YU - MEDICINE
PASSION ACADEMIC TEAM

Central Nervous System

Sheet# 5 - Physiology

Lec. Title : Somatic Sensation - Sensory Systems (Part 2)

Written By : Maie Hassan

If you come by any mistake , please kindly report it to shaghafbatch@gmail.com

Somatic sensation - Sensory systems (Part 2)

Dr.Ejlal Abu-El-Rub, Pharm.D, PhD
Physiology and Pathophysiology, Department of Basic Medical Sciences, Faculty of Medicine, Yarmouk University

- Why the Decussations are important ??????

Why the Decussations are important ??????

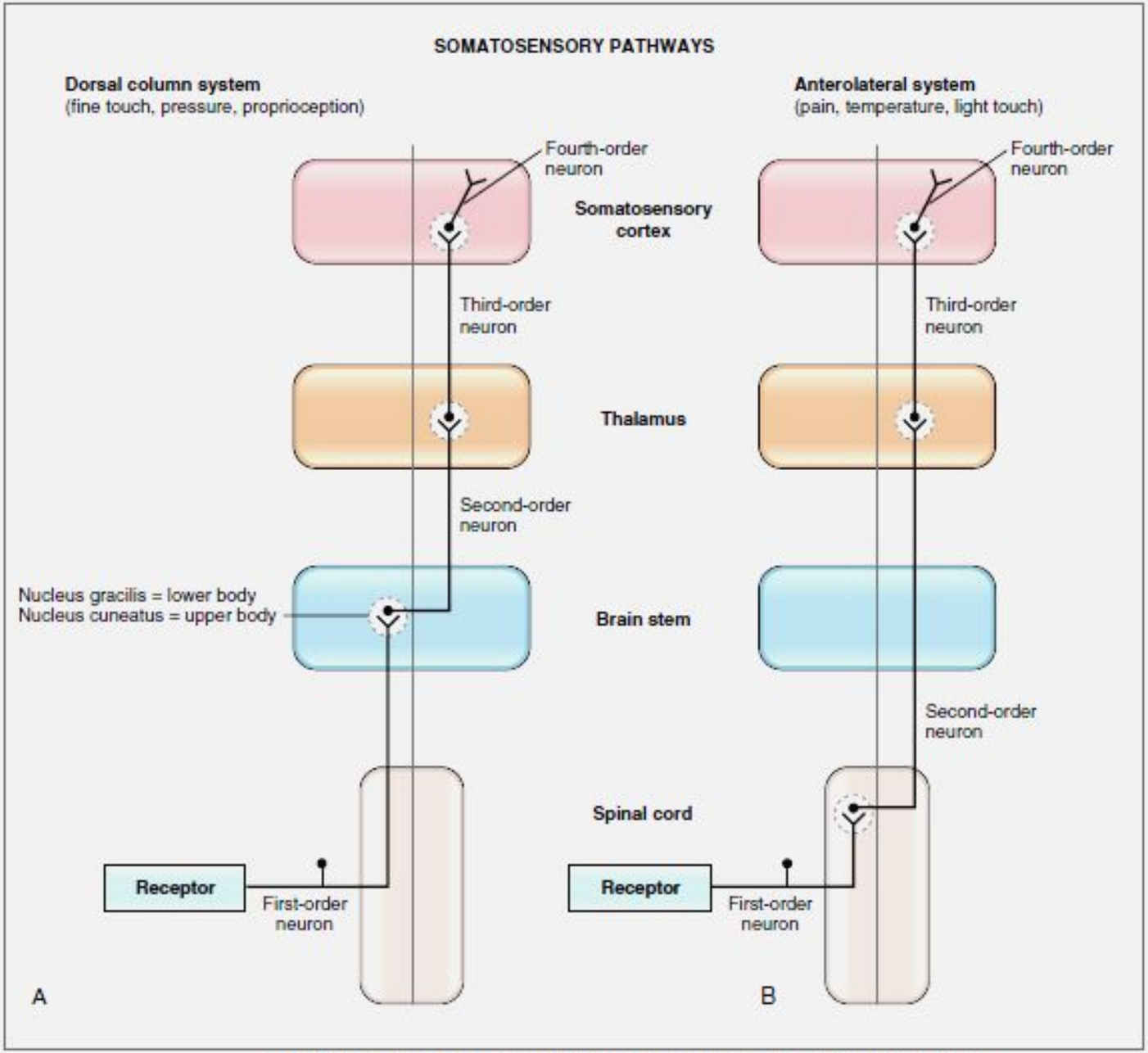
ما الهدف من ال crossing على ال midline الذي ينتج عنه قلب الpathways من ipsilateral الى contralateral مثلا؟

- لحد الآن العلماء لم يتمكنوا من تحديد السبب لكنهم وضعوا العديد من ال hypothesis لتفسير الأمر واحده منهم هي دراسة عملوها جربوا عمل presentations للneurons اي تمثيلهم على شكل wires اسلاك
- ***كل هذة النتائج الي توصلوا إليها هي بناءا على انه شبهوا ال decussation للnervous system للعمليات الي بتحدث بالكومبيوتر***
- وتوصلوا إلى أنه
- 1) نسبة حدوث الerrors عن طريق ال Decussations pathways اقل
- حتى لو كان عدد الneurons من 100 الى 1000 لما اعمل الهم decussations فانا بقلل الrate of erroneous connections by an order of magnitude
- 2) هذه الطريقة توفر الحماية genetics material
- 3)وجدوا انه لما بعمل decussation فانا بعطي خاصية a 3D spatial connections للcns الي يتيح انه ال visualization وال processing للابعاد يكون أعمق من لما ما يكون عندي decussation
- اذا صار عندي injury فانه ال ability to regenerate وال correction بكون أفضل

النظرية:

- Decussated path-ways may be prevalent in vertebrate nervous systems because decussation minimizes pathfinding errors and preserves the genetic information content required, and thereby provides significant evolutionary advantages. Surprisingly, even in small networks of only 100–1,000 neurons, the order of the number of neural connections in decussation can reduce the rate of erroneous connections by over an order of magnitude.
- To provide a 3D spatial connections and pathways.
- Allow for the sprouting at the site of crossing following any injury

Pathways in the somatosensory system



Comparison of the dorsal column (A) and the anterolateral (B) somatosensory systems. The dorsal column system crosses the midline in the brain stem. The anterolateral system crosses the midline in the spinal cord.

Dorsal column system

- Also known as *posterior column-medial lemniscus pathway.*
- Processes sensations of **fine touch, pressure, two-point discrimination, vibration, and proprioception.**
- **proprioception** ال **stimulus** هو ال القادم من الـ **Posture of body parts**
- Consists primarily of **group II fibers. (sensory fibers)**

Dorsal column system

- **Course:**

1. Primary afferent neurons have cell bodies in the dorsal root. Their axons ascend ipsilaterally to the **nucleus gracilis** and **nucleus cuneatus** of the medulla.

ال gracilis تستقبل الNeurons القادمة من الupper part اما الcuneatus من الlower part of the body

2. From the medulla, the second-order neurons cross and decussate the midline and ascend to the contralateral **thalamus**, where they synapse on third-order neurons.
3. Third-order neurons ascend to the **somatosensory cortex (الموجودة cerebral cortex)**, where they synapse on fourth-order neurons.

هذا ال pathway الخاص بال dorsal column sysem المسؤول عن ال,fine touch
pressure deep touch, vibration, proprioception

Special features

- (1) dorsal column neurons have larger receptive fields because multiple primary afferent fibers synapse on a given dorsal column neuron

(one single dorsal neuron receive multiple primary affrent fibers)

- (2) dorsal column neurons sometimes respond to more than one class of sensory receptor because of the convergence of several different types of primary afferent fibers on the second-order neurons,

Anterolateral system

- Also referred to as spinothalamic tract.
- Processes sensations of **temperature, pain, and light touch (low frequency touch) .**
- Consists primarily of **group III and IV fibers(sensory fibers),** which enter the spinal cord and terminate in the dorsal horn.

Anterolateral system

- **Course:**

1. The first-order neurons synapse on second order neurons in the **spinal cord**.
2. Second-order neurons cross the midline to the anterolateral quadrant of the spinal cord and ascend to the contralateral **thalamus**, where they synapse on third order neurons.
3. Third-order neurons ascend to the **somatosensory cortex**, where they synapse on fourth-order neurons.

Thalamus

- Information from different parts of the body is arranged somatotopically.
- الthulums لها خصوصية انها بتستقبل ال sensory Input وبتعمل الهم filtration وبتعمل **Topographic maps**
- **Destruction of the thalamic nuclei** results in loss of sensation on the contralateral side of the body.
- الthalamic nuclei مهم في توزيع الsensory inputs لtheir specific area in the cerebral cortex

Somatosensory cortex –

The sensory homunculus

- the little man of cortex
- The major somatosensory areas of the cerebral cortex are **SI and SII.**

- **SI** has a somatotopic representation similar to that in the thalamus.

في reflectionالها Thulumsبال الموجودة Topographic mapال نفس

output to translate The sensory input ال لذلك S1 ال منطقة

like this is better

Pain

Pain is a Protective Mechanism

- **Pain**

a. Pain is associated with the detection and perception of noxious stimuli **(nociception).**

mediated by the Nociceptors

b. Most ailments of the body cause pain.

c. Pain occurs when tissues are being damaged, and it causes the individual to react to remove the stimulus. ex(stimulation to inflammation, necrosis or apoptosis pathway)

Types of Pain and Their Qualities

1. **Fast Pain**

- Also called sharp pain, pricking pain, acute pain, and electric pain.

- Felt within 0.1 sec after the stimulus is applied

(slow pain within one second in average)

- Not felt in most deeper tissues of the body سطحي أكثر

Types of Pain and Their Qualities

2. Slow Pain

- Also called slow burning pain, aching pain, throbbing pain, nauseous pain, and chronic pain

- Felt only after one second or more and then increases slowly over many seconds or even minutes
- Usually associated with tissue destruction
- Can lead to prolonged, almost unbearable suffering.

(adaptation of slower receptors to pain is slower tonic adaption) يعني رح تحس بالالم لفترة أطول مقارنة مع الألم السريع

اذا ما زال ال underlying cause موجود مثل ال necrosis, رح يضل ال tissue destruction بنفس slow pain respond
درجة ال pain لهذا ال stimulus == السبب انه ال رح adaptation
يكون كثير بطيئ بعض المصادر بتحكي no adaptation at all

Types of Pain and Their Qualities

Pain Receptors and Their Stimulation

- Pain receptors are free nerve endings.
- Two major classes:

1. Thermal or mechanical supplied by finelt myelinated A-δ afferent nerve fibers and respond to mechanical stimuli (sharp, pricking pain).
2. Polymodal supplied by unmyelinated C fibers and respond to high-intensity mechanical or chemical stimuli, and hot and cold stimuli. (it can detect and turn any stimulus to two type of sensation ex one stimulus == sense of heat and pain (two sensation)

Types of Pain and Their Qualities

Pain Receptors and Their Stimulation

- Widespread in the superficial layers of the skin, muscles and certain internal tissues (periosteum, arterial walls, joint surfaces, falx and tentorium in the cranial vault).

Pain Receptors and Their Stimulation

- Fast pain is elicited by mechanical and thermal
- Slow pain by all three types
- Damaged skin releases chemicals, such as: bradykinin(most imp), serotonin, K ions, histamine, acids, ACh, proteolytic enzymes **inflammatory response.**
- **Prostaglandins** and **substance P** enhance the sensitivity of pain endings but do not directly excite them **hyperalgesia**. (more sensitive. lower than usual stimuli cause pain)

Non-Adapting Nature of Pain Receptors

- Pain receptors adapt very little, and sometimes not at all.

- Under some conditions, excitation of pain fibers becomes progressively greater as the pain stimulus continues(especially for slow-aching-nauseous pain).

- Increase in sensitivity of the pain receptors is called **hyperalgesia**. *mediated by prostaglandin and substance p*

Rate of Tissue Damage as a Stimulus for Pain

- Pain is usually felt when the skin is heated above 45°C = the same temperature at which tissues begin to be damaged by heat.

- Intensity of pain is also closely correlated with *the rate of tissue damage* from causes other than heat (bacterial infection, tissue ischemia, tissue contusion, etc.)

Importance of Chemical Pain Stimuli During Tissue Damage

a. **Bradykinin** is thought to be the agent most responsible for causing pain following tissue damage.

b. Intensity of pain felt correlates with local increase in K^+ concentration *or* increase in proteolytic enzymes (which attack nerve endings and make membranes more permeable to ions excite pain).

Tissue Ischemia as a Cause of Pain

- When blood flow is blocked, the tissue often becomes very painful and the greater the rate of metabolism, the more rapidly the pain occurs. قل الاكسجين الجسم بعمل shift على ال anaerobic path.
- May be due to the large accumulation of lactic acid (consequence of anaerobic metabolism), as well as bradykinin and proteolytic enzymes (formed in the tissues because of cell damage).

Muscle Spasm as a Cause of Pain

- Results from:
  - the direct effects of muscle spasm in stimulating mechanosensitive pain receptors
  - the indirect effects of muscle spasm to compress blood vessels and cause ischemia

- Spasm increases the rate of metabolism in the muscle tissue, making the relative ischemia even greater release of chemical pain-inducing substances.

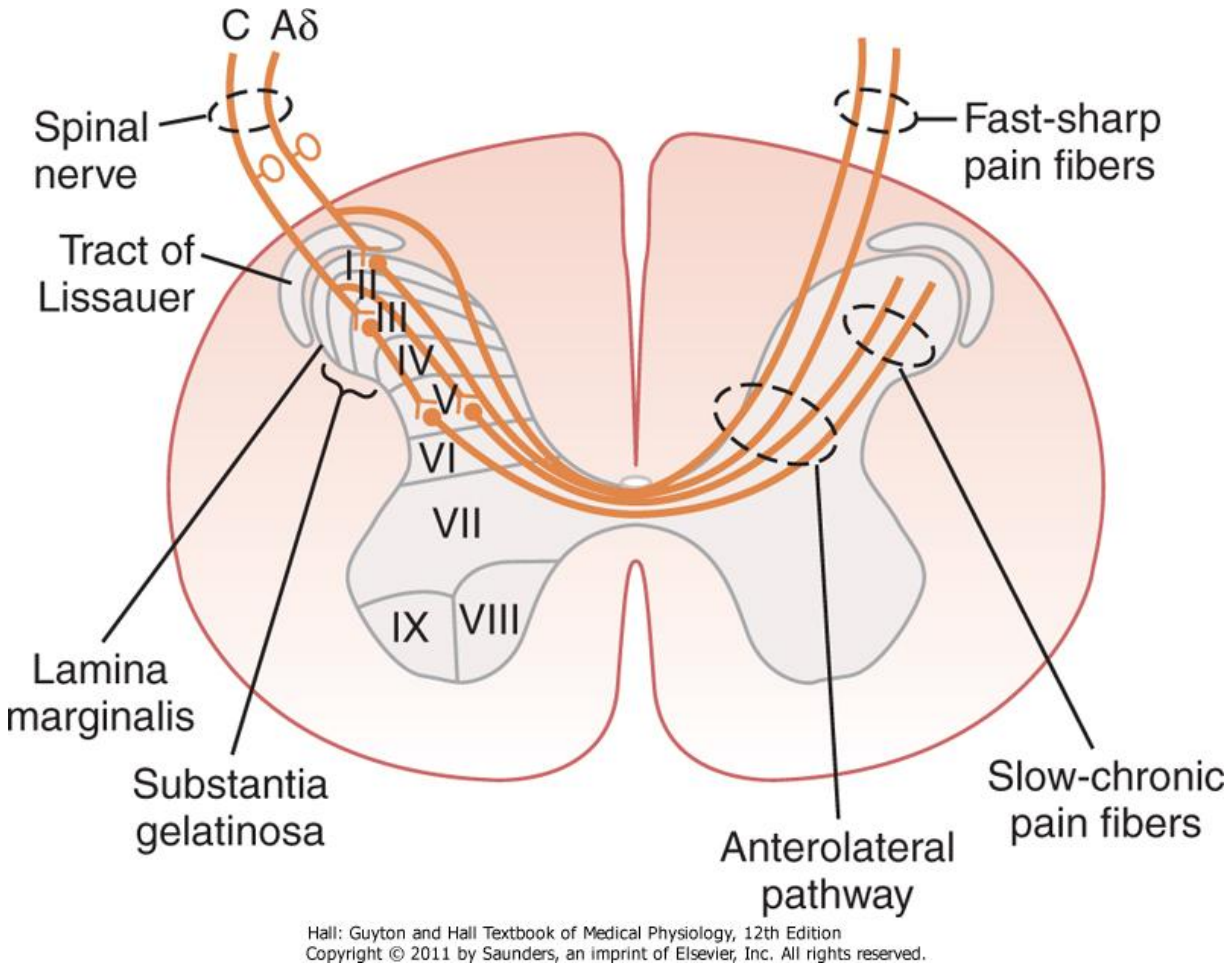
Dual Pathways for Transmission of Pain Signals

- Pain receptors use two separate pathways for transmitting pain signals into the CNS.

- They correspond to the two types of pain:
  1. Fast – sharp pain pathway
  2. Slow – chronic pain pathway

  THEY ARE BOTH PART OF ANTEROLATERAL PATHWAY

Peripheral Pain Fibers- Fast and Slow Fibers



Transmission of both "fast-sharp" and "slow-chronic" pain signals into and through the spinal cord on their way to the brain.

Peripheral Pain Fibers- Fast and Slow Fibers

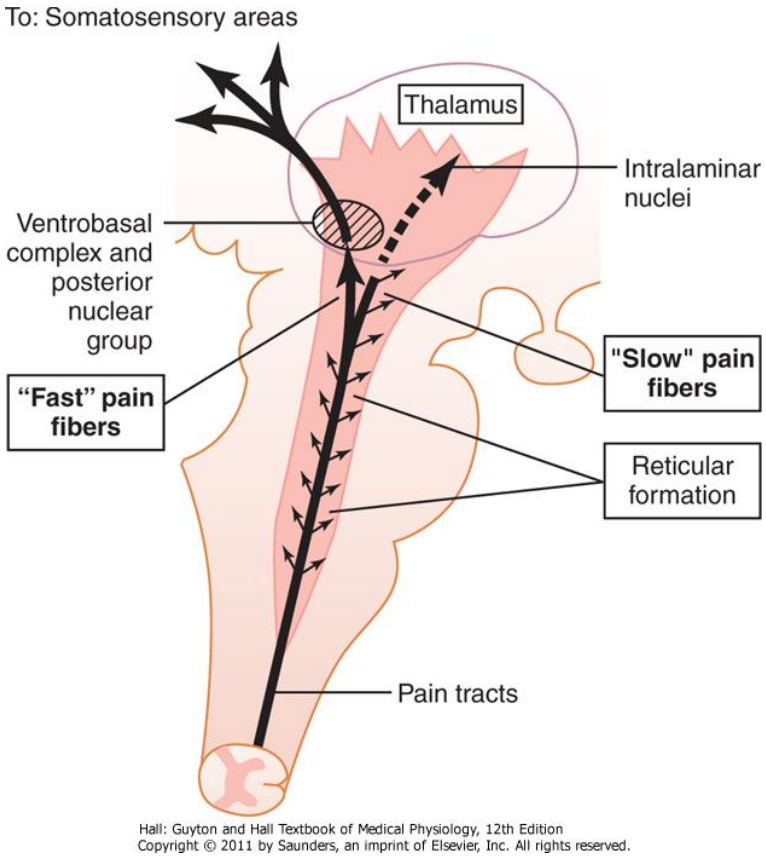
Slow-chronic pain	Fast-sharp pain	
Chemical or prolonged mechanical and thermal	Mechanical or thermal	Types of stimulus
C fibers (large)	Aδ fibers (small)	Type of fiber
0.5-2 m/sec	6-30 m/sec	Velocity

- A sudden painful stimulus often gives a "double" pain sensation: a fast-sharp pain makes the person react immediately; then a slow pain that increases with time intolerable the person tries to relieve the cause of pain. (ex sudden stimulus will make you feel a sharp pain put then after time pain will continue without relieve become chronic pain)
- Pain fibers enter the spinal cord from the dorsal spinal roots pain terminate on relay neurons in the dorsal horns.

Dual pain pathways in the cord and brain stem

- On entering the spinal cord the pain signals take two pathways to the brain:

1. Neospinothalamic tract
2. Paleospinothalamic tract



Transmission of pain signals into the brain stem, thalamus, and cerebral cortex by way of the fast pricking pain pathway and the slow burning pain pathway

1. **Neospinothalamic Tract** (for fast pain)

- Type Aδ pain fibers Terminate mainly in lamina I of the dorsal horn excite second-order neurons long fibers cross immediately to the opposite side of the cord anterolateral columns brain.
- A few fibers terminate in the *reticular areas of the brain stem.*
- Most fibers pass all the way to the *thalamus*, terminating in *the ventrobasal complex* along with the dorsal column-medial lemniscus tract (touch).
- A few fibers also terminate in the *posterior nuclear group of the thalamus.*

1. **Neospinothalamic Tract** (for fast pain)

- Fast-sharp pain is localized much more exactly than slow pain.
- Localization is more exact when tactile receptors are stimulated simultaneously. (the site of pain تحديده ادق)

- ***Glutamate*** is the primary neurotransmitter secreted in the spinal cord at Aδ fiber endings.

2. **Paleospinothalamic Pathway** (for slow-chronic pain)

- Transmission of slow-chronic pain (*C pain fibers + some signals from type Aδ fibers*).
- Fibers terminate in laminae II and III of the dorsal horns (*substantia gelatinosa).* Most of the signals then pass through one or more additional short fibers within the dorsal horns themselves before entering lamina V.
- These last neurons give rise to long axons that mostly join the fibers from the fast pain pathway pass through the anterior commissure to the opposite side of the cord, then upward to the brain in the anterolateral pathway.

2. **Paleospinothalamic Pathway** (for slow-chronic pain)

- Type C pain fiber terminals entering the spinal cord release both *glutamate* transmitter (rapid and short) and *substance P* transmitter (builds up over seconds and minutes).

- Substance P is the main neurotransmitter for slow-chronic pain.

- *Inhibition of the release of substance P is the basis of pain relief by* ***opioids. ex morphine***

- كثير بحتاج اعلي الdoes لل opioids مشان مفعولهم بقل مع الوقت والسبب هو ان الslow pain ال adaptation عنده قليل

2. **Paleospinothalamic Pathway** (for slow-chronic pain)

- Localization of pain transmitted by the paleospino-thalamic pathway is imprecise

- Projects widely into the *brain stem*.
- 1/10 - ¼ fibers pass all the way to the *thalamus*; most terminate in the:
  - reticular nuclei of the medulla, pons and mesencephalon
  - tectal area of the mesencephalon
  - periaqueductal gray (PAG)
- Then short fibers intralaminar and ventrolateral nuclei of the thalamus, hypothalamus and others.

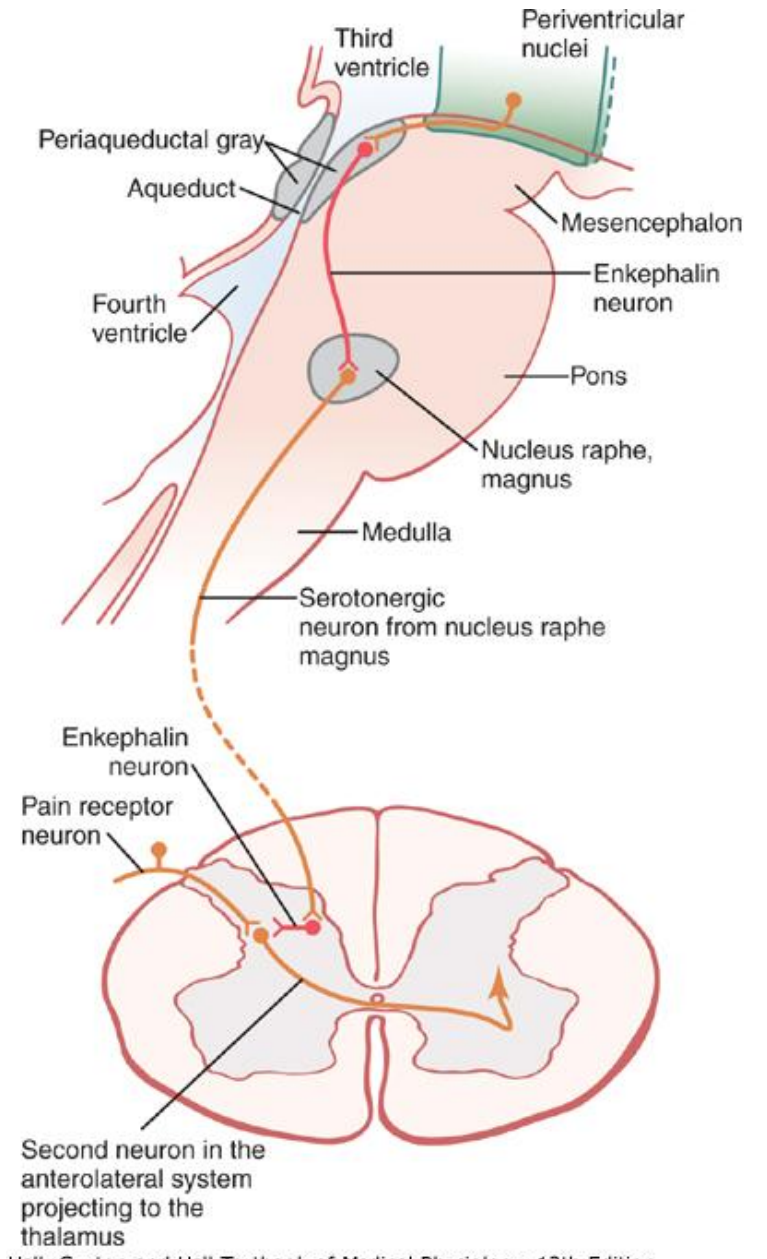
Pain Suppression ("Analgesia") System in the Brain and Spinal Cord

- **Analgesia** system has three components

1. Periaqueductal gray (PAG) and periventricular areas of mesencephalon and pons

2. Raphe magnus nucleus in the pons and the nucleus reticularis in the medulla

3. Pain inhibitory complex in the dorsal horns of the spinal cord



Analgesia system of the brain and spinal cord

Transmitter substances involved in the analgesia system

1. Enkephalin

- Many nerve fibers derived from the periventricular nuclei and from the periaqueductal gray area secrete enkephalin at their endings (in the raphe magnus nucleus) when stimulated.

  - Enkephalin is believed to cause both *presynaptic and postsynaptic inhibition of incoming* type C and type Aδ pain fibers where they synapse in the dorsal horns.

Transmitter substances involved in the analgesia system

2. Serotonin

- Fibers originating in raphe magnus nucleus send signals to the dorsal horns to secrete serotonin.
- Serotonin causes the release of enkephalin from local cord neurons.

Brain's Opiate System – Endorphins and Enkephalins

- About a dozen opiate-like substances have been found at different points of the nervous system.

- All are breakdown products of three large protein molecules:
  - *pro-opiomelanocortin,*
  - *proenkephalin,*
  - *prodynorphin.*

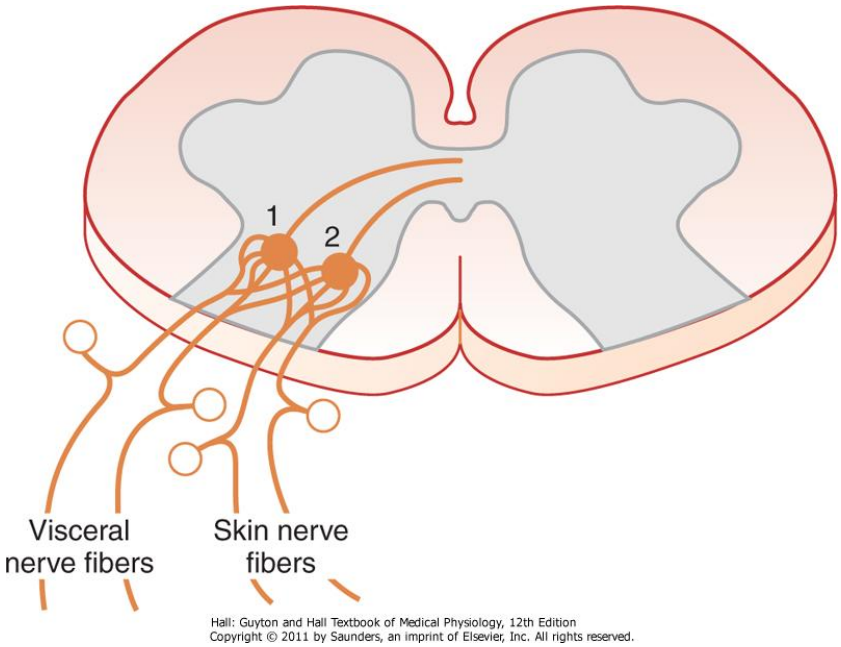
Brain's Opiate System – Endorphins and Enkephalins

- Among the most important of these opiate-like substances are
  - *β-endorphin* *met-enkephalin,*
  - *leu-enkephalin* *dynorphin.*

- Enkephalins found in the brain stem and spinal cord.
- β-endorphin in hypothalamus and pituitary gland
- Dynorphin in the same areas as enkephalins, but in much lower quantities.

Referred Pain

- Mechanism



Mechanism of referred pain and referred hyperalgesia

- Branches of visceral pain fibers synapse in the spinal cord on the same second-order neurons that receive pain signals from the skin.

- When the visceral pain fibers are stimulated, pain signals from the viscera are conducted through at least some of the same neurons that conduct pain signals from the skin Feeling that the sensations originate in the skin itself.

(convergence–projection theory)

مثلا لو الواحد معو سكته قلبيه رح يحس بالم بكتفه الايسر بغير مكانه وسطحي

Visceral pain

- Visceral pain differs from surface pain in several important aspects.
  - highly localized types of damage to the viscera seldom cause severe pain (ex: cut in surgery)
  - any stimulus that causes *diffuse stimulation of pain nerve endings throughout* a viscus causes pain that can be severe (ex.: ischemia)

Causes of true visceral pain

- All visceral pain that originates in the thoracic and abdominal cavities is transmitted through small type C pain fibers and, therefore, can transmit only the chronic-aching suffering type of pain.

1. Ischemia

2. Chemical stimuli: proteolytic acidic gastric juice may leak through a ruptured gastric or duodenal ulcer widespread to the visceral peritoneum stimulating broad areas of pain fibers excruciating and severe pain.

Causes of true visceral pain

3. Spasm of a hollow viscus

   causes pain, possibly by mechanical stimulation of the pain nerve endings or by dimishing blood flow to the muscle.

   Often occurs in the form of intermittent cramps.

4. Overdistension of a hollow viscus

   because of overstretch of the tissues themselves and collapse of the blood vessels.