



Stretch reflex and Golgi Tendon Reflex

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• **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	

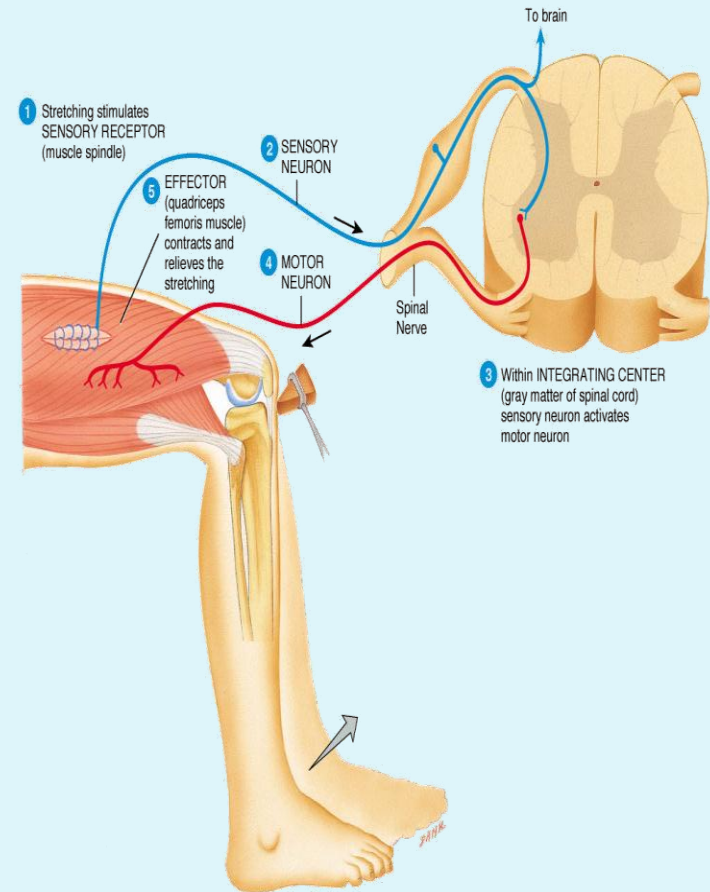
What is the Stretch Reflex ?

- 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



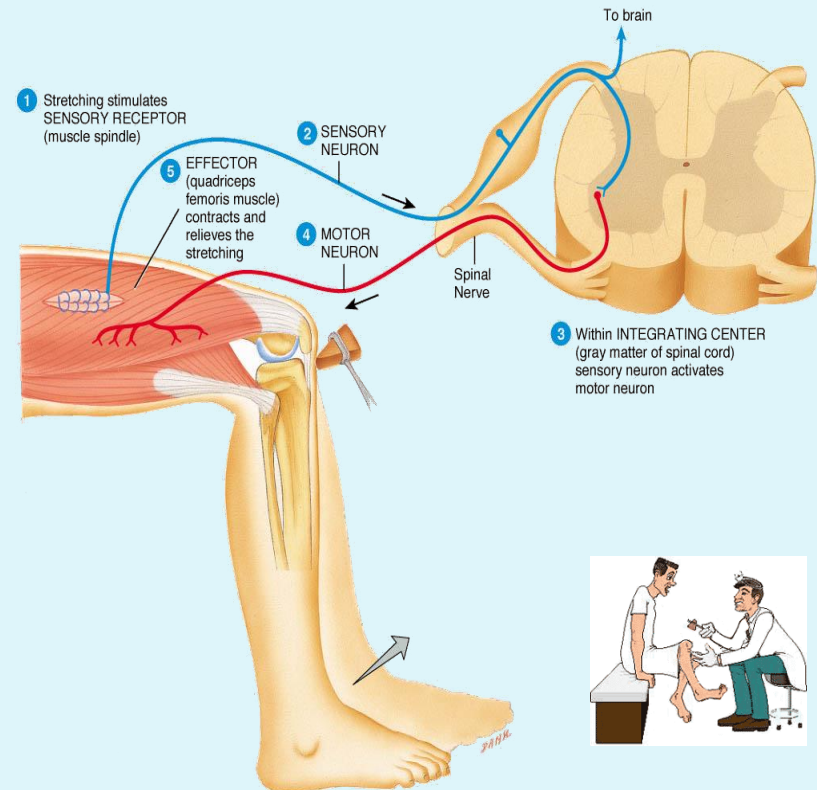
THE STRETCH REFLEX

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

- **Efferent include/**

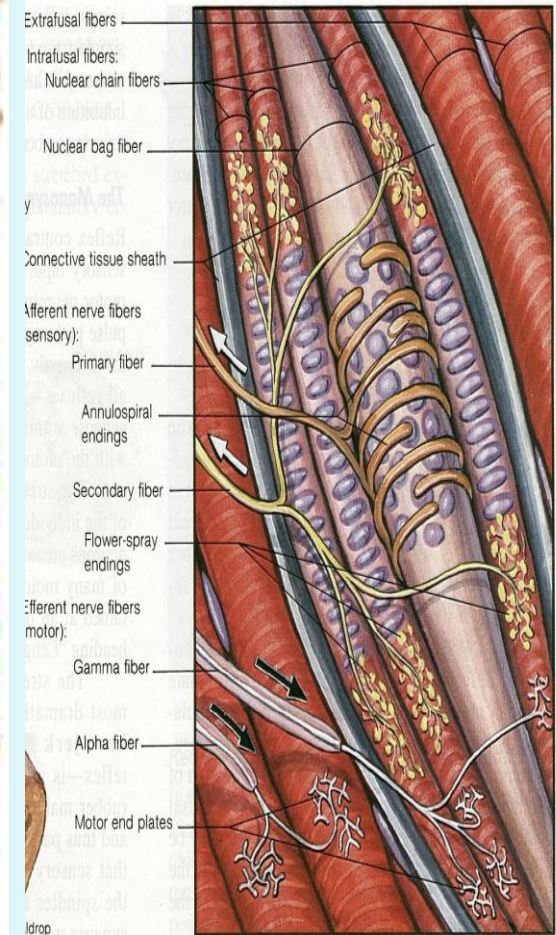
- **1- alpha motor fibers(70% of motor supply, arise from alpha motor neurons to supply extrafusal muscle fibers)**

- **2- gamma efferent (from gamma motor neurons ,30% of motor supply to muscle (intra-fusal muscle fibers inside muscle spindle)**

- **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:

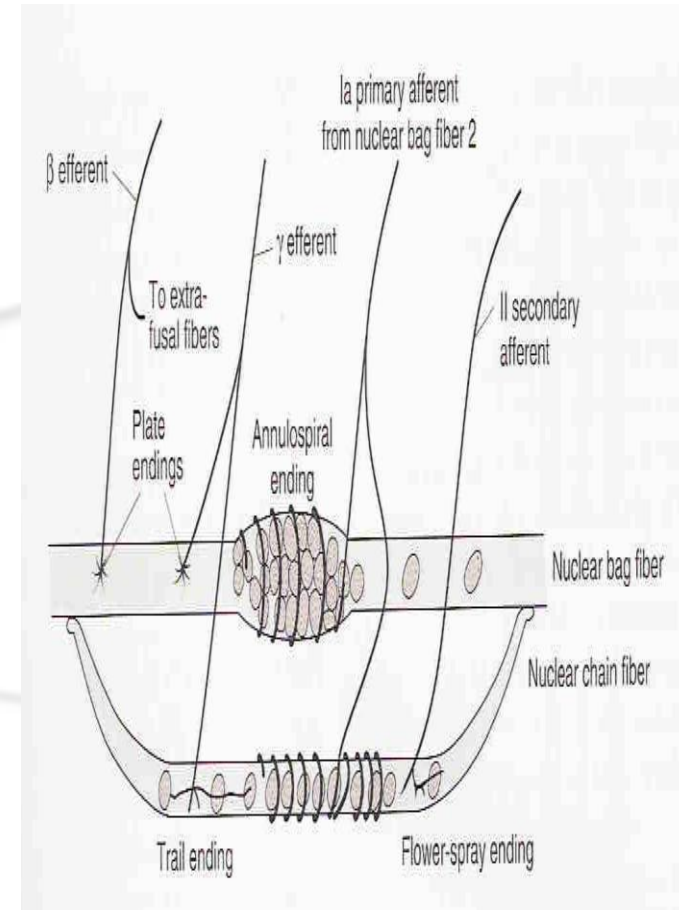
1-Nuclear bag fibres : (2 / spindle)

- Central area is dilated with group of nuclei

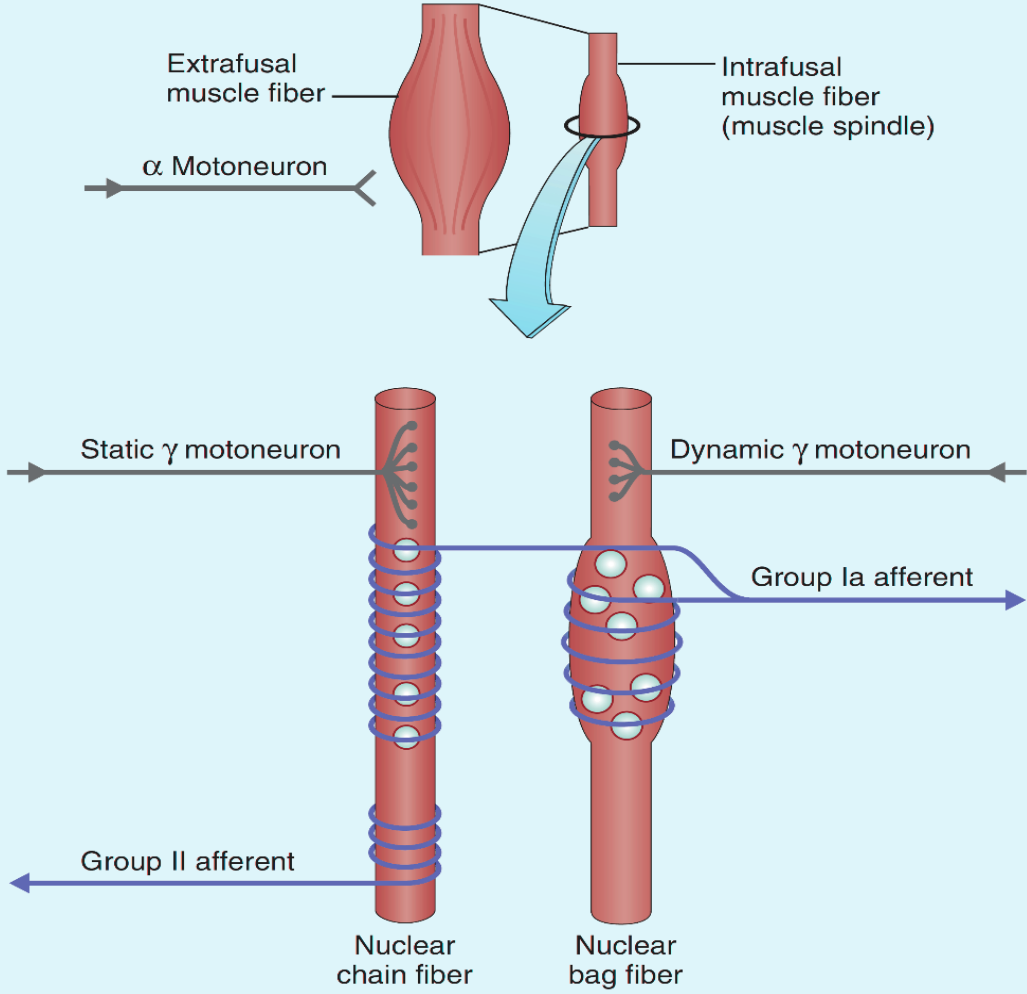
2-Nuclear chain fibres: (about 4 or more /spindle) . Thinner & shorter -

-one line of nuclei in a chain in the -receptor zone

- bind to nuclear bag on each side



STRUCTURE OF MUSCLE SPINDLE



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:

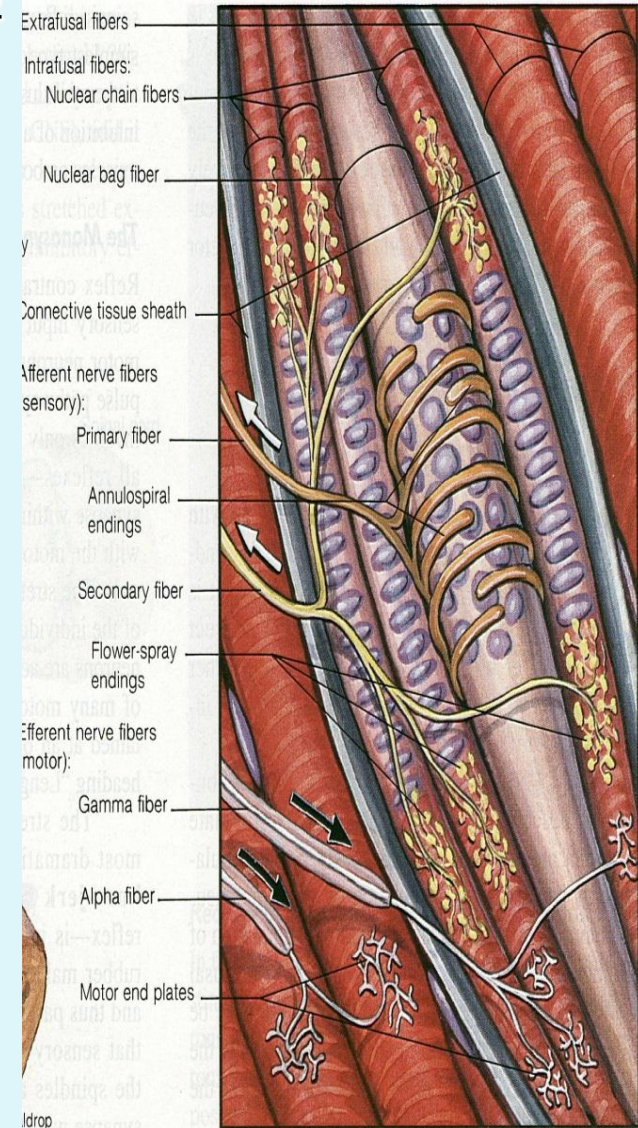
1-Primary (annulospiral) endings (Ia fibres):

-**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

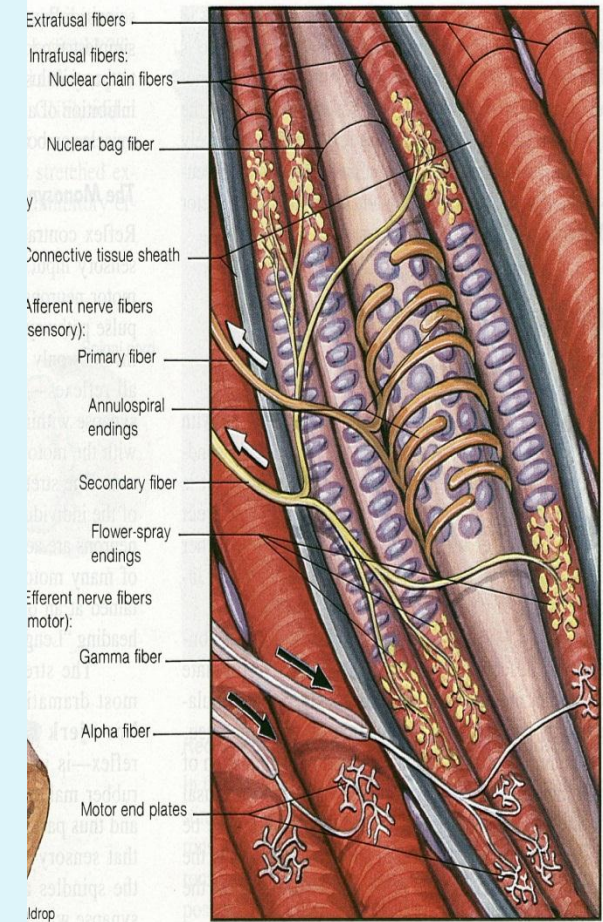
- Measure **the rate & or velocity of change in muscle length** of nuclear bag fibres (This response is called the **Dynamic response** (**as in tendon jerks**))



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

- type II fibers, diameter of 8 micrometers—inervate 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**).
- Responsible for 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

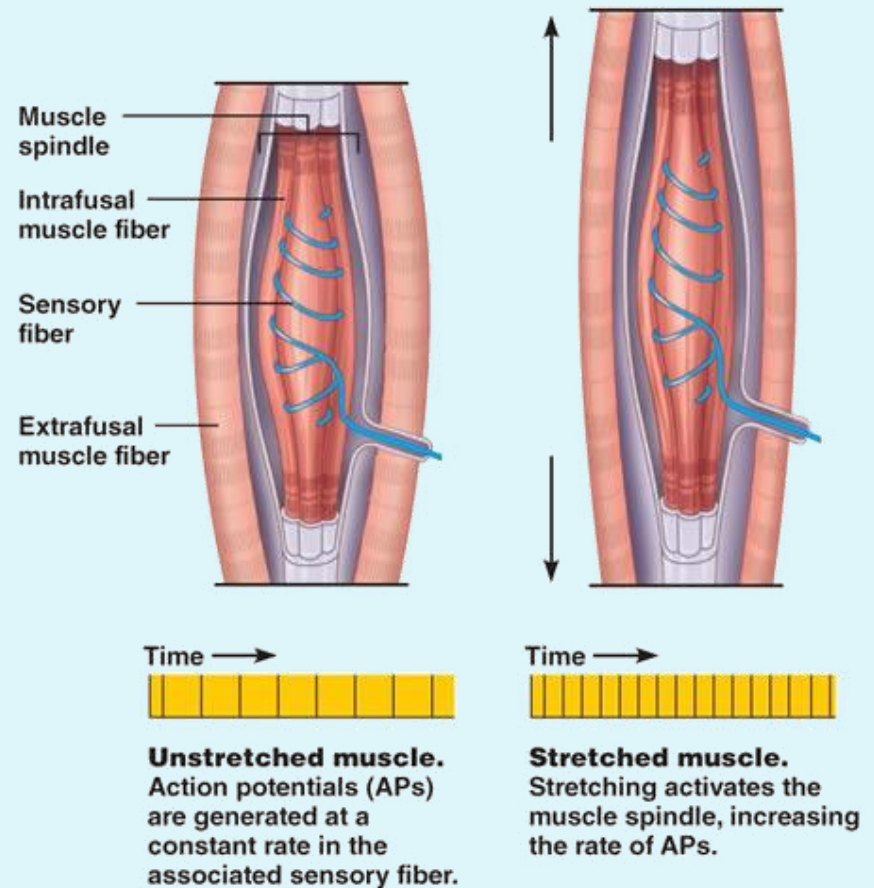
- CAN SENSE A SUSTAINED STRETCH



- 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

(a) How muscle stretch is detected



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

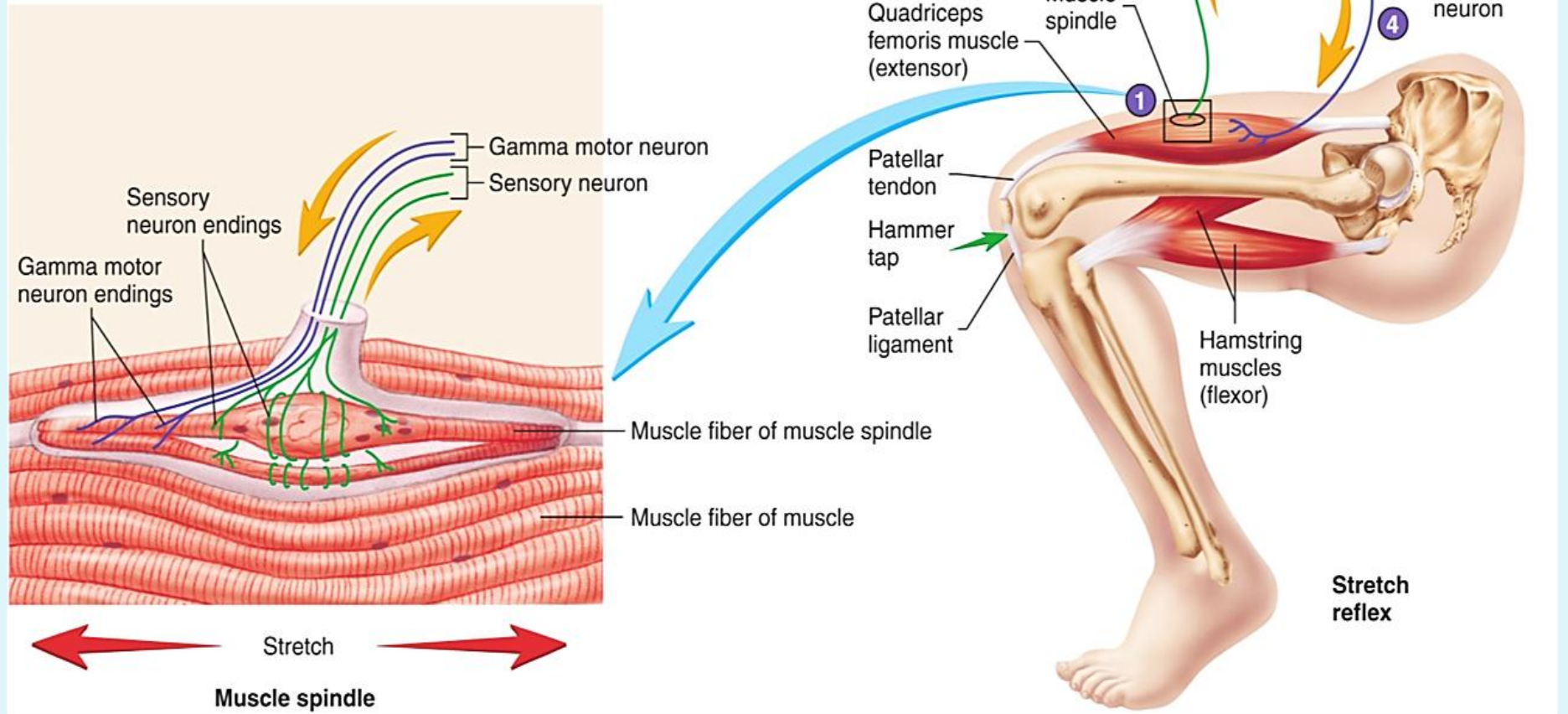
- to apprise the spinal cord it of any change in length of the spindle receptor

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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.



(Motor Efferent fibres to muscle spindle)

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

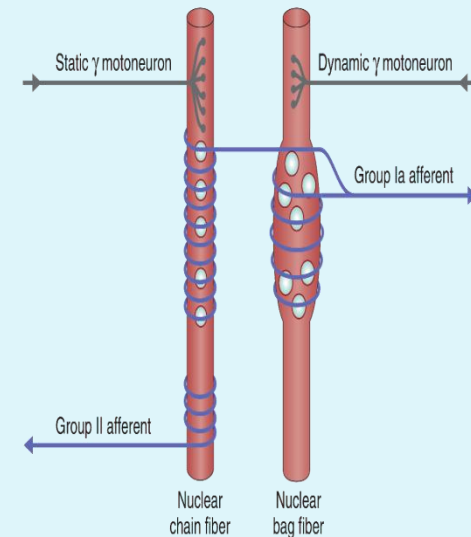
1-Plate endings / end mainly on the nuclear bag fibres (called Dynamic gamma efferent) = γ - d.

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 peripheral parts of the muscle spindles contract

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:



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 more & more**

Types of responses

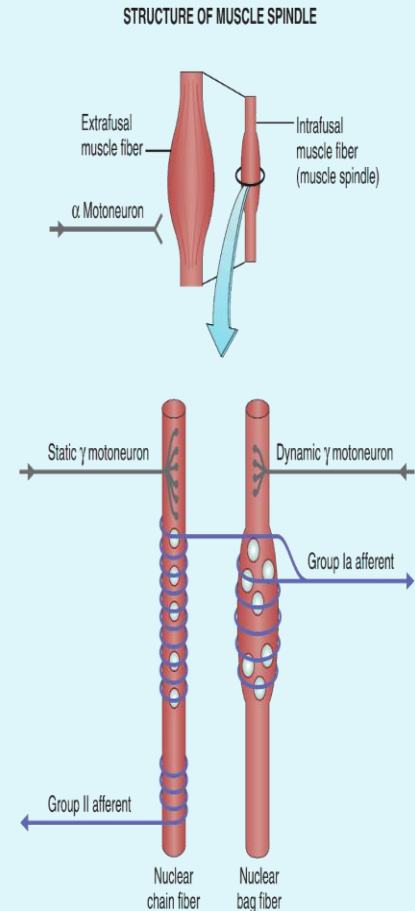
Component of stretch reflex

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

- .



-Dynamic stretch reflex is the

Basis of tendon jerk (contraction followed by relaxation) (knee,biceps,triceps)

Clinical Applications of the Stretch Reflex

-Role of 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)

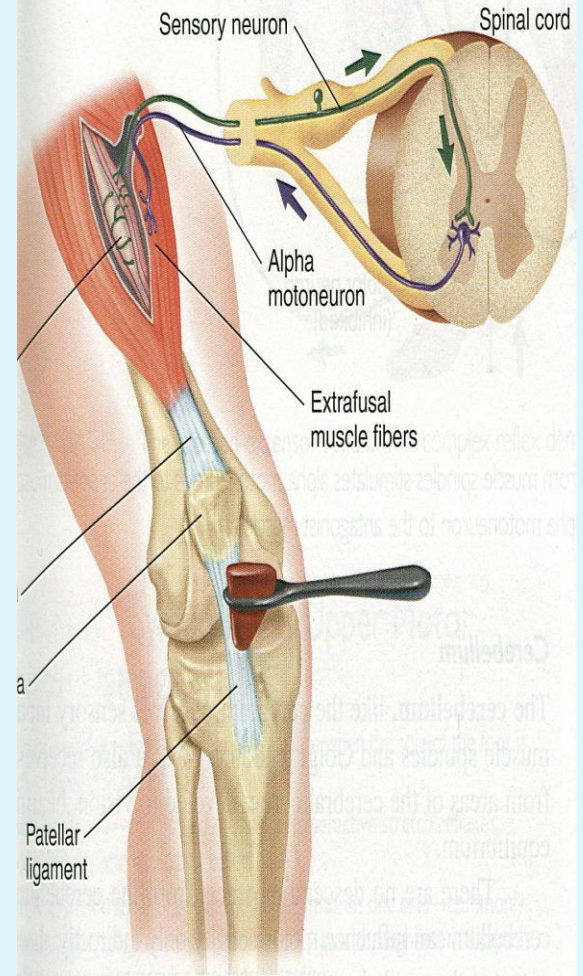


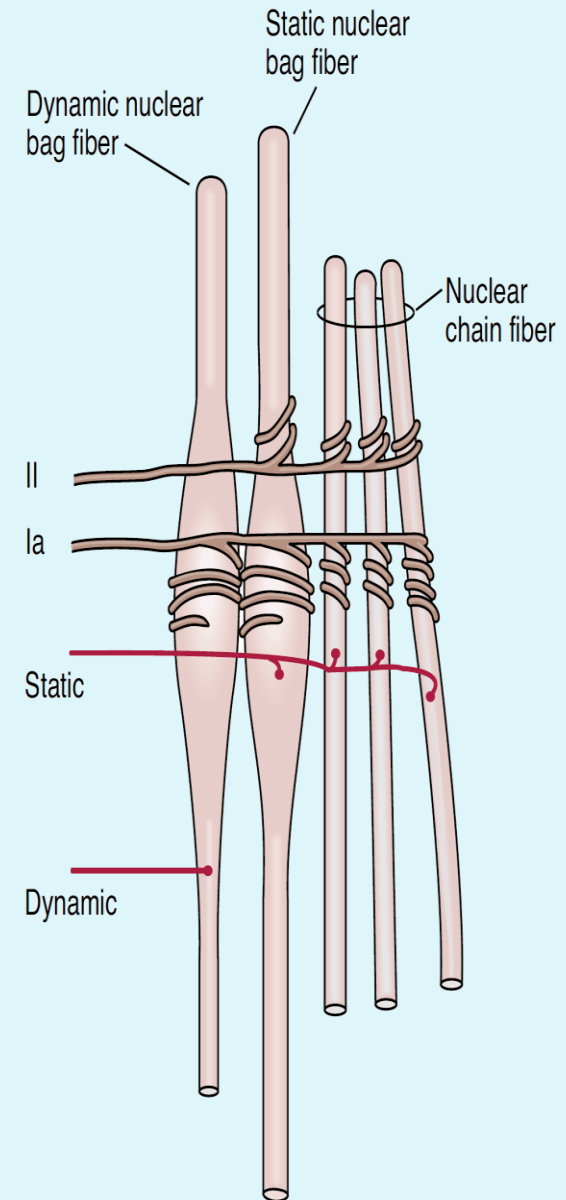
Figure 12.27 The knee-jerk reflex. This is an example of a synaptic stretch reflex.

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 muscle or flaccidity**

-if increased by high gamma efferent discharge to muscle
>>>>>>**hypertonic muscle , 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 than the incoming signals from S.C .

Functions of muscle spindle:-

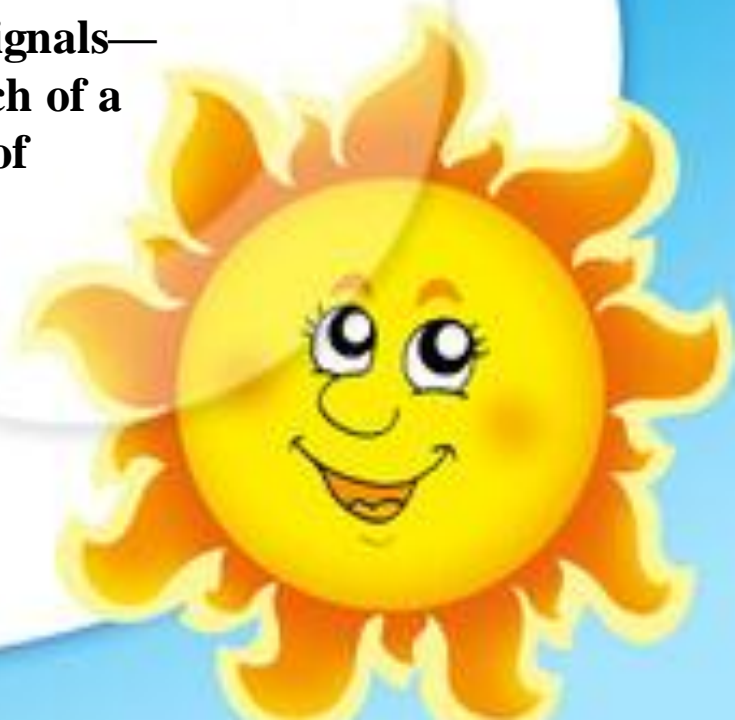
1-keep CNS informed about muscle length & rate or velocity of change in muscle length & , provide information about position, that is called PROPRIOCEPTION

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

-)

2-muscle spindle act to maintain muscle length against rupture

-



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 .

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

-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



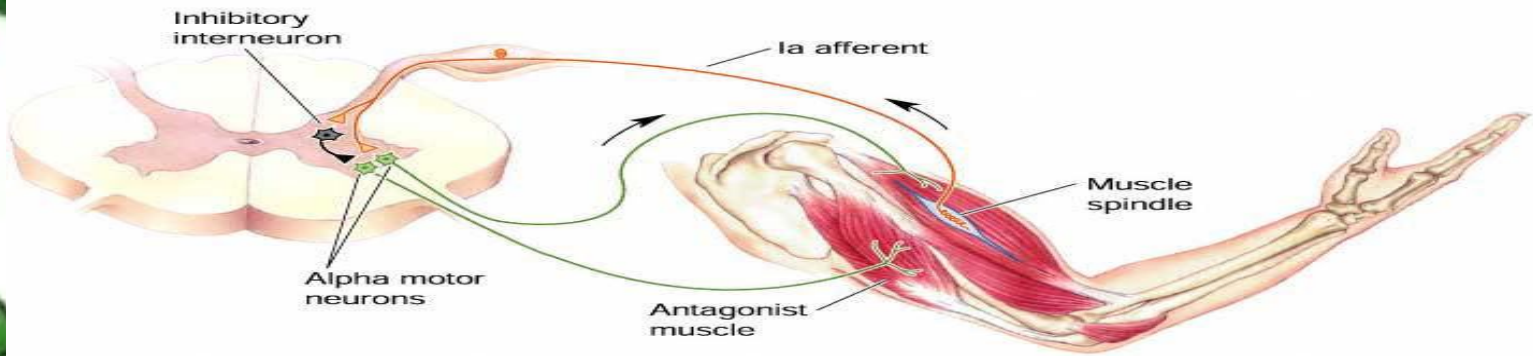
Reciprocal inhibition with stretch reflex (Reciprocal innervation)

-as IN 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>>>> SC to cause:-

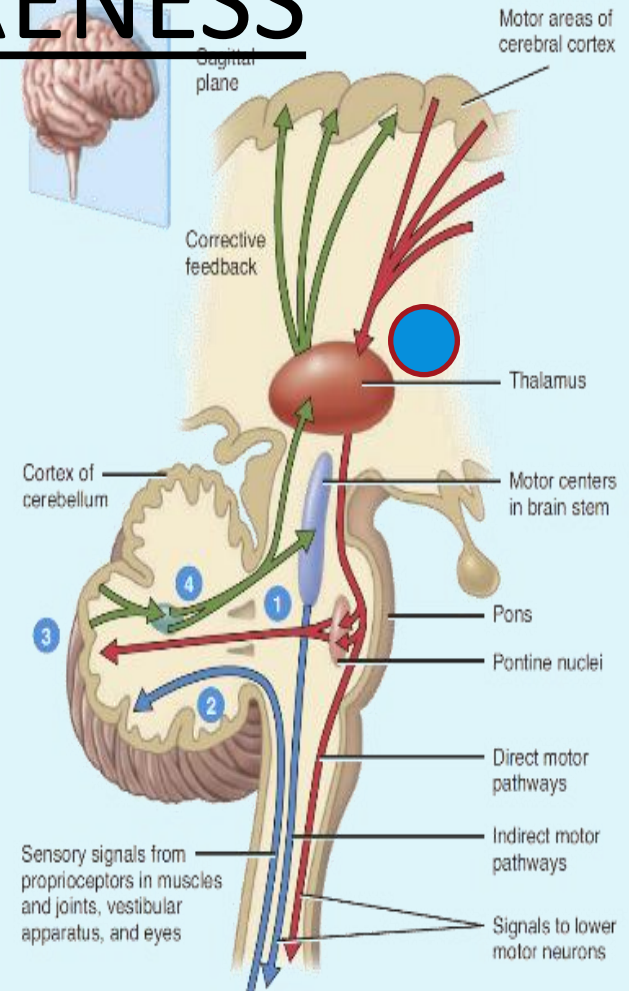
1-stimulate the motor neurons of the stimulated muscle to contract (**by glutamate**)

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)

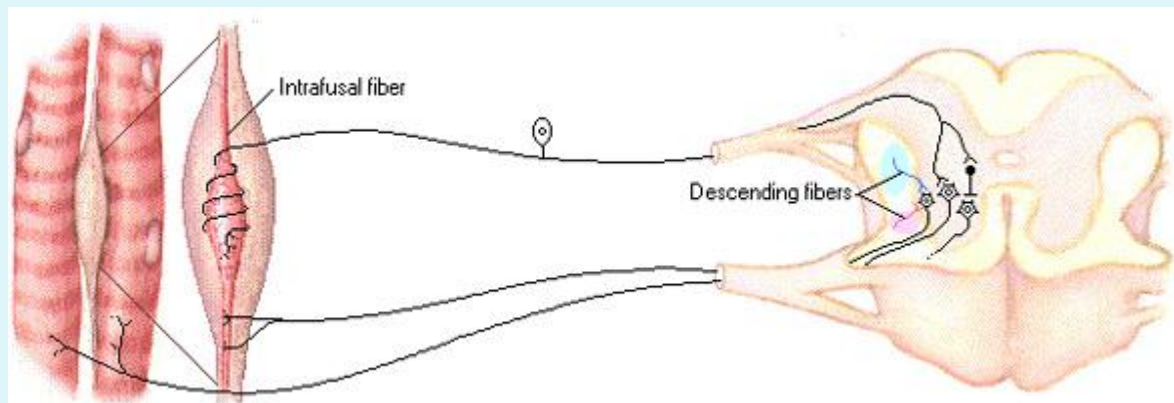
CONSCIOUS AWARENESS

- 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.

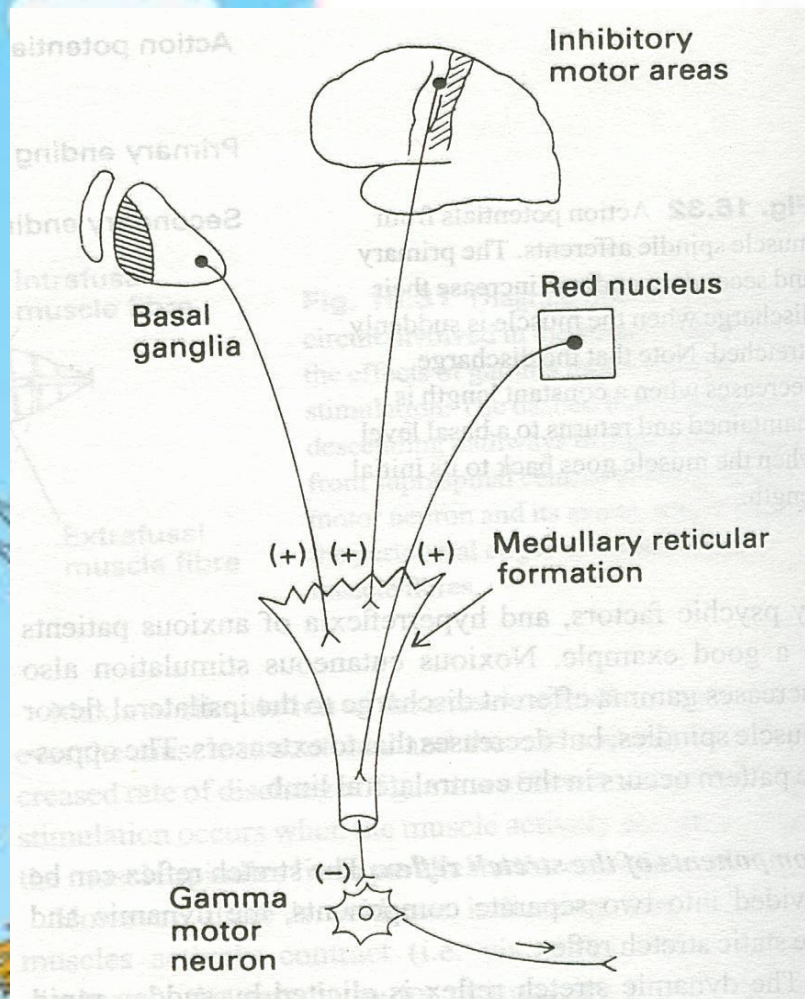


SUPRASPINAL REGULATION OF THE STRETCH REFLEX

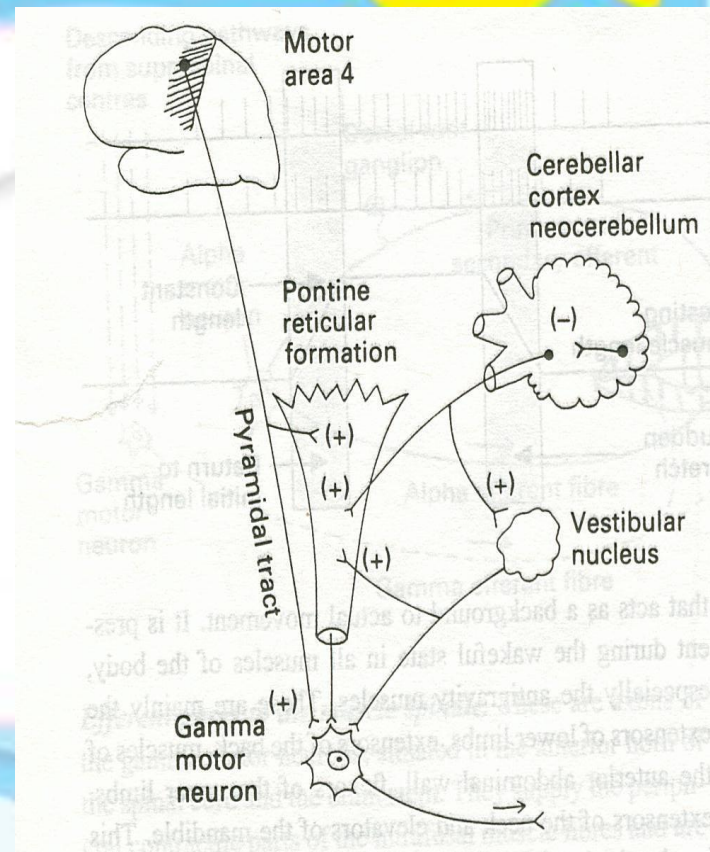
- Stretch reflexes are subject to strong regulation by supraspinal centres, especially certain motor centres in the brainstem and cerebral cortex. changes in reflex threshold, amplitude, and/or pattern are common following supraspinal lesions that affect these centres or their fibre tracts.
- the stretch reflex is controlled by supraspinal centres & gamma motor neurons are mainly controlled by inputs from descending fibres from supraspinal centres e.g., reticulospinal and vestibulospinal



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-Supraspinal

- 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	

The Golgi tendon reflex

- Deep & polysynaptic reflex (**opposite response to stretch reflex**).

Mechanism/Excessive tension in the muscle (by passive overstretch of tendon or active muscle contraction) >>> cause muscle relaxation

- Receptors are Golgi tendon organs (3-25) present in tendons , 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 sever 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

i.e (lengthening reaction)

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

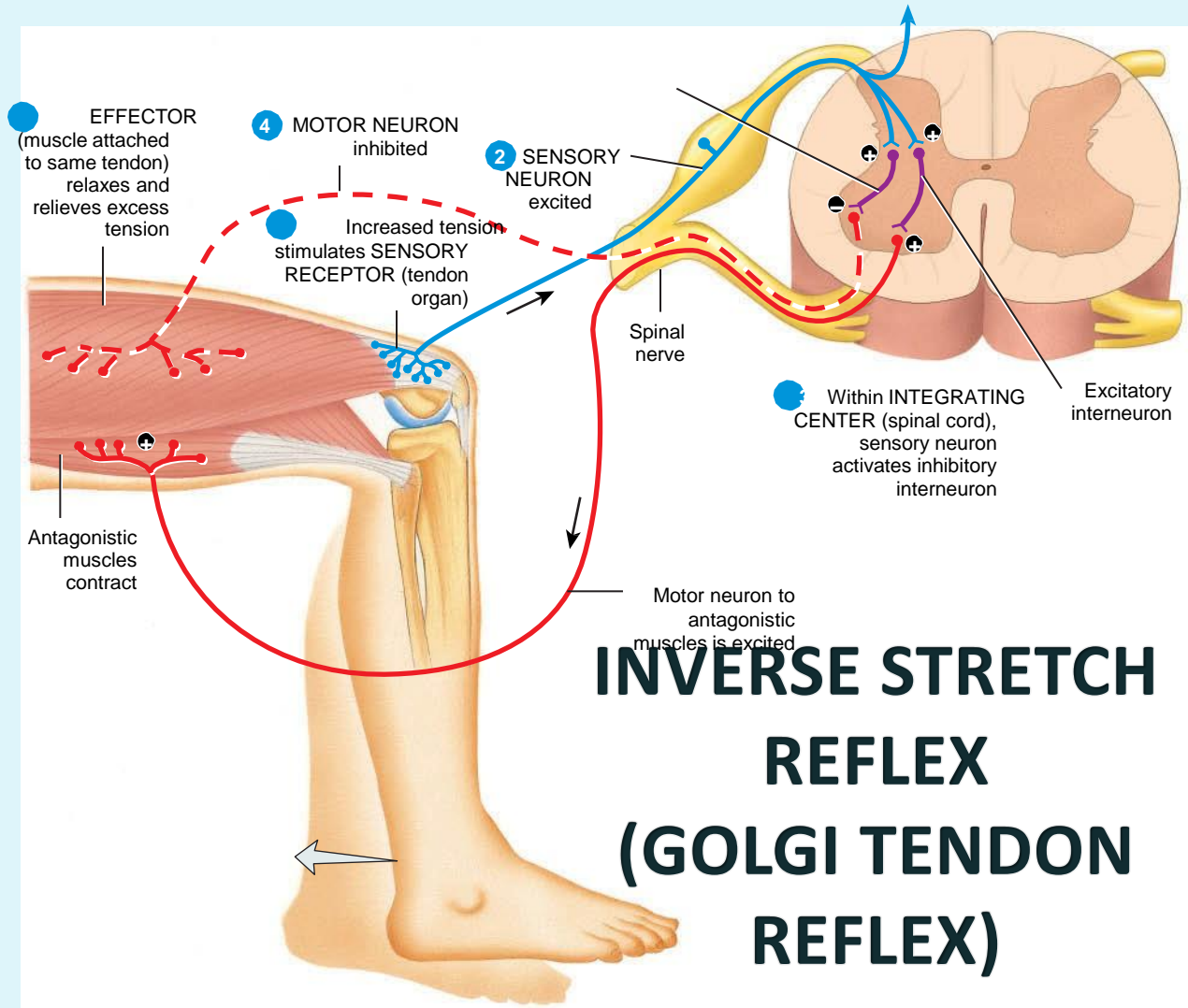
-**Value**/Protect muscle from rupture& tendon from avulsion& tear

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)

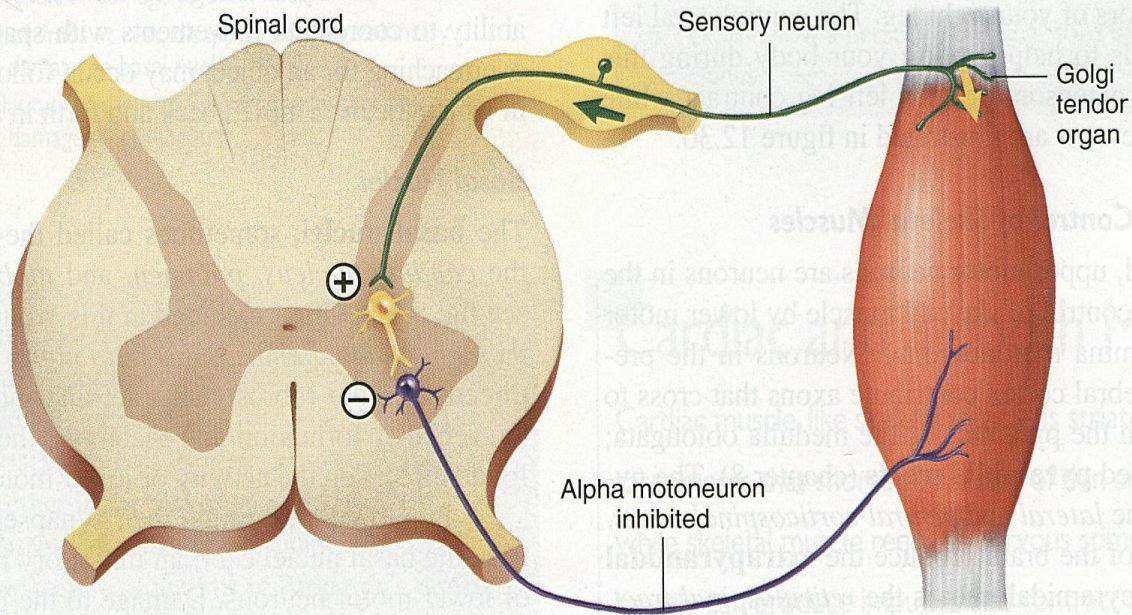


Figure 12.28 The action of the Golgi tendon organ. An increase in muscle tension stimulates the activity of sensory nerve endings in the Golgi tendon organ. This sensory input stimulates an interneuron, which in turn inhibits the activity of a motor neuron innervating that muscle. This is therefore an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