This Lecture is about **The Motor System**:

-The motor system consists of: muscle fibers (skeletal muscles) that undergo contraction when signals are received.

-This signal is: an action potential > Acetyl choline is released > Calcium channels open > contraction.

-The amount of contraction, its force, and the tension and length of the muscle depend on the amount of acetyl choline or amount of action potential frequency.

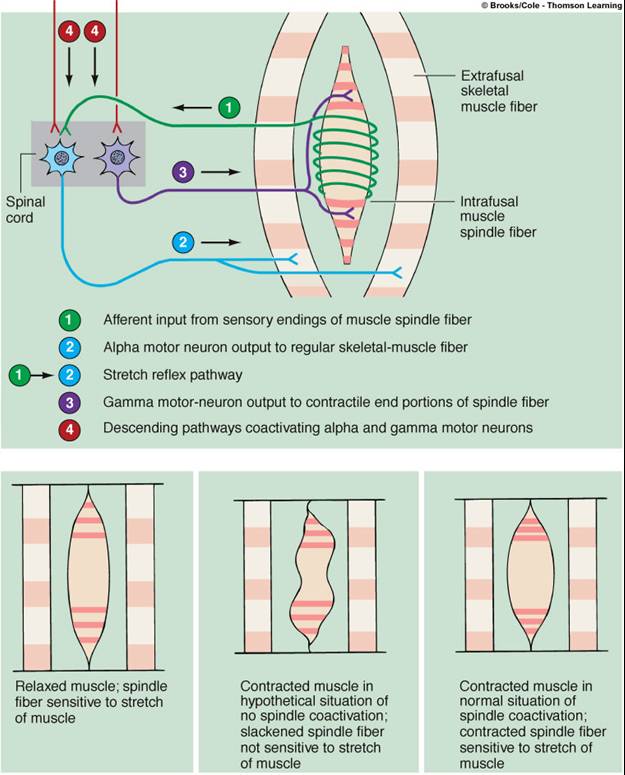
-Motor neuron should have base line firing > this base line firing makes a base line contraction in muscle, but we don’t need only a base line because we want to move > movement is by contraction that comes from an AP . (We need contraction more than one time)

-The neuron that sends an order to muscle is a motor neuron; its cell body is located in anterior horn of the spinal cord.

-Motor unit: a single neuron supply muscle fibers in a certain muscle>each muscle is supplied by more than one neuron.

-A single big neuron will supply more muscle fibers than a smaller neuron.

-The sensory receptor that is responsible about muscle length is>**Muscle spindle**, it sends signals to the brain in the form of AP to allow the brain to know about muscle length.



-Now look at the picture above: as we know muscle spindle is inside the muscle itself, when the muscle is contracted the length of sacromere will shorten however the muscle spindle will be slackened and will stop sending information or any AP, but we always need the muscle spindle to give an AP, because we need to know about it and about the muscle continuously. So when the muscle is contracted🡪Muscle spindle length should be shortened as well by sending it an order. HOW? By sending signal to motor neuron to change its length when the muscle contracts.

**Note:** Muscle spindle already contains Sensory neuron to send information about the muscle length.

-So now we need 2 neurons for each muscle or motor unit: one is for extrafusal fibers (muscle fibers), one to fibers in muscle spindle (intrafusal fibers), the extrafusal fibers are larger, and that’s why we need larger neuron for it and is called alpha motor neuron.

-The muscle spindle part of it is sensory fibers and other part is muscle fiber.

-The neuron that supplys intrafusal fiber is smaller and slower: gamma motor neuron.

-Any order that comes from higher levels will move both Alpha and Gama motor neurons.

-Motor system components:

Motor neuron (Alpha and Gamma) each has base line firing and different destination extrafusal or intrafusal.

Motor Orders pathway:

First is spinal cord: it houses reflexes and we also said it contains hard core circuits to many movements one of them is the reflexes so this means we have motor neurons other than Alpha and Gama🡪 it contains motor neurons that connect 2 laminas (motor circuit).

-First we will talk about Reflexes that protect and maintain proper function of the motor system (means that the spinal cord will inhibit any movement without higher order level by brain) e.g.: if the brain gave an order to maintain the arm on 90 degree if it changed without a brain order , spinal cord will make it back to 90 degrees by sensing the length and tension of muscles, because if these 2 characteristics change the spinal cord will think that the muscle might get damaged and it will bring it back to 90, so SC function is to protect these muscles by controlling muscle spindle and golgi tendon.

-**Muscle length:**

If muscle length changed suddenly and without any higher order, muscle spindle will sense that, and bring it back to normal length by sending an order to contract the muscle.

If we stretched the muscle, this will lead to an order to contract it back; this is known as **muscle stretch reflex.**

This reflex is seen when we hit a person on his knee it will stretch and then contract back when the muscle stretches we actually hit the tendon of the knee joint.

This reflex could occur to ALL joints but the easiest one is the knee joint because its tendon is long.

So by hitting the tendon > muscle will stretch > muscle spindle will sense > give order to SC > to brain by PCML pathway, but as this order goes up it has to give info. to SC so a branch is given to the SC because it's responsible for reflexes,in the SC information about sudden stretch (increase in length) of muscle was delivered so now we want to shorten/contract the muscle this is done by sending AP to motor neuron( alpha and gamma ), to increase AP of alpha and gamma neurons they have to be activated ( excitation ).

Steps again: length of muscle increases > muscle spindle senses that > send an AP to brain > and another branch to SC > excitation > AP increases > contraction. This is **muscle stretch reflex**.

**Note (1):** each order will go to alpha and gamma.

**Note (2)**: the branch to SC is to allow SC to function before the brain does

**Note (3):** in each reflex we have sensory arch and motor arch.

-The end result of the reflex is contraction, but the reciprocal muscle will undergo stretching, and reflex will be repeated in the other muscle, resulting in stretching and bending to infinity, to avoid that, when the muscle spindle causes contraction in a muscle, at the same instance it should send inhibition order to the reciprocal muscle not to relax without an order🡪 this inhibition is done by decreasing the activity of motor neuron. (For more explanation the neuron that comes from muscle spindle is an activator neuron we don’t have neurons to do relaxation unless by decreasing the base line firing of the motor neuron, thus relaxation is obtained by decreasing the activity of motor neuron.)

-Look at **slide #11**: So the blue neuron (from muscle spindle) is excitatory don’t make inhibition, but it switch on inhibitory neurons (purple interneuron) for the reciprocal muscle.

🡪So the excitatory neuron from muscle spindle will give 3 branches: one to the brain, other to move the muscle, third to switch on an inhibitory neuron because this excitatory neuron can't give inhibitory order by itself!

-The brains function is that, it switches and regulates the circuits that already exist, if brain doesn’t want a reflex to go, even if you hit the tendon. There is no reflex. That's why when we want to test the tendon we tell the patient to relax his body otherwise the reflex won't occur.

-This reflex is not only in the case of hitting the tendon instead it's an everyday routine e.g.: when you are holding a cup to fill it. At first the brain will send order that you are holding a cup with 100 g(empty cup), as you start filling, we are now holding a cup with 500 g you need a stronger order to make more contraction in sarcomeres, as the cup becomes heavier the muscle will stretch (will go down) without any command , so as your arm goes down you'll notice it'll immediately go back to normal , because stretching at the beginning is corrected by contraction to biceps, relaxation to triceps by the **muscle stretch reflex.** If this reflex was not working then we'll never be able to fill a cup because as u wait for the brain to calculate that the cup is getting heavier and then send an order to contract the muscle then the liquid that we were pouring is spilled all over !

So this reflex is for everyday functioning, even walking is done by this reflex and regulated by brain.

**-Tension:**

-Now we'll talk about tendon reflex

-Tension is sensed by tendon organ that senses tension.

-If tension increases > damage to the muscle (increasing in tension could be done by internal or external stimulus.)

-If you want to lift a heavy table, and it seemed to be heavier than what u thought then the brain will send more orders but still I cannot lift it, the brain will keep on increasing the AP (remember that contraction is 2 types Isotonic and isometric) Here we have isometric (tension is increasing with increasing no. of orders), but still I'm not able to lift it the brain will keep sending more contraction > damage to muscle because tension is increasing continuously without moving or relieving tension or moving the table , so muscle must sense this extra tension and make inhibition to decrease the tension , first signals must be delivered to the brain that it must stop sending more AP and then making reflex at level of SC the sensation of extra tension is sensed by golgi tendon organ the excitatory neuron will send Info to brain to inform it , and will send to inhibit by an interneuron .

-If brain continue to send orders to increase tension without stopping > muscle will be damaged

-Other name for this reflex ( autogenic inhibition) because here we inhibit the same muscle , but in previous reflex we activate the muscle and inhibit the other one.

**Third: reflex to protect the skin from thermal or pain source.**

Here pain is sensed by free nerve ending > give order to brain by ALS (slow) because we have other source to protect me from pain which is the SC.

As we go up to brain to give it info about pain we will give another branch to SC to allow me to move away from pain source

Pain > SC which will give order to move away by activating flexor muscles(flexing to the limb/knee), if orders are given only to flexors without inhibiting Extensors then we have a problem 🡪so at the same time we activate flexors we have to inhibit extensors, so here also we have 3 branches , one to brain , other excitation of flexors by activating of interneuron to flexors , third through activating of inhibitory neuron to extensors.

BUT why did we use an interneuron to excite the flexors? (We used to know that interneurons were used because an excitatory neuron cannot order for inhibition)

The answer is because we want to excite and move more than one muscle , it's not 1:1 , so if we want to move all muscle in leg For example we need to do that through a circuit , and regulate that through the neuron that is responsible of that circuit, by switching the whole circuit on and off not only switching one neuron ,so we need to deal with more than one nerve here and each on different level of SC (just like the hand ( c6-c8))

-Sometimes when there is sudden pain the whole body will move away not just the area of pain.(trunk)

-so we conclude that in this reflex (withdrawal reflex) even the excitatory has interneuron.

-While walking if you stepped on a pin you will raise your leg 🡪note that our brain in this instance it was programmed to walk so we need an order to balance my body otherwise you will fall. So you will move the pained leg up and the other leg must increase its extension because now this leg is holding the weight of the whole body, so an order to extensor muscles of uninjured leg > by activating extensors and inhibiting to flexors, by excitatory and inhibitory neurons, and we need the neurons to do cross to other side to function from right to left or vice versa...

- So two neurons do the crossing, one excitatory for excitatory program, one inhibitory for inhibition of flexors.

-This reflex on other side named as crossed extension reflex.

-The neurons that give orders to muscles are called motor neurons (alpha and gamma) or lower motor neuron.

-Lower motor neuron can be switched on by SC so they're called spinal cord neurons or SC circuit, however normally we send info from upper part of CNS to lower part SC to switch either the motor neuron or its circuit so Motor system is not just orders from up to down it's like a network.

Parts of Motor system

Motor neurons (upper and lower motor neurons), the upper motor neuron will send orders to low levels and is divided to 2 parts **Tract** and **regulator**.

**Tract**: any neuron or system that sends order directly to SC.

Any other part of brain that works with motor system to calculate and regulate and don’t send order to low level is called > **regulators**

-Muscles don’t move unless by lower motor neuron

-Tracts are 2 types: corticospinal (pyramidal), extrapyramidal tracts.

1-Corticospinal comes from cortex (voluntary, conscious) through pyramids to SC to give orders,Usually its orders are excitatory but it can directly go to motor neurons and send excitatory ,or go to inhibitory Interneuron and do inhibition.

2-Extrapyramidal tract: 4 in number: tectospinal,vestibulospinal,reticulospinal , rubrospinal.

Tectospinal: is from sup. and inf. coliculus > function is > reflexes due to vision or auditory stimuli.

Rubrospinal:is from red nucleus > function is >to distal muscle of upper limp > to help in fine movement.

Vestibulospinal tract: balance and posture info from vestibular system > to axial and proximal muscles of Lower limb

Reticulospinal : is from reticular formation in pons or medulla > to all muscles > responsible of muscle tone.

