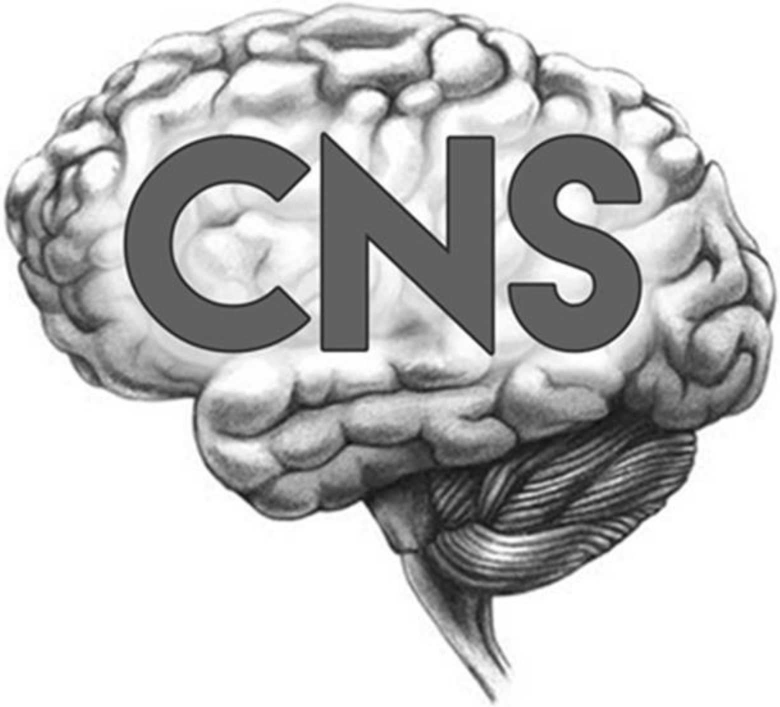

PHYSIOLOGY

☑ Sheet ○ Slide ○ Handout

Number

9

Subject

Reflexes

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In this sheet, we will talk about motor system of the spinal cord including muscle spindles and Golgi tendon organs, then we will talk about reflexes and different spinal cord circuits.

- The Muscle Spindles are parallel to the muscle fibers and sense a change in **length**.
- Golgi Tendon Organs are in series with the muscle fibers and sense a change in **tension**.

The Muscle Spindle (المغزل العضلي) is composed of a central part (receptor part / non-contractile part) which is connected by two types of sensory fibers (afferents):

- **Ia fibers (Primary endings)**: Responsible for **dynamic response** and sense the **rate of change** in length. Major fibers for Deep Tendon Reflexes.
- **II fibers (Secondary endings)**: Responsible for **static response** and **sense the actual length** (degree of stretch). Major fibers for Muscle Tone.

And an outer part (the contractile part) which is supplied by Gamma motor neurons efferent fibers. Gamma fibers are of two types; Dynamic and Static fibers (Gamma-d and Gamma-s, respectively).

Note: Density of muscle spindles is more in the muscles that are used too much; these are axial and antigravity muscles.

The muscle spindle is responsible of the **stretch reflex**.

When a muscle spindle is stretched, afferents will generate impulses that will reach Alpha motor neurons and cause muscle contraction. This is how the stretch reflex happens.

Spindles are stretched by Gamma fibers or when the whole muscle is stretched.

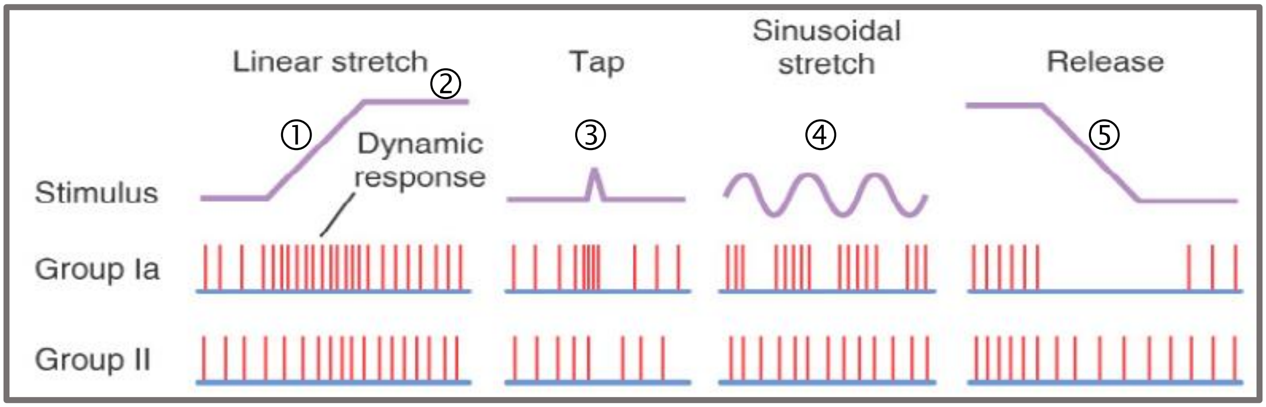
A muscle spindle is either a:

- Nuclear bag spindle: Connected to Ia fibers only.
- Nuclear chain spindle: Connected to Ia and II fibers.

In the static response, the number of impulses generated by the secondary endings increases in proportion to the **degree** of stretch.

In the dynamic response, the number of impulses generated by the primary endings increases in proportion to the **rate** of change in length.

❖ The responses of 1ry and 2ry endings:



Ia and II fibers have a basal rate of firing. This is very important for positive and negative control.

When the muscle is stretches ①, dynamic fibers (Ia) will fire more impulses **during the change.** And it is proportional to the rate, the more fast the change is, the more the impulses generated.
If the stretch is fixed ②, impulses will decrease to the basal rate (rate of change is zero).

In the static response (II fibers), impulses also increase during the stretch ①, but here it is in response to the increase in length and **not due to the rate** (so even if the rate was faster it will have the same response).
And when the stretch is fixed ②, the high rate of firing remains.

③ The tap (reflex); when you hit the tendon, muscle will be stretched and the reflex will cause the muscle to contract. Muscle contraction shortens the muscle spindle and hence it is inhibited and the muscle relax. (Reflexes are explained in more detail later in this sheet)

④ Clonus is example on the sinusoidal stretch.

If the muscle is released from stretch ⑤, muscle spindle shortens and Ia impulses will decrease proportional to the rate of release, so if the release is too fast the impulses may stop at all. After the release is finished the fibers will return to the basal rate.

II fibers impulses also decrease, but again, note here that the decrease is not proportional to the rate and also the new rate of firing is fixed after the release is finished (because it cares about muscle length only, it will give certain number of impulses to a certain length regardless if you reached that length rapidly or slowly).

The same is seen in the efferent fibers; Gamma-d is related to the Ia fibers and Gamma-s is related to the II fibers (See slide 25)

Note: As the dynamic fibers sense the change in rate, they help in the predictive function of the cerebellum. So they help us to stop the movement at the intended point. (Remember Ia fibers reach the cerebellum through spinocerebellar tracts).

❖ Alpha Gamma Coactivation:

This figure shows an expirement that illustrates the importance of Alpha Gamma Coactivation.

(A) Is a contraction seen in a normal muscle, and (B) is in a muscle whose muscle spindles were denervated by section of the posterior roots of the spinal cord.

As you see in (B) the contraction curve goes up and down (contractions & relaxations), you **can't maintain the contraction.**

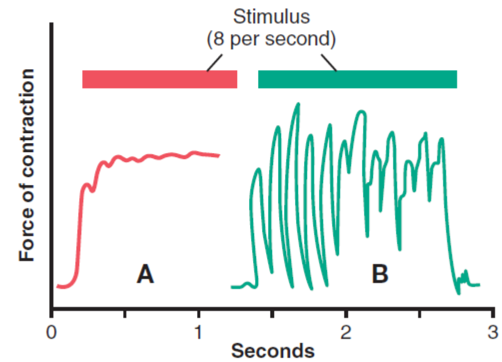


Figure 55-6. Muscle contraction caused by a spinal cord signal under two conditions: *curve A*, in a normal muscle, and *curve B*, in a muscle whose muscle spindles were denervated by section of the posterior roots of the cord 82 days previously. Note the smoothing effect of the muscle spindle reflex in *curve A*. *(Modified from Creed RS, Denney-Brown D, Eccles JC, et al: Reflex Activity of the Spinal Cord. New York: Oxford University Press, 1932.)*

The doctor by mistake explained this saying that when you contract the muscle, the spindle is shortened and inhibited, so it won't stimulate Alpha motor neurons in the spinal cord so the extrafusal fibers (the muscle) will relax. When the muscle relaxes it elongates and this will stimulate the spindle which will stimulate Alpha fibers and cause contraction, and then relaxation and then contraction and so on. But that's can't be true because, as mentioned, the muscle spindles are denervated.

So I will quote the related text from Guyton:

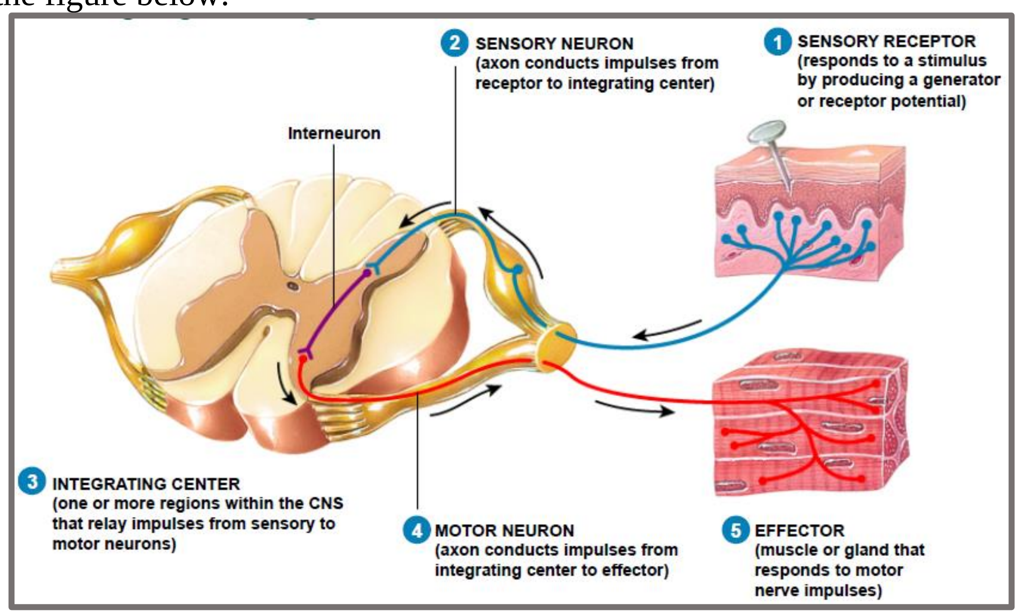
"" **Damping Function of the Dynamic and Static Stretch Reflexes in Smoothing Muscle Contraction.** An especially important function of the stretch reflex is its ability to prevent oscillation or jerkiness of body movements, which is a *damping*, or smoothing, function. Signals from the spinal cord are often transmitted to a muscle in an unsmooth form, increasing in intensity for a few milliseconds, then decreasing in intensity, then changing to another intensity level, and so forth. When the muscle spindle apparatus is not functioning satisfactorily, the muscle contraction is jerky during the course of such a signal. This effect is demonstrated in **Figure 55-6**. In curve A, the muscle spindle reflex of the excited muscle is intact. Note that the contraction is relatively smooth, even though the motor nerve to the muscle is excited at a slow frequency of only eight signals per second. Curve B illustrates the same experiment in an animal whose muscle spindle sensory nerves had been sectioned 3 months earlier. Note the unsmooth muscle contraction. Thus, curve A graphically demonstrates the damping mechanism's ability to smooth muscle contractions, even though the primary input signals to the muscle motor system may themselves be jerky. This effect can also be called a *signal averaging* function of the muscle spindle reflex."”

So the function of Alpha Gamma coactivation is to maintain the contraction. This happens because when Gamma fibers are stimulated at the same time of Alpha stimulation, **the central part of the spindle will remain stretched** even that the extrafusal fibers are stretched, and this will send more impulses to Alpha fibers and contraction will be maintained.

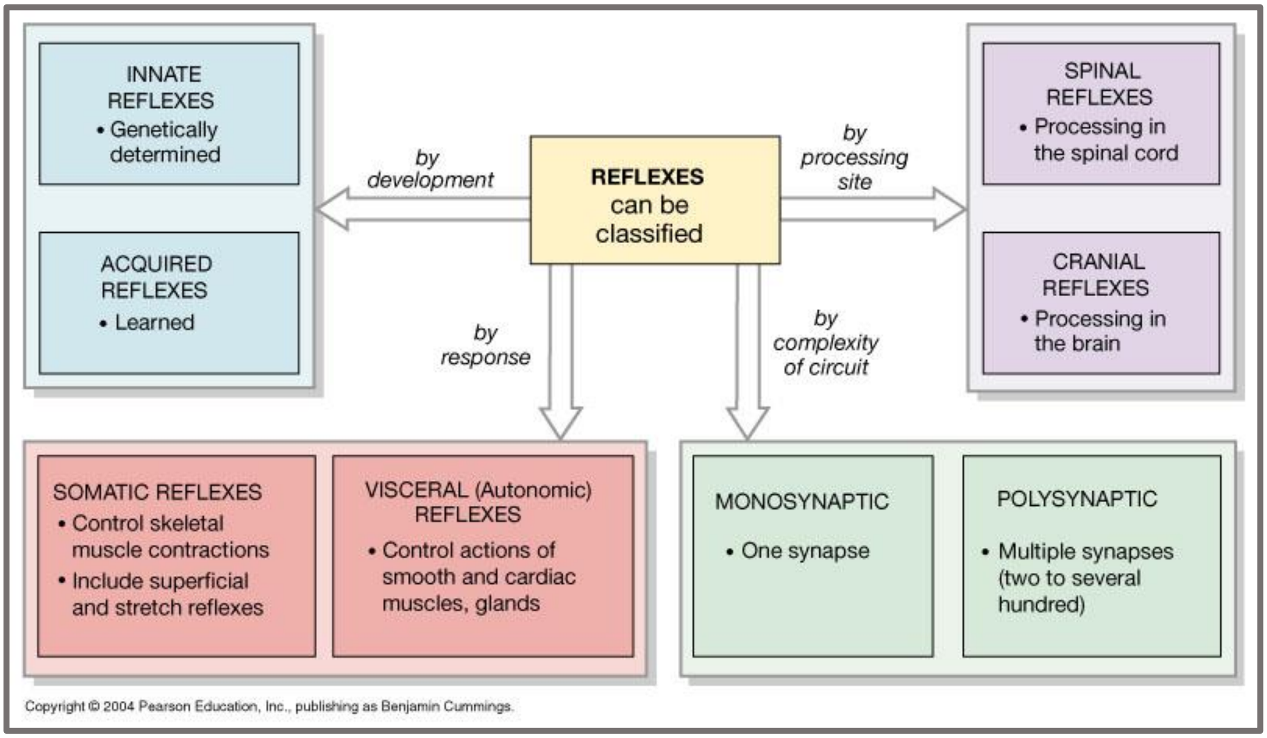
Control of Gamma system: Little is known about the precise control of the Gamma system, but it's thought that Gamma signals are excited by the bulboreticular facilitatory area of the brain stem. And secondarily by areas that send impulses to this area (cerebellum, basal ganglia, cortex). For example a motor impulse comes from the corticospinal tract to Alpha motor neurons, and cerebellar impulses will reach the Gamma neurons through the reticulospinal tract, and Gamma fibers will cause a facilitatory effect to the original impulse (So one may lose some of the facilitatory effects by a cerebellar lesion).

❖ Reflexes (المنعَكَسات):

A reflex is an involuntary movement in response to a stimulus. Any reflex has what is called **Reflex Arc (قوس المنعَكَس).** This arc starts with a sensory receptor and ends with an effector organ (muscle or gland). Damage to any part of the arc will affect the reflex. Follow the figure below.



- Methods of Classifying Reflexes:



Reflexes can be classified in different ways. We can classify them to the number of synapses (Monosynaptic or Polysynaptic).

They can also be classified according to the response; which can be Somatic or Visceral. Stretch reflexes are Somatic reflexes. An example on the Visceral reflex is when someone has appendicitis and after sometime he gets muscle rigidity as a reflex for the pain.

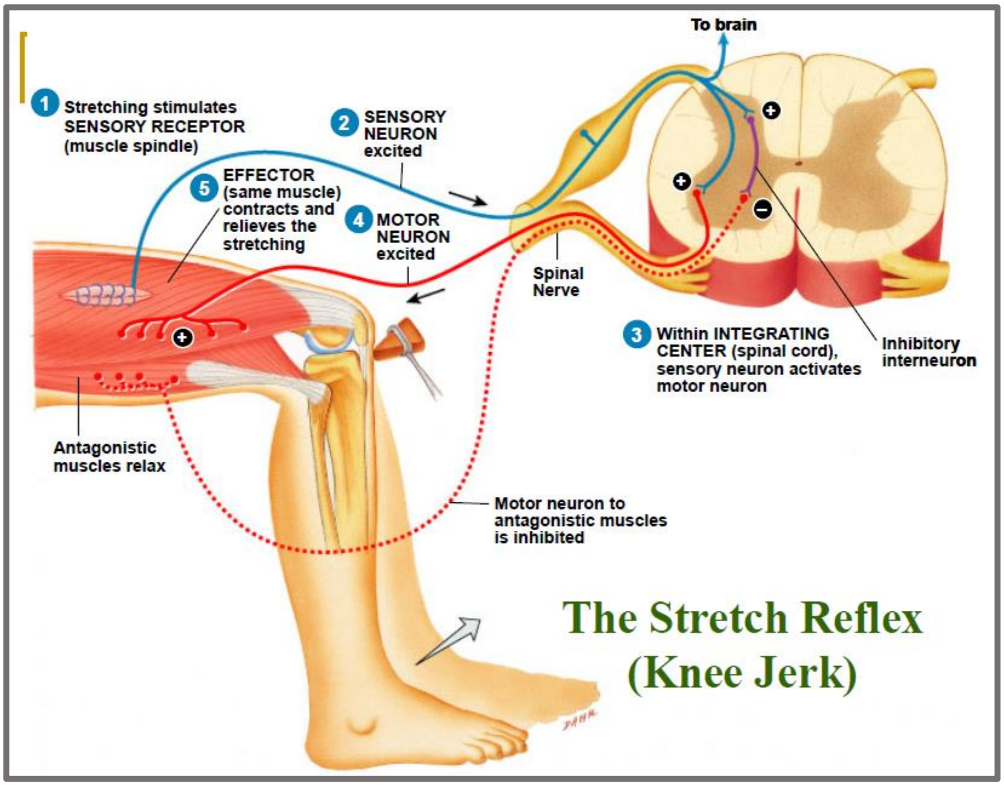
Also they can be classified by development; Innate reflexes (which are genetically determined) or Acquired reflexes that are learned.

Lastly by processing site; Spinal reflexes processed in the spinal cord and Cranial reflexes processed in the brain.

Now we will talk about **Deep Tendon Reflexes**, as a clinical application of the stretch reflexes.

Example: Knee Jerk (Quadriceps muscle) (نفضة الركبة)

In the Knee Jerk, you hit the patellar tendon so the Quadriceps muscle will be stretched, the muscle spindle afferents (**Ia)** will generate impulses that will cross the posterior horn of the spinal cord and synapse with Alpha neurons in the anterior horn, Alpha fibers send the impulse to the muscle and the muscle contracts. Follow the figure below.



Notice that there is only one synapse in this reflex (Between Ia and Alpha fibers), so it is considered **Monosynaptic.**

Important note before we continue: Remember that the Dorsal SpinoCerebellar tract receives its input from Muscle Spindles and Golgi Tendon Organs to correct the actual movement, so it has the same afferent fibers of the stretch reflex. So notice in the figure above that in the knee jerk some afferents will go to the brain through the dorsal column. Which means that there are no specific fibers that will do stretch reflex and other specific fibers for the cerebellum (Both are Ia). Other reflexes may use this circuit also, simply because all of them will reach the motor neurons of the muscles finally. So please don't get confused by this

Also note: that the impulse will go, thorough an inhibitory interneuron, to the antagonist muscle and relax it (Reciprocal Innervation).

Characteristics of Deep Tendon Reflex: Monosynaptic reflex / Ipsilateral / Receptors are located in the same muscle stimulated by lengthening of muscle (stretch).

Deep tendons reflex circuit is at the level of the spinal cord, so it's better to distract the patient when doing the reflex (by telling the patient to clench their teeth, flex both sets of fingers into a hook-like form and interlocks those sets of fingers together)* so that the cerebral cortex won't affect the reflex consciously.

* : This is called Jendrassik maneuver.

Deep tendon reflexes can be done with almost any muscle. Cortical lesions usually increase muscle stretch reflexes.

Other Reflexes:

1) Tendon Reflex (Inverse Myotatic Reflex):

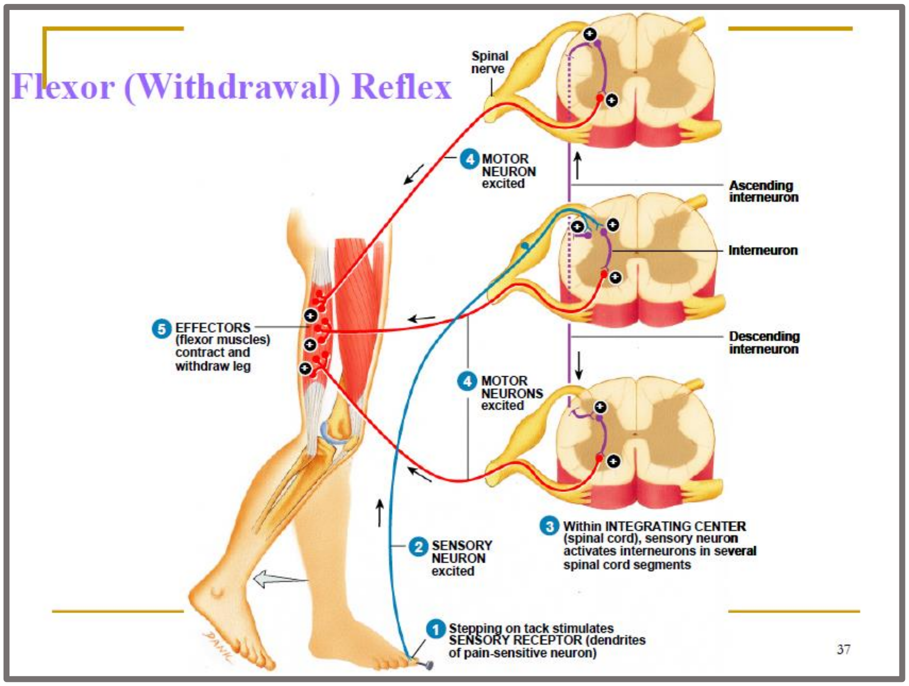
When a muscle tension increase too much, Golgi Tendon Organs will be stimulated (remember that they respond to tension), and they will send impulses through **Ib fibers** to the spinal cord. These **fibers will synapse with Inhibitory Interneurons that will inhibit Alpha fibers and cause muscle relaxation**. (Also it will cause antagonist muscle contraction through excitatory interneurons, and again, some fibers will go to the brain).

So unlike the stretch reflex, this reflex is inhibitory. And it is a protective mechanism that prevent tendon tearing or damage.

Characteristics of Tendon Reflex: Disynaptic (You can also say polysynaptic) **/ Control muscle tension by causing muscle relaxation when muscle tension is great.**

2) Flexor Reflex (Withdrawal Reflex):

The stimulus in this reflex is nociceptive (pain). So the afferents to this reflex are carried by **Aδ and C** fibers (that carry pain). Remember that these fibers are relatively slow.



The afferent fibers will synapse with **interneurons as well as propriospinal** tracts so it will travel to other segments of the spinal cord and the final effect will be contraction to a **whole group of muscle** (Flexors of the leg for example).

As always, there is reciprocal inhibition of antagonist group of muscles on the same side.

Characteristics of Withdrawal Reflex: Polysynaptic reflex / Ipsilateral / Pain Stimulus.

The Flexor reflex has another part, which is called the **Crossed Extensor Reflex**. When a person flexes his leg due to a pain stimulus, he will fall if the other leg didn't extend. So the function of the Crossed Extensor Reflex is to extend the other leg during the flexor reflex.

This happens by interneurons that cross the middle line to the other side, and do the exact opposite of the flexor reflex (i.e. stimulate extensors and inhibit flexors).

Note: Remember that the central canal is in the middle, so a problem in the central canal may affect this reflex.

Characteristics of Crossed Extensor Reflex: Polysynaptic reflex / Contralateral reflex / Multi-Segmented / Pain stimulus.