جامعة الملك سعود
King Saud University

MED437

5th Lecture |The Physiology Team

Stretch reflex and tendon jerks

Objectives :

- Describe the structure, innervation and function of the muscle spindle.
- Describe the components of monosynaptic muscle stretch reflexes, including the role of alpha (α) and gamma (γ) motorneurons.
- Distinguish between a static and dynamic stretch reflex.
- Describe the spinal and supra-spinal regulation of the stretch reflex.
- Describe the structure and function of the Golgi tendon organ and the inverse stretch reflex.
- Appreciate the clinical importance of the stretch reflexes.

Done by:

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Colour index :
- important
- Numbers
- Extra

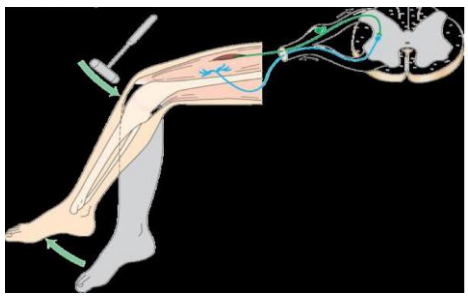
وَأَن لَّيْسَ لِلْإِنسَانِ إِلَّا مَا سَعَىٰ

The stretch reflex:

Reflex	Stretch "myotatic "reflex
Clinical stimulus	Rapid stretch of of muscle (tap on muscle tendon)
Response	Contracted rapidly "i.e knee jerk"
Sensory Receptor	Muscle spindle
Synapse involved	Mono-synaptic
Effector muscle	Contract same muscle & synergistic muscles
Other effects	Relax antagonist muscles
Function	Aids in maintaining Posture, Avoiding muscle rupture, Counter sudden loads

What is the stretch reflex "myotatic reflex? "

- It is reflex contraction of muscle when it is moderately stretched.
- it has two components:
  - **dynamic stretch reflex**
    - patellar-tendon or knee jerk reflex
  - **static stretch reflex**
    - muscle tone



IT IS:

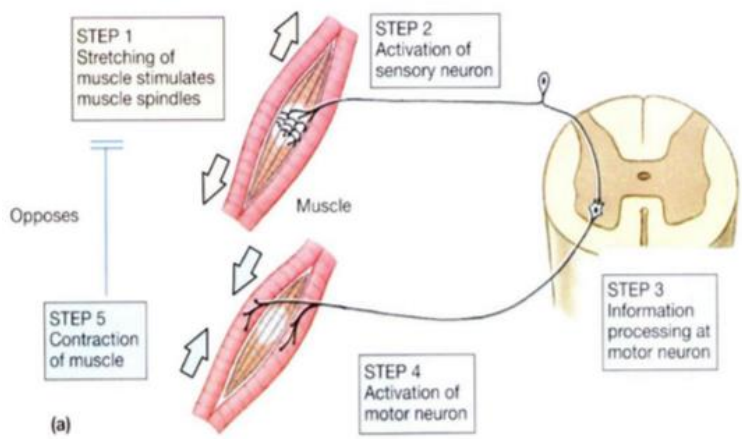
- Deep monosynaptic reflex.
- The simplest ;it involves only 2 neurons & one synapse.

Pathway Of the Stretch Reflex" Reflex Arc:"

1. **Sensory Receptor**eldnips elcsum :
2. **Afferent fibers**(stnereffa II & al puorg)
3. **Integrating center:**droc lanips
4. **Efferent fibers** include/ axons arise from α-and γ-spinal motor neurons
   a. alpha motor efferent from alpha motor neurons to supply extrafusal muscle fibers
   b. gamma efferent (from gamma motor neurons to supply intrafusal muscle fibers
5. **Effector**selcsum latelekS :

Doctor's note:
- **stretch reflex is the only monosynaptic reflex in the body**
(snoruen tnereffe dna tnereffa eht neewteb espanys tcerid)
- **because it is the only monosynaptic that means it is very fast**

Doctor's note:
- **the reflex is very fast because**
(1 sensory afferent is type 1A
(2center is monosynaptic
(3efferent is alpha motor neuron

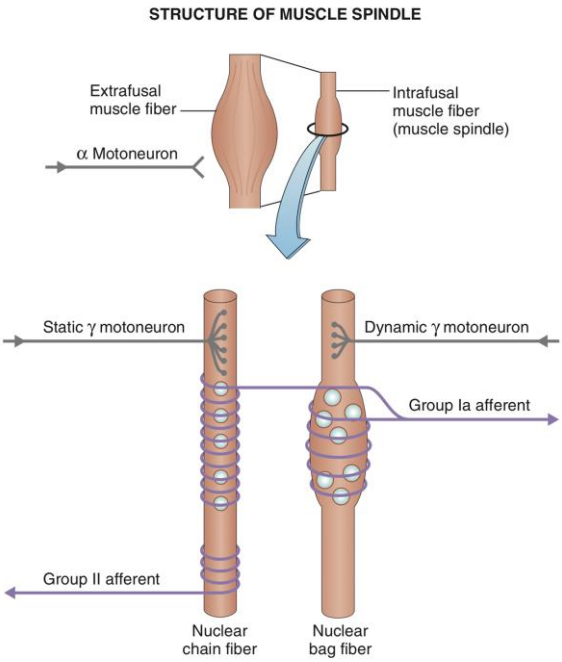


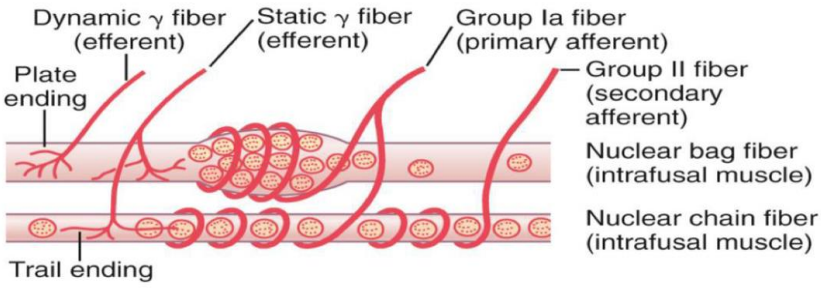
-1Stretch reflex receptor (Muscle Spindle):

- is located in the fleshy part of the muscle
- consist of 12-3small intrafusal fibers within a capsule
  - each intrafusal fiber has a central "non-contractile "area (receptor), and a contractile area on each side. the contractile area has **myosin & actin** so that's why it can contract.

There are two types of intrafusal muscle fibers:

1. Nuclear bag fibers:
   a. have a dilated central area filled with nuclei
   b. are 3-1of these fibers per spindle
2. Nuclear chain fibers:
   a. have nuclei which are arranged as a chain in the receptor area
   a. are 9-4of these fibers per spindle

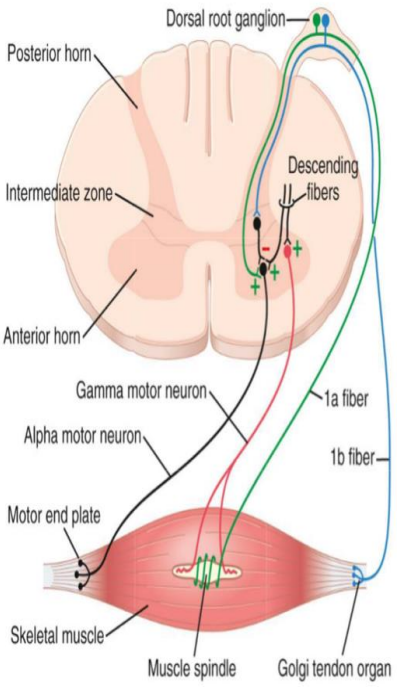




-2Sensory "Afferent "innervation of the muscle spindle

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

1. GROUP Ia
2. GROUP II



A-primary (annulospiral) ending:

- ★ GROUP Ia fiber: 17 micrometers diameter, transmits sensory signals to the spinal cord at a velocity of 70to 120 m/sec .
- ★ encircle receptor areas of both nuclear bag (mainly) but also with nuclear chain fibres.
- ★ discharge most rapidly if the muscle is suddenly stretched **"dynamic response "**and less rapidly (or not) during sustained stretch "Static response."
- ★ measures the rate & or velocity of change in muscle lengt of nuclear bag fibers.

B-Secondary (flower-spray) ending:

- ★ Group II fibers "diameter of 8 micrometers niahc raelcun eht YLNO etavrenni ," .rotpecer
- ★ Discharge at an increased rate throughout the period of muscle stretch, (sustained stretch) (measure mainly muscle length) .
- ★ directly proportional to the degree of stretch.

N.B :

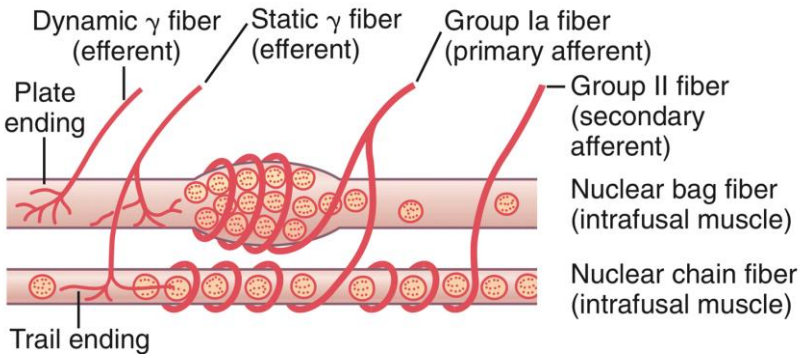
- ❖ **Nuclear bag fibres** cimanyd eht rof elbisnopser & ,ylno sgnidne yramirp yb deilppus era .esnopser
- ❖ **Nuclear chain fibres** rof elbisnopser & sgnidne yradnoces dna yramirp htob yb deilppus era .esnopser citats eht

-2Efferent innervation of the muscle spindle

- ★ Gamma (γ) efferent endings terminate on the peripheral contractile parts of the intrafusal fibers as:
  - **plate endings**" srebif gab raelcun eht no ylniam dne :called **dynamic gamma efferent**"
  - **Trail endings**" srebif niahc raelcun eht no ylniam dne :called **static gamma efferent**"

Doctor's note:

- they are smaller the alpha but they are very important (they represent around 30% of all motor neuron in the spinal cord)
- if we increase gamma we will increase the sensitivity of the muscle e.g. If I want to contract a muscle through the corticospinal tract I need for example 5 impulses for contraction if gamma discharge we will need 2 impulses



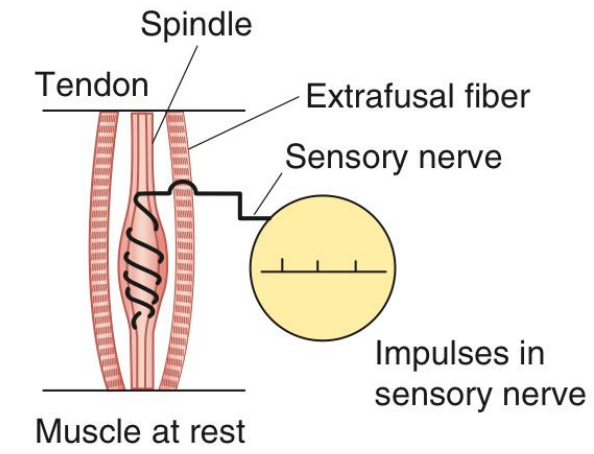
- ★ The function of γ-motor neurons is to regulate the sensitivity of the intrafusal muscle fibers, but **HOW** .ytivitisnes eldnips elcsum fo gnisaercni yb ?
  - they adjust the muscle spindle sensitivity.
  - → srebif lasufartni fo strap larehpirep eht fo noitcartnoc esuac sNM-γ ↑ stretch of central parts of muscle spindle ↑ →the sensitivity of the muscle spindle to stretch →muscle spindle needs a small amount of passive stretch to be stimulated.

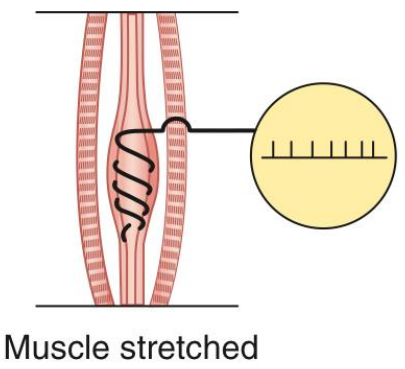
Functions of muscle spindle

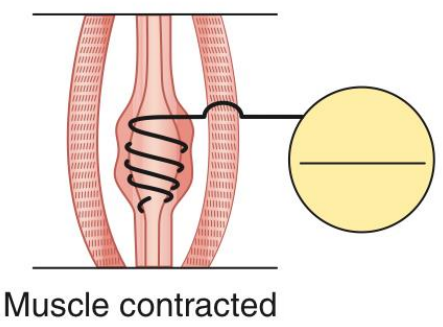
1. keep CNS informed about muscle length & rate or velocity of change in muscle length.
2. provide information about position, that is called **PROPRIOCEPTION.**
3. muscle spindle act to oppose stretch & maintain muscle length against rupture.

How Muscle Stretch Is detected?

- stretching of the muscle also stretches the spindle.
- this sends impulses to the spinal cord.
- the number of impulses sent are proportional to the stretched length of the muscle.







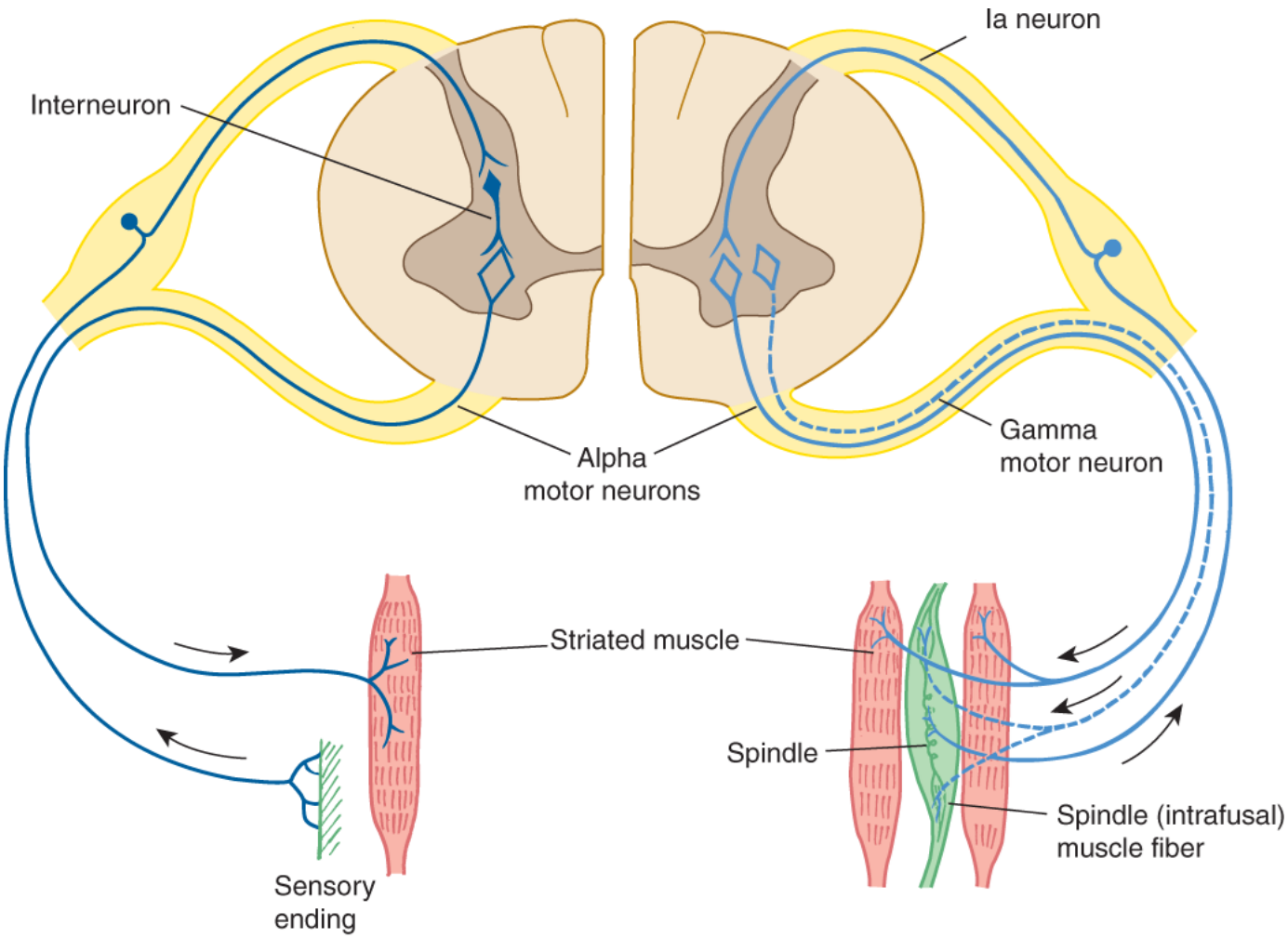
The components of monosynaptic muscle stretch reflexes, including the role of alpha (α) and gamma (γ) motorneurons

Stretching of the muscle →Stretching extrafusal muscle fibers →Stretching intrafusal peripheral contractile fibers →stretching receptor zone (central) in intrafusal fiber →stimulation of sensory afferent endings encircling receptor area →Afferent impulses →spinal cord →stimulate:

Stretch reflex cont:

1. **alpha motor neurons** 70%) of supply) which send impulses to extrafusal ordinary muscle fibres →muscle to contract.

1. **gamma motor neurons** 30%) of supply) which send impulses to intrafusal peripheral contractile fibers causing contraction of the peripheral contractile parts of the intrafusal fibres & stretch central area "receptor."



Dynamic stretch reflex

- sudden "phasic "rapid stretch of a muscle causes synchronous strong burst of excitatory discharges from **Nuclear bag**" laripsolunna ni srebif Primary " afferents to the alpha motor neuron .
- this causes the latter to send strong motor excitatory impulses to extrafusal fibers →causing sudden, jerky "brief "muscle contraction **.(tnemevom ykreJ)**
- as the muscle shortens →the spindle becomes lax →and ceases to discharge →no more stimulation of alpha motor neuron →no more excitatory impulses from alpha motor neuron to the extrafusal fibers → muscle relaxes.
- This is the basis of **Tendon Jerks "Dynamic stretch reflexes."**

Static stretch reflex

- Maintained "Tonic "stretch of muscle →
- impulses from **Nuclear chain** ylniam) srebif tnereffa eldnips hguorht levart srebif " yarpS rewolF gnolasecondary "ending) to alpha motor neuron, stimulating it to produce muscle contraction.
- Causing sustained "continuous "contraction of the muscle as long as it is stretch .
- The static stretch reflex is the basis of **muscle tone;** sa yllacinilc denifed si hcihw .hcterts elcsum ot ecnatsiser

Types of Responses of muscle spindle to stretch

)Types of Stretch Reflexes(

	Dynamic response	Static response
Stimulus	Sudden stretch	Maintained "steady " stretch
Receptors	Nuclear bag	Nuclear chain
Afferent	Primary ending	Primary & Secondary ending
Efferent	Dynamic γ efferent	Static γ efferent
Center	Spinal cord "AHC"	Spinal cord "AHC"
Response	Rapid contraction followed by rapid relaxation	Maintained subtetanic contraction
Examples	Tendon jerk	Muscle tone

Muscle Tone

- ★ is defined as a state of continuous partial "mild "contraction of skeletal muscle during rest.
- ★ it is present in all skeletal muscle but specially in the **antigravity muscles:**
  - extensors of LL, back, neck
  - Flexors of UL
  - Muscles of abdominal wall and elevator of mandbile
- ➔ if lost by low gamma efferent discharge to muscle →hypotonic muscle or flaccidity.
- ➔ if increased by high gamma efferent discharge to muscle →hypertonic muscle , spastic muscle.

Doctor's question & answer
Q: **why there's a muscle tone?**
A :
-1muscles are always shorter than their origin-insertion distance, so the always will be contracted
-2Gravity
-3Gamma motor neuron discharges from higher centers

Functions of Muscle tone:

A. postural control.
B. help in heat production and maintain of body temperature.
C. it helps both the venous return & lymph flow.
D. keeps viscera in position.

"Damping "or smoothing function of Stretch Reflexes

- Is the stretch reflex ability to prevent oscillation or jerkiness of body movements.
- Motor Signals from the motor area are transmitted to the muscle in an **unsmooth form**.sdnocesillim wef rof ytisnetni gnisaerced ro gnisaercni htiw ,
- this causes **irregularities** or **oscillation** of movements
- the signals discharged from from the muscle spindle cause partial activity of a-MNs of the muscle.
- So, the motor signals find a-MNs in esuac yeht os ,**ytivitca laitrap fo etats**
  → meht fo noitavitca suounitnoc**cause smooth muscle contraction.**

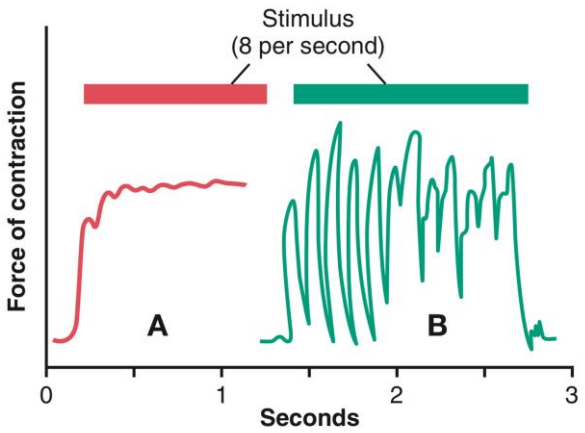


Figure 55-6. Muscle contraction caused by a spinal cord signal under two conditions: *curve A,* in a normal muscle, and *curve B,* in a muscle whose muscle spindles were denervated by section of the posterior roots of the cord 82 days previously. Note the smoothing effect of the muscle spindle reflex in *curve A.*

Doctor's note about the figure:
▪when the cut the posterior root of the spinal cord (denervation)(that supply the muscle spindle) →we will have irregular jerking or oscillations (that means that the muscle spindle will smooth contraction (damping) →the theory of the cause is that when we have muscle contraction the muscle will shorten and then we will have relaxation →the muscle will stretch → activation of gamma motor neuron will do the contraction (the area in B we wont have activation of gamma that will fill the space make and make it smooth(

CONSCIOUS AWARENESS

- Axon collaterals of the muscle spindle sensory neuron also relay nerve impulses to the brain over specific ascending pathways, to allow conscious awareness that the reflex has occurred.

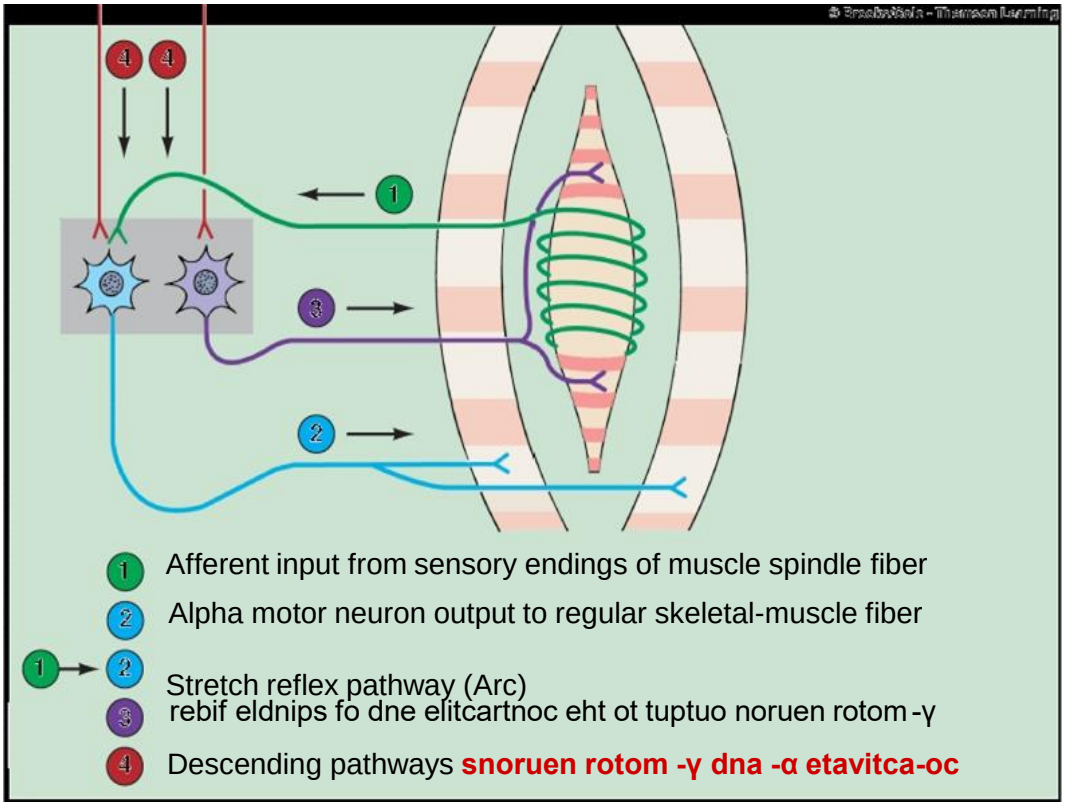
- In this way, the brain receives input about the state of stretch or contraction of skeletal muscles to coordinate.

How Are Muscle Spindles Stimulated?

1. **Passive stretch of the whole muscle:**
   a. it causes stretch of muscle spindle which lies parallel to muscle fibers
2. **Activation of the γ-MNs:**
   a. by supraspinal centers or reflexely
   b. it causes contraction of the peripheral part of the intrafusal fibers → stretch of receptor area
3. **Co-activation of α-and γ-Motor Neurons :"egakniL γ-α "**
   a. Signals from motor cortex to the alpha motor neuron, mostly transmitted to the gamma motor neurons simultaneously, an effect called **Coactivation.**

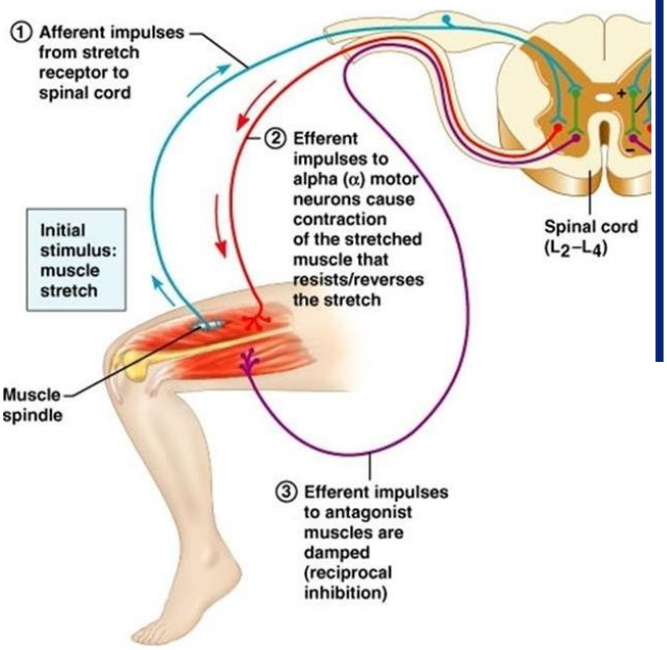
★ **what is the significance of this coactivation?**

- Regulate the sensitivity of the spindle by keeping its length constant
- oppose sudden changes in muscle length.



Reciprocal inhibition with stretch reflex (Reciprocal innervation)

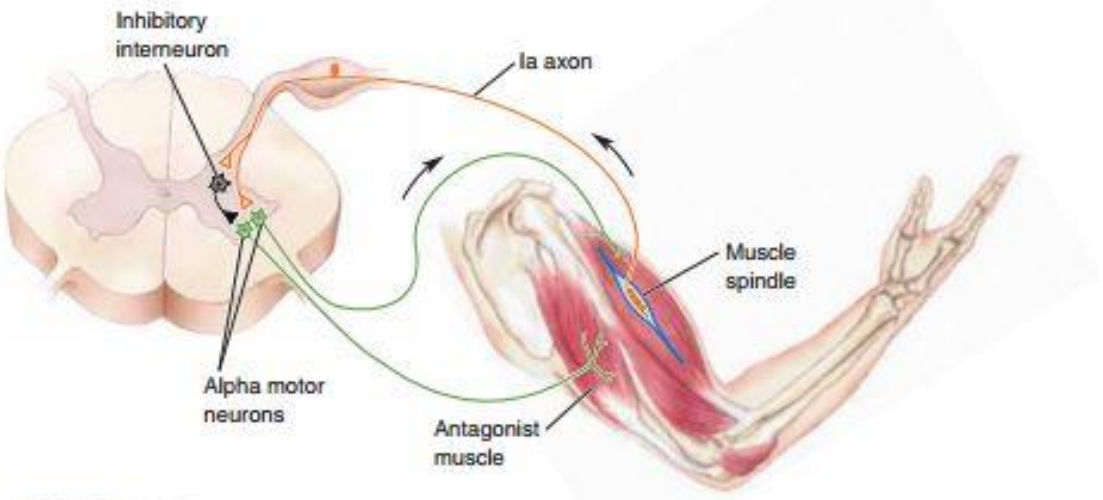
- as in a knee jerk
- Contraction of EXTENSOR of thigh cause Relaxation of FLEXORS
- Reflex contraction of an agonistic muscle is accompanied by inhibition of the antagonist



Impulses from stretched muscle reach spinal cord to cause:

1. stimulate the motor neurons of the stimulated muscle to contract (by glutamate)
2. send collaterals to the inhibitory interneurons synapse on the AHCs of the antagonistic muscle & inhibit them (by GABA)

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

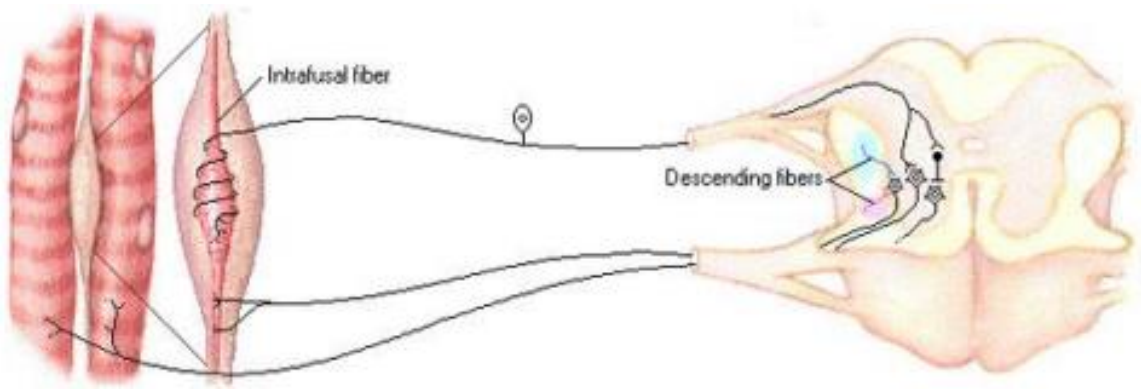


▲ FIGURE 13.25
Reciprocal inhibition of flexors and extensors of the same joint.

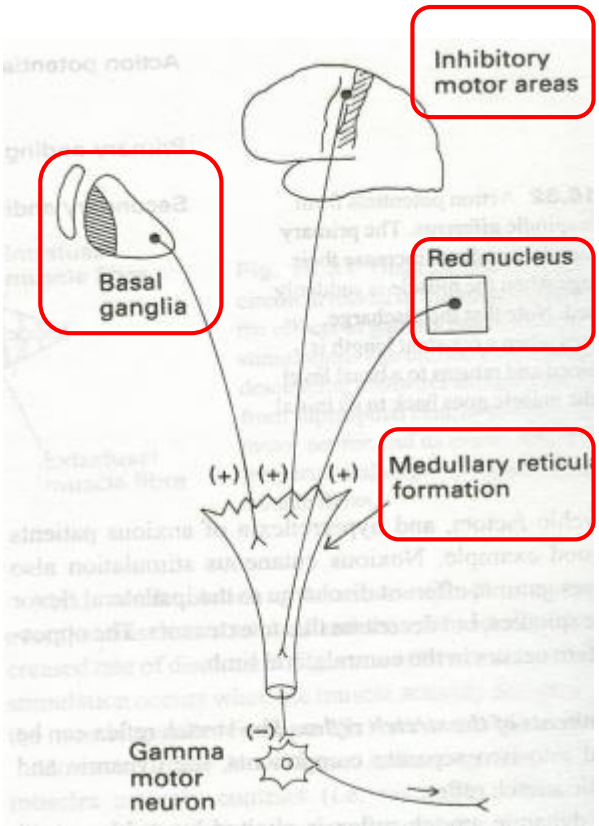
SUPRASPINAL REGULATION OF THE STRETCH REFLEX

Stretch reflexes are subject to strong regulation by supraspinal centres, especially certain motor centres in the brainstem and cerebral cortex.

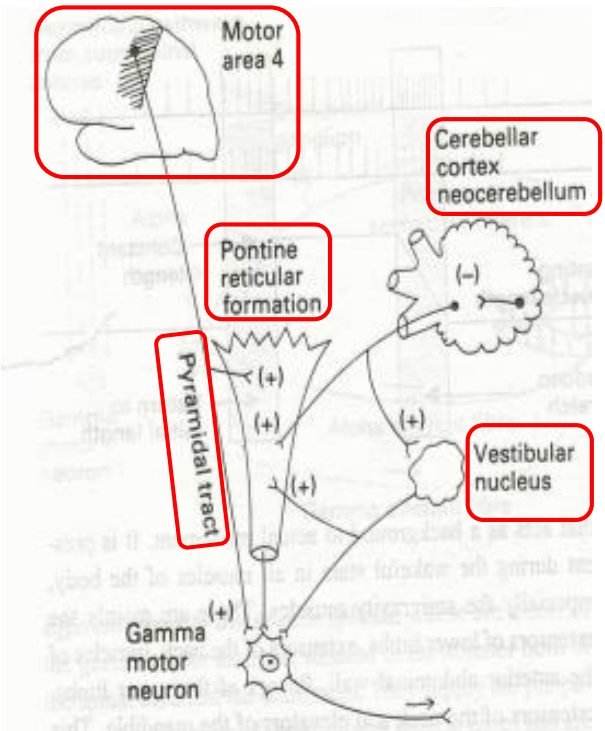
These supraspinal centres send to gamma motor neurons through descending fibres.



Inhibitory supra spinal centers to gamma motor



Facilitatory supra spinal centers to gamma motor neurons



Factors influence stretch reflex

"all act on gamma motor neurons"

Enhances	Inhibits
Supraspinal: • Primary motor area 4 • Vestibular N • Pontine RF • Neocerebellum "Cortex"	Supraspinal - Cortical: •)suppressor area (6 aerA &4 • Basal ganglia • Medullary RF • Red nucleus • paleocerebellum "Deep"

• Spinal mechanisms:
  ○ Noxious "painful "stimuli
• Anxiety
• Jendrassik maneuver
	• Spinal mechanisms:
	  ○ Excessive muscle stretch (stimulation of golgi tendon organ)
	  ○ Muscle contraction

Jendrassik maneuver

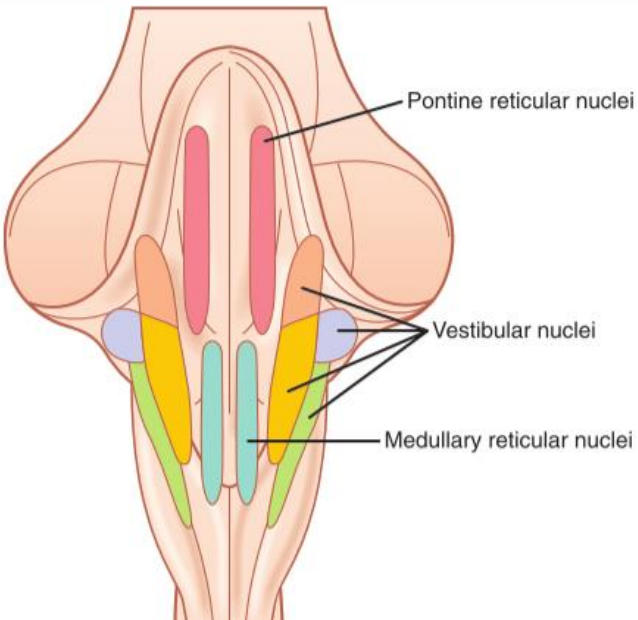
Patient locks fingers together and pulls hard as you tap the quadriceps tendon

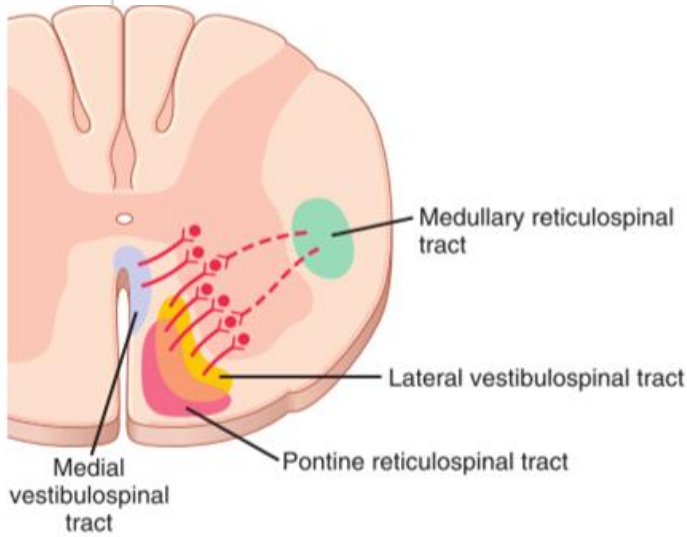
Explanation (FYI):

- 'Voluntary UMN innervation of the arm "overflows" to increase the excitability of the LMN pool of the lower extremities' – (makes easier to elicit the reflex)

Doctor's note:

▪Jendrassik-maneuver e.g. if you do the stretch reflex and don't find a response (could be problem with the reflex arc to make sure it Is not we do the maneuver) →I will tell the patient to clenches his teeth and flexes both sets of fingers into a hook-like form, and interlocks those sets of fingers together →this will increase the gamma discharge → facilitate the stretch reflex





Clinical application of stretch reflex: Knee Jerk Reflex

- ➔ contraction of the muscle being stretch "Quadriceps."
- ➔ Reciprocal inhibition of the antagonist muscle "Hamstring "through reciprocal innervation.

What is the Clinical Significance of Tendon Reflexes?

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

Areflexia 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, **Diabetic neuropathy**
- ❑ Neuromuscular junction disorder e.g. myasthenia gravis
- ❑ Primary muscle disorder e.g. myopathy

Hyper-reflexia (hyper-tonia): exaggerated deep reflexes.

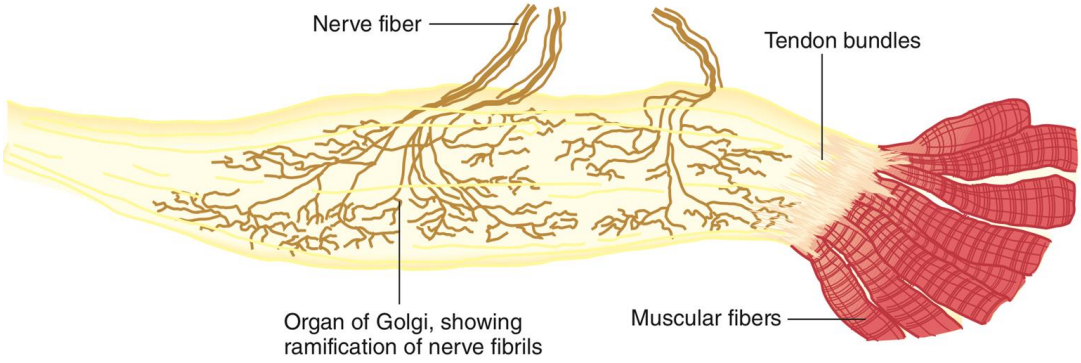
- ❑ Upper motor neuron lesion.
- ❑ Anxiety

Hyperreflexia.

Inverse Stretch Reflex

)Golgi Tendon Reflex(

- up to a point, the harder a muscle is stretched, the stronger is the reflex contraction.
- however, when the tension becomes great enough, contraction suddenly ceases and the muscle relaxes.
- This relaxation in response to strong stretch is called **Inverse Stretch Reflex.**
- The Receptor for the inverse stretch reflex **is in the Golgi Tendon Organ.**

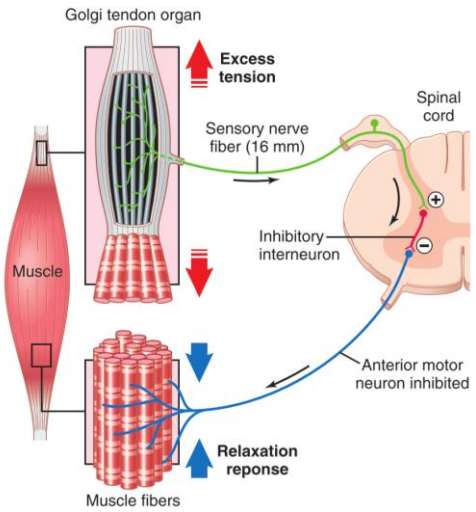


The inverse stretch reflex:

Reflex	Golgi tendon or inverse stretch reflex (autogenic inhibition)
Clinical test stimulus	increased tension by large force on tendon (pull on muscle when rested)
Response	Muscle tendon decreases) calsped knife reflex(
Sensory receptors	Golgi tendon organ "at the **tendon** yhself eht ton , "trap
Synapses involved	Polysnaptic (via interneuron)
Afferent	Type Ib afferent fibres
Effects on muscle	• Relaxes same muscle • Relaxes synergistic muscles
Other effects	Contraction(+) of an antagonistic muscle
Function	Protective (prevents damage to tendon)

The golgi tendon reflex (Inverse stretch reflex):

- It is a deep and polysynaptic reflex
- Opposite response to stretch reflex



mechanism:

excessive tension in the muscle (By passive over stretch of tendon or severe active muscle contraction (causes muscle relaxation

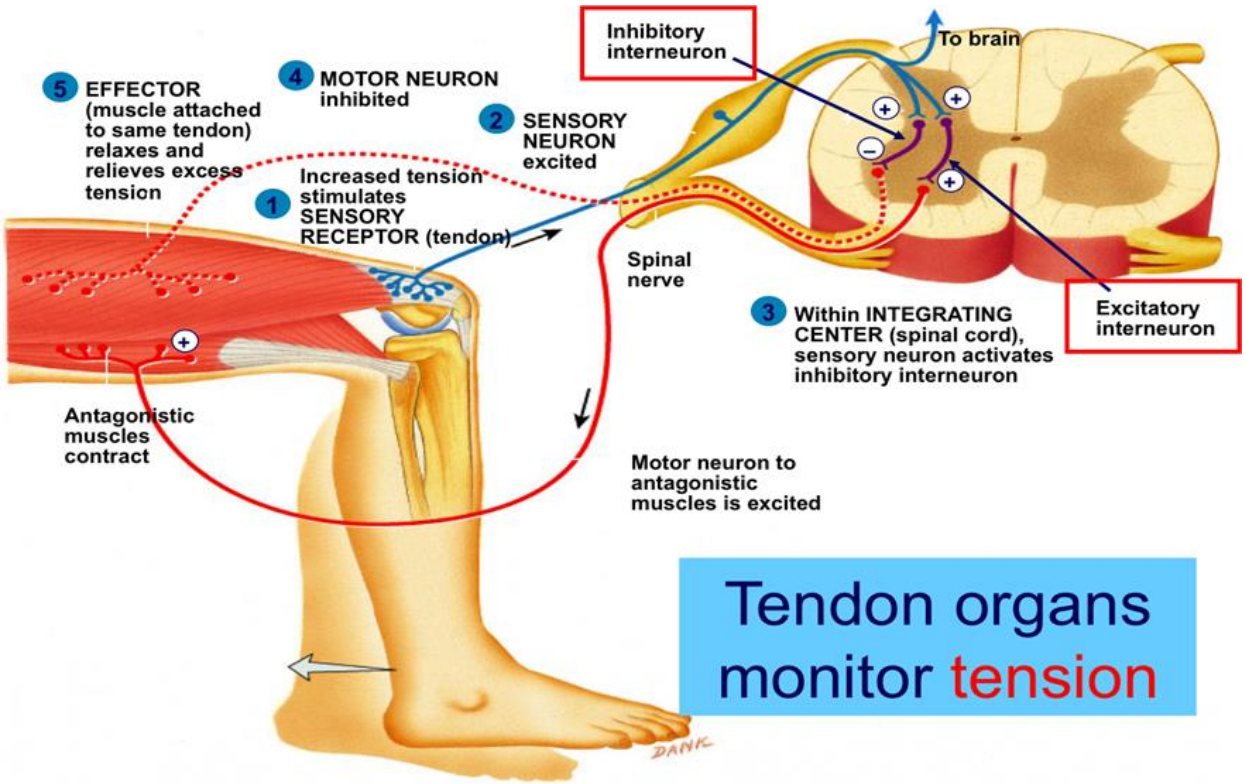
Receptor Golgi tendon organs

Golgi tendon organs :(25-3) They are present in tendons and encapsulated sensory receptors through which muscle tendon fibers pass.

- About 10 to 15 muscle fibers are usually connected to each golgi tendon organ
- they Transmit information about tendon tension or rate of change of tension.
- the organ is stimulated when this small bundle of muscle fibers is "tensed "by severe contraction.
- Thus, the major difference in excitation of the Golgi tendon organ versus the muscle spindle **,htgnel elcsum ni segnahc dna htgnel elcsum stceted eldnips eht taht si .flesti ni noisnet eht yb detcelfer sa noisnet elcsum stceted nagro nodnet eht saerehw**

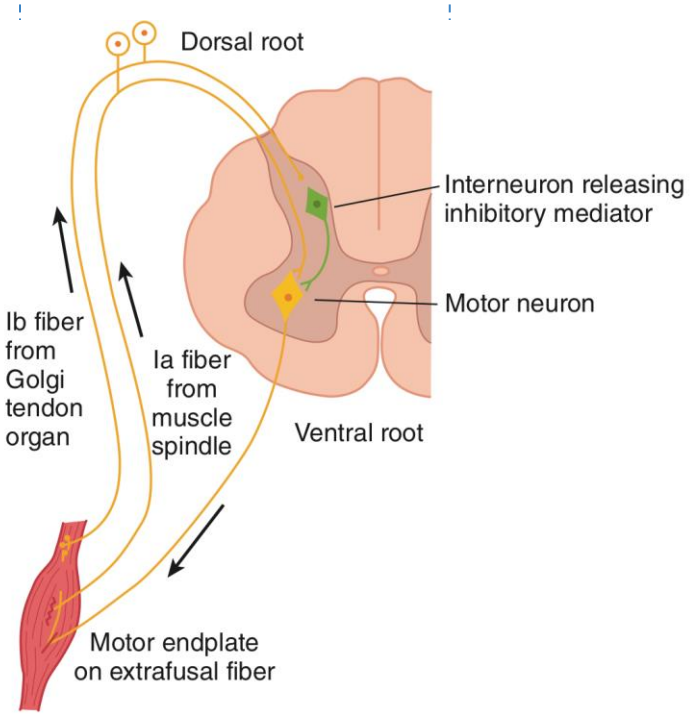
Inhibitory Nature of the Tendon Reflex and Its Importance:

- Stimulated golgi tendon organ by an increase in muscle tension → impulses via fast **Ib** evren 16 egareva taht srebif gnitcudnoc yldipar ,egral ,srebifmicrometers in diameter → SC → The local cord signal excites *inhibitory* rotom ahpla tibihni (enicylG eterces) noruenretni noruen ***negative feedback mechanism*** *(noitcaer gninehtgnel)* noitaxaler elcsum
- Also stimulate *excitatory interneuron to antagonist (Reciprocal Innervation)*
- **Value:**raet dna noisluva nodnet dna erutpur morf selcsum stcetorP



Comparison Between Stretch & Inverse Reflexes:

	Stretch reflex	Inverse stretch reflex
Stimulus	Increased muscle length	Increased muscle tension
Response	Muscle contraction	Muscle relaxation
Receptor	Muscle spindles	Golgi tendon organs
Afferents	Type IA and Type II fibers	Type IB fibers
Synapses	Mono-synaptic	Poly-synaptic
Reciprocal Innervation Regulation	Inhibit antagonists through inhibitory interneurons	Excites antagonistic muscles through excitatory Interneurons
Physiological significance	Regulate muscle length Genesis of muscle tone	Regulate muscle tension to prevent excessive tension increase
Clinical assessment	Sudden tap of muscle causes brisk contraction muscle jerk	Over stretch of muscle-sudden muscle relaxation (lengthening reaction)



1. The number of synapses in the stretch reflex are:
   A. .One (monosynaptic)
   B. .Two (disynaptic)
   C. .Three (trisynaptic)
   D. .B&C

.2the spindles can send to the spinal cord in:
   A. .Positive signals
   B. .Negative signals
   C. .No signal
   D. .A&B

.3Which of the following is not a factor INHIBIT the stretch:
   A. .Anxiety
   B. .Basal ganglia
   C. .excessive stretch reflex of muscle
   D. .medullary RF

.4The response of golgi tendon reflex is:
   A. .Muscle contraction
   B. .no response
   C. .muscle relaxation
   D. .A&C

.5Muscle spindle is:
   A. .sensory neuron
   B. .motor neuron
   C. .effector
   D. .sensory receptor

.6motor neuron of stretch reflex:
   A. .Alpha
   B. .Type II
   C. .Gamma
   D. .A&C

.7Which of the following is NOT a factor enhance the stretch:
   A. .Anxiety
   B. .Jendrassik-manuver
   C. .Excessive stretch of muscle
   D. .Noxious painful stimuli

.8muscle spindles detect:
   A. .Length
   B. .Tension
   C. .nothing
   D. .A&B

.9golgi tendon organ activates group:
   A. .Ib afferent nerves
   B. .II afferent nerves
   C. .Ia afferent nerves
   D. .A&B

.10When a person steps on a tack with their left foot, flexor muscles on the right leg and extensor muscles on the left leg will be stimulated:
   A. .True
   B. .False

Answers:
.1A
.2D
.3A
.4C
.5D
.6D
.7C
.8A
.9A
.10B