CNS

PHYSIOLOGY

10+11

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Motor system – Motor of the spinal cord

Before we start talking about the motor function of the spinal cord, let's first take a quick look at the motor system and the incredible connections taking place inside it: [please refer to the pictures for better understanding]

1- Motor command

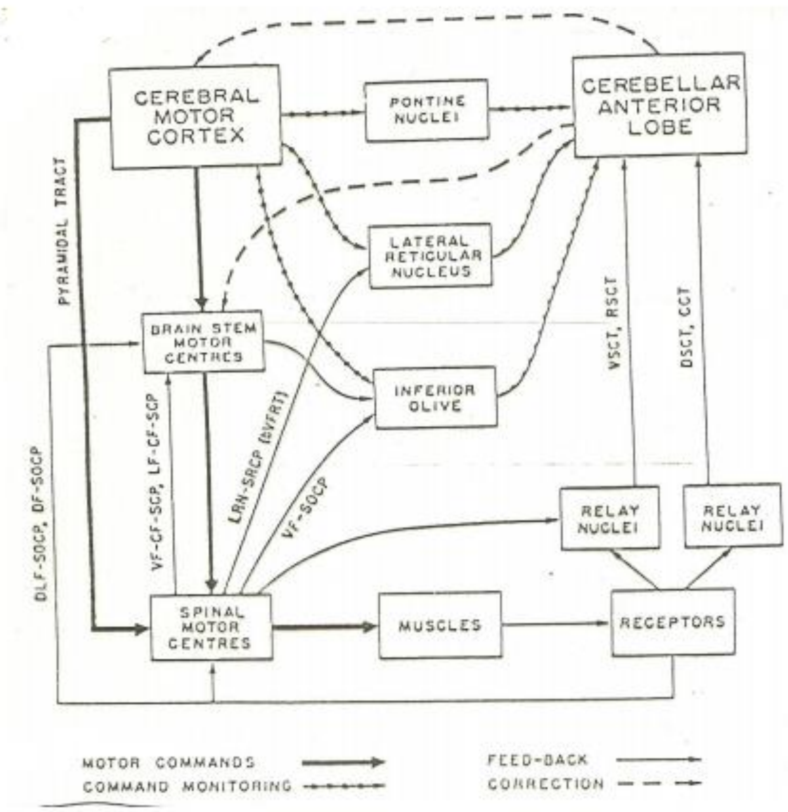
For any motor function (movement) to occur, the nervous system has motor command that comes **from the cerebral motor cortex to the spinal cord** and these descending tracts (**corticospinal**) are called also **pyramidal tracts** and that's because they pass through the pyramids of medulla oblongata.

The neuronal fibers coming from the cortex ending in the spinal cord are considered **upper motor neurons**, while the neuronal fibers going out from the spinal cord to reach the muscles are called **lower motor neurons**.

There are other origins for the motor commands such as the brain stem and the red nucleus that send neuronal fibers to the spinal cord in order to control the activity of the muscles.

2- Motor command intension

At the same time, there are some tracts going from the cortex to the cerebellum through the brain stem like the corticopontocerebellar, corticoreticulocerebellar, corticolivarycerebellar tracts. And these tracts are telling the cerebellum about the intended movements. (= the movements we want to do)



3-motor command monitor/ feedback system

a- Inside the muscles we have receptors (**muscle spindles/ stretch receptors**, **Golgi tendon organs**) that are connected to sensory (afferent) neuronal fibers that goes to the spinal cord relay nuclei.

b- From the spinal cord they go to the cerebellum through **ventral and dorsal spinocerebellar tracts** to tell the cerebellum what is exactly happening down at the level of the muscles.

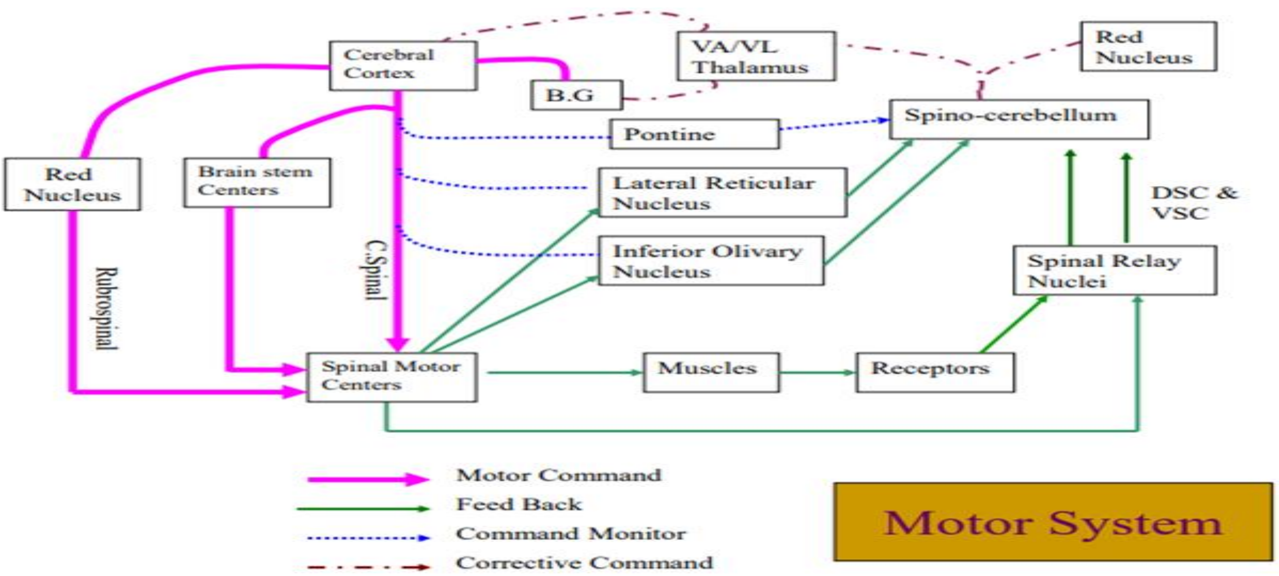
c- Then the cerebellum will do its job and send orders through the thalamus (ventroanterior **VA** and ventrolateral **VL** parts) to the cerebral cortex to monitor the motor commands.

[receptors -> spinal cord -> ventral and dorsal spinocerebellar tracts -> cerebellum -> thalamus VA/VL -> cerebral cortex]

Remember that the sensory (ascending) tracts go to the cerebral cortex through the ventral basal complex (VPL, VPM) of the thalamus.

4-Correction process

What will the cerebellum do with this information? It compares motor command intension with motor command monitor/ feedback system to see if they meet or not. And if they don't meet, the cerebellum will send orders to the cerebral cortex to correct it.

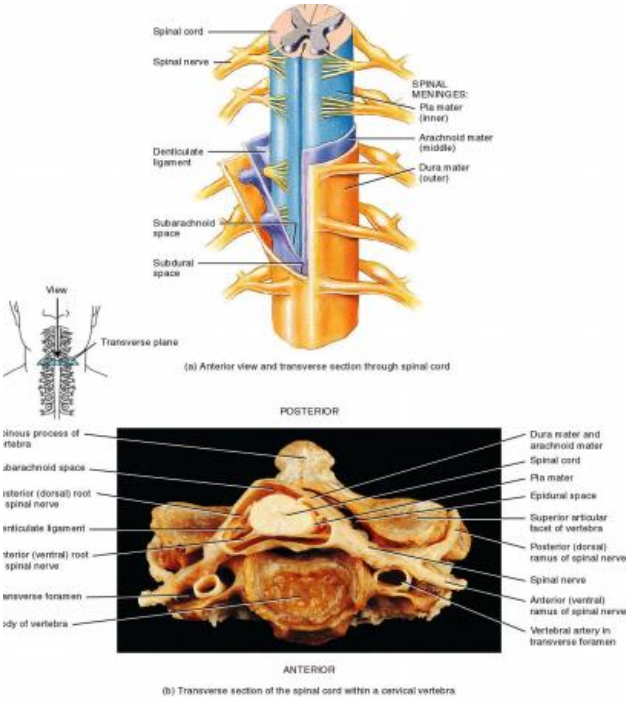


Why all of this is happening ? Usually the cerebral motor cortex doesn't send exact signals to the spinal cord (corticospinal tract), it sends either more or less than what is intended, so the muscles react more or less than what is intended. The cerebellum will know what is going on the level of the muscles (motor command monitor) and what is the movement we were trying to do (motor command intension) and is going to correct it by sending orders to the cerebral motor cortex through the thalamus [the secretary of the cerebral cortex]. This correction process is continuous and very fast, we don't feel that the muscle movement is hectic [having tremors].

➔ We can say that if the *movements* come from the cortex without the correction and the monitoring from the cerebellum, they *will be pendular* [= with a lot of tremors], and that's what exactly happens *when there is disease or damage of the cerebellum.*

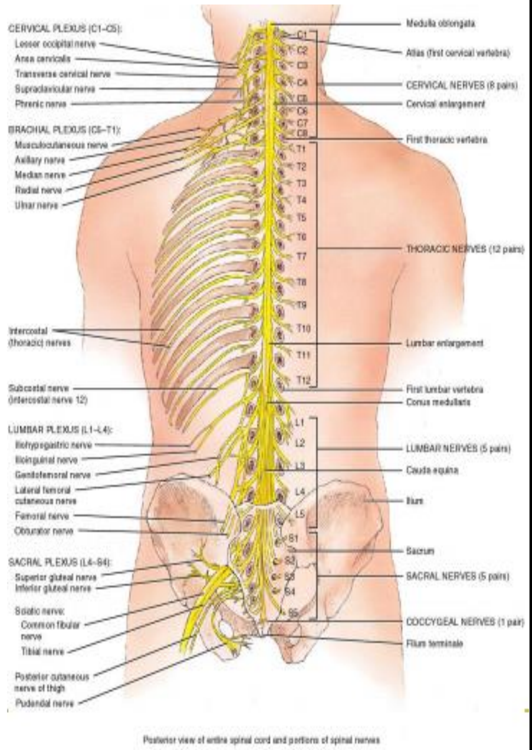
After this heavy introduction, we reached to the easy part in this sheet – motor function of the spinal cord 😊

The Spinal Cord is More Than Just a Conduit for Nerve Fibers



The spinal cord is the lowest part of this motor system, it is a pathway for the nerve fibers, Neuronal circuits for walking and various reflexes. And from the introduction we noticed that higher brain centers activate and command these circuits.

What we should know is that <u>we can use the same circuit for more than one function,</u> because we don't have a lot of circuits, the same circuit used for walking can be used for maintaining equilibrium [anti-gravity muscles/ extensors] and for other functions like reflexes.



- The spinal cord consists of 31 segments (8 cervical, 12 thoracic, 5 lumber, 5 sacral, 1 coccygeal). From each segment, there is a pair of spinal nerves (right and left) coming out from the intervertebral foramen.
- The spinal cord is so delicate structure but has a hard covering (vertebral column).
- Because the bony tissue grows faster than the neural tissue, spinal cord ends at the level of L1/L2 vertebrae. Below this level, where is no spinal cord, there are nerves coming from higher spinal cord segments forming a structure called **cauda equina**.
- The Spinal cord is covered with the meninges: dura matter [close to the vertebral column/ hardest], arachnoid matter and pia matter [close to the spinal cord].
- Between the arachnoid matter and pia matter is the subarachnoid space filled with CSF. To collect a sample of this fluid, we do a lumber puncture below the level of L1/L2 [usually at the level of L4/L5].

  CSF is produced in the ventricles by the choroid plexus and absorbed by the arachnoid villi. We have 4 ventricles: 2 in the left and right hemispheres called lateral ventricles -lateral ventricles -> 3rd ventricle -> 4th ventricle ->the central canal of the spinal cord.

Internal Anatomy of Spinal Cord

Inside a spinal cord segment, we can find an anterior median fissure and a posterior median sulcus dividing the segment into right and left part. The H- shaped gray matter in the middle of the segment is divided into anterior, posterior and [in some segments especially thoracic] lateral horns. The gray matter is a collection of neuronal cell bodies and dendrites. And the central canal with its CSF in the center of the segment.

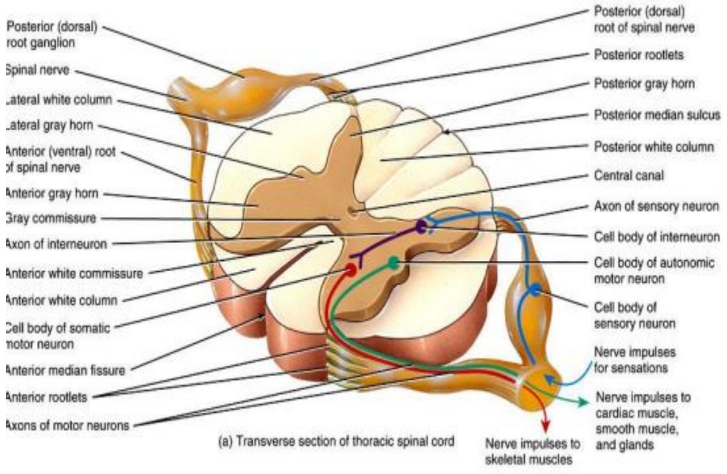


Figure 13.03 Tortora - PAP 12/e

Around the gray matter, we find the white matter consisting of columns (2 posterior, 2 anterior and 2 lateral). The white matter is a collection of myelinated axons. 2 = right and left

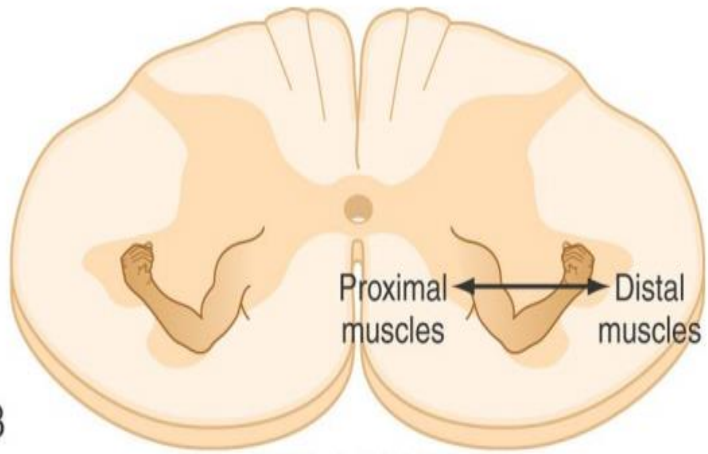
Sensory neurons have their cell bodies in the dorsal root ganglia, they enter the spinal cord through the dorsal root and synapse in the dorsal horn with interneurons. Interneurons synapse with motor neurons going out from the spinal cord through the ventral root to the effectors (skeletal muscle, gland, smooth muscle (ANS)).

Remember that **tract** is a collection of neuronal axons in the CNS and **nucleus** is a collection of neuronal cell bodies in the CNS . While a **nerve** is a collection of neuronal axons in the PNS and **ganglion** is a collection of cell bodies in the PNS.

We studied a lot about the amazing organization of the CNS, and this is applied on the motor system too, the spinal cord motor system has a very organized structure that if one area is destroyed, one muscle might be affected only.

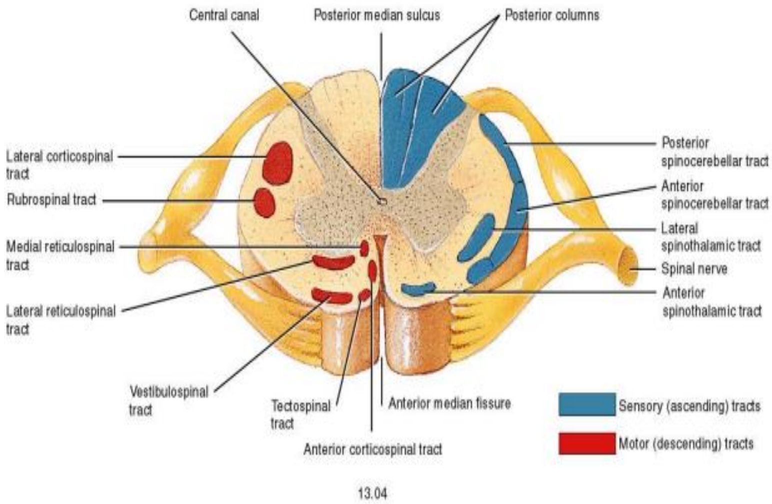
We can find the neuronal cell bodies of the proximal [axial] muscles in the medial part of the gray matter, and the distal muscles in the lateral part.

B



(Redrawn from Purves D et al[eds]: Neuroscience, 3rd ed. Sunderland, MA, Sinauer, 2004.)

In the picture to the right, you can find all the sensory [ascending] tracts, we are concerned here with motor [descending] ones. We have **the lateral system tracts** consisting of **the lateral corticospinal tract** [crossed] and **the rubrospinal tract** [from the red nucleus in the midbrain], both tracts excite the flexors and inhibit the extensors. Other tracts are the **lateral reticulospinal tract** from medulla oblongata, **medial reticulospinal tract** from the pons, **vestibulospinal tract** and **tectospinal tract** coming from the tectum.



The tectum has:

1. 2 superior colliculi [for vision] which moves the head in response to light.
2. 2 inferior colliculi [for hearing] which moves the head in response to sounds.

Motor Organization of the Spinal Cord

- The Sensory fibers enter the spinal cord and are transmitted to higher centers [ascending tracts], or they synapse locally to elicit motor reflexes. [will be discussed later]
- Motor neurons are located in the anterior portion of the spinal cord.
- motor neurons are 50 - 100 % bigger than other neurons.

Anterior Motor Neurons [lower motor neurons]

Any muscle has two types of fibers: extrafusal fibers responsible for the contraction of the muscle and intrafusal fibers related to muscle spindles (stretch receptors).

There are two types of lower motor neurons:

1- Alpha motor neurons: give rise to large **type A alpha** fibers (~14 microns).
   - stimulation can excite 3 - 100 **extrafusal** muscle fibers collectively called a motor unit. Motor unit: the motor neuron and the muscle fibers it supplies.

2- Gamma motor neurons: give rise to smaller **type A gamma** fibers (~5 microns),
   -stimulation excites **intrafusal** fibers, a special type of sensory receptor.

Interneurons and Propriospinal Fibers

Interneurons: 30 times as many as anterior motor neurons, small and very excitable, comprise the neural circuitry for the motor reflexes. Most of the neurons in any segment are interneurons.

Propriospinal fibers: travel up and down the cord for 1 - 2 segments, provide pathways for multisegmental reflexes. They connect segments together.

Sensory Receptors of the Muscle

There are two types of **receptors** in muscles:

1- **Muscle Spindle**
   sense muscle length and change in length
2- **Golgi Tendon Organ**
   sense tendon tension and the change in tension

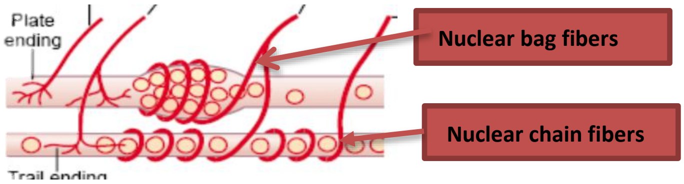
Tension refers to the increase in the length of the muscle.

These receptors sense the tension and the rate of change in tension, some of them are **static** and some are **dynamic**.

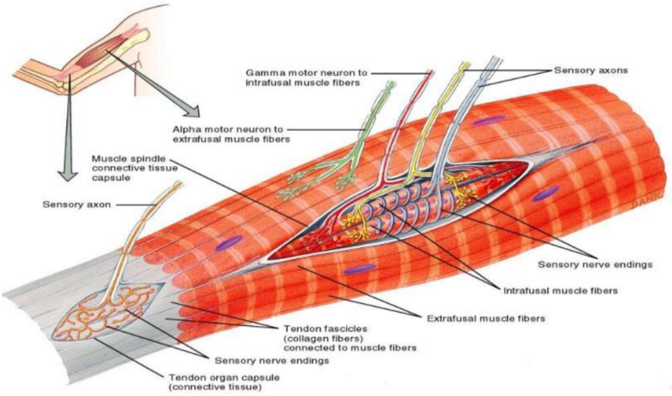
The density of the receptors is proportional to the importance of the signals/ information they collect. Important sensations have a high density of receptors. Muscles that are used most often like muscles working against the gravity (antigravity muscles) have a lot of muscle spindles and Golgi tendon organs.

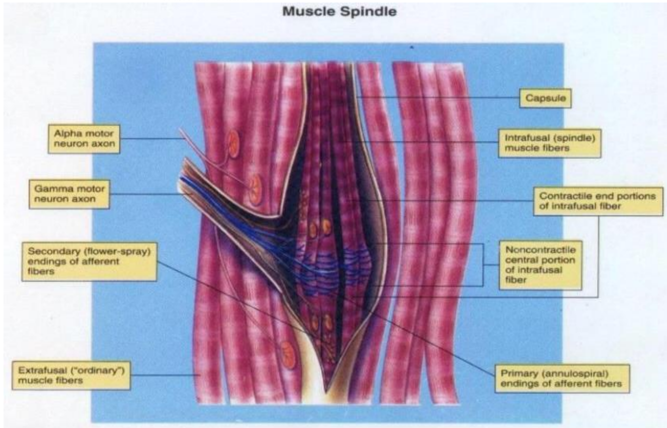
Now let's talk about the structure of the muscle spindle:

- ✓ Muscle spindle consists of capsule, stretch receptor and intrafusal fibers. It is almost non-contractile except for small regions in the two peripheries that are contractile.
- ✓ The non-contractile (sensory) part is present in the center of the muscle spindle and is supplied by **sensory neurons** while the contractile part is present in the periphery of the muscle spindle and is supplied by **gamma motor neurons** (static and dynamic).
- ✓ Two types of muscle spindles exist: **the nuclear bag form** where the nuclei of the muscle fibers are organized in the core in a shape like a bag and **the nuclear chain form** where the nuclei of the muscle fibers are spread along the whole length of the muscle spindle.



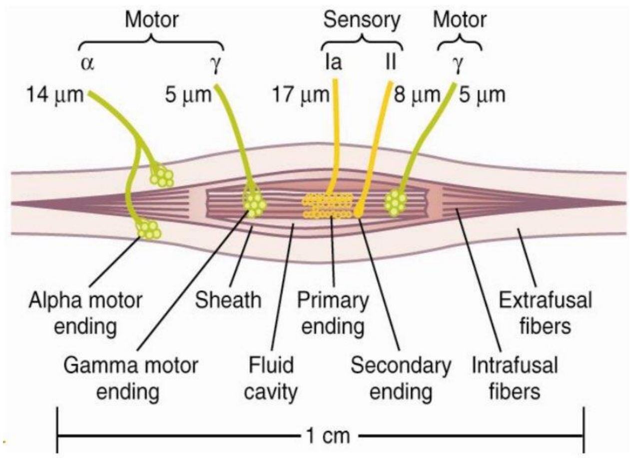
- ✓ Each type is supplied as we said by **sensory neurons**.
  - The nuclear bag fiber is supplied with **group 1a fibers** (large myelinated) which are considered **the primary afferent fibers** (called annulospiral) and **dynamic**.
  - **The nuclear chain fiber** is supplied with **group 2 fibers** which are considered **secondary afferent fibers** (called flower-spray) and **static**. [it is supplied also by primary afferent fibers]





✓ There are two ways to activate a muscle spindle (stretch receptors):

1- Any stretch in the muscle that lengthens it will stimulate the center of the muscle spindle.
2- Activation of gamma motor fibers will contract the contractile parts of the muscle spindle stimulating and keeping it stretched.



Static Response of the Muscle Spindle

When the center of spindle is stretched slowly - the number of impulses generated by the primary and secondary endings increases in proportion to **the degree of stretch**. This is the 'static response'.

Function of the static nuclear bag and nuclear chain fibers.

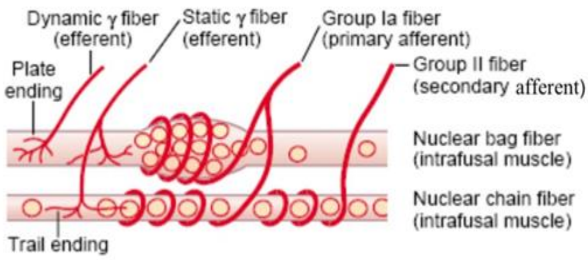


Figure 54–3

Details of nerve connections from the nuclear bag and nuclear chain muscle spindle fibers. (Modified from Stein RB: Peripheral control of movement. Physiol Rev 54:225, 1974.)

Dynamic Response of the Muscle Spindle

When the center of the spindle is stretched rapidly - the number of impulses generated by the primary endings increases in proportion to **the rate of change of the length.** This is the 'dynamic response'.

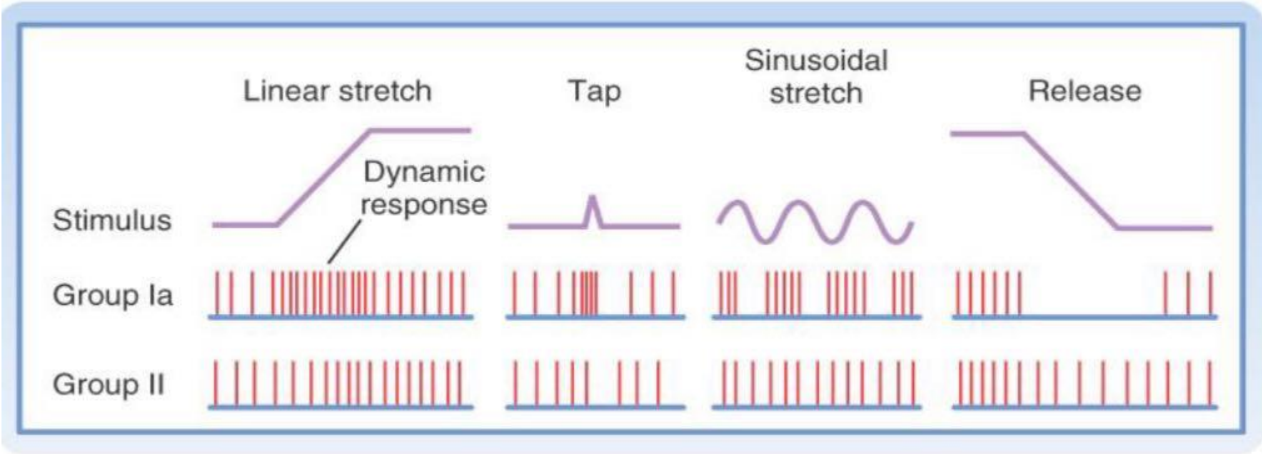
function of the dynamic nuclear bag fiber ONLY.

Why is it important to sense the rate (speed) of the change of the length?

When our nervous system knows the rate (speed) of change of the length and the distance we want to go through, it will calculate the time predicted to cut this distance and it will stop when we reach the intended place.

Imagine someone having a problem or damage in the muscle spindles, making his nervous system unable to know the rate of change of the length and therefore can't predict when he will reach the intended place, so if he wanted to reach a wall far from him 10m , he will not stop when he finishes those 10m instead he will stop when he hits the wall.

Let's study the difference between group 1a fibers (dynamic) and group 2 fibers (static)



- ✓ Normally both types of receptors (nuclear bag and nuclear chain) have basal rate of firing and that's important because it makes positive and negative (inhibition) control possible. When the basal rate is 100 impulse/sec we can increase it to 200 impulse/sec or decrease it to 50 impulse/sec. If there is no basal rate (equals zero), we can't decrease the rate of firing.
- ✓ In the first case we have a dynamic change in it then it backs to static :
  - During the dynamic change the rate of firing in group 1a fibers (dynamic) has increased a lot [when rate of stretch increases, rate of firing increases], while in group 2 fibers (static) the rate of firing has increased but lesser than group 1a ➔ positive control
  - Now back to static stretch, group 1a fibers decrease their rate of firing returning to the basal rate, while with group 2 fibers firing rate stays almost the same.
- ✓ When there is a release of stretch (stretch decreases), the rate of firing in group 1a fibers will decrease a lot, while in group 2 fibers will decrease to lesser extent staying almost basal ➔ negative control
- ✓ How much increase or decrease in firing rate **depends on the rate of change**.

Something important to know before we proceed is that when the muscle is stretched, the muscle spindle will sense that stretch whether it was static or dynamic and those sensory neurons will go back to the spinal cord and to the brain telling it about this change (as we explained earlier), the same sensory neurons will synapse in the spinal cord with interneurons and those interneurons synapse with alpha motor neurons that supply the extrafusal muscle fibers contracting them that's because we don't want the muscle to stretch (increase in length) more than normal, contraction will shorten the muscle preserving it. Another explanation we took in anatomy, is that the muscle length in rest is shorter than its origin and insertion, which means that when the muscle is between its origin and insertion it is stretched – that stretch will stimulate muscle spindles which in turn will stimulate alpha motor neurons keeping the muscle contracting almost all the time maintaining its tone which helps us against the gravity.

Physiologic Function of the Muscle Spindle

1- Comparator of length between the intrafusal and extrafusal muscle fiber.
2- Opposes a change in length of the muscle.
3- When the muscle is stretched the spindle returns it to its original length.
4- Leads to the stretch reflex.

Smoothening effect of the Muscle Spindle

Now, let's get things together by talking about a phenomenon known as **alpha- gamma coactivation**

When the muscle is going to contract, alpha fibers must be stimulated. Sustained contraction will cause muscle spindle to become loose not sensing any change in stretch. Here comes the role of gamma fibers (which are co-stimulated with alpha fibers) causing contraction in the contractile parts of the muscle spindle stretching it (the same cycle is repeated | muscle spindle senses that stretch -> sends it back to the spinal cord -> activating alpha motor fibers allowing it to sustain the contraction)

Let's think about having those muscle spindles denervated (no gamma motor neurons are there) this will definitely lead to not having stretch in it, no feedback stimulation for alpha motor fibers (inhibition), no sustained contraction, the contraction will lead to relaxation after it.

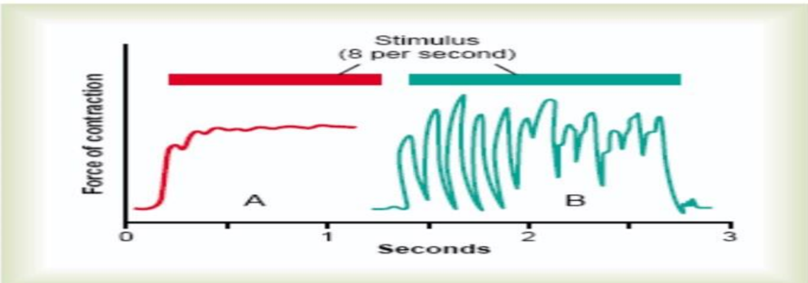


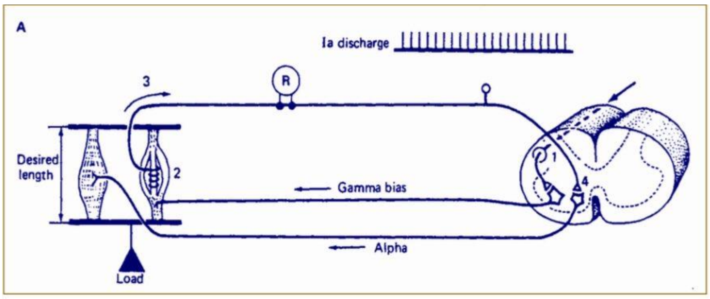
Figure 54–5

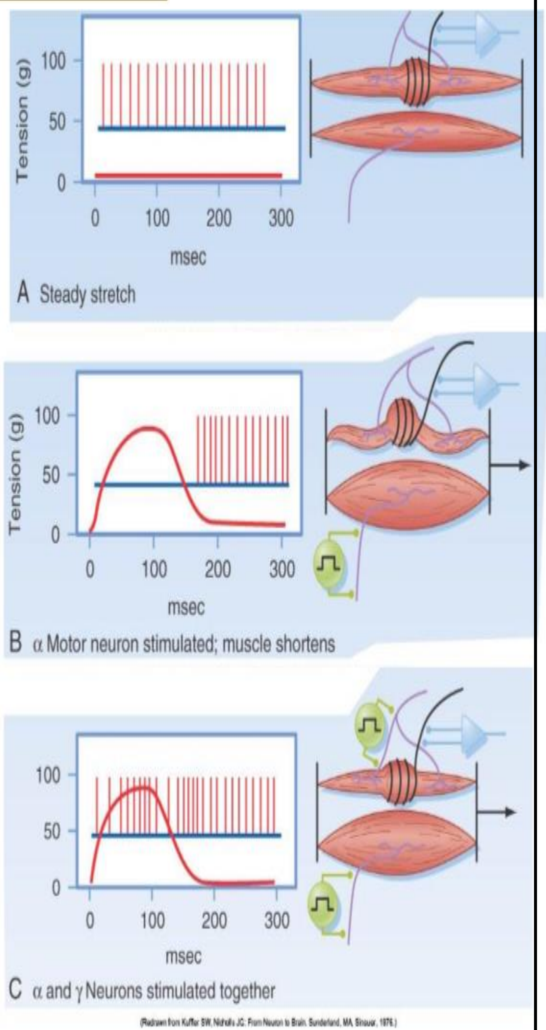
Muscle contraction caused by a spinal cord signal under two conditions: curve A, in a normal muscle, and curve B, in a muscle whose muscle spindles were denervated by section of the posterior roots of the cord 82 days previously. Note the smoothing effect of the muscle spindle reflex in curve A. (Modified from Creed RS, et al: Reflex Activity of the Spinal Cord. New York: Oxford University Press, 1932.)

In this experiment we are recording 1a fibers (supplying nuclear bag fibers) (the same sensory fibers that take information from muscle spindle to the spinal cord) and we have a desired length and load. The load will stretch the muscle and the muscle spindles in it, the muscle spindles will sense this stretch and will send it through 1a fibers to the spinal cord. There will be activation of the alpha motor fibers contracting the muscles.

When the muscle contract the length of the muscle spindle will decrease, inhibiting this receptor. But with alpha- gamma coactivation, gamma motor fibers will contract the muscle spindles laterally keeping the center of the spindle stretched and active.

<u>Alpha-gamma coactivation helps to maintain muscle contraction. Without this muscle spindle innervation through the coactivation, contraction can't be maintained.</u>





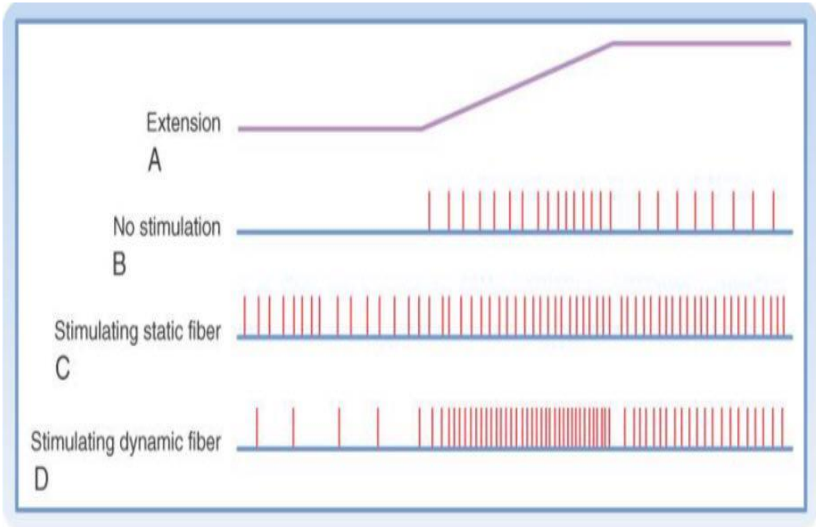
- In A we are recording a (static) stretch, there is basal firing in muscle spindle sensory fibers, without any change in the length of the muscle (isotonic).
- In B we are recording change in stretch (dynamic) but only alpha motor neurons are stimulated, that means we have contraction in the muscle, but notice there is no firing in the muscle spindle sensory fibers (why?) because muscle contraction will shorten muscle spindles loosening and inhibiting them, <u>without the presence of gamma fibers there will be no recording of any tension sensed by muscle spindle</u>.
- In C we are recording change in stretch (dynamic) with alpha and gamma neurons stimulated together (coactivated), muscle spindle will be contracted and activated all the time, when the muscle contracts there will be a decrease in the firing rate of muscle spindles. (<u>There is always a feedback to the CNS about the degree and change in stretch even in the case of contraction</u>)

Function of the Gamma System:

1- Spindle is normally tonically active as a result of input from higher brain centers. Alpha-gamma co-activation helps maintain muscle contraction.
2- Controls the intensity of the stretch reflex.
3- Performs a damping function by adjusting sensitivity.

Effect of gamma motor fibers (Dynamic and static)

When there is stretch change (dynamic), this will stimulate static gamma fibers increasing their impulse rate and stimulate dynamic gamma fibers increasing their impulse rate more. And when this change finishes, they will go back to their basal rate. Just like what happens with group 1a and 2 sensory fibers.



(Redrawn from Crowe A, Matthews PBC: J Physio174:109, 1964.)

Control of the Gamma Motor System (Fusimotor System)

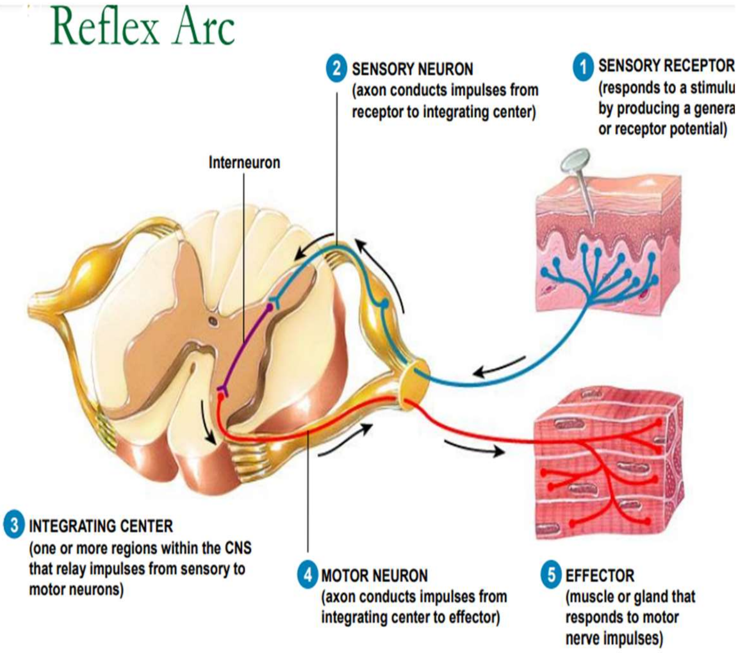
- Gamma signal excited by the bulboreticular facilitatory area of the brain stem.
- Secondarily by areas that send impulses to this area. [cerebellum, basal ganglia, cortex]
- Little is known about the precise control of this system.

Reflexes in general are very important in testing the functions of the spinal cord because they happen mainly within the spinal cord. so, when we test the reflexes, we're actually testing the integrity of the spinal cord.

It is true that those reflexes work through spinal cord, but they can be affected by the cortex, to avoid the effect of the cortex we ask the patient to hold his hands together and keeps holding them until we finish to distract him.

A reflex is a rapid automatic (involuntary) movement upon a specific stimulus.

Reflex Arc:



for any reflex to occur it needs the following parts:

1-receptor

2-sensory (afferent) neuron

3-interneuron (integrating center)

4-motor (efferent) neuron

5-effector

Notice that the start of any reflex which is the stimulus isn't part of the reflex arc and it can be any type of sensation (pain, touch…)

Let's start with our first reflex:

Stretch reflex

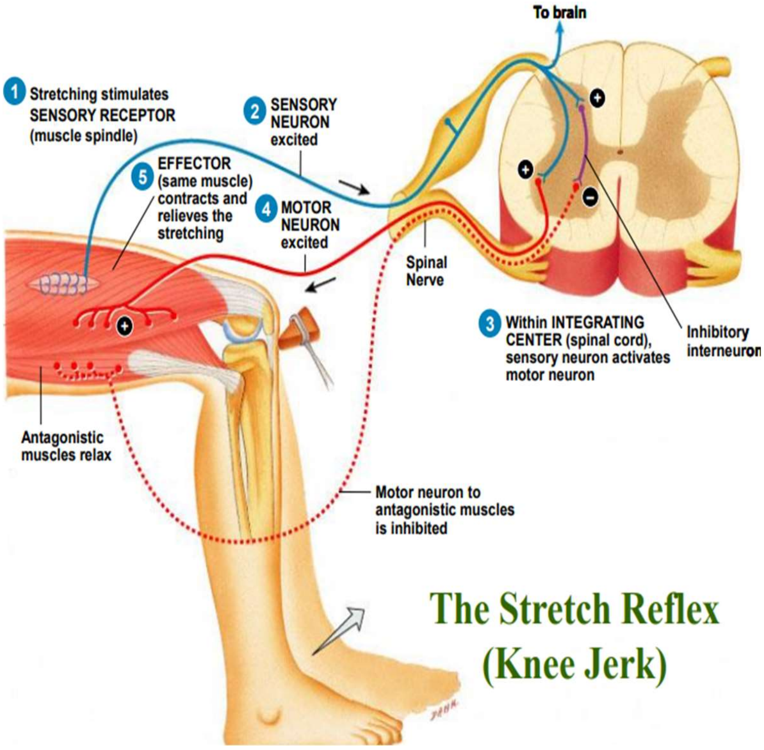
This reflex can be done with almost any muscle, as an example we will focus on the knee jerk reflex. Jerk means something abnormal or can't be expected. / other examples: ankle reflex [gastrocnemius muscle], biceps, triceps…..

In this reflex we will test the movement of the quadriceps muscle around the knee.

We start by hitting the patellar tendon with a hammer -> this will create an artificial **stretch in the quadriceps muscle** -> the stretch is sensed by the muscle spindles found inside the quadriceps muscle -> the afferent sensory fibers connected with these receptors are going toward the spinal cord to:

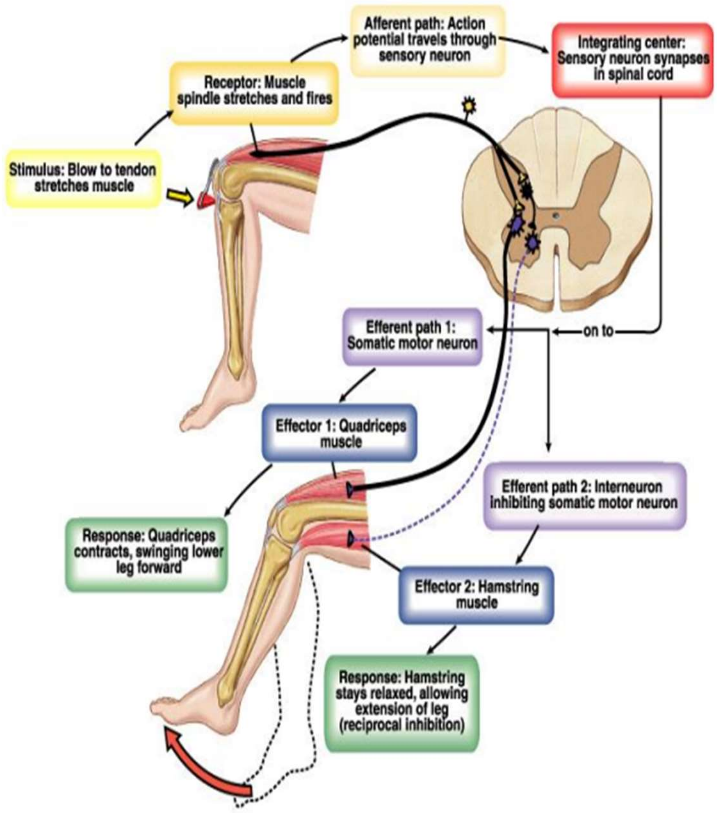
1- send information about the stretch to higher centers (brain) and, as we know from the previous sheet, these spinocerebellar fibers are responsible of telling the cerebellum what is exactly happing down on the level of the muscle regarding the tension (length).

2- Synapse with -> alpha motor fibers that are going to the quadriceps muscle -> **the quadriceps muscle will contract** -> the knee is extended (moves forward)



→ Index of the facilitation of the gamma efferents. [recall that whenever there is muscle contraction this will shorten the muscle spindles inhibiting them. And gamma motor efferents will stretch the spindles again activating them]

→ Cortical lesions usually increase muscle stretch reflexes [specifically UMNLs]



- In the pictures to the right, you can find that the antagonistic muscle (hamstring muscle = flexor) is inhibited by the same sensory afferent neurons synapsing with inhibitory interneurons. And that's phenomenon is called **reciprocal inhibition**.
  When the agnostic muscle contracts, the antagonistic muscle relaxes and vice versa.

Special features of stretch reflex:

1- Causes **contraction** of a skeletal muscle in response to stretching of the muscle.

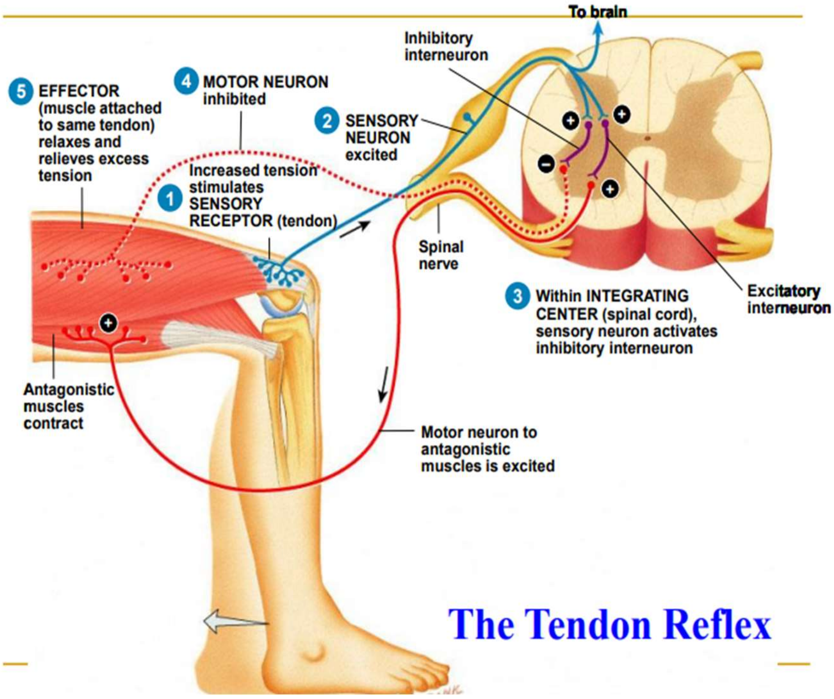
Patellar or knee-jerk reflex: Stretching of a muscle →activation of muscle spindles →sensory neuron → spinal cord → motor neuron → muscle contraction. (**Excitatory** reflex)

2- **Monosynaptic** reflex.
3- **Ipsilateral**. [when you hit the right tendon, the right knee will extend]
4- Receptors are in **the same** muscle stimulated by lengthening of muscle (stretch).

Tendon reflex

Keep in your mind that this reflex is **protective**. Because when the muscle is contracted a lot, this creates a very high stretch on the tendon, so we must inhibit this contraction to keep the tendon safe without torn.

contraction of a muscle causes too much tension in the tendon which might separate the tendon from the tibia -> Golgi tendon organs (receptors) sense this stretch -> the sensory afferent neurons (group 1b fibers) connected with these receptors will go back to the spinal cord to:

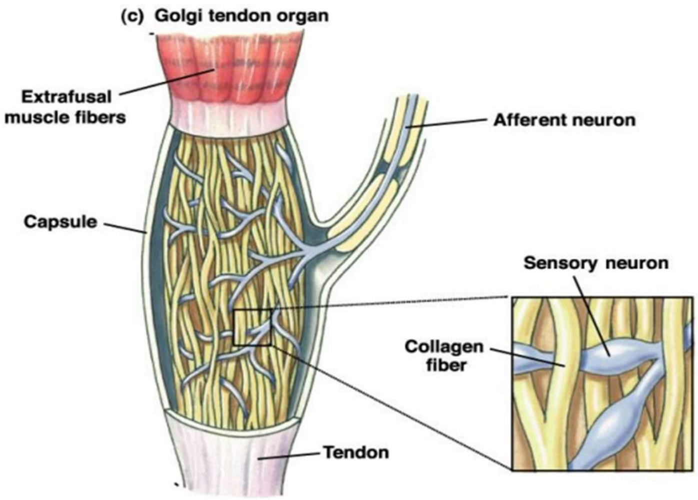


1- send information to the brain about the tension and the rate of change in tension [static/dynamic]
2- synapse with inhibitory interneurons that are synapsing with alpha motor fibers -> relaxation in the muscle (tension in the tendon decreases)

special features of tendon reflex:

1- **Polysynaptic** reflex. (Di-synaptic)
2- Control muscle tension by causing muscle **relaxation** when muscle tension is great.
↑ Tension applied to the tendon → tendon organ stimulation → nerve impulse → spinal cord → motor neuron causes muscle relaxation and relieves tension (**inhibitory** reflex)
3- Sensory receptors- Golgi tendon organs (**same muscle** stimulated by tension applied on the muscle in series with muscle fibers).
4- **Ipsilateral**

Just read 😊 Golgi Tendon Reflex: Mediated by the Golgi tendon organ receptor located in the tendon. This receptor responds to tension. When the tension becomes too great the reflex inhibits the motor fibers attached to the tendon. Function is to equalize force among muscle fibers.



Notes on stretch reflex and Golgi tendon reflex:

- Stretch reflex is faster than tendon reflex that's because stretch reflex is monosynaptic while tendon reflex is polysynaptic
- Both work in the same segment where the interneurons enter the spinal cord [**unisegment**]
- Reciprocal inhibition is present in both
- Transmission of Stretch Information to Higher Centers: Muscle spindle and Golgi tendon signals are transmitted to higher centers. This informs the brain of the tension and stretch of the muscle. Information is transmitted at 120 m/sec. Important for feedback control of motor activity.
- Golgi tendon organs are in series with muscle fibers [tension] على التوالي
  While muscle spindles are in parallel with muscle fibers [length/stretch] على التوازي

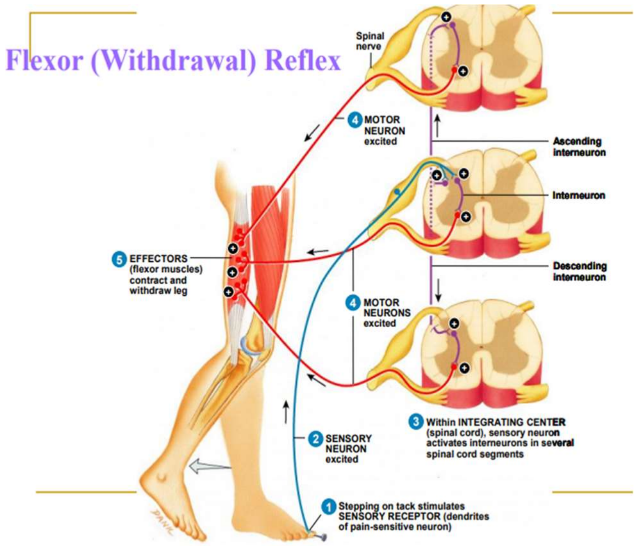
Flexor (withdrawal) reflex

A painful stimulus causes the limb to automatically withdraw from the stimulus.

Here we start with pain receptor (nociceptor) activation, this receptor is present in the skin -> through C and Aδ fibers (slow fibers) this sensation will be transmitted to the spinal cord -> they go up or down(one or two segments) then they synapse with interneurons -> interneurons synapse with alpha motor fibers activating the flexor muscles -> flexion of the leg. [there is also inhibition of the extensors in the same leg / reciprocal innervation]

nociceptor activation transmitted to the spinal cord -> synapses with pool of interneurons that diverge the to the muscles for withdrawal, inhibit antagonist muscles, and activate reverberating circuits to prolong muscle contraction -> duration of the after discharge depends on strength of the stimulus

what is after discharge? EPSP stays for 20ms while AP occurs within <1ms // if one stimulus gives us an ESPS that is above the threshold generating AP, it will continue producing this AP for 20ms



special features of flexor (withdrawal) reflex:

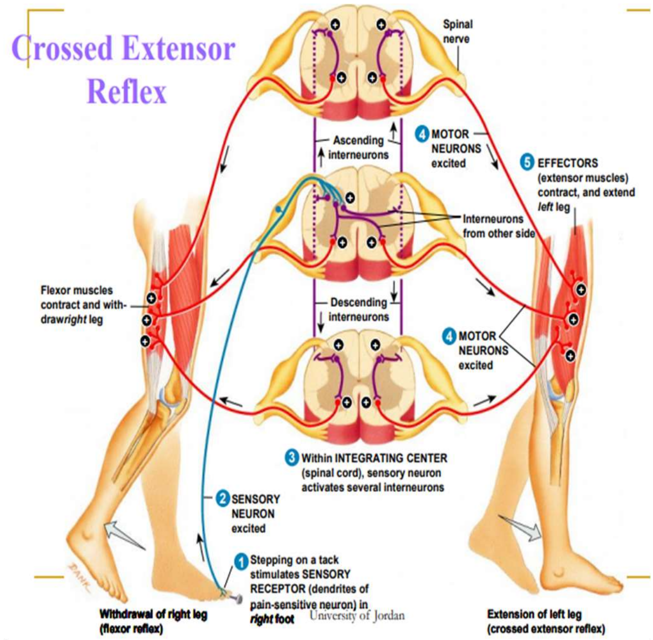
Any synapse has a synaptic delay that is about 0.5ms.

1- **Polysynaptic** reflex [slower than stretch reflex and tendon reflex]
2- **Ipsilateral**.
3- **Multi segmental**
4- The receptor **isn't present in the same muscle**! It is in the skin. Stepping on a tack (stimulus) → nerve impulse → activation of the interneuron → activation of the motor neuron →muscle **contraction** →withdrawal of the leg (**excitatory** reflex) // There is reciprocal inhibition (i.e. inhibition of antagonist group of muscles on the same side)

Crossed extensor reflex

<u>Painful stimulus elicits a flexor reflex in affected limb and an extensor reflex in the opposite limb</u>. Extensor reflex begins 0.2 - 0.5 seconds after the painful stimulus. Serves to push body away from the stimulus, also to shift weight to the opposite limb.

we start here also from a pain receptor (nociceptor) activation, this receptor is present in the skin -> through C and Aδ fibers this sensation will be transmitted to the spinal cord -> they go up or down one or two segments then they synapse with interneurons-> these interneurons will cross the midline and synapse with alpha motor fibers that activate the extensors and inhibit the flexor in the other side -> to support the body while it's doing the flexor (withdrawal) reflex



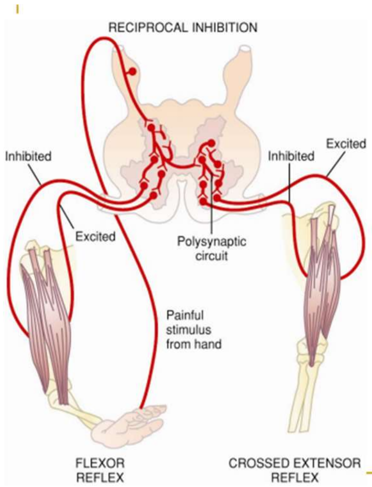
Special features of crossed extensor reflex:

1- **Polysynaptic** reflex. [slower than stretch reflex and tendon reflex]

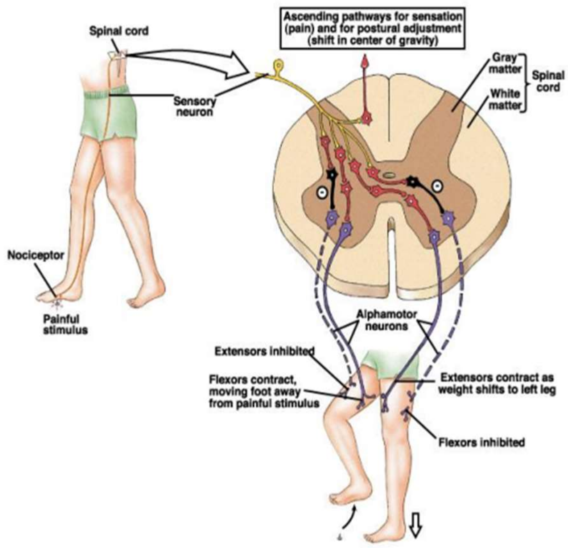
2- **Contralateral** reflex.
Contraction of muscles that extend joints **in the opposite** limb in response to a painful stimulus.
Stepping on a tack (stimulus) → nerve impulse → activation of several interneuron → activation of the motor neurons → muscle contraction causing **flexion** of the leg stepping on a tack & **extension** on the opposite side. There is reciprocal inhibition (i.e. inhibition of antagonist group of muscles on the same side)

3- **Multi segmental**

4- The receptor **isn't present in the same muscle**! It is in the skin



Neuronal Circuits for Withdrawal and Crossed Extensor Reflex



Myograms of flexor and crossed extensor reflexes

The onset of flexor (withdrawal) reflex is faster than crossed extensor reflex. That's crossed extensor reflex needs more time to develop because of having too many synapses.

(in terms of speed: stretch reflex > tendon reflex > flexor (withdrawal) reflex > crossed extensor reflex)

Regarding after discharge, crossed extensor reflex have longer after discharge than flexor (withdrawal) reflex. That's crossed extensor reflex needs more time to stop.

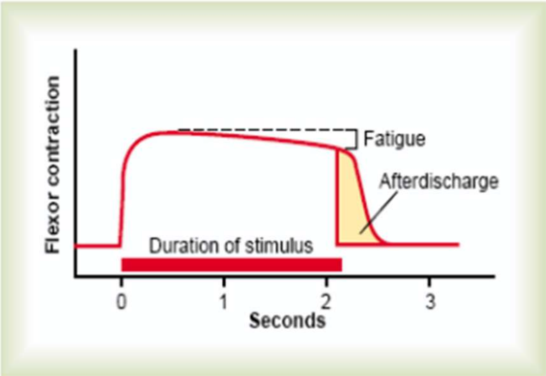


Figure 54–9

Myogram of the flexor reflex showing rapid onset of the reflex, an interval of fatigue, and, finally, afterdischarge after the input stimulus is over.

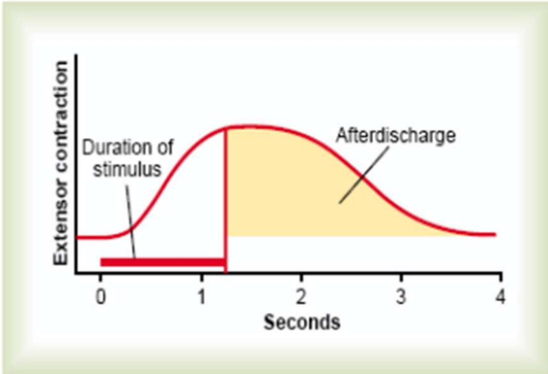


Figure 54–10

Myogram of a crossed extensor reflex showing slow onset but prolonged afterdischarge.

Other Reflexes for Posture and Locomotion [important for babies]

- Pressure on the bottom of the feet cause extensor reflex - more complex than flexor-crossed extensor reflex
- Basic walking reflexes reside in the spinal cord.

Reflexes that Cause Muscle Spasm

- Pain signals can cause reflex activation and spasm of local muscles.
- Inflammation of peritoneum can cause abdominal muscle spasm.
- Muscle cramps caused by painful stimulus in muscle: can be due to cold, ischemia, of overactivity [distension]. reflex contraction increases painful stimulus and causes more muscle contraction.

Examples: when there is inflammation in the appendix, in the beginning the pain will be referred around the umbilicus then when the inflammation increases and reach the peritoneum, the pain will be transmitted to the spinal cord by spinal nerves/sensory neurons, those neurons will cause excitation and spasms in the muscles around the area of the appendix [LRQ]. the same happens when there is inflammation in the gallbladder it starts as referred pain in the right shoulder then it will cause muscle spasm around the area of gallbladder.