Neurophysiology

Control of body movements

Fatima Ryalat, MD, PhD

Motor cortex

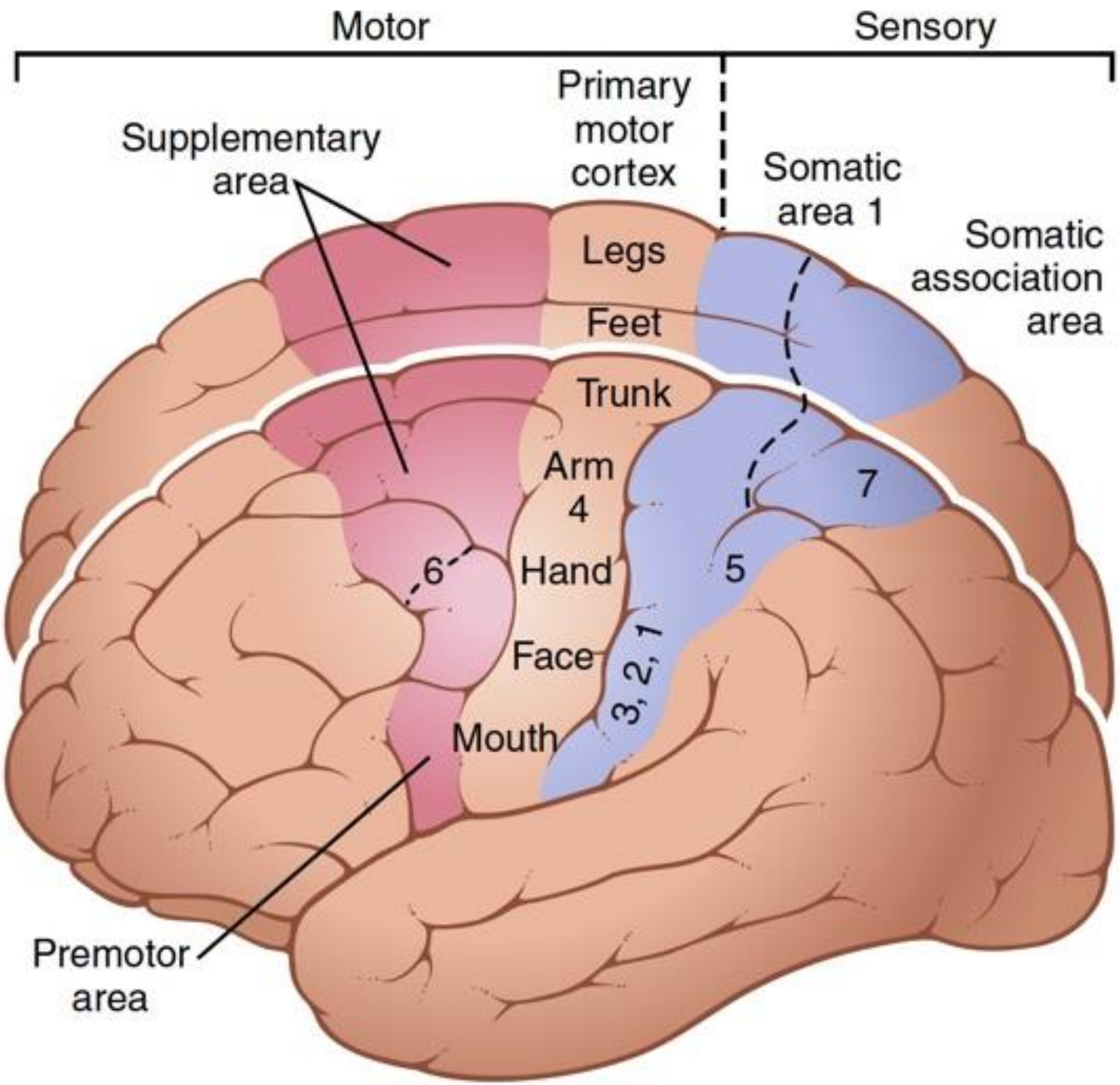
- Most voluntary movements initiated by the cerebral cortex are achieved when the cortex activates patterns of function stored in lower brain areas: the cord, brain stem, basal ganglia, and cerebellum.

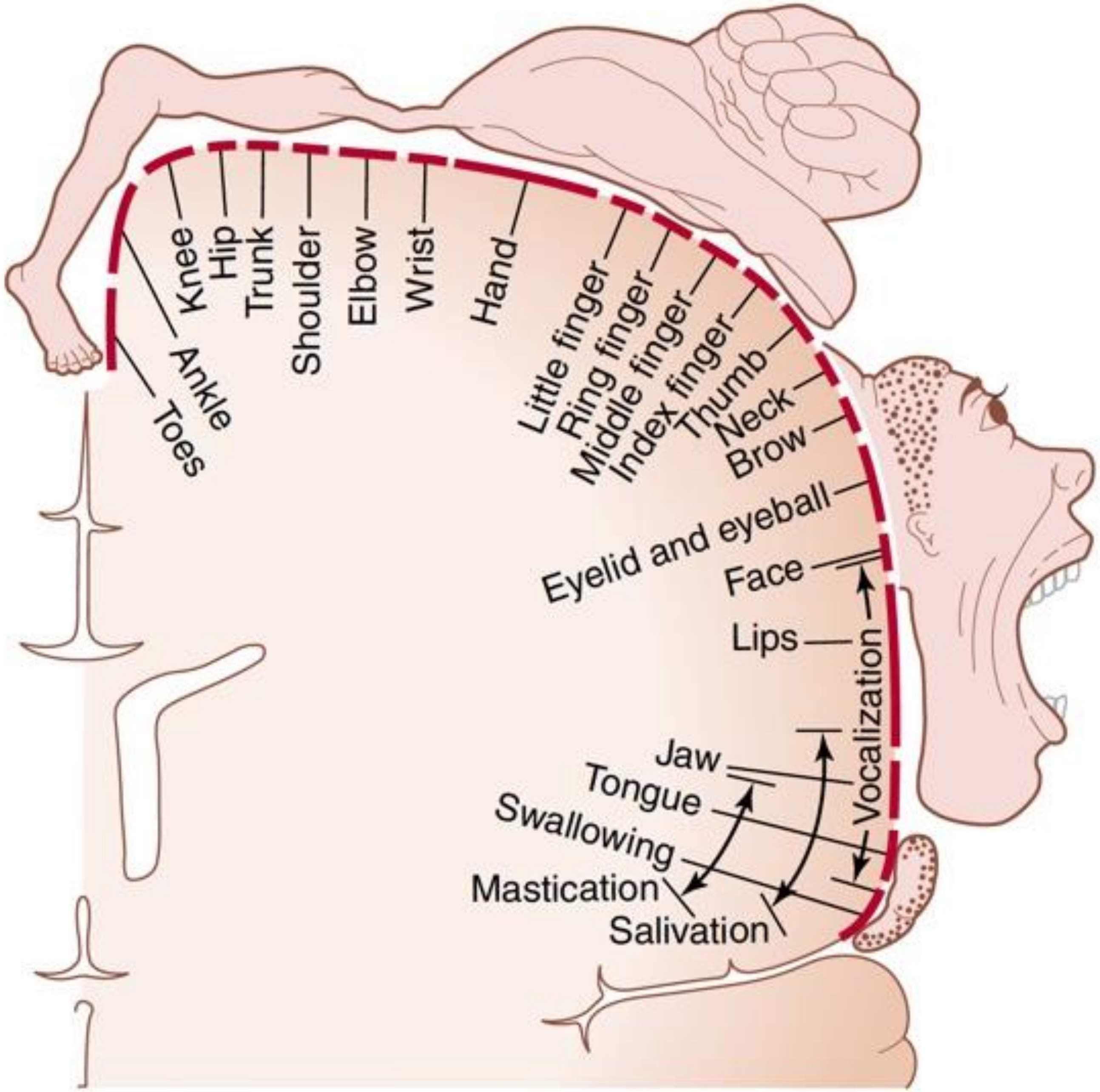
- These lower centers, in turn, send specific control signals to the muscles.

Motor cortex

- For a few types of movements, however, the cortex has almost a direct pathway to the anterior motor neurons of the cord, bypassing some motor centers on the way.

- This is especially true for control of the fine dexterous movements of the fingers and hands.


Motor
Sensory
Primary motor cortex
Supplementary area
Somatic area 1
Somatic association area
Legs
Feet
Trunk
Arm
4
Hand
Face
Mouth
6
3, 2, 1
5
7
Premotor area



Toes
Ankle
Knee
Hip
Trunk
Shoulder
Elbow
Wrist
Hand
Little finger
Ring finger
Middle finger
Index finger
Thumb
Neck
Brow
Eyelid and eyeball
Face
Lips
Vocalization
Jaw
Tongue
Swallowing
Mastication
Salivation

Primary motor cortex

- more than half of the entire primary motor cortex is concerned with controlling the muscles of the hands and the muscles of speech.

- excitation of a single motor cortex neuron usually excites a specific movement rather than one specific muscle.

Premotor area

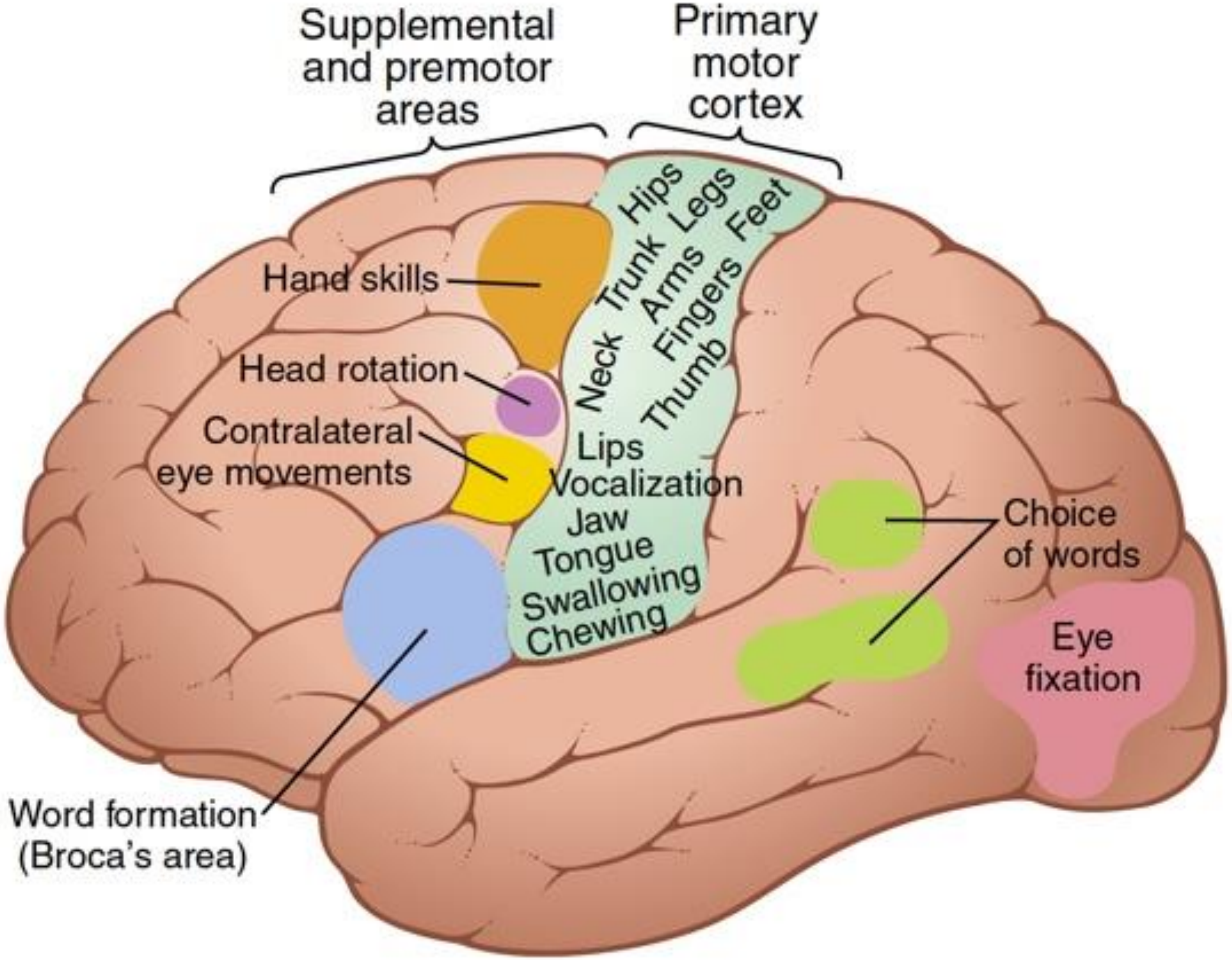
- The most anterior part of the premotor area first develops a “motor image” of the total muscle movement that is to be performed.
- Then, in the posterior premotor cortex, this image excites each successive pattern of muscle activity required to achieve the image.
- it sends signals either directly to the primary motor cortex or to the basal ganglia and thalamus back to the primary motor cortex.

Premotor area

- A special class of neurons called **mirror neurons** becomes active when a person performs a specific motor task or when he or she observes the same task performed by others.
- Thus, the activity of these neurons “mirrors” the behavior of another person as though the observer was performing the specific motor task.
- important for understanding the actions of other people and for learning new skills by imitation.

Supplementary area

- Contractions elicited by stimulating this area are often bilateral rather than unilateral.
- In general, this area functions in concert with the premotor area to provide body-wide attitudinal movements, fixation movements of the different segments of the body, positional movements of the head and eyes, and so forth, as background for the finer motor control of the arms and hands by the premotor area and primary motor cortex.



Supplemental and premotor areas
Primary motor cortex
Hips
Legs
Feet
Trunk
Arms
Fingers
Neck
Thumb
Lips
Vocalization
Jaw
Tongue
Swallowing
Chewing
Hand skills
Head rotation
Contralateral eye movements
Choice of words
Eye fixation
Word formation (Broca's area)

Broca's

- Damage to it does not prevent a person from vocalizing but makes it impossible for the person to speak whole words.
- A closely associated cortical area also causes appropriate respiratory activation of the vocal cords that occur simultaneously with the movements of the mouth and tongue during speech.
- Thus, the premotor neuronal activities related to speech are highly complex.

Voluntary eye movement area

- Allows a person to voluntarily move the eyes toward different objects.
- When damaged, the eyes tend to lock involuntarily onto specific objects, an effect controlled by signals from the occipital visual cortex.
- This area also controls eyelid movements such as blinking.

Head rotation area

- This area is closely associated with the eye movement field; it directs the head toward different objects.

Hand skills area

- destruction in this area causes hand movements to become uncoordinated and nonpurposeful, a condition called motor apraxia.

Columns in motor cortex

- Each column of cells functions as a unit, usually stimulating a group of synergistic muscles, or just a single muscle.
- Also, each column has six distinct layers of cells, as is true throughout nearly all the cerebral cortex.
- The pyramidal cells that give rise to the corticospinal fibers all lie in the 5th layer.

Columns in motor cortex

- The neurons of each column operate as an integrative processing system, using information from multiple input sources to determine the output response from the column.
- In addition, each column can function as an amplifying system to stimulate large numbers of pyramidal fibers to the same muscle or to synergistic muscles simultaneously.
- This ability is important because stimulation of a single pyramidal cell seldom excites a muscle.

Dynamic vs static signals

- each column of cells excites two populations of **pyramidal cell neurons**, one called dynamic neurons and the other static neurons.
- The dynamic neurons are excited at a high rate for a short period at the beginning of a contraction, causing the initial **rapid development of force**.
- The static neurons then fire at a much slower rate, but they continue firing at this slow rate to **maintain the force of contraction** as long as the contraction is required.

Motor pathways

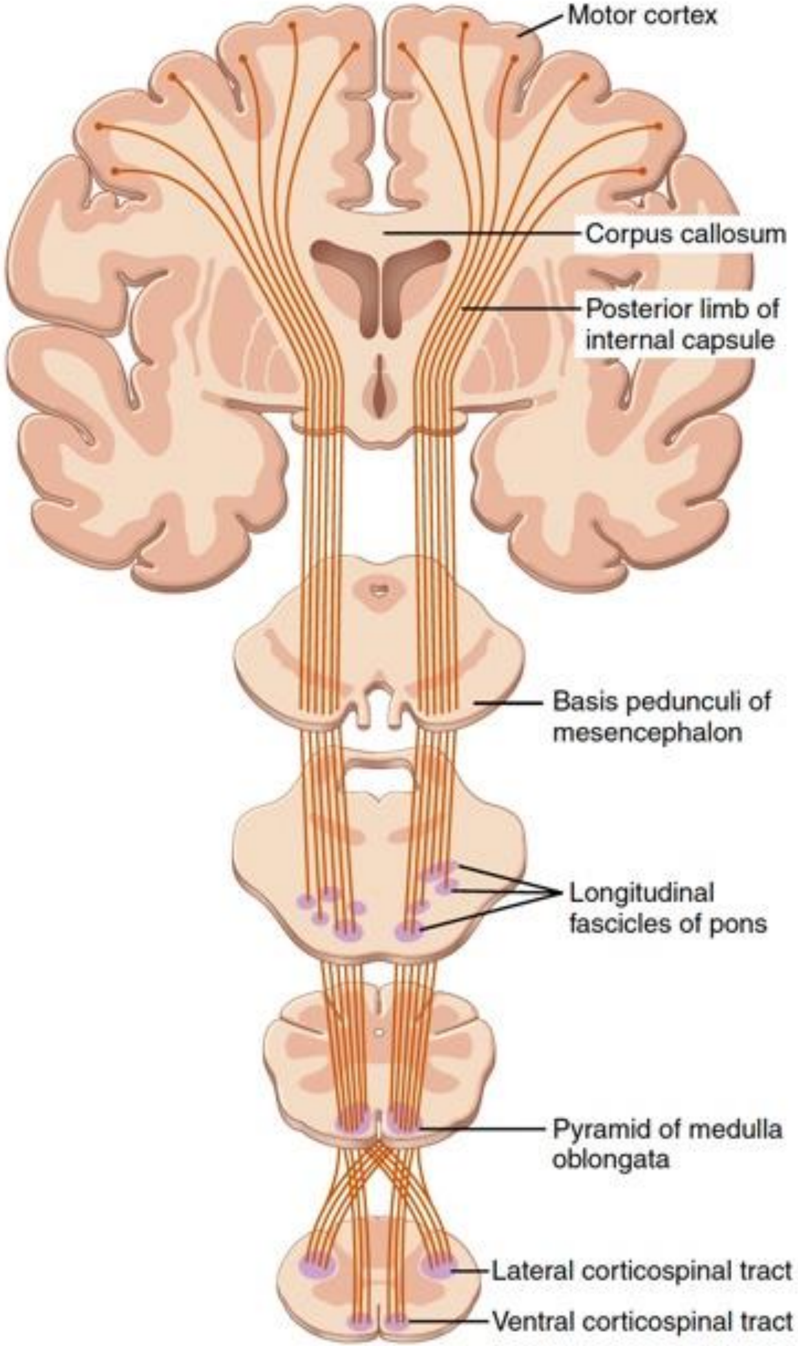
- Motor signals are transmitted directly from the cortex to the spinal cord through the corticospinal tract and indirectly through multiple accessory pathways that involve the basal ganglia, cerebellum, and various nuclei of the brain stem.

- In general, the direct pathways are concerned with discrete and detailed movements, especially of the distal segments of the limbs, particularly the hands and fingers.

Corticospinal tract

- The most important output pathway from the motor cortex is the corticospinal tract, also called the pyramidal tract.

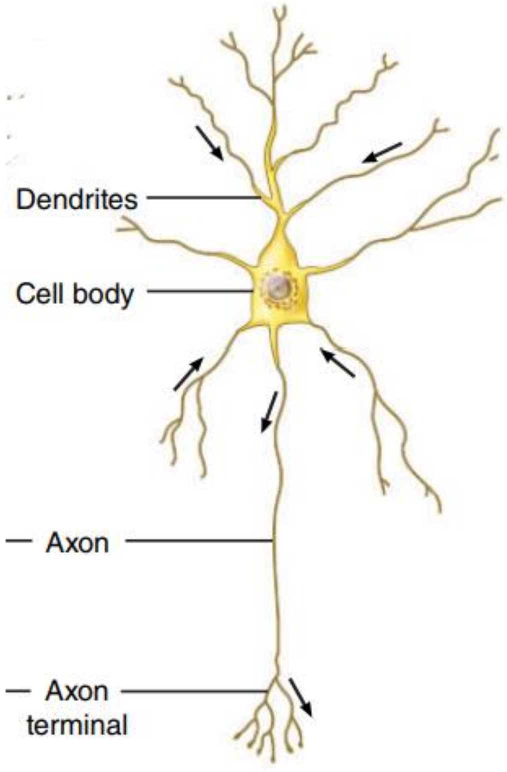
- Giant pyramidal cells, called **Betz cells**, have the most rapid rate of transmission of any signals from the brain to the cord.


Motor cortex
Corpus callosum
Posterior limb of internal capsule
Basis pedunculi of mesencephalon
Longitudinal fascicles of pons
Pyramid of medulla oblongata
Lateral corticospinal tract
Ventral corticospinal tract

Direct motor pathways, also known as the **pyramidal pathways**.

Pyramidal cells are upper motor neurons that have pyramid-shaped cell bodies. They are the main output cells of the cerebral cortex.

The direct motor pathways consist of corticospinal pathways and the corticobulbar pathway



Pyramidal cell

Corticospinal pathways

- Axons of UMNs in the cerebral **c**ortex form the corticospinal tracts, which descend through the internal **c**apsule of the cerebrum and the **c**erebral **p**eduncle of the **m**idbrain.

- In the **m**edulla oblongata, the axon bundles of the corticospinal tracts form the ventral bulges known as the **p**yramids.

- About 90% of the corticospinal axons decussate to the contralateral side in the medulla oblongata and then descend into the spinal cord where they synapse with a local circuit neuron or a lower motor neuron.

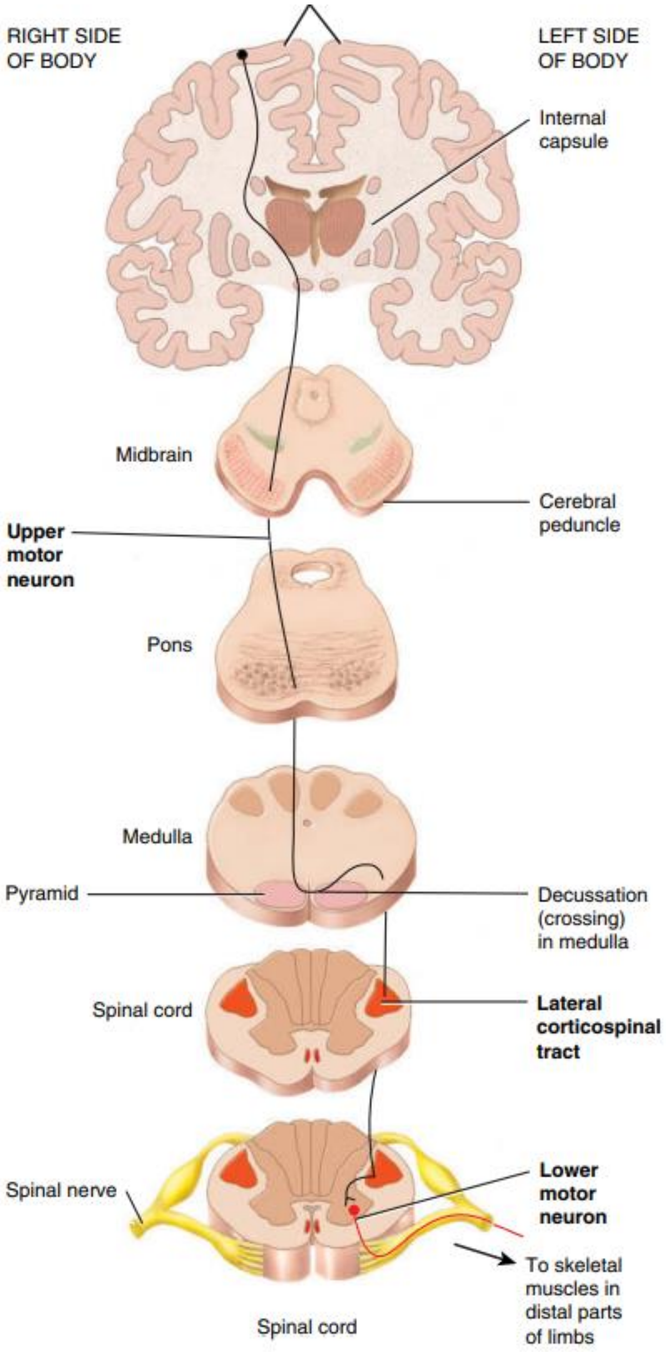
Corticospinal pathways

- The 10% that remain on the ipsilateral side eventually decussate at the spinal cord levels where they synapse with a local circuit neuron or lower motor neuron.
- Thus, the right cerebral cortex controls most of the muscles on the left side of the body, and the left cerebral cortex controls most of the muscles on the right side of the body.
- There are two types of corticospinal tracts: the lateral corticospinal tract and the anterior corticospinal tract

Lateral corticospinal tract

- Corticospinal axons that decussate in the medulla form the lateral corticospinal tract in the lateral white column of the spinal cord.
- These axons synapse with local circuit neurons or lower motor neurons in the anterior gray horn of the spinal cord.
- Axons of these lower motor neurons exit the cord in the anterior roots of spinal nerves and terminate in skeletal muscles that control movements of the **distal parts of the limbs**.
- The distal muscles are responsible for precise, agile, and highly skilled movements of the hands and feet.

Lateral corticospinal tract



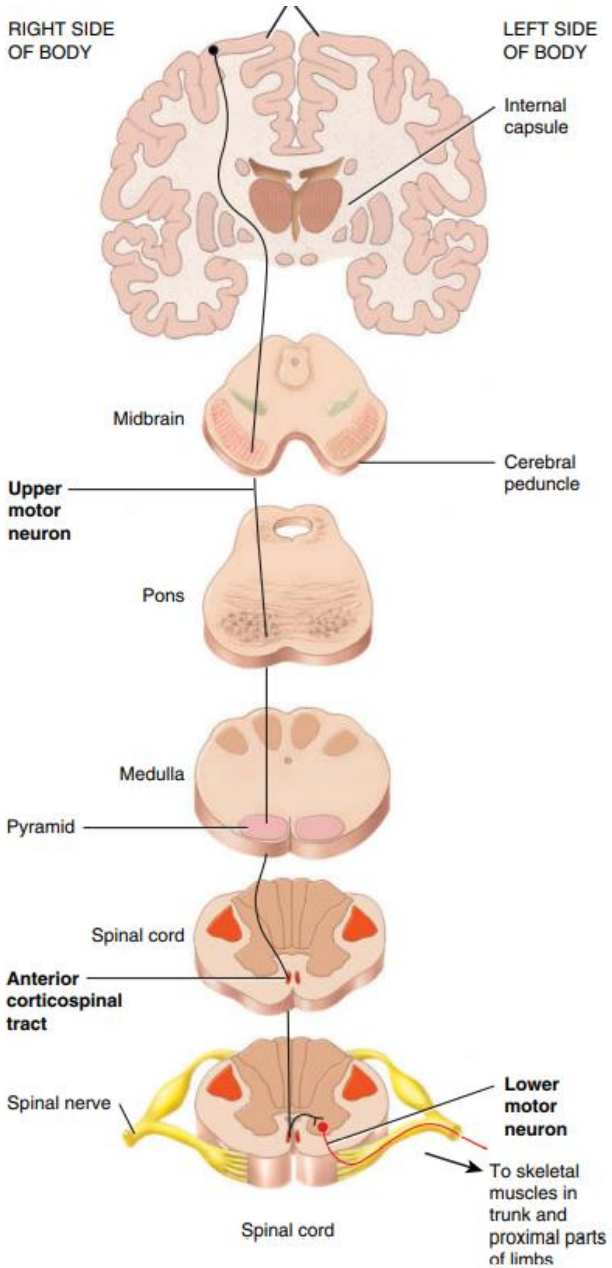
Anterior corticospinal tract

- Corticospinal axons that do not decussate in the medulla form the anterior corticospinal tract in the anterior white column of the spinal cord.

- At each spinal cord level, some of these axons decussate via the anterior white commissure. Then, they synapse with local circuit neurons or lower motor neurons in the anterior gray horn.

- Axons of these lower motor neurons exit the cord in the anterior roots of spinal nerves. They terminate in skeletal muscles that control movements of the **trunk and proximal parts of the limbs**

Anterior corticospinal tract



Corticobulbar tract

- Conducts impulses for the control of skeletal muscles in the head.

- Axons of upper motor neurons from the cerebral cortex form the corticobulbar tract, which descends along with the corticospinal tracts through the internal capsule of the cerebrum and cerebral peduncle of the midbrain.

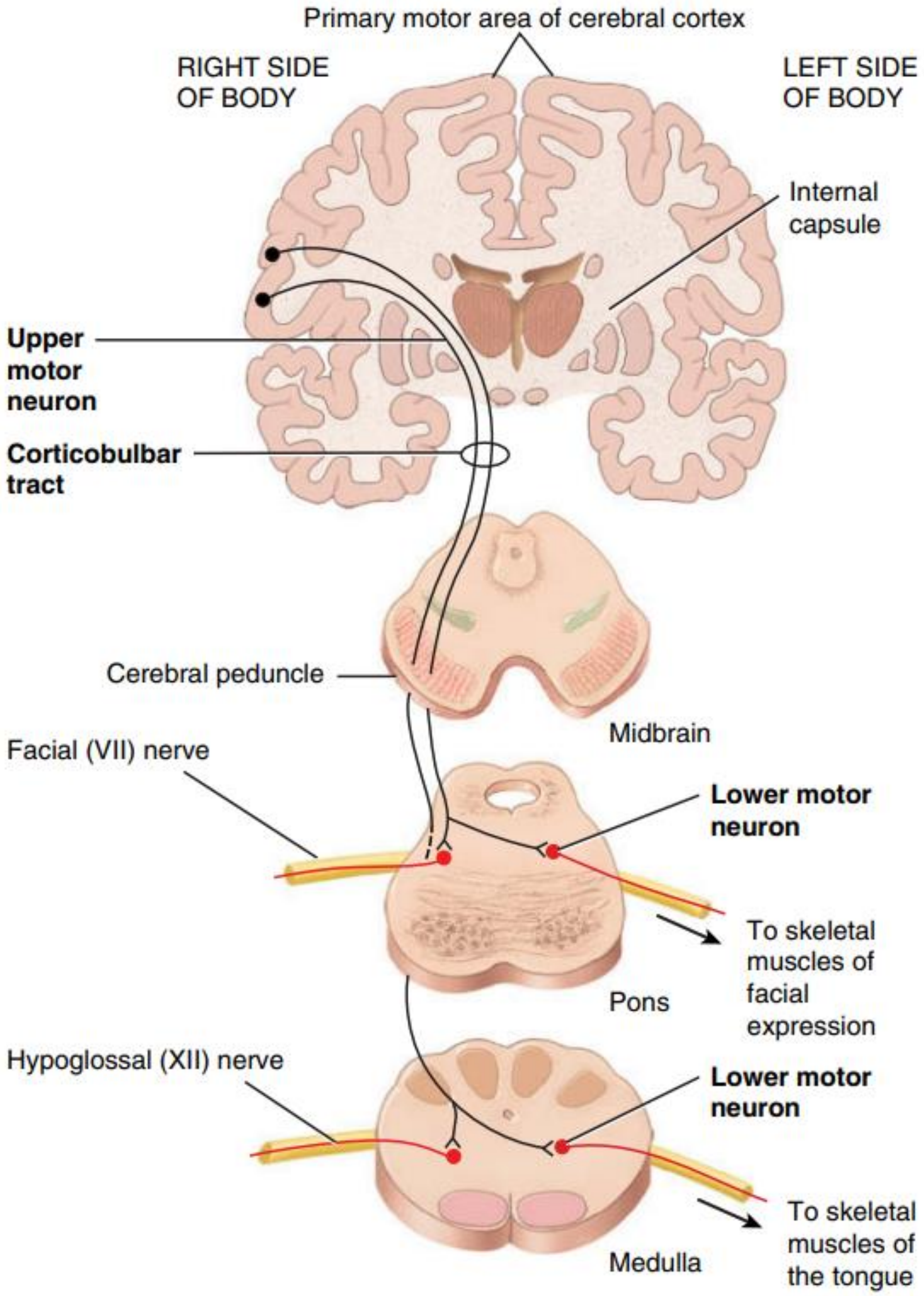
- **Some** of the axons of the corticobulbar tract decussate; others do not.

Corticobulbar tract

- The axons terminate in the motor nuclei of 9 pairs of cranial nerves in the brain stem: the oculomotor (III), trochlear (IV), trigeminal (V), abducens (VI), facial (VII), glossopharyngeal (IX), vagus (X), accessory (XI), and hypoglossal (XII).

- The lower motor neurons of the cranial nerves convey impulses that control precise, voluntary movements of the eyes, tongue, and neck, plus chewing, facial expression, speech, and swallowing.

Corticobulbar tract



Other pathways from motor cortex

- The motor cortex gives rise to large numbers of additional, mainly small fibers that go to deep regions in the cerebrum and brain stem.

Incoming sensory pathways to motor cortex

- The functions of the motor cortex are controlled mainly by nerve signals from the sensory system.

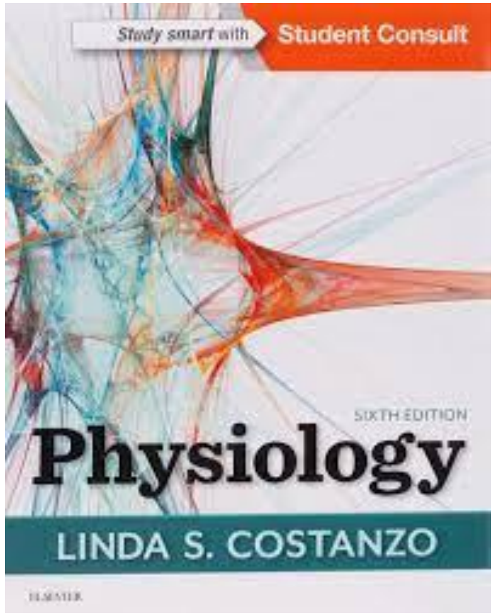
- Once the sensory information is received, the motor cortex operates in association with the basal ganglia and cerebellum to excite appropriate motor actions.

Incoming sensory pathways to motor cortex

- The most important incoming fiber pathways to the motor cortex are:

- fibers from adjacent regions of the cerebral cortex.
- fibers that arrive through the corpus callosum from the opposite cerebral hemisphere.
- Fibers from different thalamic nuclei.

References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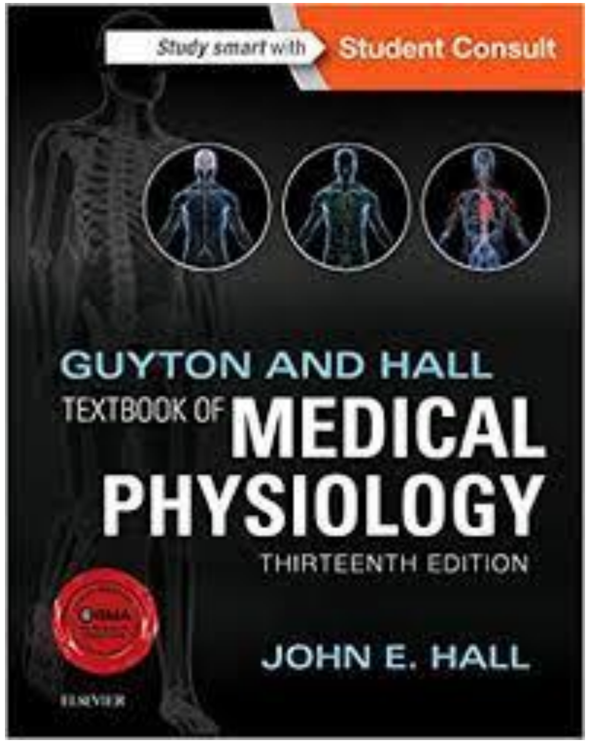
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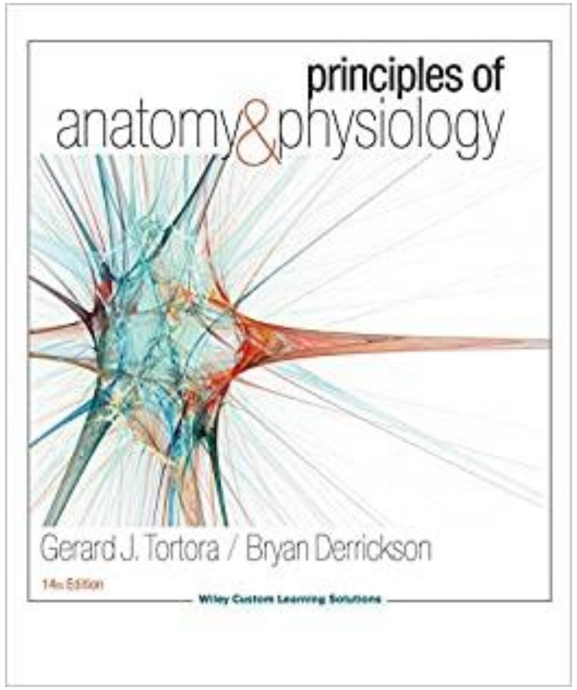
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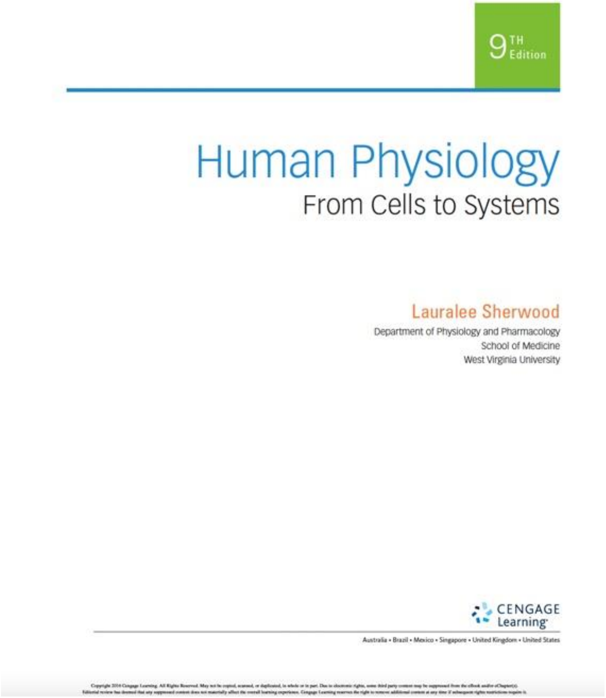
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