Note: Please go back to the illustrating diagrams in the slides.

Today we are going to talk about the motor system

The motor system is a complicated system that has more than one component. To simplify it , we divide into tracts and regulators. The descending pathways control the muscle or any motor function.

The **motor system** is the part of the central nervous **system** that is involved with movement. It consists of the pyramidal and extrapyramidal **system**. [1]

Motor system is divided into two components:

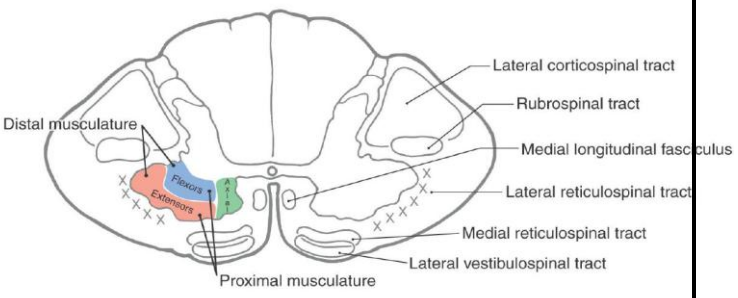
- Tracts: any upper nervous system part (UMN) that gives orders to the alpha or gamma neurons. They descend and give orders:

1) Corticospinal tract (pyramidal tract).
2) Extrapyramidal tract.

- Regulators which regulate the function of these tracts; they do not give orders:

1) Basal ganglia.
2) Cerebellum.

❖ Tracts will be divided into **voluntary** which is corticospinal **pyramidal tract**, and the **extrapyramidal** which is **involuntary** and mainly originates from the brain stem



Motor neurons are found in the anterior horn of the gray matter of the spinal cord, their sequence is:

- More medially we have the axial or the proximal muscle.
- More laterally the distal muscles.
- Extensors are located more anterior.
- Flexors more posterior.

A **motor unit** consists of one somatic efferent (**motor**) neuron and all of the muscle fibers (cells) that it innervates.[2]

As you know from the skeletal system that there is a motor unit which is the alpha motor and the muscles that it innervates it.

Smaller motor units then more fine movements and found in hand

[1] en.wikipedia.org/wiki/**Motor_system**
[2] courses.washington.edu/conj/**motor**/**motorunit**.htm

- Bigger motor unit found in the lower limb

Major receptors involved in spinal cord reflexes:

1) **Muscle spindle:** They sense change and rate of change in muscle length: Related to the stretch of the muscle or the movement of the muscle.

2) **Golgi tendon organ:** sense the force of muscle contraction (tension).

(spinal cord contains alpha α motor neurons mainly for the skeletal fibers, and gamma γ motor neurons mainly for the intrafusal fibers or muscle spindle fibers to maintain the same relationship between them and also sensory which send a sensory feed back to the muscle, As you took in the skeletal system and nervous system, the different activation for both and the result of either activation of gamma motor neuron or the alpha motor neuron or the sensory will do flexion or contraction).

Spinal cord Reflexes:

1) **Muscle stretch reflex**
   Based on the muscle spindle connection, mechanism of muscle stretch reflex; it is the only monosynaptic reflex in the body (slide 14):

a) Stretching will stimulate the **sensory receptor** which is the **muscle spindle**:
   If the muscle has been stretched suddenly without any order from up it will start the firing rate in the sensory fiber or the sensory arm from the muscle spindle.
b) Sensory neuron excited :
   It will fire both Through the PCML pathway to the brain, and while entering the brain the spinal cord it will give collaterals to activate the circuits or the gray matter.
c) Within integrating center (spinal cord) sensory neuron activate motor neuron:
   And the muscle stretch reflex is the only one which goes directly to stimulate the alpha motor neuron. (monosynaptic)
d) Motor neuron excited, and the muscle will contract and relieve the stretching:
   This will lead to muscle contraction, it is the only monosynaptic reflex and that because it has very important role in maintaining muscle tone.
   The result of muscle stretch reflex that we will have jerking in the joint whatever joint,
   Jerking will occur as a protective mechanism.
e) Motor neuron of antagonistic muscle will be inhibited, then the antagonistic muscle relaxes:

The other antagonistic muscle should be inhibited, collateral inhibiting to the other side muscles, where the same neuron will give another collateral to inhibit through an inhibitory interneuron, inhibit the other side muscles to have movement.

Knee jerk reflex can be done on almost all joints as a muscle stretch reflex.

- This reflex it is not just for being tested by the doctors, it is mainly for maintaining muscle tone and to help maintain proper daily functions, for example (slide 15-17):

  - When you are holding a cup, the orders from your brain is prepared just to hold the cup alone(empty),
  - if someone filled the cup for you then its weight become heavier than the weight of the cup our brain orders prepared to maintain it,
  - what will happen is that when the weight increase then the hand will directly descend down, and is objected to passive stretch,
  - and directly we will have a stretch reflex (without waiting the sensation to reach the brain and sending orders again) to maintain our hand holding the cup,
  - Then our brain will interfere to order to the biceps muscle to increase its tone in order to maintain the hold over the cup

  Also this stretch reflex is applied on many things such as walking, which is by the spinal cord reflexes mainly and the control from the cortex is just to control the speed or the type.

2) Tendon reflex or the autogenic reflex

Here we have Golgi tendon organ, its function is to maintain or to regulate the tension on the muscle, mechanism of tendon reflex (slide 19):

a) Increase tension stimulate sensory receptor (golgi organ):

So if there is either an internal or external stimulus that increases the tension on the muscle this sensory organ will fire. (such as weight lifting)

b) Sensory neuron excited.
c) Within integrating centers in spinal cord sensory neurons activate inhibitory neurons:
d) Through an inhibitory interneuron it will inhibit the alpha motor neuron to decrease the tension.
e) Muscle attached to same tendon relaxes and relieve muscle tension.

3) Flexor withdrawal reflex

Mechanism of this reflex (slide21):

a) Pain stimulus stimulate sensory receptor (dendrites of pain sensitive neuron)and sensory neuron will be excited:

If a pain or nociceptive stimuli affects the skin, that will initiate firing in ALS pathway and spinal nerve- in order to be on ALS system the same through it is getting up to the brain-.

b) Within integrating center (spinal cord) sensory neuron activate interneurons in several spinal cord segments:
It will give collateral to activate flexors and to inhibit extensors; all these will be done through interneurons.
c) Motor neuron excited.
d) Flexor muscle contract and withdrawal leg on the ipsilateral side.
e) On the contralateral side, the extensors will be activated while inhibiting the flexors. This is to prevent the person from toppling

Extra note: for a better understanding, review Dr. Faraj's explanation of the flexor reflex. This is what the Dr. said during the lecture :/

Question: The original excitatory nerve synapse with an inhibitory interneuron for inhibiting extensor muscles, and also synapse with an excitatory interneuron to excite flexor muscles (although it is an excitatory nerve). Why do we have interneurons to activate flexors and also an interneuron to inhibit extensors?
Because there are many spinal segments involved in this extended reflex not only one muscle involved, so we need to work on multi segments. The spinal cord have circuits that do flexion or do extension to the flexor and extensor muscles respectively all together, instead of stimulating each muscle alone, they are connected by spinal cord neurons located in the gray matter, one is connected to the whole extensors and other one connected to the whole flexors, so all this needs many segments, so it does not go directly but instead through an excitatory interneuron of flexors and inhibitory interneurons of extensors, also we have an additional one **on the other side to activate the other side to shift the weight** , through an interneurons **activating the extensors and inhibiting the flexors**, producing **Crossed Extension Reflex (slide23),** note that all this activation on both sides, and multisegments are initiated by a painful stimulus on the skin. The degree of response depends on the strength of the stimulus.

- This flexor withdrawal reflex found in the upper limb and lower limb, and sometimes in upper limb reflexes it control the trunk, because as we said it is a simply?? part of it because when you touch something painful stimulus, your upper limb and trunk participate in the reflex, because it is an internal circuits all work together, with control from the upper.
- The most important thing to remember is that this reflex involves multiple segments

4) Crossed Extension Reflex

Mentioned with the previous reflex.

Extrapyramydal Tracts:

Every tract that functions on the alpha motor neurons other than the pyramidal tract which is corticospinal tract, all the extrapyrmidal tract will go to the spinal cord activating the alpha and gamma motor neurons in the spinal cord other than the pyramid or the corticospinal (they do not pass through the pyramid of the medulla) which are

1) **Reticulospinal Tract (reticular formation)**
2) **Vestibulospinal tract (vestibular nucleus)**
3) **Rubrospinal tract (red nucleus)**
4) **Tectospinal tract**

- The name indicates the origin of the tract and all of them end at the spinal cord at the alpha motor neuron.

1) Reticulospinal Tract

- Originate from the reticular formation in the (brain stem) medulla and Pons.
- Descend down in the spinal cord to activate the alpha and gamma motor neurons.
- Mainly all the body muscles although its concentration on the proximal and axial muscle that are the weight bearing muscles.
- Its function is to regulate the muscle tone and maintain posture.
- Mainly descend on gamma motor neuron.
- It can be regulated by the cortex
- Mainly each nerve has more than one collateral in more than one segment especially the medial part of the tract.
  It consist of two parts: lateral and medial from medulla and Pons respectively,
- The lateral (medullary) is ipsilateral and the medial (pontine) is bilateral but mainly ipsilateral.

2) Vestibulospinal tract

- Originate from the vestibular nucleus although it is mostly sensory.
- it is known that the vestibulospinal tract function is balance, posture, and orientation in space, then this information go through the vestibular nuclei down to the spinal cord to the vestibulospinal tract.
- mainly activate the proximal and trunk and weight bearing muscles
- it consists of two parts: lateral and medial:
  - lateral is mainly ipsilateral in lateral vestibular nuclei
  - medial from medial and inferior vestibular nuclei
- go in both sides although it is innervate the same type of muscles as reticulospinal tract but it is innervate mainly the alpha motor neuron, and the second difference is that it is mainly one segment at a time doesn't have a lot of collaterals.

3) Rubrospinal tract

- Come from red nucleus in the mid brain
- Descend down to the spinal cord mainly to the upper extremities (in humans) and some to the lower extremities (only few or almost none in human).
- Its function mainly is innervating the flexors, unlike the reticulospinal tract which is mainly for the extensors, its function: for the fine skilled movement, it increases the muscle tone to increase control by the corticospinal in a fine way and remember that the corticospinal is excitatory and inhibitory.

4) Tectospinal tract

- come from the tectum (which is the dorsal part of the mid brain) and mainly come from the superior and inferior colliculi
- this tract is for visual and auditory reflexes, control the rotation of the neck and the upper part of the trunk
- it mainly innervates the upper part of the trunk and the head moving muscles
- It helps to move you towards or away from the auditory or visual stimulus.

** What is the difference between the **reticulospinal** and **vestibulospinal** in term of **function** since both go to the proximal and weight bearing muscles?

One of them main function is **balance** and the other one is **muscle tone**, a one will control the gamma keep the **balance in the weight bearing muscles**, and the other if there is **disturbances,** which is the vestibular.

Pyramidal tract: Corticospinal pathway

- it is a coticospinal pathway starting from the cortex
  - mainly from the primary motor cortex which is area 4
  - the supplementary motor area
  - the secondary motor cortex which is area 6
  - some from the somatosensory
  - few from the parietal although it is neglected
- It descends down in the pyramid to control the alpha and gamma motor neurons to do voluntary muscle contraction and movement
- Crossing occurs in the inferior part of the brain stem, and there is an upper motor neuron which is corticospinal.

Upper and lower motor neuron lesions:

- ✓ If a lesion occur in the UMNs then it will be:
  - a spastic paralysis
  - hyperreflexia and
  - positive babinski's sign, normally any adult if you stroke the sole of the feet, toes will curl down (flexion) this is normal, but if there is no regulation for the circuits of the LMN this stroking action will initiate fanning of the toes with the big toe curling up, this is called positive babinski's sign, it is also important in the development of the baby, because newborns do not have good myelination nor good control, and the circuits are incomplete, so the newborn would have an initially positive babinski's sign, which will disappear by 6,9,or 12 months, doctor can follow the development of the baby through this sign.

- ✓ While if it is LMNs lesion there will be:
  - no activation of the muscle at all not from up nor from somatosensory nor from any feedback or any reflexes so it is a **flaccid paralysis**
  - no reflexes or hyporeflexia
  - Finally if there is no activation it will develop atrophy.
  - Fasciculations and fibrillations

- ◆ Corticospinal fibers, there is **crossing** in the lower part of the brain stem or medulla, there is a fibers that stay in the same side **ipsilateral**, but **90% will undergo crossing**.

- ◆ Note about the crossing (Here, look at the diagram in the slides; The Dr. explained on the diagram. It will make the picture clearer)
  - ❖ We usually have the lower extremities fibers more lateral, and the upper extremities fibers are more medial
  - ❖ so when crossing occur the upper extremities fibers will undergo crossing first then at the lower part of the medulla the lower extremities fibers crossing will occur
  - ❖ so the site of the lesion that would occur at the crossing area will differ from site to another, only which is ipsilateral or contralateral, and also a lesion might occur at the upper part of the crossing, which can make upper extremities lesion, lower or alternating

the somatotopic organization is very important to know

If we didn't take them in anatomy the doctor will tell us whether it is rostral or caudal crossing of the motor.

Done by: Hala Makahleh.

Good luck