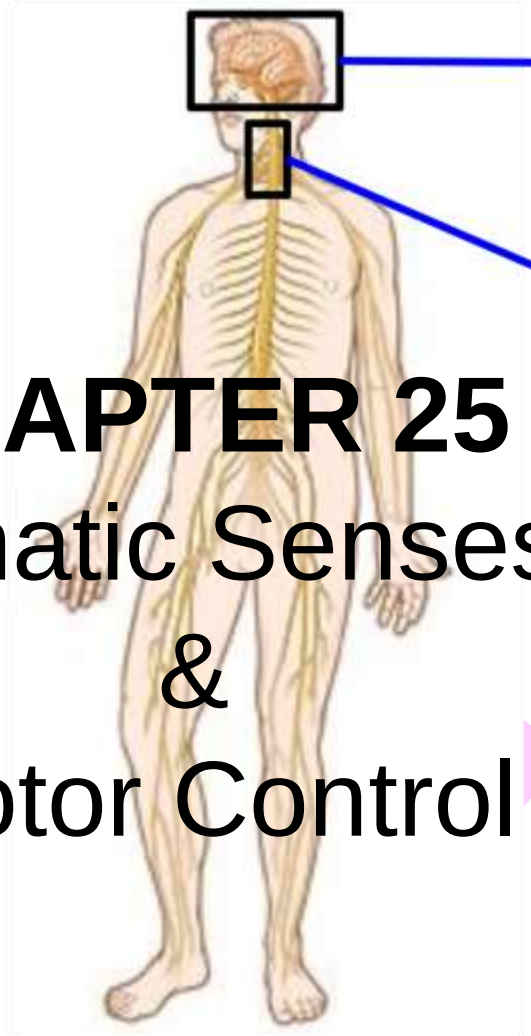

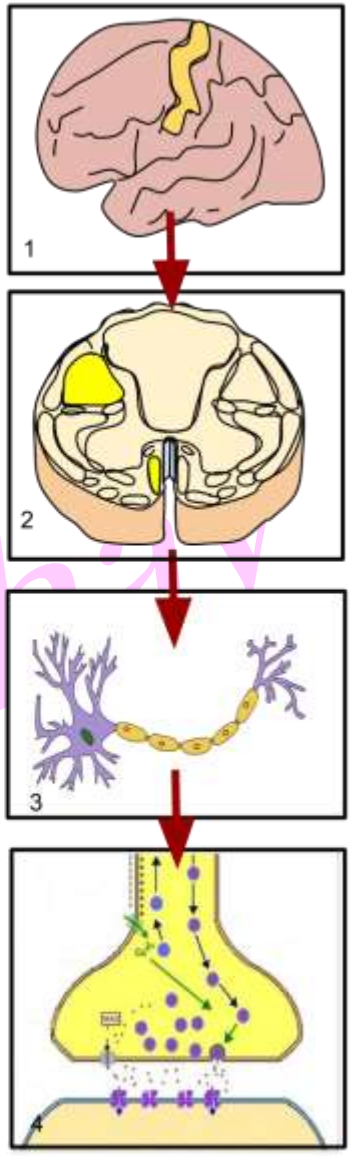

CHAPTER 25

Somatic Senses

&

Motor Control

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Definition of Sensations

- A sensation is the conscious or subconscious awareness of changes in the external or internal conditions of the body.
- For a sensation to occur, four conditions must be satisfied:
  1. Stimulus
  2. Sensory receptor
  3. Conduction
  4. Integration

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Characteristics of Sensations

- Perception
- Sensory modality
- Adaptation

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Classification of Sensations

- Sensations can be grouped into two classes:
  - General senses
    - Somatic senses
    - Visceral senses
  - Special senses

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Types of Sensory Receptors

- Sensory receptors can be grouped in three ways:
  - Structures of their sensory receptors
  - Type of stimulus they detect
  - Location of the receptors and the origin of the stimuli

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Types of Sensory Receptors

- Sensory receptors defined by the structures of their sensory receptors:
  - Free nerve endings
  - Encapsulated nerve endings
  - Separate cells

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Types of Sensory Receptors

- Sensory receptors defined by type of stimulus they detect:
  - Photoreceptors – LIGHT
  - Mechanoreceptors – PRESSURE AND STRETCHING
  - Thermoreceptors - HEAT
  - Osmoreceptors – CONCENTRATION GRADIENT
  - Chemoreceptors - CHEMICALS
  - Nociceptors – PAIN

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Types of Sensory Receptors

- Sensory receptors defined by the location of the receptors:
  - Exteroceptors: Receptors to external stimuli
  - Interoceptors: Receptors to internal stimuli
  - Proprioceptors: Receptors to sense of position,
  - i.e. mixed stimuli

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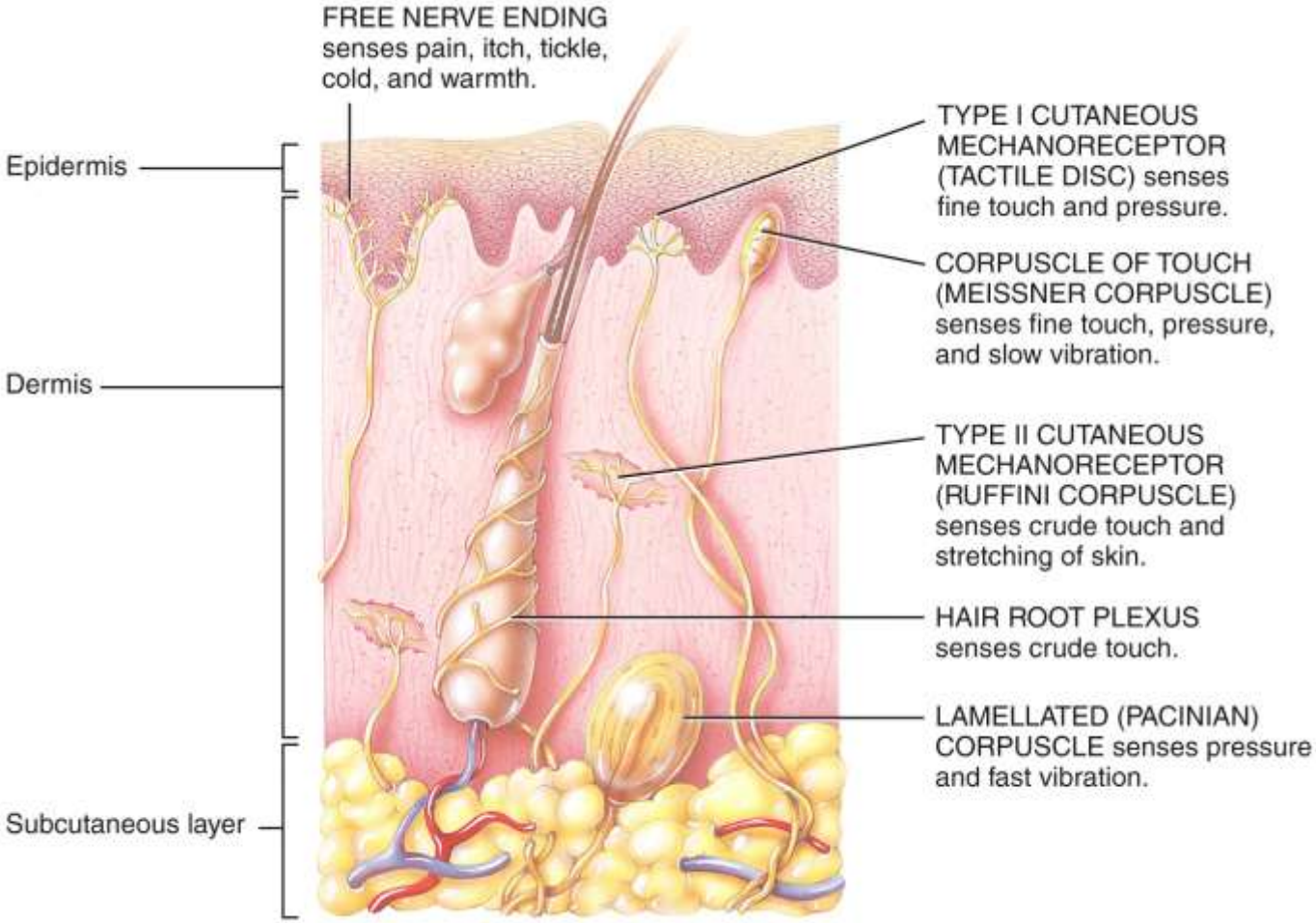
Sensory Receptors in the Skin and Subcutaneous Layer



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Somatic Sensations

- Somatic sensations arise from the stimulation of sensory receptors embedded in:
  - Skin or subcutaneous layer
  - Mucous membranes of the mouth, vagina, and anus
  - Muscles, tendons, and joints
  - Inner ear
- Cutaneous sensations

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Touch

- Fine touch
- Crude touch
- Corpuscles of touch or Meissner corpuscles
- Hair root plexuses
- Type I cutaneous mechanoreceptors or tactile discs
  - Merkel cells
- Type II cutaneous mechanoreceptors or Ruffini corpuscles

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Tactile Sensations

- Touch (fine and crude)
- Pressure
- Lamellated or pacinian corpuscles
- Vibration (slow and fast)
- Itch (some times pleasurable and may be
- annoying)
- Tickle: It appears that the tickle
- sensation involves signals from nerve fibres
- associated with both pain and touch

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Thermal Sensations

- Thermoreceptors are free nerve endings.
- Two distinct thermal sensations—coldness and warmth—are detected by different receptors:
  - Cold receptors
  - Warm receptors

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Pain Sensations

- Pain is indispensable for survival. It serves a protective function by signaling the presence of noxious, tissue-damaging conditions.
- Nociceptors: A nociceptor ("pain receptor") is a sensory neuron that responds to damaging or potentially damaging stimuli by sending "possible threat" signals to the spinal cord and the brain.

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Types of Pain

- Fast: Stimulation and transmission of nerve impulses over A delta fibres

- Slow: Stimulation and transmission over non- myelinated C fibres

- Superficial somatic: refers to pain in the skin
- Deep somatic: refers to pain that a person might feel in muscles or bone
- Visceral: that results from the activation of nociceptors of the thoracic, pelvic, or abdominal viscera (organs). ... The pain may be described as sickening, deep, squeezing, and dull.

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Clinical Connection

- **Analgesia:** the inability to feel pain
- **Analgesics** are a class of drugs used to relieve analgesia (pain). They work by blocking pain signals to the brain or interfering with the brain's interpretation of those signals.

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Localization of Pain

- **Referred pain:** Referredpain is pain perceived at a location other than the site of the painful stimulus/ origin.
- It is the result of a network of interconnecting sensory nerves, that supplies many different tissues.

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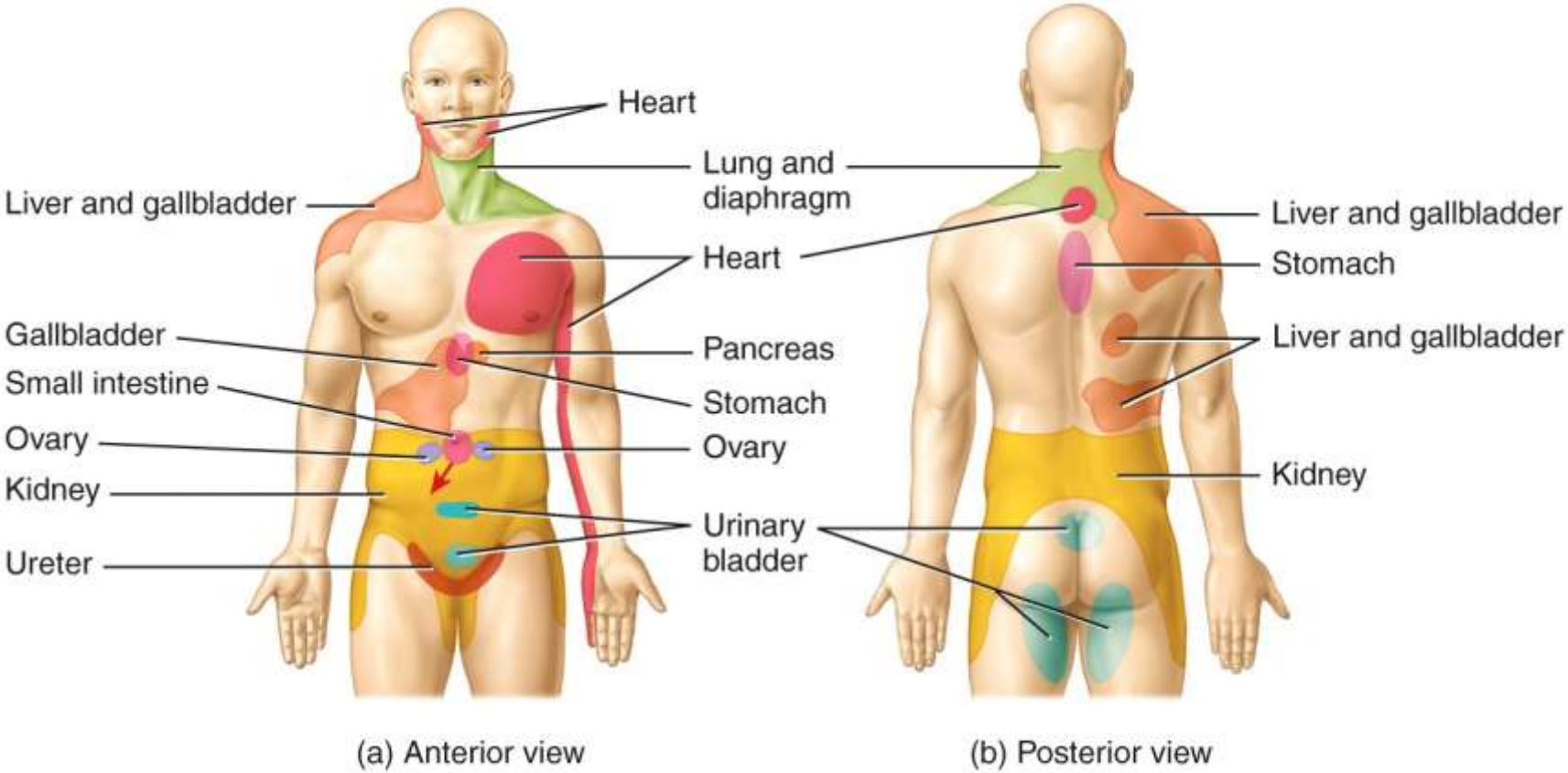
Distribution of Referred Pain



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Clinical Connection

- **Phantom limb sensation:** is the sensation that an amputated or missing limb is still attached.

  Approximately 80 to 100% of individuals with an amputation experience phantom sensations in their amputated limb.
- The exact cause of phantom pain is unclear, but it appears to come from the spinal cord and brain.
- A number of other factors are believed to contribute to phantom pain, including damaged nerve endings, scar tissue at the site of the amputation and the physical memory of pre-amputation pain in the affected area

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Proprioceptive Sensations

- Also called **proprioception**
- **Kinesthesia:** awareness of the position and movement of the parts of the body by means of sensory organs (proprioceptors) in the muscles and joints

- **Proprioceptors:** Proprioception is the awareness of joint position, whereas kinesthesia is the recognition of joint movement. ... These mechanoreceptors act together to give sensory awareness of joint position, movement, acceleration, and strain via afferent pathways to the CNS
- Weight discrimination

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Proprioceptive Sensations

- **Weight discrimination:** Weight bias is pervasive in medicine, as communicated in a recent article in the Journal of the American Medical Association. The prevalence of weight bias in medicine may stem, at least in part, from minimal education about obesity in undergraduate and graduate medical education.

  And there is even less education about weight bias and stigma and its impact on the health of individuals who struggle with obesity.

R. Bishay

Muscle Spindles

- **Muscle tone:** (residual muscle tension or tonus) is the continuous and passive partial contraction of the muscles, or the muscle's resistance to passive stretch during resting state. It helps to maintain posture and declines during REM sleep

- **Intrafusal muscle fibers:** Are skeletal muscle fibers that serve as specialized sensory organs (proprioceptors) that detect the amount and rate of change in length of a muscle. They constitute the muscle spindle and are innervated by both sensory (afferent) and motor (efferent) fibers.

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Muscle Spindles

- **Gamma motor neurons:** are the efferent (sending signals away from the central nervous system) part of the fusimotor system
- **Extrafusal muscle fibers:** Are the skeletal standard muscle fibers that are innervated by alpha motor neurons and generate tension by contracting, thereby allowing for skeletal movement
- Muscles have receptors for stretch and force. Extrafusal muscle fibers comprise the bulk of muscle and form the major force-generating structure. Intrafusal muscle fibers are buried in the muscle, and they contain afferent receptors for stretch, but they also contain contractile elements

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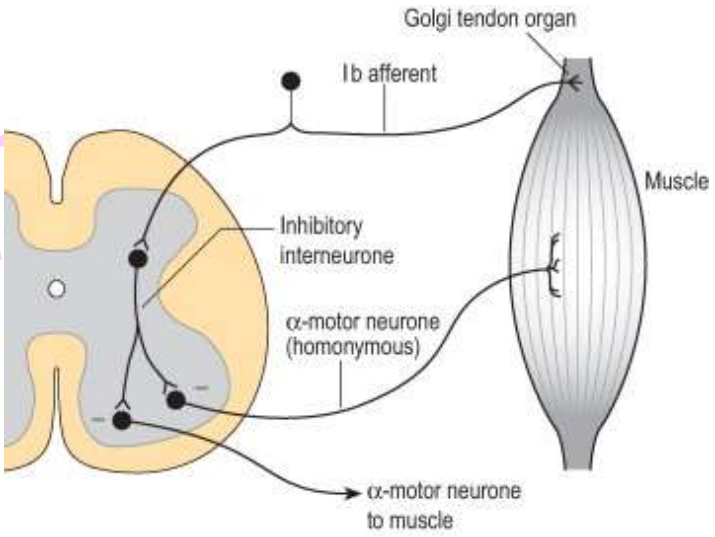
Muscle Spindles

- **Alpha motor neurons:** are lower motor neurons whose cell bodies are found in the anterior horn of the spinal cord and whose axons travel down to the body to innervate skeletal muscle to cause muscle contraction



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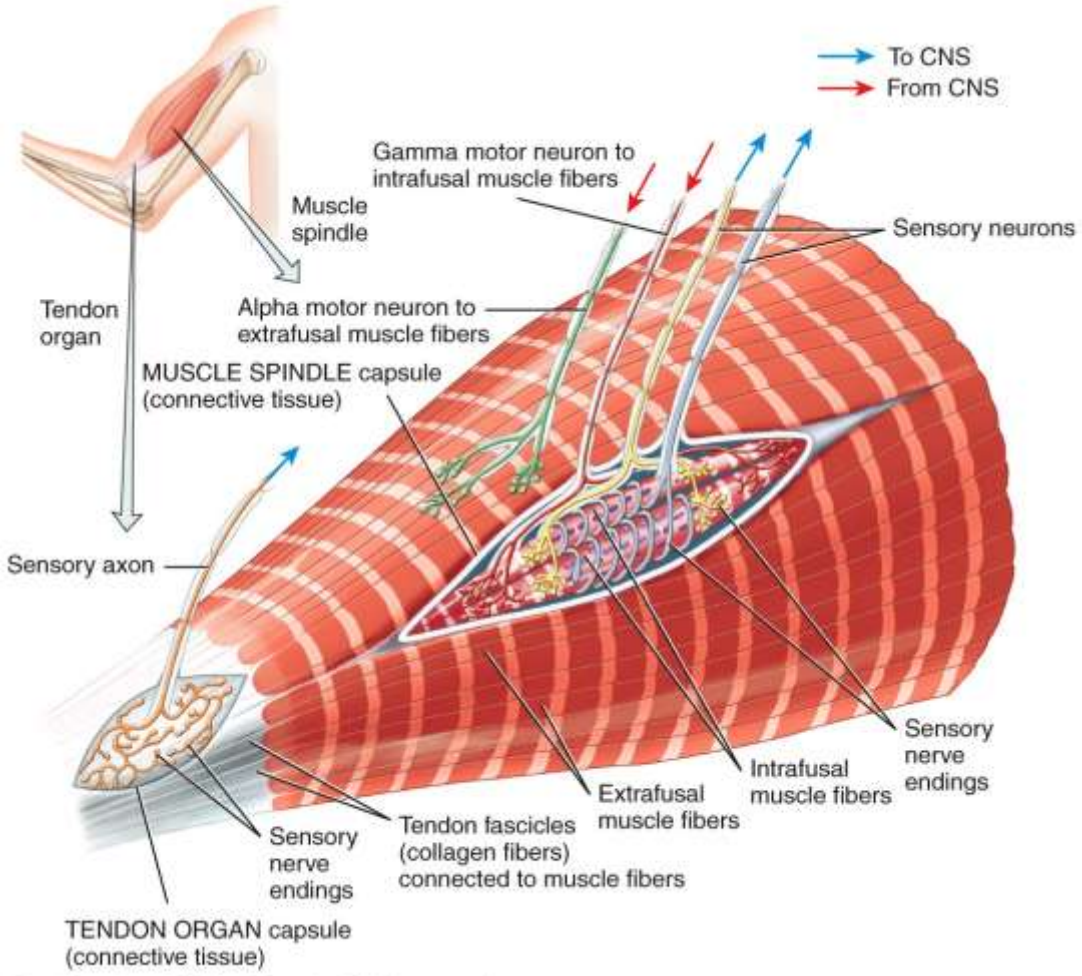
Two Types of Proprioceptors: Muscle Spindle and Tendon Organ



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Somatic Sensory Pathways

- The primary somatosensory area in each parietal lobe has been mapped out—some parts of the body are represented by large areas while other parts of the body are represented by small areas in the primary somatosensory cortex.

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Somatic Sensory Pathways

- Somatic sensory pathways:
  - First-order neurons: Carry signals from the periphery to the spinal cord;
  - Second-order neurons: Carry signals from the spinal cord to the thalamus
  - Third-order neurons: Carry signals from the thalamus to the primary sensory cortex.

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Somatic Sensory and Motor Pathways
Interactions Animation

- Somatic Sensory and Motor Pathways

R. Bishay

You must be connected to the internet to run this animation.

Somatic Sensory Pathways

- There are ***two general pathways*** by which somatic sensory signals entering the spinal cord ascend to the cerebral cortex:
  - **Posterior column–medial lemniscus pathway:** is a sensory pathway of the central nervous system that conveys sensations of fine touch, vibration, two-point discrimination, and proprioception (position) from the skin and joints
  - **Anterolateral (or spinothalamic) pathways:** is a sensory pathway of the central nervous system that conveys sensations of coarse touch and pressure.

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Posterior Column–Medial Lemniscus Pathway to the Cortex

- **Posterior (dorsal) columns:**
- Gracile fasciculus: carries sensory information from the lower half of the body entering the spinal cord at the lumbar level.
- Cuneate fasciculus: is located laterally in the upper thoracic and cervical (C1 to T6) spinal cord segments; it contains afferents from the upper trunk and extremities.

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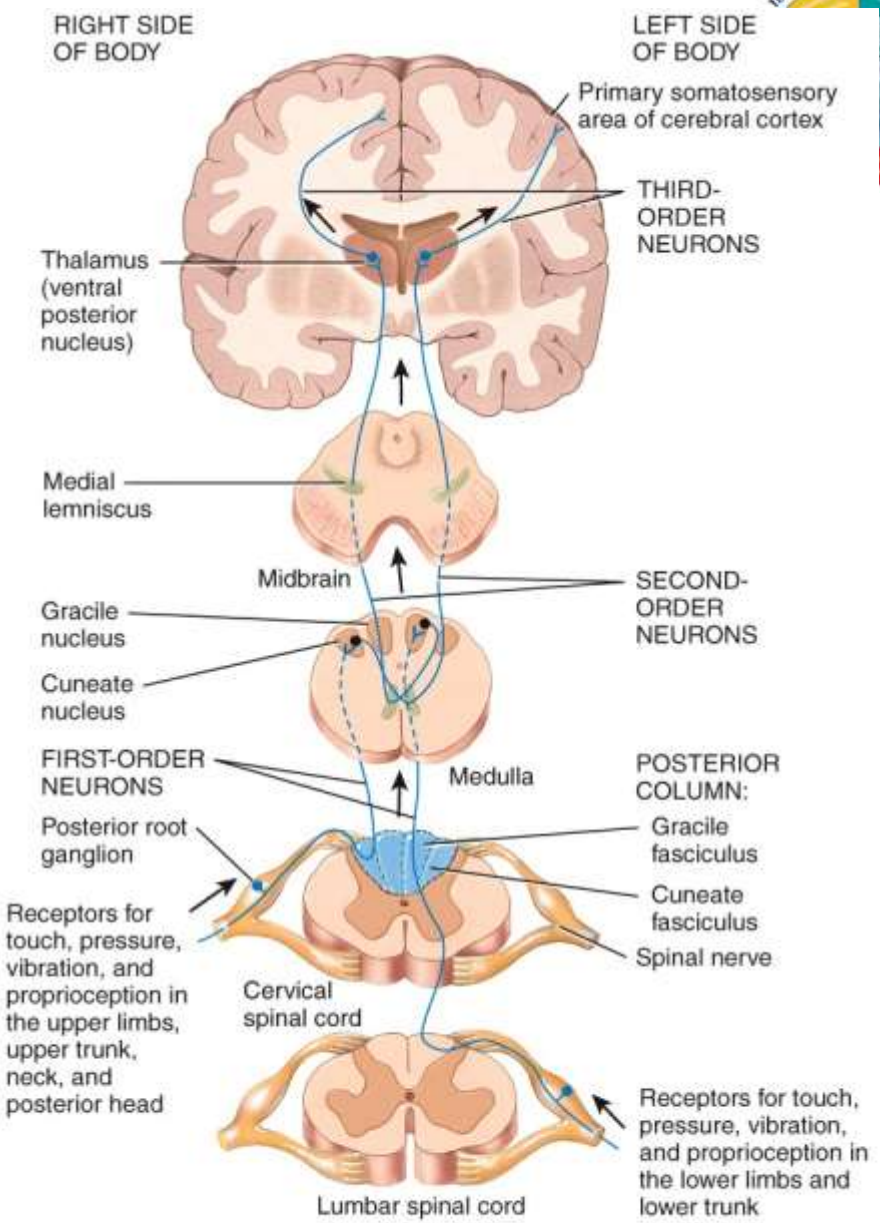
Somatic Sensory Pathways



(a) Posterior column–medial lemniscus pathway

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R. B

Anterolateral Pathways to the Cortex

- **Anterolateral or spinothalamic pathways**
  - Lateral spinothalamic tract: It is primarily responsible for transmitting pain and temperature as well as coarse touch
  - Anterior spinothalamic tract: primarily responsible for transmitting coarse touch and pressure

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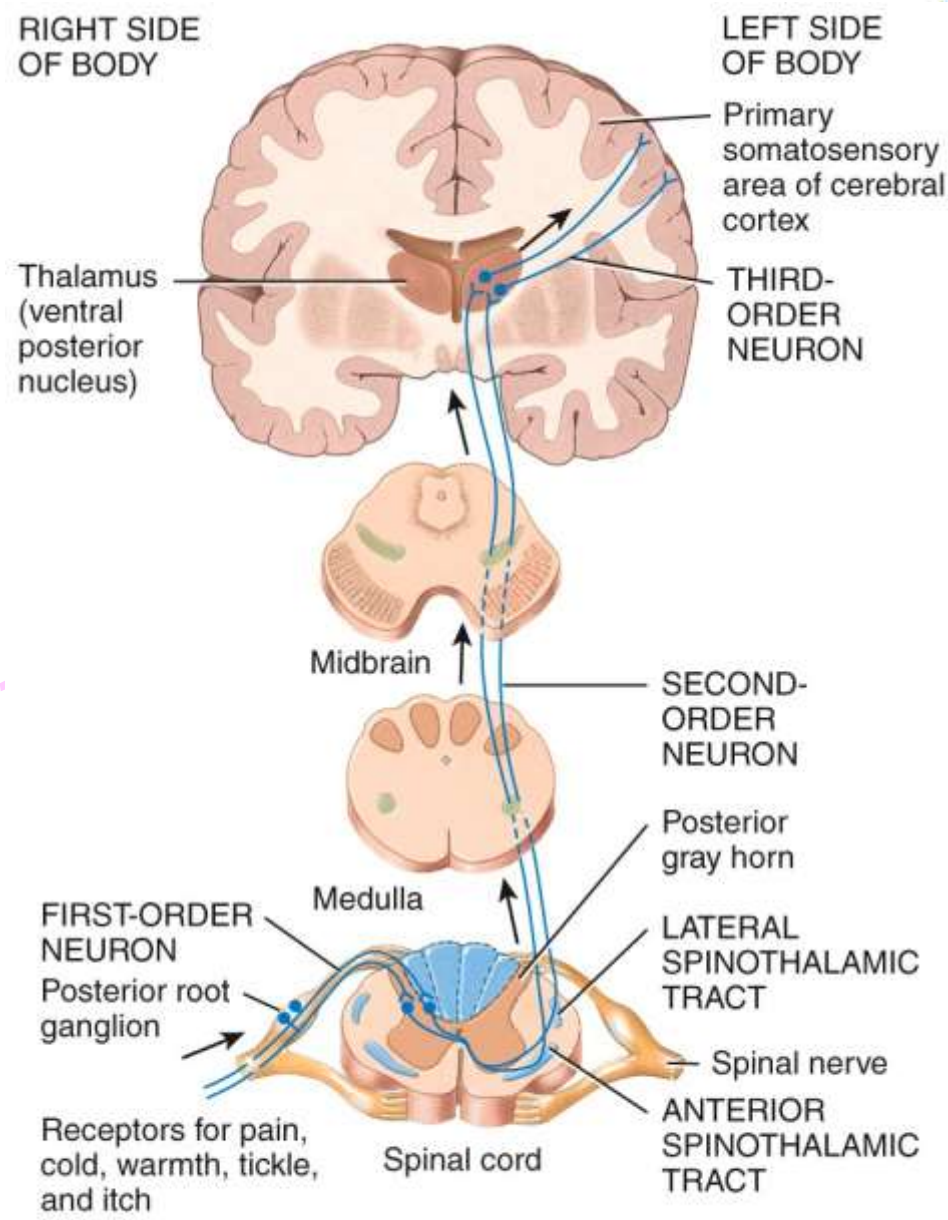
Somatic Sensory Pathways



(b) Anterolateral (spinothalamic) pathways

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Somatic Sensory Pathways to the Cerebellum

- **Posterior spino-cerebellar tract:** conveys proprioceptive information from proprioceptors in the skeletal muscles and joints to the cerebellum
- **Anterior (ventral) spino-cerebellar tract:** conveys proprioceptive information **from the body** to the cerebellum

R. Bishay

Clinical Connection

- **Syphilis:** is a bacterial infection usually spread by sexual contact. The disease starts as a painless sore — typically on your genitals, rectum or mouth. Syphilis spreads from person to person via skin or mucous membrane contact with these sores.
- **Neurosyphilis** presenting as pure cerebellar ataxia: usually lie within the spectrum of meningovascular syphilis, tabes dorsalis or general paresis of the insane.

R. Bishay

Somatic Motor Pathways

- **Lower motor neurons (LMNs):** A nerve cell that goes from the spinal cord to a muscle. The cell body of a lower motor neuron is in the spinal cord and its termination is in a skeletal muscle. It is located in either the anterior grey column, anterior nerve roots (spinal lower motor neurons) or the cranial nerve nuclei of the brainstem and cranial nerves with motor function (cranial nerve lower motor neurons) The loss of lower motor neurons leads to weakness, twitching of muscle (fasciculation), and loss of muscle mass (muscle atrophy)

R. Bisbay

Somatic Motor Pathways

- **Four groups of neurons** participate in control of movement by providing input to LMNs:

- **Local circuit neurons:** are neurons that connect two brain regions, i.e. not direct motor neurons or sensory neurons

- **Upper motor neurons:** They are found in the cerebral cortex and brainstem and carry information down to activate inter-neurons and lower motor neurons, which in turn directly signal muscles to contract or relax

R. Bisht

Somatic Motor Pathways

- **Basal nuclei neurons:** A region located at the base of the brain composed of 4 clusters of neurons, or nerve cells. This area of the brain is responsible for body movement and coordination. ... The basal nuclei are also called the basal ganglia

- **Cerebellar neurons:** Five types of neurons inhabit the cerebellar cortex, with a sixth type being found primarily in the floccular lobe and the vermis (the unipolar brush cell). Four are inhibitory (Purkinje, basket, stellate and Golgi cells) and two are excitatory (granule cells, unipolar brush cells)

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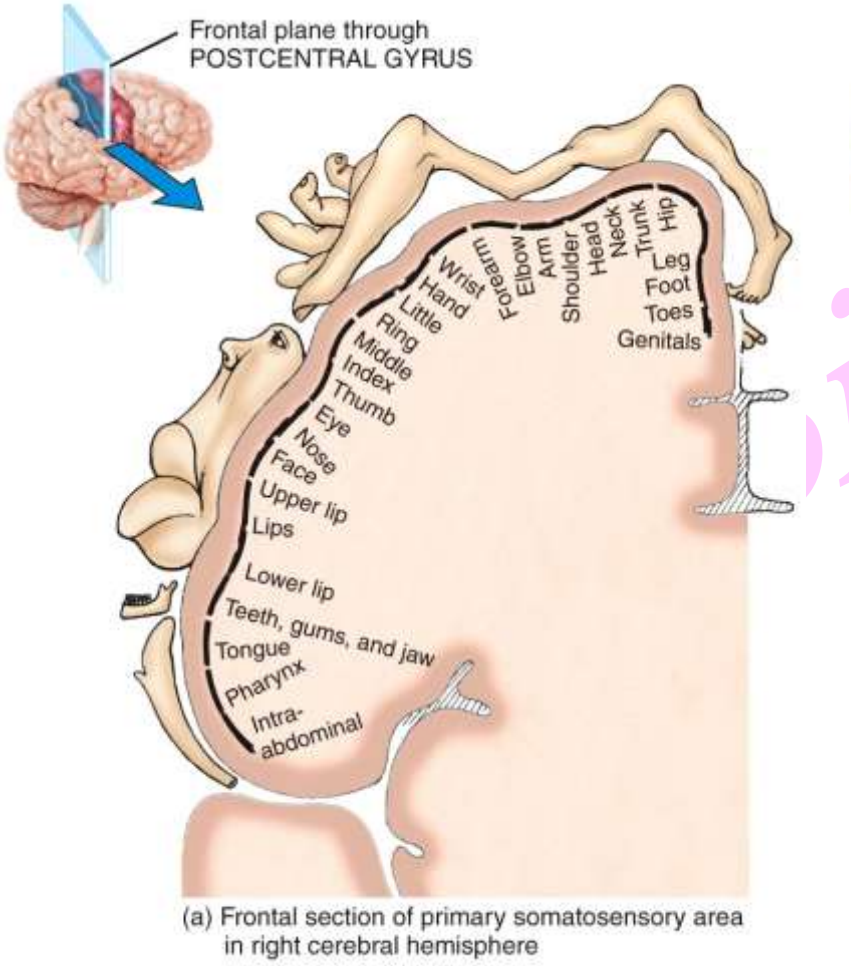
Somatic Sensory and Somatic Motor Maps in the Cerebral Cortex



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

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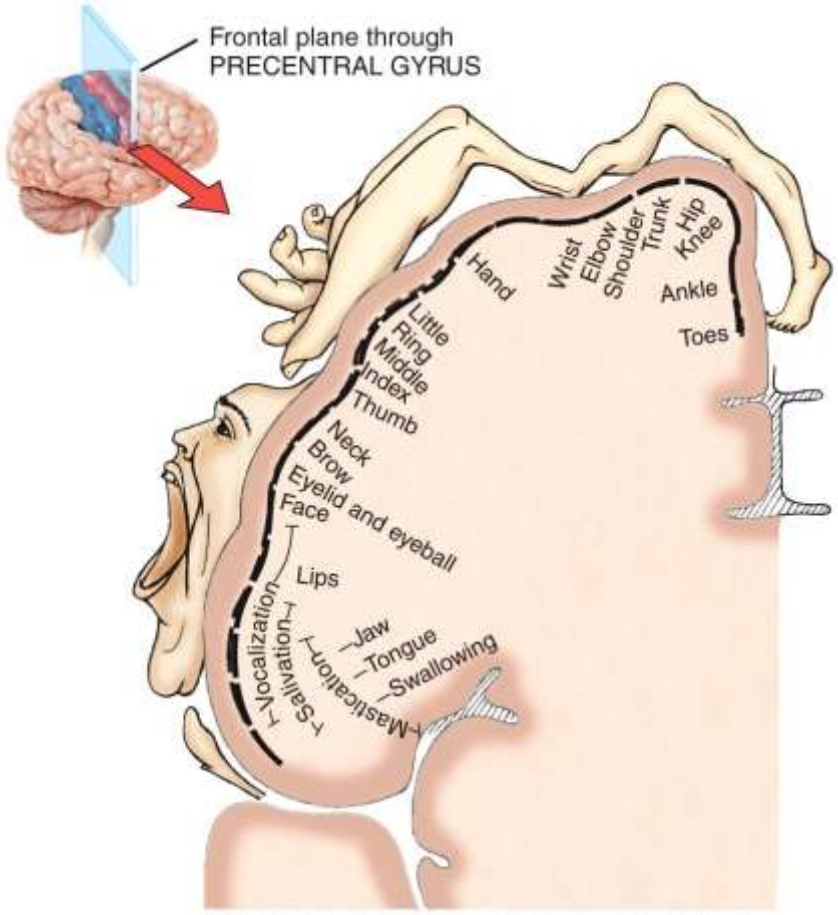

(b) Frontal section of primary motor area in right cerebral hemisphere

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Somatic Motor Pathways

- **Upper motor neurons**
- **Direct motor pathways (Pyramidal):** lateral corticospinal tract, the anterior corticalspinal tract AND ***Corticobulbar*** tract: **c**ranial nerves V, VII, IX, and XII.
- **Indirect motor pathways (Extra-pyramidal):**

  The direct pathway is excitatory and is in charge for the initial part of the movements, while the indirect pathway is inhibitory and it prevents the unnecessary movements:
- *Rubrospinal tract:* large muscle movement regulation flexor and inhibiting extensor tone
- *Tectospinal tract:* coordinates head and eye movements.
- *Vestibulospinal tract:* supporting posture and maintaining balance of the body and head
- *Reticulospinal tracts:* Medial and lateral.

F. Bisbay

Somatic Motor Pathways

- **Lateral and anterior corticospinal tract**
- In contrast to the *lateral* corticospinal tract which controls the movement of the *limbs*, the **anterior** corticospinal tract controls the movements of **axial muscles** (of the trunk).
- **Cortico-bulbar:** motor to the non-oculomotor.

R. Bishay

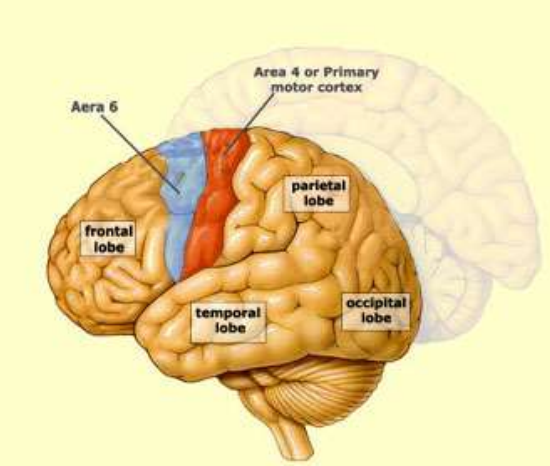
Clinical Connection

- **Paralysis**
  - **Flaccid paralysis:** flaccid paralysis occurs when your muscles can no longer contract. The messages sent from the brain to the muscle are interrupted by either infections (like polio), toxins (like botulism or curare), or from brain and spinal cord injuries
  - **Spastic paralysis:** caused by damage to the portion of the brain or spinal cord that controls voluntary movement. Since the normal flow of nerve messages to below the level of injury is interrupted, those messages may not reach the reflex control center of the brain.

R. Bishay

Mapping the Motor Areas

- **Primary motor area:** or M1, is one of the principal brain areas involved in motor function. M1 is located in the frontal lobe of the brain, along a bump called the precentral gyrus.
- The role of the primary motor cortex is to generate neural impulses that control the execution of movement.
- **Premotor area:** is located just in front of the primary motor cortex in the brain.
- Its job is to prepare the body's muscles for the exact movements the will make. In other words, it helps you control your movements



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Direct Motor Pathways

- Nerve impulses for voluntary movements propagate from the cerebral cortex to lower motor neurons via the direct motor pathways, also known as the pyramidal pathways.
- Three tracts of upper motor neuron axons:
  - Lateral corticospinal tracts
  - Anterior corticospinal tracts
  - Corticobulbar tracts

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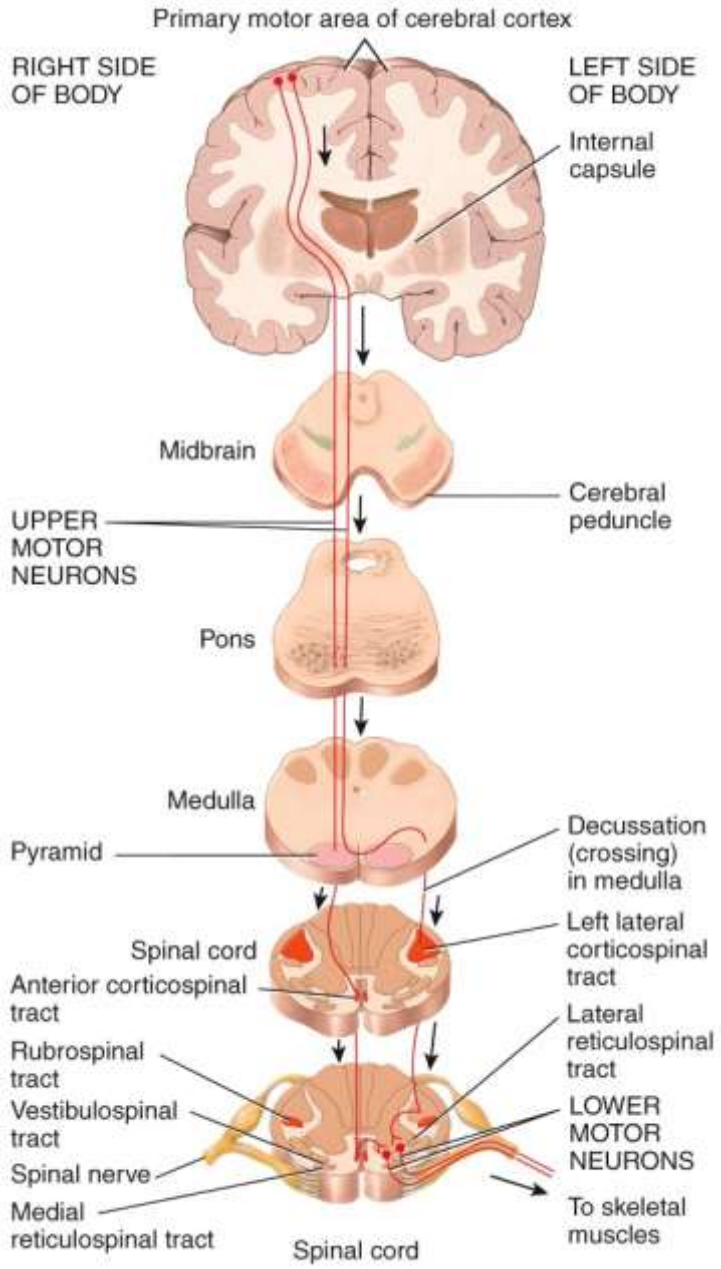
Direct Motor Pathways



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Clinical Connection

- **Amyotrophic lateral sclerosis (ALS):** also known as motor neurone disease (MND) or Lou Gehrig's disease, is a disease that causes the death of neurons controlling voluntary muscles.
- ALS is characterized by stiff muscles, muscle twitching, and gradually worsening weakness due to muscles decreasing in size

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Indirect Motor Pathways

- Also called extrapyramidal pathways
- Rubrospinal tract
- Tectospinal tract
- Vestibulospinal tract
- Medial reticulospinal tract
- Lateral reticulospinal tract

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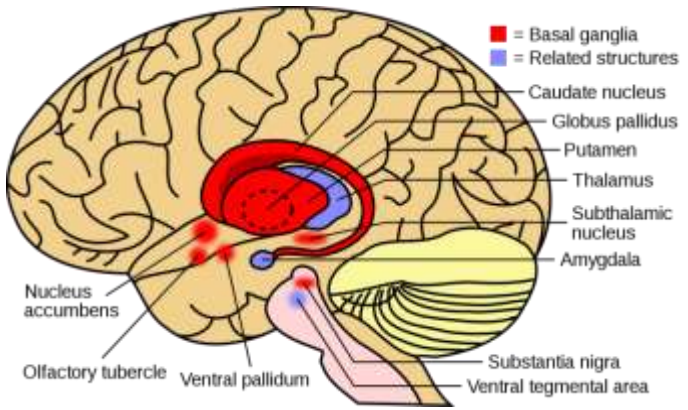
Roles of the Basal Ganglia

- **The basal ganglia** are a group of structures found deep within the cerebral hemispheres. The structures generally included in the basal ganglia are the caudate, putamen, and globus pallidus in the cerebrum, the substantia nigra in the midbrain, and the subthalamic nucleus in the diencephalon
- **The functions of the basal ganglia:**

  1. Initiation and termination of movements
  2. Suppression of unwanted movements
  3. Control of muscle tone
  4. Influence on cortical function



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Roles of the Cerebellum

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

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Clinical Connection

- **Parkinson's disease:** is a progressive nervous system disorder that affects movement. Symptoms start gradually, sometimes starting with a barely noticeable tremor in just one hand.

  Tremors are common, but the disorder also commonly causes stiffness or slowing of movement
- *Tremor:* an unintentional and uncontrollable rhythmic movement of one part or one limb of your body. A tremor can occur in any part of the body and at any time. It's usually the result of a problem in the part of your brain that controls muscular movement.
- *Bradykinesia:* slowness of movement and is one of the cardinal manifestations of Parkinson's disease. Weakness, tremor and rigidity may contribute to but do not fully explain bradykinesia.
- *Hypokinesia:* refers to decreased bodily movement. One of the two categories of movement disorders, hypokinesia is characterized by a partial or complete loss of muscle movement due to a disruption in the basal ganglia

R. Bishay