Anatomy

Sheet

Lec No: 5

Subject: Extrapyramidal pathways +stretch reflex

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Before we start..

- This sheet was written according to the recording that belongs to section 3.
- The order of ideas in this sheet is a little bit different from that in the recording.
- Enjoy :3

I. Revision

- In the previous lectures, we have talked about general anatomy and functional areas of the CNS, then we started with the motor part of it

  - When we talk about the motor part, we will study it in this sequence: The histology of the cerebral cortex (the order of action) → the motor areas in the spinal cord (conduction of the action)→ pyramidal pathways → extrapyramidal pathways → the response of the muscle and muscle reflex.
  - Make sure that you have studied it in this arrangement.

- Remember also that motor pathways are classified into *pyramidal* and *extrapyramidal*;

  - Pyramidal tracts are *corticospinal* and *corticobulbar*.
  - <u>These tracts are concerned with the movement of the limbs and facial muscles.</u>
  - *Corticospinal tract* originates from the *cerebral cortex* and terminates in the lower motor neurons of the spinal cord either directly by direct synapse on alpha and gamma neurons, or through an interneuron and mainly through interneurons.
  - In the lower part of the medulla 80-90% of these fibers decussate (cross to the other side) forming *lateral corticospinal tract*, which is <u>the most important motor pathway in our bodies</u>, this tract affects mainly the distal muscles but it has some fibers that supply proximal ones.
  - The remining 10% of these fibers will not cross to the other side, forming the *ventral corticobulbar tract*, that affects mainly the axial and the proximal muscles bilaterally (muscles of the vertebral column, shoulders and the hips).

Now think about it, how can we coordinate our movements?? How can we move muscles at different levels to generate complex movements?? Or even how can lower animals do such movements without having cerebral cortex or brain at all??

- This is done by the *propriospinal tracts*.
- ***Propriospinal tracts*** are collections of nerve fibers, ascending, descending, crossed and uncrossed, that interconnect various segments of the spinal cord in order to coordinate movement between these segments.
- So these neurons don't leave the spinal cord, that's why they are called tracts.
  #Note: propriospinal tracts have nothing to do with proprioceptors.
- We have three groups of intraspinal neurons whose axons influence homologous areas of the spinal cord gray matter at different levels by traveling through the *fasciculi proprii* bordering the gray matter:

1. ***The long propriospinal tracts***: they ascend and descend all through the spinal cord through the *anterior fasciculus proprius* and have bilateral influence. So they coordinate the movement of the axial muscles (extensors of the spinal cord)
2. ***The intermediate propriospinal tracts:*** extend for shorter distance in the ventral part of the *lateral fasciculus proprius*.
3. ***The short propriospinal tracts:*** limited to cervical and lumbosacral enlargements of the spinal cord through the *lateral fasciculus proprius.*

- Example of their action: if you want to write on the board, you have to coordinate many movements between different levels at the upper limb; Abduct your shoulder (C5), flex your elbow and wrist (C5, C6, C7), and move your hand muscles (C8, T1). So intermediate propriospinal tracts and short propriospinal tracts can coordinate these movements.

And remember that ***corticobulbar tract*** controls facial movement through suppling cranial nerves bilaterally, except for the lower facial nucleus that's supplied contralaterally.

II. Extrapyramidal tracts

We said that the pyramidal tracts supply the muscles of the limbs and face, while extrapyramidal tracts supply the axial and proximal muscles.

- An important role to start with, is the role of fibers distribution in the spinal cord. (see figure 1)

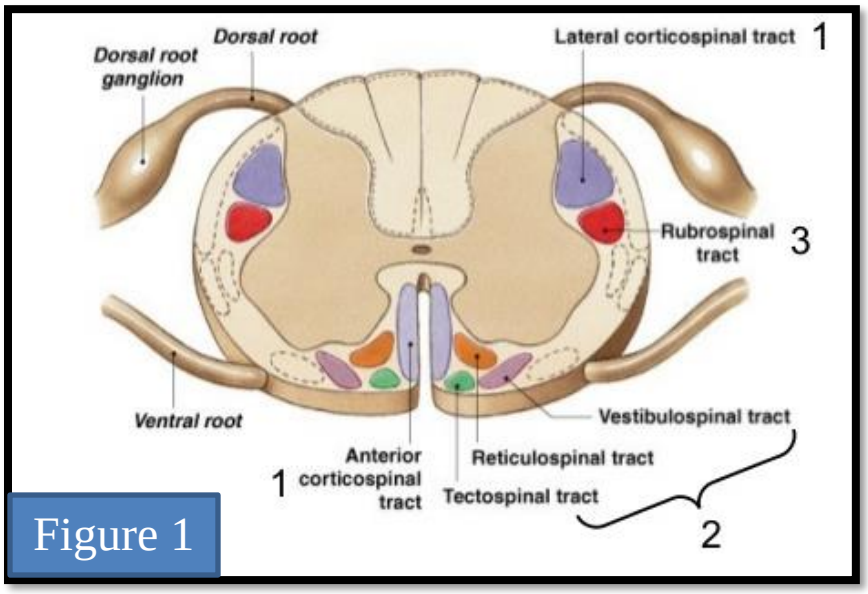


Figure 1

- Remember that each spinal segment is divided into gray matter (cell bodies) and white matter (axons).
- The gray matter contains many laminae, *lamina IX* is the main motor one and its located in the ventral horn.
- The medial side of lamina IX contains cell bodies lower motor neurons that move the axial muscles, while the lateral side is concerned with the distal muscles of the limbs.
- And remember that the white matter is classified into anterior (ventral/medial) column, lateral column and posterior (dorsal) column.
- Ventral and lateral columns contain axons of motor neurons.
- Now If a motor tract, descends on the lateral column, usually it's going to synapse with a cell body located in the lateral part of lamina IX, supplying distal muscles. While if it descends on the medial column, it's going to synapse with a cell body located in the medial part of lamina IX, supplying axial muscles.

So let's start with the first extrapyramidal tract, shall we?

1) Rubrospinal tract (rubro means red)

As the name implies, it originates in the red nucleus in the midbrain.

- It starts apparently from the red nucleus, but actually the input to the red nucleus comes from area 4 and 6 but mainly 6 of the cortex.
- The *rubrospinal tract* should be really called *cortico-rubro-spinal*

The axons of this red nucleus go down and cross (decussate) immediately (in the brain stem) and descend in the midbrain, pons, medulla and spinal cord. Then, they synapse with alpha and gamma.

- the rubrospinal tract is very close to the lateral corticospinal tract in the spinal cord. They form the lateral motor system. ***(see figure 2)***

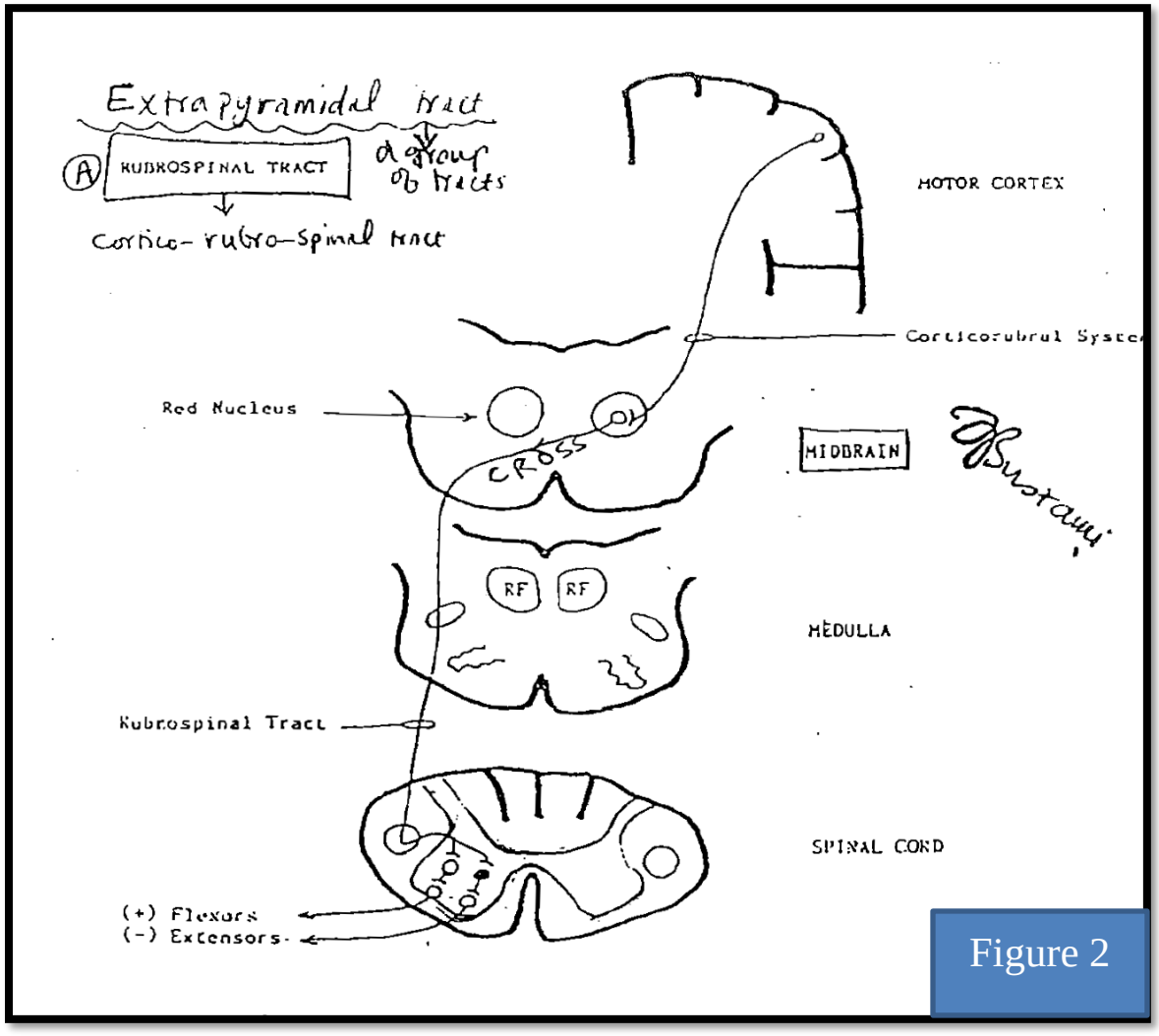


Figure 2

Like corticospinal tract, rubrospinal tract synapses with alpha and gamma through interneurons. We have excitatory and inhibitory interneurons.

- If the red nucleus is stimulated, the flexors will be excited through the excitatory interneurons and the extensors will be inhibited through the inhibitory interneurons.

And because they run in the lateral column of the white matter, they affect the motor neurons laterally (the lateral alpha and gamma) that supply the distal flexors muscles mainly with little effect on the proximal muscles.

2) Reticulospinal tract

It originates from the reticular formation in the pons and medulla.

- These two pathways apparently begin in the pons and Medulla, respectively, but in fact they receive inputs from the cortex so they are actually corticoreticulospinal.

Accordingly, we have two *reticulospinal* tracts: ***(see figure 3)***

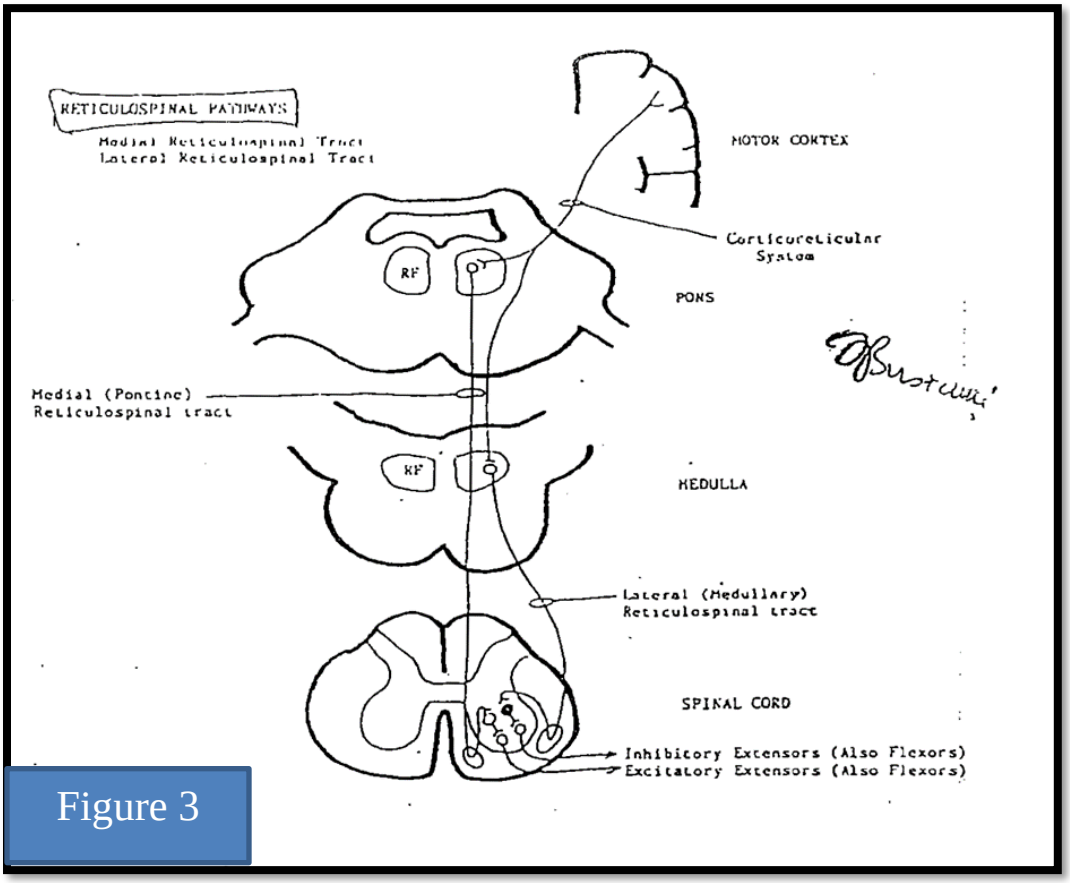


Figure 3

- *Pontine (medial) reticulospinal tract* →starts from the pons (pontine reticular formation i.e ~~*nucleus pontis caudalis and nucleus reticularis pontis oralis*~~)→ runs in the ventral (medial) column of the white matter.
- *Medullary (lateral) reticulospinal tract* → start from the medulla (*medullary reticular formation i.e* ~~*nucleus reticularis gigantocellularis*~~)→ runs in the lateral column of the white matter.
  #Note: The names of the nuclei are not required.
- Both *reticulospinal tracts* descend ipsilaterally from the upper motor neurons Crossing here is in the spinal cord.
  Note_1: they used to say that *reticulospinal tracts* supply ipsilateral side only, but nowadays they discovered that they me supply both sides; ipsilateral and contralateral.
  Note_2: notice that, the crossing in *reticulospinal tracts*, if present, occur at the level of the spinal cord. while crossing of *rabrosoinal tract* is in the brain stem.
- It will Terminate in the lower motor neurons to alpha and gamma motor neurons indirectly through interneurons within laminae VII &VIII.
- *Pontine reticulospinal tract* has an excitatory effect on extensors and flexors, but it affects extensors (of the shoulders and thighs for example) mainly.
- *Medullary reticulospinal trac*t has an inhibitory effect on extensors mainly (and flexors).
- So, there's a balance between both pathways, one pathway excites the extensors and the other inhibits them.

3) Vestibulospinal tract

When we say "Vestibule" in anatomy, the first thing that crosses our minds is the vestibular nerve which is a branch of *vestibulocochlear nerve* (cranial nerve number VIII), that's important for balance.

- Cranial nerve VIII (vestibulocochlear) has 4 nuclei in pons and medulla (2 in the pons and 2 in the medulla).
- And as you know, vestibular nerve is important for balance.
- So *Vestubulospinal tracts* try to maintain the balance (posture) of the body.
- We have two important Vestubulospinal tracts; Lateral and medial:

a) Lateral *Vestibulospinal tract: (figure 4)*

Remember that vestibulocochlear nerve has 4 nuclei in pons and medulla.

- One of these nuclei is called lateral vestibular nucleus (*Deiter's nucleus*) that gives axons that go down ipsilaterally, then synapse with alpha and gamma motor neurons <u>medially indirectly</u>.
- "<u>Medially</u>" means that it affects axial proximal muscles.
- "<u>indirectly</u>" means that they synapse with interneurons:
  - excitatory interneurons for extensors.
  - Inhibitory interneurons for flexors.

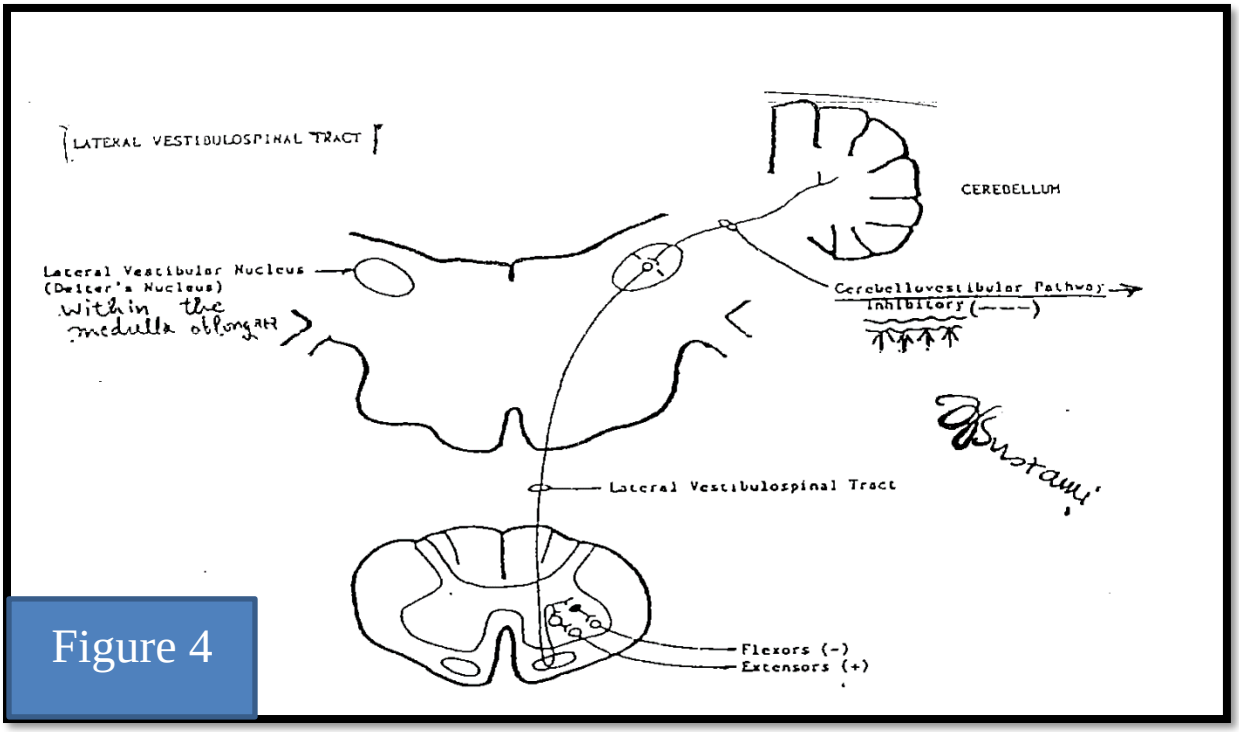


Figure 4

So Maximal excitation of the extensors is made by:

1. Pontine reticulospinal tract
2. Lateral vestibulospinal tract

Lateral vestibular nucleus or Deiter's nucleus is inhibited by projections from the cerebellum.

- So if we remove the cerebellum from an experimental animal, we will find an increase in the activity of this pathway which means an increase in excitation → continuous contraction of the extensors.

b) Medial Vestibulospinal tract

It starts from *Medial Vestibular nucleus* and found in the junction between pons and medulla.

- *Medial vestibulospinal tract* doesn't descend alone; it descends as a component of an important bundle of fibers. This bundle is called *Medial longitudinal fasciculus (MLF)* that contains descending and ascending fibers.
- MLF links the vestibular nuclei with the cerebellum and Nerves of ocular movement (III, IV, and VI).
- MLF present all through the brain stem (midbrain, pons and medulla) plus upper cervical region.
- It's important to coordinate head movement with the eye movement.
- Vestibular system (vestibular apparatus in middle ear) is stimulated when you move your head to the right or left. It coordinates the movement of the eyes with the movement of the head through MLF.
- *Medial vestibulospinal* tract has an important role in ***Vestibulocular reflex***: when you move your head to the right → your eyes will move to the left (thus preserving the image).
  #Note: when you move your eyes to the left, your left eye will be abducted → *lateral rectus* muscle contraction → abducent nerve (VI)
  The right eye will be adducted → Medial rectus muscle contraction → oculomotor (III). So I have to coordinate the movement of nerve 2 and 6, this is accomplished by MLF.

***Clinical correlate_1: Multiple sclerosis (MS)**

MS Is one of the demyelinating diseases that acts centrally.

- If we lose the myelin sheath, the nerve will be damaged and it won't be able to conduct the impulse.
- If a middle age patient is complaining from *nystagmus* and *double vision*, so his eyes don't move together (MLF is damaged)→ one of the earliest symptoms of MS.
- MLF links the vestibular nuclei (that is stimulated by head movement) with the cerebellum and nuclei of III, IV, and VI. → Movement of the eye opposes the movement of the head → focusing on certain point (vestibuloocular reflex)

4) Tectospinal tract

The Tectum is the posterior part of midbrain, It has 2 superior colliculi and 2 inferior colliculi. (see figure 5)

- Superior colliculi → vision
- inferior colliculi →hearing

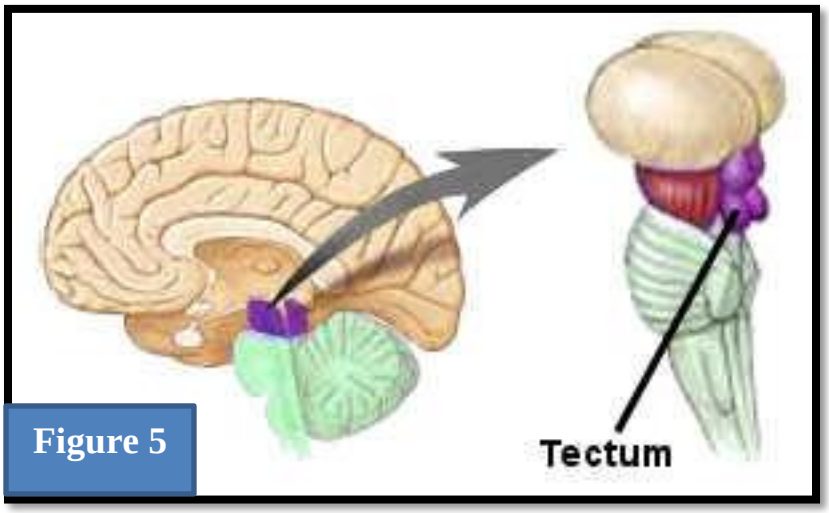


Figure 5

Tectospinal tract originates from the superior colliculus and descends to alpha and gamma in the neck that control neck movement towards light.

- So it presents in the cervical region only.

5) So what now ??

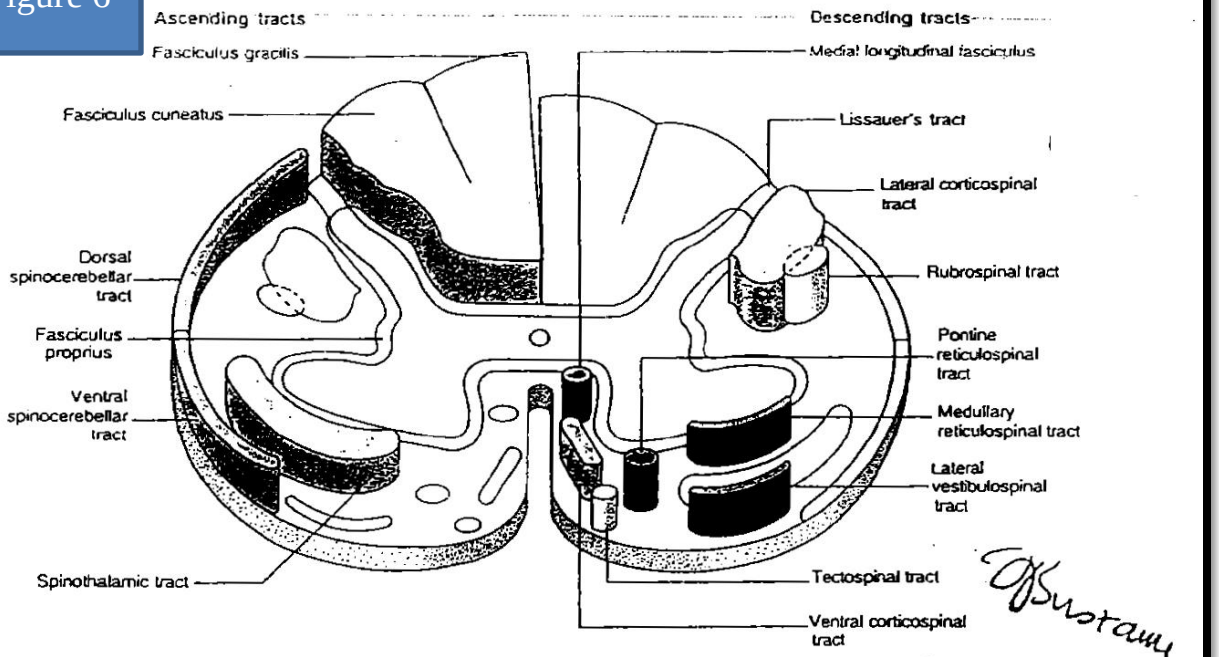
By that we have finished our talking about the major motor pathways..

- But this is only the beginning of our story, the motor pathway is much more complicated. So it's important to be able to differentiate between these pathways in terms of origin, termination and functions in order to be able to diagnose motor lesions.
- Moreover, there's another classification of the motor pathways according to their site of termination in the spinal cord.

The motor pathways are classified into: ***(see figure 6)***

1. Medial Motor system →medial alpha and gamma → axial & proximal muscles.
2. Lateral Motor system → lateral alpha and gamma →distal mainly.

Figure 6



Lateral Motor system includes:

1. lateral corticospinal tract
2. rubrospinal tract distal muscles mainly (and proximal).
3. part of corticobulbar that affects the lower face. (facial VII)
4. part of corticobulbar that affects the tongue. (hypoglossal XII)

- but why do we conceder Corticobulbar as a part of lateral Motor system?
  - Remember Hemiplegia and hemiface → A lesion in the internal capsule→ Hemiplegia → the lower face is affected → hemiface.
  - But ***Why***? The lower nucleus of the facial nerve supplies the lower muscles. They receive contralateral corticobulbar fibers only, If one side is affected, the muscles of the other side will be affected→ hemiface.

Medial motor system: affects alpha and gamma medially that affects the axial and proximal muscles responsible for posture and walking (Axial muscles and girdle), part of it affects certain muscles in the head (for the eyes, mastication, swallowing and phonation)

1. Ventral corticospinal tract.
2. Extrapyramidal pathway in general
3. Part of the corticobulbar tract.

III. The stretch reflex and skeletal muscle tone

Why is it important to study this??

- First of all because, simply, it's the typical sequence of information, we started from the highest point in the Motor pathway and the last episode will be in the lowest part in the motor system. ;P
- But the real reason is to be able to understand signs and symptoms of Motor lesions like internal capsule strokes.

1) Stretch reflex

Stretch reflex (aka *myotatic reflex, deep tendon reflex, and jerk*): When a skeletal muscle passively stretched, it contracts reflexly. This response of a skeletal muscle to stretch, is known as the stretch reflex.

- The outcome of this reflex is the tone شد العضلة, which is the partial contraction of the muscle.
- Importance of muscle tone: (1) maintaining posture, (2) walking and (3) the tone of the muscles in your lower limb directs the venous return toward your heart (muscle pump)

Any reflex must have these Components:

1- ***Receptor***: It is considered as the beginning of the reflex, The receptor for the stretch reflex of skeletal muscles is found inside them and is named as: *intrafusal muscle spindle*.
2- ***A sensory nerve*** coming out from the receptor and it's called: afferent and passes along the dorsal root of spinal nerve, which have a central process that enters and synapse directly with alpha Motor neurons.
3- ***A Motor nerve fiber,*** which is the alpha motor neuron in our situation.

This single synapse is called *monosynaptic reflex* and it's exclusively the only monosynaptic reflex in our body. its importance is being a very rapid pathway of transmission in comparison with a polysynaptic reflex.

- This Monosynaptic stretch reflex maintains the muscle tone in our body.
- But remember, if I stimulate the quadriceps for example, I have to inhibit the antagonists (the hamstring muscles), this is accomplished by inhibitory interneuron: stretching muscle fibers→ sensory nerve→ inhibitory interneuron→ inhibition of the antagonist muscle.
- So during any reflex, the relaxation of antagonist is polysynaptic reflex → the stimulated muscle (agonist) will respond faster than antagonist. ***(see figure 7)***

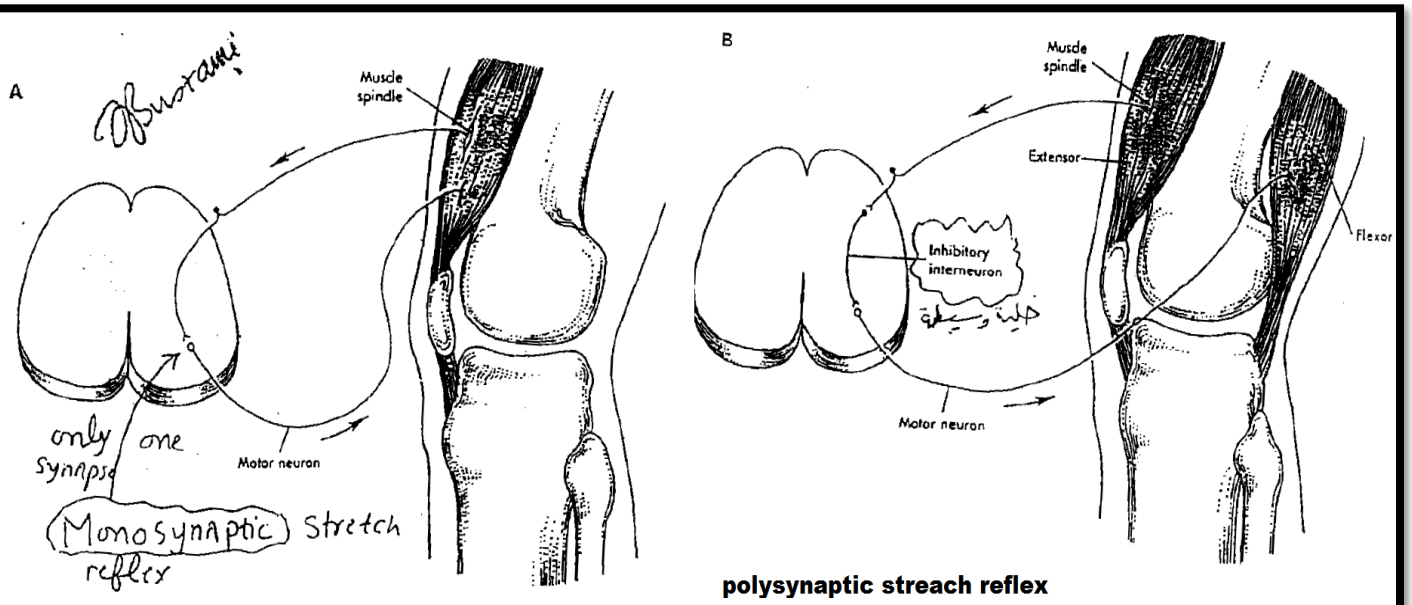


Figure 7

In order to activate the stretch reflex and thus maintain the tone we have 2 mechanisms:

1- ***Stretching the muscle***.
2- ***Through Gamma motor neurons***.

A) Stretching The muscle fibers

All our muscles are under the stretch خلقيًا , even if you are relaxed, because all our skeletal muscles are shorter than the distance between its origin and insertion.

- So all our muscles are under the stretch, you have continuous stimulation of the muscle spindle → continues contraction (muscle tone).
- This is called ***passive stretching*** of the muscle.

Another way to stretch a muscle fiber is through tapping on its tendon, shortening it→ increase stimulation of the muscle spindle→ increase its tone.

- But how does this occur?
    1. when you tap on a tendon, The muscle fibers will be stretched, and thus muscle spindle will be activated.
    2. Activation of the muscle spindle will create receptor potential that will be converted to action potential through sensory nerve fibers.
    3. These fibers will reach the dorsal root --> to the ventral→ activate alpha motor neurons → contraction of the muscle.

But how do we stimulate the muscle spindle ??

- In order to understand its function, we have to look at its structure first ***(figure8).***

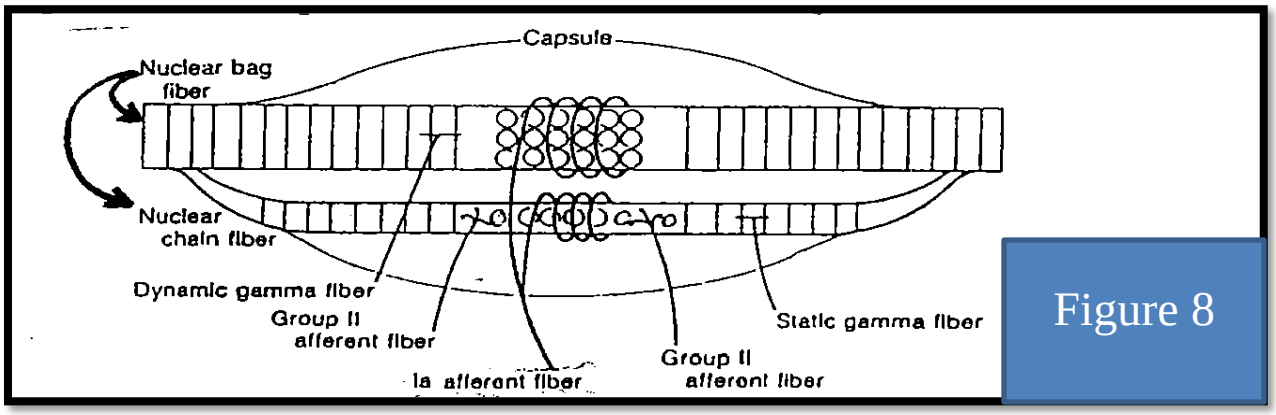


Figure 8

- ***Muscle spindle*** are modified skeletal muscles fibers that are surrounded by sensory nerves.
- Now, looking at the figure above, we classify intrafusal muscle fibers (you can notice the capsule surrounding it) into two types:

A. ***Nuclear Bag Fibers***: These have many nuclei, which are grouped together forming a dilated bag in the central part of the receptor area.
B. ***Nuclear chain fibers:*** These have a smaller number of nuclei, forming a chain throughout the receptor area. These fibers are thinner and shorter than the nuclear bag fibers, and their ends are connected to the sides of nuclear bag fibers.

- Both Nuclear bag and chain Don't contain sarcomeres, thus they are stretchable but not contactable.
- These non-contractile inrafusal fibers are located in the center of the muscle spindle and surrounded by some contractile fibers (in the periphery of muscle spindle). These contractile fibers are innervated by gamma motor neurons.
- So any change in the tension in nearby muscle fibers will affect the stretch of muscle spindle.
- Also notice in the figure the sensory nerve fibers:

A. ***Primary afferent***: type Ia, winds around both nuclear bag and chain fibers
B. ***Secondary afferent:*** type II, found only in nuclear chain fibers.

- These fibers will go and synapse directly with the alpha nuclei in the ventral horn .

B) Gamma motor neurons

Another completely different way to stimulate muscle spindle is through Gamma motor neurons, the mechanism and significance of this pathway will be discussed Next. ***(see figure 9)***

How can gamma Motor neurons stimulate the muscle spindle?

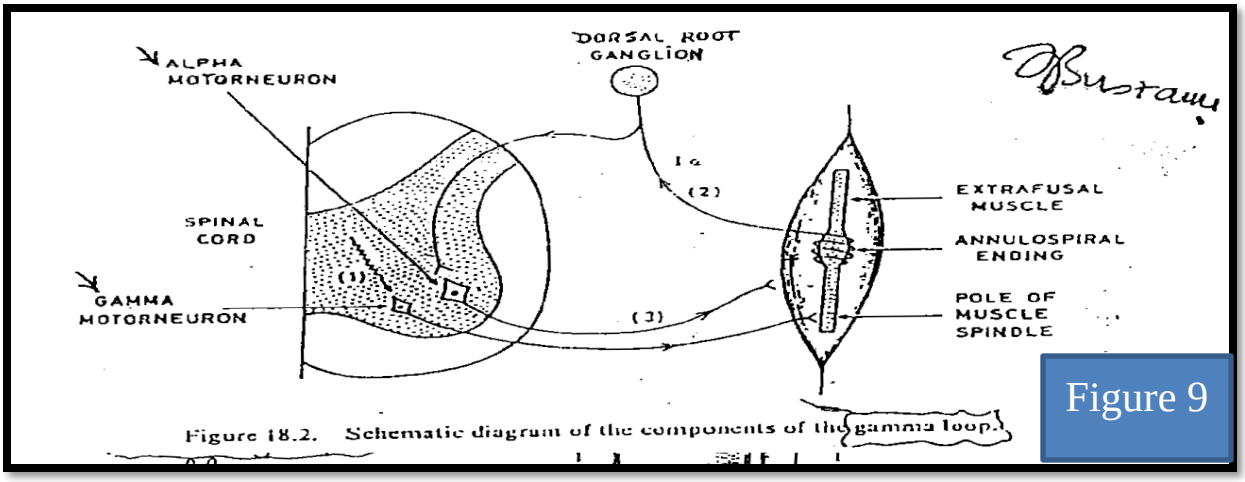


Figure 9

1. those axons, like the alpha motor neuron, starts at the ventral root of the spinal nerve. It innervates the outer contractile part of the muscle spindle causing its contraction and shortening, this leads to stretching the central part activating the spindle. (Notice that when the outer part contracts, the inner part stretches because the inner part is not contractile!)
2. Formation of a receptor potential (recall that muscle spindles are receptors), then action potential that runs with afferent fibers (primary Ia and secondary II) to alpha motor neuron through the dorsal root.
3. Activation of alpha motor neurons causes stretch reflex, which is partial contraction of extrafusal muscle fibers.

Note: Higher centers (cortex, brain stem, descending motor pathways) control gamma as well as alpha directly or indirectly (through interneurons), so all motor pathways (whether pyramidal or extrapyramidal) should reach alpha motor neurons either directly or through interneurons.

Now the strong question is : what's the importance of having gamma loop??

- When a muscle contracts, contracting muscle fibers will push muscle spindles to inside, relieving the stretch from it→ inhibition of the receptor→loss of the stretch reflex→ loss of tone→ termination of the contraction, so every time you want to move a muscle (for walking for example) you will lose its tone, and you will fall down. (there's no contraction without tone).
- So contraction is nothing without the tone.

لفهم أهمية شد العضلة (muscle tone) تخيل برجًا مبنيًا من المكعبات، إن أساس هذا البرج هو المكعب الذي في الأسفل، فإن قمت بسحب أو إزالة هذا المكعب، سيسقط البرج كاملًا ولا فائدة من وضع مكعبات أخرى في الأعلى. هذا ينطبق على الألياف العضلية كذلك، فإن قمت بإلغاء شد العضلة، فلا فائدة تذكر من انقباضها.

- This scenario does not occur in normal persons, because of the presence of gamma loop. So whenever a muscle is activated, two nerve fibers will activate it. The first one (alpha) will activate normal muscles fibers (to have contraction) and the second one (Gamma) will activate contractile part of the muscle spindle to maintain the tone.
- So in order to have continues contraction, I have to stimulate alpha and gamma neurons (alpha-gamma coactivation).

In order to produce a continuous contraction, we must stimulate both alpha and gamma, because if we stimulate only alpha it causes fast contraction and as mentioned before, contraction inhibits the spindle, so gamma takes action to keep the spindle active and alpha would receive afferent fibers resulting in continuous contraction.

- Stimulation of gamma is easier and simpler than alpha by higher centers, Since gamma motor neurons are smaller than alpha motor neurons, they have lower threshold for excitability than the alpha motor neurons thus they are easily excited and have higher tonic discharge rates.
- But remember that, even though Gamma fibers are exited easily, they activate the muscle fibers indirectly, while alpha fibers do it directly. As a result, Alpha fibers give faster but short lived contraction, while Gamma fibers give slow but long lived contraction.

So to sum up:

- For fast contraction: stimulate alpha.
- For muscle tone: stimulate gamma.
- For continuous contraction and a certain movement: stimulate both.

Does the stretch reflex maintain normal length of muscle? How?

- Yes, whenever a muscle is stretched the stretch reflex is activated causing contraction of muscle and leading to the return of the muscle to its original length.

Remember when we said that the afferent nerve fibers are either primary or secondary endings, what's the difference between them?? ***(see figure 10)***

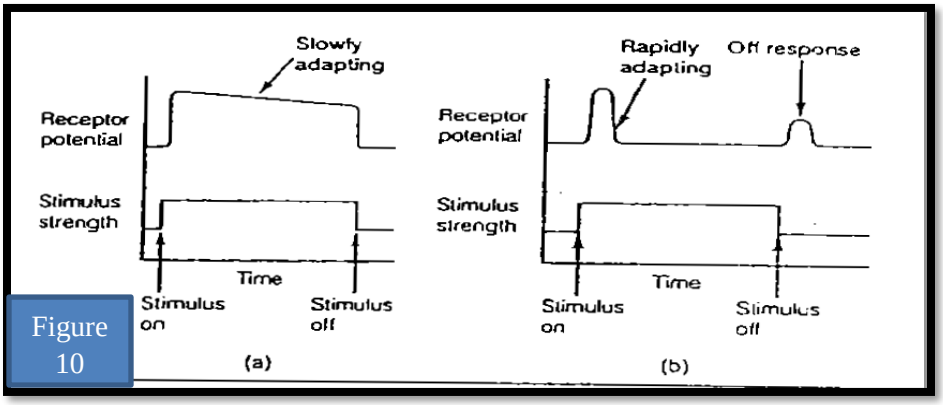


Figure 10

- We have rapidly adapting receptors (at first it will be stimulated strongly then it

will stop firing) and slowly adapting (as long as you have stimulation it will respond).

- Now look at the figure and notice the different responses from the afferent fibers:
  - Figure A- ***Static response of Secondary endings***: slowly adapting receptors, as long as there is a stimulus they continue to discharge, stimulated by gamma-s.
  - Figure B- ***Dynamic Response of Primary Ending:*** rapidly adapting receptors, gives a fast response and then quickly goes back to baseline, stimulated by gamma-d.

Accordingly stretch reflex can be divided into:

A- ***Dynamic stretch reflex***:

- Whenever we stimulate the tendon of a certain muscle, we can notice fast contraction of that muscle followed by rapid relaxation, because by this way we stimulated the primary endings (Ia).
- **Example: Tendon Jerk**.

B- Static stretch reflex:

- This occurs upon stimulation of slowly adapting secondary never endings.
- **This is the basis of muscle tone**.

Notes:

- Keep in mind that the primary endings are found in both nuclear bag and nuclear chain, whereas secondary is found only in nuclear chain.
- Gamma-s supplies nuclear chain (hence secondary endings) whereas gamma-d supplies nuclear bag (hence primary endings).

2) The muscle tone

The muscle tone: is a sub-tetanic continues contraction, that originates from the stretch reflex due to the fact that our muscles are shorter than the distance between its origin and insertion.

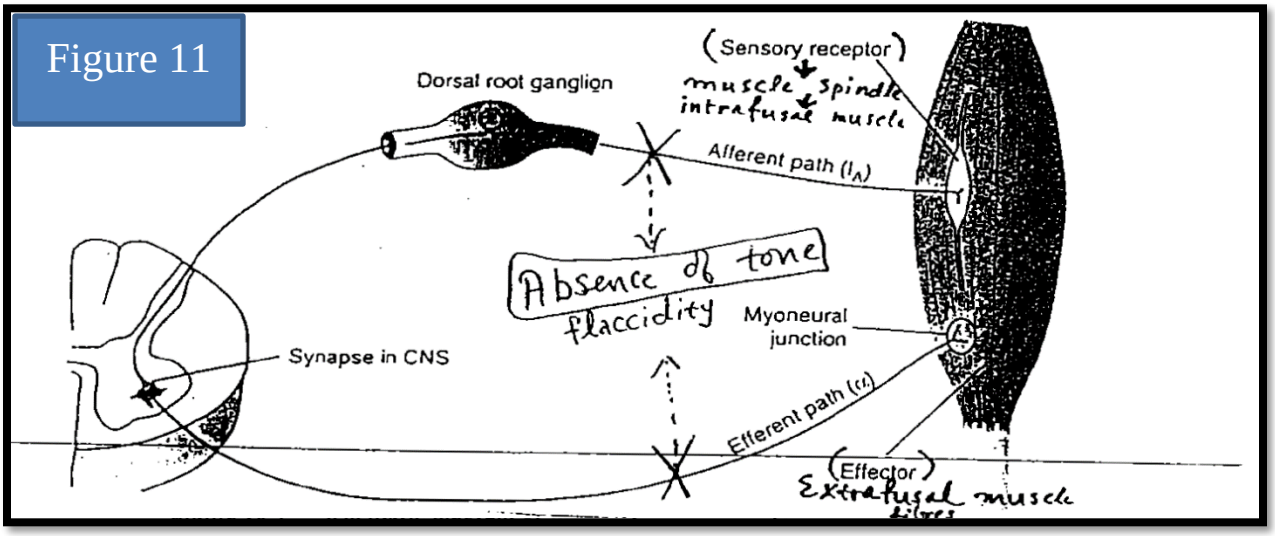
- We said that the muscle tone is sub-tetanic, *the strong question is*: can we generate continues tetanic contraction in our muscles????

3: هذا ما سنراه في الصفحة القادمة

- The answer is Yes, In fact, most of our movements are tetanic contractions. So when you try carry heave object, you will create tantanization in your muscles in order not to drop it.

And remember that the muscle tone is due to the stretch reflex, and it's neurogenic ***(see figure 11)***

Figure 11



- The stretch reflex is a closed circuit, if you interrupt any of these components, you will lose muscle tone as well as the reflex.
- So for example, if a patient has a myositis, his muscle spindles will be destroyed → no tone
- If the afferent or efferent nerve fibers are destroyed →no tone
- And if the cell bodies are destroyed as in *polio* (see clinical correlate 2)→ no tone.

*****Clinical correlate_2: Poliomyelitis***

Poliomyelitis virus (شلل الأطفال) attacks and destroys alpha cells in the ventral horn of the spinal cord alpha cells

- Destruction of alpha cells will break the circuit→ no muscle tone → flaccid paralysis → atrophy after a while.
- A patient that has polio, will not have any tone or power in his affected muscles, so you have to exaimne both.

- **<u>We examine the tone Passively</u>** → you move patient's affected muscle in all directions and look for any resistance, as normal muscles have a certain resistance for change in its location due to the stretch reflex, while muscles that have lost their tone don't.

- On the otherhand, **<u>we examine the power actively</u>** → so you ask him to grip your hand for example, and estimate his power in a certain scale.

And that concludes this lecture.

- *"Ability may get you to the top, but it takes character to keep you there."*
- *Best wishes*
- *Mohammad Qussay Al-Sabbagh*

ThE eNd