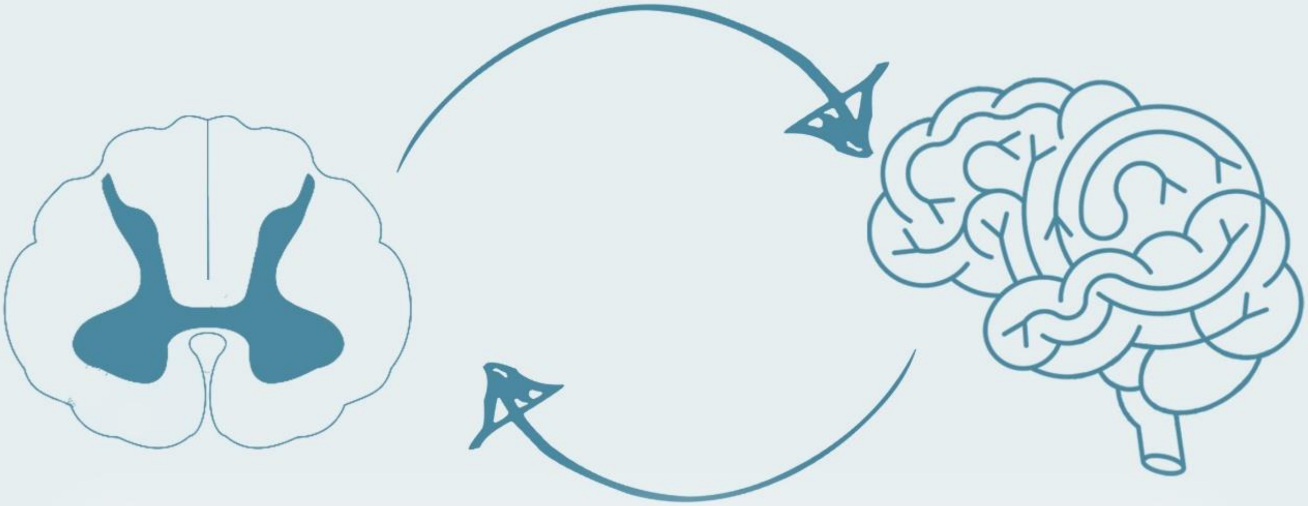

CNS

physiology

slides sheets

number 6

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Correction Abdullah AlZibdeh

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Recall: somatosensation of the body reaches the spinal cord then ascends (ALS or PCML) to the thalamus then to the somatosensory cortex in three neuronal levels (first, second and third order neurons).

The somatosensation of the face (pain, proprioception, touch and thermal sensation) is already in the head, so it doesn't have to descend back to the spinal cord, instead, it is carried through the cranial nerves, specifically, **the trigeminal system.**

Peripheral receptors of the face will transmit the signal through peripheral nerves (the trigeminal nerve in this case) reaching the **trigeminal ganglion (**equivalent to the posterior root ganglion**)**, but instead of entering the spinal cord **they will enter the brainstem directly** (at the level of the pons). From here there will be a three-neuronal cascade that will pass through **the thalamus** to reach the cortex **(somatosensory cortex)** as **the most lateral part of the somatosensory cortex.**

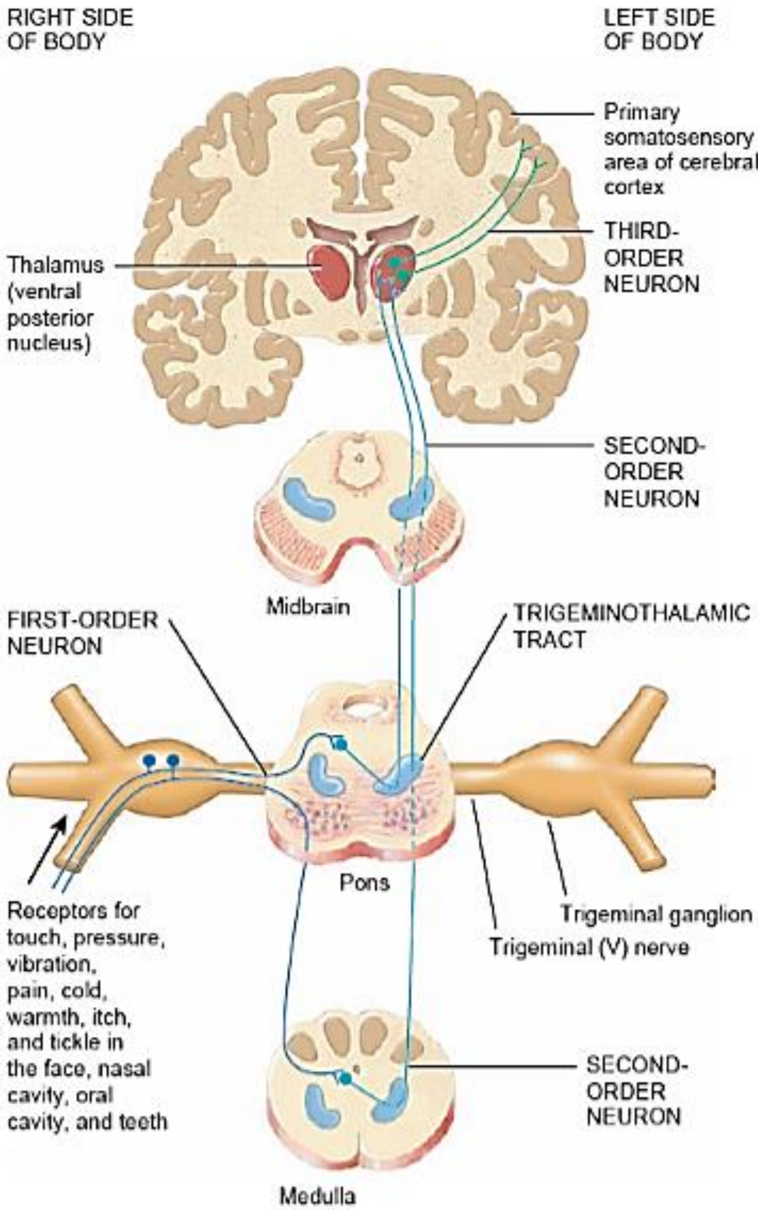
At the level of brainstem, both ALS and PCML has already synapsed (they are composed of second order neurons now) and both already crossed (ALS crossed its fibers in the spinal cord while PCML crosses its fibers in the medulla).

So, the trigeminal system needs to be **running in several tracts**, one of them carries **PCML modalities** and process them the same way they are processed in the spinal cord, and the other is for **ALS modalities** (crude touch and fine touch cannot run and synapse together for example, that's why splitting PCML modalities form ALS ones is necessary). That's why the trigeminal system has **four** nuclei with different functions**: the principal sensory nucleus, the spinal trigeminal nucleus, the mesencephalic nucleus and the motor trigeminal nucleus.**

1- The principal sensory nucleus:

In the PCML system, the first order neuron cell bodies are in **the dorsal root ganglia**, the second order neuron cell bodies are in **gracile and cuneate nuclei** while the third order neurons are **in the VPL of the thalamus**.

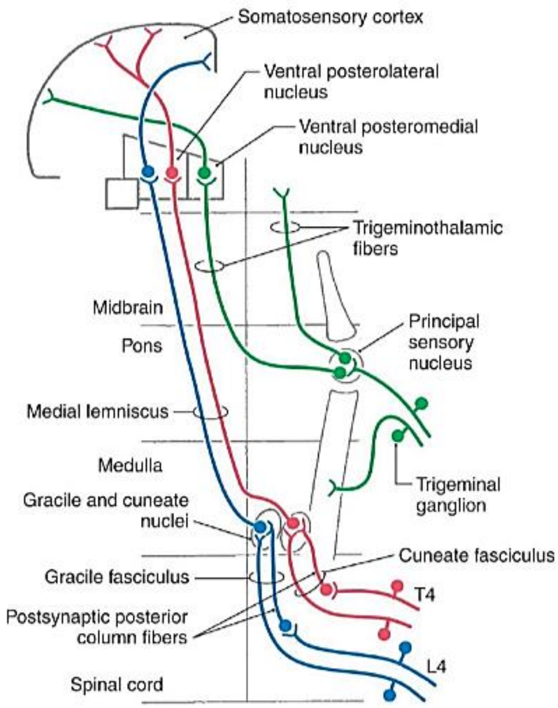
That is not very different in the trigeminal system, the first order neurons are in the **trigeminal ganglia**, then it will enter **the principal sensory nucleus** (main or chief sensory nucleus) where the second order neurons are located, the second order neurons cross there, then it will head to **the ventral posteromedial nucleus (VPM) in the thalamus**.

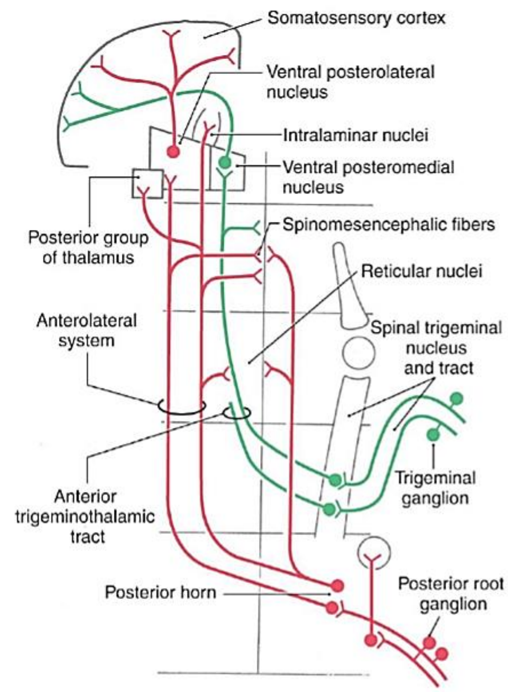


Fibers that synapse in the principal sensory nucleus will either go contralateral (anterior trigeminothalamic tract), or ipsilateral (posterior trigeminothalamic tract).

Collectively, the nucleus responsible for the somatosensory sensation is called the **ventroposterior nucleus complex**, composed of **VPL** which is responsible for the somatosensation in the **body** and the **VPM** which is responsible for the somatosensation of the **face**.

After synapsing in the VPM, third order neuron will head **to the most lateral part of the somatosensory cortex.**





2- The spinal trigeminal nucleus

In the ALS system, the first order neuron cell bodies are in **the dorsal root ganglia**, the second order neuron cell bodies are in **gray matter of the spinal cord** while the third order neurons are **in the VPL of the thalamus**.

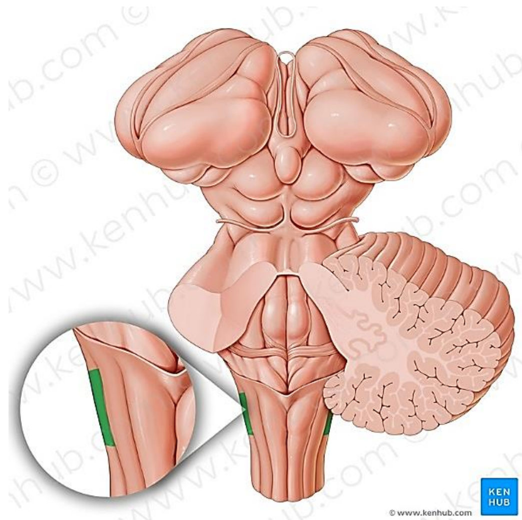
While in the trigeminal system, the first order neurons will be in **the trigeminal ganglia**, the second order neurons will be in **the spinal trigeminal nucleus** (caudal trigeminal nucleus) where the fibers cross to the other side, then to **the VPM nucleus of the thalamus** to the most lateral part of the somatosensory cortex.

The spinal trigeminal nucleus doesn’t only receive its fibers directly from the trigeminal nerve, but also indirectly from the ear and the external auditory meatus traveling through **cranial nerves VII, IX and X**. They synapse in the nucleus and cross to the other side then they ascend to the VPM nucleus of the thalamus to the somatosensory cortex.

00:00 – 10:00

3- **The mesencephalic nucleus** is responsible for the sensory part of reflexes.
4- **The motor trigeminal nucleus** is responsible for the motor part of the reflexes (jaw reflex during chewing food).

The trigeminal tubercle is a very important landmark that should be targeted when doing **a trigeminal cordectomy**. The trigeminal nerve enters the brainstem almost at the level of the pons, while the spinal trigeminal nucleus extends almost all the length of the medulla, the descending fibers are lateral and outside while cell bodies are mostly anterior. So, we can do a trigeminal cordectomy for people with severe facial pain to solve their problem.



Clinical correlation:

Brown-Séquard syndrome, damage to one half of the spinal cord segment, it is rare clinically, because the segment is supplied by both anterior and posterior arteries and the obstruction of both arteries is unlikely to happen, but it can happen due to a physical injury such as a stab.

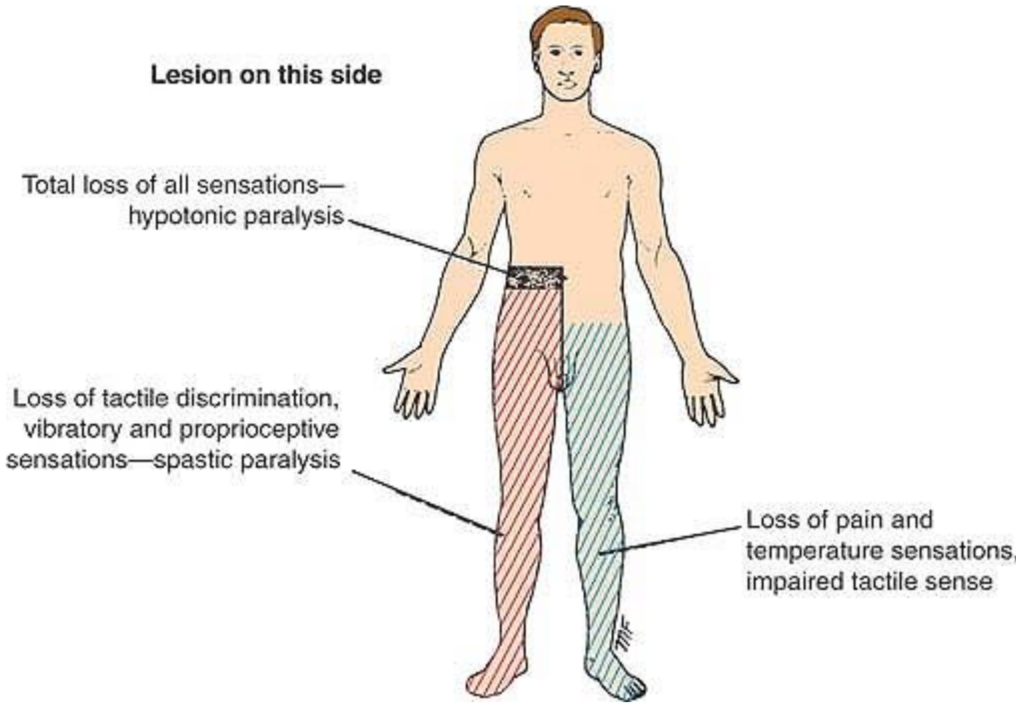
If the damage happened at the level of C5 on the left segment of the spinal cord, what will happen?

On the right side (opposite side): loss of crude touch, pain and thermal sensation will be lost at the level of C6 and below.

On the left side (same side): loss two-point discrimination, vibration and propriosensation at the level of C5 and below.

At the level of the same segment (C5) on the same side (left): complete loss of both ALS and PCML modalities.

Motor effects (corticospinal tract): hypotonic paralysis at the level of the segment, spastic paralysis below the level of the segment on the same side (ipsilateral).



10:00 – 20:00

⚠ Diseases related to somatosensation:

➔ Tabes dorsalis (progressive locomotor ataxia) or tertiary syphilis:

This disease is caused by infection with Treponema pallidum and is associated with neurosyphilis. The fibers of the posterior column degenerate causing loss of the PCML modalities, and the patient will have ataxia (related to the lack of sensory input, clinically referred to as sensory ataxia), loss of muscle stretch (tendon) reflexes, and proprioceptive losses from the extremities. In sensory ataxia, the patient may also have a wide-based stance and may place the feet to the floor with force to create the missing proprioceptive input.

➔ Friedreich ataxia:

Degeneration of the major spinocerebellar tracts caused by genetic disorders mainly, the result is cerebellar ataxia—lack of coordination during walking and other movements that occurs because the cerebellum is not receiving the sensory feedback necessary to regulate movement.

*Remember:

-Extramedullary tumors will suppress the cord lateral to medial, so it suppresses the sacral fibers of the spinothalamic tract first.

-Intramedullary tumors will suppress the cord medial to lateral, so it suppresses the cervical fibers of the spinothalamic tract first.

Motor system

It Is the system responsible for delivering motor signals from the central nervous system to the muscles.

The origin of the motor signal can be:

1- **The spinal cord** (spinal cord reflexes).
2- **The subcortex** (unconscious involuntary movement).
3- **The cortex** (conscious voluntary movement).

The signal will originate from one of those three, then it will descend **to the anterior horn of the gray matter in the spinal cord** where the cell bodies for the **lower motor neurons** are located, once these neurons are activated, the signal will continue its way towards the muscle causing contraction.

The axons of anterior horn motor neurons exit the spinal cord via the anterior roots and course distally in peripheral nerves. These fibers represent **the final common path** that links the nervous system and skeletal muscles.

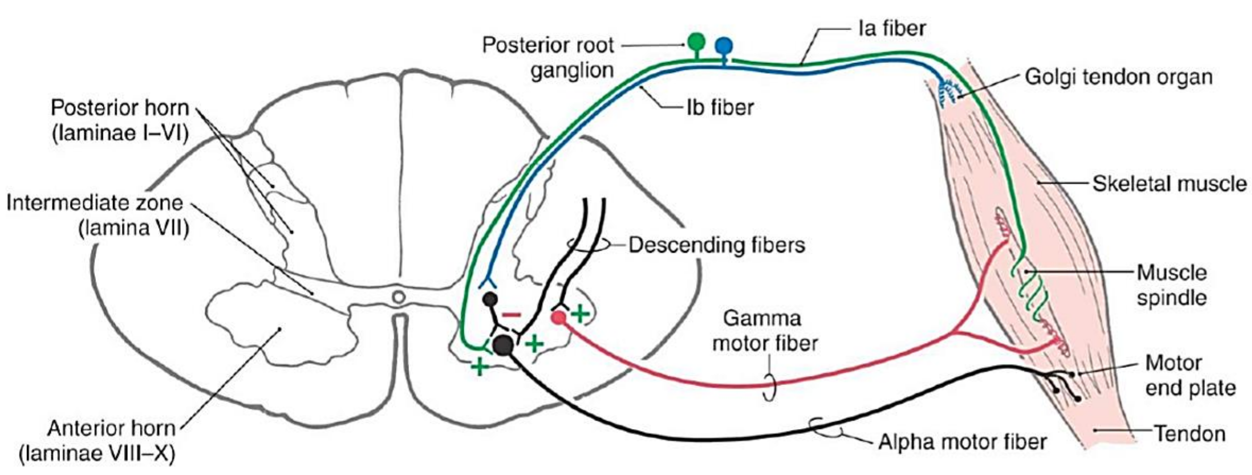
A motor unit is made up of a motor neuron and the skeletal muscle fibers innervated by that motor neuron's axonal terminals. Small motor units will be helpful in fine and delicate movements such as writing and drawing, while big motor units will be helpful in gross movements such as walking.

To sense the muscle position, we have **two** types of receptors: **Muscle spindle** (stretch and length of the muscle) **and Golgi tendon organ** (tension in the muscle).

20:00 – 30:00

-Muscle spindle is needed to maintain a constant muscle length that can be changed by stretch, if your muscle is at a certain length and it was stretched for some reason (applying weight suddenly on your hand for example), the muscle spindle will **sense the stretch** and send it as a sensation via **sensory afferent fibers (Ia),** those will enter the spinal cord from the posterior horn and synapse with **alpha motor fibers** (which supply the extrafusal muscle fibers / fibers outside of the muscle spindle), **causing contraction of the muscle to resist the sudden stretch**. The more the stretch, the more the firing from the muscle spindle, results with more contraction in the muscle.

It is not logical that we maintain the muscle length by sending continuous signals from the cortex, it's the job of **the muscle spindle**, when a signal comes from the cortex it will **activate Gamma motor fibers that are going to the periphery of the muscle spindle**, contraction of the periphery will cause the center of the muscle spindle **to stretch,** that will send signals through **afferent sensory fibers** that will synapse with **alpha-motor neurons** causing the muscle to contract, this is known as the **Gamma-loop**.



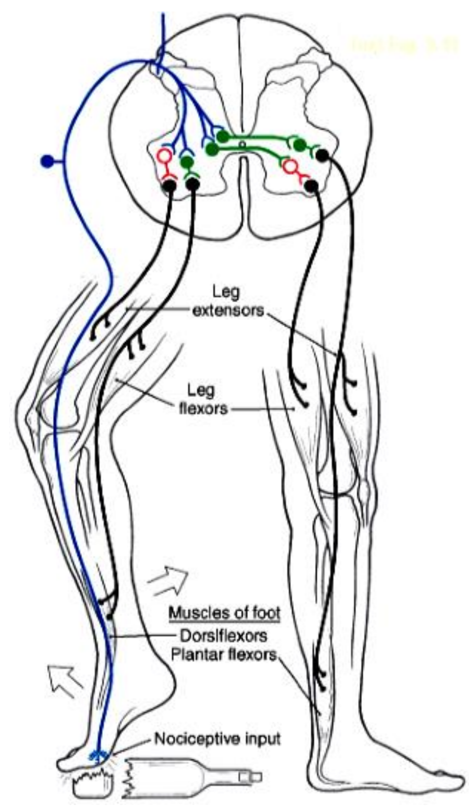
=> Spinal cord reflexes: (keeping the muscle length constant**)**

1- **Muscle stretch reflex:** stretch the muscle will activate the muscle spindle which will send sensory signals to the brain and to the spinal cord. The ones in the spinal cord will synapse with the alpha-motor fibers causing contraction of the muscle to resist the stretch (monosynaptic loop).
2- **Reciprocal inhibition:** the sensory fibers from the muscle spindle will not only synapse with alpha-motor neurons but also <u>with inhibitory interneuron</u> which will inhibit muscles on the opposite side (if extensors are activated, flexors will be inhibited).

Because of the two previous reflexes, when hit a tendon of a muscle causing sudden stretch, it will contract suddenly, this is called **Jerk reflex**, which is tested usually in the knee joint.

Example: if you are holding an empty cup and suddenly filled it, the muscle spindle in your biceps will detect sudden stretch in the fibers, it will send a signal to the spinal cord causing contraction of the biceps muscle and inhibition of the extensors.

3- **Tendon reflex (autogenic inhibition):** Golgi tendon organ is needed to protect the muscle from excessive load, it is located in the tendon of the muscle, increased tension in the muscle will cause Golgi tendon organ to send signals to the spinal cord that will synapse with an inhibitory interneuron that will inhibit the alpha motor fibers causing the muscle to relax in order to drop the weight.
4- **Flexor** (withdrawal) **reflex** (nociceptive reflex): when you step on something sharp for example a nociceptive input will enter the dorsal horn of the spinal segment and synapse with motor neurons that supply the flexors to cause flexion and avoid whatever caused the nociceptive input. (inhibition of extensors and activation of flexors).



5- **Crossed Extension Reflex:** when the flexor reflex happens, more weight will be applied on the other leg, that's why the nociceptive input will not synapse with the fibers of the same leg only, but will cross to the other side and synapse with the fibers of the other leg, causing activation of extensors and inhibition of flexors in order to stabilize the body.

***Note:** the muscle stretch reflex is mono-synaptic; it doesn't need interneurons, while the flexor reflex and the crossed extension reflex need interneurons even for both inhibition and activation, and also to send the signal to other segments (multi-level).

30:00 – 44:00

End of record 6

Back to the trigeminal nuclei:

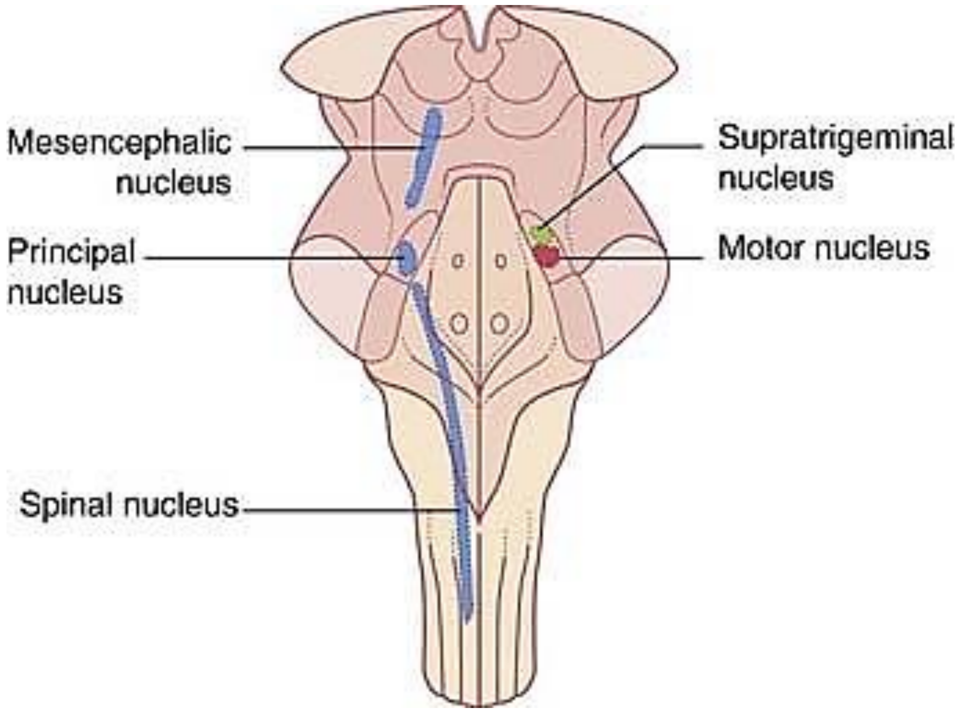
We mentioned that the trigeminal system contains four nuclei: the principal sensory nucleus, the spinal trigeminal nucleus, **the mesencephalic nucleus and the motor trigeminal nucleus.**

The motor trigeminal nucleus: This nucleus is located in the mid-pons next to the chief sensory nucleus and is responsible for the innervation of the muscles of mastication.

The mesencephalic nucleus: This nucleus is located in the upper part of pons and is involved with proprioception of the face, specifically, the proprioception of the muscles of mastication, temporomandibular joint and the periodontal ligament (for force of mastication). It is involved in chewing and masticatory reflexes.

The sensory nerves of the jaw reflex (periodontal ligament for example) don't have cell bodies in the trigeminal ganglion, instead, then their cell bodies are acutally in the **mesencephalic nucleus** (because the reflex works bilaterally). The signal is transmitted to the second order neurons in **the principle sensory nucleus**, then to the thalamus and then to the cortex (three neuronal pathway: 1st order is in the mesencephalic nucleus, 2nd order is in the principle sensory nucleus and the 3rd order is in the VPM of the thalamus).

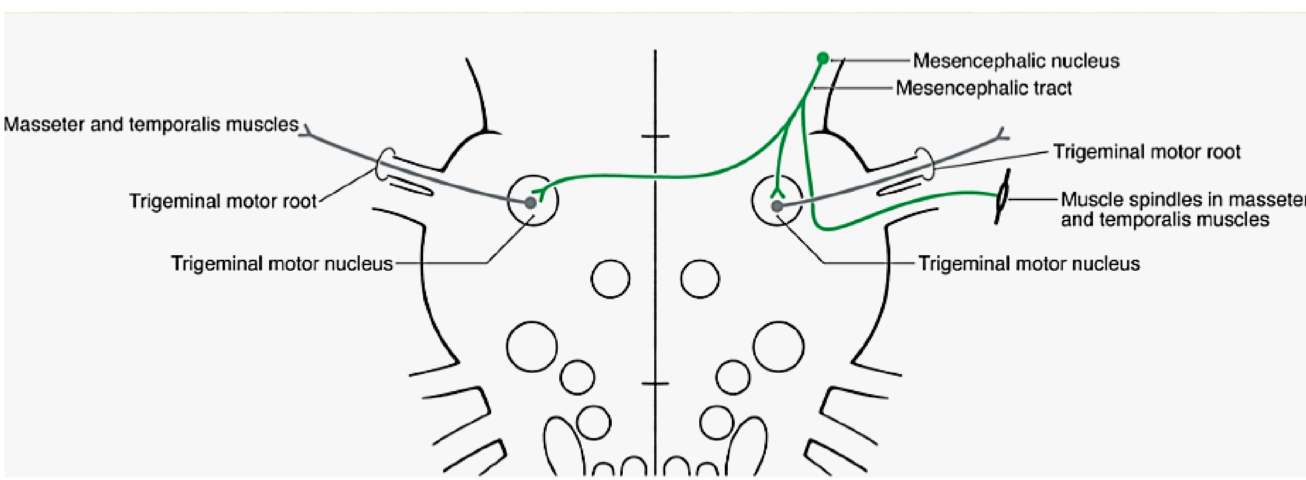
Both of **the mesencephalic nucleus and the motor trigeminal nucleus** work together to mediate the Jaw-Jerk-Reflex.



➔ **Jaw-Jerk-Reflex:**

The afferent neurons of the mesencephalic nucleus will send **signals to the motor trigeminal nucleus on both sides** (because mastication is a bilateral action) and it will be conducted to the muscles by **the mandibular branch** of the trigeminal nerve.

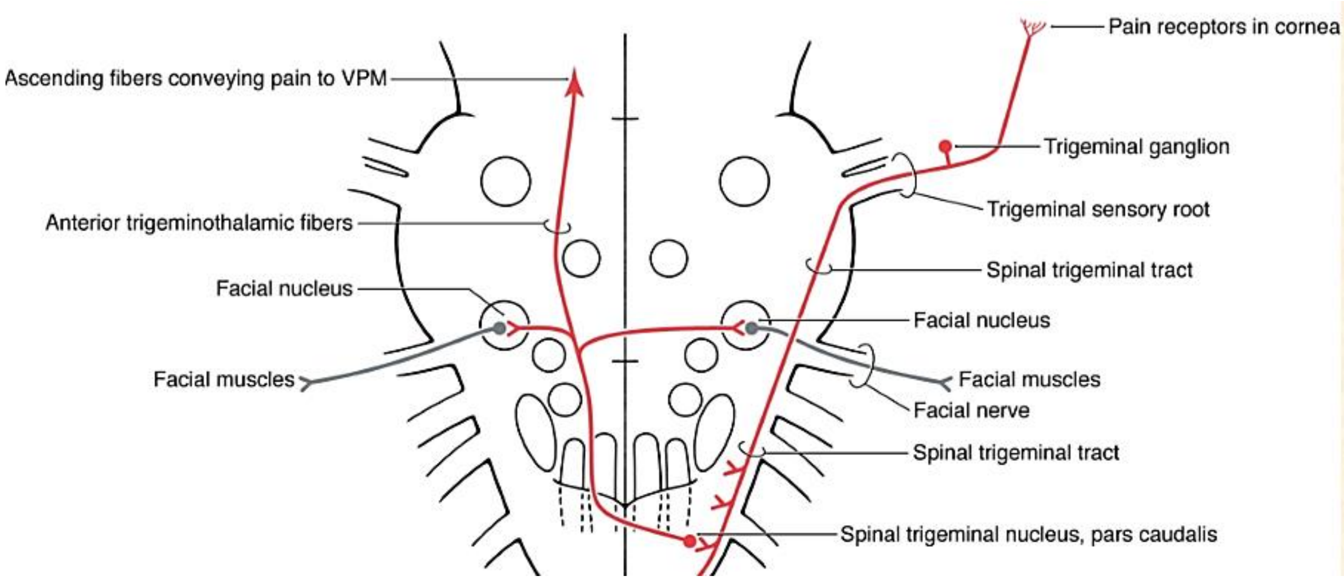
Jaw reflex can be tested by pressing on the tendons of the jaw muscles.



➔ **Corneal blink reflex pathway:**

The afferent neurons will carry the sensation of the cornea **via the ophalmic branch of the trigeminal nerve** to the trigeminal ganglia, then it will descend to spinal trigeminal nucleus and synapse with the second order neurons which will:

1- Convey the message to the VPM of the thalamus and then to the cortex.
2- Synapse with the **facial nerve fibers** in **the facial nucleus** on both sides to induce blinking by activation of the orbicularis oculi muscle.



Record 7
00:00 – 10:30

Thank you