Human Anatomy

Pathways and Integrative Functions

Pathways of the Nervous System

- CNS communicates with body structures via pathways.
  - sensory or motor information
  - processing and integration occur continuously
- Pathways travel through the white matter of the spinal cord.
- Connect various CNS regions with peripheral nerves.

Pathways of the Nervous System

- Consists of a tract and a nucleus.
- Tracts are groups or bundles of axons that travel together in the CNS.
- Each tract may work with multiple nuclei groups in the CNS.
- A nucleus is a collection of neuron cell bodies located within the CNS.

Nervous System Pathways

- Ascending pathways
  - carry sensory information from the peripheral body to the brain
- Descending pathways
  - transmit motor information from the brain or brainstem to muscles or glands
- Pathway crosses over from one side of the body to the other side at some point in its travels.
- The left side of the brain processes information from the right side of the body, and vice versa.

Nervous System Pathways

- Most exhibit a precise correspondence between a specific area of the body and a specific area of the CNS.
- Pathways that connect these parts of the primary motor cortex to a specific body part exhibit somatotopy.

Nervous System Pathways

- All pathways are composed of paired tracts.
- A pathway on the left side of the CNS has a matching tract on the right side of the CNS.
- Both left and right tracts are needed to innervate both the left and right sides of the body.
- Pathways are composed of a series of two or three neurons that work together.

Nervous System Pathways

- Sensory pathways
  - have primary neurons, secondary neurons, and sometimes tertiary neurons that facilitate the pathway's functioning
- Motor pathways
  - use an upper motor neuron and a lower motor neuron
  - the cell bodies are located in the nuclei associated with each pathway

Nervous System Pathways

- Sensory pathways
  - conduct information about limb position and the sensations of touch, temperature, pressure, and pain
- Somatosensory pathways
  - process stimuli received from receptors within the skin, muscles, and joints
- Viscerosensory pathways
  - process stimuli received from the viscera

Sensory Receptors

- Detect stimuli and then conduct nerve impulses to the CNS
- Sensory pathway centers within either the spinal cord or brainstem process and filter the incoming sensory information.
  - They determine whether the incoming sensory stimulus should be transmitted to the cerebrum or terminated.
- More than 99% of incoming impulses do not reach the cerebral cortex and our conscious awareness.

Primary (First-Order) Neuron

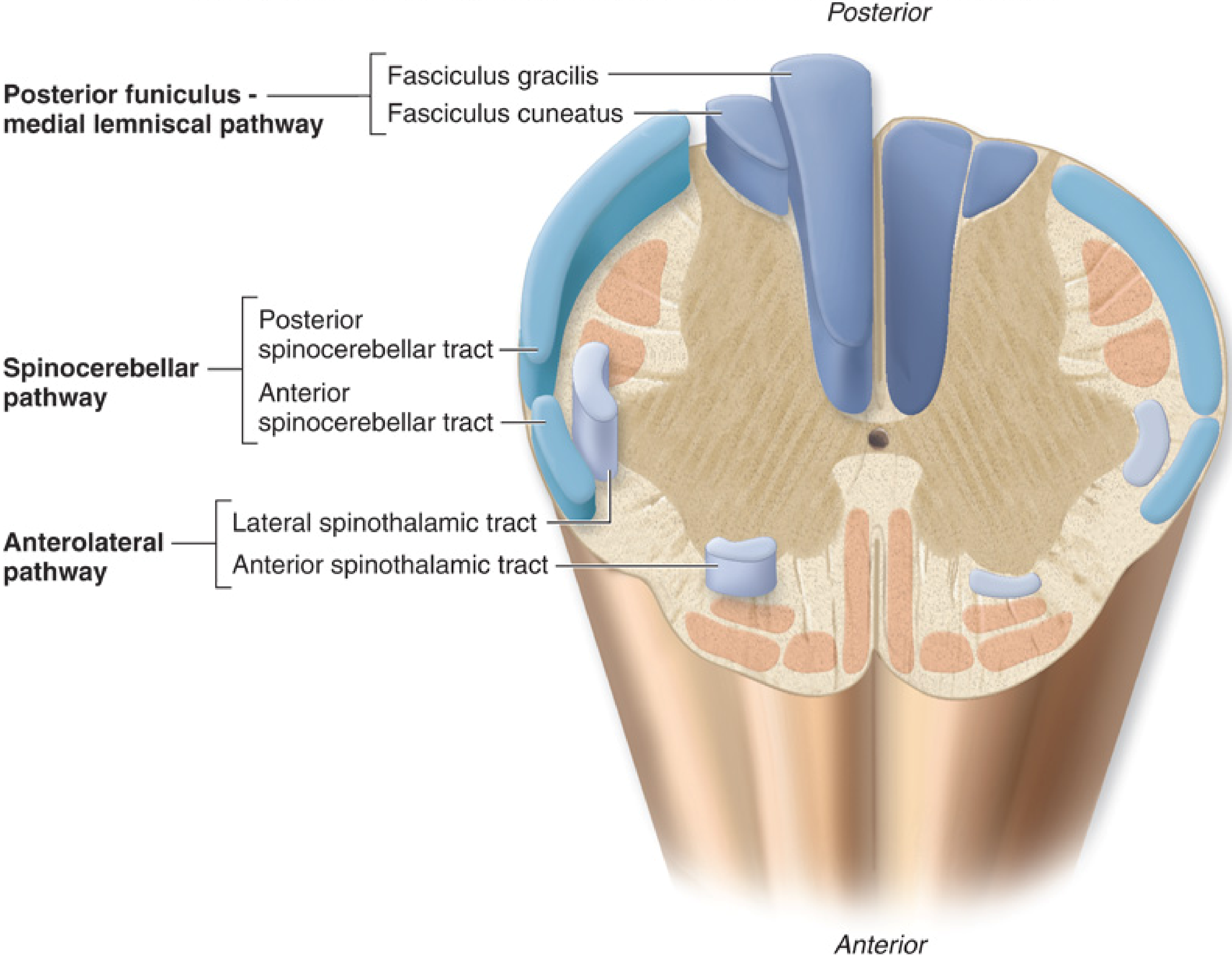
- Sensory pathways utilize a series of two or three neurons to transmit stimulus information from the body periphery to the brain.
- The first neuron is the primary (first-order) neuron
- The dendrites are part of the receptor that detects a specific stimulus.
- The cell bodies reside in the posterior root ganglia of spinal nerves or the sensory ganglia of cranial nerves.

Secondary (Second-Order) Neuron

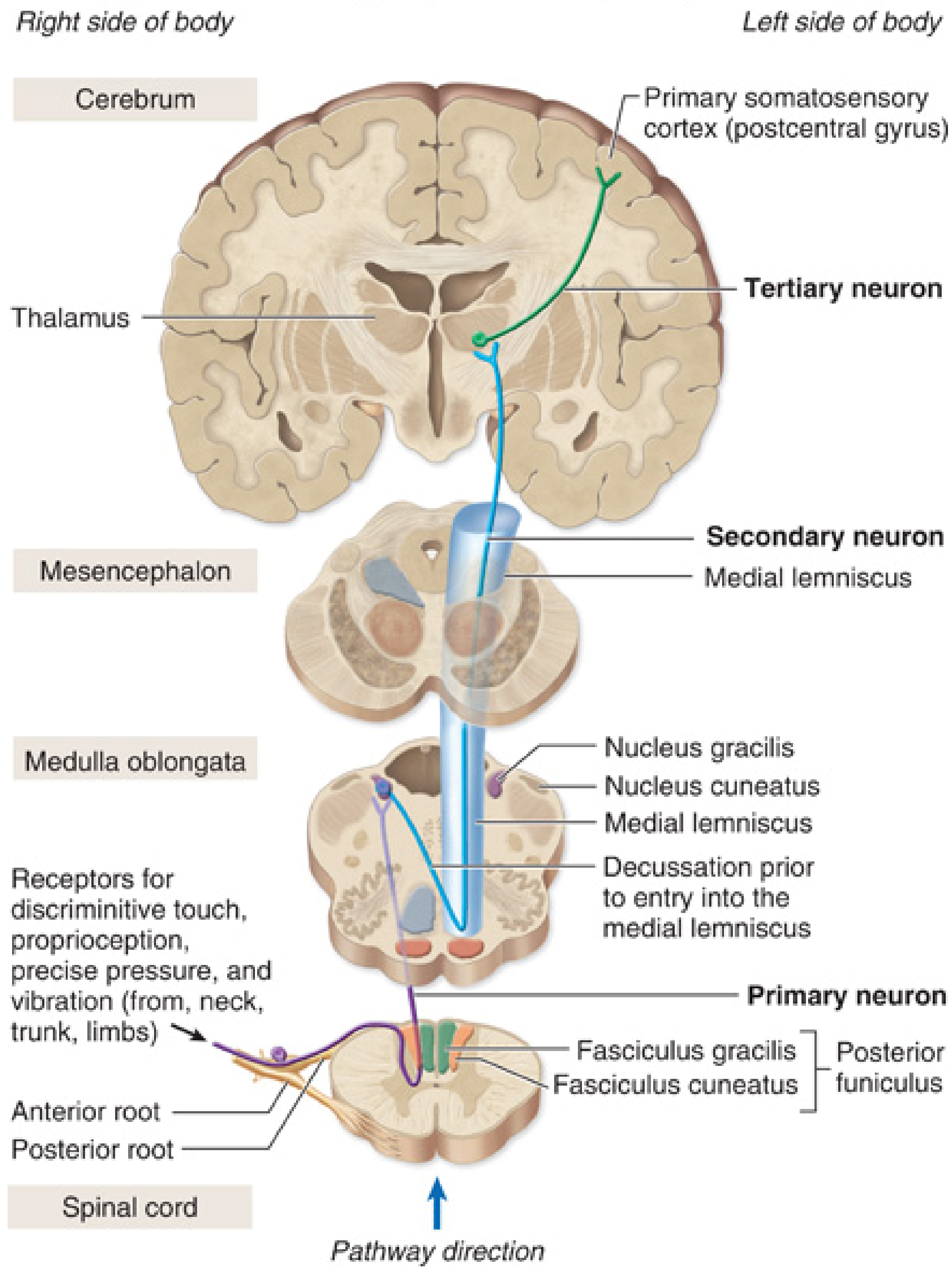
- The axon of the primary neuron projects to a secondary neuron within the CNS.
- Is an interneuron.
- The cell body resides within either the posterior horn of the spinal cord or a brainstem nucleus.
- The axon projects to the thalamus, where it synapses with the tertiary neuron.

Tertiary (Third-Order) Neuron

- Also an interneuron.
- Its cell body resides within the thalamus.
- The thalamus is the central processing and coding center for almost all sensory information.

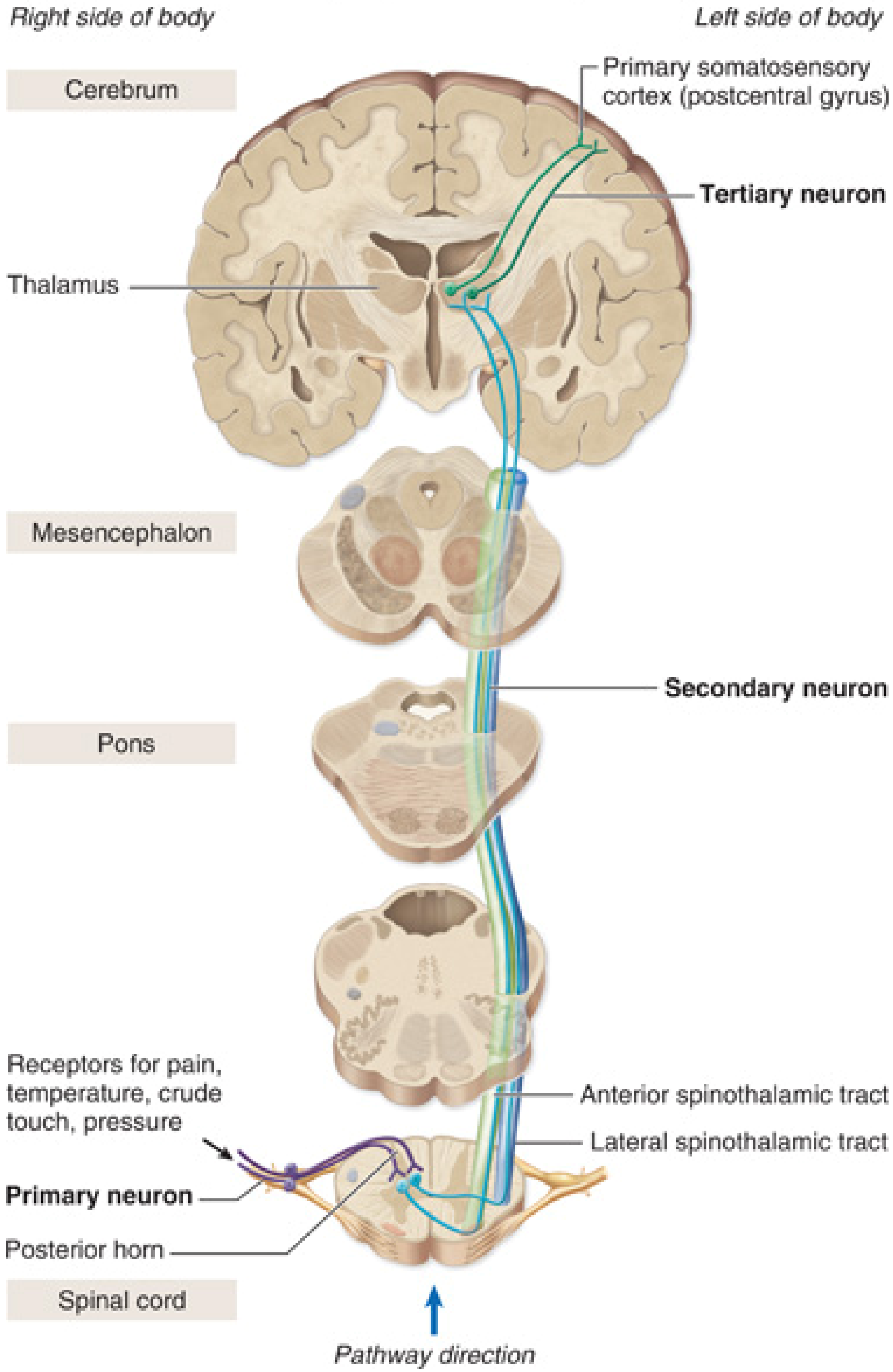


Posterior
Posterior funiculus - medial lemniscal pathway
Fasciculus gracilis
Fasciculus cuneatus
Spinocerebellar pathway
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Anterolateral pathway
Lateral spinothalamic tract
Anterior spinothalamic tract
Anterior


Right side of body
Left side of body
Cerebrum
Primary somatosensory cortex (postcentral gyrus)
Tertiary neuron
Thalamus
Secondary neuron
Medial lemniscus
Mesencephalon
Medulla oblongata
Nucleus gracilis
Nucleus cuneatus
Medial lemniscus
Decussation prior to entry into the medial lemniscus
Receptors for discriminitive touch, proprioception, precise pressure, and vibration (from, neck, trunk, limbs)
Primary neuron
Fasciculus gracilis
Fasciculus cuneatus
Posterior funiculus
Anterior root
Posterior root
Spinal cord
Pathway direction

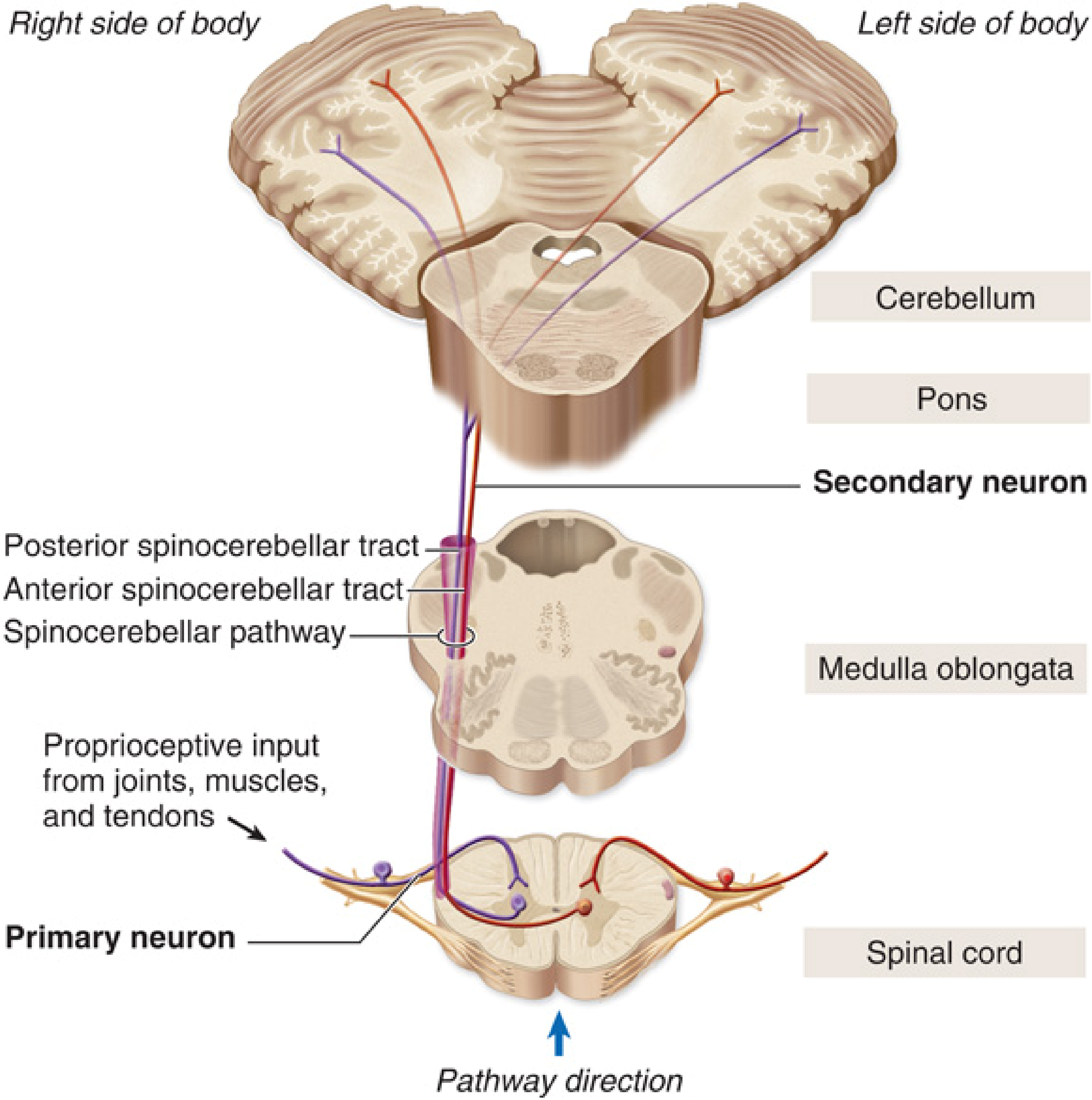
Posterior Funiculus-Medial Lemniscal Pathway

- Projects through the spinal cord, brainstem, and diencephalon before terminating within the cerebral cortex.
- tracts within the spinal cord
  - posterior funiculus
- tracts within the brainstem
  - medial lemniscus
- Conducts sensory stimuli concerned with proprioceptive information about limb position and discriminative touch, pressure, and vibration sensations.


Right side of body
Left side of body
Cerebrum
Primary somatosensory cortex (postcentral gyrus)
Tertiary neuron
Thalamus
Mesencephalon
Secondary neuron
Pons
Receptors for pain, temperature, crude touch, pressure
Anterior spinothalamic tract
Lateral spinothalamic tract
Primary neuron
Posterior horn
Spinal cord
Pathway direction

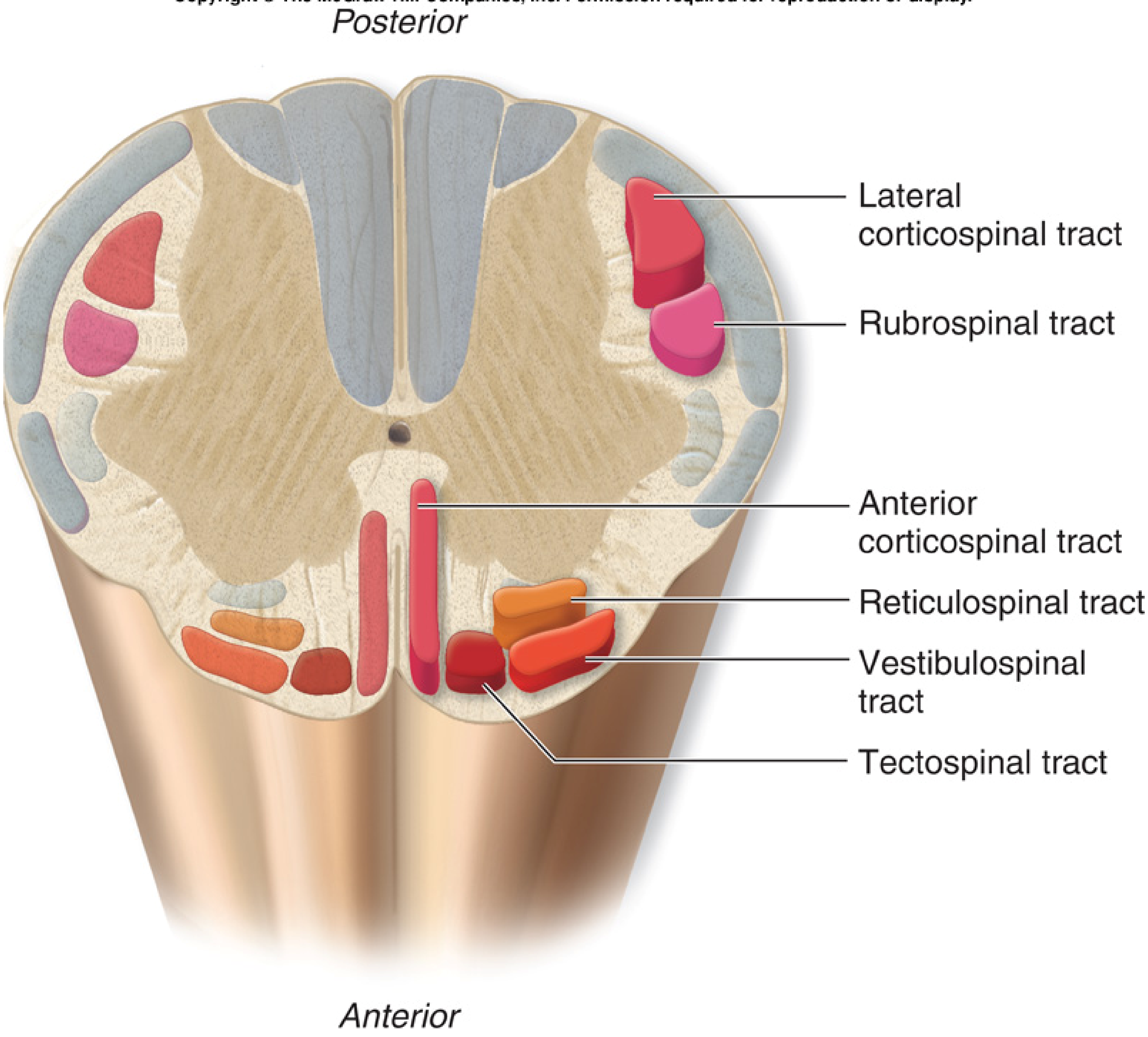
Anterolateral Pathway

- Located in the anterior and lateral white funiculi of the spinal cord.
  - anterior spinothalamic tract
  - lateral spinothalamic tract
- Axons projecting from primary neurons enter the spinal cord and synapse on secondary neurons within the posterior horns.
- Axons entering these pathways conduct stimuli related to crude touch and pressure as well as pain and temperature.
- Axons of the secondary neurons cross over and relay stimulus information to the opposite side of the spinal cord before ascending toward the brain.


Right side of body
Left side of body
Cerebellum
Pons
Secondary neuron
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Spinocerebellar pathway
Medulla oblongata
Proprioceptive input from joints, muscles, and tendons
Primary neuron
Spinal cord
Pathway direction

Spinocerebellar Pathway

- Conducts proprioceptive information to the cerebellum for processing to coordinate body movements.
- Composed of anterior and posterior spinocerebellar tracts.
  - the major routes for transmitting postural input to the cerebellum
- Sensory input is critical for regulation of posture and balance and coordination of skilled movements.
- These are different from the other sensory pathways in that they do not use tertiary neurons.
  - they only have primary and secondary neurons


Posterior
Lateral corticospinal tract
Rubrospinal tract
Anterior corticospinal tract
Reticulospinal tract
Vestibulospinal tract
Tectospinal tract
Anterior

Motor Pathways

- Descending pathways in the brain and spinal cord that control the activities of skeletal muscle.
- Formed from the cerebral nuclei, the cerebellum, descending projection tracts, and motor neurons.
- Regulate the activities of skeletal muscle.

Corticobulbar Tracts

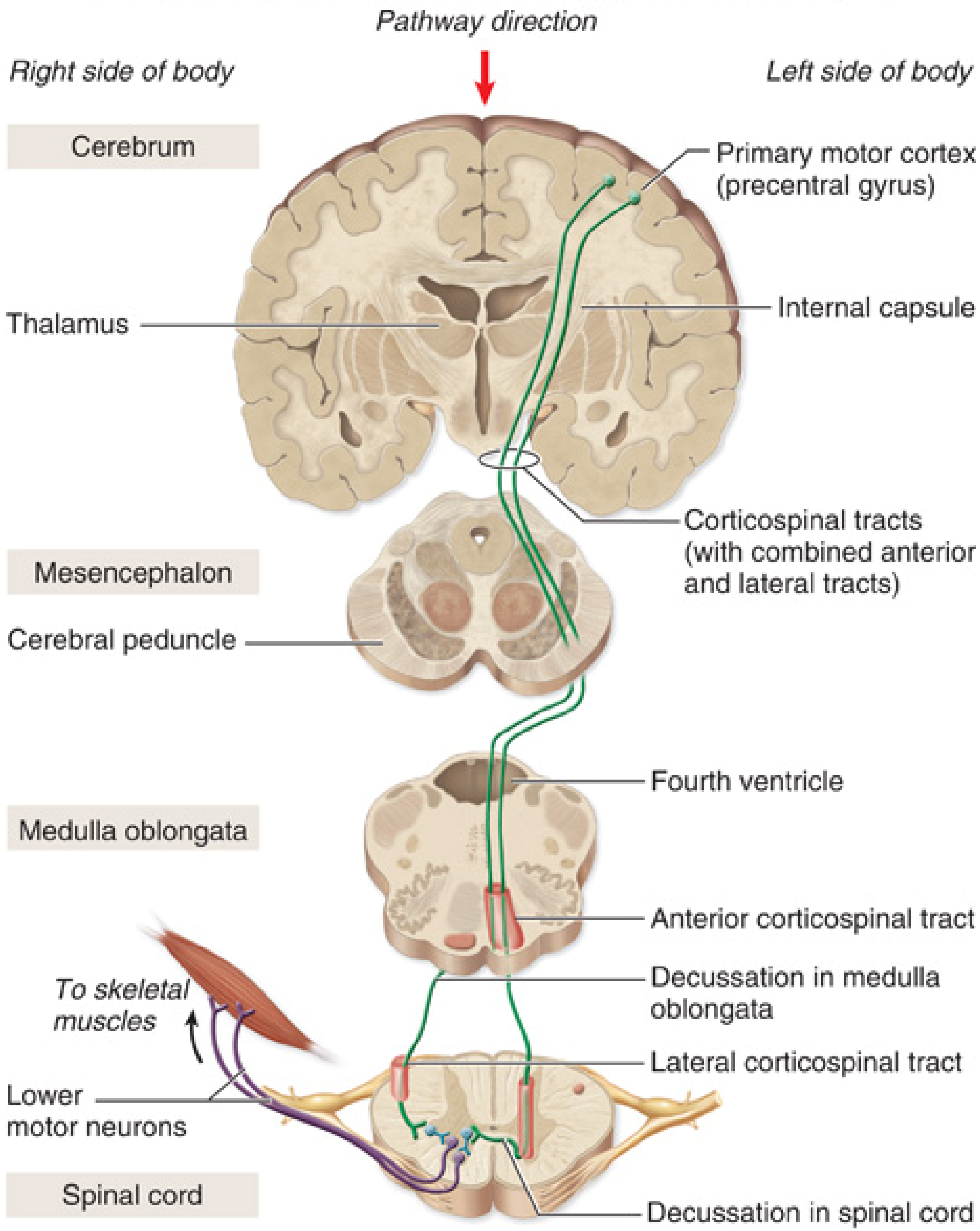
- Originate from the facial region of the motor homunculus within the primary motor cortex.
- Axons extend to the brainstem, where they synapse with lower motor neuron cell bodies that are housed within brainstem cranial nerve nuclei.
- Axons of these lower motor neurons help form the cranial nerves.

Corticobulbar Tracts

- Transmit motor information to control:
  - eye movements (via CN III, IV, and VI)
  - cranial, facial, pharyngeal, and laryngeal muscles (via CN V, VII, IX, and X)
  - some superficial muscles of the back and neck (via CN XI)
  - intrinsic and extrinsic tongue muscles (via CN XII)

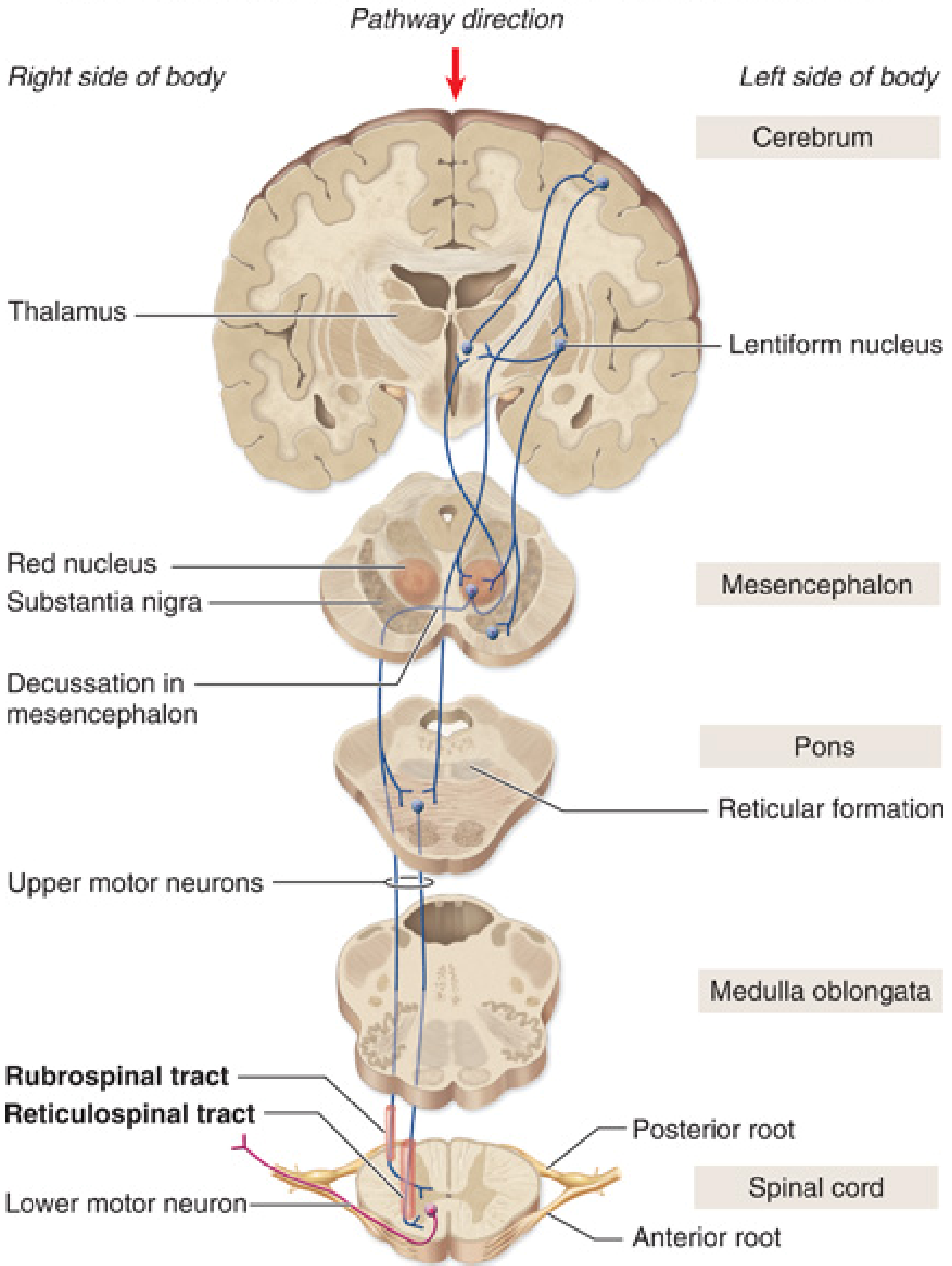
Corticospinal Tracts

- Descend from the cerebral cortex through the brainstem and form a pair of thick bulges in the medulla called the pyramids.
- Continue into the spinal cord to synapse on lower motor neurons in the anterior horn of the spinal cord.


Pathway direction
Right side of body
Left side of body
Cerebrum
Primary motor cortex (precentral gyrus)
Thalamus
Internal capsule
Corticospinal tracts (with combined anterior and lateral tracts)
Mesencephalon
Cerebral peduncle
Fourth ventricle
Medulla oblongata
Anterior corticospinal tract
To skeletal muscles
Decussation in medulla oblongata
Lateral corticospinal tract
Lower motor neurons
Spinal cord
Decussation in spinal cord

Indirect Pathway

- Several nuclei within the mesencephalon initiate motor commands for activities that occur at an unconscious level.
- Nuclei and their associated tracts.
- Cell bodies of its upper motor neurons are located within brainstem nuclei.
- Axons take a complex, circuitous route before finally conducting the motor impulse into the spinal cord.

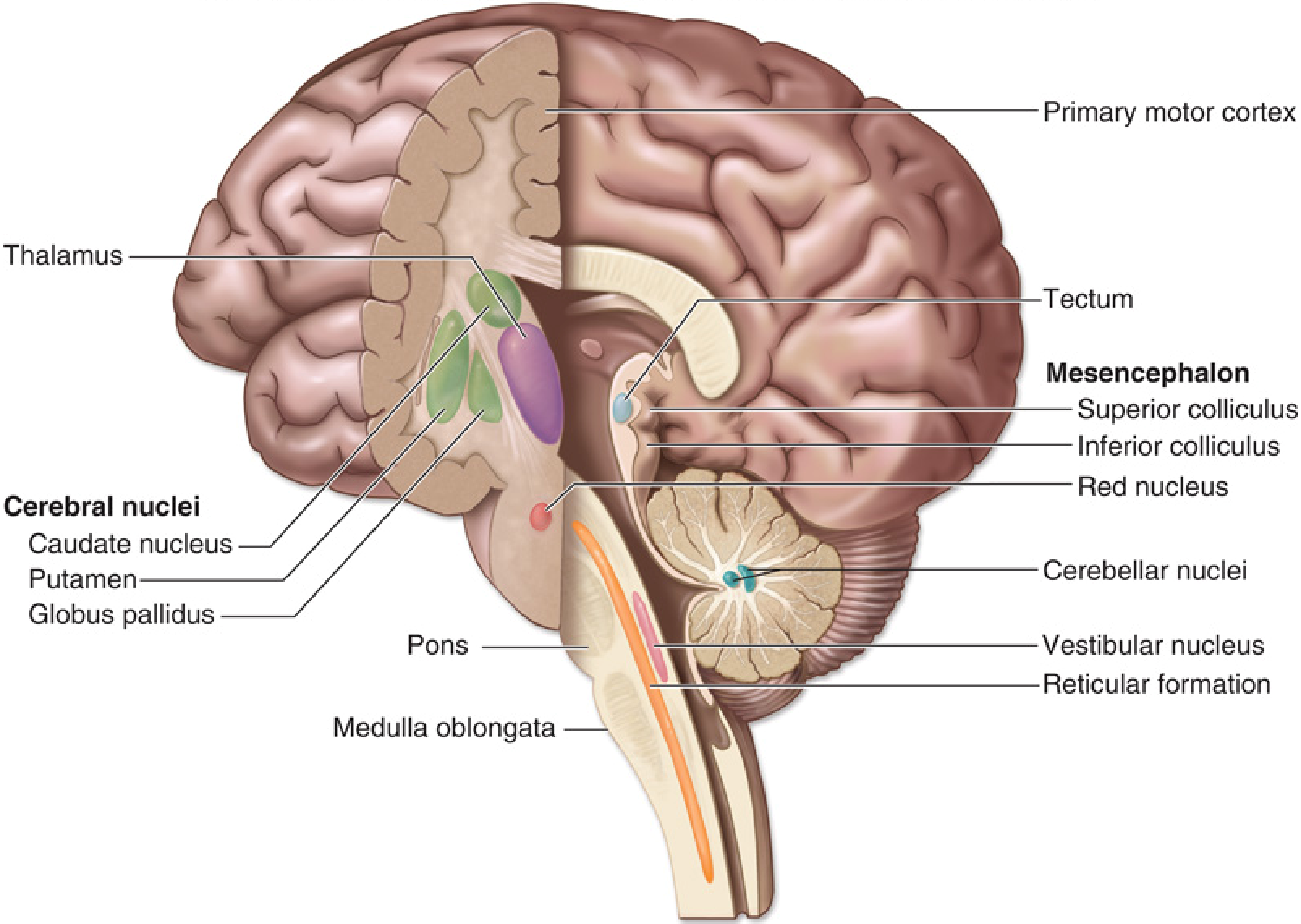

Pathway direction
Right side of body
Left side of body
Cerebrum
Thalamus
Lentiform nucleus
Red nucleus
Substantia nigra
Mesencephalon
Decussation in mesencephalon
Pons
Reticular formation
Upper motor neurons
Medulla oblongata
Rubrospinal tract
Reticulospinal tract
Posterior root
Spinal cord
Lower motor neuron
Anterior root

Indirect Motor Pathways in the Spinal Cord

- Originate from neurons housed within the brainstem.
- Muscular activity localized within the head, limbs, and trunk of the body.
- Multisynaptic.
- Exhibit a high degree of complexity.

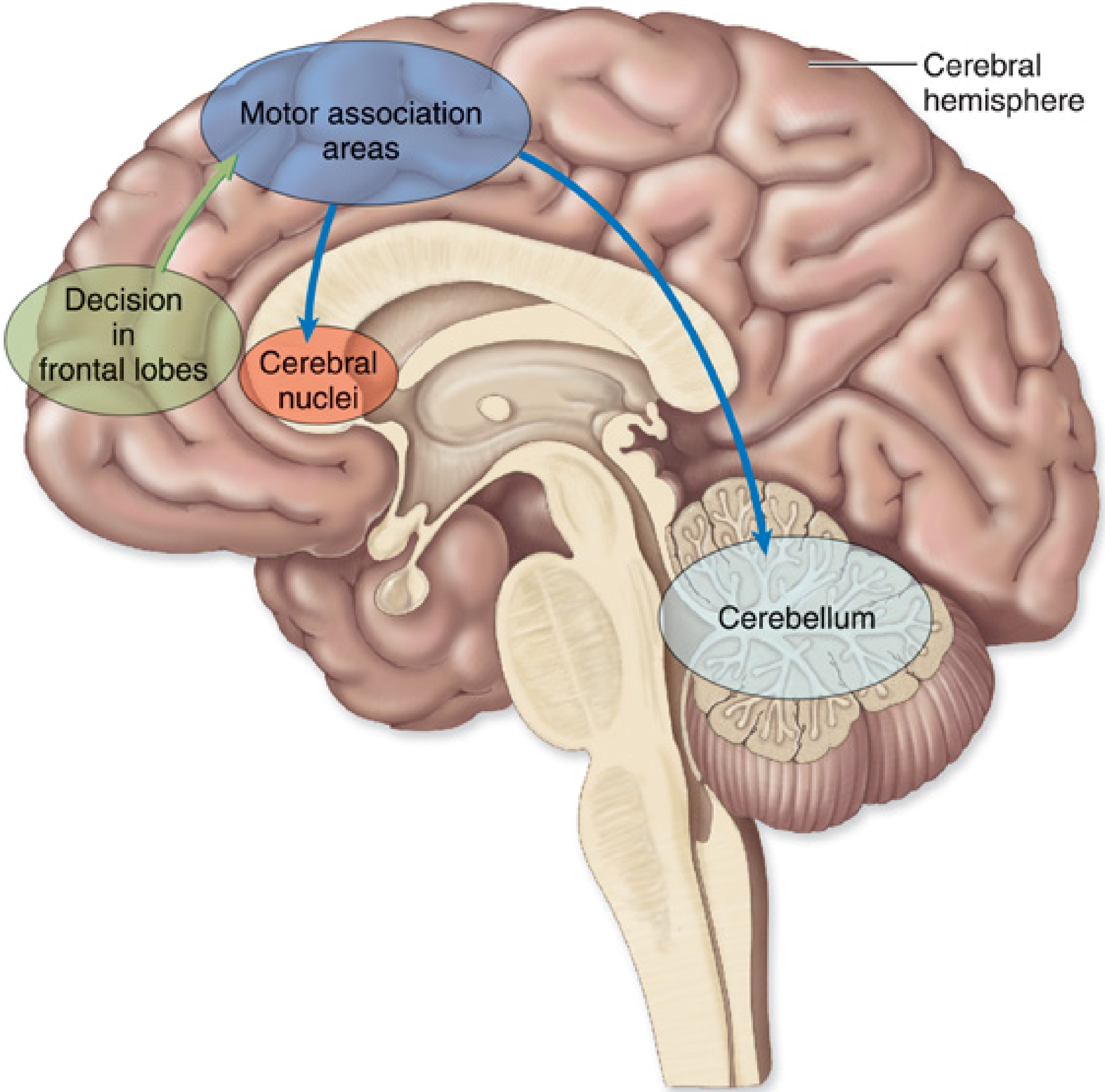
Role of the Cerebral Nuclei

- Receive impulses from the entire cerebral cortex, including the motor, sensory, and association cortical areas, as well as input from the limbic system.
- Most of the output goes to the primary motor cortex.
- Do not exert direct control over lower motor neurons.
- Provide the patterned background movements needed for conscious motor activities by adjusting the motor commands issued in other nuclei.

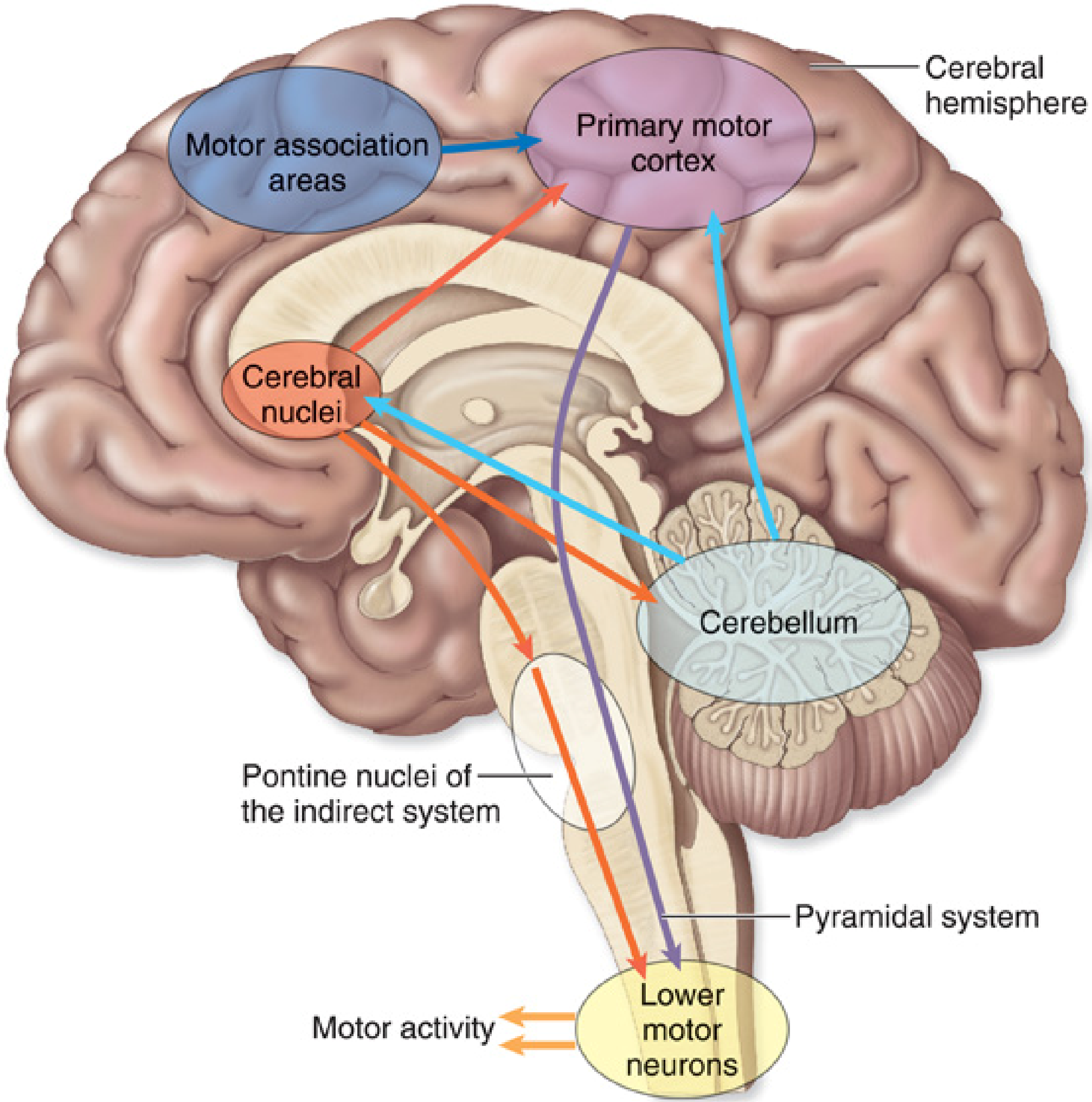

Primary motor cortex
Thalamus
Tectum
Mesencephalon
Superior colliculus
Inferior colliculus
Red nucleus
Cerebral nuclei
Caudate nucleus
Putamen
Globus pallidus
Cerebellar nuclei
Pons
Vestibular nucleus
Reticular formation
Medulla oblongata

Somatic Motor Control

- Several regions of the brain participate in the control of motor activities.
- Motor programs require conscious directions from the frontal lobes.
- Movement is initiated when commands are received by the primary motor cortex from the motor association areas.
- The cerebellum is critically important in coordinating movements because it specifies the exact timing of control signals to different muscles.



(a) Motor programming



(b) Process of movement

Levels of Processing and Motor Control

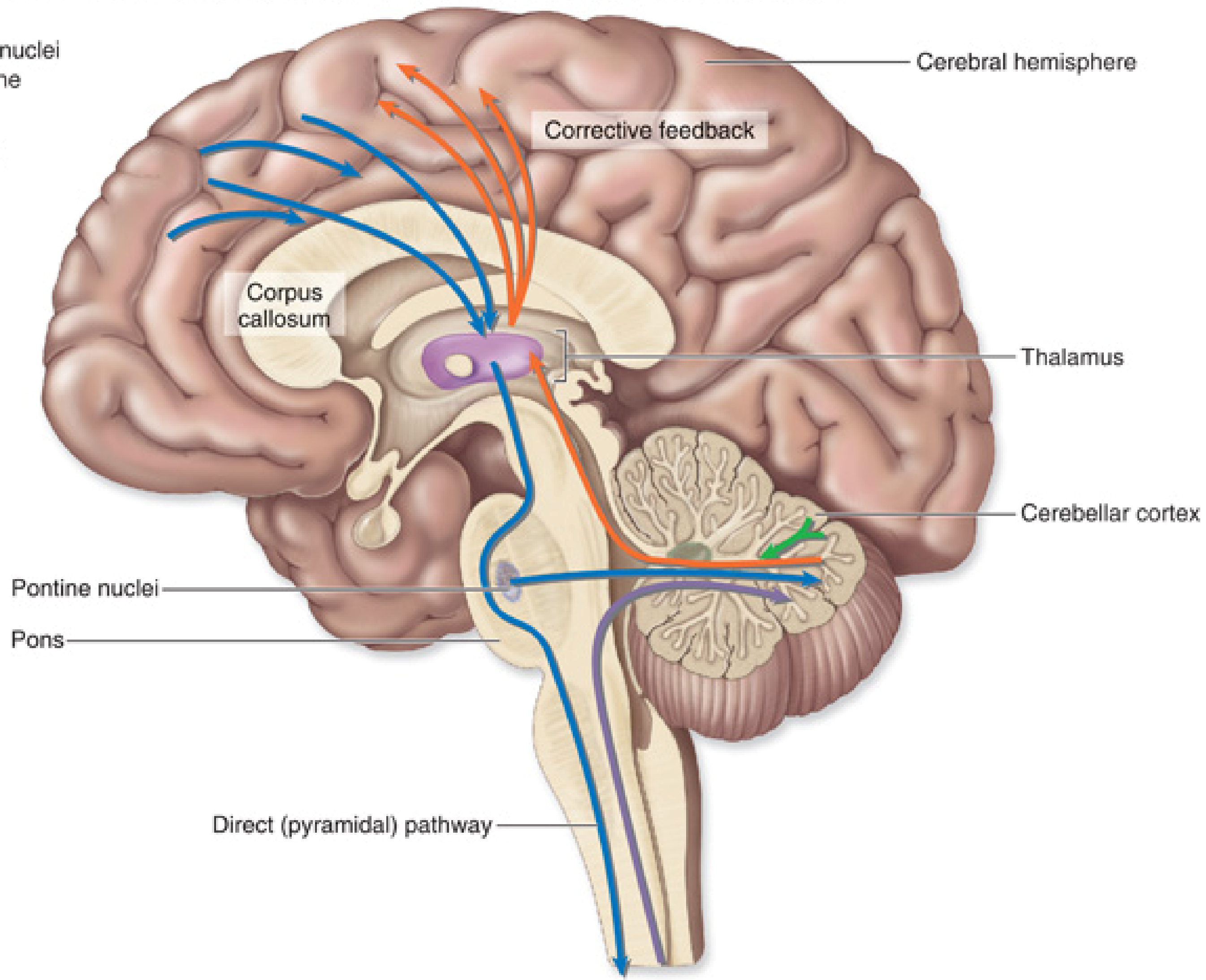
- Simple reflexes that stimulate motor neurons represent the lowest level of motor control.
- The nuclei controlling these reflexes are located in the spinal cord and the brainstem.
- Brainstem nuclei also participate in more complex reflexes.
- Initiate motor responses to control motor neurons directly.
- Oversee the regulation of reflex centers elsewhere in the brain.

Voluntary movements
The primary motor cortex and the basal nuclei in the forebrain send impulses through the nuclei of the pons to the cerebellum.

Assessment of voluntary movements
Proprioceptors in skeletal muscles and joints report degree of movement to the cerebellum.

Integration and analysis
The cerebellum compares the planned movements (motor signals) against the results of the actual movements (sensory signals).

Error-correcting signals
The cerebellum sends impulses through the thalamus to the primary motor cortex and to motor nuclei in the brainstem.



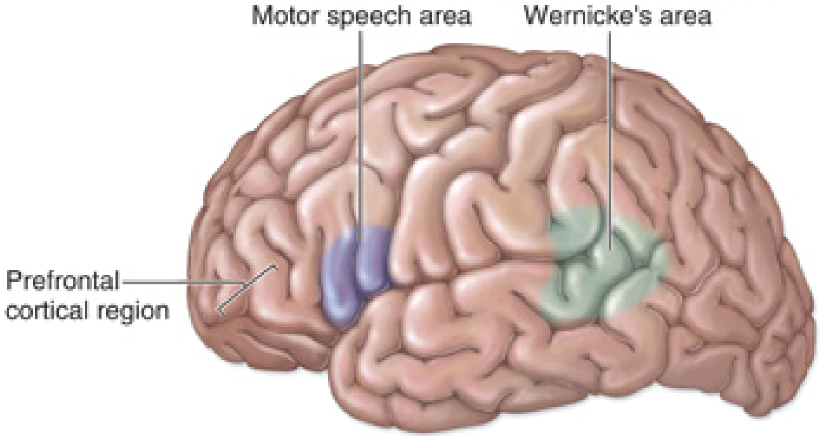
Sagittal section

Cerebral Cortex

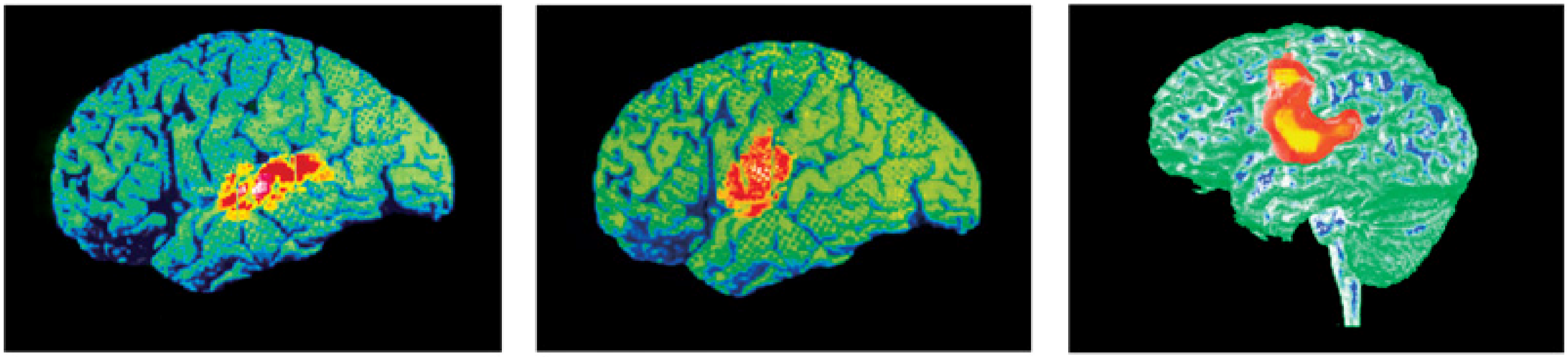
- Control highly variable and complex voluntary motor patterns.
- Occupy the highest level of processing and motor control.
- Motor commands may be conducted to specific motor neurons directly.
- May be conveyed indirectly by altering the activity of a reflex control center.

Cerebral Cortex

- Higher-order mental functions:
  - consciousness, learning, memory, and reasoning
  - involve multiple brain regions connected by complicated networks and arrays of axons
  - conscious and unconscious processing of information are involved in higher-order mental functions
  - may be continually adjusted or modified



(a)



1 Auditory information about a sentence travels to the primary auditory cortex. Wernicke's area then interprets the sentence.

2 Information from Wernicke's area travels to the motor speech area.

3 Information travels from the motor speech area to the primary motor cortex, where motor commands involving speech muscles are given.

(b)

Cerebral Lateralization

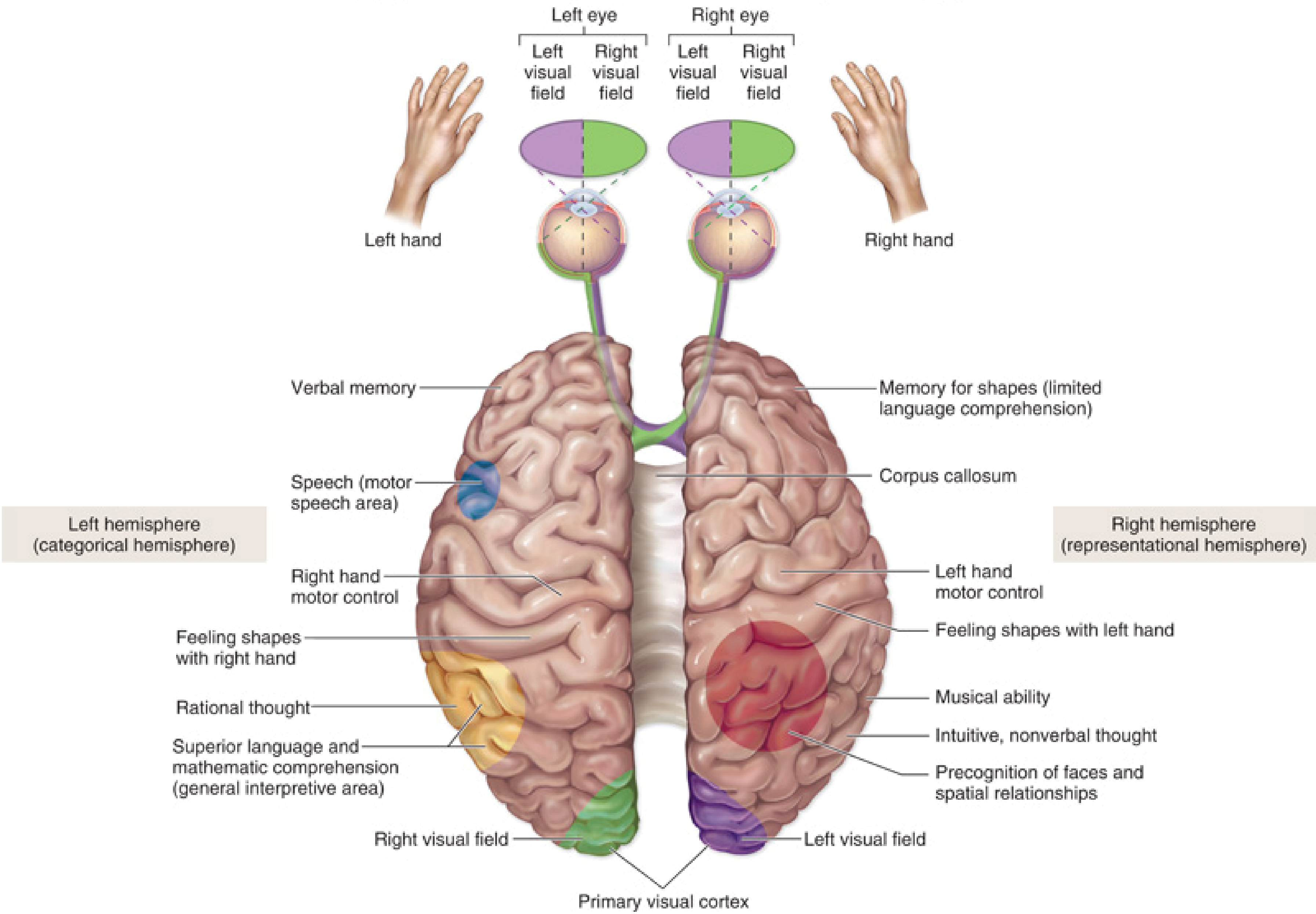
- Each hemisphere tends to be specialized for certain tasks.
- Higher-order centers in both hemispheres tend to have different but complementary functions.

Cerebral Lateralization

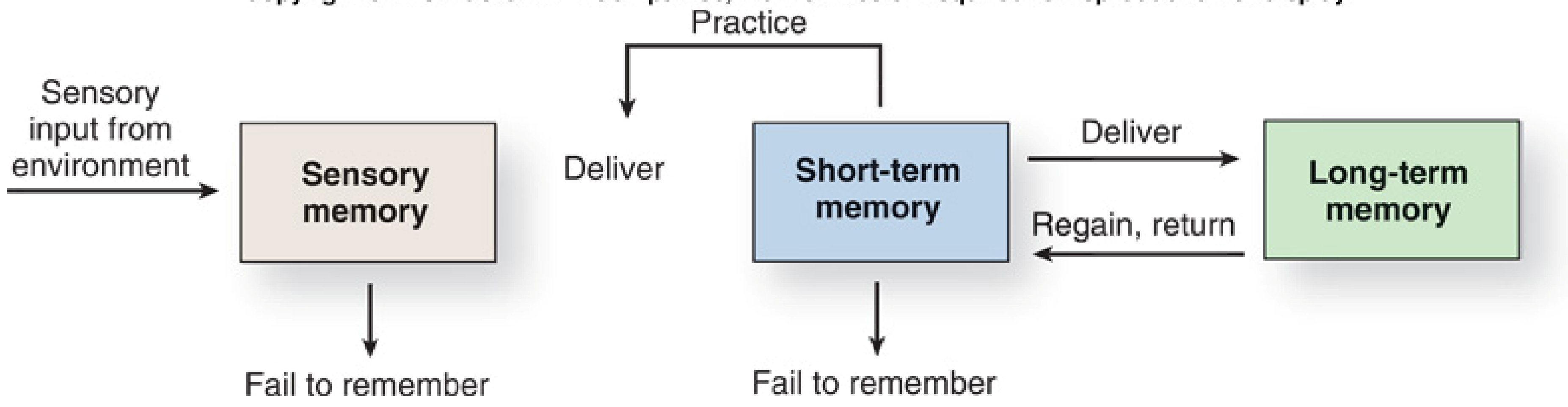
- **Left hemisphere** is the categorical hemisphere and it functions in categorization and symbolization.
  - contains Wernicke's area and the motor speech area
  - specialized for language abilities
  - important in performing sequential and analytical reasoning tasks (science and mathematics)
  - appears to direct or partition information into smaller fragments for analysis
- Speech-dominant hemisphere.
  - controls speech in almost all right-handed people as well as in many left-handed ones

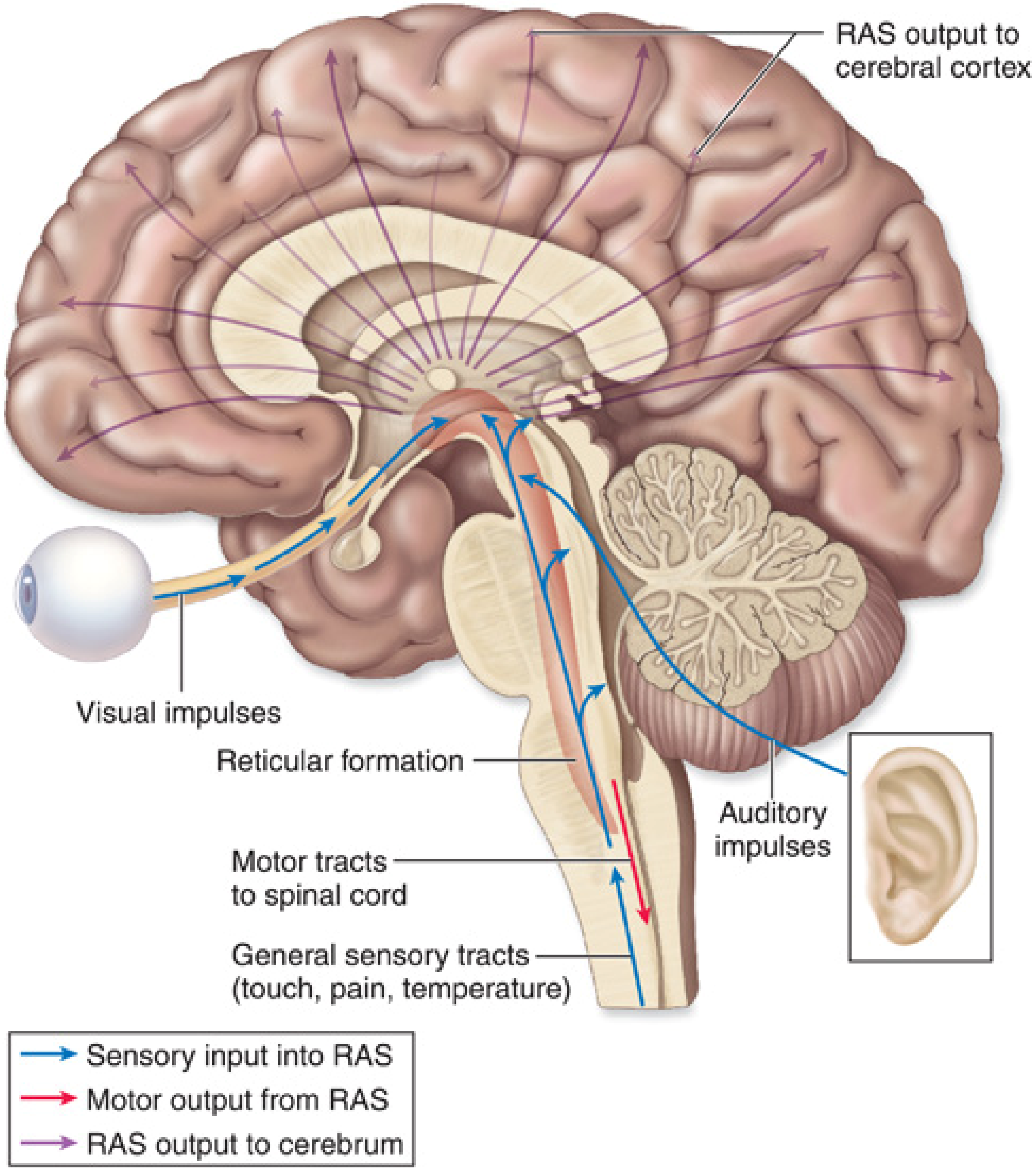
Cerebral Lateralization

- **Right hemisphere** is called the representational hemisphere.
  - concerned with visuospatial relationships and analyses
  - the seat of imagination and insight, musical and artistic skill, perception of patterns and spatial relationships, and comparison of sights, sounds, smells, and tastes
- Both cerebral hemispheres remain in constant communication through commissures, especially the corpus callosum, which contains hundreds of millions of axons that project between the hemispheres.

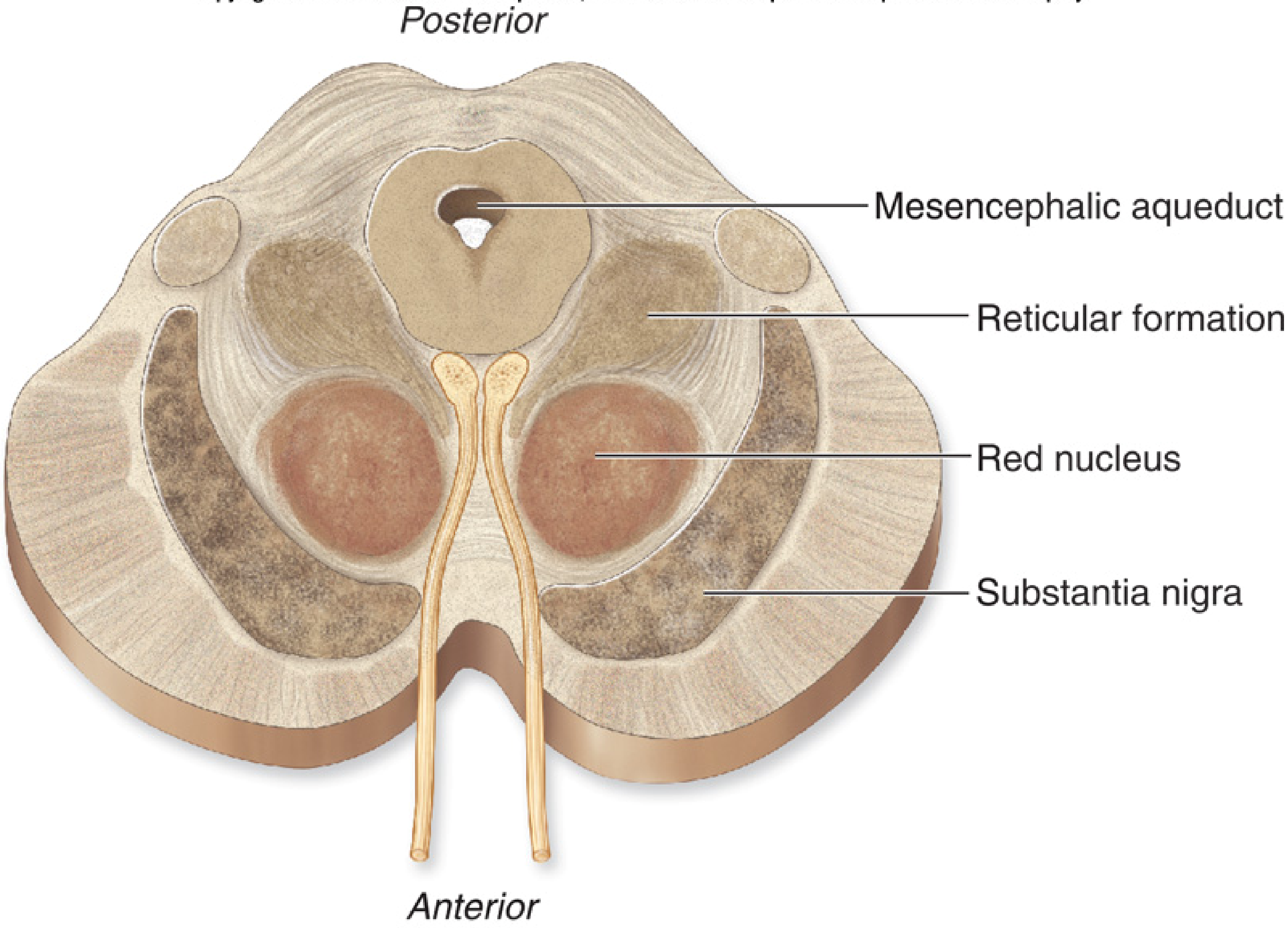


Left eye
Right eye
Left visual field
Right visual field
Left visual field
Right visual field
Left hand
Right hand
Verbal memory
Speech (motor speech area)
Left hemisphere (categorical hemisphere)
Right hand motor control
Feeling shapes with right hand
Rational thought
Superior language and mathematic comprehension (general interpretive area)
Right visual field
Memory for shapes (limited language comprehension)
Corpus callosum
Right hemisphere (representational hemisphere)
Left hand motor control
Feeling shapes with left hand
Musical ability
Intuitive, nonverbal thought
Precognition of faces and spatial relationships
Left visual field
Primary visual cortex


Practice
Sensory input from environment
Sensory memory
Deliver
Short-term memory
Deliver
Regain, return
Long-term memory
Fail to remember
Fail to remember



(a) Reticular formation



(b) Mesencephalon