if can answer the study objectives all good, high yield is the videos, poll everywhere need to know
read it like a book chapter then watch the video and do the poll everywhere then can use pdf to help with anything you don't understand

Spinal Cord Pathways
Objectives

B. Puder, Ph.D.

1. Define the course and function of the following pathways:
   Anterolateral system
   Posterior columns/medial lemniscus
   Voluntary motor pathway

2. Define visceral vs. somatic pain and explain how these pathways differ.

3. Define referred pain.

4. Describe some examples in terms of origin of visceral pain and the region of the body to which it may be referred.

5. Be able to list the expected signs or symptoms that would result from the following:
   transection of the cord at the cervical, thoracic, or lumbar levels
   hemisection of the cord (right or left half)

6. Define the difference between an upper and a lower motor neuron lesion

7. Describe the signs/symptoms a patient will exhibit if there is a lesion along one of the following pathways: Anterolateral system, Posterior columns/medial lemniscus, Voluntary motor pathway, OR if given an image which depicts a lesion in one of the these 3 pathways, be able to describe the signs of symptoms.

Spinal cord Pathways
Outline

I. Tracts and Pathways – Sensory

NOTE: The Lateral and Ventral Spinothalamic Tracts are now generally referred to as the spinothalamic tract or Anterolateral tract of the Anterolateral system (ALS). This tract or System carries Pain, Temperature, and Crude or Light Touch.

A. Pain and Temperature pathway = Anterolateral system (Lateral Spinothalamic tract).
   1. Somatic – crossed pathway
   2. To conscious levels
   3. Posterior root ganglion (PRG) (cell bodies of neuron #1) / posterolateral fasciculus (axons of neuron # 1) → Substania Gelatinosa (cell bodies of neuron #2) / Anterior white commissure (axons of neuron # 2 crossing) & Anterolateral system (lateral spinothalamic tract) (axons of neuron # 2) → Thalamus [Ventral posterolateral nucleus] (cell bodies of neuron # 3) /Thalamocortical fibers (axons of neuron # 3) → Cortex (postcentral gyrus –area 3,1,2, or paracentral lobule

B. General Tactile – Crude and Light Touch = Anterolateral System (Ventral Spinothalamic Tract).
   1. Somatic – crossed pathway
   2. To conscious levels
   3. PRG (cell bodies of neuron 1) /posterolateral fasciculus (axons of neuron # 1) → Nucleus Proprius (cell bodies of neuron # 2) / Anterior white commissure (axons of neuron # 2 crossing) & Anterolateral system (Ventral Spinothalamic Tract) axons of neuron # 2 → Thalamus [Ventral Posterolateral nucleus] (cell bodies of neuron # 3) / Thalamocortical fibers (axons of neuron # 3) → Cortex (postcentral gyrus –area 3,1,2, or paracentral lobule).

C. Visceral Pain = Anterolateral system (lateral spinothalamic tract) and reticular formation
   1. Visceral – crossed and uncrossed pathway
   2. To conscious levels
   3. PRG (cell bodies of neuron #1) / posterolateral fasciculus (axons of neuron # 1) → Sub. Gelatinosa (cell bodies of neuron #2) / ipsi and contralateral Anterolateral system (axons of neuron # 2) → Thalamus [Ventral posterolateral nucleus] (cell bodies of neuron #3) / Thalamocortical fibers (axons of neuron # 3) → Cortex (postcentral gyrus –area 3,1,2, and paracentral lobule).
   4. Pathway tends to follow the distribution of sympathetic nerves (visceral afferent nuclei = T1 – L2).

D. Conscious proprioception and fine or discriminatory touch (2 point discrimination) = Posterior columns/Medial Lemniscus

1. Somatic – uncrossed in the cord, crossed in the brainstem
2. To conscious levels
3. PRG (cell bodies of neuron #1) / Fasciculus Gracilis or Cuneatus (axons of neuron # 1) → Nucleus gracilis or cuneatus (cell bodies of neuron # 2) / Medial Lemniscus(axons of neuron # 2) → Thalamus [Ventral Posterolateral nucleus] (cell bodies of neuron #3)/ Thalamocortical fibers(axons of neuron # 3 → Cortex (postcentral gyrus area 3,1,2, of paracentral lobule).

E. Reflex Proprioception = Posterior and Anterior Spinocerebellar tracts

1. Somatic – crossed and uncrossed in the cord, but termination is ipsilateral.
2. To subconscious levels (2 neuron pathway)
3. PRG (neuronal cell body 1) , posterior columns (axons) → spinal border cells/or Dorsal nucleus of Clarke (C8-L3) (cell body 2) Posterior and Anterior Spinocerebellar tracts and Cuneocerebellar tract (axons) via Inferior or Superior cerebellar peduncle → Cerebellum

II. Sensory Cortex

A. Functional localization patterns, homunculus
B. Connections

III. Motor Pathway

A. Motor - voluntary - pyramidal - lateral corticospinal tract

1. somatic

2. Motor cortex - cell bodies are in the precentral gyrus and paracentral lobule. The axons will descend through the posterior limb of the internal capsule, through the cerebral peduncles of the midbrain, through the anterior aspect of the pons, through the pyramids of the medulla. These axons are called the corticospinal tracts.The axons cross in the medulla at the pyramidal/motor decussation in the medulla and is then called the lateral corticospinal tracts.

These axons will synapse on lower motor neuronal cell bodies in the anterior horn of the spinal cord whose axons willl project out to innervate skeletal muscle.

3. Upper vs. lower motor neuron lesions

IV. Motor cortex

Introduction to Tracts and Pathways

Pathway = chain of neurons

Tract = 1 group of neurons (their axons) in a pathway

Tracts/fibers are named according to origin and termination:

eg. Corticospinal tract begins in the cortex and terminates in the spinal cord.

The tract /pathway name indicates:

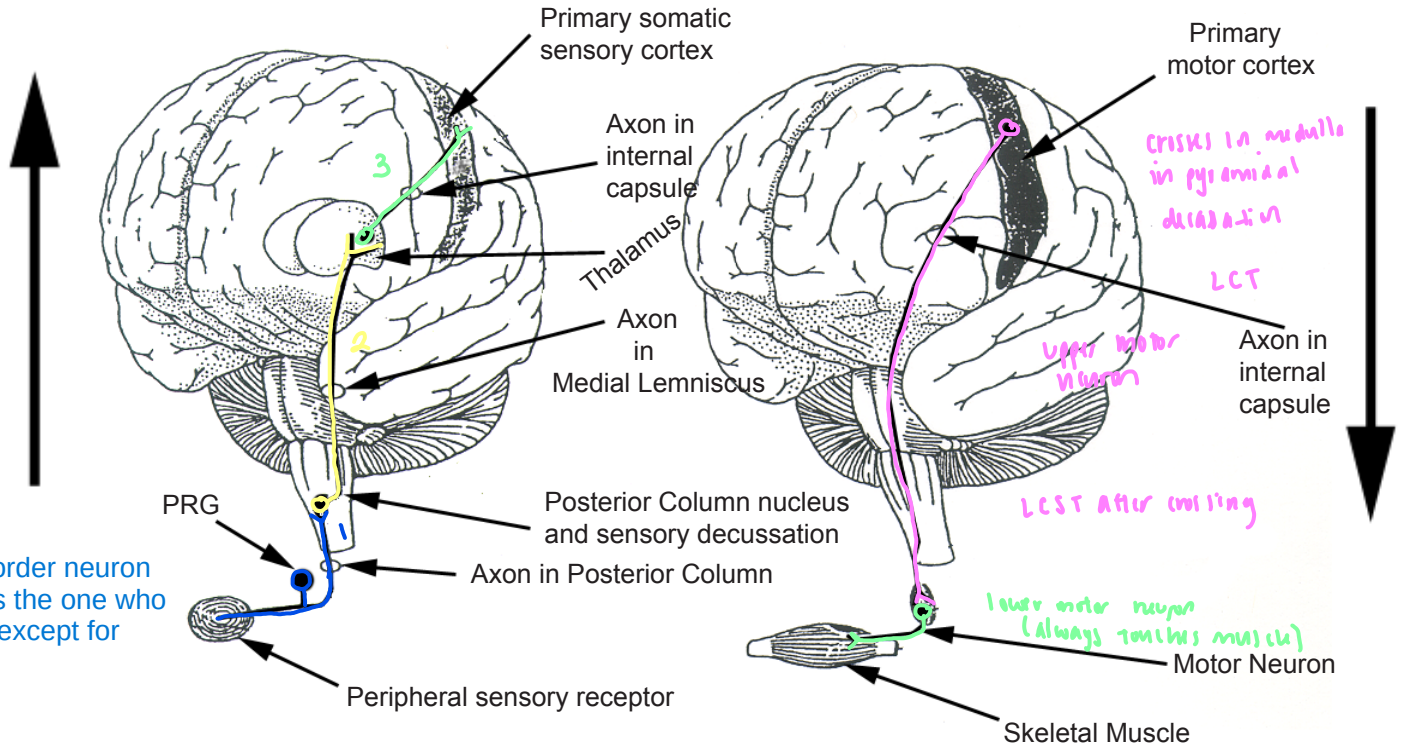
1. Whether the tract is ascending or descending
2. Location of the cell body
3. The place where the axons terminate

Sensory Pathway

(e.g. Posterior Column/Medial Lemniscus)

Motor Pathway

(e.g. Corticospinal Tract)



second order neuron is always the one who crosses except for taste

Sensory Pathway:

- Brings **sensory information to** conscious levels **(cortex)**
- **3 Neurons** in the pathway
  1. Receptor (Pseudounipolar)
  2. Relay from lower center to Thalamus
  3. Relay from Thalamus to Cortex

- **3 Tracts** (axons of the 3 neurons in the pathway)
  For the posterior columns/medial lemniscus pathway:
  1. Axons in the cord form posterior columns
  2. Relay axons to thalamus form medial lemniscus
  3. Relay axons from thalamus to cortex form Thalamocortical Tracts

Motor Pathway:

- Relays **motor information** from cortex **to muscle**
- **2 neurons** in pathway - the cell bodies are located:
  1. 1 in cortex sending info to spinal cord (UMN)
  2. 1 in anterior horn of the spinal cord sending info to muscle (LMN)
- **2 Tracts** in pathway
  1. Axons from cortical neurons (cortical spinal neurons)
  2. Axons from spinal cord to muscle (peripheral nerve)

Key pathways seen in the spinal cord: nociception/thermoception

1. Anterolateral System (AKA: The Pain and Temperature Pathway for the body)

The anterolateral system (pain and temperature pathway - for the body) relays:

1. somatic pain -sharp, well localized, easy to describe precisely
2. temperature - hot or cold or degrees in between

This pathway is used to test the integrity of the nervous system and the location of the lesions. free neuron ending

1. First order neurons that relay pain, temperature, and crude touch are in the periphery and correspond to its respective dermatome level. (e.g. a sharp piece of glass piercing the bottom and center of the foot would use peripheral sensory nerves from the L5 dermatome, while pain sensation from cutting the palm of your hand will travel via C6/C7/C8).

ascending

2. First order neurons are pseudounipolar neurons whose cell bodies are located in the posterior root ganglion. This first order neuron projects into the spinal cord through the posterolateral sulcus (the first order axons are called the posterolateral fasciculus.) The first order neurons will synapse in the substantia gelatinosa (cell bodies of the second order neuron) of the posterior horn of the gray matter of the spinal cord.

3. The second order neuronal axons will decussate through the anterior white commissure and become the anterolateral system. (specifically, this group of axons is called the spinothalamic tracts).

4. The anterolateral system (spinothalamic tracts) will project up through the brainstem, synapse in the ventral posterolateral nucleus of the thalamus (third order neuron) and then synapse in the posterior aspect of the paracentral lobule or postcentral gyrus.

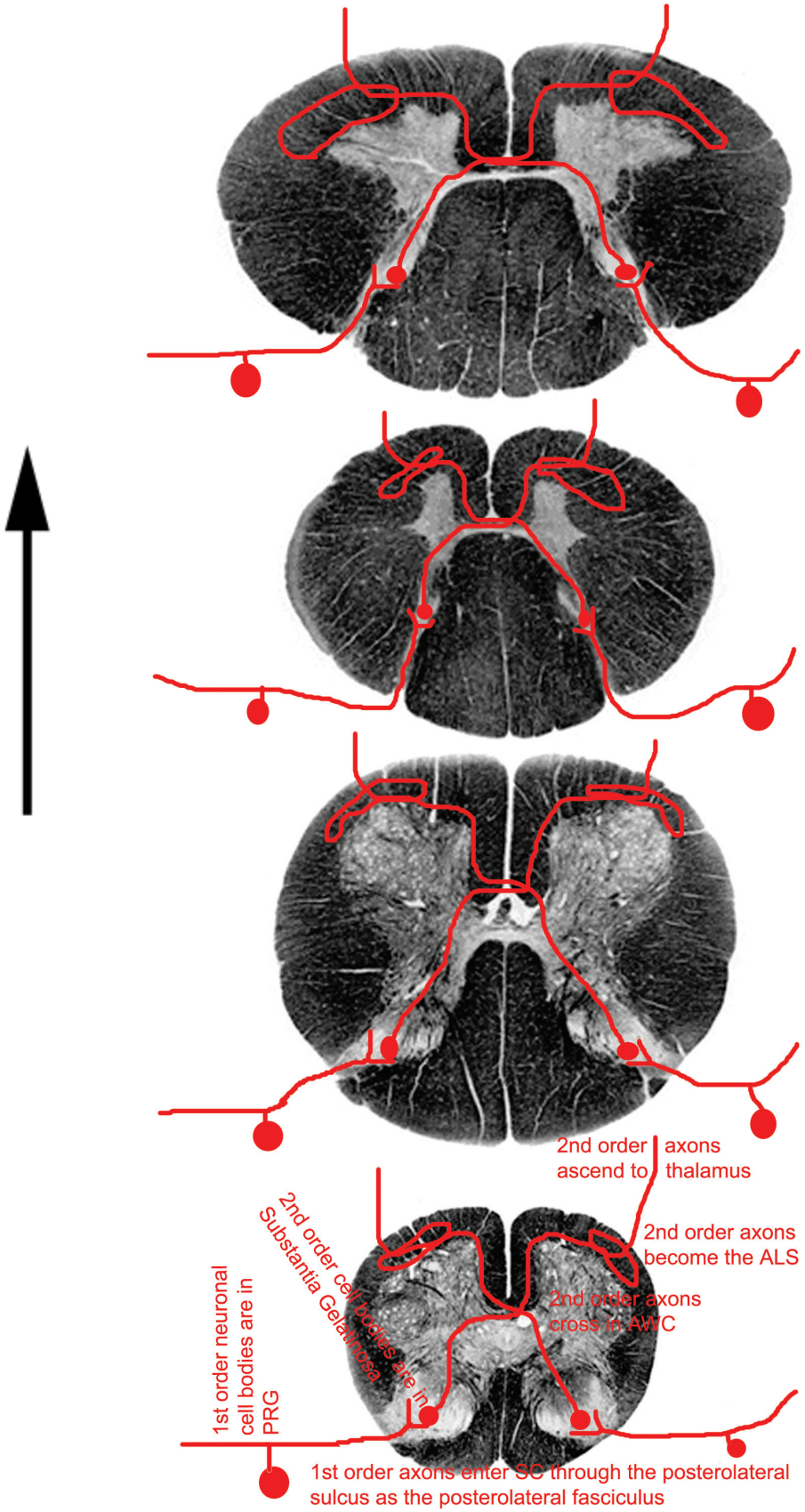
There exists a somatotopic pattern in the ALS (spinothalamic tracts)
-1st fibers to enter and cross from the sacral cord are the most lateral.
-2nd fibers to enter and cross from the lumbar cord are added more medially.
-3rd fibers to enter and cross from the thoracic cord are added even more medially.
-4th fibers to enter from the cervical cord are added most medially

Key Points:

- **3 Neuron Pathway (3 tract system)**
- The **main** named **tract** (lateral **spinothalamic** tract - aka -Anterolateral System/ALS) **crosses in the spinal cord. This is the second order neuronal axons.**
- The **2 other tracts** in this system are the **axons of the peripheral nerve** (pseudounipolar neuron) and the **thalamocortical axons**.

Clinical Aspects: Lesions:
Lesion in the **peripheral nerve** = **loss of P&T** (pain and temp) **at that dermatome level**
Lesion in the **spinothalamic tract (after crossing)**, or in the **thalamocortical fibers** = **loss** of **P&T on the contralateral side** of the **body below the level of the lesion.**

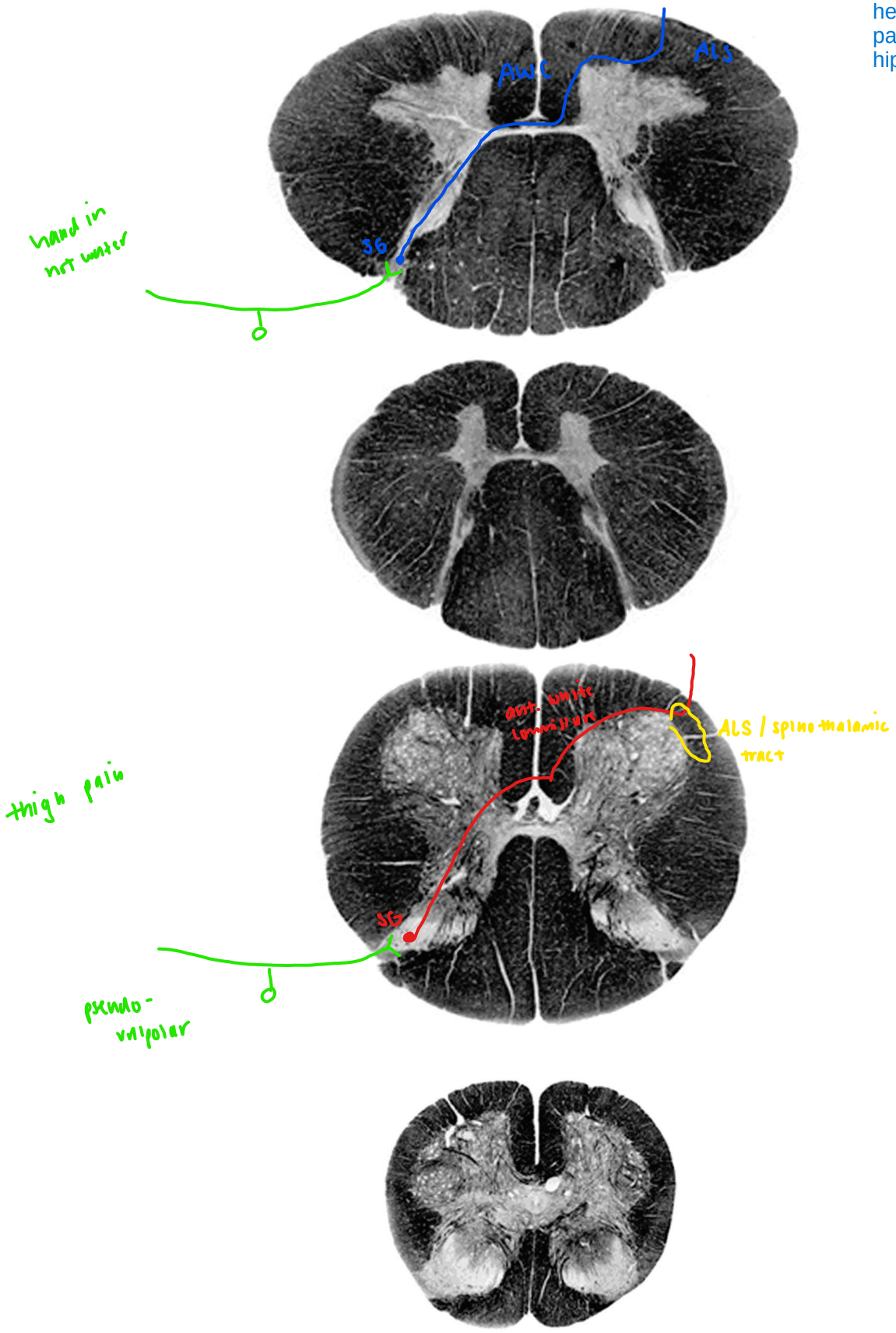
Anterolateral System (AKA: The Pain and Temperature Pathway for the body)



neuron 1 from periphery
neuron 2 is crosser
neuron 3 lives in thalamus

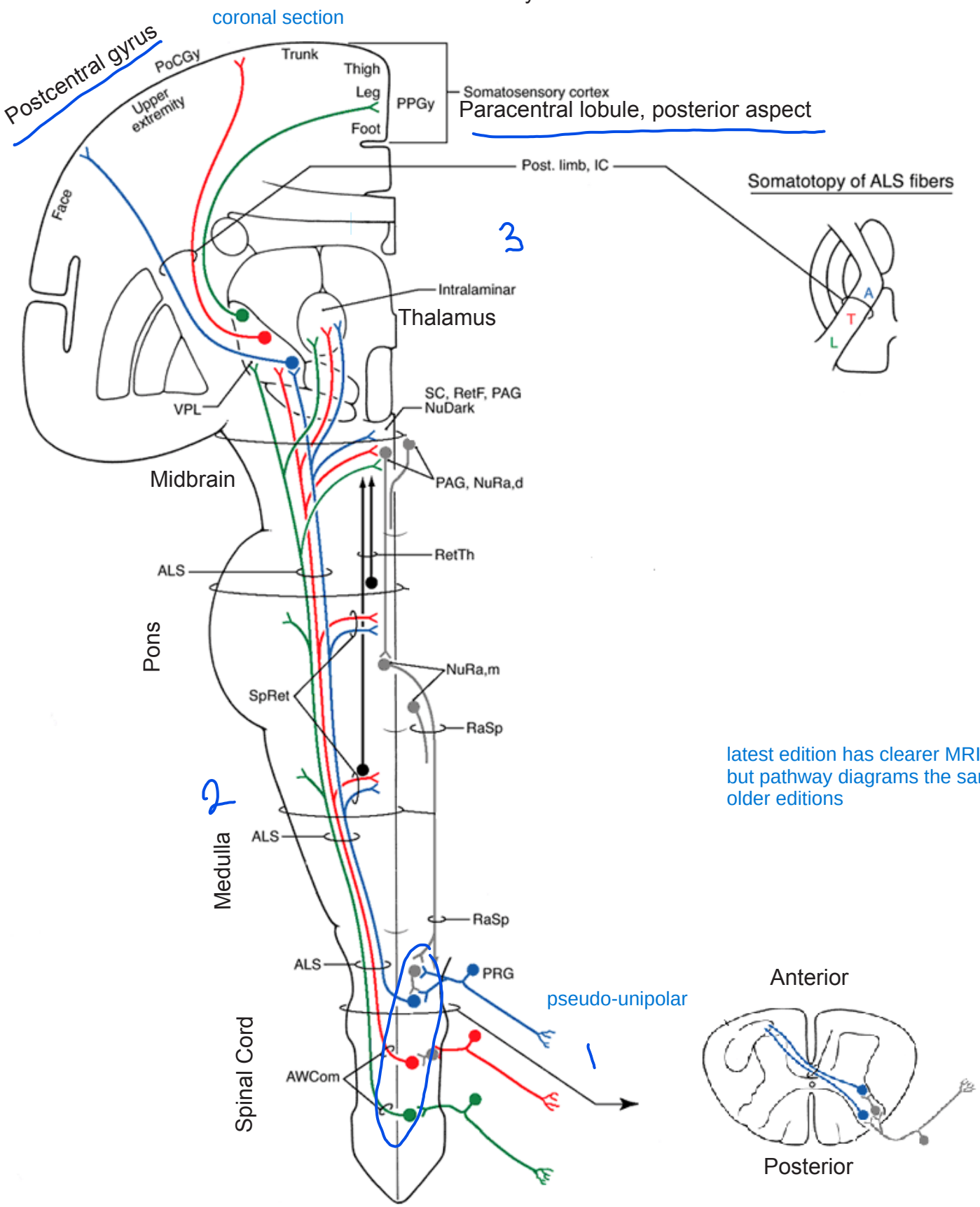
We will use this page to draw in the anterolateral system pathway

post central gyrus - head to hip
paracentral lobule - hip, knee, foot



not used on test but is big picture of what's happening

The Anterolateral System



latest edition has clearer MRI and CT but pathway diagrams the same in older editions

Adapted from Neuroanatomy: An atlas of Structures, Sections, and Systems, D.E.Haines

Visceral Pain Pathway - To Consciousness

- Pain (nociceptive information) from the body cavities - e.g. pelvic, peritoneal, and pleural to the Cortex
- Poorly localized, diffuse ,dull, aching pain. Can be excruciating -e.g. -Pain from the ureter from a kidney stone

clinician will talk about
Multi-synaptic
not as distinct as pain/temp pathway, visceral pain is diffuse

Visceral Sensory fibers travel with sympathetic nerves from the viscera. **1st** neuronal cell body is in the **PRG**, **2nd** neuronal cell body is in the **nucleus proprius (or nearby)**. After this point, many neurons **relay in the reticular formation** , then go to the **thalamus**, then to the **postcentral gyrus (areas 3,1,2)** for conscious appreciation of pain. Because this is a **polysynaptic pathway,** conduction is **slow,** and because the information is carried **bilaterally**, **localization is poor**.

spinal cord (axon of first neuron) medial lemniscus in medulla (neuron 2 in pathway)

2. Posterior Columns/Medial Lemniscus (PC/ML) Pathway

This pathway carries **Fine or Discriminatory Touch, 2-point discrimination**, **Position** and **Vibratory sense** from the body

does not cross in spinal cord crosses in medulla at medial lemniscus

1. First order neurons that relay fine,discriminatory touch, 2point discrimination, position and vibratory sense are in the periphery and correspond to its respective dermatome level. (e.g. pressing/touching on the bottom and center of the foot would use peripheral sensory nerves from the L5 dermatome, while touch sensation from the palm of your hand will travel via C6/C7/C8).
Sounds just like the first order neurons for the ALS pathway - doesn't it???
The only difference is the type of peripheral receptors that they contain. Pain and temperature sensation has free nerve endings, while fine touch, 2point discrimination, vibratory sense uses peripheral receptors called Merkels disks, Pacinian, Ruffini , Meisner's corpuscles.

2. First order neurons are pseudounipolar neurons whose cell bodies are located in the posterior root ganglion. This first order neuron projects into the spinal cord through the posterolateral sulcus (the first order axons are called the posterolateral fasciculus.)

3. If the first order axons are entering spinal cord sections T6 or below, then these axons will go into the posterior columns of the spinal cord and are called the fasciculus gracilus.
If the first order axons are entering spinal cord sections above T6, then these axons go into the posterior columns and are called the fasciculus cuneatus.

So, the posterior columns/medial lemniscus pathway is still at neuron #1 within the spinal cord.

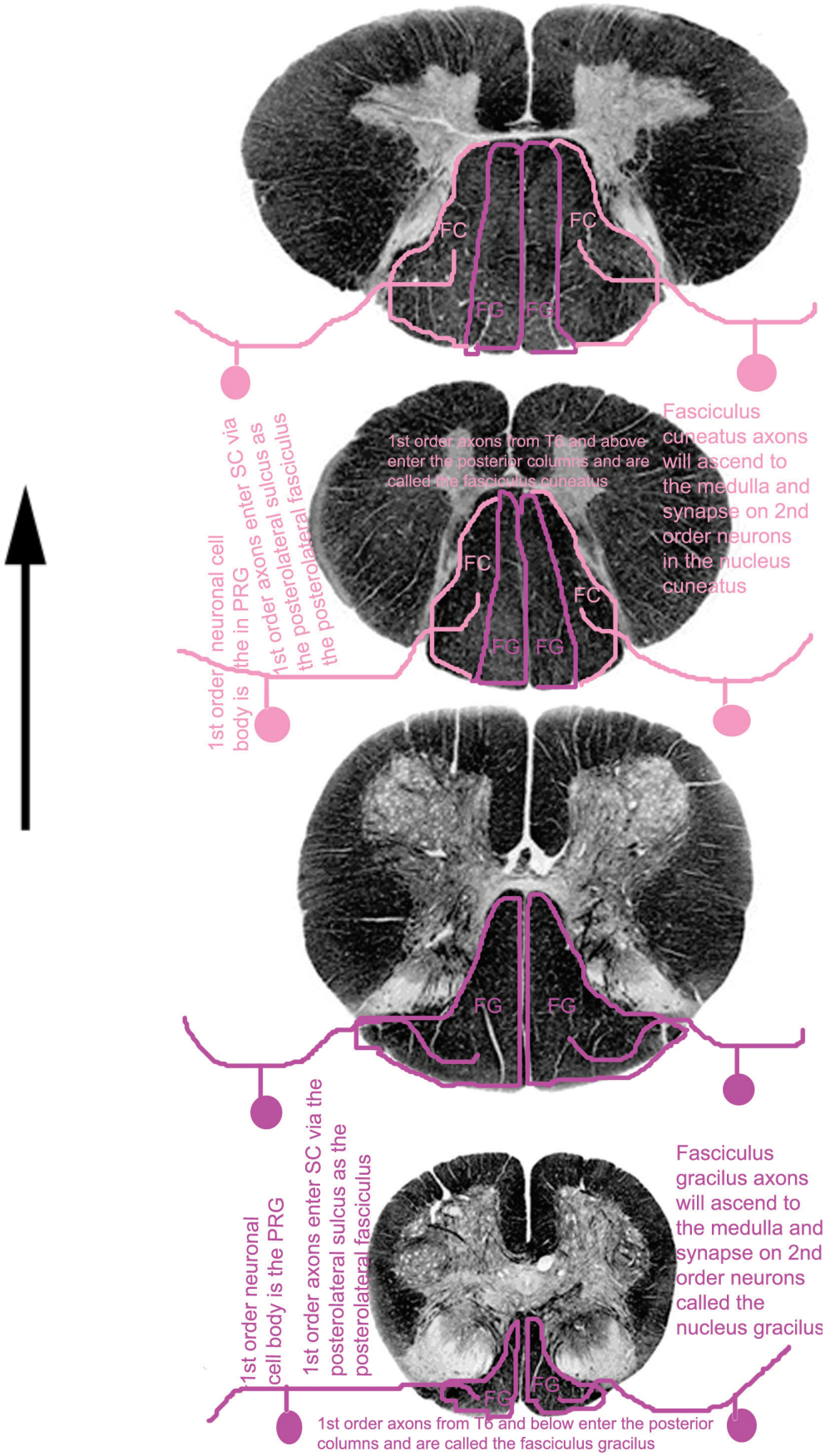
4. Cell bodies of neuron #2 (second order neuron) will not be seen until the caudal medulla as the nucleus gracilus and nucleus cuneatus respectively. The second order neuronal axons will decussate and become the medial lemniscus.

5. The medial lemniscus will project up through the brainstem, synapse in the ventral posterolateral nucleus of the thalamus (third order neuron) and then synapse in the posterior aspect of the paracentral lobule or the postcentral gyrus.

Key Point: The **Posterior Column/Medial Lemniscus (PC/ML)** Pathway **DOES NOT CROSS** in the **Spinal Cord. Therefore any lesion to this pathway in the spinal cord will produce ipsilateral losses of fine touch, vibratory, postition sense etc...**

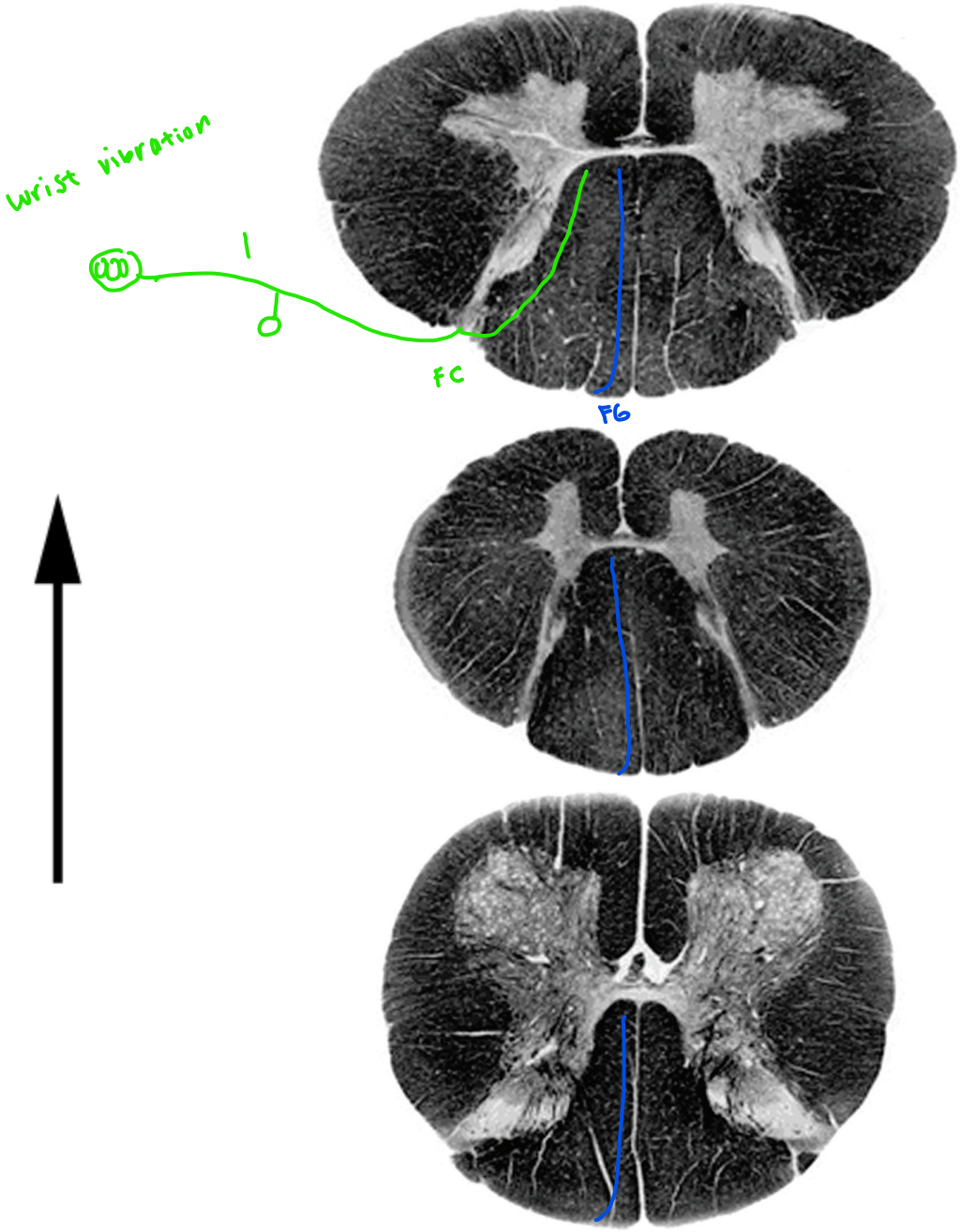
Posterior columns/medial lemniscus pathway in the spinal cord

no neuron number 2 in this pathway in spinal cord

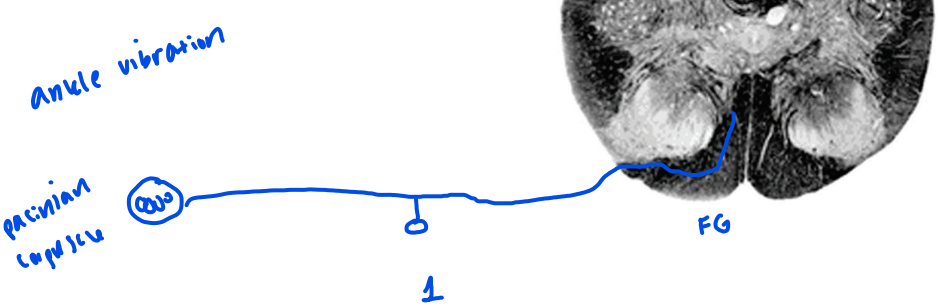


discriminative touch or vibratory sense

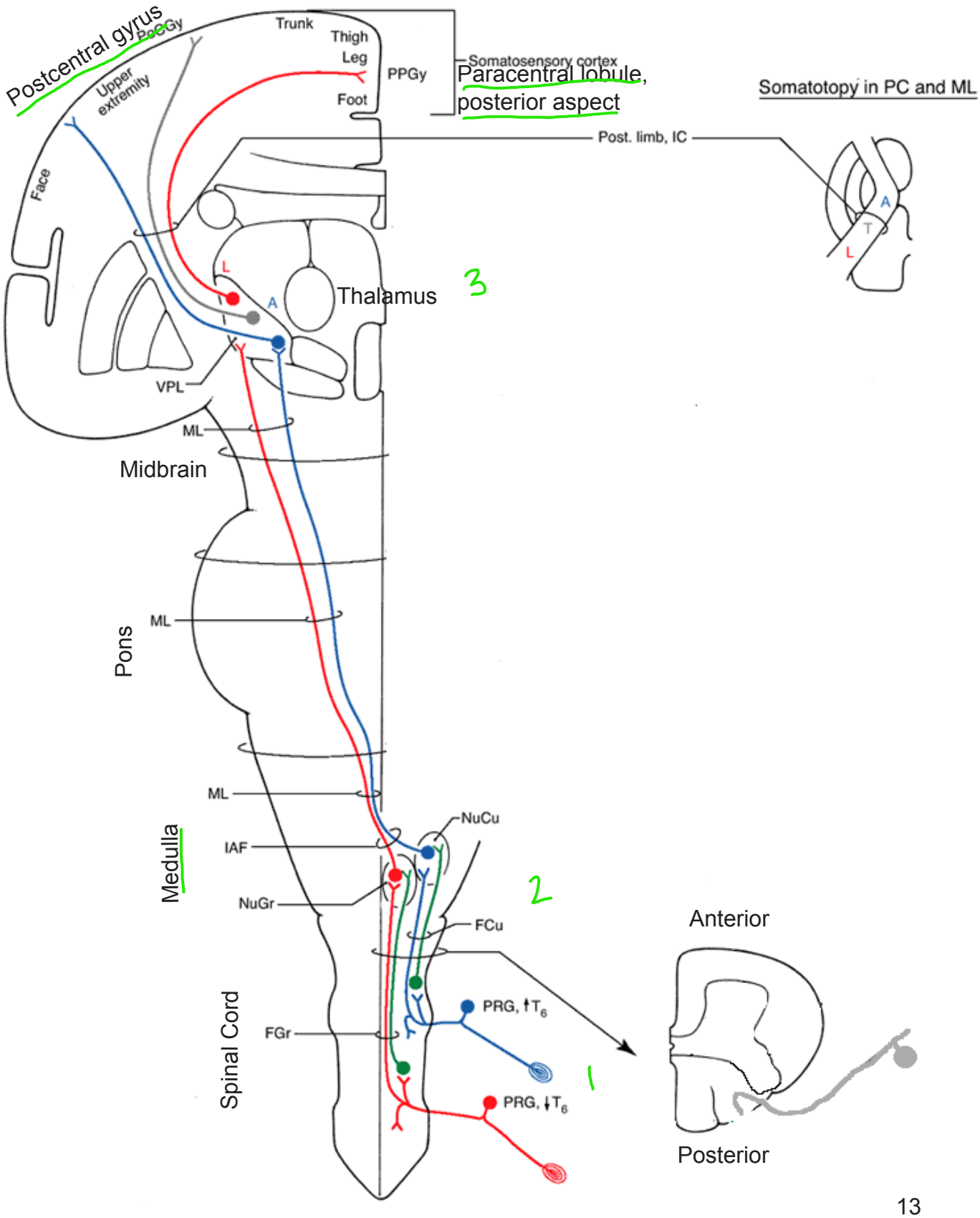
We will use this page to draw the Posterior columns/medial lemniscus pathway.



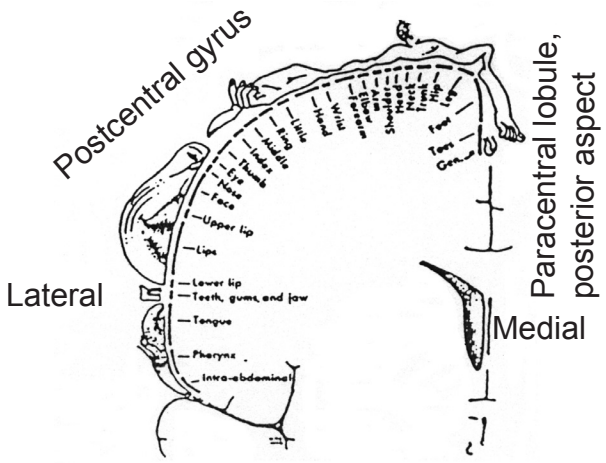
generally T6 and above going into FC over FG but has some overlap (above diaphragm = FC, below diaphragm = FG)



Posterior Columns/Medial Lemniscus Pathway



Adapted from Neuroanatomy: An atlas of Structures, Sections, and Systems, D.E.Haines



The sensory homunuculus = paracentral lobule on the medial aspect and postcentral gyrus on lateral aspect.
Genitalia, feet and legs are represented in the paracentral lobule, posterior part, while the rest of the body is represented in the postcentral gyrus.

Pathway for Reflex Proprioception

- This pathway **does not go to consciousness** - **Only to cerebellum**
  Pathway does not go to cortex for perception.
  Pathway goes to cerebellum for **feedback from muscles** for **influencing muscle coordination and muscle tone.**
- There are **3 main tracts:**
  1. **Anterior Spinocerebella**r Tract -**Lower Extremities** (we will ID in SC)
  2. **Posterior Spinocerebellar** Tract -**Lower Extremities** (we will ID in SC)
  3. **Cuneocerebellar** Tract - **Upper Extremities and Neck** (we will not ID)

(The Cerebellum is part of the motor system and participates in muscle coordination and tone. **Cerebellar influences are ipsilateral**; i.e. the right cerebellum influences right body and gets input from right body. We will talk more about the cerebellum in later lectures.)

Clinical Aspects : These correlate with tracts and pathways on previous pages.

Syringomyelia is a cavitation of the central canal of the spinal cord, usually beginning in the cervical region and **destroys the anterior white commissural fibers** of the spinothalamic tracts **(ALS). Pain sensation is lost bilaterally** but tactile sensation is intact because there is no damage to the posterior columns (PC/ML).

Referred Pain is **pain** from a **visceral source referred to an area of the body surface with the same segmental innervation.** For example: early pain in appendicitis is referred to the peri-umbilical region. This is due to the fact that the visceral pain pathway is multisynaptic, bilateral , and slow.

The **Brown-Sequard syndrome** follows **spinal hemisection** (damage to half of the spinal cord). **P&T are lost contralateral** to the lesion, **paralysis and posterior column i nformation** (tactile discrimination, vibratory, and position sense) are **lost ipsilaterally**.
All lossses occur caudal to the lesion site.

consciously thinking about moving a body part
descending

3. Voluntary Motor Pathway

This pathway **initiates skilled movements** carried out by somatic skeletal muscle especially hand and finger movements.

1. Cell bodies **originate** from the **cerebral motor cortex** in the precentral gyrus (Brodman's area 4) or paracentral lobule, and their axons form the corticospinal tract (also called the pyramidal tract). This group of neurons are also upper motor neurons.

2. The axons of the corticospinal tract will decussate in the caudal medulla and continue to descend in the lateral funiculus of the spinal cord as the lateral corticospinal tract. (Remember this is still neuron # 1 - an upper motor neuron).

3. At the appropriate level of the spinal cord, the lateral corticospinal tracts will synapse on cell bodies of lower motor neurons located in the anterior horn of the spinal cord.

4. The lower motor neuronal axons will project out to the periphery to innervate skeletal muscle.

Additional note:
There exists a somatotopic localization patern in the corticospinal/lateral corticospinal tracts whereas the lower extremity is represented laterally and the upper extremity is represented medially throughout the brainstem and spinal cord.

Key Ideas:

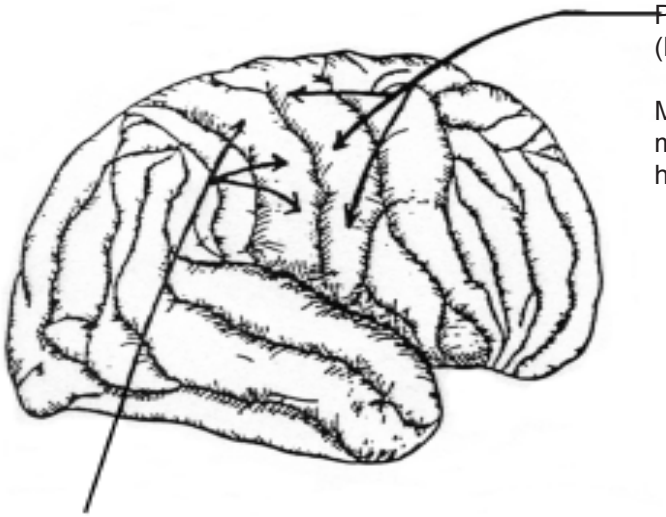
1. The voluntary motor pathway is a 2 neuron pathway consisting of:
   A. An upper motor neuron (corticospinal/lateralcorticospinal tracts)
   B. A lower motor neuron (cell bodies located in anterior horn of spinal cord and axons are peripheral nerves.)

2. There are a different set of signs/symptoms depending on whether the upper motor neuron or lower motor neuron is lesioned. Also keep in mind that the upper motor neuron originated in the contralateral cortex and crossed over in the lowest section of brainstem so that in the spinal cord the upper motor neuron is now on the ipsilateral side, This means you can have upper motor neuron signs/symptoms contralateral to the body part affected (lesion in the brainstem or above), or ipsilateral to the body part affected (in the spinal cord in the lateral corticospinal tracts).

   Lower motor neuronal lesions are ipsilateral.

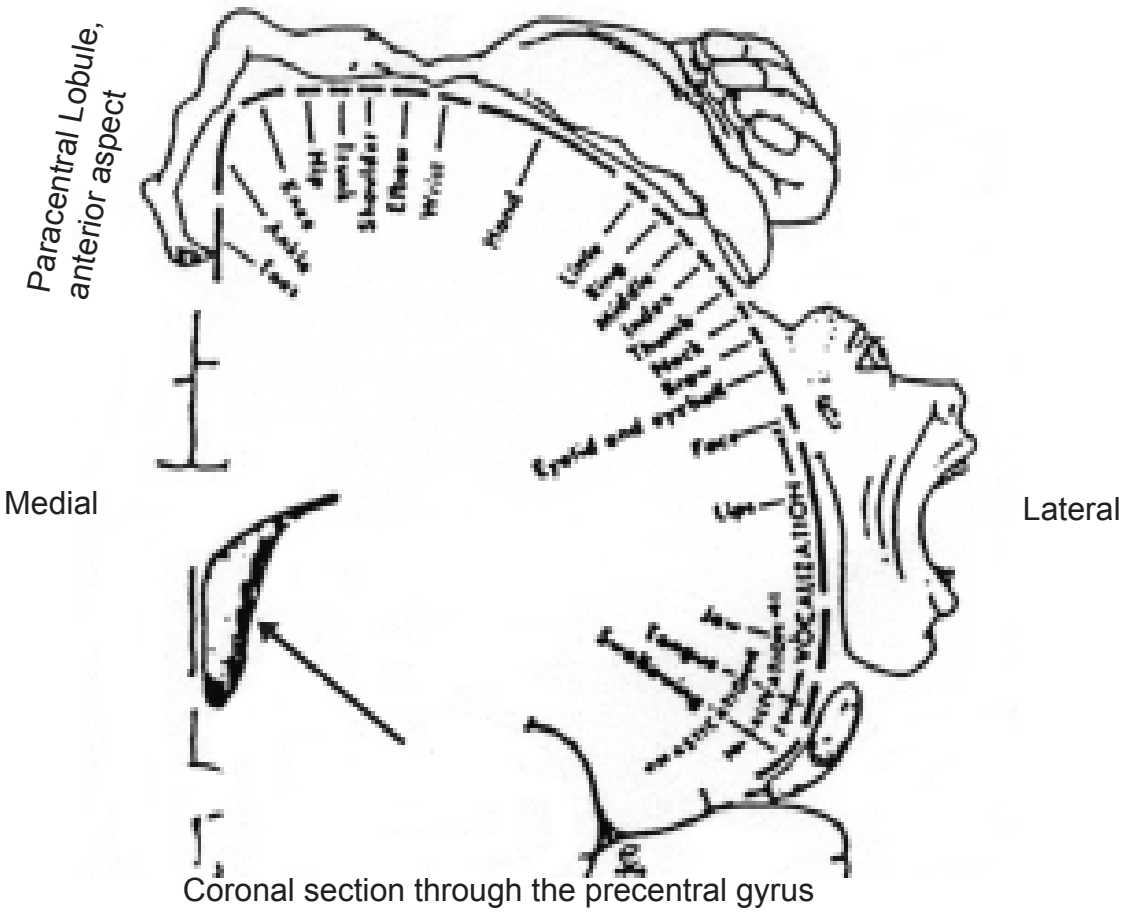
Upper motor neuronal signs/symptoms:	**Lower motor neuronal signs/symptoms:**
Spastic paresis	Flaccid paralysis
Hyperreflexia	Hyporeflexia
Babinski sign	Muscle atrophy/fasciculations

Motor Cortex



Precentral Gyrus
(Brodman's Area 4)
Motor
Many motor fibers that initiate motor movements at lower levels originate here.

Precentral Gyrus - Motor fingers, wiggle toes is paracentral lobule
Coronal Section



Coronal section through the precentral gyrus

Corticospinal Tracts - Upper vs. Lower Motor Neuron Lesions

- **Lateral Corticospinal tracts** -Have axons whose **cell bodies originate** from **upper motor neurons** in the **primary motor cortex** (Brodman's area 4).
- These **axons descend** through the core of the brain and brainstem as **corticospinal/ pyramidal tracts.**
- In the **medulla 90%** of these axons **cross (decussate)** to the **opposite (contralateral) side** and continue **down** through the **cord** in the **lateral funiculus** as the **lateral corticospinal tracts.**
- The 1**0% that did not decussate** in the medulla **remain** on the **same (ipsilateral) side** and **descend** in the **ventral funiculus** as the **Ventral (anterior) corticospinal tract** and they **decussate at their level of termination in the cord.**
- All of these **UMN** axons **terminate contralateral to** their **side of origin** in the cortex.
- They **innervate Lower Motor Neurons** (LMN) in the **ventral horn** of the **spinal cord.**
- Axons of **LMN innervate skeletal muscle.** They mainly stimulate muscle contraction **=** movement.
- This is a **2 neuron chain** consisting of an **UMN** and a **LMN**.
- **Lesions** affecting **either one** of these **neurons** exhibit **different sets of symptoms.**

Upper Motor Neuron vs. Lower Motor Neuron

Upper Motor Neuron lesion:
-**Spastic** Paralysis
-**Hyper**reflexia
-**No** muscle atrophy, except by misuse
-Abnormal reflexes, **Babinski sign**

hypers/spastics

Lower Motor Neuron Lesion:
-**Flaccid** Paralysis
-**Hypo**reflexia
-**Muscle atrophy**
-Fasciculations

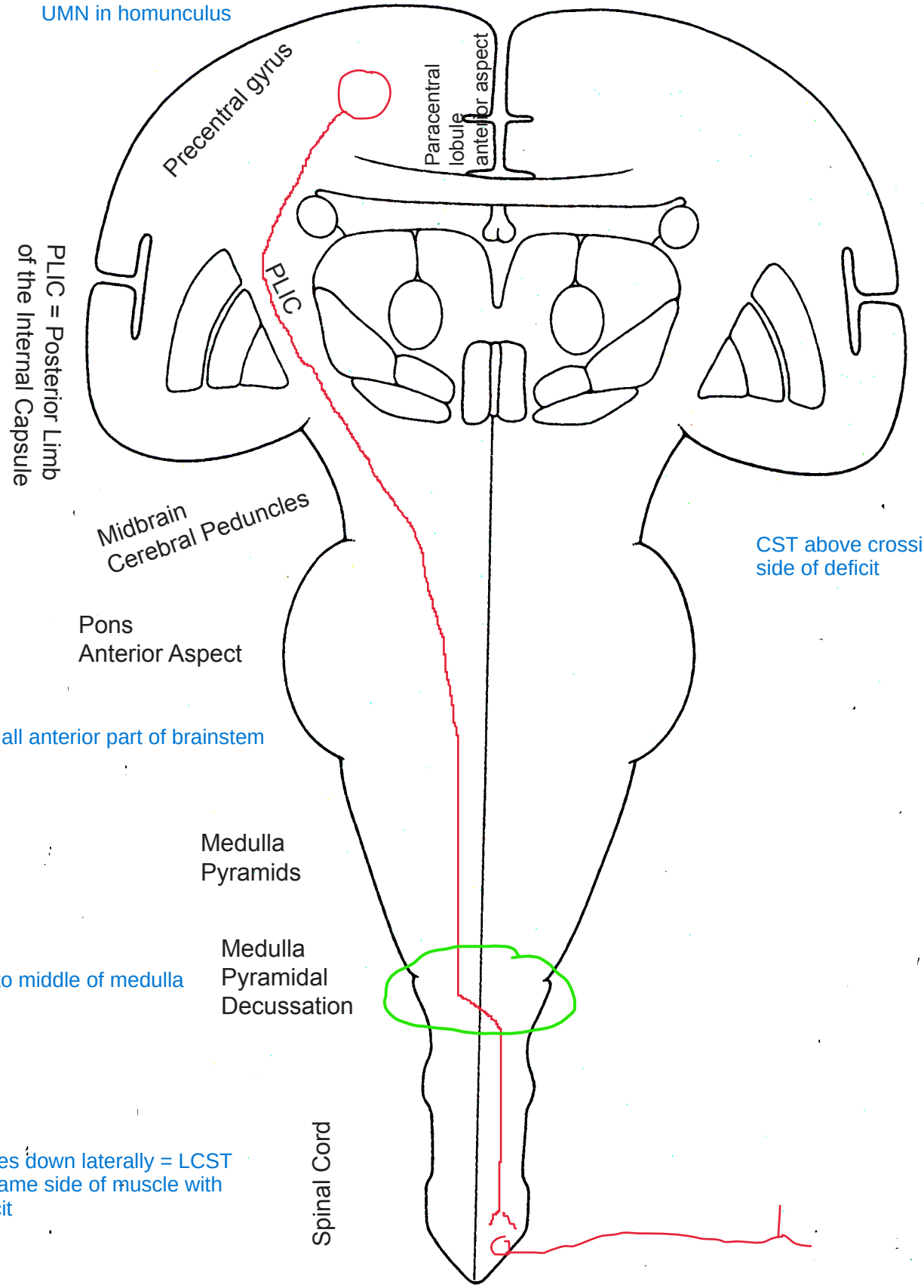
hypos

Clinical Aspect: Some **UMN axons** from area 4 (paracentral lobule) travel very close in the lateral corticospinal tract **bilaterally**. Thus in order to **cause loss of urinary bladder function,** one must have a **bilateral lesion.** So the most **common site** for this is something on the **midline (possibly a tumor)** impinging on the **medial side** of the **hemispheres bilaterally** (possibly a meningioma).

Clinical Aspect:

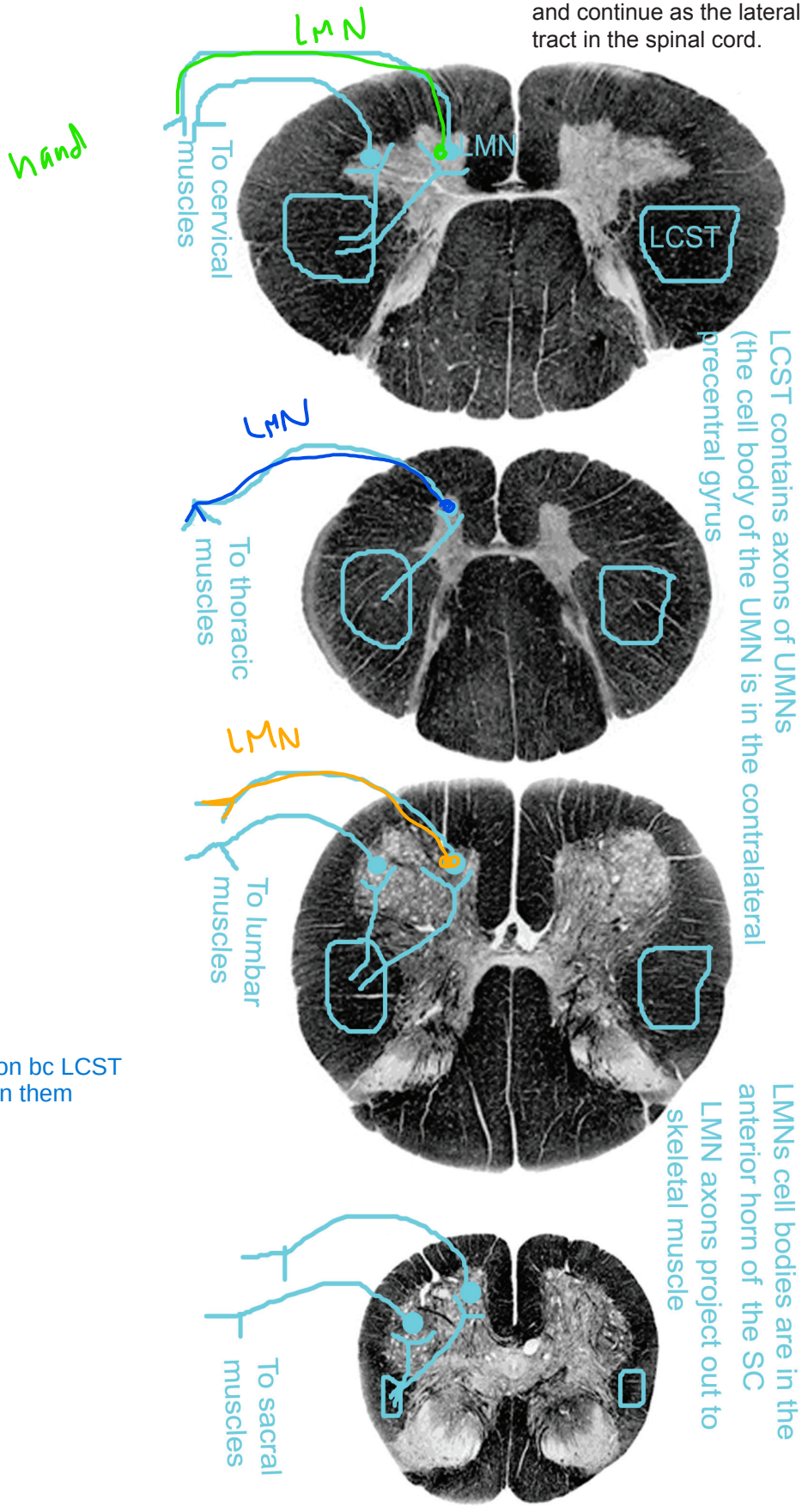
Spinal shock is a condition that occurs immediately after a spinal cord injury in which the patient has no spinal reflexes caudal to the spinal cord lesion site. Over time, the patient will regain these reflexes distal to the lesion site and will be hyperreflexic, while directly at the lesion site may remain areflexic (no reflexes) or hyporeflexic. Reflexes rostral to the lesion site remain intact.

The Voluntary Motor Pathway



Adapted from Neuroanatomy: An atlas of Structures, Sections, and Systems, D.E.Haines

Upper motor neuronal cell body is located in the precentral gyrus or paracentral lobule. Its axons are called the corticospinal tract and will decussate in the caudal medulla and continue as the lateral corticospinnal tract in the spinal cord.



LCST has UMN axons

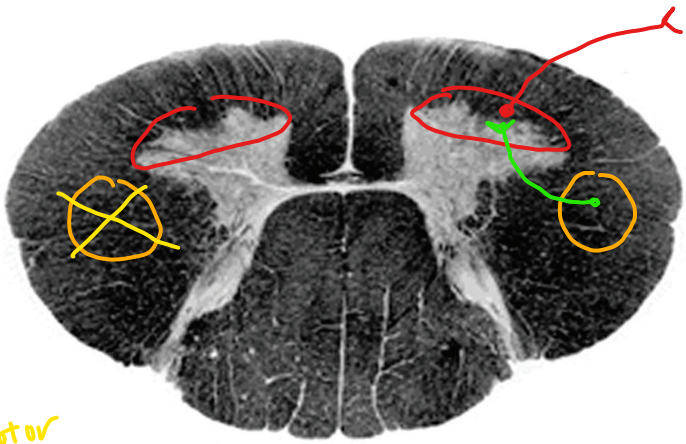
LMN turn on bc LCST synapse on them

LCST gets smaller as go down the spinal cord - each time need to use will peel off and go to muscles activating

We will use this page to draw in the Voluntary motor pathway (in the spinal cord)

lesion = part is not working

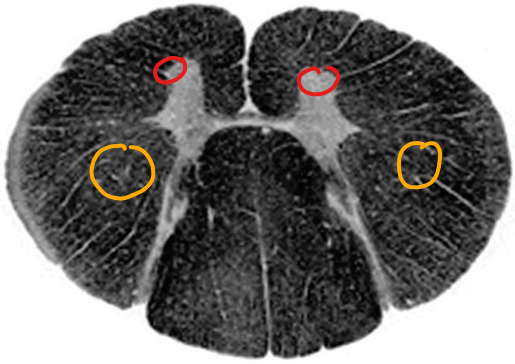
below crossing = IPSI
above crossing = CONTRA



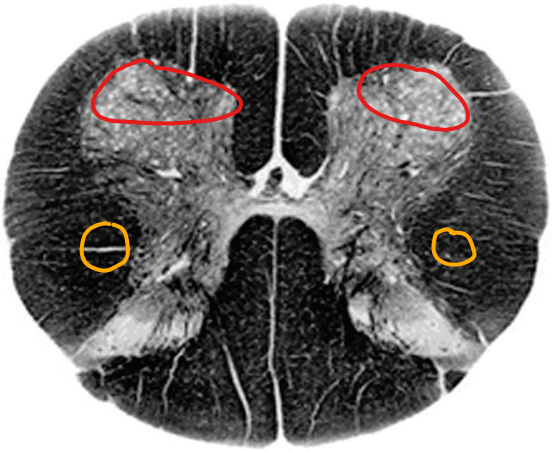
red and orange go together

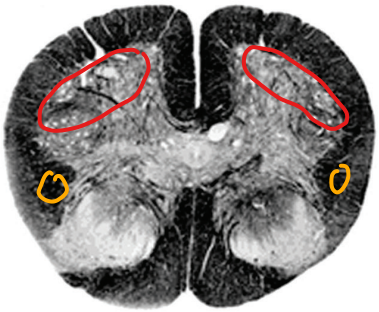
LCST
UMN

Lesion
White matter
LCST Voluntary motor
UMN signs - hyperr
IPSI
damaged at this level & all below



at thalamus - all 3 pathways crossing is below = contralateral deficits

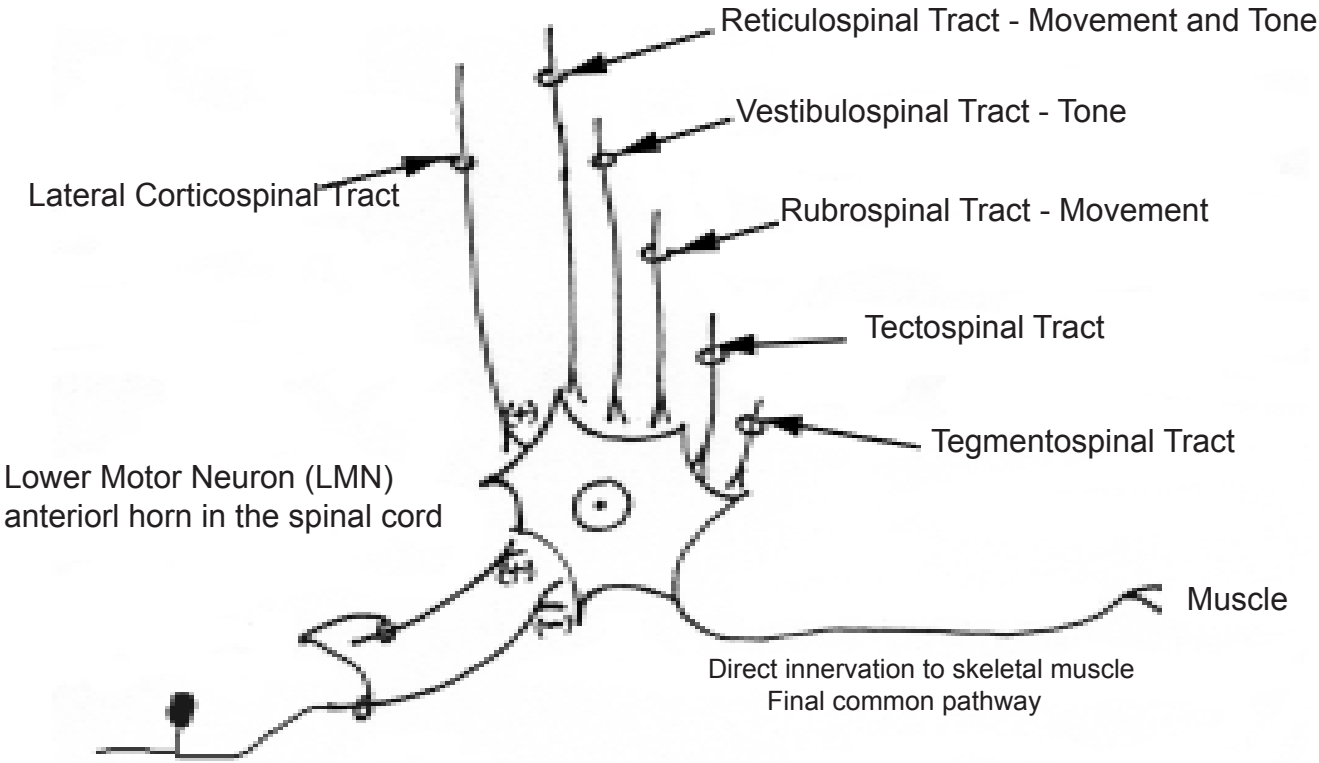




Ant horn
LMN

Influences on Lower Motor Neurons

- The cerebral cortex (via the corticospinal tracts) are not the sole influence/input to the LMN.
- Many other inputs to the LMN originate from brainstem levels and posterior root ganglion primary sensory neurons.



- Some of these synaptic inputs are **excitatory (+)** and some are **inhibitory (-).**

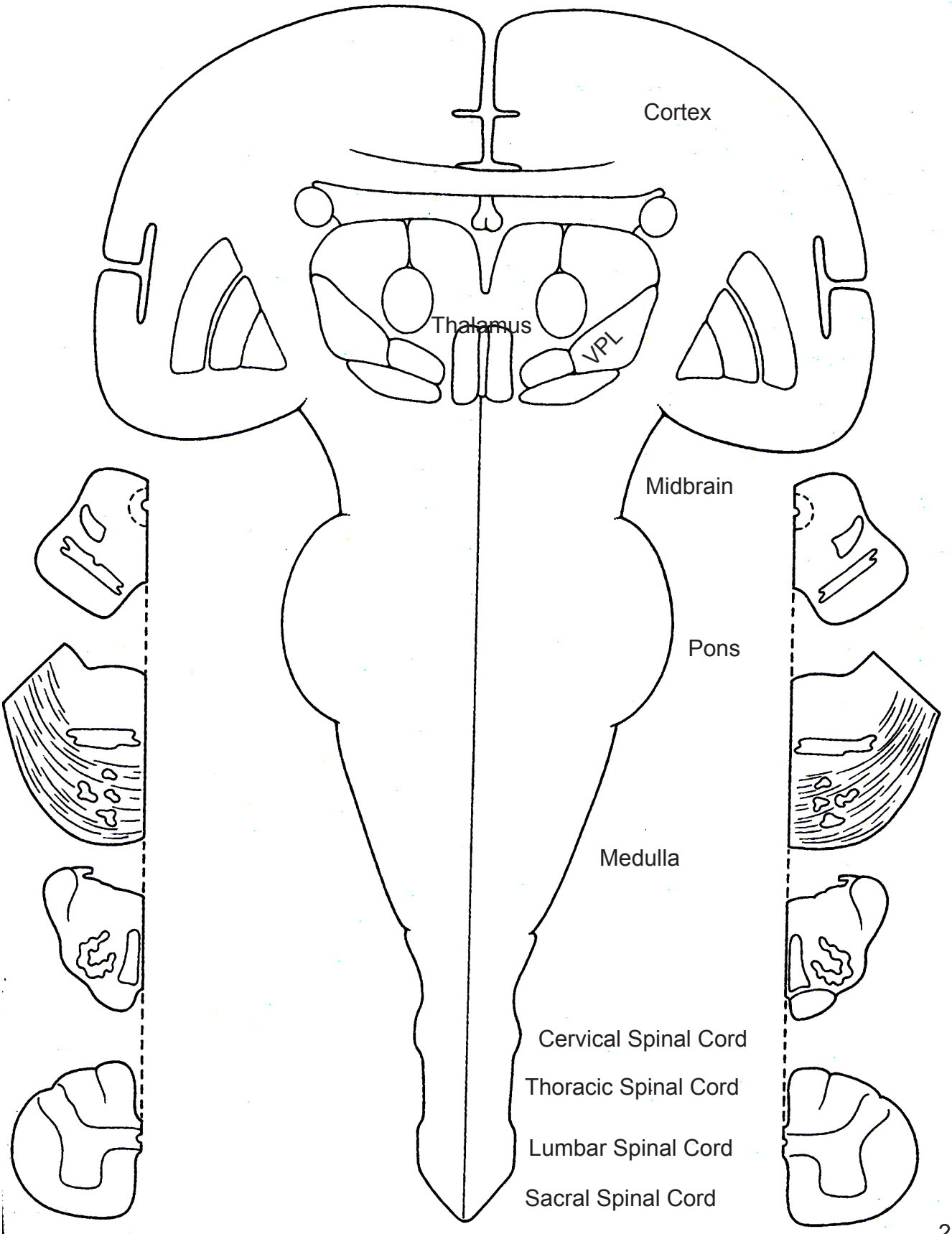
- Summation of the (+) and (-) inputs occurs at the LMN and it either fires or not.

- The LMN is the final or direct input to muscle and carries information about movement and tone.

- **Corticospinal tract** carries information **directly from the cortex to the LMN**, so it is sometimes called the **direct path for motor information to LMNs.**

- All the **tracts from the brainstem** receive input form the cortex (maybe through several synapses) and they **relay information to the LMN**, often through several synapses. So this motor information gets to the **LMNs through several relays, or indirectly.** So these tracts are sometimes referred to as the **indirect motor system.**

- So a single lesion will involve many or all of these tracts to produce the symptoms that we attribute to motor dysfunction.



Adapted from Neuroanatomy: An atlas of Structures, Sections, and Systems, D.E.Haines