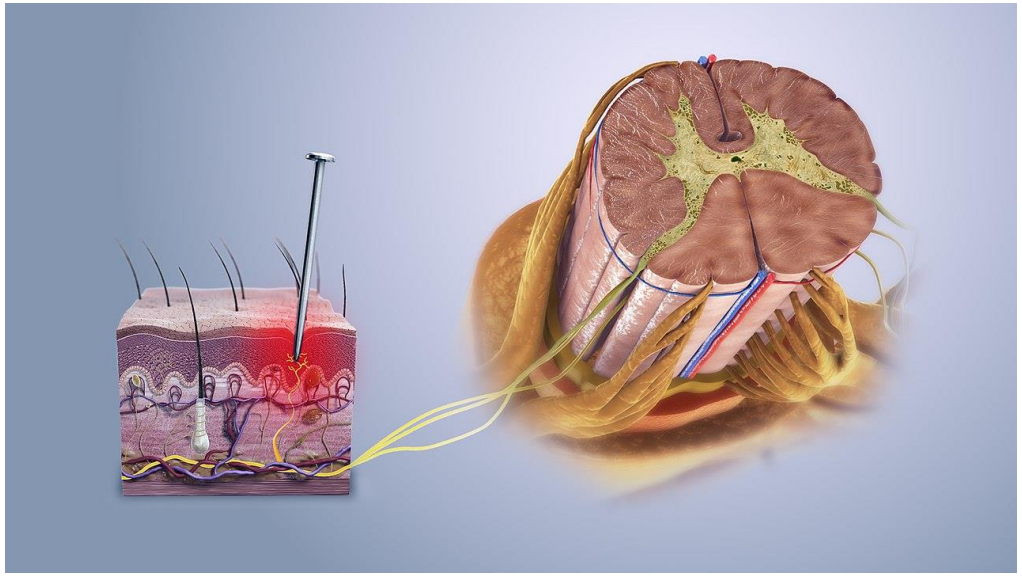
# Pain theory



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# Pain theory

- **SomaticTheory**

**Somatic theory** is a theory of human social behavior based loosely on the somatic marker hypothesis of António Damásio, which proposes a mechanism by which emotional processes can guide behavior, particularly decision-making.

- **Diathesis-Stress"**

Theory that mental and physical disorders develop from a genetic or biological predisposition for that illness (**diathesis**) combined with **stressful** conditions that play a precipitating or facilitating role.

The **diathesis–stress model** is a psychological theory that attempts to explain a disorder, or its trajectory, as the result of an interaction between a predispositional vulnerability and a **stress** caused by life experiences.

- **Gate Theory**

# Gate Theory Explains Pain Variations

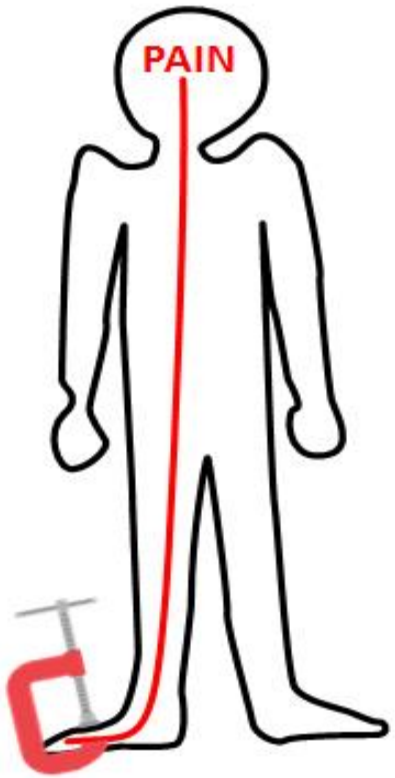
- In an effort to improve scientific understanding, the Gate Control Theory of pain was advanced by psychologist **Ronald Melzack** and biologist **Patrick Wall** in 1965.
- Although the theory has gone through some critiques and modifications to take into account new findings, its heuristic value has held up to this day.

# How Gate Control Works

- Following an injury, pain signals are transmitted to the spinal cord and then up to the brain.
- Melzack and Wall suggest that before the information is transmitted to the brain, the pain messages encounter "nerve gates" that control whether these signals are allowed to pass through to the brain.
- In some cases, the signals are passed along more readily and pain is experienced more intensely. In other instances, pain messages are minimized or even prevented from reaching the brain at all.

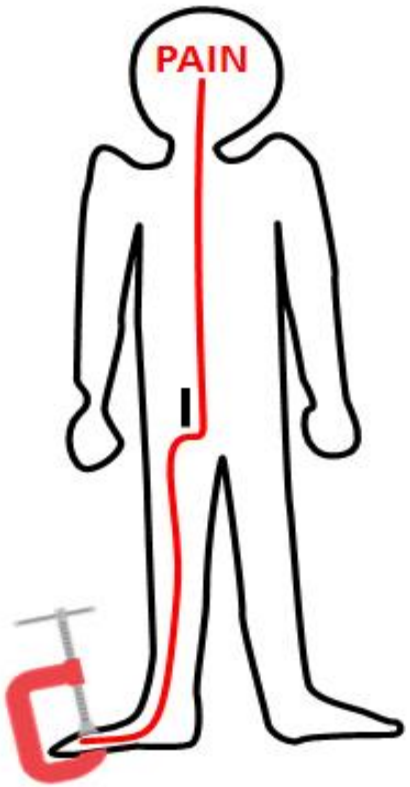
# Changing Paradigms

**Descartes**

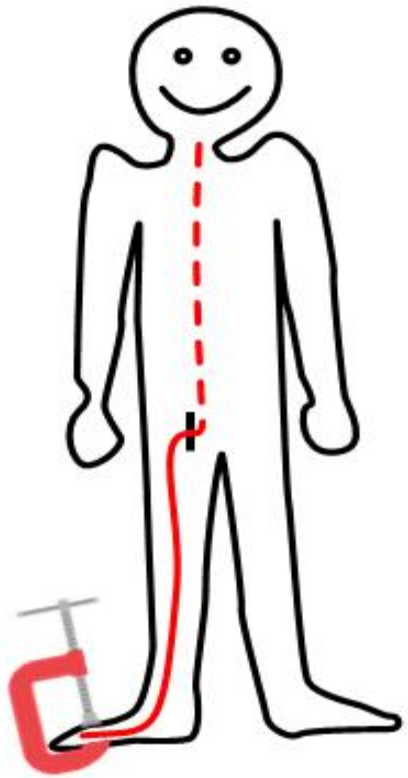



A direct connection

**Gate Control Theory**



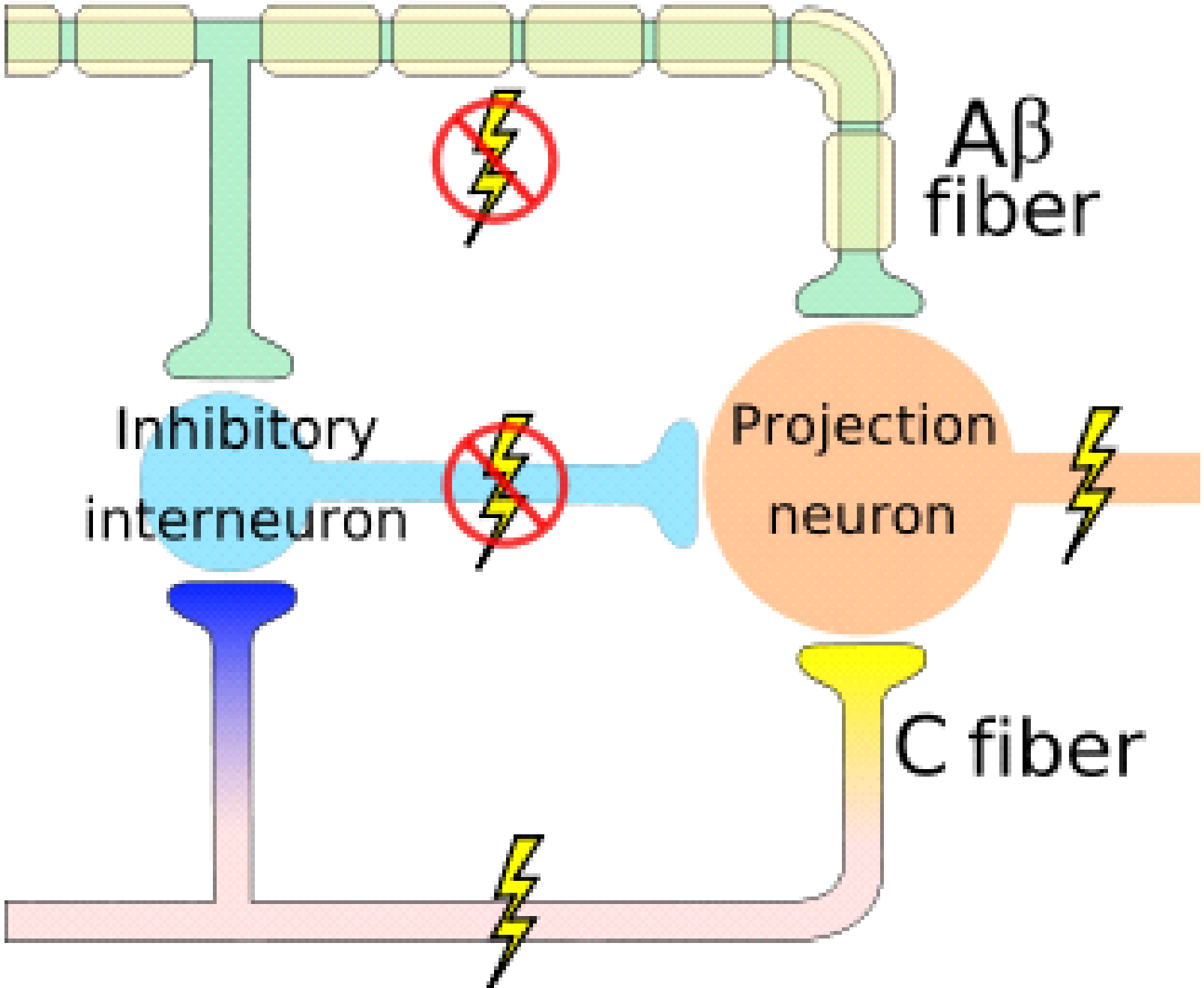

Gate open



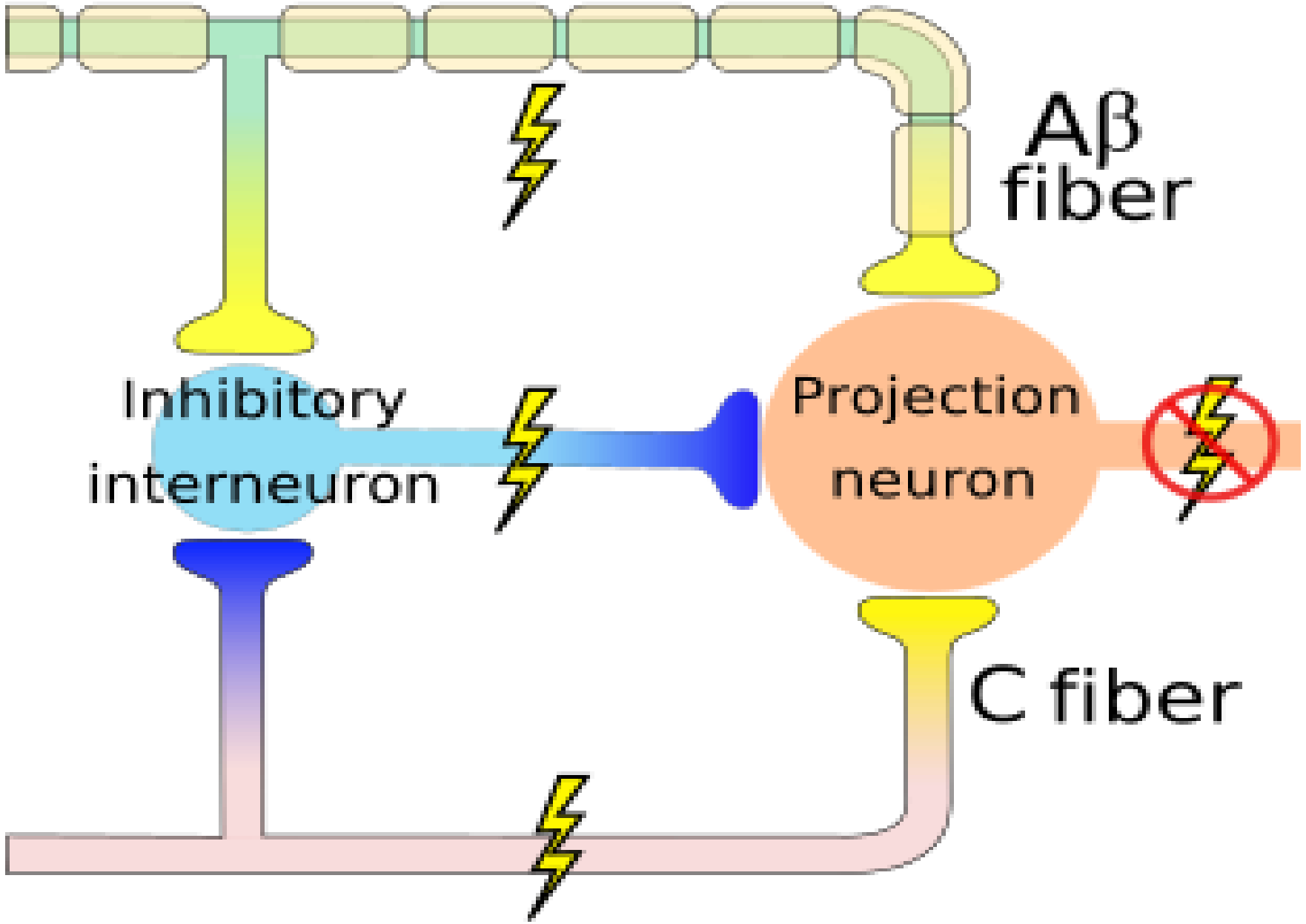
Gate closed

# The gate control theory

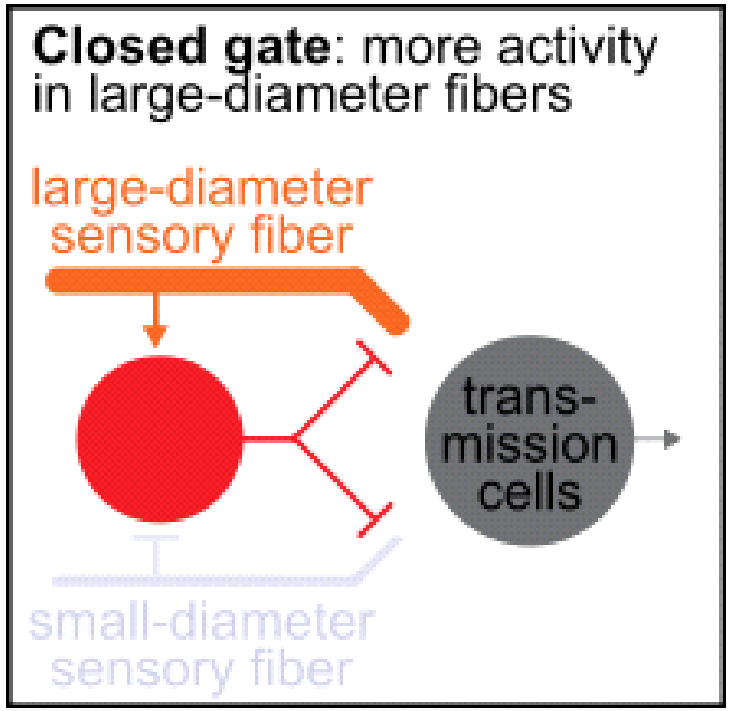
- The gate control theory of pain asserts that non-painful input closes the nerve "gates" to painful input, which prevents pain sensation from traveling to the central nervous system.
- Gate Control Theory of Pain describes how non-painful sensations can override and reduce painful sensations.

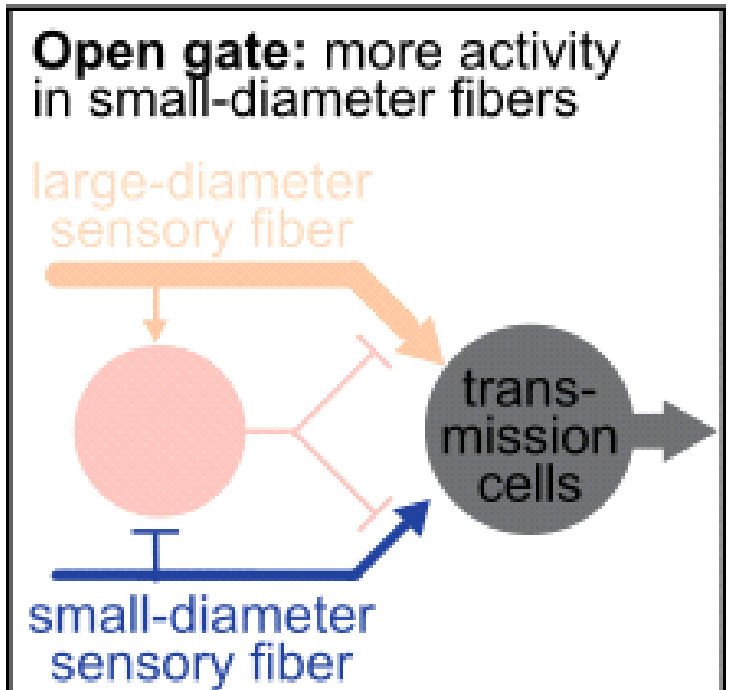



The firing of the projection neuron determines pain.
The inhibitory interneuron decreases the chances that the projection neuron will fire.
Firing of C fibers inhibits the inhibitory interneuron (indirectly), increasing the chances that the projection neuron will fire.
Inhibition is represented in blue, and excitation in yellow..




Firing of the Aβ fibers activates the inhibitory interneuron, reducing the chances that the projection neuron will fire, even in the presence of a firing nociceptive fiber

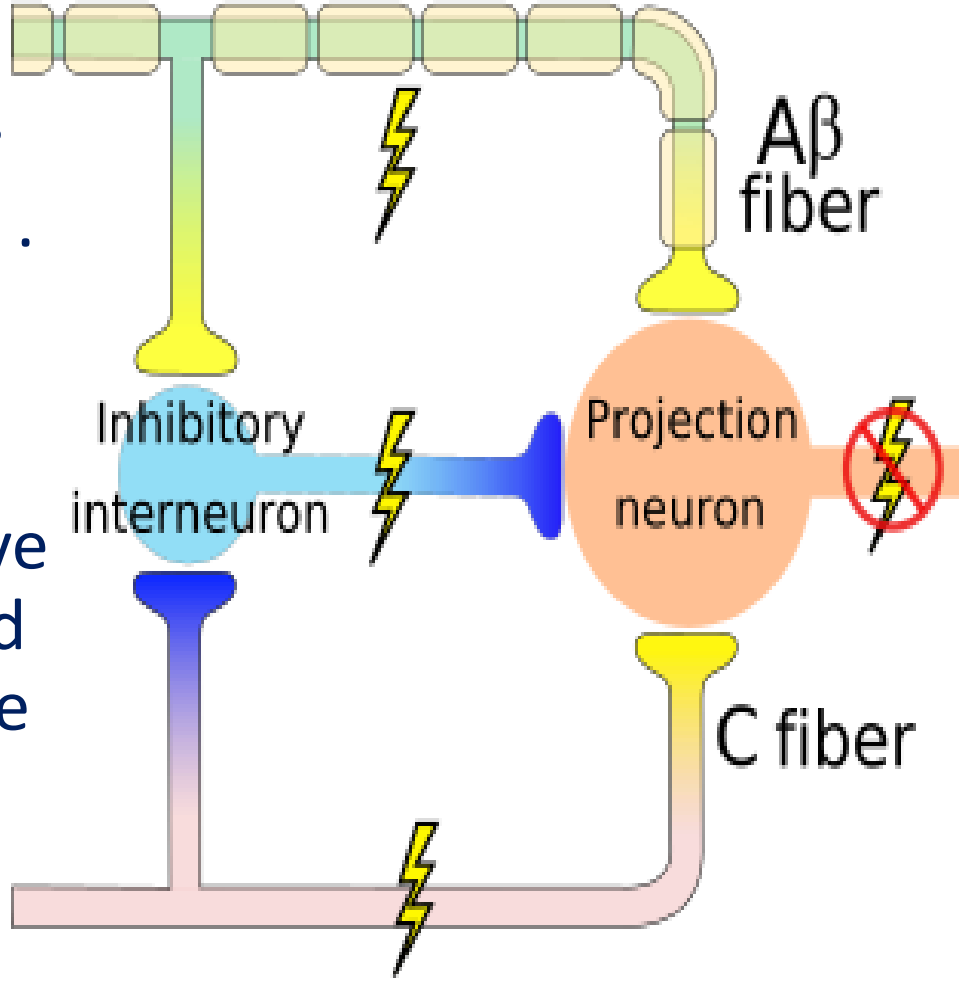

**Closed gate**: more activity in large-diameter fibers
large-diameter sensory fiber
trans-mission cells
small-diameter sensory fiber


**Open gate:** more activity in small-diameter fibers
large-diameter sensory fiber
trans-mission cells
small-diameter sensory fiber

# There are 3 factors which influence the 'opening and closing' of the gate

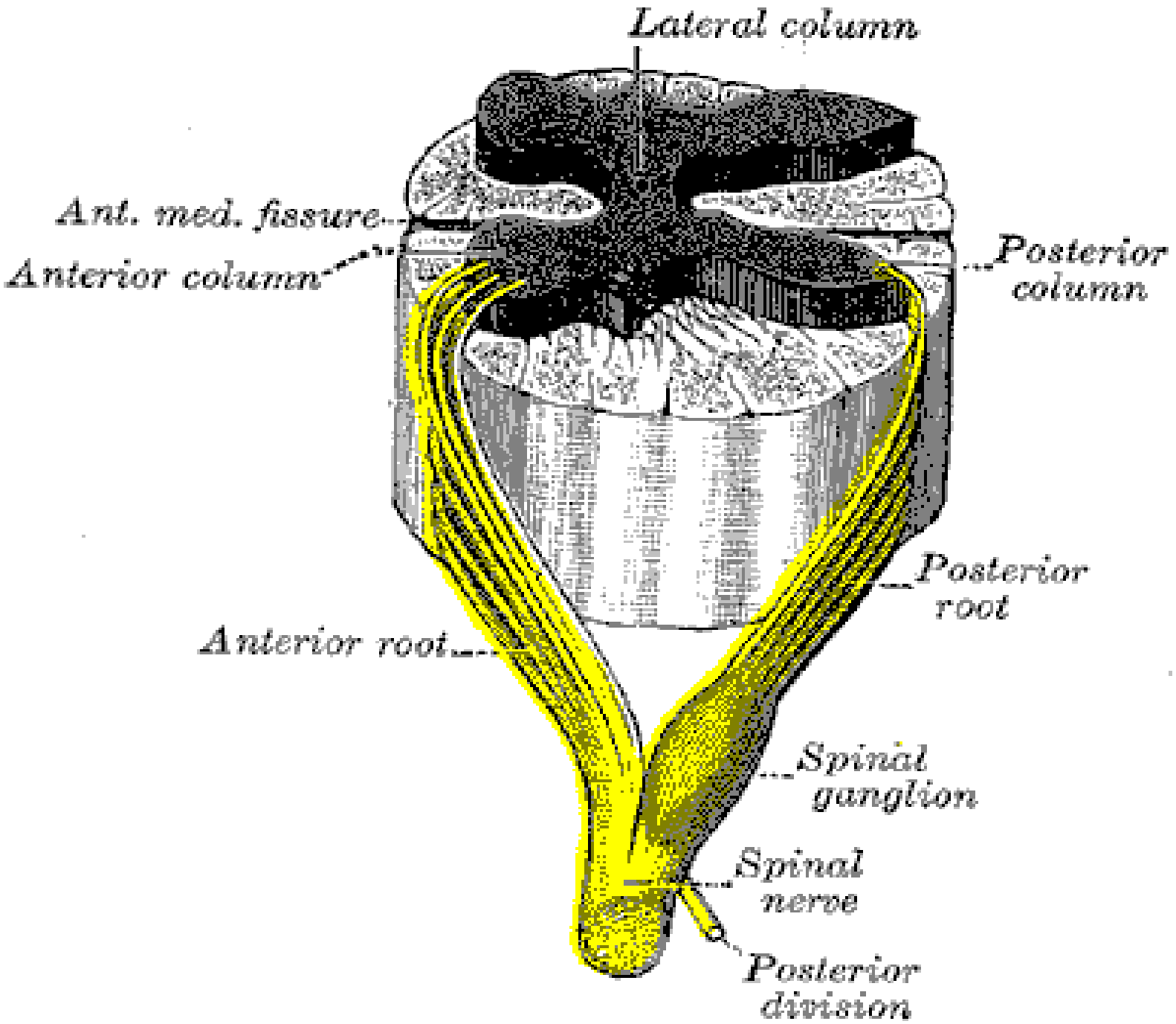
- The amount of activity in the pain fibers.
- The amount of activity in large-diameter .
- Messages that descend from the brain.

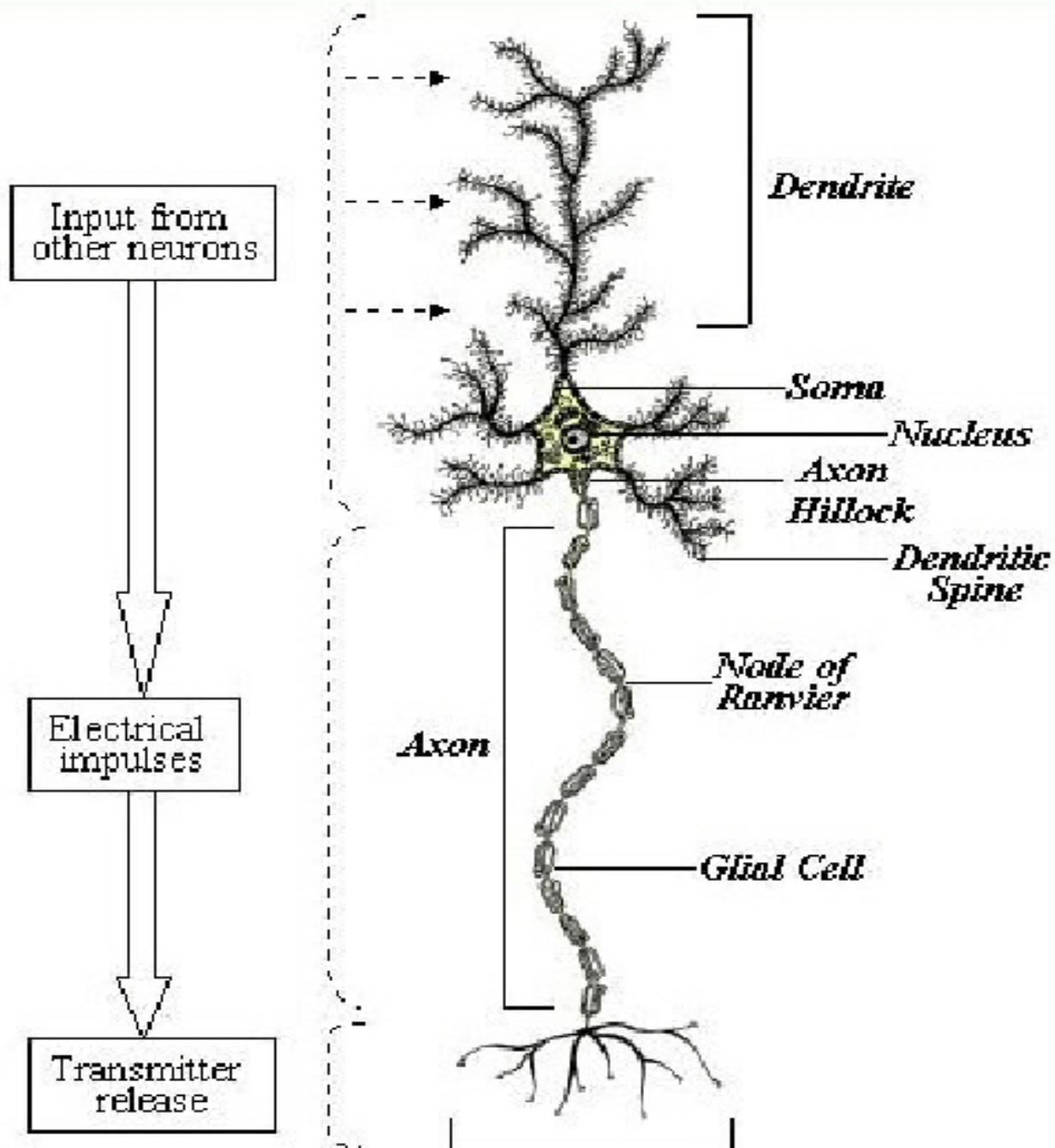
Neurons in the brainstem and cortex have efferent pathways to the spinal cord, and the impulses they send can open or close the gate.



# Note

- A-delta (fast myelinated)
- C-fibers (slow unmyelinated)

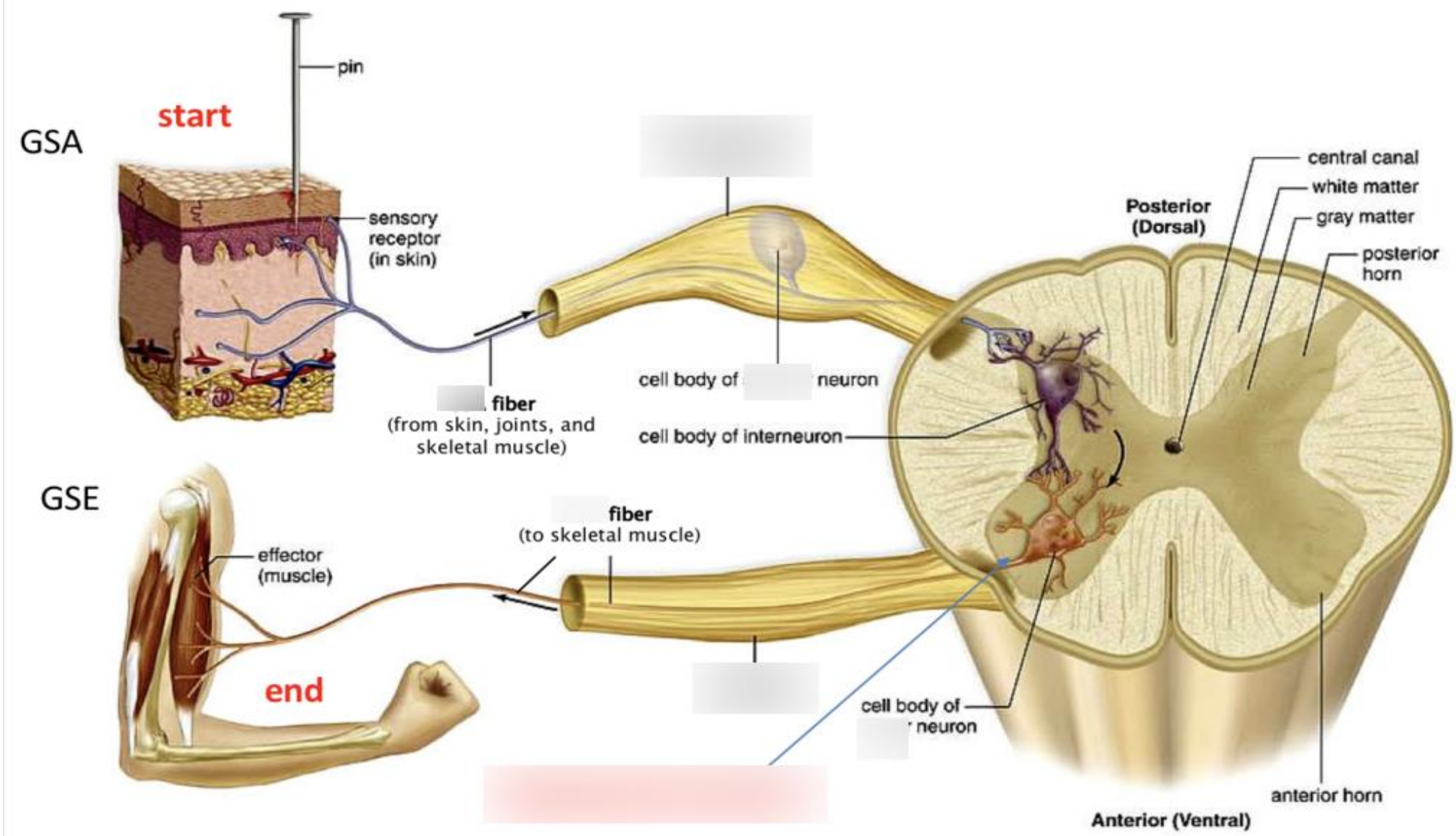

Lateral column
Ant. med. fissure
Anterior column
Posterior column
Posterior root
Anterior root
Spinal ganglion
Spinal nerve
Posterior division

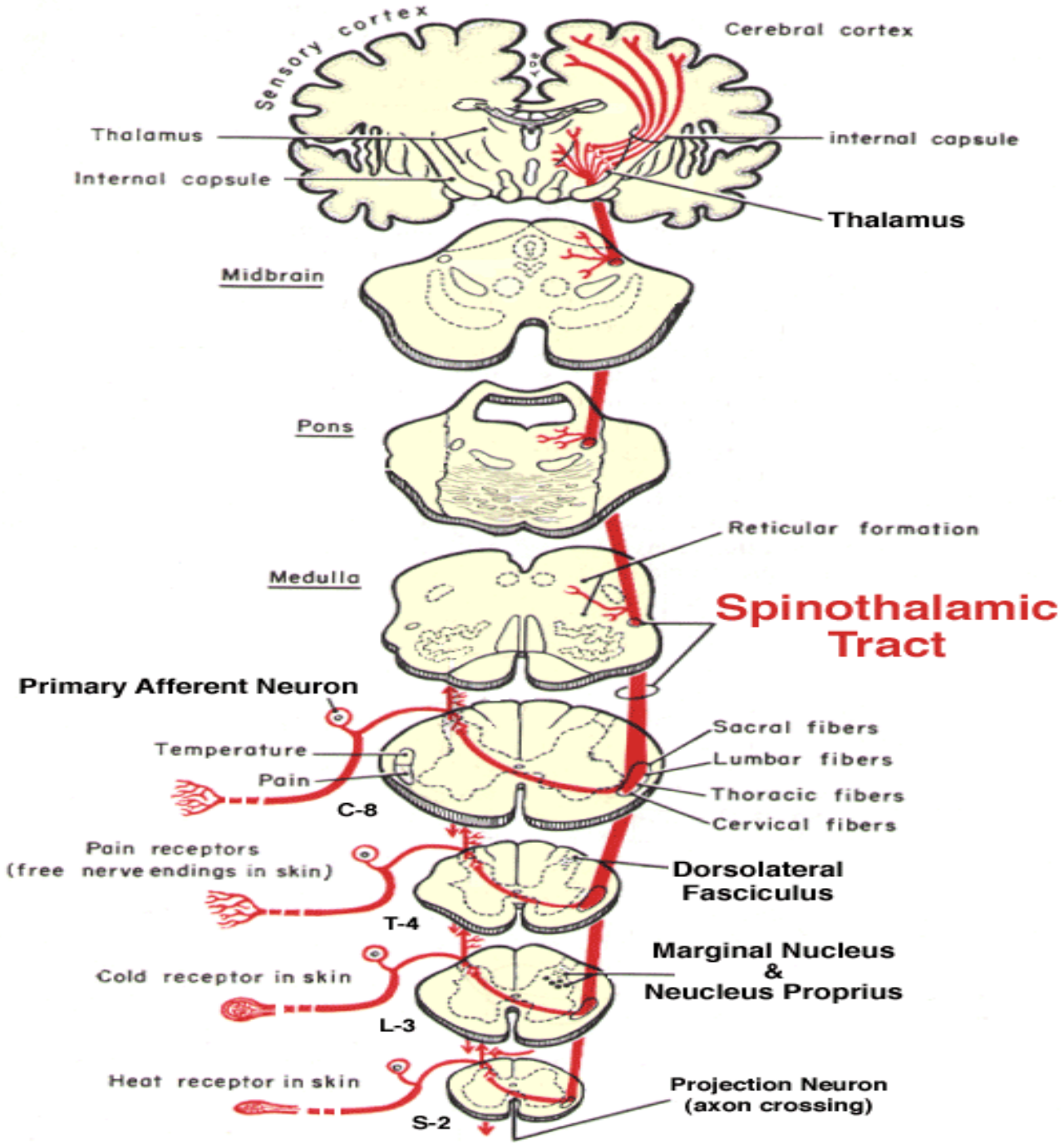

Input from other neurons
Electrical impulses
Transmitter release
Dendrite
Soma
Nucleus
Axon Hillock
Dendritic Spine
Node of Ranvier
Axon
Glial Cell

# Interneuron

- The grey column of the spinal cord appears to have groups of small neurons, often referred to as spinal interneurons, that are neither primary sensory cells nor motor neurons.
- The sensory information that is transmitted to the spinal cord is modulated by a complex network of excitatory and inhibitory interneurons.
- Different neurotransmitters are released from different interneurons, but the two most common neurotransmitters are GABA, the primary inhibitory neurotransmitter and glutamate, the primary excitatory neurotransmitter.
- Acetylcholine is a neurotransmitter that often activates interneurons by binding to a receptor on the membrane.

# Sharp pain (Acute pain )

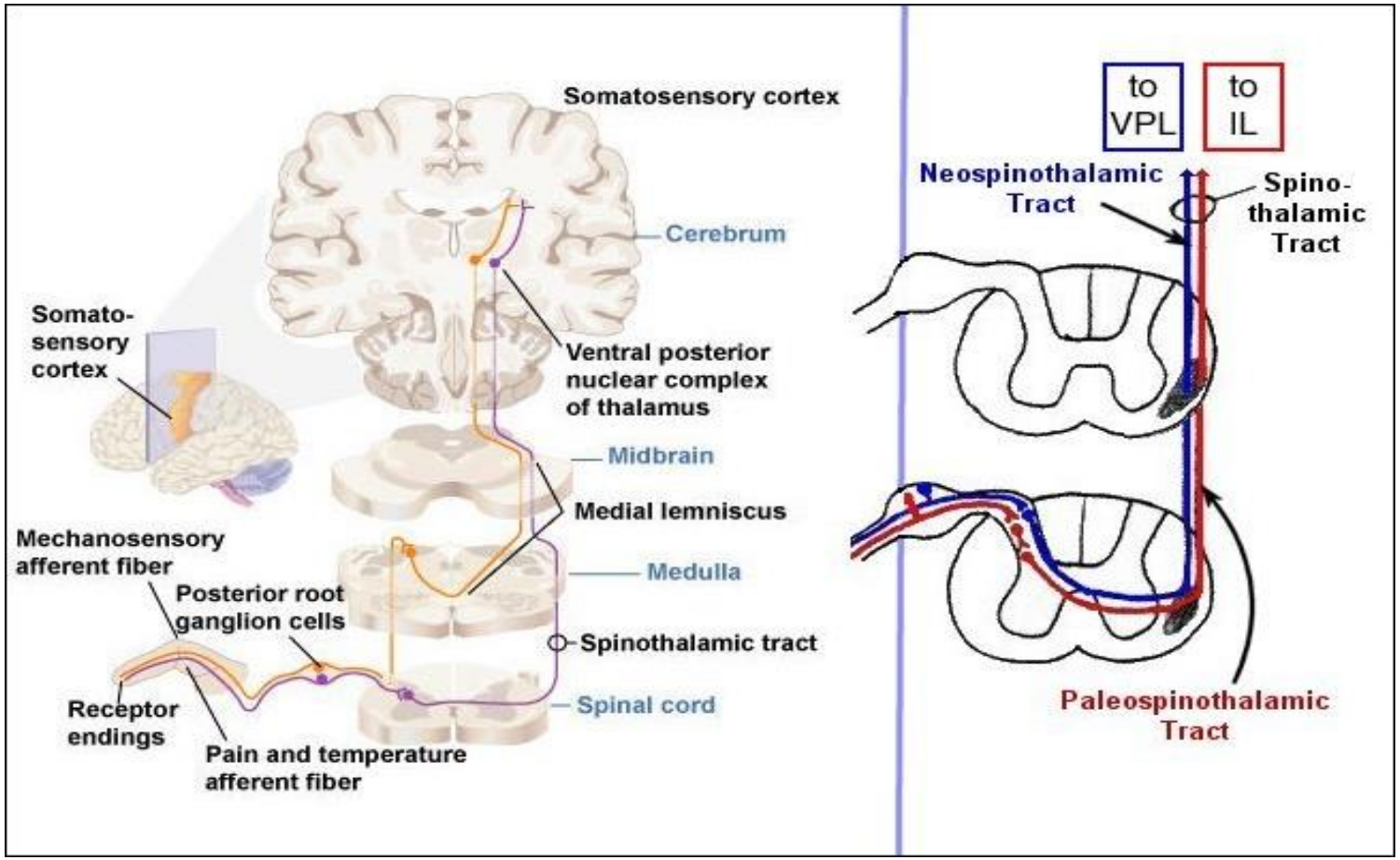





Pain and Temperature receptors are mainly free nerve endings. Axons of the **primary afferent neurons** are nonmyelinated (C-fibers) or thin myelinated axons (A-delta fibers) that bifurcate in the **dorsolateral fasciculus**.

Throughout the length of the spinal cord, projection neurons are concentrated in the **marginal nucleus** and **nucleus proprius** of the dorsal horn. Axons of the projection neurons decussate (cross) and ascend in the **spinothalamic tract** to reach the contralateral thalamus.

Thalamic projection neurons send axons through the internal capsule to the some sthetic area of the cerebral cortex.




**There are two well-defined spinothalamic pathways, chiefly concerned with pain and *temperature* sensations and with crude touch.:**

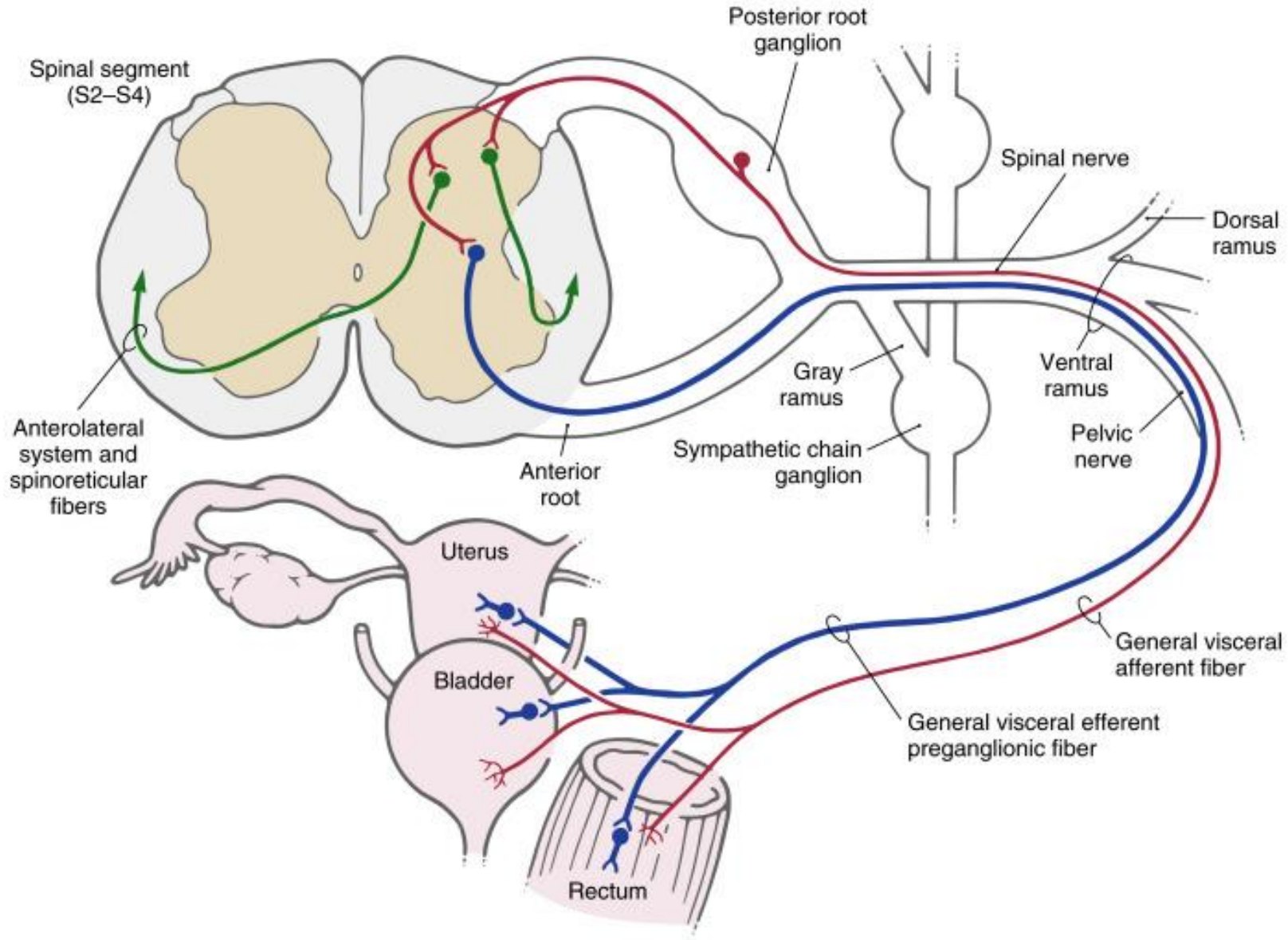
**1-The "fast" conducting neospinothalamic pathway is involved in conveying the "sharp/cutting" pain elicited at the time tissue is damaged.**

**2-The "slower" conducting paleospinothalamic pathway is involved in conveying the "dull/burning" pain that accompanies the later inflammatory reaction in the damaged tissue as well as temperature and crude touch information.**

**Both acute and chronic  pain messages use the same routes through the spinal cord, but their paths diverge in the brain.**

- Acute pain messages are sent to the brain's cortex.
- Chronic  messages go to the parts of the brain that release stress hormones and handle emotions, the hypothalamus and the limbic system.
- The pathway of these chronic messages is one factor in the role of stress, depression, and anxiety in chronic pain.te

# Visceral nerves

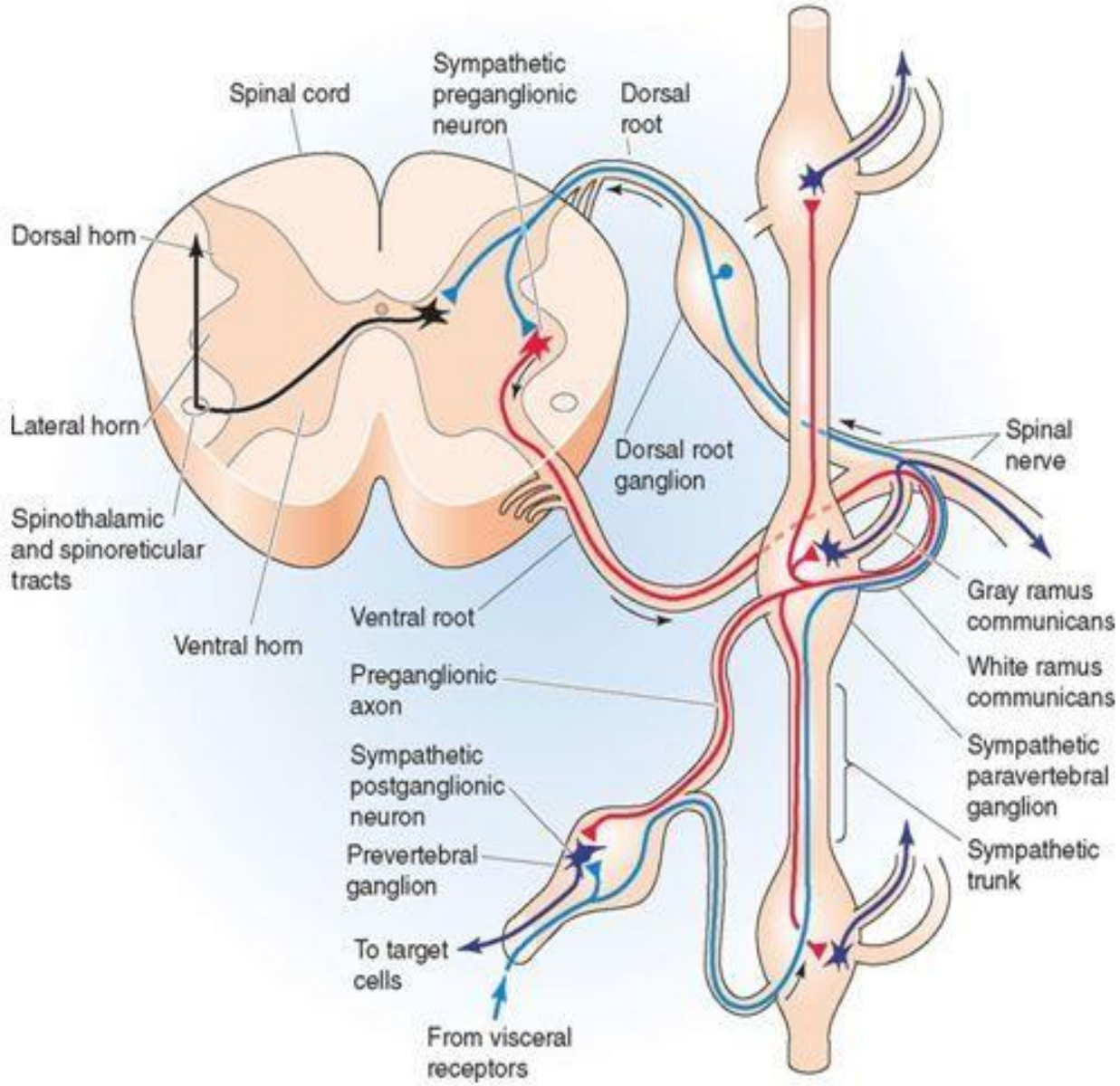


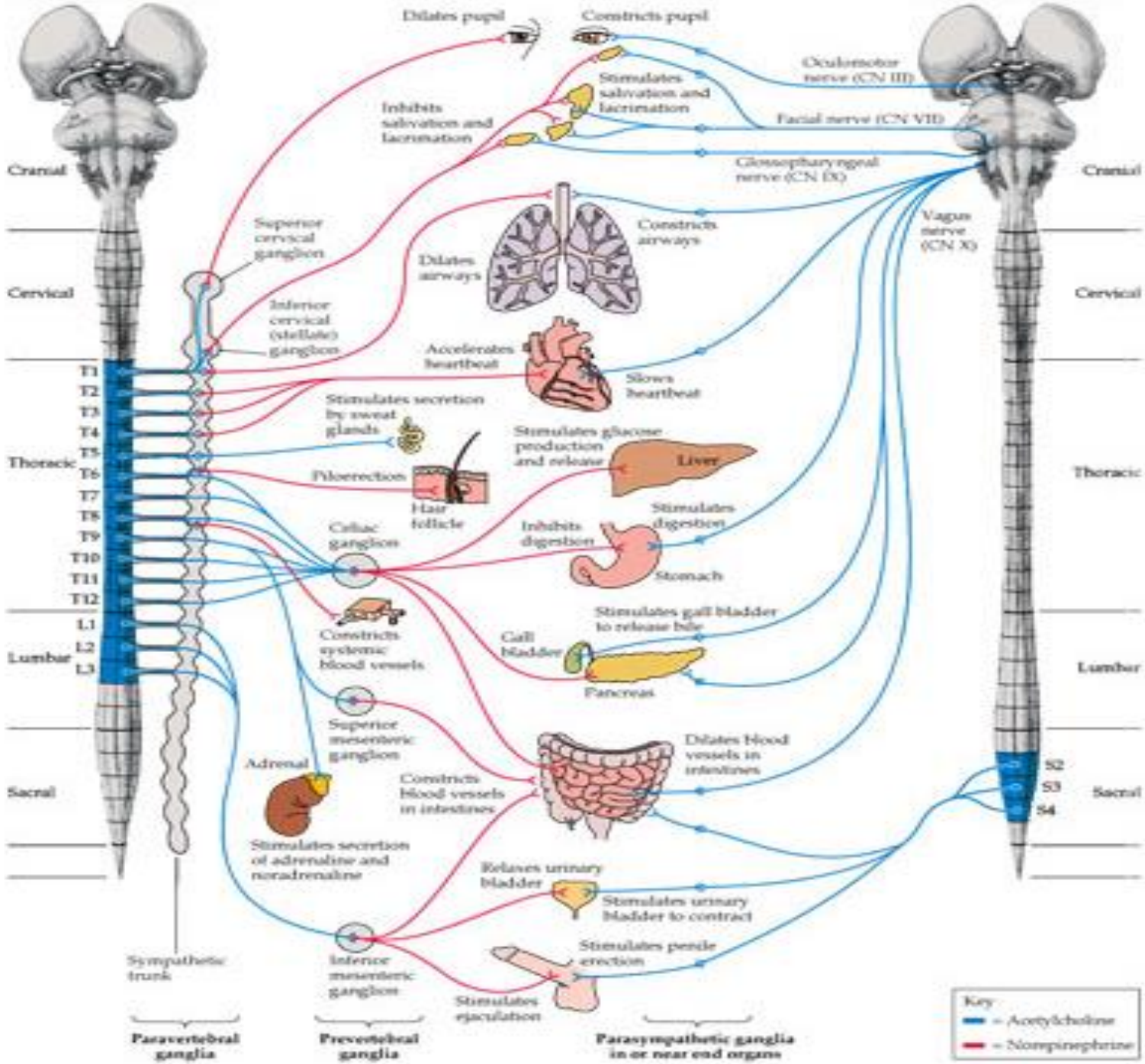
# Visceral Afferents

- Internal organs are densely innervated by visceral **afferents**. These receptors monitors either nociceptive (painful) input or sensitive to mechanical and chemical stimuli (stretch of the heart, blood vessels, and hollow viscera, and changes in $PCO_2$, $PO_2$, pH, blood glucose, temperature of skin and internal organs)

- Most of the visceral nociceptive fibers travel with sympathetic nerves, while axons from physiological receptors travel with parasympathetic fibers.

- The visceral afferent axons are mainly concentrated in the vagus nerve, which carries non-nociceptive afferent input from the viscera of thorax and abdomen to the CNS.
  - The cell bodies of vagal afferents are located in the nodose ganglion of medulla.




Dilates pupil
Constricts pupil
Oculomotor nerve (CN III)
Stimulates salivation and lacrimation
Inhibits salivation and lacrimation
Facial nerve (CN VII)
Glossopharyngeal nerve (CN IX)
Cranial
Vagus nerve (CN X)
Superior cervical ganglion
Constricts airways
Dilates airways
Cervical
Inferior cervical (stellate) ganglion
Accelerates heartbeat
Slows heartbeat
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Thoracic
Stimulates secretion by sweat glands
Stimulates glucose production and release
Liver
Piloerection
Hair follicle
Stimulates digestion
Inhibits digestion
Celiac ganglion
Stomach
L1
L2
L3
Lumbar
Constricts systemic blood vessels
Stimulates gall bladder to release bile
Gall bladder
Pancreas
Superior mesenteric ganglion
Dilates blood vessels in intestines
Adrenal
Constricts blood vessels in intestines
S2
S3
S4
Sacral
Stimulates secretion of adrenaline and noradrenaline
Relaxes urinary bladder
Stimulates urinary bladder to contract
Stimulates penile erection
Sympathetic trunk
Inferior mesenteric ganglion
Stimulates ejaculation
Paravertebral ganglia
Prevertebral ganglia
Parasympathetic ganglia in or near end organs
Key
– Acetylcholine
– Norepinephrine

# Messages that descend from the brain.

- Cognitive factors include focusing on the pain, a lack of outside or pleasurable interests, worrying about the pain, and focusing on bad things associated with the pain.
- Emotional factors include depression, anger, anxiety, stress, frustration, hopelessness, and helplessness.

# Chronic pain

- **Chronic pain** is defined as **pain** that lasts at least 12 weeks.
- The **pain** may feel sharp or dull, causing a burning or aching sensation in the affected areas.
- It may be steady or intermittent, coming and going without any apparent reason.
- **Chronic pain** can occur in nearly any part of body.

# Pain Signals Travel at Different Speeds

- **Acute pain signals,** are crucial to protecting the body from injury. These nerve fibers send a quick message if a person touches something sharp, for instance.
- This type of pain is sometimes called "warning pain." While these signals are felt quickly, they generally don't last long.
- **Chronic pain messages** move more slowly along and the pain last longer.
- It is often described as aching, dull, cramping, burning, or nagging pain.
- This type of pain—called “reminder pain” for its role in ensuring that the brain is aware of them.
- It is the type of pain that can continue after the injury heals.

# Nerve Supply of the Pelvis

Pain in the pelvic region belong to the :

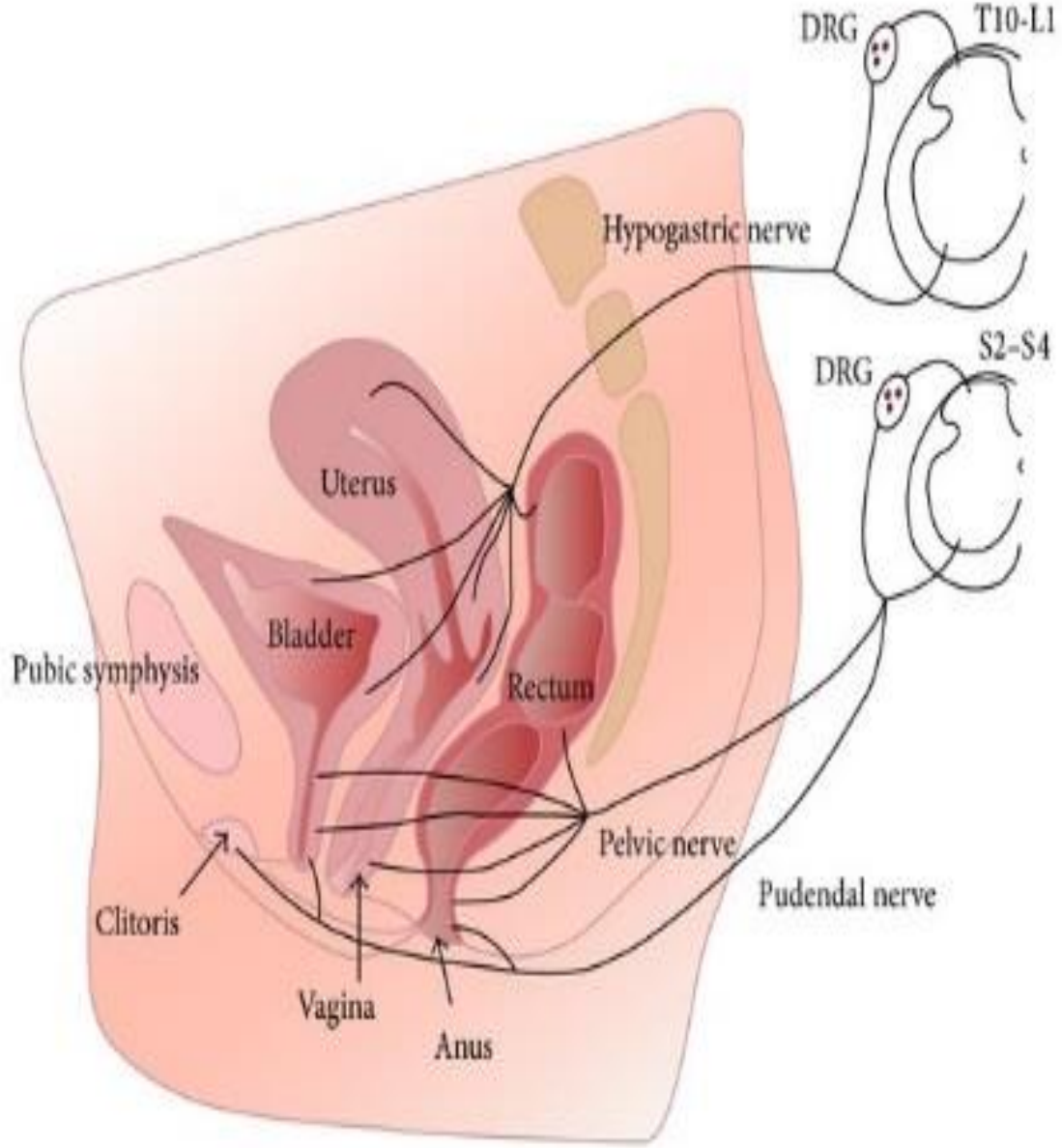
1. Urinary
2. Reproductive
3. Gastrointestinal

And to their associated blood and lymphatic vessels.

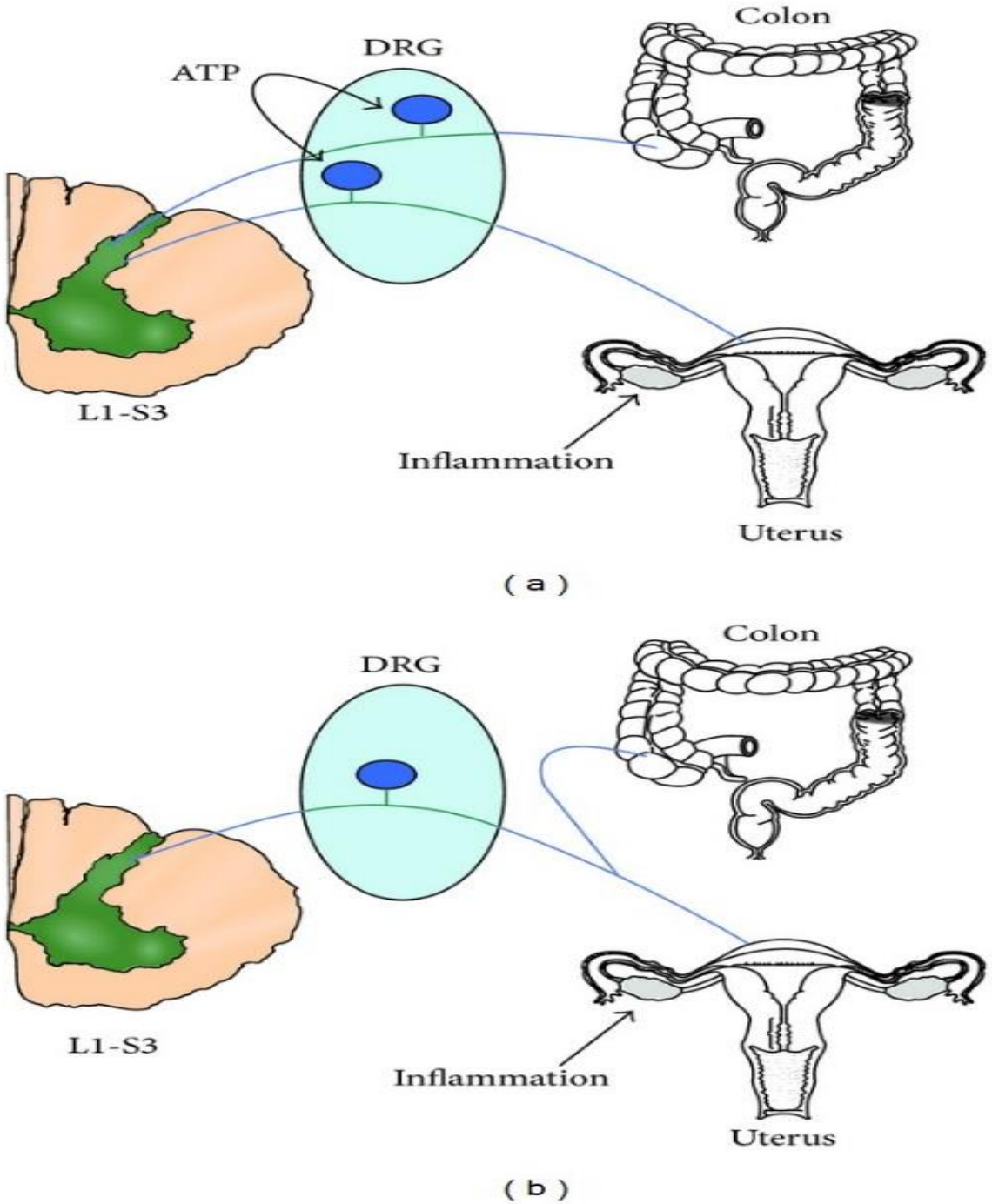
These structures, innervated by the :
Somatic (T12-S5) and
Visceral (T10-S5) nervous system, create a complex anatomical and neurobiological network .

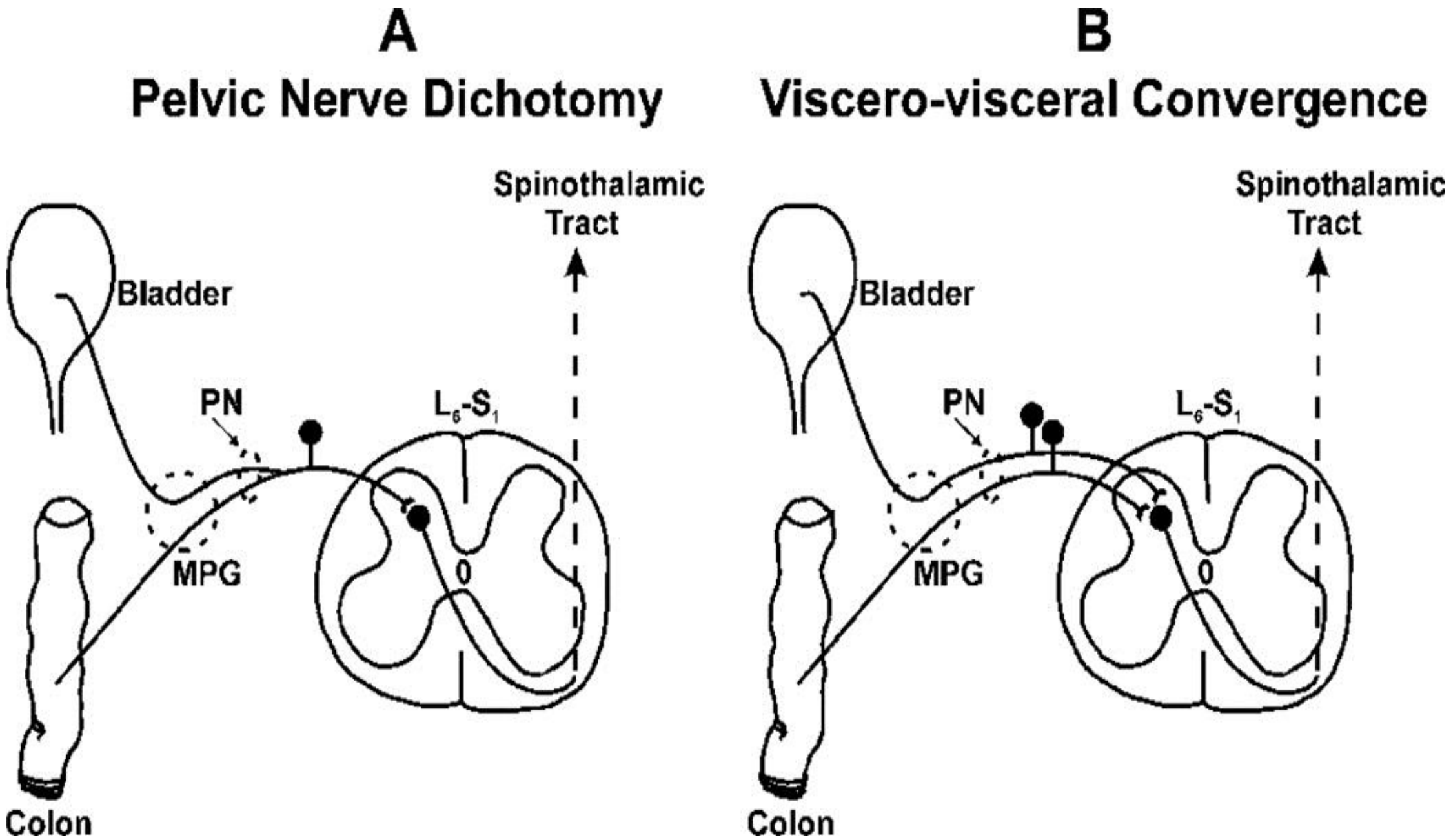
# Innervation of pelvic organs

- Innervation of pelvic organs. Sensory axons innervating the vagina reach the spinal cord via pelvic nerves and terminate in sacral spinal cord segments (S2-S4).
- Axons innervating the uterus travel in the hypogastric nerves and terminate in the thoracolumbar spinal cord segments (T10-L2).
- The region surrounding the cervix represents a transitional zone and is innervated by fibers that travel in both nerves.
- Sensory axons from the clitoris and vulva follow the pudendal nerves to sacral spinal cord.
- Note that sensory information from all pelvic organs may converge on to the same spinal cord neural circuits. DRG (dorsal root ganglia).
- The visceral afferents travelling the sympathetic trunk have cell bodies in the thoracolumbar dorsal root ganglia (DRG), and those that travel with the parasympathetic fibers have cell bodies in the sacral DRG

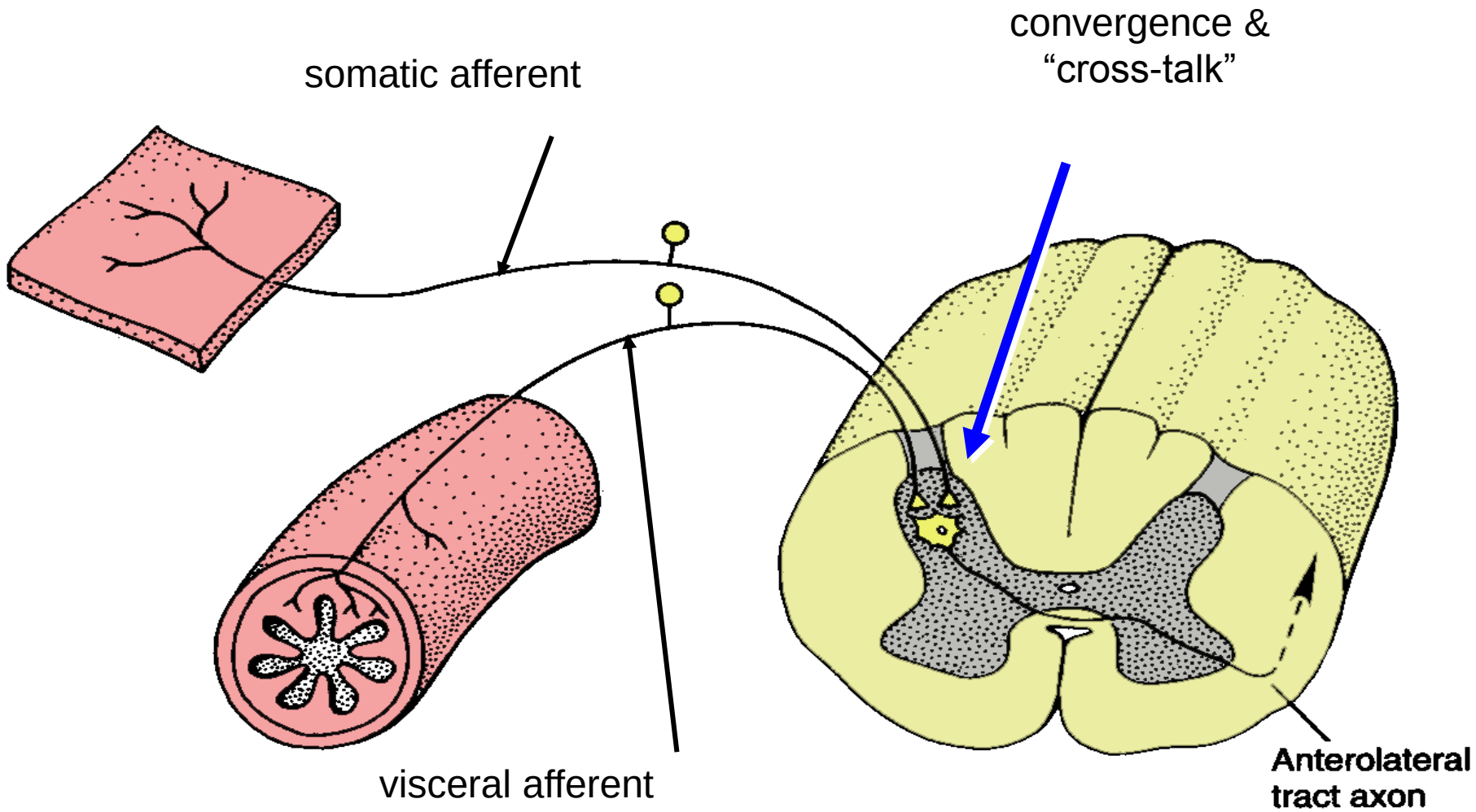


# Cross-System, Viscerovisceral Interactions




A
Pelvic Nerve Dichotomy
Spinothalamic Tract
Bladder
PN
$L_6$-$S_1$
MPG
0
Colon
B
Viscero-visceral Convergence
Spinothalamic Tract
Bladder
PN
$L_6$-$S_1$
MPG
0
Colon

# Visceral Afferents and Referred Pain




*Kandel et al.* 2000

# Viscerosomatic convergence

- Viscerosomatic convergence may occur as a result of the scarcity of visceral afferent fiberes with spinal cord terminations; the relative contribution of visceral afferent fibres to the total spinal cord afferent input is less than 10%.
- Visceral afferent terminals also show extensive divergence and intra spinal distribution compared to cutaneous afferents .

# Convergent visceral and somatic inputs

- Visceral receptors are innervated by small myelinated and unmyelinated fibers that have cell bodies in the dorsal root ganglia of the spinal or cranial nerves.
- In the spinal cord, they branch extensively and synapse on viscero somatic neurons in the dorsal horn and intermediate gray matter.
- These neurons receive convergent visceral and somatic inputs and are the substrate for referred pain (i.e., visceral pain referred to overlying or nearby somatic structures).

# Pelvic pain

- In pelvic pain, nociceptive pain is usually visceral and results from pelvic organs distension, ischemia, or spasm, secondary to thermal, chemical, and mechanical stimuli.
- Deep visceral pain is poorly localized and has some overlap with somatic sensory tracts in the spinal cord, causing “referred pain.”

# General Visceral Afferent (GVA) fibers

- The **general visceral afferent** (**GVA**) **fibers** conduct sensory impulses (usually pain or reflex sensations) from the internal organs, glands, and blood vessels to the central nervous system.
- They are considered to be part of the autonomic nervous system. However, unlike the efferent fibers of the autonomic nervous system, the afferent fibers are not classified as either sympathetic or parasympathetic.
- **A special group of these fibers called "silent" afferents have the potential to transmit pain, but do not unless they are stimulated (activated) by a prolonged or particularly noxious insult.**
- **Thirty to 80% of all afferent nerves traveling from the viscera are of this silent type.**
- Generally, they are insensitive to cutting, crushing or burning; however, excessive tension in smooth muscle and some pathological conditions produce visceral pain (referred pain).

# Neuroplasticity of the nervous system

- This barrage of noxious stimuli results in measurable metabolic, biochemical, and electrophysiologic changes in the dorsal horn.
- Thus, the amount of stimuli necessary to be perceived as a painful stimulus is reduced.
- Clinically, this is referred to as ***allodynia*** and is demonstrated when a stimulus that would not normally be considered painful, is perceived as painful.
- When a patient who voids volumes of 1 to 4 ounces feels uncomfortably full each time she decides to void, this is obviously a sign that the bladder has become allodynic.

# Neuroplasticity of the nervous system

- Structural changes have been reported at the cerebral level, with decreased density and volume of grey matter in prefrontal and dorsolateral cortex, thalamus, brainstem, and somatosensory cortex , as well as an increase in grey matter volume in the right hippocampus and parahippocampal gyrus.
- These changes that appear when pain is perpetuated , seem to be involved in the dysfunction of the descending inhibitory pathways motor control alterations , and the emergence of neural phenomena of long-term potentiation that these patients present. ...

# Therapies Using Gate Control Theory to Reduce Pain

- **Transcutaneous Electrical Stimulation (TENS), spinal cord stimulation, and peripheral nerve field stimulation** offer counter-irritants—a buzzing or tingling feeling—to compete with signals of chronic pain. This is a more technical approach to the same process discussed earlier of rubbing one's head after banging a cabinet.
- **Acupuncture's** thin needles activate small pain fibers designed to close pain gates.
- **Music therapy and auditory interventions** tap the power of distraction, allowing the brain to send a signal down the spinal cord to close the pain gates while also minimizing the pain signal arriving to the brain itself.

# Neonatal Maternal-Separation-Induced Stress Model

- The early neonatal period is a critical time for the development of the nociceptive neural pathways, which require use-dependent activity for normal development.
- The objective of developing the neonatal maternal-separation (MS)-induced stress model was to evaluate the effects of stress early in life on visceral sensitivity in the absence of visceral inflammation.
- However, abnormal stimuli such as stress, sustained pain, or inflammation in the neonatal period may adversely affect the development and subsequently lead to lower thresholds for pain in later life

THANK YOU