Central Nervous System

Sheet 4

Subject | Physiology

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Correction | ...

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In the previous lecture, we discussed some clinical aspects regarding the anterolateral system in general. Now, we will discuss it in more details:

Cont. Clinical Aspects

- In the **ALS**, the 1st order neurons arise from the sensory receptors in the periphery. They **enter** the spinal cord through the **dorsal nerve root**. After synapsing, 2nd order neurons ascend **obliquely** 2 vertebral levels as the decussate, and finally **synapse** in the ventral posterolateral nucleus of the thalamus.

In the PCML pathway, nerves **directly** enter the spinal cord and **ascend** in a **straight** line. Whereas in the ALS pathway, the pattern of '0-1-2' suggests that in the **anterolateral tract**:

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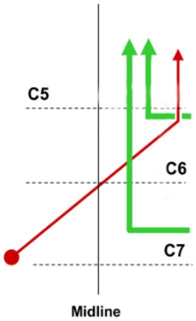
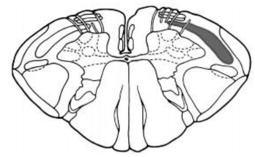
- ⇨ **At level 0**: the 1st order neurons enter the spinal cord at the level of C7 for example and synapse there.
- ⇨ **At level 1**: the 2nd neurons' fibers keep ascending obliquely through the **midline** of C6.
- ⇨ **At level 2**: decussation finally ends at C5, which is 2 segments above the point of entry.

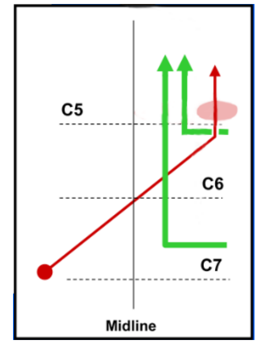


Key:

Red lines: ALS pathway
Green lines: PCML pathway
Pink circles: Lesions

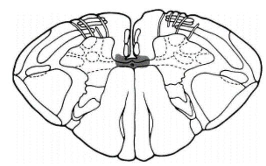
- **Example 1:** **damage to the anterolateral tract of C5 segment**.
    - ⇨ Fibers passing through the anterolateral tract at C5 will be the ascending fibers of C7 (2 levels below). This will cause loss of **ALS** sensations, on the **contralateral** side of the lesion, **C7 and below**.

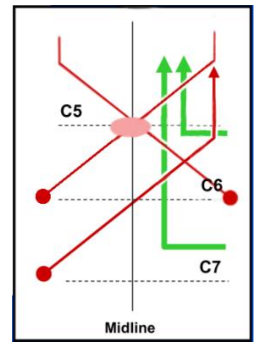




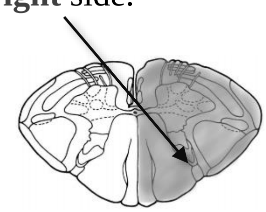
- **Example 2:** **damage to C5 at the midline**.
    - ⇨ Loss of **ALS** modalities of **C6** on **both sides**.

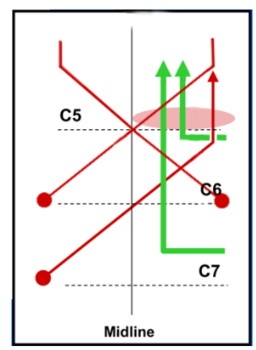
> **Note**: this represents **syringomyelia**, in which a fluid-filled cyst forms within the spinal cord. It lengthens over time and **damages** part of the spinal cord **centrally**.



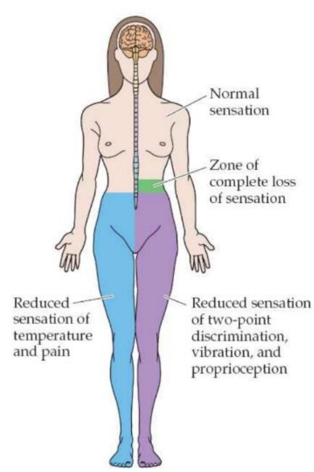


- **Example 3:** **damage to the right half of the spinal cord at C5 causes**:
    1. Loss of **ALS** modalities on the **left** side, **C6 and below**.
    2. Loss of **PCML** modalities on the **right** side, **C5 and below**.
    3. Damage to the **entry zone** of 1st order neurons will cause loss to **both** PCML and ALS sensations at the level of **C5** on the **right** side.





> **Note 1**: This represents Brown-Séquard syndrome, which is caused by damage to one half of the spinal cord, i.e. **Hemisection** of the spinal cord.
>
> **Note 2**: Notice that the affected **central area** in this example is **not fully** damaged as in example 2; only half of it is. Thus, only the fibers ascending from **C6** on the **left** side are affected **sparing** the **right** side *'refer to the image'*.



⇨ **Rule**: **Hemisection damage to the spinal cord causes**:

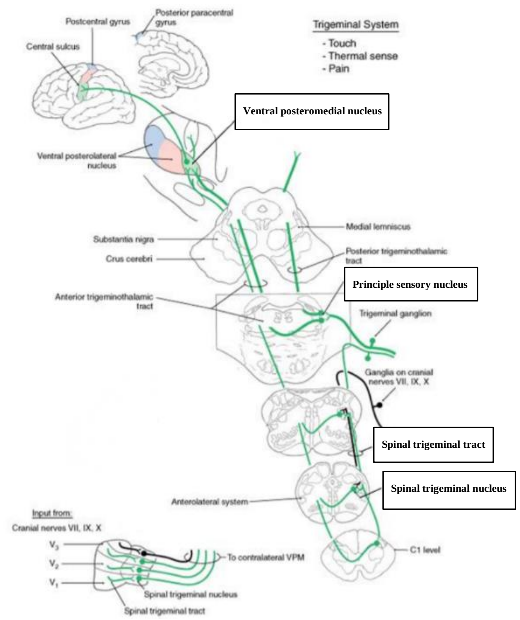
1. **Complete loss** of sensations at the **level of the damage** ipsilaterally.
2. PCML sensations loss **ipsilaterally** all the way below the damage.
3. ALS sensation loss **contralaterally** all the way below the damage.

The Trigeminal System

- The general senses of somatosensation for the **face** travel through the **cranial nerves**, specifically, the **trigeminal system**.
- The trigeminal pathway carries somatosensory information from the face, head, mouth, and nasal cavity. As with the previously discussed nerve tracts, the sensory pathways of the trigeminal pathway each involve three successive neurons:

1- **First-order neurons:**

Fibers of the first-order neurons passing through the **trigeminal ganglion** enter the brain stem at the level of the **pons** (not at the level of the spinal cord as in other previously discussed systems). These axons project to the **trigeminal nuclei** to synapse with the 2nd order neurons cell bodies. There are 4 major trigeminal nuclei, we will discuss 2 of them:



a- **<u>The spinal trigeminal nucleus</u>** in the **medulla** receives **ALS** modalities, similar to those carried by the spinothalamic tract, such as pain and temperature sensations.

b- **<u>The chief sensory nucleus</u>** in the **pons** receives **PCML** modalities, similar to those carried by the dorsal tracts, such as two-points discrimination and pressure.

> **<u>Note</u>**: the chief sensory nucleus is also known as the main/principle sensory nucleus.

2- **Second-order neurons:**

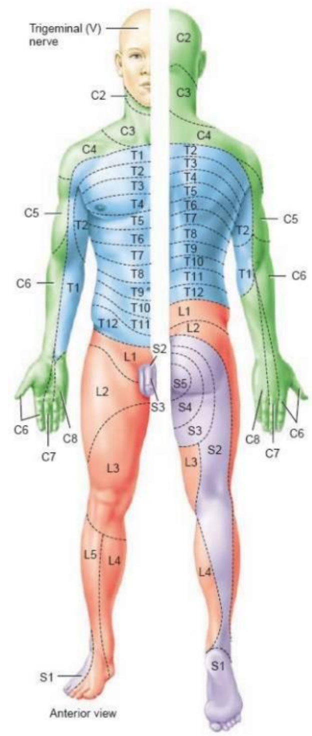
Axons from the second neuron leave their respective nucleus, decussate and ascend to the **thalamus** along the **trigeminothalamic tracts**. In the thalamus, each axon, in its particular pathway, synapses with the 3rd neurons cell bodies in the **ventral posteromedial nucleus** (in the PCML and ALS pathways, they synapsed in the VPLN).

3- **Third-order neurons:**

Axons from the third neuron then project from the thalamus to the **primary somatosensory cortex** of the cerebrum.

Dermatomes

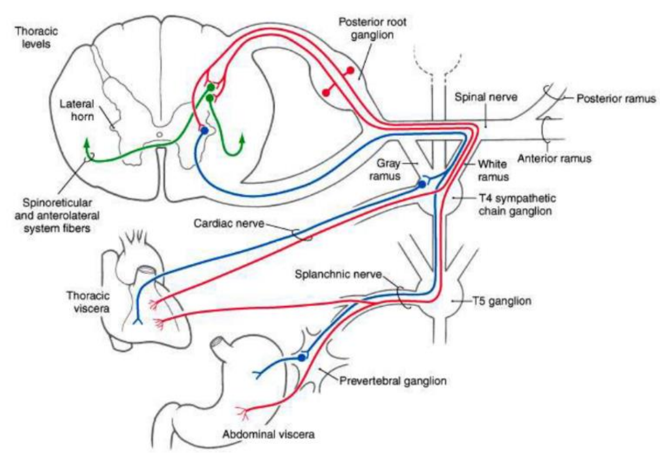
- A dermatome is the area of the skin of the human anatomy that is mainly supplied by branches of a **single spinal sensory nerve root**.
- Most important dermatomes to memorize are:



Organ	Dermatome
Shoulder	C5 - C6
Hand	(C6-C8): 6= thumb, 7= index, 8= small finger
Nipple	T4
Umbilicus	T10
Inguinal region	T12 - L1
knee	L3 - L4
The big toe	L4 - L5
Small toe	S1
Genitalia and anus	S4 - S5

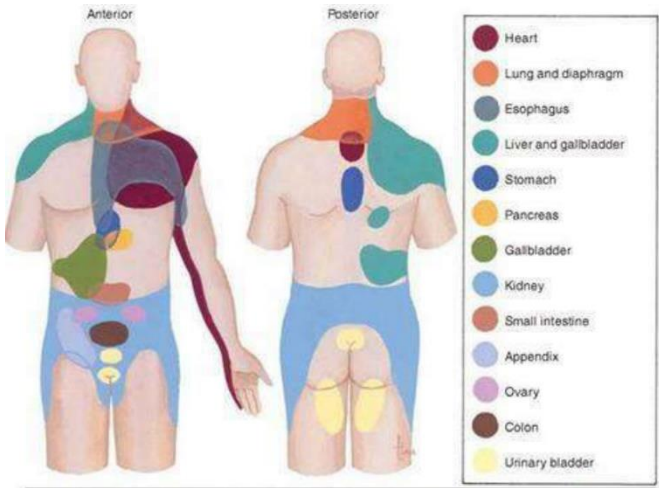
Visceral sensory and Referred pain

- Visceral sensory neurons transmit conscious sensations arising from the **viscera**, which can be pain, bloating, dyspnea, etc.
- Visceral pain is **referred** to other, often **remote,** locations. It is **diffuse** and **poorly** localized.
- Referred pain is presumed to occur because the information from **multiple** nociceptor afferents (body surface and visceral) usually **converges** onto individual spinothalamic tract neurons.
- The brain, therefore, interprets the information coming from visceral receptors as having arisen from receptors on the **body surface**, since this is where nociceptive stimuli originate **more** frequently.



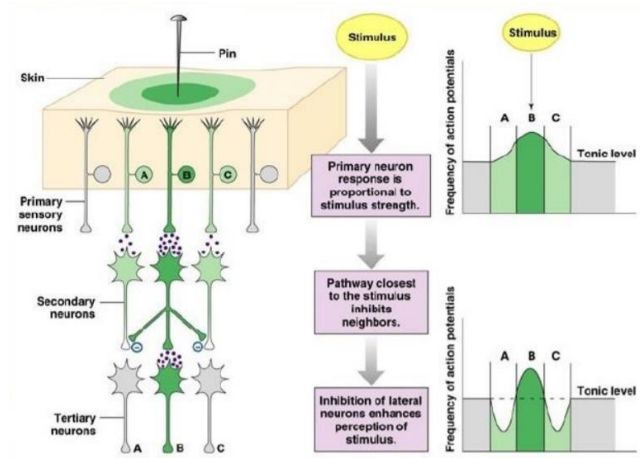
This picture shows how the pain from each visceral organ (color-coded) is referred to a specific area of the body's surface.

(memorize)

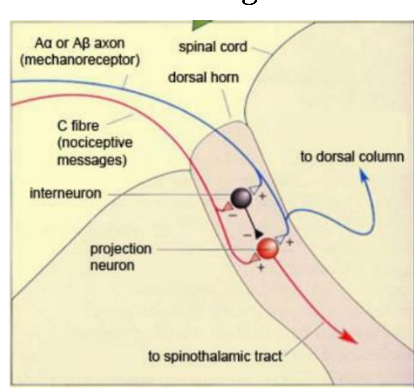


Lateral Inhibition

- Lateral inhibition involves the **suppression** of neurons by **other** neurons. **Stimulated** neurons **inhibit** the activity of nearby neurons, which helps **sharpen** our sense perception.
- **Base-line firing**: receptors are **always** firing a constant rate of action potentials. Thus, neurons can be either **excited** 'above base-line', or **inhibited** 'below base-line'.
    - ⇨ When applying **pressure** to a specific point on the skin, the neuron responsible for that point is **stimulated** 'above the base-line', while the area around the point of pressure is **laterally inhibited** 'below base-line' to **sharpen** the sensation.



- **Pain Gate theory**: it suggests that **non-painful** input **closes** the nerve "gates" to **painful** input through **lateral inhibition**, which prevents pain sensation from traveling to the central nervous system.
    - ⇨ Exciting the **PCML** pathways causes **lateral inhibition** to the **ALS** pathway. When PCML fibers enter the spinal cord, it sends many **collateral axons**, one of them **inhibits** the ALS fibers. Thus, pain in a certain area (ALS sensation) tempts us to apply pressure (PCML sensation) on it to reduce the pain by lateral inhibition.



Sensation Adaptation

- Adaptation is the decline of the electric responses of a receptor over time despite the continued presence of a stimulus. It can occur through 3 mechanisms:

1- **Receptor adaptation:** frequency of action potentials decrease as the receptor adapts. Types:

   a- **Rapidly adapting**: receptors quickly adapt, they reactivate if the stimulus keeps changing (on/off), e.g. the rapidest adapting receptors are vibration receptors.

   b- **Slowly adapting**: these receptors adapt slowly, thus they remain active for the duration of the stimulus, e.g. the slowest adapting receptors are pain and pressure receptors.

   c- **Non-adapting**: they continuously keep responding to stimuli, e.g. olfactory receptors.

2- **Central adaptation:** it is done at the level of the CNS. Some non-adaptable receptors may have **adaptable** neurons ($2^{nd}/3^{rd}$ order neurons) causing a **decrease** in the output after a while. It may also occur due to **neuronal exhaustion** (fatigue).

3- **Central regulation:** the CNS can send fibers to sensory pathways and either **increase** (sensitize) or **decrease** (desensitize) their outputs and activity.

   Example: all odorant receptors are **2^{nd}-messenger types** of receptors, hence olfaction sensation has almost **no receptor adaptation**. In the olfactory system, **centrifugal fibers** are sent to provide feedback to the olfactory bulb from the central nervous system and influence the processing taking place in the olfactory bulb by either sensitization or desensitization.

Good Luck