NeuroPsychiatry Block

Stretch reflex and Golgi Tendon Reflex

By

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NeuroPsychiatryBlock

- **Motor Functions of the Spinal Cord, The cord Reflexes**
- **Chapter 55 (Guyton & Hall)**

- **-Reference book/Ganong review of medical physiology**

- **Objectives:**

Upon completion of this lecture, students **are expected** to :

- Describe the stretch reflex and ts icomponents
- Describe the structure and function of the muscle spindle
- Differentiate between primary and secondary afferent fibres of muscle spindle, Intrafusal nuclear bag &nuclear chain fibers
- Differentiate between the Dynamic gamma efferent and Trail endings discharge and their functional role
- Differentiate between static and dynamic stretch reflex& damping mechanism
- Describe muscle tone and its abnormalities
- Disscuss spinal and supraspinal regulation of the stretch reflex
- Describe the components of the inverse stretch reflex (golgi tendon reflex)and its function

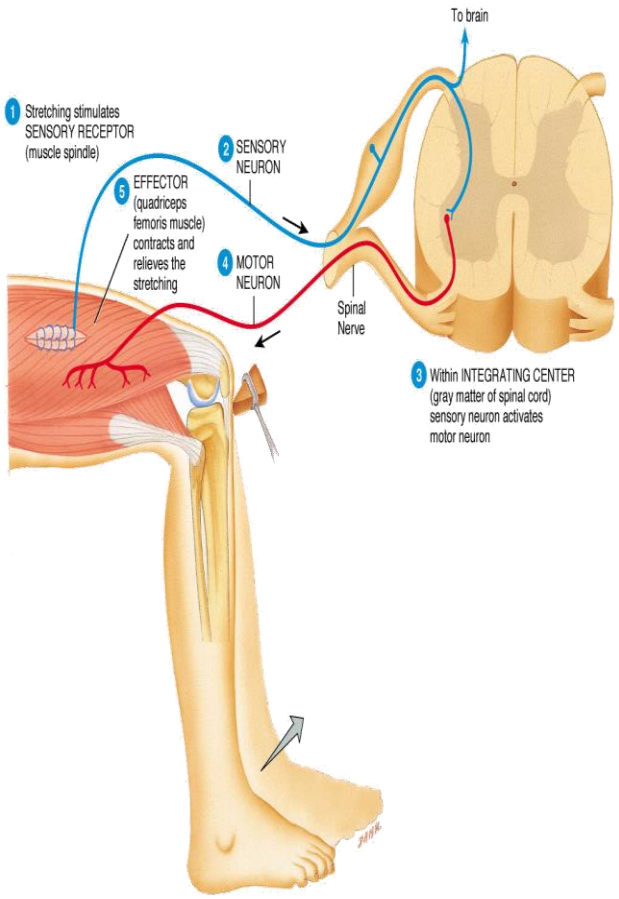
THE STRETCH REFLEX

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 or myotatic Reflex?

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



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

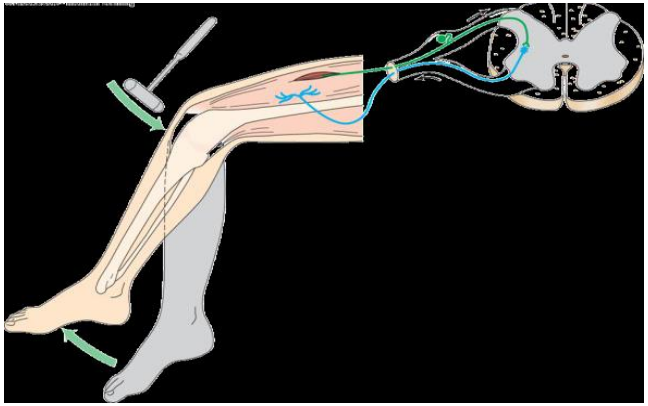
-**Monosynaptic Deep reflex**(one sensory neuron synapse with one motor neuron)

-Example/tendon jerks as **patellar-** or **knee jerk**

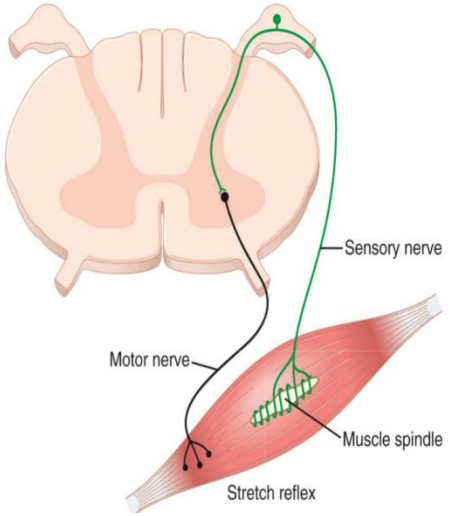
It is:-

-Deep-monosynaptic reflex

-The simplest; it involves only 2neurons & one synapse



Components of the Stretch Reflex Arc

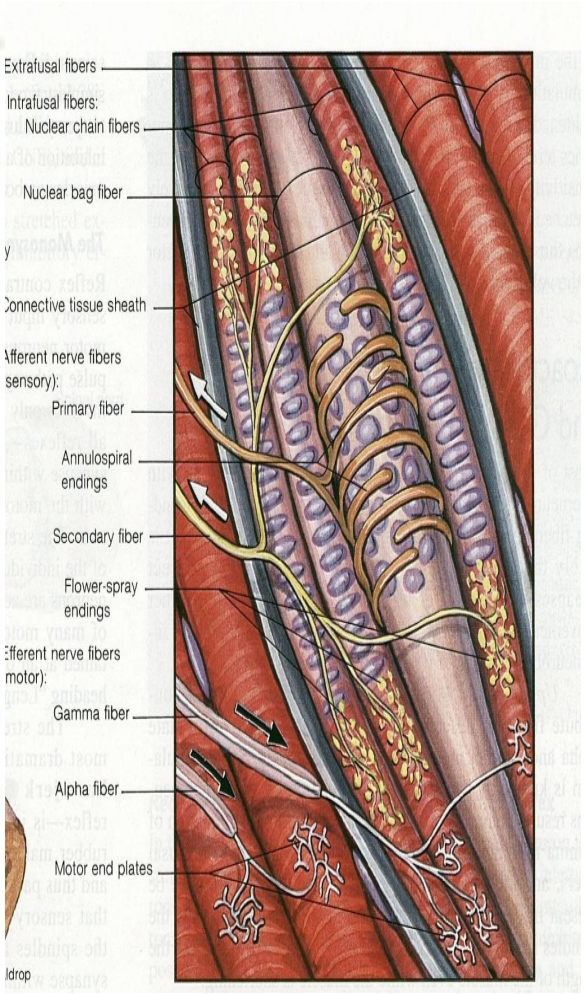


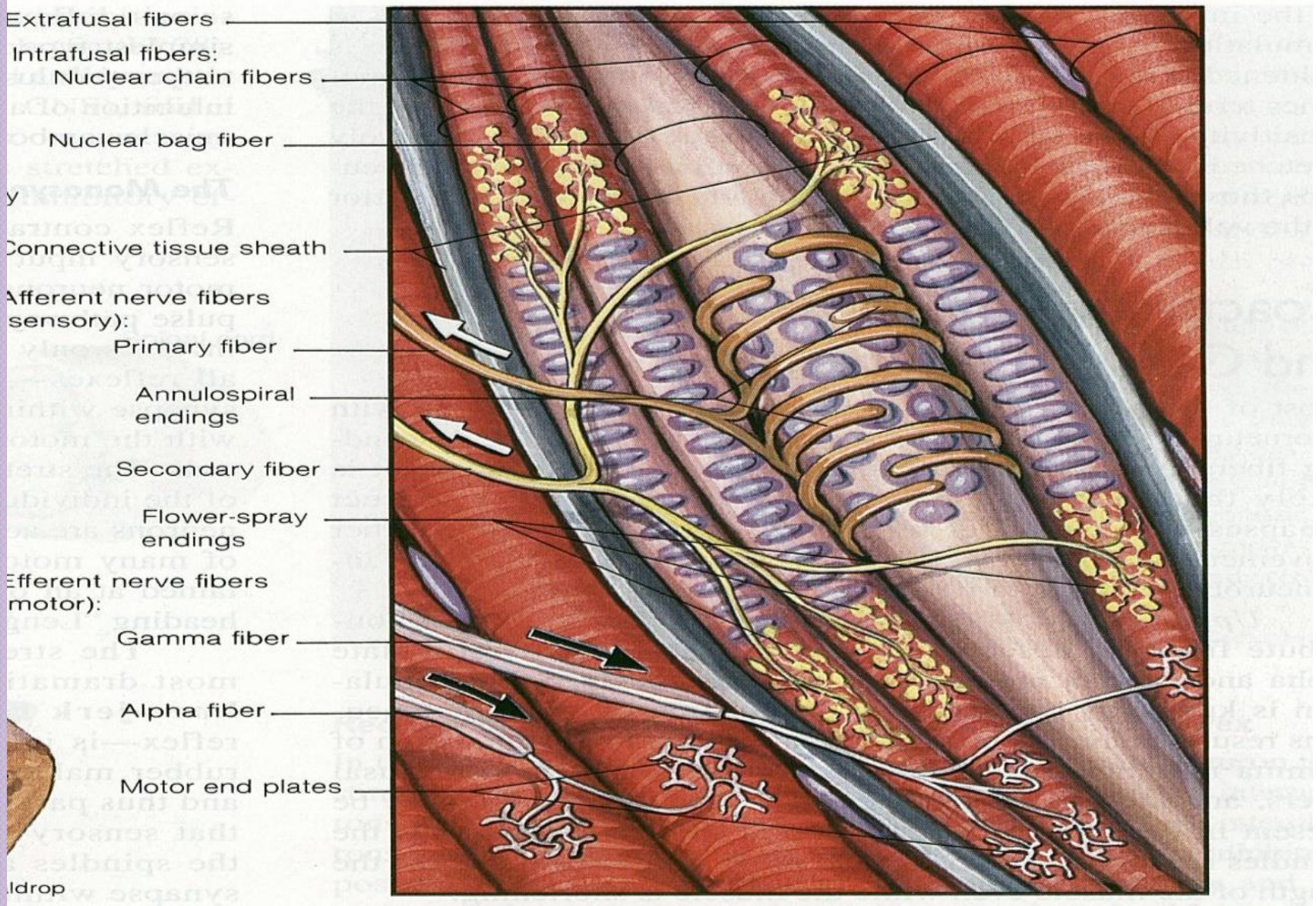
- **Sensory Receptor : muscle spindle**
- **Afferent (group Ia &II afferents)**
- **Integrating center (spinal cord) AHC**
- **-alpha motor neurons synapse with the afferent sensory neurones in the spinal cord**
- **Efferent include/ axons arise from α-and γ-spinal motor neurons**
- **1- alpha motor efferent from alpha motor neurons to supply extrafusal muscle fibers**
- **2- gamma efferent (from gamma motor neurons to supply intra-fusal muscle fibers**
- **Effector / Skeletal muscle**

1- 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.

-**Each intrafusal fibre has:**
-**Central** non-contractile area (**receptor**)
-**Peripheral contractile** area on each side of central zone,
- it has actin & myosin.



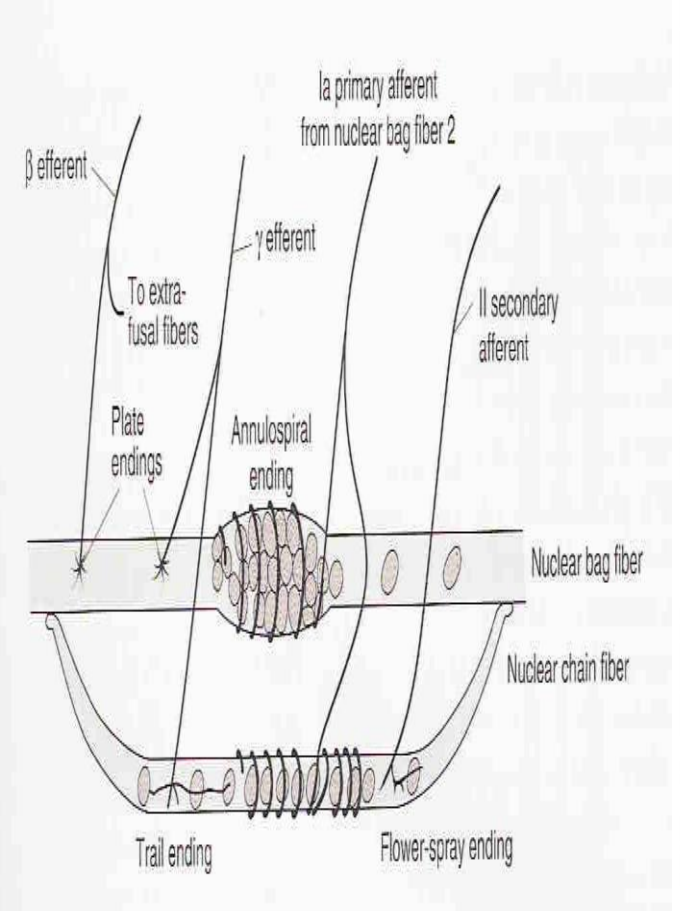

Extrafusal fibers
Intrafusal fibers:
Nuclear chain fibers
Nuclear bag fiber
Connective tissue sheath
Afferent nerve fibers
(sensory):
Primary fiber
Annulospiral
endings
Secondary fiber
Flower-spray
endings
Efferent nerve fibers
(motor):
Gamma fiber
Alpha fiber
Motor end plates

Muscle Spindle(cont)

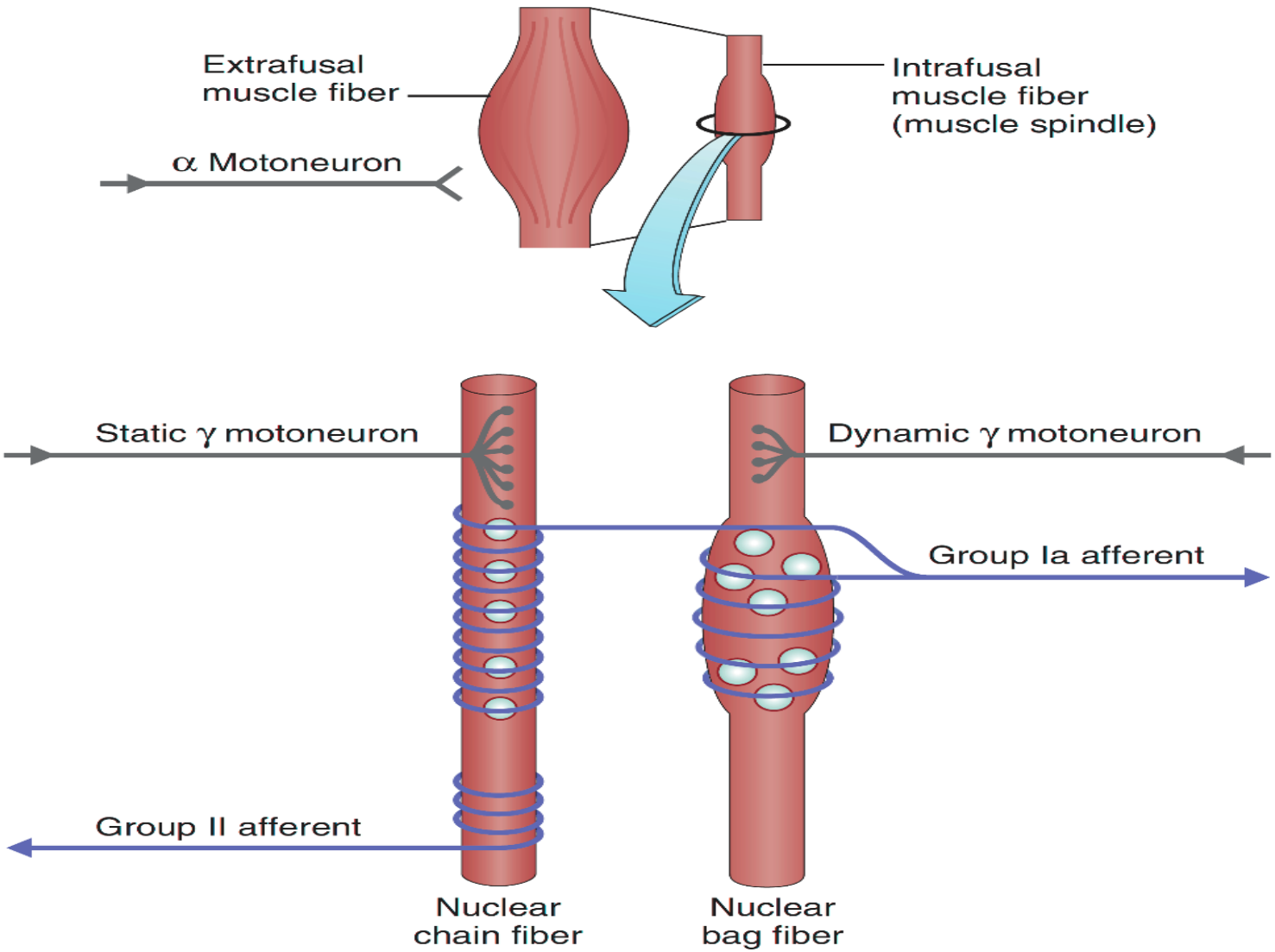
Has two types of intrafusal fibres:

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



2-Innervation of the muscle spindle(afferents)

-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:

- **GROUP Ia**
- **-GROUP II**

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

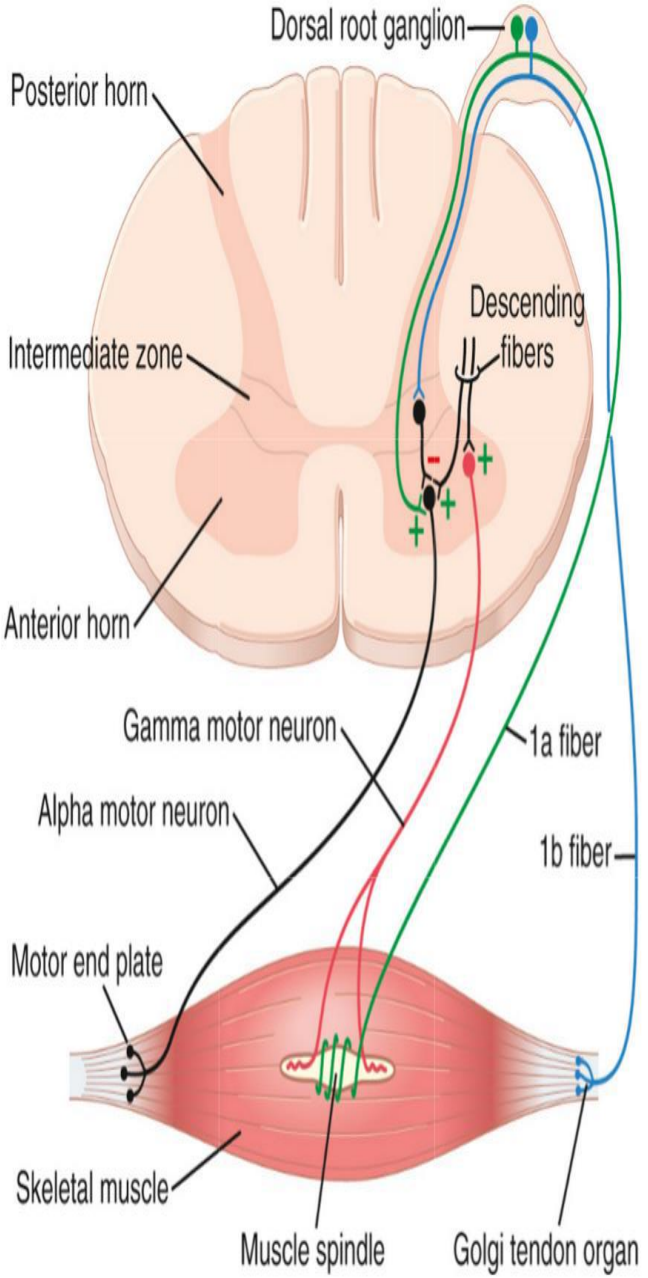
-Fast, encircle receptor areas of **both** nuclear bag (mainly) and nuclear chain fibres ,synapse directly with the motor neurons (AHC)

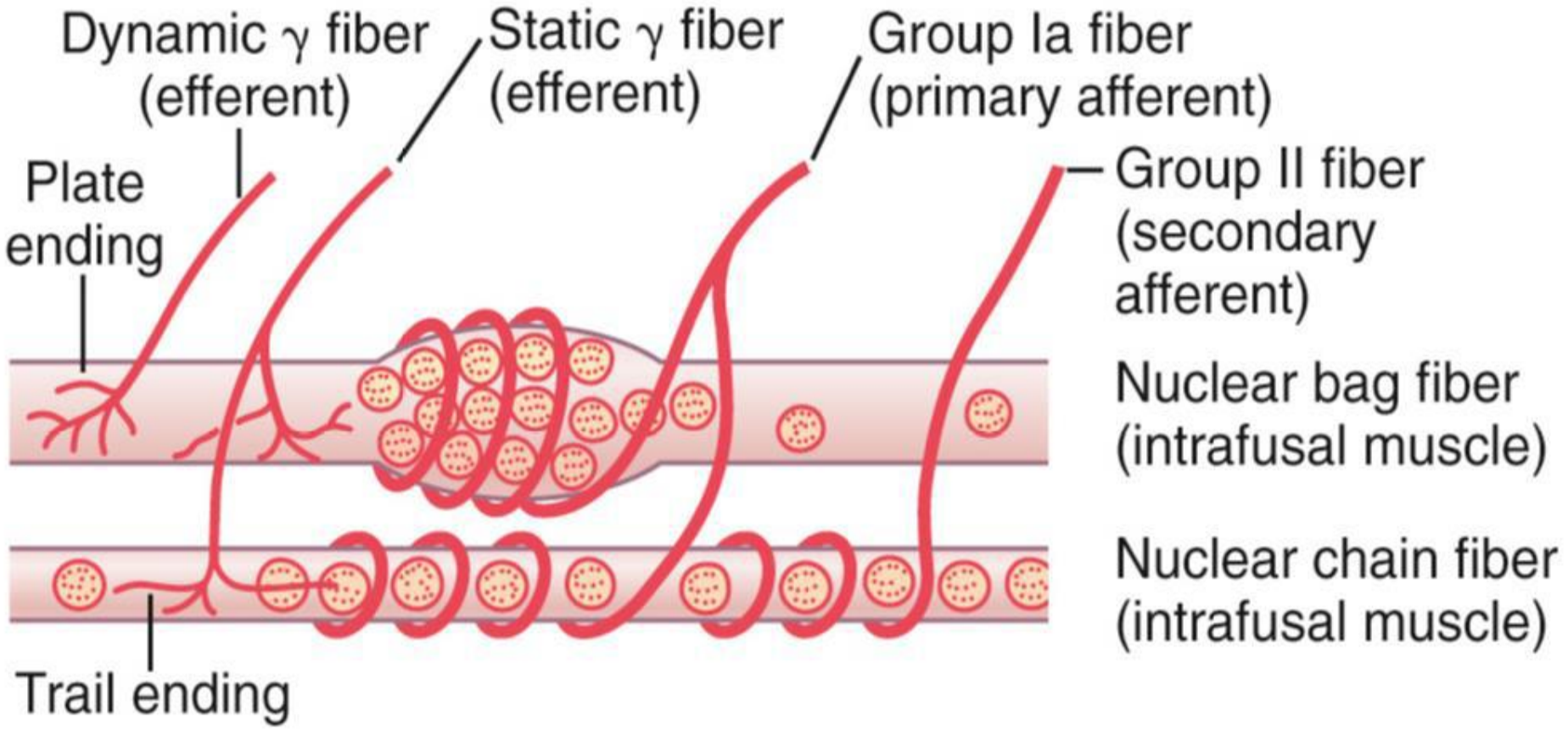
-Discharge most **rapidly** if the muscle is **suddenly** stretched and less rapidly (or not) during **sustained stretch**

- Type Ia fiber, 17 micrometers 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)



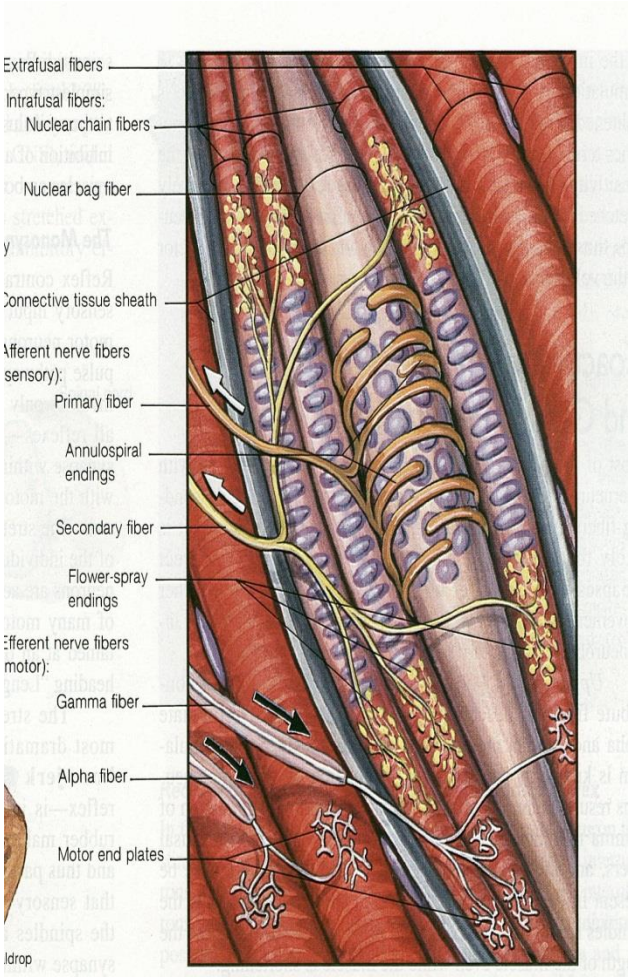

Dynamic γ fiber
(efferent)
Static γ fiber
(efferent)
Group Ia fiber
(primary afferent)
Group II fiber
(secondary
afferent)
Plate
ending
Nuclear bag fiber
(intrafusal muscle)
Nuclear chain fiber
(intrafusal muscle)
Trail ending

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** 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/

-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

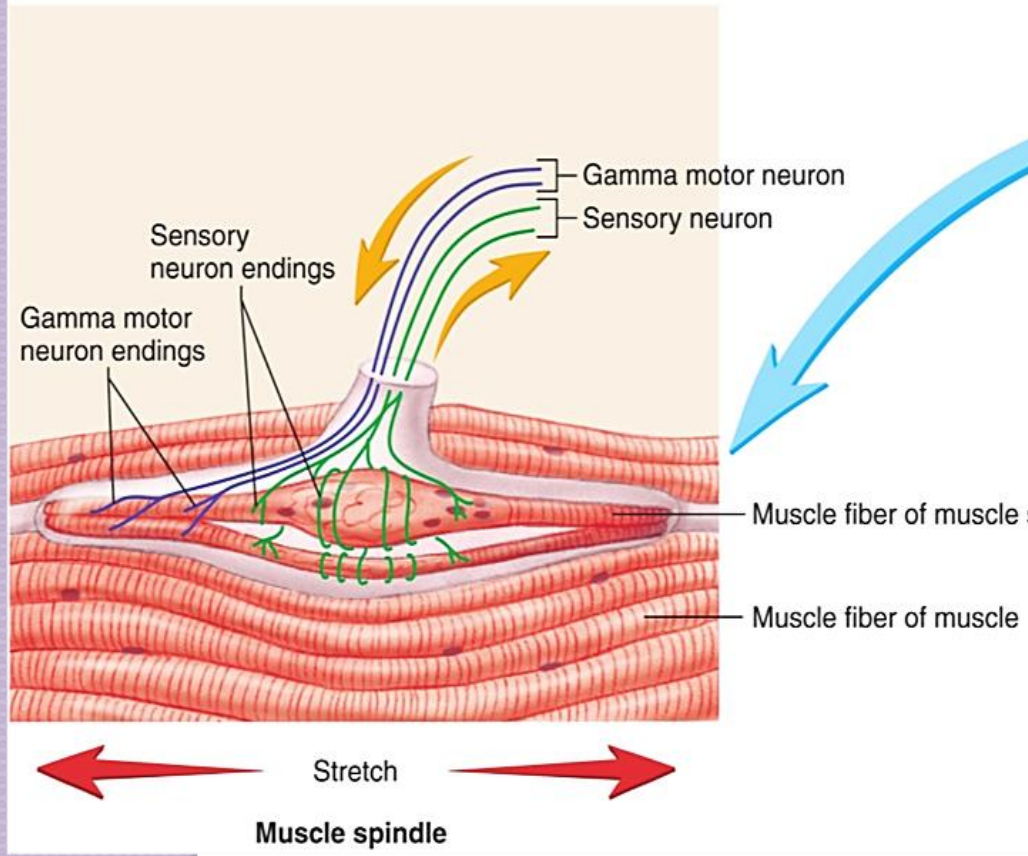
- NUCLEAR BAG FIBRES
  - CAN SENSE THE ONSET OF STRETCH
  - CAN RESPOND TO RAPID STRETCH

- NUCLEAR CHAIN FIBRES
  - CAN SENSE A SUSTAINED STRETCH

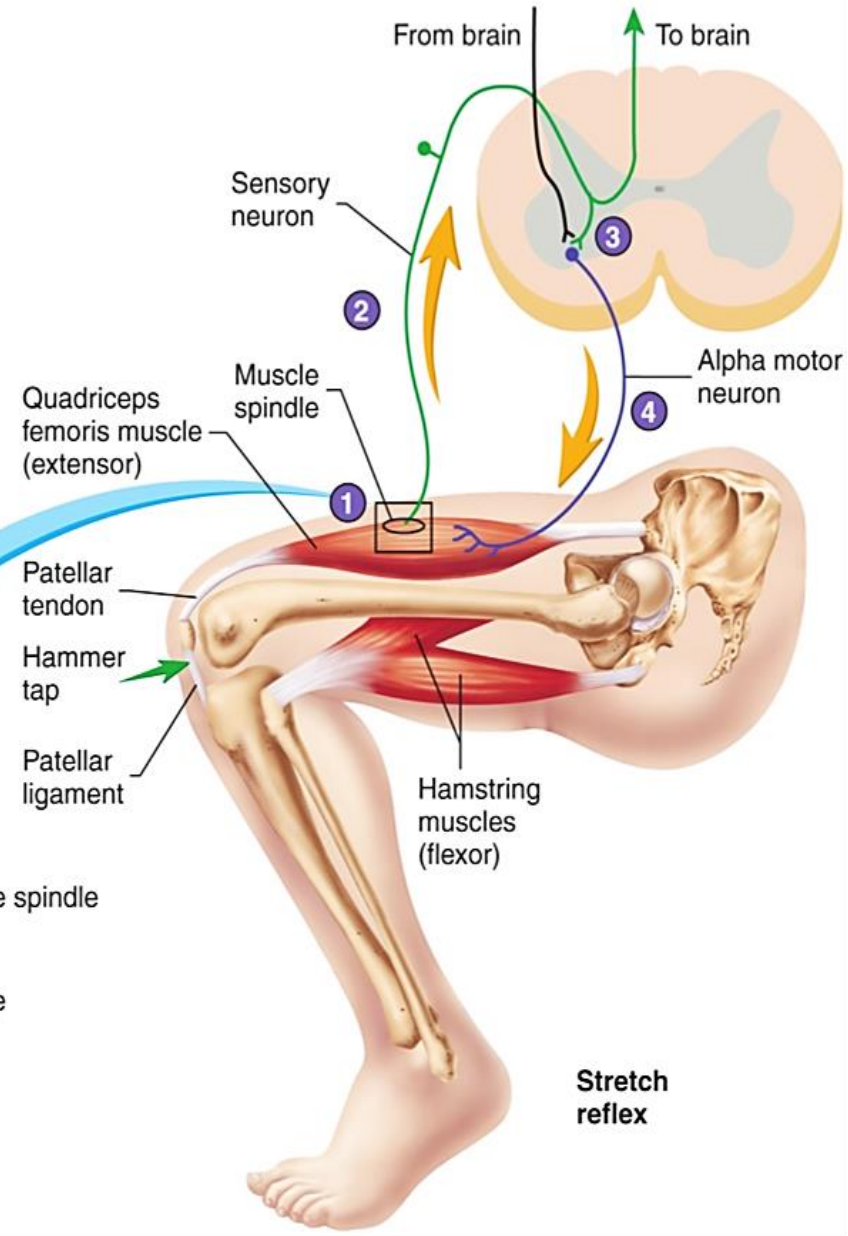
- THESE PREVENT MUSCLE INJURY BY ACTIVATING EXTRAFUSAL FIBRES IN RESPONSE TO FORCE ACTING ON THE MUSCLE
- IT PRODUCES AN ANTAGONISM OF THAT FORCE

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

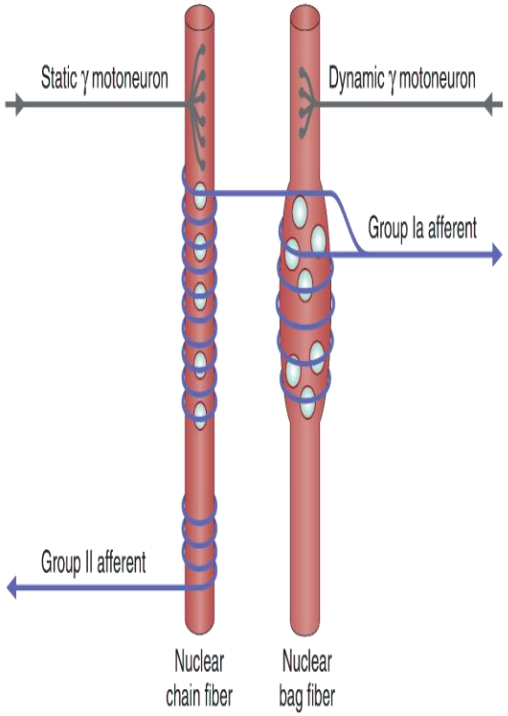
3- (Motor Efferent fibres to muscle spindle)

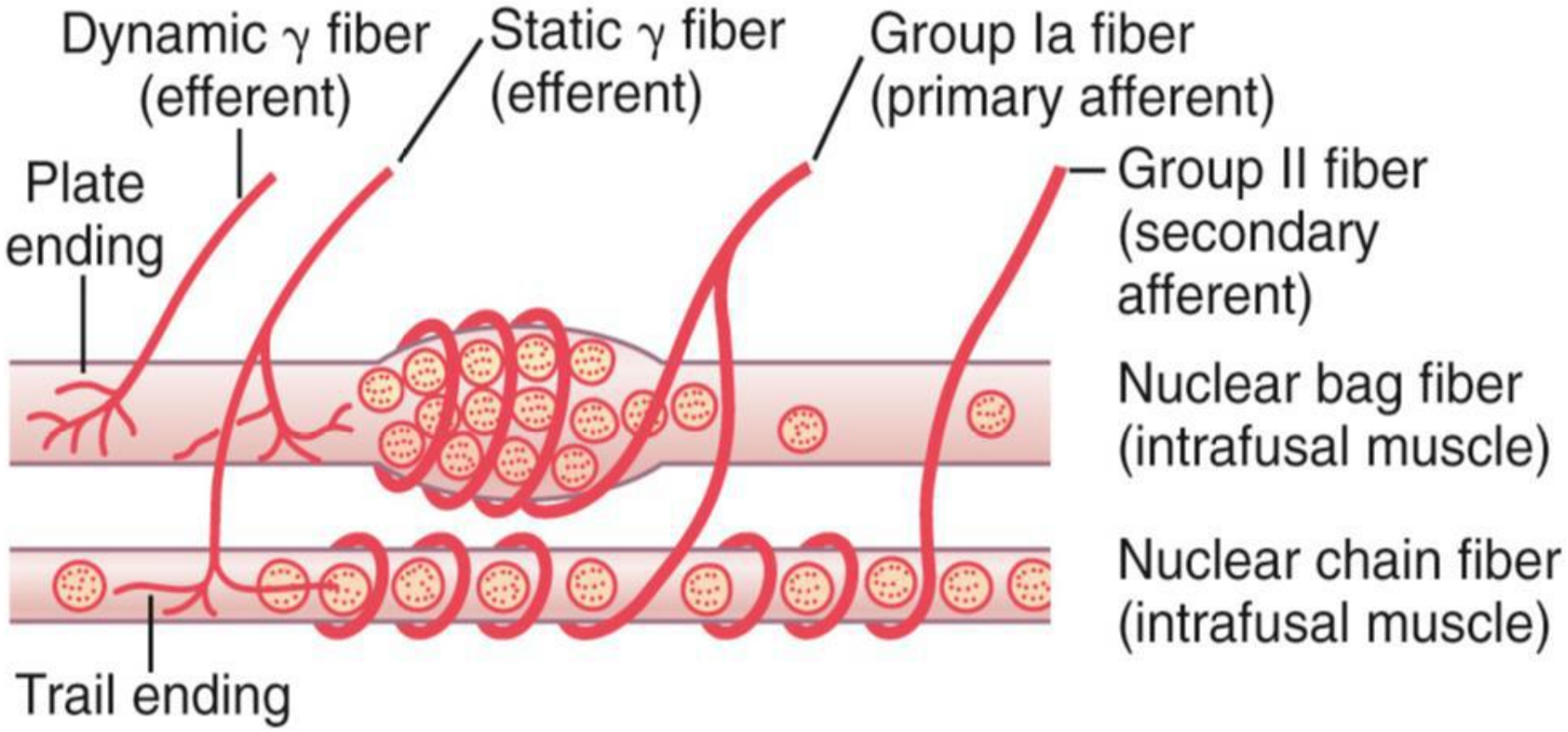
-Gamma motor neurons >>>>gamma efferent>>>>> to the peripheral contractile parts of the intrafusal muscle fibres , of two types:

1-Plate endings / end mainly on the nuclear bag fibres (called Dynamic gamma efferent

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

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

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(intrafusal muscle)
Nuclear chain fiber
(intrafusal muscle)
Trail ending

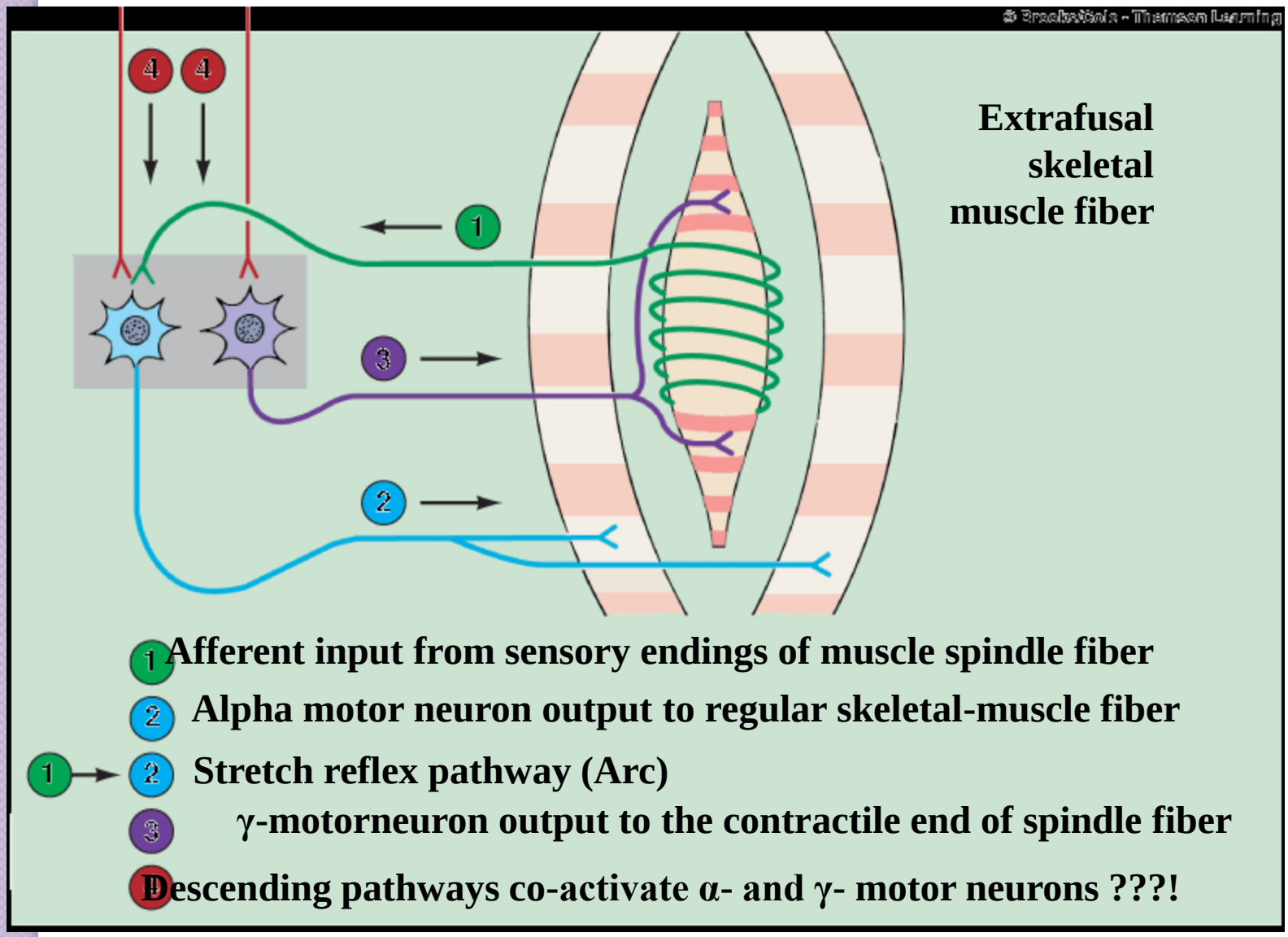
Gamma motor neurons function:-

.-When Gamma motor neurons activated, can make - peripheral parts of the muscle spindles to contract

- They increase muscle spindle sensitivity to stretch

-When the gamma-d fibers excite the nuclear bag fibers, the dynamic response of the muscle spindle becomes enhanced

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


4
4
1
3
2
Extrafusal skeletal muscle fiber
1 Afferent input from sensory endings of muscle spindle fiber
2 Alpha motor neuron output to regular skeletal-muscle fiber
1 → 2 Stretch reflex pathway (Arc)
3 γ-motorneuron output to the contractile end of spindle fiber
Descending pathways co-activate α- and γ- motor neurons ???!

Stretch reflex. cont

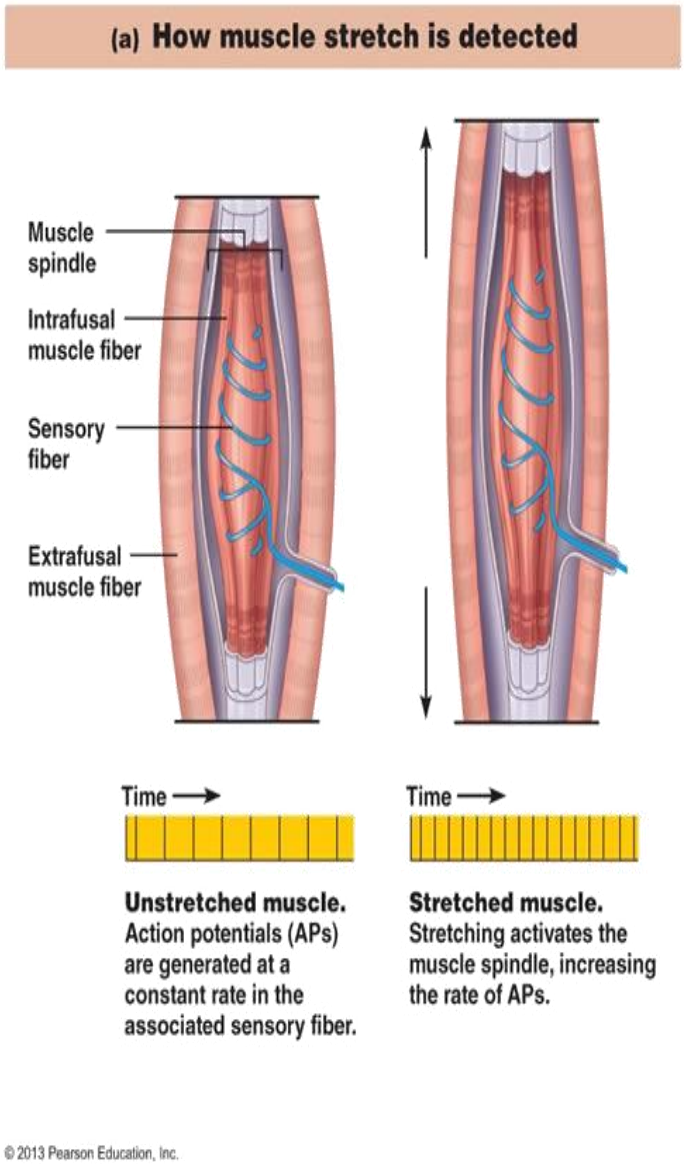
1- Stretching of the muscle>>>>Stretching extrafusal muscle fibers >> Stretching intrafusal peripheral contractile fibers>>>>>> + stretch receptor zone (central) in intrafusal fibre >> +stimulation of sensory afferent endings encircling receptor area. Afferent impulses >> spinal cord >> stimulate:

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

2-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 receptor zone to excite afferent fibers more & more

How Muscle Stretch Is detected

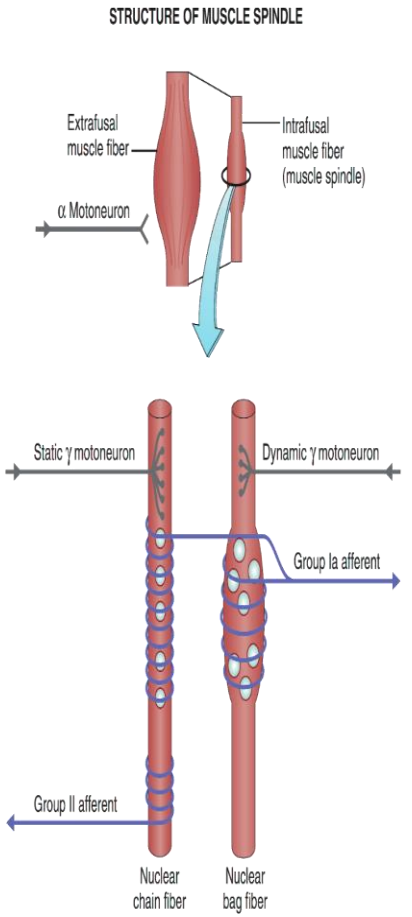
- stretching of the muscle also stretches the spindle
- this sends impulses to the spinal cord
- the number of impulses sent are proportional to the stretched length of the muscle



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 >>> alpha motor neuron >>>motor alpha nerve efferent >>>>causing sudden contraction of muscle extrafusal fibers synchronously (jerk movement)



-Conversely, when the spindle receptor shortens, the primary ending sends less signals to inform it about muscle unstretch

.

1-Dynamic stretch reflex is the

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

-Role of Dynamic gamma efferent (plate endings)

-When nuclear bag fibres relax during muscle contraction , its sensitivity to stretch decreases.

Plate gamma endings which end mainly on the nuclear bag fibres periphery, send signals to contract the peripheral contractile part of nuclear bag fibres, so it stretch the central part. -

-It increases sensitivity of muscle spindle to rate and velocity of change of length & enhances the dynamic response)

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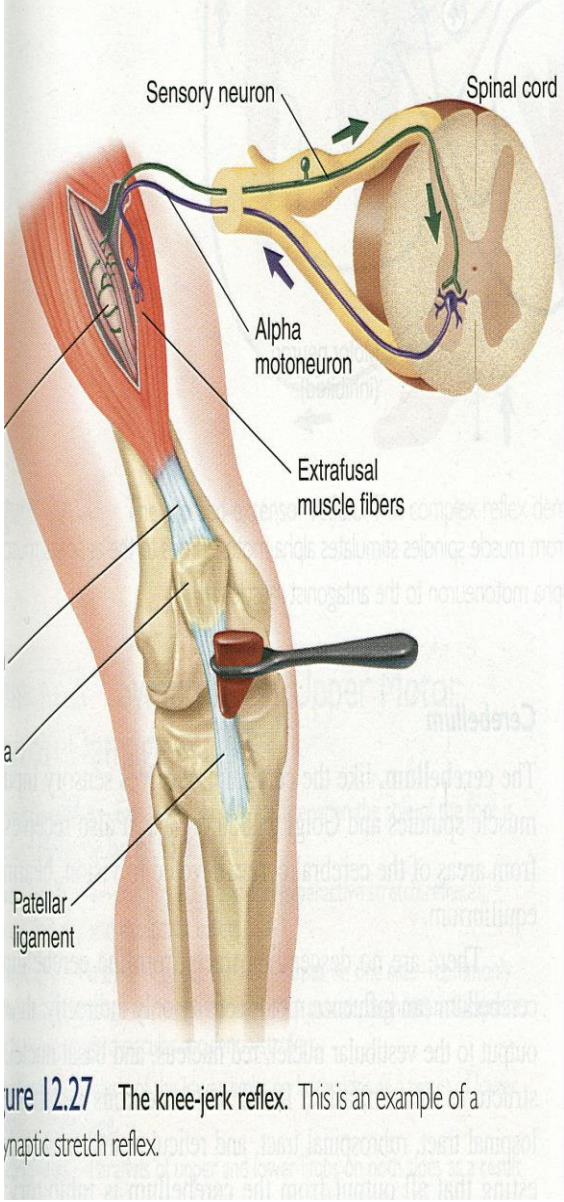


ure 12.27 The knee-jerk reflex. This is an example of a ynaptic stretch reflex.

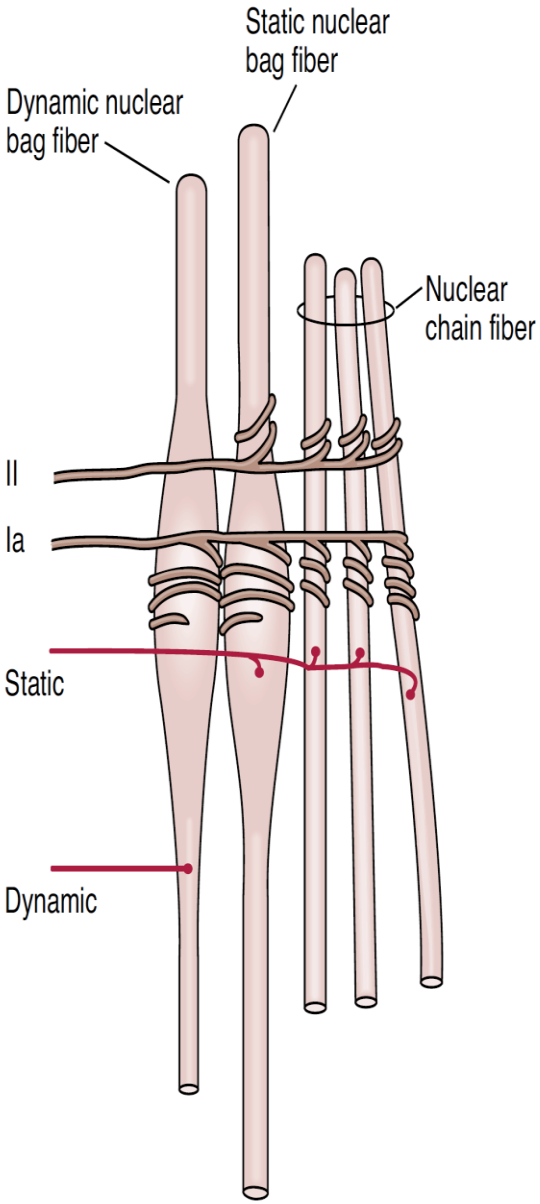
2- Static stretch reflex(static response)

- **Maintained** stretch of muscle>>> stimulates **Nuclear chain fibers** to discharge with increased rate >>>Impulses in the **secondary sensory afferents** (flower-spray)>>>>alpha motor neuron >>> motor effernts>>> contraction of extrafusal 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 (gamma –s) 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 flacidity

-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 transmitted to a muscle in an unsmooth form, with increasing or decreasing intensity for few milliseconds, the muscle contraction will be jerky
- -Muscle spindle reflexes make the contraction 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

2-muscle spindle act to oppose stretch& maintain muscle length against rupture

-

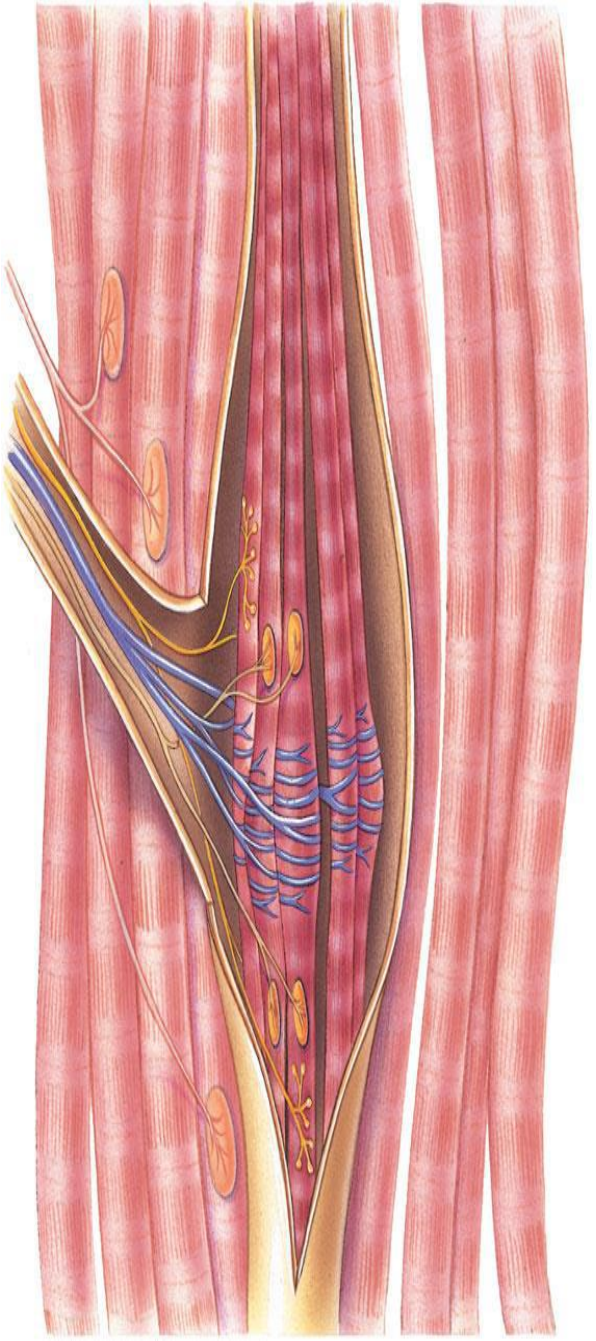
How Are Muscle Spindles Activated?

Muscle spindles are stimulated by stretching of their mid-portion.

They can be excited in two ways:

1. Lengthening of the whole muscle which stretches the mid-portion of the spindle and, therefore excites the receptor.

2.Contraction of the peripheral contractile portions of the spindle's intra-fusal fibers which stretches the mid-portions of the spindle & excites the receptor during γ-efferent discharge



Muscle can contract by:-

1- **Stimulation of alpha motor neurons by muscle stretch** which stretchesthe mid-portion of the spindle and, therefore excites the receptor.

2- **Stimulation of gamma motor neurons by supraspinal signals**

3- **Co-activation of α-and γ-Motor Neurons.**

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.

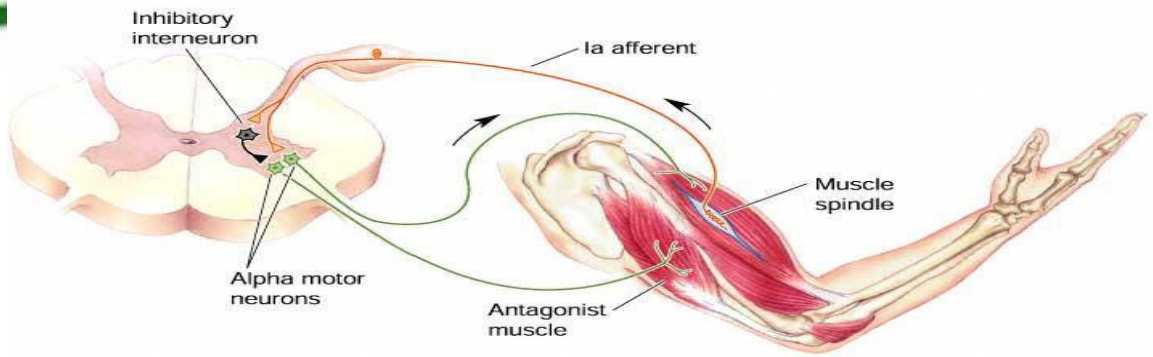
Reciprocal inhibition with stretch reflex (Reciprocal innervation)

-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 <u>cause:-</u>

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

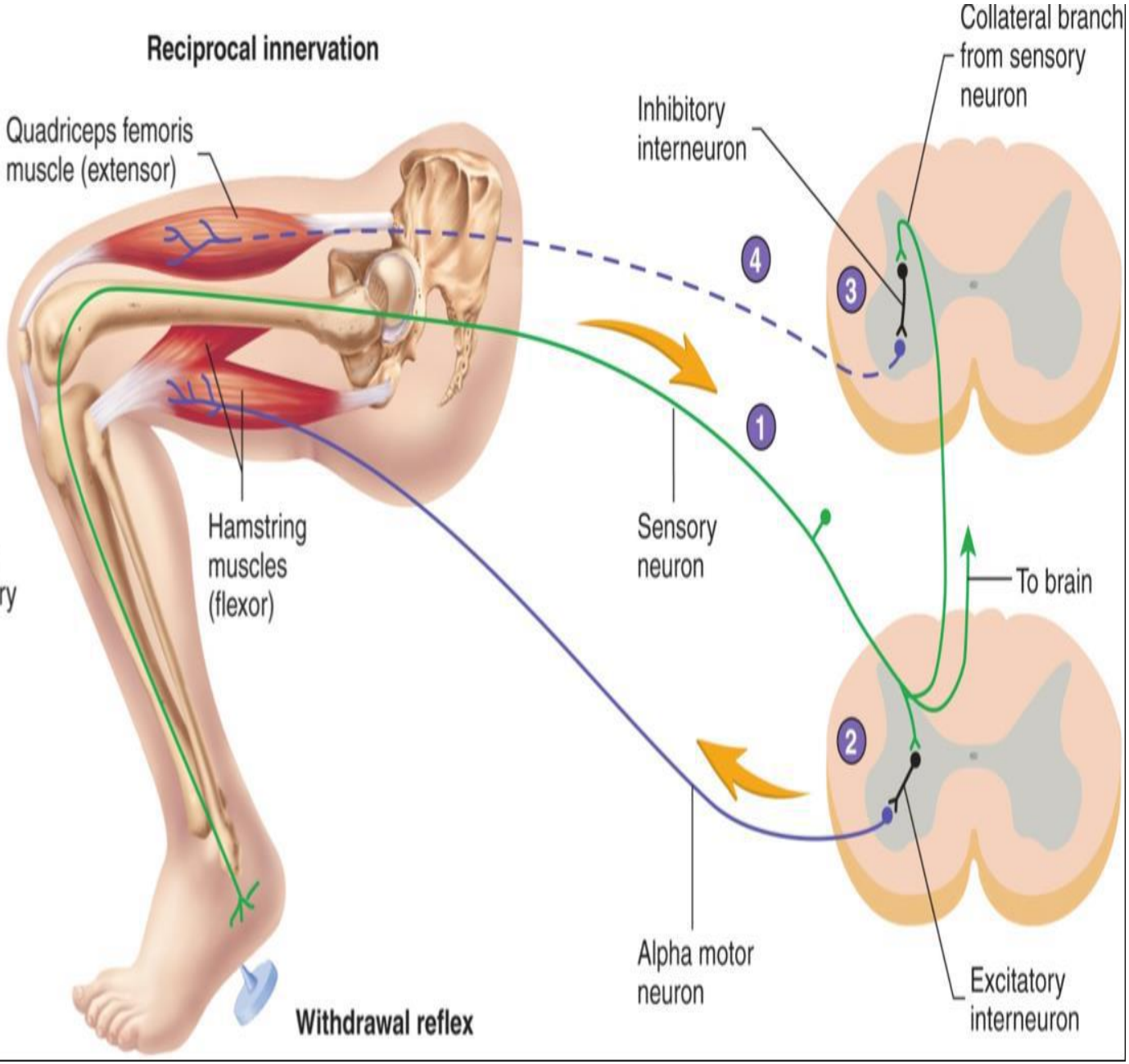
2- send collaterals >>>> inhibitory interneurons synapse on the AHCs of the antagonistic muscle & inhibit them (by GABA

- <u>Reciprocal innervation prevents conflict between opposing muscles</u> and is vital in coordinating body movements)

Reciprocal innervation

1. During the withdrawal reflex, sensory neurons conduct action potentials from pain receptors to the spinal cord.
2. Sensory neurons synapse with excitatory interneurons that are part of the withdrawal reflex.
3. Collateral branches of the sensory neurons also synapse with inhibitory interneurons that are part of reciprocal innervation.
4. The inhibitory interneurons synapse with alpha motor neurons supplying the extensor muscles, causing them to relax and not oppose the flexor muscles of the withdrawal reflex, which are contracting.

Reciprocal innervation



What is the Clinical Significance of Tendon Reflexes ?

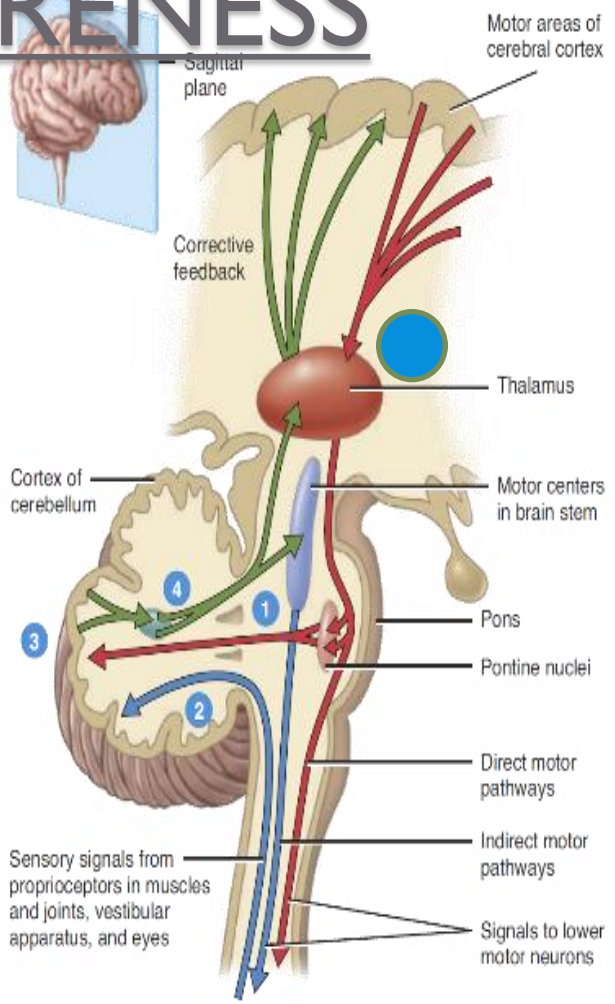
They are carried out clinically to test the integrity of reflex arc.

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

CONSCIOUS AWARENESS

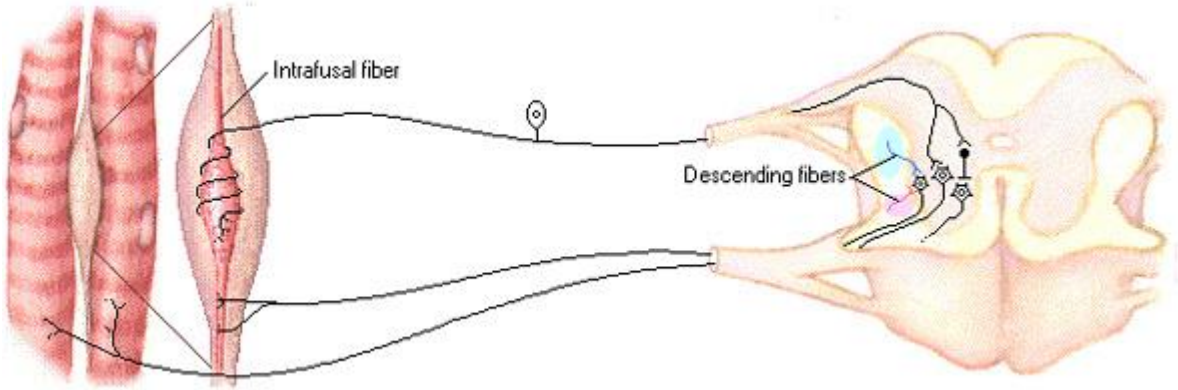
- **Axon collaterals of the muscle spindle sensory neuron also relay nerve impulses to the brain over specific ascending pathways, to allow conscious awareness that the reflex has occurred.**

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



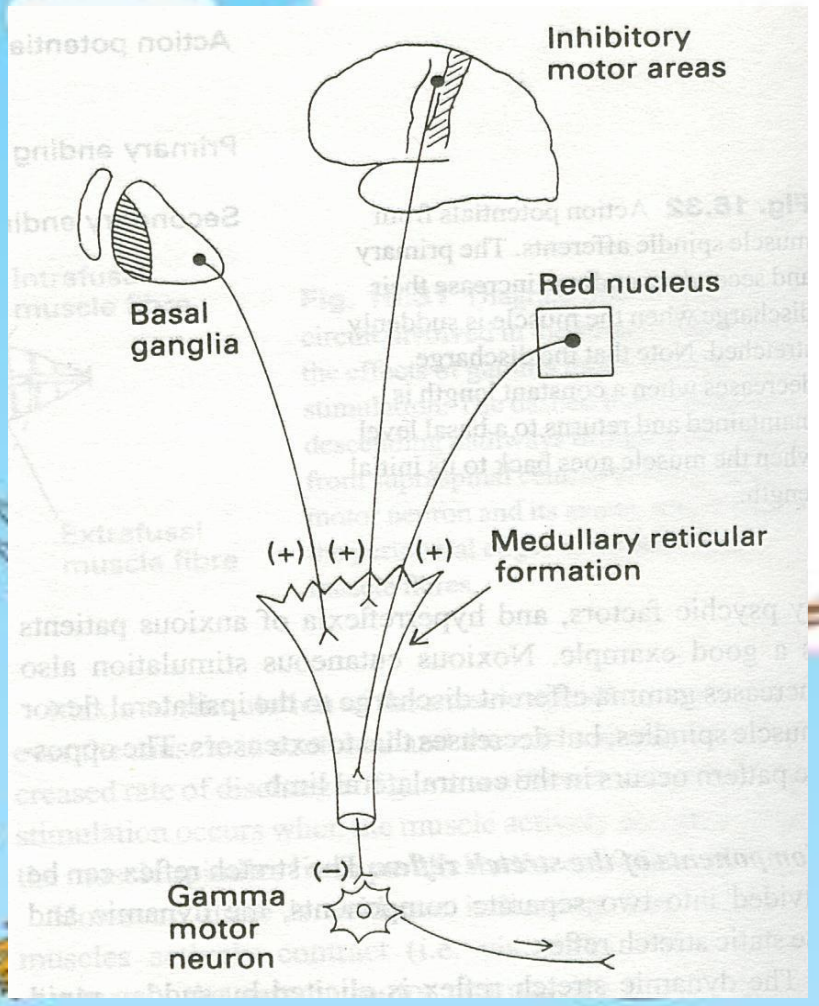
SUPRASPINAL REGULATION OF THE STRETCH REFLEX

- 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

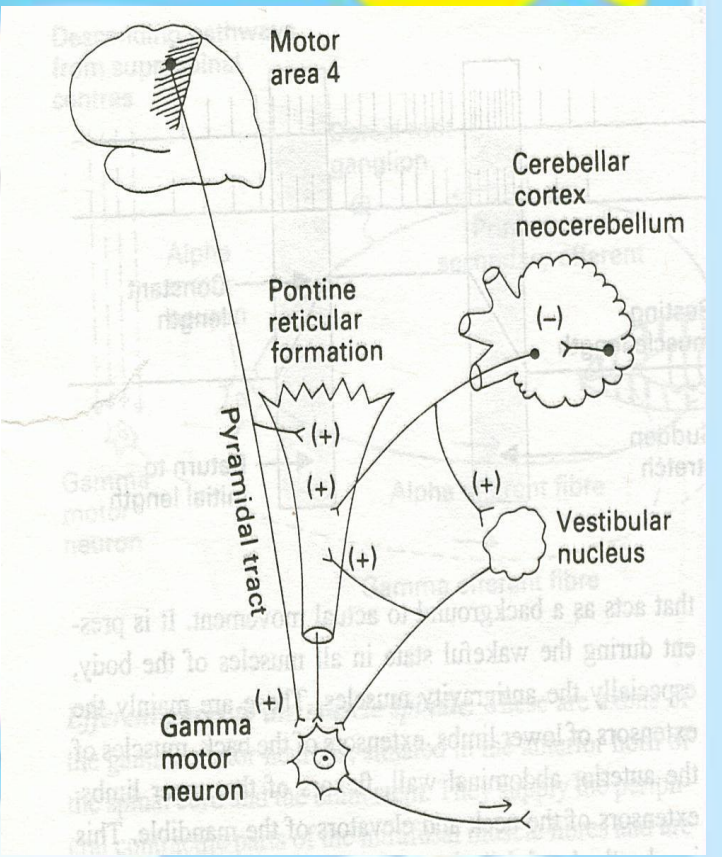


http://humanphysiology.tuars.com/program/section8/8ch3/s8ch3_20.htm

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-
- -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	

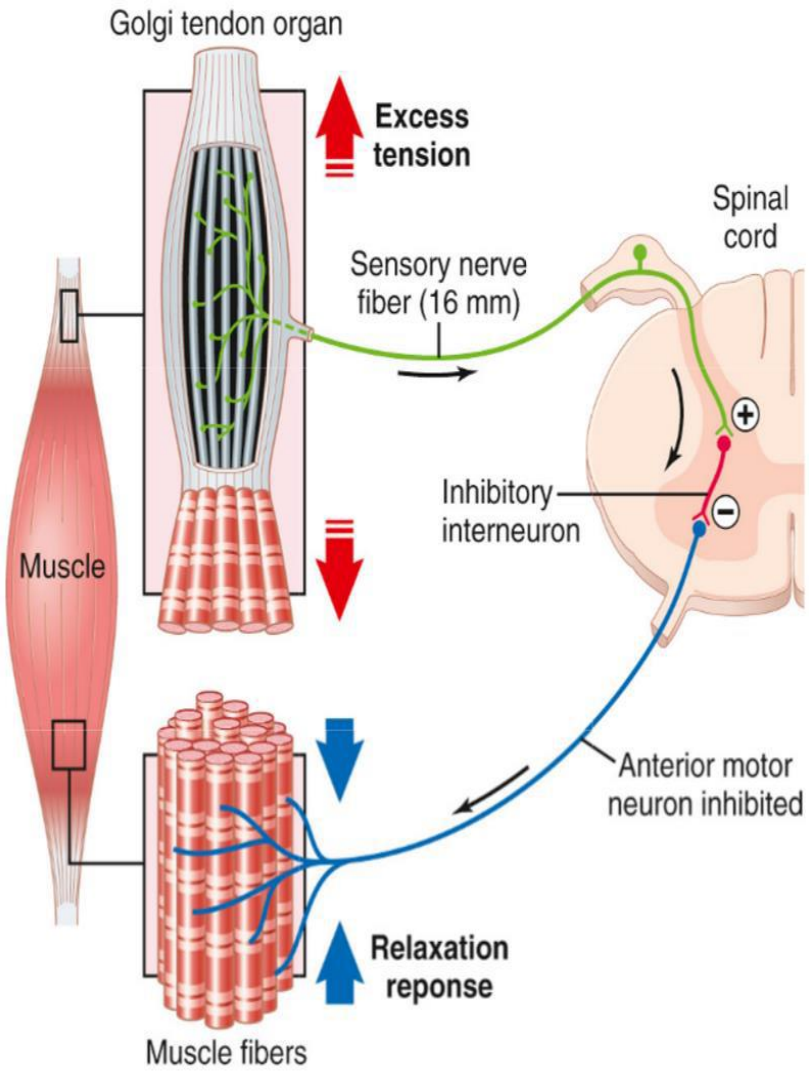
https://musom.marshall.edu/anatomy/grosshom/allppt/pdf/Spinalreflexes.pdf

(Inverse Stretch Reflex)- The Golgi tendon reflex

- **- 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 severe active muscle contraction) >>> cause muscle relaxation



RECEPTOR

Golgi tendon organs

-

Transmit information about tendon tension or rate of change of tension.

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

-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 by an increase in muscle tension>>> 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)

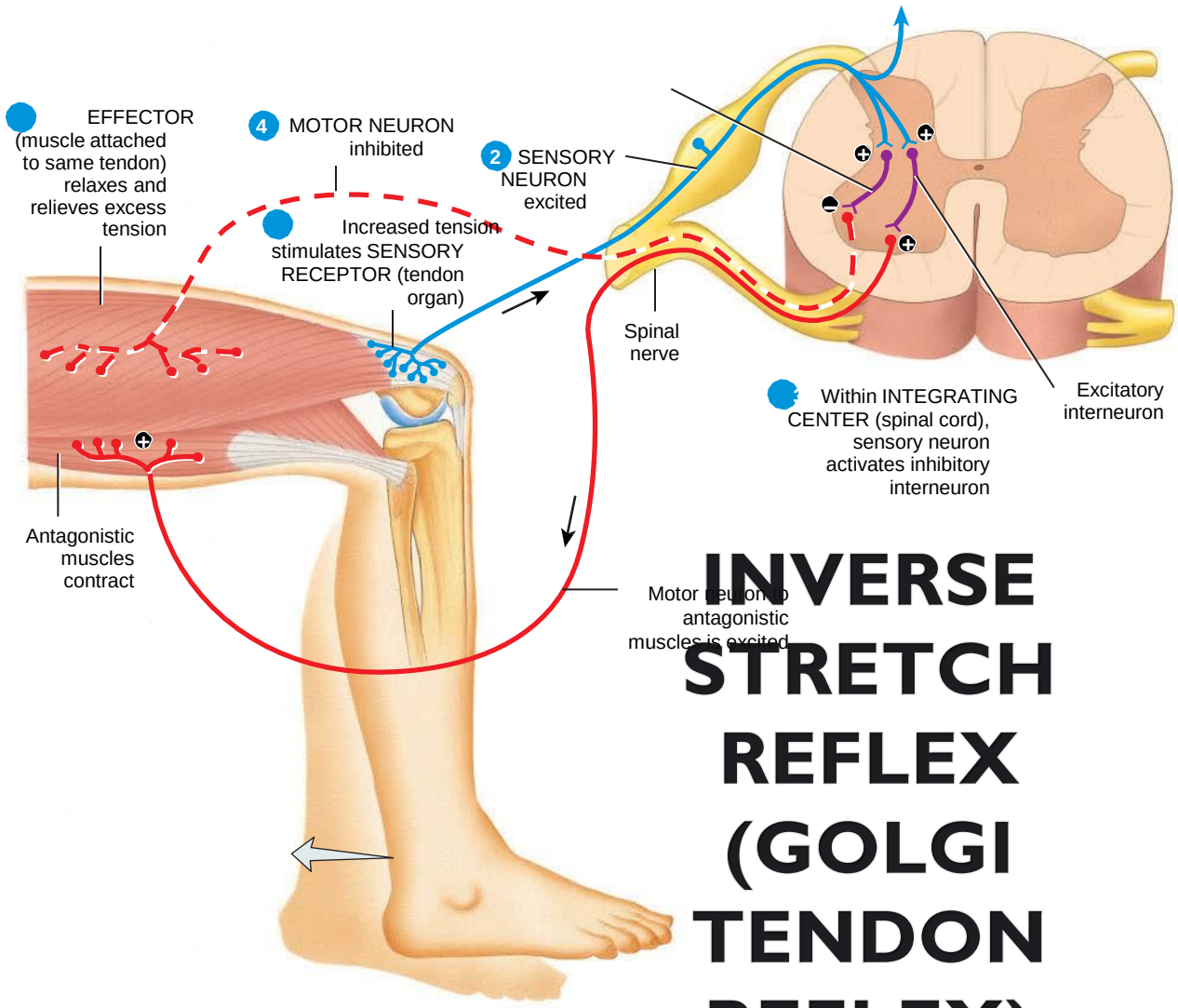
-Value/Protect muscle from rupture& tendon from avulsion& tear

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.

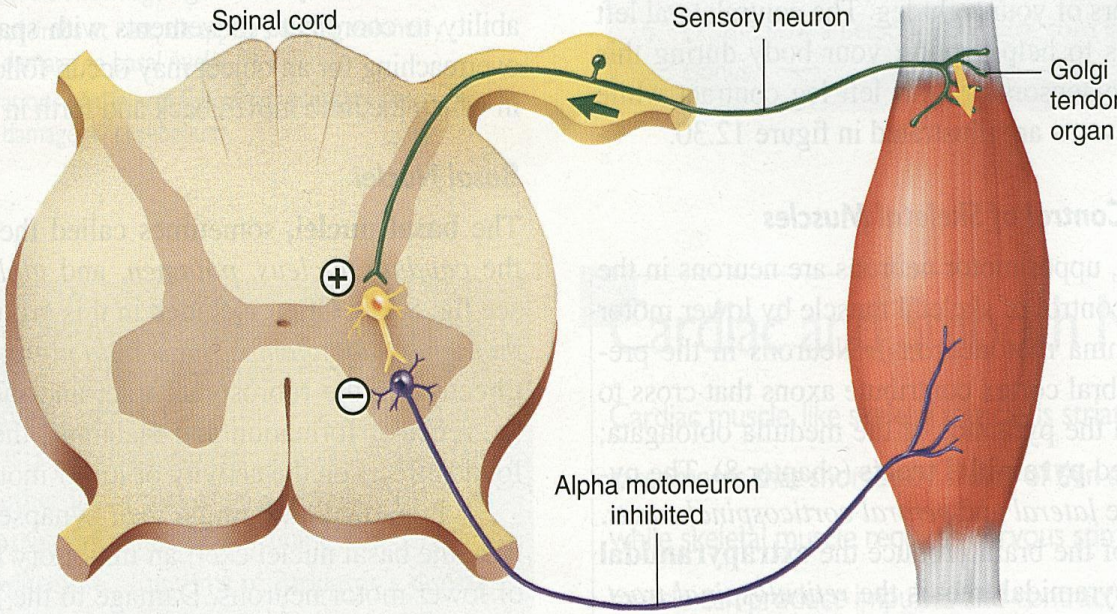
THIS RELAXATION IN RESPONSE TO STRONG STRETCH IS CALLED THE **INVERSE STRETCH REFLEX .**

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



INVERSE STRETCH REFLEX (GOLGI TENDON REFLEX)

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.

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 & II fibers	Type Ib fibers

SYNAPSES	Monosynaptic	Polysynaptic
RECEPROCAL INNERVATION Regulation	**Inhibit** antagonists through inhibitory interneurons	Excites antagonistic muscles through excitatory interneurons
PHYSIOLOGICAL SIGNIFICANCE	Regulate muscle length	Regulate muscle tension to prevent excessive tension increase
CLINICAL ASSESSMENT	Sudden tap of muscle causes brisk contraction muscle jerk	Overstretch of muscle-sudden muscle relaxation (lengthening reaction)