Somatosensory System

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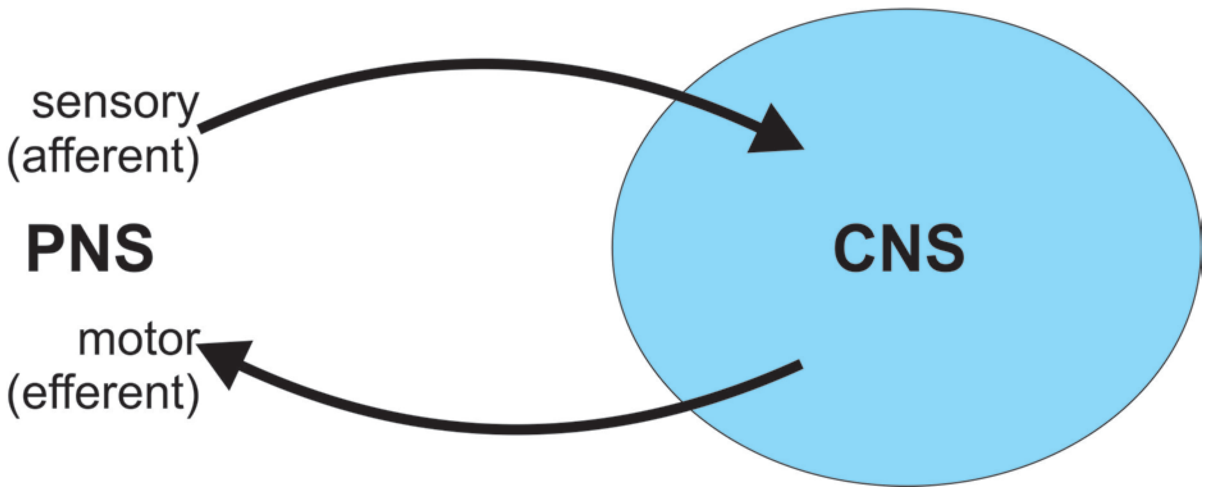
Sensory systems are used by an organism to monitor the state of it's body and its environment.



There are several sensory systems.

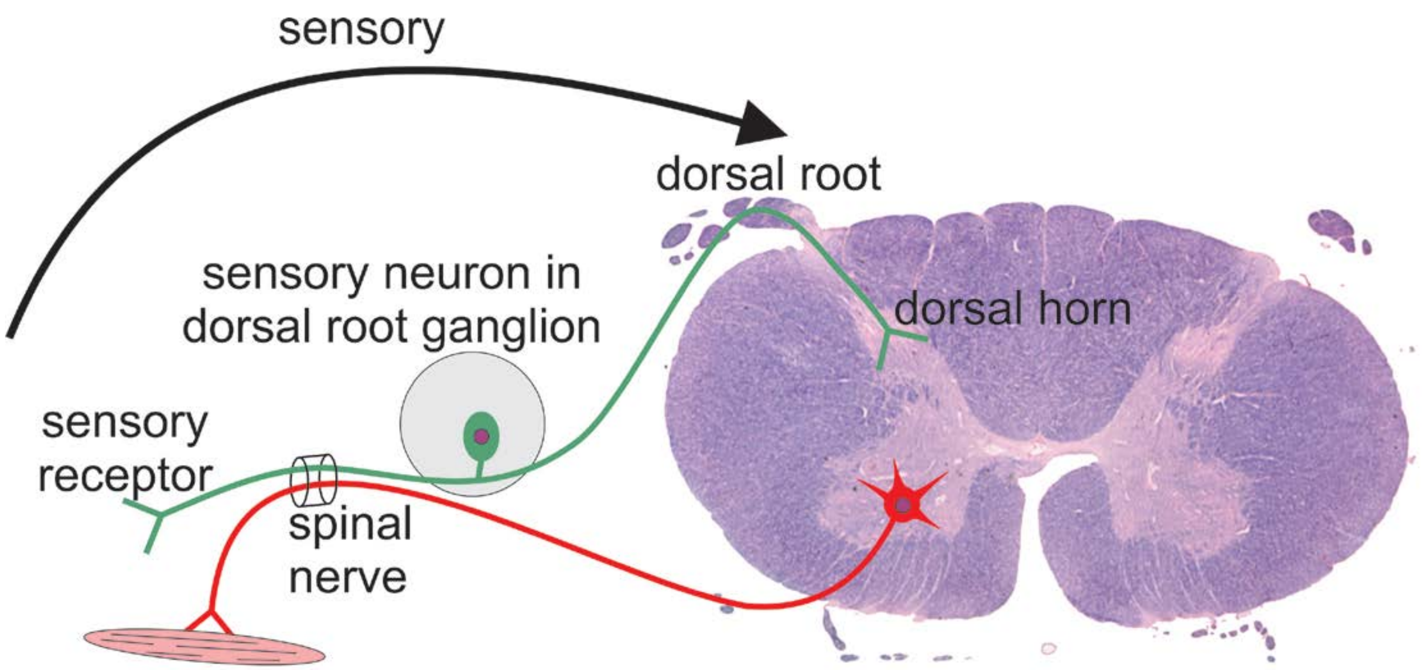
- Somatosensory
- Visceral sensory
- Special sensory
  - Vision
  - Auditory
  - Vestibular
  - Gustatory (taste)
  - Olfactory (smell)

The somatosensory system detects multiple sensations.

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

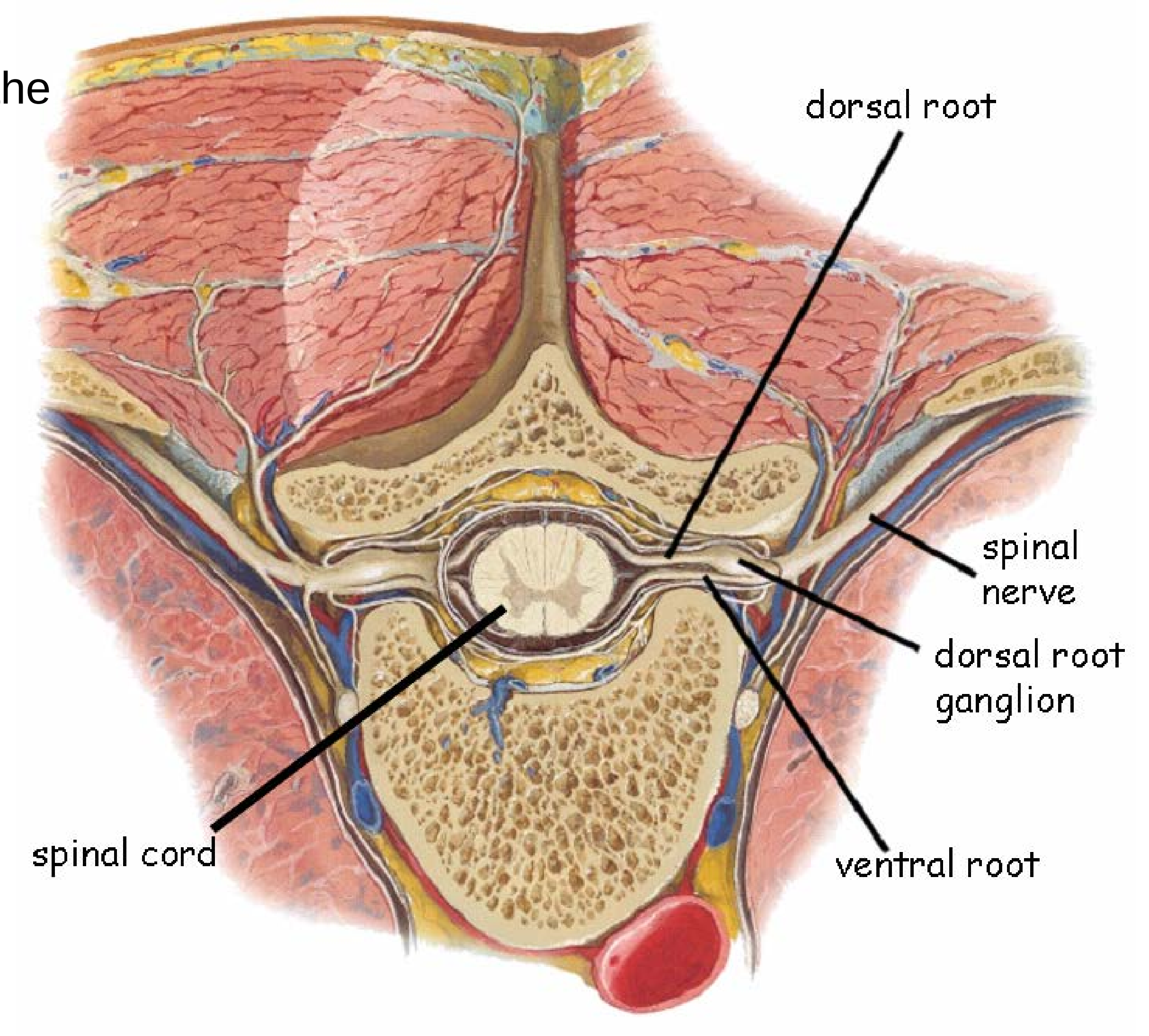
Somatosensory Primary Afferent Neurons

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



Somatosensory Primary Afferent Neurons: Body

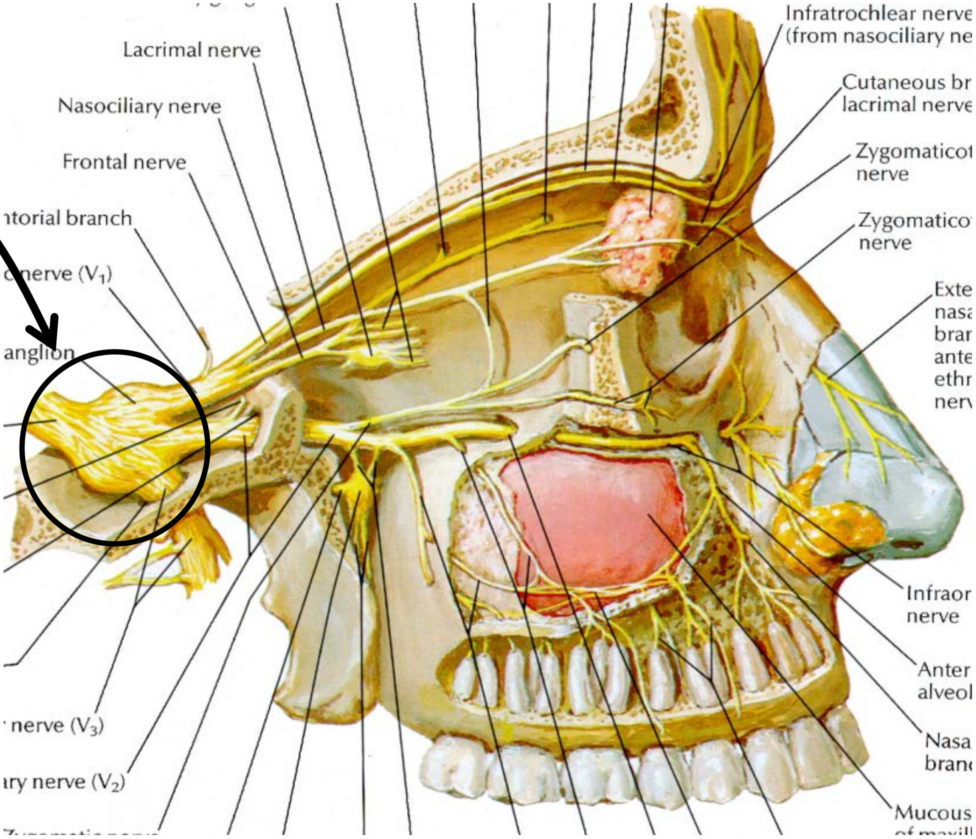
- Dorsal root ganglia are in the intervertebral foramena.



Somatosensory Primary Afferent Neurons: Head

- The main somatosensory nerve for the head is the trigeminal nerve (cranial nerve V).

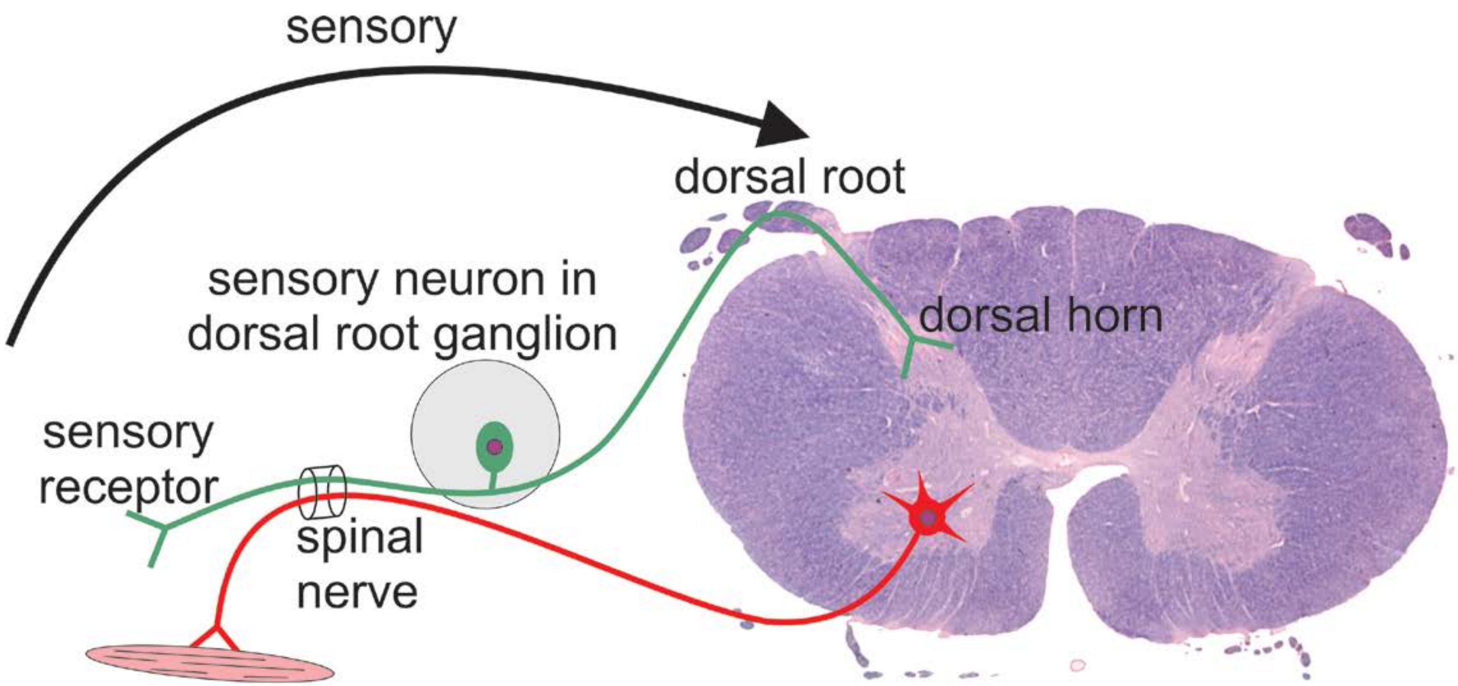
- The **trigeminal ganglion** is in the skull near where the trigeminal nerve joins the pons, deep to the lower jaw.



Somatosensory Primary Afferent Neurons

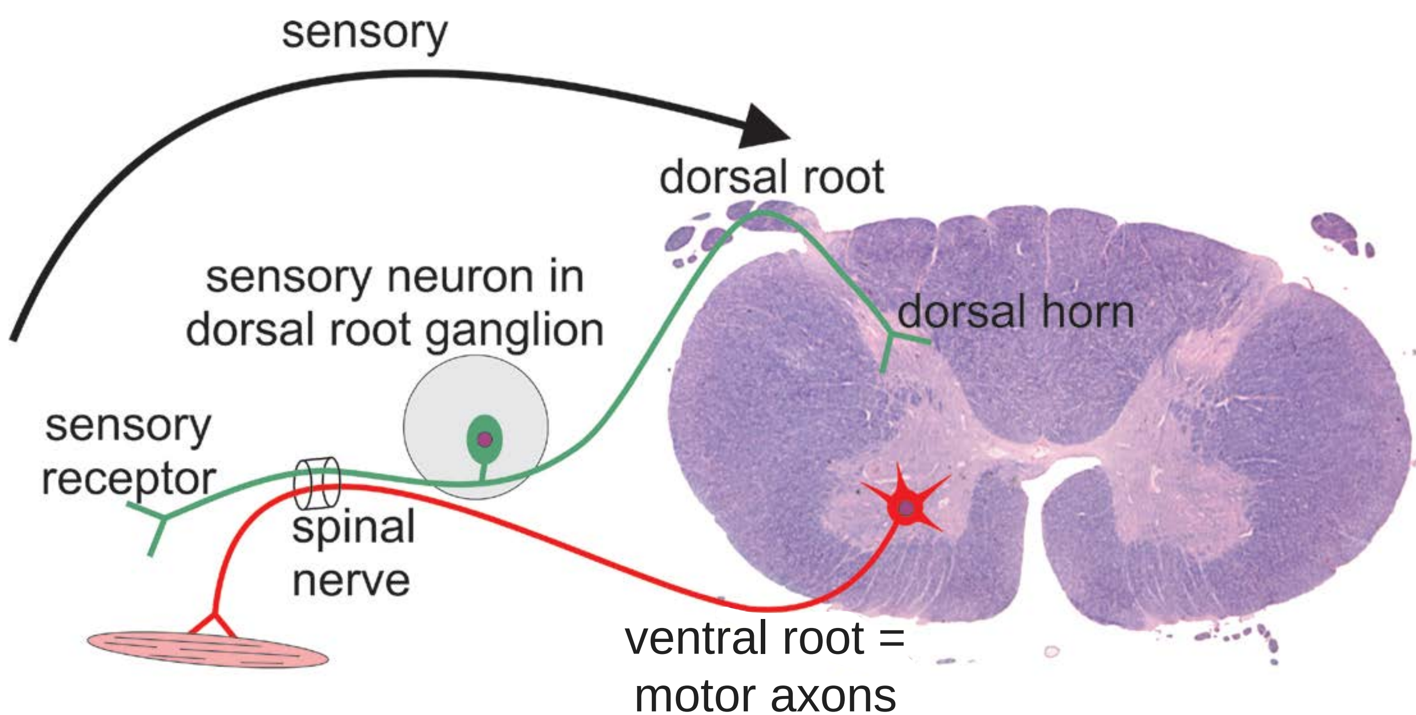
- The peripheral processes of somatosensory primary afferent neurons remain outside the CNS. However, their central processes enter the CNS as ***dorsal roots***.

- **Dorsal roots contain only axons of sensory neurons.**

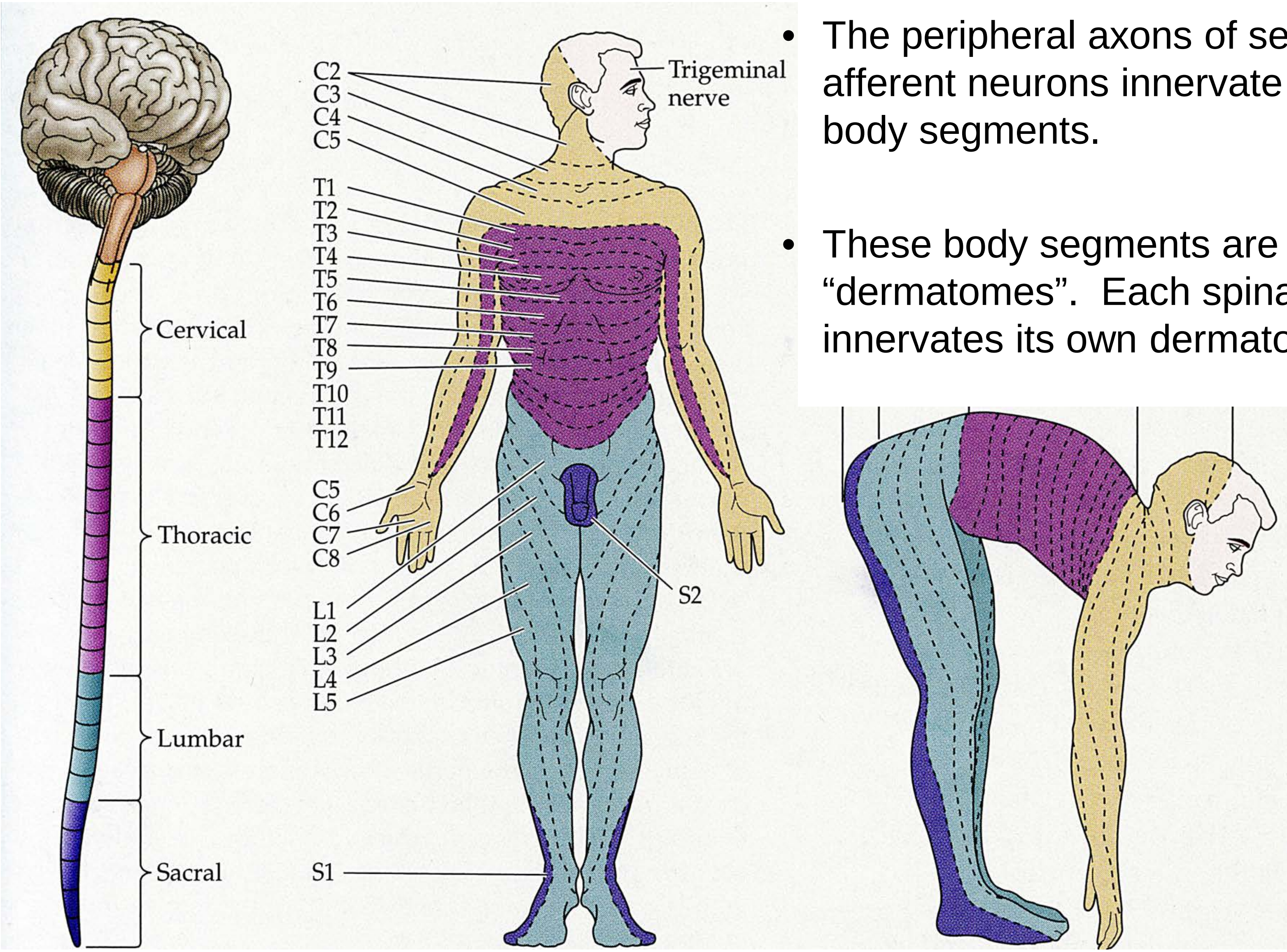


Somatosensory Primary Afferent Neurons

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



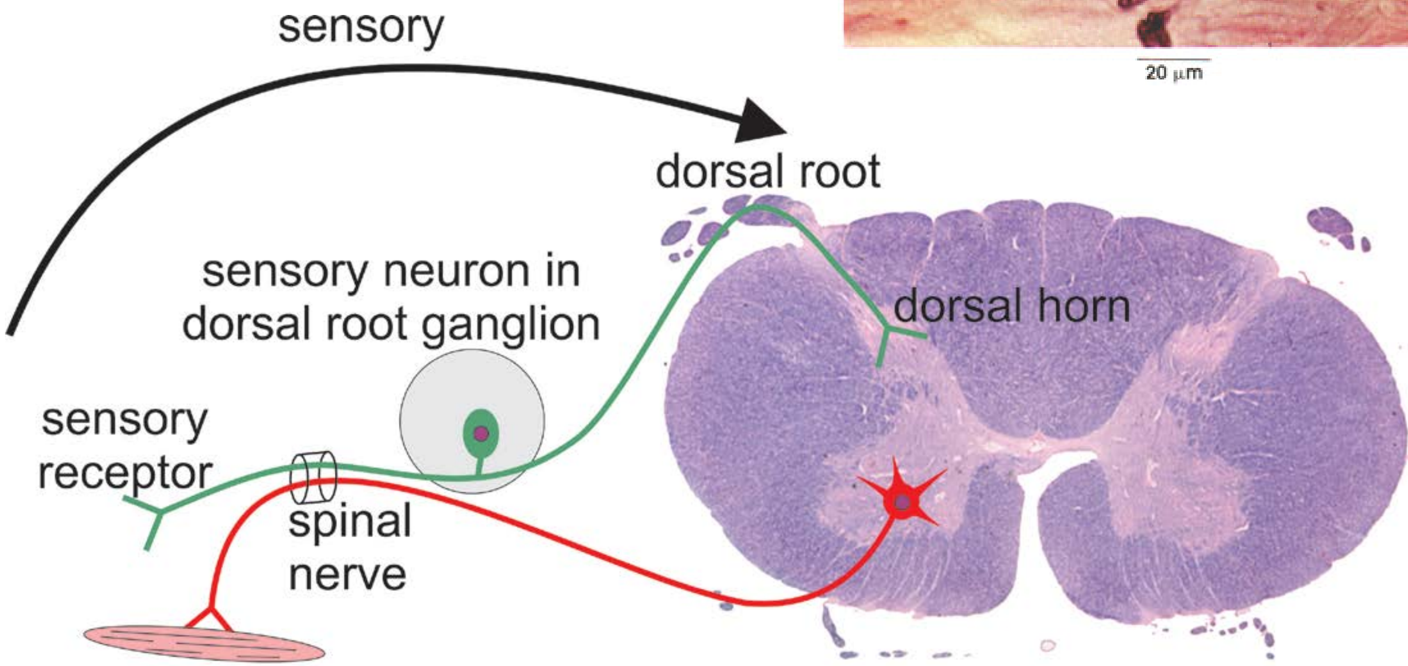
Peripheral Distribution of Somatosensory Axons



- The peripheral axons of sensory primary afferent neurons innervate only specific body segments.
- These body segments are called "dermatomes". Each spinal nerve innervates its own dermatome.

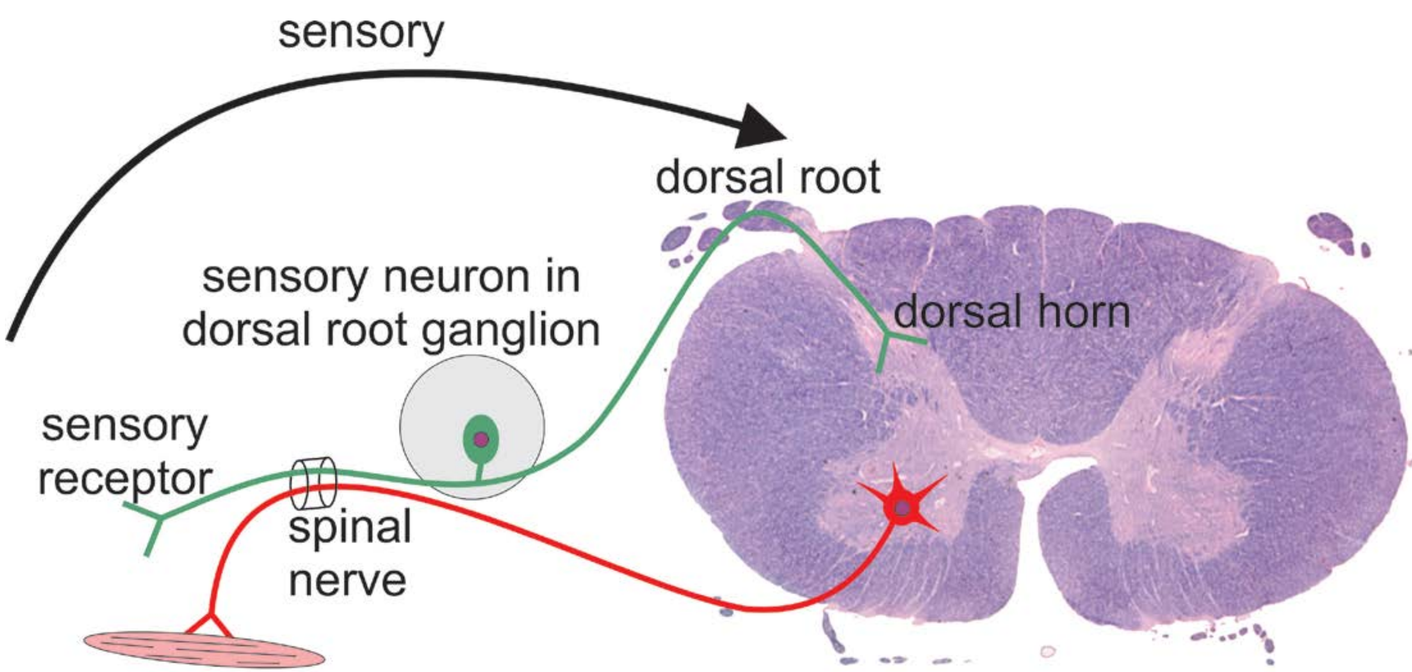
Somatosensory Primary Afferent Neurons

- The peripheral process of a sensory neuron receives (sensory) information and in this way resembles a dendrite. The peripheral process connects directly with the axon. The soma (cell body) hangs off the middle of the axon in the ganglion.



Somatosensory Primary Afferent Neurons

- Sensory receptors are found at the ends of the peripheral processes of the sensory neuron.
- Each sensory neuron's receptors are specialized to respond to particular stimuli.



Somatosensory Primary Afferent Neurons

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

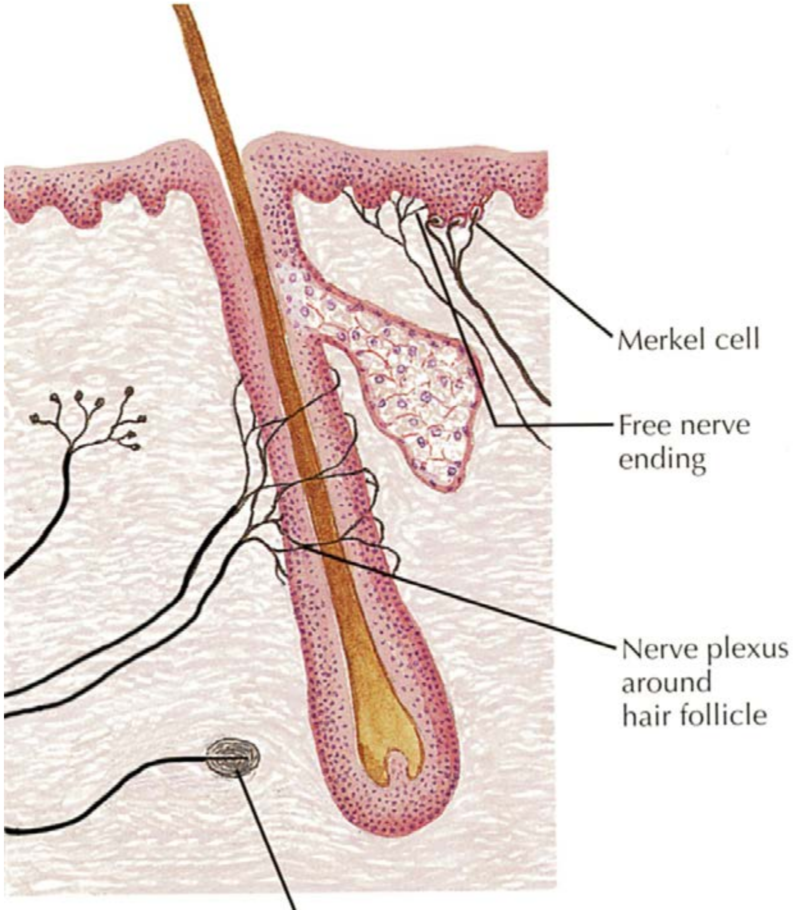
Touch

- Mechanoreception (mechanoception) is detection of mechanical force (texture, pressure, vibration, movement)

- Receptors are broadly distributed through the body. They are most concentrated in the skin.

Touch

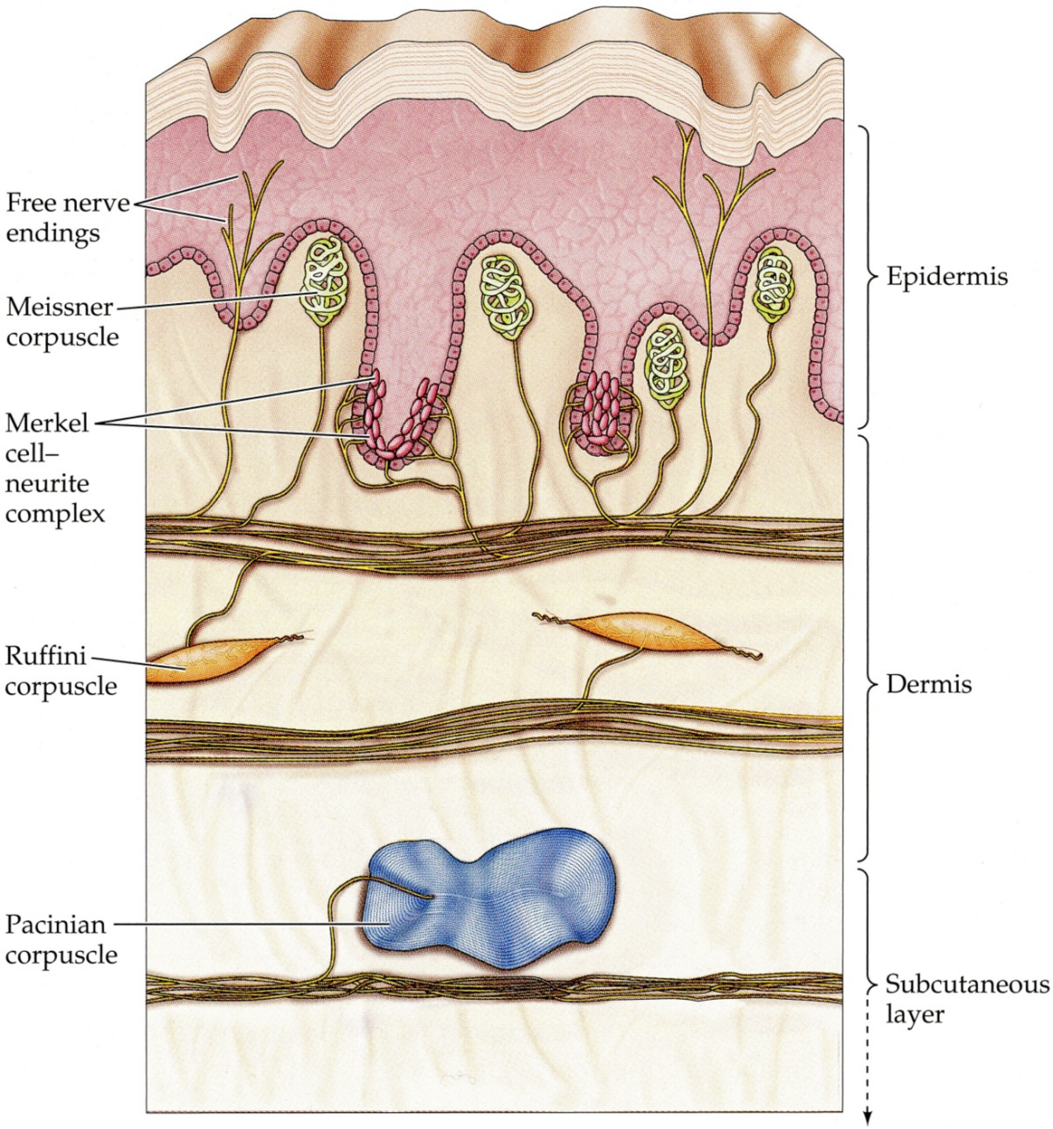
- Most touch receptors are encapsulated by other cells or are associated with hair follicles.
- Encapsulation changes the nature of the sensitivity of the neuron.



pacinian corpuscles in skin

Touch

- The type of encapsulation, depth in the skin and response properties of the neuron determine the <u>stimulus</u> that activates a sensory cell.

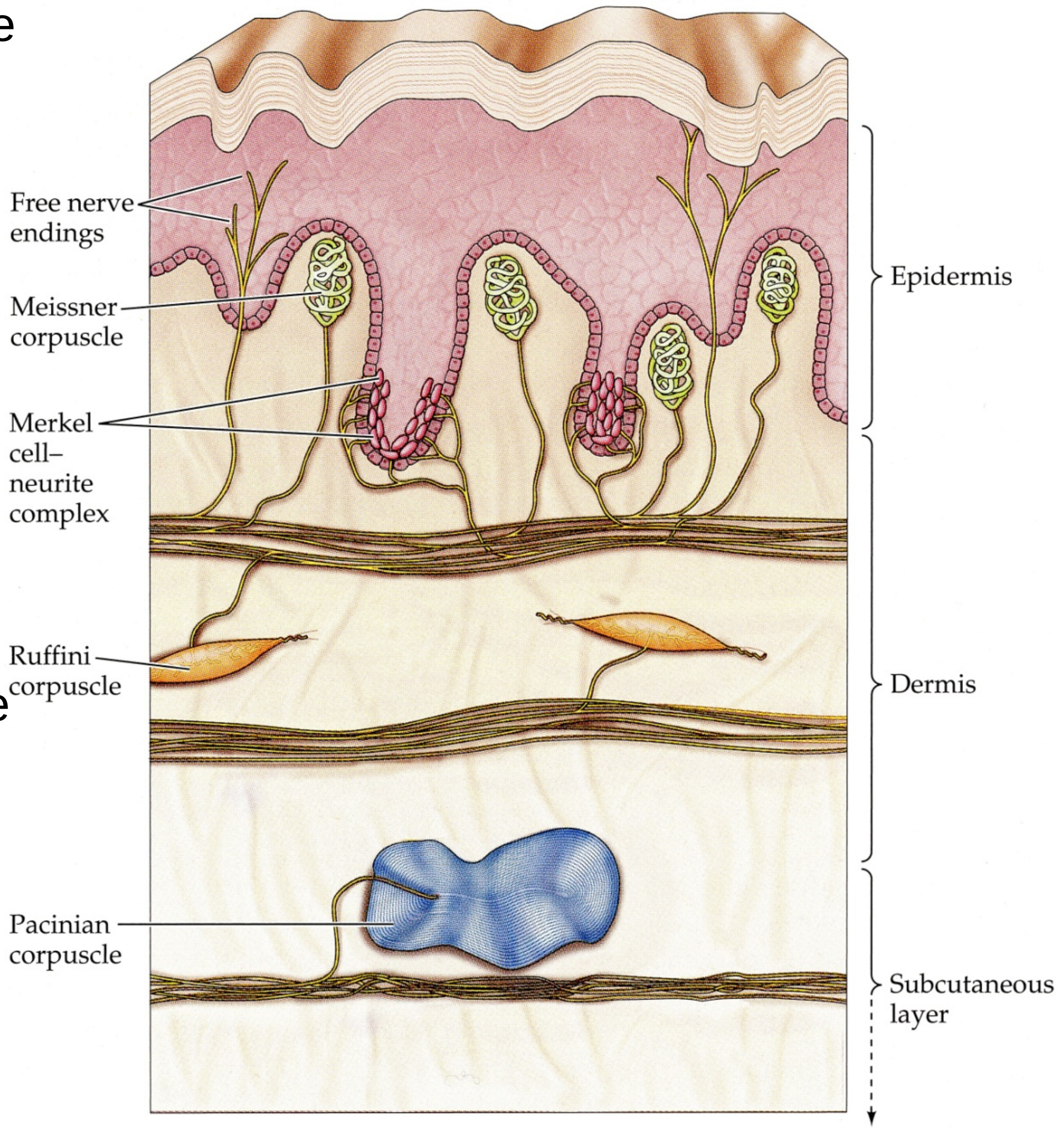


Touch

- 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.

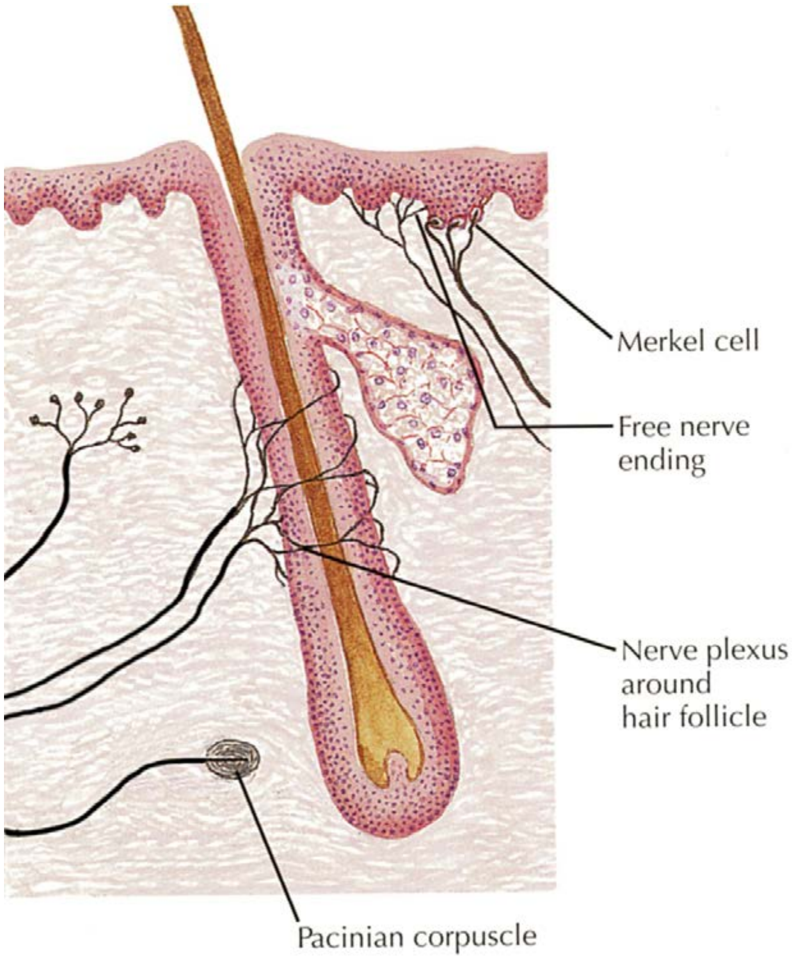
- Meissner corpuscle: encapsulated in layers of Schwann cells; in dermis; sensitive to light touch and vibration; mostly in hairless skin.

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



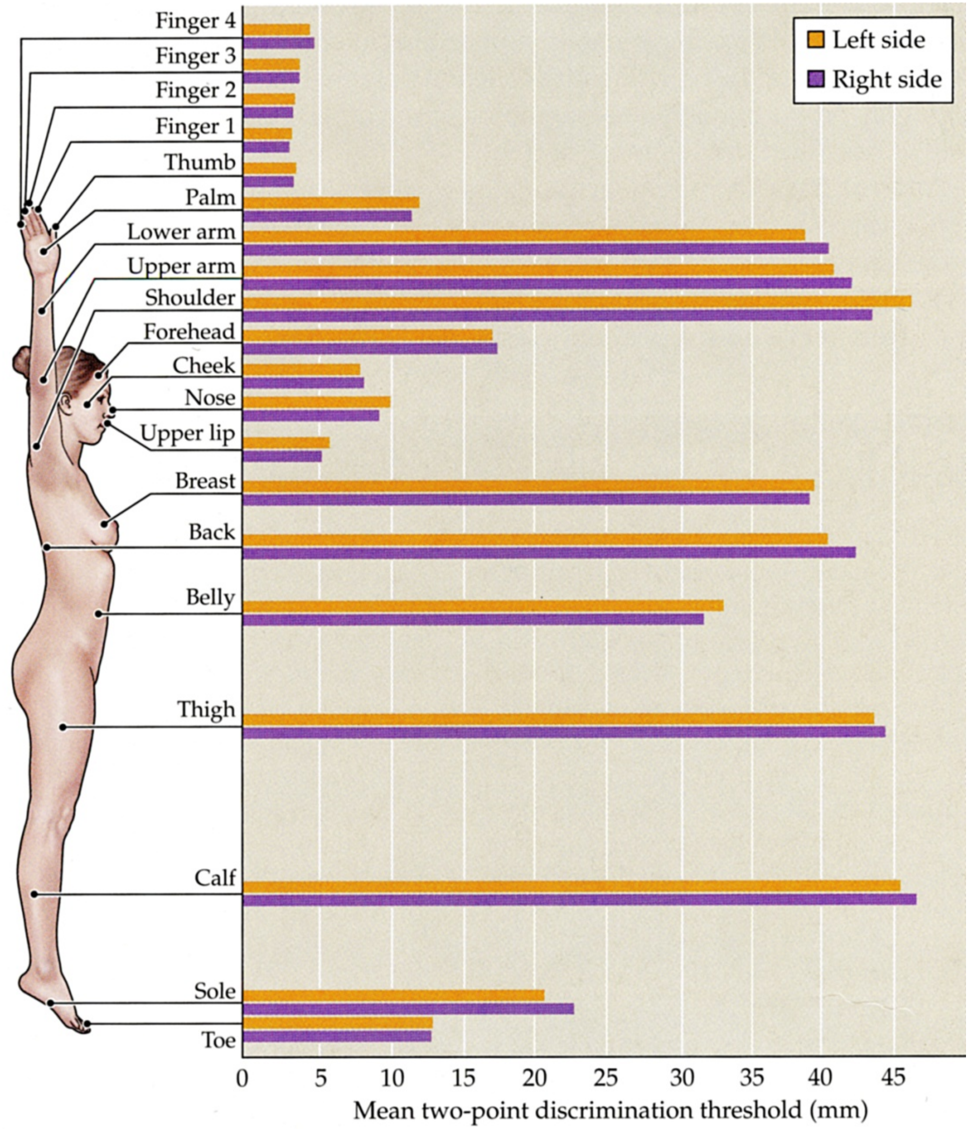
Touch

- 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.



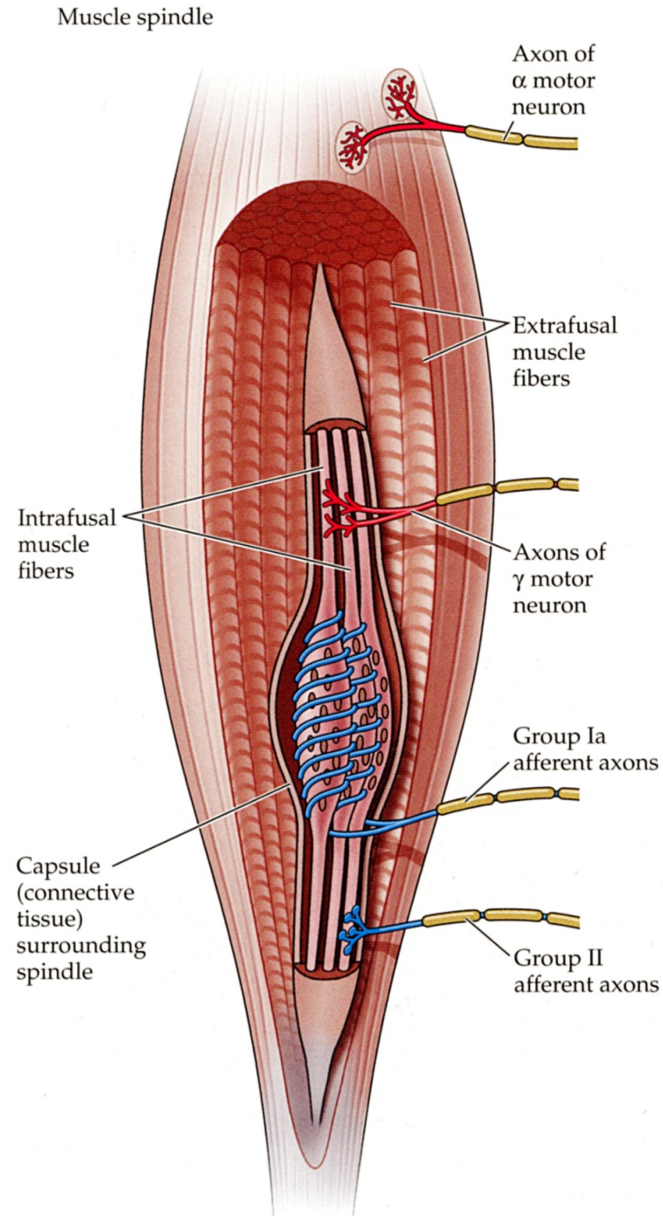
Proprioception

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

- Proprioceptors are specialized mechanoreceptors.

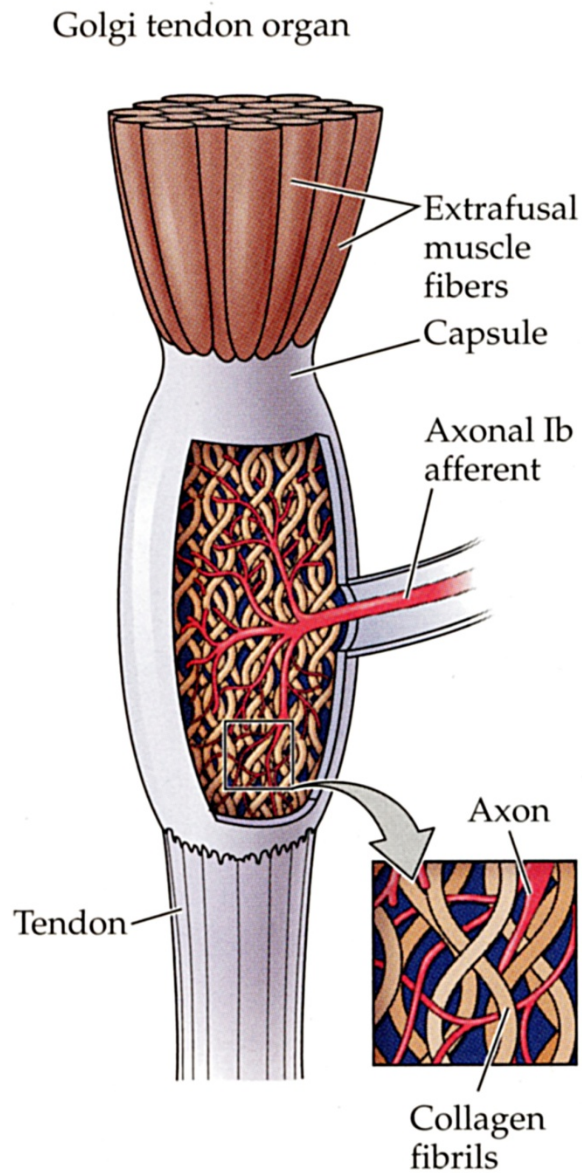
Proprioception

- **Muscle spindles**: nerve endings wrapped around an intrafusal muscle fiber; embedded in muscle; sensitive to muscle length; provides information required to adjust the strength of contraction.
  (Knee-jerk reflex)



Proprioception

- Golgi tendon organs: embedded in collagen fibers of tendons; compressed by tension in tendon; sensitive to force exerted by tendon.



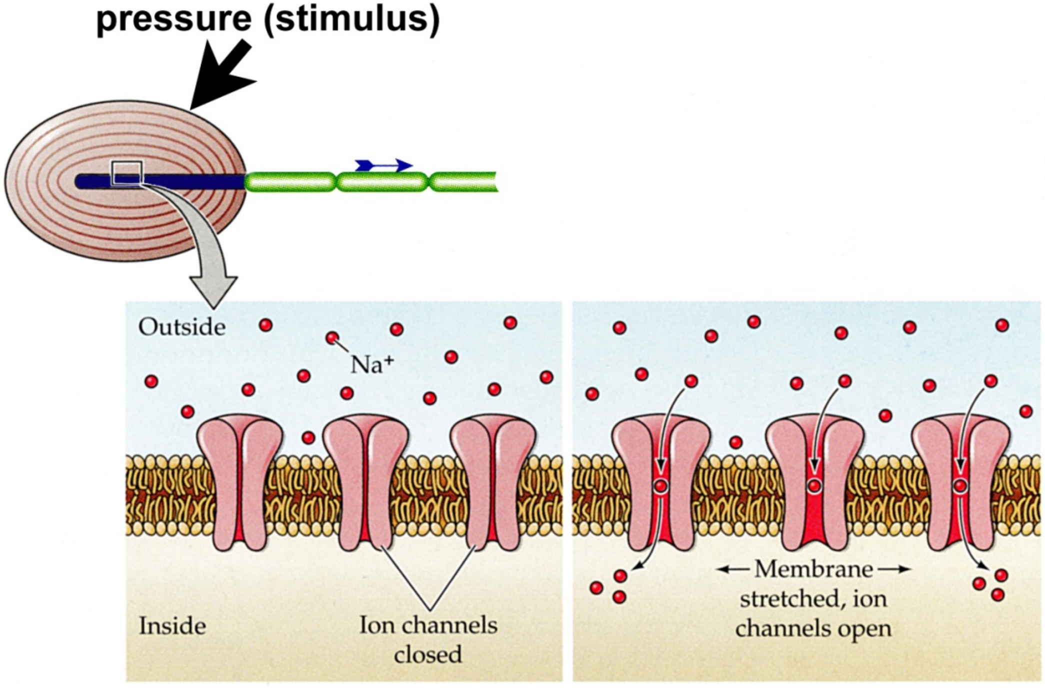
Somatosensory Receptors

- 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

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

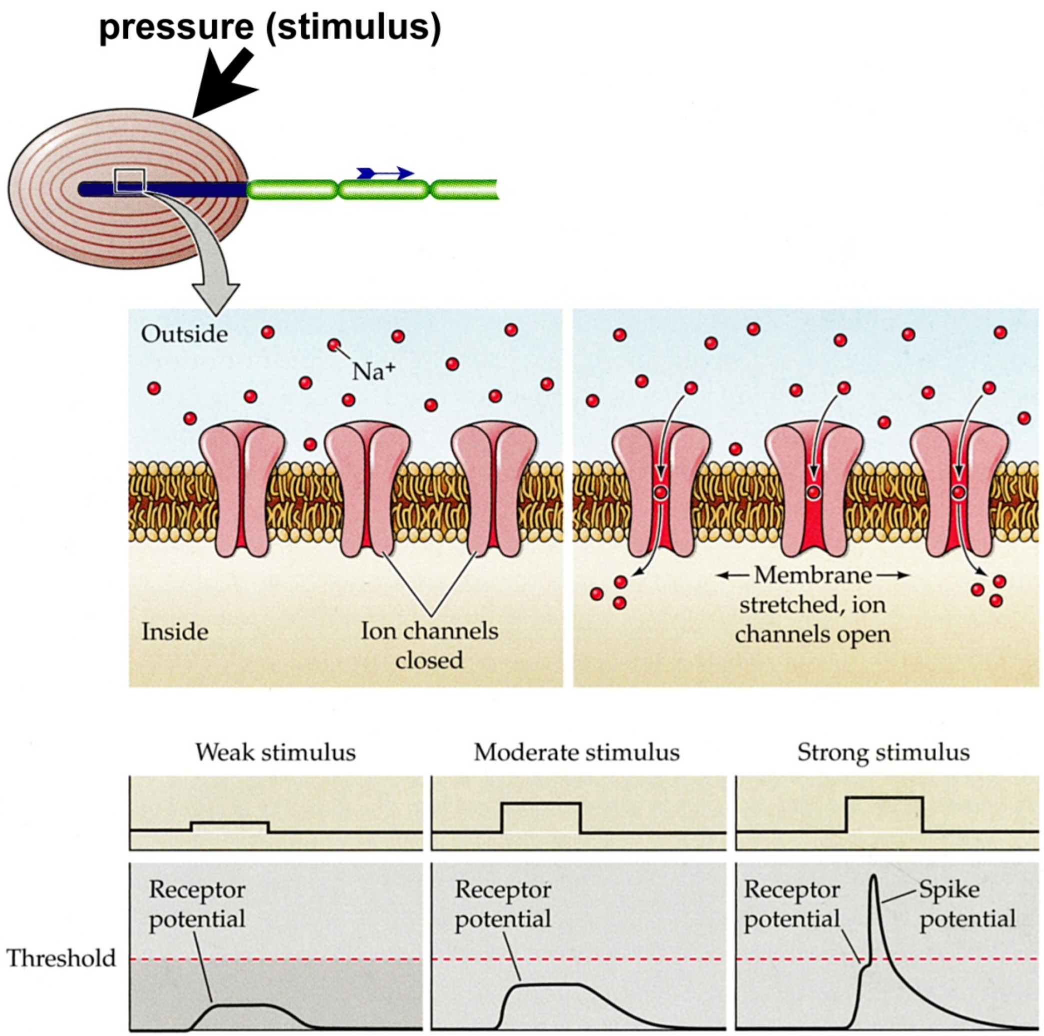


Somatosensory Receptors

- Piezo2:
  - Mechanoreceptor neurons express the receptor protein, Piezo2.
  - Trimers of Piezo2 form the mechanically gated ion channel in most mechanoreceptive neurons.
  - Piezo2 is found in the membrane of the nerve ending, and is typically associated with other cells such as in Merkel’s disks or muscle spindles.
  - Opening of the Piezo2 channel depolarizes the nerve ending.

Somatosensory Receptors

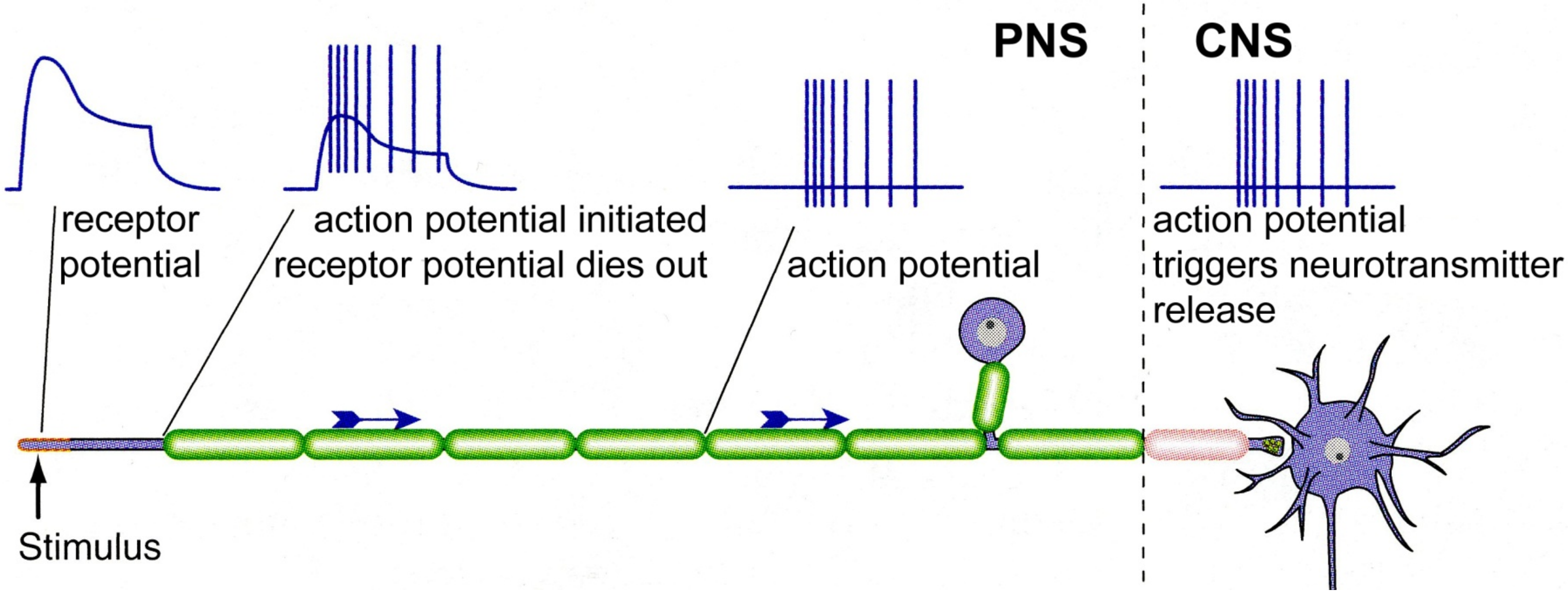
- The stronger the stimulus, the larger the membrane depolarization.



Somatosensory Receptors

- With sufficient depolarization (i.e., greater than 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.

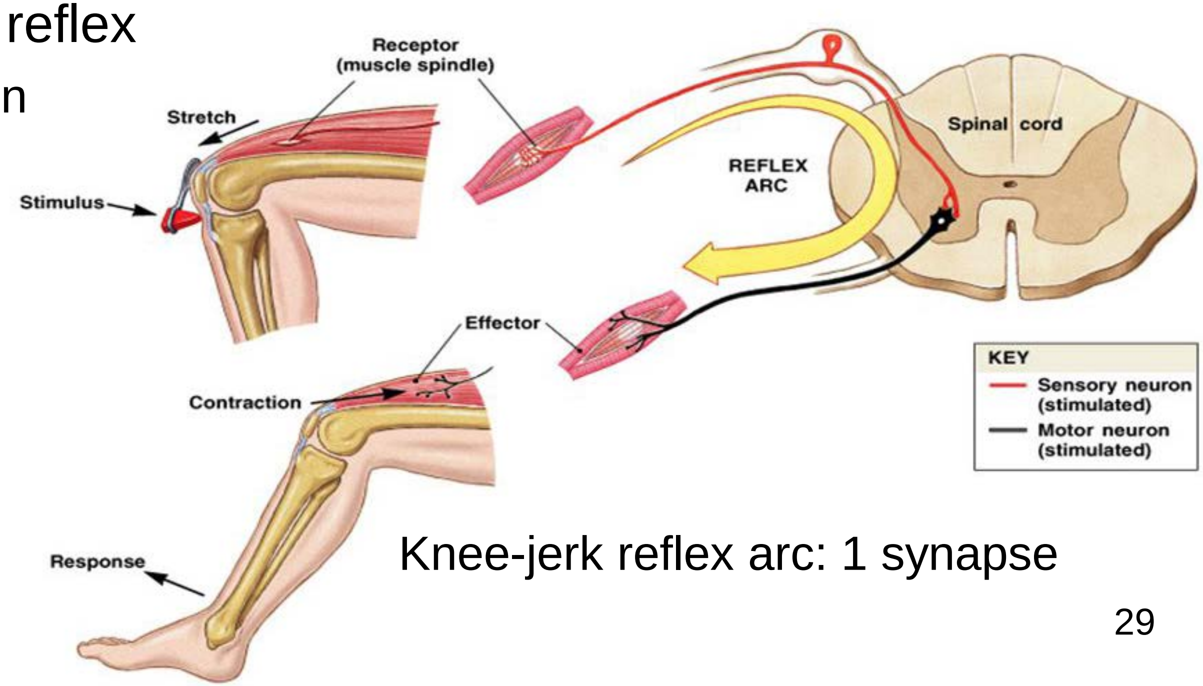


Functions of somatosensory input

- Local (spinal) reflexes
- Ascend to brain

Somatosensory spinal reflexes

- Require few (e.g. 1 or 2) synapses; all synapses occur in spinal cord
  - Knee-jerk reflex
    - Response to muscle stretch
  - Flexor-withdrawal reflex
    - Response to pain
  - Crossed-extensor reflex
    - Response to pain



Knee-jerk reflex arc: 1 synapse

Ascending somatosensory pathways

- To (ipsilateral) cerebellum
  - Spinocerebellar neurons: proprioception

- To (contralateral) cerebral cortex
  - Dorsal column pathway: touch, vibration
  - Spinothalamic tract pathway: temperature, pain, itch, some touch

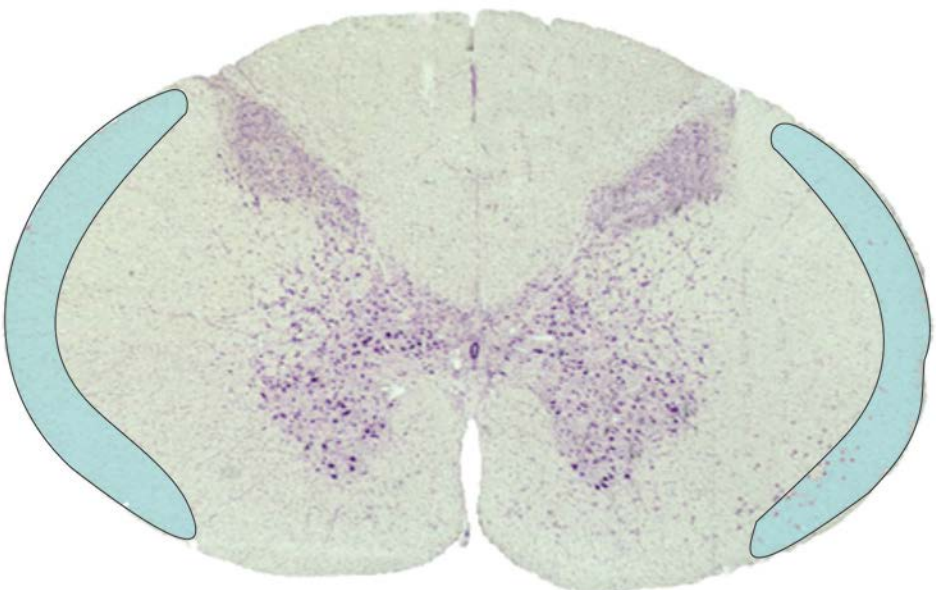
Spinocerebellar Pathway

- 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 ipsilateral side of the cerebellum.
- The cerebellum has important roles in maintaining balance and coordinating movements.

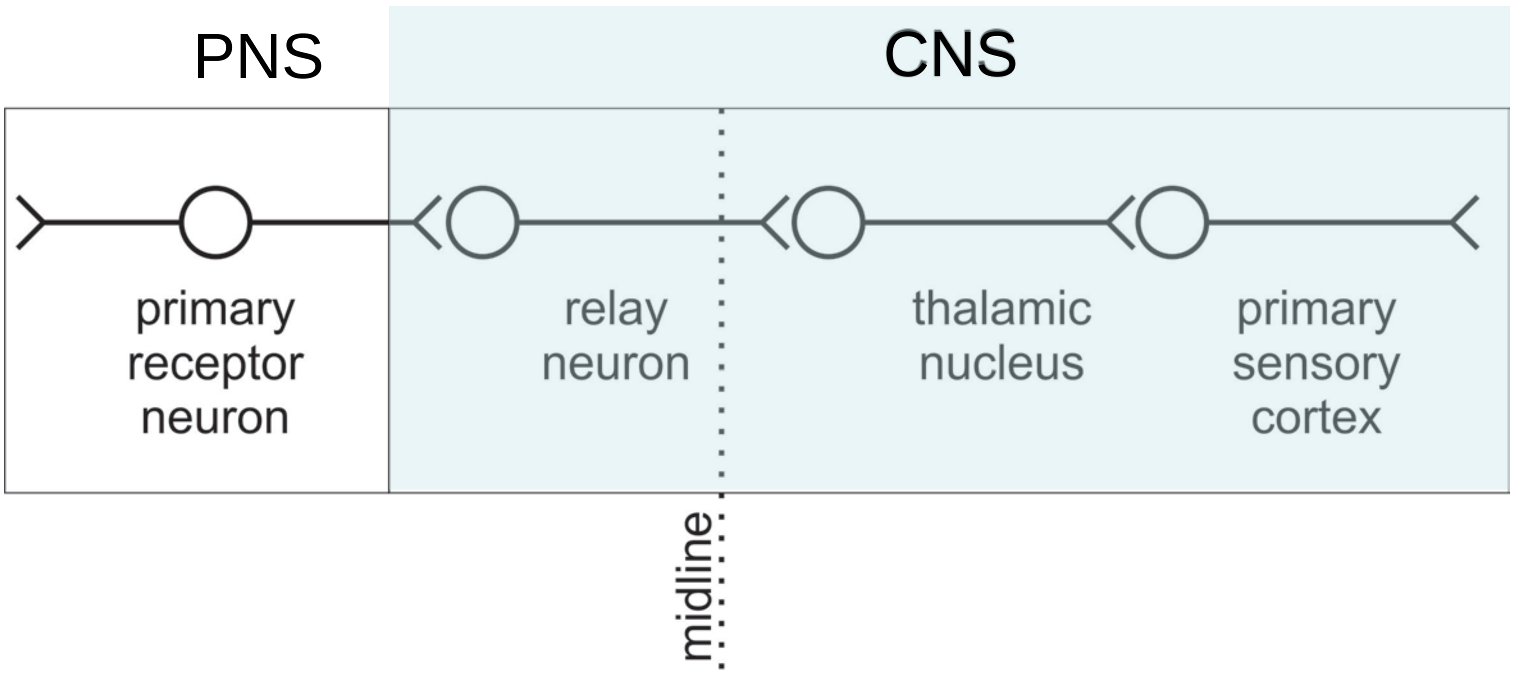
Spinocerebellar Pathway

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

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



Somatosensory Projections to Cerebral Cortex



Somatosensory Projection to Cerebral Cortex

Two pathways from periphery to cerebral cortex:

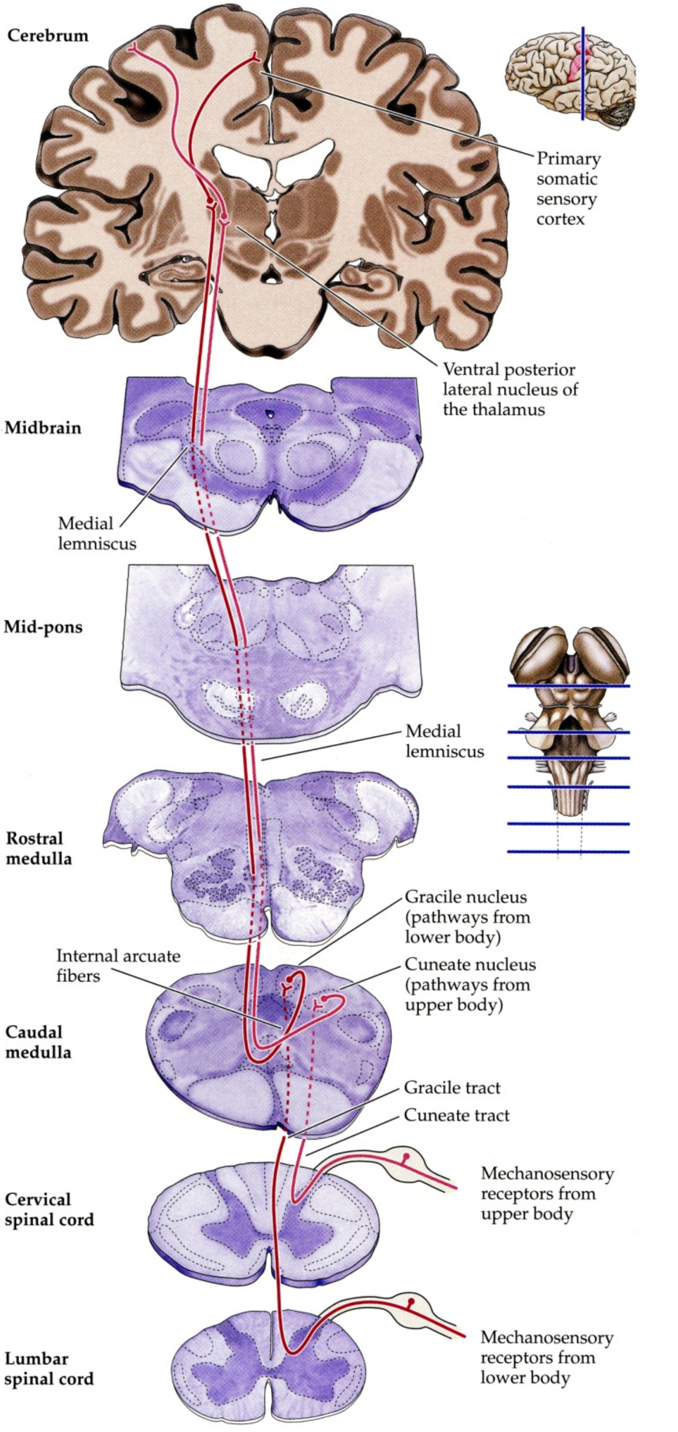
- Proprioception and most touch via the dorsal columns.

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

Somatosensory Projection to Cerebral Cortex

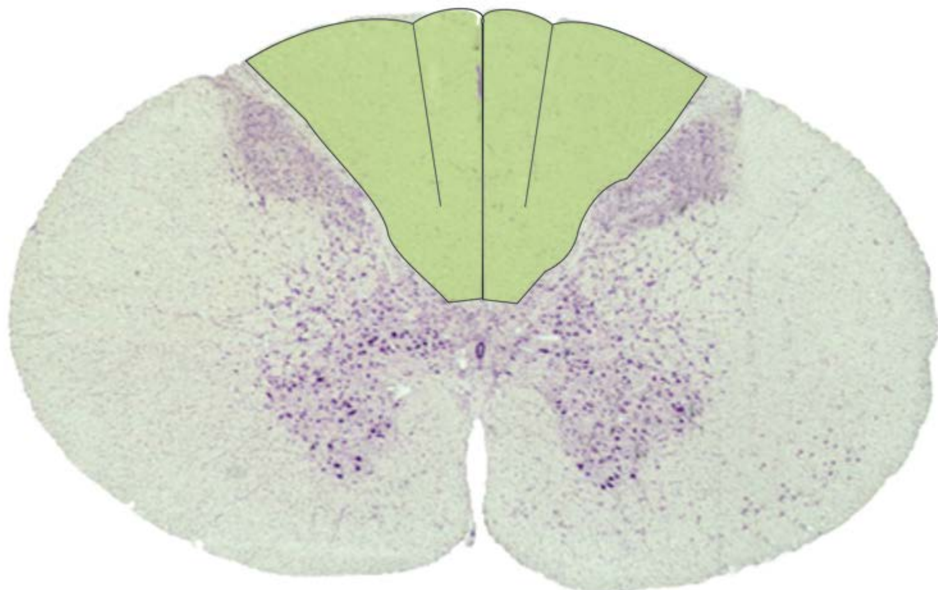
Dorsal column projection:

- Primary sensory axons for proprioception and most touch enter the dorsal horn and ascend in the ipsilateral 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.



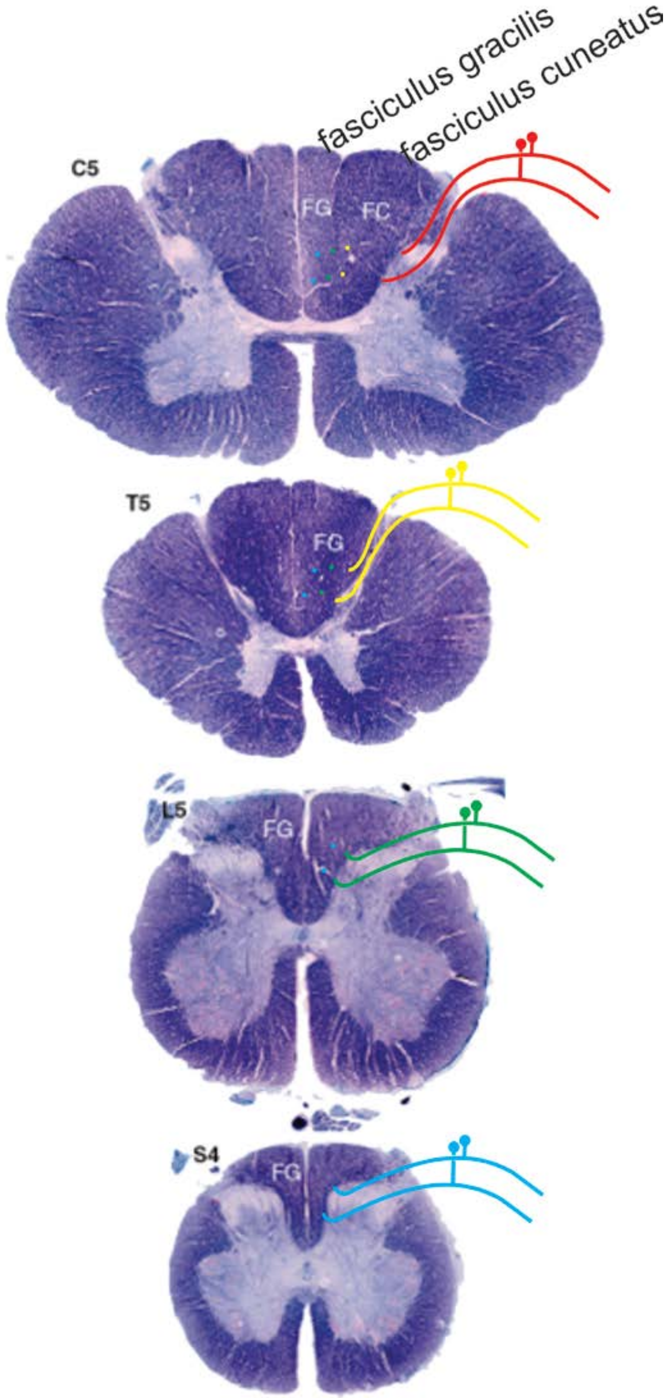
Somatosensory Projection to Cerebral Cortex

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



Somatosensory Projection to Cerebral Cortex

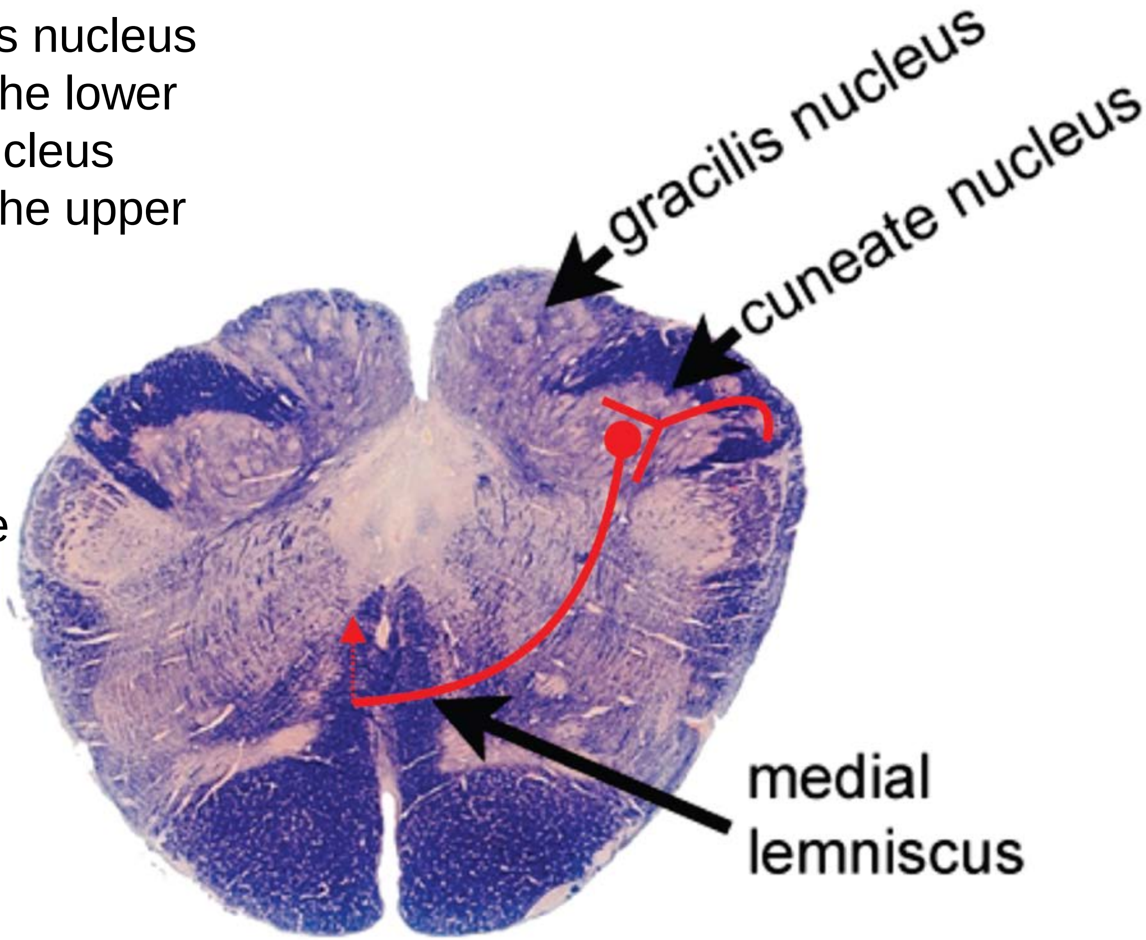
- Axons entering via the dorsal root join the dorsal column along the border of the dorsal horn.
- Fasciculus gracilis carries axons from the lower body.
- Fasciculus cuneatus carries axons from the upper body.



Somatosensory Projection to Cerebral 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.

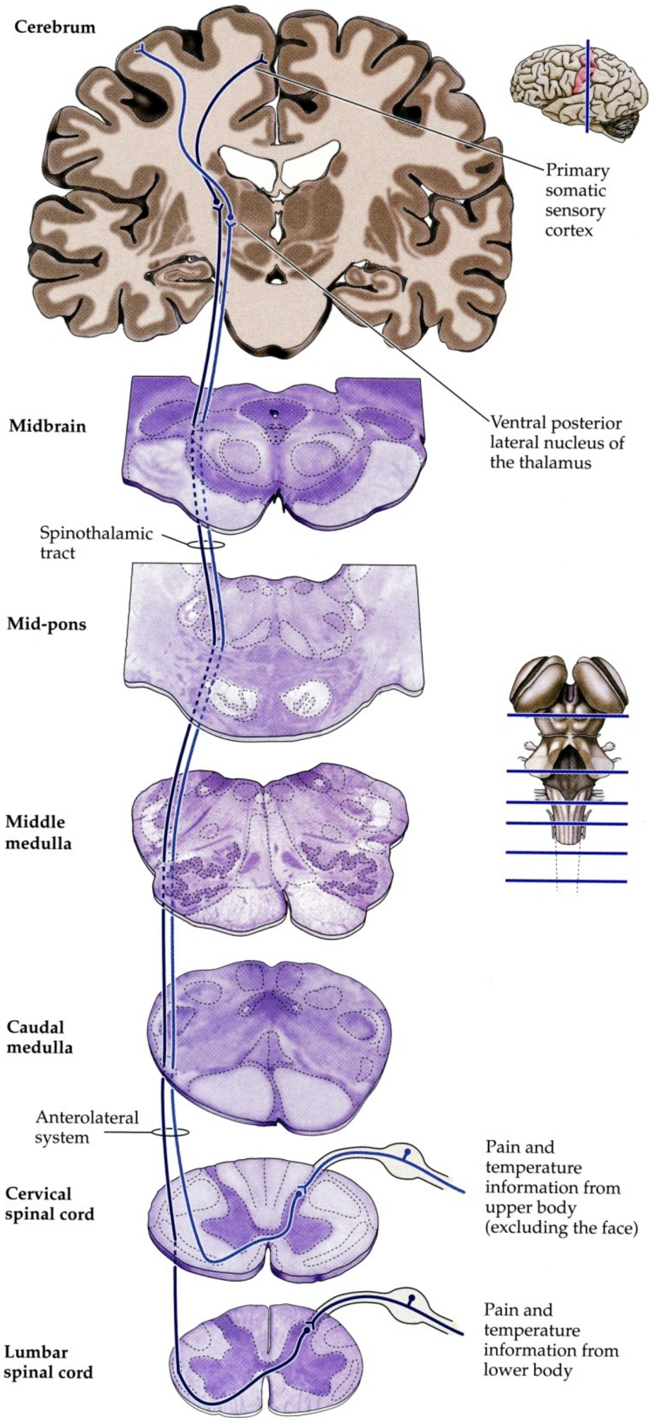
- The output axons from these nuclei cross the midline and ascend to the thalamus as the medial lemniscus.



Somatosensory Projection to Cerebral Cortex

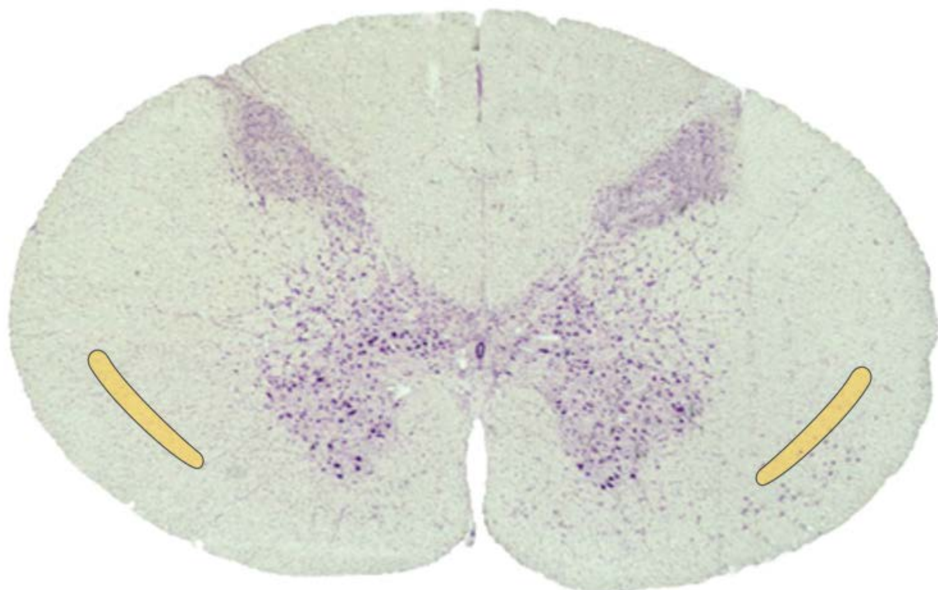
Spinothalamic projection:

- 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.



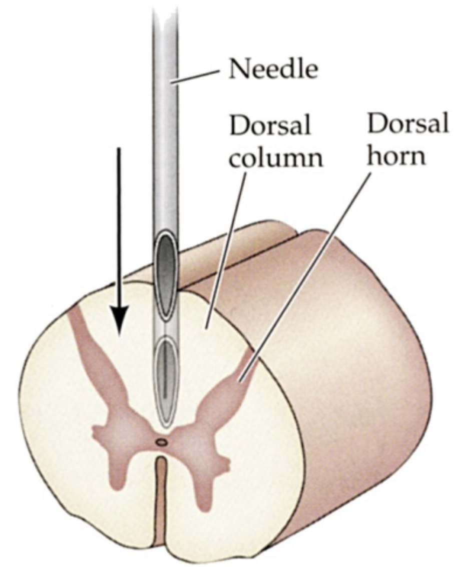
Somatosensory Projection to Cerebral Cortex

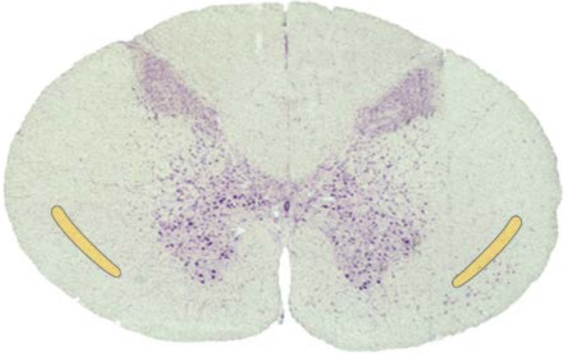
- The spinothalamic tracts are in the lateral funiculus of the spinal cord.



Somatosensory Projection to Cerebral Cortex

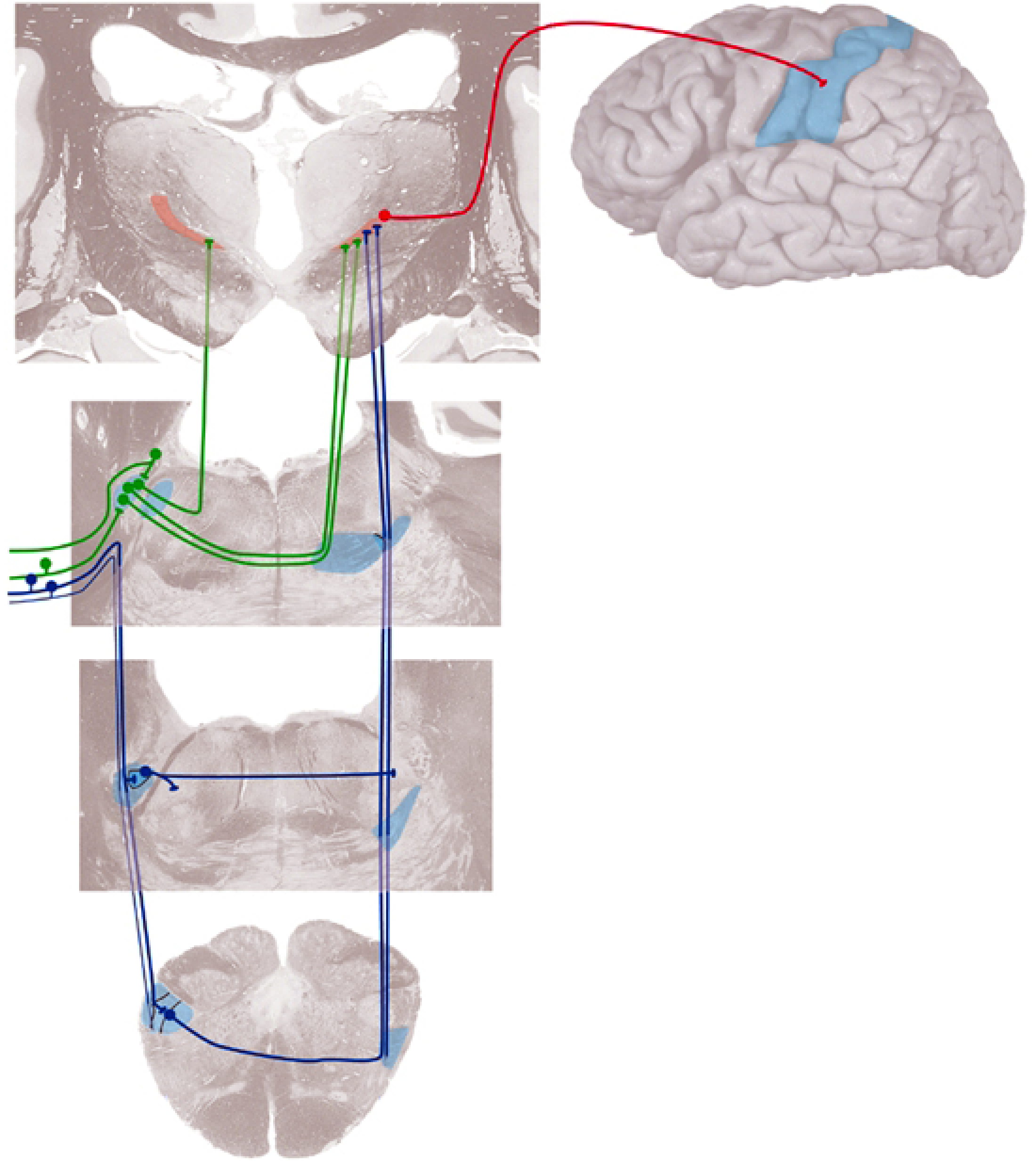
- For intractable pain, spinothalamic axons can be cut surgically as they cross the midline or as they ascend in the spinothalamic tract.





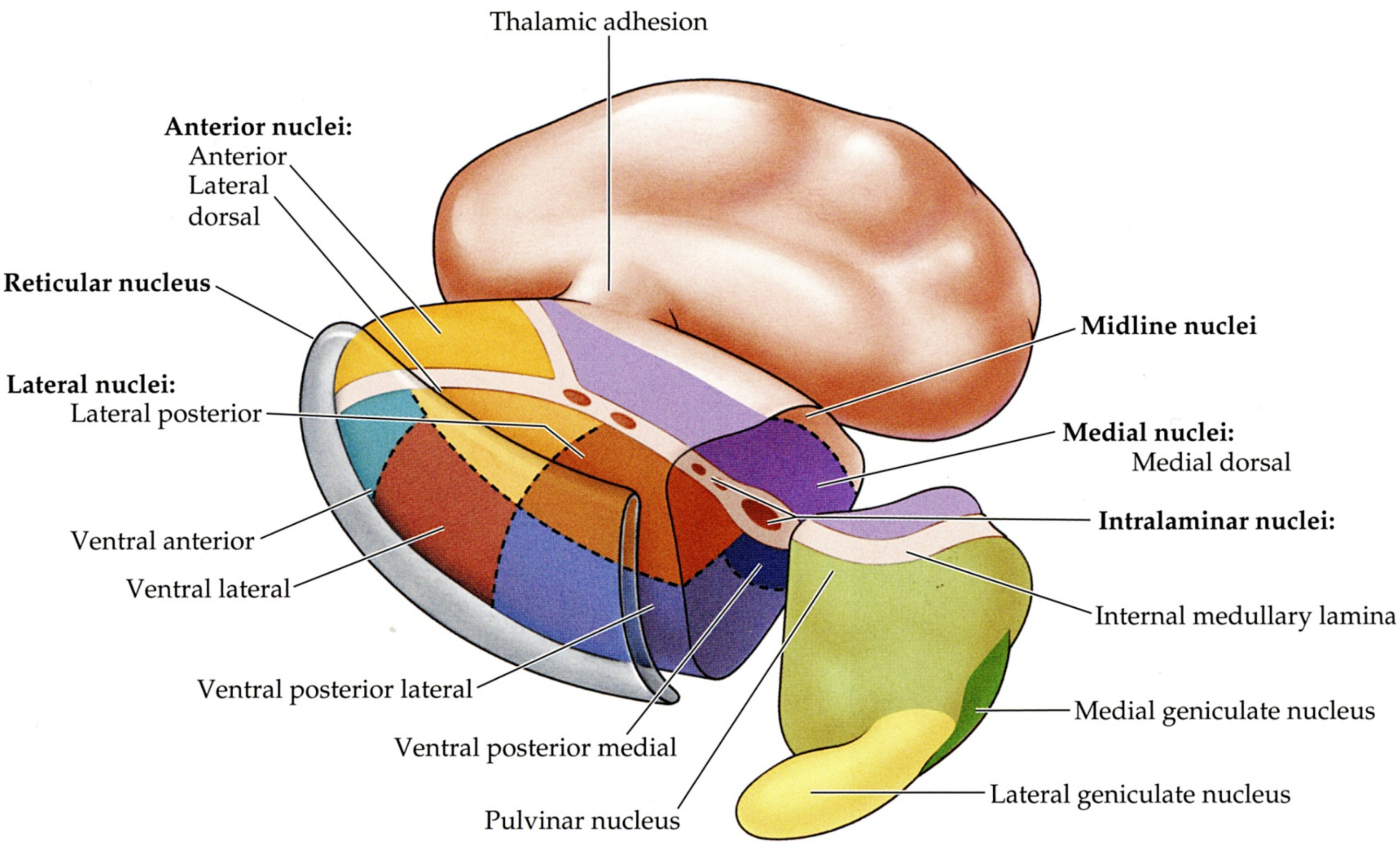
Somatosensory Projection to Cerebral Cortex: Trigeminal System

- 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 Cerebral Cortex

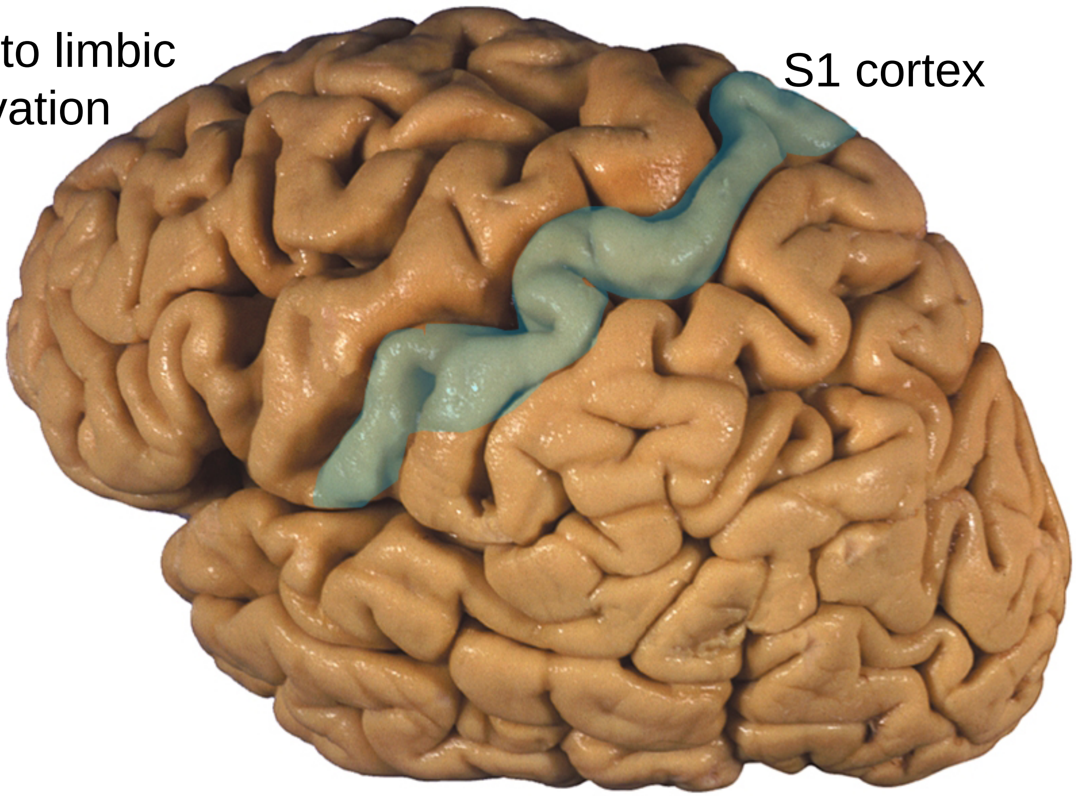
Somatosensory information is relayed via the ventral posterior nucleus (medial and lateral divisions) of thalamus to primary somatosensory cortex.



Somatosensory Projection to Cerebral Cortex

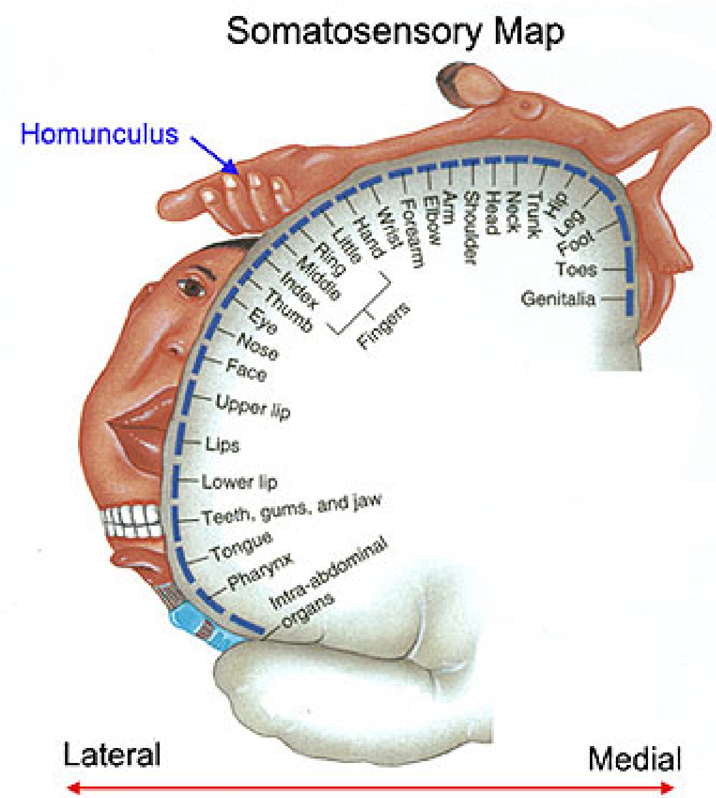
- Primary somatosensory cortex (S1 cortex) is in the <u>postcentral gyrus</u> of the parietal lobe.

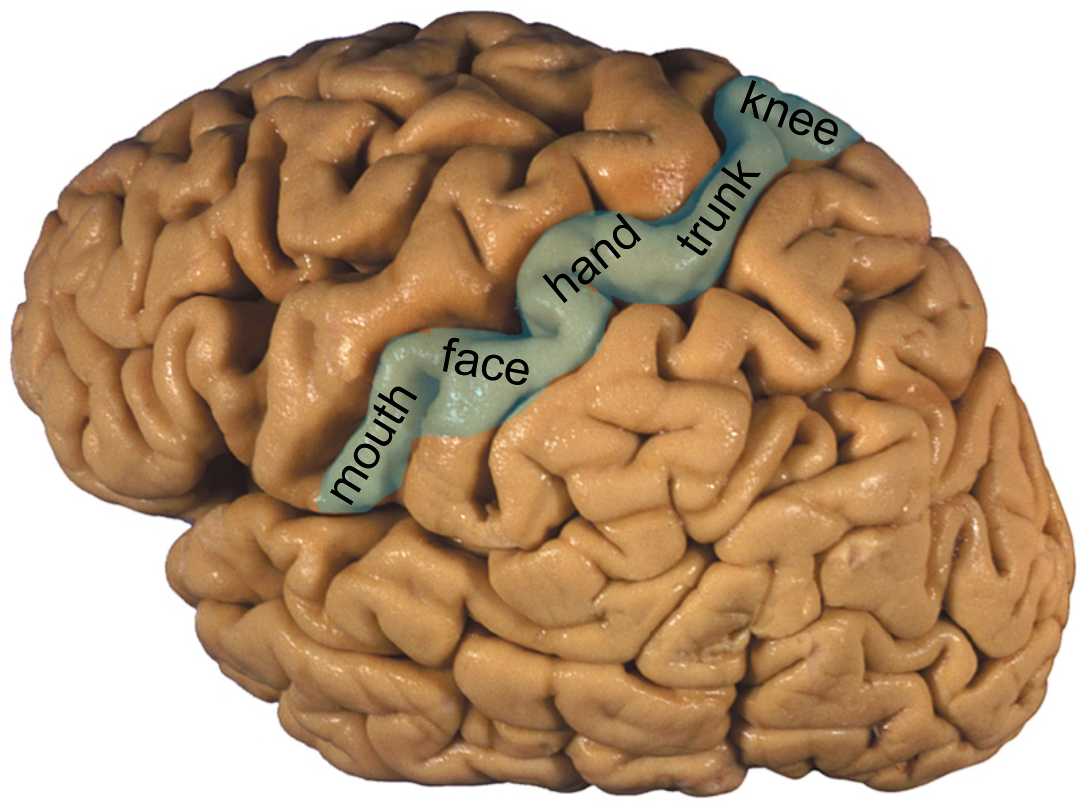
- Pain information also projects to limbic cortex → unhappiness & motivation to avoid



Somatosensory Projection to Cerebral Cortex

- The somatosensory projection to primary sensory cortex (S1) has a somatotopic organization throughout the pathway
- The pattern of the projection to cortex is said to be a *homunculus* (little person).





Somatosensory System: crossed and uncrossed projections

- Somatosensory axons project ***ipsilaterally*** to the cerebellum. --We'll find that a stroke in the right side of the cerebellum is likely to affect motor control of the right side of the body.

- Somatosensory axons project ***contralaterally*** to the cerebral cortex. --Thus a stroke in the right somatosensory cortex is likely to affect sensory perception of the left side of the body.