

Question 1 - Mechanoreceptors

Explain the primary sensory transduction process in a touch receptor. What is a mechanosensitive ion channel, and for which ions is it permeable to?

When the skin experiences touch or pressure, that skin deformation in the tissue is sensed by specialized structures embedded in the skin called mechanoreceptors and transformed into an electrical signal (action potential).

More precisely, skin deformations cause the opening of mechanosensitive ion channels embedded in the cell membrane of mechanoreceptor cells (e.g., Merkel cells, Meissner's corpuscles,). Those ion channels are selective to cations (Na^+) which means that their opening leads to the depolarization of the mechanoreceptor cell. If the mechanoreceptor membrane potential is sufficiently depolarized, an action potential is generated and sent to the brain via afferent fibers.

Question 2 – proprioception:

a) Explain what proprioception is.

b) Name and describe the main sensors that mediate proprioception.

c) What everyday life disabilities do you expect in patients with deficits in proprioception?

a) Proprioception is the body's ability to sense its own position, movement, and orientation in space without relying on visual input.

b) Muscle Spindles: Located within muscles, these structures detect changes in muscle length (stretch). Muscle spindles are made up of small, specialized muscle fibers called *intrafusal fibers*, which are encapsulated within connective tissue. Muscle spindles are found among regular muscle fibers (extrafusal fibers) used for muscle contraction. When a muscle is stretched, the intrafusal fibers also stretch which causes the opening of mechanosensory channels in the respective sensory neuron and thus increases the rate of action potentials.

Other sensor types:

- Golgi Tendon Organs: Found in tendons (connective tissue that links muscles to bones), these receptors monitor muscle tension.
- Joint Receptors: Located within joints help to sense the angle, rotation, and movement of joints

c) Some examples:

- Difficulty or inability to walk or grasp objects without looking at their limbs/objects
- Abnormal gait
- Difficulty to maintain upright and stable posture
- Increasing risk of falling
- Inability to self-regulate movement e.g., when grasping something

Question 3 – Neural pathway of touch:

Think about the electrical signal that a tactile stimulus applied at the fingertip generates. Describe as precisely as you can the path that this electrical signal will take to reach the cortex.

- **First-Order Neurons:**

The action potential travels along the first-order sensory neuron, which is a type of fast-conducting A β fiber. This neuron's cell body resides in the *dorsal root ganglion* located near the spinal cord, where the signal bypasses the cell body and continues along the axon toward the spinal cord.

The axon of the first-order neuron enters the spinal cord through the dorsal root. Instead of making synaptic connections immediately, it enters the dorsal columns of the spinal cord (specifically the cuneate tract for signals from the upper body) and ascends toward the brainstem.

The first-order neuron travels ipsilaterally (on the same side as the stimulus) up the spinal cord through the dorsal column, reaching the medulla in the brainstem.

- **Second-Order Neurons:**

In the medulla, the first-order neurons make synaptic connections with the second-order neurons in the nucleus cuneatus. The second-order neurons then decussate (crosses over) to the opposite side, joining the medial lemniscus pathway, which continues to carry the signal up to the thalamus.

- **Third-Order Neurons:**

The second-order neurons make synaptic connections with third-order neurons in the ventral posterior lateral (VPL) nucleus of the thalamus. The thalamus acts as a relay station, processing the sensory information before sending it to the cerebral cortex.

The third-order neurons project from the thalamus to the primary somatosensory cortex (S1), located in the parietal lobe.

Question 4 – Homunculus:

- a) What does the homunculus illustrate?**
- b) If you had to derive the homunculus experimentally, how would you proceed?**
- c) Choose one animal model (e.g., the mouse) and think about how its somatotopic map or” animal-culus” might differ from a human’s homunculus**

a) The better the tactile acuity in a body region, the higher the density of touch receptors in that region and the bigger the dedicated brain area in S1 will be. The S1 area dedicated to one body region is not always proportional to the physical size of that body region. This is what the homunculus illustrates. For example, in the homunculus, the hands, lips and tongue are disproportionately large because those body regions have a very high touch receptors density and fine tactile acuity.

b) One could measure the tactile acuity (e.g., using 2-points discrimination task) over all body regions.

Alternatively, one could map the cortical somatotopy (e.g., using fMRI, electrical stimulation during surgery...) and then measure the brain regions size.

c) Some examples:

- A monkey-culus would have equal-sized feet and hands because monkeys use their feet a lot more (e.g., to grasp objects...).
- Most tailed animals would have an additional S1 region dedicated to their tail, it would probably be adjacent to the back or legs region.
- A mouse-culus would have a very large snout area because they use whisker-based touch a lot.