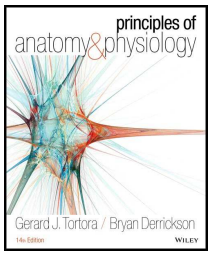


Principles of Anatomy and Physiology

14th Edition

CHAPTER 16
Sensory, Motor, and Integrative Systems

Sensation

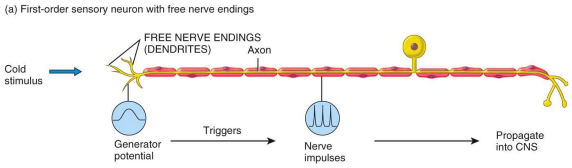
- **Sensation** is the conscious or subconscious awareness of changes in the external or internal environment.
- **Perception** is the conscious interpretation of sensations performed mainly by the cerebral cortex.

Sensation

- Each type of sensation is called a **sensory modality**. This includes: **touch**, **pain**, **vision** and **hearing**.
- Sensory modalities are grouped into either **general senses** or **special senses**.
- General senses: **somatic-(tactile, thermal, proprioceptive); visceral-pressure, chemicals, stretch, nausea, hunger, temperature**.

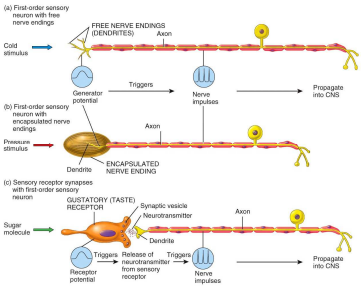
Sensation

- Special senses: **smell**, **taste**, **vision**, **hearing** and **equilibrium**.
- Different types of **sensory receptors** are involved in the different senses.



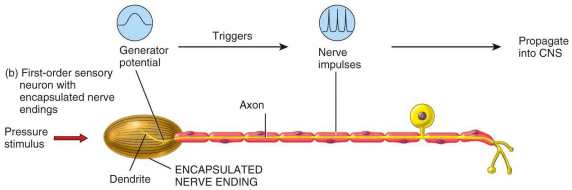
Sensation

Free nerve endings are used to detect **pain**, **temperature**, **tickle**, **itch** and **some touch**.



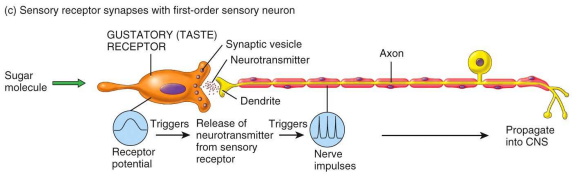
Sensation

Encapsulated nerve endings are used to detect **pressure**, **vibration** and **some touch**.



Sensation

Sensory receptors for some special senses include **gustatory receptor cells** in taste buds, **photoreceptors** in the retina of the eye and **hair cells** in the inner ear for hearing.



Sensation

Anatomy Overview

- The Nervous System

You must be connected to the Internet and in Slideshow Mode to run this animation.

Sensation

- Receptors may also be grouped based on location of the receptors and the origin of the stimuli that activate them.
- **Exteroreceptors** include: **hearing**, **vision**, **smell**, **taste**, **touch**, **pressure**, **vibration** and **pain**.

Sensation

- **Interoreceptors** monitor the body's **internal environment**.
- **Proprioceptors** provide information about **body position**, **muscle length** and tension and the **position and movement of joints**.

Sensation

TABLE 16.1

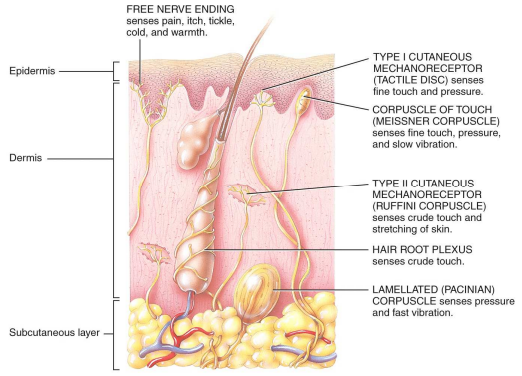
Classification of Sensory Receptors

BASIS OF CLASSIFICATION	DESCRIPTION
MICROSCOPIC STRUCTURE	
Free nerve endings	Bare dendrites associated with pain, thermal, tickle, itch, and some touch sensations.
Encapsulated nerve endings	Dendrites enclosed in connective tissue capsule for pressure, vibration, and some touch sensations.
Separate cells	Receptor cells synapse with first-order sensory neurons; located in retina of eye (photoreceptors), inner ear (hair cells), and taste buds of tongue (gustatory receptor cells).
RECEPTOR LOCATION AND ACTIVATING STIMULI	
Exteroceptors	Located at or near body surface; sensitive to stimuli originating outside body; provide information about external environment; convey visual, smell, taste, touch, pressure, vibration, thermal, and pain sensations.
Interoceptors	Located in blood vessels, visceral organs, and nervous system; provide information about internal environment; impulses usually are not consciously perceived but occasionally may be felt as pain or pressure.
Proprioceptors	Located in muscles, tendons, joints, and inner ear; provide information about body position, muscle length and tension, position and motion of joints, and equilibrium (balance).
TYPE OF STIMULUS DETECTED	
Mechanoreceptors	Detect mechanical stimuli; provide sensations of touch, pressure, vibration, proprioception, and hearing and equilibrium; also monitor stretching of blood vessels and internal organs.
Thermoreceptors	Detect changes in temperature.
Nociceptors	Respond to painful stimuli resulting from physical or chemical damage to tissue.
Photoreceptors	Detect light that strikes the retina of the eye.
Chemoreceptors	Detect chemicals in mouth (taste), nose (smell), and body fluids.
Osmoreceptors	Sense osmotic pressure of body fluids.

Somatic Sensations

- **Somatic sensations** include **tactile**, **thermal**, **pain** and **proprioceptive**.
- **Tactile sensations**: **touch**, **pressure**, **vibration**, **itch** and **tickle**.

Somatic Sensations



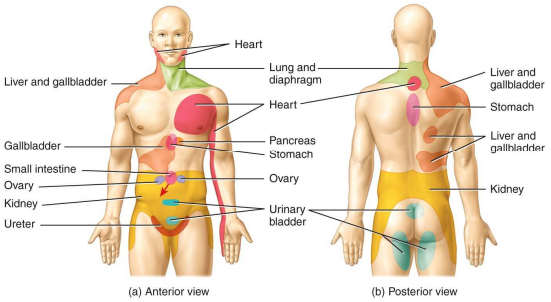
Somatic Sensations

- There are two types of **pain**: **fast** and **slow**. Fast pain (acute, sharp or pricking) perceived within 0.1 second.
- Slow pain (chronic, burning, aching or throbbing) is perceived a second or more after the stimulus.
- **Superficial somatic pain**: arising from skin receptors.

Somatic Sensations

- **Deep somatic pain**: skeletal muscles, joints, tendons and fascia.
- Stimulation of pain sensors in visceral organs is **visceral pain**. This type of pain usually presents in or just deep to the skin that overlies the stimulated organ.

Somatic Sensations



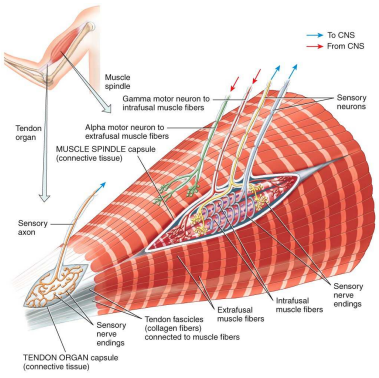
Somatic Sensations

- **Proprioception**: recognizing position of body parts.
- **Proprioceptors**: in muscles and tendons.

Somatic Sensations

- Two types of proprioceptors are **muscle spindles** and **tendon organs**. Muscle spindles: in skeletal muscles monitor their length and are involved in stretch reflexes.
- Tendon organs: at the junction of a tendon and a muscle protect muscles and tendons from damage due to overstretching.
- **Joint kinesthetic receptors** exist within and around the joint capsule of synovial joints. They respond to pressure and acceleration and deceleration during movement. Joint ligaments contain receptors to protect against excessive strain.

Somatic Sensations



Somatic Sensations

TABLE 16.2

Summary of Receptors for Somatic Sensations

RECEPTOR TYPE	RECEPTOR STRUCTURE AND LOCATION	SENSATIONS	ADAPTATION RATE
TACTILE RECEPTORS			
Corpuscles of touch (Meissner corpuscles)	Capsule surrounds mass of dendrites in dermal papillae of hairless skin.	Touch, pressure, and slow vibrations.	Rapid.
Hair root plexuses	Free nerve endings wrapped around hair follicles in skin.	Touch.	Rapid.
Type I cutaneous mechanoreceptors (tactile discs)	Saucer-shaped free nerve endings make contact with tactile epithelial cells in epidermis.	Touch and pressure.	Slow.
Type II cutaneous mechanoreceptors (Ruffini corpuscles)	Elongated capsule surrounds dendrites deep in dermis and in ligaments and tendons.	Touch and stretching of skin.	Slow.
Lamellated (pacinian) corpuscles	Oval, layered capsule surrounds dendrites; present in dermis and subcutaneous layer, submucosal tissues, joints, periosteum, and some viscera.	Pressure and fast vibrations.	Rapid.
Itch and tickle receptors	Free nerve endings in skin and mucous membranes.	Itching and tickling.	Both slow and rapid.
THERMORECEPTORS			
Warm receptors and cold receptors	Free nerve endings in skin and mucous membranes of mouth, vagina, and anus.	Warmth or cold.	Initially rapid, then slow.
PAIN RECEPTORS			
Nociceptors	Free nerve endings in every body tissue except brain.	Pain.	Slow.
PROPRIOCEPTORS			
Muscle spindles	Sensory nerve endings wrap around central area of encapsulated intrafusal muscle fibers within most skeletal muscles.	Muscle length.	Slow.
Tendon organs	Capsule encloses collagen fibers and sensory nerve endings at junction of tendon and muscle.	Muscle tension.	Slow.
Joint kinesthetic receptors	Lamellated corpuscles, type II cutaneous mechanoreceptors, tendon organs, and free nerve endings.	Joint position and movement.	Rapid.

Somatic Sensory Pathways

Somatic sensory pathways carry information from somatic sensory receptors to the primary somatosensory area in the cerebral cortex and to the cerebellum. The pathways to the cortex consist of thousands of sets of three neurons classified as first, second and third-order neurons.

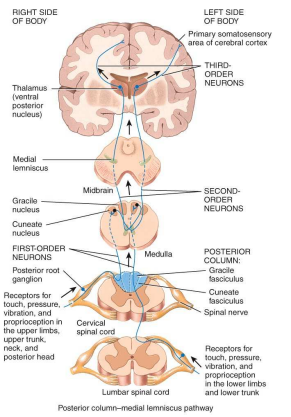
Somatic Sensory Pathways

- **First-order neurons**: impulses from somatic receptors to the brain stem or spinal cord.
- **Second-order neurons**: impulses from the brain stem and spinal cord to the thalamus.
- **Third-order neurons**: impulses from the thalamus to the primary somatosensory area of the cortex on the same side.

Somatic Sensory Pathways

- Somatic sensory impulses ascend to the cerebral cortex along three general pathways:
- The **posterior column-medial lemniscus** pathway (impulses from the limbs, trunk, neck and posterior head).

Somatic Sensory Pathways

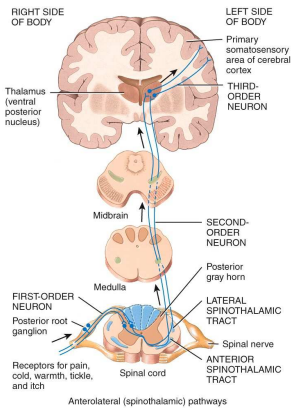


Posterior column–medial lemniscus pathway

Somatic Sensory Pathways

The **anterolateral (spinothalamic)** pathway (impulses for pain, temperature, itch, tickle and posterior head).

Somatic Sensory Pathways

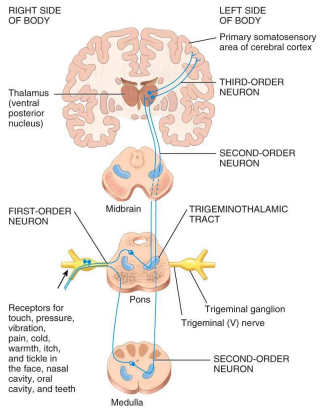


Anterolateral (spinothalamic) pathways

Somatic Sensory Pathways

- The **trigeminothalamic pathway** (impulses for most somatic sensations—tactile, thermal and pain—from the face, nasal cavity, oral cavity and teeth).
- Somatic sensory impulses reach the **cerebellum** via the **spinocerebellar tracts**.

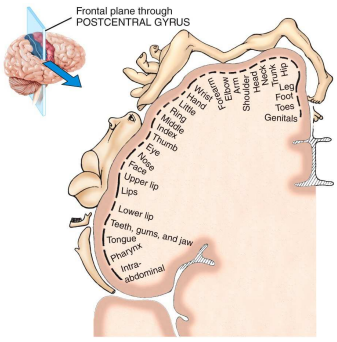
Somatic Sensory Pathways



Somatic Sensory Pathways

- **Postcentral gyri** located on both parietal lobes of the brain are the sites for the **primary somatosensory area**.
- Each region in this area receives sensory input from a different part of the body on the opposite side.

Somatic Sensory Pathways



(a) Frontal section of primary somatosensory area in right cerebral hemisphere

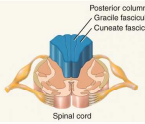
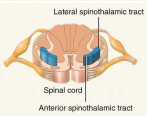
Somatic Sensory Pathways

The **posterior spinocerebellar tract** and the **anterior spinocerebellar tract** carry proprioceptive impulses to the cerebellum.

Somatic Sensory Pathways

TABLE 16.3

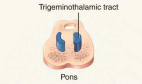
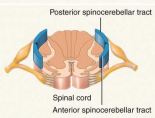
Major Somatic Sensory Tracts and Pathways

TRACTS AND LOCATIONS	PATHWAY FUNCTIONS
	**Posterior column:** Consists of two tracts: (1) **cuneate fasciculus**, which conveys nerve impulses for touch, pressure, vibration, and conscious proprioception from upper limbs, upper trunk, neck, and posterior head, and (2) **gracile fasciculus**, which conveys nerve impulses for touch, pressure, and vibration from lower limbs and lower trunk. Axons of first-order neurons from one side of body form posterior column on same side and end in medulla, where they synapse with dendrites and cell bodies of second-order neurons. Axons of second-order neurons decussate, enter medial lemniscus on opposite side, and extend to thalamus. Third-order neurons transmit nerve impulses from thalamus to primary somatosensory cortex on side opposite the site of stimulation.
	**Spinothalamic:** Conveys nerve impulses for pain, cold, warmth, itch, and tickle from limbs, trunk, neck, and posterior head. Axons of first-order neurons from one side of body synapse with dendrites and cell bodies of second-order neurons in posterior gray horn on same side of body. Axons of second-order neurons decussate, enter spinothalamic tract on opposite side, and extend to thalamus. Third-order neurons transmit nerve impulses from thalamus to primary somatosensory cortex on side opposite the site of stimulation.

Somatic Sensory Pathways

TABLE 16.3

Major Somatic Sensory Tracts and Pathways

TRACTS AND LOCATIONS	PATHWAY FUNCTIONS
	**Trigeminothalamic:** Conveys nerve impulses for touch, pressure, vibration, pain, cold, warmth, itch, and tickle from face, nasal cavity, oral cavity, and teeth. Axons of first-order neurons from one side of head synapse with dendrites and cell bodies of second-order neurons in pons and medulla on same side of head. Axons of second-order neurons decussate, enter trigeminothalamic tract on opposite side, and extend to thalamus. Third-order neurons transmit nerve impulses from thalamus to primary somatosensory cortex on side opposite the site of stimulation.
	**Anterior and posterior spinocerebellar:** Convey nerve impulses from proprioceptors in trunk and lower limb of one side of body to same side of cerebellum. Proprioceptive input informs cerebellum of actual movements, allowing it to coordinate, smooth, and refine skilled movements and maintain posture and balance.

Somatic Motor Pathways

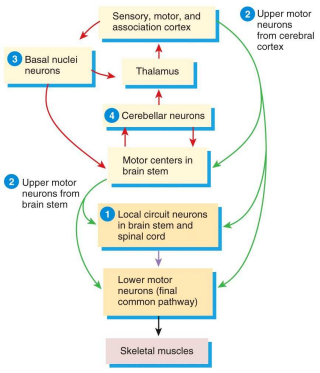
Nerves that extend out of the brain stem and spinal cord are called **lower motor neurons (LMNs)**. These nerves innervate skeletal muscles of the face and head through **cranial nerves**, and skeletal muscles of the limb and trunk through **spinal nerves**.

Somatic Motor Pathways

Somatic motor pathways provide the input into lower motor neurons and are divided into four distinct circuits.

1. **Local circuit neurons** are located close to LMNs in the brain stem and spinal cord.
2. **Upper motor neurons (UMNs)**: input to both lower circuit neurons and LMNs.
3. **Basal nuclei neurons**: assist movement by providing input to UMNs.
4. **Cerebellar neurons**: assist movement via control of activity of UMNs.

Somatic Motor Pathways



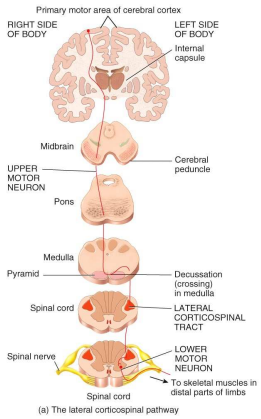
Somatic Motor Pathways

- UMNs extend to LMNs via two types of pathways:
- **Direct motor pathways** deliver signals to LMNs from the **cerebral cortex**.
- **Indirect motor pathways** deliver signals to LMNs from motor centers in the **basal nuclei**, **cerebellum** and **cerebral cortex**.

Somatic Motor Pathways

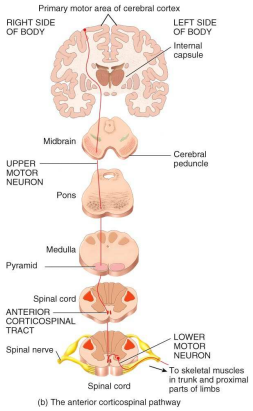
There are two **direct motor pathways** used for voluntary movement. These are the two **corticospinal pathways** (the **lateral corticospinal tract** and the **anterior corticospinal tract**) and the **corticobulbar pathway**.

Somatic Motor Pathways



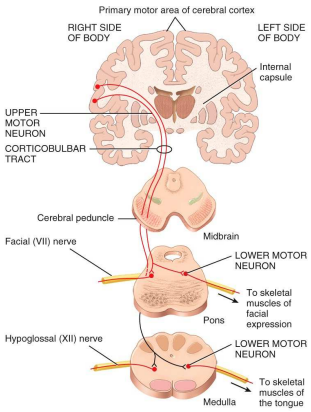
(a) The lateral corticospinal pathway

Somatic Motor Pathways



(b) The anterior corticospinal pathway

Somatic Motor Pathways



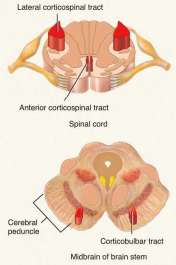
Somatic Motor Pathways

Indirect motor pathways (**extrapyramidal pathways**): **rubrospinal**, **tectospinal**, **vestibulospinal**, **lateral reticulospinal** and **medial reticulospinal tracts**.

Somatic Motor Pathways

TABLE 16.4

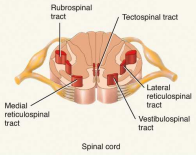
Major Somatic Motor Tracts and Pathways

TRACTS AND LOCATIONS	PATHWAY FUNCTIONS
DIRECT (PYRAMIDAL) PATHWAYS	
	**Lateral corticospinal:** Conveys nerve impulses from motor cortex to skeletal muscles on opposite side of body for precise, voluntary movements of distal parts of limbs. Axons of upper motor neurons (UMNs) descend from precentral gyrus of cortex into medulla. Here 90% decussate (cross over to opposite side) and then enter contralateral side of spinal cord to form this tract. At their level of termination, UMNs end in anterior gray horn on same side. They provide input to lower motor neurons, which innervate skeletal muscles. **Anterior corticospinal:** Conveys nerve impulses from motor cortex to skeletal muscles on opposite side of body for movements of trunk and proximal parts of limbs. Axons of UMNs descend from cortex into medulla. Here the 10% that do not decussate enter the spinal cord and form this tract. At their level of termination, UMNs decussate and end in anterior gray horn on opposite side of body. They provide input to lower motor neurons, which innervate skeletal muscles.
	Corticobulbar: Conveys nerve impulses from motor cortex to skeletal muscles of head and neck to coordinate precise, voluntary movements. Axons of UMNs descend from cortex into brain stem, where some decussate and others do not. They provide input to lower motor neurons in nuclei of the oculomotor (III), trochlear (IV), trigeminal (V), abducens (VI), facial (VII), glossopharyngeal (IX), vagus (X), accessory (XI), and hypoglossal (XII) nerves, which control voluntary movements of the eyes, tongue, and neck; chewing; facial expression; and speech.

Somatic Motor Pathways

TABLE 16.4

Major Somatic Motor Tracts and Pathways

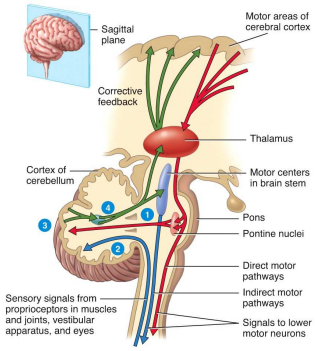
TRACTS AND LOCATIONS	PATHWAY FUNCTIONS
INDIRECT (EXTRAPYRAMIDAL) PATHWAYS	
	**Rubrospinal:** Conveys nerve impulses from red nucleus (which receives input from cerebral cortex and cerebellum) to contralateral skeletal muscles that govern precise, voluntary movements of distal parts of upper limbs. **Tectospinal:** Conveys nerve impulses from superior colliculus to contralateral skeletal muscles that reflexively move head, eyes, and trunk in response to visual or auditory stimuli. **Vestibulospinal:** Conveys nerve impulses from vestibular nucleus (which receives input about head movements from inner ear) to ipsilateral skeletal muscles of trunk and proximal parts of limbs for maintaining posture and balance in response to head movements. **Medial and lateral reticulospinal:** Conveys nerve impulses from reticular formation to ipsilateral skeletal muscles of trunk and proximal parts of limbs for maintaining posture and regulating muscle tone in response to ongoing body movements.

Somatic Motor Pathways

The **cerebellum** performs 4 activities:

1. Monitoring intentions for movement
2. Monitoring actual movement
3. Comparing command signals with sensory information
4. Sending out corrective feedback

Somatic Motor Pathways



Sagittal section through brain and spinal cord

Integrative Functions of the Cerebrum

- **Wakefulness and sleep**: relies on the **reticular activating system (RAS)**.
- **Learning and memory**: includes **immediate, short-term and long-term memory**.

End of Chapter 16