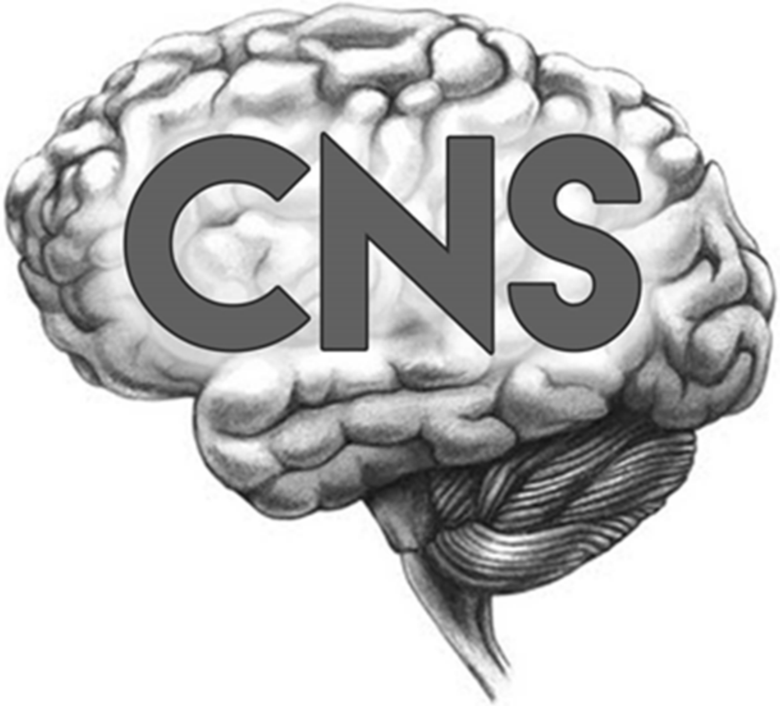

PHYSIOLOGY

☑ Sheet ○ Slide ○ Handout

Number

12

Subject

Sensory Pathways

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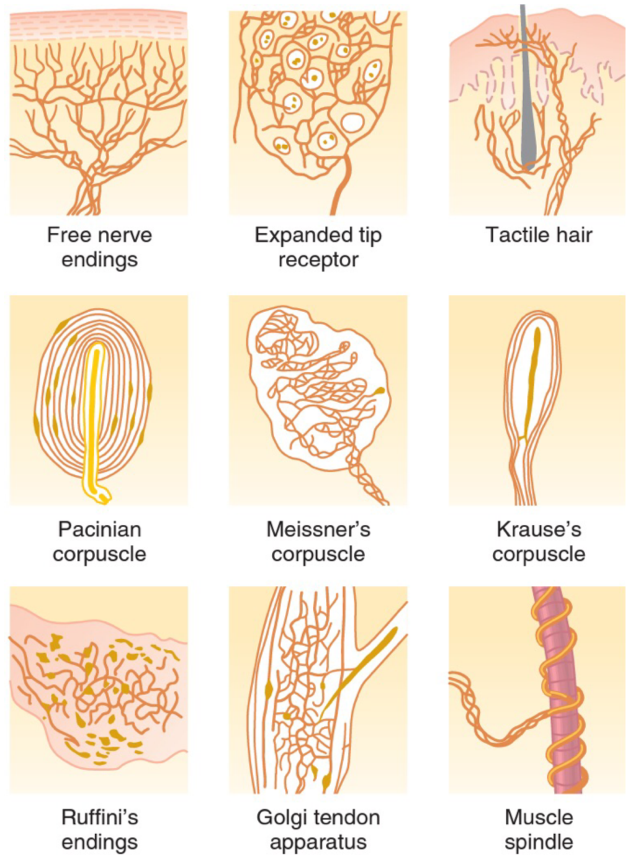
Date: **00/00/2016**

Price:

In the previous lecture, we started talking about the somatic sensory system. And we classified the receptors according to modality and location.

Types of receptors:



1. Free nerve endings: (Aδ)
    - Detect touch and pressure.
    - Found everywhere in the skin and other tissues.

2. Expanded tip receptors

3. Merckle's discs: (Aβ)
    - Found in both in both hairy and glabrous (non hairy) skin.
    - Rapidly adapting.
    - Form a ridge under the epidermis (Iggo dome).

4. Meissner's corpuscles: (Aβ)(encapsulated)
    - Rapidly adapting.
    - Detect low frequency vibrations.
    - Found in hairy and glabrous (non hairy) skin, fingertips and lips.

5. Pacinian corpuscles: (encapsulated)
    - Very rapidly adapting.
    - Detect high frequency vibration.
    - Onion ring appearance.

6. Muscle spindle and Golgi tendon organ (1a and 1b respectively)
    - For proprioception.

7. Ruffini's end organs:
    - Deep in the dermis and around the joints>>> for proprioception.
    - Slowly adapting.

8. Hair End organs:
    - Rapidly adapting.
    - Sensitive to hair movement (located along the hair shaft).

These receptors are connected to neurons that are mostly myelinated, for example, free nerve endings are connected to:

1. Aδ fibers (small myelinated fibers, transmit signals at a velocity of 5-30 m/sec).
2. C fibers (non-myelinated, transmit signals at a velocity of 0.5m/sec).

While Meissner's corpuscles, hair receptors, Pacinian corpuscles and Ruffini's end organs are connected to Aβ (myelinated and fast-conducting: 30-70m/sec).

The more critical the information, the faster the rate of transmission.

- Once the spinocerebellar tract receives the input, velocity may reach up to 120m/sec.
- The velocity of the conduction is a reflexion of faithfulness (fidelity) and orientation of the tract.
- Fast conduction: Good spatial (space) and temporal (time) orientation.
- If a system is fast-conducting, it will transmit the signal before the arrival of the second signal, while if it was slow-conducting, the second signal might catch up with the first one, i.e. less faithfulness and less orientation in terms of space and time.

Pathways for the Transmission of Sensory Information:

1- **Dorsal column-medial lemniscus:**

- For transmission of fine touch, stereognosis, vibration and two-point discrimination, in other words: discrete types of mechanoreceptive information.
- Transmits information rapidly and with a high degree of spatial and temporal fidelity throughout the tract, so sensations will be well-localized.

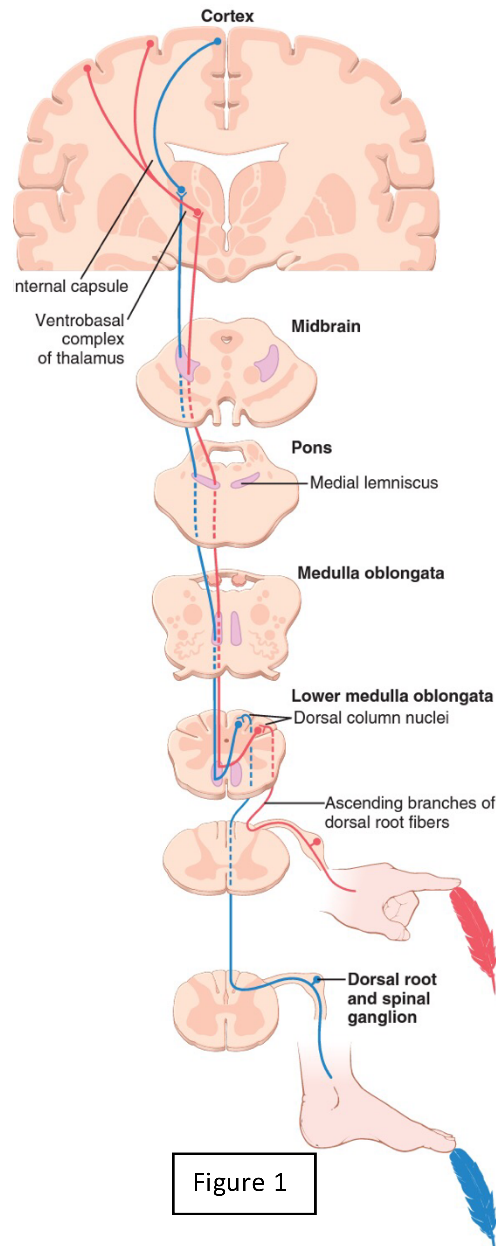


Figure 1

Look at figure 1:

1. Fibers coming from the receptor enter the spinal cord through the dorsal horn and ascend up through their tracts in the dorsal cloumn; cuneate tract for the upper limb and gracile for the lower limb.
2. They keep ascending up till reaching their corresponding nuclei (cuneatus and gracilis) where they synapse with the second-order neurons.
3. Second-order neurons decussate immediately to the opposite side of the brain stem and continue upward through the medial lemnisci to the thalamus where they synapse in the ventrobasal complex.
4. From the ventrobasal complex, third-order nerve fibers project, mainly to the postcentral gyrus of the cerebral cortex, which is called somatic sensory area.

Notes:

1. The dorsal column system relays signals from the lower part of the body to the medial aspect of the dorsal column, as the tracts ascend up, the fibers will be arranged excellently from lateral to medial with those coming from the lower limb lying most medially (remember gracile and cuneate tracts).

2. If the medial aspect is destroyed, pathways coming from the lower limb are destroyed. (In other systems the arrangement is a bit more crude).

3. The effect of destruction of gracile or cuneate tracts below the nucleus is ipsilateral, while if the destruction happens above the level of the nucleus the effect will be contralateral.

Remember that the area in cerebral cortex that represents any part of our body is proportional to the density of the receptor of that area.

Two point discrimination is very fine in the tips of the fingers and the lips>>>>>high density of receptors. In the back it’s more crude because the density of the receptors is low. The larger the receptor field, the less the localization is and vice versa.

The somatic sensory area: (figure 2)

- Behind the somatic sensory area is the secondary association area, which determines the meaning of the sensation (remember when we said that each primary area has a secondary association area, such as areas 17 (primary visual cortex) and areas 18&19 are association areas).

Figure 2 shows two separate sensory areas in the anterior parietal lobe called somatosensory area I and area II.

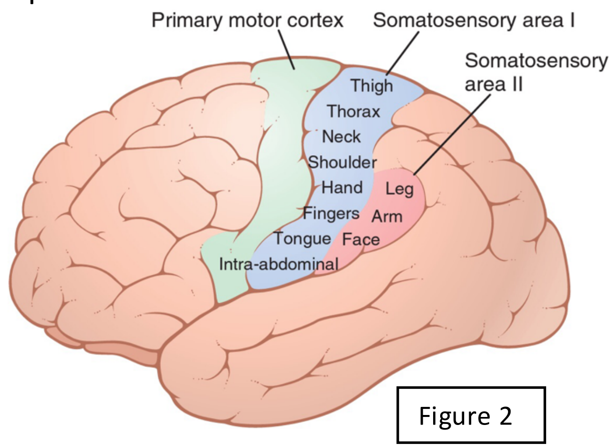


Figure 2

- The reason for this division into two areas is that a distinct and separate spatial orientation of the different parts of the body is found in each of these two areas.
- Somatosensory area I has a high degree of localization of the different parts of the body, as shown by the names of virtually all parts of the body in the figure.
- By contrast, localization is poor in somatosensory area II and the representation is rough.
- Somatosensory area I is so much more extensive and so much more important than somatosensory area II that in popular usage, the term "somatosensory cortex" almost always means area I.

Mapping of the Primary Somatosensory Area: (figure 3)

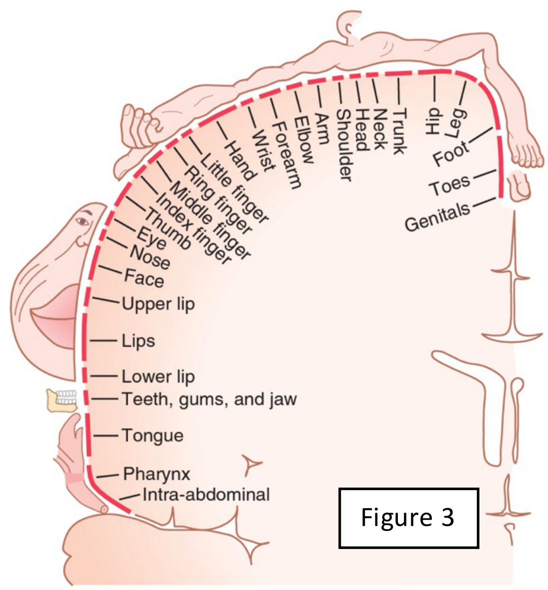


Figure 3

- The size of the cortical region representing a body part depends on the density of the receptors on that part and sensory impulses received from that part.
- The somatic sensory area has high organisation, contralateral unequal representation.
- The area of the lower limb and trunk is small compared to the area of the upper limb
- The area of the face is very large >>> high density of receptors.
- Some believe that visceral structures are represented in the insula, but the viscera actually have no representation in the cortex and that's why we have referred pain (to be discussed).

Dermatomes and referred pain:

- During embryogenesis, segment T10 will supply the skin surrounding the umbilicus by spinal nerves (the skin is a somatic organ arising from ectoderm), at the same time, segment T10 will also innervate the appendix via autonomic nerves (the appendix is a visceral organ arising from mesoderm).

- So sensory fibers coming from the skin and the appendix will enter the spinal cord at the same segment, and since viscera has no cortical representation, the cortex will explain it as a somatic pain coming from the skin around the umbilicus. Referred pain will be discussed later in more details.

1- **Anterolateral system-spinothalamic pathway:**

- This system transmits crude touch, crude pressure, nociceptive sensation, itch, tickle, thermal and sexual sensation through **Aδ and C** fibers so it has poor fidelity and faithfulness compared to dorsal column system.
- In addition to that, the sensations are poorly localized hence it transmits broader modalities of sensation (pain, temperature, sexual...) and the grades of intensity are much less due to slow velocity.

  What are the grades of intensity?

  Grading intensities is similar to our marks, they can be absolute from 1-100, i.e., you have 100 different grades. Or they can be expressed by letters from A-F and you'll have 11 different grades.

  The grades of the anterolateral system can be imagined as the alphabetical grading, and the grades of the dorsal column system can be imagined as the absolute grading. Meaning that the dorsal column system is more specific.

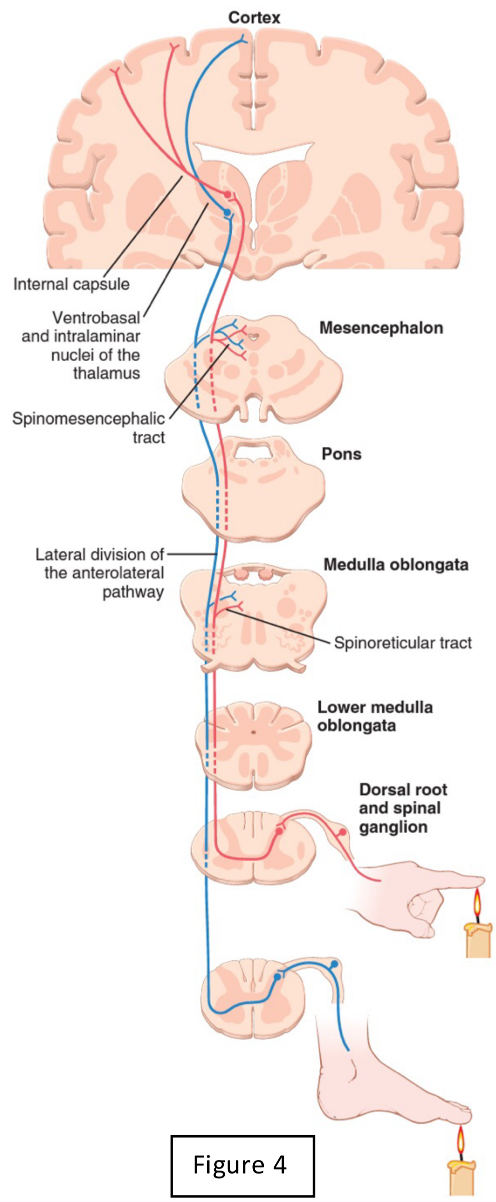


Figure 4

- As shown in figure 4, from the receptors, afferent neurons enter the spinal cord through the dorsal root ganglion, and before entering the posterior horn, they go 1-2 segments up or down (the same happens in reflexes when the stimulus is pain).
- After entering the posterior horn they synapse with the 2nd motor neuron and cross immediately anterior to the central canal to the opposite side.
- Fibers then ascend up to the thalamus (VPL and intralminar nuclei).

Notes:

- Basal ganglia (caudate) receive pain afferents from the intralaminar nuclei of the thalamus for the cognitive function, because pain has an emotional aspect (the expressions and emotions of someone in pain).
- Some fibers of the anterlolateral pathway end in the thalamus (don't reach the cortex), so when the cortex is destroyed, crude pain and temperature can still be sensed at the level of the thalamus (but not fine touch and pressure).
- The anterolateral pathway transmits pain which is either fast or slow.
  - Fast pain is transmitted through Aδ fibers. Fast pain is acute, pricking and sharp, for example: when you cut your finger with a blade.
  - Slow pain is transmitted through C fibers. Slow pain is nauseating, throbbing, dull, aching and accumulating example: tooth ache.
- Pain is an unpleasant feeling due to tissue damage and it is a protective mechanism, because when you feel pain you'll try to treat it by stopping the tissue damage, otherwise tissue damage will continue. Pain is not adapting in nature and this is of great benefit especially in diabetics with peripheral neuropathies, they lose pain sensation from the lower limb so they may not be aware of injury in their feet>>>gangrene>>>amputation.
- Pain receptors are polymodal; they can be mechanical, chemical or electric.
- Chemical mediators of pain are Bradykinins, calcium, serotonin....etc
- Prostaglandins don't cause pain, they decrease the threshold for pain so you feel pain easily >>> aspirin blocks the pathway of cyclooxygenase (which produces prostaglandins and thus reliefs pain.

Clinical correlate:

- Syringomyelia (a cyst within the spinal cord closely related to the central canal) disrupts the fibers as they cross, leading to segmental loss of pain sensation in 2-3 segments.

Comparison between the two systems:

Dorsal column system	Anterolateral system
Well localized	Poorly localized
High spatial and temporal orientation	Lower spatial and temporal orientation
Mechanoreceptive sensation	Broad modalities of sensation
Transmits vibration	Doesn't transmit vibration

Trigeminothalamic pathway: (figure 5)

It conveys all somatic sensations from the face whether through the dorsal column or the anterloateral system.

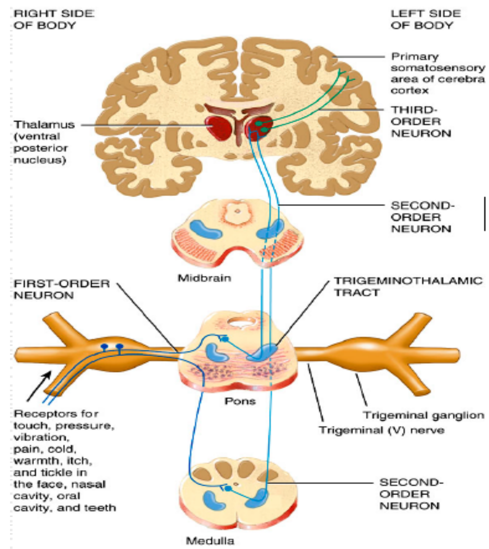


Figure 5

Cellular Organization of the Cortex:

The cerebral cortex is arranged into 6 layers:

- Within the layers, the neurons are also arranged in columns.
- Each column serves a specific sensory modality (i.e., stretch, pressure, touch).
- Different columns are interspersed among each other.
- Interaction of the columns occurs at different cortical levels which allows the beginning of the analysis of the meaning of the sensory signals.
- Incoming signals enter layer IV and spread both up and down.
- Layers I and II receive diffuse input from lower brain centers.
- Layer II and III neurons send axons to closely related portion of the cortex presumably for communicating between similar areas.
- Layer V and VI send axons to more distant parts of the nervous system (efferent); layer V to the brainstem and spinal cord, layer VI to the thalamus.

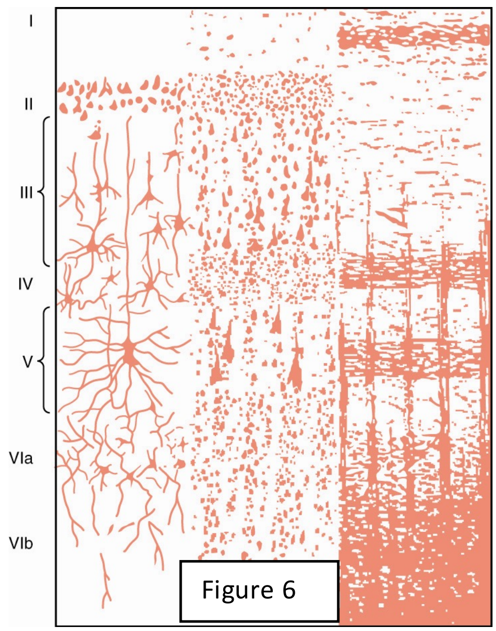


Figure 6

Function of the Somatic Sensory Cortex:

Destruction of postcentral gyrus leads to:

1. Loss of discrete localization and inability to determine the degree of pressure.
2. Astereognosis: the inability to determine the shape of the objects by touch.

Note: Stereognosis is highly developed in blind people: Braille language.

Function of the somatic association cortex:

- The somatic association cortex is located behind the somatic sensory cortex in the parietal area of the cortex.
- Association area receives input from somatic sensory cortex and explains the meaning of the sensation.
- Destruction of this area leads to **amorphosynthesis**, which is the inability to recognize complex objects and complex forms felt on the other side of the body. He/she loses most of the sense of form of his or her own body parts on the opposite side. The patient forgets that the opposite part of the body is there, so he/she forgets to use this part for motor functions: **hemineglect.**

Special Aspects of Sensory Function:

- Some fibers project downwards from the cortex for lateral inhibition (sharpening) and increasing the sensitivity of the receptors. Lateral inhibition is needed for two-point discrimination.
- How the does system code for intensity? (Figure 7)
  By: 1- number of impulses, and 2- number of stimulated fibers. When the stimulus is weak, it's able to stimulate the central area only. A stronger stimulus will stimulate a larger area and generate more impulses.

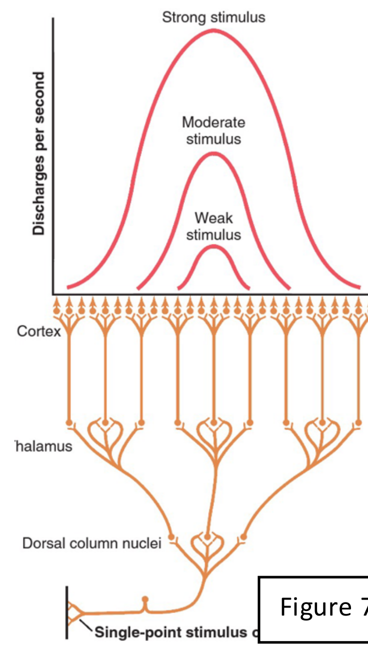


Figure 7

Processing of Position sense:

The movement of a limb (flexion or extension) will cause many neurons to discharge; some neurons will increase their discharge while other neurons decrease their discharge. The combination of increased and decreased discharges is going to be interpreted by the cortex as the degree of extension/flexion.

(Figure 8)

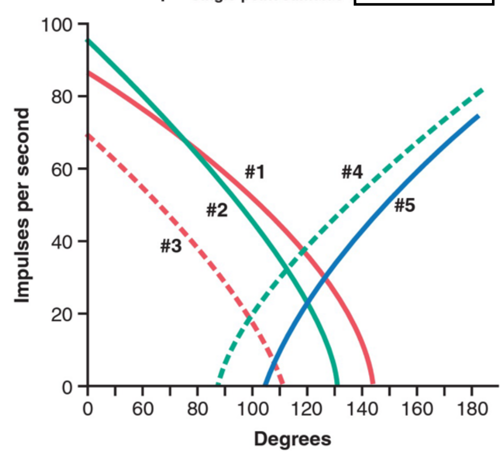


Figure 8

- Suppose there are 5 neurons, if you’re extending your hand at 150 degrees, impulses will come from #4 & #5, while if you’re flexing your hand, impulses will come from #1 & #2 & #3, this combination is interpreted by the cortex to define the degree of extension/flexion.