

Motor and Sensory Neurophysiology

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Knowledge that will change your world

Outline

- Sensation: Tracking it from the nerves to the Brain
- Motor: Tracking it from the brain to the muscle!
- Practice Localization

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What are Tracts?

- The path that information follows in the nervous system



- 3 Basic Principles / Types of Tracts
 - MOTOR (Descending)
 - SENSORY (Ascending)
 - Modulating

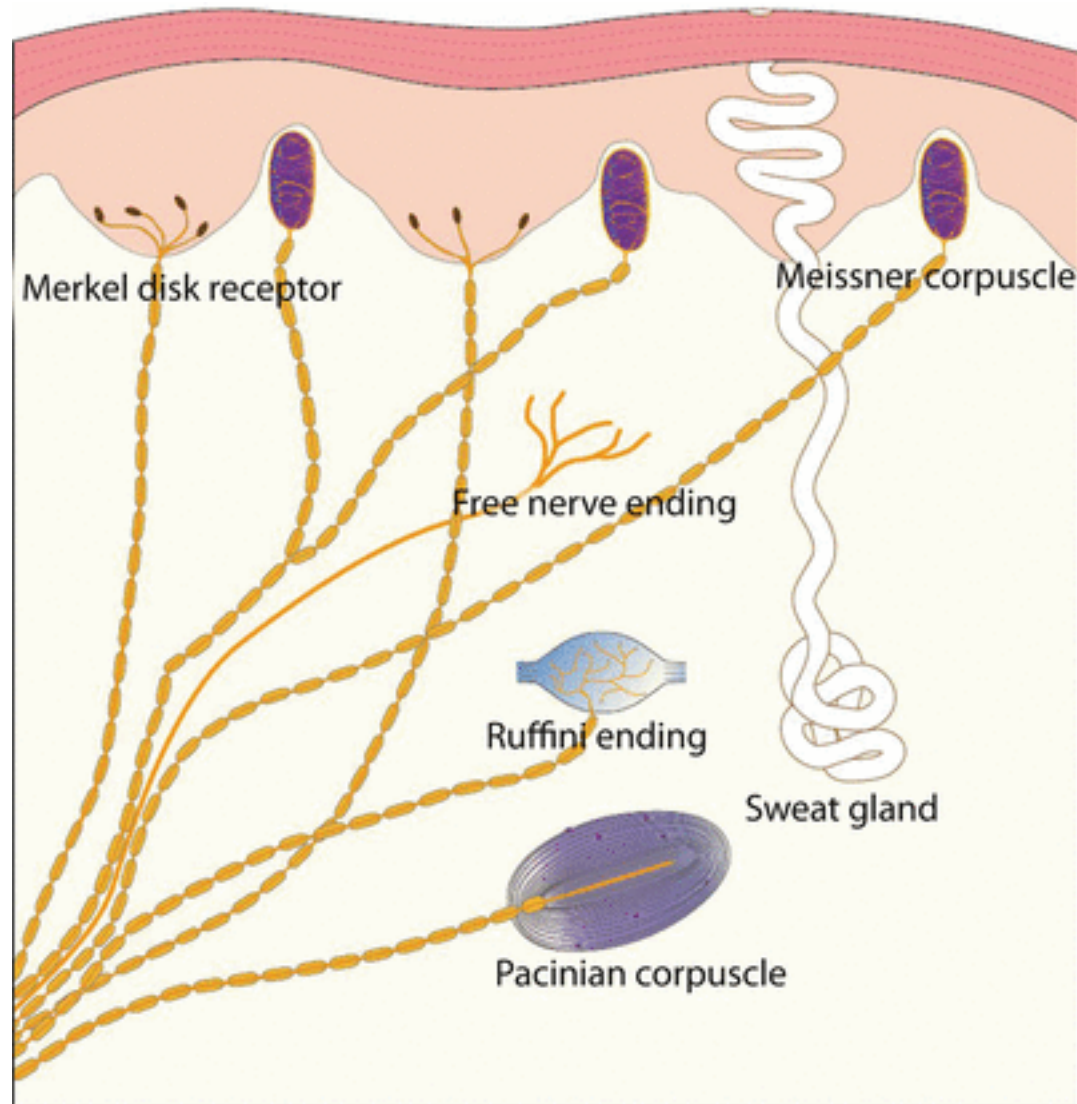
Keys to Understanding Tracts

- Different information travels separately
 - Because has different starting and ending points
 - Very orderly (somatotopy)
 - Within the tract, information acquired in close proximity stays in close proximity
- Lesion anywhere along the tract will disrupt the information from reaching the target

ASCENDING (Sensory)

NERVE ENDINGS

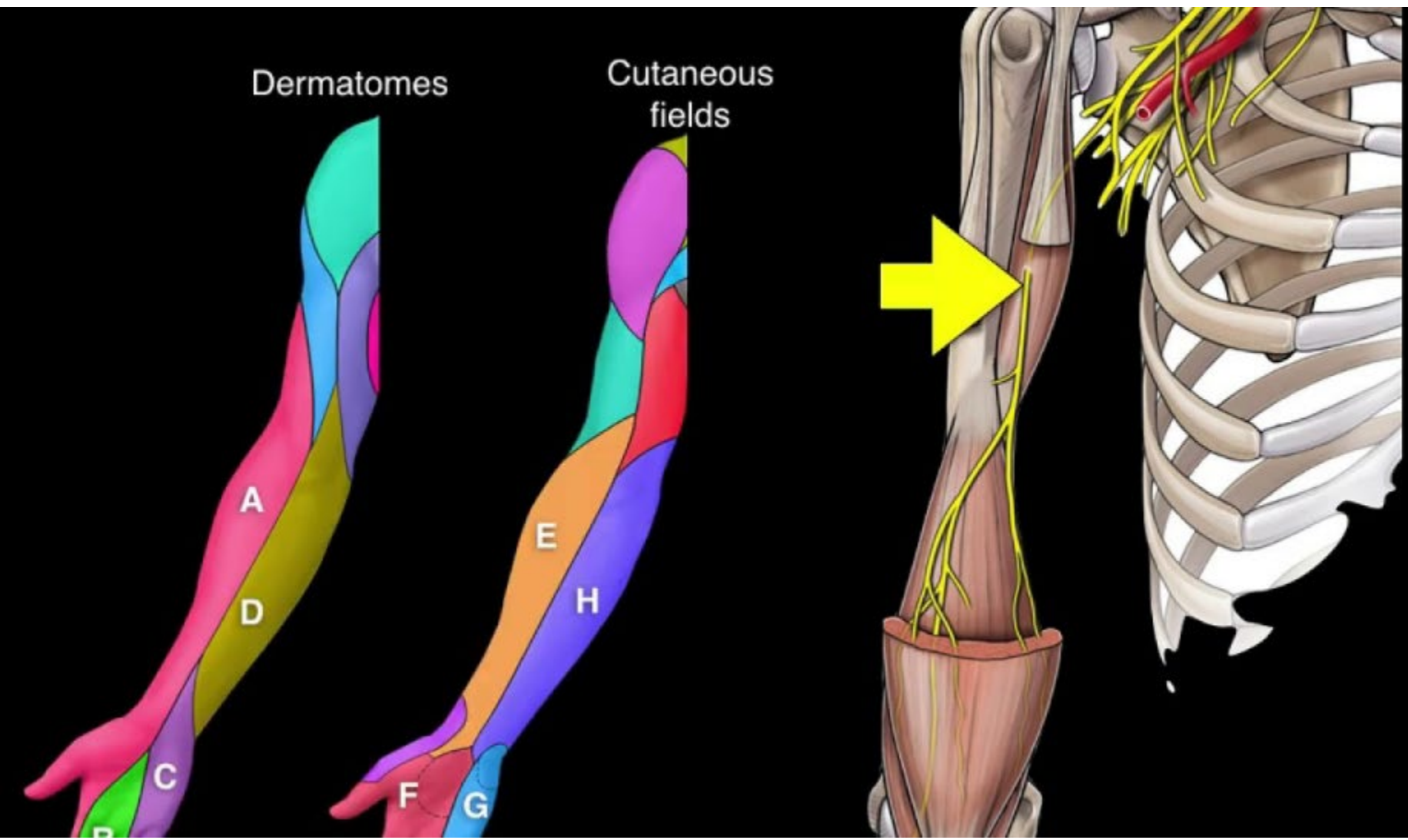
- Different nerve endings sense different sensations:
 - Pain
 - Pressure
 - Vibration
 - Temperature



Types of Sensory Nerves

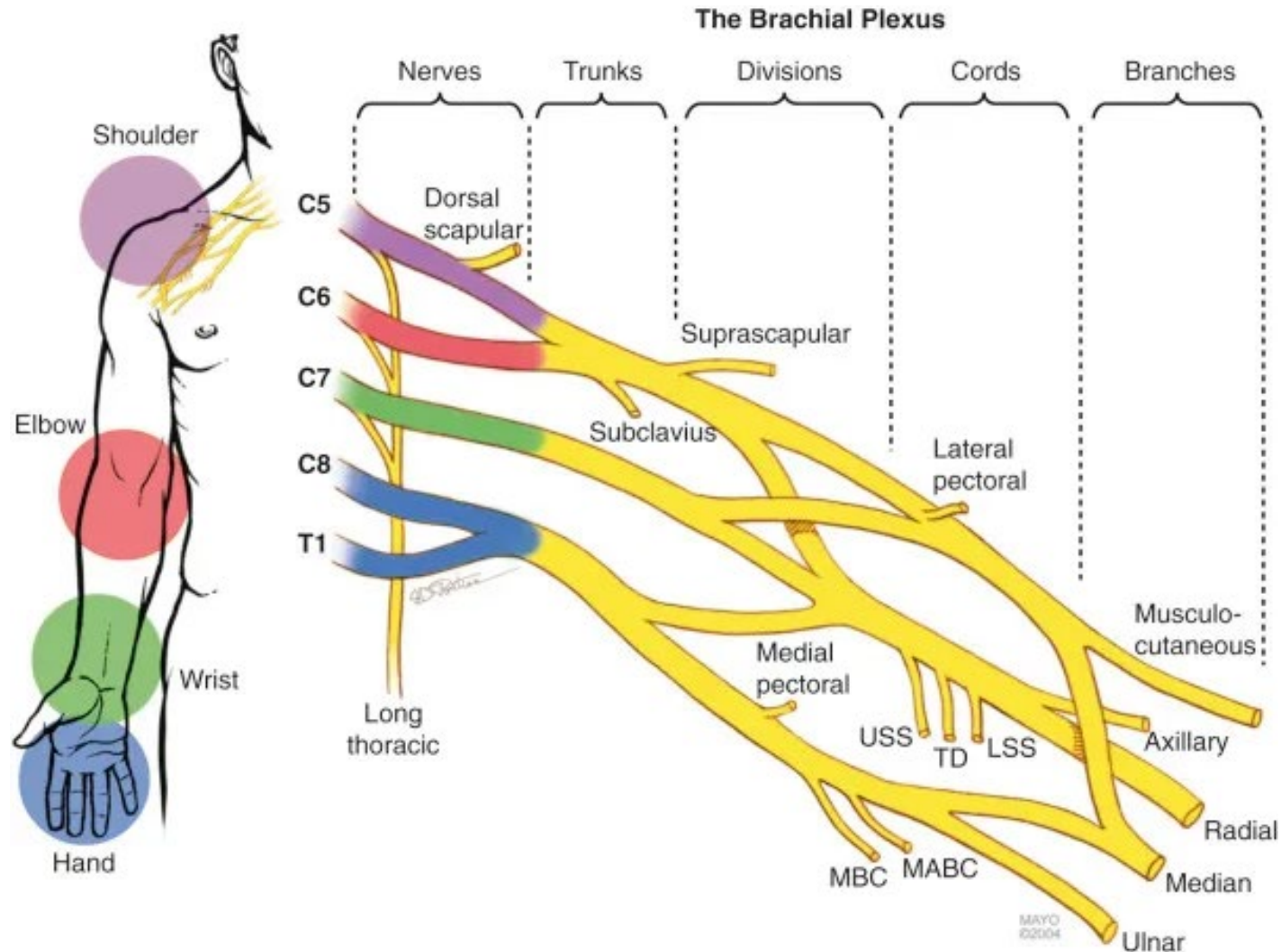
- Small fibers
 - Carry pain and temperature sensation
 - Slow speed of conduction
- Large fibers (myelinated)
 - Carry proprioception and vibration sensation
 - FAST speed of conduction!
- Question: What are your patients going to complain about if they have a problem with large fibers?

Dermatomes from the peripheral nerves

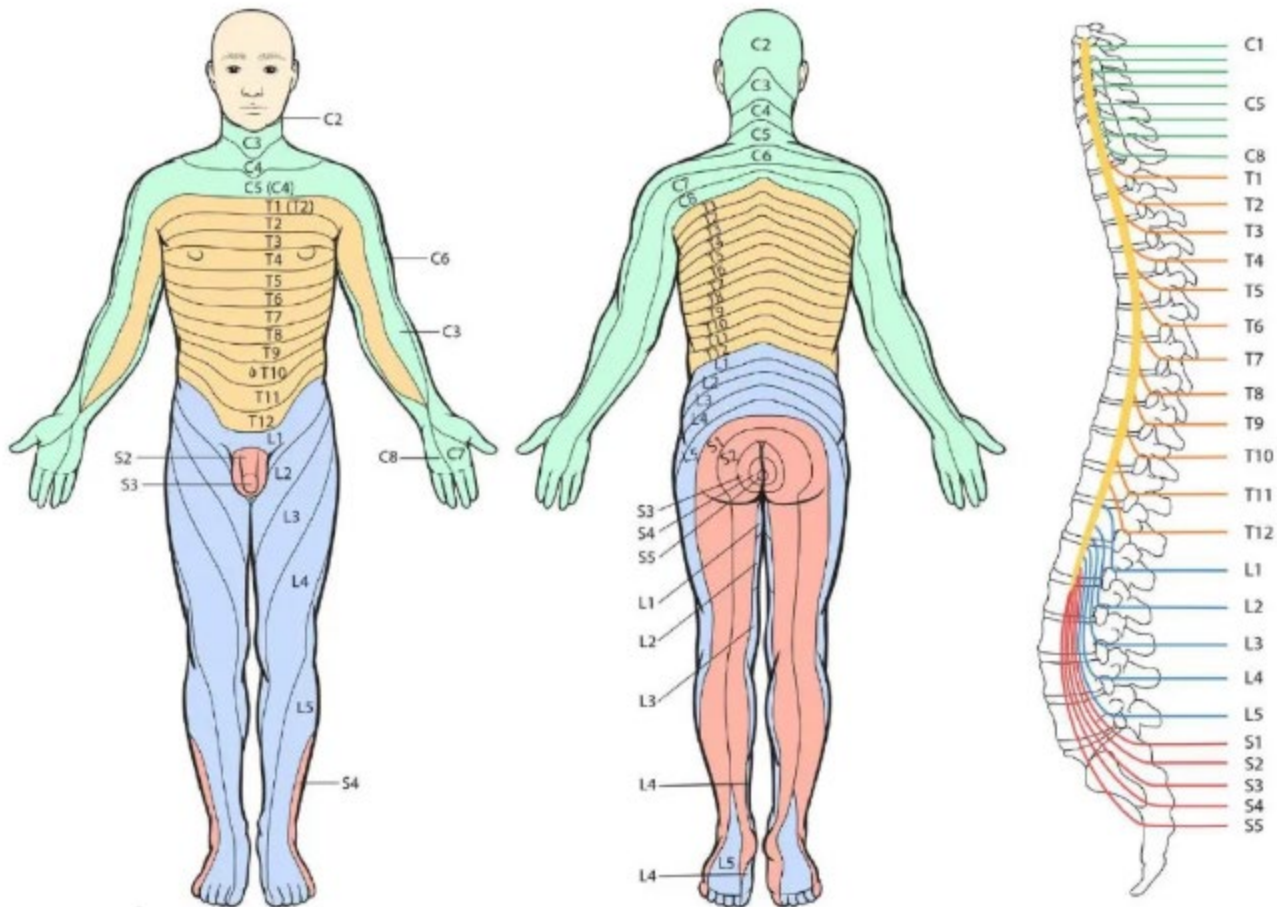


The mergers of radicular nerves

- Brachial Plexus



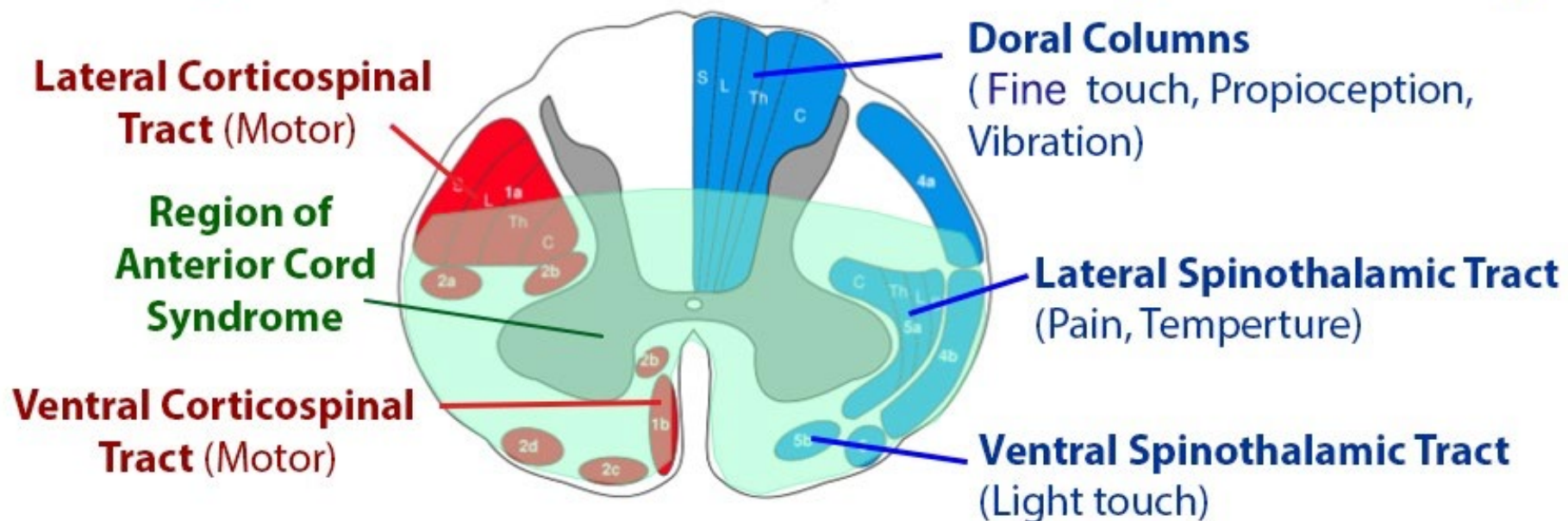
Uh oh! Now they all look different!



Spinal Cord

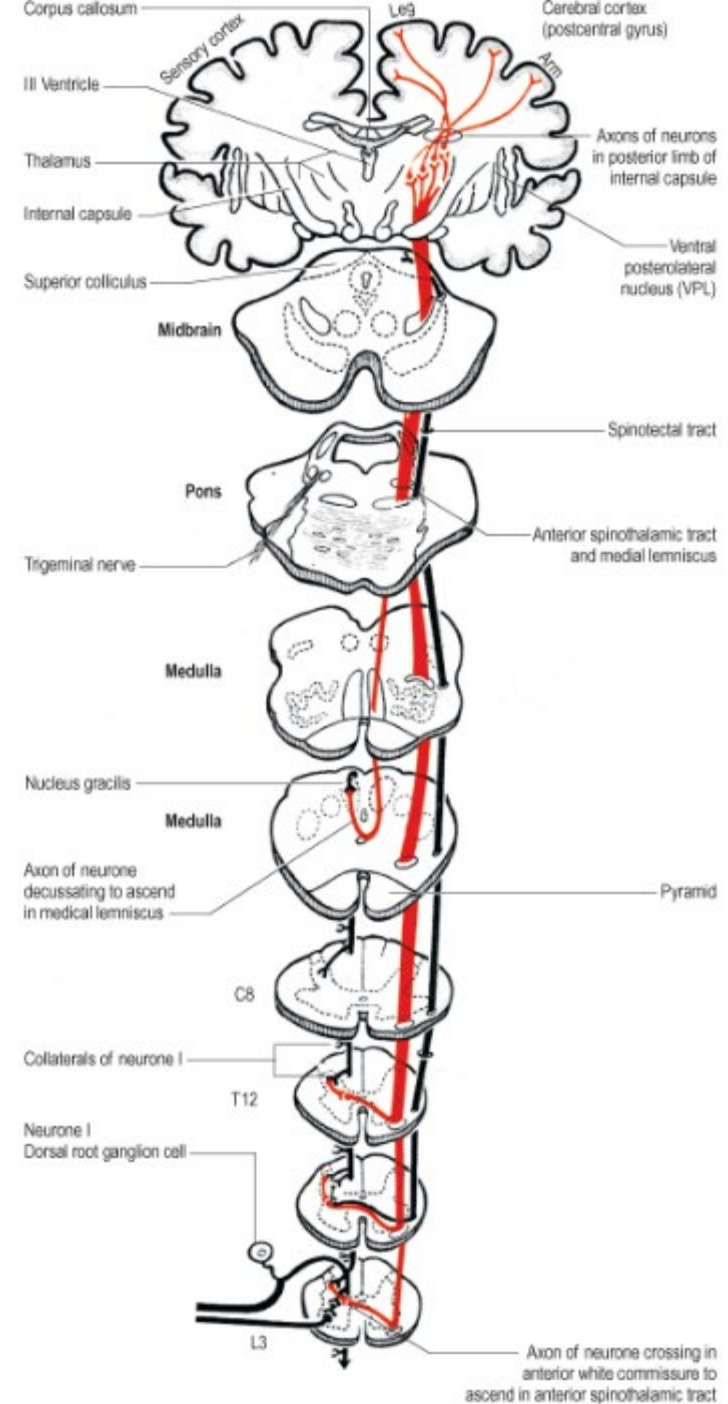
Descending Tracts (Motor)

Ascending Tracts (Sensory)



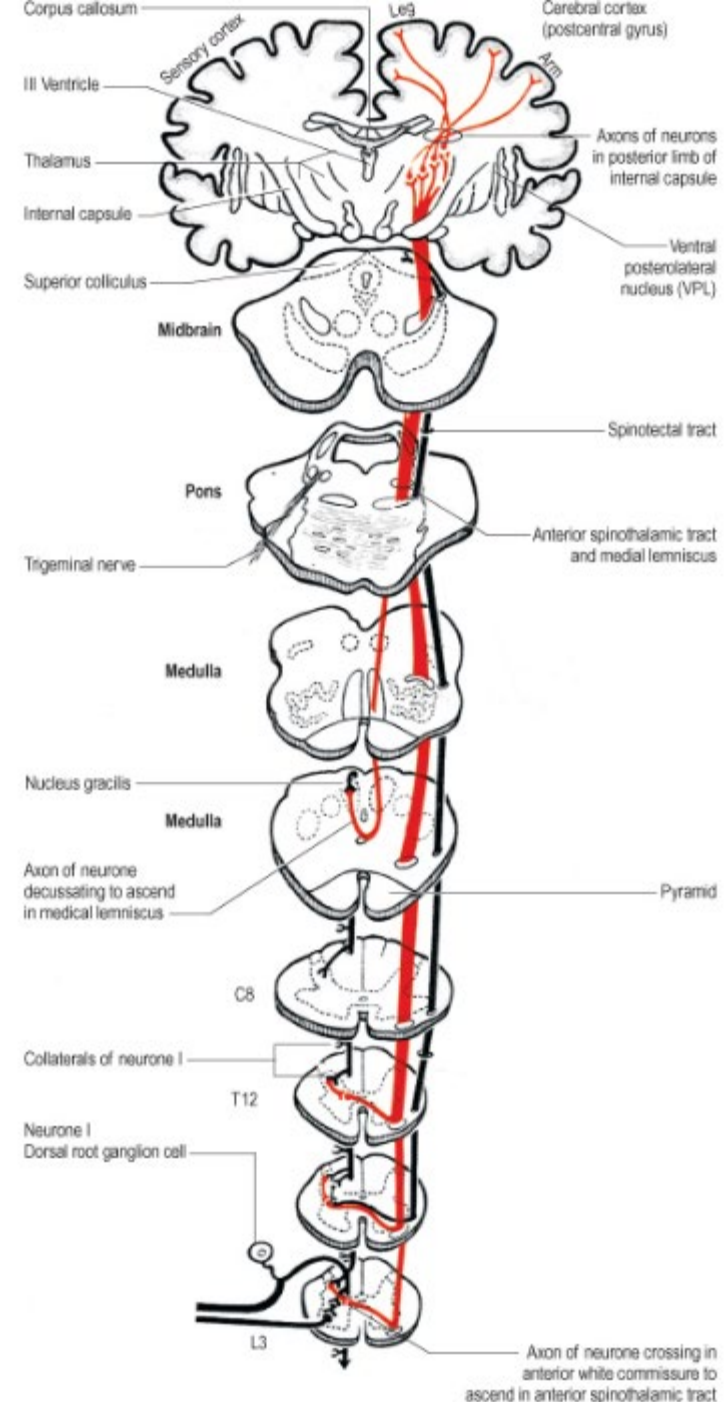
Spinothalamic Tract

- One of TWO primary ascending tracts
- sPinoThalamic = Pain / Temperature sense
- Question: Which type of nerve fibers are becoming this spinal tract?

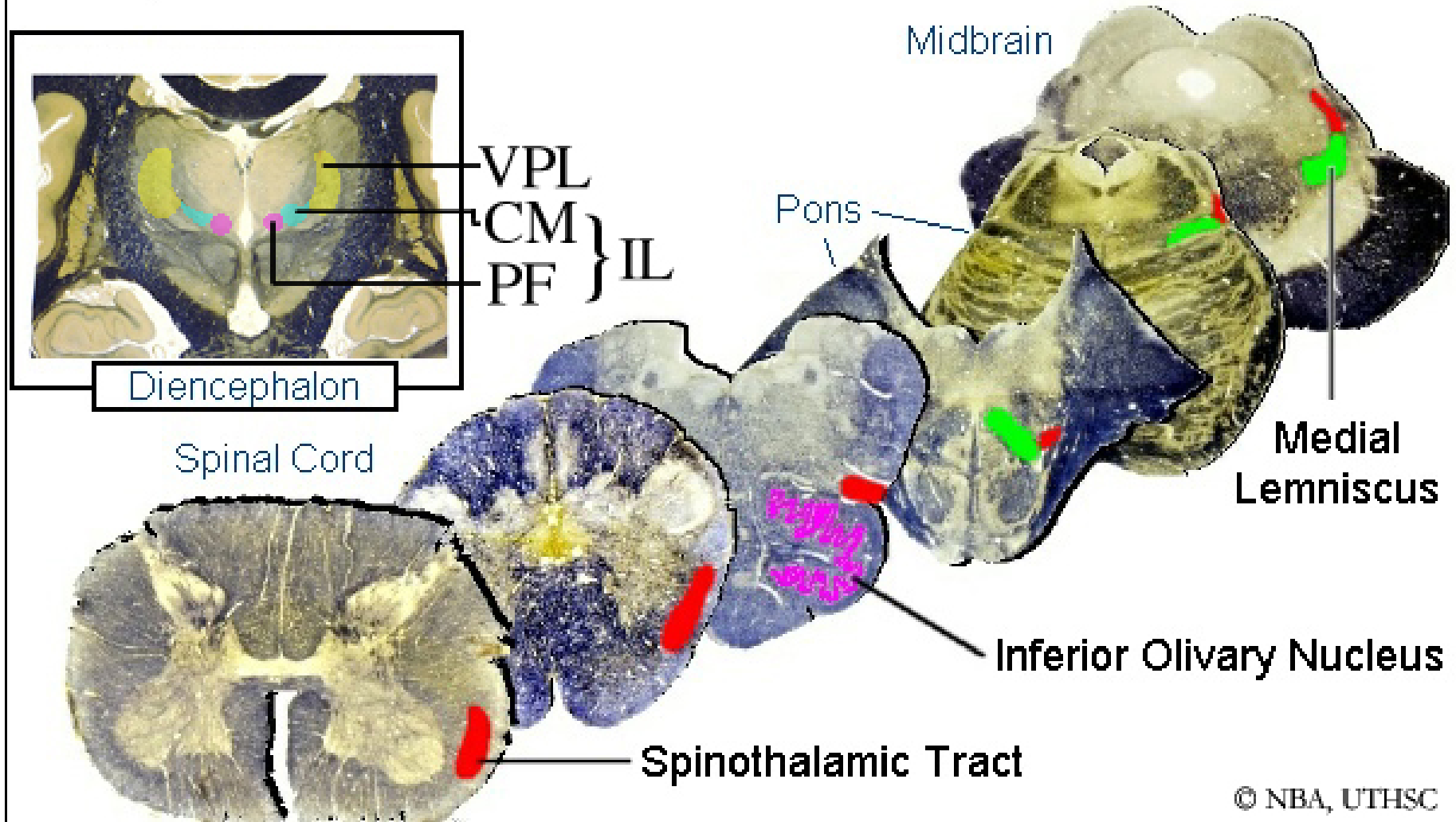


Spinothalamic Tract

- DRG (receives input from pain/temp sensors)
- Enters/synapses in Spinal cord at level of nerve root
- Crosses within a few levels of entry
- Synapses again in Thalamus
- Projects to Sensory Cortex



Spinothalamic Tract and Associated Structures



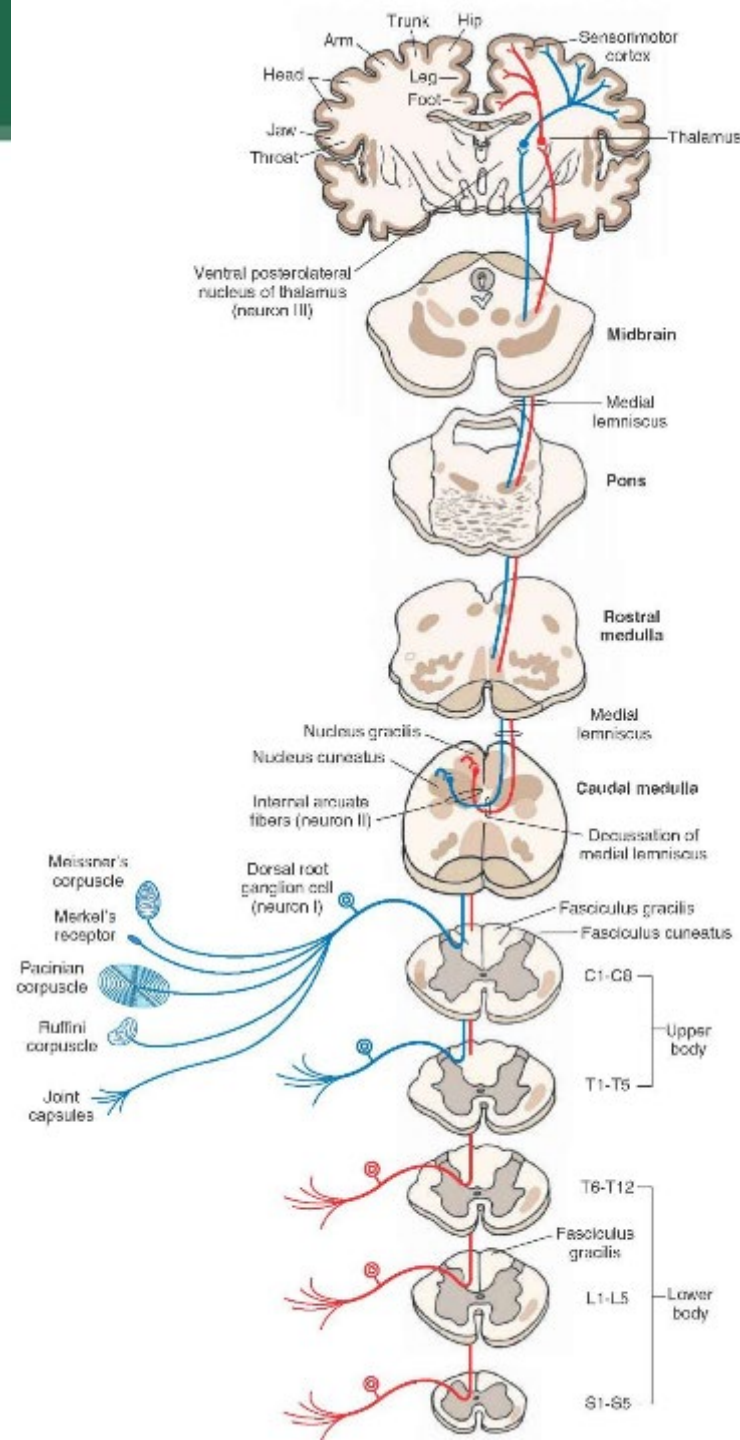
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Question:

- How do you test for a problem in the spinothalamic tract or the small fiber nerves on physical exam?

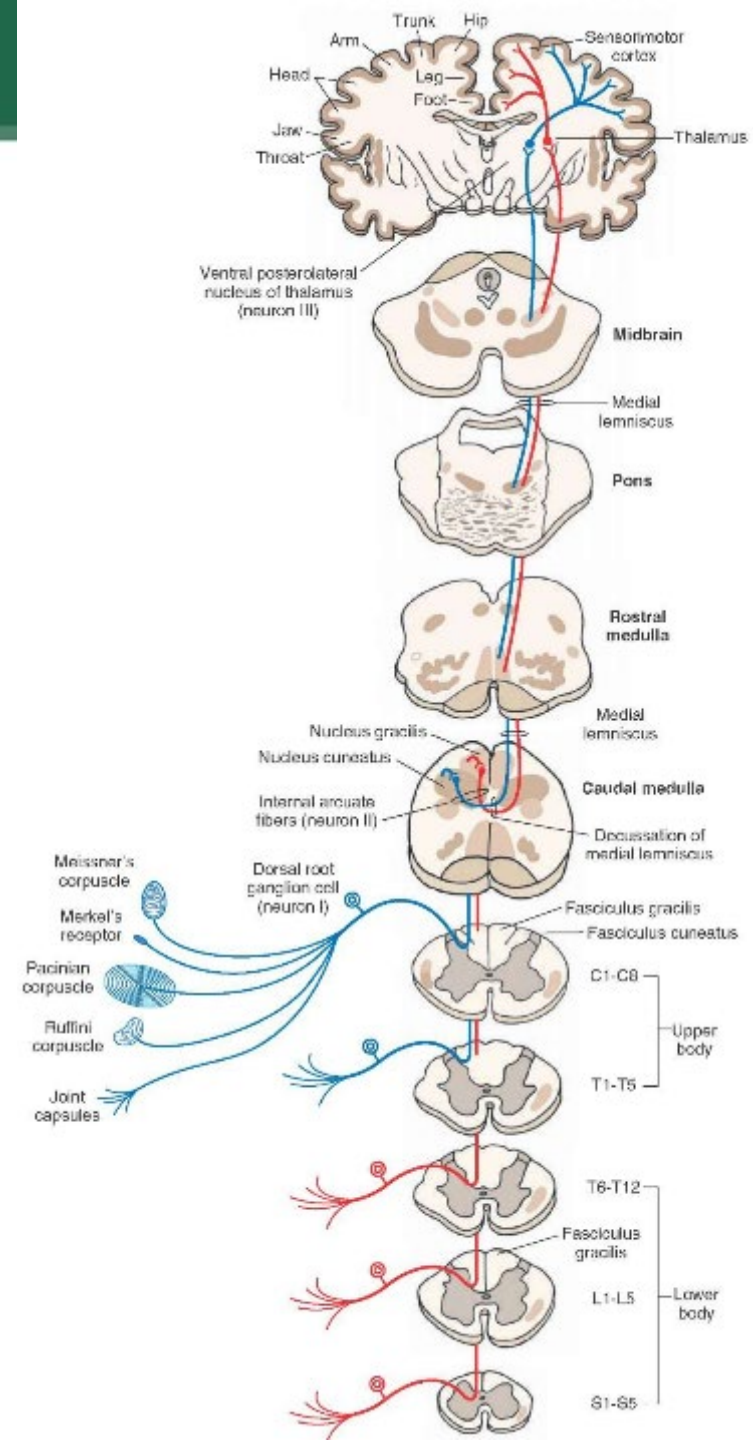
Dorsal Columns – Medial Lemniscus Pathway

- Second of 2 Major ascending tracts
- Consist of:
 - Fasciculus gracilis
 - Fasciculus cuneatus
- Contain vibration/proprioception information
- Question: Which type of nerve fibers become the dorsal columns?

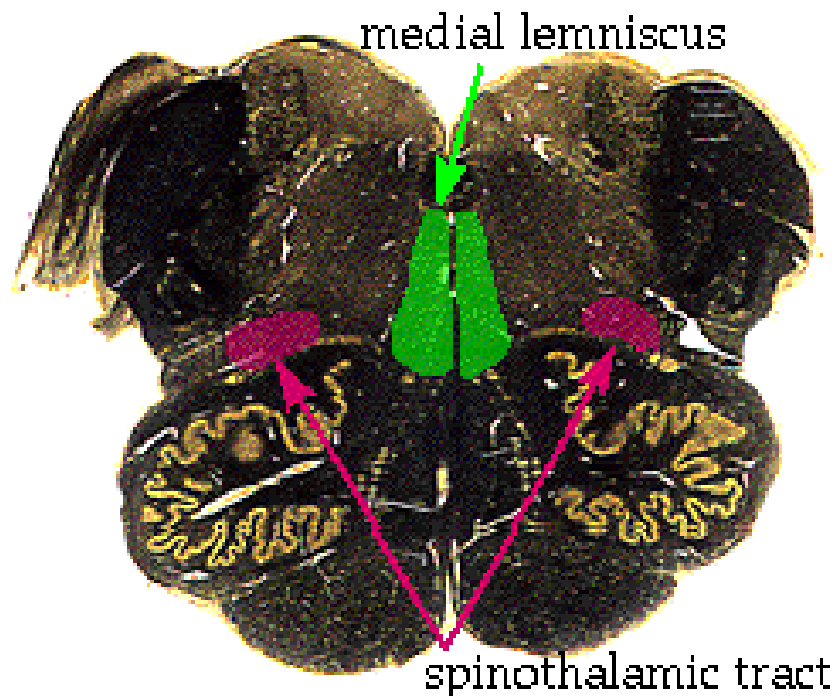


Dorsal Columns

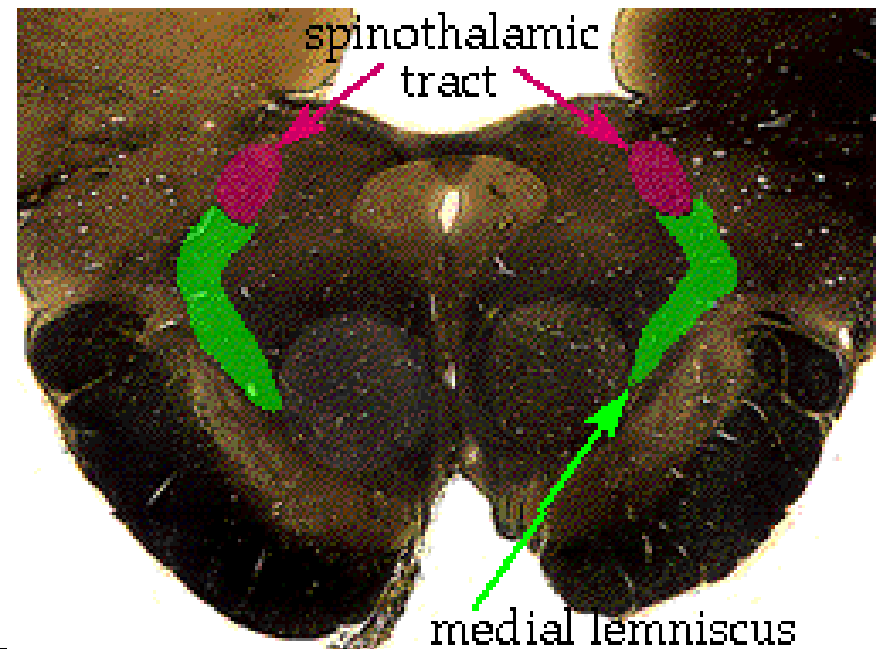
- DRG (receives input from vib/prop receptors in muscles/tendons)
- Spinal cord at level of nerve root
- Stays ipsilateral and then crosses in medulla (**medial lemniscus**)
- Synapses again in thalamus
- Projects to Sensory cortex



Representative Brainstem Slices – Sensory Tracts



Medulla



Midbrain

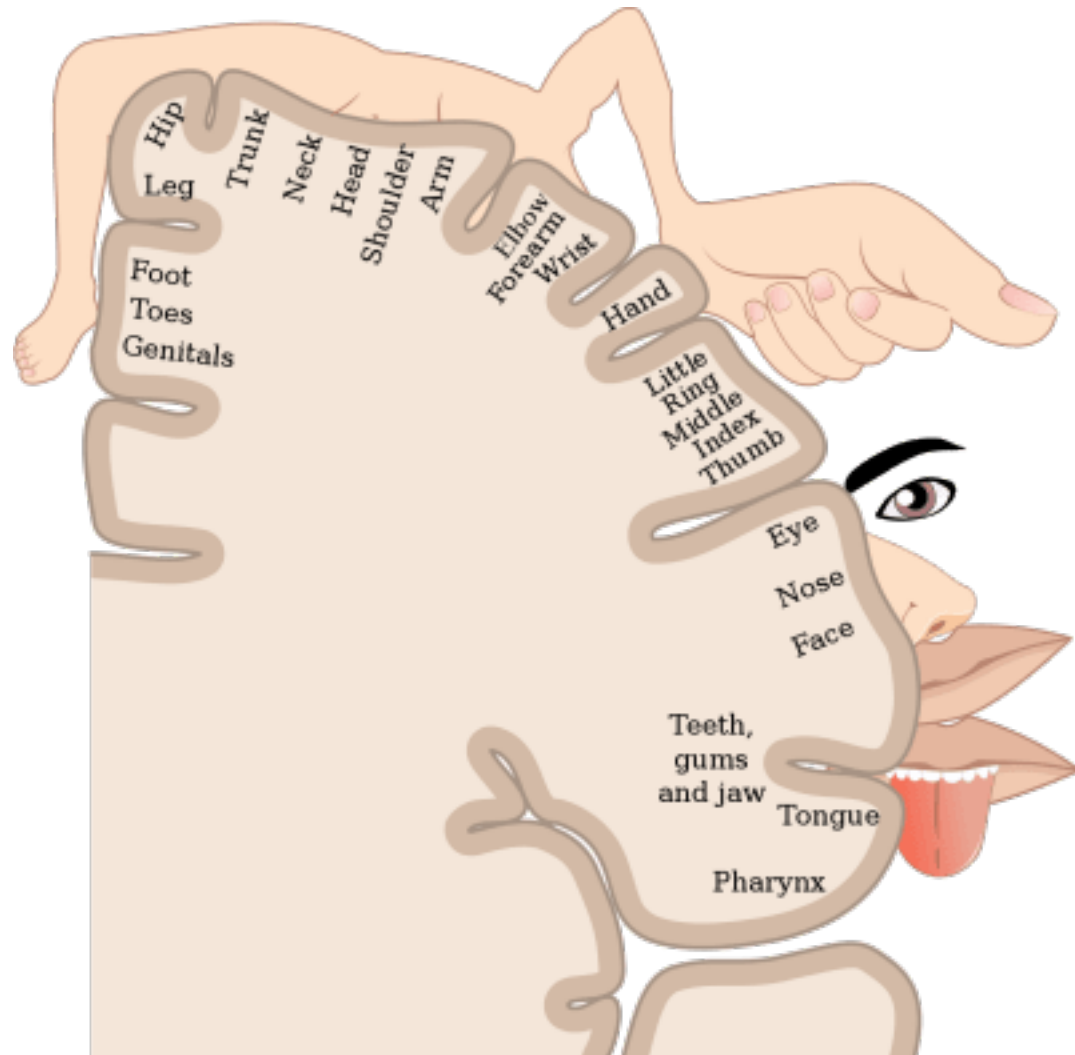
Question:

- How do you test for a problem in the large fibers or the dorsal columns on physical exam?

Primary Sensory Cortex

- Homunculus

Question: How would a stroke-related sensation loss seem on a person? A strip of skin that looks like a dermatome? Or a patch of body that does not stay within a particular nerve distribution?



Cortical Sensation Deficits

Nerves and spinal cord bring sensation to the thalamus where it is processed a little bit.

The cortex tells us what the sensation means.

Question: How do you test for cortical sensory problems?

Two point discrimination

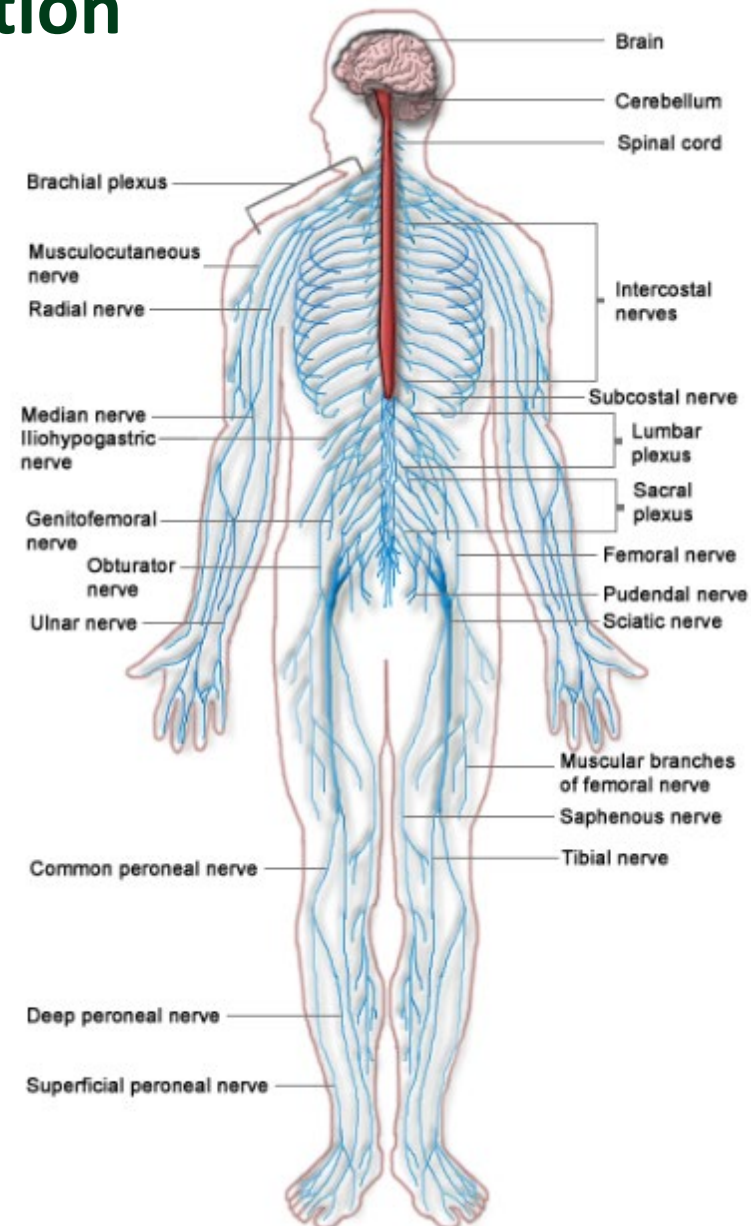
Recognition of an object by touch with eyes closed

Graphaesthesia

DESCENDING (Motor)

Motor Nervous System Orientation

- Brain (and CN)
- Brainstem
- Spinal Cord
-----Ant. Horn Cell
- Nerve Root
- Peripheral Nerve
- NMJ
- Muscle



Descending MOTOR Tracts

- Pyramidal Tracts
 - Corticospinal Tract
 - Corticobulbar Tract
- Extrapyramidal Tracts
 - Vestibulospinal
 - Tectospinal
 - Reticulospinal
 - Rubrospinal

Primary Descending (Motor) Pathways

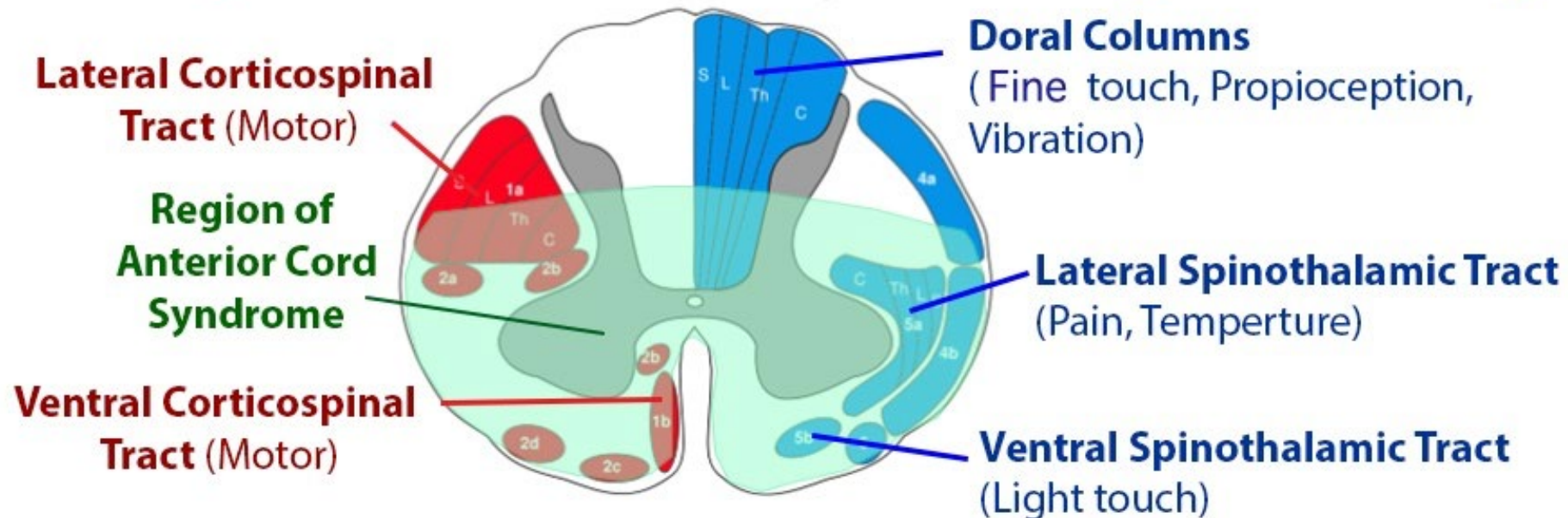
Tract	Location of Upper Motor Neurons	Destination (termination)	Site of Decussation (crossover)	Function
CORTICOSPINAL PATHWAY				
Corticobulbar tracts	Primary motor cortex (cerebral hemispheres)	Lower motor neurons of cranial nerve nuclei in brainstem	Brainstem	Conscious motor control of skeletal muscles
Lateral corticospinal tract	As above	Lower motor neurons of anterior gray horns of the spinal cord	Pyramids of medulla oblongata	As above
Anterior corticospinal tract	As above	As above	Level of lower motor neuron	As above
MEDIAL PATHWAY				
Vestibulospinal tracts	Vestibular nuclei (at the border of pons and medulla oblongata)	As above	None (uncrossed)	Subconscious regulation of balance and muscle tone
Tectospinal tract	Tectum (mesencephalon; superior and inferior colliculi)	Lower motor neurons of anterior gray horns (cervical spine only)	Brain stem (mesencephalon)	Subconscious regulation of eye, head, neck, and upper limb position in response to visual and auditory stimuli
Reticulospinal tracts	Reticular formation (network of nuclei in brainstem)	Lower motor neurons of anterior gray horns of spinal cord	None (uncrossed)	Subconscious regulation of reflex activity
LATERAL PATHWAYS				
Rubrospinal tracts	Red nuclei of mesencephalon	As above	Brain stem (mesencephalon)	Subconscious regulation of upper limb muscle tone and movement

Corticospinal Tract

- Lateral corticospinal Tract
 - Motor information for the limbs

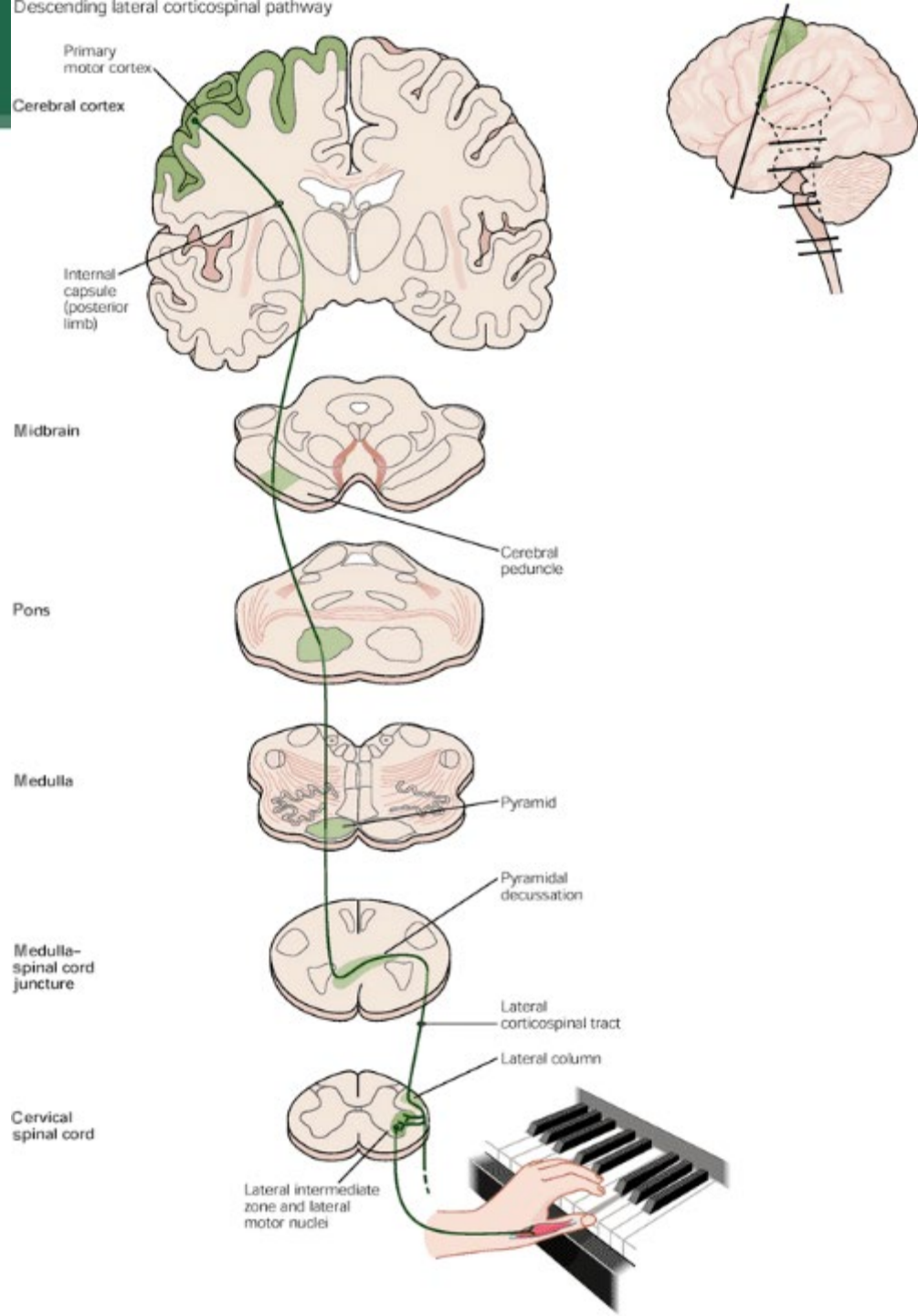
Descending Tracts (Motor)

Ascending Tracts (Sensory)



Corticospinal Tract AKA Pyramidal (MOTOR)

- Primary Descending Tract
- Information Carried:
 - Voluntary movement
- Begins in Primary Motor Cortex (cortico-)
- Synapses in spinal cord (-spinal)
- Alpha motor neuron goes from spinal cord to NMJ/muscle



Corticospinal Tract - Midbrain

Descending lateral corticospinal pathway

Primary motor cortex
Cerebral cortex

Internal capsule (posterior limb)

Cerebral aqueduct

Central (periaqueductal) gray

Medial longitudinal fasciculus

Anterolateral system

Anterior trigeminothalamic tract

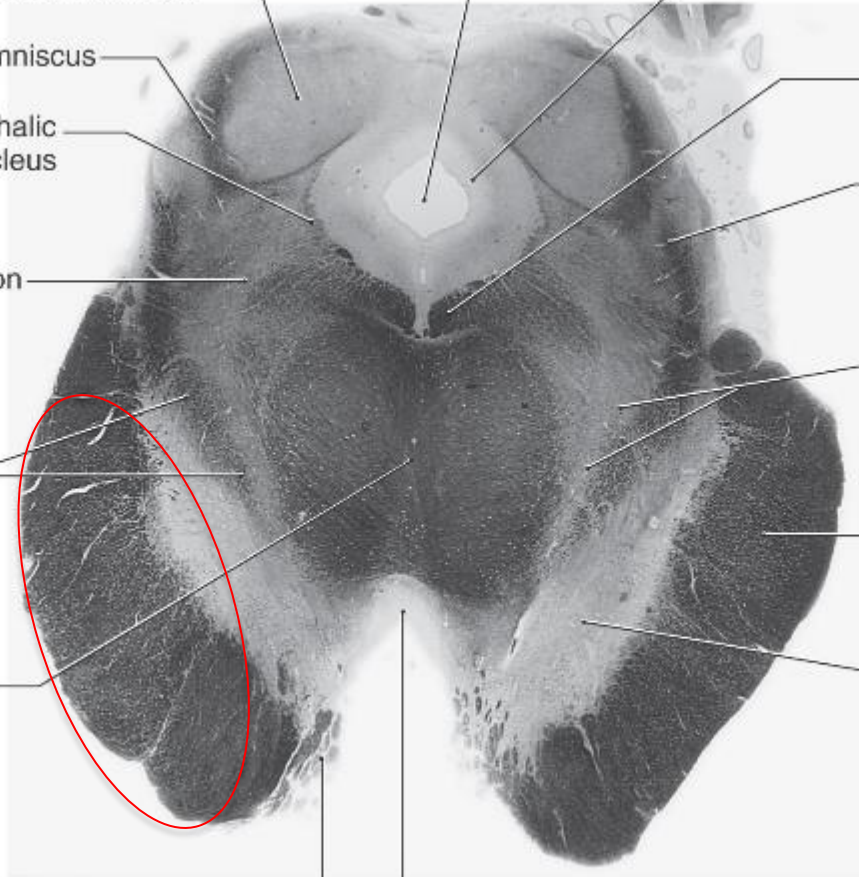
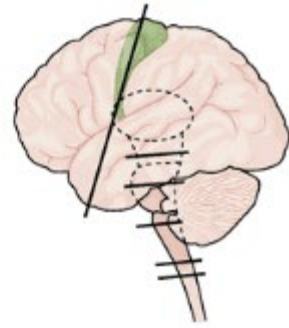
Crus cerebri

Substantia nigra

Inferior colliculus
Lateral lemniscus
Mesencephalic tract and nucleus
Reticular formation
Medial lemniscus
Decussation of superior cerebellar peduncle

Oculomotor nerve

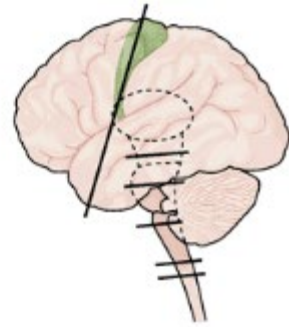
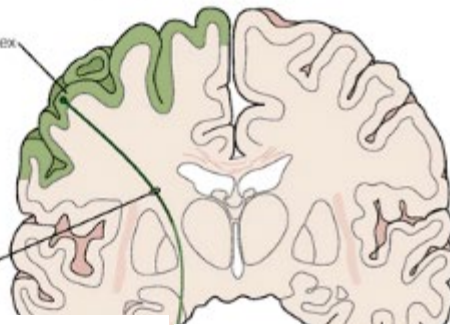
Interpeduncular fossa



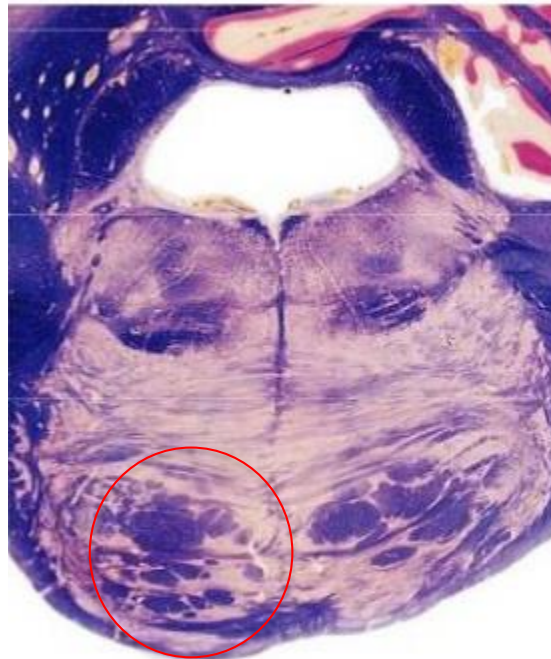
Corticospinal Tract – Pons

Descending lateral corticospinal pathway

Primary motor cortex
Cerebral cortex
Internal capsule (posterior)



Rostral Pons



Mid Pons

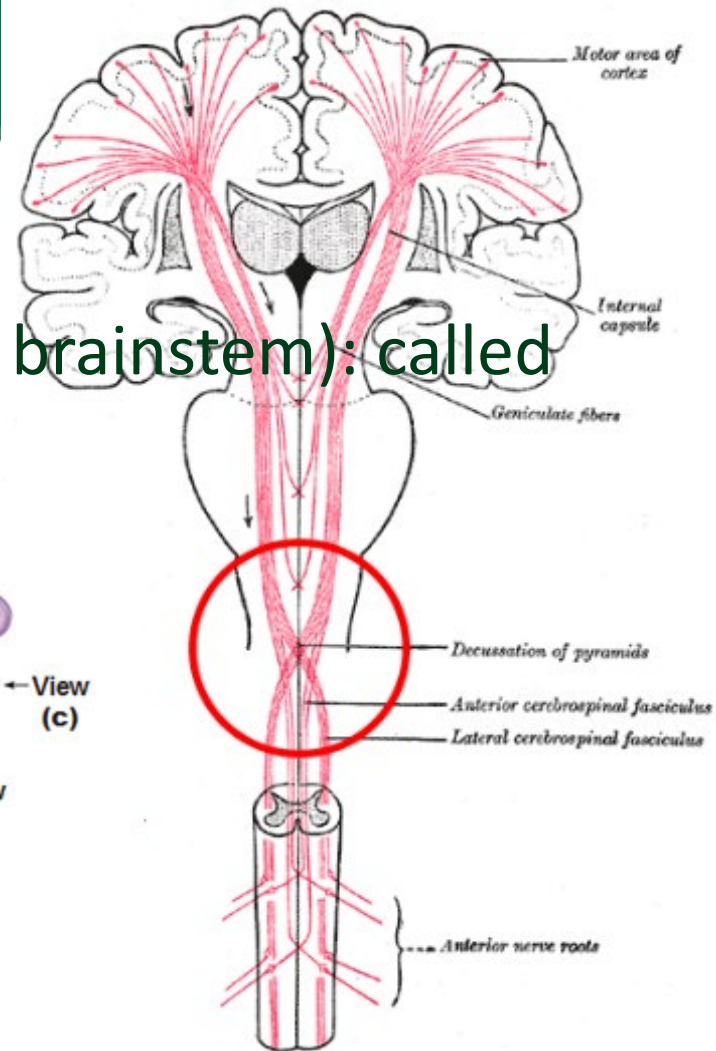
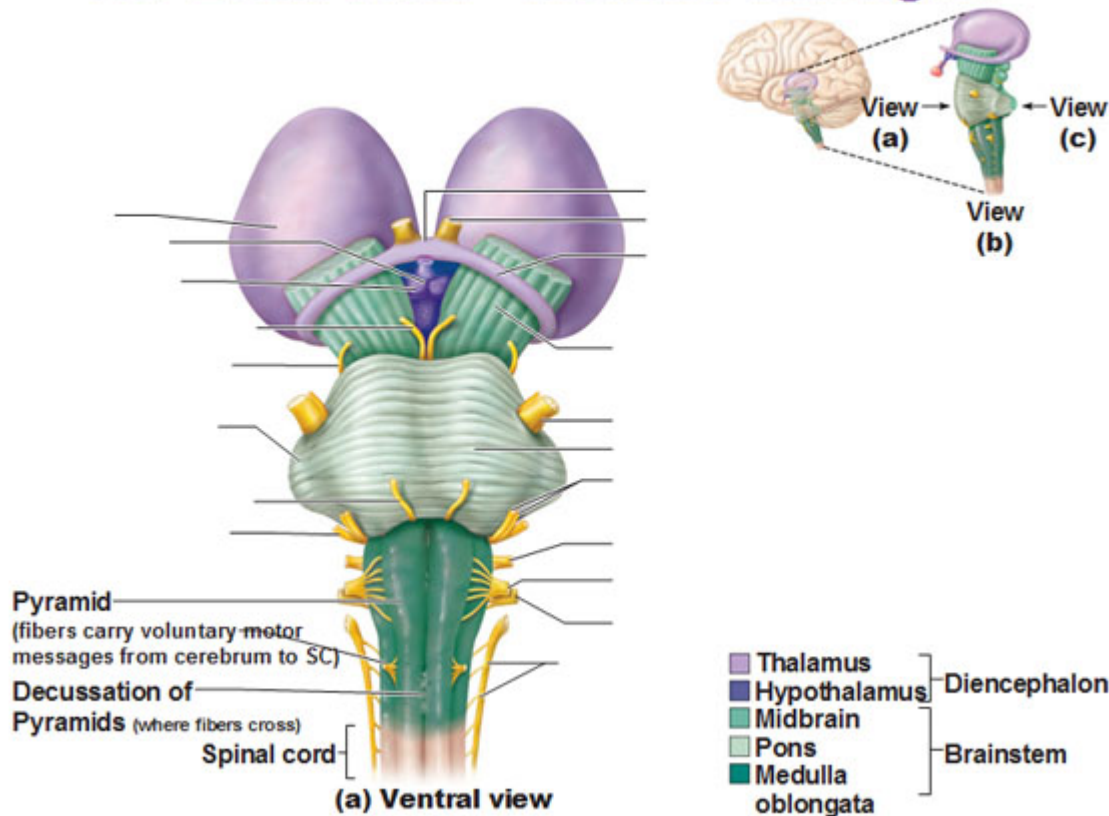


Caudal Pons

Corticospinal Tract

- Crosses in medulla (lowest part of brainstem): called **DECUSSATION OF THE PYRAMIDS**

The Brain Stem—Medulla Oblongata



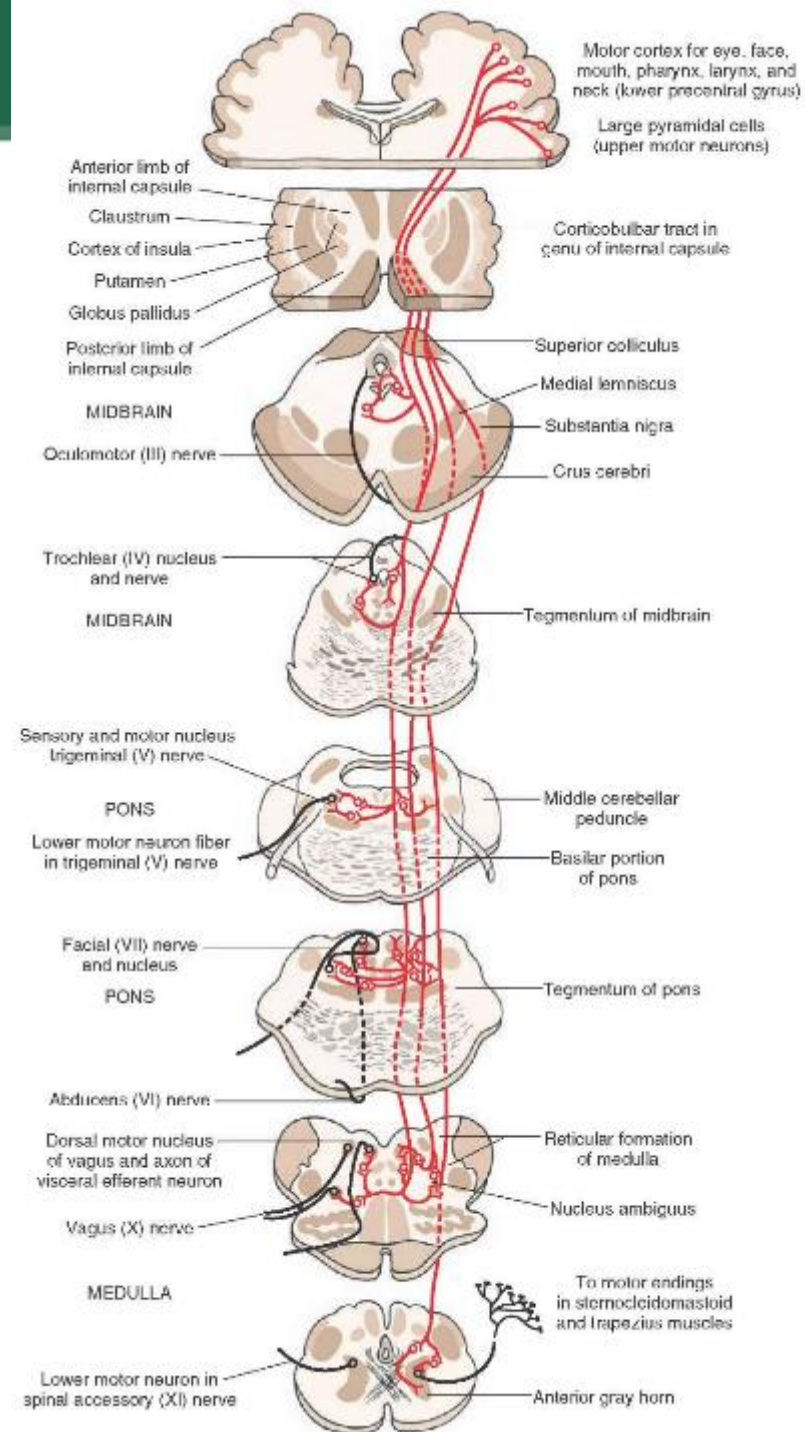
Corticospinal Tract – Clinical Correlation

- A Train Crossing – So What?
- Means that ABOVE the decussation (medulla and higher)
 - Lesion will produce contralateral weakness
- And BELOW the decussation (spinal cord and lower)
 - Lesion will produce ipsilateral weakness



Corticobulbar Tract

- Start: Primary Motor Cortex
- End: Nuclei for the MOTOR Cranial Nerves (motor to the face)
 - III, IV, VI – Eye movement
 - V – Muscles of mastication
 - VII – Facial muscles
 - IX, X – Muscles of pharynx
 - XII – Tongue movement



Corticospinal Tract – Clinical Correlation

- The **UPPER MOTOR NEURON** travels within the corticospinal tract
- Lesion anywhere along the course of CS tract will give UMN signs *BELOW* that level
 - Damage the tracks and train can go no further

Question:

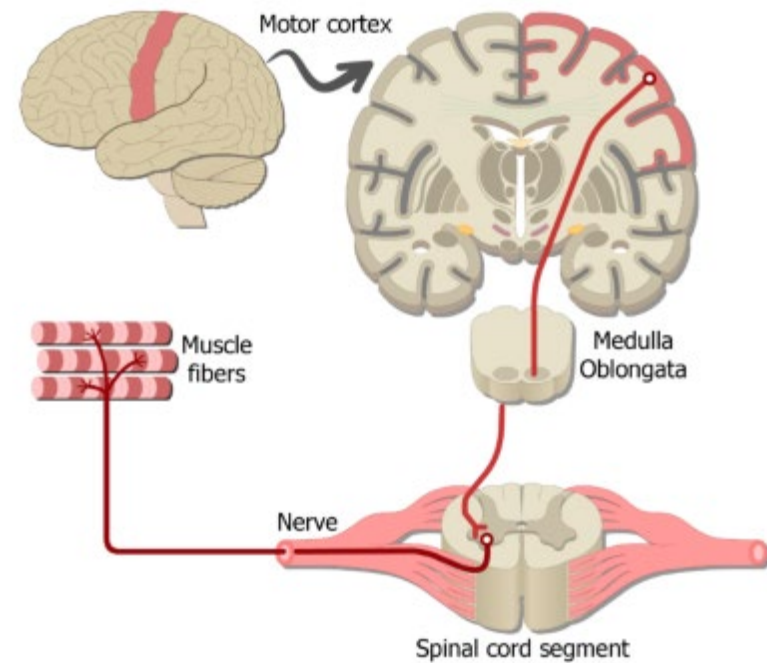
- How do you tell on exam if there is a problem in the Upper motor neuron?

Table 4. Upper Motor Neuron vs. Lower Motor Neuron Signs.

<u>Clinical test</u>	<u>Upper motor neuron</u>	<u>Lower motor neuron</u>
Reflexes	Hyperreflexia	Hyporeflexia
Muscle tone	Increased/Spastic	Decreased/Flaccid
Fasciculation	None	Present
Atrophy	None	Severe
Babinski sign	Present	Absent

Motor Nerves

- Myotomes
 - Synapse in the Anterior Horn of the Spinal Cord.
 - Lower motor Neuron (LMN)
 - Every bit as complicated as dermatomes



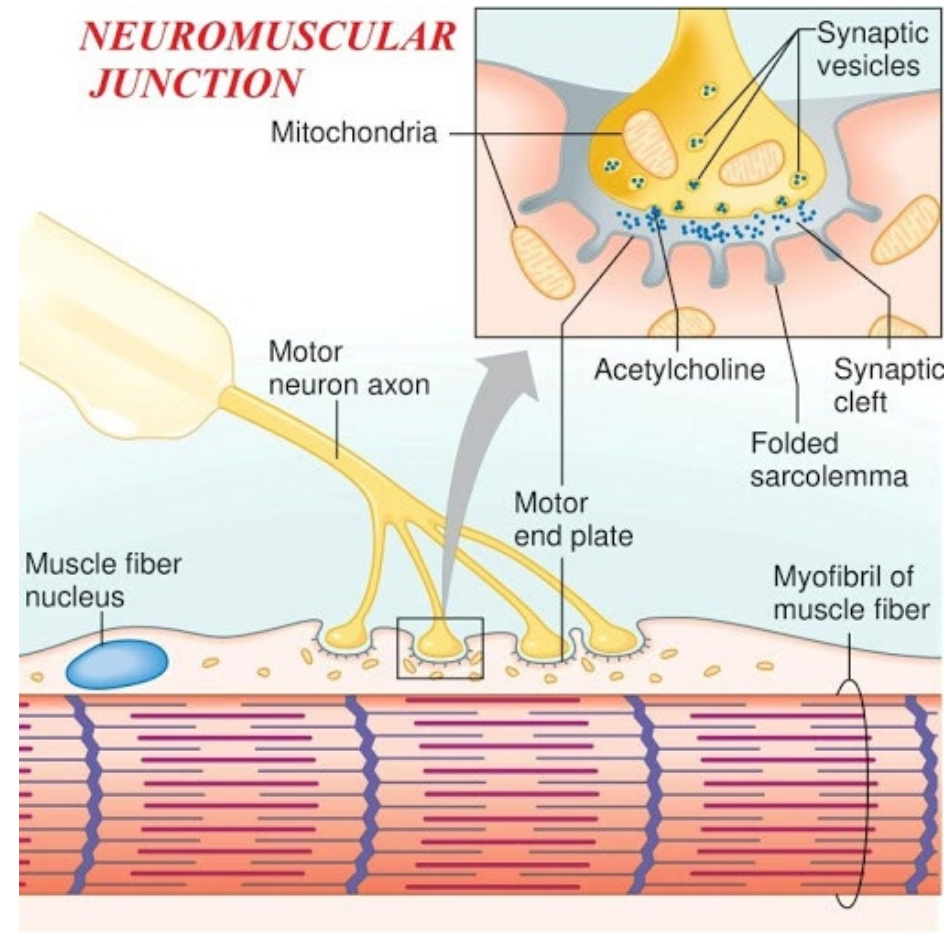
<u>Myotome</u>	<u>Action</u>
C5	Shoulder abduction and external rotation; elbow flexion
C6	Wrist extension
C7	Elbow extensors and wrist flexion
C8	Thumb extension and finger flexion
T1	Finger abduction
L1/L2	Hip flexion
L3	Knee extension
L4/L5	Ankle dorsiflexion
L5	Great toe extension
S1	Ankle plantar flexion
S4	Bladder and rectum motor supply

Question:

- What viral disease of childhood causes the Lower Motor Neuron to die at the Anterior Horns?

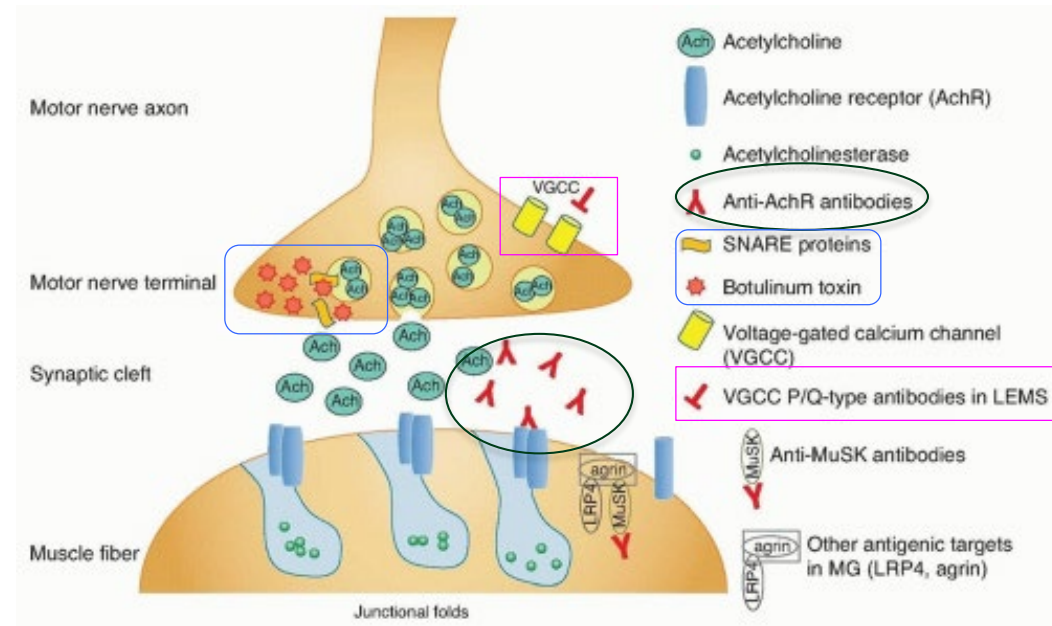
Neuromuscular Junction

- Signal is transmitted from the motor axon to the muscle at the NMJ.
- The neurotransmitter: acetylcholine
- The final goal is to achieve muscle contraction.



What happens in NMJ disorders?

- Failure of neuromuscular transmission due to different mechanisms:
- ✓ **Presynaptic:** impaired Ach release.
 - Lambert-Eaton myasthenic syndrome (LEMS): antibodies against P/Q voltage-gated calcium channels (VGCC) in the nerve terminal.
 - Botulism: botulin toxin cleaves various docking proteins (SNARE complex).
- ✓ **Postsynaptic:** impaired Ach signaling.
 - Myasthenia gravis: antibodies against nicotinic Ach R.

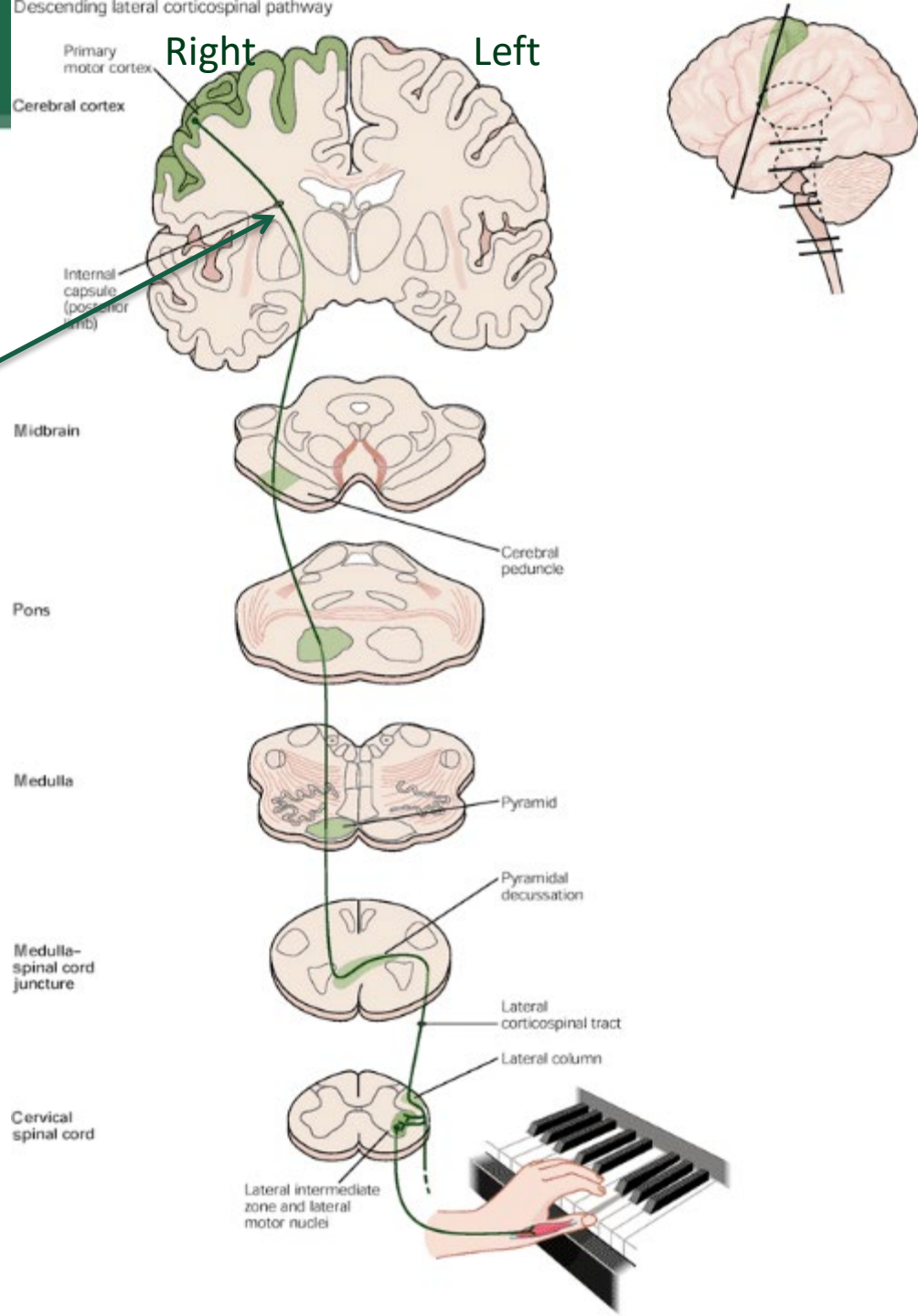
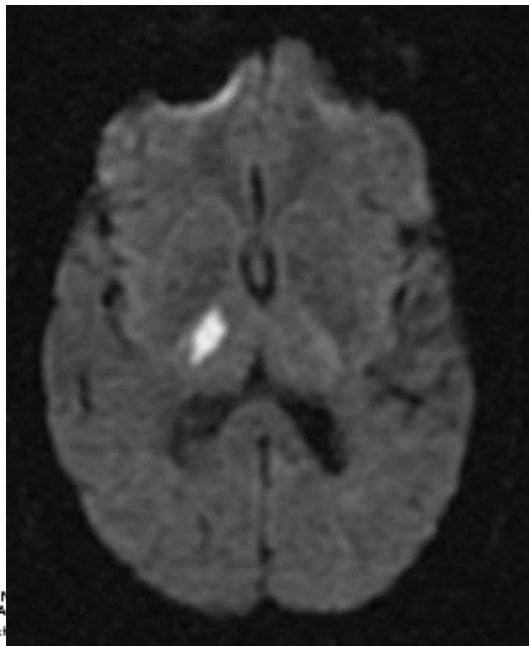


Localization Practice

- A patient presents with the sudden onset of loss of sensation as well as weakness in the left face, arm, and leg. They have no changes in their cognition and no neglect.
- What is the most likely etiology? Where is the lesion?

Localization Practice

- Refresh Corticospinal Tract
- A lesion here would cause what symptoms?

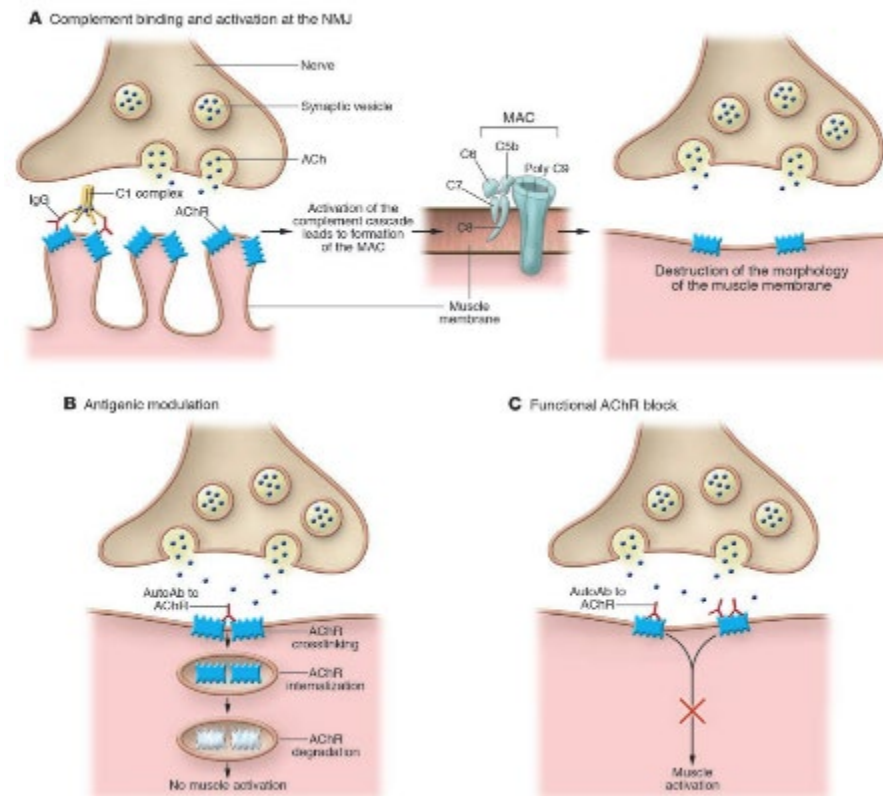


Localization

- A 21 year old woman has had about 4 months of increasing double vision, slurred speech, and difficulty climbing stairs and raising her arms above her head. Her sensation is all totally normal. But you find on your exam that she has weakness in her arms and legs worse proximally as well as facial, eyelid, and eye muscle weakness. Where is the localization?

Myasthenia Gravis – Neuromuscular Junction

- First recognized neurological autoimmune disease.
- Postsynaptic disorder: autoimmune attack by antibodies targeting AchR (binding, blocking, modulating). Other antibodies: MUSK, LRP4.
- Often associated with thymoma.
- Ocular myasthenia is the mildest form.
- Highly variable disease with fatigable weakness.
- Generalized MG can be fatal with respiratory failure (and aspiration pneumonia).

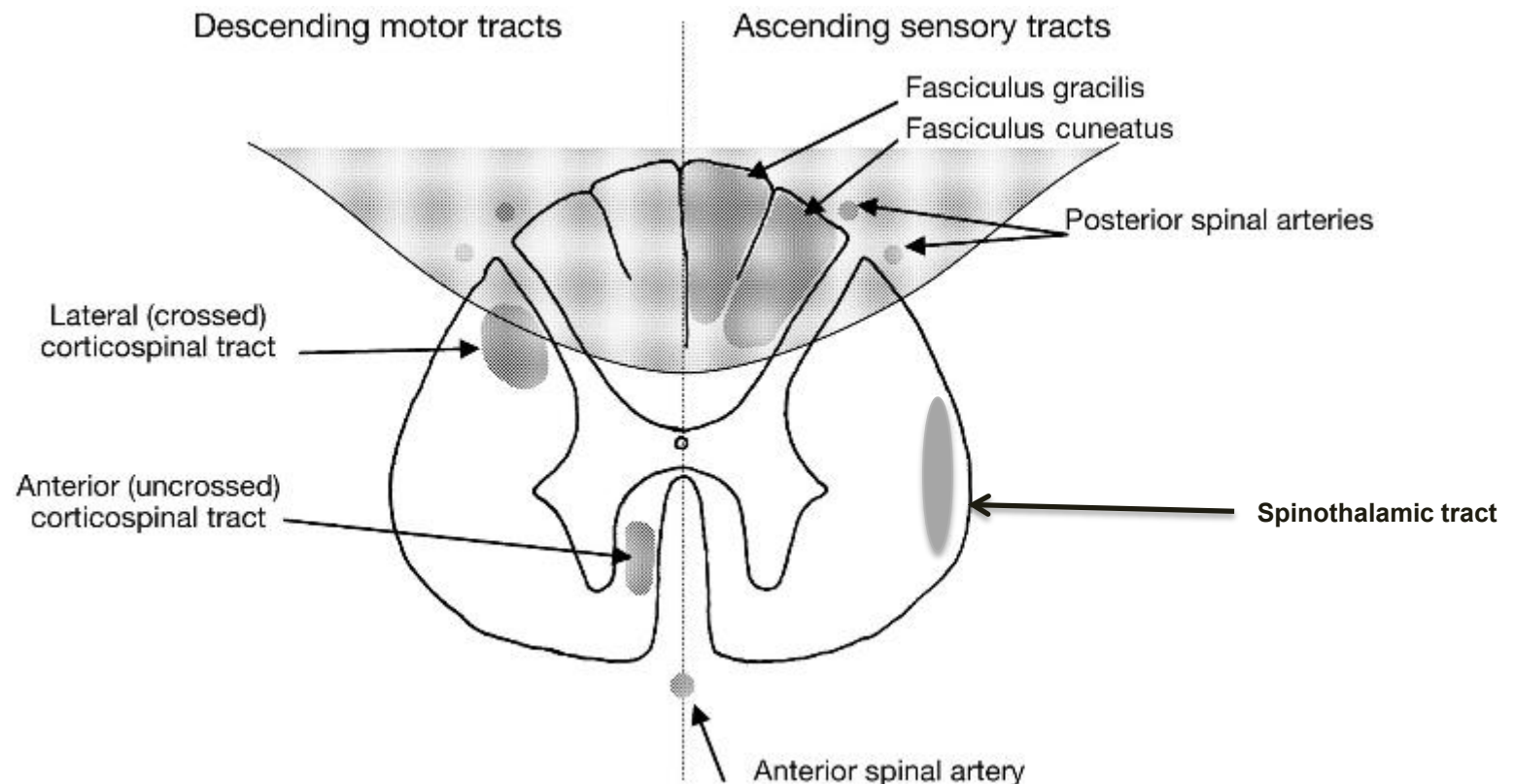


Localization Practice

- A patient was getting an abdominal surgery. Post operatively, he had weakness in both legs with increased reflexes at both ankles and both knees and increased tone (spastic) in both legs two weeks later. This patient also lost the ability to feel pinprick in the legs. However, strength, reflexes, and tone are all normal in the arms. And the patient can feel vibration in their feet. Where is the lesion?

Localization Practice

- Anterior spinal artery syndrome – at T6 level



Localization

One day Jesus was teaching, and Pharisees and teachers of the law were sitting there. They had come from every village of Galilee and from Judea and Jerusalem. And the power of the Lord was with Jesus to heal the sick. **Some men came carrying a paralyzed man on a mat and tried to take him into the house to lay him before Jesus. When they could not find a way to do this because of the crowd, they went up on the roof and lowered him on his mat through the tiles into the middle of the crowd, right in front of Jesus.**

Localization

When Jesus saw their faith, he said, “Friend, your sins are forgiven.” The Pharisees and the teachers of the law began thinking to themselves, “Who is this fellow who speaks blasphemy? Who can forgive sins but God alone?” Jesus knew what they were thinking and asked, “Why are you thinking these things in your hearts? Which is easier: to say, ‘Your sins are forgiven,’ or to say, ‘Get up and walk’? But I want you to know that the Son of Man has authority on earth to forgive sins.” So he said to the paralyzed man, “I tell you, get up, take your mat and go home.” Immediately he stood up in front of them, took what he had been lying on and went home praising God. Everyone was amazed and gave praise to God. They were filled with awe and said, “We have seen remarkable things today.”

By Next Week!

- Reading assignment on Vision
- Handout assignment