



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

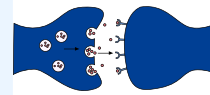


# Cerebral Cortex Function

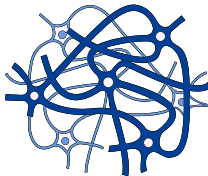
FINAL | Lecture 6

﴿إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ مَا مِنْ دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا إِنَّ رَبِّي عَلَى صِرَاطٍ مُسْتَقِيمٍ﴾

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# Cortical Control of Motor Function

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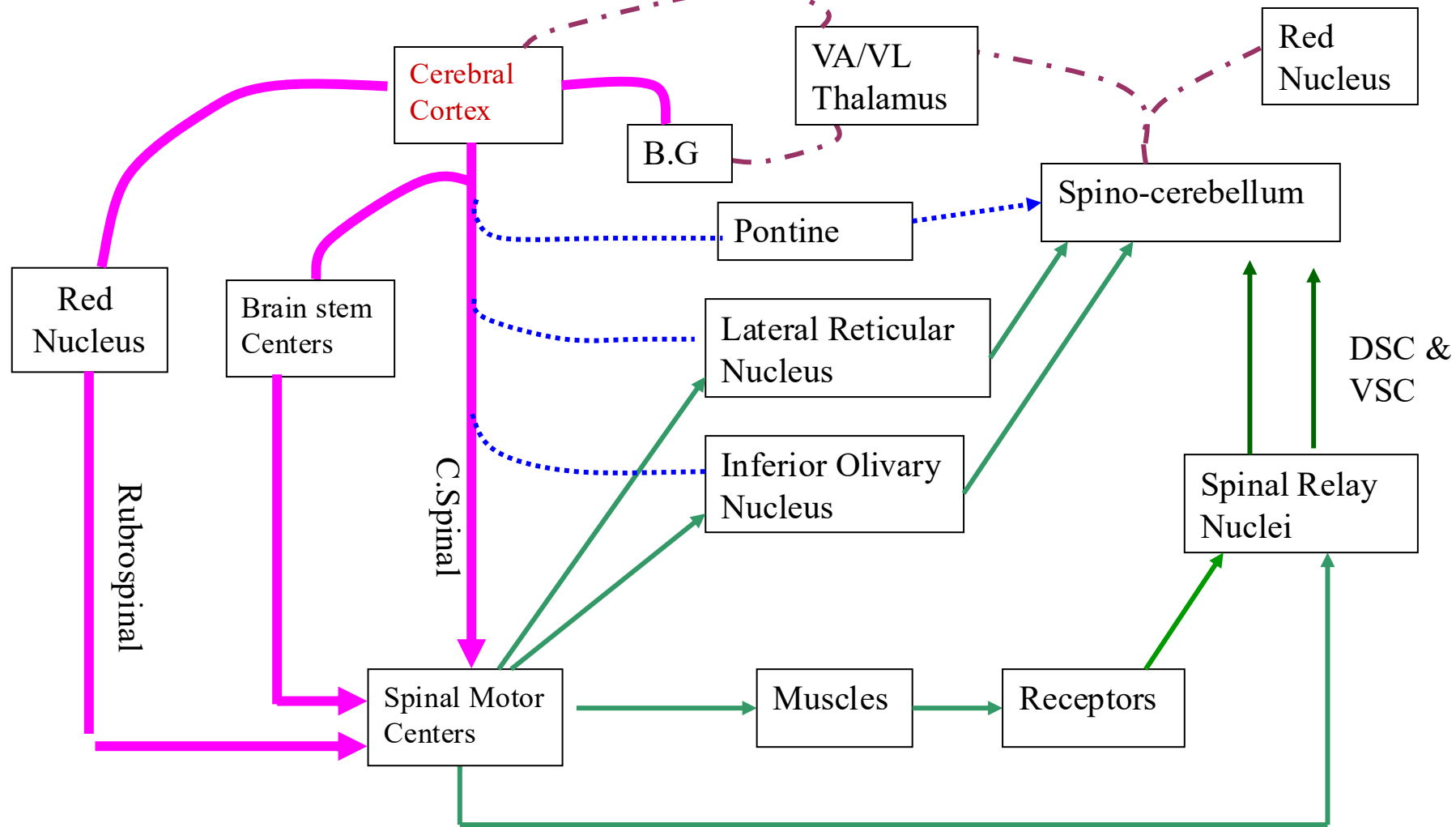
# Objectives





- Recognize cerebral cortical motor areas
- Delineate the cortical control of the corticospinal pathways This is the main one that comes from the cerebral cortex and interpret some of cortical abnormalities
- Interpret some of the cortical abnormalities

# Recap of previous lectures

In the previous lectures, we discussed the motor functions of the spinal cord, brainstem, cerebellum and basal ganglia. Today, we will cover the cerebral cortex, which is the highest level of motor control.

- First, we reviewed the **spinal cord** and the **feedback** from muscle spindles and Golgi tendon organs. This **sensory** information is sent to the cerebellum to inform it about **actual movements**, specifically, how muscle length and tension are changing.
- At the same time, the cerebellum receives input from the cerebral cortex via the **corticopontocerebellar pathway**, which conveys information about the **intended movement**. Using additional input from the **inferior olive**, the cerebellum **compares** the actual movement with the intended movement. It then sends corrective signals to the cerebral cortex via the **ventral anterior (VA)** and **ventral lateral (VL)** nuclei of the thalamus, which are the motor nuclei of the thalamus.
- Next, we covered the brainstem and its descending pathways, including the **reticulospinal and vestibulospinal tracts**. We also noted that the **red nucleus** receives input from the cerebral cortex.
- Finally, we discussed the **basal ganglia**, which are involved in the **patterns of movement**. So, in this lecture we going to dig deeper into the role of the cerebral cortex



-  Motor Command
-  Feed Back
-  Command Monitor
-  Corrective Command

**Motor System**

# Motor Cortex

- Divided into 3 sub areas:

## ❖ Primary motor cortex

- Located in the **precentral gyrus**
- unequal topographic representation, the area of cortex representing any body part is proportional to the number of **motor units** in that area. (Remember: representation of body parts in the primary sensory cortex is proportional to the number of **receptors**).
- fine motor movement elicited by stimulation
- Stimulating the primary motor cortex typically results in contraction of a **single muscle fiber**, not a purposeful movement. **Purposeful movement** requires sequential contraction of different areas within the primary cortex.

## ❖ Premotor area

- Located anterior to the primary motor area
- topographical organization similar to primary motor cortex
- Contains programs for movement (go to slide 10) . Stimulation of this area sends input to different parts of the primary motor area, resulting in **sequential contractions** of different muscles, thereby producing a **purposeful movement**.
- stimulation results in movement of muscle groups to perform a specific task
- works in concert with other motor areas

# Motor Cortex (Cont.)

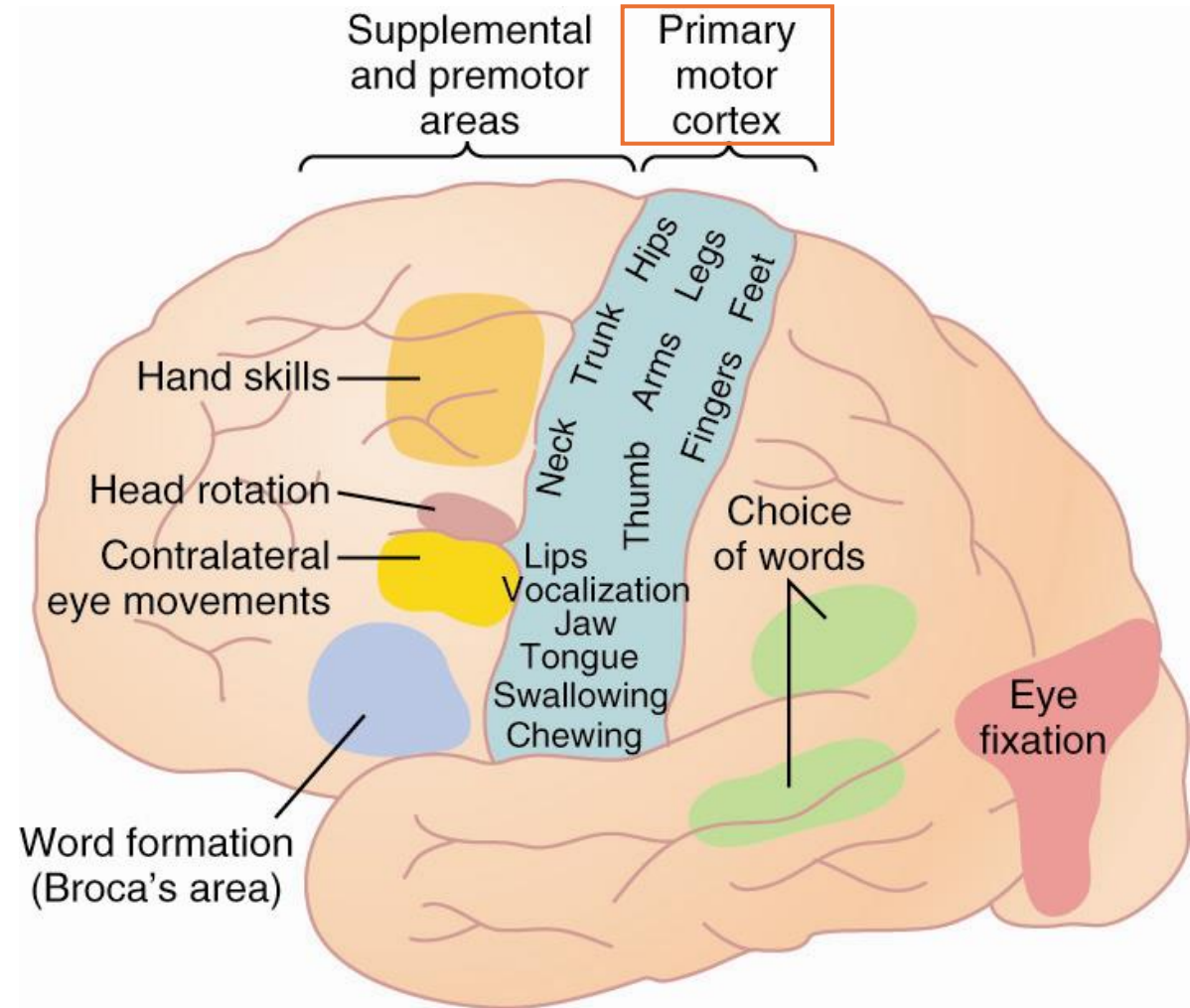
## ❖ Supplemental motor area

- located anterior to the primary motor area, on the superior part of the cerebral cortex.
- topographically organized
- simulation often elicits bilateral movements.
- functions in concert with premotor area to provide attitudinal, fixation or positional movement for the body (This area is involved in stabilizing or fixing other body parts to ensure smooth execution of a movements like writing).
- it provides the background for fine motor control of the arms and hands by premotor and primary motor cortex

# Motor Areas of the Cortex

## Primary Motor Cortex:

- Body representation is **contralateral**: the right cortex controls the left side and vice versa.
- Representation is **upside down** (motor homunculus): legs represented superiorly, head inferiorly.
- The cortical area for each body part is **proportional to the number of motor units**, not the size of the part. (Recall for the  $10^9$  time : sensory areas are proportional to the number of receptors)
- Stimulation results in contraction of a **single muscle fiber**, which does not produce a purposeful movement.

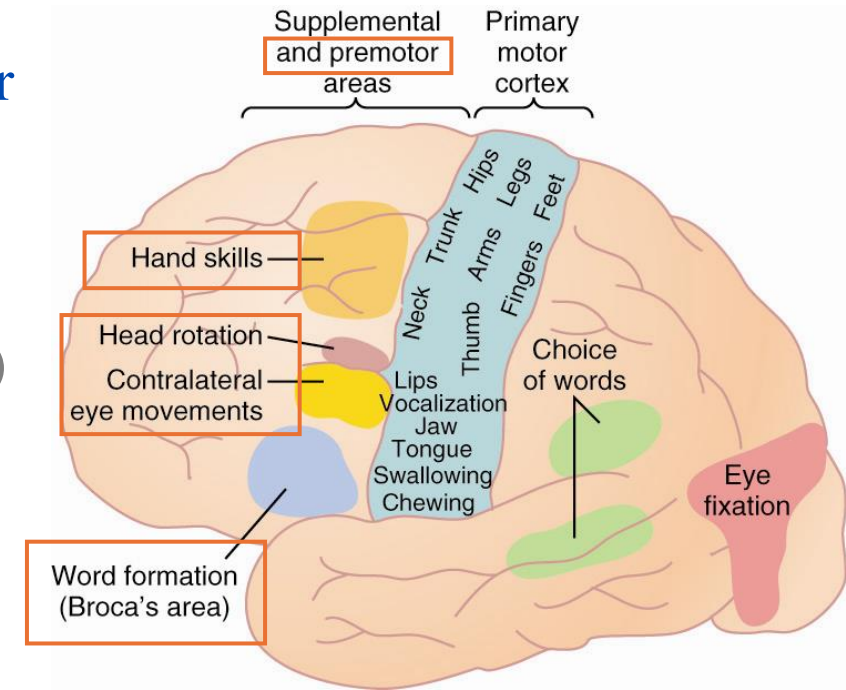


More details in the next slide

# Motor Areas of the Cortex

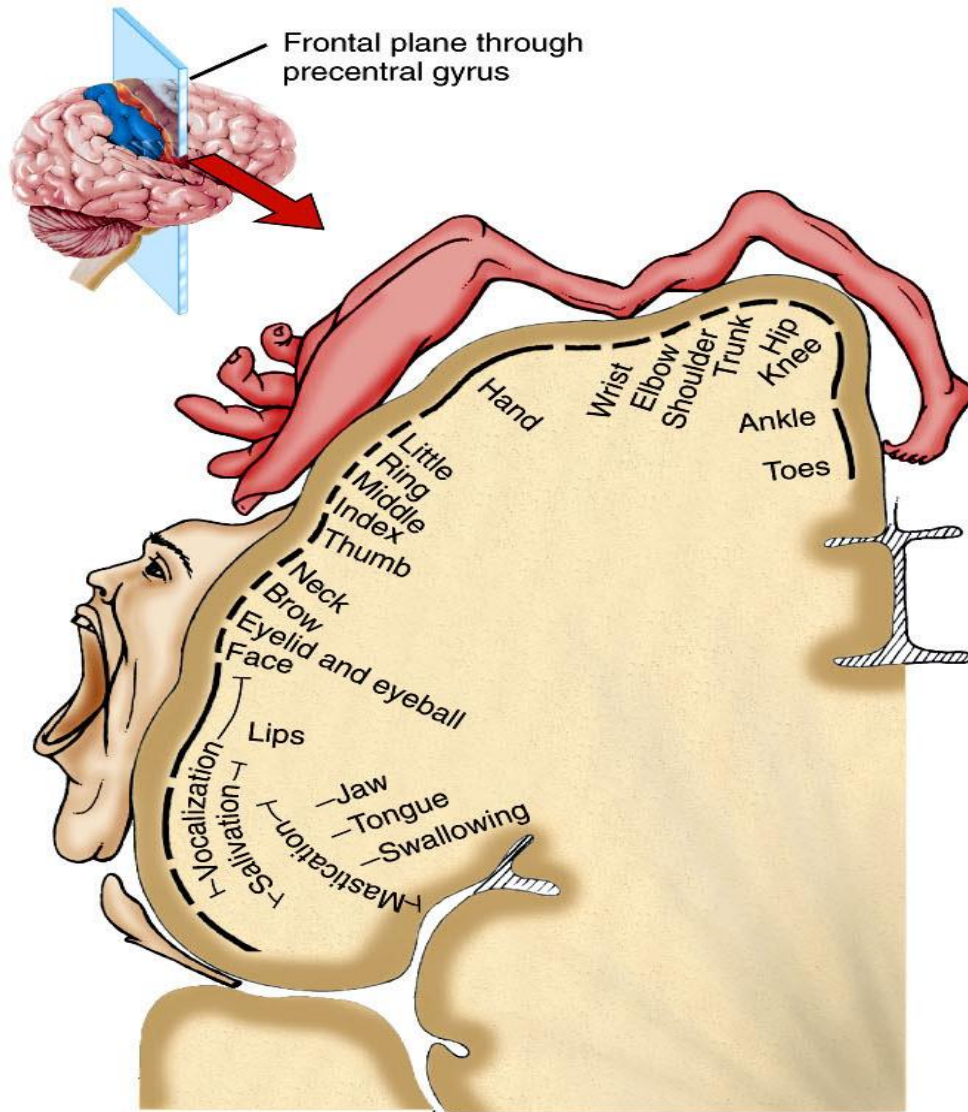
## Premotor Area:

- Contains **programs for movement**.
- The lowermost part is **Broca's area** (motor speech area), responsible for word formation.
- Broca's area is located at the same level as the representations for tongue, vocalization, and jaw in the primary motor cortex.
- When this area is stimulated, the program for talking sends information to the primary motor cortex to execute speech.
- Other regions in this area contain programs for: (to be discussed)
  - Contralateral voluntary eye movements (above Broca's area)
  - Head rotation
  - Hand skills (e.g., writing, typing)
  - Lower limb movements
- Stimulation here leads to **purposeful movements** by activating sequential contractions of different muscles via the primary motor cortex, unlike stimulation of the primary cortex itself.



Broca's area is named after the scientist who named it first

# Functional organization of the primary Motor Cortex



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

Figure 16.08 Tortora - PAP 12/e  
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- Located in the precentral gyrus of the frontal lobe.
- More cortical area is devoted to those muscles involved in skilled, complex or delicate movements, that have more motor units i.e the cortical representation is proportional to the No. of motor units
- The thumb is represented by a large area on the motor cortex because it is used for many functions such as writing and eating, reflecting its high number of motor units.
- The lips similarly have a large cortical representation due to their extensive use.
- The functional importance of the thumb is so significant that a life insurance company may pay 50% of the policy if a person loses their thumb.

# Specialized Areas of the Motor Cortex

- **Broca's area**
  - damage causes decreased speech capability.
  - **Aphasia** refers to the inability to speak; the type associated with Broca's area is called **motor aphasia** or **expressive aphasia**.
  - In this condition, the individual has the **ideas** (which are formed in **Wernicke's area**), but they are unable to express themselves
  - closely associated area controls appropriate respiratory function for speech
- **Eye fixation and head rotation area**
  - for coordinated head and eye movements
- **Hand skills area**
  - damage causes **motor apraxia** the inability to perform fine hand movements (write, type)

# Transmission of Cortical Motor Signals

- **Direct pathway**
  - corticospinal tract
  - for discrete detailed movement of **distal muscles**
- **Indirect pathway**
  - signals to basal ganglia, cerebellum, and brainstem nuclei
  - **control of antigravity muscles / extensors**

More details in the following slides...

# Corticospinal Fibers

- 34,000 **Betz cell** (which are **large** neurons located in the primary motor cortex) fibers, make up only about **3%** of the total number of fibers.
- **97%** of the 1 million fibers are **small** diameter fibers
  - conduct background tonic signals
  - feedback signals from the cortex to control intensity of the various sensory signals to the brain
  - smaller cortical neurons send corticofugal fibers that carry feedback signals—such as those from the vestibular system—to help adjust the sensitivity and responsiveness of motor and sensory pathways.

# Corticospinal pathways

The **corticospinal tract** originates in the **motor cortex** and descends through the **posterior limb of the internal capsule** (the anterior limb mainly carries sensory fibers, while the genu contains corticobulbar fibers).

From the internal capsule, the fibers continue downward to the **medulla oblongata**, where most fibers **decussate (cross over)** at the **pyramids**: fibers from the **left motor cortex cross to form the right lateral corticospinal tract**, and fibers from the **right cortex cross to the left**.

The **majority** of fibers form the **lateral corticospinal tract**, while a smaller portion does **not** decussate at the medulla. These fibers descend in the **anterior column** of the **spinal cord** as the **anterior corticospinal tract**, crossing over later at the spinal level to innervate their target muscles.

Because the **pyramids** are the main site of decussation, **damage to the medulla** can disrupt this crossing and affect motor function.

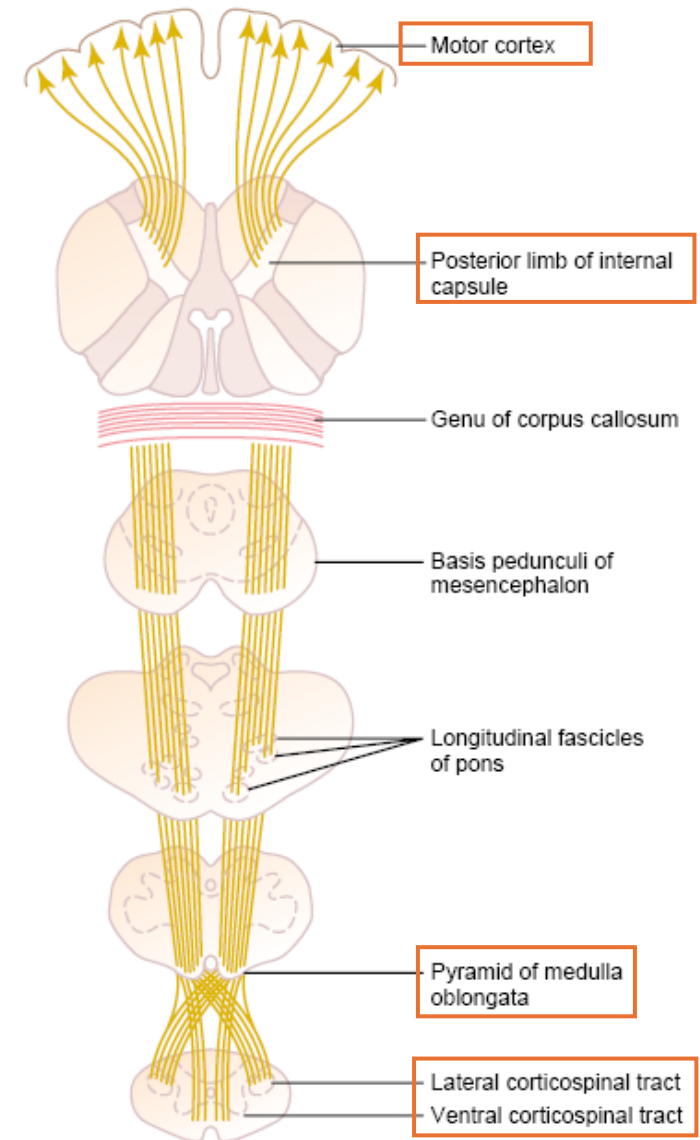


Figure 55-4

Pyramidal tract. (Modified from Ranson SW, Clark SL: Anatomy of the Nervous System. Philadelphia: WB Saunders, 1959.)

# Other Pathways from the Motor Cortex

- **Betz collaterals** back to cortex sharpen the boundaries of the excitatory signal
- **Fibers to caudate nucleus and putamen** of the basal ganglia. They are called **corticostriatal** fibers, because the caudate and putamen together form the **striatum**.
- **Fibers to the red nucleus** which are called **corticorubral** fibers, which then sends axons to the cord in the **rubrospinal** tract, which—together with the lateral corticospinal tract—facilitates flexor muscles and inhibits extensor muscles. For this reason, they are collectively referred to as the **lateral system pathways**.
- **Reticular substance, vestibular nuclei and pons** then to the **cerebellum**. Cortical fibers project to the reticular formation through pathways such as **corticoreticular and corticomedullary** fibers.
- When the cortex stimulates the **medullary reticular formation**, it exerts an inhibitory effect on the **pontine reticulospinal tract**, which is **intrinsically active** and therefore needs to be checked by the medullary.
- If this cortical–medullary reticular connection is **disrupted**, the **inhibitory** control is **lost**. As a result, the pontine reticulospinal tract becomes **overactive**, leading to **excessive extensor activity** and the development of **decerebrate rigidity**.
- Therefore the basal ganglia, brain stem and cerebellum receive a large number of signals from the cortex.

# Incoming Sensory Pathways to Motor Cortex

1. **Subcortical fibers** from adjacent areas of the cortex especially from **somatic sensory areas** of parietal cortex and **visual** and **auditory** cortex in a process called **sensorimotor integration**, which is the **coordination** between **sensory** inputs and **motor** outputs.
2. **Subcortical fibers** from **opposite hemisphere** to control the movement, which pass through *corpus callosum* ( the main fiber bundle connecting the two cerebral hemispheres. In addition to the corpus callosum, there are other **commissural fibers**, including the **anterior commissure** and **posterior commissure**, which also provide inter-hemispheric connections, though on a smaller scale.)
3. **Somatic sensory fibers** from **ventrobasal** complex of the **thalamus** (i.e., cutaneous and proprioceptive fibers). **Also important for motor integration**

# Incoming Sensory Pathways to Motor Cortex (Cont.)

4. **Ventrolateral** and **ventroanterior** nuclei of thalamus for coordination of function between motor cortex, basal ganglia, and cerebellum.

The (VL) and (VA) thalamic nuclei receive corrective signals from the **cerebellum** and **basal ganglia**. They then relay these signals to the cerebral cortex.

5. Fibers from the **intralaminar nuclei** of thalamus (control level of excitability of the motor cortex), some of these may be pain fibers.

The intralaminar nuclei, particularly the **centromedian nucleus**, are connected with the basal ganglia. Signals from the basal ganglia project to these thalamic nuclei. In addition, the intralaminar nuclei are considered part of the sensory system, as they receive and process sensory information before relaying it to other brain regions.

# Sensory Feedback is Important for Motor Control

1. Feedback from muscle spindle, tactile receptors (located around the joints, and are called **Pacinian corpuscles**), and proprioceptors fine tunes muscle movement.
  - Length mismatch in spindle causes auto correction.
  - Sensory feedback is crucial for motor control. Signals from sensory receptors travel to the **cerebellum** via the **dorsal spinocerebellar tract**, allowing the cerebellum to monitor ongoing movements. The cerebellum then sends **corrective commands** back to the cortex through VA and VL.
2. Compression of skin provides sensory feedback (from sensory receptors around the joints) to motor cortex on degree of effectiveness of intended action.

# Excitation of Spinal Motor Neurons

- Motor neurons in cortex reside in **layer V**.
- Excitation of 50-100 giant pyramidal cells is needed to cause muscle contraction.
- Most corticospinal fibers synapse with **interneurons** which then synapses with **alpha motor neurons**.
- Some corticospinal and rubrospinal neurons synapse **directly** with alpha motor neurons (**final common pathway**) in the spinal cord especially in the **cervical** enlargement.
- These motor neurons innervate muscles of the fingers and hand.
- If a stimulus reaches a **motor neuron directly**, without involving an interneuron, the resulting movement tends to be **more precise**. This is because the signal goes straight to the target muscle without diversion. In contrast, when **interneurons** are involved, the impulse can be distributed to multiple pathways or neurons, which may **dissipate or modulate the signal, reducing** precision.

Recall : The cerebral cortex has **six layers**, organized from **deep (inner)** to **superficial (outer)**:  
✓ **Layer IV** is the **afferent layer**, where most incoming sensory signals from the thalamus terminate.  
✓ **Layers V and VI** are the **efferent layers**

# Motor system organization & final common pathway

Regarding motor system organization:

- **The lateral system pathways**—including the **medullary reticulospinal**, **rubrospinal**, and **lateral corticospinal tract**—are located in the lateral columns of the spinal cord. They are **excitatory** to **flexors** and **inhibitory** to **extensors**.
- **The medial system pathways**—including the **anterior corticospinal**, **vestibulospinal**, and **pontine reticulospinal tracts**—are located in the anterior columns. They are **excitatory** to **extensors** and **inhibitory** to **flexors**.

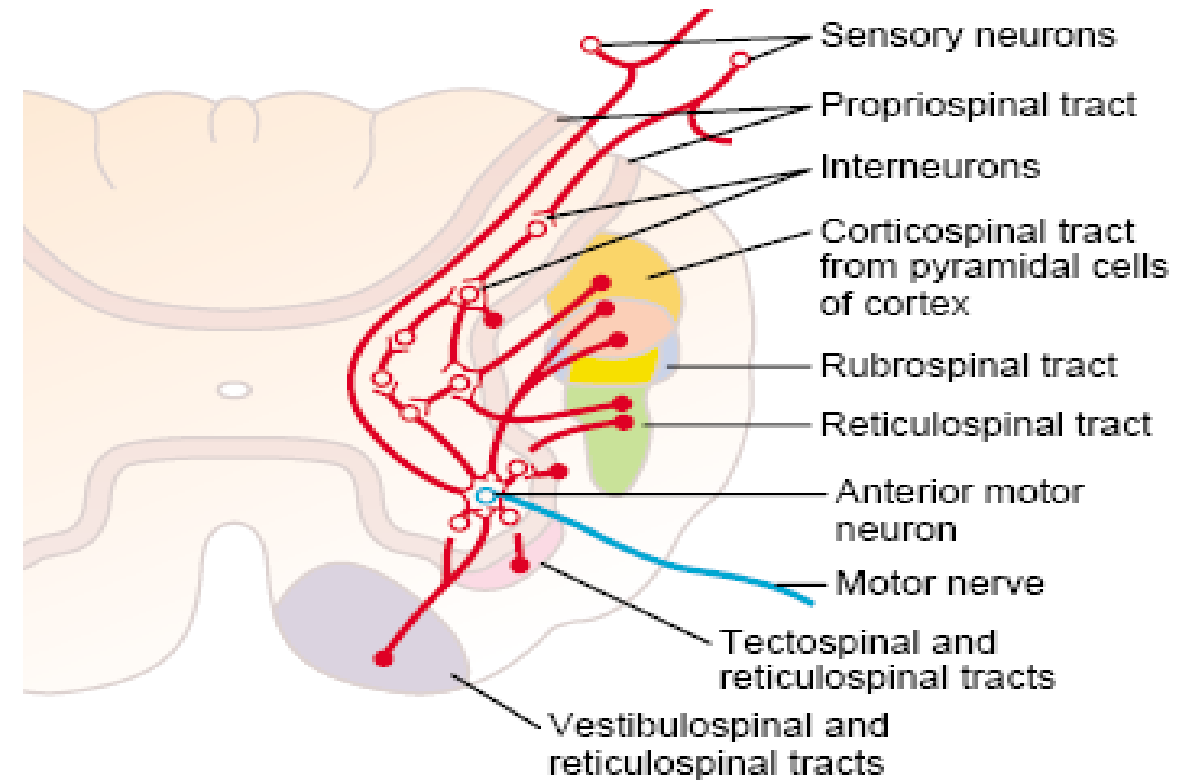


Figure 55-6

Convergence of different motor control pathways on the anterior motor neurons.

# Final Common Pathway

The **final common pathway** in the spinal cord primarily consists of **alpha motor neurons**. It receives input from multiple sources:

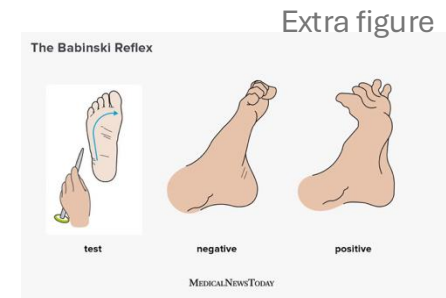
- **Interneurons** carrying signals from various fibers and tracts.
- **Corticospinal fibers**, which may synapse **directly** on alpha motor neurons or **indirectly** via interneurons.
- **Sensory neurons**, important for **reflexes**.
- **Propriospinal fibers**, connecting different spinal segments.
- **Reticulospinal and vestibulospinal fibers**, also projecting to alpha motor neurons.

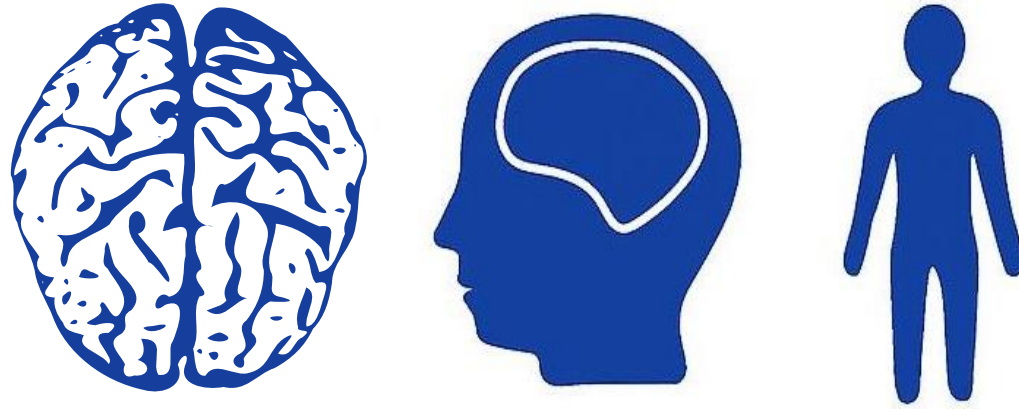
This final common pathway integrates all inputs, generating **excitatory and inhibitory postsynaptic potentials** (EPSPs and IPSPs). The alpha motor neurons produce **grand potentials**, which are also copied and sent to the **cerebellum** via the **ventral spinocerebellar tract**. Unlike other sensory tracts, this signal originates from the alpha motor neurons themselves, effectively providing the cerebellum with a copy of the motor command for monitoring and adjustment.

(Recall lecture 2)

# Lesions of the Motor Cortex

- **Primary motor cortex** - loss of voluntary control of discrete movement of the distal segments of the limbs.
- **Basal ganglia** - muscle spasticity from loss of inhibitory input from accessory areas of the cortex that inhibit excitatory brainstem motor nuclei.
- A lesion of the **corticospinal tract** results in upper motor neuron signs. One classic sign is a **positive Babinski reflex**: when the lateral aspect of the sole of the foot is stimulated from heel to toe, the big toe moves upward (**dorsiflexion**) and the other toes fan out.





**PHYSIOLOGY  
QUIZ  
LECTURE 6**

# External Resources

# رسالة من الفريق العلمي

Additional sources:

1. Guyton and Hall Textbook of Medical Physiology 14th Edition 697-702

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقه من فتنة القبر وعذاب النار، أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.



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