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Stretch reflex & Tendon jerks

PHYSIOLOGY
CNS Block
Team 443

MED 443
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Objectives:

Upon completion of this lecture, students are expected to :

-Describe the stretch reflex and its components and its function

- Describe the structure , innervations and function of the muscle spindle .

- Explain the roles of alpha and gamma motor neurons in the stretch reflex

- Differentiate between primary and secondary afferent fibres of muscle spindle .

- Differentiate between the Dynamic gamma efferent and Trail endings discharge and their functional role .

- Differentiate between static and dynamic stretch reflex .

- Describe muscle tone and its abnormalities .

- Discuss spinal and supraspinal regulation of the stretch reflex .

-Describe the components of the inverse stretch reflex (golgi - tendon reflex) and its function.

Stretch (Myotatic) Reflex

Reflex : It is a reflex contraction of a muscle when it **is moderately stretched,** It results from stimulation of the muscle spindle by stretching the whole muscle.

-It is a monosynaptic deep reflex (one sensory neuron synapse with one motor neuron) also known as myotatic reflex

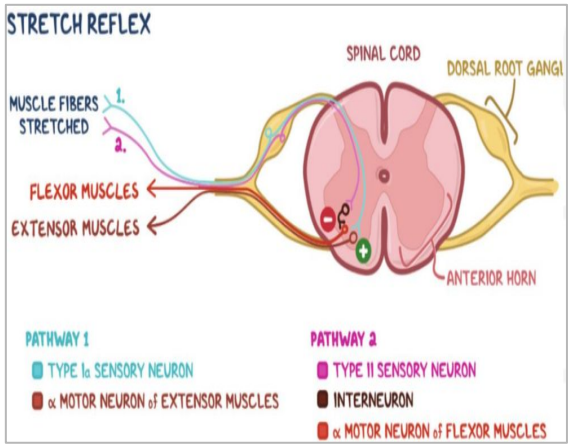
-It has two components:

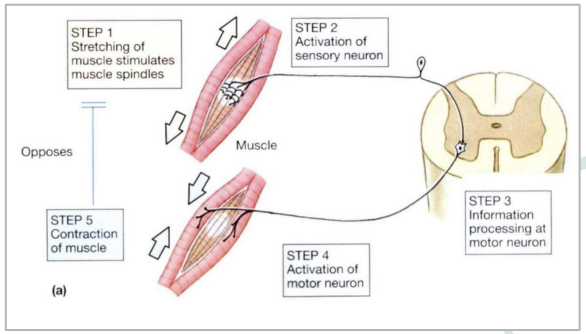
I)Dynamic stretch reflex (patellar-tendon or knee jerk reflex) 2)static stretch (muscle tone)

Value/ aids in maintaining posture, avoid muscle rupture.

-**Components of the stretch reflex arc:**

Sensory receptors	**Muscle spindles**
Afferents	**Fast conducting group Ia & II afferents** (slower)
Integrating center	Anterior horn of spinal cord (AHC) →alpha motor neurons synapse with the afferent sensory neurons in the spinal cord secreting glutamate
Efferents	• α motor neurons → supply extrafusal muscle fibers • γ motor neurons → supply intrafusal muscle fibers (it is not a part of reflex)(fibers inside the muscle spindle). it will be discussed
Effector	**extrafusal muscle fibers**
Response	muscle contraction & reciprocal inhibition of antagonist
aim	**to maintain muscle length**





إذا حصل انقباض تُثبط عضلات الإنبساط والعكس صحيح= inhibition Reciprocal

Stretch (Myotatic) Reflex

- **Types:** based on the number of synapses

	Monosynaptic	Polysynaptic
Definition	I sensory neuron synapses with I motor neuron → very rapid response.	More than 2 synapses are involved; there is at least I interneuron.
Examples	Stretch reflex (the only example)	● Golgi tendon reflex ● Flexor-withdrawal reflex

Clinical classification:
Superficial
Deep
Visceral

Note: spinal reflexes do not involve the brain. However, upper motor neurons may modify the intensity of the reflex response via supraspinal control.

○ Example: when you want to pick up a dish from the stove, but you uncertain whether it is hot or not, you may attempt to lightly touch the surface, which will often lower the threshold of the flexor reflex, making you more likely to pull your hand away even if it's not really hot.

Stretch (Myotatic) Reflex

Physiological significance:

- Aids in maintaining normal posture.
-They function to oppose sudden changes in muscle length
-Damping or smoothing muscle contraction.
-Generation of muscle tone

Male slides

Clinical application of stretch knee reflex:

knee jerk reflex

→contraction of the muscle stretch (quadriceps)
-reciprocal inhibition of antagonistic muscle (hamstrings) through reciprocal innervation.

Female slides

Proprioceptors (Muscle Sensory Receptors):

I) Excitation of the muscle by anterior motor neurons in the spinal cord.
2) Continuous feedback of sensory information from the muscle to spinal cord, indicating:
a) What is the length of the muscle?
b) What is its tension?

Female slides

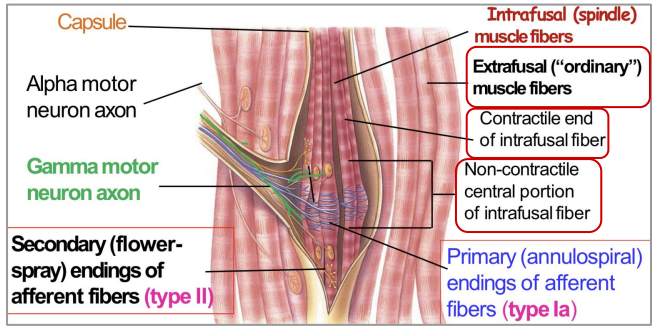
Muscle can contract by:

I- Muscle stretch & Stimulation of alpha motor neurons by,therefore excites the receptor.
2- Stimulation of gamma motor neurons by supraspinal signals
3- Co-activation of α-and γ-Motor Neurons.

Muscle Spindle

Muscle spindle: is the receptor located inside muscle

Function	detects changes in muscle length.
Structure	consist of 3-12 small intrafusal fibers within a capsule
Intrafusal fibers	has a central (non-contractile) area (receptor), and a contractile area on each side.



	Central	Peripheral
Function	**Non-contractile** → receptor	**area on each side of central zone** (has actin & myosin)
Supplied by	Sensory neurons (Ia & II)	Motor neurons (γ)

• How are muscle spindles activated?

By stretching their mid-portion, which can be accomplished in 2/3 ways:

1 Passive stretch (lengthening) of the whole muscle

It causes stretch of the muscle spindle which lies parallel to muscle fibers. which stretches the mid-portion of the spindle and, therefore excites the receptor. If the whole muscle is stretched → the central area of the muscle spindle is also stretched → receptors are excited.

2 Activation of the γ-MNs:

It causes contraction of the peripheral contractile part the intrafusal fibres→ stretch of receptor area./the mid-portions of the spindle & excites the receptor during γ-efferent discharge

Supraspinal centers can activate γ motor neurons that innervate the peripheral contractile area → it contracts

3 Maximal stimulation

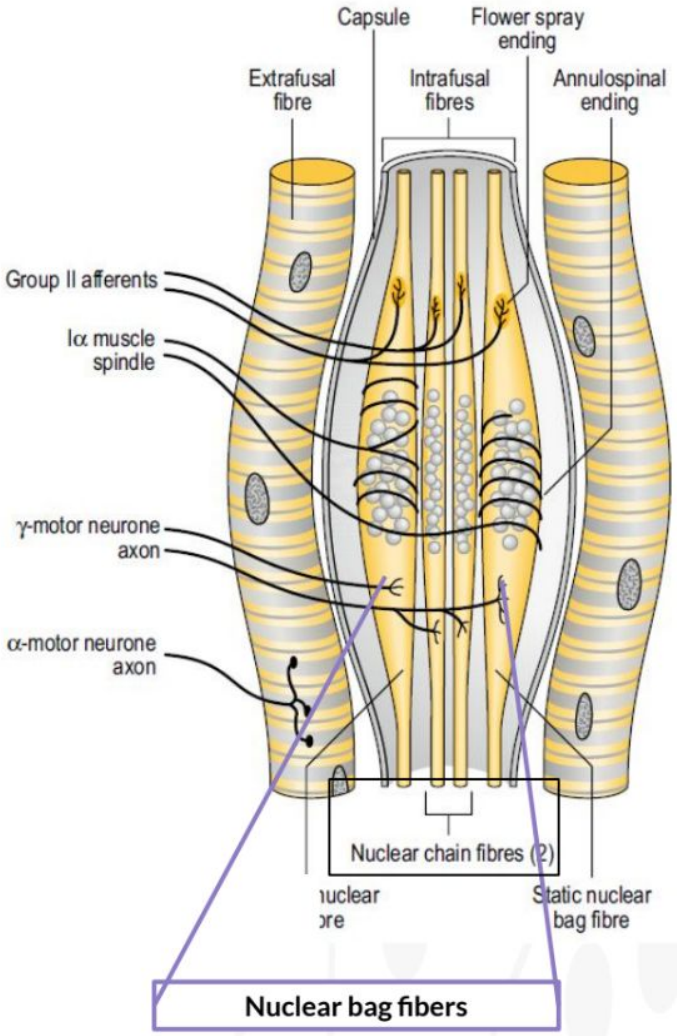
occurs if the whole muscle is stretched during stimulation γ-motor neurons

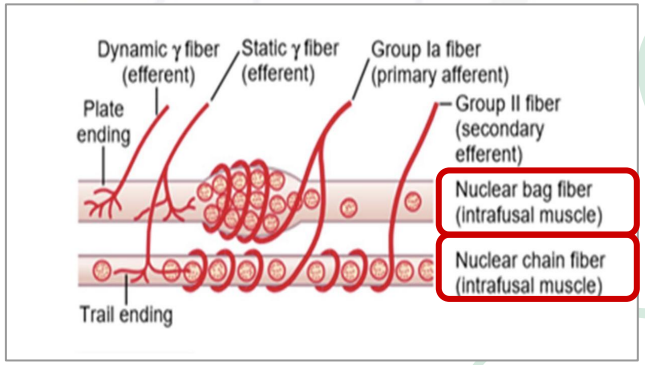
Together: if the whole muscle is stretched during stimulation of γ motor neurons, the rate of discharge in sensory fibers is further increased.

Muscle Spindle

Types of Intrafusal Fibers

	Nuclear Bag Fibers	Nuclear Chain Fibers
Spindle	2 spindles (1-3)	≥4 spindles (3-9)
Structure	Dilated central area with group of (bag) nuclei.	one Line of nuclei arranged as a chain in the receptor zone.
Role	Dynamic response	Static response
Supplied by (afferent)	Primary (Ia)	Primary (Ia) & secondary (II)
Supplied by (efferent)	γd (gamma d) fibers excites nuclear bag	γs (gamma s) fibers excites the nuclear chain





Innervation of the muscle spindle

1- sensory afferent fibers

	Primary Afferents (annulospiral) (Group Ia; Dynamic)	Secondary Afferents (Flower-spray) (Group II)
Features	• Diameter = 17 µm • Transmits sensory signals to the spinal cord at the highest conduction velocity of 70-120 m/s (highest conduction velocity) • Discharge most rapidly if the muscle is rapidly stretched (dynamic response) or less rapidly (or not) during sustained stretch (static response).	• Diameter = 8 µm • Discharge an increased rate throughout the period during which the muscle is being stricted, directly proportional to the degree of stretch, (sustained stretch) • Associated with: static response. (Doesn't respond at all in sudden change)
Measure	Rate & or velocity of change in muscle length of nuclear bag fibers	Mainly Muscle length (static response) (so directly proportional to degree of stretch)
Innervate	Fast, encircle receptor area of both Nuclear bag fibers mainly and Nuclear chain fibers. synapse directly with the motor neurons (AHC)	Receptor area of nuclear chain fibers only
Endings	Annulospiral	Flower-spray

Innervation Of Muscle Spindle

2- moter efferent fibers

- Muscle spindle is the only sensory receptor to have its own motor supply.
- Why? The function of γ- motor neurons is to regulate the sensitivity of the intrafusal muscle fibers
- How? Gamma (γ) efferent endings cause contraction of the peripheral parts of intrafusal fibers → stretch of central parts of muscle spindle → ↑es the sensitivity of the muscles spindle to stretch i.e. muscle spindle needs a small amount of passive stretch to be stimulated

Dynamic γ-d motor neurons	Static γ-s motor neurons
Synapse mainly on **nuclear bag fibers** as "**plate endings**"	Synapse mainly on **nuclear chain fibers** as "**trail endings**"
Excite nuclear bag fibers → **dynamic response** is enhanced.	Excite nuclear chain fibers → **static response** is enhanced.

Dr.Faten: The names of fibers are important

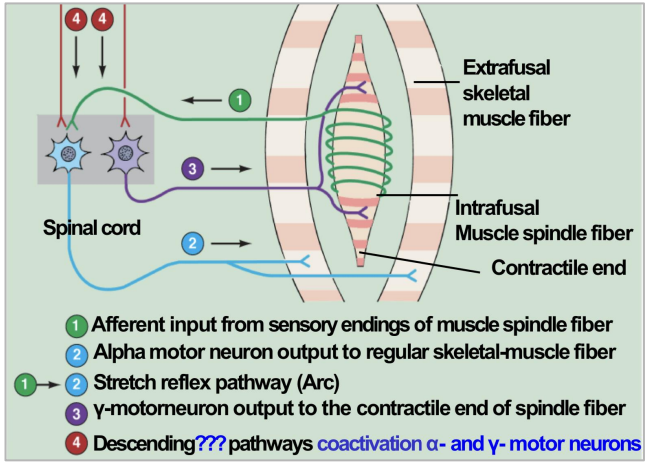
Co-activation of α- and γ- Motor Neurons

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

2. What is the significance of this coactivation?
Is to keep the length of the central reception portion of the muscle constant

3. What is the significance of this coactivation?
Oppose sudden changes in muscle length and prevents
unloading of the spindle

442:A problem: we've learned that skeletal muscles are innervated by 2 motor neurons: α & γ. But there is a problem with that, if α works alone to contract extrafusal fibers, the stretch on the muscle spindles will be reduced and sensory information will stop! In other words, the spindle will not be updated.
The solution: α-γ are activated together to ensure that the muscle spindle is shortened at the same rate as the extrafusal fibers & that the sensitivity of the muscle spindle is maintained despite shortening of the muscle.



Types of strech reflex

	Dynamic (Phasic) Response	Static (Tonic) Response
Description	Sudden stretch → sudden contraction.	Maintained stretch → sustained contraction.
Mechanism	Sudden, rapid stretch of muscle → **nuclear bag fibers** are stimulated → discharge strong **synchronous** impulses via the fast Ia afferents → spinal cord → activation of α-motor neurons → strong excitatory impulses to extrafusal fibers → sudden, jerky (brief) contraction. as muscle shortens → spindle becomes **lax** (مرتخية) & ceases to discharge → no more activation of α motor neurons → no more excitatory signals to extrafusal fibers → muscle relaxes.	Maintained (steady) stretch of muscle → **nuclear chain fibers** are stimulated → discharge slowly via both Ia & II afferents (but mainly II) → activation of α motor neurons → **asynchronous** contraction of the muscle (motor units will not discharge all together) → mild sustained contraction as long as it is stretched. عضلاتنا دائما منقبضة الى حد معين حتى واحنا مرتاحين لأنها مشدودة بين الorigin و الinsertion عن طريق الstatic reflex. هذا الشد الدائم يعرف ب"muscle tone".
Basis of	**Tendon jerks** (contraction followed by relaxation; of knee, biceps & triceps)	**of the Muscle tone** **which is defined clinically as resistance to muscle stretch**

Muscle Tone

- **Definition**: resistance to muscle stretch.
  - A state of continuous partial contraction of skeletal muscles during rest.
  - Sustained stretch of skeletal muscles between origin & insertion.
- **Present in**: all skeletal muscles but specially in **antigravity muscles** (extensors of lower limb, back & neck; flexors of upper limb; muscles of abdominal wall; elevator of mandible).
- **Functions**
  - Postural control
  - Helps in heat production & maintain of body temperature
  - Helps both the venous return & lymph flow
  - Keep viscera in position

Abnormalities :

Hypotonicity or Flaccidity	Hypertonicity or Spasticity
If muscle tone is lost by ↓ γ efferent discharge to muscle	If muscle tone is increased by ↑ γ efferent discharge to muscle

Role of Dynamic gamma efferent (plate endings)

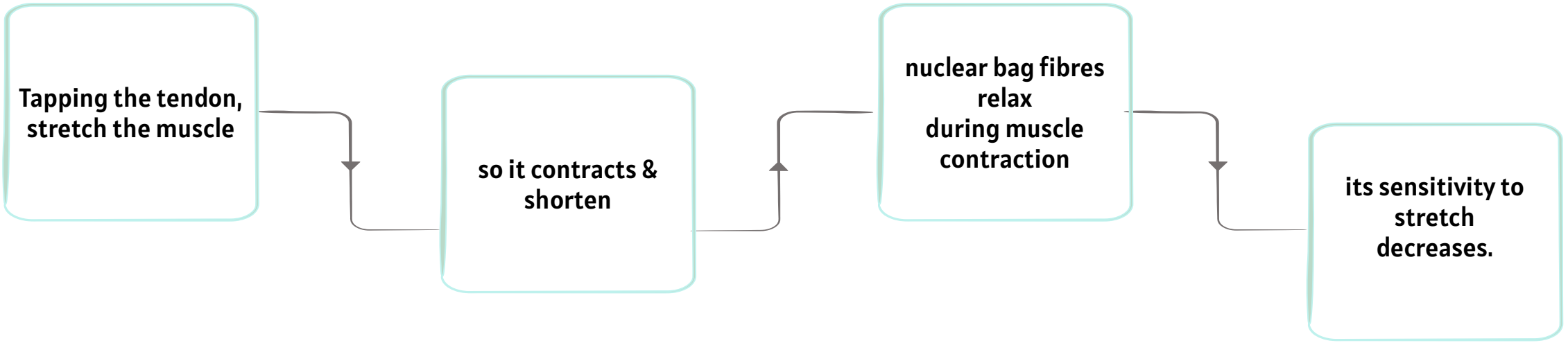


Plate gamma endings which end **mainly on the nuclear bag fibres periphery** , stretching it to increase sensitivity of muscle spindle to new sudden stretch & enhances the dynamic response

Male slides

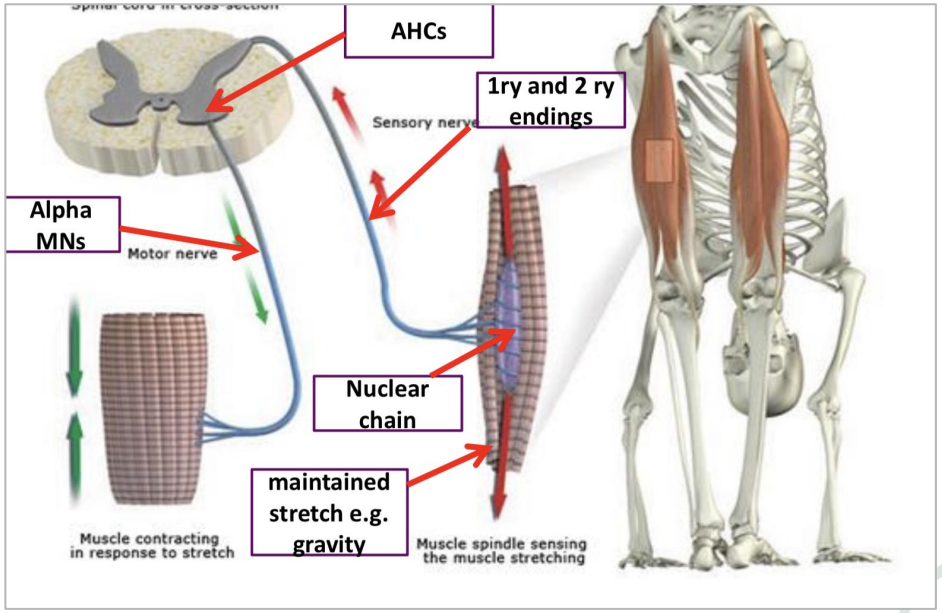
MCQ

Important

Summary of types of stretch reflex

	Dynamic Response	Static Response
Stimulus	Sudden stretch	Maintained (steady) stretch
Receptors	nuclear bag	nuclear chain
Afferents	Iry endings	primary and secondary endings
Center	Spinal cord	Spinal cord
Response	Rapid contraction followed by rapid relaxation	Maintained subtetanic contraction
Examples	e.g. tendon jerk	e.g. muscle tone

Static stretch reflex



Clinical application of stretch reflex: Knee Jerk Reflex

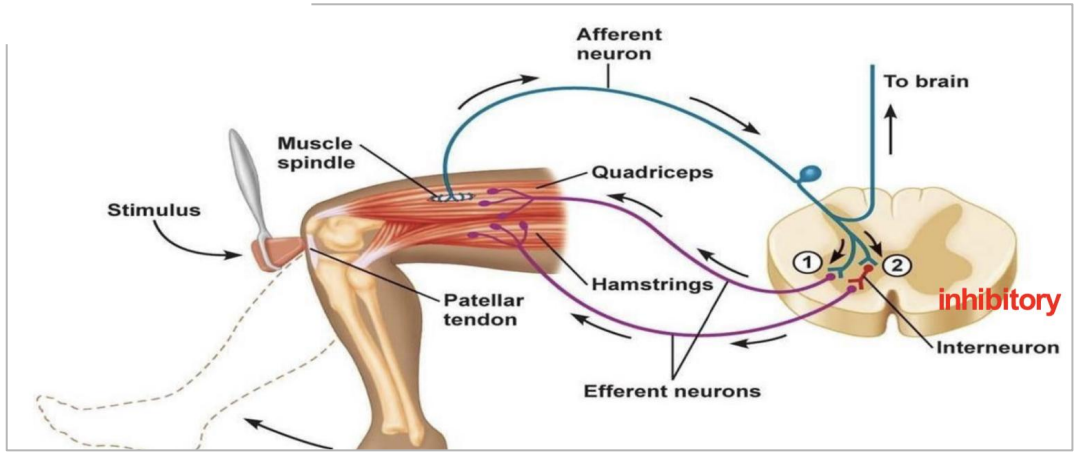
It's composed of

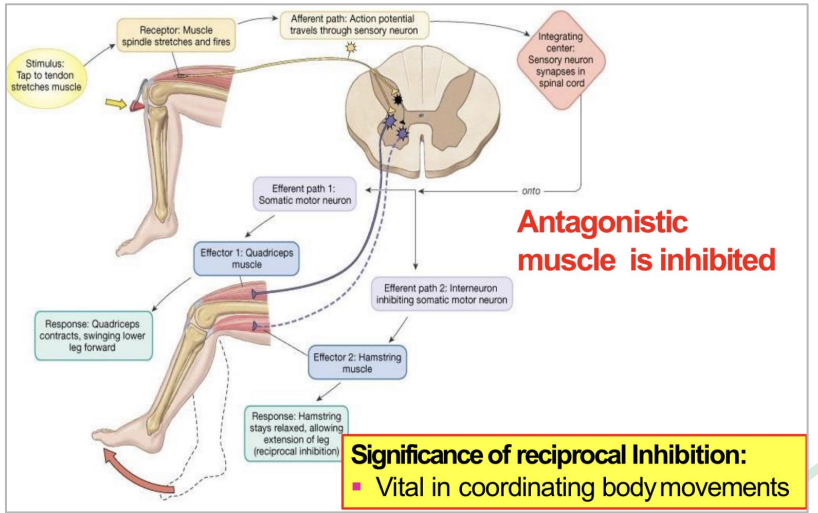
Contraction

of the muscle being stretched (quadriceps)

Reciprocal inhibition

of the antagonistic muscle (hamstring) through reciprocal innervation





Clinical application of stretch reflex: Knee Jerk Reflex

1 They are carried out clinically to test the integrity of reflex arc:

Hypotonia (Areflexia or Hyporeflexia)	Hypertonia (Hyperreflexia)
Indicates that the reflex arc is interrupted at one of its components by:	Exaggerated deep reflexes
● Lesions of lower motor neuron ○ Example: poliomyelitis ● Peripheral nerve lesions ○ Example: peripheral neuropathy ● Neuromuscular junction disorder ○ Example: myasthenia gravis ● Primary muscle disorder ○ Example: myopathy	● Upper motor neuron lesion ● Anxiety

2 Localization of spinal cord lesions:

● Example: ankle jerk is lost in sacral region lesion.

3 Assessment of the state of supraspinal centers:

● Hyperactive (exaggerated) tendon jerk a lesion in area 6.
● Hypoactive (decreased) tendon jerk due to a lesion in area 4.

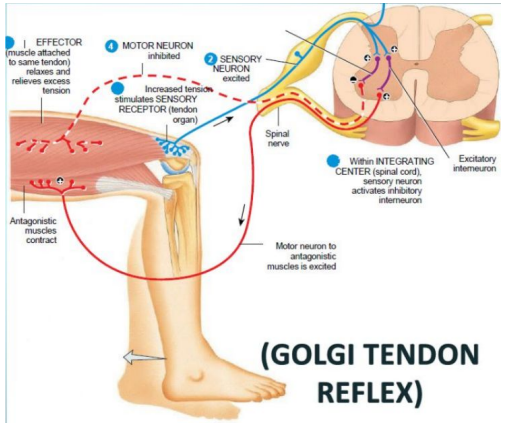
The Golgi Tendon Reflex (Inverse Stretch Reflex)

1. It is a reflex in which there is a reflex relaxation (or lengthening) of a muscles in response to excessive stretch or contraction of that muscles.
It is Deep & polysynaptic reflex.
- Opposite response to stretch reflex = Inverse Stretch Reflex).
mechanism:Excessive tension in the muscle (by passive over-stretch of tendon or active muscle contraction) >>> cause muscle relaxation

2. stimulated golgi tendon organ by an **increase in muscle tension** if the muscle overstretch → impulses travel via fast **Ib** nerve fibers, large, rapidly conducting fibers (16 micrometers in diameter) → to spinal cord → the local cord signal excites inhibitory interneurons (secreting glycine) → inhibit α motor neuron→ negative feedback mechanism → **muscle relaxation** (lengthening reaction).

3. also stim excitatory interneuron to antagonist (reciprocal innervation).

4. Value/significance :
protects from muscle rupture & tendon avulsion or tear.



(GOLGI TENDON REFLEX)

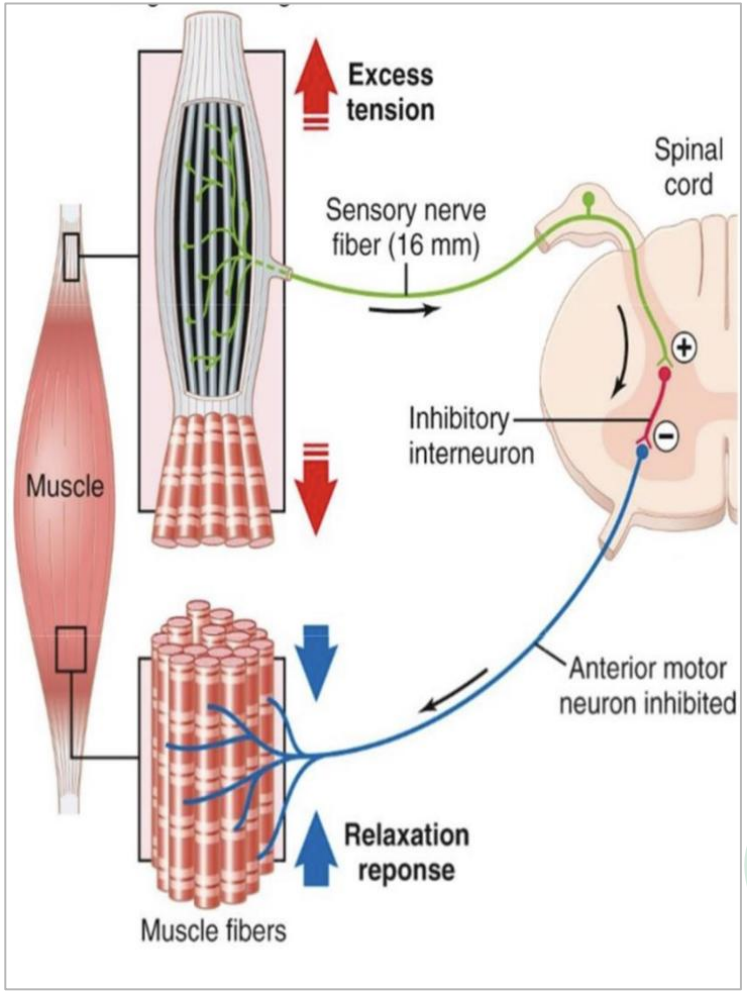
1. Up to a point the harder a muscle is stretched, the stronger is the reflex contraction.
2. However, when the tension becomes great enough, contraction suddenly ceases and the muscle relaxes.
3. This relaxation in response to strong stretch is called the inverse stretch reflex.
4. The receptor for the inverse stretch reflex is in the golgi tendon organ

Important

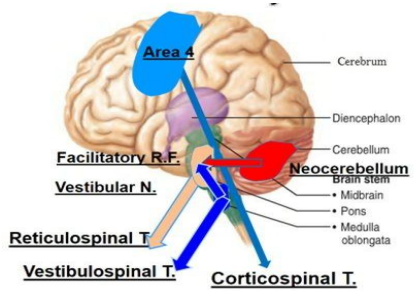
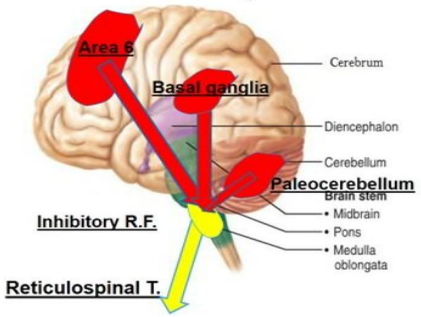
Male slides

The Golgi Tendon Reflex (Inverse Stretch Reflex) summary

receptor (golgi tendon)	Stimulated by ↑ed muscle tension caused by passive overstretch or active contraction of the muscle
Afferents	Ib fibers
Central(spinal cord)	a)inhibitory interneurons→ inhibit the α-MNs supplying the same muscle b)excitatory interneurons→ excite the α-MNs supplying the antagonistic muscle
Response	• Relaxation of the same muscle • Contraction of antagonistic group of muscles.



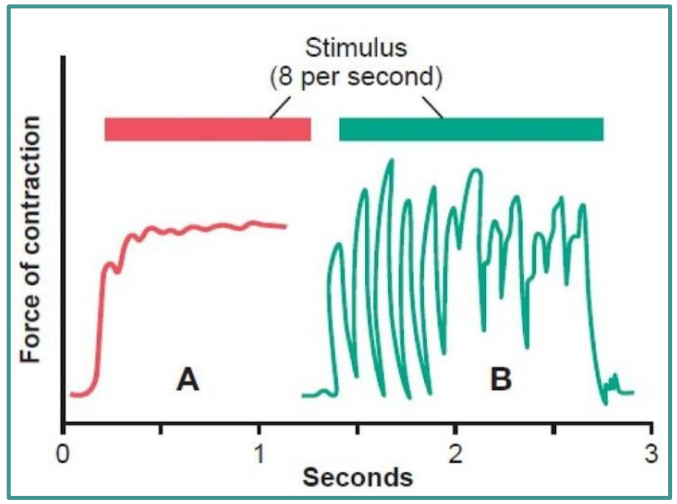
Factors Influencing the stretch reflex

Enhanced By	Inhibited By
Supraspinal regulation: stretch reflexes are subject to strong regulation by supraspinal centers, especially certain motor centers in the brainstem & cerebral cortex. These may stimulate or inhibit γ motor neurons via the descending tracts.	
I) Facilitatory centers • Primary motor area 4 • Vestibular nucleus • Pontine reticular formation (bulboreticular) • Neocerebellum	**I) Inhibitory centers** • Cortical suppressor areas 4 & 6 • Red nucleus • Medullary reticular formation • Basal ganglia • Paleocerebellum Suppressor area 4 & basal ganglia are involved in the origin of extrapyramidal tracts.
	
Other factors	Pay attention to "excessive"
2) Anxiety 3) Noxious painful stimuli 4) Jendrassik-maneuver Pain excites γ	2) **Excessive** muscle stretch (stimulation of Golgi tendon organs) 3) Muscle contraction

هذا تكنيك يقوي الreflex أثناء الclinical exam.
نقول للمريض عض أسنانك مثلا فترسل الcortex ihibitory impulses للأسنان بدل الreflex اللي نختبرها وبالتالي توضح الreflex بشكل اقوى .

Damping Function of the muscle spindle

Another problem: without muscle spindles, signals are often *unsmooth*. **The solution:** an important function of the muscle spindle is its ability to *smooth* or "*dampen*" muscle contractions.



A: normal muscle with *functional* muscle spindles

B: muscle whose muscle spindles where *denervated*

Without the muscle spindle: signals from the spinal cord are transmitted to a muscle in an ***unsmooth*** form (i.e. increasing in intensity for a few milliseconds, then decreasing in intensity, then changing to another intensity level), leading to oscillation or jerkiness or irregularities of movement.

With the muscle spindle: contractions are ***smooth*** → oscillation & jerkiness of movements are prevented.

- How?
  1) The motor nerve to the muscle is excited at a **slower frequency*** than the incoming signals from the spinal cord.
  2) The signals discharged from the muscle spindle cause **partial activity** of α motor neurons. So, the motor signals find α motor neurons in a state of partial activity → activate them continuously → *smooth* contraction.
  3) α-γ **Co-activation.**

*It reduces the muscle tone → that's why it is called "damping" function (تخميد).

Reciprocal inhibition

Definition	reflex contraction of an agonistic muscle is accompanied by inhibition of the antagonist.
Example	in knee jerk, **contraction of extensors** of thigh (e.g. quadriceps) causes **relaxation of flexors** (hamstrings).
Mechanism	impulses from stretched muscle reach the spinal cord to cause I) Stimulation of the motor neurons of the muscle being stretched by **glutamate** (excitatory neurotransmitter). 2) send collaterals >>>> inhibitory interneurons synapse on the AHCs of the antagonistic muscle & inhibit them (by GABA)
Physiological significance	. prevents conflict between opposing muscles, which is vital in coordinating body movements

Summary

Spinal reflexes :

	STRETCH REFLEX	INVERSE STRETCH REFLEX
SYNAPSES	Mono-synaptic	Bisynaptic
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 & tendon avulsion (protective role)
clinical assessment	Sudden tap of muscle causes brisk contraction muscle jerk	Overstretch of muscle- sudden muscle relaxation (lengthening reaction)

	Stretch reflex	Inverse stretch reflex
STIMULUS	Increased muscle length	Increased muscle tension
RESPONSE	Muscle contraction	Muscle relaxation
RECEPTORS	Muscle spindles	Golgi tendon organs
AFFERENTS	*Type Ia & II fibers*	Type *Ib* fibers

TEST YOURSELF !

1- Which one is golgi tendon reflex?

A)transmitted through 1a sensory fibers

B) stimulated by tension developed by the muscle

C)causes contraction of agonist muscle

D)causes relaxation of antagonist muscle

2- Which of the following is true concerning the muscle tone?

A)Is a static stretch reflex

B)Is a polysynaptic reflex

C)Lost in hypertonia

D)Is initiated by sudden muscle stretch

3- Which of the following is Excitatory centers to gamma efferents?

A)Red nucleus

B)motor area 4

C)paleocerebellum

D)Basal ganglia

4- Which of the following spinal reflexes has lowest synaptic delay?

A)Withdrawal reflex

B)Crossed extensor reflex

C)Stretch reflex

D)Inverse Stretch Reflex

Answers : B, A, B, C

SAQ

What's the result of static stretch reflex ?

Mild sustained contraction of muscle extrafusal fibers as long as it is stretched

What are the factors that influence Stretch Reflex?

Slide 18

What is the value of The Golgi Tendon Reflex?

protects from muscle rupture & tendon avulsion or tear.

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PHYSIOLOGY
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Team logo and design was done by **Rafan Alhazzani**
Special Thanks to Physiology **Team441 And ALEEN ALKULYAH** for the Theme!!

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