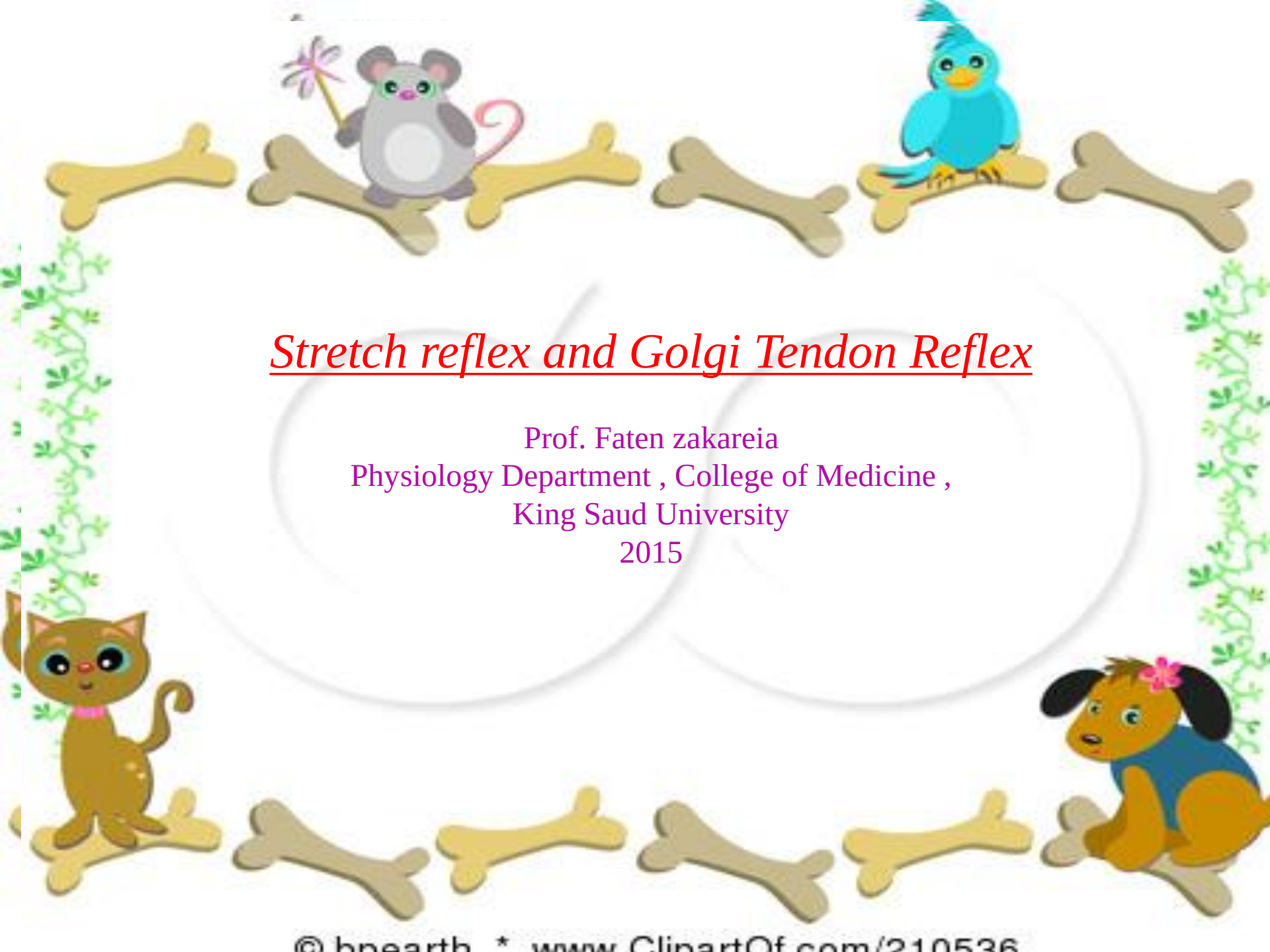


Stretch reflex and Golgi Tendon Reflex

Prof. Faten zakareia
Physiology Department , College of Medicine ,
King Saud University
2015

- **Objectives:**

Upon completion of this lecture, students should be able to know and explain :

- The definition and components of stretch reflex
- The structure , innervations and function of the muscle spindle
-Sensory primary and secondary (flower-spray) sensory afferent fibres 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

Textbook/Guyton & Hall

Reference book/Ganong review of medical physiology

THE STRETCH REFLEX

REFLEX	STRETCH (MYOTACTIC) REFLEX	
CLINICAL TEST | STIMULUS	RAPID STRETCH OF MUSCLE (TAP ON MUSCLE TENDON)	
RESPONSE	STRETCHED MUSCLE CONTRACT RAPIDLY (I.E. KNEE JERK)	
SENSORY RECEPTOR	MUSCLE SPINDLE PRIMARY	
SYNAPSES INVOLVED	MONOSYNAPTIC	
EFFECTS ON MUSCLE	CONTRACTS (+) SAME MUSCLE AND SYNERGISTIC MUSCLES	
OTHER EFFECTS	RELAXES (-) ANTAGONISTIC MUSCLE	
FUNCTION	AIDS IN MAINTAINING POSTURE, avoid muscle rupture,counters sudden loads	

https://musom.marshall.edu/anatomy/grosshom/allppt/pdf/Spinalreflexes.pdf

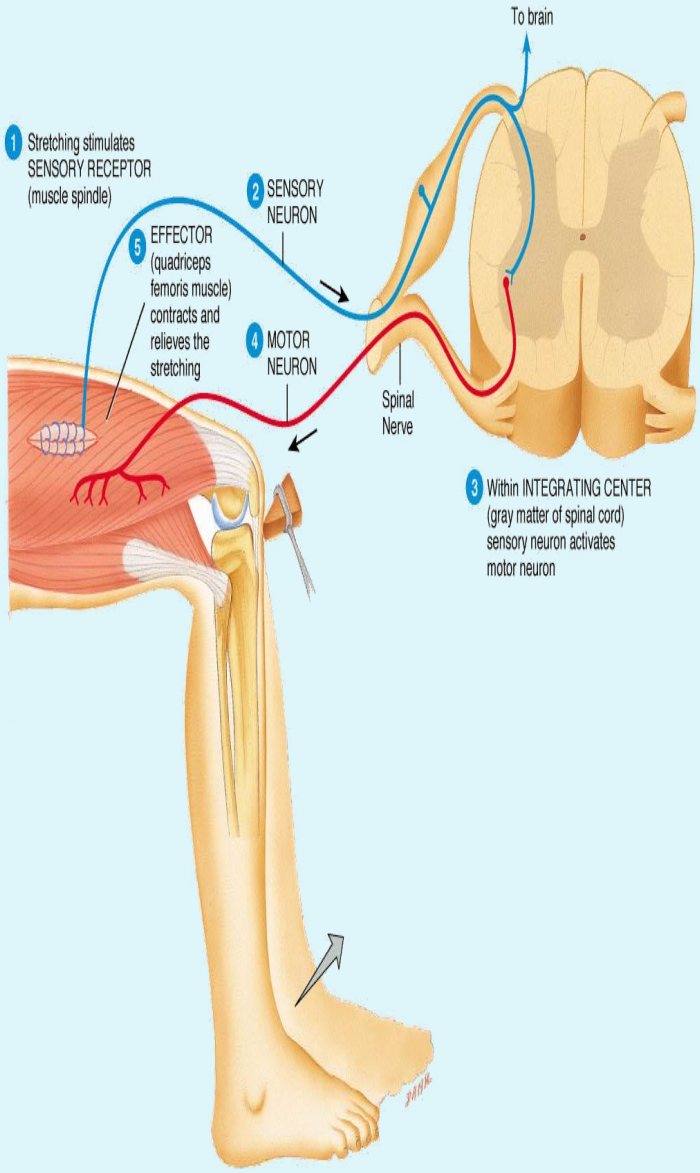
What is the Stretch Reflex ?

• It is reflex contraction of muscle resulting from stimulation of the **muscle spindle** by stretch

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

-Monosynaptic Deep reflex(one sensory neuron synapse with one motor neuron)

-Example/tendon jerks)



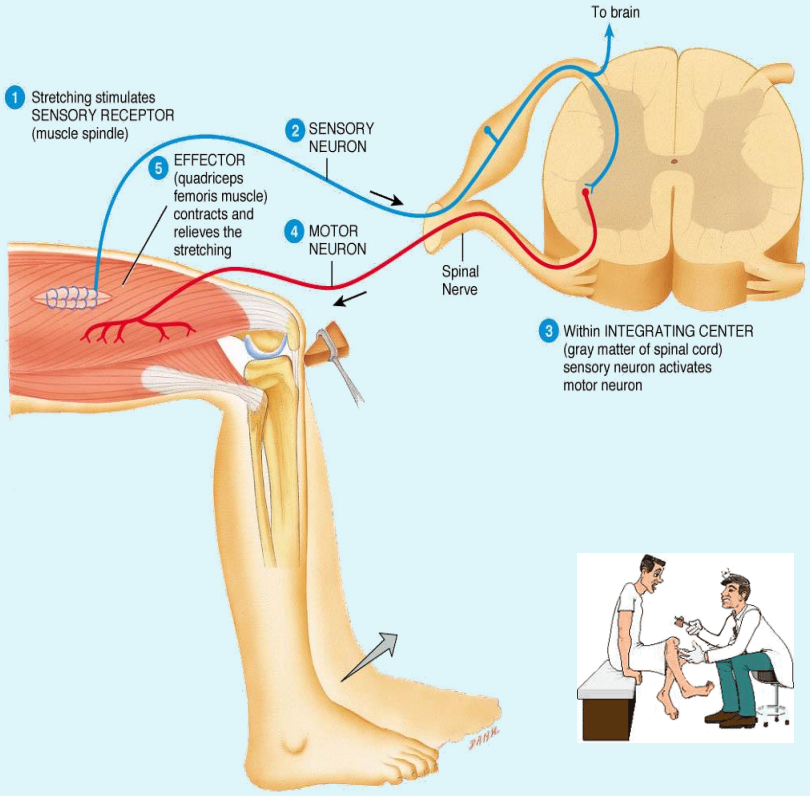
THE STRETCH REFLEX

A **STRETCH REFLEX** CAUSES CONTRACTION OF A SKELETAL MUSCLE (THE EFFECTOR) IN RESPONSE TO STRETCHING OF THE MUSCLE

THIS TYPE OF REFLEX OCCURS VIA A MONOSYNAPTIC REFLEX ARC

THE REFLEX CAN OCCUR BY ACTIVATION OF A SINGLE SENSORY NEURON THAT FORMS ONE SYNAPSE IN THE CNS WITH A SINGLE MOTOR NEURON

AN EXAMPLE OF A STRETCH REFLEX IS THE PATELLAR REFLEX (KNEE JERK)



Stretch reflex

1-Deep-monosynaptic reflex

Components:-

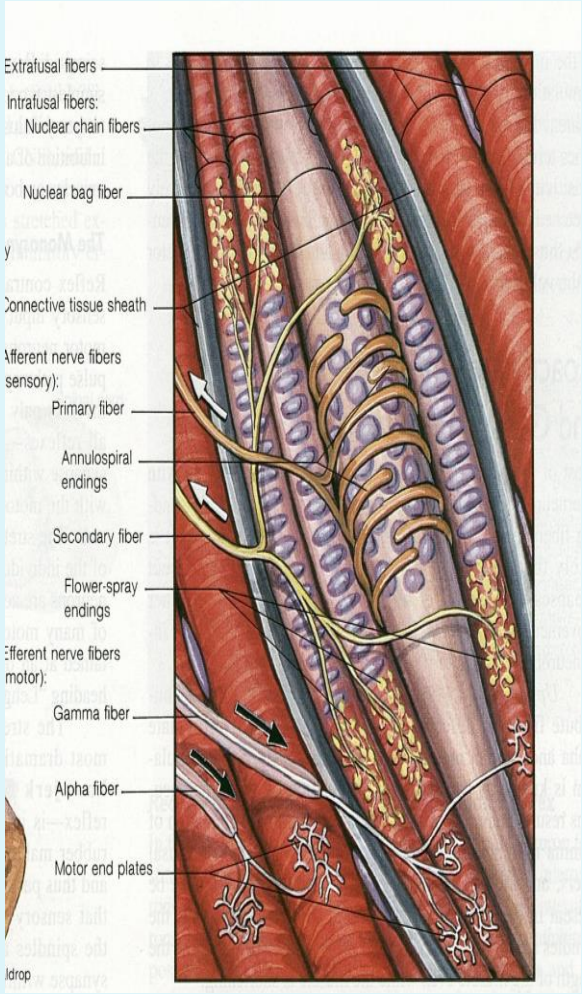
- **Receptor : muscle spindle**
- **Afferent (annulo-spiral + flower spray)**
- **AHC (center)**

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

- **Efferent include/**
- **1- alpha motor fibers(70% of motor supply, arise from alpha motor neurons to supply extrafusal muscle fibers)**
- **2- gamma efferent (from gamma motor neurons 30% to muscle spindle (intra-fusal fibers)**
- **Effector /muscle**

Structure of Stretch reflex receptor (Muscle Spindle:-

-Muscle spindle consists of 3-12 small muscle fibres (intrafusal fibres) within CT capsule.
- parallel to extrafusal fibres & attached to it or to tendons.
-Each intrafusal fibre has:
-Central non-contractile area (receptor)
-Peripheral contractile area on each side of central zone, it has actin & myosin.

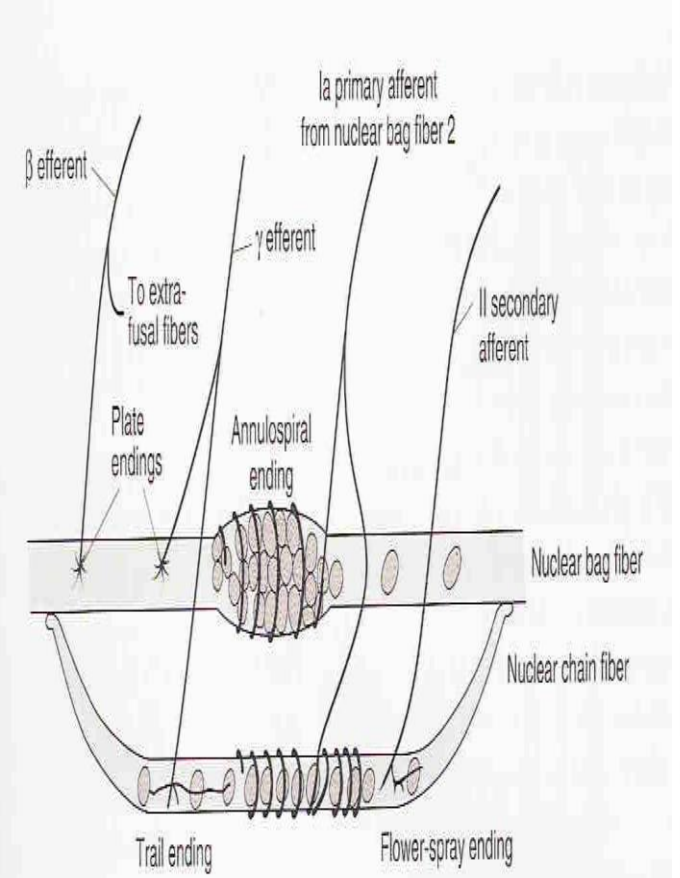


Muscle Spindle(cont)

Has two types of intrafusal fibres:

1-Nuclear bag fibres : (2 / spindle)
- Central area is dilated with group of nuclei

2-Nuclear chain fibres: (about 4 or more /spindle) . Thinner & shorter - -one line of nuclei in a chain in the - receptor zone
- bind to nuclear bag on each side



MUSCLE SPINDLES

THERE ARE TWO TYPES OF INTRAFUSAL FIBRES PRESENT IN MUSCLE SPINDLES:

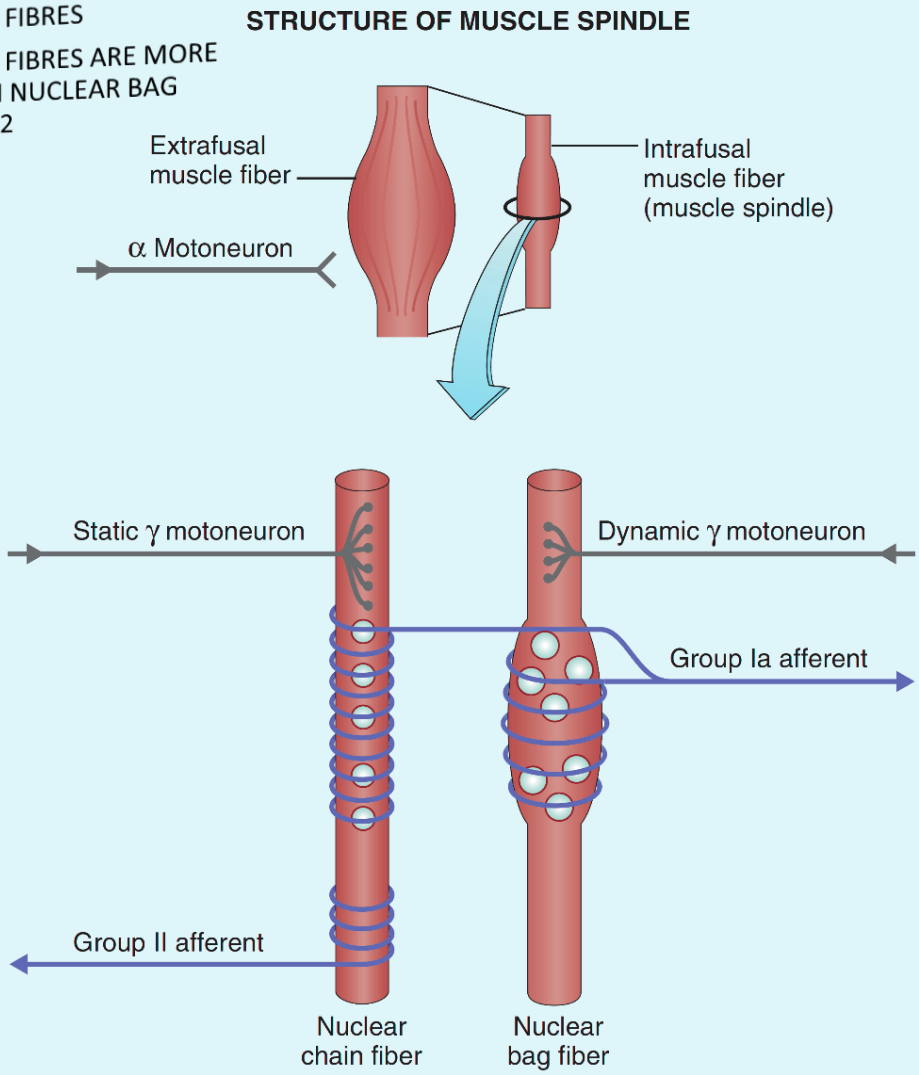
NUCLEAR BAG FIBRES

NUCLEAR CHAIN FIBRES

NUCLEAR CHAIN FIBRES ARE MORE PLENTIFUL THAN NUCLEAR BAG FIBRES. RATIO 5:2

NUCLEAR BAG FIBRES ARE LARGER, AND THEIR NUCLEI ARE ACCUMULATED IN A CENTRAL ("BAG") REGION

NUCLEAR CHAIN FIBRES ARE SMALLER, AND THEIR NUCLEI ARE ARRANGED IN ROWS ("CHAINS")



Innervation of the muscle spindle

It has afferent & efferent nerve fibers

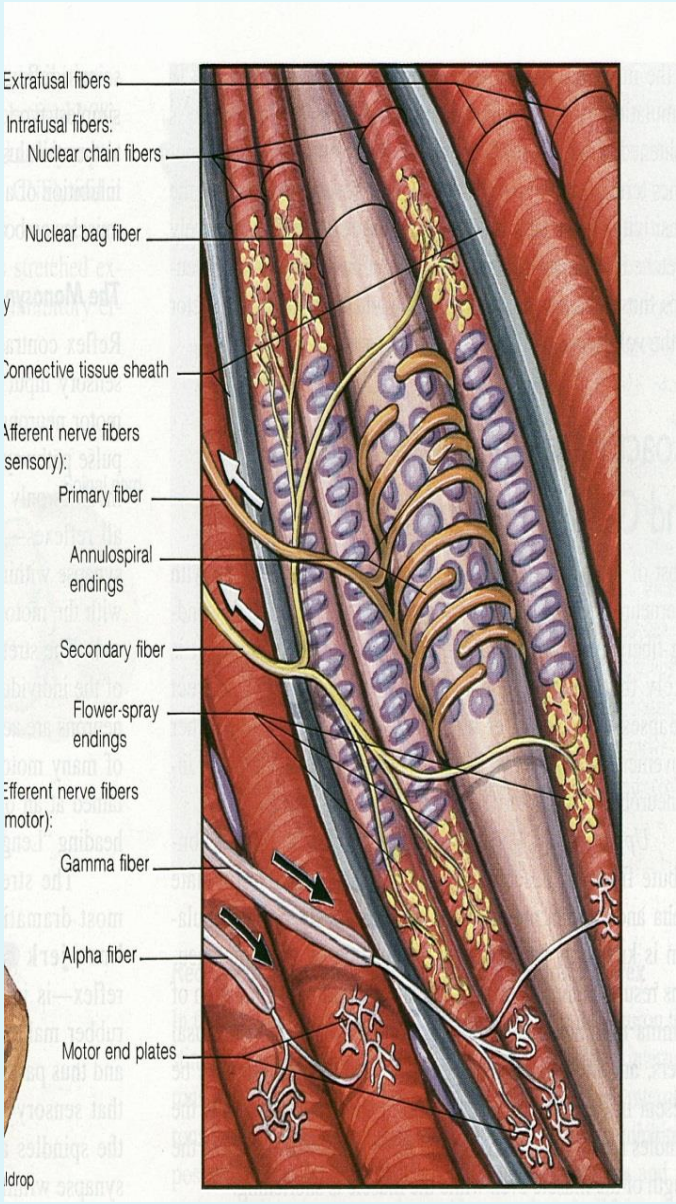
1-Sensory Afferent fibres:

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

1-Primary (annulospiral) endings (Ia fibres): fast, encircle receptor areas of both nuclear bag (mainly) and nuclear chain fibres ,synapse directly with the motor neurons (AHC)

-discharge most rapidly if the muscle is suddenly stretched and less rapidly (or not) during sustained stretch

- Type Ia fiber,17 micrometers in diameter , transmits sensory signals to the spinal cord at a velocity of 70 to 120 m/sec
- -Measure the rate & or velocity of change in muscle length of nuclear bag fibres (This response is called the Dynamic response (as in tendon jerks)



2-Secondary (flower-spray) (Group II) sensory endings:

-

-type II fibers ,diameter of 8 micrometers—innervate the receptor **area of the nuclear chain fibres ONLY.**

on one or both sides of the primary ending

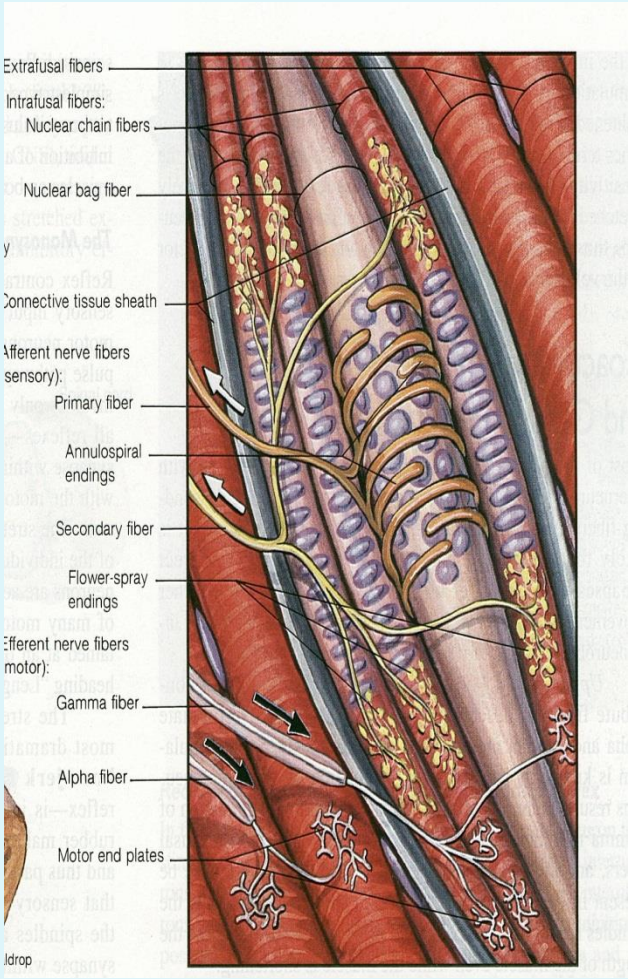
--Discharge throughout the period of muscle stretch, (sustained stretch) (measure mainly muscle length).

- This response is known as the((Static response)

- **N.B/**
- The primary sensory nerve ending is excited by both the nuclear bag *and* the nuclear chain fibers. Conversely, 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.



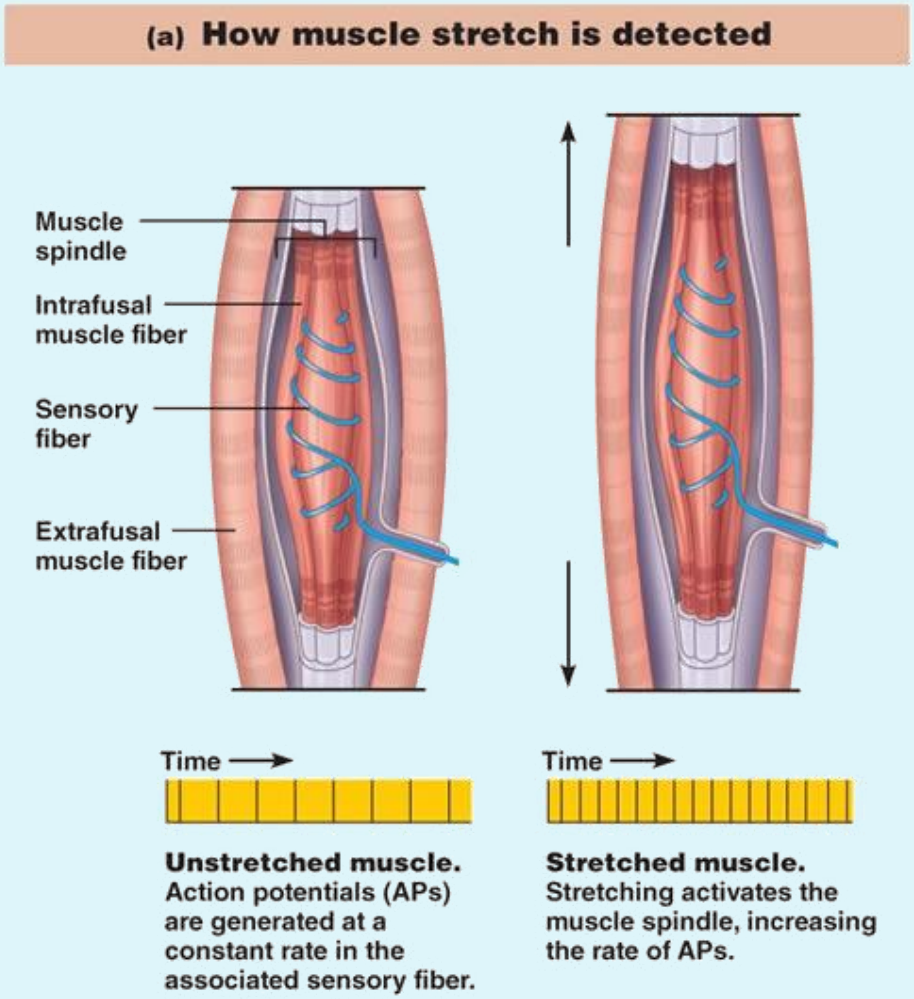
THE ROLE OF MUSCLE SPINDLES

- NUCLEAR BAG FIBRES
  - CAN SENSE THE ONSET OF STRETCH
  - CAN RESPOND TO RAPID STRETCH

- NUCLEAR CHAIN FIBRES
  - 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

- 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



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

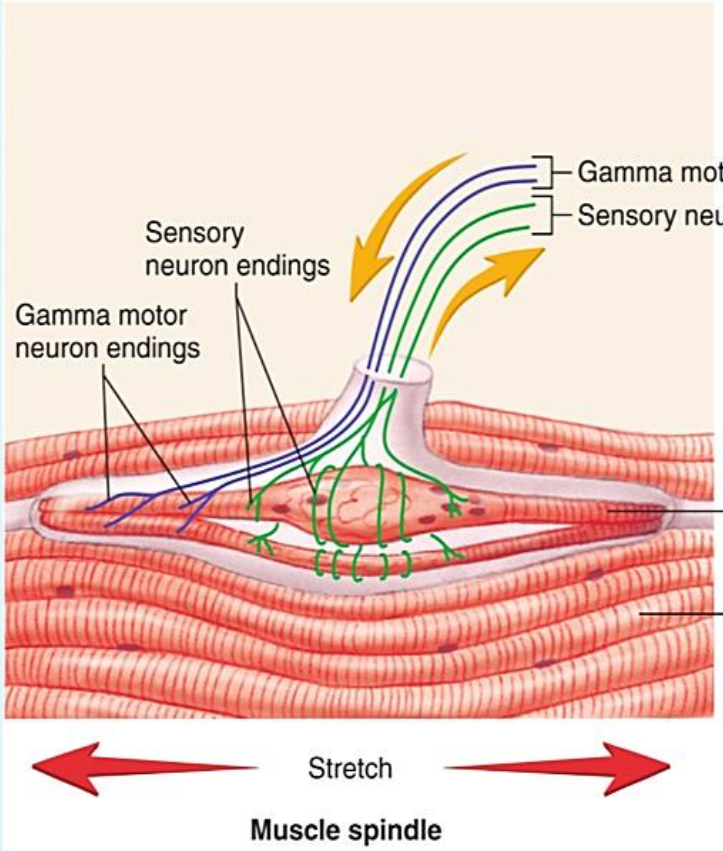
-Conversely, when the spindle receptor shortens, exactly opposite sensory signals occur.
-- Thus, the spindles can send to the spinal cord either *positive signals*—that is, increased numbers of impulses to indicate stretch of a muscle—or *negative signals*—below- normal numbers of impulses to indicate that the muscle is unstretched

- to apprise the spinal cord it of any change in length of the spindle receptor

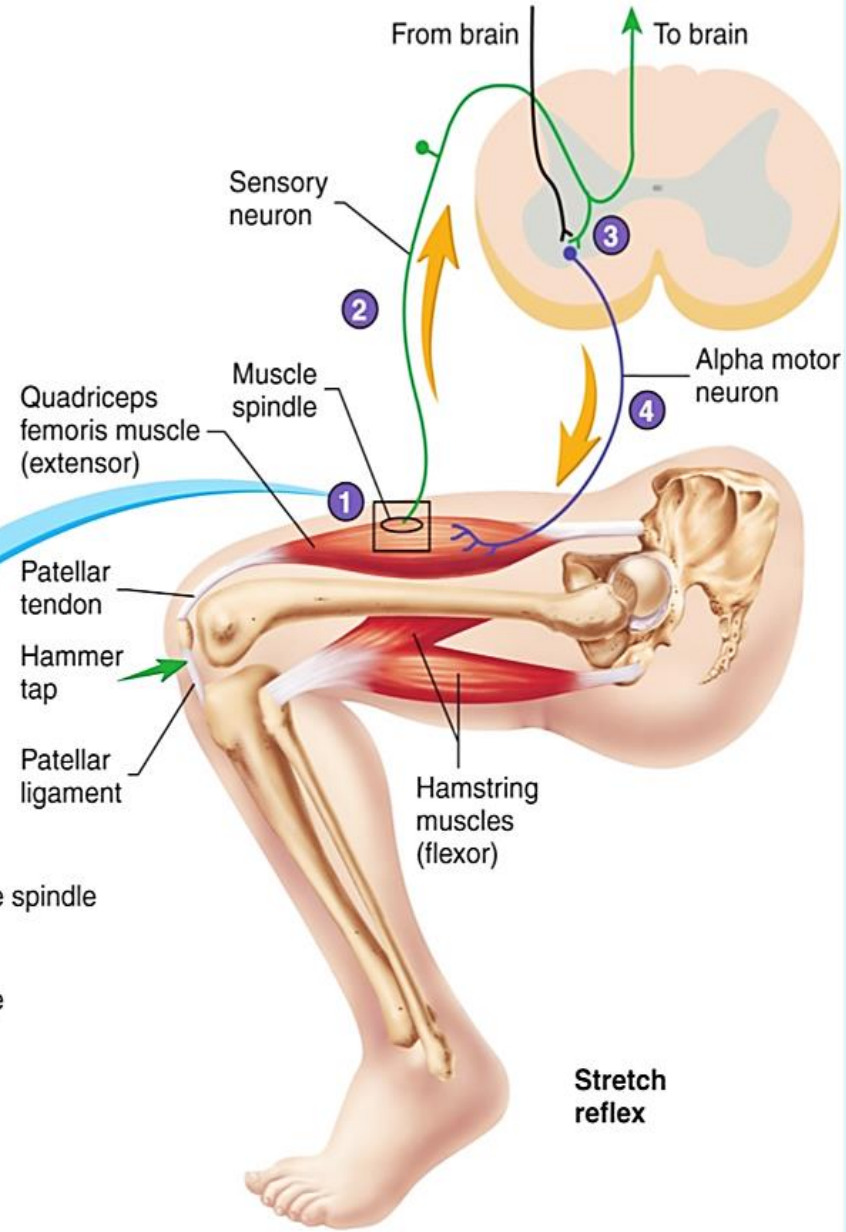
.

Sudden stretch of a muscle results in:

1. Muscle spindles detect stretch of the muscle.
2. Sensory neurons conduct action potentials to the spinal cord.
3. Sensory neurons synapse directly with alpha motor neurons.
4. Alpha motor neurons conduct action potentials to the muscle, causing it to contract and resist being stretched.
   Note: The muscle that contracts is the muscle that is stretched.



Muscle spindle



Stretch reflex

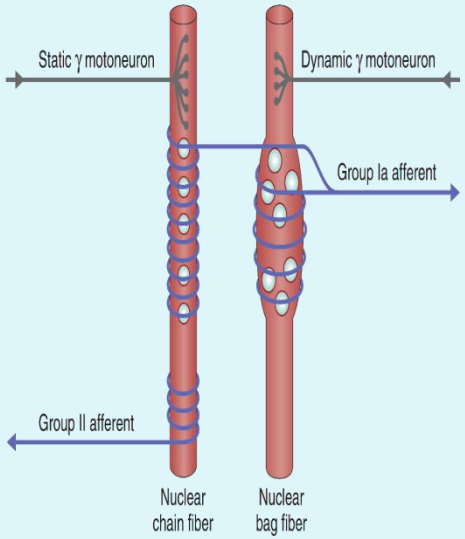
(Motor Efferent fibres to muscle spindle)

-Gamma motor neurons >>>>gamma efferent>>>>> to the peripheral contractile parts of the intrafusal muscle fibres ,of two types:

1-Plate endings / end mainly on the nuclear bag fibres (called Dynamic gamma efferent)= γ - d.

2-Trail endings / end mainly on nuclear chain fibres (called Static gamma efferent) = γ –s

-The function of the γ motoneurons (either static or dynamic) is to regulate the sensitivity of the intrafusal muscle fibres they innervate



-when **Gamma motor neurons** activated, can make the muscle spindles 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

Stretch reflex

1- Stretching of the muscle>>>>Stretching extrafusal muscle fibers >> Stretching intrafusal peripheral contractile fibers>>>>>> + stretch receptor zone (central) in intrafusal fibre >> +stimulation of sensory afferent endings encircling receptor area.

-Afferent impulses >> spinal cord >> stimulate:

1-alpha motor neurons,(70%) which send impulses to extrafusal ordinary muscle fibres >>muscle to contract.

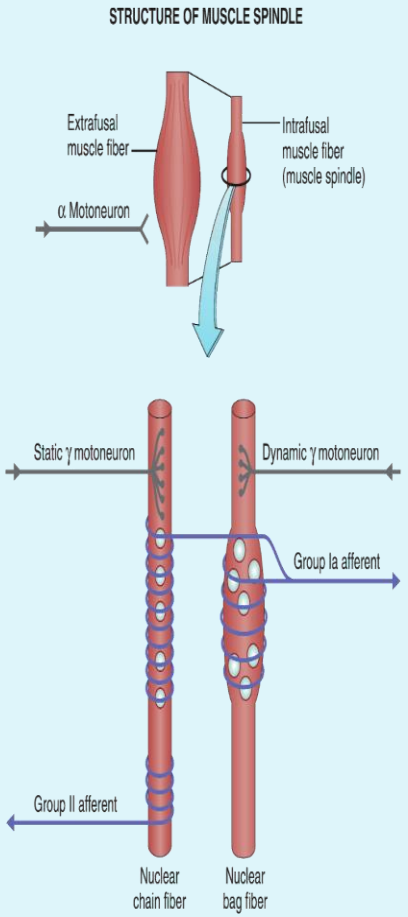
2-gamma motor neurons (30%) which send impulses to intrafusal peripheral contractile fibers causing contraction of the peripheral contractile parts of the intrafusal fibres & stretch central receptor zone to excite afferent fibers

Types of responses

Component of stretch reflex

1-Dynamic stretch reflex (dynamic or phasic response)

- **Sudden rapid stretch of a muscle >> stimulate Nuclear bag fibers which respond to rate or velocity of stretch>>>> discharge Synchronous 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)**



- -Conversely, when the spindle receptor shortens, the primary ending sends extremely strong, negative to inform it about muscle unstretch
- -a strong signal is transmitted to the spinal cord; this causes an instantaneous strong reflex contraction (or decrease in contraction)
- -Thus, the reflex functions to oppose sudden changes in muscle length.

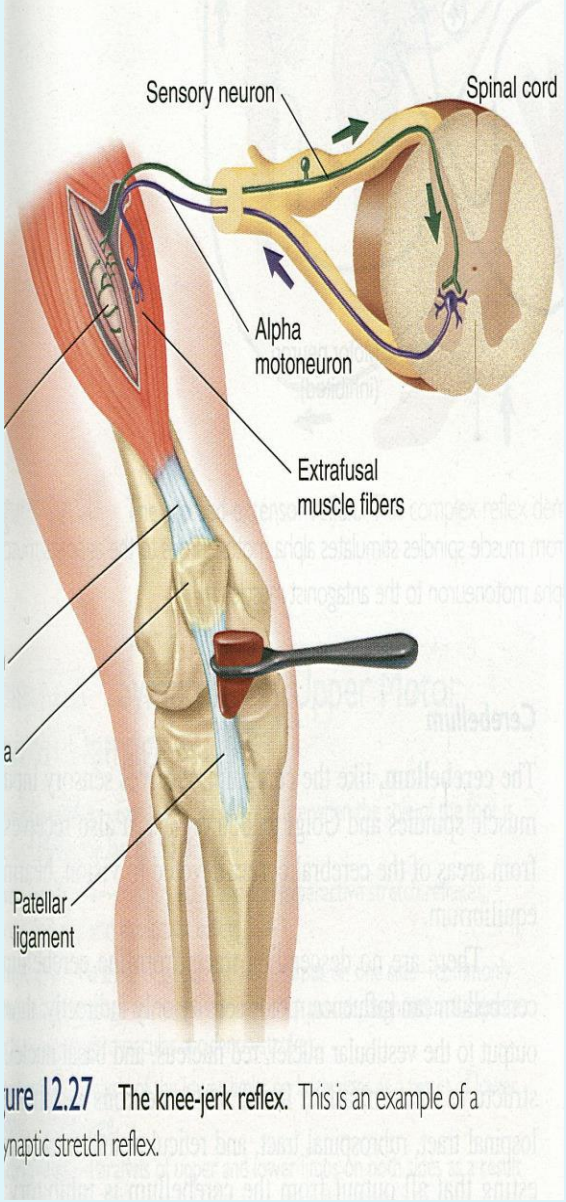
-Dynamic stretch reflex is the Basis of tendon jerk (contraction followed by relaxation) (knee,biceps,triceps)

Clinical Applications of the Stretch Reflex

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

-Dynamic gamma efferent (plate 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)



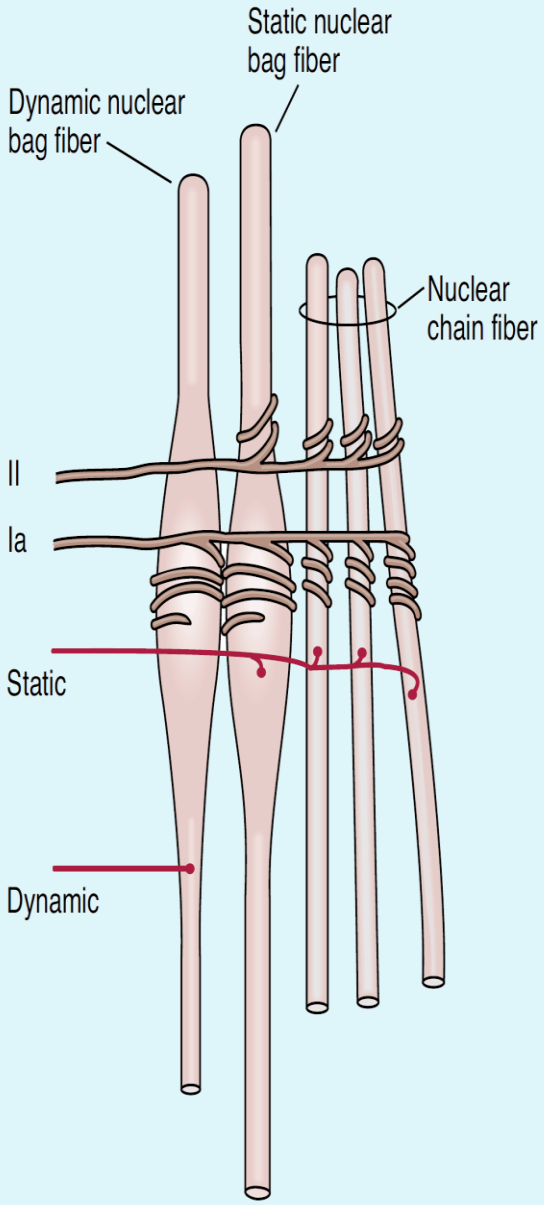
ure 12.27 The knee-jerk reflex. This is an example of a ynaptic stretch reflex.

2- Static stretch reflex(static response)

- 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

-Basis of muscle tone

- B-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 Tone(Static stretch reflex)

Dif/ resistance of muscle to stretch

-Stimulus for muscle tone /Is sustained Stretch of skeletal muscle between origin and insertion

-Present in antigravity muscle (extensors of LL, back, neck, flexor of UL, muscle of abdominal wall and elevator of mandible

-if lost by low gamma efferent discharge to muscle
>>>>>hypotonic or flacidity

-if increased by high gamma efferent discharge to muscle
>>>>>>hypertonic , spastic muscle
.

- **Damping" or smoothing Function of the Dynamic and Static Stretch Reflexes**

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

Functions of muscle spindle:-•

1-keep 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 **(PROPRIOCEPTION)**

2-muscle spindle act to maintain • muscle length against rupture:-

-

Muscle can contract by:-

1- stimulation of alpha motor neurons by muscle stretch:

- **Stretching the muscle bulk (extrafusal fibers) stretches the receptor (muscle spindle)**
- **AP discharges in the spindle afferents (annulospiral or flower-spray)to Alpha Motoneuron ,**

2- stimulation of gamma motor neurons

-By stimulating Gamma Efferents by supraspinal impulses . Gamma efferent discharge cause contraction of peripheral ends of intrafusal fiber stretching the receptor zone

3- Coactivation stim of both alpha&gamma .

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

- This causes both the extrafusal skeletal muscle fibers and the muscle spindle intrafusal muscle fibers to contract at the same time.

-The purpose of **Coactivation**

- First, it keeps the length of the receptor portion of the muscle spindle constant

.

- - Second, it maintains the proper damping function of the muscle spindle

-One of the most important functions of the muscle spindle system is to stabilize body position during tense motor action and during walking and running

- the bulboreticular facilitatory region transmit excitatory signals through the gamma nerve fibers to the intrafusal muscle fibers of the muscle spindles. This shortens the ends of the spindles and stretches the cen- tral receptor regions, thus increasing their signal out- put.

-However, if the spindles on both sides of each joint are activated (for agonist & antagonist), reflex excitation of the skeletal muscles on both sides of the joint also increases, producing tight, tense muscles opposing each other at the joint. The net effect is that the position of the joint becomes strongly stabilized,

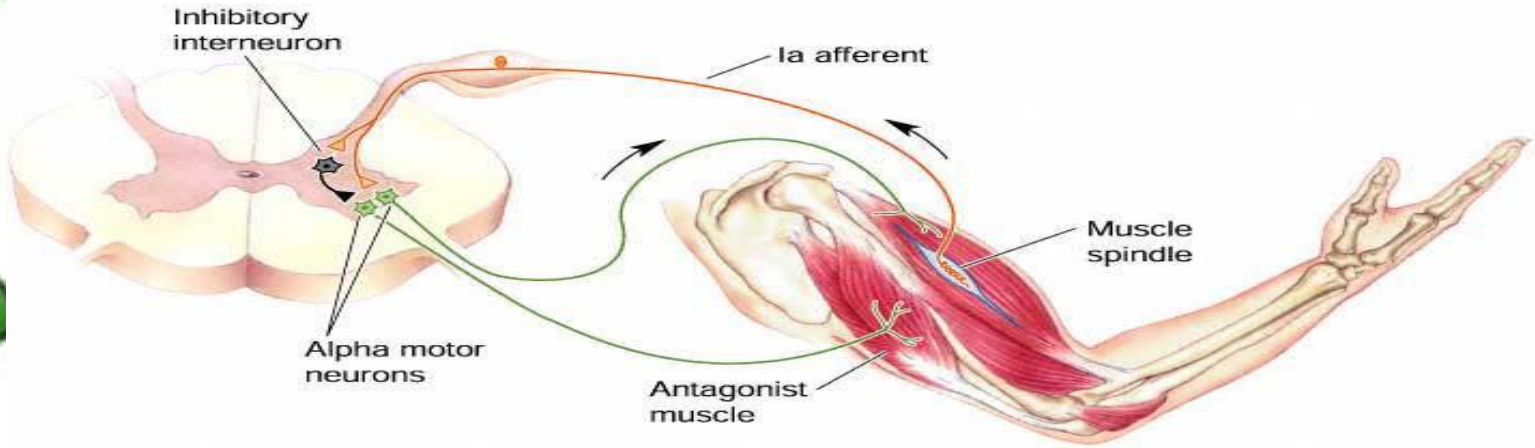
.

Reciprocal inhibition with stretch reflex as IN KNEE JERK,Biceps 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>>>> SC to <u>cause:-</u>

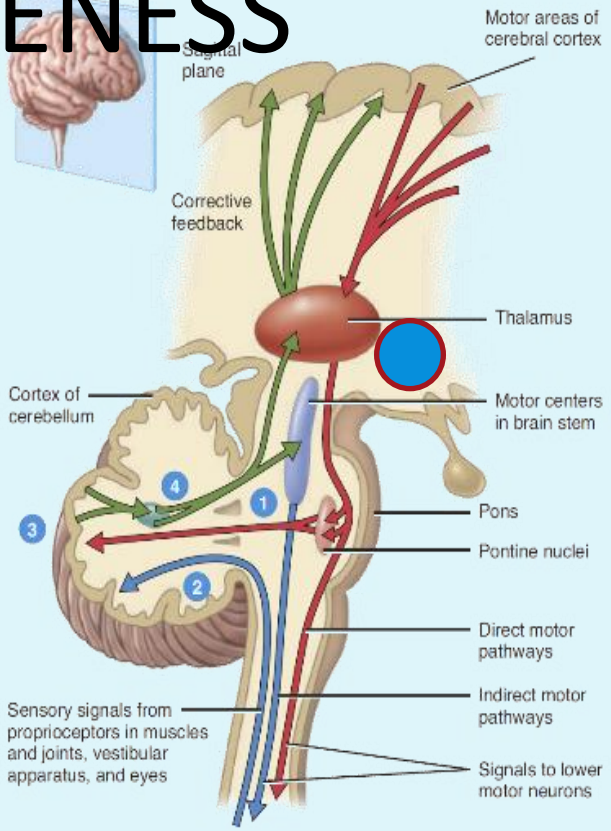
1-stimulate the motor neurons of the stimulated muscle to cotract (by glutamate)

2- send collaterals >>>> 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)

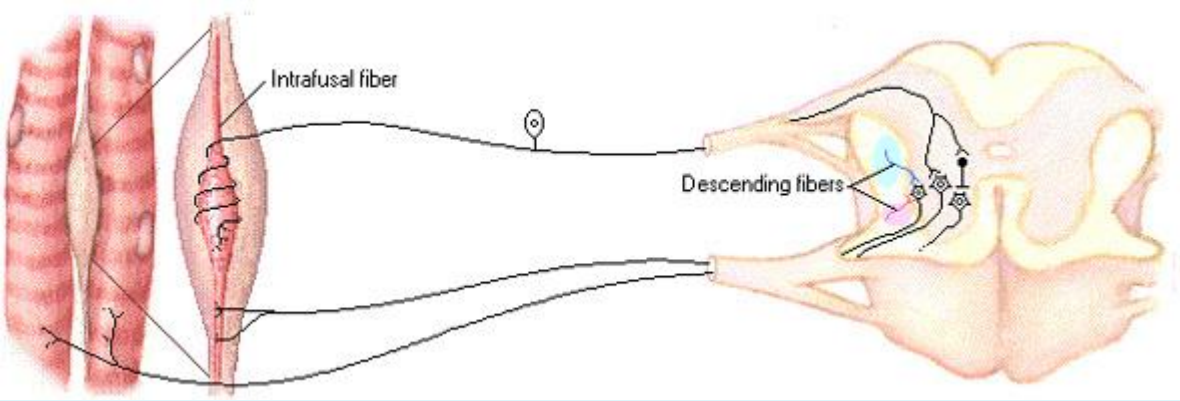
CONSCIOUS AWARENESS

- 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.



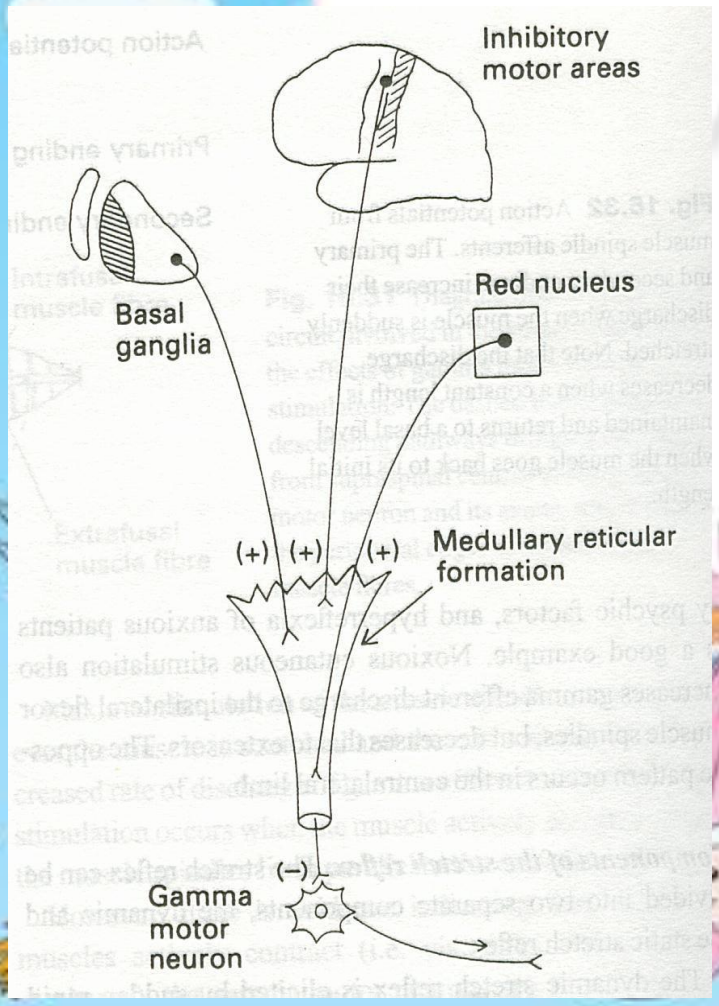
SUPRASPINAL REGULATION OF THE STRETCH REFLEX

- 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., <u>reticulospinal and vestibulospinal</u>

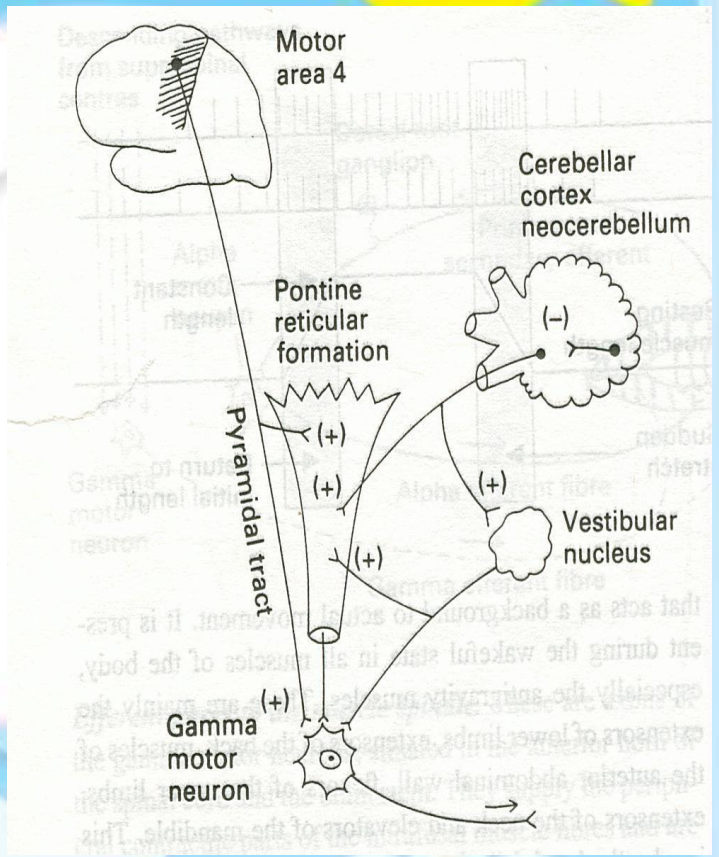


http://humanphysiology.tuars.com/program/section8/8ch3/s8ch3_20.htm

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

1-Suprspinal

- -Primary motor area4
- -Vestibular N
- -Pontine RF(bulboreticular)
- -Neocerebellum

2-Anxiety

3-Noxious painful stimuli

4-Jendrassik-manuver

Inhibits

1-Supraspinal

- -Cortical (suppressor area4&Area 6)
- -Basal ganglia
- -Medullary RF
- -Red nucleus
- -paleocerebellum

2-Excessive stretch of muscle(golgi tendon reflex)

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 (CLASPED KNIFE REFLEX)	
SENSORY RECEPTOR	GOLGI TENDON ORGAN	
SYNAPSES INVOLVED	POLYSYNAPTIC (VIA INTERNEURON)	
EFFECTS ON MUSCLE	RELAXES SAME MUSCLE	RELAXES SYNERGISTIC MUSCLES
OTHER EFFECTS	CONTRACTION (+) OF ANTAGONISTIC MUSCLE	
FUNCTION	PROTECTIVE | PREVENTS DAMAGE TO TENDON	

https://musom.marshall.edu/anatomy/grosshom/allppt/pdf/Spinalreflexes.pdf

The Golgi tendon reflex

- Deep & polysynaptic reflex

-(opposite response to stretch reflex).

-Excessive tension in the muscle (by passive over-stretch of tendon or active muscle contraction) >>> cause muscle relaxation

-The receptors are Golgi tendon organs (3-25) present in tendons are encapsulated sensory receptor through which muscle tendon fibers pass. About 10 to 15 muscle fibers are usually connected to each Golgi tendon organ, and the organ is stimulated when this small bundle of muscle fibers is "tensed" by contracting

Inhibitory Nature of the Tendon Reflex and Its Importance

-Stimulated golgi tendon organ>>> impulses via fast Ib nerve fibers , large, rapidly conducting fibers that average 16 micrometers in diameter >>>> SC >>> The local cord signal excites *inhibitory* interneuron (secrete Glycine)>> inhibit alpha motor neuron >>> negative feedback mechanism>>>>>muscle relaxation(lengthening reaction)

- Also stim excitatory interneuron to antagonist.(reciprocal innervation)

Value/Protect muscle from rupture& tendon from avulsion& tear

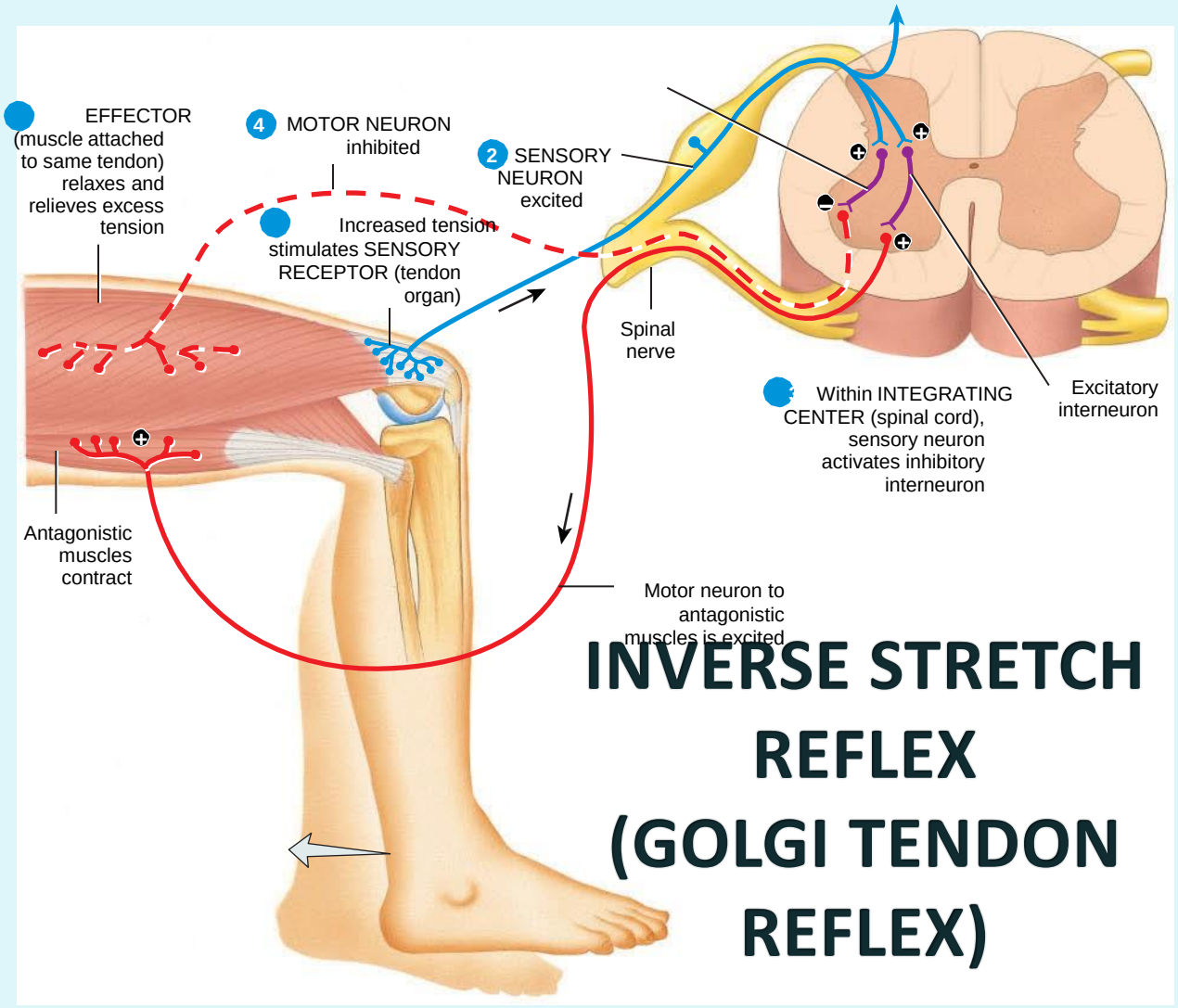
-

UP TO A POINT, THE HARDER A MUSCLE IS STRETCHED, THE STRONGER IS THE REFLEX CONTRACTION.

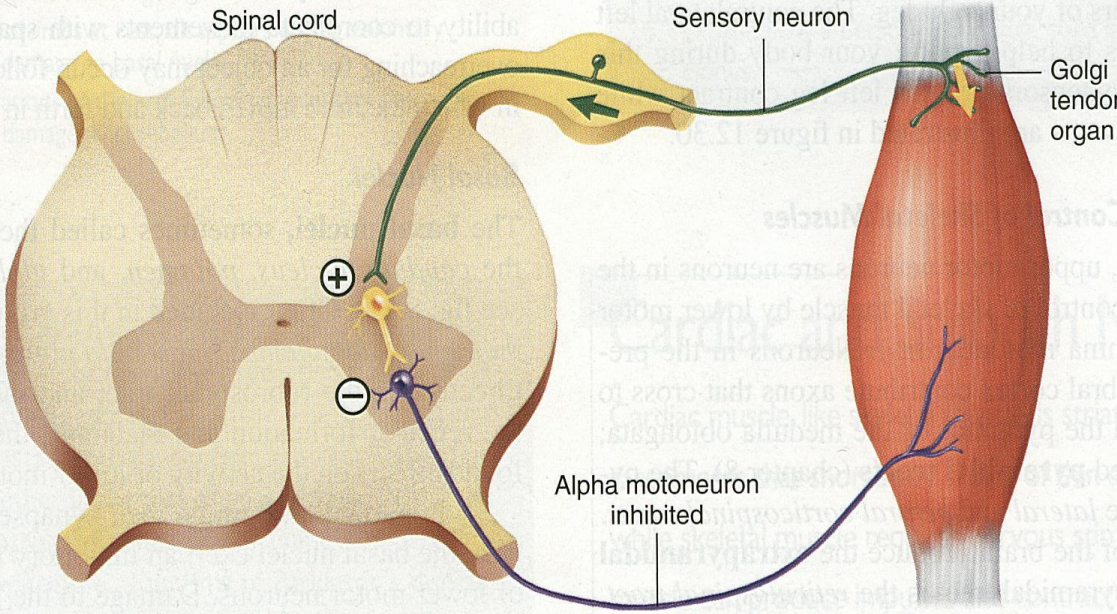
HOWEVER, WHEN THE TENSION BECOMES GREAT ENOUGH, CONTRACTION SUDDENLY CEASES AND THE MUSCLE RELAXES.

THIS RELAXATION IN RESPONSE TO STRONG STRETCH IS CALLED THE **INVERSE STRETCH REFLEX .**

THE RECEPTOR FOR THE INVERSE STRETCH REFLEX IS IN THE **GOLGI TENDON ORGAN**



The Golgi tendon reflex (inverse stretch reflex)



ure 12.28 **The action of the Golgi tendon organ.** An increase in muscle tension stimulates the activity of sensory nerve endings in the Golgi organ. This sensory input stimulates an interneuron, which in turn inhibits the activity of a motor neuron innervating that muscle. This is therefore a tic reflex.