Somatosensory System

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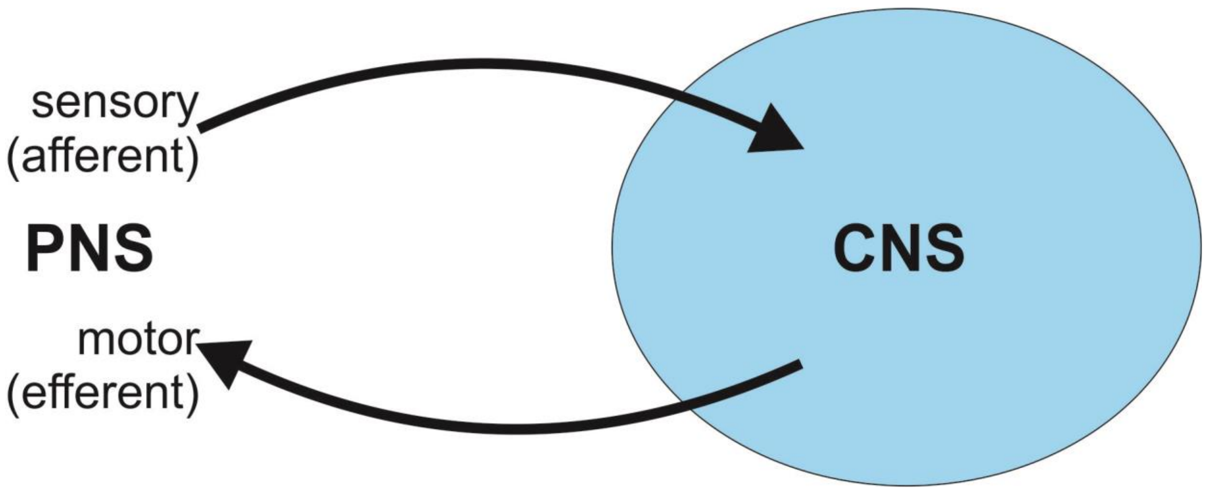
Sensory systems are used by an organism to monitor the state of it's environment and body.



There are several sensory systems.

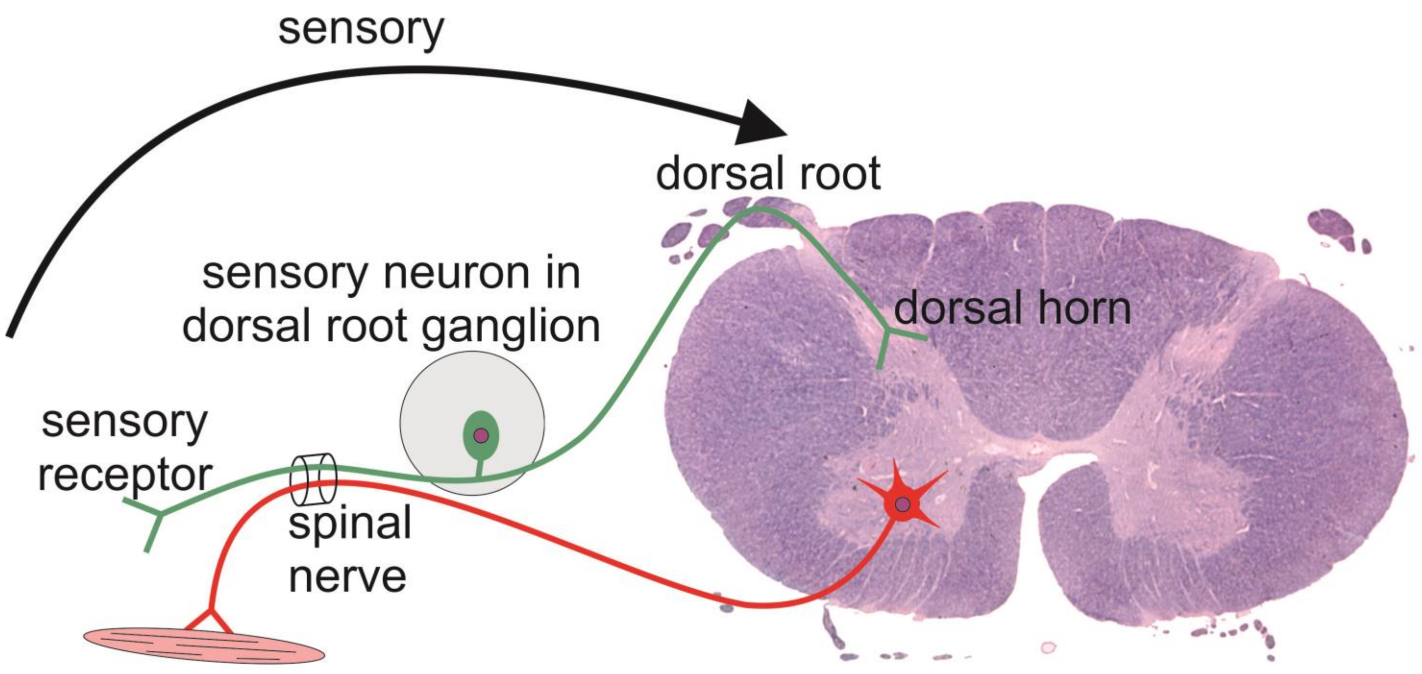
- Somatosensory
- Visceral sensory
- Special sensory
  - Vision
  - Auditory
  - Vestibular
  - Gustatory (taste)
  - Olfactory (smell)

The somatosensory system detects multiple sensations.

- Touch
  - fine touch
  - pressure
  - vibration
  - movement against the skin
- Proprioception
  - limb & trunk position
  - movement
  - load
- Thermoception (temperature)
  - heat
  - cold
- Nociception (pain – tissue damage)
- Pruritic reception (itch)

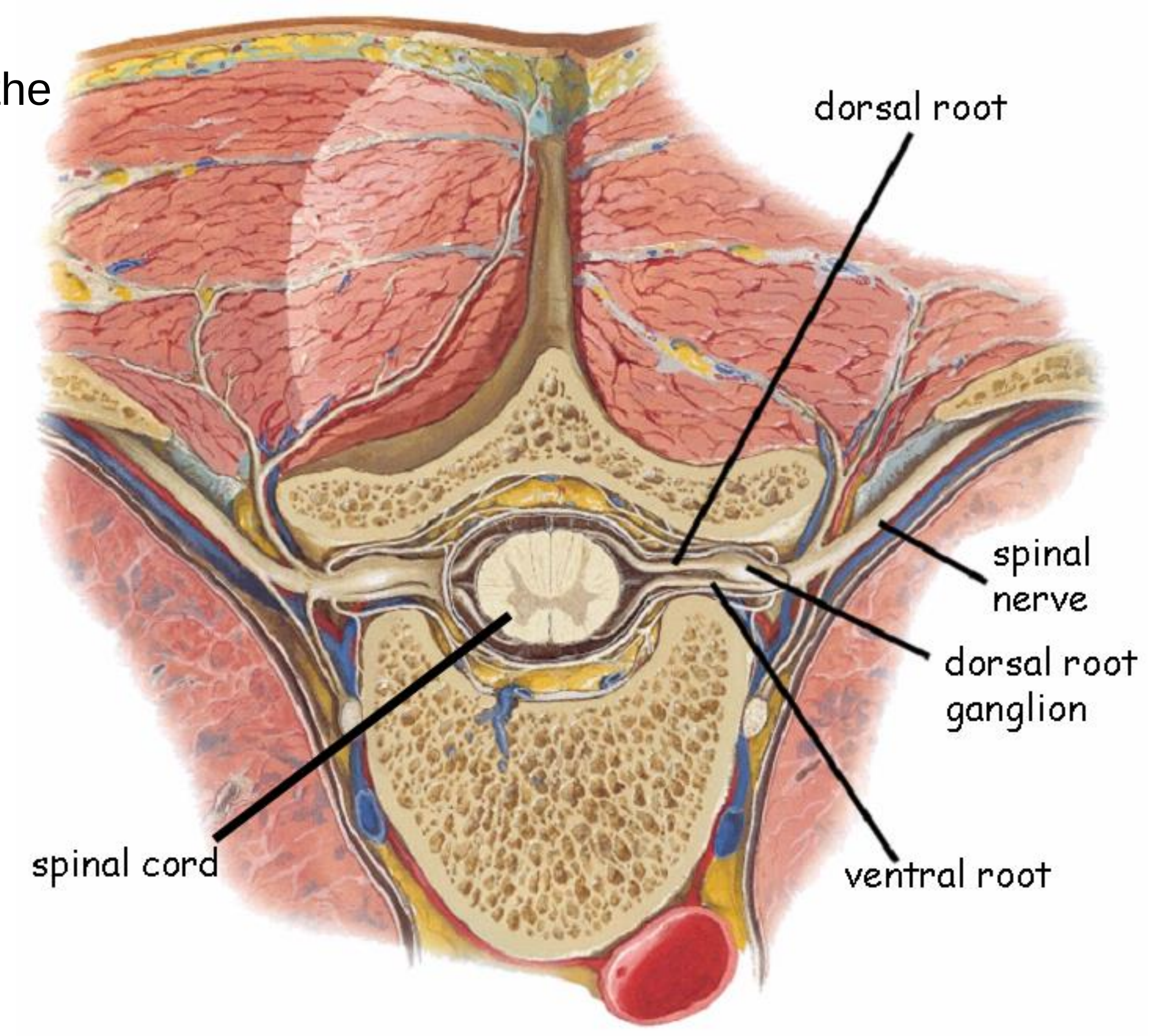
Primary Somatosensory Neurons

- The somas of primary somatosensory neurons are in:
  - cranial nerve sensory ganglia
  - dorsal root (spinal) ganglia



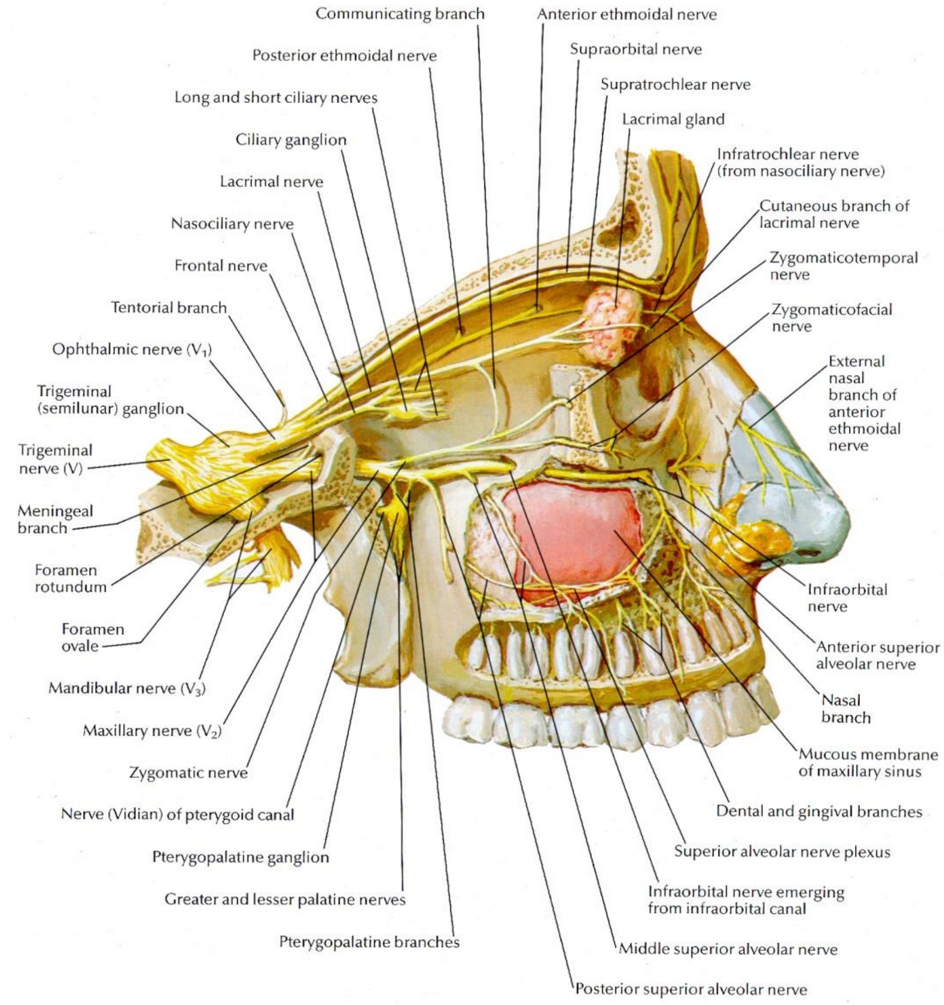
Primary Somatosensory Neurons

- Dorsal root ganglia are in the intervertebral foramen.



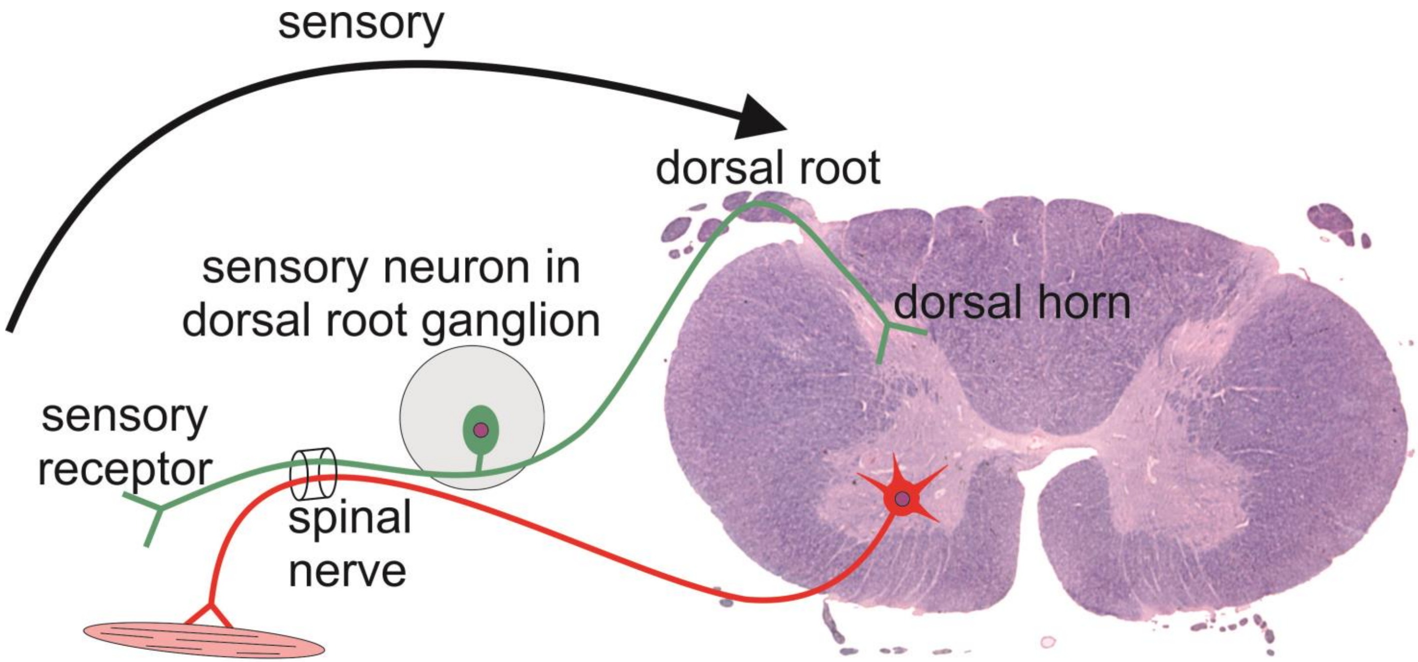
Primary Somatosensory Neurons

- The main somatosensory nerve for the head is the trigeminal nerve (cranial nerve V).
- The trigeminal ganglion is in the skull near where the trigeminal nerve joins the pons.
- Three nerves emanate from the ganglion and distribute across much of the head and face.



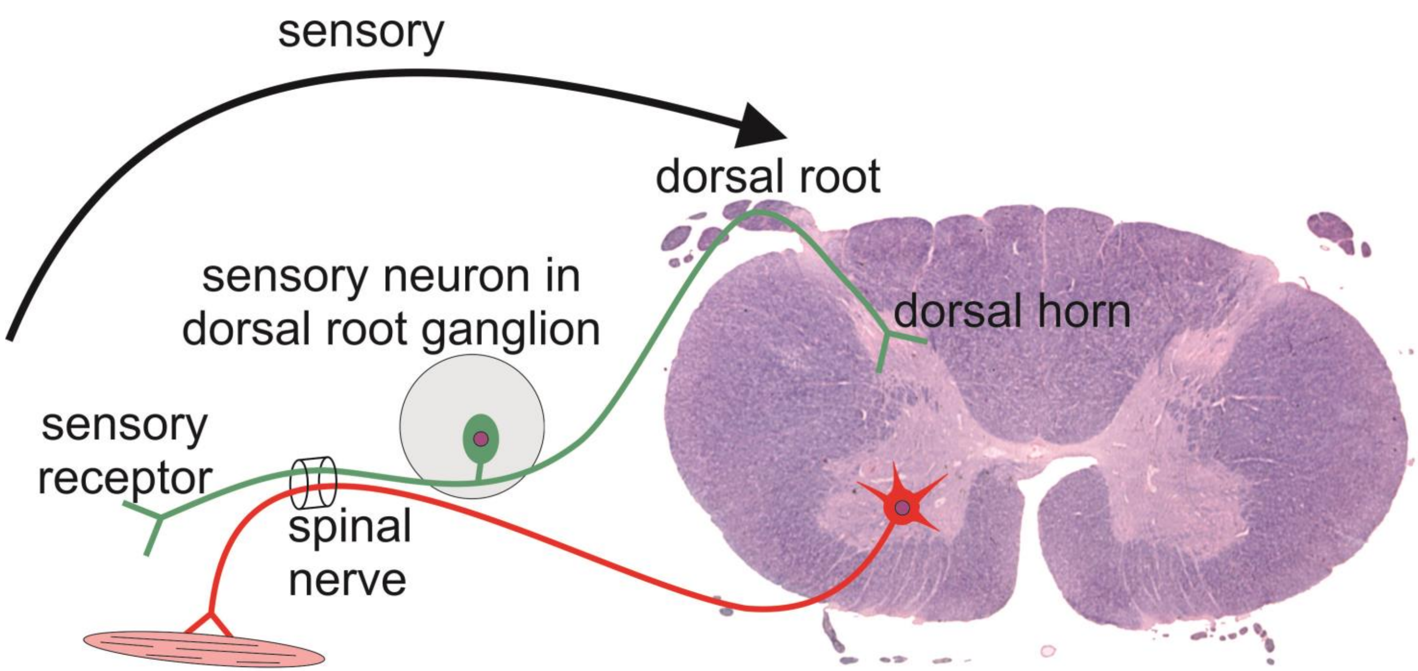
Primary Somatosensory Neurons

- The central processes of primary sensory neurons enter the CNS.
- For spinal cord, the central processes of dorsal root ganglion neurons form the dorsal roots.
- Dorsal roots are axons of sensory neurons only.



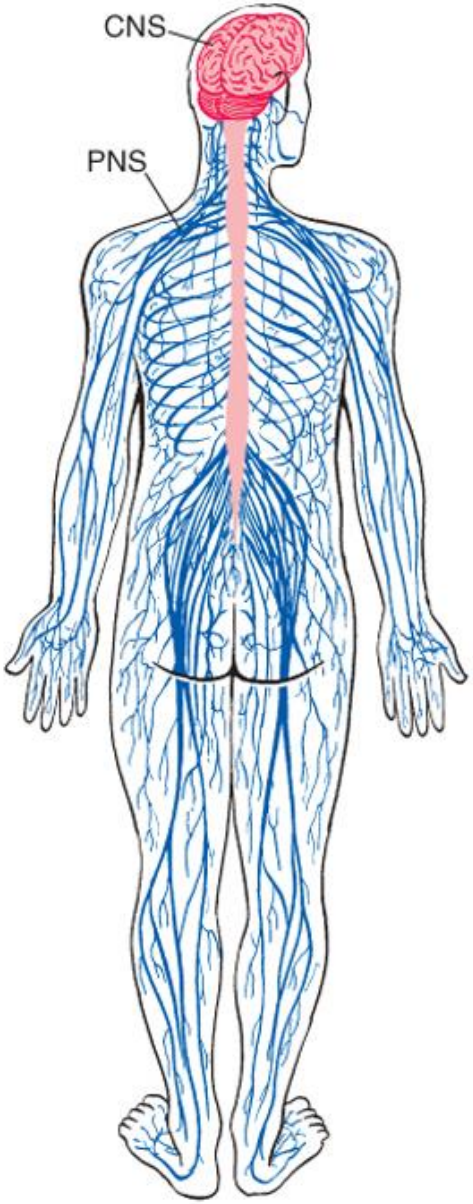
Primary Somatosensory Neurons

- The peripheral processes of dorsal root ganglion neurons are distributed throughout the body via spinal nerves.
- Spinal nerves are composed of a mixture of motor and sensory axons.



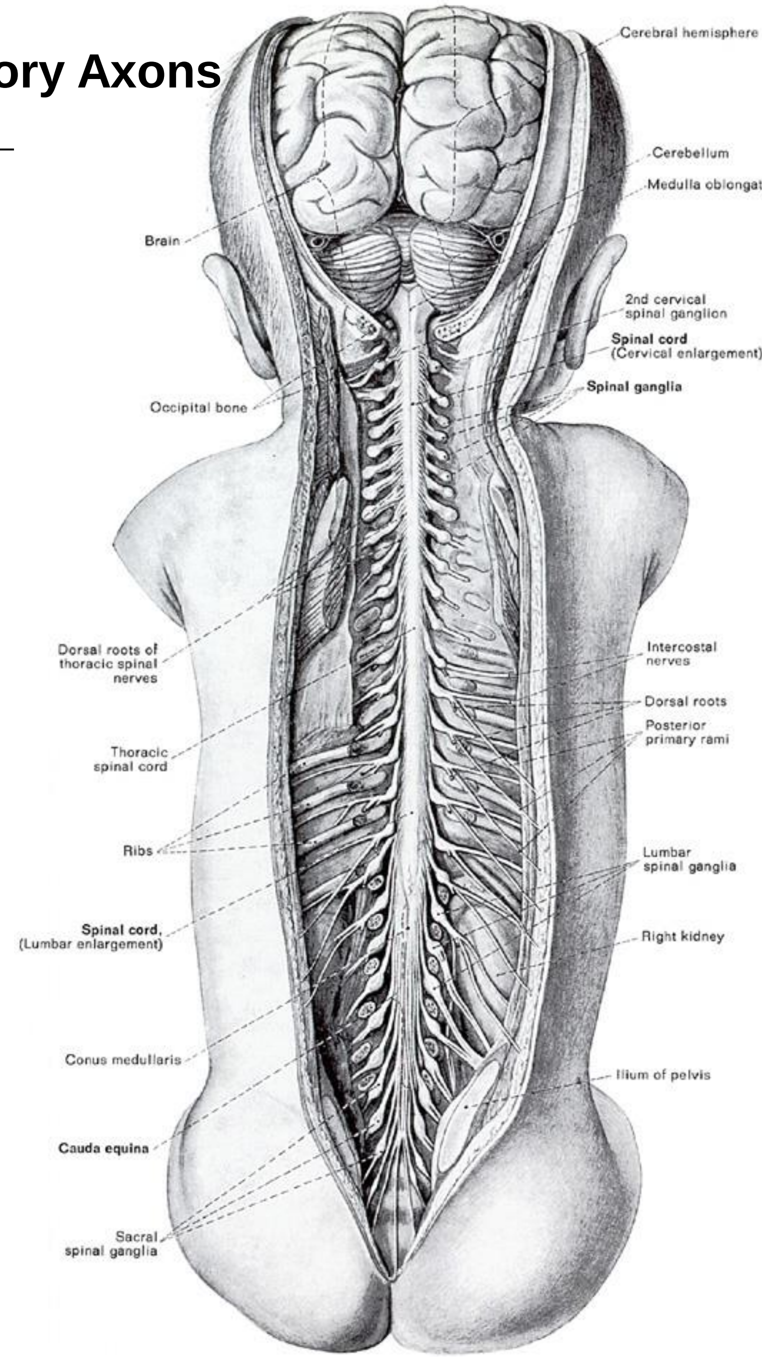
Peripheral Distribution of Somatosensory Axons

- Axons of primary sensory neurons are distributed throughout the body.

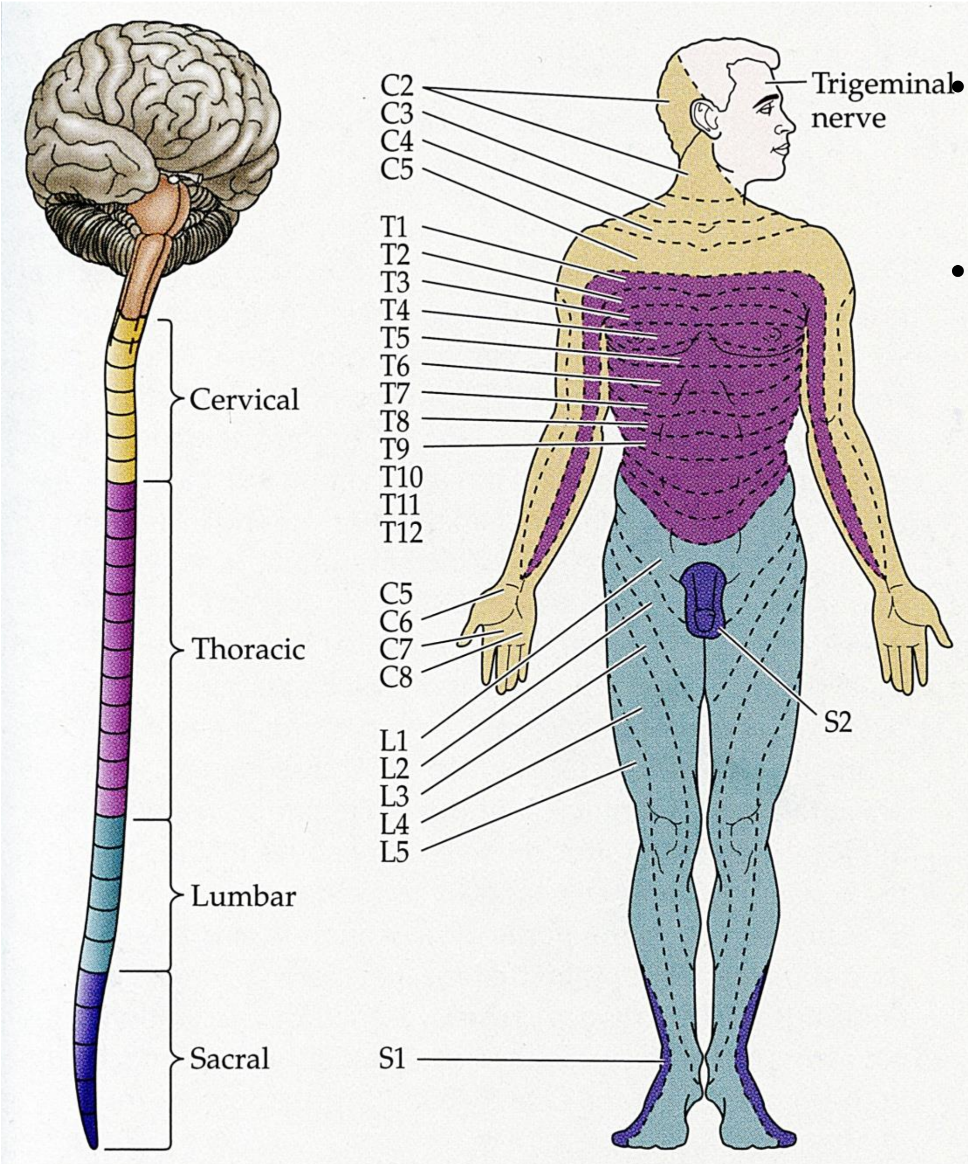


Peripheral Distribution of Somatosensory Axons

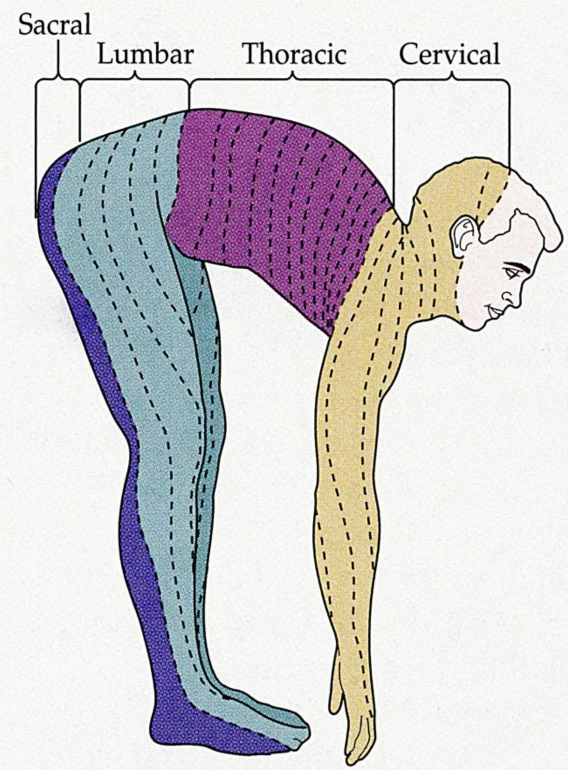
- Every level of the spine (i.e. each vertebrae) has a pair of dorsal root ganglia and spinal nerves.



Peripheral Distribution of Somatosensory Axons

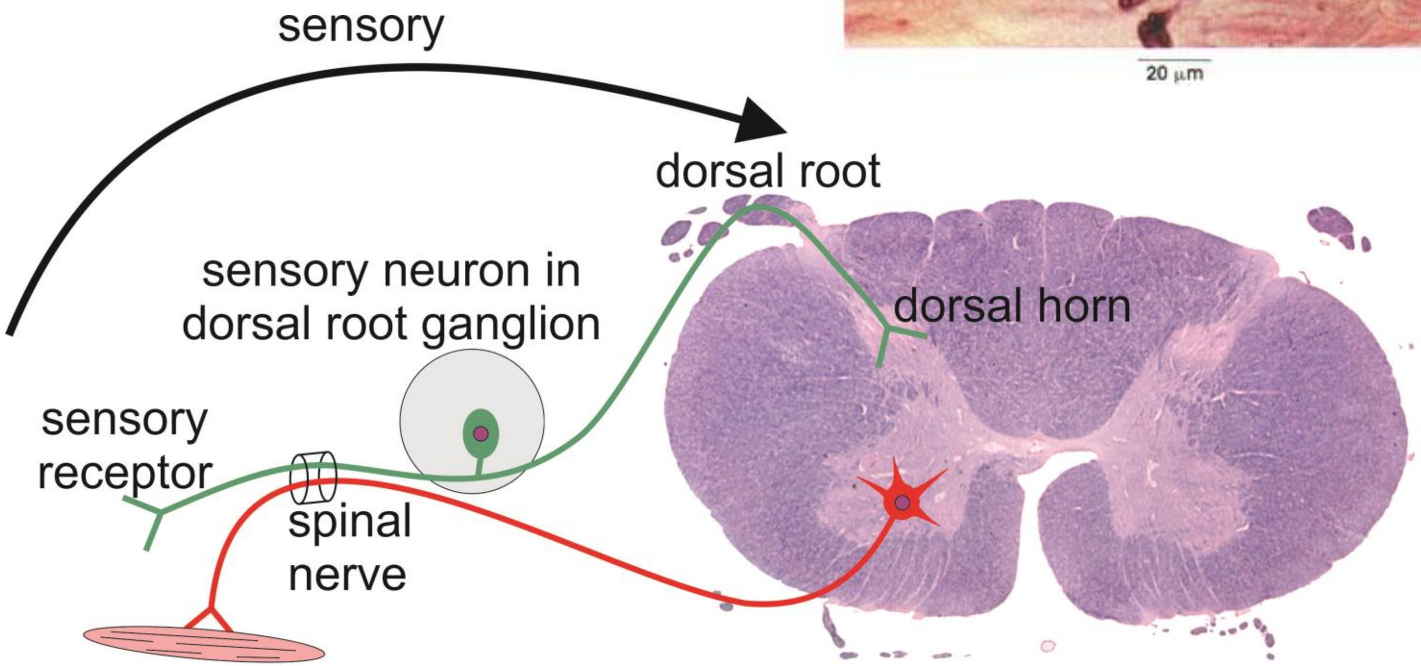


- The body is organized in segments, and each segment receives its own spinal nerve.
- Each segment of the somatosensory system is a dermatome.



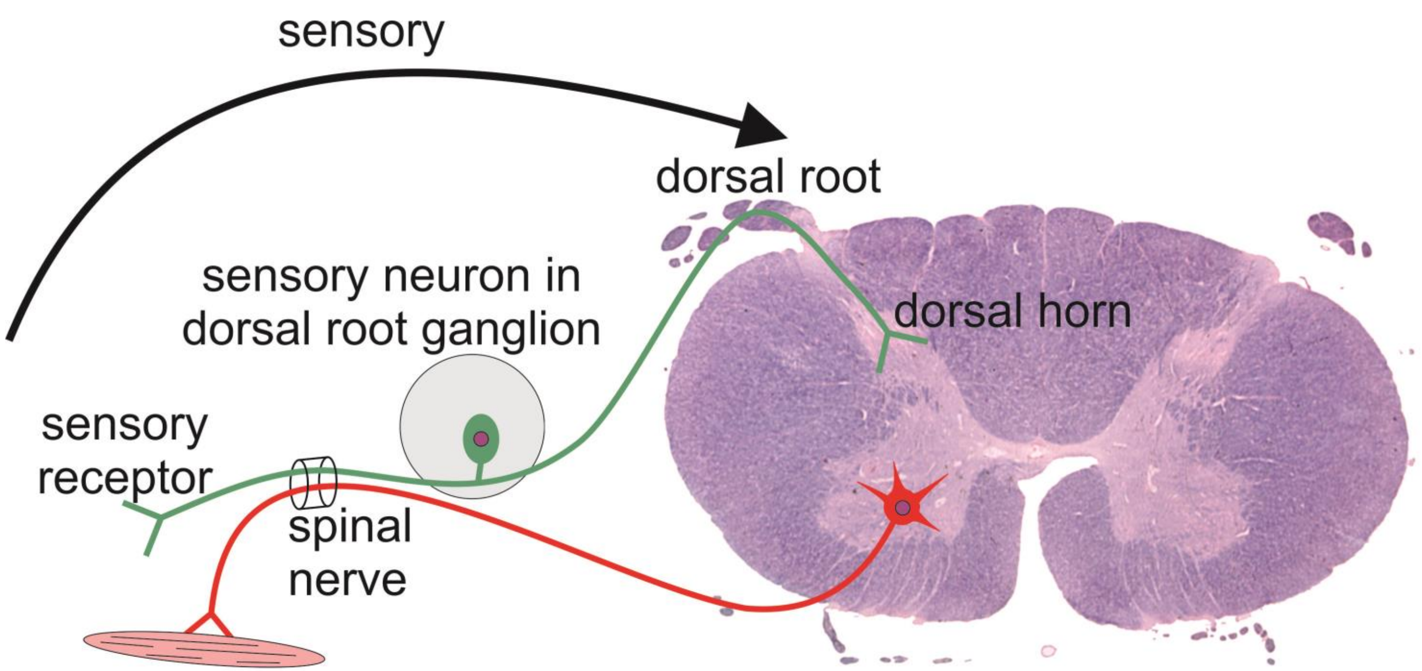
Primary Somatosensory Neurons

- For somatosensory neurons, the most peripheral process functions as the dendrite, and it connects directly with the axon. The soma (cell body) hangs off the middle of the axon in the ganglion.



Primary Somatosensory Neurons

- The terminal end of the peripheral process of the sensory neuron functions is the receptor.
- Each sensory neuron's receptors are specialized to respond to a single type of stimulus.



Primary Somatosensory Neurons

- Touch
  - fine touch
  - pressure
  - vibration
  - movement against the skin
- Proprioception
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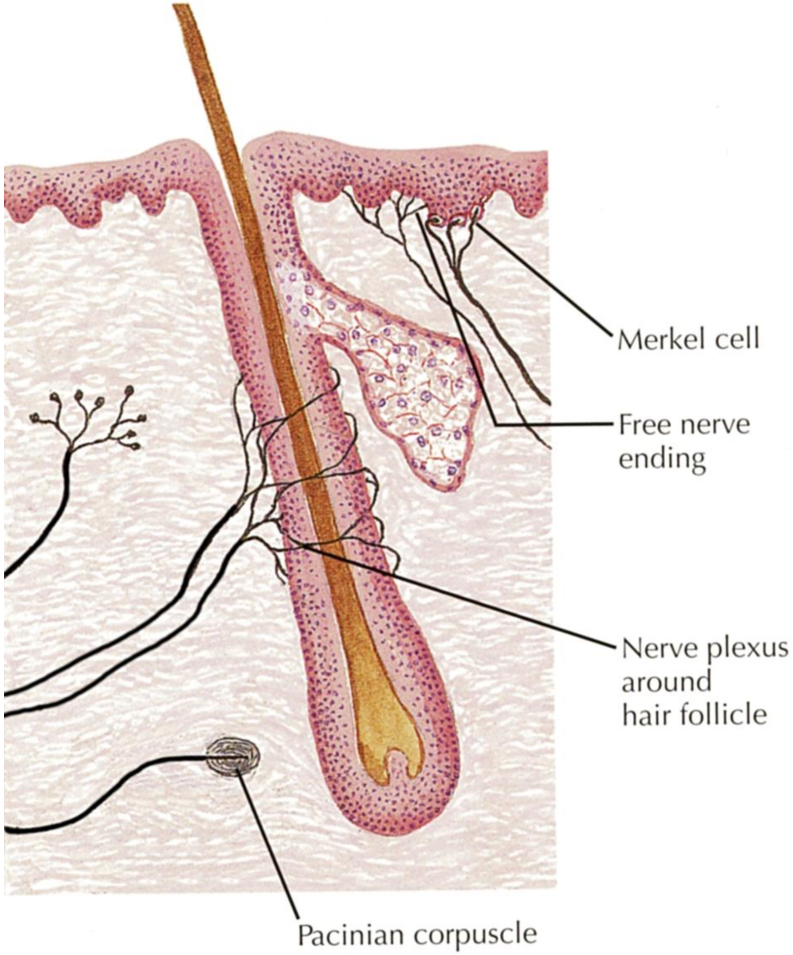
Touch

- Mechanoreception (mechanoception) is detection of mechanical force (tecture, pressure, vibration, movement)
- Receptors are broadly distributed through the body. They are most concentrated in the skin.

Touch

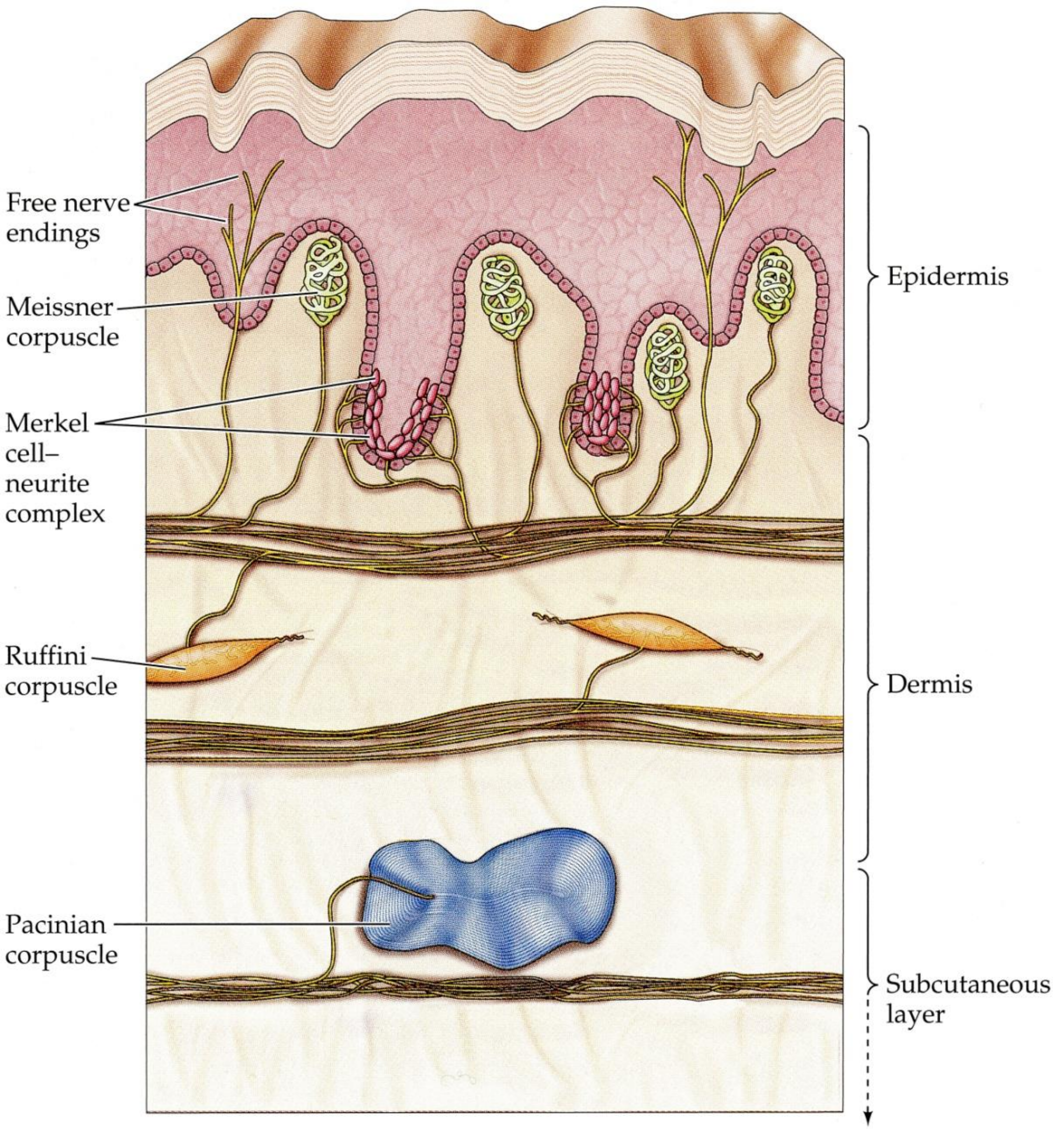
- Most touch receptors are encapsulated by other cells or are associated with hair follicles.
- Encapsulation changes the nature of the sensitivity of the neuron.



pacinian corpuscles in skin

Touch

- The type of encapsulation, depth in the skin and response properties of the neuron determine the stimulus to which a receptor cell is activated.

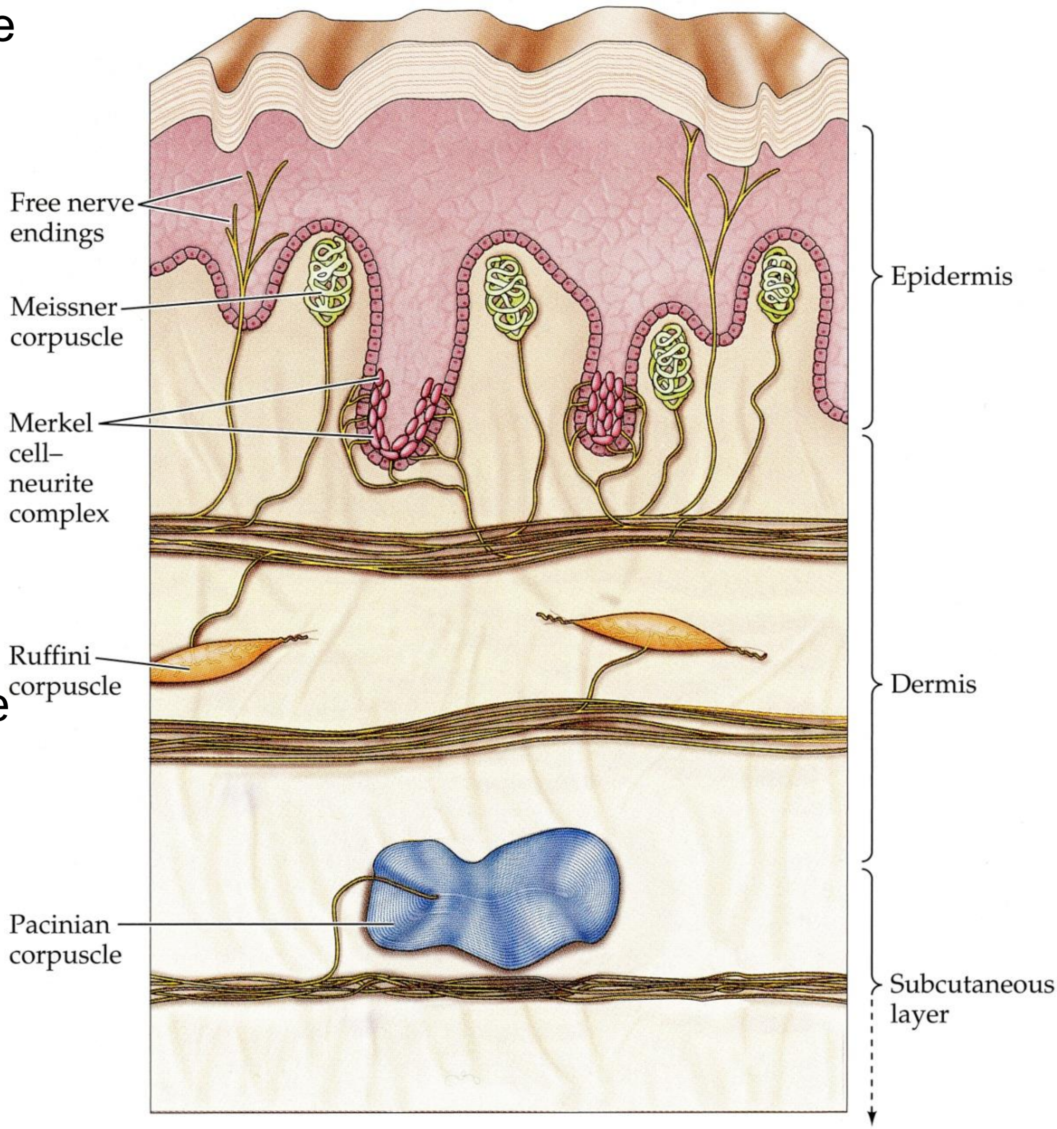


Touch

- Merkel's disk: under each ridge of the fingerprint; in epidermis; Merkel cells (capsule) amplifies signal; sensitive to light touch and movement via different axons; mostly in hairy skin.

- Meissner corpuscle: encapsulated in layers of Schwann cells; in dermis; sensitive to light touch and vibration; mostly in hairless skin.

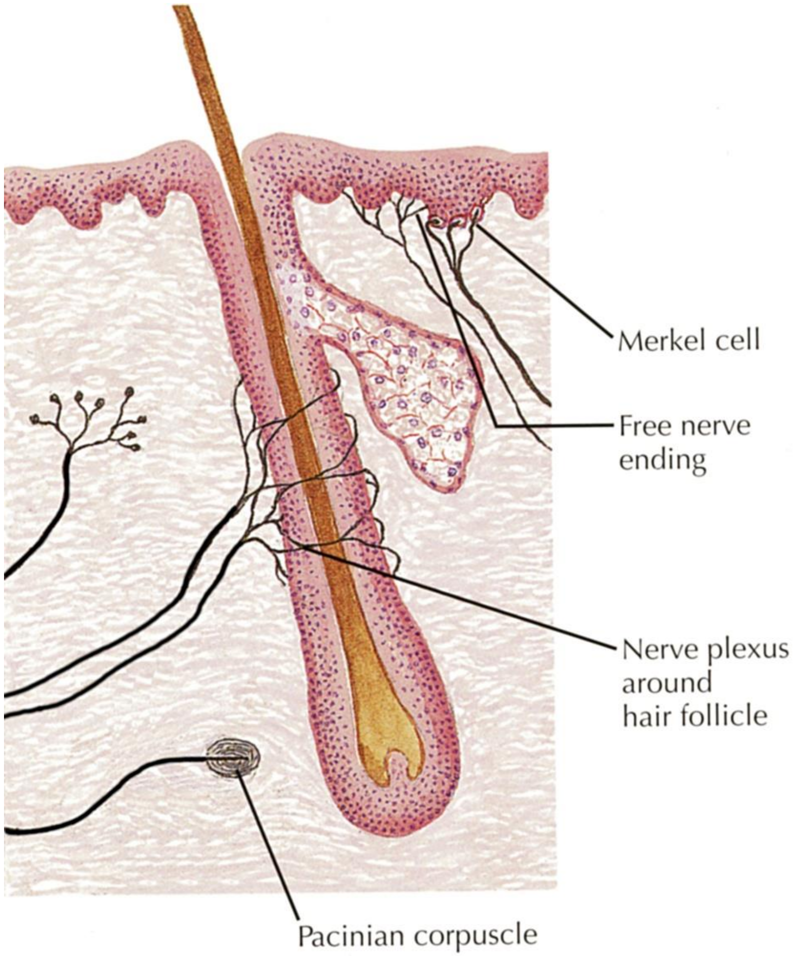
- Ruffini corpuscles: in dermis; capsule is elongated; sensitive to direction of movement across skin and to stretch of skin and other tissues.



Touch

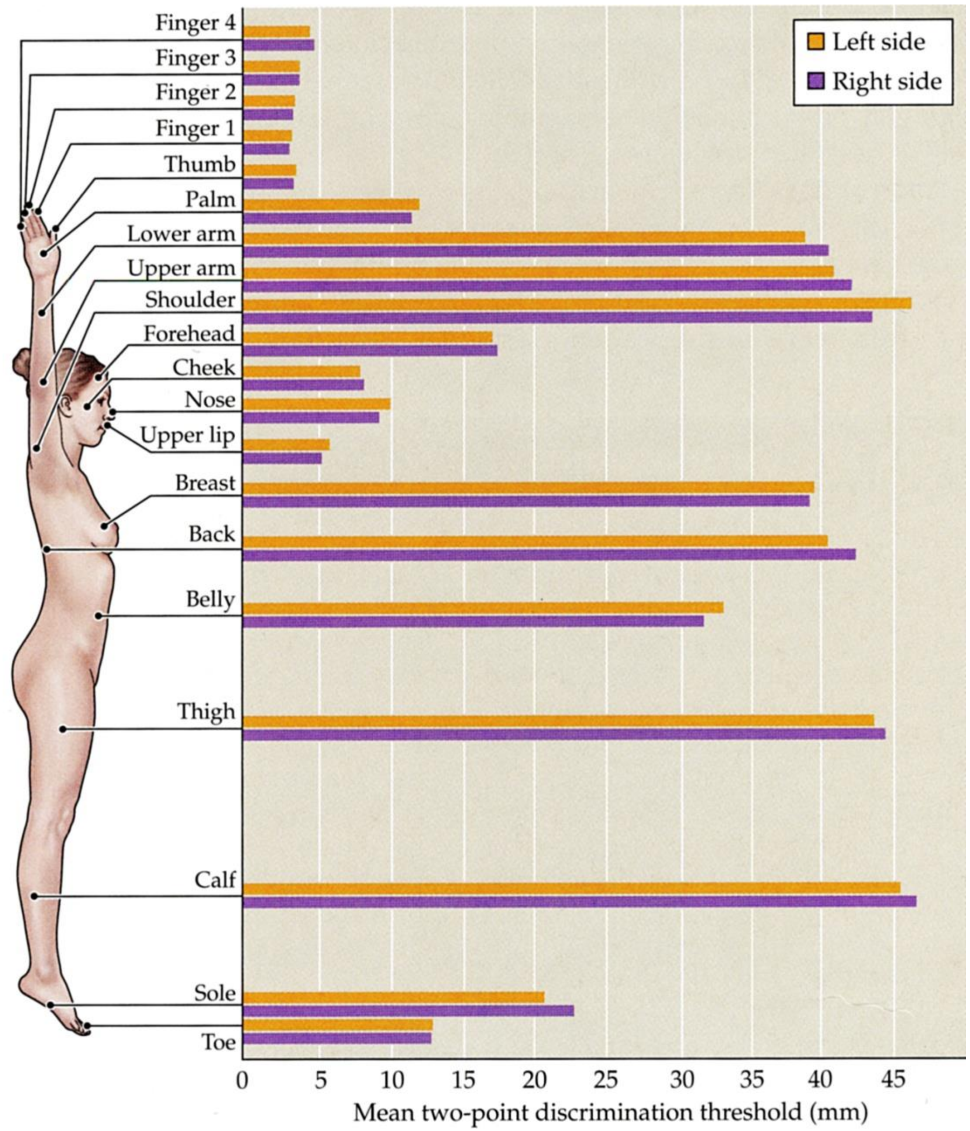
- Pacinian corpuscle: deep in skin; rapidly responding; sensitive to vibration and deep pressure.

- Hair follicle receptor: axons forms a plexus around hair follicle; detects movement of the hair.



Touch

- The density of touch receptors determines the resolution of our sense of touch in different parts of the body – two point discrimination.



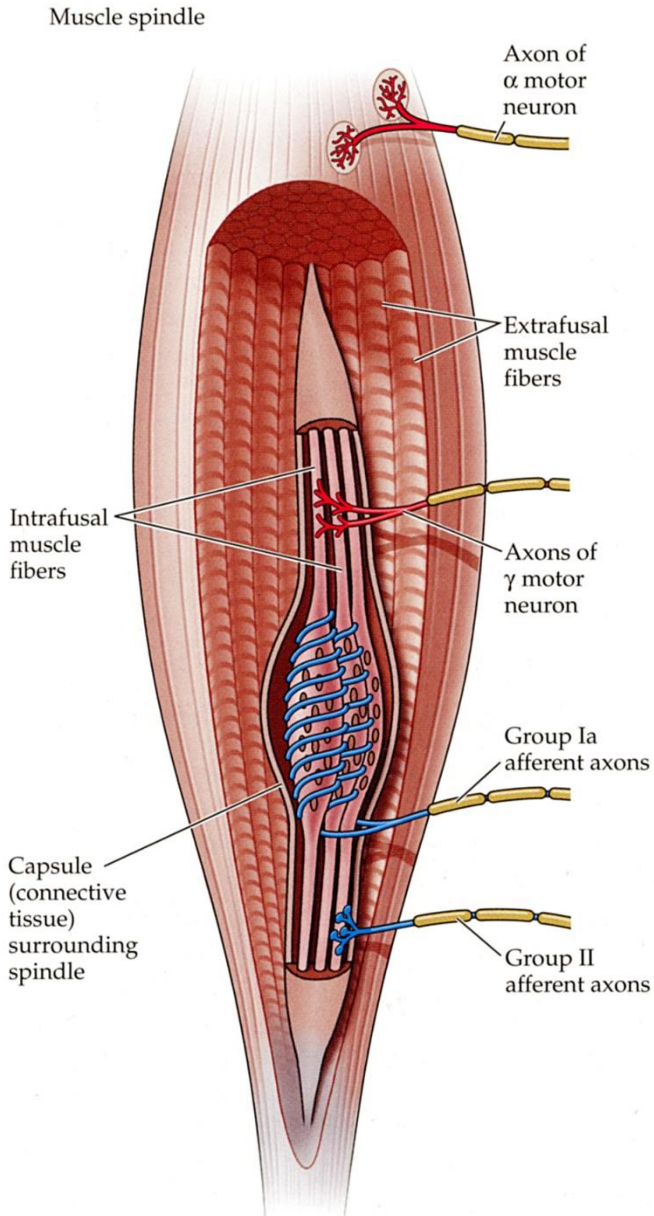
Proprioception

- Proprioception is the sense of the position, movement and load of the limbs and trunk.

- Proprioceptors are specialized mechanoreceptors.

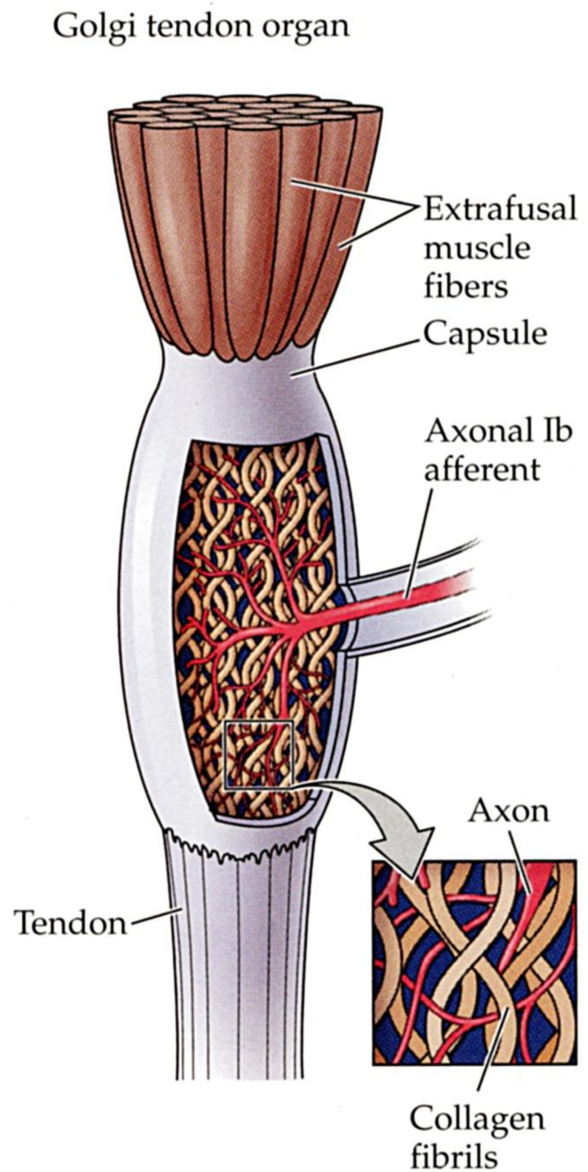
Proprioception

- Muscle spindles: nerve endings wrapped around an intrafusal muscle fiber; embedded in muscle; sensitive to muscle stretch and contraction; provides information required to adjust the strength of contraction.



Proprioception

- Golgi tendon organs: embedded in collagen fibers of tendons; compressed by tension in tendon



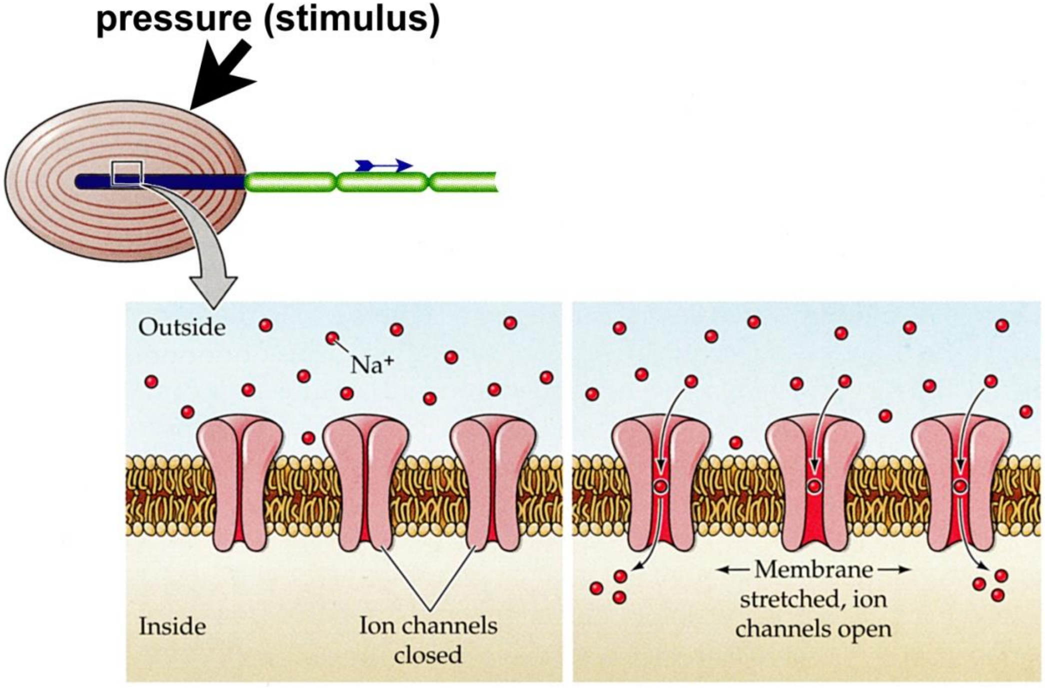
Somatosensory Receptors

- Table of receptors.

class	***receptor***	***sensitivity***	***axon diameter***	***axon type***
touch receptor	merkel's disk meissner's corpuscle ruffini corpuscle pacinian corpuscle hair follicle nerve	light touch movement movement vibration movement	medium medium medium medium small	myelinated myelinated myelinated myelinated unmyelinated
proprioceptor	muscle spindle golgi tendon organ	muscle stretch tendon stretch	large large	myelinated myelinated
thermoceptor	cold receptor heat receptor	cold heat	small small	myelinated unmyelinated
nociceptor (pain)	nociceptor (free nerve endings)	tissue damage	small	myelinated & unmyelinated
pruritic (itch)	pruritic	skin irritation	small	unmyelinated

Somatosensory Receptors

- An appropriate stimulus results in sodium channels opening and an influx of sodium into the nerve ending. This results in a graded depolarizing membrane potential.

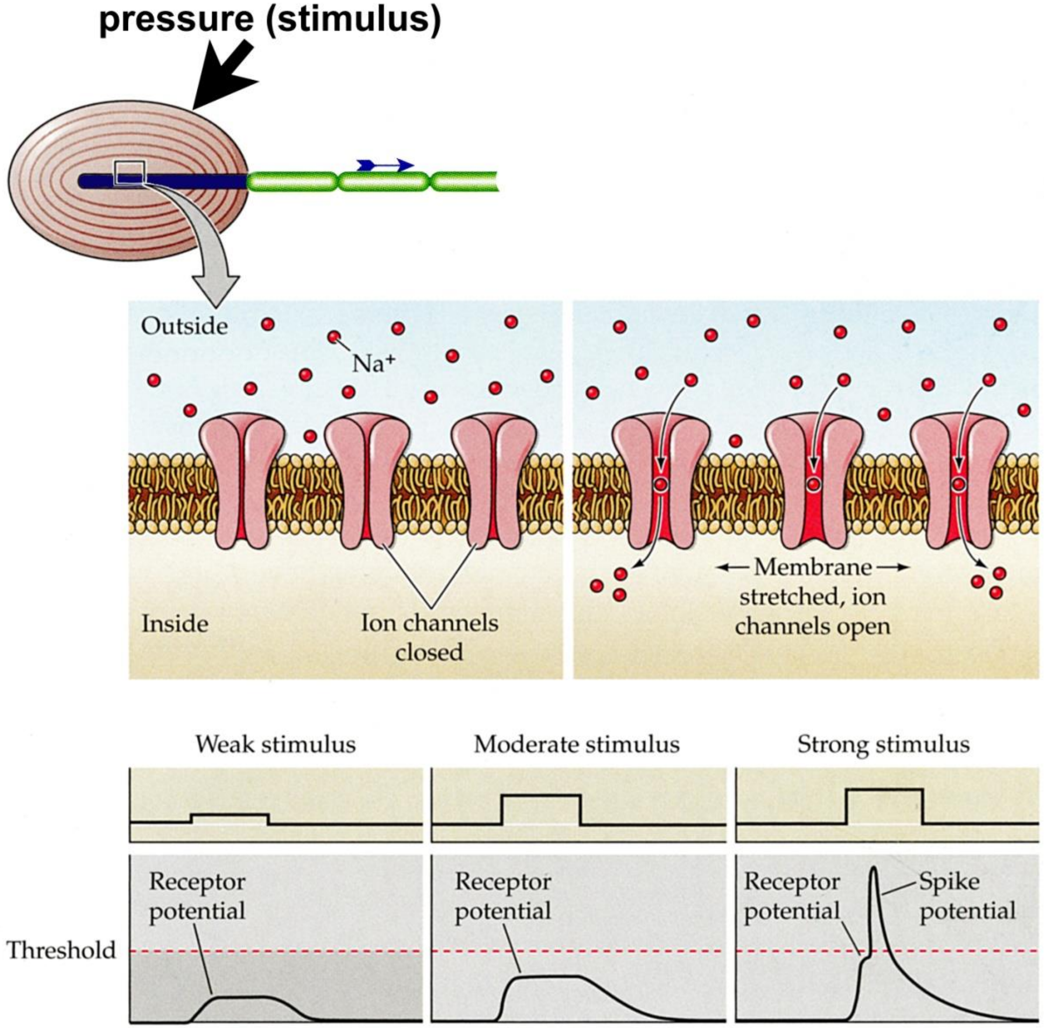


Somatosensory Receptors

- Piezo2:
  - Mechanoreceptor neurons express the receptor protein, Piezo2.
  - Piezo2 is a gated ion channel that opens in response to mechanical force.
  - This receptor is in the membrane of the nerve ending, typically encapsulated by other cells such as in Merkel's disks.
  - Opening of the Piezo2 channel depolarizes the nerve ending.

Somatosensory Receptors

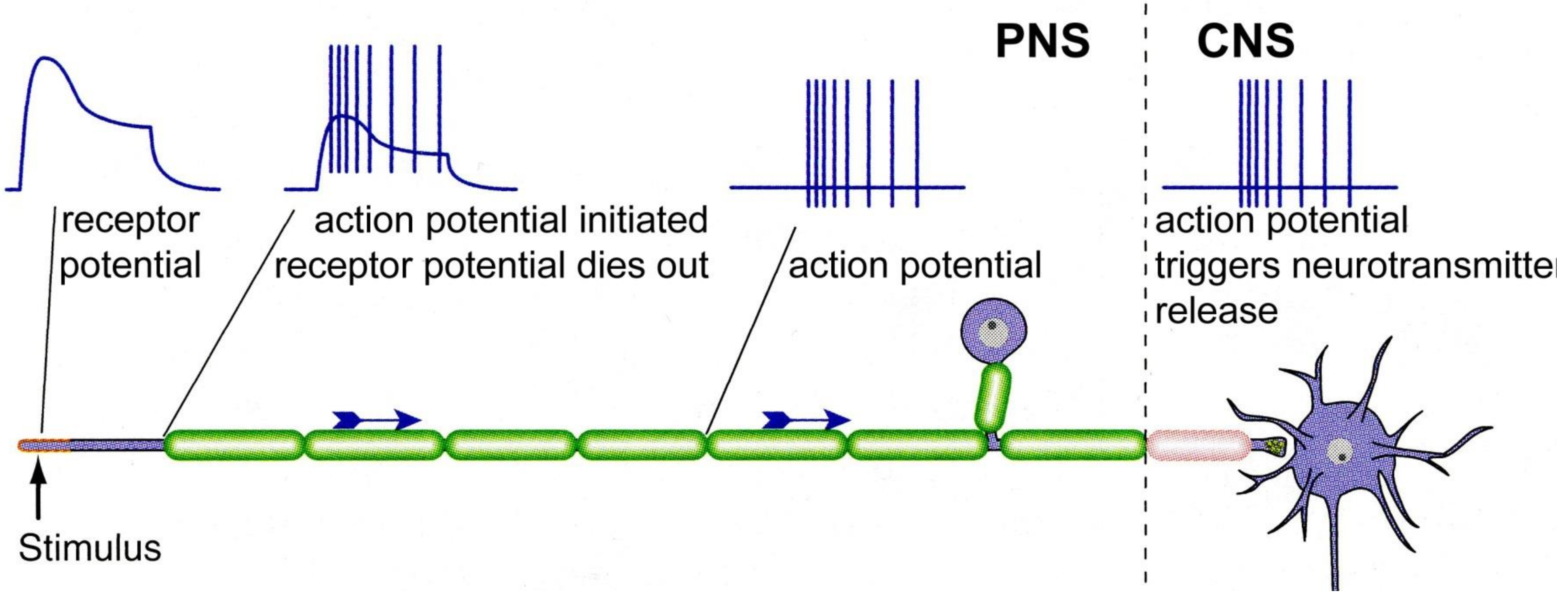
- The stronger the stimulus, the larger the membrane depolarization.



Somatosensory Receptors

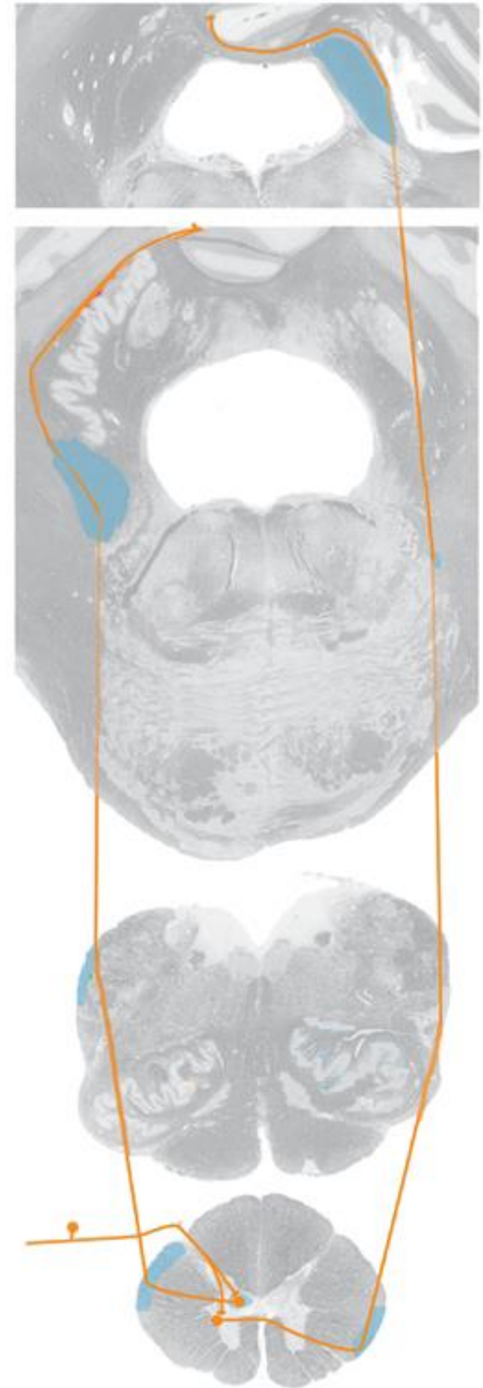
- With sufficient depolarization (threshold), voltage-gated sodium channels open in the initial segment of the axon, and an action potential is generated.

- The frequency of action potentials encodes the strength and duration of the stimulus.



Spinocerebellar Pathway

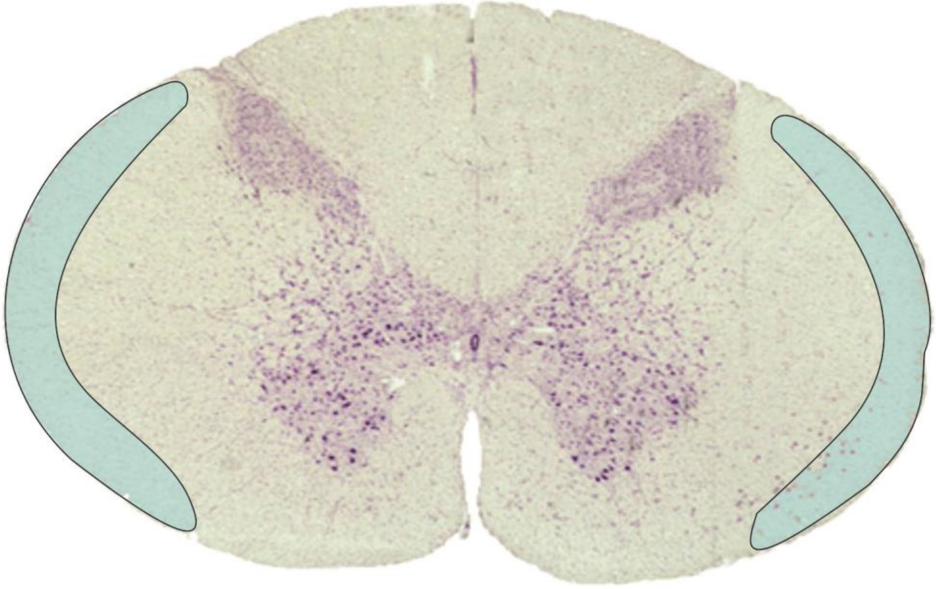
- Primary sensory neurons carrying proprioceptive information synapse deep in the dorsal horn.
- Second order neurons ascend on both sides of the spinal cord in the spinocerebellar tracts.
- These axons synapse mainly on the <u>ipsilateral</u> side of the cerebellum.
- The cerebellum has important roles in maintaining balance and coordinating movements.



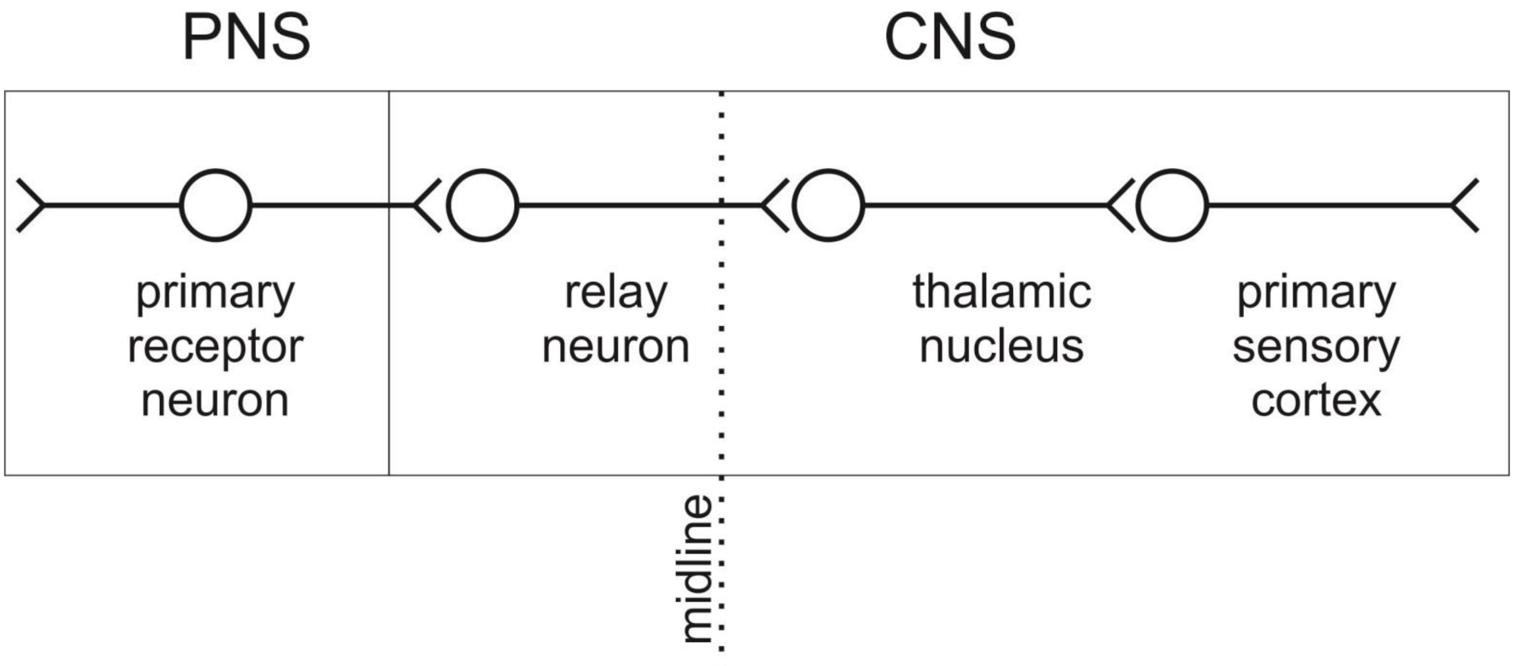
Spinocerebellar Pathway

- The spinocerebellar tracts are in the lateral funiculus of the spinal cord.

[Note how tracts are often labeled by their origin and target.]



Somatosensory Projection to Cortex



Somatosensory Projection to Cortex

Two pathways:

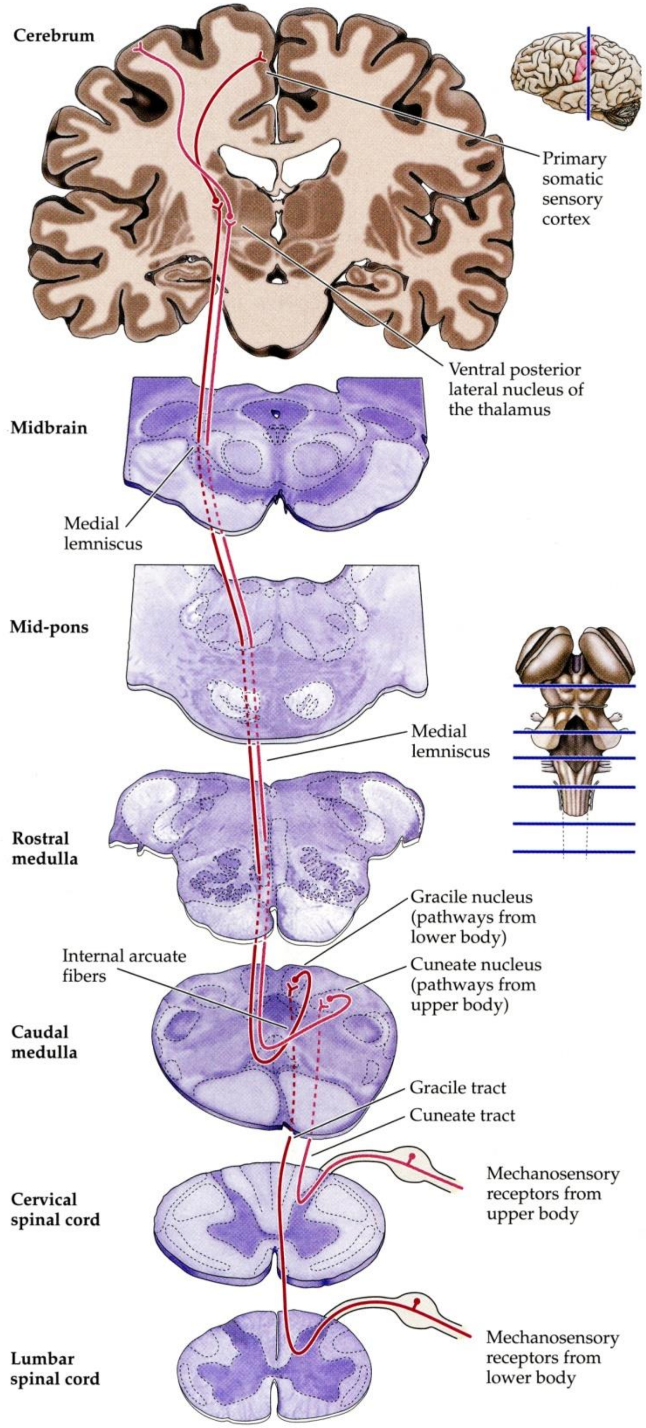
- Proprioception and most touch via the dorsal columns.

- Pain, temperature and some touch via the spinothalamic tracts.

Somatosensory Projection to Cortex

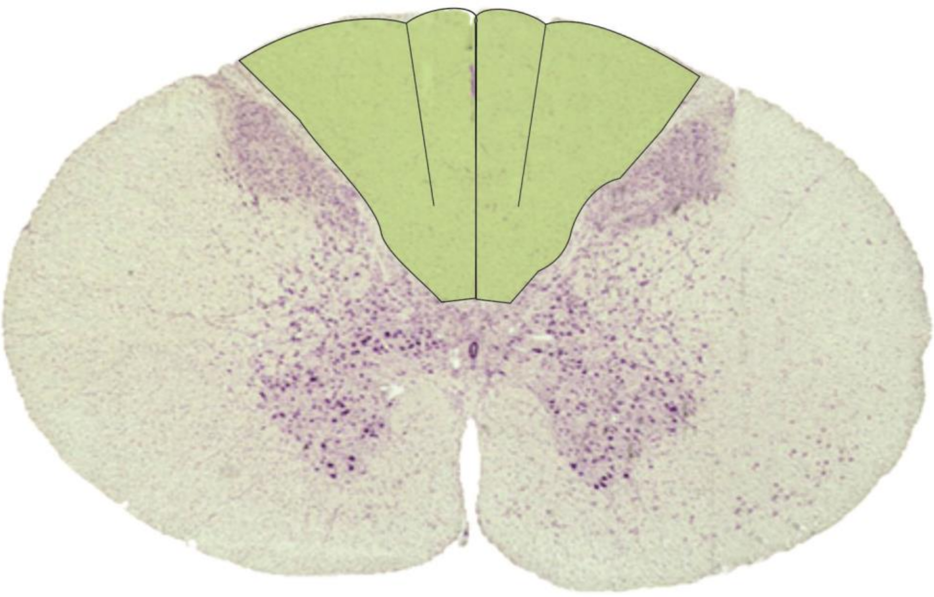
Dorsal column projection:

- Primary sensory axons for proprioception and most touch enter the dorsal horn and ascend in the dorsal columns.
- These axons synapse in nucleus gracilis (from lower body) and nucleus cuneatus (from upper body) in the medulla.
- Axons from these nuclei cross the midline and ascend to synapse in the ventral posterolateral nucleus (VPL) of the thalamus.
- Axons from the VPL neurons ascend through internal capsule to synapse in primary somatosensory cortex.



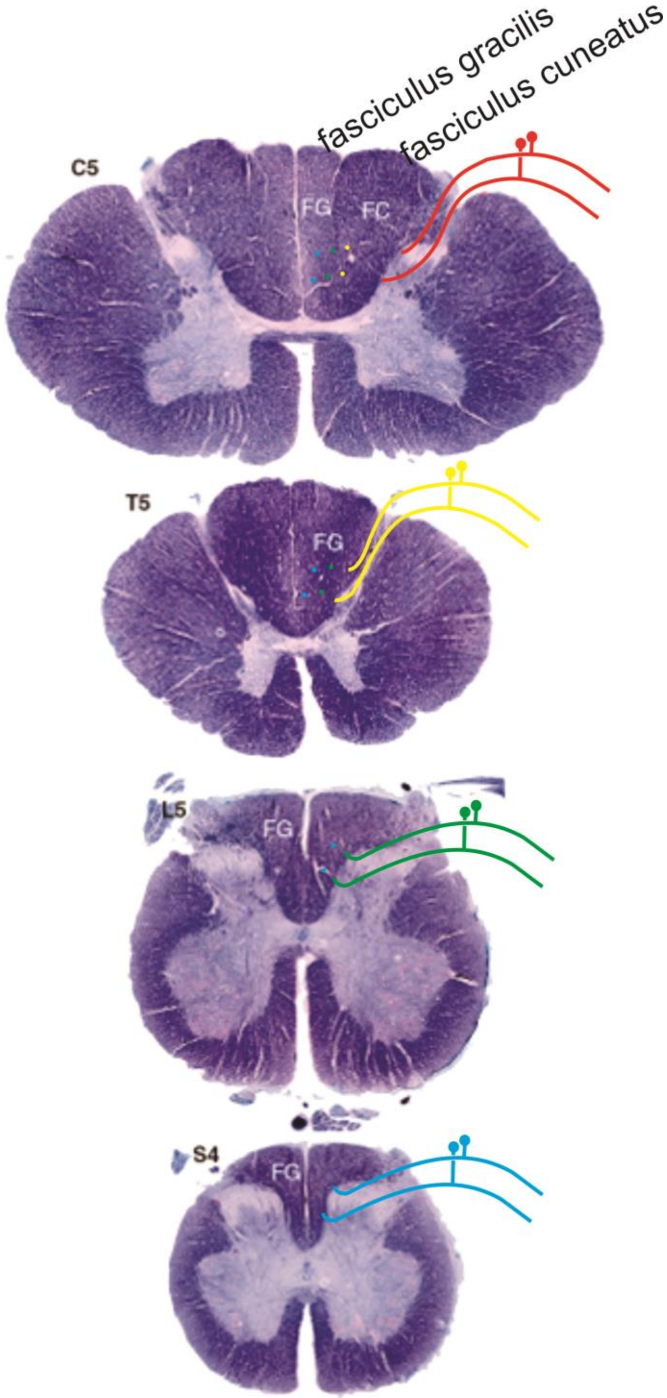
Somatosensory Projection to Cortex

- The dorsal columns are in the dorsal funiculus of the spinal cord.



Somatosensory Projection to Cortex

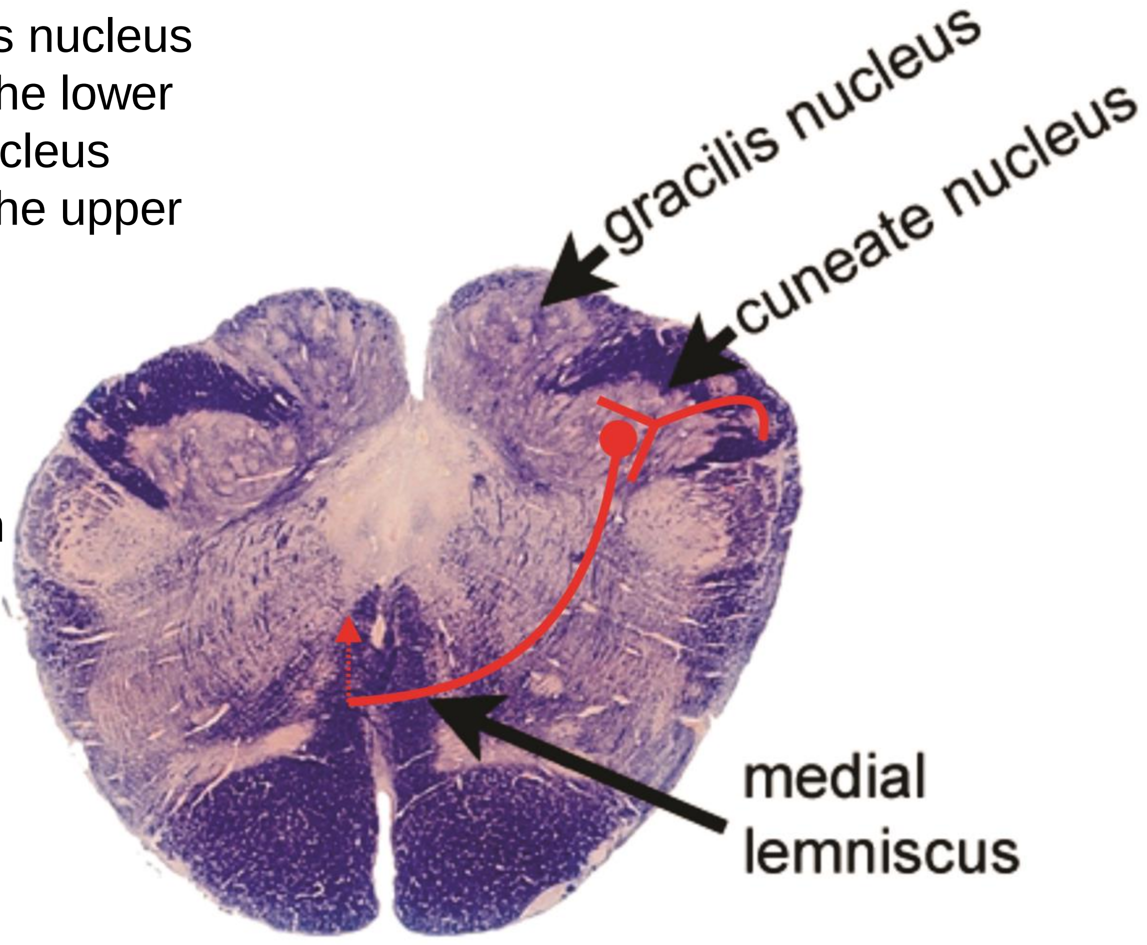
- Axons entering via the dorsal root join the dorsal column along the border of the dorsal horn.
- Fasciculus gracilis carries axons from the lower body.
- Fasciculus cuneatus carries axons from the upper body.



Somatosensory Projection to Cortex

- In the medulla, the gracilis nucleus receives the axons from the lower body, and the cuneate nucleus receives the axons from the upper body.

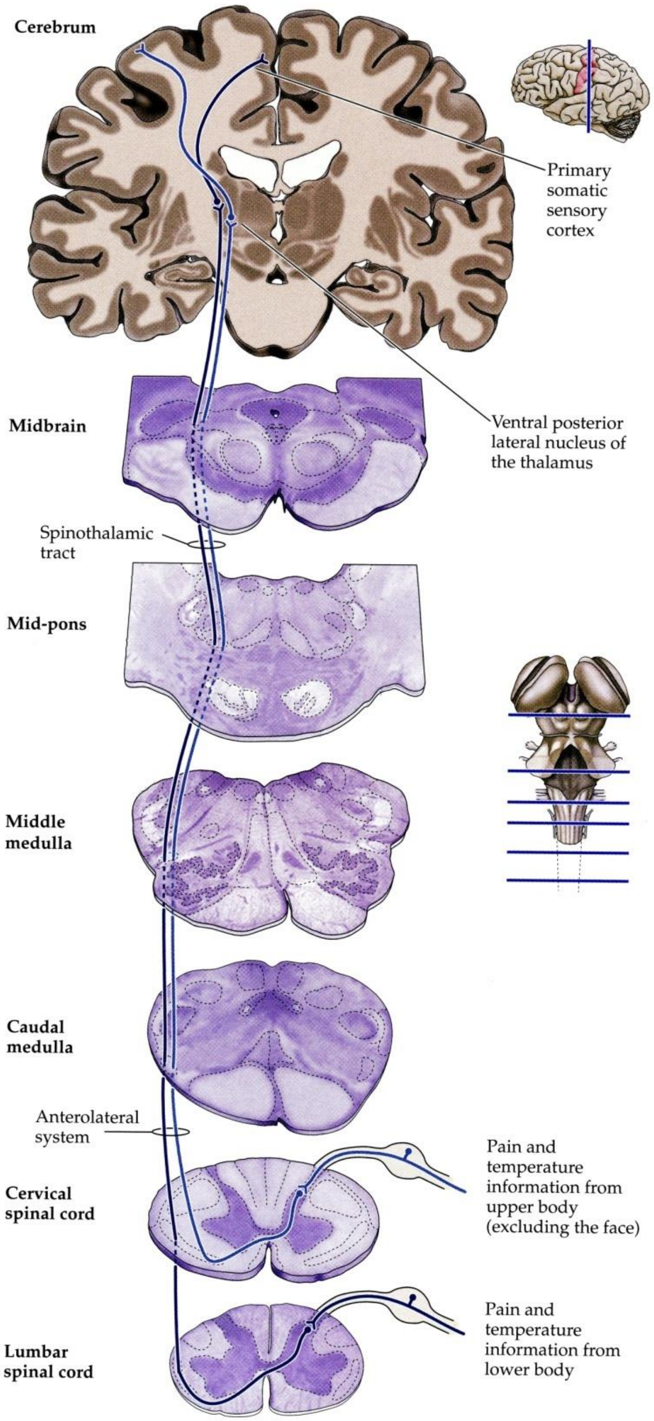
- Axons from neurons in these nuclei cross and ascend to the thalamus in the medial lemniscus.



Somatosensory Projection to Cortex

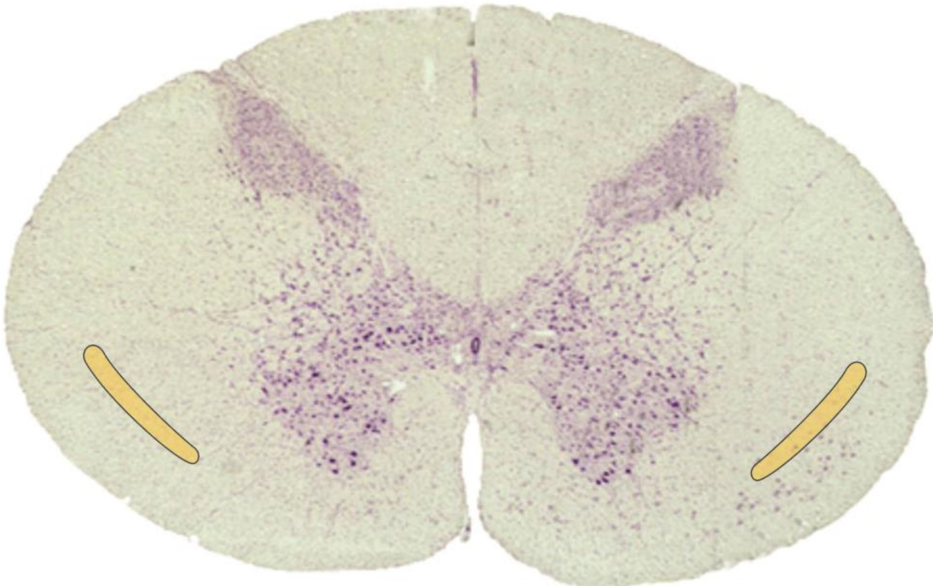
Spinothalamic projection:

- Primary sensory axons for pain, temperature and some touch synapse on neurons in the dorsal horn.
- Axons of these dorsal horn neurons cross the spinal cord and ascend in the spinothalamic tract.
- They synapse in the ventral posterolateral nucleus (VPL) of the thalamus.
- Axons from the VPL neurons ascend through internal capsule to synapse in primary somatosensory cortex.



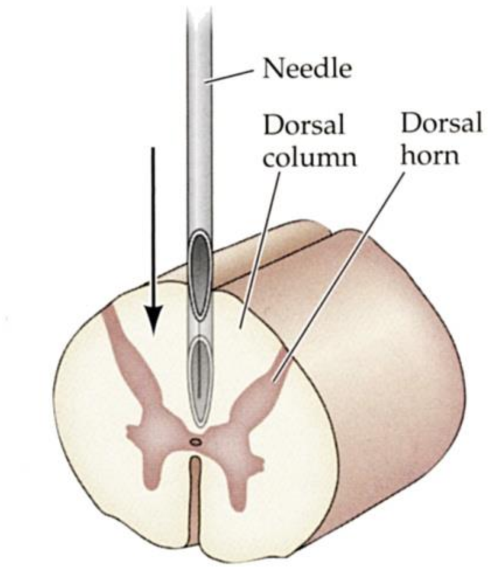
Somatosensory Projection to Cortex

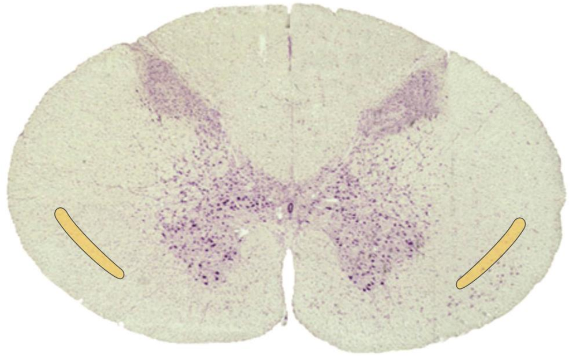
- The spinothalamic tracts are in the lateral funiculus of the spinal cord.



Somatosensory Projection to Cortex

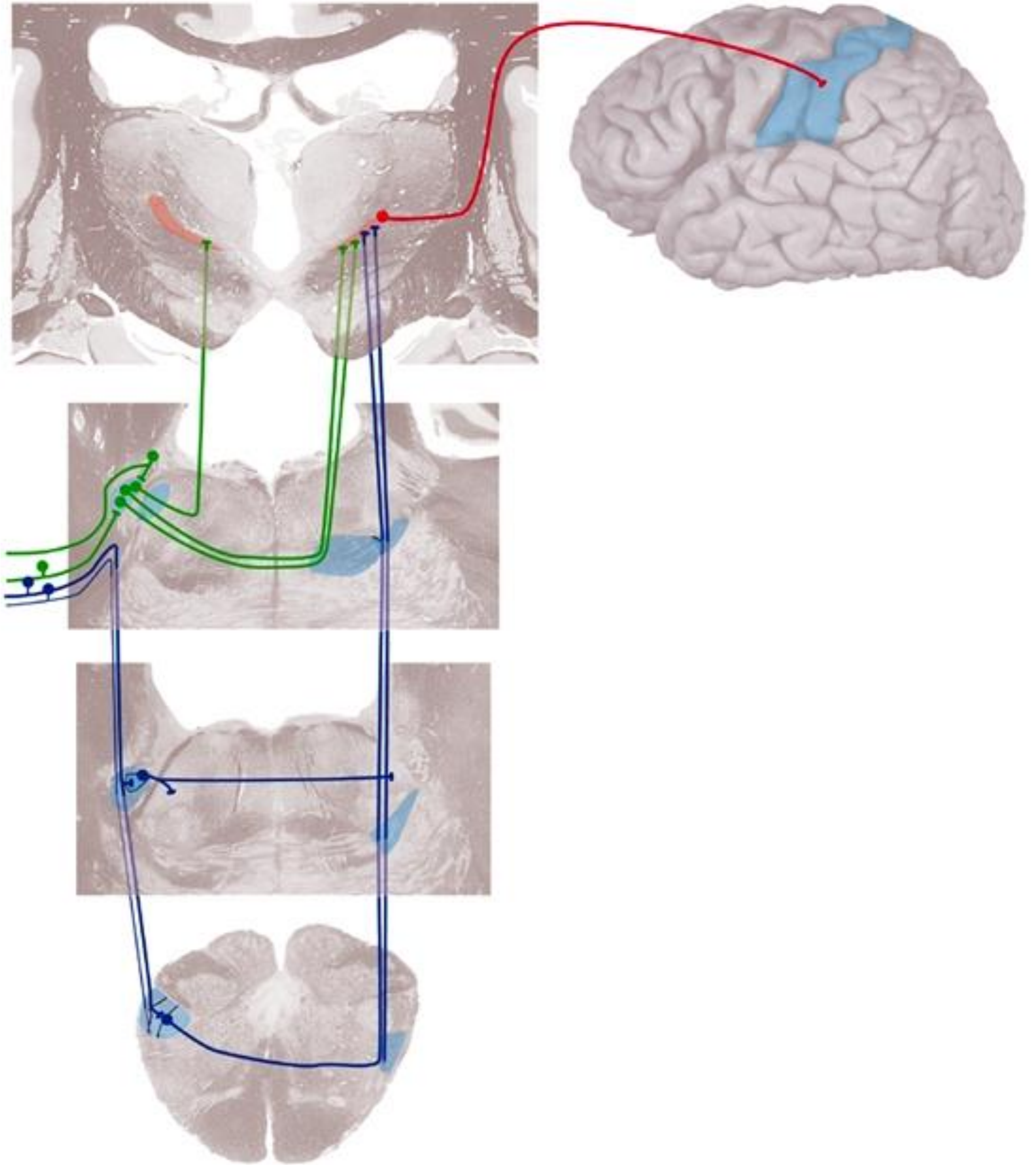
- For intractable pain, spinothalmic axons can be cut surgically as they cross the midline or as they ascend in the spinothalmic tract.





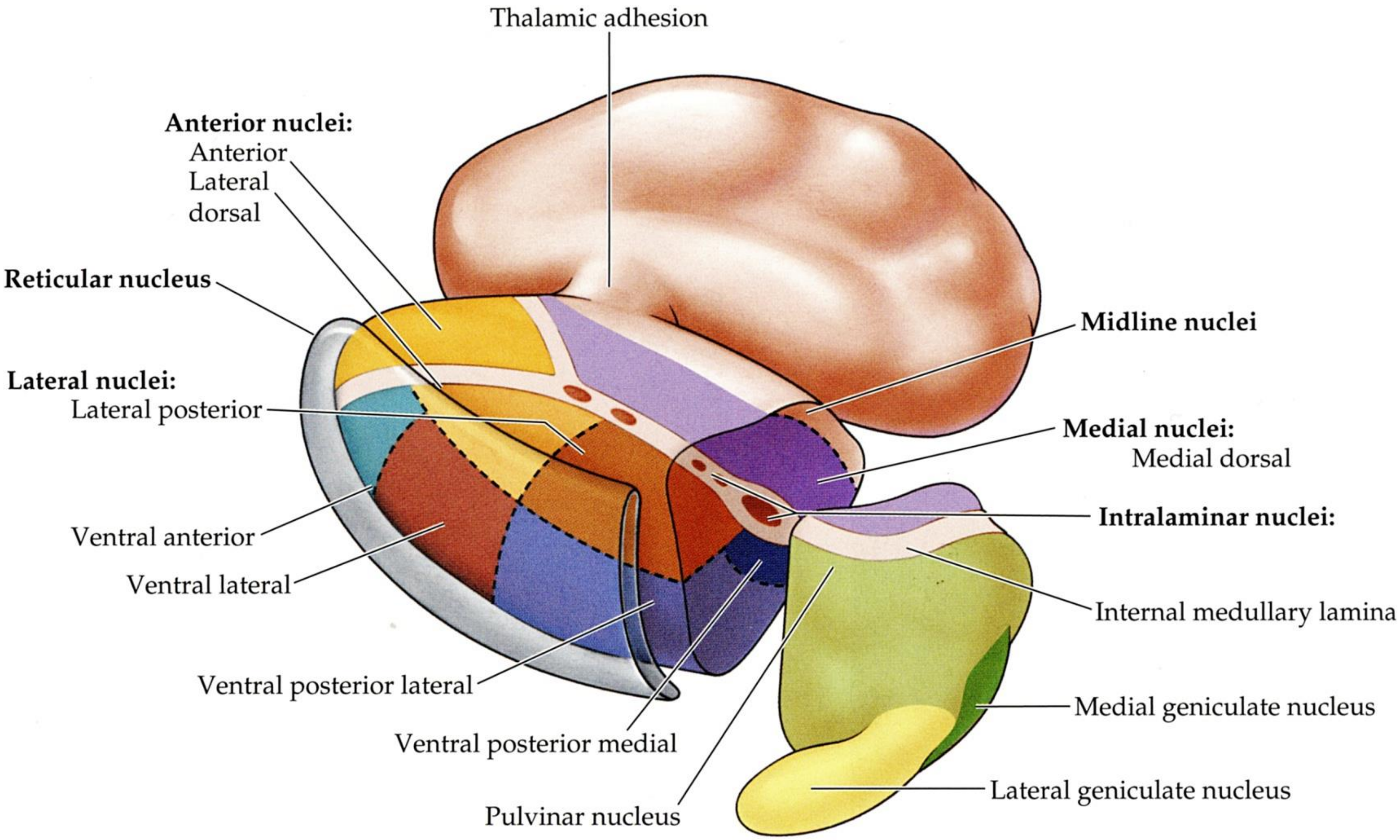
Somatosensory Projection to Cortex

- Trigeminal sensory pathways in the brain are similar to that for the rest of the body.
- Somatosensory information from the trigeminal nerve goes to the ventral posteromedial nucleus (VPM) of the thalamus.



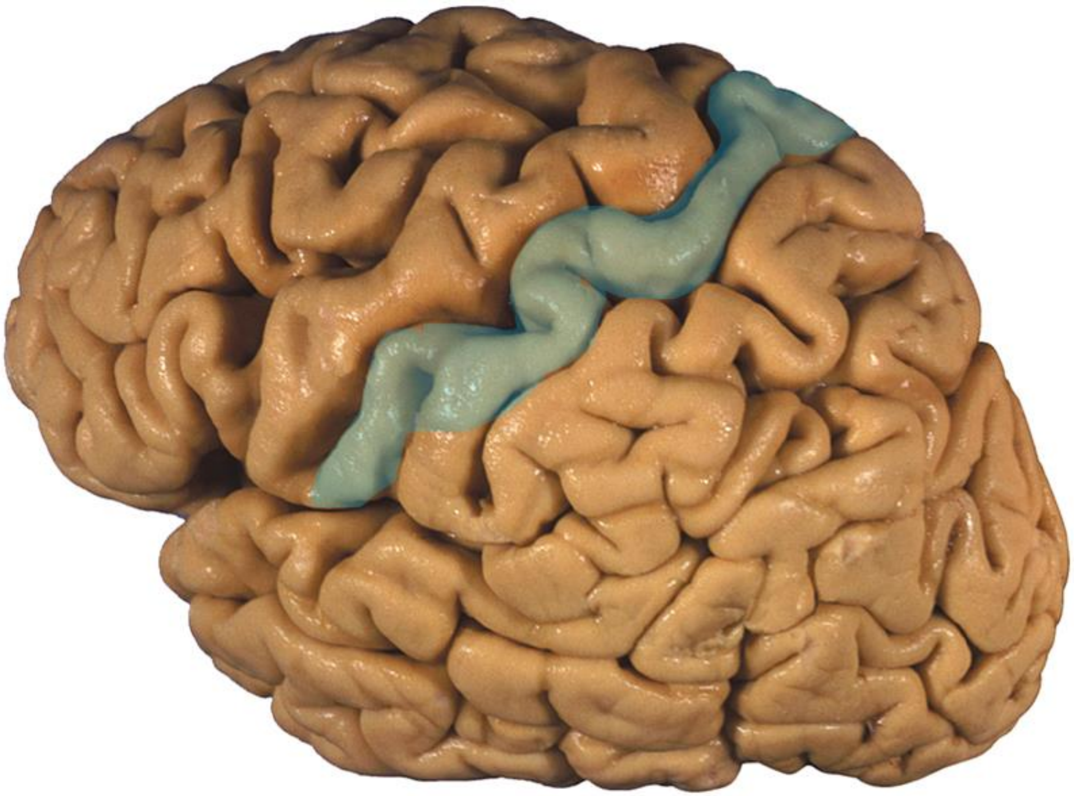
Somatosensory Projection to Cortex

Somatosensory information is relayed via the ventral posterior nucleus (medial and lateral divisions) of thalamus to primary somatosensory cortex.



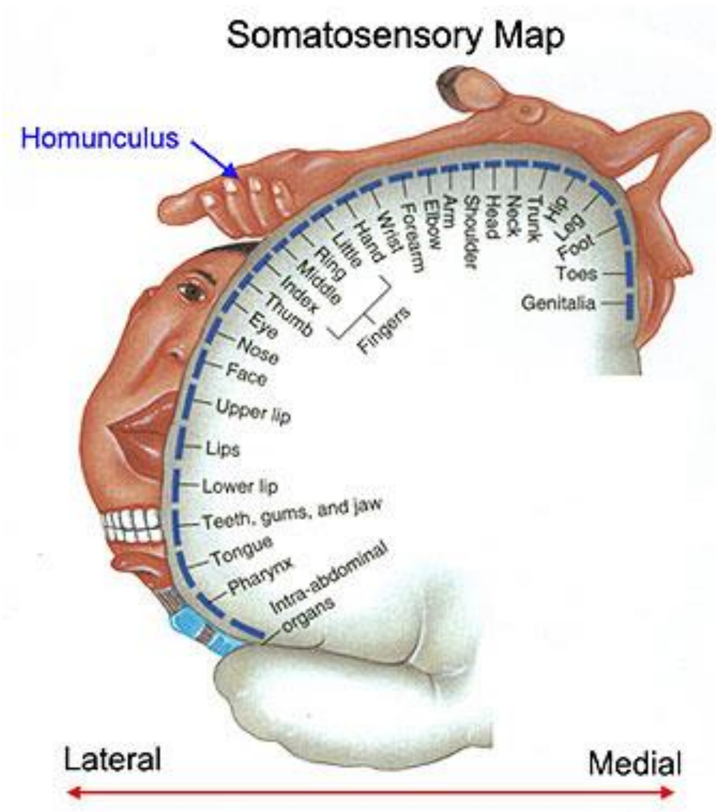
Somatosensory Projection to Cortex

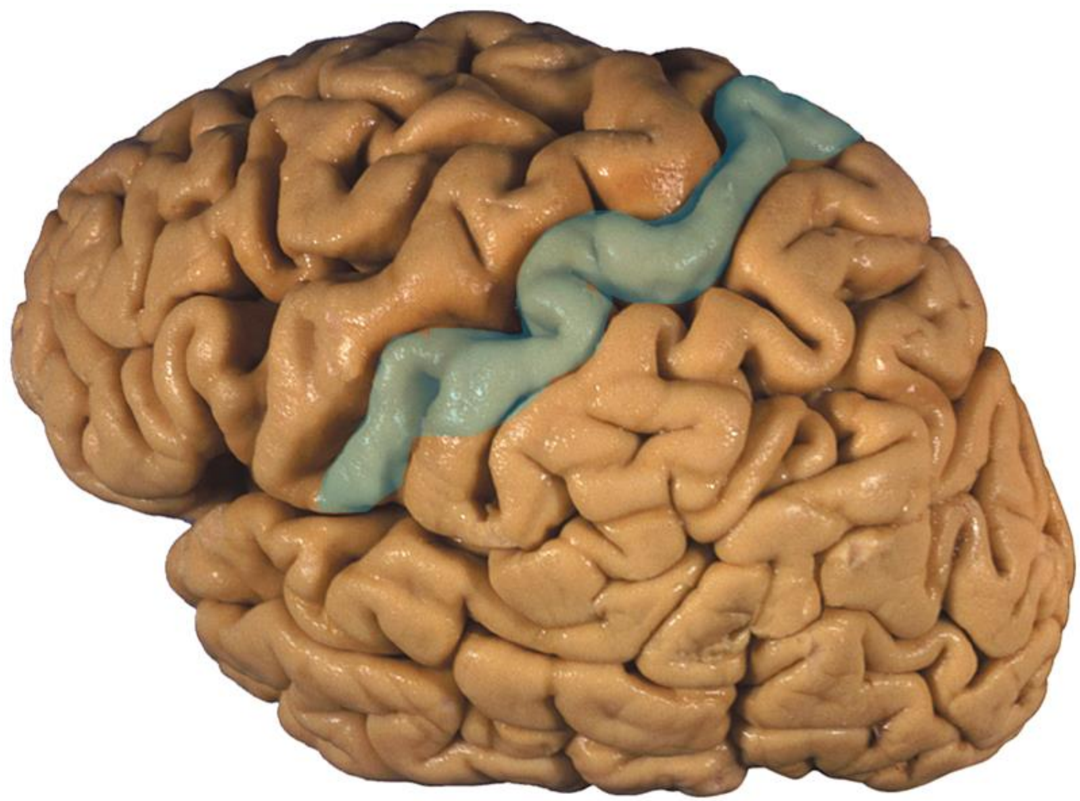
- Primary somatosensory cortex (S1 cortex) is in the postcentral gyrus of the parietal lobe.



Somatosensory Projection to Cortex

- The somatosensory projection has a somatotopic organization throughout the pathway
- The pattern of the projection to cortex is said to be a homunculus (little person).





Somatosensory Projection to Cortex

- A stroke in the right side of the cerebellum is likely to affect movements of the right side of the body.
- A stroke in the right somatosensory cortex is likely to affect sensory perception of the left side of the body.