Central Nervous System

Sheet 9b

Subject | Physiology

Done by | Bahaa Jaradat

Correction | Izzidin

Doctor | Loai Al-Zghoul

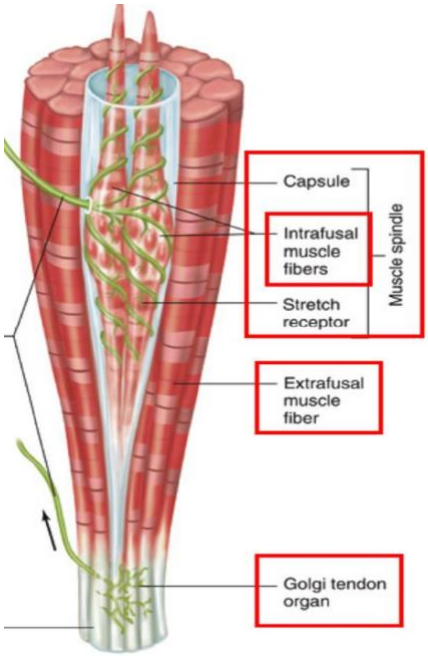
This sheet is a continuation of lecture 9, the half that wasn't included for the midterm material.
Main topics to be covered :-
1-Muscle-tendon receptors and motor stretch reflex.

Motor system represents an output of CNS, after the processing of related sensory information, a motor output will be decided by the CNS.
The information controlling our muscles are conducted through the motor system, these information may be the result of :-
A- Subconscious involuntary orders from the subcortical level, an example is the motor information and orders, carried out by the extrapyramidal tracts at the subcortical level to control the tone of muscles.
B- Quick spinal reflexes, these happen at the level of the spinal cord, so they tend to be fast and -of course- involuntary.
C- Conscious cortical motor decisions and orders (mainly originate in 1ry motor cortex and other motor cortices), an example is the voluntary control of body muscles transmitted through corticospinal tracts.

-Regardless of the origin of a certain motor order (cortical, subcortical or spinal), all motor information must pass through a common motor pathway in order to reach the muscle, that is the lower motor neurons whose cell bodies are in the anterior horn of gray matter.

We will focus on 2 receptors present in muscles; these are:

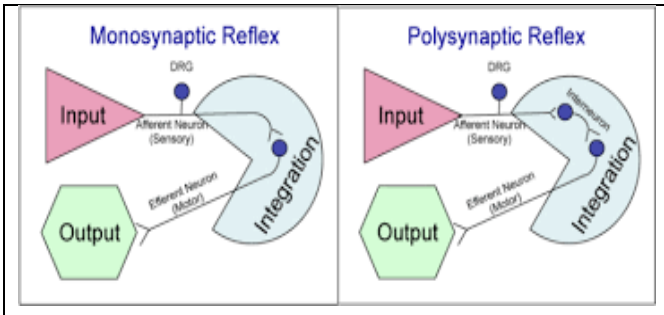
1- Muscle spindle.
2- Golgi tendon organ.



-These two types of receptors have 2 different functions, but are of course related to each other as they both share the ultimate goal of controlling muscles contractions and/or relaxations.
-Muscle spindle receptor is within the belly of the muscle and it detects changes in the muscle's length, whereas Golgi tendon organs detect and transmit information about the tension present in a muscle.

-Muscles are supplied by 2 types of lower motor neurons, alpha (α) and gamma (γ). Alpha neurons are larger, faster and supply the majority of muscle fibers (extrafusal fibers). Whereas gamma neurons are smaller, slower and mainly supply the contractile fibers of the muscle spindle (intrafusal fibers).

We will now go into details about the exact function of the muscle spindle:-
-When a muscle is stretched, its length will increase, so the stretch over the muscle spindle will also increase, causing the activation of the sensory fibers from the muscle spindle that mono-synapticaly activates the lower motor neuron causing contraction of the muscle.

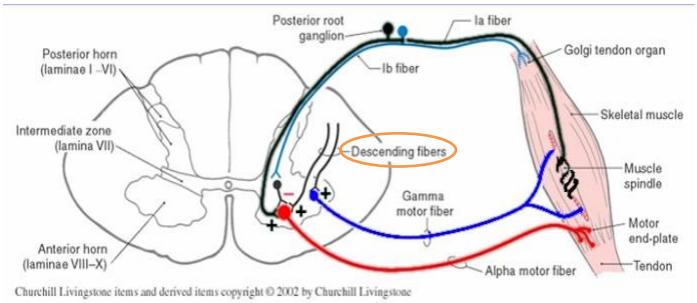


A figure that shows the difference between mono and poly synaptic pathways (notice the presence of an interneuron in the poly synaptic).

That was a simple way to describe the mechanism and role of the muscle spindle as a length detector. But in order for the changes in a muscle's length to affect the muscle spindle stretch, a fixed ratio must be maintained between the length of the muscle and the length of the muscle spindle within it. The significance of this fixed ratio is to avoid over stretching or over relaxation of the muscle spindle, which both can make it nonfunctional, to further explain this point, let's say that for example a muscle is 30cm long and within it there is a 10cm long muscle spindle, now suppose the muscle has contracted and thus its length decreased to let's say 15 cm, if the muscle spindle in this case didn't contract with this muscle, the spindle will be over relaxed because the muscle is too short now, and the stretch over the spindle is too little, which will make the muscle spindle a non-functional receptor which means that when the now 15 cm long muscle changes its length again for let's say 25 cm, the muscle spindle will not detect this change because it is already over relaxed, and the 15 to 25 cm increase in the muscle length wasn't able to stretch the spindle to a level that

leads to increased firing, because as we earlier said, it was relaxed too much. But fortunately, this is not what happens within our bodies, as in most of the cases, both alpha and gamma neurons are co-activated, so both the muscle fibers (extrafusal fibers) and the muscle spindle (intrafusal fibers) get contracted decreasing their length in a way that maintains the fixed ratio between them.

-In another hypothetical scenario, imagine that the muscle's length wasn't changed, but the muscle spindle length decreased due to gamma motor neuron activation, then this will cause an interruption of the fixed ratio between muscle length and the length of the muscle spindle, to restore that ratio again, the muscle spindle will send sensory information through its afferent fibers activating the alpha motor neuron fibers, the alpha motor fibers then will cause a contraction in the muscle fibers decreasing its length to re-establish the fixed ratio, this mechanism is called **gamma loop**.



If you didn't understand this, please check out this helpful interactive animation:
https://www.liverpool.ac.uk/~rbj/RBJ/rbjteaching/Gamma%20loop.html

Note: if a muscle's length is 30 cm, and its muscle spindle is 10 cm long, then the ratio is 3:1, and this ratio must be maintained whenever there is a contraction or a relaxation of the muscle.

Note 2: Remember that the muscle spindle's information is sent through the PCML pathway to area 3a of the brain. (refer to sheet 4 anatomy)

-Alpha and Gamma co-activation (notice the descending fibers in the pic above) is the way our muscles contract in the case of activation through most motor systems like spinal reflexes, corticospinal, vestibulospinal, tectospinal. Etc.

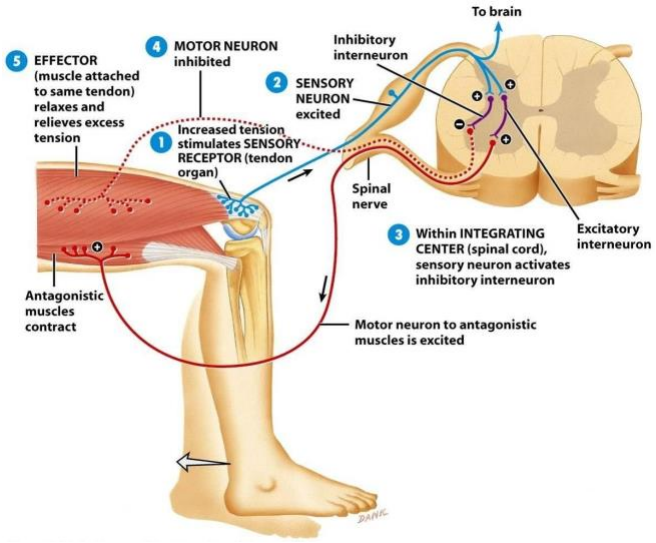
-Reticulospinal tract is a special case since its function is to maintain the muscle's tone not their lengths. So it works by activating gamma neurons only.

-In most cases, the contractions that change muscle length are carried out by the alpha gamma co-activation, and the last scenario where we changed the muscle's length (extrafusal fibers)

after activating the gamma motor neuron (intrafusal fibers) only is a rare case, so what's the importance of the gamma loop?

Gamma loop is important to maintain the muscle tone without affecting its length, this happens through an iso-metric contraction of that muscle, such a thing is needed when you stand upright, your lower limb extensors will be contracted, but their length will be fixed, in other words, for a person who is standing up, although there is no change in the length of the lower limb muscles, these muscles are indeed contracted or otherwise the person will fall off to the ground if his/hers lower limb extensors got relaxed. Now the question is, how do we maintain this "muscle tone" without changing the muscle length? Well, this is the function of the reticulospinal tract, it activates the gamma fibers, this activation increases the tension within the muscle spindle without changing it length, this increased tone in muscle spindles will cause increased firing of the sensory afferent fibers from the muscle spindle, activating the alpha motor neuron and causing muscle contraction without changing its length. This function is mainly carried out by the reticulospinal tract.
NOTE: Reticulospinal tract's UMN synapses with only gamma LMN almost exclusively.

-Muscle stretch reflex and jerk reflexes:-
When a muscle is stretched, muscle spindle length increases, so this will activate the afferent sensory fibers that enters the spinal cord and activates the alpha motor neuron of the stretched muscle leading to its contraction, in addition, the afferent fibers will also inhibit the antagonizing muscles leading to their relaxation, this will collectively cause a movement of the associated joints (jerk movement). This is important for a more accurate and functional everyday activity, to further explain this, imagine you were holding an empty cup, and suddenly someone came in and poured water in it, this will increase the weight of the cup and this will increase the force stretching your biceps muscle, the **<u>stretch reflex</u>** in this case works to cause an immediate contraction of your biceps to counter-act the new force, and prevent you from spilling the water, the effect of this reflex will last for a short duration, enough to give your corticospinal tracts the time needed to activate other muscles to help you bear the new weight of the cup.



Please note that:-
1- The afferent fibers of the muscle spindle ascends in PCML to relay proprioceptive information to the somatosensory cortex, and also gives branches that synapses in the spinal cord with lower motor neurons directly.
2-We can elicit a jerk reflex in almost all the joints of the body, more details on this subject will be included in future lectures.
Sorry for mistakes, feel free to reach us, thank you and good luck. THE END.