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**QUESTION**

Discuss the somatosensory pathways

**ANSWERS**

The somatosensory system is composed of the neurons that make sensing touch, temperature, and position in space possible.

The somatosensory system is distributed throughout all major parts of our body. It is responsible for sensing touch, temperature, posture, limb position, and more. It includes both sensory receptor neurons in the periphery (eg., skin, muscle, and organs) and deeper neurons within the central nervous system.

## Structure

A somatosensory pathway will typically consist of three neurons: primary, secondary, and tertiary.

1. In the periphery, the primary neuron is the sensory receptor that detects sensory stimuli like touch or temperature. The cell body of the primary neuron is housed in the dorsal root ganglion of a spinal nerve or, if sensation is in the head or neck, the ganglia of the trigeminal or cranial nerves.
2. The secondary neuron acts as a relay and is located in either the spinal cord or the brainstem. This neuron's ascending axons will cross, or decussate, to the opposite side of the spinal cord or brainstem and travel up the spinal cord to the brain, where most will terminate in either the thalamus or the cerebellum.
3. Tertiary neurons have cell bodies in the thalamus and project to the postcentral gyrus of the parietal lobe, forming a sensory homunculus in the case of touch. Regarding posture, the tertiary neuron is located in the cerebellum.

## Processing

The primary somatosensory area of the human cortex is located in the postcentral gyrus of the parietal lobe. The postcentral gyrus is the location of the primary somatosensory area, the area of the cortex dedicated to the processing of touch information. At this location there is a map of sensory space referred to as a sensory homunculus.

A cortical homunculus is the brain's physical representation of the human body; it is a neurological map of the anatomical divisions of the body. The surface area of cortex dedicated to a body part correlates with the amount of somatosensory input from that area.

For example, there is a large area of cortex devoted to sensation in the hands, while the back requires a much smaller area. Somatosensory information involved with proprioception and posture is processed in the cerebellum.

### Functions

The somatosensory system functions in the body's periphery, spinal cord, and the brain.

- Periphery: Sensory receptors (i.e., thermoreceptors, mechanoreceptors, etc.) detect the various stimuli.
- Spinal cord: Afferent pathways in the spinal cord serve to pass information from the periphery and the rest of the body to the brain.
- Brain: The postcentral gyrus contains Brodmann areas (BA) 3a, 3b, 1, and 2 that make up the somatosensory cortex. BA3a is involved with the sense of relative position of neighboring body parts and the amount of effort being used during movement. BA3b is responsible for distributing somatosensory information to BA1 and shape and size information to BA2.

## Tactile Sensation

Touch is sensed by mechanoreceptive neurons that respond to pressure in various ways.

A mechanoreceptor is a sensory receptor that responds to mechanical pressure or distortion. For instance, in the periodontal ligament, there are mechanoreceptors that allow the jaw to relax when biting down on hard objects; the mesencephalic nucleus is responsible for this reflex.

In the skin, there are four main types in glabrous (hairless) skin:

1. Ruffini endings.
2. Meissner's corpuscles.
3. Pacinian corpuscles.
4. Merkel's discs.

There are also mechanoreceptors in hairy skin. The hair cells in the cochlea are the most sensitive mechanoreceptors, transducing air pressure waves into nerve signals sent to the brain.

### Cutaneous Mechanoreceptors

Cutaneous mechanoreceptors are located in the skin, like other cutaneous receptors. They provide the senses of touch, pressure, vibration, proprioception, and others. They are all innervated by Aβ fibers, except the mechanoreceiving free nerve endings, which are innervated by Aδ fibers.

They can be categorized by morphology, by the type of sensation they perceive, and by the rate of adaptation. Furthermore, each has a different receptive field:

- Ruffini's end organs detect tension deep in the skin.
- Meissner's corpuscles detect changes in texture (vibrations around 50 Hz) and adapt rapidly.
- Pacinian corpuscles detect rapid vibrations (about 200–300 Hz).
- Merkel's discs detect sustained touch and pressure.
- Mechanoreceiving free nerve endings detect touch, pressure, and stretching.
- Hair follicle receptors are located in hair follicles and sense the position changes of hair strands.

### Ruffini Ending

The Ruffini ending (Ruffini corpuscle or bulbous corpuscle) is a class of slowly adapting mechanoreceptors thought to exist only in the glabrous dermis and subcutaneous tissue of humans. It is named after Angelo Ruffini.

This spindle-shaped receptor is sensitive to skin stretch, and contributes to the kinesthetic sense of and control of finger position and movement. It is believed to be useful for monitoring the slippage of objects along the surface of the skin, allowing the modulation of grip on an object.

Ruffini endings are located in the deep layers of the skin. They register mechanical information within joints, more specifically angle change, with a specificity of up to two degrees, as well as continuous pressure states. They also act as thermoreceptors that respond for a long time, such as holding hands with someone during a walk. In a case of a deep burn to the body, there will be no pain as these receptors will be burned off.

### Meissner's Corpuscles

Meissner's corpuscles (or tactile corpuscles) are responsible for sensitivity to light touch. In particular, they have the highest sensitivity (lowest threshold) when sensing vibrations lower than 50 hertz. They are rapidly adaptive receptors.

### Pacinian Corpuscles

Pacinian corpuscles (or lamellar corpuscles) are responsible for sensitivity to vibration and pressure. The vibrational role may be used to detect surface texture, e.g., rough versus smooth.

### Merkel Nerve

Merkel nerve endings are mechanoreceptors found in the skin and mucosa of vertebrates that provide touch information to the brain. The information they provide are those regarding pressure and texture. Each ending consists of a Merkel cell in close apposition with an enlarged nerve terminal.

This is sometimes referred to as a Merkel cell–neurite complex, or a Merkel disk receptor. A single afferent nerve fiber branches to innervate up to 90 such endings. They are classified as slowly adapting type I mechanoreceptors.

### Proprioceptive Sensations

Proprioception refers to the sense of knowing how one's body is positioned in three-dimensional space.

Proprioception is the sense of the relative position of neighboring parts of the body and the strength of effort being employed in movement. It is distinguished from exteroception, perception of the outside world, and interoception, perception of pain, hunger, and the movement of internal organs, etc.

The initiation of proprioception is the activation of a proprioreceptor in the periphery. The proprioceptive sense is believed to be composed of information from sensory neurons located in the inner ear (motion and orientation) and in the stretch receptors located in the muscles and the joint-supporting ligaments (stance).

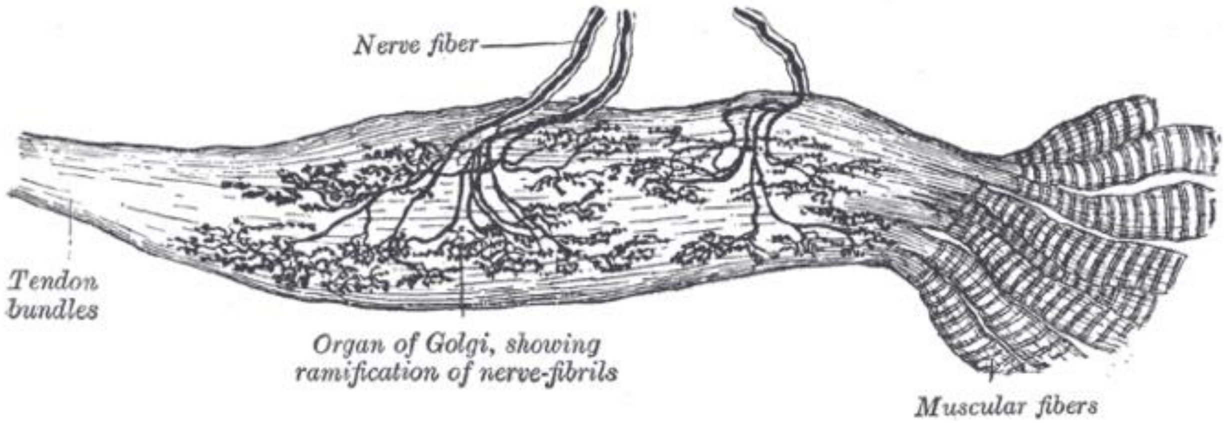
Conscious proprioception is communicated by the posterior ( dorsal ) column–medial lemniscus pathway to the cerebrum. Unconscious proprioception is communicated primarily via the dorsal and ventral spinocerebellar tracts to the cerebellum.

An unconscious reaction is seen in the human proprioceptive reflex, or Law of Righting. In the event that the body tilts in any direction, the person will cock their head back to level the eyes against the horizon. This is seen even in infants as soon as they gain control of their neck muscles. This control comes from the cerebellum, the part of the brain that affects balance.

Muscle spindles are sensory receptors within the belly of a muscle that primarily detect changes in the length of a muscle. They convey length information to the central nervous system via sensory neurons. This information can be processed by the brain to determine the position of body parts. The responses of muscle spindles to changes in length also play an important role in regulating the contraction of muscles.

The Golgi organ (also called Golgi tendon organ, tendon organ, neurotendinous organ or neurotendinous spindle) is a proprioceptive sensory receptor organ that is located at the insertion of skeletal muscle fibers onto the tendons of skeletal muscle. It provides the sensory component of the Golgi tendon reflex.

The Golgi organ should not be confused with the Golgi apparatus—an organelle in the eukaryotic cell — or the Golgi stain, which is a histologic stain for neuron cell bodies.



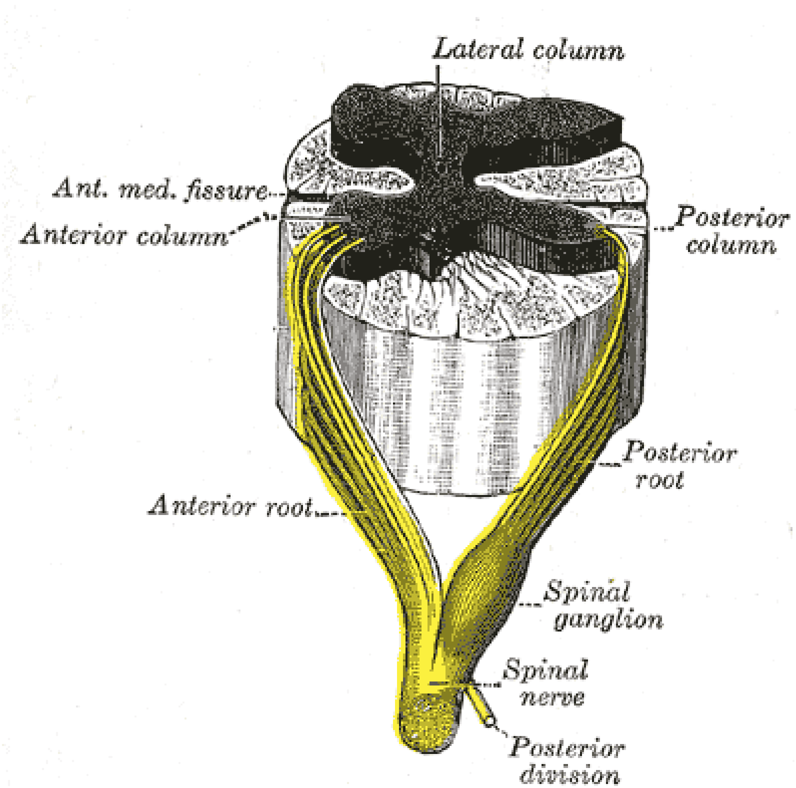

The Golgi tendon reflex is a normal component of the reflex arc of the peripheral nervous system. In a Golgi tendon reflex, skeletal muscle contraction causes the agonist muscle to simultaneously lengthen and relax. This reflex is also called the inverse myotatic reflex, because it is the inverse of the stretch reflex.

Although muscle tension is increasing during the contraction, alpha motor neurons in the spinal cord that supply the muscle are inhibited. However, antagonistic muscles are activated.

### Somatic Sensory Pathways

The somatosensory pathway is composed of three neurons located in the dorsal root ganglion, the spinal cord, and the thalamus.

A somatosensory pathway will typically have three long neurons: primary, secondary, and tertiary. The first always has its cell body in the dorsal root ganglion of the spinal nerve.




**Dorsal root ganglion**: Sensory nerves of a dorsal root ganglion are depicted entering the spinal cord.

The second has its cell body either in the spinal cord or in the brainstem; this neuron's ascending axons will cross to the opposite side either in the spinal cord or in the brainstem. The axons of many of these neurons terminate in the thalamus, and others terminate in the reticular activating system or the cerebellum.

In the case of touch and certain types of pain, the third neuron has its cell body in the ventral posterior nucleus of the thalamus and ends in the postcentral gyrus of the parietal lobe.

In the periphery, the somatosensory system detects various stimuli by sensory receptors, such as by mechanoreceptors for tactile sensation and nociceptors for pain sensation. The sensory information (touch, pain, temperature, etc.,) is then conveyed to the central nervous system by afferent neurons, of which there are a number of different types with varying size, structure, and properties.

Generally, there is a correlation between the type of sensory modality detected and the type of afferent neuron involved. For example, slow, thin, unmyelinated neurons conduct pain whereas faster, thicker, myelinated neurons conduct casual touch.

## Ascending Pathways

In the spinal cord, the somatosensory system includes ascending pathways from the body to the brain. One major target within the brain is the postcentral gyrus in the cerebral cortex. This is the target for neurons of the dorsal column–medial lemniscal pathway and the ventral spinothalamic pathway.

Note that many ascending somatosensory pathways include synapses in either the thalamus or the reticular formation before they reach the cortex. Other ascending pathways, particularly those involved with control of posture, are projected to the cerebellum, including the ventral and dorsal spinocerebellar tracts.

Another important target for afferent somatosensory neurons that enter the spinal cord are those neurons involved with local segmental reflexes.

### Parietal Love: Primary Somatosensory Area

The primary somatosensory area in the human cortex is located in the postcentral gyrus of the parietal lobe. This is the main sensory receptive area for the sense of touch.

Like other sensory areas, there is a map of sensory space called a homunculus at this location. Areas of this part of the human brain map to certain areas of the body, dependent on the amount or importance of somatosensory input from that area.

For example, there is a large area of cortex devoted to sensation in the hands, while the back has a much smaller area. Somatosensory information involved with proprioception and posture also target an entirely different part of the brain, the cerebellum.

### Cortical Homunculus

This is a pictorial representation of the anatomical divisions of the primary motor cortex and the primary somatosensory cortex; namely, the portion of the human brain directly responsible for the movement and exchange of sensory and motor information of the body.

### Thalamus

The thalamus is a midline symmetrical structure within the brain of vertebrates including humans; it is situated between the cerebral cortex and midbrain, and surrounds the third ventricle.

Its function includes relaying sensory and motor signals to the cerebral cortex, along with the regulation of consciousness, sleep, and alertness.

## Mapping the Primary Somatosensory Area

The cortical sensory homunculus is located in the postcentral gyrus and provides a representation of the body to the brain

### Cortical Homunculus

A cortical homunculus is a pictorial representation of the anatomical divisions of the primary motor cortex and the primary somatosensory cortex; it is the portion of the human brain directly responsible for the movement and exchange of sensory and motor information of the body.

It is a visual representation of the concept of the body within the brain—that one's hand or face exists as much as a series of nerve structures or a neuron concept as it does in a physical form. There are two types of homunculus: sensory and motor. Each one shows a representation of how much of its respective cortex innervates certain body parts.

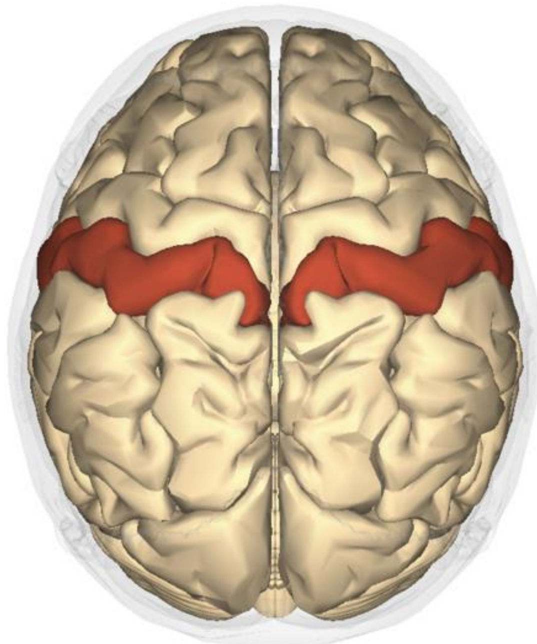
The primary somesthetic cortex (sensory) pertains to the signals within the postcentral gyrus coming from the thalamus, and the primary motor cortex pertains to signals within the precentral gyrus coming from the premotor area of the frontal lobes.

These are then transmitted from the gyri to the brain stem and spinal cord via corresponding sensory or motor nerves. The reason for the distorted appearance of the homunculus is that the amount of cerebral tissue or cortex devoted to a given body region is proportional to how richly innervated that region is, not to its size.

The homunculus is like an upside-down sensory or motor map of the contralateral side of the body. The upper extremities such as the facial body parts and hands are closer to the lateral sulcus than lower extremities such as the leg and toes.

The resulting image is a grotesquely disfigured human with disproportionately huge hands, lips, and face in comparison to the rest of the body. Because of the fine motor skills and sense nerves found in these particular parts of the body, they are represented as being larger on the homunculus. A part of the body with fewer sensory and/or motor connections to the brain is represented to appear smaller.

### Somatotopy



**Postcentral gyrus**: The postcentral gyrus is located in the parietal lobe of the human cortex and is the primary somatosensory region of the human brain.

This is the point-for-point correspondence of an area of the body to a specific point on the central nervous system. Typically, the area of the body corresponds to a point on the primary somatosensory cortex (postcentral gyrus).

This cortex is typically represented as a sensory homunculus which orients the specific body parts and their respective locations upon the homunculus. Areas such as the appendages, digits, and face can draw their sensory locations upon the somatosensory cortex.

Areas that are finely controlled, such as the digits, have larger portions of the somatosensory cortex, whereas areas that are coarsely controlled, such as the trunk, have smaller portions. Areas such as the viscera do not have sensory locations on the postcentral gyrus.

### Montreal Procedure

Wilder Penfield was a groundbreaking researcher and highly original surgeon. With his colleague, Herbert Jasper, he invented the Montreal procedure, in which he treated patients with severe epilepsy by destroying nerve cells in the brain where the seizures originated.

Before operating, he stimulated the brain with electrical probes while the patients were conscious on the operating table (under only local anesthesia), and observed their responses. In this way he could more accurately target the areas of the brain responsible, reducing the side-effects of the surgery.

This technique also allowed him to create maps of the sensory and motor cortices of the brain, showing their connections to the various limbs and organs of the body. These maps are still used today, practically unaltered.

Along with Herbert Jasper, he published this landmark work in 1951 as *Epilepsy and the Functional Anatomy of the Human Brain.*This work contributed a great deal to understanding the lateralization of brain function.

Penfield's maps showed considerable overlap between regions (for instance, the motor region controlling muscles in the hand sometimes also controlled muscles in the upper arm and shoulder), a feature that he put down to individual variation in brain size and localization; we now know that this is due to the fractured somatotropy of the motor cortex.

## Somatic Sensory Pathways to the Cerebellum

The ventral and dorsal spinocerebellar tracts convey proprioceptive information from the body to the cerebellum.

A sensory system is a part of the nervous system responsible for processing sensory information. A sensory system consists of sensory receptors, neural pathways, and the parts of the brain involved in sensory perception. Commonly recognized sensory systems are those for vision, hearing, somatic sensation (touch), taste, and olfaction (smell).

In short, senses are transducers from the physical world to the realm of the mind where we interpret the information, creating our perception of the world around us.

The ventral spinocerebellar tract conveys proprioceptive information from the body to the cerebellum. It is part of the somatosensory system and runs in parallel with the dorsal spinocerebellar tract.

Both tracts involve two neurons. The ventral spinocerebellar tract will cross to the opposite side of the body then cross again to end in the cerebellum (referred to as a double cross). The dorsal spinocerebellar tract does not decussate, or cross sides, at all through its path.

The ventral tract (under L2/L3) gets its proprioceptive/fine touch/vibration information from a first order neuron, with its cell body in a dorsal ganglion. The axon runs via the fila radicularia (nerve rootlets) to the dorsal horn of the gray matter. There it makes a synapse with the dendrites of two neurons that send their axons bilaterally to the ventral border of the lateral funiculi (transmit the contralateral corticospinal and spinothalamic tracts). The ventral spinocerebellar tract then enters the cerebellum via the superior cerebellar peduncle (connects the cerebellum to the midbrain).

This is in contrast with the dorsal spinocerebellar tract (C8 – L2/L3), which only has one unilateral axon that has its cell body in Clarke's nucleus (only at the level of C8 – L2/L3). The fibers of the ventral spinocerebellar tract then eventually enter the cerebellum via the superior cerebellar peduncle.

This is one of the few afferent tracts through the superior cerebellar peduncle. Axons first cross midline in the spinal cord and run in the ventral border of the lateral funiculi. These axons ascend to the pons where they join the superior cerebellar peduncle to enter the cerebellum.

Once in the deep, white matter of the cerebellum, the axons recross the midline, give off collaterals to the globose and emboliform nuclei (deep cerebellar nuclei), and terminate in the cortex of the anterior lobe and vermis of the posterior lobe.

The dorsal spinocerebellar tract (also called the posterior spinocerebellar tract, Flechsig's fasciculus, or Flechsig's tract) conveys inconscient proprioceptive information from the body to the cerebellum. It is part of the somatosensory system and runs in parallel with the ventral spinocerebellar tract.

Proprioceptive information is taken to the spinal cord via central processes of the dorsal root ganglia (where first order neurons reside). These central processes travel through the dorsal horn where they synapse with second order neurons of Clarke's nucleus.

Axon fibers from Clarke's nucleus convey this proprioceptive information in the spinal cord to the peripheral region of the posterolateral funiculus ipsilaterally until it reaches the cerebellum, where unconscious proprioceptive information is processed. This tract involves two neurons and ends up on the same side of the body.