4. Spinal cord reflexes.

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Classification of human reflexes

Human reflexes can be classified into two groups:

I-Peripheral reflexes: which have **no centers inside C.N.S**. but **outside** it, most of these reflexes are found in the G.I.T :

a- Local enteric reflex which causes gastrin hormone release from the stomach or the duodenum.

b- Ganglionic reflex ; gastro-colic reflex, here center lies in the collateral autonomic ganglia.

c- Local axon reflex: (anti-dromic response) which occur in the tripple response and the primary hyperalgesia.

II- **Central reflexes:** these reflexes have a **center inside C.N.S**. These are further sub-divided into two groups:

A- Inborn or **unconditioned** reflexes: which need no education and all of us have them since birth e.g. micturition reflex.

These reflexes are classified according to the **site** of their **centers** into:

1-Spinal reflexes: their centers lie in the spinal cord.

2- Brain stem reflexes; centers lie in the brain stem. As vomiting, deglutition, cough reflexes, which have their centers in the medulla.

3-Hypothalamic reflexes: centers lie in the hypothalamus. An example of it is adrenaline secretion due to drop in B.P or reflex skin vessels vasoconstriction secondly to exposure to cold.

B- Conditioned reflexes: they are so called because they **need previous education** or training, intact cerebral cortex and **Stimulus must be present**.
As when we think in delicious food while we are hungry, a reflex salivation occur to us.

Spinal reflexes

These are unconditioned reflexes which have their centers in the **spinal cord**. Spinal reflexes are further subdivided into **3 main** groups according to site of their receptors into:

1-<u>Cutaneous spinal reflexes</u> in which receptors lie in **the skin** they are also called "**superficial reflexes**"

2- <u>Deep reflexes</u> in which their receptors lie in the **deep structures** as muscles, ligaments Joints and inner ear.

3- <u>Visceral reflexes</u> in which their receptors lie in the **viscera** e.g micturition, defecation, and erection reflexes.

-The most important **superficial reflexes** are:

1- **Planter reflex:** Scratch in lateral aspect of the foot by blunt object causes reflex planter flexion of the big toe and other toes, this is "normal planter response". This normal response means intact pyramidal and extra-pyramidal systems. The abnormal response in planter reflex is called "Babiniski's sign" as the scratch causes dorsi-flexion of the big toe (indicates pyramidal lesion) or fanning in other toe (indicates extra pyramidal lesion). Babiniski sign may **occur normally** in a newly born due to lack of meylination of the tracts, deep sleep, Coma and in anesthesia.

2-Withdrawal reflex; injurious stimulus to the skin leads to reflex muscle contraction to withdraw body from this harmful stimulus.
It is lost in Tabes dorsalis and stage of the spinal shock in complete transaction of the spinal cord.

3-Positive supporting reflex: Pressure on the **sole** of the foot even by body weight leads to reflex contraction **of both the flexors and the extensors** muscles of the lower limb to **support standing position** and to **keep equilibrium** it is the exception of "reciprocal innervation".

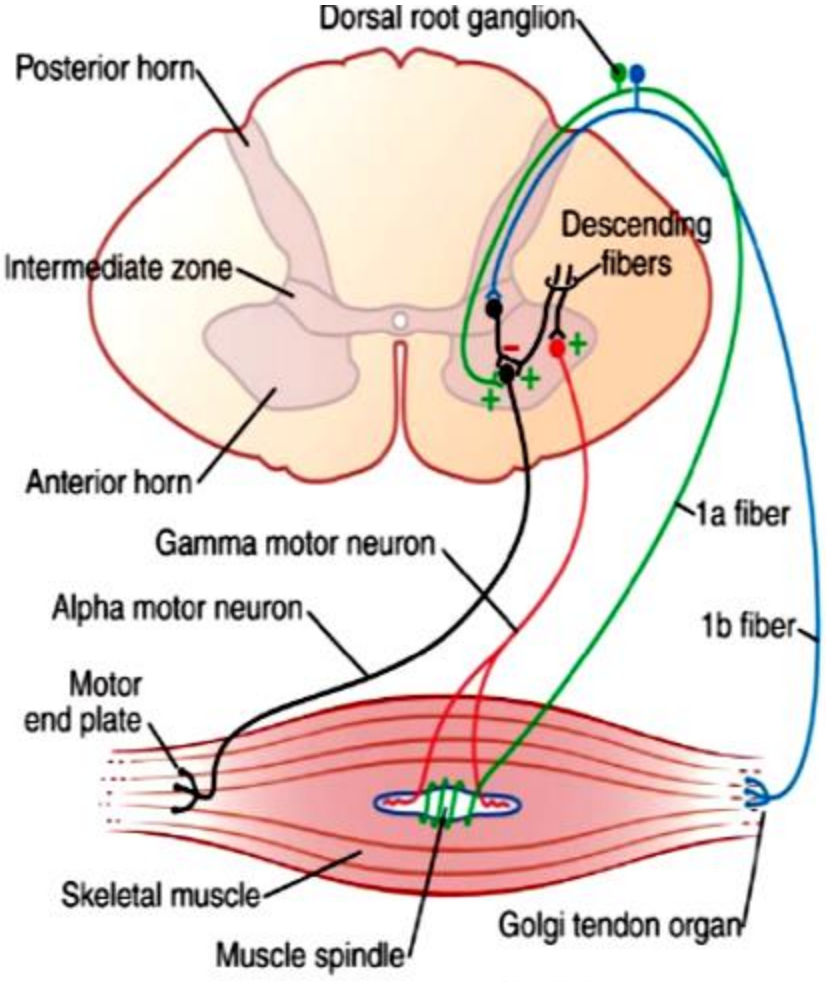
4- Crossed extensor reflex; injurious stimulus to one limb leads to reflex withdrawal of that limb and reflex extension of the **opposite** limb to support body equilibrium.
5- Cremasteric reflex: Scratch in medial side of the thigh in males leads to reflex contraction of cremasteric muscle as indicated by **elevation** of the testicles.
6- Abdominal reflex: touching the **skin** over the abdomen leads to reflex contraction of the abdominal **muscles**. The importance of this reflex is that it masks examination of abdominal organs as liver and spleen during clinical examination by the contracted abdominal muscles.

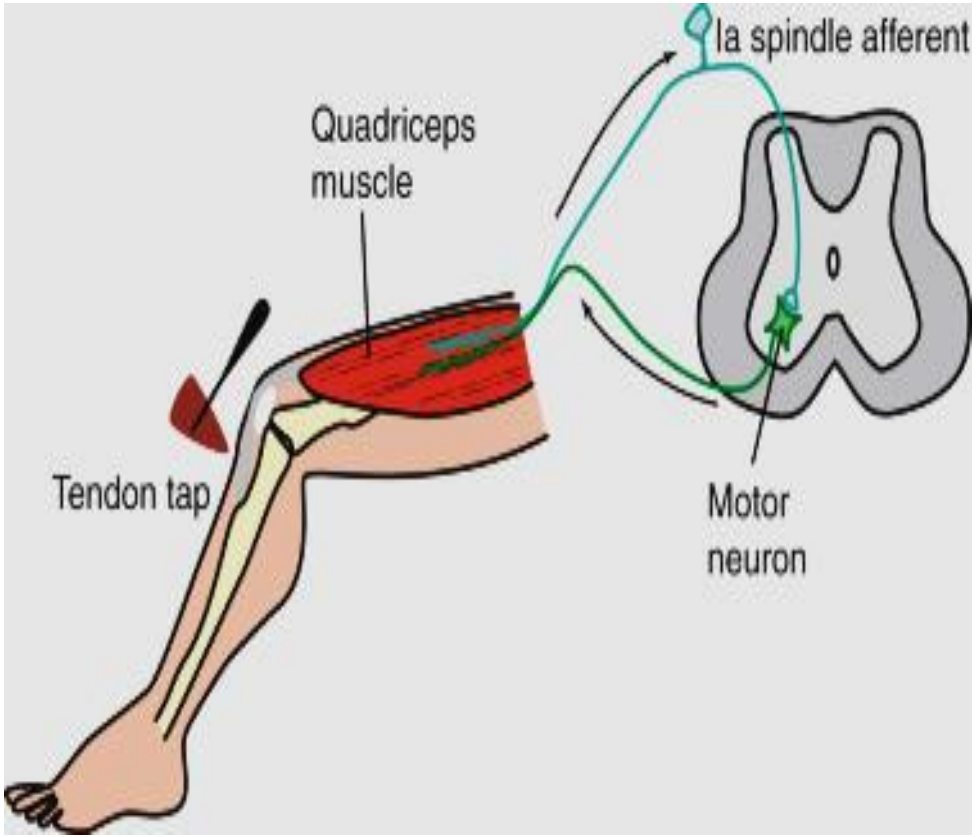
-The most important deep reflexs are:
1-Stretch reflex (myotatic reflex)
2- Stepping reflexes (direct - crossed - diagonal).
3- The "**lengthening reaction**" which is evoked by the **Golgi organ tendon**.
4- In pathological conditions the "ankle clonus" and Philipson's reflex (passive flexion of one limb leads to extention of other limb) are considered as deep reflexes.

Stretch reflex and skeletal muscle tone

The stretch reflex means stretch of a muscle leads to reflex contraction. In the skeletal muscle it is deep **spinal mono-synaptic** reflex mediated by a center in the spinal cord.

This state of maintained stretch initiate in our muscles a state of sub-tetanic maintained rhythmic contraction called the "skeletal muscle tone" which enable us to keep our erect posture.
On the other hand, **sudden tap** on a tendon of any muscle leads to its **sudden stretch** which stimulate a deep receptor in its fleshy fibers called "the **muscle spindle**" with subsequent sudden visible reflex **contraction** "tendon jerk".
-Thus the **stretch reflex has two phases** :-
1 - The **static** phase, the muscle tone .
2 - The **dynamic** phase, the tendon jerk.





Stretch reflex

-The receptor of both static and dynamic phases is deep receptor situated in the fleshy part of the muscle called "the **muscle spindle**“

-Structure of the muscle spindle:-

It has an **outer** skeleton of ordinary contractile fibers called "the extrafusal muscle fibers". It is about **4 mm** in length and **0.2 mm** in width. It is spindle in shape and contains **3-10 intrafusal** muscle fibers which are smaller than the surrounding extrafusal muscle fibers and their striations are not clear.
The **ends of the intrafusal** muscle fibers are **contractile**, tapering and are connected to the sarcolemma of the extrafusal muscle fibers. The spindle is surrounded by connective tissue capsule.

-There are **two types of intrafusal** muscle fibers in the muscle spindle

1-Nuclear bag fibers : 2-3/ spindle, the central part of the fibers is dilated as a **bag** and contains many nuclei in its center, while the two terminal regions of the fiber are striated and **contractile**. However, the **central** part is **non- contractile**.

2-Nuclear chain fibers : 4-5/ spindle also they are shorter and more thinner than the nuclear bag, they are so called "chain" because the central part of which contain a **raw of nuclei**.

This central part of the intrafusal muscle fibers does not contain actin or myosin filaments, thus it is also **non- contractile**. On the other hand, the peripheral parts of it contains actin and myosin filaments, thus they are contractile.

The central part of the intrafusal muscle fibers is called sensory receptor area. The muscle spindle is a **mechano-receptors** which is very slowly adapting receptors.

Innervation of the muscle spindle

There are **two** types of afferent fibers and also **two** types of efferents fibers .

A) Afferent innervation :- There are **two** types:

1- Type-I afferent fibers, primary endings (annulo-spiral) :

These are thick **myelinated** fibres 16 µ in diameter and the rate of conduction up to 100 meter/second. These fibers end by making spirals or rings around the central part of both nuclear bag and nuclear chain fibers.

2- Type II afferent fibers or secondary (flower spray) endings :

These are **myelinated** nerve fibers having diameter 8 µ and rate of conduction 40 meter/second. This type of afferent fiber end by making flower spray endings only on the **nuclear chain fibers**.

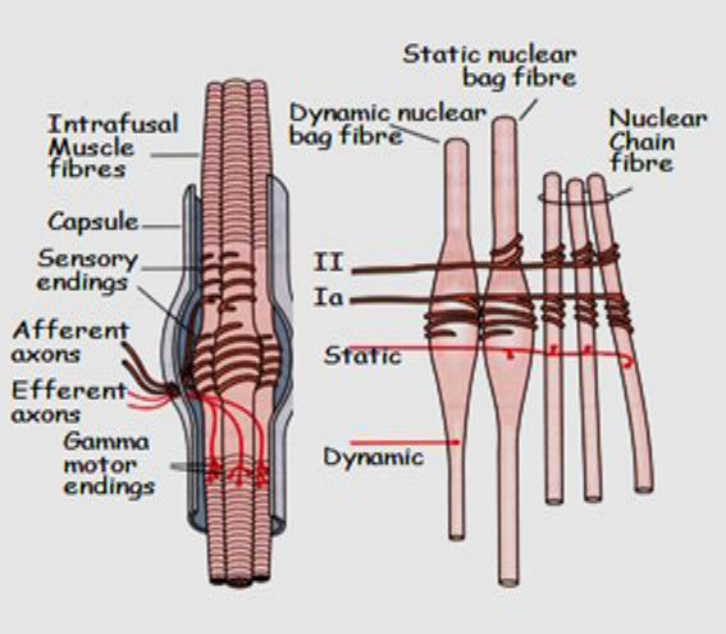
Both type I and type II sensory fibers enter the spinal cord through the dorsal roots to synapse directly with the alpha cells in the anterior horn (**no interneurons**).

B) Efferent innervation*:* leaves the spinal cord with ventral roots. They are also two types:

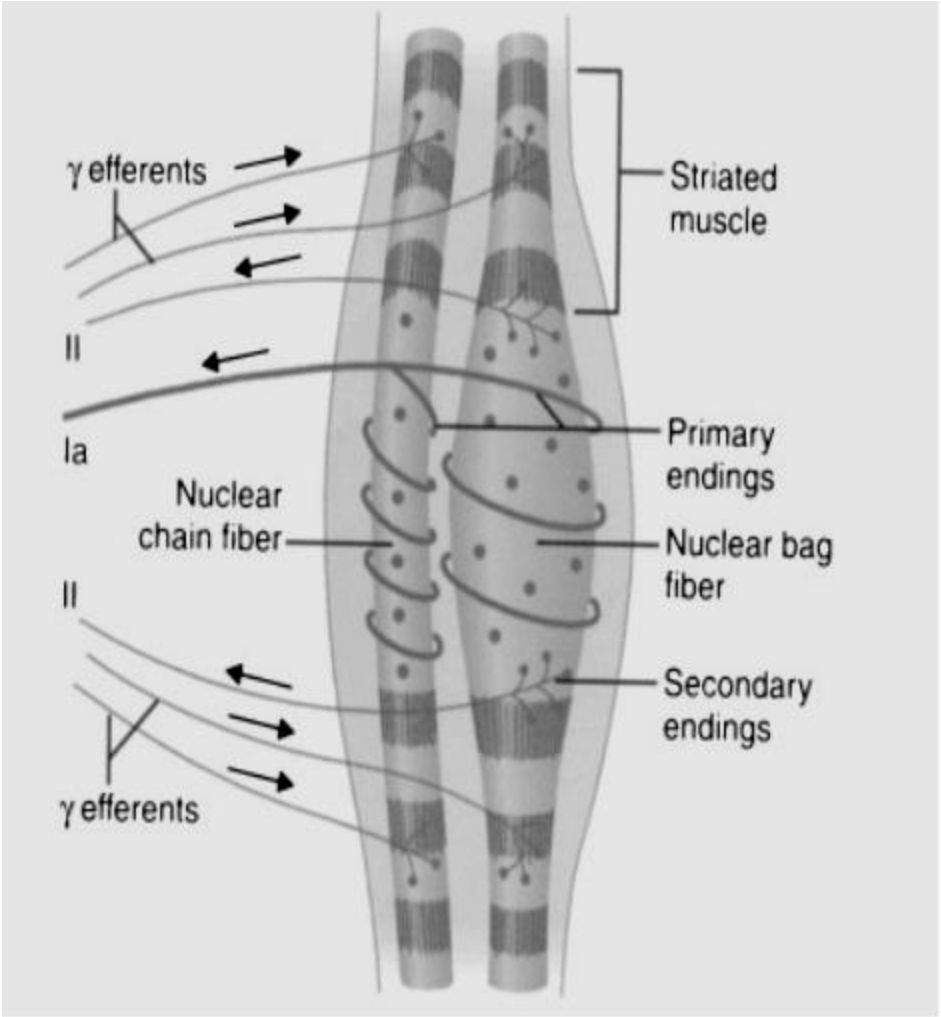
(1) Alpha fibers which innervate **extrafusal** muscle fibers they are the axons of the **large alpha cells** in the **anterior horn** having a diameter **14 µ** and a velocity of conduction 60 m/sec .

(2) The gamma efferent neurons in the **anterior horn** of the spinal cord send their γ- efferent motor fibers which have a diameter of **4 µ** and velocity of conduction 4 m/sec to supply the peripheral contractile parts of the intrafusal muscle fibers.

-Stimulation of the **γ- efferent** motor fibers will lead to contraction of the **peripheral** contractile parts of the intrafusal muscle fibers and stretching of their **central** non contractile part, resulting in stimulation of the **primary** or annulo-spiral endings or **secondary** endings or flower spray or static receptors.



Muscle Spindle



Mode of stimulation of the muscle spindle

1-Application of a sudden stretch **on the extrafusal muscle** fibers like during tapping on muscle's tendons (tendon jerk), stimulate the nuclear bags in the spindle and evokes the **dynamic** response.

2-Contraction of the periphery of the intrafusal fibers due to efferent discharge from gamma γ fibers that innervate both the nuclear bag (γ-d) and the nuclear chain (γ-S) evoke the **static** response of the stretch reflex.

3-Contraction of antagonist of any muscle leads to it's stretch and stimulation of muscle pindle in it e.g. contraction of biceps leads to stretch of triceps and stimulation of muscle spindle in it.

4-Pulling effect of gravity, exerts a sort of stretch specially in the antigravity muscles stimulating the static phase of the stretch reflex.

- **Maximal stimulation** of the muscle spindle occurs when the muscle is **passively stretched** (like during tapping its tendon).
- However, M**inimal stimulation** of the spindle occurs during **voluntary contraction**, as the activity of alpha cells leads to shortening of the extrafusal fibers which release tension on the muscle spindle.

-The most important differences between the **two phases** of the stretch reflex are :-

Static phase	Dynamic phase
1-**Receptors** are nuclear chain.	1-**Receptors** are nuclear bag.
2-Discharge in **both** primary and secondary afferent.	2-Discharge **only** in the primary afferent.
3-Its **receptors** are stimulated with maintained stretch.	3-Its receptors are stimulated with sudden stretch.
4-Activity in muscle fibers are alternating.	4-The whole muscle fibers are stimulated at the same time.
5- **Physiologically** it is represented by the **muscle tone**.	5-**Physiologically** it is represented by the **tendon jerk**.
6- The proper **stimulus** is the **continuous** stretch by effect of gravity.	6- The proper **stimulus** is the **sudden** tap on the tendon of the muscle.

- Types of the stretch reflex;-

1- Static stretch reflex (**monosynaptic)**.

2- Dynamic stretch reflex (**monosynaptic)**.

3- Negative stretch reflex (**monosynaptic)**: shortening of the muscle by its contraction, leads to reflex relaxation.

4-Cerebellar stretch reflex "load reflex", (**polysynaptic**):. When your forearm is flexed, your biceps muscle is contracted, if we suddenly apply an extra-weight on your hand, your forearm will not fall down but remains flexed by the assist of this reflex. Here the proprioceptive impulses reach cerebellum, which responds by sending strong facilitatory impulses from the new-cerebellum to the gamma motor neurons leading to increase in muscle tone, and strengthen your forearm contraction.

5-Inverse stretch reflex (**polysynaptic)**: marked over stretch of the muscle leads to reflex relaxation (inhibition), the receptors are Golgi tendon organ.

On **over stretch** it sends **inhibitory** impulses to the muscle protecting it from rupture either by **inhibitory interneurons** or by inhibitory **cerebellar impulses** over AHC.

-Function of stretch reflex:

1-Keeping equilibrium and adjusting body posture.

2-Help venous return through muscle tone and help lymphatic drainage.

3-Muscle tone causes heat production and regulates body temperature.

4-Tone of the abdominal muscle keeps viscera in position. Also tone of mastication muscle prevents drop of the mandible .

5-**Damping** function (**Signal averaging function**): it prevent skeletal muscle oscillations. This is because motor area "4" sends **unequal** discharge to anterior horn cells, with **weak** impulses the muscle tone becomes **stronger** and with **strong** impulses the muscle tone becomes **weak**, thus all the contractions becomes more or less finally homogenous which prevent oscillations.

6-Servo - assist function **(α-γ Co- activation):** this means that the stretch of the intrafusal muscle fibers can assist or increase force of contraction of the extrafusal fiber without increasing discharge from higher motor areas and thus increasing force of contraction of the whole muscle producing stronger contraction with minimal energy consumption.

This servo-assist function is especially active when the muscle lifts a heavy weight against gravity. This weight all the time exerts stretching effect on the tendon of the muscle stimulating intrafusal fibers.

-The most-important <u>characters</u> of the stretch reflex are:-

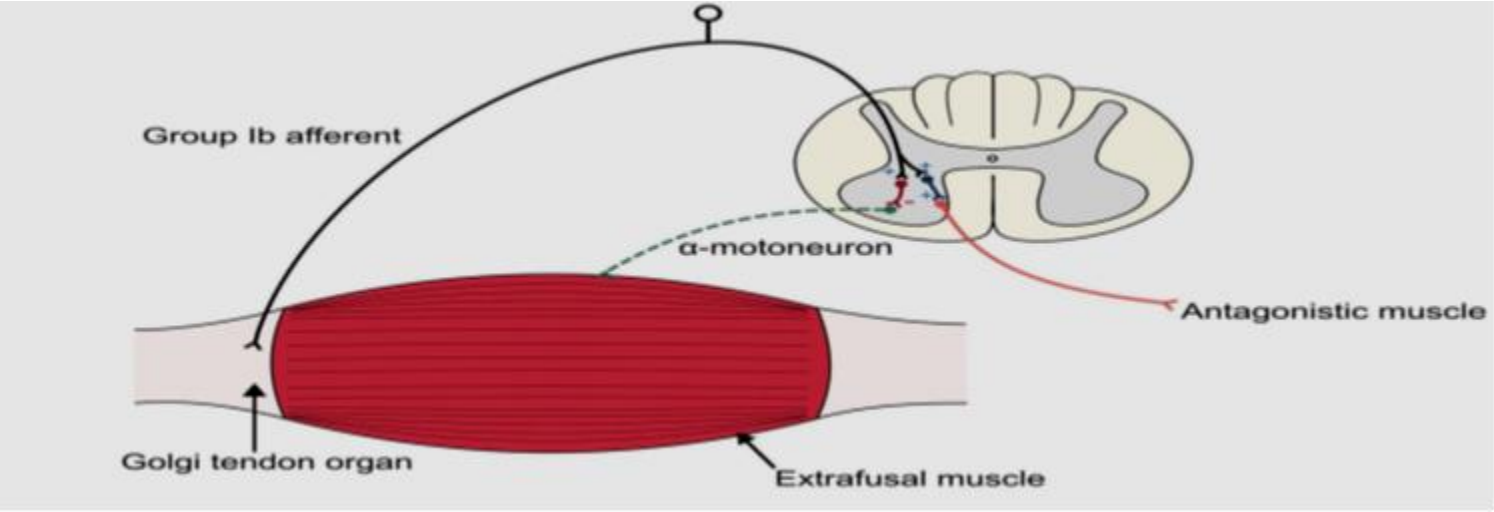
1-The muscle tone is deep, spinal, **mono**synaptic reflex.

2-The muscle tone is the **static** phase of the stretch reflex.

3-Skeletal muscle tone consumes very **little energy** and **never fatigued** and is very slowly adapting.

4-When the tone is increased in a certain muscle, it is inhibited in its antagonistic one.

5-Because there is no interneuron in the reflex arc of the stretch reflex, there is no after discharge or reverberating circuits and the reflex is extremely localized.



-Differences between Golgi tendon organ and the muscle spindle:-

Muscle spindle	Golgi tendon organ
1- Receptor is found in **fleshy** muscle fibers.	1 - Receptor is found in **tendons** of muscles.
2-Formed of intrafusal & extrafusal m. fibers.	2- Encapsulated network of knobby nerve endings.
3-Stimulated by muscle **stretch.**	3-Stimulated by **over stretch**.
4-When stimulated it leads to muscle **contraction**.	4-When stimulated it leads to **muscle inhibition**.
5-**Monosynaptic** connection in the spinal cord only.	5-**Polysynaptic** connection in the spinal cord and may reach cerebellum.
6-Connected by **two types of afferent** fibers to the spinal cord (primary & secondary endings).	6- Only **one afferent** rapidly conducting fibers 16 µ in diameter.
7-Its stimulation elicits "**stretch reflex**"	7-Its stimulation elicits the "**inverse stretch reflex**".
8-Has **static and dynamic** components.	8- Has **static and dynamic** components.

--N.B:- The γ cells in the anterior horn which innervate the intrafusal muscle fibers are controlled by many higher centers through the descending tracts. Some of these centers increase the activity of the stretch reflex and are called "**supraspinal facilitatory centers**". While others diminish it's activity and are called "**supraspinal inhibitory centers**":

Supra-spinal facilitatory centers	Supra-spinal inhibitory centers
1-Primary motor area "**4**"	1-Suppressor cortical areas "**4s**
2-Facilitatory pontine reticular formation.	2-Inhibitory medullary reticular formation.
3-**Neocerebellum** .	3-**Paleocerebellum**.
4-Vestibular nucleus.	4- Red nucleus.
5- **Caudate nucleus** of the basal ganglia.	5-**lentiform** nucleus.

-Clinical abnormalities of the tendon jerk:

A-Tendon jerk may be **"Exaggerated"**, hypereflexia in :-

1-Upper motor neuron lesion due to damage in the internal capsule which destroys the descending tracts.

2- Hyperthyrodisim. 3- Tetany (Ca^{++} deficiency).

4- Anxiety. 5- Paleocerebellum syndrome.

6- Eclampsia (toxicity of pregnancy).

B-Tendon jerk may be **"Inhibited",** hyporeflexia in :-

1 - Sleep 2 - Come 3 - Shock

4- Anathesia 5-Myxodema (hypothyrodisim)

C-Completely **absent,"Areflexia**" in:

1-Advanced tabes dorsalis. 2- Lower motor neuron lesion.

3- shock Stage of complete transection of the spinal cord.

D- "Pendular" knee jerk (hypotonia): looks like the "pendulum" of the watch; this is abnormal condition of hypotonia. On tapping the tendon there will be a weak contraction of the muscle, then the limb is dropped like a dead object which causes another stretch of the tendon and a second weaker contraction occurs and the limb oscillates for few times then stops.

-Pendular knee jerk occurs in :-

1 - Neocerebellar syndrome 2 - Thalamic syndrome 3- Chorea (lesion in basal ganglia) 4- Anterior quadrant lesion of the spinal cord 5- Pure motor area "4" lesion. 6-Pyramid lesion in medulla oblongata.

Thank You