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

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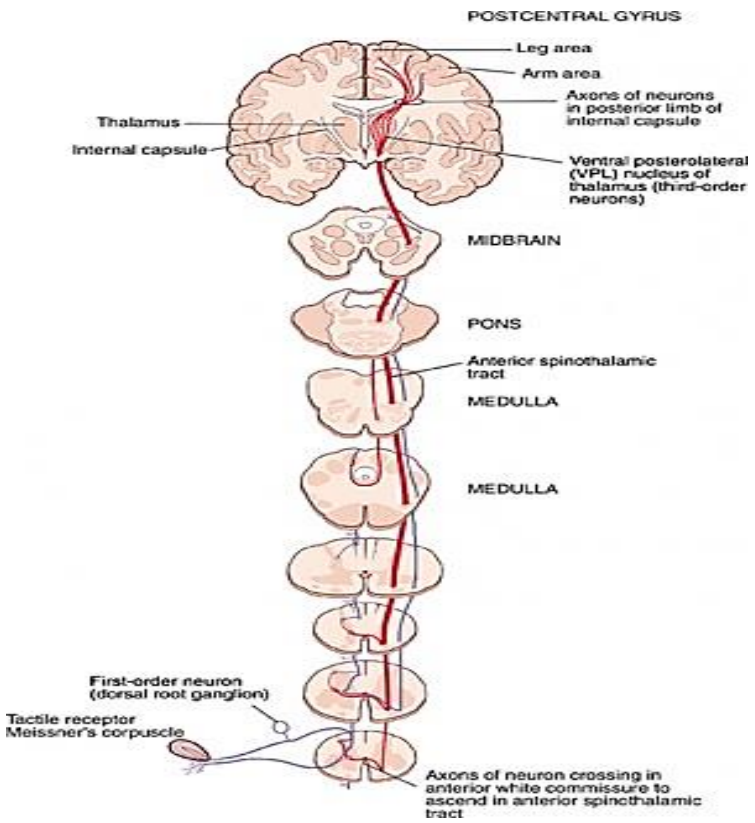
SENSORY PATHWAY (AXIS)

The perception of a sensation requires that its pathway (or axis) should be intact.

A sensory axis includes:

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



SENSORY RECEPTORS

Definition: Are specialized structures located at the peripheral ends of sensory (afferent) neurons.

Functions of sensory receptors:

- Detectors and transducers: They detect energy changes 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.

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

(1) 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.

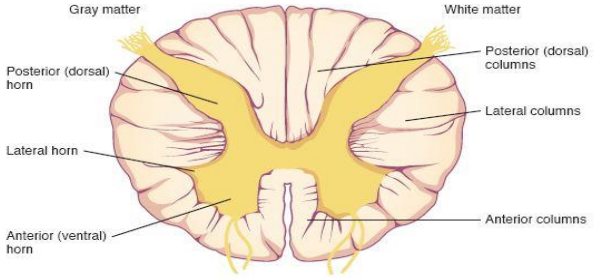
Central pathway: Ventral spinothalamic tract.

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 beta nerve fibers.

Central pathway: The gracile and cuneate tracts.



1. Tactile localization (topognosis)

- 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 receptors 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 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).
- N.B. Discrimination acuity is maximal in fovea centralis (the central part of the eye's retina) which can distinguish very close light rays.

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 (somatic sensory association area; area 5,7).

2. The Pressure Sensation

- Receptors: It is perceived mainly by 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 which respond to vibrations up to 80 Hertz (cycle/second) and Pacinian corpuscles which respond to vibrations up to 500 Hertz).
- Vibration and proprioception are transmitted by gracile and cuneate tracts and are 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.

(2) 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).

The sensory pathways (ascending tracts)

- Each of the various sensory pathways consists of 3 order neurons;
- The **first** of which are the **dorsal root ganglia (DRG).**
- The **second** order neurons form bundles called the **ascending tracts**, which ascend in the spinal cord and brainstem and transmit sensory signals upwards to subcortical centers (**thalamus**), from which **third** order neurons arise 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.

A. THE ANTEROLATERAL 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 and crude pressure as well as the tickle and itch sensations.

Its pathway consists of 3 neurons which are:

- First order neurons: **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: These 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 **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 (Somatic sensory 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.

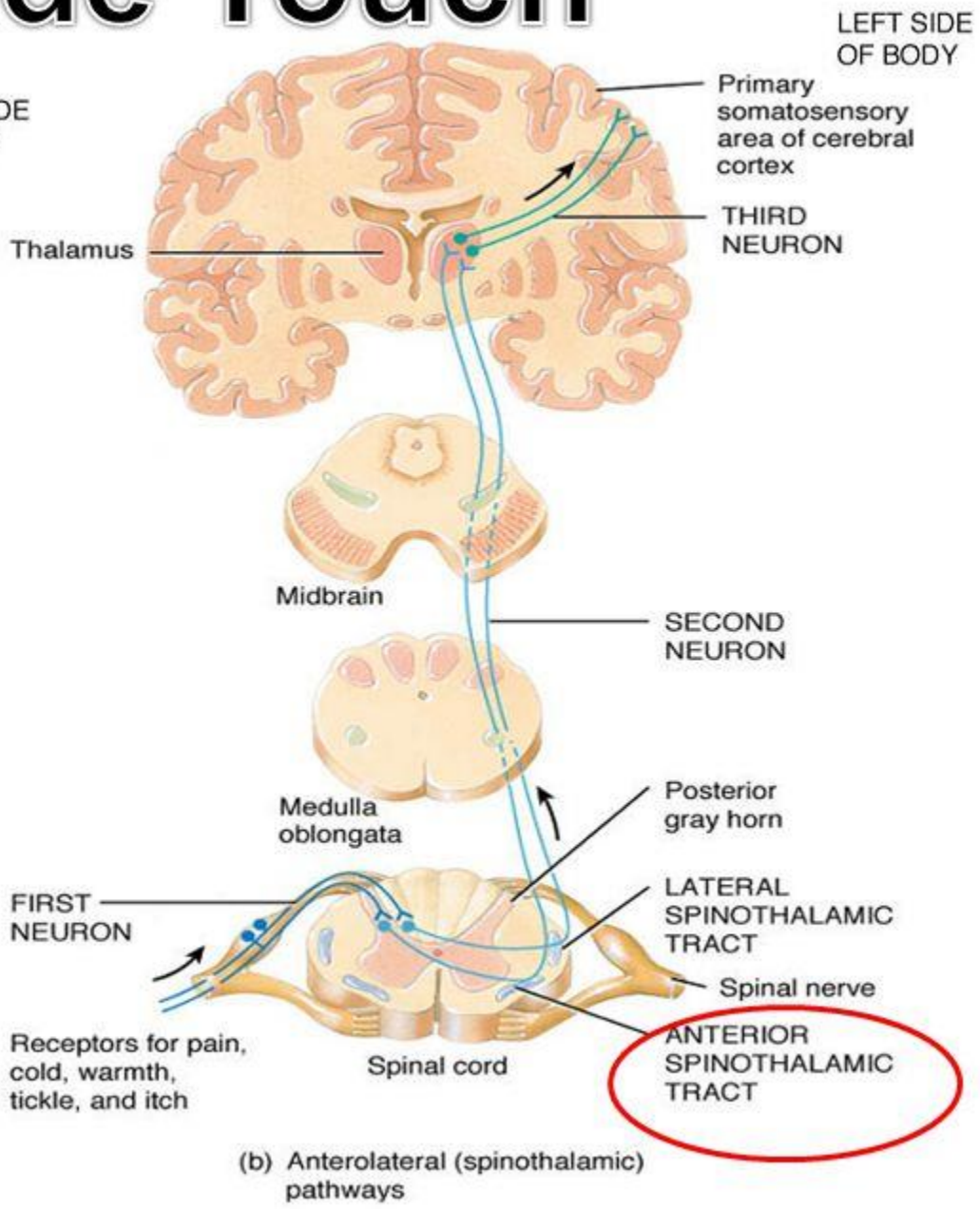
Crude Touch

Receptors:

- Free nerve endings
- Hair end organs

Pathway:

- Ventral or anterior spinothalamic tract



B. THE DORSAL COLUMN LEMNISCAL SYSTEM

1. This system consists of the gracile and cuneate tracts as well as the spinocervical tract.
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 (epicretic) sensations.
- ✓ It conducts signals from the same side.

THE GRACILE AND CUNEATE TRACTS

These tracts transport:

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

THE GRACILE AND CUNEATE TRACTS

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

- First order neurons: **DRG ; A-alpha and beta afferent nerve fibers** enter the spinal cord, then immediately divide into medial and lateral branches. The **medial branch** turns upwards in the ipsilateral dorsal column and ascend 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 in the sensory decussation 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 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 inf. Cerebellar peduncle.
- The lateral branches of A-beta afferent nerve fibers form spinocervical tract.

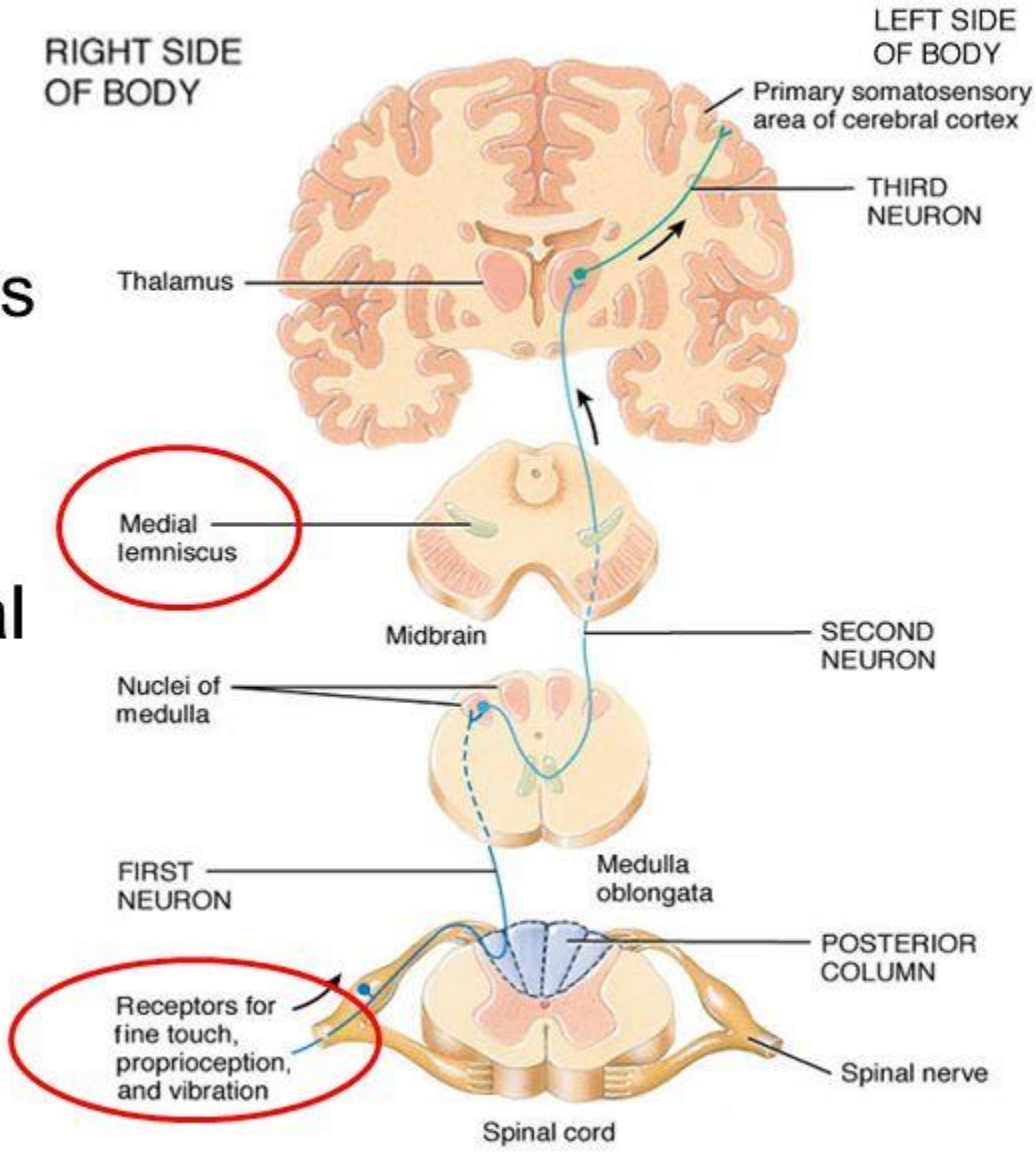
Fine Touch

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

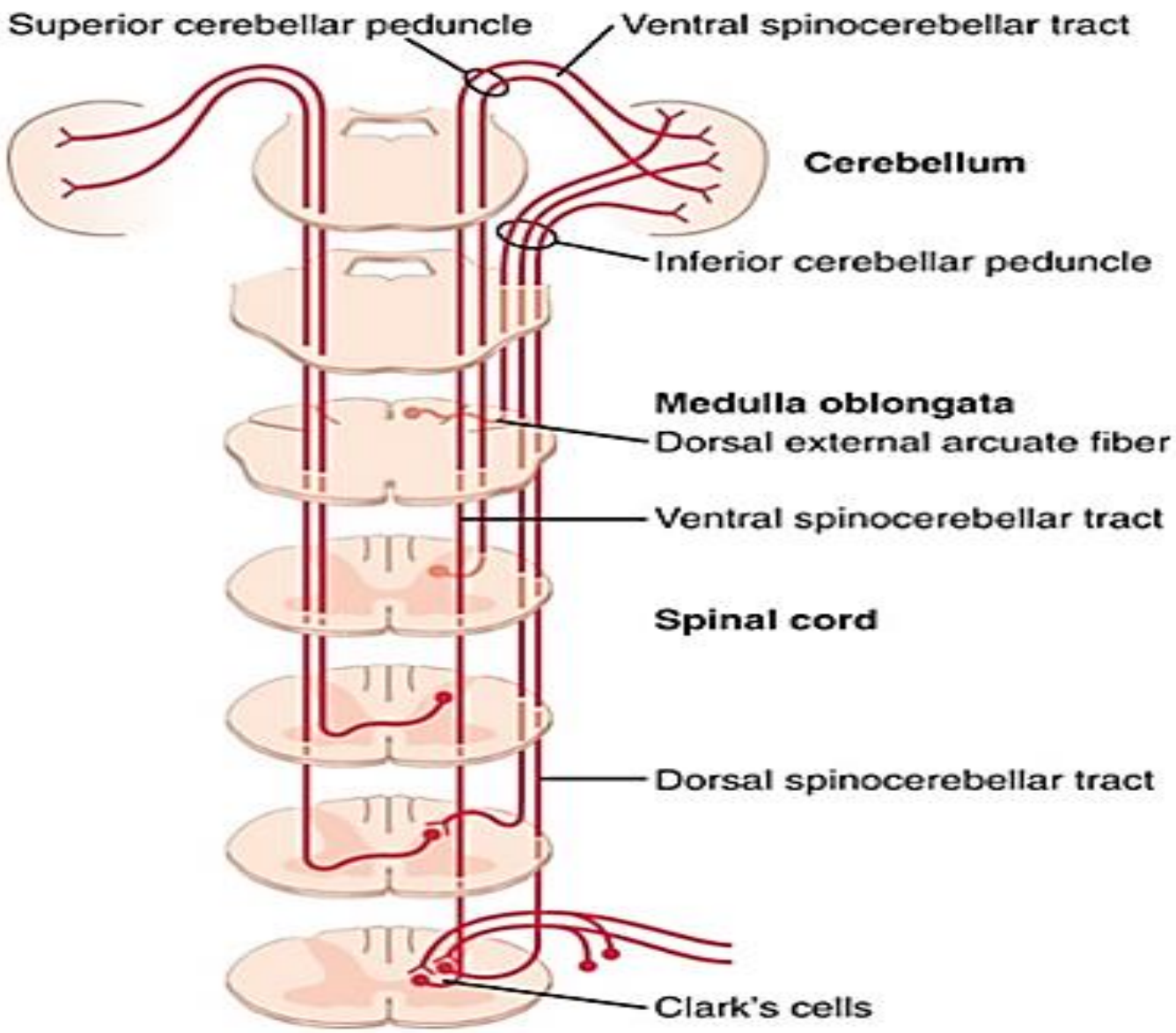
These are dorsal & ventral spinocerebellar tracts (but both are located in the lateral column of spinal cord).

They carry subconscious proprioceptive signals to the cerebellum, and they consist of the following neurons:

First order neurons: **DRG;** A-beta afferent nerve fibers.

Second order neurons: These form the tracts and they start at the **Clarke's nucleus** at the base of the dorsal horns. Those of the **dorsal tract ascend in the same side**, enter the cerebellum via the **inferior cerebellar peduncle** and terminate in the vermis and intermediate zones, while those of the **ventral tract ascend at both sides** (due to crossing of some fibers in the spinal cord), enter **both cerebellar hemispheres via the superior cerebellar peduncles** and terminate as the dorsal tracts.

The Spinocerebellar tracts



SENSORY DISTURBANCES

(1) Syringomyelia:

This is a slowly progressive disease that is probably congenital in origin. It occurs in middle ages and females are more affected. There is cavitation (cyst formation) around the central canal of the spinal cord.

Manifestations:

1. **Dissociated sensory loss** (= loss of some sensations and preservation of others). Because the lesion damages the crossing fibers of the lateral and ventral spinothalamic tracts in front of the central canal, there is **bilateral loss of pain and temperature sensations at the level of the lesion**. On the other hand, fine tactile and proprioceptive sensations are preserved because the dorsal columns are not affected.
2. The lesion usually affects the lower cervical and upper thoracic segments of the spinal cord (cervicothoracic region) , so its manifestations often have “a jacket distribution”.

(2) TABES DORSALIS

This is a disease that occurs in late stages of neurosyphilis as a result of inflammation of the posterior (or dorsal) nerve roots (which is commonly bilateral at the lower thoracic and lumbosacral regions of the spinal cord).

Manifestations:

A. Early manifestations:

1. Attacks of severe lancinating (very sharp) pain known as lightning pain due to irritation of the pain-conducting afferent nerve fibers by the inflammatory process.
2. Degeneration of the gracile and cuneate tracts (because these tracts are formed mainly of thick A nerve fibers which are more readily affected by compression), and no regeneration occurs because these tracts have no neurolemma. This leads to atrophy of the dorsal column of the spinal cord (tabes=atrophy), as well as to the following symptoms:

(1) Loss of fine tactile sensations and the vibration sense.
(2) Loss of the conscious proprioceptive sensations as well as the subconscious proprioceptive information to the cerebellum that is conveyed by the spinocerebellar tracts.

Sensory ataxia:

Definition: This is incoordination of voluntary movements due to loss of both conscious and subconscious proprioceptive signals. Its main symptoms include the following:

a. The patient walks at a broad base and finds difficulty in walking (even at daylight) and often looks at his feet.

b. Equilibrium disturbances: on closing his eyes, the patient sways and may fall. This is called **Romberg's sign**, and is due to loss of the main mechanisms that maintain equilibrium i.e. vision and proprioceptive sensations.

(3) **Stamping gait:** during walking, the patient raises his legs too high and drops them forcefully on the ground (because he is unaware of their position).

At the terminal stage, syphilis may damage the pretectal area in the midbrain, causing the **Argyll-Robertson pupil**.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