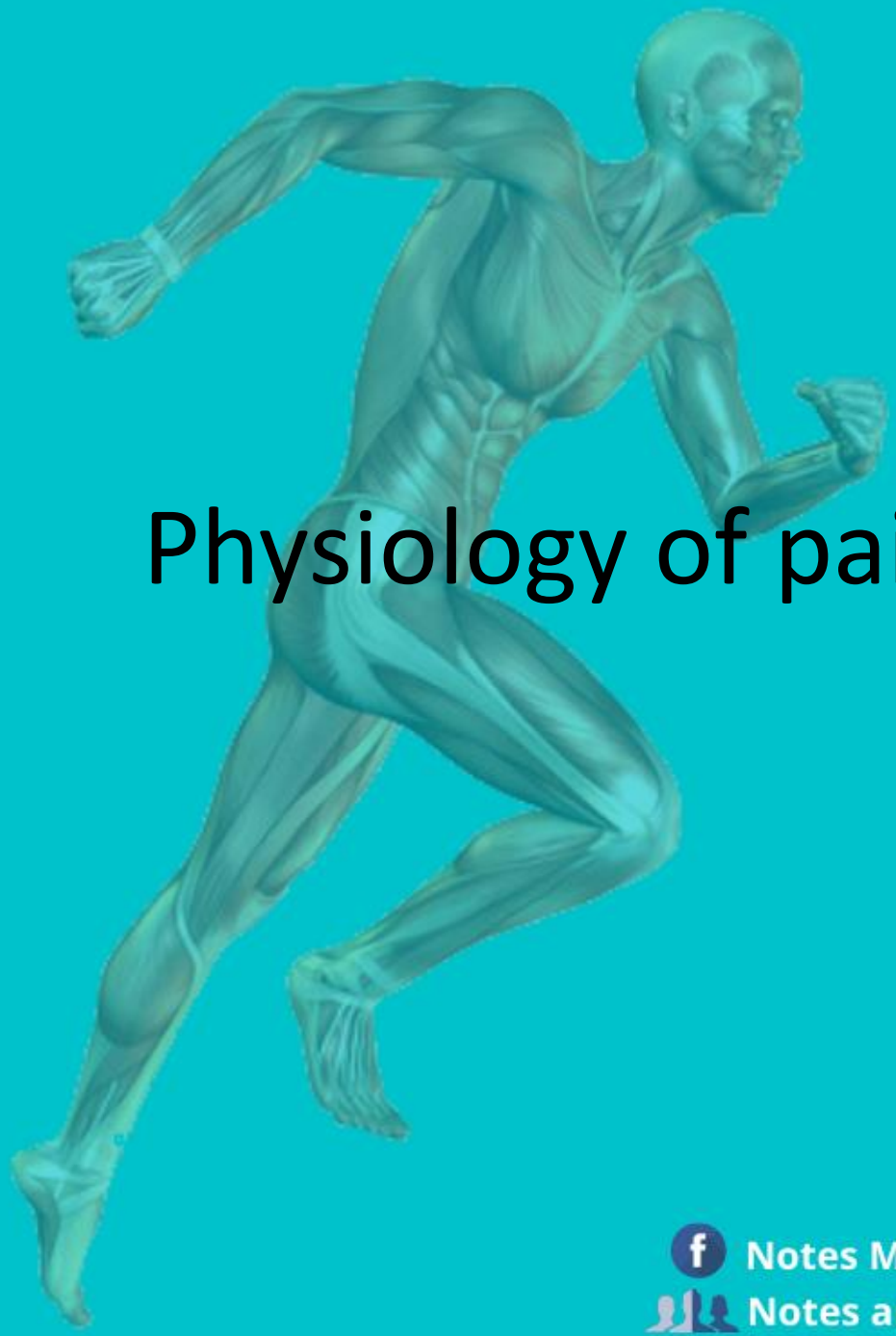
Physiology of pain

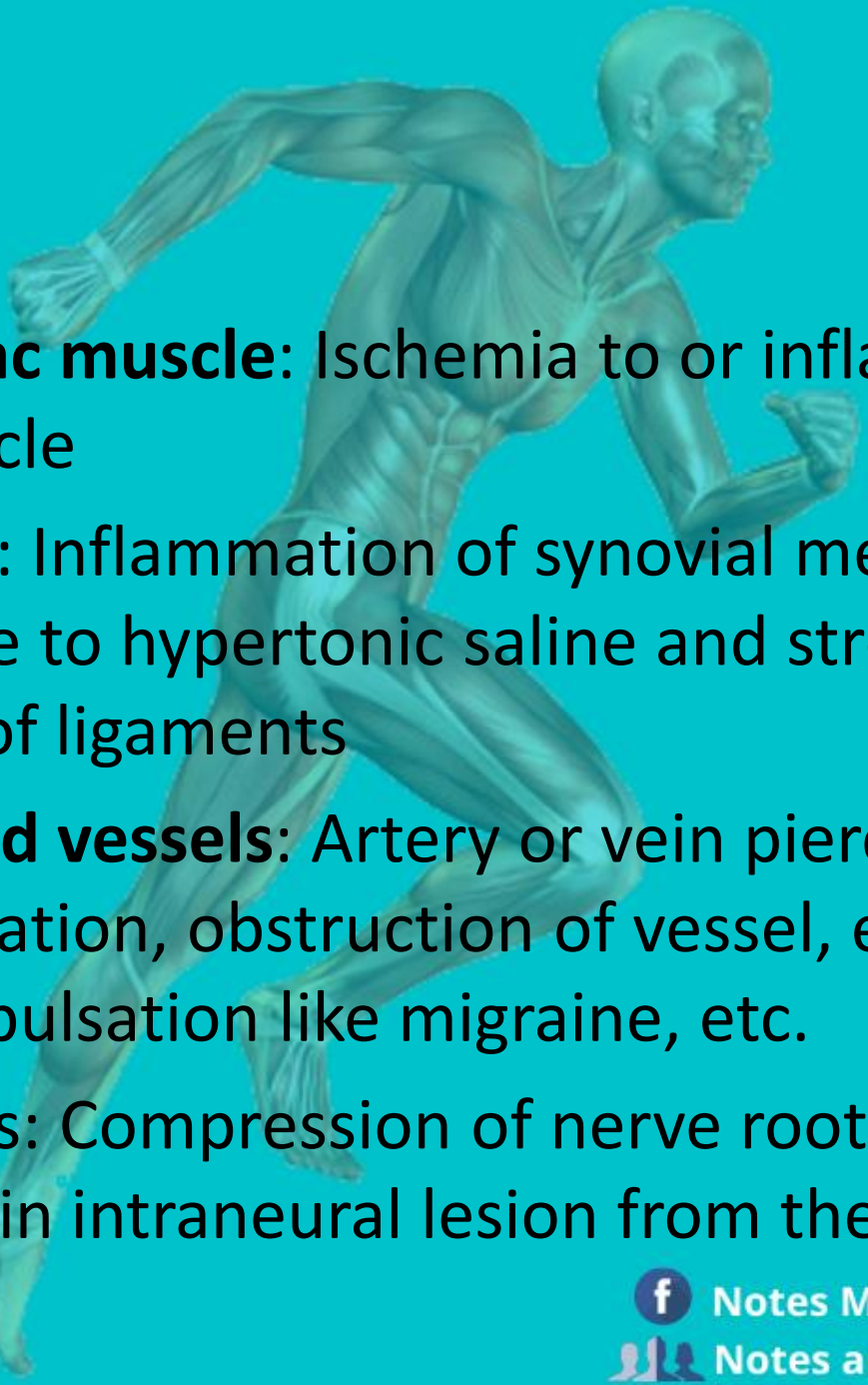


Pain

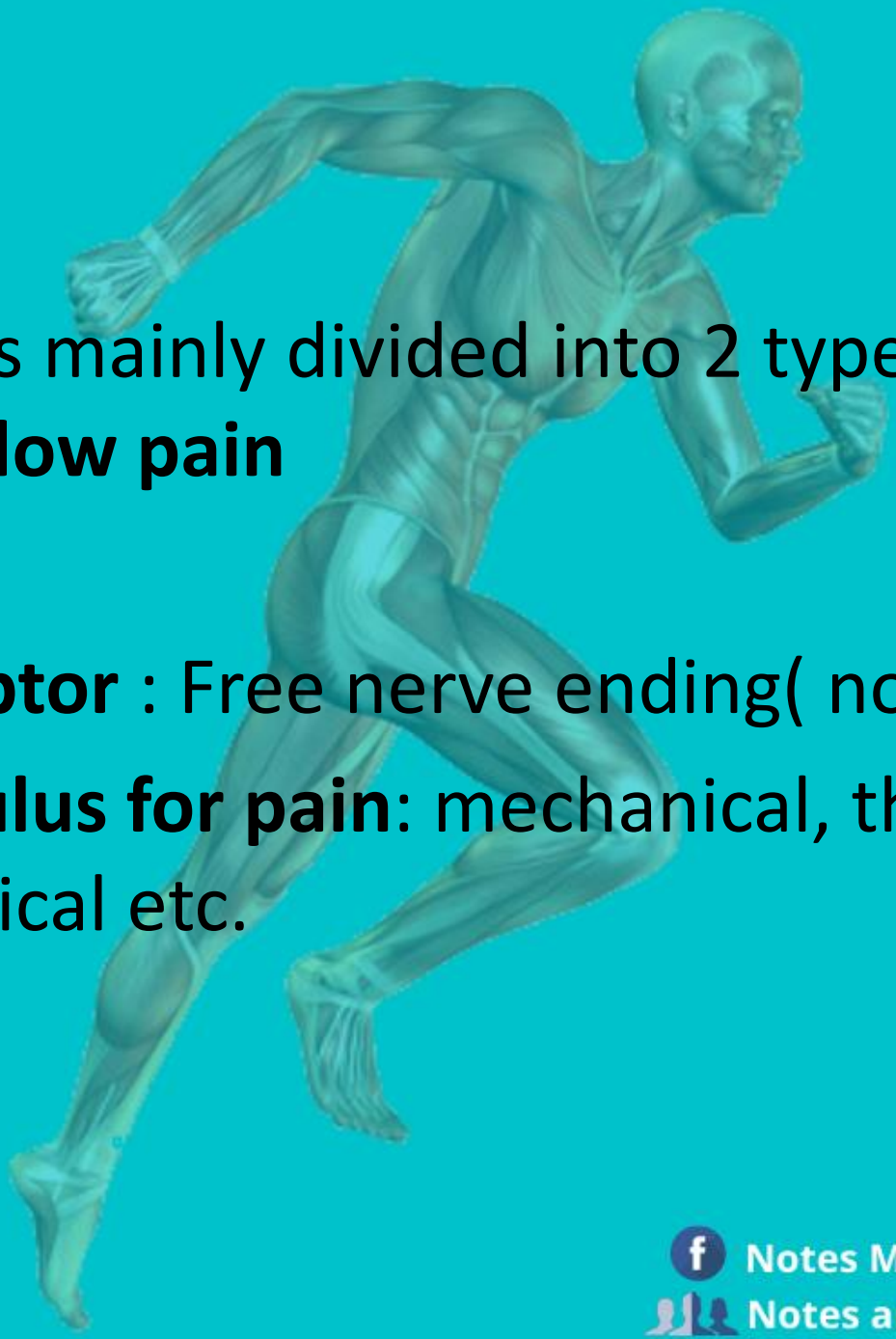
- A stimulus that is capable of damaging or causing harm to the tissue is a nociceptive stimulus and the sensation elicited is called nociception **(pain sensation). Or**
- Pain is an unpleasant sensory and emotional experience associated with potential or actual tissue damage.
- It is considered as protective mechanism.
- Nociceptive stimuli are different for different tissue

Types of stimuli

- **For skin**: Pricking, cutting, crushing, burning, freezing, etc.
- **For GIT**: Inflammation of mucosa, distension or spasm of smooth muscle and traction on the mesenteric attachment
- **In skeletal muscle**: Ischemia, necrosis, hemorrhage, injection of irritating solution and injury of the connective tissue sheath
- **In brain**: Traction on cerebral arteries or meningeal structures



- **In cardiac muscle**: Ischemia to or inflammation of the muscle
- **In joints**: Inflammation of synovial membrane, exposure to hypertonic saline and stretching or tearing of ligaments
- **For blood vessels**: Artery or vein pierced by needle, inflammation, obstruction of vessel, excessive arterial pulsation like migraine, etc.
- In nerves: Compression of nerve root or sensory ganglia (in intraneural lesion from the sheath of nerves.)



- Pain is mainly divided into 2 types**: Fast pain and slow pain**

- **Receptor** : Free nerve ending(non adapting)
- **Stimulus for pain**: mechanical, thermal, chemical etc.

a. Fast pain

- Sharp pain/ pricking pain/ pain from superficial structures like skin and subcutaneous tissue.
- Is felt within about 0.1sec after stimulus
- Receptor is stimulated by mechanical or thermal pain stimuli
- A delta fiber carry it & terminate in lamina I and V, velocity about 6-30m/sec
- Neospinothalamic tract is main pathway which is Well localized
- Neuro Transmitter(NT) is glutamate at the spinal cord level

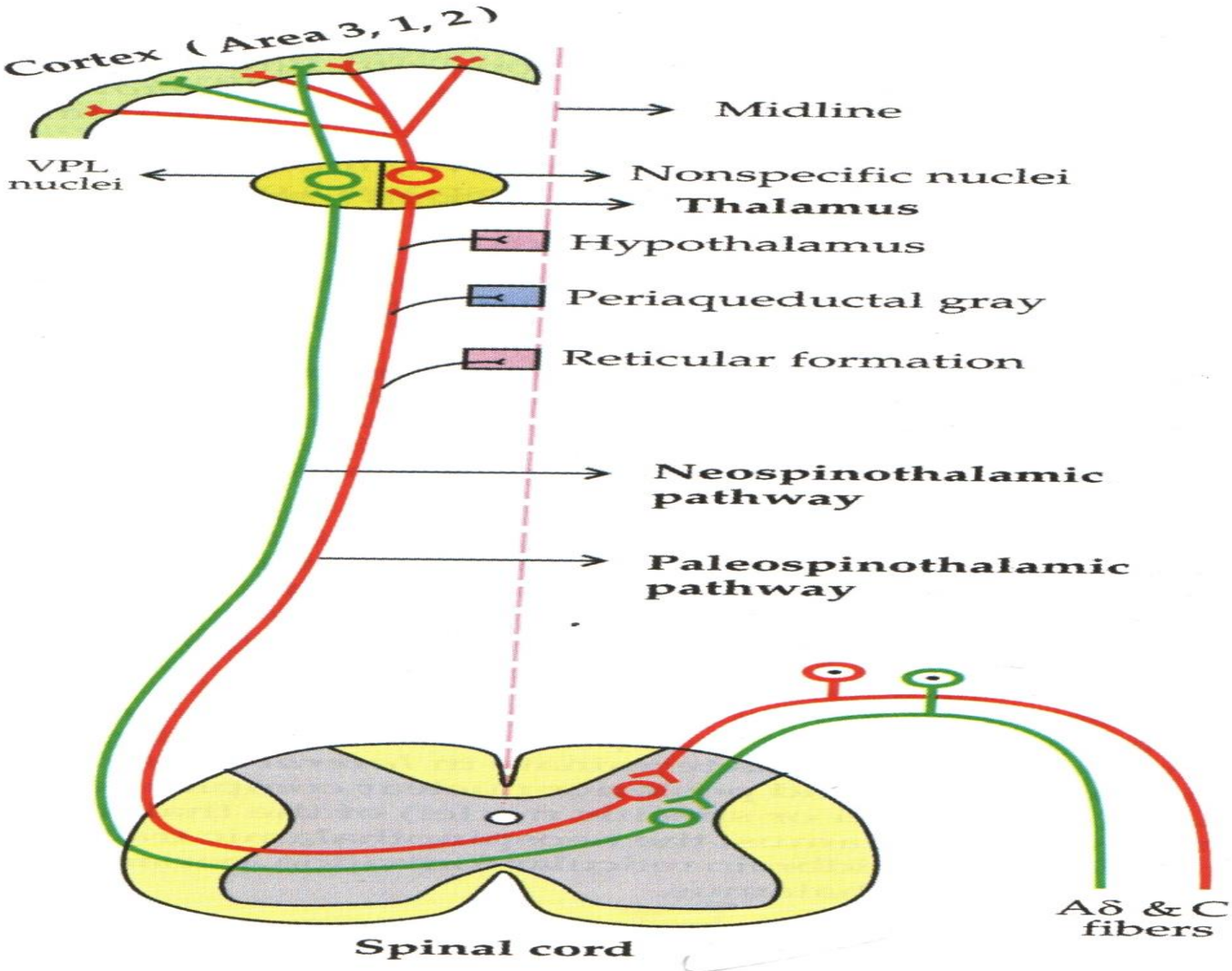
b. Slow pain

- Slow burning type of pain/ aching pain, throbbing pain/ pain from deep structures like bones and muscles.
- Elicited by chemical types of pain stimulus(persisting mechanical or thermal)
- Type C fiber carry it & terminate in lamina II in dorsal horn, **velocities 0.5 -2m/sec**
- Paleospinothalamic tract is pathway and Poorly localized
- NeuroTransmitter-glutamate, substance P at the spinal cord level

Other types of pain

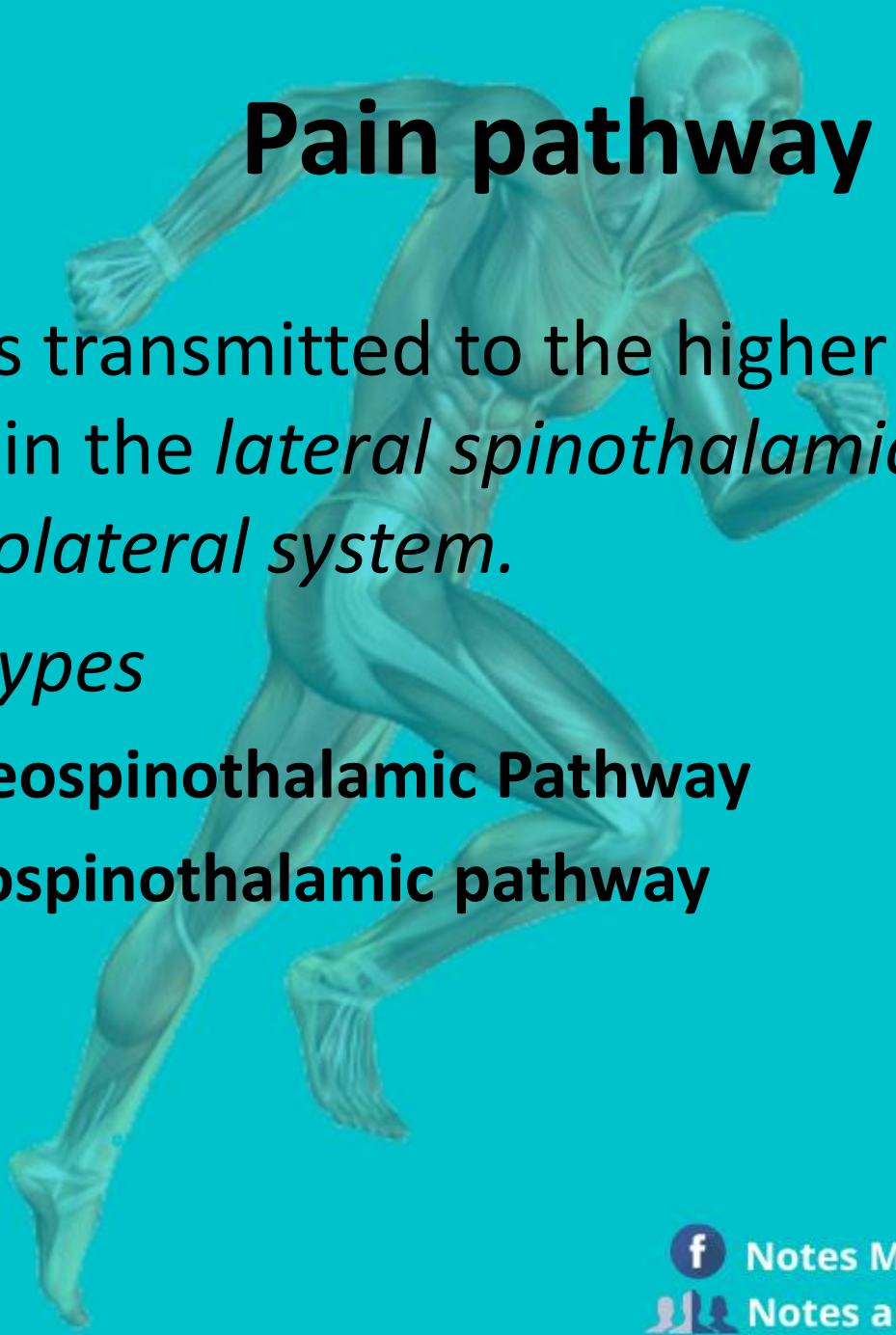
- **Superficial Pain vs Deep Pain :**The pain elicited in the superficial structures like skin and s.c. tissues is the superficial pain(fast pain). The pain felt in the deeper structures like bones, muscles, connective tissue is deep pain(slow pain).
- **Somatic Pain vs Visceral Pain:** Pain originating in the somatic structures is the somatic pain and pain originating in the visceral structures is the visceral pain.
- **Peripheral Pain vs Central Pain:** Pain occurring due to direct stimulation of receptors/ nerves is the peripheral pain(i.e.neuropathic or neurogenic pain in neuralgias). Stimulation of central pain fibers resulting in pain is called central pain(i.e,pain below the level of lesion in spinal transection.)

Pain pathway



gure 104.2: Paleospinothalamic and neospinothalamic pain hways. Note the collaterals in the brainstem from paleospinothalamic hway terminating in different brainstem nuclei.

Pain pathway

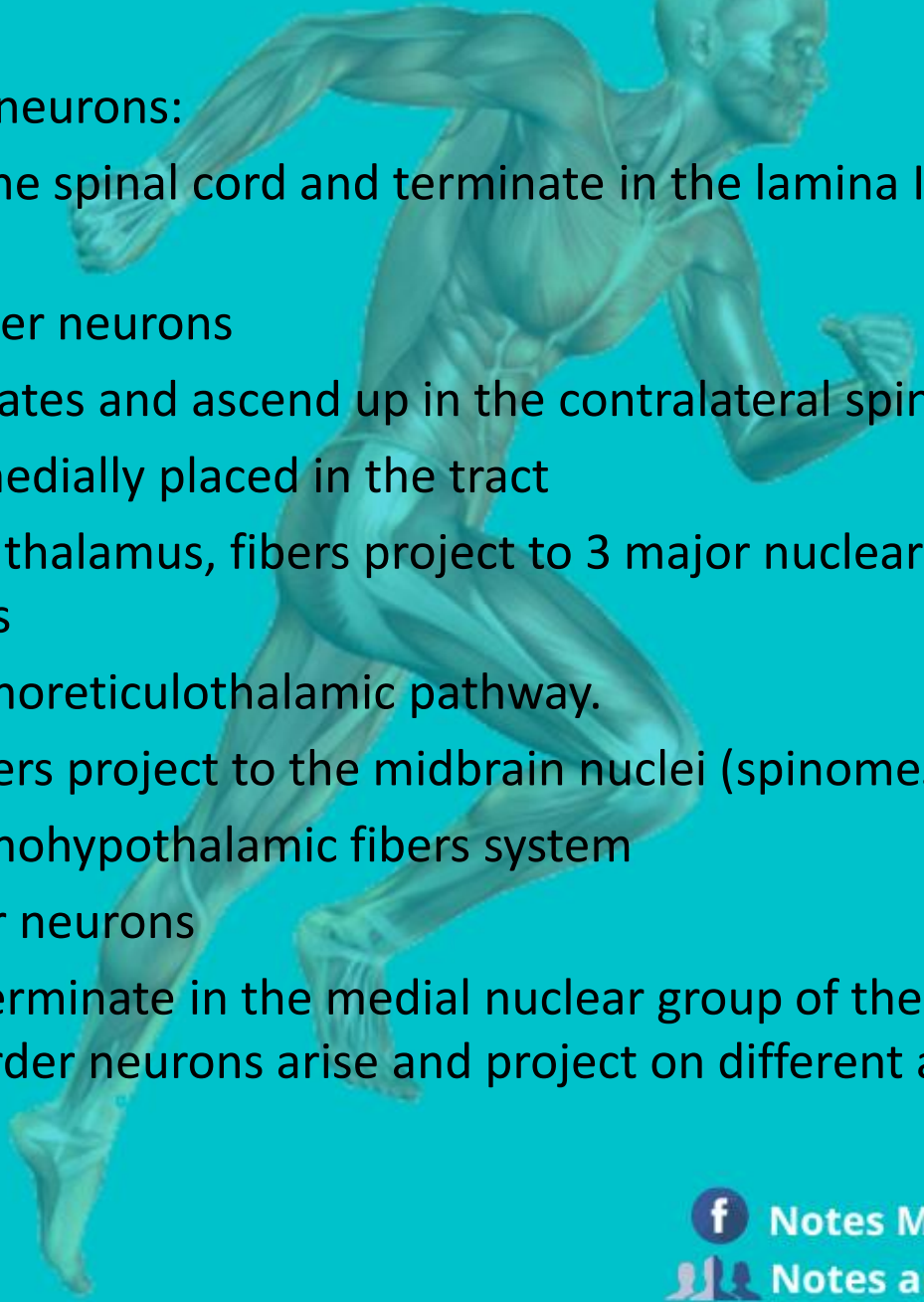


- Pain is transmitted to the higher centers in the brain in the *lateral spinothalamic tract of the anterolateral system.*
- *Two types*
  - **Paleospinothalamic Pathway**
  - **Neospinothalamic pathway**

Paleospinothalamic Pathway

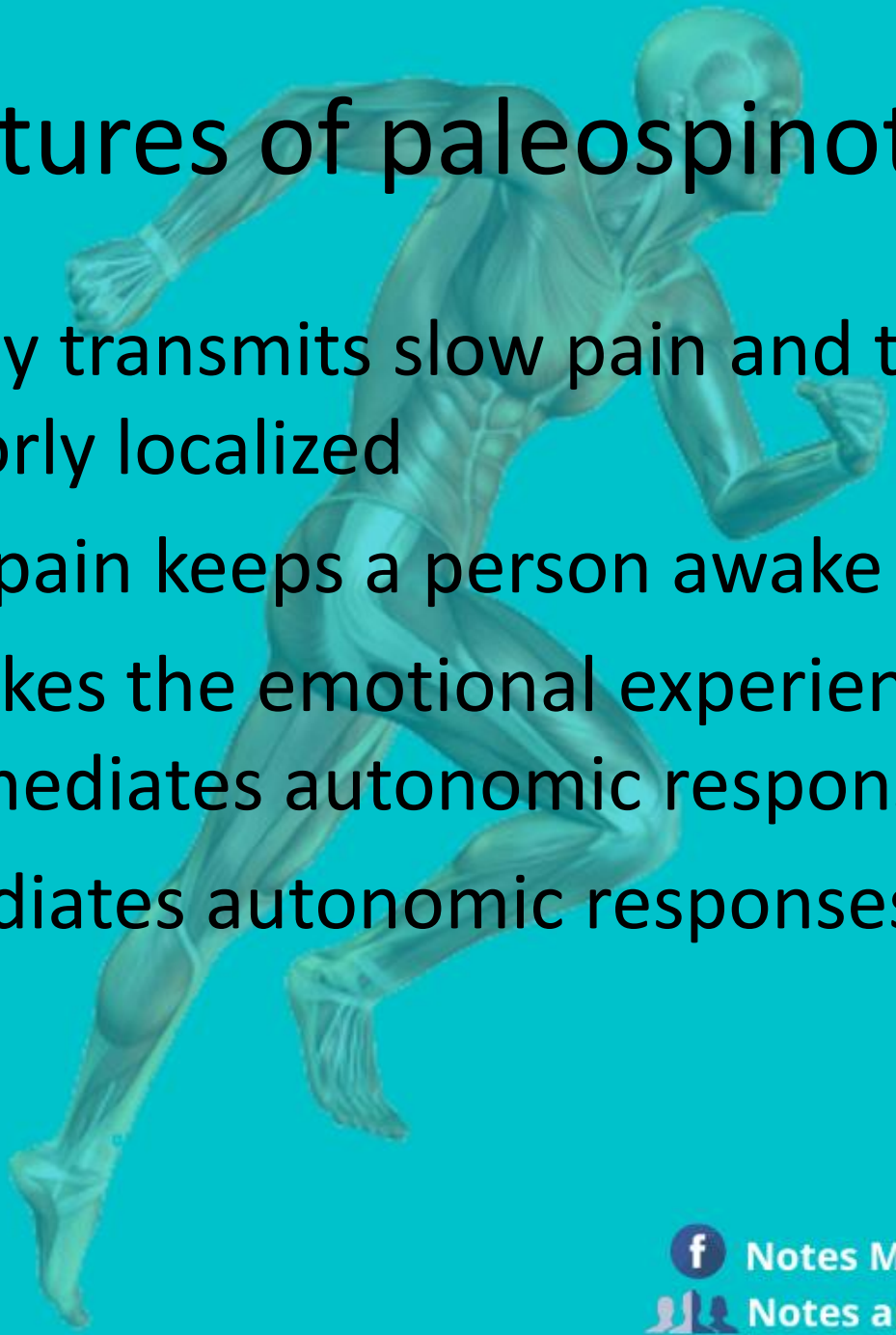
- Oldest pathway and mainly carries the sensation of slow pain
- Multineuron slow conducting system that mediates the poorly localized pain from deep and visceral structures
- Mostly C fibers
- Order of neurons
  - First order
  - Second order
  - Third order

Order of neurons



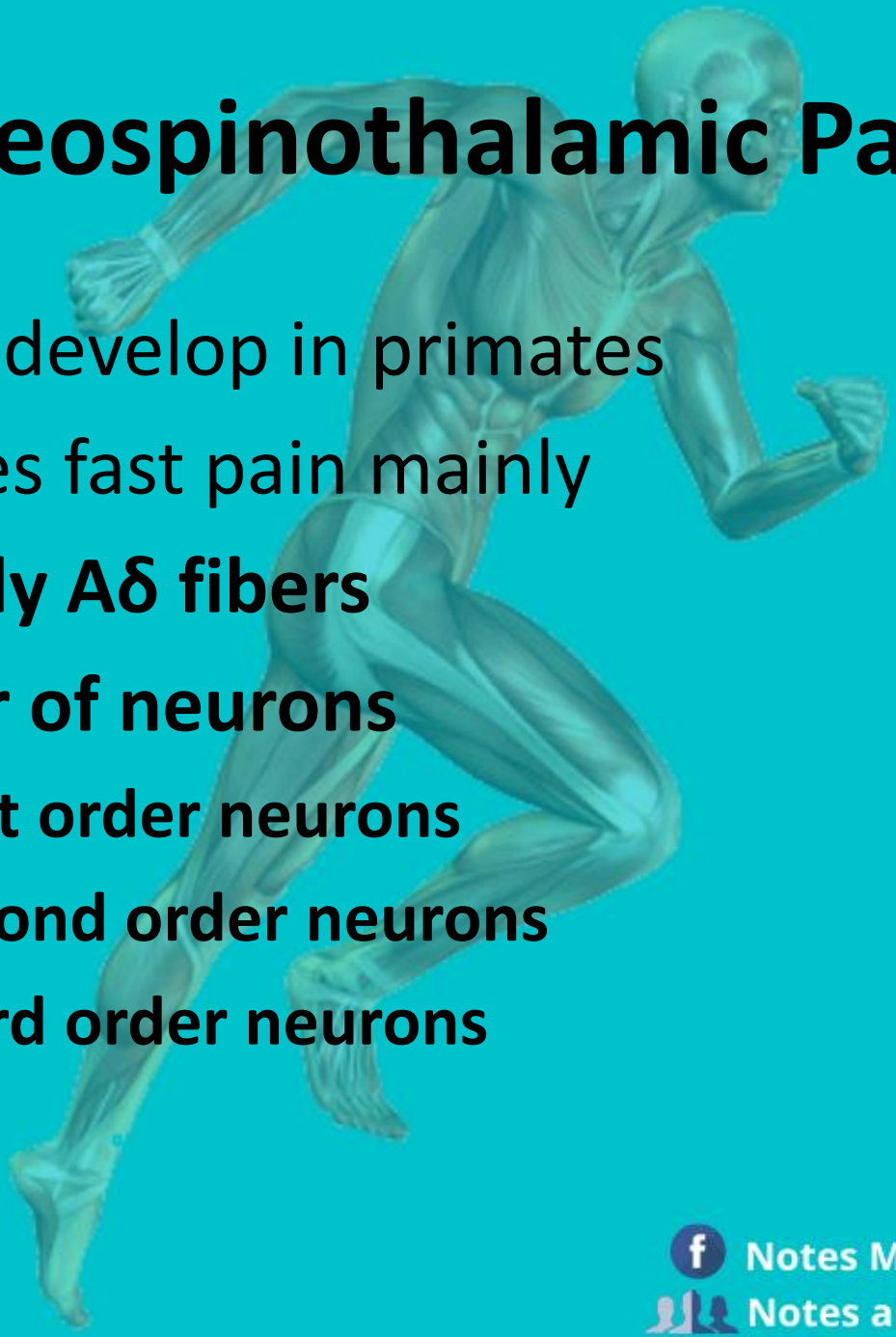
- First order neurons:
  - Enter the spinal cord and terminate in the lamina II of the dorsal horn mainly.
- Second order neurons
  - DecusSates and ascend up in the contralateral spinothalamic pathway
  - Fiber medially placed in the tract
  - Way to thalamus, fibers project to 3 major nuclear groups forming three systems
    - Spinoreticulothalamic pathway.
    - Fibers project to the midbrain nuclei (spinomesencephalic fibers)
    - Spinohypothalamic fibers system
- Third Order neurons
  - Fiber terminate in the medial nuclear group of the thalamus from where third order neurons arise and project on different areas of cortex.

Features of paleospinothalamic



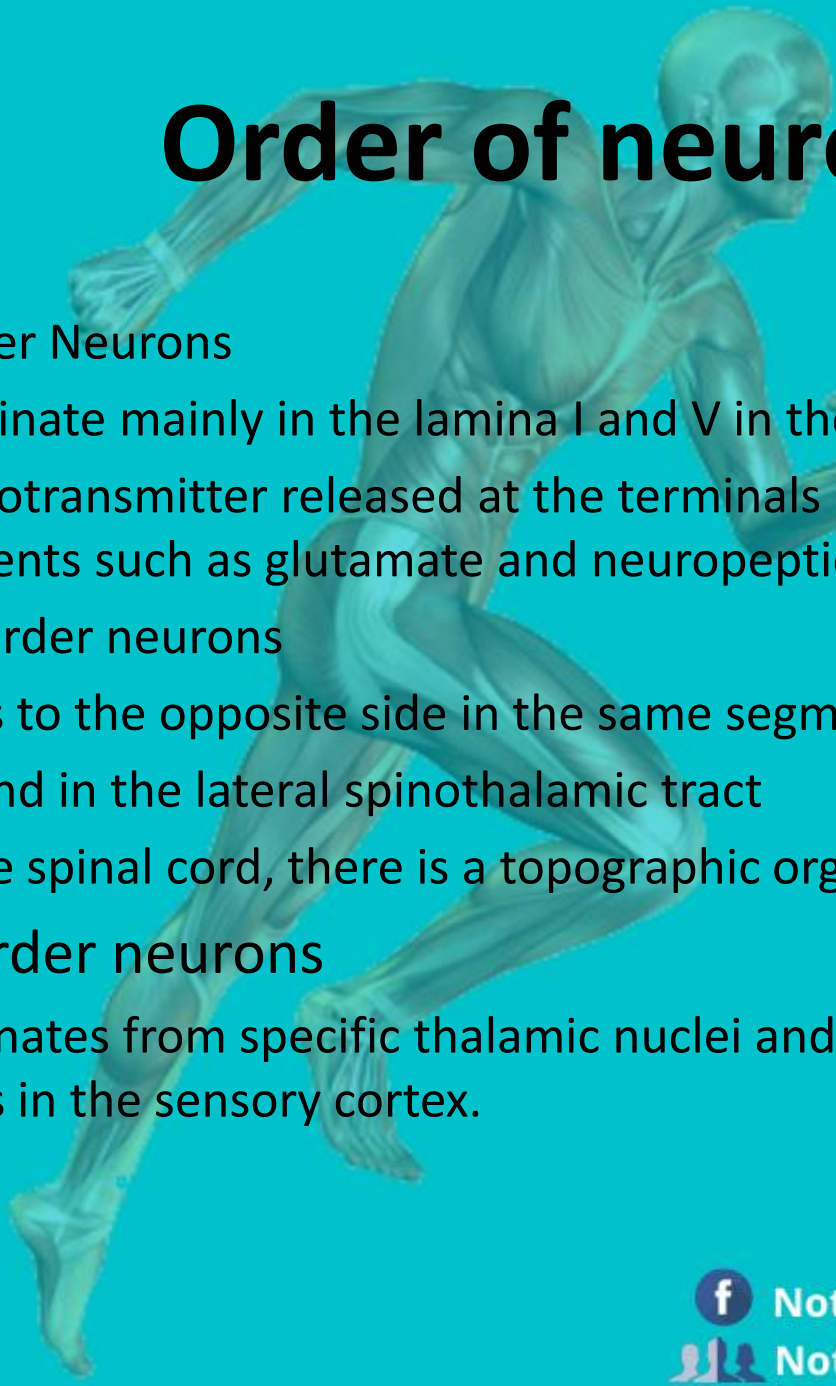
- Mainly transmits slow pain and the slow pain is poorly localized
- Slow pain keeps a person awake
- It evokes the emotional experience of pain and mediates autonomic responses
- It mediates autonomic responses

Neospinothalamic Pathway



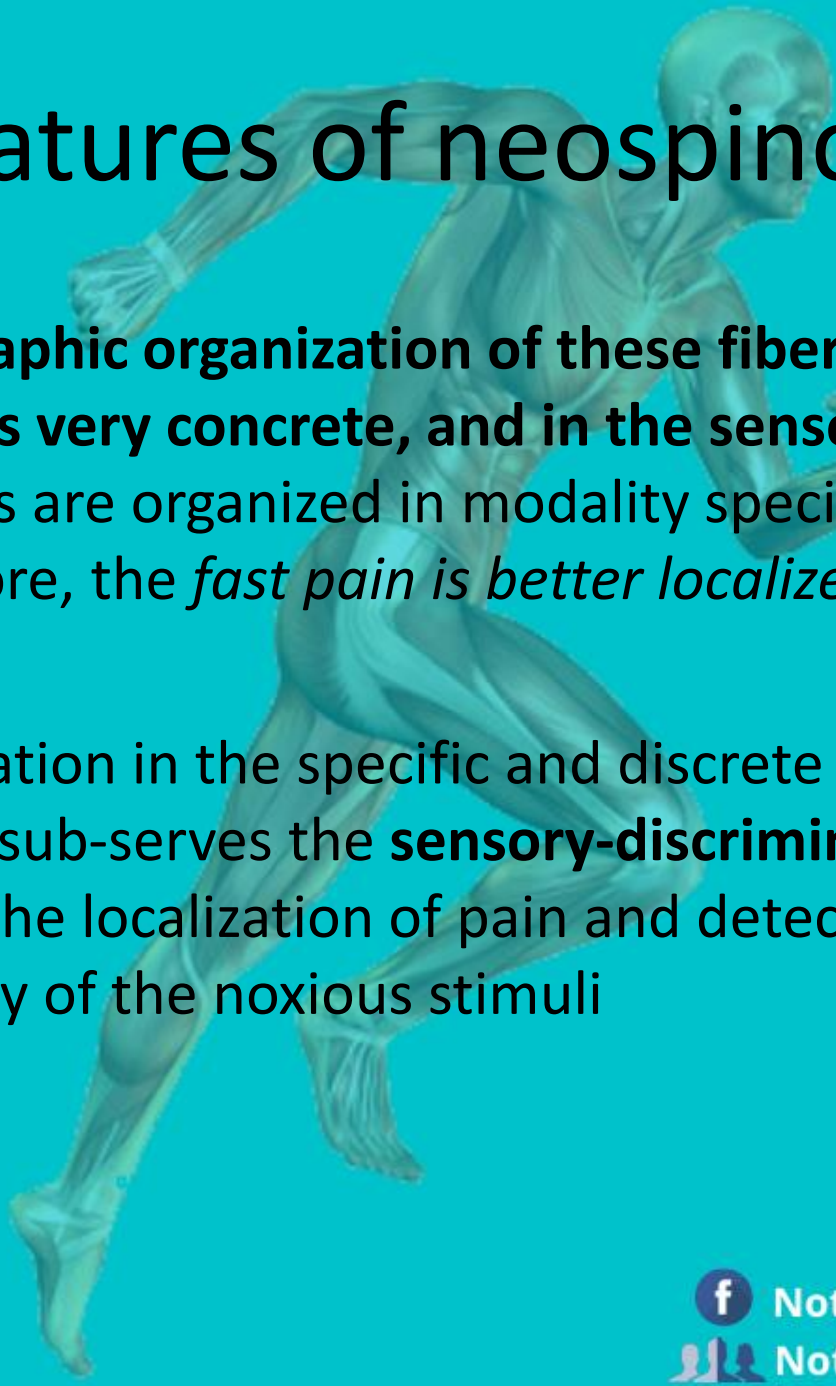
- Most develop in primates
- Carries fast pain mainly
- **Mostly Aδ fibers**
- **Order of neurons**
  - **First order neurons**
  - **Second order neurons**
  - **Third order neurons**

Order of neurons



- First Order Neurons
  - Terminate mainly in the lamina I and V in the dorsal horn of spinal cord
  - Neurotransmitter released at the terminals of primary nociceptive afferents such as glutamate and neuropeptides (substance P)
- Second order neurons
  - Cross to the opposite side in the same segment of spinal cord
  - Ascend in the lateral spinothalamic tract
  - In the spinal cord, there is a topographic organization of fibers
- Third order neurons
  - Originates from specific thalamic nuclei and projects to the postcentral gyrus in the sensory cortex.

Features of neospinothalamic



- **Topographic organization of these fibers in** the thalamus and cortex **is very concrete, and in the sensory** cortex, the neurons are organized in modality specific columns. Therefore, the *fast pain is better localized.*

- Termination in the specific and discrete areas in thalamus and cortex, sub-serves the **sensory-discriminative aspects of pain** that is the localization of pain and detection of quality and intensity of the noxious stimuli

Endogenous pain relief system

A.k.a. central analgesia system :inbuilt system for pain reduction

Consists of three components:

1. The periaqueductal gray & periventricular area
2. The raphe magnus nucleus
3. Pain inhibitory complex located in the dorsal horn of spinal cord

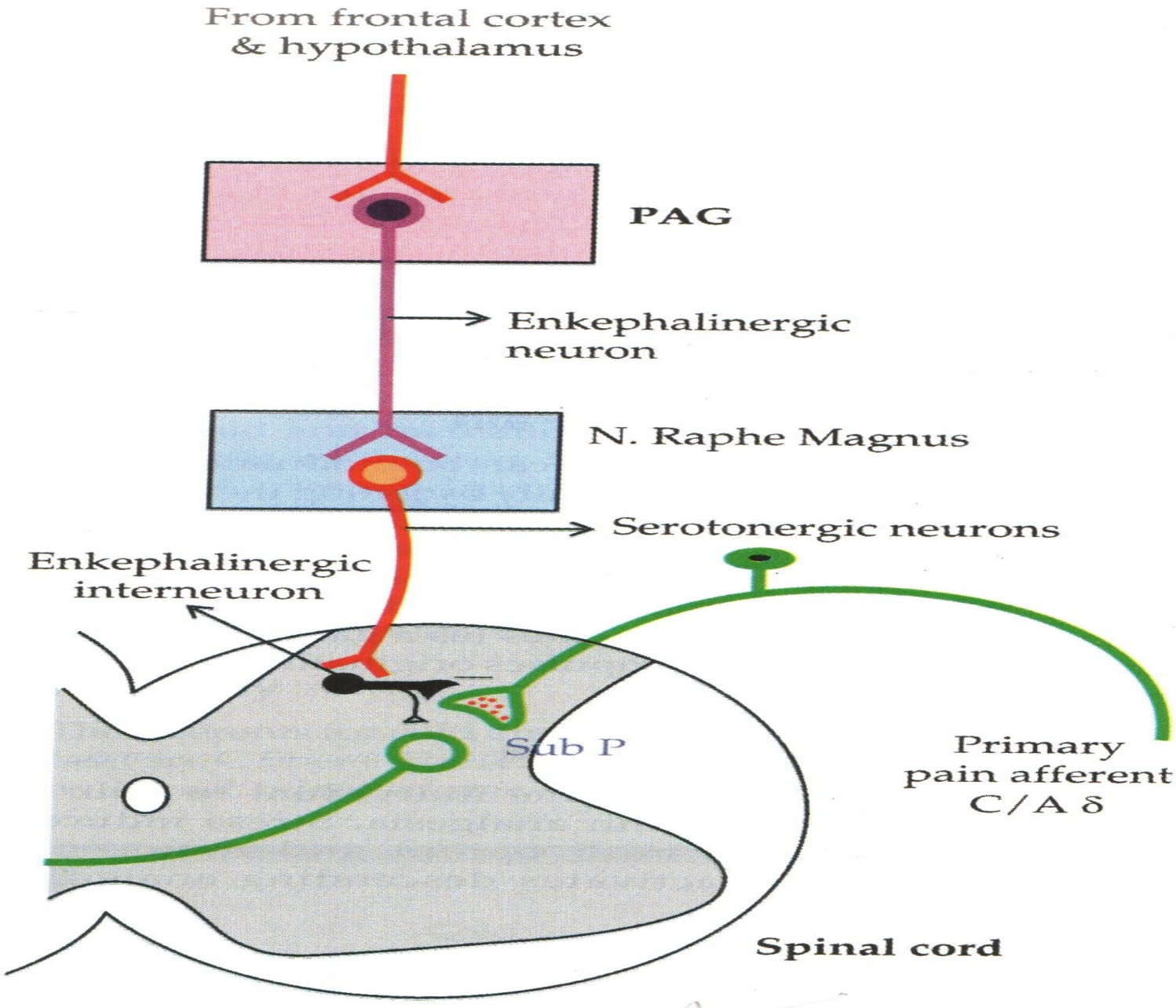
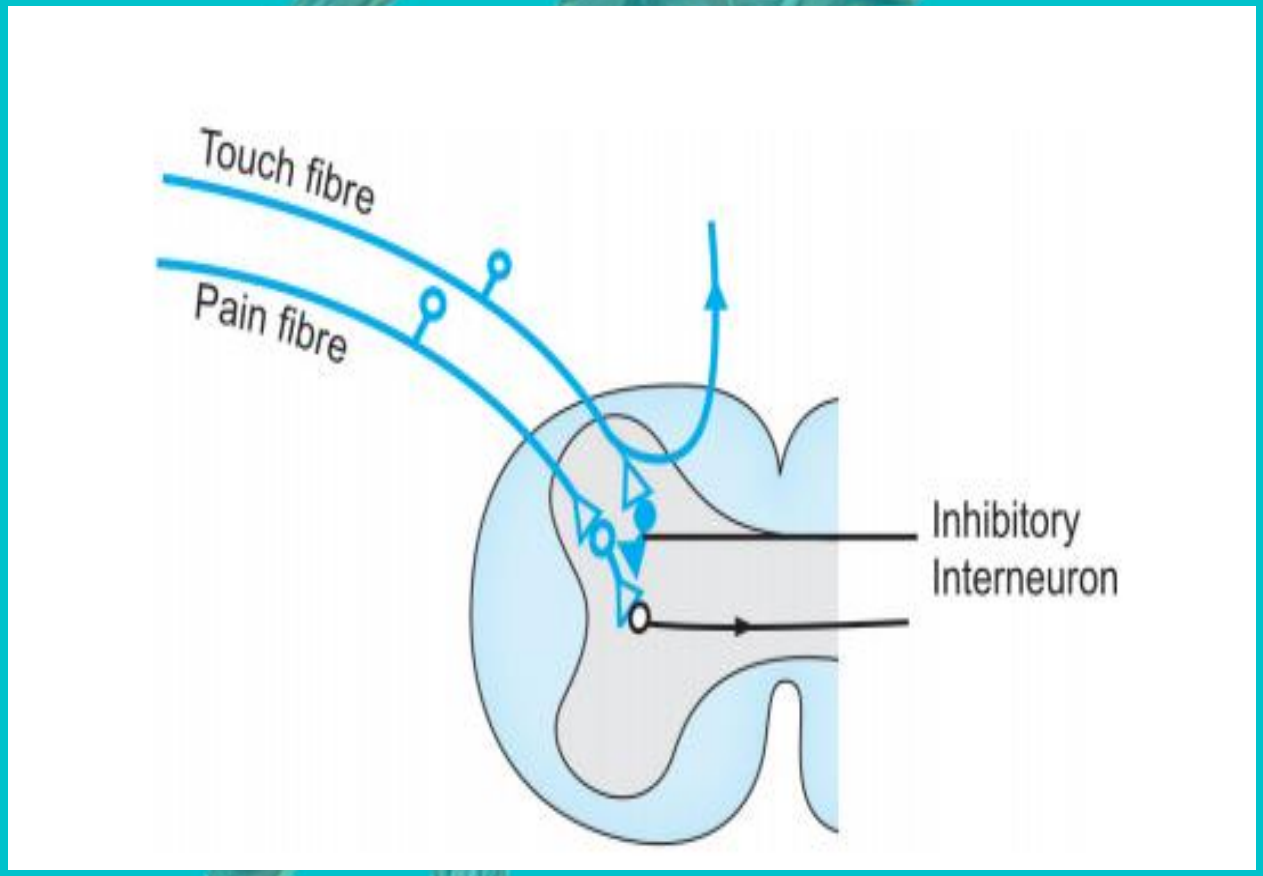


Figure 104.7: Endogenous neural analgesia system.

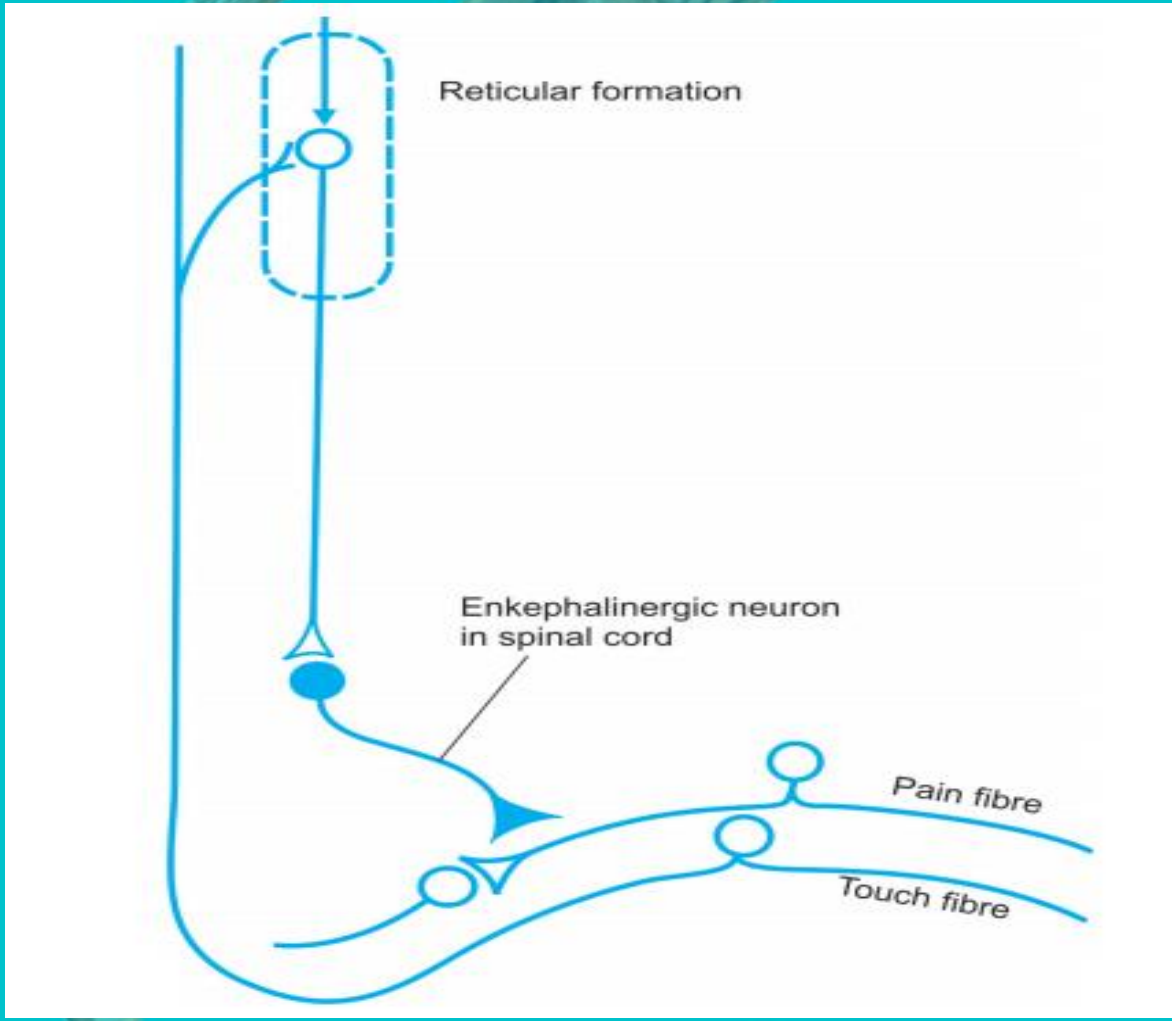
Gate control theory of pain

- According to this,pain can be modulated by the peripheral mechanisms, especially by gating the impulses in the spinal cord.
- Collaterals from large myelinated afferent fibers associated with tactile sensation produce presynaptic inhibition in dorsal horn of spinal cord.
- Thus activity in large afferent fibers regulate (act as gate)transmission of impulse originating in pain receptors.
- Eg: acupuncture, balm

Gate control mechanism

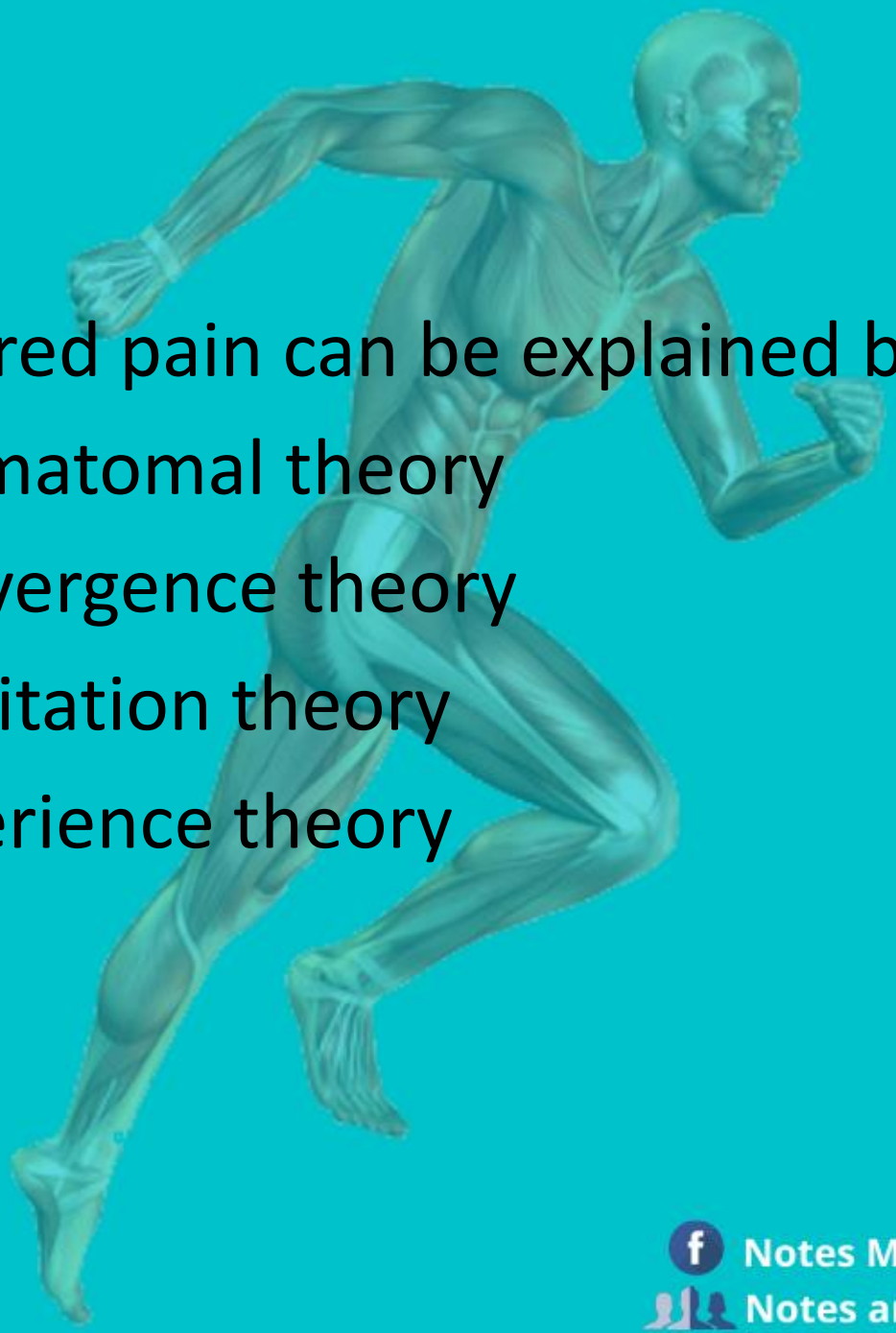


Gate control theory revisited



Referred pain

- The pain perceived in somatic structure due to visceral irritation or injury is called referred pain.
- The visceral pain is not referred to the skin overlying the viscera, but to the other areas of the skin innervated by the same embryonic spinal segment.
- Example: in acute myocardial infarction, pain is referred to the inner aspects of the left arm.
- Acute cholecystitis pain is referred to right shoulder.

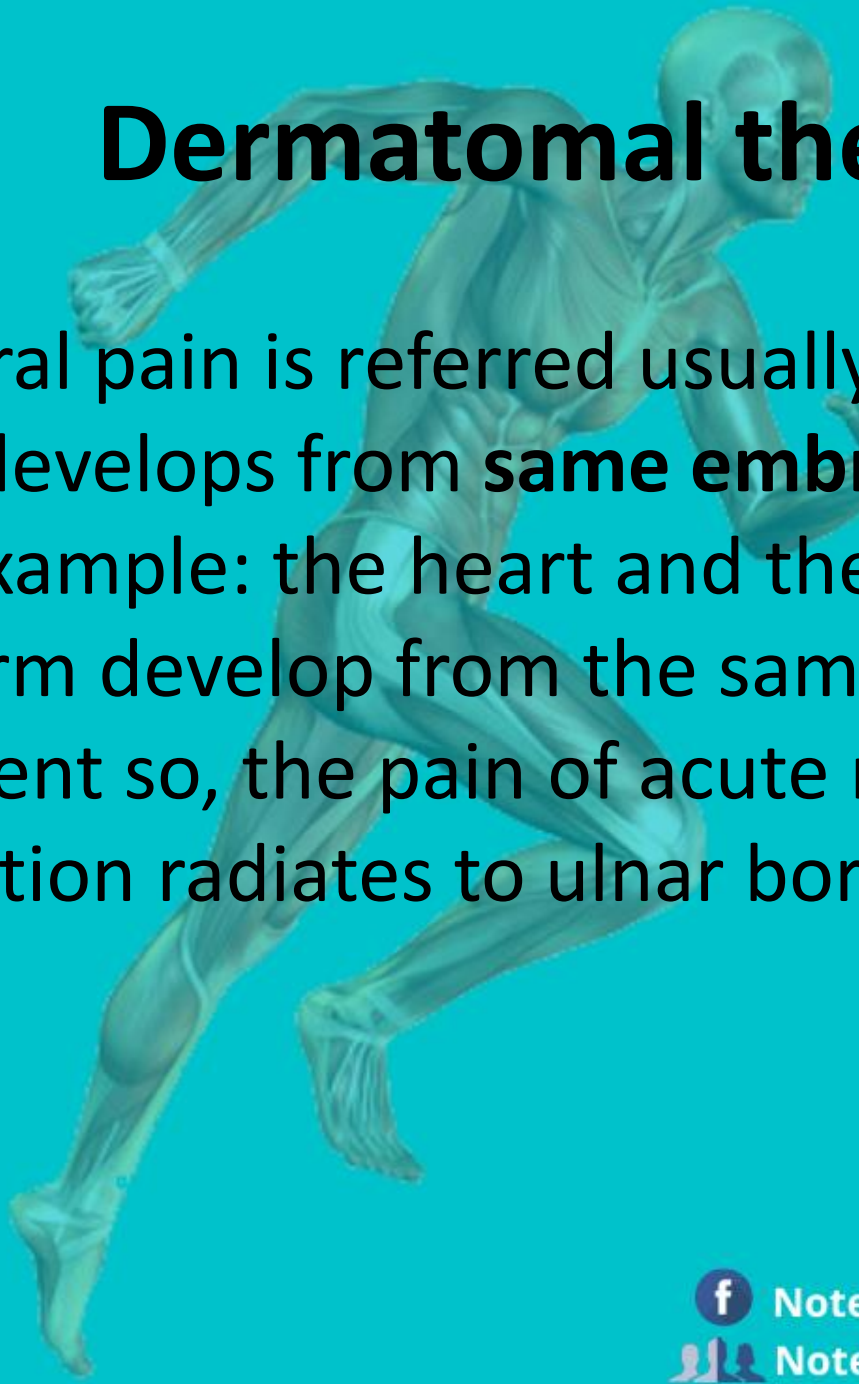


- Referred pain can be explained by following:

a. Dermatomal theory
b. Convergence theory
c. Facilitation theory
d. Experience theory

Dermatomal theory

Visceral pain is referred usually to a structure that develops from **same embryonic segment**. For example: the heart and the inner aspect of the arm develop from the same embryonic segment so, the pain of acute myocardial infarction radiates to ulnar border of the left arm.



Convergence theory

The visceral and the somatic afferent fibers converge on the **second order of neuron in the spinothalamic** tract i.e. the fibers carrying the pain sensation from the somatic structures also carry the pain from the visceral structures.

The cortex sometimes can’t differentiate the site of origin so signal conveyed by brain for perception is also referred to the somatic area in addition to the projection to the viscera.

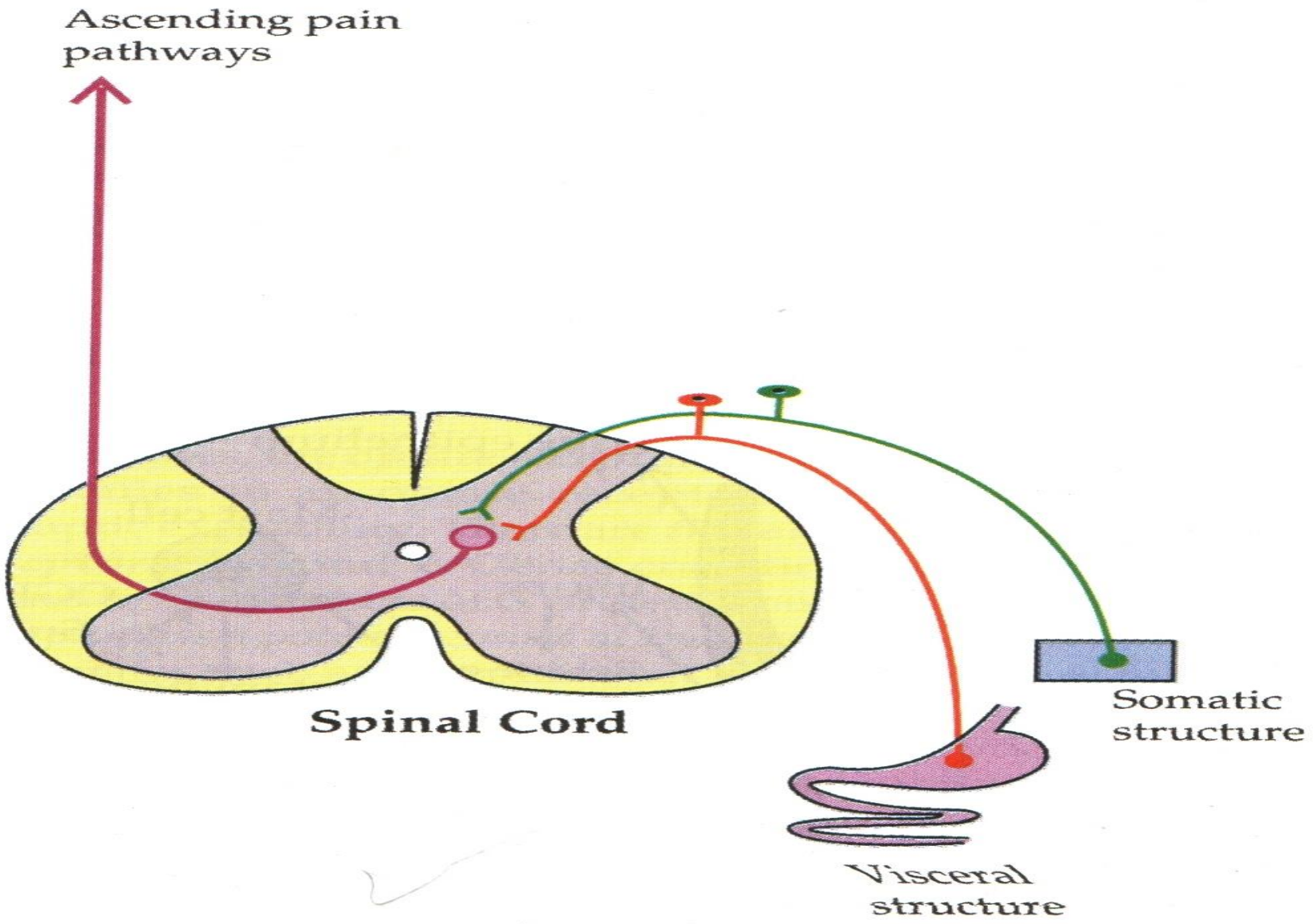


Figure 104.4: Convergence theory of referred pain. Note, due to convergence of fibers from somatic and visceral structures on a single second order neuron, fibers transmitting pain sensation from the somatic structure also carry the pain sensation arising from the visceral structures.

Facilitation theory

- The collaterals arising from the visceral afferent fibers project to the spinothalamic neurons that receive afferents from somatic structures.
- So, the pain sensation arising from somatic structure is facilitate (strengthened) by the activity in visceral afferent. Thus, minor activity in the somatic afferent can cause pain.

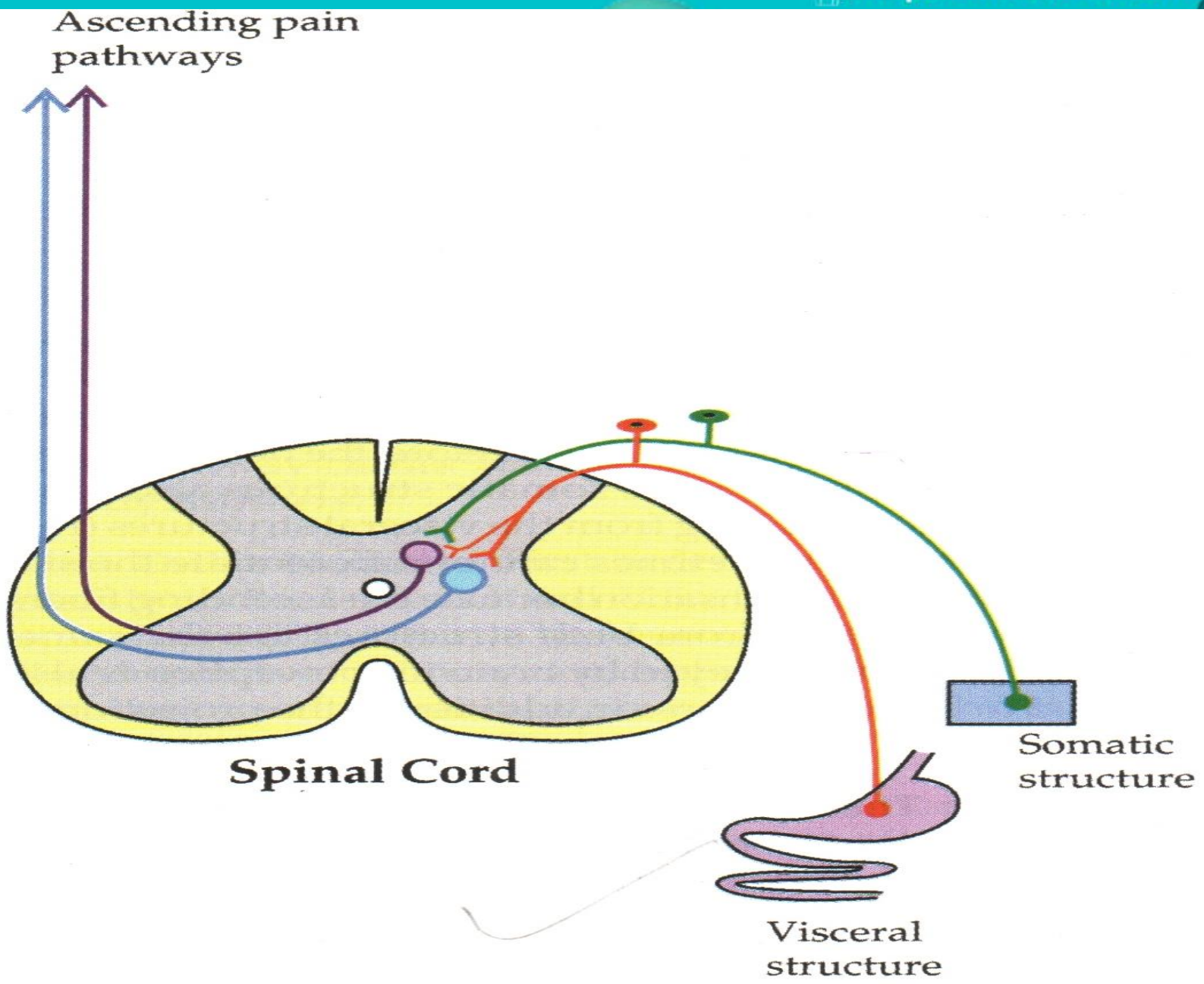
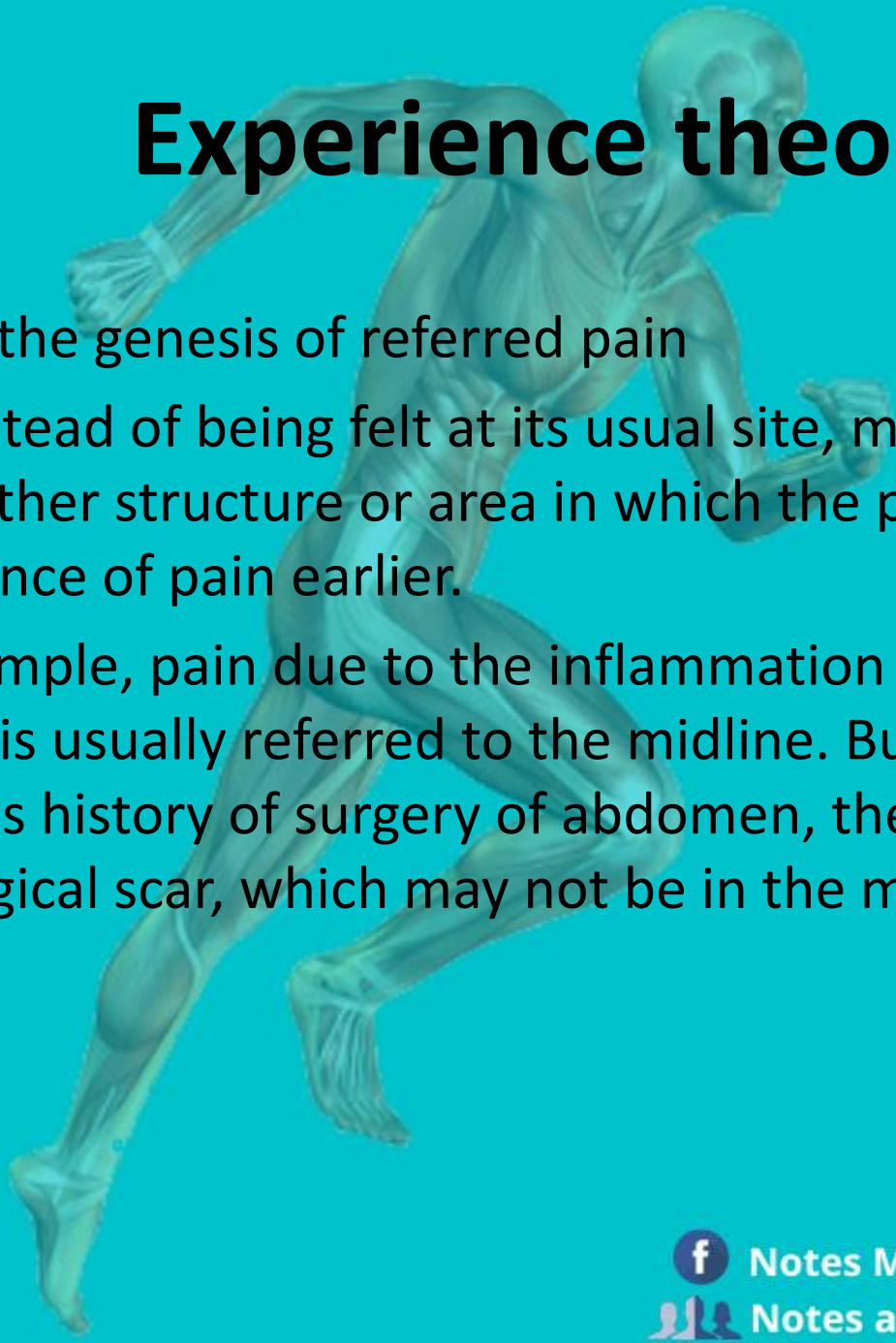


Figure 104.5: Facilitation theory of referred pain.

Experience theory



- Role in the genesis of referred pain
- Pain instead of being felt at its usual site, may be referred to some other structure or area in which the patient had experience of pain earlier.
- For example, pain due to the inflammation of abdomen viscera is usually referred to the midline. But, in patients with previous history of surgery of abdomen, the pain is referred to the surgical scar, which may not be in the midline

Clinical abnormalities of pain

- **Hyperalgesia**: increased sensitivity and lowered threshold to painful stimuli. Inflammation of skin is main cause.
- **Hypoalgesia/** Hypalgesia: decreased sensitivity and raised threshold to painful stimuli.
- **Analgesia**: Complete loss of pain sensation.It may not be associated with loss of other sensations.
- **Hyperpathia**: defect in pain perception i.e.associated with an increased reaction to the pain stimulus once it is perceived. Or, it is the exaggerated response to pain. In this condition there is also an increased reaction to other stimuli.

- **Allodynia**: This is a state in which there is excessive response to even mild stimuli. For example, a stimulus like light touch which is never painful, elicits pain in allodynia.
- **Herpes Zoster infection**:

➢ It is a type of neuropathic pain

➢ Injury to the nerves result this type of pain.

➢ Herpesvirus infects a dorsal root ganglion, causes pain in the dermatomal segment served by the ganglion.

Tic douloureux: it is also known as trigeminal neuralgia. The lancinating pain occurs in some people on the sensory distribution area of V or IX cranial nerve.

- **Causalgia**
  - Burning pain that usually develops following a **traumatic peripheral nerve injury**
- **Inflammatory Pain**
- **Neuropathic Pain**