STRETCH REFLEX

Objectives:

- **Definition** and **components** of stretch reflex.
- The **structure**, **innervation** and **function** of the muscle spindle.
- **Sensory primary** and **secondary** (flower-spray) **sensory afferent fibers** of muscle spindle, intrafusal muscle fibers (nuclear bag & nuclear chain fibers).
- The dynamic gamma efferent and trail endings discharge and their functional role.
- What is meant by **static** and **dynamic stretch reflex** & **damping mechanism**.
- **Muscle tone** and its **abnormalities**.
- The spinal and supraspinal **regulation** of the stretch reflex.
- The **inverse stretch reflex** (Golgi tendon reflex) and its function.

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Color index: Important - Further explanation - Doctors Notes - Numbers.

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*Please check out this link before viewing the file to know if there are any additions or changes.

Muscle stretch reflex (Duration 9:33 - Khan academy channel) General idea.

What is a stretch reflex "myotatic reflex" ? (Guyton 12th edition Page 658)

Definition:	The **reflex contraction** of muscle resulting from stimulation of **the muscle spindle** by stretching the whole muscle (also known as: myotatic reflex).
Type:	**Mono**synaptic (one sensory neuron synapse with one motor neuron), **Deep reflex**,).
Example:	Patellar-tendon or knee jerk.
What's the significance of stretch reflexes?	1- They help **maintain** a normal posture 2- They function to **oppose sudden changes in muscle length.**

Components of the stretch reflex: (Guyton 12th edition Page 658)

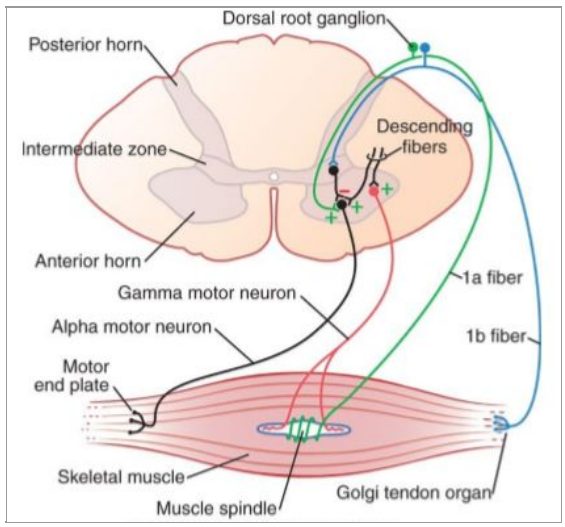
1. Receptor :

Muscle spindle - the receptor that is located inside the muscle and detects changes in muscle length.

2. Afferent (sensory) nerves: Will be discussed later in this lecture

a. **Annulo-spiral** "group Ia afferents".

b. **Flower spray** "group II afferents".



3. AHC[1] (center)

Alpha motor neurons synapse with the afferent sensory neurones in the **spinal cord** , then stimulate the extrafusal fibres by alpha motor fibers.

4. Efferent include:

[1] Anterior horn cell.

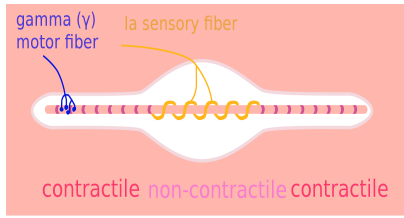
a. **Alpha motor fibers** (70% of motor supply, arise from alpha motor neurons to supply **extrafusal muscle** fibers)

b. **Gamma efferent** (from gamma motor neurons 30% to muscle spindle "**intrafusal fibers**").

5. **Effector:** (the same muscle of the muscle spindle)

Structure of Muscle Spindles : (Guyton 12th edi. Page 657)

Muscle spindle consists of:



1. **Intrafusal Fibers:**

3-12 small specialized muscle fibers within CT capsule, and are **parallel** to the extrafusal fibers "attached to it or to tendons".

- **Each intrafusal fiber has:**
  - **Central** - noncontractile area (**receptor area**).
  - **Peripheral** - contractile area on each side of central zone, it has actin & myosin [2].

The reason why the central portion doesn't contract while the peripheral portion does, is due to the presence of the actin and myosin filaments :O! The central portion has a few or no actin & myosin filaments while the peripheral portion has, so instead of contracting the central portion acts as a sensory receptor!!

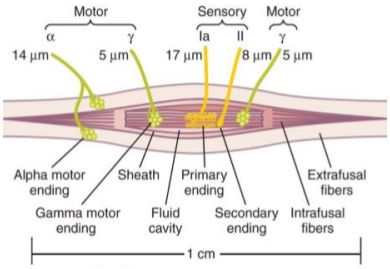
- **Types of the intrafusal fibers:**

Nuclear bag fibers (2-3 per spindle)	Nuclear chain fibers (3-9 per spindle):
Larger	Thinner and shorter
Dilated central area (bag) with group of nuclei.	Nuclei are aligned in a chain throughout the receptor area
	Bind to nuclear bag on each side
Supplied by primary endings only	Supplied by **both** primary and secondary endings.
Responsible for **the dynamic response**	Responsible for **the static response**.
- Can sense the onset of stretch. - Can respond to **rapid** stretch,	- Can sense a **sustained** stretch.
- These prevent muscle injury by activating **extrafusal fibres** in response to force acting on the muscle. - It produces an antagonism of that force.	

[2] Actin filaments, usually in association with myosin, are responsible for many types of cell movements.

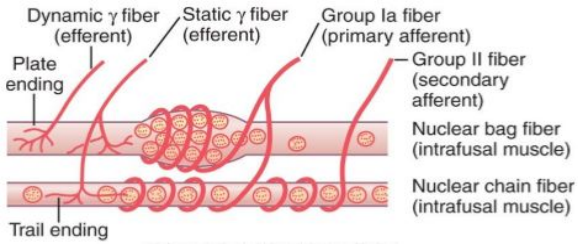
2. **Afferent nerves,** originating in the central portion of the intrafusal fibers .
3. **Efferent nerves,** supplying the contractile regions of the intrafusal fibers.

Extra pics for better understanding of the muscle spindle from Guyton page 656 & 657



Muscle spindle, showing its relation to the large extrafusal skeletal muscle fibers. Note also both motor and sensory innervation of the muscle spindle.

Details of nerve connections from the nuclear bag and nuclear chain muscle spindle fibers.



Innervation of the muscle spindle (Guyton 12th edition Page 657)

1- Sensory Afferent fibers

Central receptor area of the intrafusal muscle fibers is supplied by TWO types of afferent fibers:

A- Group Ia afferent nerve (annulospiral)	**B- Group II afferent nerves (flower spray)**
-Fast, Encircles receptor areas of **BOTH** nuclear bag (mainly) and nuclear chain fibers, synapse directly with the motor neurons (AHC).	- Innervate the receptor area of the **nuclear chain fibres ONLY**.
Diameter: 17 micrometers. -Transmits sensory signals to the spinal cord at a velocity of 70 to 120 m/sec.	**Diameter: 8 micrometers.** - Slower and thinner than group Ia.
Discharge most **rapidly** if the muscle is suddenly stretched and less rapidly (or not) during sustained stretch “dynamic response”	Discharge throughout the period of muscle stretch, **(sustained stretch)**
Measures \ signals : **The rate** or **velocity** of change in muscle length of nuclear bag fibres. (This response is called the **Dynamic response** “as in tendon jerks”) tendon jerks are always dynamic response because it happens suddenly	**Measures \ signals:** Mainly **muscle length.** This response is known as the **Static response.**

IMPORTANT NOTES!

- The **primary sensory nerve ending** is excited by **both** nuclear bag & nuclear chain fibers.
- **The secondary ending** is usually excited **only** by **nuclear chain fibers**.
- **Nuclear bag fibres are** supplied by primary endings **only** & responsible for the **dynamic response**.
- **Nuclear chain fibres** are supplied by **both** primary and secondary endings & responsible for the **static** response.

2- Motor Efferent fibers

A-Dynamic gamma motoneurons (plate endings)	B- Static gamma motoneurons (trail endings)
Synapse\end on nuclear bag fibers .	Synapse\end on nuclear chain fibers.

Their function is to **regulate** the sensitivity of the intrafusal muscle they innervate.
Both of their endings terminate on the peripheral contractile parts of the **intrafusal** muscle fibers.

When they're activated they can make the peripheral parts of muscle spindle contract. However, contraction of the spindle **CANNOT** cause contraction of the muscle!

Control of Intensity of the Static and Dynamic Responses by the Gamma Motor Nerves:

-When the **gamma-d** fibers excite the nuclear bag fibers → the **dynamic response** of the muscle spindle becomes tremendously enhanced.

-Conversely, stimulation of the **gamma-s fibers**, which excite the nuclear chain fibers → enhances **the static response.**

How the muscle stretch is detected?

- Normally, MS discharges continuously (spontaneous activity).
- Stretching of the muscle spindle **increases** the rate of firing (positive signal to the brain).
- Shortening of the spindle **decreases** the rate of firing (negative signal).
- THE **NUMBER** OF IMPULSES (APs) SENT ARE **PROPORTIONAL** TO THE STRETCHED **LENGTH** OF THE MUSCLE (Important concept).

It means that stretching the muscle **increases** the rate of firing positive signal to the brain and vice versa.

Functions of muscle spindle

1. **PROPRIOCEPTION**[3] - keeps the CNS informed about muscle length & rate or velocity of change in muscle length.

   the spindles can send to the spinal cord either **positive** signals that is, increased numbers of impulses to indicate stretch of a muscle or **negative** signals below normal numbers of impulses to indicate that the muscle is unstretched muscle spindles provide information about position.

2. **Maintain muscle length against rupture.**

Muscle contraction:

Muscle can contract by:-

1. **Stimulation of alpha motor neurons by muscle stretch.**
2. **Stimulation of gamma motor neurons.**
3. **Coactivation stim of both alpha & gamma.** (الحالة التي نستخدمها بحياتنا اليوميه)

   - Signals from the motor cortex to the alpha motor neurons, mostly transmitted to the gamma motor neurons simultaneously, an effect called **coactivation.**

   Whenever signals are transmitted from the motor cortex or from any area of the the brain to the alpha motor neurons, in most instances the gamma motor neurons are stimulated simultaneously.

   - **This causes** both the **extra**fusal skeletal muscle fibers and the muscle spindle **intra**fusal muscle fibers to contract at the same time.
   - **The purpose (significance) of Coactivation:**

It keeps the length of the receptor portion of the muscle spindle constant and that will **regulate** its sensitivity.

- It maintains the proper damping function of the muscle spindle.
- Oppose sudden changes in muscle length.

★ **Explanation:**

Signals sent to a whole muscle (like the biceps) causing it to contract, travel from the spinal cord through alpha motor neurons. When this occurs, only extrafusal muscle fibers would contract. Meanwhile, the intrafusal muscle fibers within the muscle spindles would go slack and information from the muscle spindle would stop. To keep muscle spindles operating (in their sensitive range) during a muscle contraction, commands are simultaneously sent through gamma motor neurons to the intrafusal fibers. This causes the contraction of the intrafusal fibers, which maintains stretch on the central region (where the

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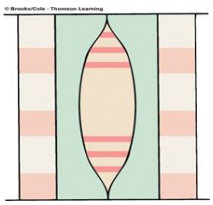
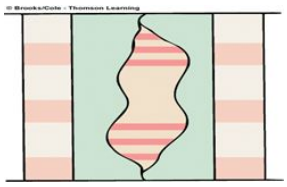
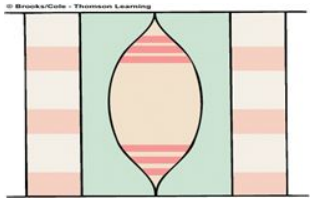
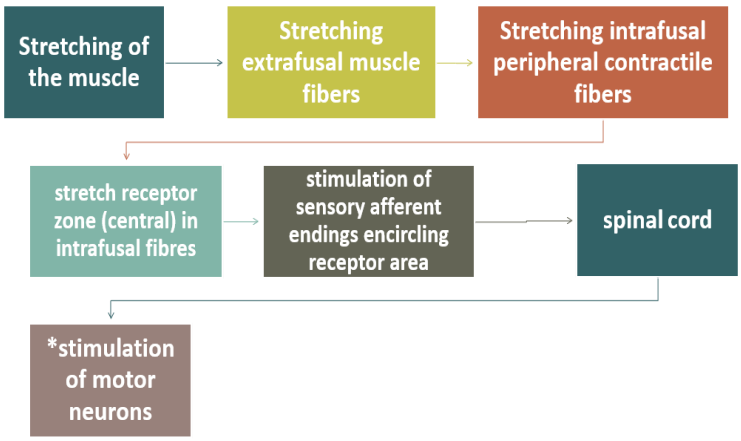
[3] **Proprioception** means "sense of self". In the limbs, the proprioceptors are sensors that provide information about joint angle, muscle length, and muscle tension, which is integrated to give information about the position of the limb in space. The muscle spindle is one type of proprioceptor that provides information about changes in muscle length. من مهم تفهمونه

stretch receptors are located) at the same rate as the whole muscle. Therefore, during a muscle contraction, alpha-gamma coactivation ensures that the muscle spindles continue to send information to the brain about muscle and limb position.

Co-activation of α - and γ - Motor Neurons		
Relaxed muscle:	**Contracted muscle in hypothetical situation of no spindle coactivation;**	**Contracted muscle in normal situation of spindle coactivation**
spindle fiber sensitive to stretch of muscle 	Slackened spindle fiber **not sensitive to stretch of muscle** 	contracted spindle fiber **sensitive to stretch of muscle** 

Stretch reflex



***Stimulation of motor neurons:**

1-alpha motor neurons: (70%) which send impulses to **extrafusal** ordinary muscle fibres → muscle to contract.

2-gamma motor neurons: (30%) which send impulses to **intrafusal** peripheral contractile fibers → causing contraction of the peripheral contractile parts of the intrafusal fibres & stretch central receptor zone to excite afferent fibers.

Muscle spindles basic mechanism (Duration 8:20)

Types of responses

1. **Dynamic stretch reflex (dynamic or phasic response).** (Guyton 12th edition Page 659)

- **Mechanism:**
  - **In case of Sudden stretch:**

    Sudden rapid stretch of a muscle → stimulate **Nuclear bag fibers** which respond to rate or velocity of stretch → discharge Synchronous[4] strong impulses from spindles → **primary ending** (annulospiral) send potent dynamic signals → alpha motor neuron → motor alpha nerve → causing sudden contraction of muscle extrafusal fibers synchronously (jerk movement).
  - **In case of Unstretch:**

    Conversely, when the spindle receptor **shortens** (unstretched)→ the primary ending sends extremely strong, negative to inform it about muscle unstretch.
  - **Finally(in both cases),:**
    - A strong signal is transmitted to the spinal cord.
    - this causes an instantaneous strong reflex **contraction** "in case of sudden stretch"(or decrease in contraction "in case of unstretch").

- **The reflex functions to** **oppose** **sudden** changes in muscle length.

- **Dynamic stretch reflex is the bases of:**

tendon jerk, contraction followed by relaxation(knee,biceps,triceps,ankle).

- **Clinical Applications of the Stretch Reflex:**

  - **Knee Jerk** and Other Muscle Jerks Can Be Used as clinical application.
  - **The purpose is to:** **determine** how much background excitation, or "tone," the brain is sending to the spinal cord.

- **Dynamic gamma (plate efferent endings)**

  because if nuclear bag fibres relax during muscle contraction ,its sensitivity to stretch decreases, plate endings which end mainly on the nuclear bag fibres , prepare it to sense a new sudden stretch of the muscle by **contracting** the peripheral contractile part of nuclear bag fibres, so **stretch** the central part. It increases sensitivity of muscle spindle to rate and velocity of change of length & enhances the dynamic response.

Note: if only alpha motor neurons are activated without gamma. the spindle gets flaccid. we won't have that feedback going back to our brain telling us what that muscle tone is like right now. so we might misjudge by contracting it too much or not enough.

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[4] occurring at the same time; coinciding in time; contemporaneous;simultaneous.

Summary - IMPORTANT TO UNDERSTAND:

- When the length of the spindle receptor increases **suddenly**, the primary ending (but not the secondary ending) is stimulated powerfully.
- This is called the *dynamic response*, which means that the primary ending responds extremely actively to a rapid rate of change in spindle length.
- Conversely, when the spindle receptor **shortens**, exactly opposite sensory signals occur.
- Thus, the spindles can send to the spinal cord either **positive signals**—that is, increased numbers of impulses to indicate stretch of a muscle—or **negative signals**—below- normal numbers of impulses to indicate that the muscle is **unstretched.**
- to apprise the spinal cord it of any change in length of the spindle receptor.

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2. Static stretch reflex(static response).(Guyton 12th edition Page 659)

○ Mechanism:

- **Maintained** stretch of muscle → stimulates **Nuclear chain fibers** to discharge with increased rate → Impulses in the **secondary** sensory nerve (flower-spray) → **alpha** motor neuron → **motor nerve** → **contraction of muscle fibers Asynchronously**(motor units not discharge all together) → resulting in **mild sustained contraction** of muscle extrafusal fibers as long as it is stretched.

why asynchronously? Because we need to stimulate motor units gradually so a maintained contraction can take place for a long time.

○ Static gamma efferent (Trail endings)

- Trail endings which end mainly on the **nuclear chain fibres** periphery , stretching it to increase sensitivity of muscle spindle to **steady maintained** stretch & enhances the static response.

Muscle spindle reflex(dynamic and static) smoothes the body movements and prevent oscillation and jerkiness.

Muscle Tone[5]

Dif/ resistance of muscle to stretch

- **Stimulus for muscle tone is:**

sustained Stretch of skeletal muscle between origin and insertion

- **Present in antigravity muscle[6]** (extensors of LL, back, neck, flexor of UL, muscle of abdominal wall and elevator of mandible).
- **abnormalities:**

- If lost by **low** gamma efferent discharge to muscle → **hypotonic** or **flacidity**
- If increased by **high** gamma efferent discharge to muscle → **hypertonic** , **spastic muscle.**

Interesting information: Grey's Anatomy denies that it exists, but perhaps, because the topic falls under physiology rather than anatomy, He should not have the last word. He says it doesn't show up on an electromyograph, so it can't exist; but an electromyograph can't pick up low level, steady-state action unless the motor units immediately adjacent to the contact are firing.

Reciprocal inhibition with stretch reflex

- **What is it?**
  - Reflex contraction of an agonistic muscle is accompanied by *inhibition* of the antagonist. "Innervation of muscles, as around a joint, in which contraction of one set of muscles leads to the relaxation of opposing muscles."
  - **Example:** in knee jerk extensors of thigh will contract and flexors will relax. Contraction of the quadriceps accompanied by inhibition of hamstrings through reciprocal innervation.
- **Significance :**

Reciprocal innervation prevents conflict between opposing muscles and is **vital in coordinating body movements**.

- **How?**

Impulses from stretched muscle causes:-

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[5] **the amount of contraction in a resting muscle**; a more detailed definition would be a static, balanced, isometric contraction between agonist and antagonist (both internal forces) in every muscle in the body, for the purpose of maintaining joint integrity and posture.

[6] (any of the muscle groups involved in the stabilization of joints or other body parts by opposing the effects of gravity for ex: muscles of jaw that keep the mandible raised and the mouth closed.)

1-stimulate the motor neurons of the stimulated muscle to contract by **glutamate** 'Neurotransmitter'.

2- send collaterals to inhibitory interneurons synapse on the AHCs of the antagonistic muscle & inhibit them by **GABA** (or glycine)'Neurotransmitter'.

What is the Clinical Significance of Tendon Reflexes? (from boys' slides)

They are carried out clinically to test the **integrity** of reflex arc.

- **A-reflexia or hypo-reflexia (hypo-tonia)** :
  - Indicates that the reflex arc is interrupted at one of its components by:
    - Lesions of lower motor neuron e.g. ***poliomyelitis.***
    - Peripheral nerve lesions e.g. ***peripheral neuropathy.***
    - Neuromuscular junction disorder e.g. ***myasthenia gravis.***
    - Primary muscle disorder e.g. ***myopathy.***
- **Hyper-reflexia (hyper-tonia):** exaggerated deep reflexes.
  - Upper motor neuron lesion.
  - Anxiety

"Damping" or smoothing Function of the Dynamic and Static Stretch Reflexes (Guyton 12th edition Page 659) (from girs' slides)

❖ Definition:

Is the stretch reflex ability to **prevent** oscillation or jerkiness of body movements.

❖ How?

- Signals from the spinal cord are transmitted to a muscle in an unsmooth form, with increasing or decreasing in intensity for few milliseconds, the muscle contraction will be jerky such signals.
- Muscle spindle reflexes make the contraction is relatively smooth, because the motor nerve to the muscle is excited at a slow frequency.

Conscious awareness (from girs' slides)

- It is a process by brain to coordinate contraction and relaxation of spindle muscles.
- Axon collaterals of the muscle spindle sensory neuron also relay nerve impulses to the brain over specific ascending pathways.
- In this way, the brain receives input about the state of stretch or contraction of skeletal muscles, enabling it to coordinate muscular movements.
- The nerve impulses that pass to the brain also allow conscious awareness that the reflex has occurred.

Supraspinal regulation of the stretch reflex (important)

- ❑ Stretch reflexes are subject to strong regulation by supraspinal centres, especially certain motor centres in the **brainstem** and **cerebral cortex**.
- ❑ **Changes in: reflex threshold**, **amplitude**, and/or **pattern** are common following supraspinal lesions that affect these centres or their fibre tracts.
- ❑ The stretch reflex is controlled by supraspinal centres through their connections to the several types of neuron.
- ❑ **Gamma motor neurons** are mainly controlled by inputs from descending fibres from supraspinal centres (e.g., reticulospinal and vestibulospinal).

Factors influence stretch reflex *all act on gamma motor neurons*.	
Enhances (+)	Inhibits (-)
Supraspinal :- -Primary motor area 4. -Vestibular nucleus(in pons). -**Pontine** reticular formation(bulboreticular). -Neocerebellum.	**Supraspinal :-** -Cortical (suppressor area 4 & Area 6) -Red nucleus (in midbrain). -**Medullary** reticular formation. -Basal ganglia. -paleocerebellum.
Anxiety	**Excessive stretch of muscle** (golgi tendon reflex).
Noxious painful stimuli [7]	

[7] Noxious stimuli is putting something with a heavily offensive smell near the patient's nose (such as ammonia inhalants), really loud obnoxious sounds, or changing temperature. Or it can be painful stimuli, such as a sternal rub.

Jendrassik-maneuver[8]	

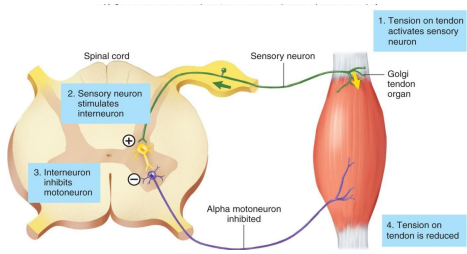
The Golgi Tendon Reflex (The inverse stretch reflex) (Guyton 12th edition Page 661)

Definition:	- Opposite response to stretch reflex - Excessive **tension** in the muscle (by passive over-stretch of tendon or active muscle contraction) → **cause muscle relaxation.**
Type:	Deep & polysynaptic reflex. (disynaptic reflex).
Receptor:	**Golgi tendon organ** - Present in tendons are **encapsulated** sensory receptor which is a netlike collections of nerve endings (**group Ib**) through which muscle tendon fibers pass. - Arranged in series with the extrafusal muscle fibers. - About 10 to 15 muscle fibers are usually connected to each Golgi tendon organ. -**The organ is stimulated when:** this small bundle of muscle fibers is **"tensed" by contracting**. - **Transmit information about:** tendon tension or rate of change of tension. (the stimulus of this reflex is the over tention in the muscle. not the stretching!)
Inhibitory Nature of the Tendon Reflex and	**Stimulated** golgi tendon organ → **impulses** via fast **Ib** nerve fibers " large, rapidly conducting fibers that average **16** micrometers in diameter and entwined within bundles of connective tissue fibers that make up the tendon" → **SC** → The local cord signal excites **inhibitory interneuron** (secrete Glycine)--> **inhibit** alpha motor neuron → **negative feedback** mechanism → muscle relaxation of the same muscle (**lengthening reaction**). Antagonist muscle is activated via **excitatory interneuron**
Significance :	- Also stim excitatory interneuron to antagonist.(reciprocal innervation(due to the relaxation response of the muscle there has to be a reciprocal muscle that contract.)

[8] The **Jendrassik maneuver** is a medical maneuver wherein the patient clenches the teeth, flexes both sets of fingers into a hook-like form and interlocks those sets of fingers together. check this video

	Value/Protect muscle from rupture, and tendon from avulsion & tear.

muscle spindle and GTO (Duration 11:27)



Comparison Between Stretch & Inverse Reflexes

	Stretch reflex	Inverse stretch reflex
STIMULUS	Increased muscle length	Increased muscle tension
RESPONSE	Muscle contraction	Muscle relaxation
RECEPTORS	Muscle spindles (MS)	Golgi tendon organs (GTO)
AFFERENTS	Type Ia & II fibers	Type Ib fibers
SYNAPSES	Monosynaptic	Disynaptic
RECIPROCAL INNERVATION	Inhibit antagonists through inhibitory interneurons	Excites antagonistic muscles through excitatory interneurons
PHYSIOLOGICAL SIGNIFICANCE	- Regulation of muscle length - Genesis of muscle tone	- Regulation of muscle tension - Prevent excessive increase in muscle tension (protective role)
CLINICAL ASSESSMENT	Sudden tap of muscle causes brisk contraction muscle jerk	Overstretch of muscle sudden muscle relaxation (lengthening reaction)

★ References:

- 435 girls and boys slides and notes.
- Guyton and hall textbook of medical physiology - 12th edition.
- Ganong's review of medical physiology - 25th edition.