Physiology for medical students

Pain

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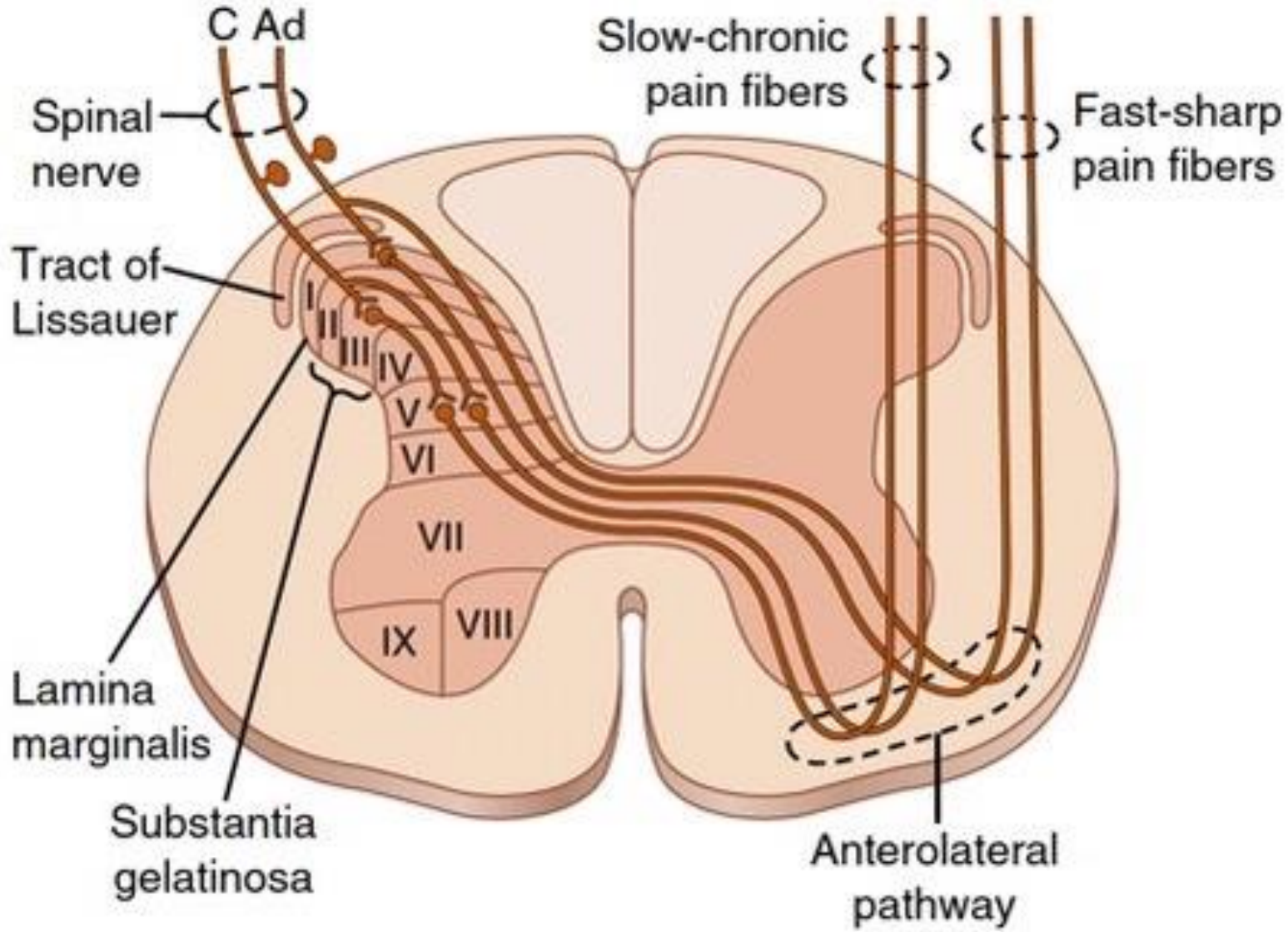
Pain

- According to the International Association for the Study of Pain, pain is defined as:

- “unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage.”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Spinal nerve
Tract of Lissauer
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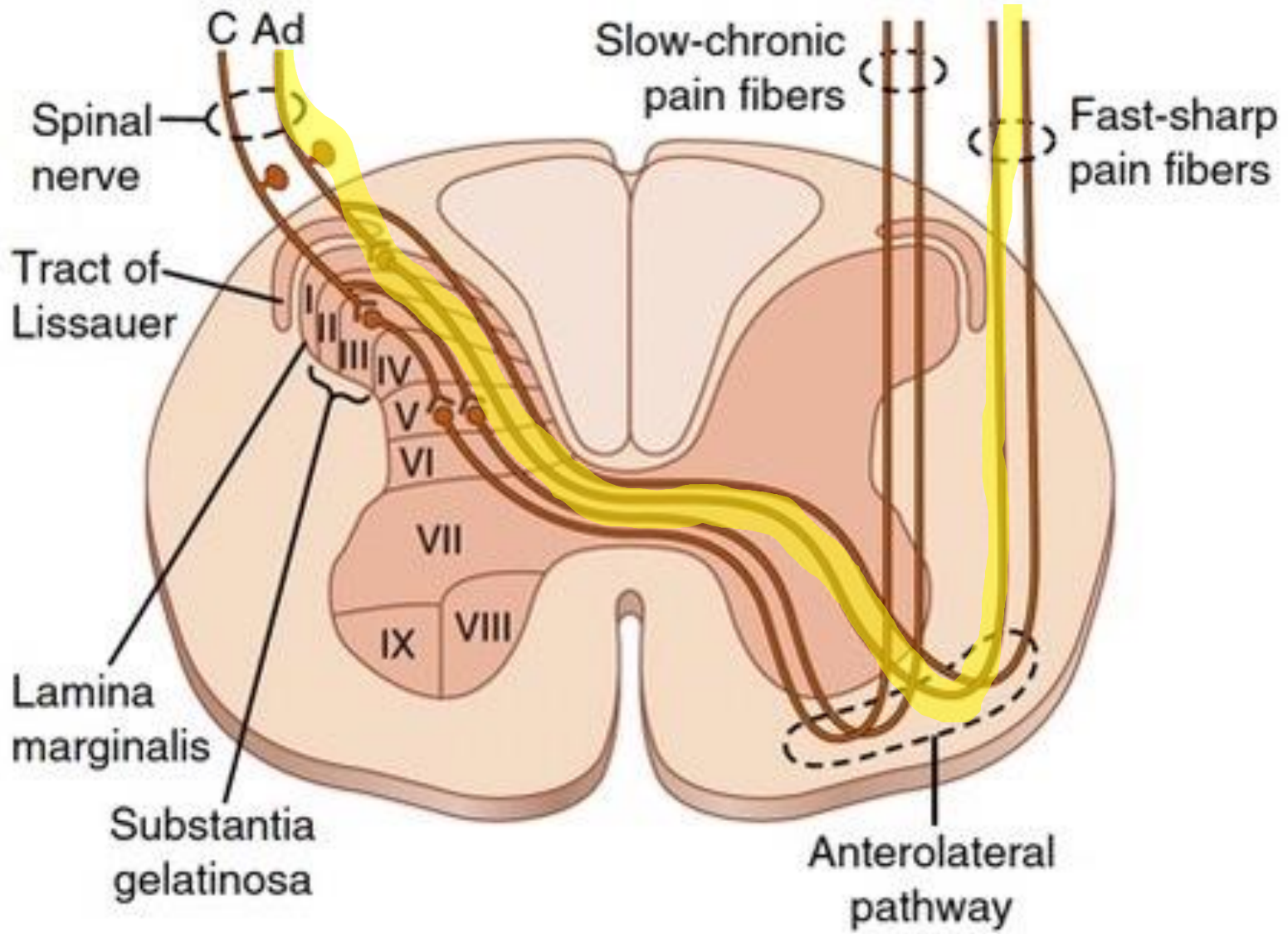
Lamina marginalis
Substantia gelatinosa
Slow-chronic pain fibers
Fast-sharp pain fibers
Anterolateral pathway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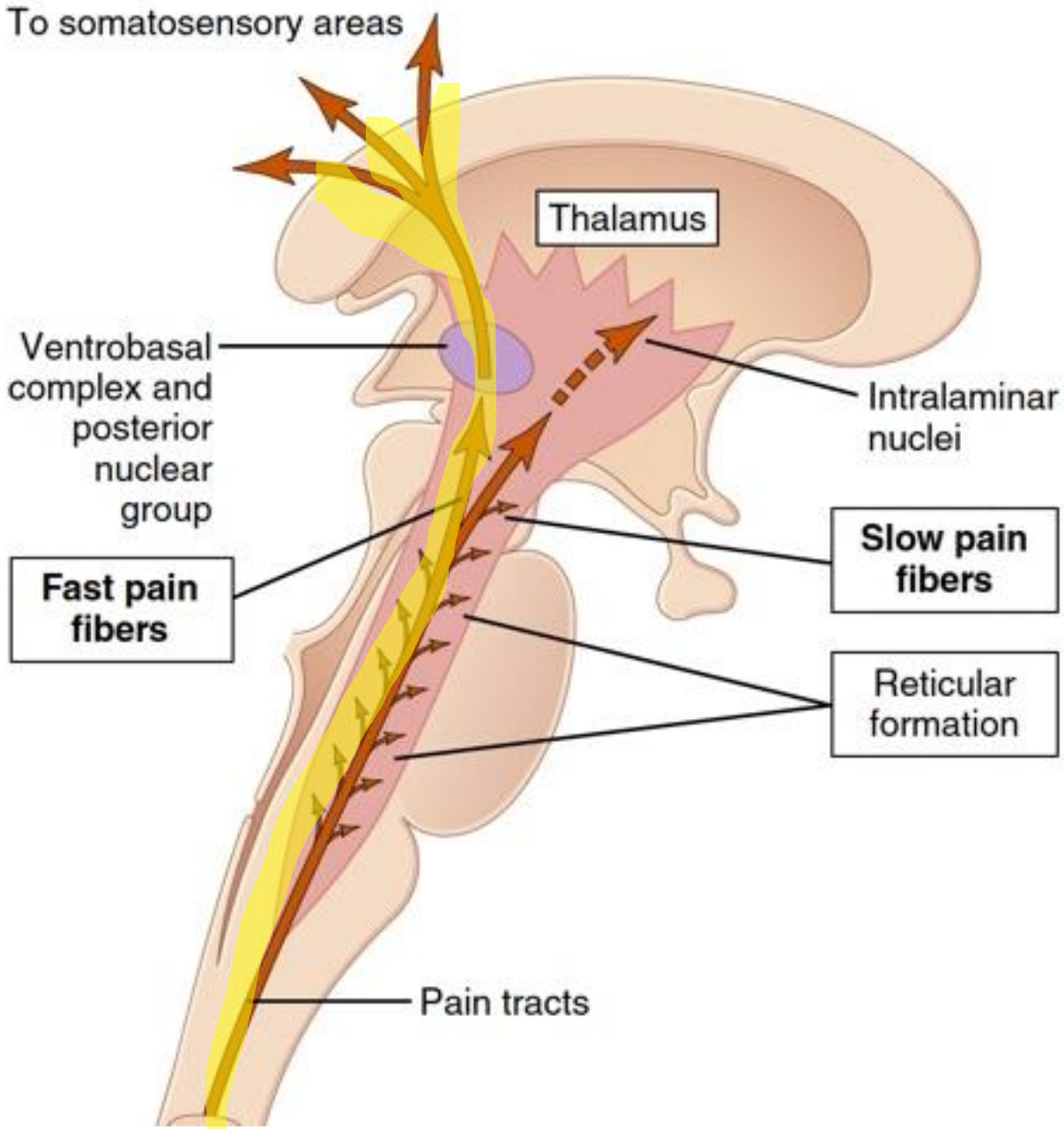

To somatosensory areas
Thalamus
Ventrobasal complex and posterior nuclear group
Intralaminar nuclei
Fast pain fibers
Slow pain fibers
Reticular formation
Pain tracts

Neospinothalamic tract

- A few fibers of the neospinothalamic tract terminate in the reticular areas of the brain stem, but most pass all the way to the thalamus without interruption, terminating in the ventrobasal complex along with the dorsal column–medial lemniscal tract for tactile sensations.

- A few fibers also terminate in the posterior nuclear group of the thalamus. From these thalamic areas, the signals are transmitted to other basal areas of the brain, as well as to the somatosensory cortex.

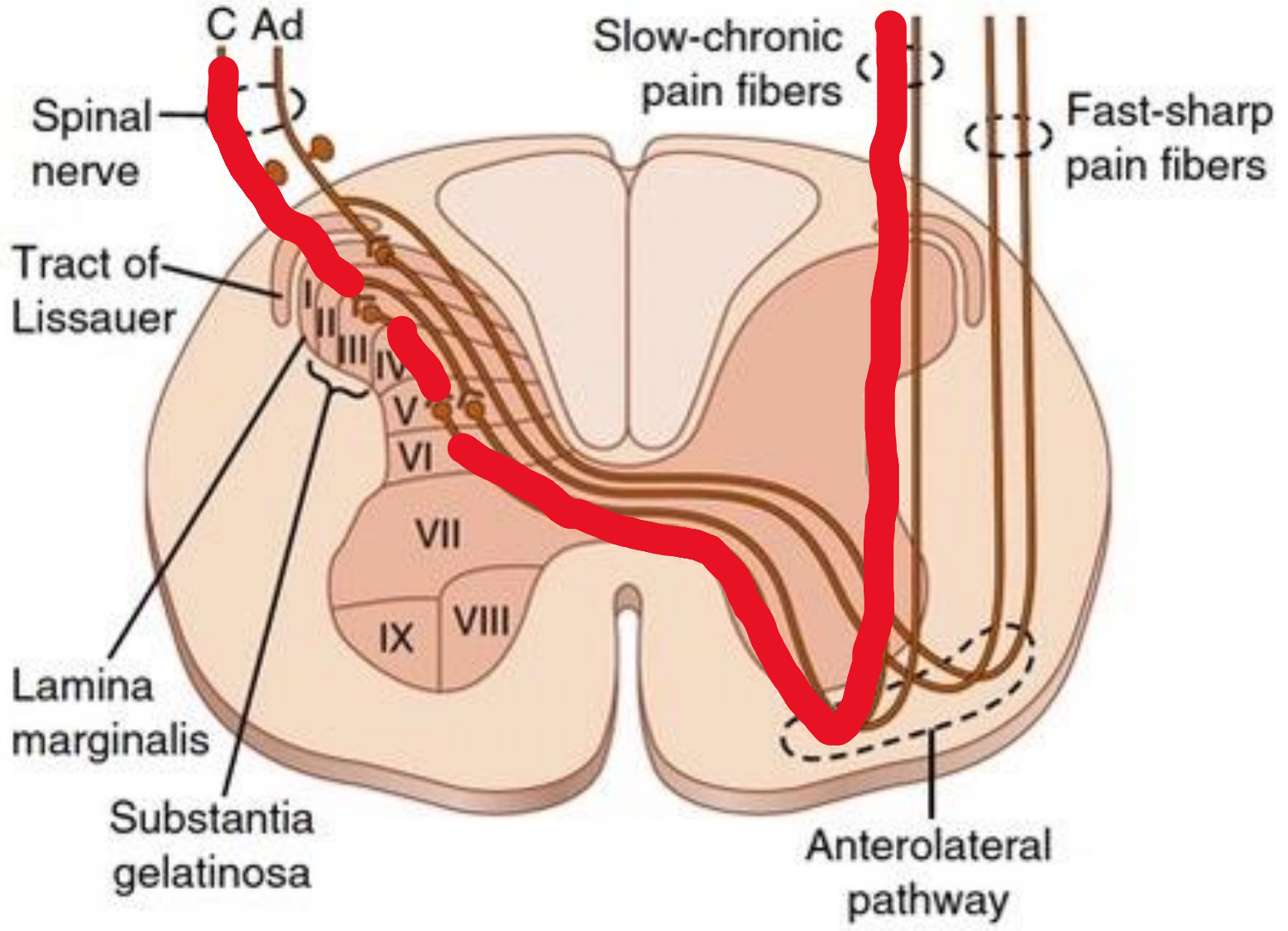
Tactile receptors and pain

- The fast-sharp type of pain can be localized much more exactly in the different parts of the body than can slow-chronic pain.

- However, when only pain receptors are stimulated, without the simultaneous stimulation of tactile receptors, even fast pain may be poorly localized.

- Yet, **when tactile receptors that excite the dorsal column–medial lemniscal system are simultaneously stimulated, the localization can be nearly exact**.

- It is believed that **glutamate** is the neurotransmitter substance secreted in the spinal cord at the type Aδ pain nerve fiber endings.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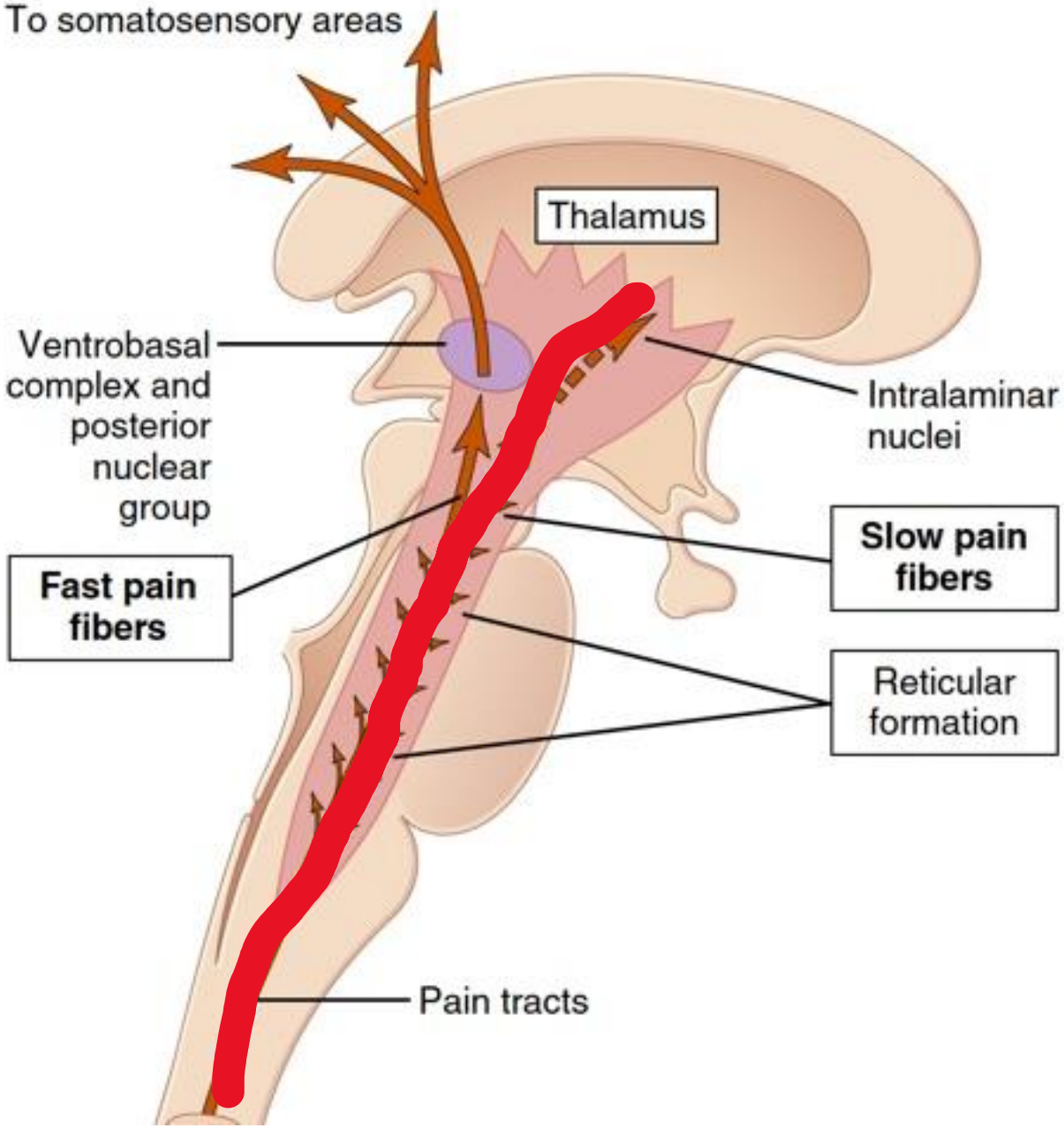
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Paleospinothalamic pathway

- The paleospinothalamic pathway transmits pain mainly from the peripheral slow-chronic type C pain fibers, although it also transmits some signals from type Aδ fibers.
- Most of the signals then pass through one or more additional short fiber neurons within the dorsal horns before entering mainly lamina V, also in the dorsal horn.
- Here, the last neurons in the series give rise to long axons that mostly join the fibers from the fast pain pathway, passing first through the anterior commissure to the opposite side of the cord and then upward to the brain in the anterolateral pathway.

Paleospinothalamic pathway

- Type C pain fiber terminals entering the spinal cord release both glutamate transmitter and substance P transmitter.

- The glutamate transmitter acts instantaneously and lasts for only a few milliseconds.

- **Substance P** is released much more slowly, building up in concentration over a period of seconds or even minutes.

Paleospinothalamic pathway

- The slow-chronic paleospinothalamic pathway terminates widely in the brain stem.

- Only 10% to 25% of the fibers pass all the way to the thalamus. Instead, most terminate in one of three areas:
- (1) the reticular nuclei of the medulla, pons, and mesencephalon.
- (2) the tectal area of the mesencephalon deep to the superior and inferior colliculi.
- (3) the periaqueductal gray region surrounding the aqueduct of Sylvius.

Paleospinothalamic pathway

- These **lower regions of the brain** appear to be important for feeling the **suffering types of pain**.

- From the brain stem pain areas, multiple short-fiber neurons relay the pain signals upward into the intralaminar and ventrolateral nuclei of the thalamus and into certain portions of the hypothalamus and other basal regions of the brain.

- Electrical stimulation in the reticular areas of the brain stem and in the intralaminar nuclei of the thalamus, the areas where the slow-suffering type of pain terminates, has a strong **arousal effect** on nervous activity throughout the entire brain.

- This explains why it is almost impossible for a person to sleep when in severe pain.

Paleospinothalamic pathway

- **Localization** of pain transmitted via the paleospinothalamic pathway is **imprecise**.
- For example, slow-chronic pain can usually be localized only to a major part of the body, such as to one arm or leg but not to a specific point on the arm or leg.

- This phenomenon is in keeping with the **multisynaptic, diffuse connectivity of this pathway.** It explains why patients often have serious difficulty in localizing the source of some chronic types of pain.

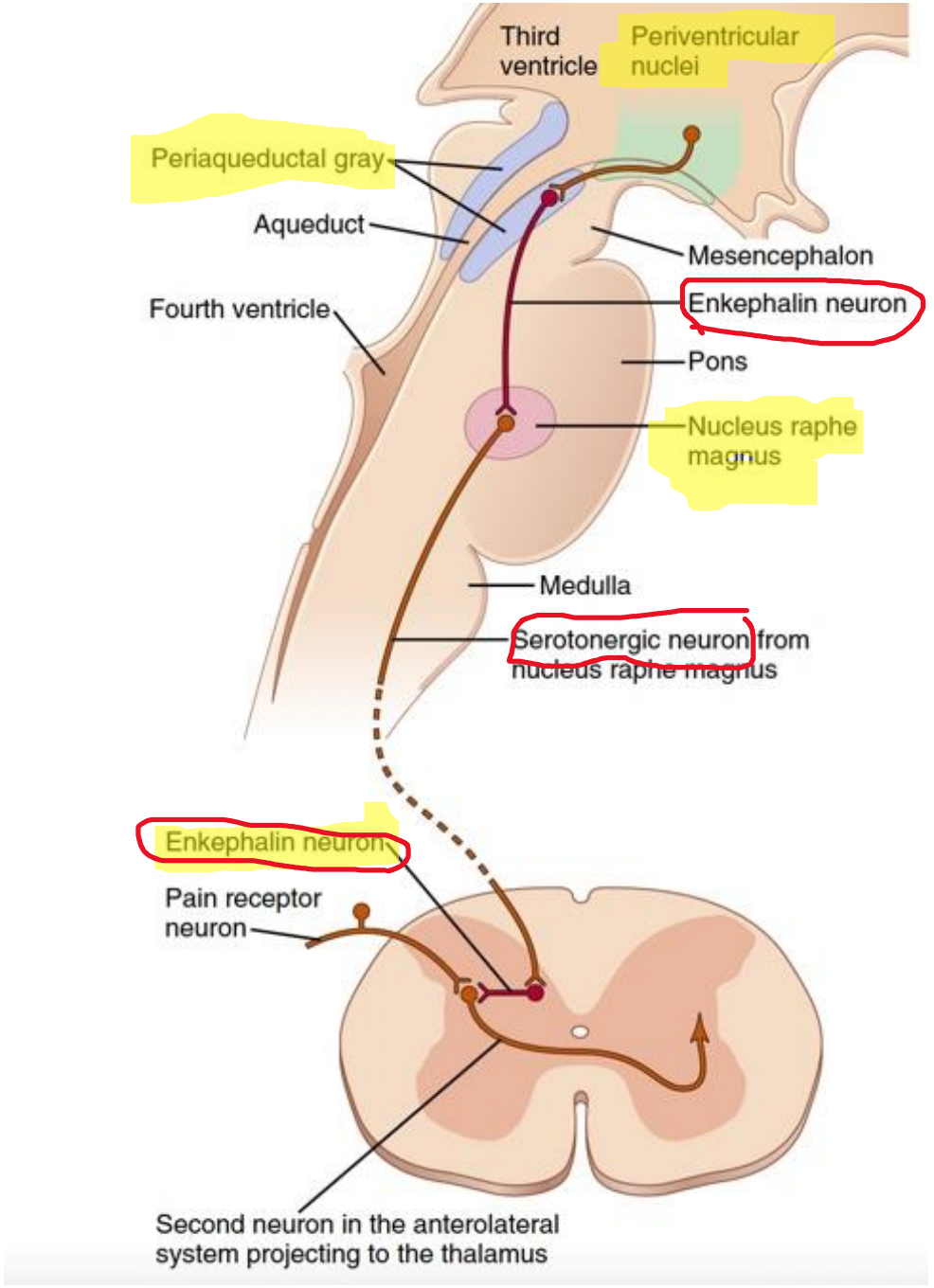
- **Complete removal of the somatic sensory areas of the cerebral cortex does not prevent pain perception**. Therefore, it is likely that pain impulses entering the brain stem reticular formation, the thalamus, and other lower brain centers cause conscious perception of pain.

- This does not mean that the cerebral cortex has nothing to do with normal pain appreciation; it is believed that the cortex plays an especially important role in **interpreting pain quality**.

Pain suppression

- The degree to which different **people react to pain varies** tremendously.

- This variation results partly from a capability of the brain itself to suppress input of pain signals to the nervous system by activating a pain control system, called an **analgesia system**.


Third ventricle
Periventricular nuclei
Periaqueductal gray
Aqueduct
Mesencephalon
Enkephalin neuron
Fourth ventricle
Pons
Nucleus raphe magnus
Medulla
Serotonergic neuron from nucleus raphe magnus
Enkephalin neuron
Pain receptor neuron
Second neuron in the anterolateral system projecting to the thalamus

Components of the analgesia system

- (1) The periaqueductal gray and periventricular areas of the mesencephalon and upper pons. Neurons from these areas send signals to
- (2) the raphe magnus nucleus, located in the lower pons and upper medulla, and the nucleus reticularis paragigantocellularis, located laterally in the medulla. From these nuclei, second order signals are transmitted down the dorsolateral columns in the spinal cord to
- (3) a pain inhibitory complex located in the dorsal horns of the spinal cord. At this point, the analgesia signals can block the pain before it is relayed to the brain.

- Electrical stimulation either in the periaqueductal gray area or in the raphe magnus nucleus can suppress many strong pain signals entering via the dorsal spinal roots.
- Also, stimulation of areas at higher levels of the brain that excite the periaqueductal gray area can also suppress pain.
- Some of these areas are the following:
- (1) the periventricular nuclei in the hypothalamus, lying adjacent to the third ventricle; and, to a lesser extent
- (2) the medial forebrain bundle, also in the hypothalamus.

- Several transmitter substances, especially **enkephalin and serotonin**, are involved in the analgesia system.
- Many nerve fibers derived from the periventricular nuclei and from the periaqueductal gray area secrete enkephalin at their endings.
- the endings of many fibers in the raphe magnus nucleus release enkephalin when stimulated.
- Fibers originating in this area send signals to the dorsal horns of the spinal cord to secrete serotonin at their endings.
- The serotonin causes local cord neurons to secrete enkephalin as well.
- The 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.

Sensitisation

- Tissue damage initiates a variety of processes that sustain and amplify pain. With repeated stimuli, the **thresholds** of primary afferent nociceptors progressively decrease, so that normally innocuous stimuli become painful (Campbell et al., 1979; Gybels et al., 1979; LaMotte et al., 1983).

- For some primary afferent nociceptors, repeated noxious stimuli may induce continuous **activity** lasting for hours (National Academy of Sciences, 1985).

Pain and Tactile Signals

- **Stimulation** of large-type Aβ sensory fibers from peripheral **tactile** receptors can **depress transmission of pain** signals from the same body area.
- This effect presumably results from local lateral inhibition in the spinal cord.
- It explains why such simple maneuvers as rubbing the skin near painful areas is often effective in relieving pain.

Acupuncture

- Acupuncture is based on the idea that vital energy called qi (pronounced chee) flows through the body along pathways called meridians.

- Acupuncture is performed by inserting fine needles into the skin at specific locations in order to unblock and rebalance the flow of qi.
- A main purpose for using acupuncture is to provide pain relief.

- According to one theory, acupuncture relives pain by activating sensory neurons that ultimately trigger the release of neurotransmitters that function as analgesics such as endorphins, enkephalins, and dynorphins.

Treatment of Pain by Electrical Stimulation

- Several clinical procedures have been developed for suppressing pain with use of electrical stimulation.
- Stimulating electrodes are placed on selected areas of the skin or, on occasion, implanted over the spinal cord, supposedly to stimulate the dorsal sensory columns.
- In some patients, electrodes have been placed stereotaxically in appropriate intralaminar nuclei of the thalamus or in the periventricular or periaqueductal area of the diencephalon. The patient can then personally control the degree of stimulation.

Visceral pain

- Can be used for diagnosing visceral inflammation, visceral infectious disease, and other visceral ailments.
- Often, the viscera have sensory receptors for no other modalities of sensation besides pain.
- One of the most important differences between surface pain and visceral pain is that highly localized types of damage to the viscera seldom cause severe pain.
- Conversely, any stimulus that causes diffuse stimulation of pain nerve endings throughout a viscus causes pain that can be severe.

Causes of visceral pain

- Any stimulus that excites pain nerve endings in diffuse areas of the viscera can cause visceral pain. Such stimuli include ischemia of visceral tissue, chemical damage to the surfaces of the viscera, spasm of the smooth muscle of a hollow viscus, excess distention of a hollow viscus, and stretching of the connective tissue surrounding or within the viscus.
- Essentially 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.

- A few visceral areas are almost completely insensitive to pain of any type.
- These areas include the parenchyma of the liver and the alveoli of the lungs.
- Yet, the liver capsule is extremely sensitive to both direct trauma and stretch, and the bile ducts are also sensitive to pain. In the lungs, even though the alveoli are insensitive, both the bronchi and the parietal pleura are very sensitive to pain.

Parietal pain

- When a disease affects a viscus, the disease process often spreads to the parietal peritoneum, pleura, or pericardium.

- These **parietal surfaces**, like the skin, **are supplied with extensive pain innervation from the peripheral spinal nerves**.

- Therefore, pain from the parietal wall overlying a viscus is frequently **sharp**.

Localization of visceral and parietal pain

- Sensations from the abdomen and thorax are transmitted through two pathways to the central nervous system, the true visceral pathway and the parietal pathway.
- True visceral pain is transmitted via pain sensory fibers in the autonomic nerve bundles, and the sensations are referred to surface areas of the body that are often far from the painful organ.
- Conversely, parietal sensations are conducted directly into local spinal nerves from the parietal peritoneum, pleura, or pericardium, and these sensations are usually localized directly over the painful area.

Referred pain

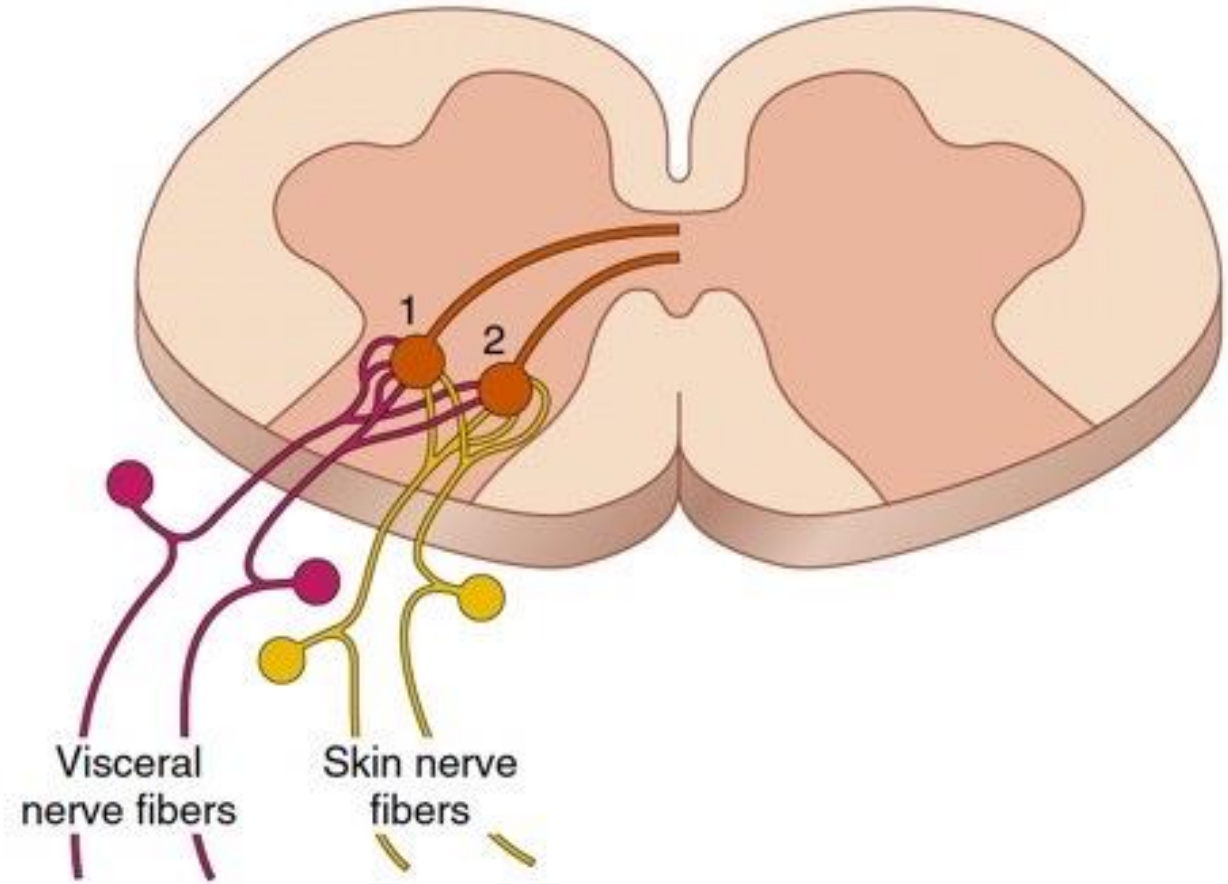
- When visceral pain is referred to the surface of the body, the person generally localizes it in the dermatomal segment from which the visceral organ originated in the embryo, not necessarily where the visceral organ now lies.

- For example, the heart originated in the neck and upper thorax, so the heart’s visceral pain fibers pass upward along the sympathetic sensory

Mechanism of referred pain

- branches of visceral pain fibers are shown to 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, and the person has the feeling that the sensations originate in the skin.


1
2
Visceral
nerve fibers
Skin nerve
fibers

- **Pain from the viscera** is frequently localized to two surface areas of the body at the same time because of the **dual transmission** of pain through the referred visceral pathway and the direct parietal pathway.

Example: inflamed appendix. Pain impulses pass first from the appendix through visceral pain fibers located within sympathetic nerve bundles and then into the spinal cord at about T10 or T11; this pain is referred to an area around the umbilicus and is of the aching, cramping type.

- Pain impulses also often originate in the parietal peritoneum where the inflamed appendix touches or is adherent to the abdominal wall.
- These impulses cause pain of the sharp type directly over the irritated peritoneum in the right lower quadrant of the abdomen.

Pain Assessment

Mnemonic :- SOCRATES

- **S** - Site
- **O** - Onset
- **C** - Character
- **R** - Radiates
- **A** - Associated Symt
- **T** - Time/duration
- **E** - Exacerbating
- **S** - Severity

Doctors-online

Thank you