CNS MODULE
PHYSIOLOGY LECTURE (3)
SOMATIC SENSATIONS; TACTILE AND PROPRIOCEPTIVE SENSATIONS

PRESENTED BY

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SENSORY PATHWAY (AXIS)

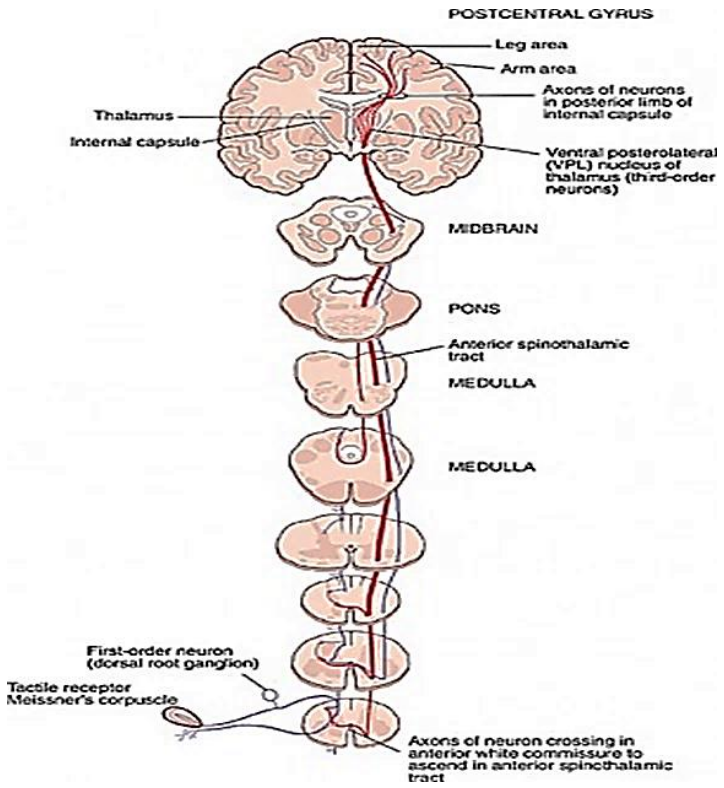
Sensation and Perception:

- **A consciously perceived stimulus is referred to as a sensation.**
- **Awareness of a stimulus combined with understanding of its meaning is called perception.**
- **The perception of a sensation requires that its pathway (or axis) should be intact.**

A sensory pathway (or axis) includes:

- The sensory receptor.
- An afferent (sensory) neuron.
- A transmitting tract to the thalamus (except in case of smell).
- The sensory areas of the cerebral cortex.

- **The higher processing of sensory information occurs in association areas of the cerebral cortex.**



Sensory Processing

- Information about the external world and about the body's internal environment exists in different forms.

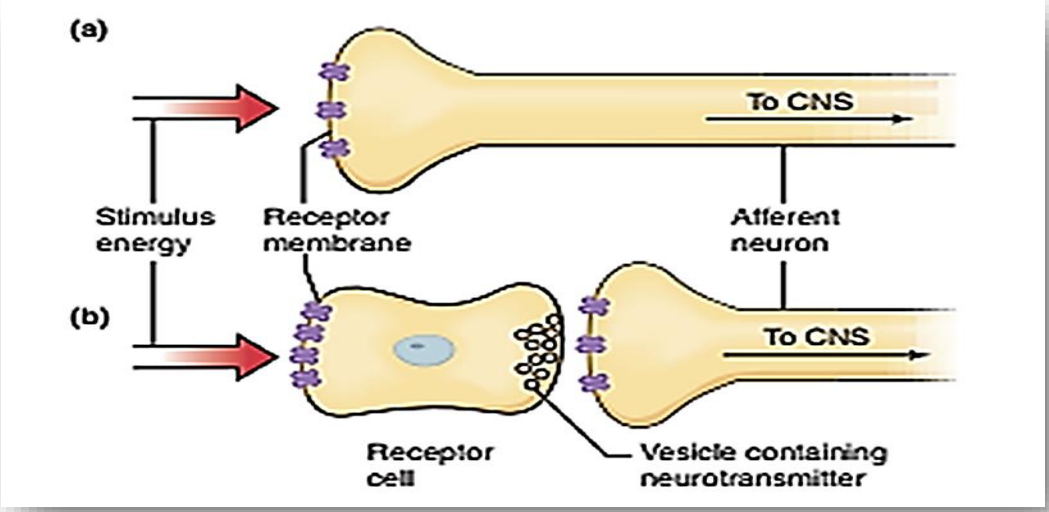
- Sensory receptors at the peripheral ends of afferent neurons change this information into graded potentials **(receptor or generator potential)** that can initiate action potentials, which travel into the CNS.

- The initial step of sensory processing is the transduction of stimulus energy first into the receptor potentials and then into action potentials in afferent neurons.
- The pattern of action potentials in particular neurons is a code that provides information about the stimulus such as its type, intensity and location.
- Primary sensory areas of the CNS that receive this input then communicate with other regions of the brain or spinal cord in further processing of the information.

SENSORY RECEPTORS

Definition:

- ✓ Are specialized structures located at the peripheral ends of sensory (afferent) neurons.
- ✓ The receptors are either specialized endings of the afferent neurons themselves or separate receptor cells that form synapses with afferent neurons and signal the afferent neurons by releasing neurotransmitters.
- ✓ They are excitable structures since they respond to various forms of energy (i.e. various stimuli) by generating action potentials.



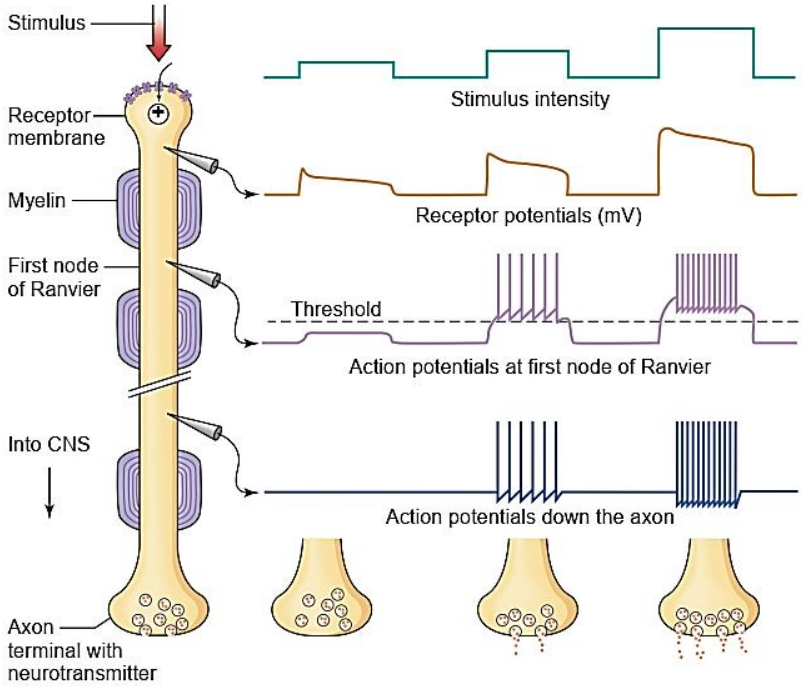
Functions of sensory receptors:

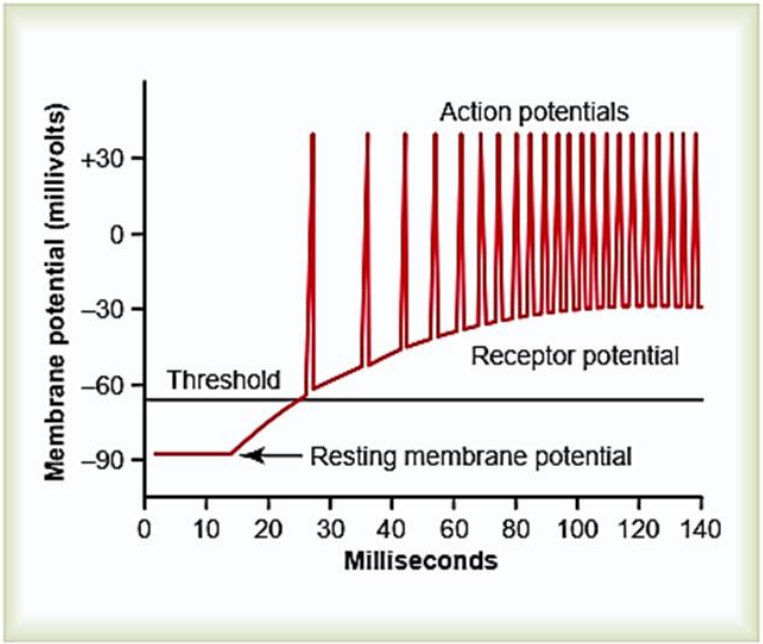
- Detectors and transducers:

They detect energy changes **(stimuli)** in both the external and internal environments and transform such changes into action potentials (i.e. nerve impulses).

- They inform the CNS about changes occurring inside and outside the body:

The nerve impulses generated at the receptors are transmitted to CNS via afferent neurons where they give rise to various sensations and initiate appropriate reflex actions that maintain homeostasis. Accordingly, without receptors, the CNS becomes almost useless.

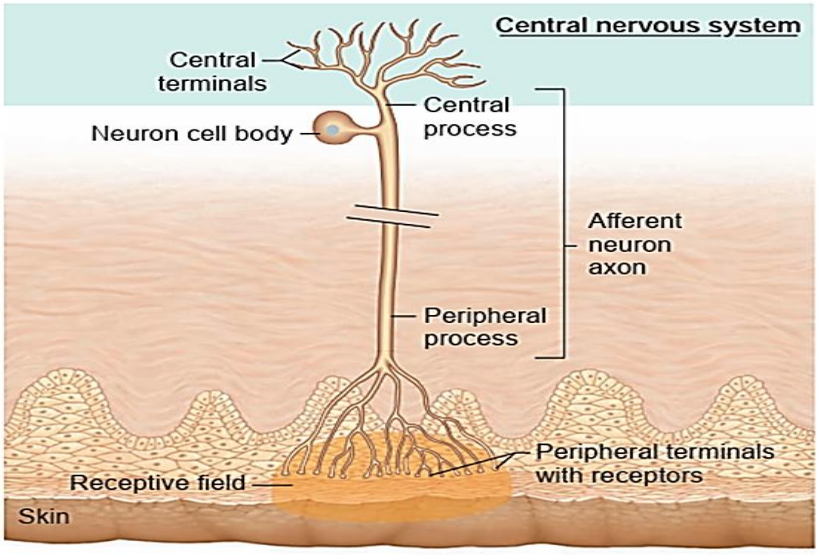

Stimulus
Receptor membrane
Myelin
First node of Ranvier
Into CNS
Axon terminal with neurotransmitter
Stimulus intensity
Receptor potentials (mV)
Threshold
Action potentials at first node of Ranvier
Action potentials down the axon


Membrane potential (millivolts)
+30
0
–30
–60
–90
Action potentials
Receptor potential
Threshold
Resting membrane potential
0
10
20
30
40
60
80
100
120
140
Milliseconds

In summary, for perception to occur, there can be no separation of the three processes involved:

- ✓ **Transducing stimuli into action potentials by the receptor.**
- ✓ **Transmitting information through the nervous system.**
- ✓ **Interpreting those inputs.**

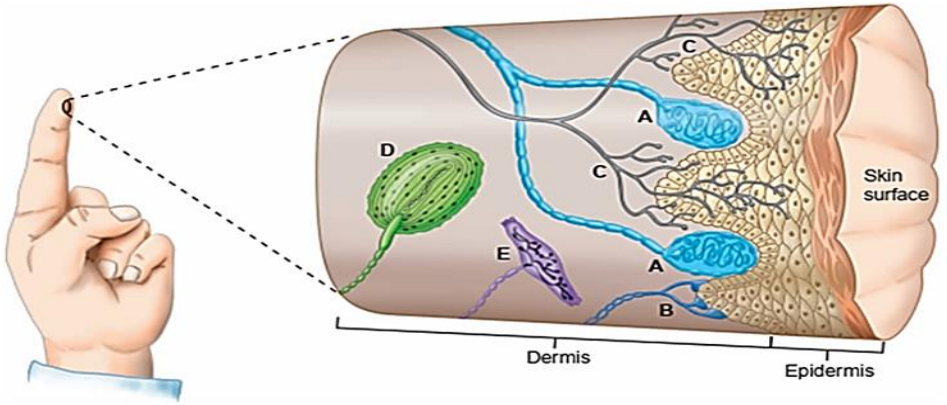
Sensory unit: A single afferent neuron with all its receptor endings.
Receptive field: Is the area supplied by a certain sensory unit.



SOMATIC SENSATIONS

Somatic sensations: Arise from the skin, skeletal muscles, bones, tendons, and joints.

They are initiated by a variety of sensory receptors collectively called **somatic receptors**.



A. Meissner's corpuscle—rapidly adapting mechanoreceptor, touch and pressure
B. Merkel's corpuscle—slowly adapting mechanoreceptor, touch and pressure
C. Free neuron ending—slowly adapting, some are nociceptors, some are thermoreceptors, and some are mechanoreceptors
D. Pacinian corpuscles—rapidly adapting mechanoreceptor, vibration and deep pressure
E. Ruffini corpuscle—slowly adapting mechanoreceptor, skin stretch

Classification of Somatic Sensations

According to the modality of sensation:

1. Mechanoreceptive sensations: These include tactile and proprioceptive sensations:

- Tactile : touch, pressure, vibration and tickle and itch sensations.
- Proprioceptive sensations: Sense of position and sense of movement.

2. Thermoreceptive sensations (heat and cold sensations).
3. Pain sensation.

MECHANORECEPTIVE SENSATIONS

(I) Tactile Sensations:

1. Touch: There are 2 types of touch:

A. Crude touch: A poorly - localized touch sensation.

Receptors: Free nerve endings and hair end organs.

Afferent nerves: A-delta nerve fibers.

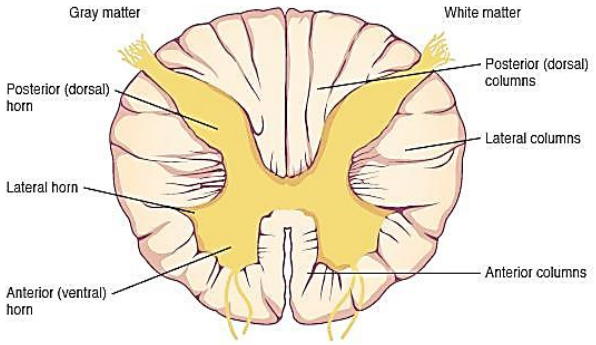
Central pathway: Ventral spinothalamic tract.

B. Fine touch: Well-localized, this includes tactile localization, discrimination and stereognosis.

Receptors: Meissner's corpuscles and Merkel's disks.

Afferent nerves: A alpha and A beta nerve fibers.

Central pathway: The gracile and cuneate tracts.



1. Tactile localization

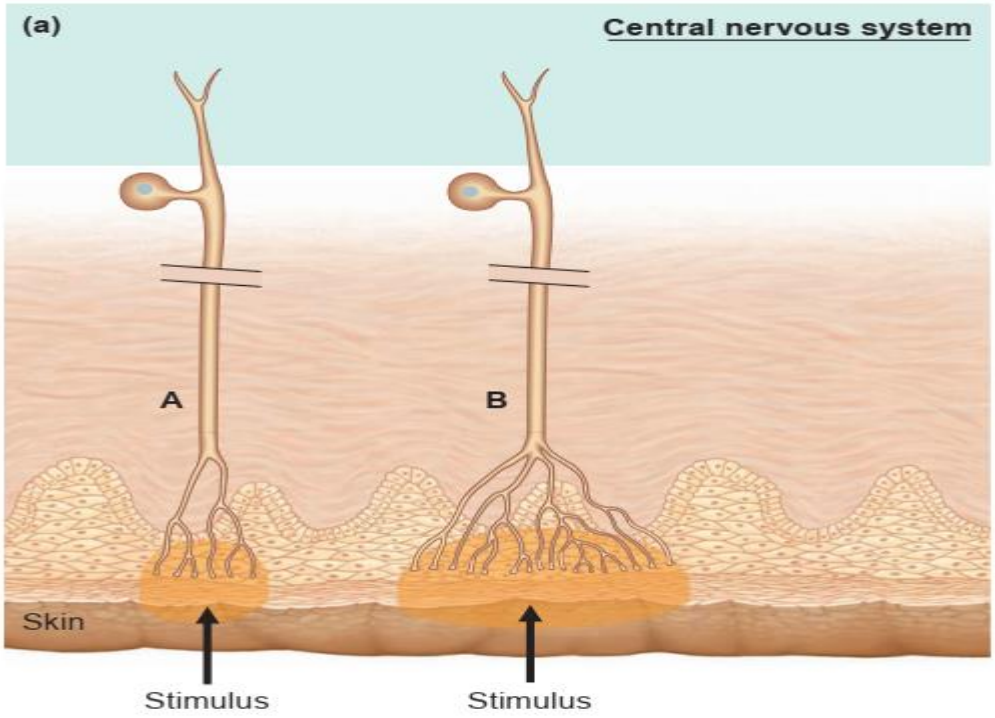
It is the ability to localize a touched skin point while the **eyes are closed**.

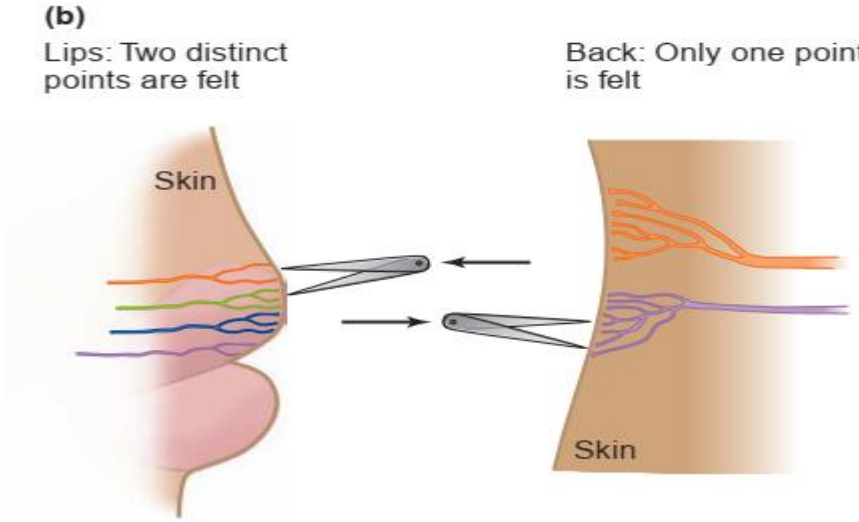
It is tested by touching the skin lightly with a marker pencil and the subject is asked to touch the stimulated point by another pencil.

The closer the 2 touch points to each other, the more accurate is the localization.

2. Tactile discrimination (T.D. or 2 point discrimination)

- It is the ability to distinguish 2 touch stimuli applied simultaneously to the skin as 2 separate points of touch **(both eyes are closed)**.
- It is tested by repeated touching the skin with the 2 blunt pints of a **Weber's compass**, starting by a closed compass, then opening it a little bit more each time till finding the **2-point threshold (the minimal distance at which the 2 points are identified)** which determines the T.D. acuity (normally unequal in different skin areas).
- T.D. requires excitation of 2 **sensory units** as well as 2 separate neurons in the sensory cortex.
- T.D. is more acute (2-point threshold is small) in areas that contain a high density of receptors **(sensory units are numerous and receptive fields are small)** and are widely represented in the sensory cortex such as lips and finger tips (2-3 mm).
- T.D. is less acute (2-point threshold is large) as in shoulders, thigh and back (60 mm or more**)(sensory units are few and widely spaced; large receptive fields).**
- N.B. Discrimination acuity is maximal in fovea centralis (the central part of the eye's retina) which can distinguish very close light rays.


(a)
Central nervous system
A
B
Skin
Stimulus
Stimulus


(b)
Lips: Two distinct points are felt
Back: Only one point is felt
Skin
Skin

3. Stereognosis

- It is the ability to **recognize** the nature of objects by handling them (from their shapes, sizes, weights,…) **(both eyes are closed)**.
- It is tested by giving the subject **a familiar object** (e.g. a key, pen or coin) and he is asked to recognize its nature.
- It depends mainly on the tactile (fine touch and pressure) sensations as well as the integrity of the high cortical sensory centers **(somatosensory association area; area 5,7)**.

2. The Pressure Sensation

- Receptors: The Pacinian corpuscles and Ruffini's endings in both the skin as well as the subcutaneous tissues.
- It is tested by the ability of the subject to differentiate between various weights without lifting them (by placing them in his hand while it is supported on a table).

Muscle tension sensation:

- It is a sensation evoked by traction on the tendons.
- Its receptors are the Golgi tendon organs.
- It is useful in discriminating weights during lifting them.
- It can be tested by the ability of the subject to differentiate between various weights placed in the unsupported hand.

3. The Vibration Sense

- It is the sense of buzzing (or thrill) that is felt when the base of a vibrating tuning fork is placed on the skin.
- During testing, it is better to place the tuning fork on a bony prominence e.g. the lower end of radius bone or one of the malleoli as bone magnifies the vibration waves.
- It is simply a **repetitive tactile sensation** that occurs as a result of **stimulation of 2 types of rapidly adapting mechanoreceptors** (Meissner's corpuscles which respond to vibrations up to 80 Hertz (cycle/second) and Pacinian corpuscles which respond to vibrations up to 500 Hertz).
- Vibration is transmitted by gracile and cuneate tracts and is commonly tested to check the integrity of these tracts.

4. Tickle and Itch sensations

- ✓ Tickle is a sensation that results from mild repeated tactile stimulation of the skin.
- ✓ On the other hand, itch is an annoying sensation that results from skin irritation by either moving tactile stimuli (e.g. a crawling flea) or certain chemical substances released in the skin e.g. histamine.

- ✓ Receptors: Free nerve endings.
- ✓ Afferent nerves: unmyelinated C nerve fibers.
- ✓ Central pathway: ventral spinothalamic tract.

(II) Proprioceptive Sensations

1) These sensations arise from deep structures (specially muscles and joints), and give rise to **conscious perception** of orientation of the various parts of the body as well as the movement of each part.
2) They are transmitted to the high centers via **gracile and cuneate tracts**.
3) They are usually divided into the following 2 types:

A. Static proprioception (sense of position)

- This is the sensation of the position of different parts of the body with respect to each other.
- Its **receptors** are **slowly adapting** and include the muscle spindles, Golgi tendon organs and Ruffini's endings.
- It can be tested by putting one of the patient's limbs (or toes or fingers) in an abnormal (unusual) position while **his eyes are closed**, then asking him to put the same part in the other side in a similar position.

B. Dynamic proprioception (sense of movement)

- This is the sensation of movement of joints.
- Its **receptors** are located around the joints and are **rapidly adapting** (including specially Pacinian corpuscles).
- It can be tested by moving one of the patients fingers or toes passively (i.e. by means of the examiner) while **his eyes are closed**, and asking him to determine the start and the end of the movement as well as its rate and direction.

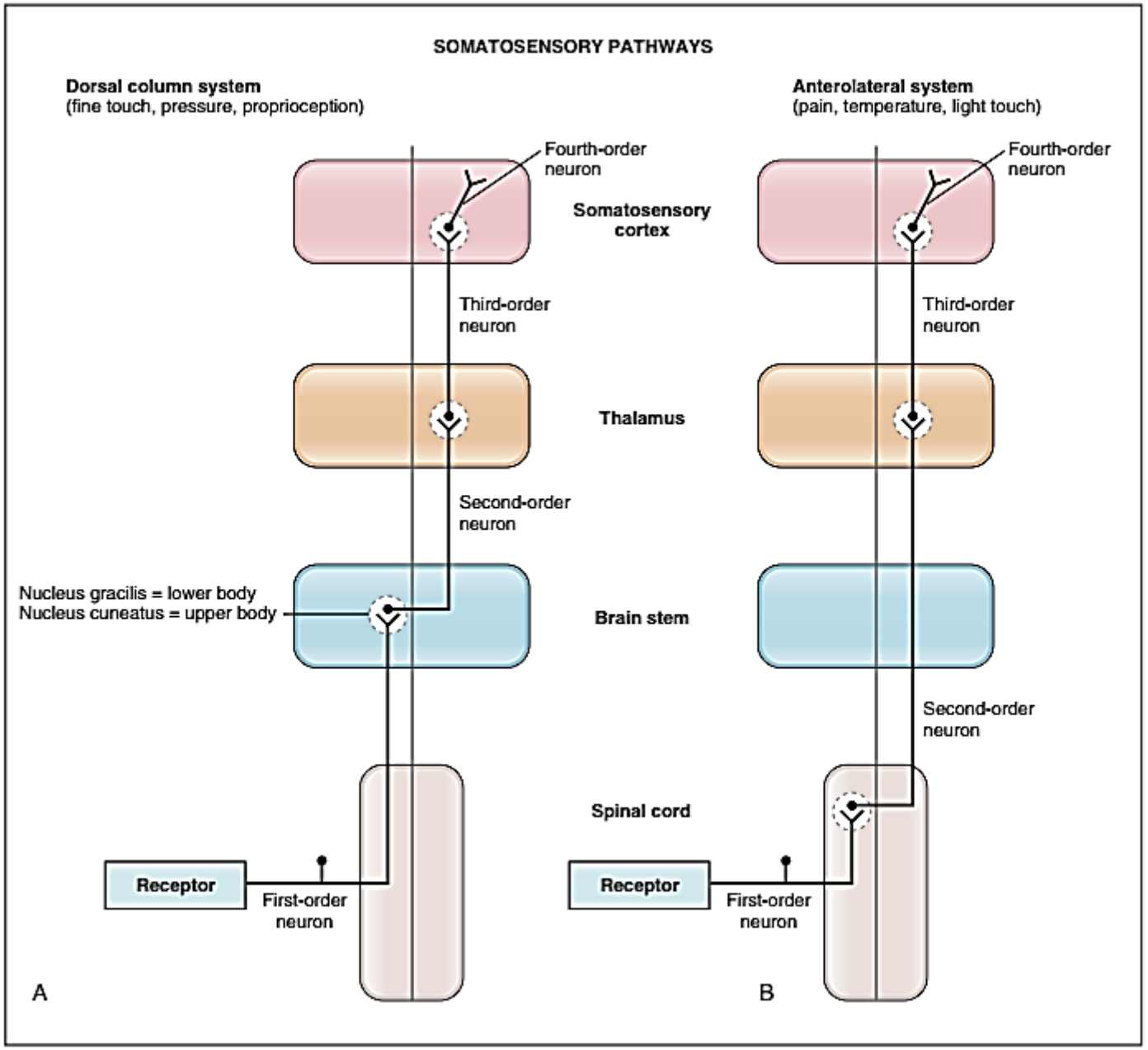
N.B.

Both types are sometimes called kinesthetic sensations (although only the dynamic type is kinetic).

Ascending Neural Pathways in Sensory System

- Afferent sensory pathways are generally formed by chains of three or more neurons connected by synapses.
- Sensory pathways are also called ascending pathways because they project “up” to the brain.
- The ascending pathways in the spinal cord and brain that carry information about single types of stimuli are known as the specific ascending pathways.
- The specific ascending pathways pass to the brainstem and thalamus, and the final neurons in the pathways go from there to specific sensory areas of the cerebral cortex**. (The olfactory pathways do not send pathways to the thalamus, instead sending some branches directly to the olfactory cortex and others to the limbic system.)**

- **Each of the various sensory pathways consists of 3 order neurons;**
  - The **first** of which are the the **primary afferent neuron**. Primary afferent neurons have their cell bodies in **dorsal root ganglia (DRG)** or cranial ganglia**.**
  - The **second order neuron** is located in the spinal cord (anterolateral system) or in the brain stem (dorsal column system). The second-order neurons receive information from first-order neurons and transmit that information to the thalamus.
  - Axons of the second-order neurons **cross the midline,** either in the spinal cord or in the brain stem (**ascending tracts)**, and ascend to the thalamus. This decussation means that somatosensory information from one side of the body is received in the contralateral thalamus.
  - The **third order neuron** is located in one of the somatosensory nuclei of the **thalamus** and transmit signals to the **cerebral cortex**.
  - **Depending on their position in the spinal cord, there are 2 systems of the ascending tracts called the anterolateral system and the dorsal column lemniscal system.**


SOMATOSENSORY PATHWAYS
Dorsal column system
(fine touch, pressure, proprioception)
Anterolateral system
(pain, temperature, light touch)
Fourth-order neuron
Somatosensory cortex
Third-order neuron
Thalamus
Second-order neuron
Nucleus gracilis = lower body
Nucleus cuneatus = upper body
Brain stem
Spinal cord
Receptor
First-order neuron
A
B

I. THE ANTEROLATERAL (SPINOTHALAMIC) SYSTEM

This system consists mainly of the ventral and lateral spinothalamic tracts.
It is characterized by the following:

- It consists mainly of A-delta nerve fibers and some C nerve fibers.
- It conducts signals from the opposite side.

THE VENTRAL SPINOTHALAMIC TRACT

This tract transmits crude touch as well as the tickle and itch sensations.

Its pathway consists of 3 neurons which are:

- First order neurons: Have their cell bodies in **DRG; A-delta and C afferent nerve fibers** enter the spinal cord via the dorsal roots and terminate at the **main sensory nucleus** of the dorsal horn.
- Second order neurons: In the spinal cord and constitute the **tract**. They start in the dorsal horn, **cross to the opposite side**, ascend in the **anterior column** of spinal cord (ventral spinothalamic tract) and terminate at the contralateral **ventral posterolateral nucleus (VPLN)**.
- Third order neurons: These start in the **thalamus**, pass in the sensory (or thalamic) radiation in the posterior limb of the internal capsule and terminate at **the cortical sensory areas (Somatosensory area I; 3,1,2)** in the postcentral gyrus.

THE LATERAL SPINOTHALAMIC TRACT

- This tract transmits pain and temperature sensations.
- In the brain stem, both lateral spinothalamic tract combine with ventral spinothalamic tract forming the spinal lemniscus.

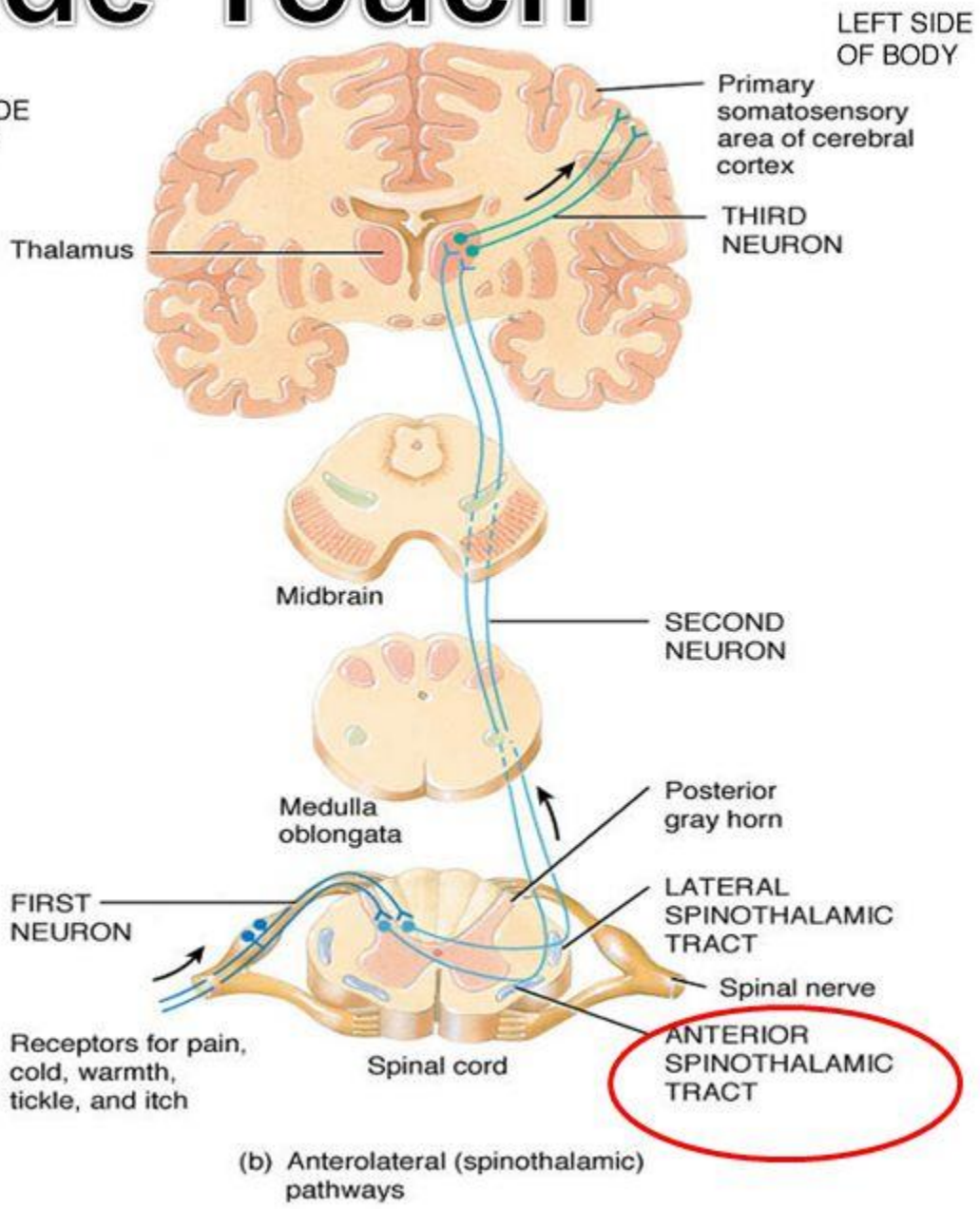
Crude Touch

Receptors:

- Free nerve endings
- Hair end organs

Pathway:

- Ventral or anterior spinothalamic tract



II. THE DORSAL COLUMN -MEDIAL LEMNISCAL SYSTEM

1. This system consists of the gracile and cuneate tracts.
2. In contrast to the anterolateral system, it is characterized by the following:

- ✓ It consists mainly of A-alpha and A-beta nerve fibers.
- ✓ It transmits fine sensations.
- ✓ It conducts signals from the same side (at the level of spinal cord).

THE GRACILE AND CUNEATE TRACTS

These tracts transport:

- ✓ Fine touch sensations (tactile localization, tactile discrimination and stereognosis).
- ✓ The vibration sense.
- ✓ The conscious proprioceptive sensations.
- ✓ Muscle tension sensations.
- ✓ Pressure sensations.

THE GRACILE AND CUNEATE TRACTS

The pathway of gracile and cuneate tracts consists of the following 3 neurons:

- First order neurons: Have their cell bodies in **DRG ; A-alpha and beta afferent nerve fibers** enter the spinal cord and ascend in the ipsilateral dorsal column without relay as the **gracile and cuneate tracts** till relaying at the **gracile and cuneate nuclei in the medulla oblongata**.
- The gracile tract carries sensations from the lower part of the body and lies medially in the dorsal column, while the cuneate tract carries sensations from the upper part of the body and lies laterally in the dorsal column.

- Second order neurons: These **start at the gracile and cuneate nuclei in the medulla**, cross the midline to the opposite side (in which the fibers are called the **internal arcuate fibers**), then they ascend as the **medial lemniscus**, and finally they terminate at the **thalamus** especially in the **VPLN**.
- Third order neurons: These start at the thalamic **VPLN** and terminate at the cortical sensory areas **(Somatosensory area I; 3,1,2)** in the postcentral gyrus.

N.B.

- Some fibers called the external arcuate fibers arise from gracile and cuneate nuclei and enter the cerebellum via the inferior Cerebellar peduncle.

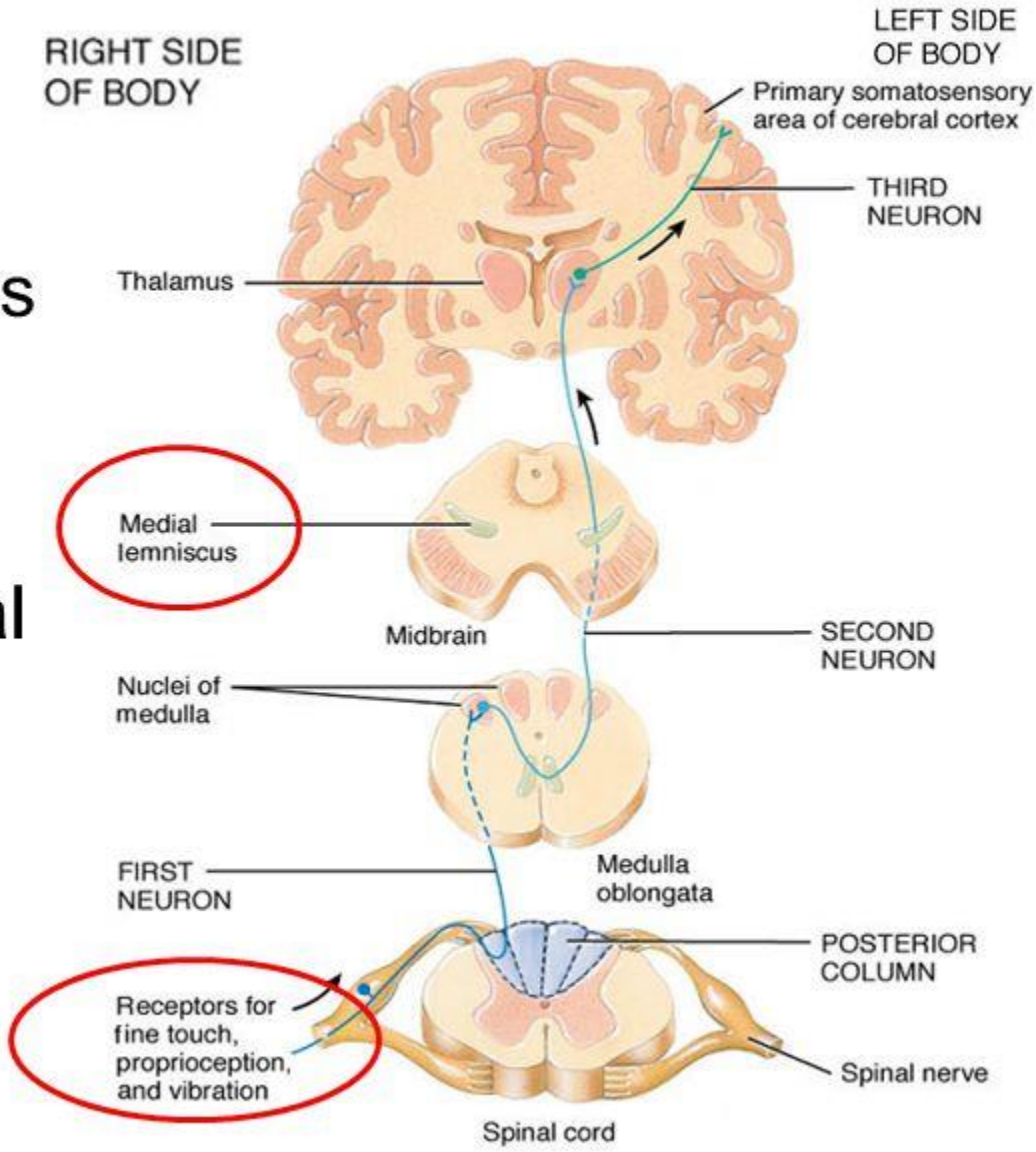
Fine Touch

Receptors:

- Meissner's corpuscles
- Merkel's discs

Pathway:

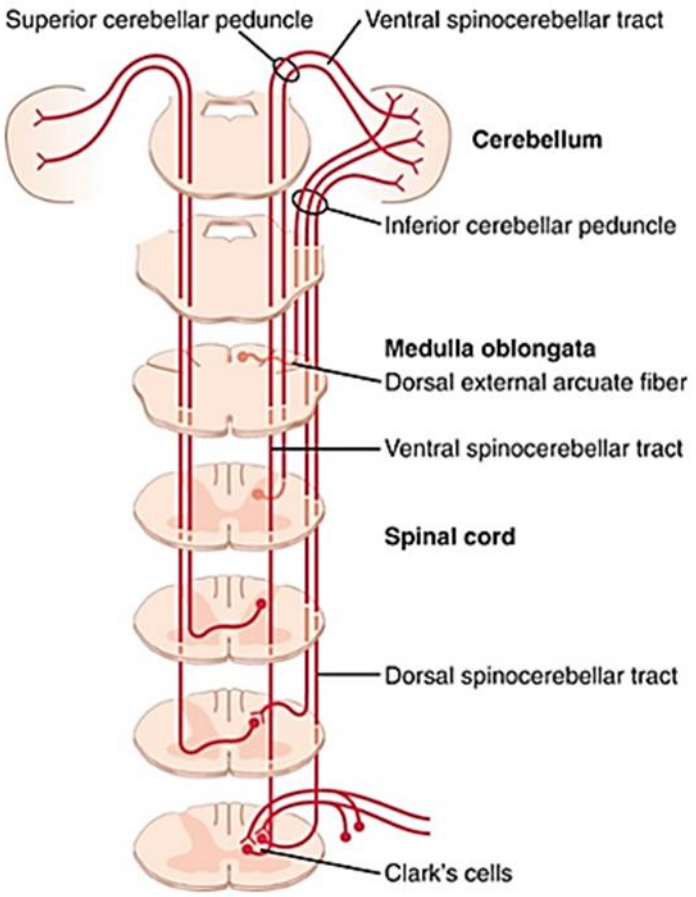
- Dorsal column **medial leminiscal system** or **gracile** and **cuneate** tracts



(a) Posterior column–medial lemniscus pathway

The Spinocerebellar tracts

These are dorsal & ventral spinocerebellar tracts.
They carry subconscious proprioceptive signals to the cerebellum.

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