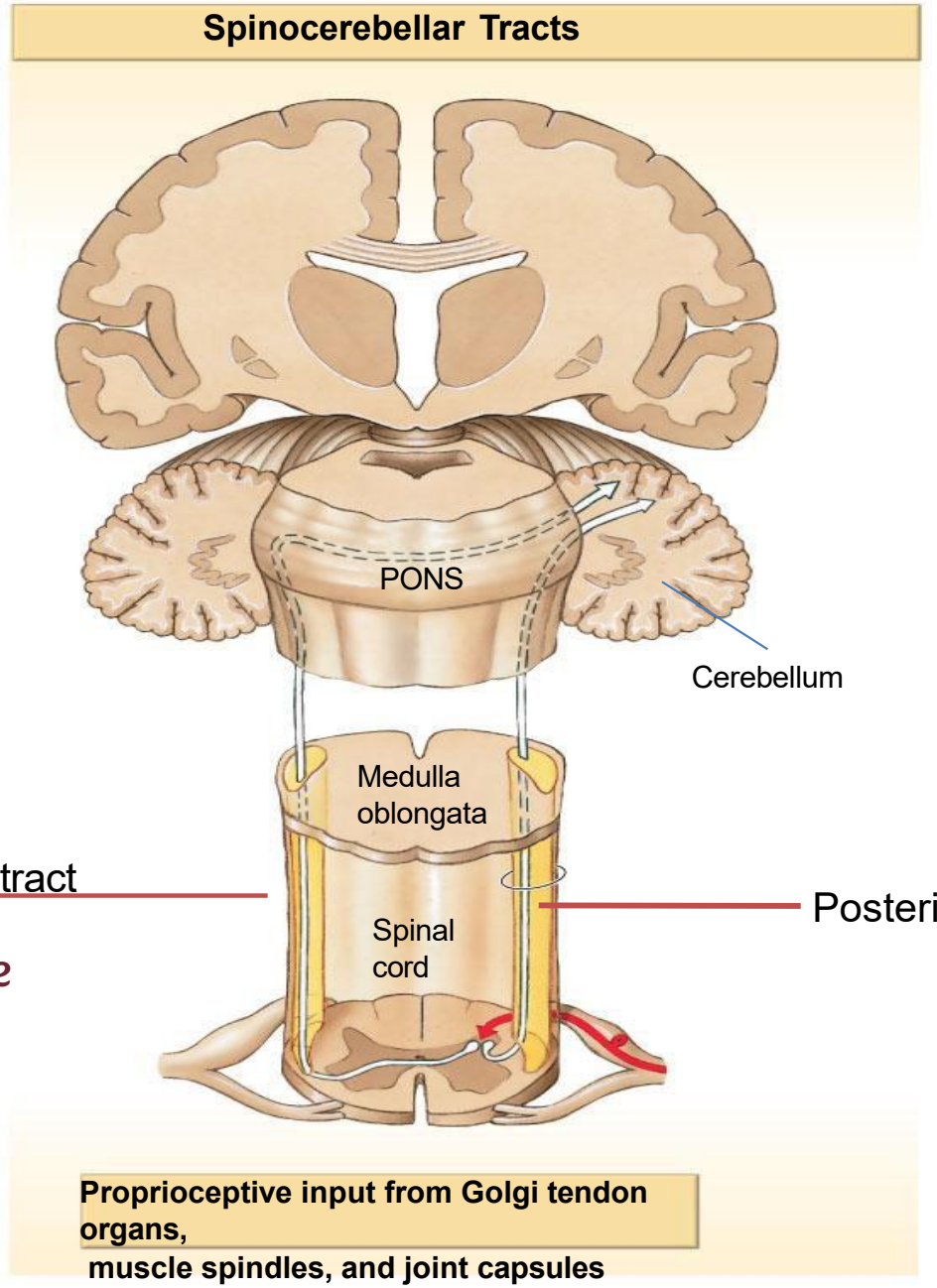
Anterior Spinocerebellar Tract

- **Muscle and joint sensation**
- **1st-order neuron axons** terminate at the base of **post gray column (nucleus dorsalis)**
- The **majority** of axons of **2nd-order neurons** cross to **opposite side** and ascend as **anterior spinocerebellar tract** in the **contralateral white column**
- The **minority** of axons ascend as **anterior spinocerebellar tract** in the **lateral white column** of the **same side**.
- Ascend as **anterior spinocerebellar tract** to **medulla oblongata and pons**
- **Terminates in cerebellar cortex** (through **superior cerebellar peduncle**)
- The fibers that crossed over in spinal cord cross back within the **cerebellum** (The majority)



Double Crossing of the Anterior Spinocerebellar Tract

- The **anterior spinocerebellar tract (AST) second-order neurons** are divided into two divisions. The **majority** of AST fibers **cross contralaterally** in the spinal cord, then ascend and enter the **contralateral cerebellar hemisphere** through the **superior cerebellar peduncle**. Within the **cerebellum**, many of these fibers **cross again**, so that they ultimately terminate in the **cerebellar hemisphere on the same side of the body (ipsilateral termination)**.
- **Commissural fibers** connect the **two cerebellar hemispheres**, emphasizing the function of the **cerebellum as a single functional unit**.



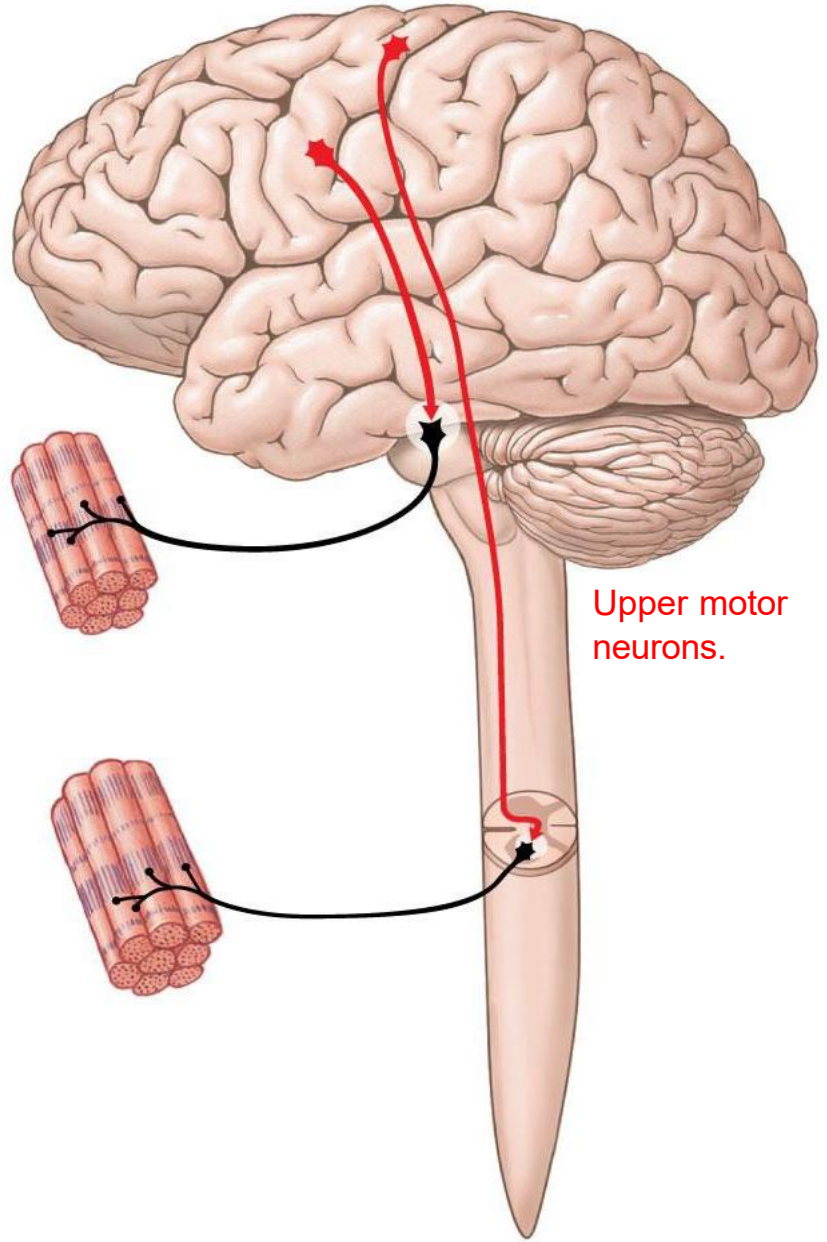
Anterior spinocerebellar tract

Posterior spinocerebellar tract

The figure shows the majority of AST.

Motor Tracts

- There are **two** major descending tracts
- **Pyramidal tracts (Corticospinal): Conscious** control of skeletal muscles
- **Extrapyramidal: Subconscious** regulation of balance, muscle tone, eye, hand, and upper limb position:
  - Vestibulospinal tracts
  - Reticulospinal tracts
  - Rubrospinal tracts
  - Tectospinal tracts



Extrapyramidal tracts arise in the **brainstem**, but are under the influence of the **cerebral cortex**

Motor Tracts

- **Upper motor neuron (UMN)** (in the **cerebral cortex**) → **interneuron** → **lower motor neuron (LMN)** (in **lamina IX**, via **lamina VIII interneurons**, in the **ventral horn**).
- In about **3% of cases (a minority)**: **UMN → LMN directly**.
- Although **skeletal muscle control** is generally **voluntary (conscious)**, the **fine tuning and coordination** occur **subconsciously**.
- **Extrapyramidal tracts** are responsible for **subconscious motor regulation** and originate from **brainstem nuclei**:
  - **Vestibulospinal tracts:** from the **vestibular nuclei** (receiving input from the **vestibular nerve**); function in **balance** important for **motor activity**.
  - **Reticulospinal tracts:** regulate **posture, tone, and automatic motor activity**.
  - **Tectospinal tracts:** not to be mixed with **spinotectal** (the **sensory tract**).
  - **Rubrospinal tracts:** "rubro" means **red**, referring to the **red nucleus** in the **midbrain** at the level of the **superior colliculus**; this nucleus has vital connections with both **cerebrum** and **cerebellum** (**Globose-Emboliform-Rubral pathway**).
- **Extrapyramidal tracts** are under the influence of the **cerebral cortex**, even though arising from **midbrain and brainstem structures**.

Rexed Laminae

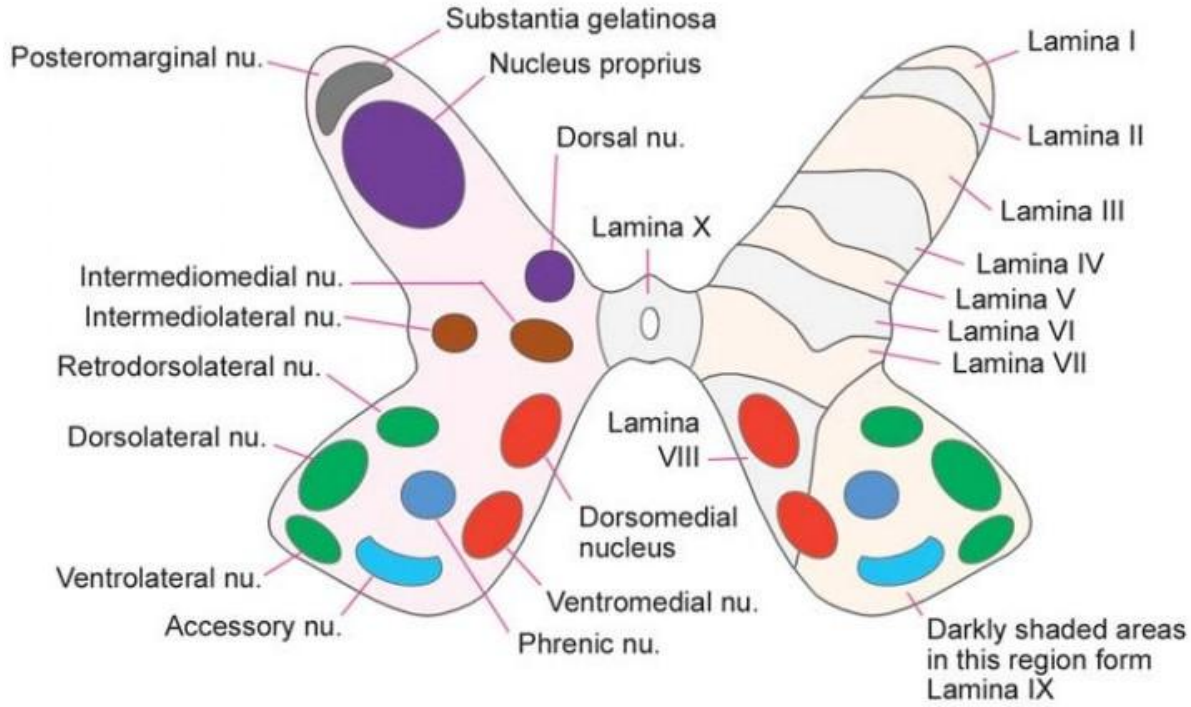
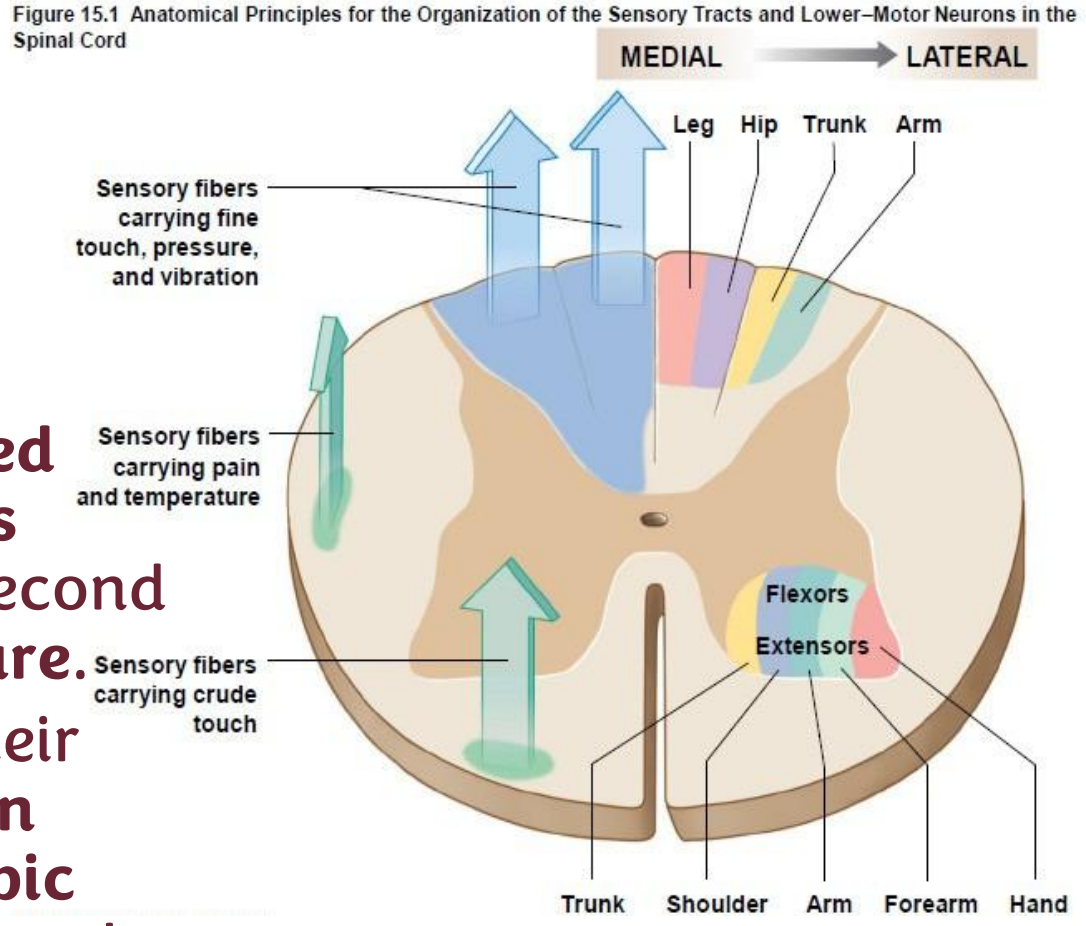


Fig. 5.2. Subdivisions of the grey matter of the spinal cord. The left half of the figure shows the cell groups usually described. The right half shows the newer concept of laminae.

- **Lamina 8:** motor interneurons, Commissural nucleus
- **Lamina 9:** ventral horn, LMN, divided into nuclei:
  - **Ventromedial:** all segements (extensors of vertebral coloumn)
  - **Dorsomedial:** (T1-L2) intercostals and abdominal muscles
  - **Ventrolateral:** C5-C8 (arm) L2-S2 (thigh)
  - **Dorsolateral:** C5-C8 (Forearm), L3-S3 (Leg)
  - **Reterodorsolateral:** C8-T1 (Hand), S1-S2 (foot)
  - **Central:** Phrenic nerve (C3-C5)
- **Lamina X:** Surrounds the central canal – the grey commissure

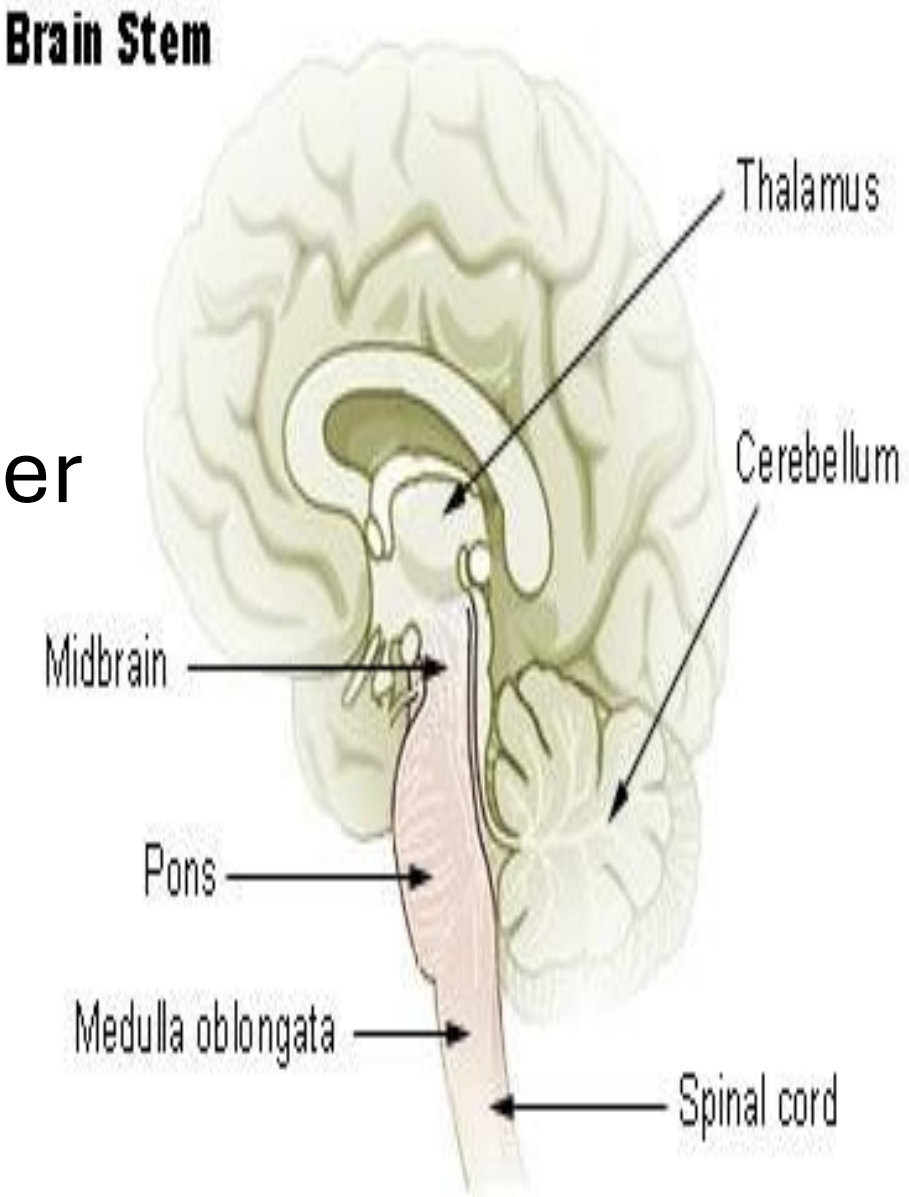
Somatotopic Organization of Anterior Horn Motor Neurons

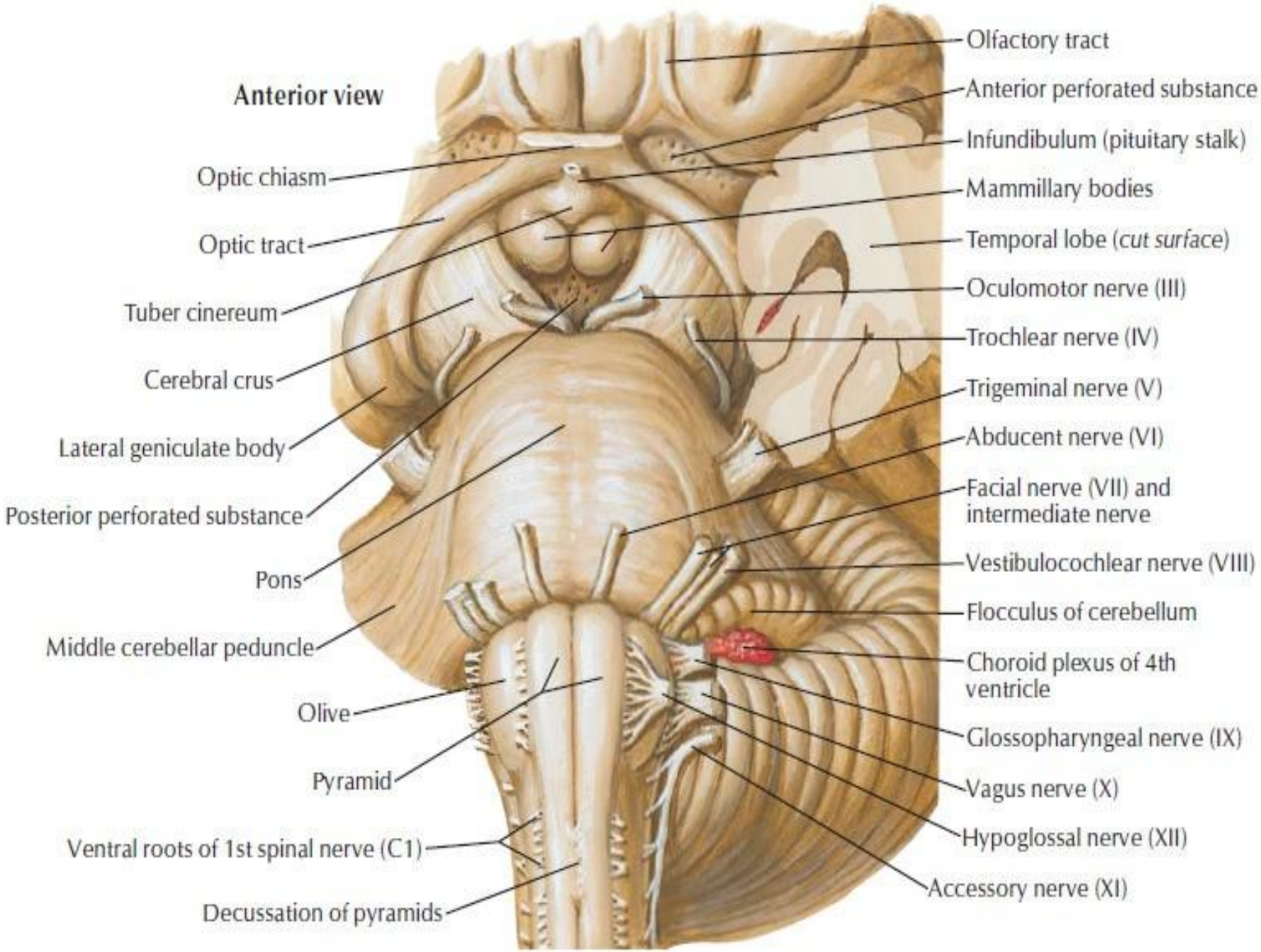
- Motor neurons of anterior horn
  - **Medial group:** (All segments)
  - **Lateral group:** only enlargements
- There are two functional groups of **skeletal muscles** (practically): the first comprises **skilled movement muscles**, such as the **hand muscles** and, to a lesser extent, the **foot muscles**; the second comprises **axial muscles** responsible for **posture.**
- These groups **coordinate** with one another. Their representation in the **spinal cord anterior horn** corresponds to their body location (**somatotopic organization**), with **hand muscle neurons** located most **laterally** and **trunk muscle neurons** located **medially.**



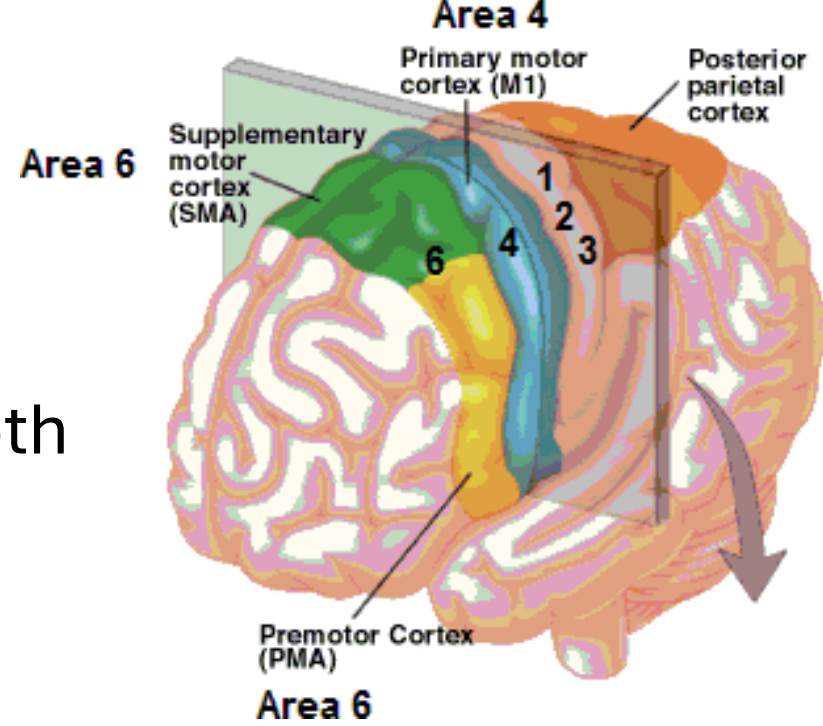
Brain Stem

- **Stalk-like** in shape
- Connects the **spinal cord** to higher centers of forebrain
- Parts:
  1. Medulla oblongata
  2. Pons
  3. Midbrain




Anterior view
Optic chiasm
Optic tract
Tuber cinereum
Cerebral crus
Lateral geniculate body
Posterior perforated substance
Pons
Middle cerebellar peduncle
Olive
Pyramid
Ventral roots of 1st spinal nerve (C1)
Decussation of pyramids
Olfactory tract
Anterior perforated substance
Infundibulum (pituitary stalk)
Mammillary bodies
Temporal lobe (*cut surface*)
Oculomotor nerve (III)
Trochlear nerve (IV)
Trigeminal nerve (V)
Abducent nerve (VI)
Facial nerve (VII) and intermediate nerve
Vestibulocochlear nerve (VIII)
Flocculus of cerebellum
Choroid plexus of 4th ventricle
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Hypoglossal nerve (XII)
Accessory nerve (XI)

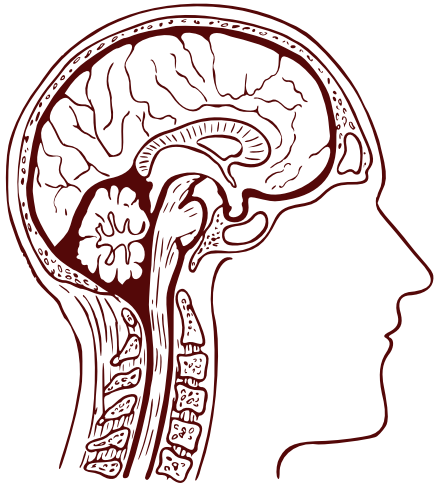
Motor Tracts

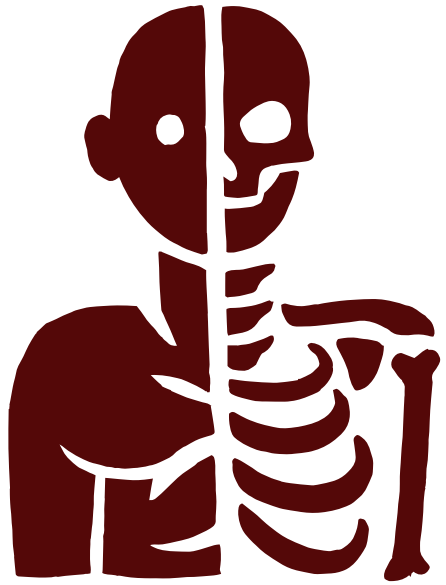


- **Both pyramidal tracts and extrapyramidal** both start from the **cortex**:
  - ➤Area 4 (primary motor cortex)
  - ➤Area 6
  - ➤Area 3,1,2
- **Pyramidal:** mainly from **area 4**
- **Extrapyramidal:** mainly from (under the influence of) **area 6**
- **Area 6:**
  - ➤**Premotor area:** uses **external cues** (**like vision**)
  - ➤**Supplementary motor area:** uses **internal cues** (**like memory**)

Motor Tracts

- The area anterior to the **central sulcus** is the **precentral gyrus**, which contains the **primary motor cortex (area 4)** as well as the **premotor and supplementary motor areas (area 6)**. Posterior to the central sulcus lies the **postcentral gyrus**.
- The **pyramidal (corticospinal) tracts** receive substantial contributions from **areas 6 and 3,1,2**. **Area 3,1,2** (the **primary somatosensory cortex**) provides sensory feedback that helps in the **coordination and fine control of voluntary movement**. For example, when holding a **fragile cup**, sensory input allows appropriate force to be applied so the **shape of the cup is maintained** without crushing it or allowing it to slip.
- A lesion in **area 4** produces **contralateral paralysis** of the body muscles represented in the affected cortical region. In contrast, a lesion in **area 6** leads to impaired **motor planning and coordination**, with difficulty performing skilled movements such as **threading a needle**.



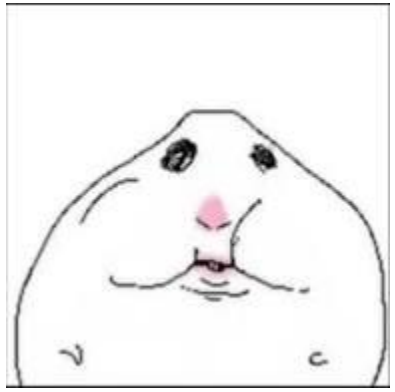


ANATOMY QUIZ LECTURE 4

External Resources

رسالة من الفريق العلمي

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقِه من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.



For any feedback, scan the code or click on

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			