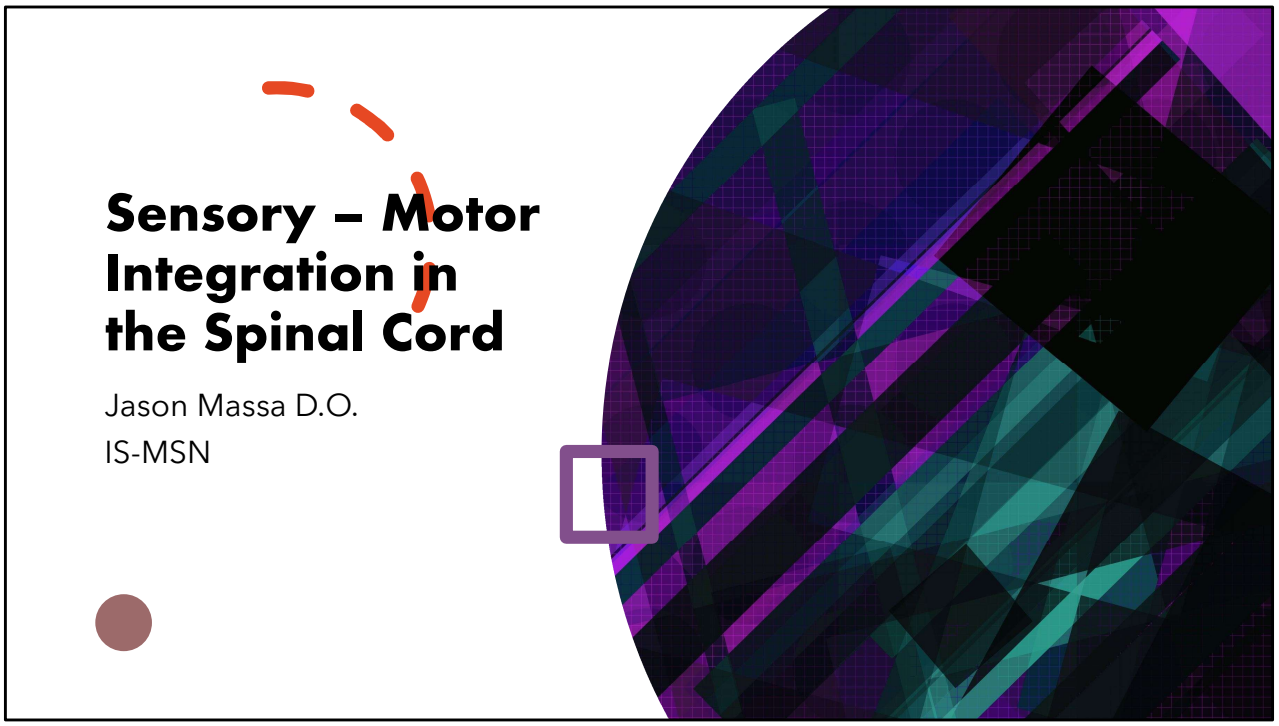

Blumenfeld's neuroanatomy through clinical cases is required reading for most of the course.
Today's lesson there is no accompanying book chapter, just this powerpoint and the lecture comments (in pdf)
Some of this will be review from your physiology and anatomy.

Today we will talk about spinal reflexes.
Tool for localization and diagnosis of neurologic dysfunction.
Upper motor vs lower motor.

Reflexes are produced by the spinal cord itself.

Structure of Series

- 10 parts
- Each part three components:
  - Self-study lecture/powerpoint +/- assigned reading
  - TBL assignment (graded for completion)
  - Q&A session with me
- Each component gets 2 hours protected time

redundancy for diff learning styles

Neurology thoughts

not organized in an intuitive manner

- More like math class than biology
- Very clinically relevant, relatively boards-lite
- You are encouraged to pursue a neurology rotation but they are not required.
- Specific clinical lectures will follow later in the semester and cover topics like stroke, seizures, peripheral nervous disease, and motor neuron disease.

lesion - deficits
exam findings - where lesion is

Learning Objectives

- Describe the functional sets of neurons found in the spinal cord.
- Explain the concept of lower motor neurons, interneurons, and central pattern generators and their role in motor function.
- Explain the concept of motor unit and describe the 3 different types of motor units in skeletal muscles.
- Tell the 3 main inputs that help regulate lower motor neuro function.
- Describe the structure and function of the muscle spindle.
- Define gamma motor neurons, explain their function, describe the interrelation of alpha and gamma motor neurons and the importance of the alpha-gamma co-activation.
- Describe the structure and function of the Golgi tendon organ.
- Describe the components of the muscle stretch reflex and indicate its clinical significance.
- Explain the function of the reverse myotatic reflex and explain its contribution to the regulation of muscle tension.
- Describe reciprocal inhibition, flexor reflex and cross- extensor reflex.
- Explain how spinal reflexes are modifiable.

spinal reflex is a tool for localization of lesi

Blumenfeld's neuroanatomy through clinical cases is required reading for most of the course. 80-90 from lectures but to really understand use textbook
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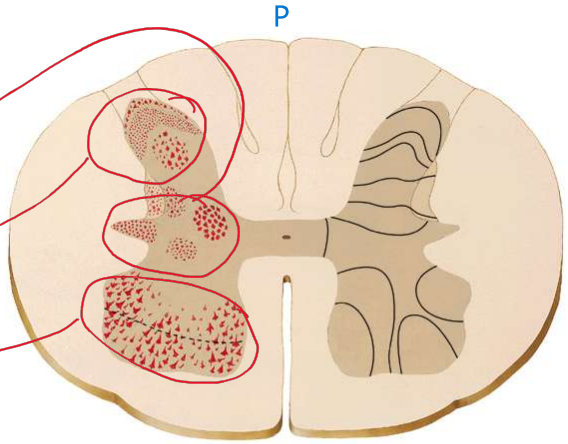
Cytoarchitecture of the Spinal Cord Grey Matter

- Three functional types of neurons:
  - Intermedial Grey Matter – interneurons
  - Dorsal Horn – Sensory neurons
  - Ventral Horn – Motor neurons

concentrated here but located throughout



FYI these diagrams are in ”anatomical orientation” which is used throughout your anatomy texts. However in clinical practice you will generally see the spinal cord and brain in the clinical orientation, with dorsal/ventral reversed.

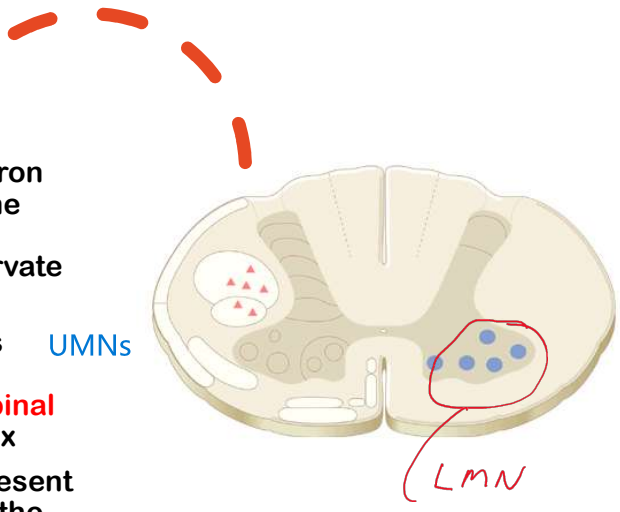
You can tell this is thoracic cord because of the presence of the lateral column (only present in the thoracic cord)

*interneurons are located throughout but concentrated in the intermedial grey matter

Lower Motor Neurons

- A lower motor neuron is a neuron located in the spinal cord or the cranial nerve nuclei of the brainstem which directly innervate muscle fibers
- Lower motor neuron activity is modulated by the descending motor pathways, the corticospinal tracts, from the cerebral cortex
- The lower motor neurons represent the final common pathway for the control of movement

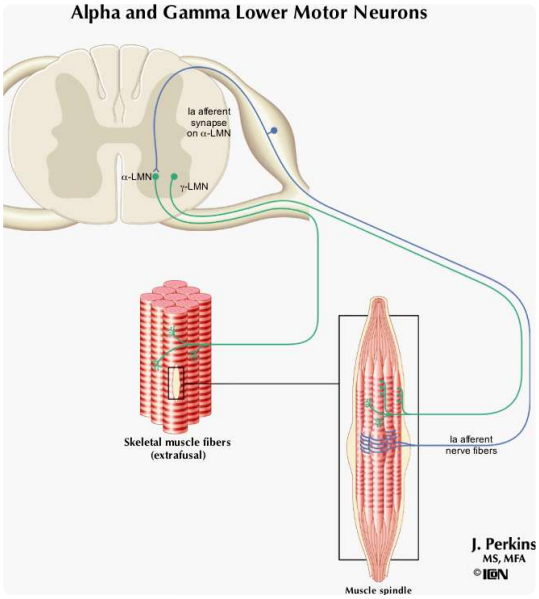
directly contact skeletal muscle



Ventral horn

Where are the cell bodies of the lower motor neurons located? Throughout the spinal cord and within the brainstem nuclei.

They make direct contact with muscle fibers. They are modulated by the upper motor neurons.



Lower Motor Neurons

- Two main types of anterior horn motor neurons:
  - **Alpha Motor Neurons** – directly innervate skeletal muscle fibers (extrafusal fibers)
  - **Gamma motor neurons** – directly innervate specialized muscle fibers in the muscle spindles

contracting muscl

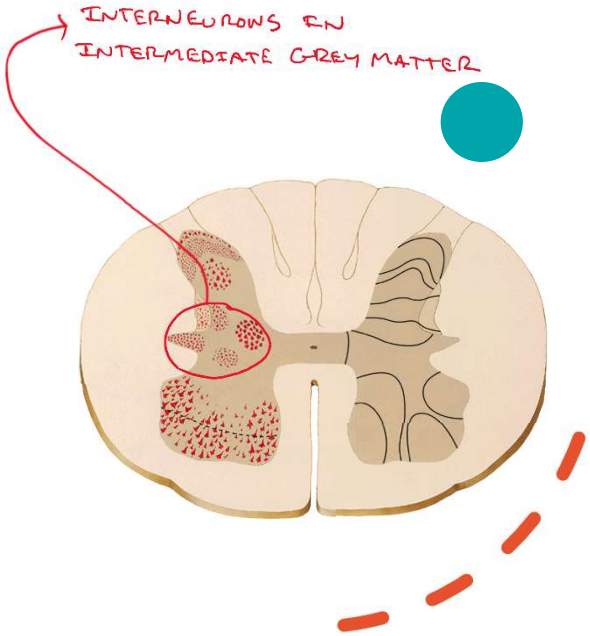
for proprioception

Alpha motor neurons are larger, gamma motor neurons are smaller.

The muscle spindles are specialized proprioceptive receptors within the muscles.

Spinal Cord Interneurons

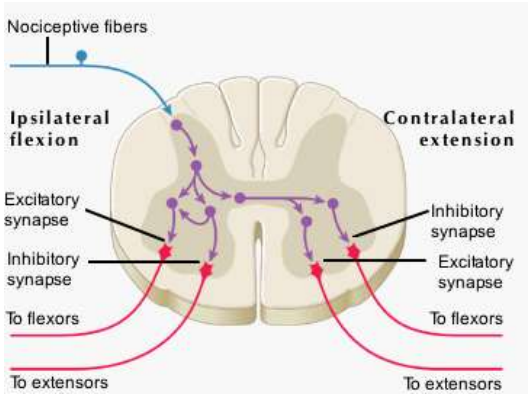
- **Interneurons** are located in the intermediate grey matter at all spinal levels
- **Important** for intra- and inter-segmental communication
- Interneurons do not project outside the spinal cord
- Can be **excitatory or inhibitory**
- Modulate function of alpha and gamma motor neurons



Many interneuron networks within the spinal cord and brainstem.
Function to communicate information between motor and sensory neurons. They do not connect directly outside the spinal cord. Can communicate with several levels of the spinal cord.

low level brain

Central Pattern Generators

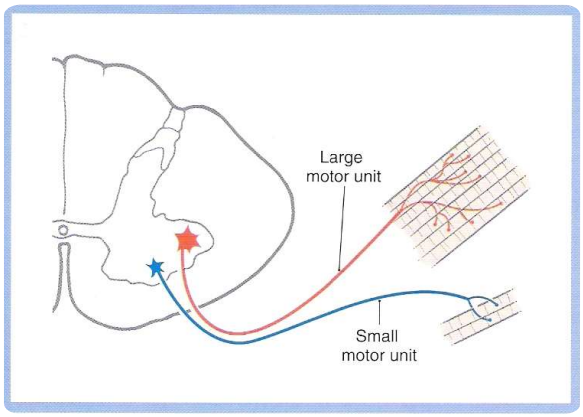


- The spinal cord contains a significant amount of circuitry for the coordinated control of movement and locomotion
- **Central Pattern Generators** consist of networks of **interneurons** that are able to generate complex rhythmic patterns of movement – locomotion without external sensory input or cerebral input

chicken with head cut off

You don't need to memorize this schematic, but it is an example of the central pattern generators. They can work independently of cortical control to coordinate movements like walking. Think of a chicken with it's head cut off.

Motor Neurons and Motor Units



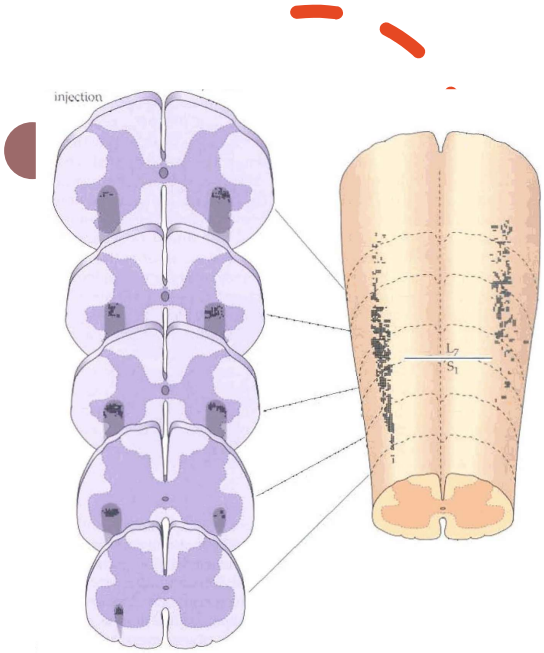
- A motor unit is a single alpha motor neuron and all the muscle fibers that are innervated by its terminal axon branches
- A muscle fiber only receives input from a single alpha motor neuron

Motor neurons form motor units – alpha motor neuron and all of the motor fibers that it innervates.

Motor Neuron Pool

- The collection of alpha motor neurons that innervate a single muscle or group of muscles is called a **motor neuron pool**

flexion unit

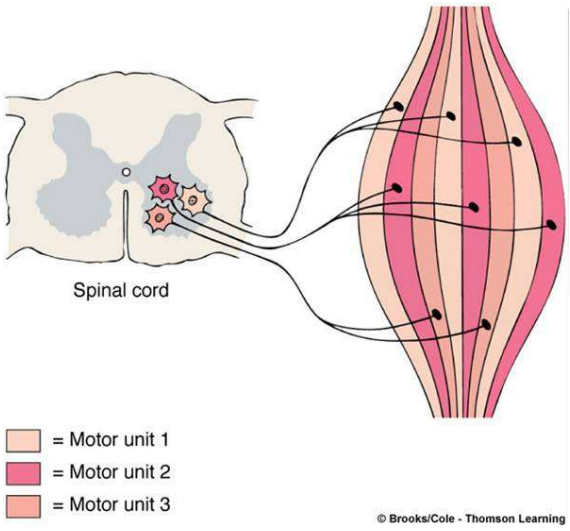


Schematic for lower motor neuron locations for synergistic muscles, located over several segments. They are located over several segments. For example this could represent a motor neuron pool responsible for flexion movements of the lower extremity.

Types of motor units

- Slow (S) motor units – smallest motor units, required for sustained muscle contraction such as maintenance of upright posture
- Fast Fatigable (FF) motor units – largest motor units, used for movements that require large but brief forces such as running and jumping
- Fast Fatigue-Resistant (FR) motor units – intermediate size motor units, not as fast as FF but produce twice the force of a slow motor unit

S – specialized for postural muscles
FF – specialized for large bursts of strength without sustain
FR – fast contraction speed but resistant to fatigue, not as fast as FF



Alpha motor neurons and motor units

The number of muscle fibers innervated by a motor unit varies with the muscle type and function

- Muscles contain a mixture of motor units of different sizes according to their function
- Muscle contraction is regulated by different mechanisms:
  - Rate of firing of motor units
  - Recruitment of additional motor units of increasingly larger size – the size principle

not as precise the more recruitment

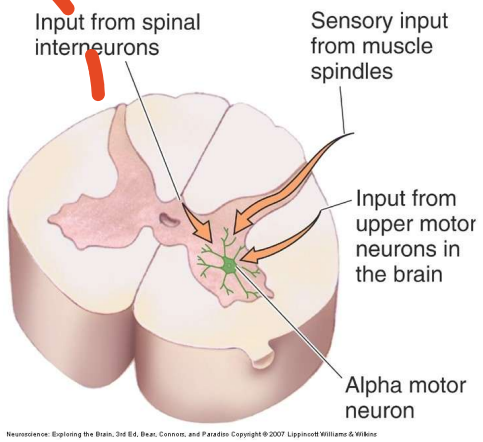
The muscle's function will dictate the ratio of different motor unit types: Postural muscles will have more S fibers; leg extensors would have more FF and FR fibers

Size principal – smaller motor units are engaged first, and larger motor units are engaged as more muscle force is required.

Regulation of lower motor neuron function

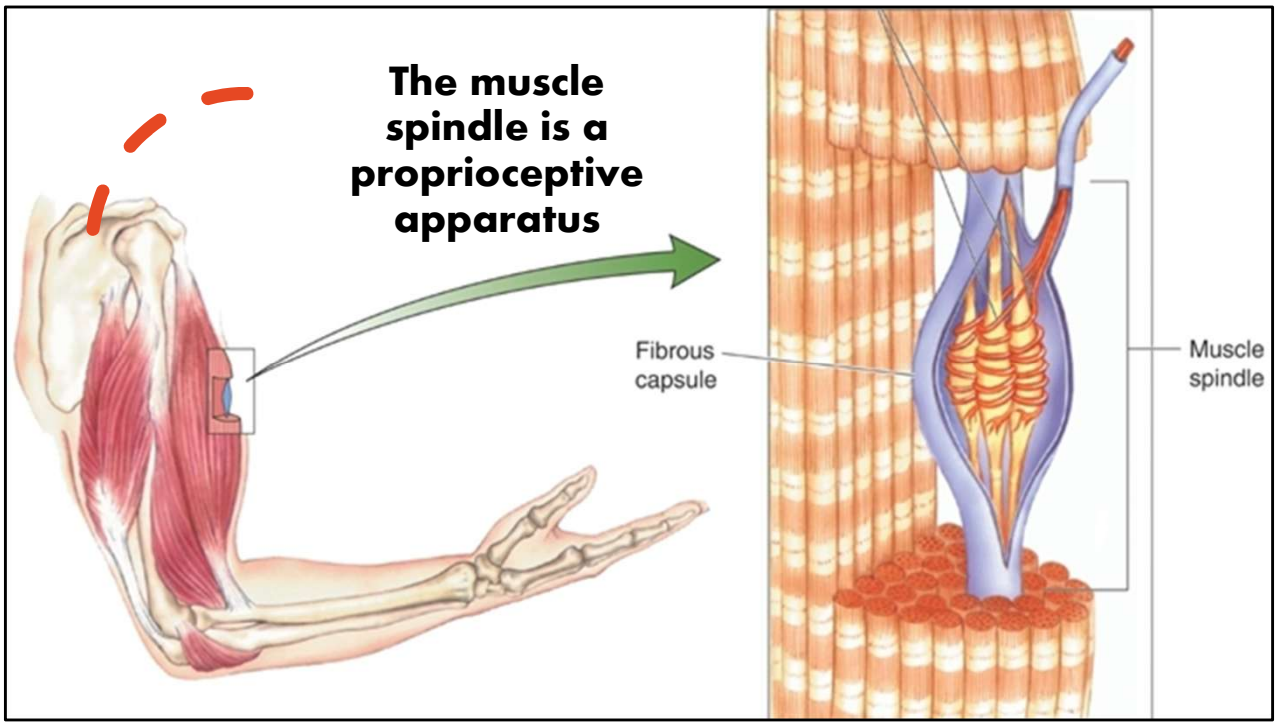
Activation is modulated by **3 major inputs**:

- Sensory input
- Upper motor neuron pathways – corticospinal tracts
- Interneurons in the spinal cord – excitatory or inhibitory



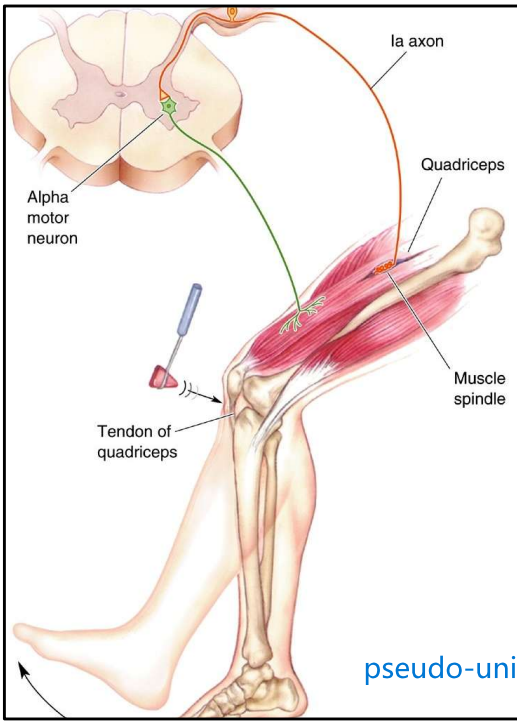
LMN do not fire spontaneously, they need input from somewhere. unless being triggered LMN will be quiet

muscle spindle and GTO



Proprioception is the sense of body part position.
We will look at the muscle spindle and the golgi tendon organ

Extrafusal fibers – muscle fibers that we've been talking about
Intrafusal fibers – muscle fibers modified to function in the muscle spindle, which are wrapped in sensory fibers that fire in response to fiber stretch and inform the CNS of muscle length/stretch, as well as the rate of change in length.



Muscle spindle function

- Informs the CNS about **muscle length and rate of change in length**
- Information transmitted along **1a sensory** axons to the dorsal horn – axon branches make synapses with multiple targets
- These fibers regulate the activity of alpha and gamma motor neurons

pseudo-unipolar neuron

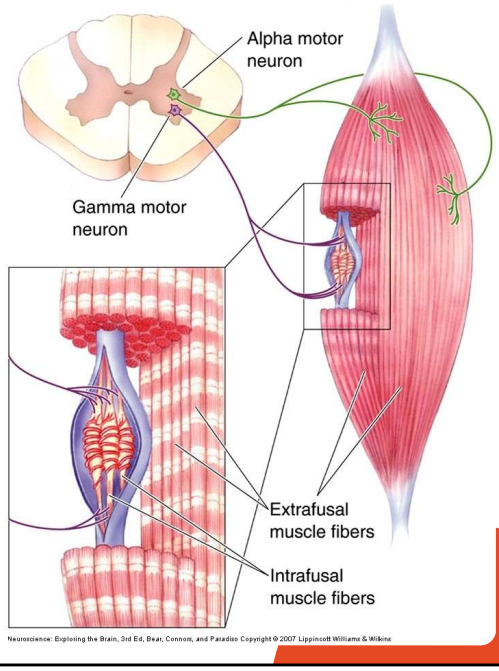
We will talk about the classification of sensory fibers later, but know that these 1a fibers carry sensory information from the muscle spindle. Cell bodies are located in the dorsal root ganglion. They are pseudounipolar neurons with a single axon that splits to project to the periphery and to the CNS.

Muscle stretch reflex – simplest of all the reflexes. A sudden stretch of the muscle causes increased firing in 1a sensory neurons from the muscle spindles. These neurons projected directly onto alpha motor neurons which in turn are activated to contract the muscle.

Gamma motor neuron

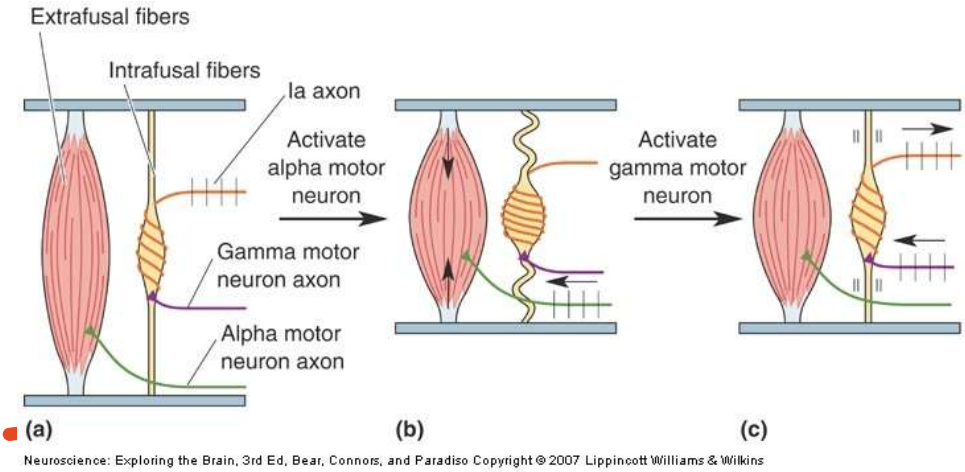
- Small motor neuron originating in ventral horn
- Function: innervate intrafusal fibers of the muscle spindle
- The muscle spindle requires adjustments in length to maintain its sensitivity, which is achieved by gamma motor neuron activation

sensitive to muscle stretch

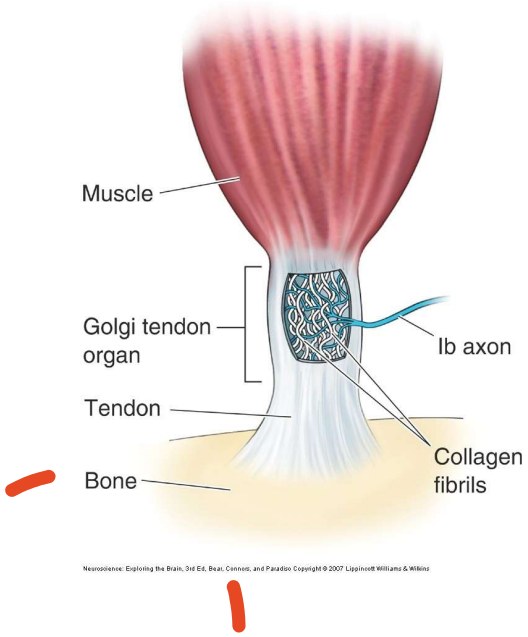


1a sensory fibers are the output signal from the muscle spindle. Gamma motor neurons are the input. These neurons are responsible for modulating the contraction of the intrafusal muscle fibers. The muscle spindle needs to contract to match the level of stretch in the muscle to remain sensitive to changes in stretch.

Alpha-Gamma Co-Activation



Alpha and gamma are always coordinated to keep the muscle spindles “primed” to remain sensitive to further changes.



Golgi Tendon Organ

- Another proprioceptive apparatus
- Informs the CNS about **muscle tension and rate of change of tension**
- Transmitted to the dorsal horn of the spinal cord via **1b axons**

need to know if tendons are overstressed

Excited by contraction of the muscle, producing tension on the tendon.

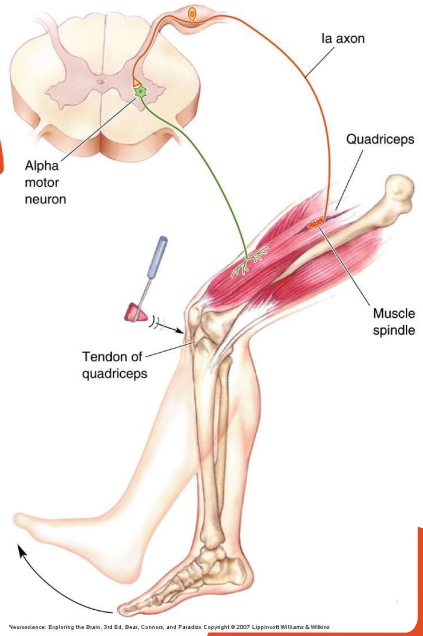
DOES NOT SENSE STRETCH – senses the tension in the tendon.

SUPER IMPORTANT

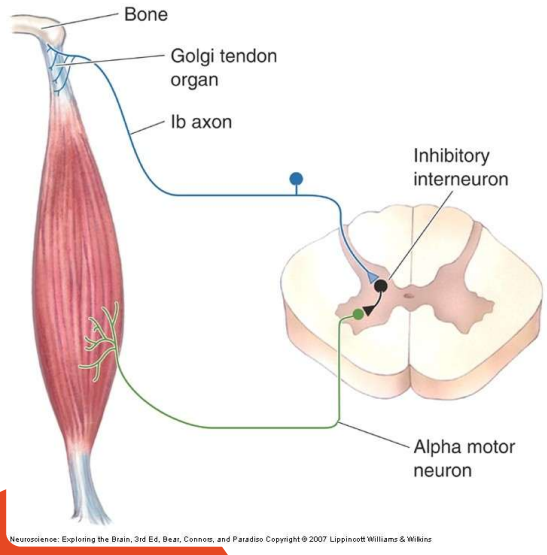
will talk about this reflex all the time

Alpha motor neuron regulation of muscle length and tone

- Regulated by the **Stretch Reflex**
- AKA Myotatic Reflex, Deep Tendon Reflex (misnomer)
- **Monosynaptic** reflex
- Muscle spindle senses sudden stretch -> activation of 1a axon -> synapse on alpha motor neuron -> activation of alpha motor neuron causes muscle contraction



Useful for checking the integrity of the lower motor neurons and proprioception. Deficits in either can lead to depressed reflexes. When there is no or little upper motor neuron input, this reflex becomes more powerful as it is disinhibited.



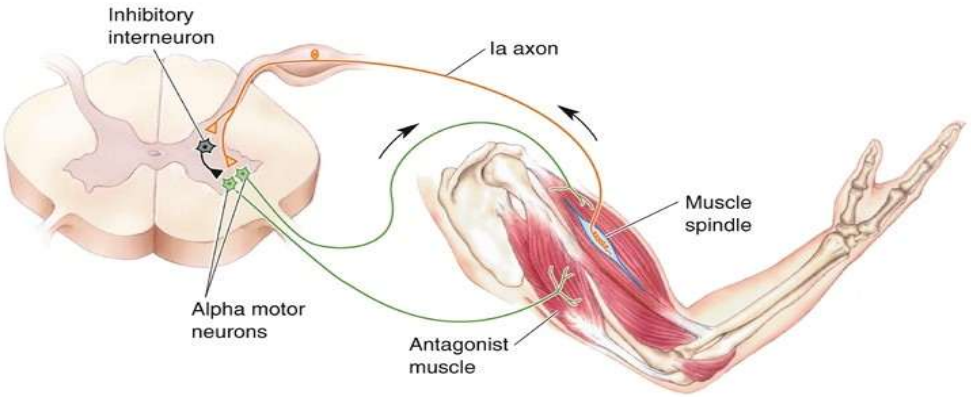
Alpha motor neuron regulation of muscle tension

Reverse Myotatic Reflex

- **Polysynaptic** reflex that regulates tension, protects from muscle overload
- **Golgi tendon organ** is the proprioceptive receptor for this reflex

Stimulation of the 1b fibers by the golgi tendon can, by this reflex, inhibit the lower motor neuron that is contracting the muscle. This is a negative feedback loop that prevents overstretching of a muscle. It may be responsible for the "clasp-knife" feel of spastic rigidity.

build tension in the tension will tell alpha motor neuron to relax muscle



Reciprocal inhibition and interneurons

- Any movement will require contraction of one set of muscles (agonist) and relaxation of another set (antagonist.)
- This is called reciprocal inhibition and is coordinated inhibitory interneurons

Polysynaptic reflex, helps to coordinate contraction and relaxation of agonist/antagonist groups of muscles.

coordination at spinal cord - contract bicep relax tricep

Flexor Reflex and Crossed-Extensor

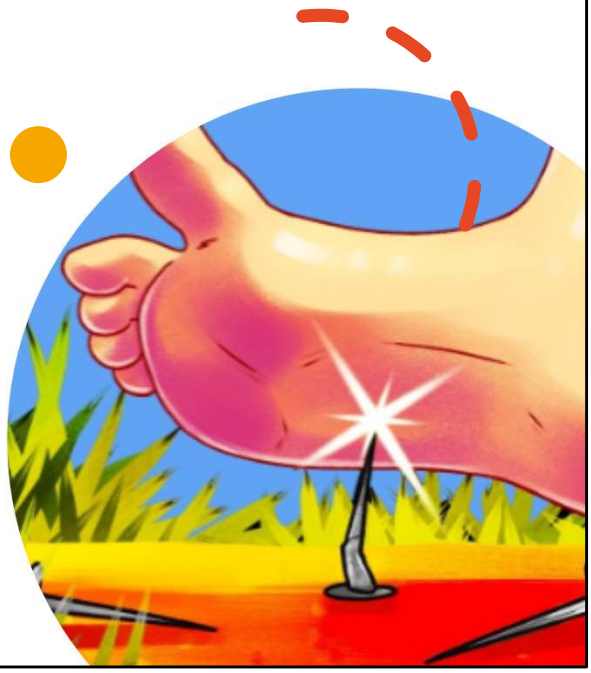
Flexor:

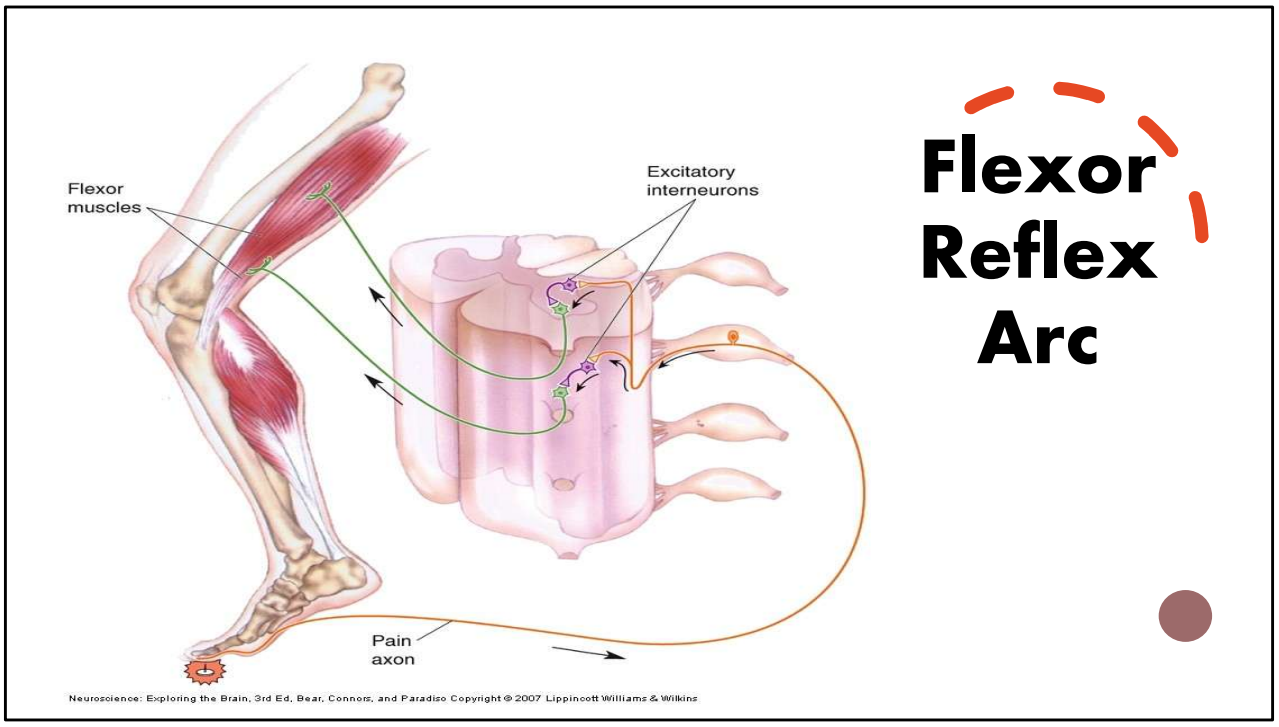
- **Polysynaptic** reflex triggered by painful stimuli on the skin
- AKA withdrawal reflex
- Mediated by spinal cord inhibitor and excitatory interneurons
- Spans several spinal segments

Crossed-Extensor:

- Used to support the body after flexor reflex is triggered
- Simultaneously activated

contralateral leg stiffens to support

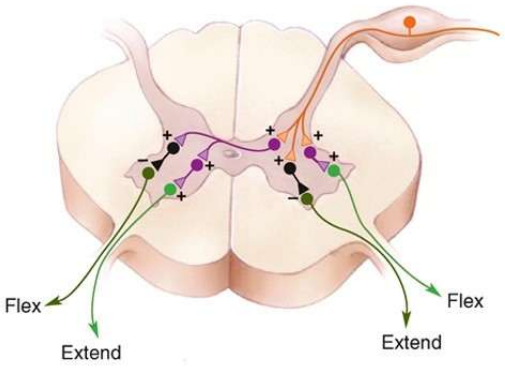




Flexor Reflex Arc

Would not be very helpful if everytime you felt pain in your feet your collapsed so…

Crossed-Extensor Reflex Arc



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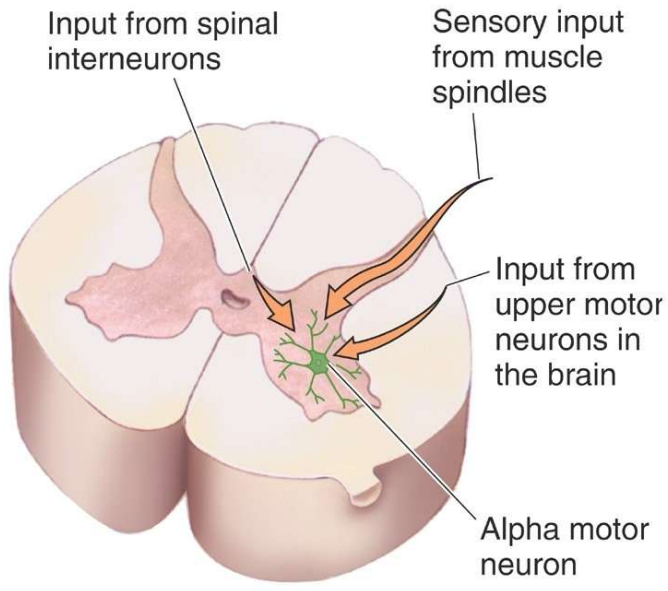
extend leg on contralateral si



Spinal reflexes are influenced by the CNS, interneurons, and input from muscles

most important is stretch reflex