The Descending Motor Pathways

Required Reading: Blumenfeld Chapter 6, page 230 to 237, the Power Pointpresentation and these notes

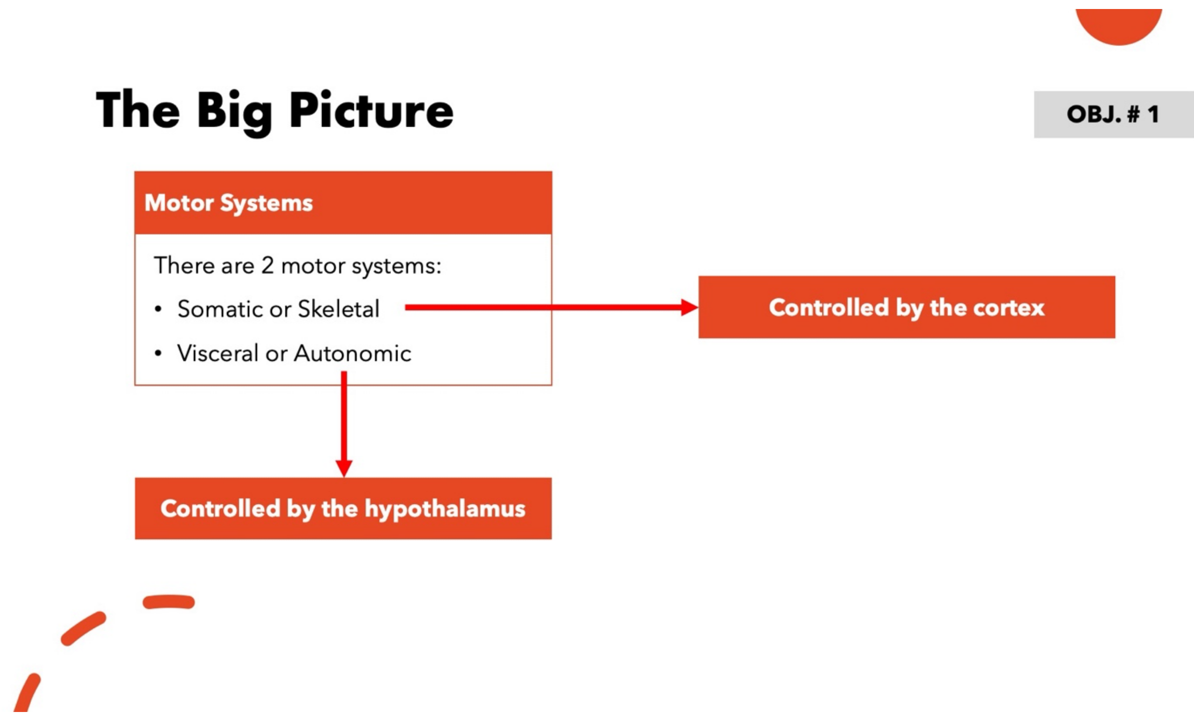
Learning Objectives: After this lecture students will be able to:

1. Explain the general organization of the motor systems.
2. Describe the names, function and trajectory, from origin to termination, of the descendingmotor pathways from the cerebral cortex to the spinal cord
3. Describe the names, function and trajectory, from origin to termination, of the descendingmotor pathways from the cerebral cortex to the brainstem
4. Name the fiber tracts from the brainstem which innervate interneuronal networks in the spinal cord.
5. Describe the organization of the motor pathways in the spinal cord
6. Explain the somatotopic organization of ventral horn motor neurons

'Motor pathways' refers to all the motor fibers originating in the cerebral cortex or in the brainstem that descend to the spinal cord to innervate interneurons and ventral horn motor neurons and through them all muscle fibers. The ventral horn motor neurons are then the final common pathway for movement. Here we will describe the name, function, and trajectory of the descending motor pathways. Please use these notes and power point presentation as a guide to your textbook readings.

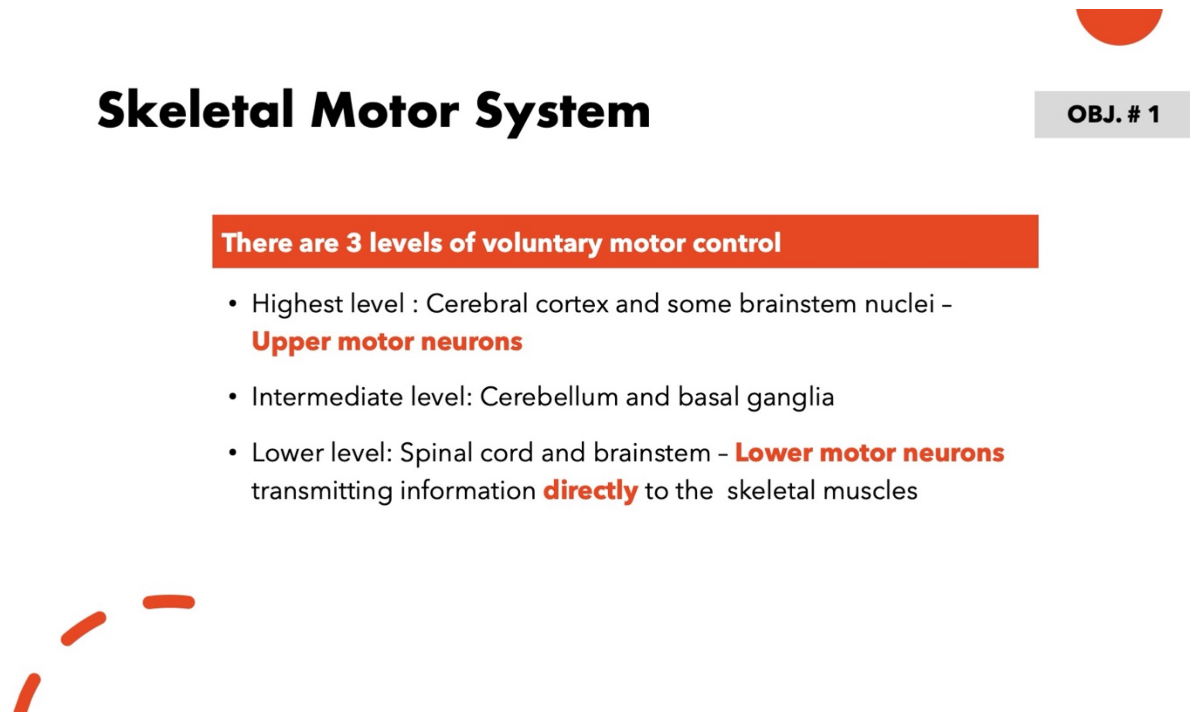
Objective #1; Slide 3

Slide 3 – Motor outputs are organized into 2 motor systems: the somatic or skeletal, which is controlled by the motor cortex and certain brainstem centers, and the autonomic motor system which innervates all the smooth muscles of our body and is controlled by the hypothalamus using inputs from other brain areas.



Objective #1; Slide 4

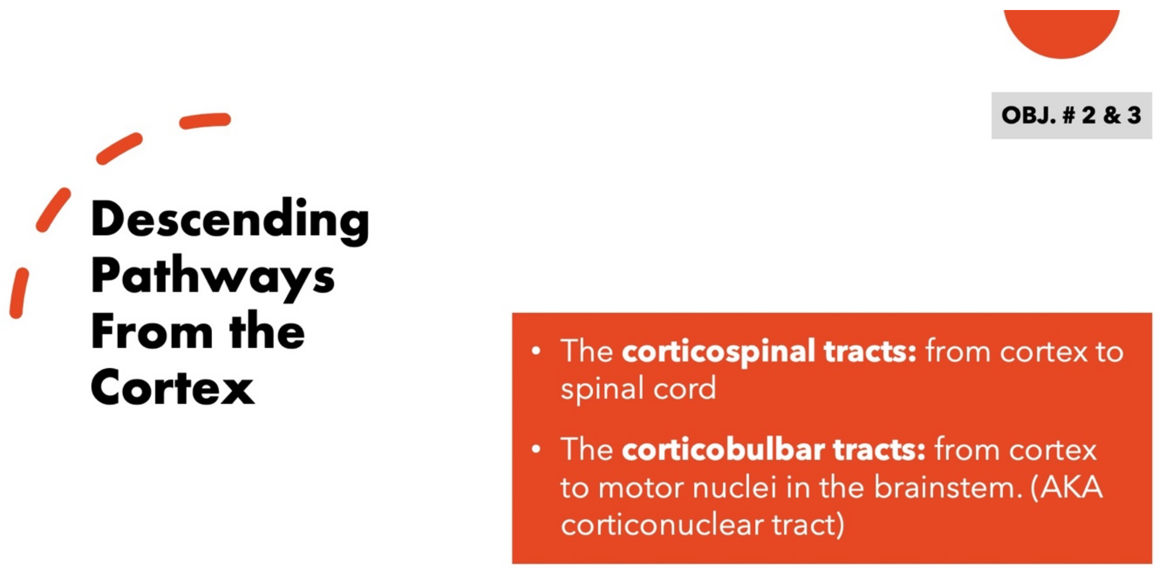
The skeletal motor system consists of an intricate network into which structures are hierarchically organized. These structures are comprised of the cerebral cortex, brainstem, cerebellum, basal ganglia, and spinal cord. The cerebral cortex provides the highest level of control and is in constant bidirectional communication with the other centers. The cerebellum and basal ganglia provide feedback loops reaching the motor cortical areas through the thalamus. This feedback information is essential to the cortex for the precise and refined coordination of movement (See Blumenfeld fig. 6.6, page 230). The motor nuclei in the spinal cord and cranial nerves motor nuclei in the brainstem provide the lower levels of control.



Objective # 2, 3; Slide 5

We will describe the pathways that originate in the cerebral cortex and innervate lower motor neurons and interneurons in the spinal cord: the corticospinal tracts and the pathways that originate in the cortex and innervate the brainstem nuclei: the corticobulbar tracts.

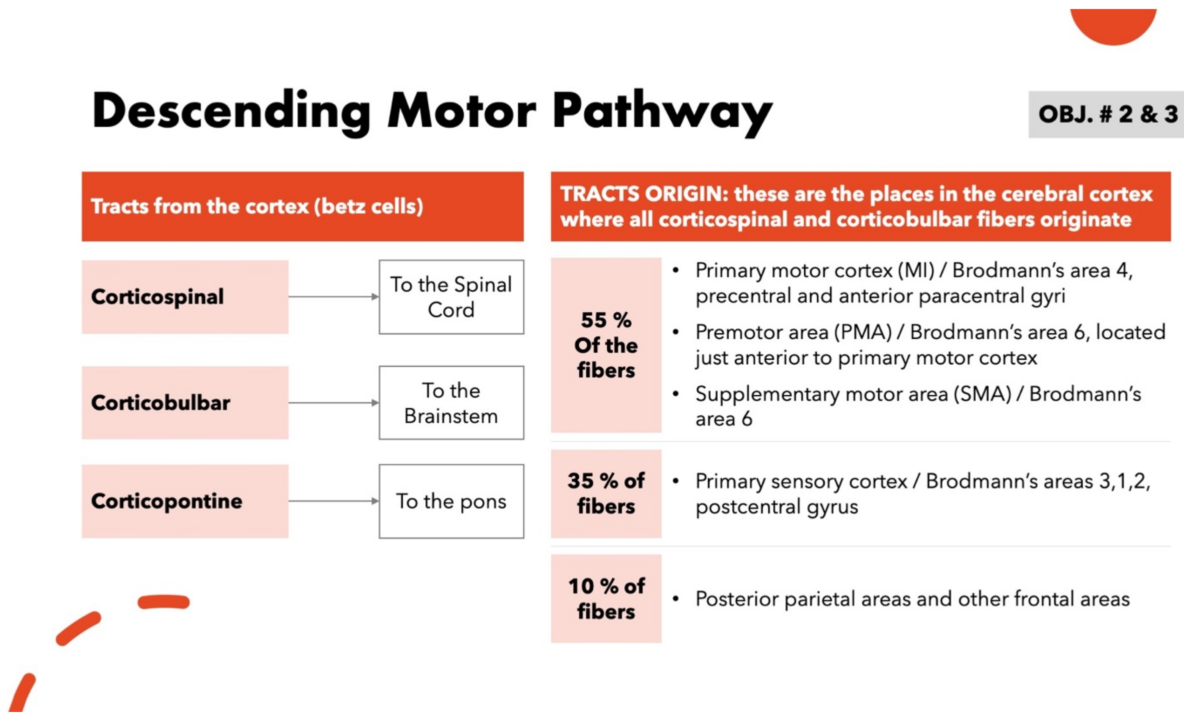
Function: the corticospinal tracts control body movement through innervation of motor neurons in the ventral horns of the spinal cord directly or indirectly through interneurons. The input fromthe cortex is integrated by lower motor neurons to activate muscle fibers. Corticospinal fibers control mostly the movements of the distal limb muscles and skilled finger movements.



Objective # 2, 3; Slide 6

The corticospinal tracts originate mostly from the primary motor cortex or Brodmann'sarea 4. However, other cortical areas such as primary sensory areas and supplementary and premotor areas, contribute various amounts of fibers to this pathway.

The corticobulbar tracts originate in the same cortical areas. The corticobulbar tracts transmit cortical input to the motor neurons in the cranial nerve motor nuclei, in the brainstem. These motor nuclei of the brainstem are the equivalents to the ventral horns of the spinal cord and theneurons there are lower motor neurons.

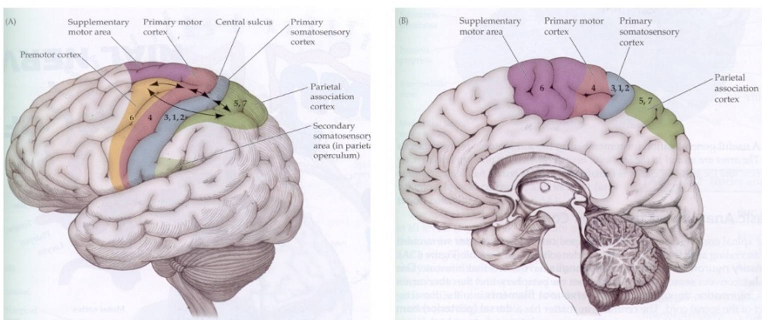


Objective # 2, 3; Slide 7

The primary motor cortex is in the precentral gyrus and anterior paracentral lobule, within the frontal lobe. The motor cortex is organized in 6 horizontal layers of neurons. The neurons in layer 5 are known as Betz cells. They are the largest neurons of the human nervous system and contribute importantly to the formation of the corticospinal and corticobulbar tracts.These neurons together with some brainstem neurons are named Upper Motor Neurons becausethey represent the highest levels of motor control.

Cortical Areas Contributing to Corticospinal and Corticobulbar tracts

OBJ. # 2 & 3

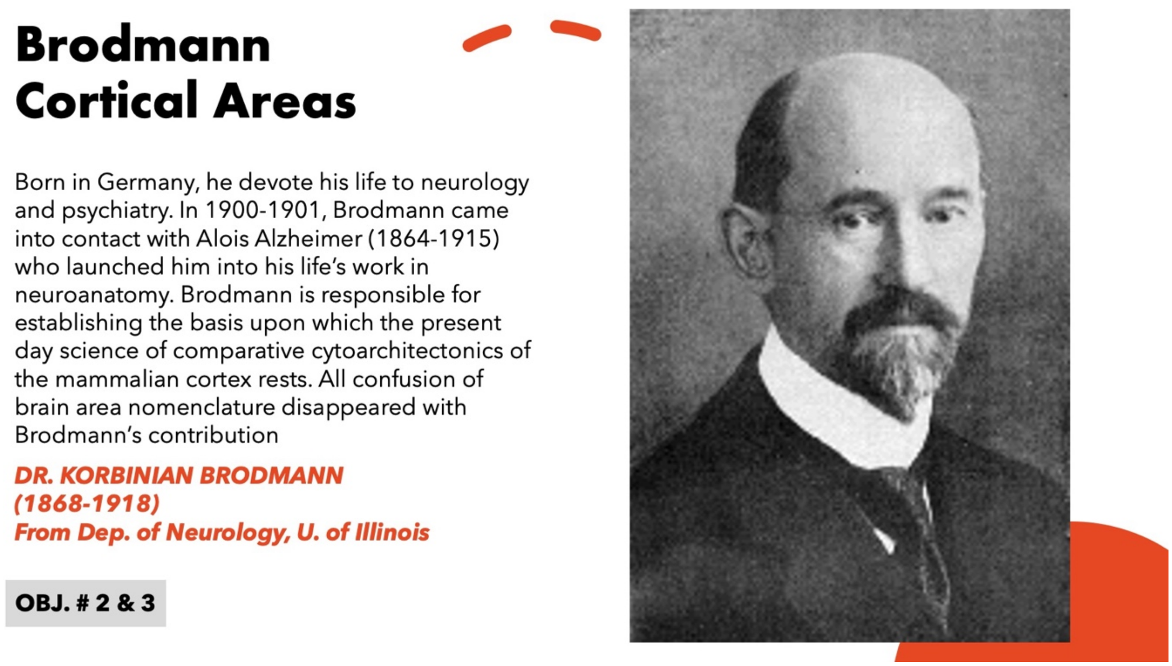


Brodmann's area 4 – Primary Motor Cortex

Brodmann's area 6 – Pre-motor and supplementary motor cortex

Objective #2, 3; Slide 8

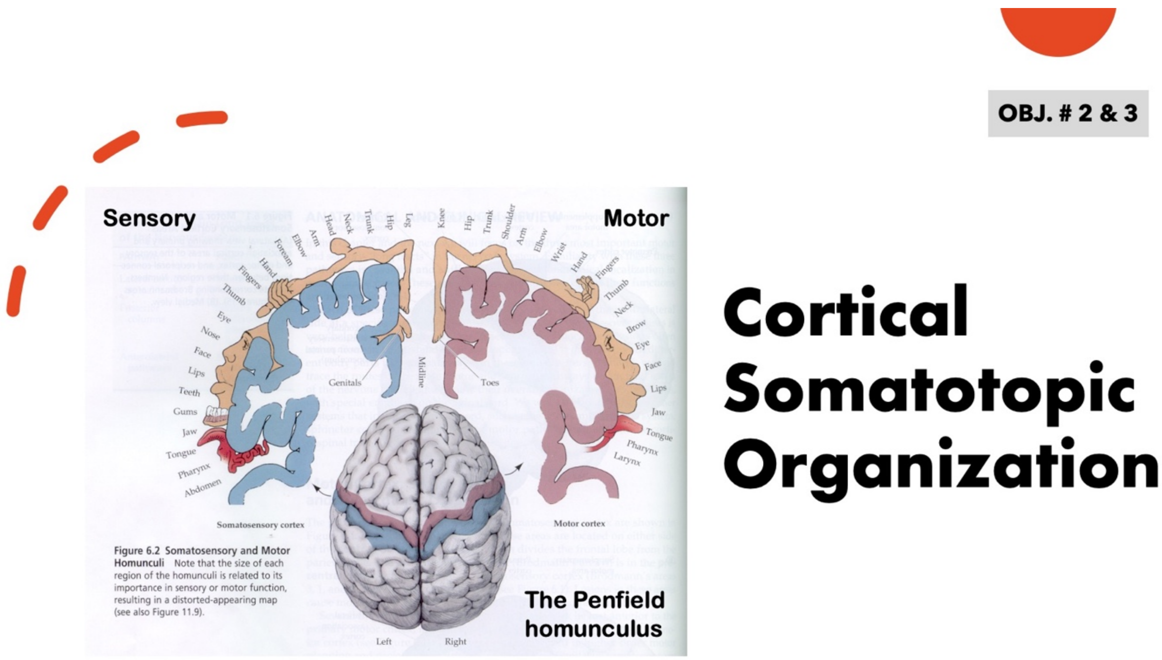
Division of the cerebral cortex into Brodmann's areas. (See Blumenfeld chapter 19, page 181 - 183) A Brodmann area is a region of the cerebral cortex with a characteristic cytoarchitecture or cell organization. The German Neurologist and Neuroanatomist Korbinian Brodmann first defined these areas in 1909 studying brains from humans and other animals. Even though this classification is not of great clinical utility, it is still used extensively to refer to different regions of the brain and will help you with learning neuroanatomy.



Objective #2, 3; Slide 9

Primary motor and sensory cortices are somatotopically organized. Somatotopic organization refers to the way in which regions of the motor and sensory cortex areas are functionally related to a specific region of the body. Through electrical stimulation of cortical neurons on awake patients undergoing brain surgery, Dr. Wilder Penfield working at McGill University in Montreal discovered that several "cortical maps" of the body can be found in the motor and sensory cortices.

The diagram shows the Penfield's homunculus or "little man".



Objective #2, 3; Slide 10

After descending through the brainstem, the motor fibers (pyramidal tracts) decussate (cross to the contralateral side) at the spinomedullary junction. At this point 85 to 90 % of the fibers cross to form the lateral corticospinal tract in the spinal cord. The rest of the fibers descend uncrossed to the spinal cord and form the anterior or ventral corticospinal tract in the ventral funiculus.

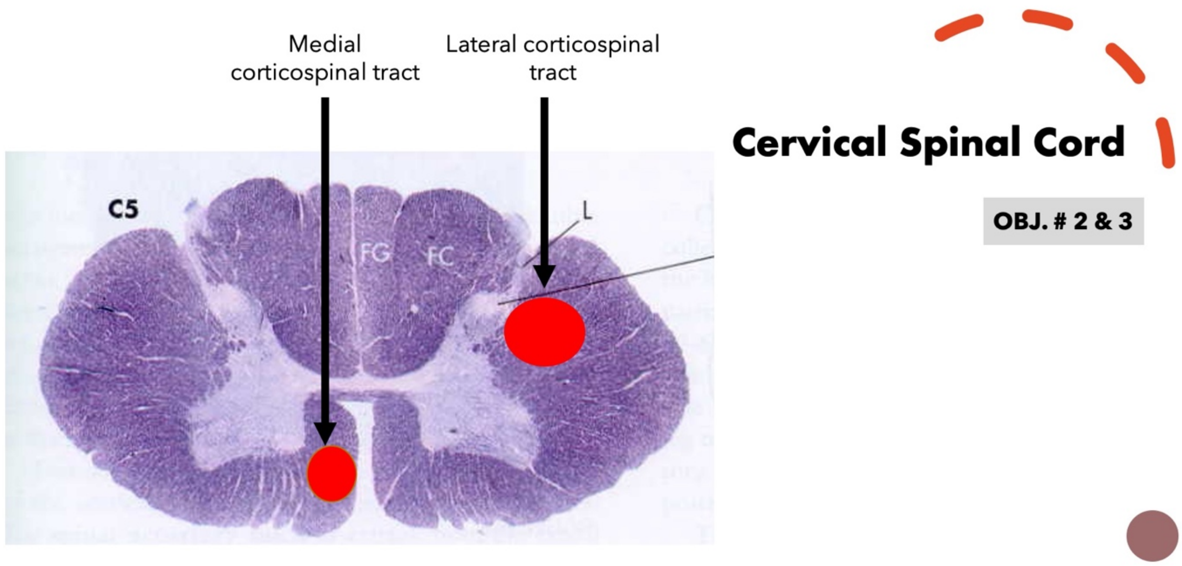
Corticospinal Tract

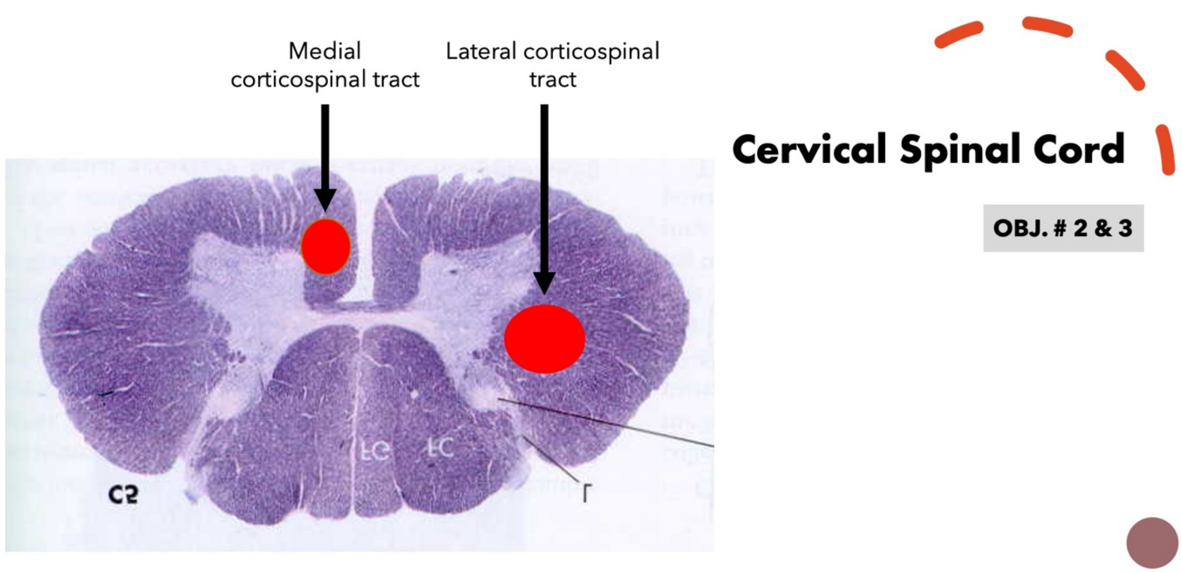
OBJ. # 2 & 3

- **Originate from Primary Motor Cortex, Supplementary Motor, Premotor, and Somatosensory Cortex**
- **85 % of fibers** decussate at spinomedullary junction **and form the** lateral corticospinal tract **in the spinal cord**
  - **Some of these fibers terminate directly on** α-motor neurons of the ventral horn **at all spinal cord levels for fine control of distal muscles**
  - **Most fibers terminate on** interneurons **at all spinal cord levels**
- **15 % of fibers descend into the spinal cord ipsilaterally and form the** anterior or ventral corticospinal tract
  - **These fibers terminate on** interneurons **at all spinal cord levels**

Objective #2, 3; Slide 11, 12

A section through the cervical spinal cord showing the location of the lateral and medial corticospinal tracts. This section is in the anatomical orientation. Slide 12 shows the sameslide in the clinical orientation.





Objective #2, 3; Slide 13

The brainstem receives motor information from cortical areas through a set of fibers known as the corticobulbar tracts. Fibers in these tracts descend in the cerebral peduncles together and medial to the corticospinal tracts. At each brainstem level, fibers leave the main pathway to innervate the motor nuclei of the cranial nerves, the reticular formation at all levels, the red nucleus, the pontine nuclei, and some sensory nuclei such as the vestibular nuclei, and the nucleus gracilis and cuneatus.

Motor information to the pontine nuclei is essential since the pontine nuclei are the origin of the contralateral middle cerebellar peduncles. Remember that the middle cerebellar peduncles are one of the communication pathways between brainstem and cerebellum. This is one way in which the cerebral cortex indirectly communicates with the cerebellum.

The corticobulbar tracts terminate in the motor nuclei in the brainstem. This pathway is essential for conveyance of cortical commands to the LMNs in the cranial nerve nuclei. As you remember from the sensory-motor integration lecture, the lower motor neurons in thespinal cord and in the cranial nerves motor nuclei directly innervate muscle fibers. The lower motor neurons do not initiate muscle contraction unless they receive outside input. They need the control from the upper motor neurons and the sensory inputs from the muscles to initiate movement.

Some of these brainstem nuclei receive cortical input from both sides of the brain while other nuclei receive either exclusive or mainly contralateral input. This fact has important clinical implications when the corticobulbar pathways are damaged.

Corticobulbar Tracts

OBJ. # 2 & 3

- Originate from Primary Motor Cortex, Supplementary Motor, Premotor, and Somatosensory Cortex
- Fibers descend in the cerebral peduncles and terminate:
  - In the red nucleus ipsilaterally
  - In the pontine nuclei ipsilaterally → Corticopontine fibers
  - In the motor nuclei of the reticular formation, bilaterally at all brainstem levels
  - In the motor nuclei of cranial nerves:

CN V → Motor nucleus, bilaterally

CN VII → Facial motor nucleus → Bilateral for forehead area; → Contralateral for lower face area

CN IX and X → Nucleus ambiguus, predominantly contralateral

CN XI → Predominantly contralateral

CN XII → Predominantly contralateral

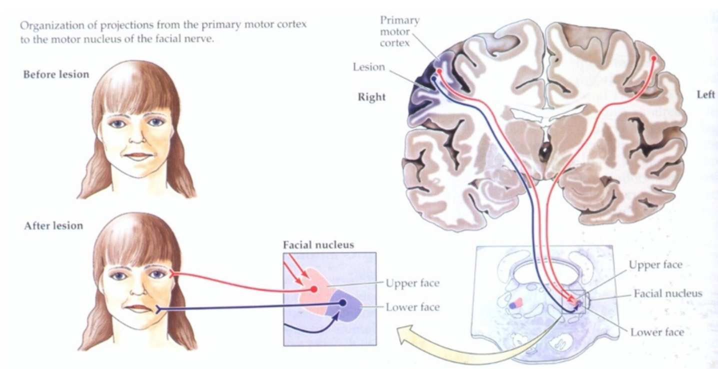
Objective #2, 3; Slide 14

The corticobulbar innervation for the facial motor nucleus is particularly important and interesting. The motor nucleus of VII is divided in 2 areas: the most rostral area innervates the muscles of the forehead, and the most caudal area innervates the facial muscles of the lower face at each side. The forehead part of the nucleus receives cortical input from both sides (bilateral innervation); the lower part of the nucleus receives only cortical information from the contralateral side of the brain. This has important clinical implications for patients affected with lesions in these pathways. As we will see in the clinical correlation section, this innervation arrangement is very useful for lesion localization.

OBJ. # 2 & 3

Cortical Innervation of the Facial Nucleus

Very important clinically to differentiate an upper vs. lower motor neuron lesion



Objective # 4; Slide 16

Some brainstem nuclei send inputs to the spinal cord. In the spinal cord most of these pathways travel in the ventral funiculus and all together make up the medial motor system. These pathways are mostly in charge of the control of head and body posture by innervating the motor neurons that control postural and proximal limb muscles. The fact that these fibers innervate interneuronal networks bilaterally by crossing extensively in the spinal cord makes their lesions less conspicuous.

Descending Motor Pathway From the Brainstem

OBJ. # 4

There are 4 main fiber tracts that originate in the brainstem and innervate spinal cord neurons:

- Rubrospinal tract
- Reticulospinal tract
- Vestibulospinal tract
- Tectospinal tract

Objective # 4; Slide 17

The red nucleus is a motor nucleus in the rostral midbrain. Fibers originating there cross to the contralateral side as they exit the nucleus and descend in the lateral brainstem tegmentum to reach the spinal cord. The tract is named the rubrospinal tract. In the spinal cord, the rubrospinal tract is located just next to the lateral corticospinal tract in the lateral funiculus. This tract is very small in humans and its function is not well understood.

The reticulospinal tracts are two descending pathways from the reticular formation, one from the pons and one from the medulla which run through the spinal cord in the anterior funiculus. They provide input to both sides of the spinal cord. Thought to be involved in more postural control and patterned movement generation.

The vestibular nuclei are the 4 nuclei associated with the vestibular nerve. They are the lateral, medial, superior, and inferior nuclei located beneath the floor of the 4th ventricle at the rostral medulla-caudal pons levels. The vestibulospinal tracts descend from these nuclei. The lateral vestibulospinal tract originates from the lateral vestibular nucleus and descends ipsilaterally to all levels of the spinal cord to influence the activity of extensor muscles. The medial vestibulospinal tract originates mostly from the medial vestibular nucleus. It descends bilaterally to terminate in the anterior funiculus at cervical cord levels where it influences the activity of postural neck muscles. This pathway travels in the medial longitudinal fasciculus (MLF). In the spinal cord both lateral and medial vestibulospinal tracts are in the ventral funiculus and are part of the ventral or anterior motor system.

The last pathway to consider is the tectospinal tract. It originates from the midbrain tectum, crosses to the contralateral side, and terminates in the anterior funiculus at cervical levels. These fibers modulate the activity of postural neck muscles. The tectum of the midbrain corresponds to the superior collicular area.

Descending Motor Pathway

OBJ. # 4

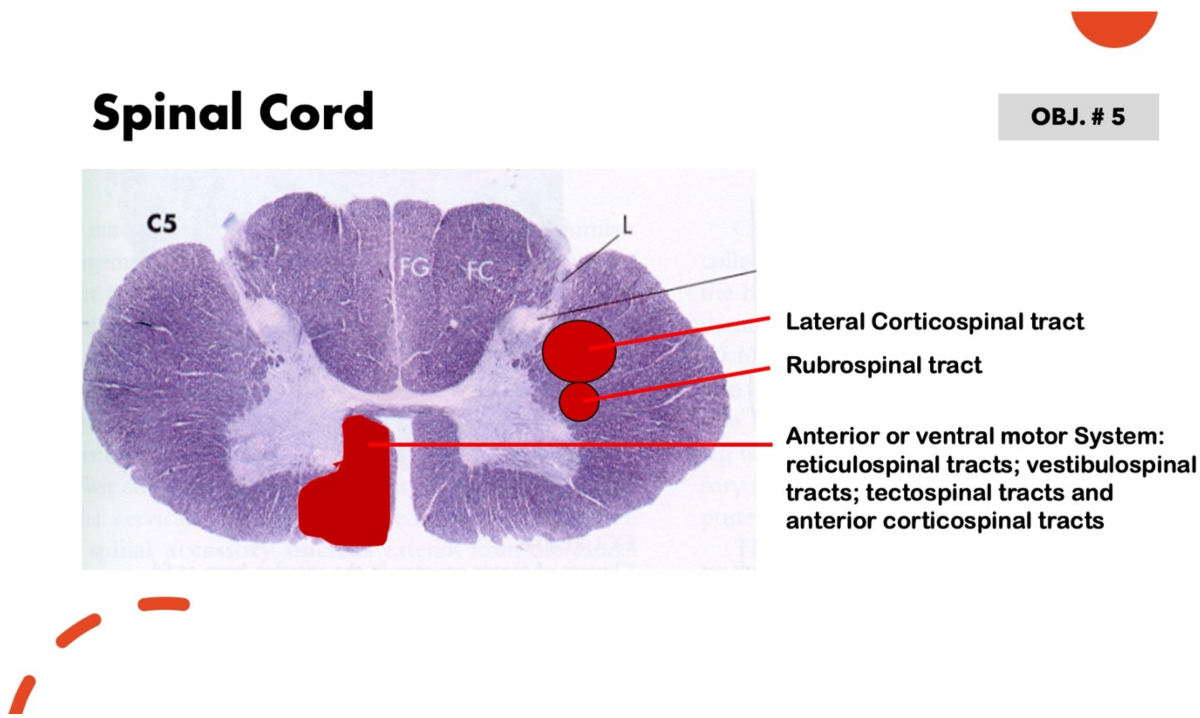
Tracts from the brainstem to the spinal cord

- **Rubrospinal tract:** Originates in the red nucleus and terminates in the spinal cord contralaterally
- **Vestibulospinal tracts:** Originates in the vestibular nuclei
  - **Lateral vestibulospinal tract:** From lateral vestibular nucleus, ipsilaterally to all levels of the spinal cord
  - **Medial vestibulospinal tract:** Mostly from medial vestibular nucleus bilaterally to cervical spinal cord levels. Travels with MLF
- **Reticulospinal tracts:** From the reticular formation to the spinal cord
- **Tectospinal tract:** From the superior colliculi to the spinal cord contralaterally

Objective # 5; Slide 19

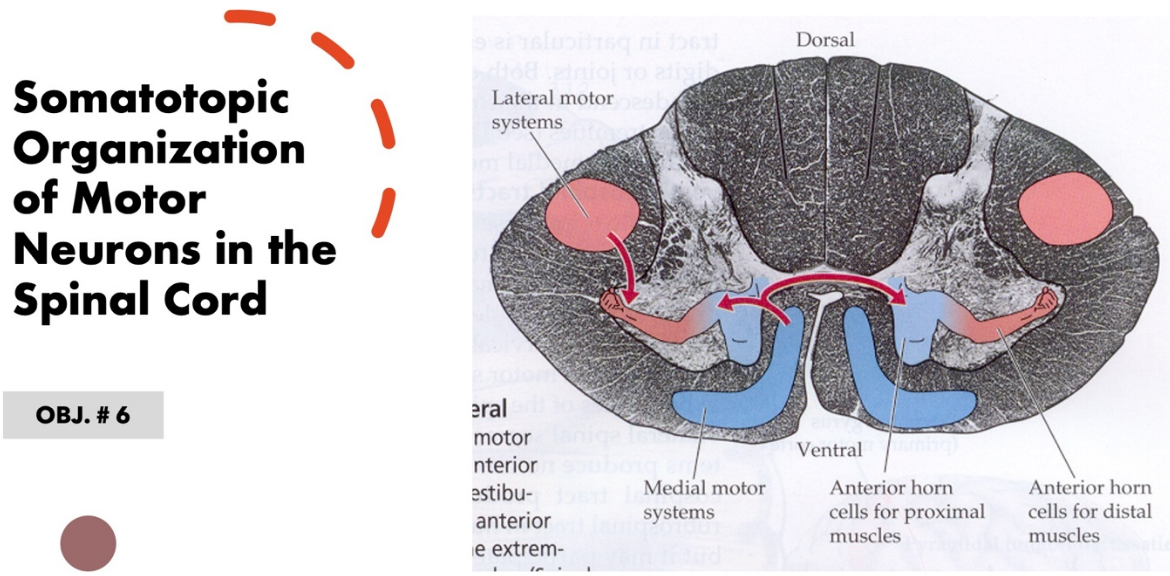
Once in the spinal cord, the descending pathways are organized into 2 major motor systems: the medial (AKA ventral or anterior) motor system, and the lateral motor system. The lateral motor system consists of fibers originating in the cerebral cortex (lateral corticospinal tracts) and brainstem (rubrospinal tract) and is essential for initiating and directing sequences of voluntary skilled movements. The dominant pathway of the lateral motor system is the lateral corticospinal tract. Some of its fibers terminate directly on α-motor neurons in the ventral horn of the spinal cord at all levels. These fibers have a role in the control of fine movement of distal, mostly flexor muscles for skilled finger movements. The other lateral system pathway, the rubrospinal tract, is very small in humans and its clinical significance is not completely understood.

The medial motor system consists of pathways originating mostly in the brainstem which are essential for the control of posture, muscle tone, and orientation of the eyes, head and body with respect to vestibular, somatic, auditory and visual sensory information. The fibers of all tracts in this motor system terminate mostly on interneurons located in the intermedial grey matter of the spinal cord at all levels and are involved in the control of proximal limb, postural body, and neck muscles. Interneurons project extensively to contact alpha and gamma motor neurons at different spinal segments on both sides of the spinal cord. For this reason, unilateral damage to one of the pathways of the medial motor system does not produce obvious motor deficits. The medial motor system consists of the medial and lateral vestibulospinal fibers, the reticulospinal fibers, the medial corticospinal fibers, and the tectospinal fibers.



Objective # 6; Slide 20

This diagram of the spinal cord shows the somatotopic organization of the alpha motorneurons in the ventral horns. The motor neurons are organized in nuclei. The medial motor nucleus contains neurons that innervate axial muscles and proximal limb muscles. The medial motor system fibers project to these neurons. Neurons in the lateral motor nucleus innervate distal muscles of the limbs and are more accessible for the lateral corticospinal fibers to control their function. The picture also shows the distribution of motor neurons in terms of the innervation of flexor vs. extensor muscles. The motor neurons for flexor muscles are located more dorsal than the ones innervating extensor muscles. See Blumenfeld page 231 and table 6.3.



Objective # 6; Slide 21

Another level of organization of the lower motor neurons in the spinal cord. Motor neurons are grouped in longitudinal columns where each column contains all the neuronsinnervating a muscle group (extensor or flexors) for upper or lower limbs. These columns are named neuronal pools. The columns expand through several spinal segments so that the musclesin each group receive fibers from several spinal nerves. This fact determines that lesions of one spinal root frequently produce only weakness of the affected muscle or muscle group and not complete paralysis.