

Reflex

Dr Raghuvveer choudhary

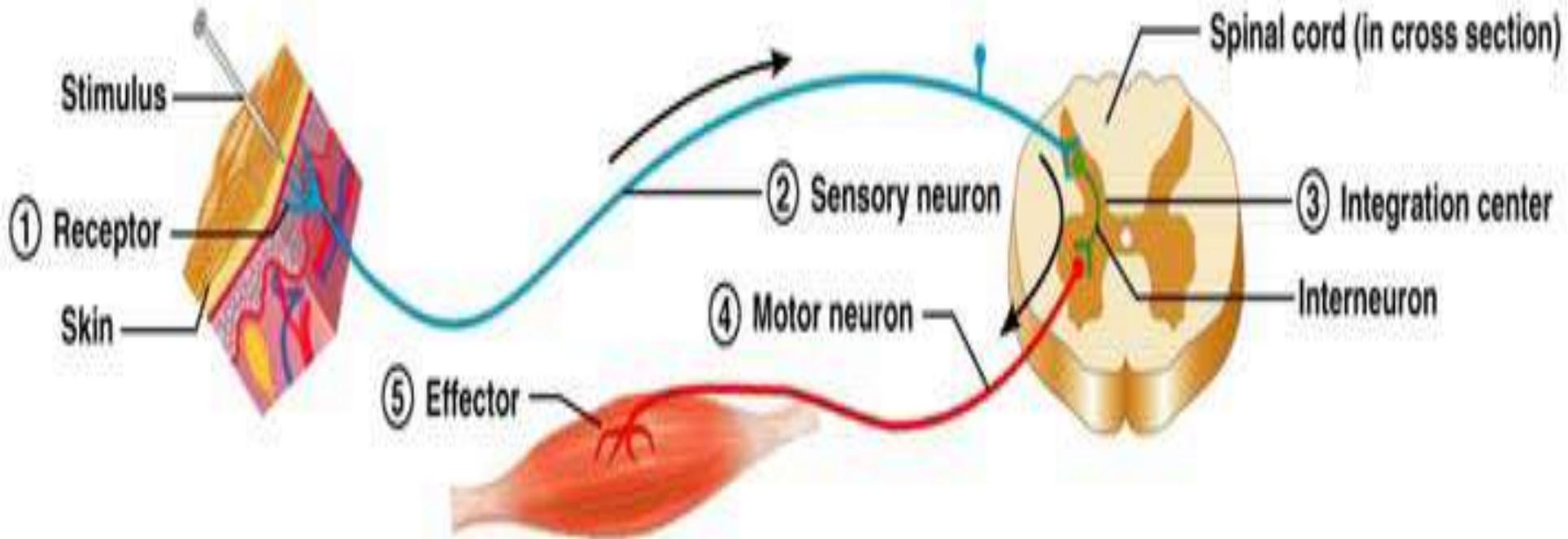
Reflexes

- Reflex - Rapid, involuntary Motor Response to Stimulus
- Reflexes may:
 - Inborn (Intrinsic) or Learned (Acquired)
 - Involve only Peripheral Nerves & Spinal Cord
 - Involve Higher Brain Centers as Well

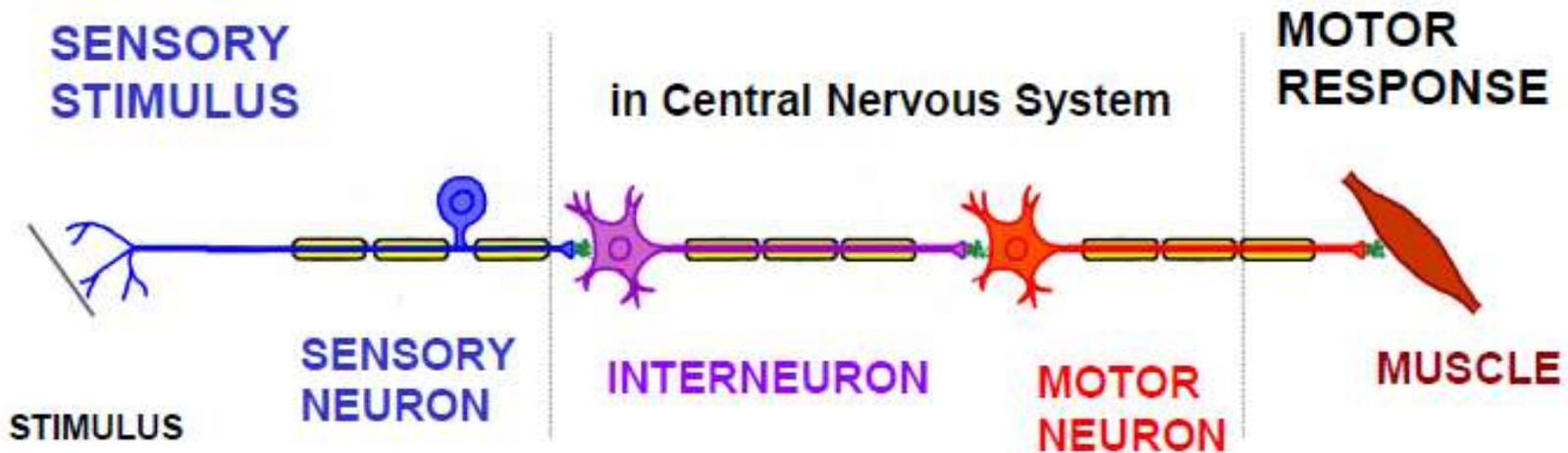
Reflex Arc

- 5 Components of Reflex Arc
 - Receptor – Site of Stimulus
 - Sensory Neuron – Transmits Afferent Impulse to CNS
 - Integration Center – Monosynaptic or Polysynaptic Region within CNS
 - Motor Neuron – Conducts Efferent Impulses from Integration Center to Effector
 - Effector – Muscle Fiber or Gland that Responds to Efferent Impulse

Reflex Arc

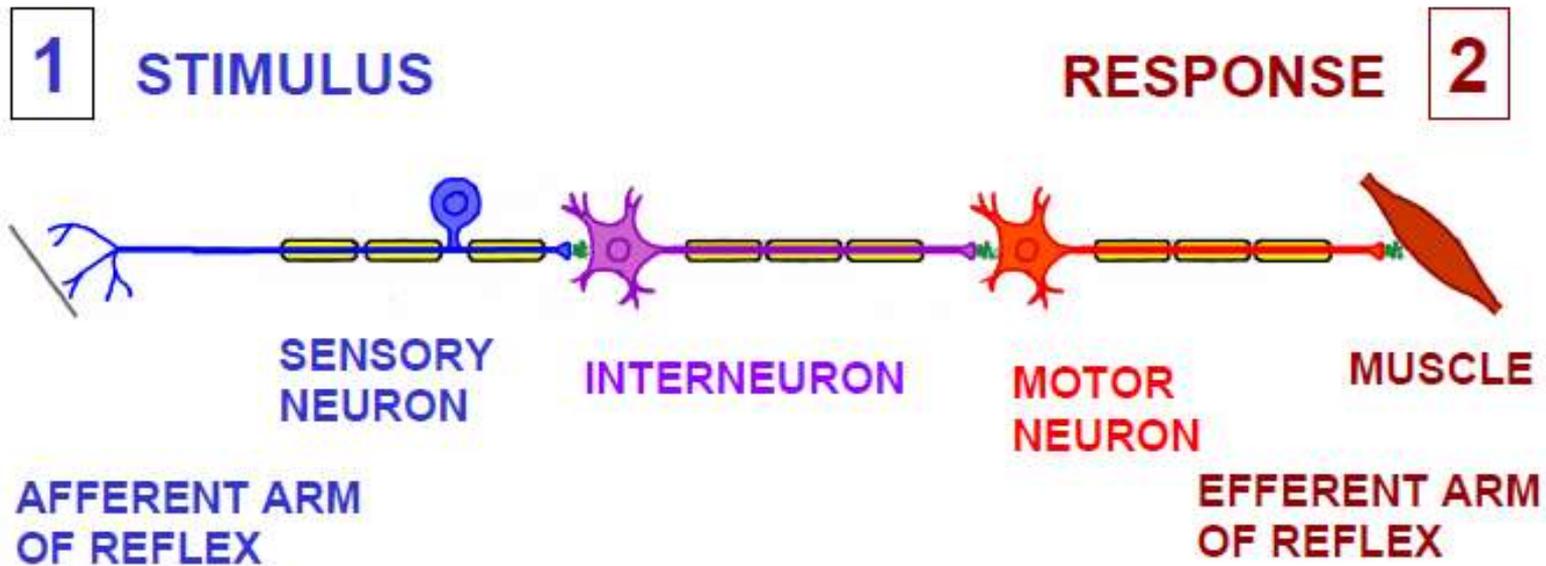


TYPICAL REFLEX



- Typical reflex arc:
- 1) **sensory neuron** - detects stimulus
 - 2) **interneurons** - (most often) can be excitatory or inhibitory
 - 3) **motor neurons** - produce **muscle contraction**, motor response

REFLEX TESTING IS A POWERFUL CLINICAL TOOL



FOR REFLEX TO OCCUR ALL ELEMENTS MUST BE FUNCTIONAL; PATHWAYS MUST BE INTACT

In clinical test apply **Stimulus 1** and see if get **Response 2**
If absent, diagnose where pathway is interrupted.
If abnormal, diagnose where pathway is compromised.

Clasification of reflexes

- Superficial reflexes ---
plantar,abdominal,corneal.conjunctival,cremastric
- Deep reflexes---- biceps,triceps,knee,ankle jerks
- Spinal
- Cranial

Anatomical classification

- Segmental
- Intersegmental
- suprasegmental

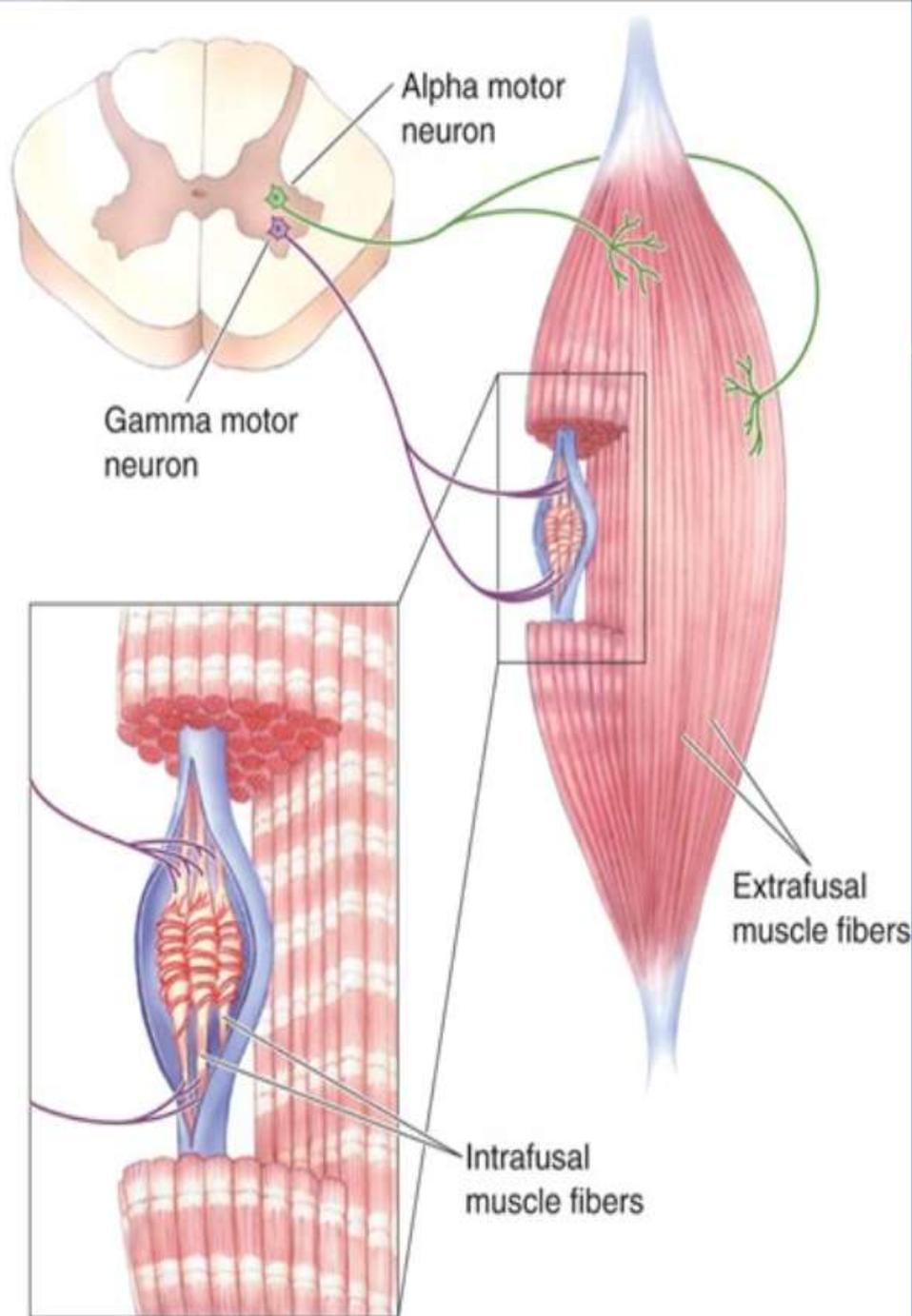
physiological

- Flexor(withdrawal reflex)
- extensor

- Monosynaptic--- stretch reflex
- Di-synaptic---- Golgi tendon Reflex
- Polysynaptic---- withdrawal reflex

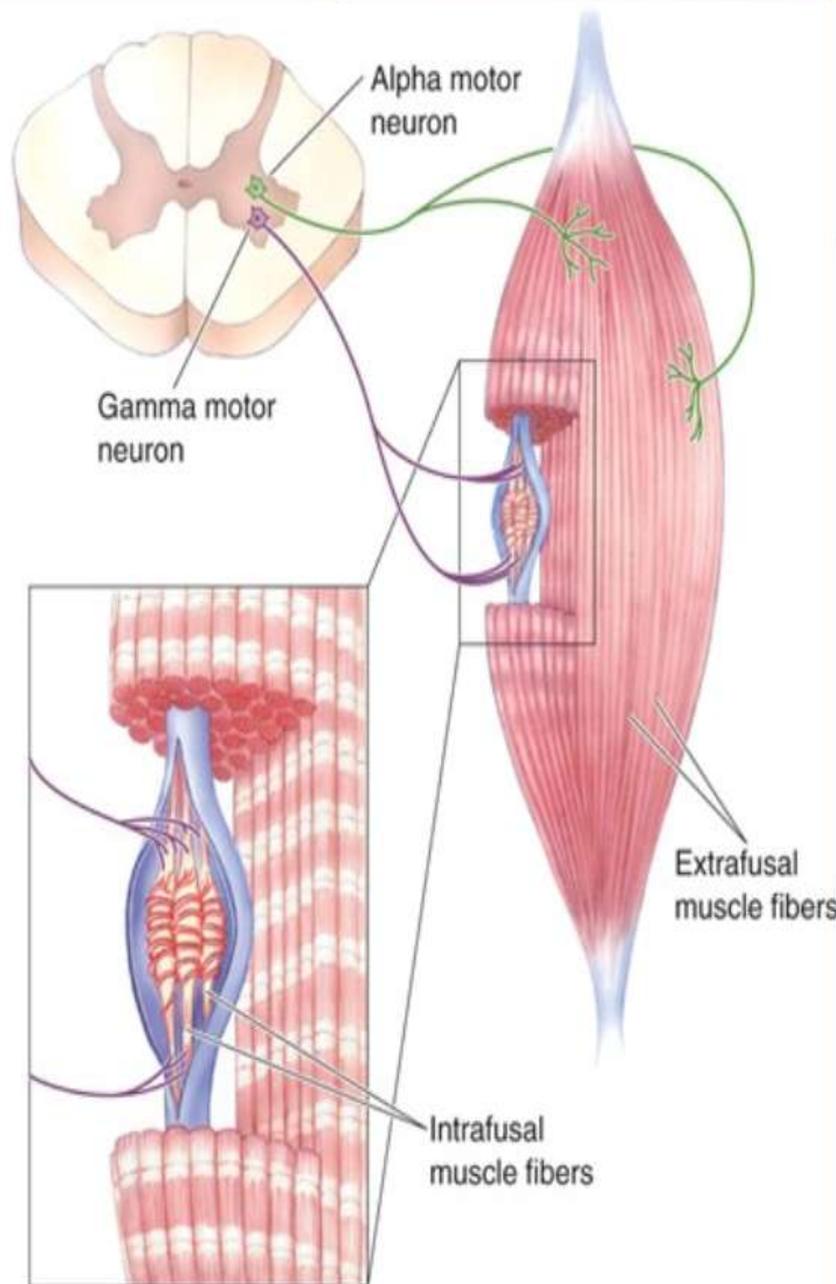
Stretch & Deep Tendon Reflexes

- For Skeletal Muscles to Perform Normally:
 - Golgi Tendon Organs (Proprioceptors)
 - Constantly Inform Brain as to State of Muscle
 - Muscle Spindles
 - Stretch Reflexes
 - Maintain Healthy Muscle Tone



- Every striated muscle has encapsulated muscle fibers scattered throughout the muscle called *muscle spindles*.

- Extrafusal and intrafusal fibers



The extrafusal muscle fibers are innervated by **Alpha** motor neuron

The intrafusal muscle fibers are innervated by **Gamma** motor neurons

Types of muscle fibers

a. Extrafusal fibers

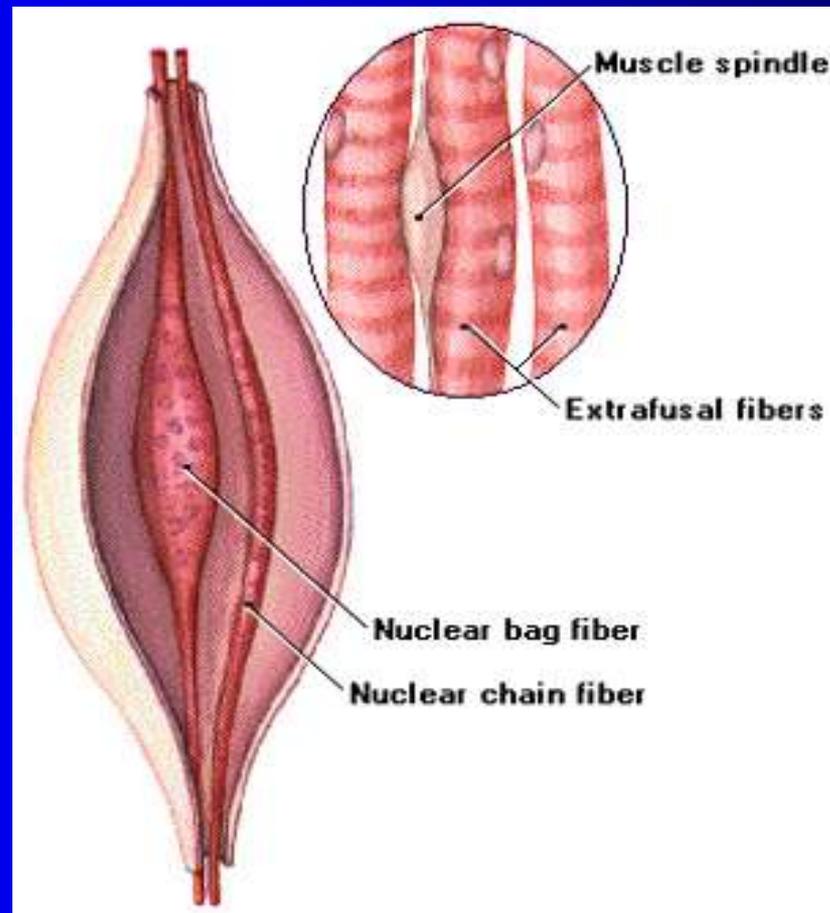
- make up the bulk of muscle.
- are **innervated by α -motoneurons.**
- provide the force for muscle contraction.

b. Intrafusal fibers

- are smaller than extrafusal muscle fibers.
- are **innervated by γ -motoneurons.**
- are encapsulated in sheaths to form **muscle spindles.**
- run in parallel with extrafusal fibers, but not for the entire length of the muscle.
- are too small to generate significant force.

Muscle spindles

- are distributed throughout muscle.
- consist of small, encapsulated intrafusal fibers connected in parallel with large (force-generating) extrafusal fibers.
- The finer the movement required, the greater the number of muscle spindles in a muscle.



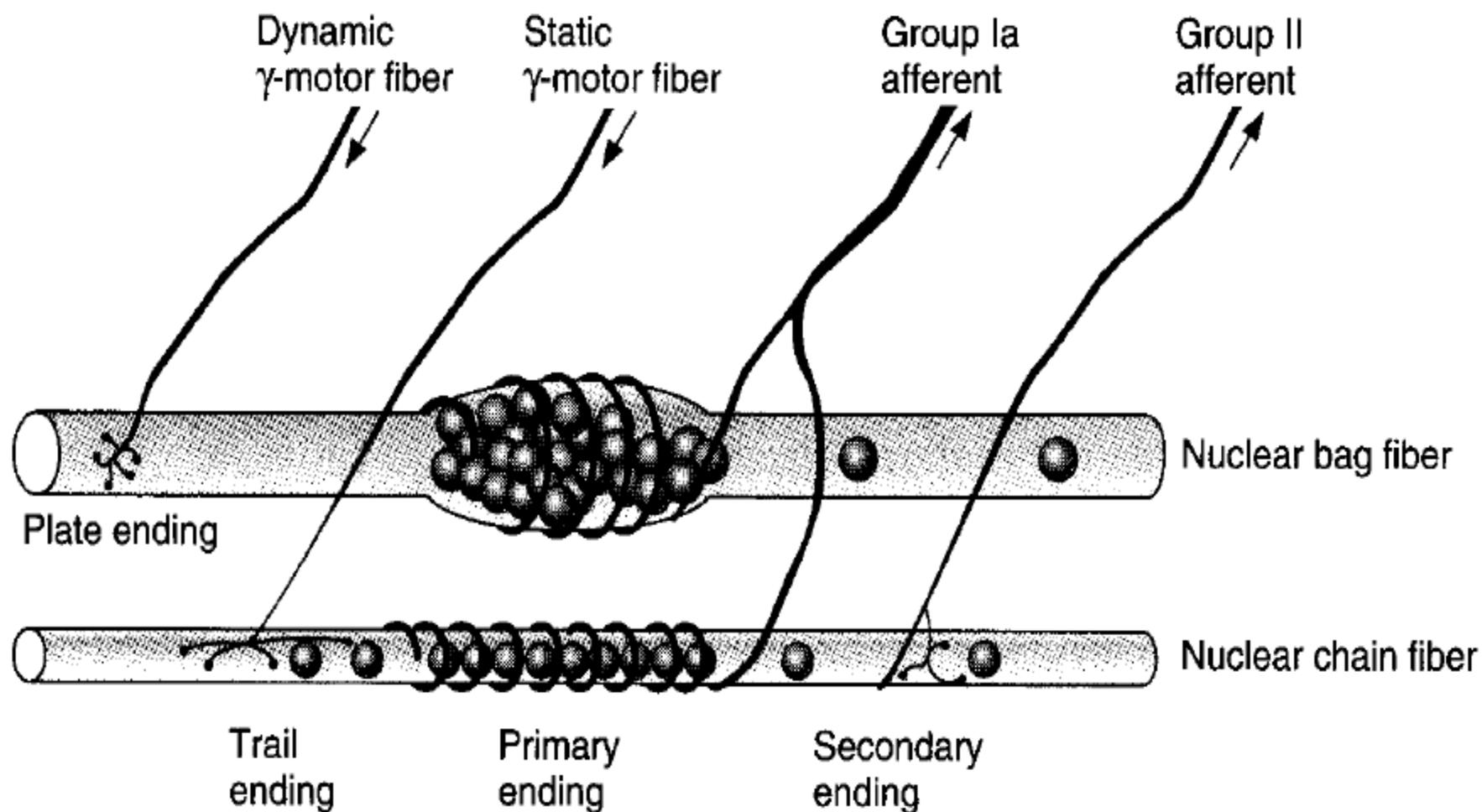


Figure 2-8 Organization of the muscle spindle. (Modified with permission from Matthews PBC. Muscle spindles and their motor control. *Physiol Rev* 1964;44:232.)

Types of intrafusal fibers in muscle spindles (Figure 2-8)

(1) Nuclear bag fibers

- detect the rate of change in muscle length (fast, dynamic changes).
- are innervated by group Ia afferents.
- have nuclei collected in a central “bag” region.

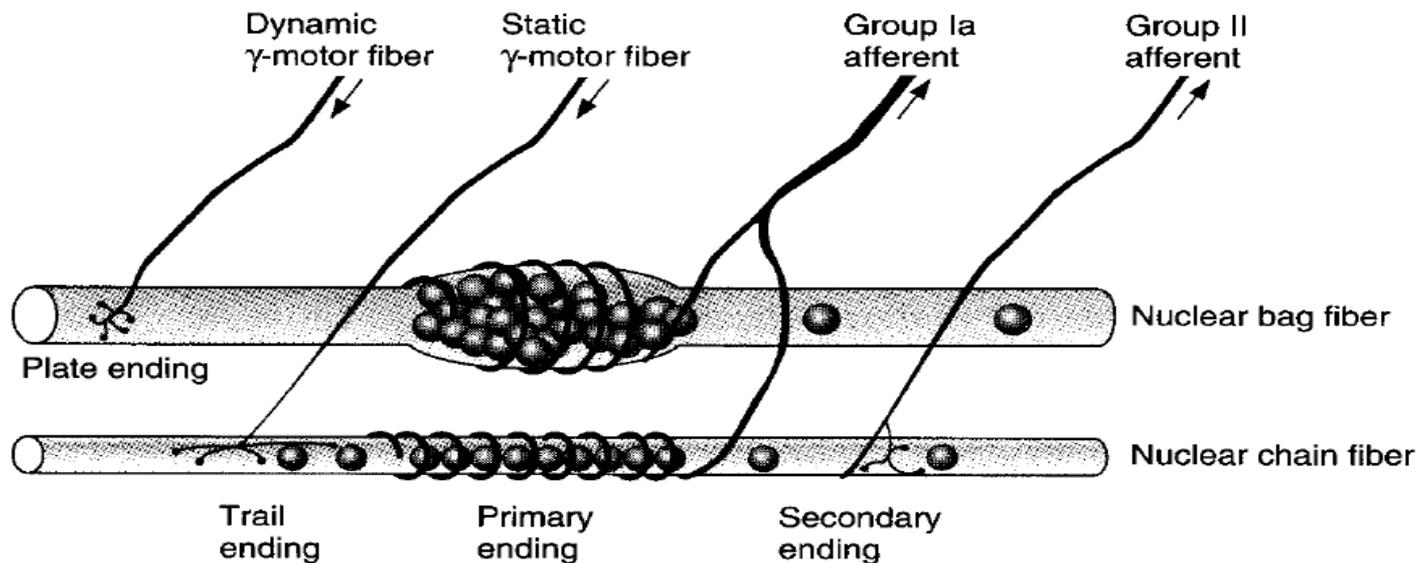


Figure 2-8 Organization of the muscle spindle. (Modified with permission from Matthews PBC. Muscle spindles and their motor control. *Physiol Rev* 1964;44:232.)

(2) Nuclear chain fibers

- detect **static** changes in muscle length.
- are innervated by group II afferents.
- are more numerous than nuclear bag fibers.
- have nuclei arranged in rows.

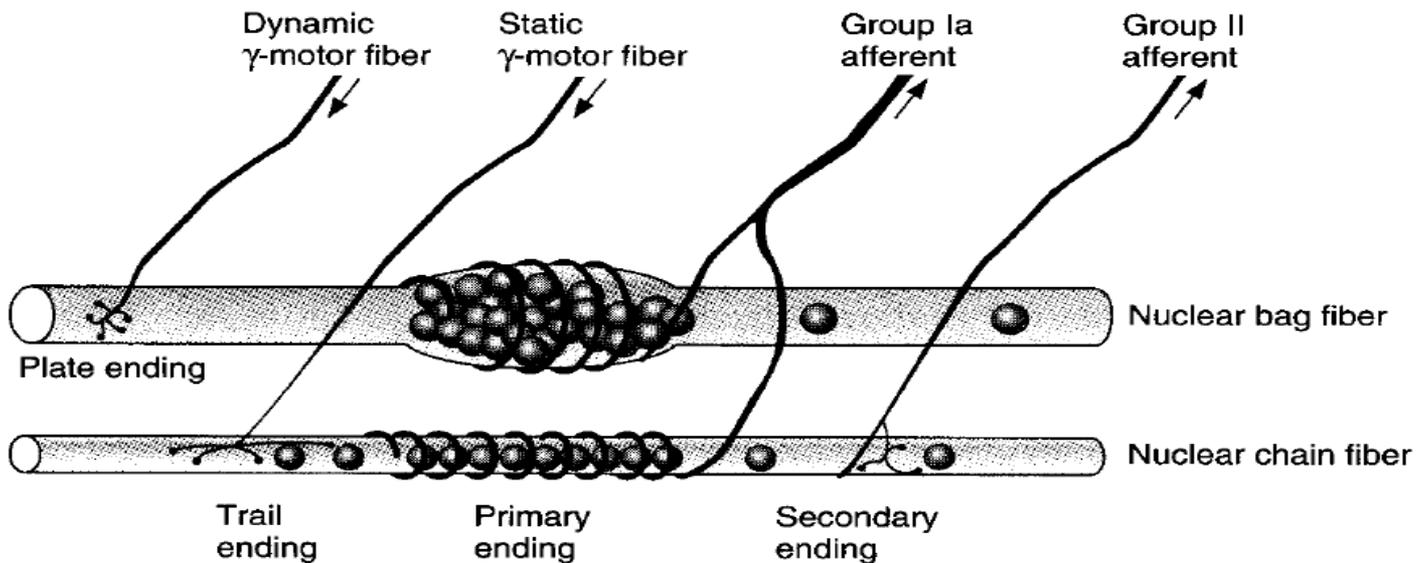


Figure 2-8 Organization of the muscle spindle. (Modified with permission from Matthews PBC. Muscle spindles and their motor control. *Physiol Rev* 1964;44:232.)

Muscle Spindles

- Composed of 3-10 Intrafusal Muscle Fibers
 - Lack Myofilaments in Central Regions
 - Non-Contractile
 - Receptive Surfaces
- Muscle Spindles Wrapped with 2 Types of Afferent Endings
 - Primary Sensory Endings of Type Ia Fibers
 - Secondary Sensory Endings of Type II Fibers
 - Innervated by γ Efferent Fibers
- Contractile Muscle Fibers
 - Extrafusal Fibers
 - Innervated by α Efferent Fibers

γ Efferent motor fiber to spindle

- Secondary sensory endings (type II fiber)
- Primary sensory endings (type Ia fiber)
- Muscle spindle
- Connective tissue capsule

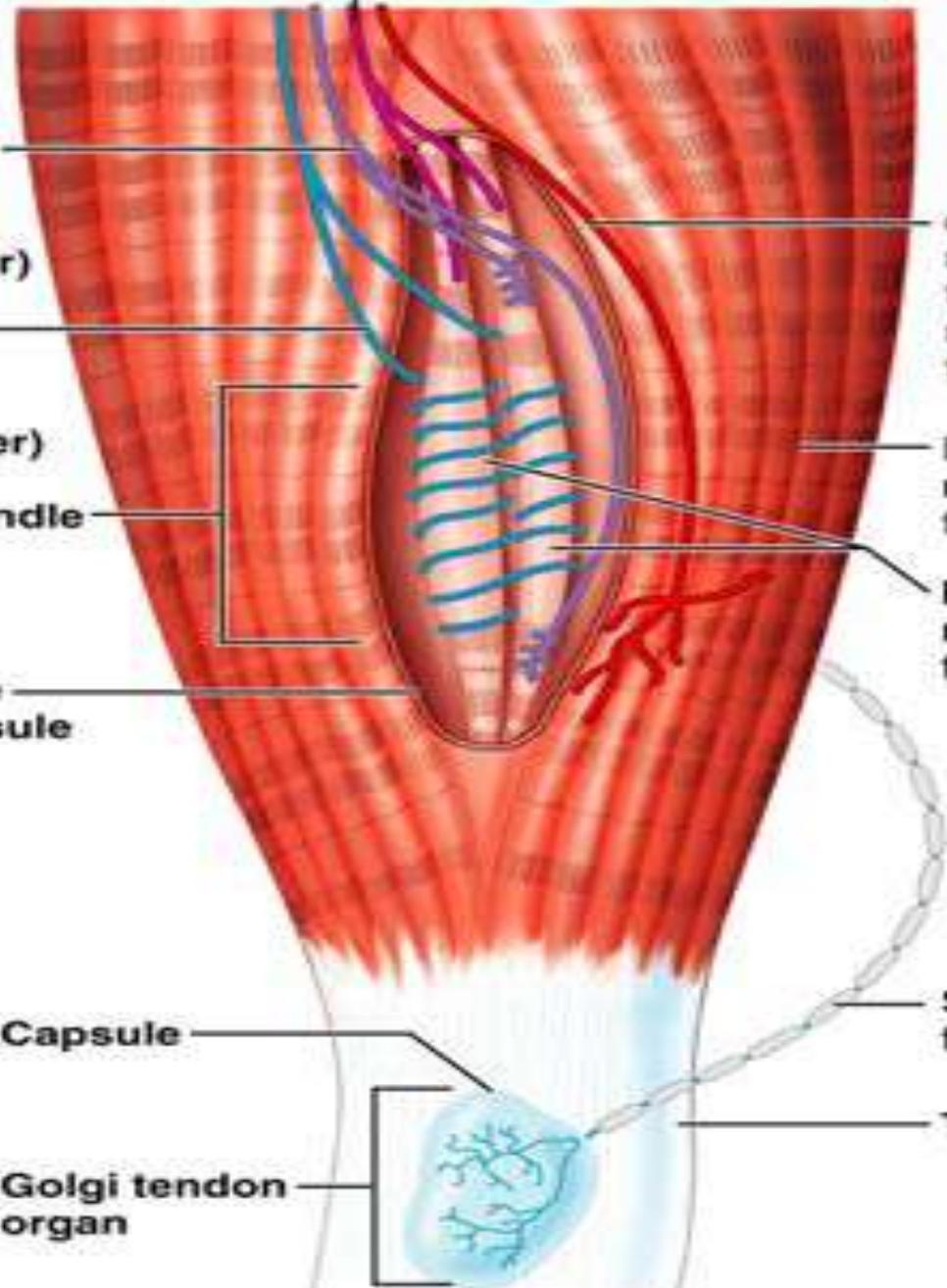
- α Efferent motor fiber to extrafusal muscle fibers
- Extrafusal muscle fiber
- Intrafusal muscle fibers

Capsule

Golgi tendon organ

Sensory fiber

Tendon



b. *How the muscle spindle works* (see Figure 2-8)

- Muscle spindle reflexes oppose (correct for) increases in muscle length (stretch).

(1) Sensory information about muscle length is received by group Ia (velocity) and group II (static) afferent fibers.

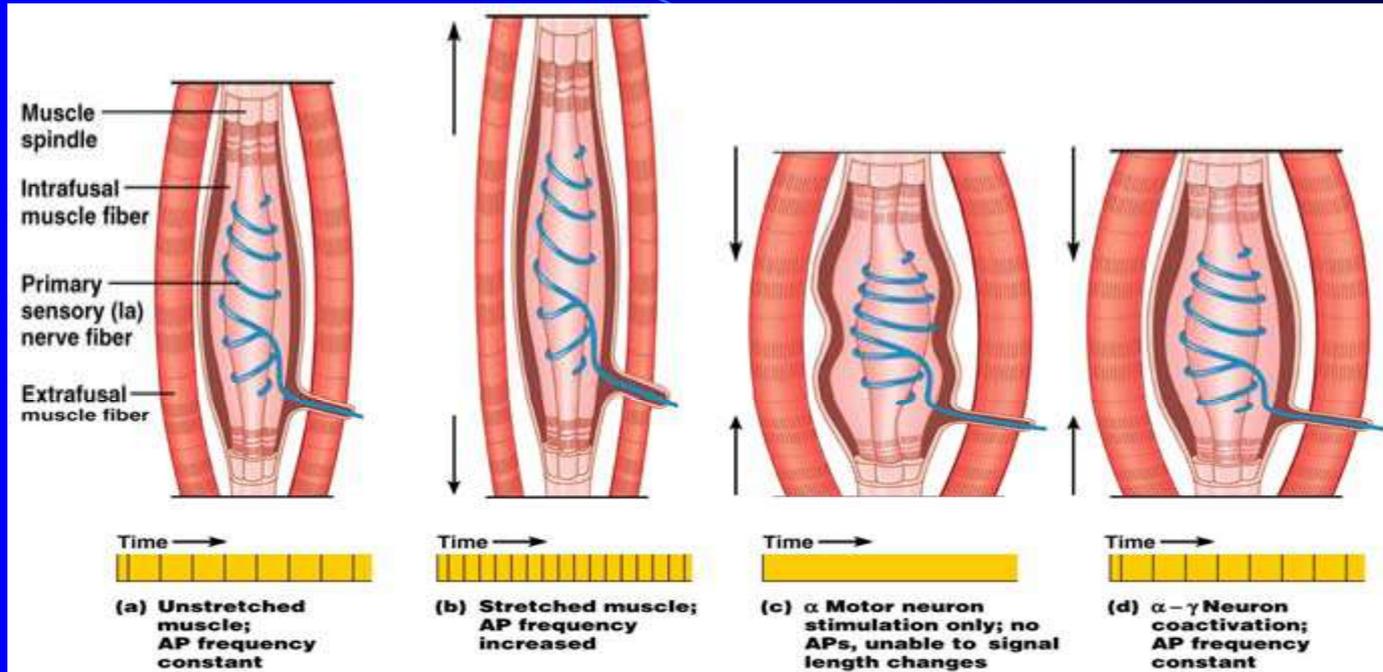
(2) When a muscle is stretched (lengthened), the muscle spindle is also stretched, stimulating group Ia and group II afferent fibers.

(3) Stimulation of group Ia afferents stimulates α -motoneurons in the spinal cord. This stimulation in turn causes contraction and shortening of the muscle. Thus, the original stretch is opposed and muscle length is maintained.

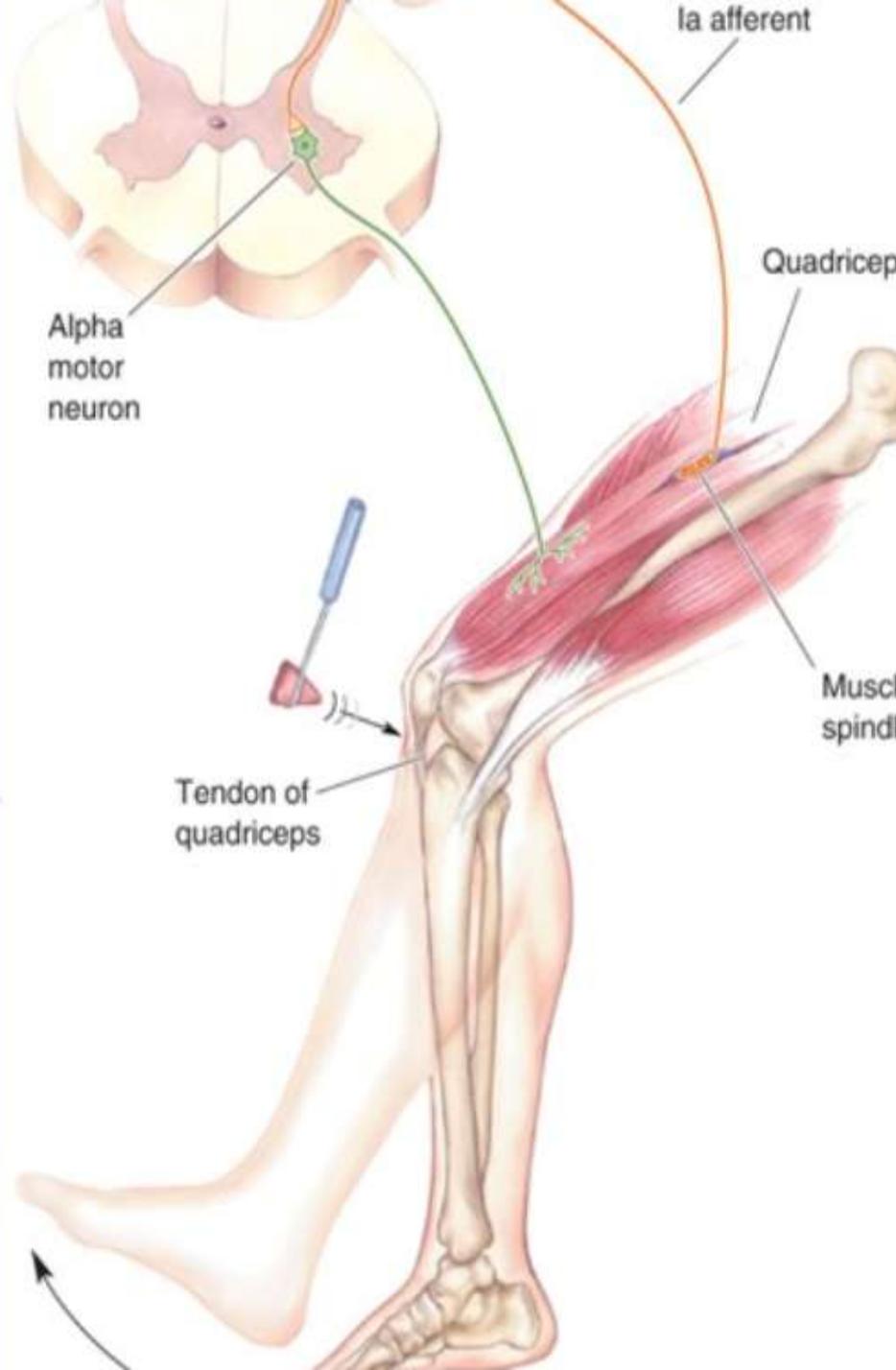
Operation of Muscle Spindles

- Stretching Muscles
 - Activates Muscle Spindle
 - ↑ Rate of Action Potential in Ia Fibers
 - Contracting Muscle ↓ Tension on Muscle Spindle
 - ↓ Rate of Action Potential on I Fibers

Operation of Muscle Spindle



Muscle stretch reflex



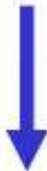
(2) Muscle stretch reflex

Definition: Whenever a muscle is stretched, excitation of the spindles causes reflexive contraction of the same muscle from which the signal originated and also of closely allied synergistic muscle.

The basic circuit: Spindle → Proprioceptor nerve fiber → dorsal root of the spinal cord → synapses with anterior motor neurons → □ -motor N. F. → the same M. from whence the M. spindle fiber originated.

STIMULUS

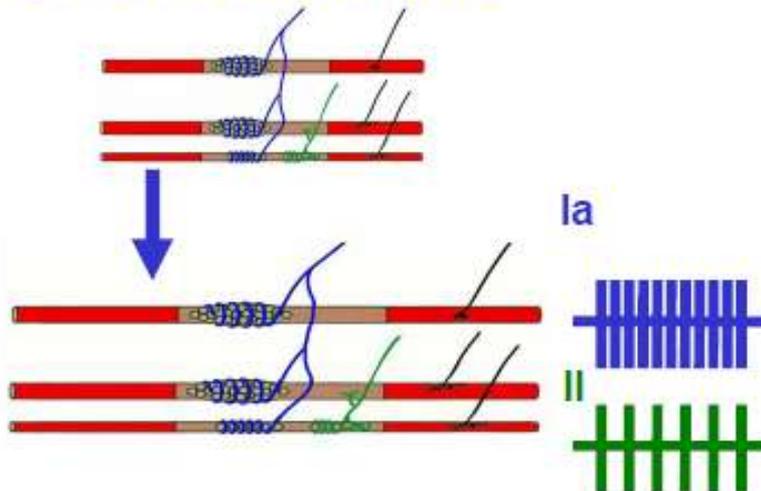
BICEPS
MUSCLE
STRETCHED



1) Stimulus -
fast stretch
of muscle

STRETCH REFLEX

BICEPS MUSCLE SPINDLE



2) Sense organ
excited - Muscle
spindle Ia and II
sensory neurons

RESPONSE

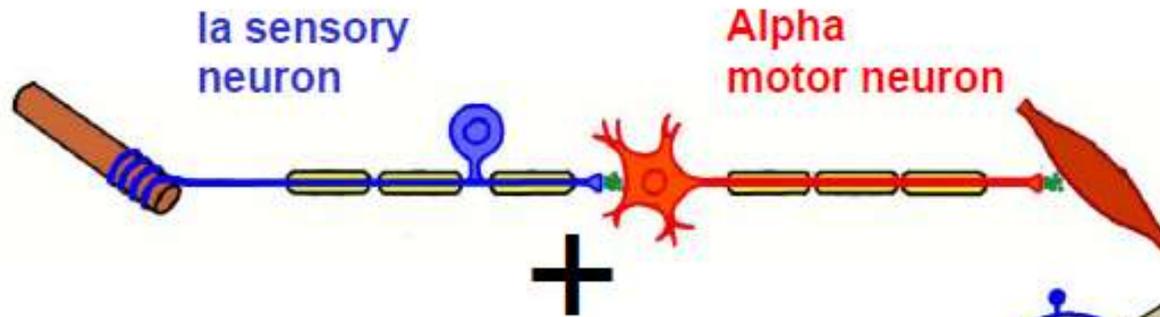


BICEPS
MUSCLE
CONTRACTS



3) Primary
response -
muscle that is
stretched
contracts rapidly

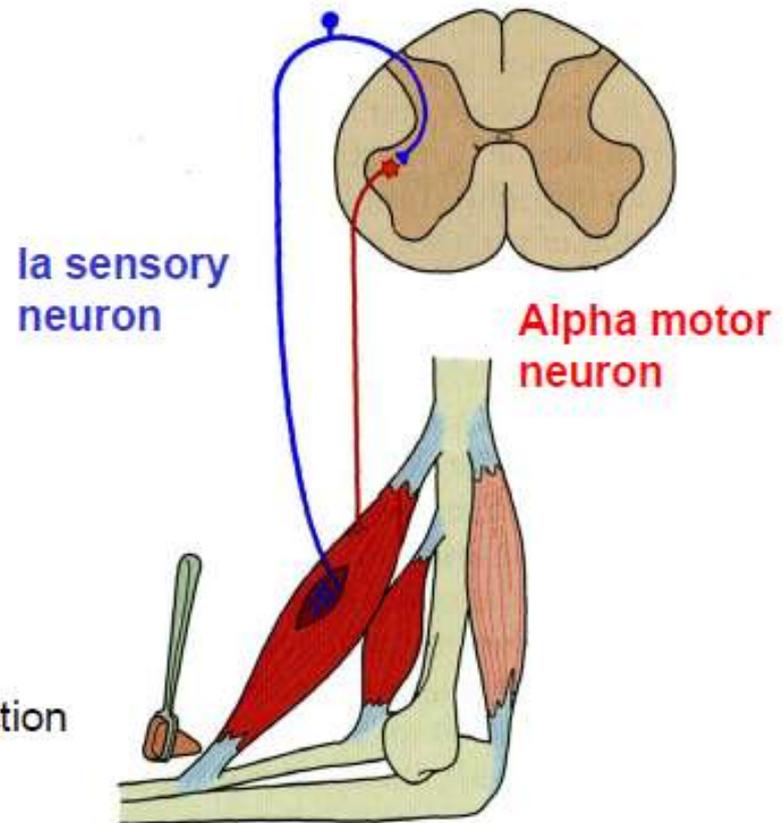
SYNAPSES



Group Ia - monosynaptic connections with alpha motor neurons (fastest reflex known, delay at synapse about 1 msec)

Group II - make 1) monosynaptic connections - direct to motor neuron and 2) polysynaptic connections to motor neurons (through interneuron)

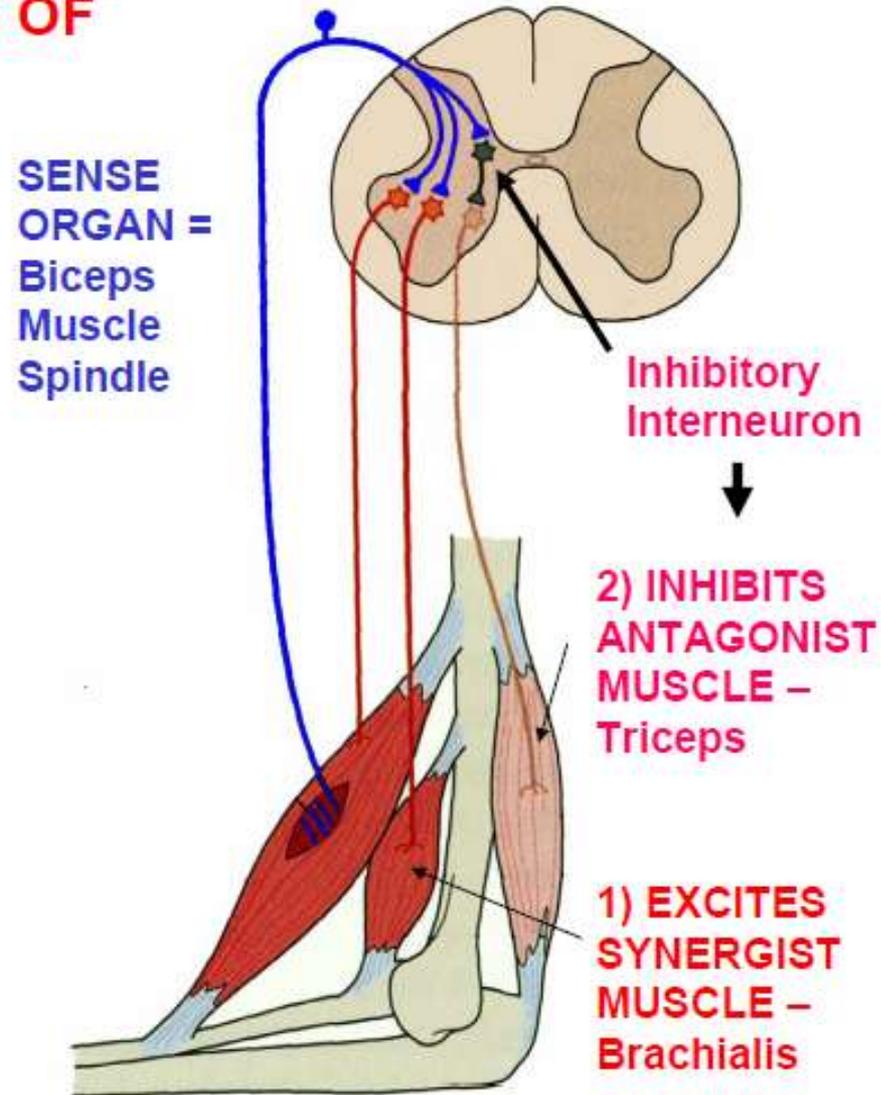
+ note: plus indicates excitatory connection



OTHER COMPONENTS OF STRETCH REFLEX

1) **Excite synergist muscles** - spindle afferents also make excitatory **monosynaptic** connections with synergist muscles

2) **Inhibit antagonist muscles - RECIPROCAL INHIBITION** - Spindle activity also excites **interneurons** that make **inhibitory synapses** on motor neurons to antagonist muscles (**polysynaptic**)



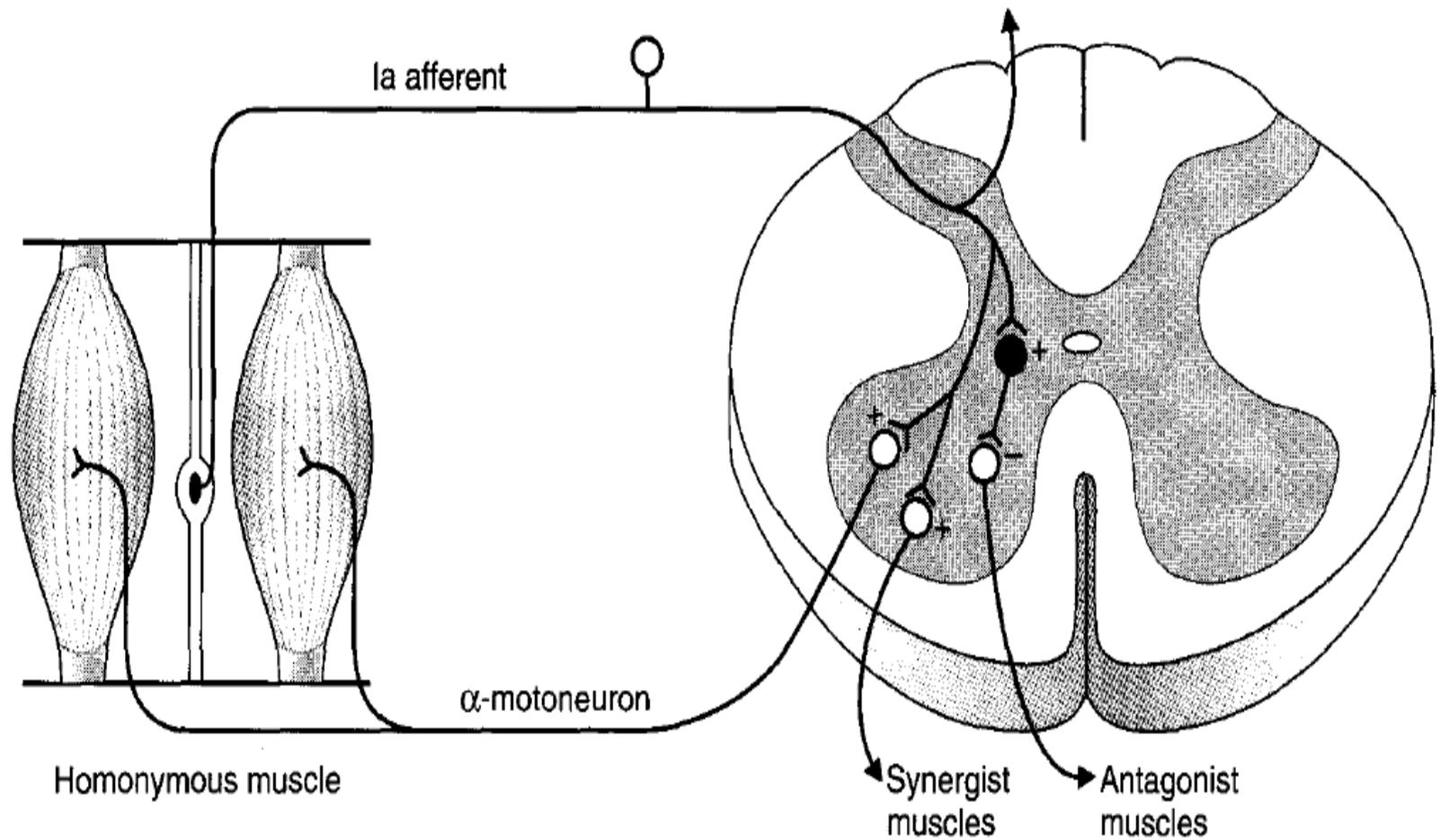


Figure 2-9 The stretch reflex.

1. *Stretch (myotatic) reflex—knee jerk* (Figure 2-9)

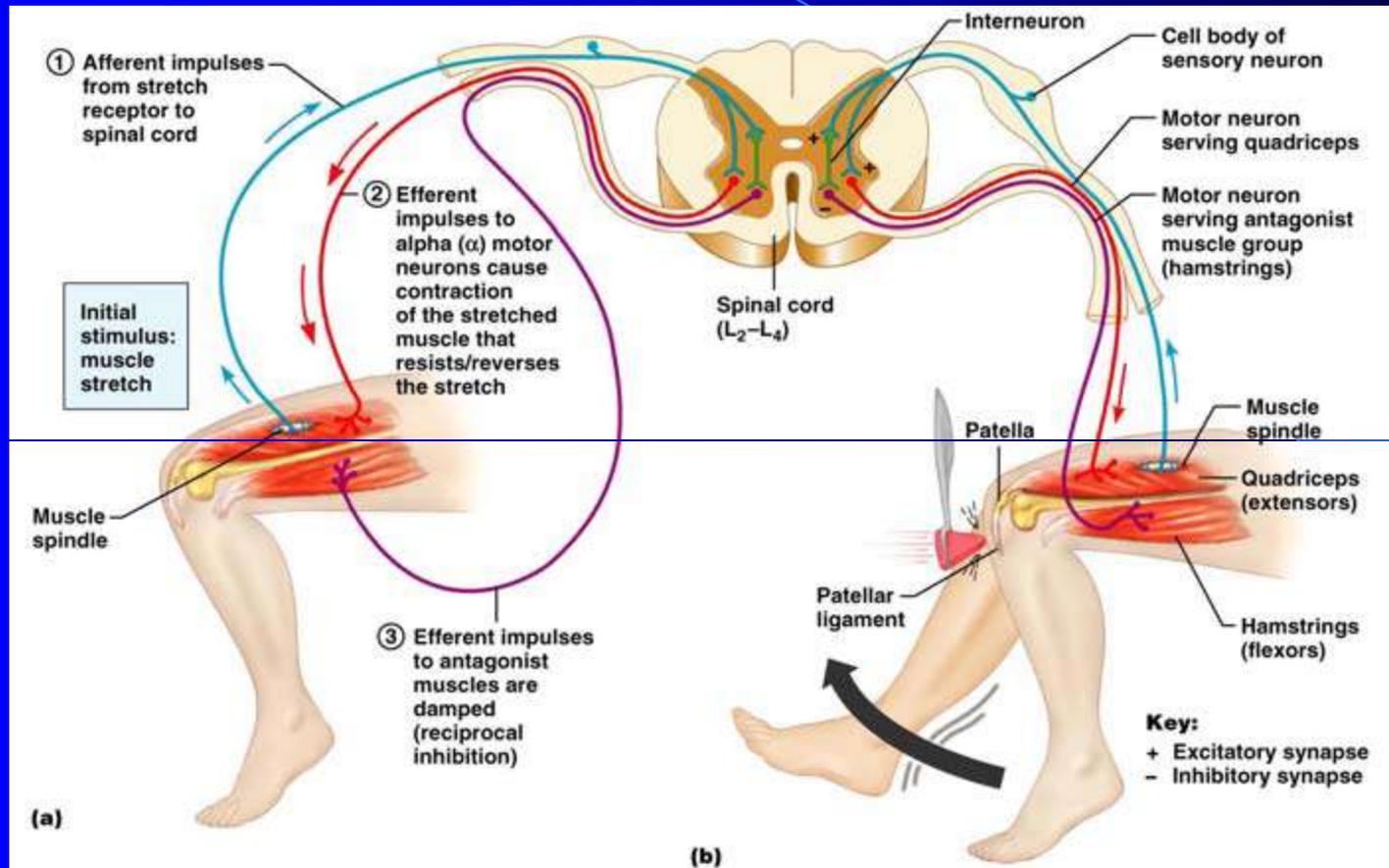
- is **monosynaptic**.

- Muscle is stretched*, and the stretching stimulates **group Ia** afferent fibers.
- Group Ia afferents synapse directly on **α -motoneurons** in the spinal cord. The pool of α -motoneurons that is activated innervates the homonymous muscle.

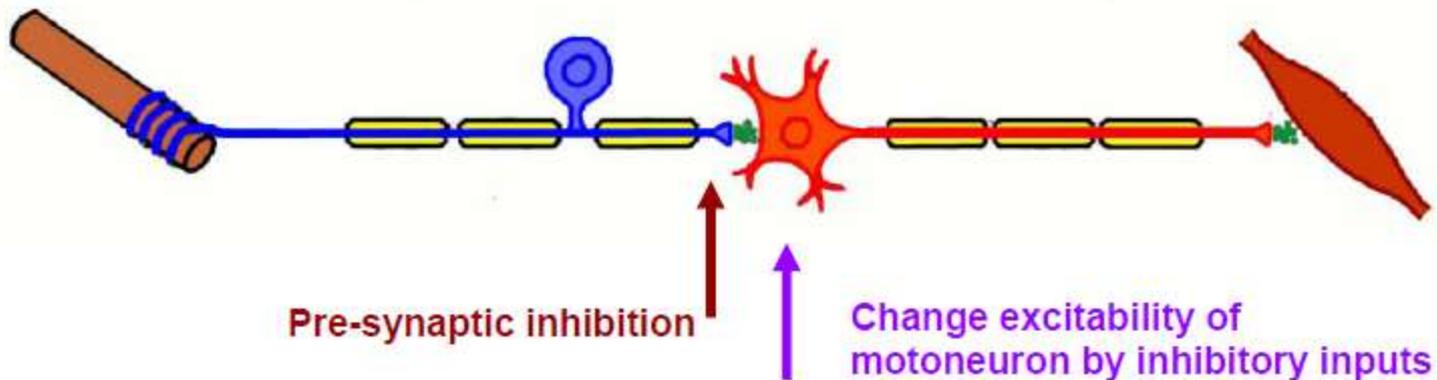
- c. Stimulation of α -motoneurons causes **contraction in the muscle that was stretched**. As the muscle contracts, it shortens, decreasing the stretch on the muscle spindle and returning it to its original length.
- d. At the same time, synergistic muscles are activated and antagonistic muscles are inhibited.

Stretch Reflex

- Stretching Muscle
 - Activates Muscle Spindle
 - Excited γ Motor Neurons of Spindle → Stretched Muscle to Contract
 - Afferent Impulses from Spindle Result in Inhibition of Antagonist
 - Patellar Reflex
 - Tapping Patellar Tendon Stretches Quadriceps Starts Reflex Action
 - Quadriceps Contract & Antagonistic Hamstrings Relax



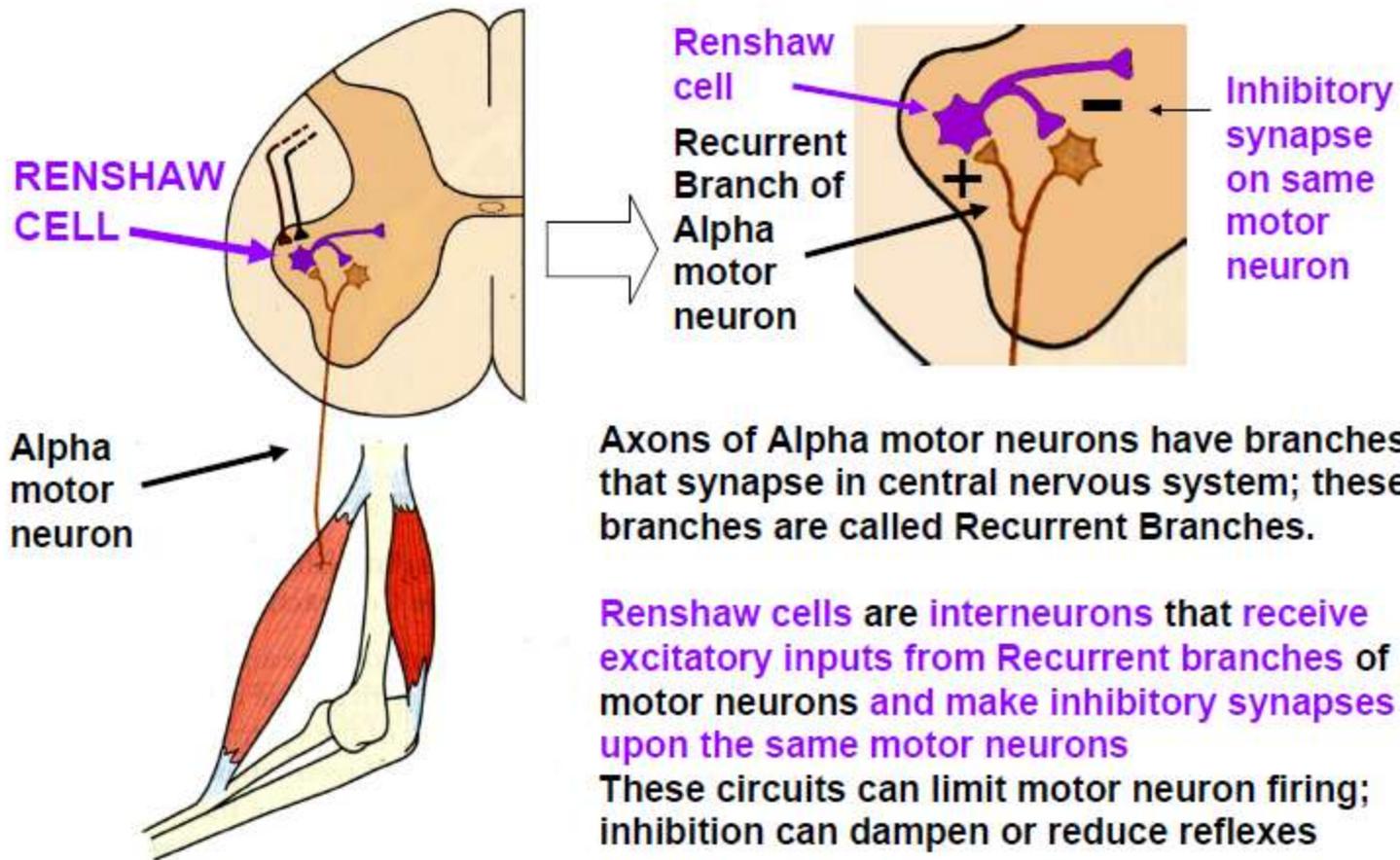
STRETCH REFLEXES CAN BE MODULATED AND MODIFIED: CHANGE IN DAMAGE AND DISEASE



- 1- Reflexes can be modulated by **pre-synaptic inhibition of Ia terminals**; this can reduce the amount of transmitter release at the synapse upon motor neuron and dampen monosynaptic reflex
- 2- **Activities of motor neurons can be decreased by inhibitory inputs.**

Changes in reflexes are symptomatic: In general, Decrease stretch reflexes can indicate Lower Motor Neuron Disorders, Increase Stretch reflexes can indicate Upper Motor Neuron Syndromes.

ACTIVITIES OF MOTOR NEURONS CAN BE MODULATED BY RENSCHAW CELLS



Axons of Alpha motor neurons have branches that synapse in central nervous system; these branches are called **Recurrent Branches**.

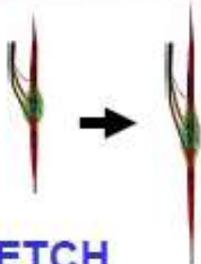
Renshaw cells are interneurons that receive excitatory inputs from **Recurrent branches** of motor neurons and make **inhibitory synapses** upon the same motor neurons

These circuits can limit motor neuron firing; inhibition can dampen or reduce reflexes

The Stretch Reflex

- The stretch reflex is most important in large extensor muscles which sustain upright posture
- Contractions of the postural muscles of the spine are almost continuously regulated by stretch reflexes

FUNCTION OF STRETCH REFLEX: MAINTAINING BALANCE WHEN STANDING

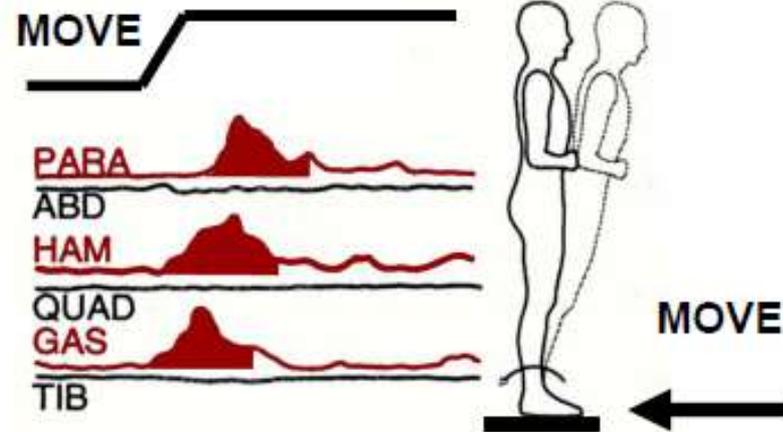


STRETCH
MUSCLE
SPINDLES

1) tilting forward stretches muscles on back of leg

2) muscles rapidly contract

TEST: STAND ON MOVING PLATFORM

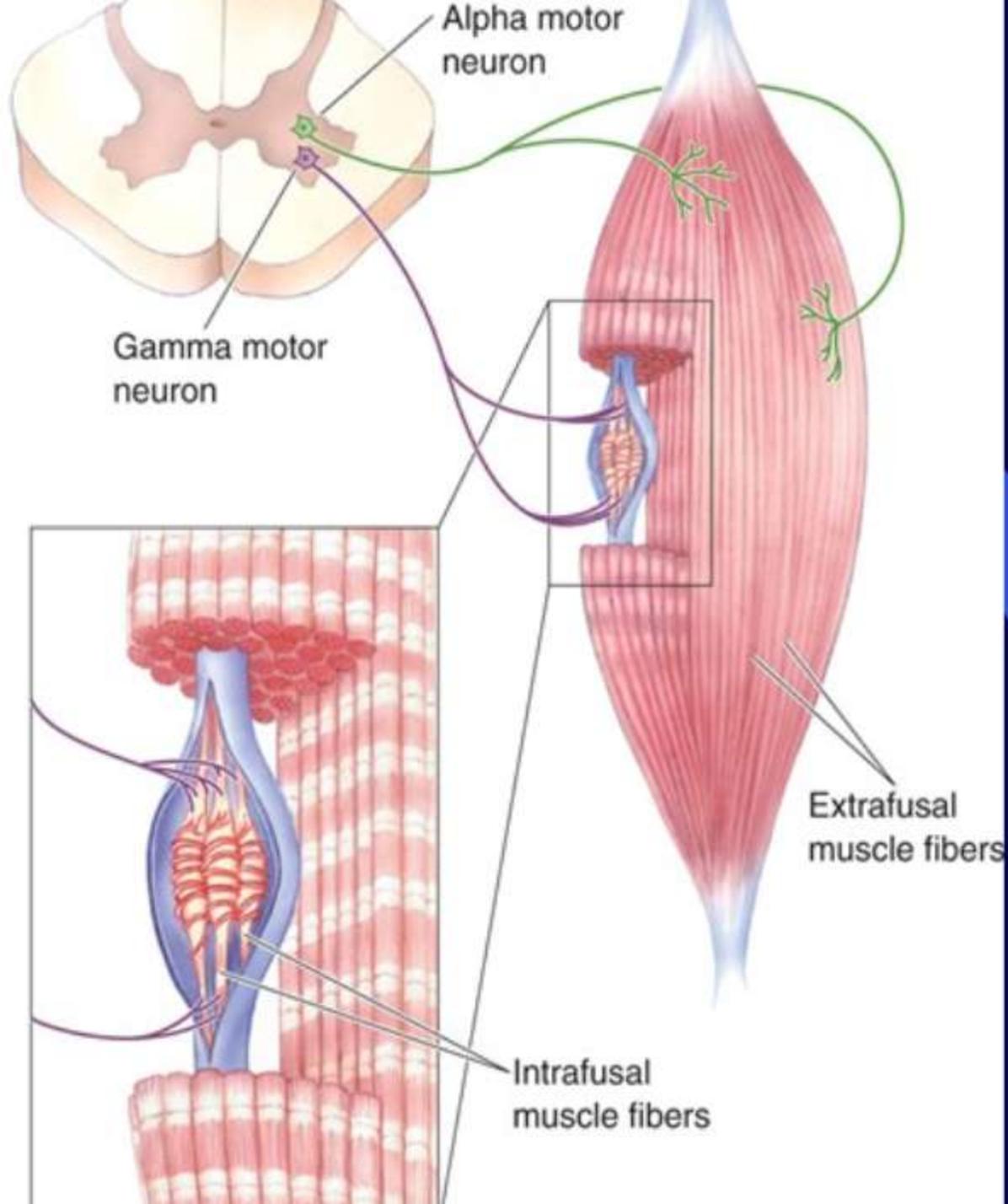


Gastrocnemius excited first (consistent with monosynaptic reflex)

However, responses

- 1) are longer in duration than stretch reflex
- 2) activate extensor muscles of back
- 3) change when wearing a backpack; influenced by other sensory inputs.

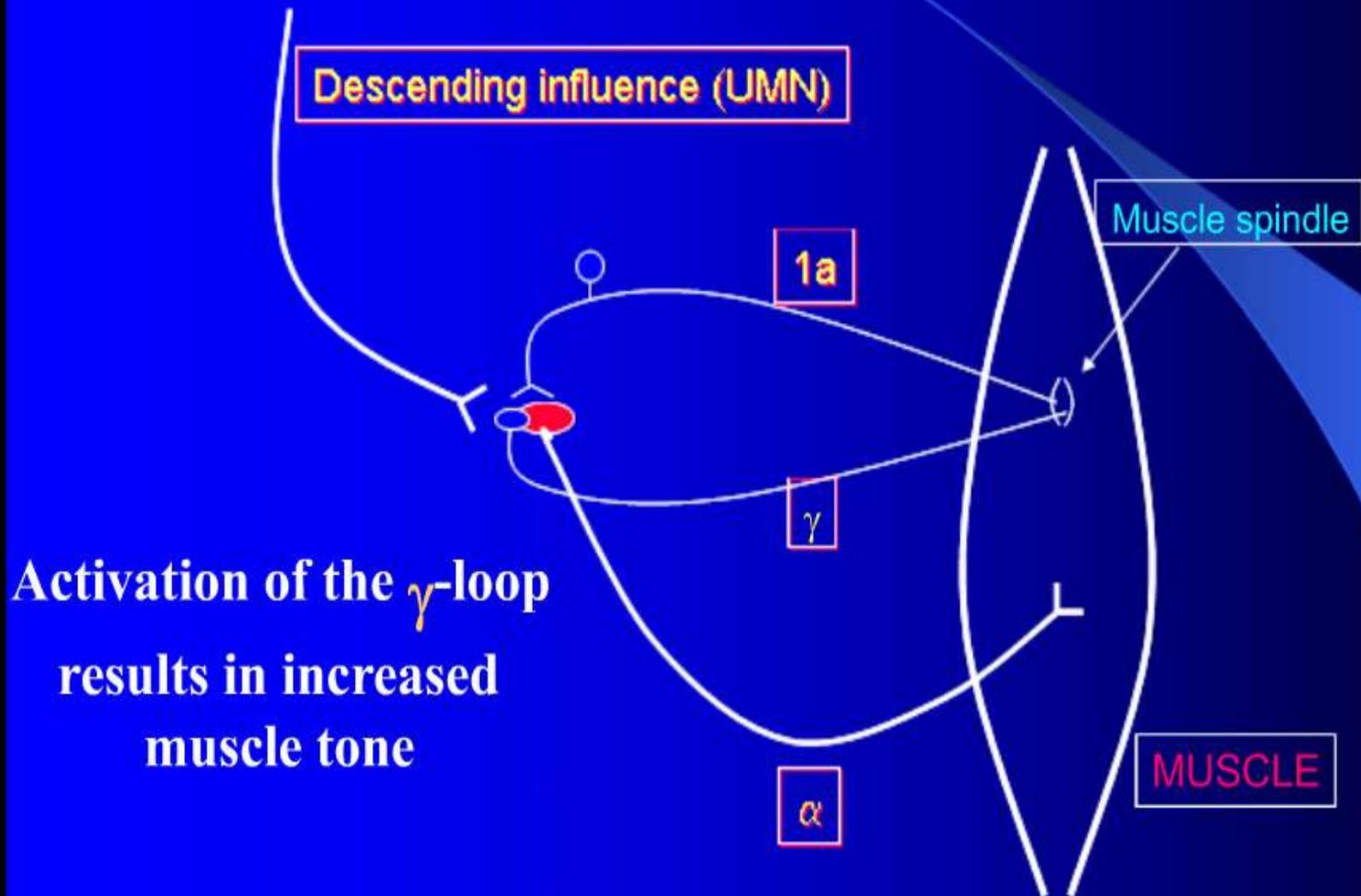
(3) Gamma impact on afferent response



Muscle spindle: motor innervation

- Gamma motoneurons:
 - Innervate the poles of the fibers.

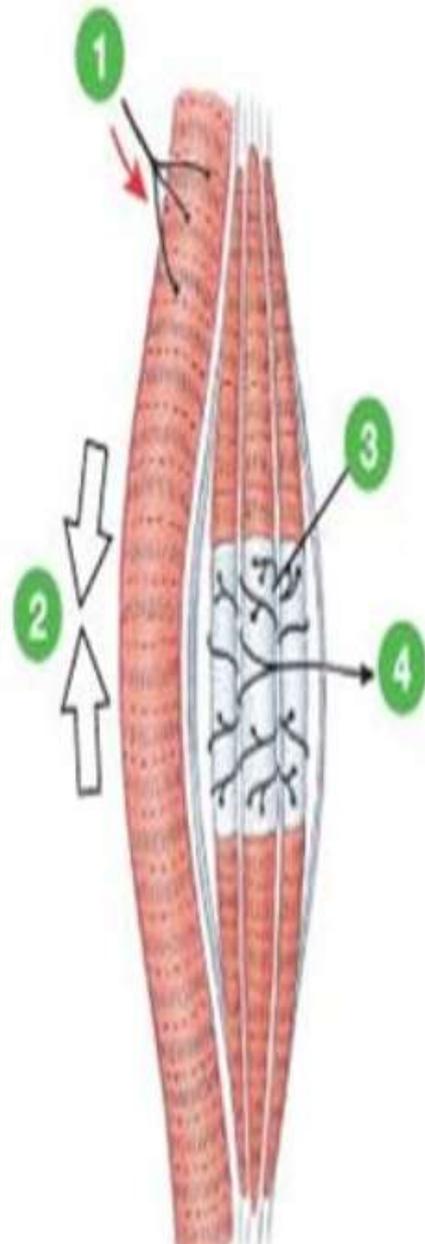
WHAT IS THE γ -LOOP?



Function of γ -motoneurons

- innervate intrafusal muscle fibers.
- adjust the sensitivity of the muscle spindle so that it will respond appropriately during muscle contraction.
- **α -Motoneurons and γ -motoneurons are coactivated** so that muscle spindles remain sensitive to changes in muscle length during contraction.

(a) If gamma motor axons are cut, the spindle loses activity when muscle contracts.

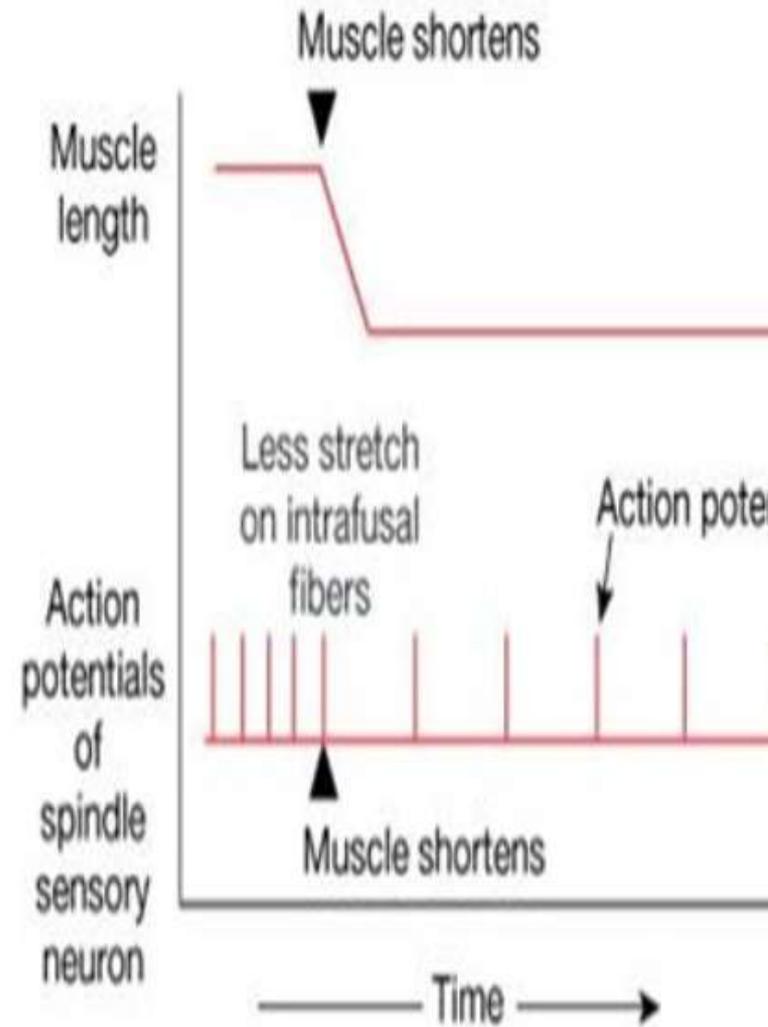


1 Alpha motor neuron fires.

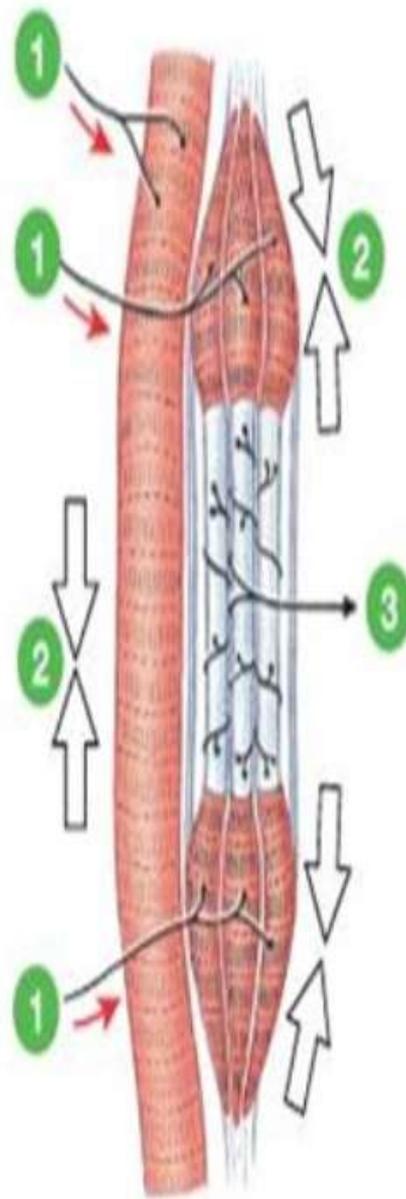
2 Muscle contracts.

3 Less stretch on center of intrafusal fibers

4 Firing rate of spindle sensory neuron decreases.



(b) **Alpha-gamma coactivation** maintains spindle function when muscle contracts.

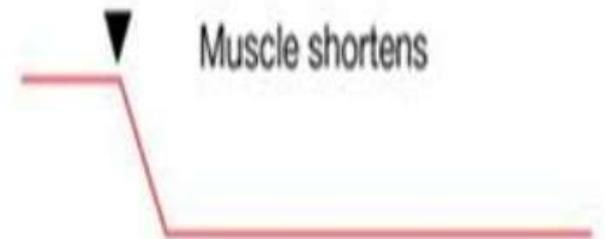


1 Alpha motor neuron fires and gamma motor neuron fires.

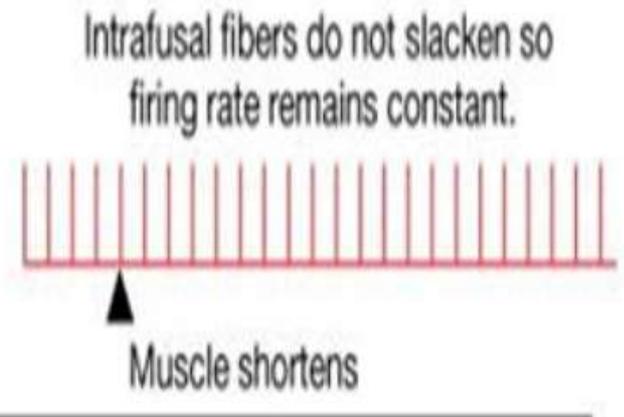
2 Muscle contracts.

3 Stretch on centers of intrafusal fibers unchanged. Firing rate of afferent neuron remains constant.

Muscle length



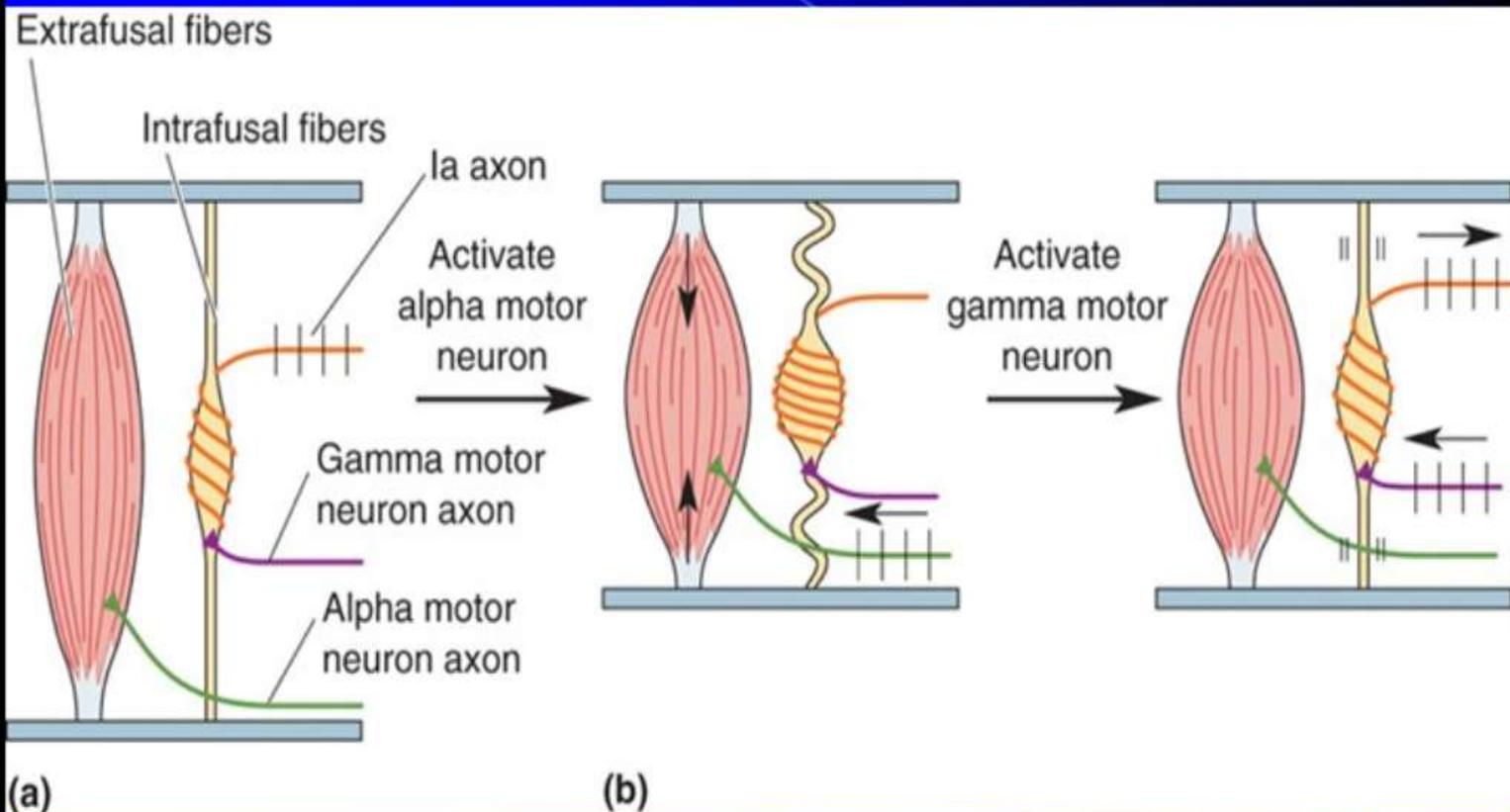
Action potentials of spindle sensory neuron



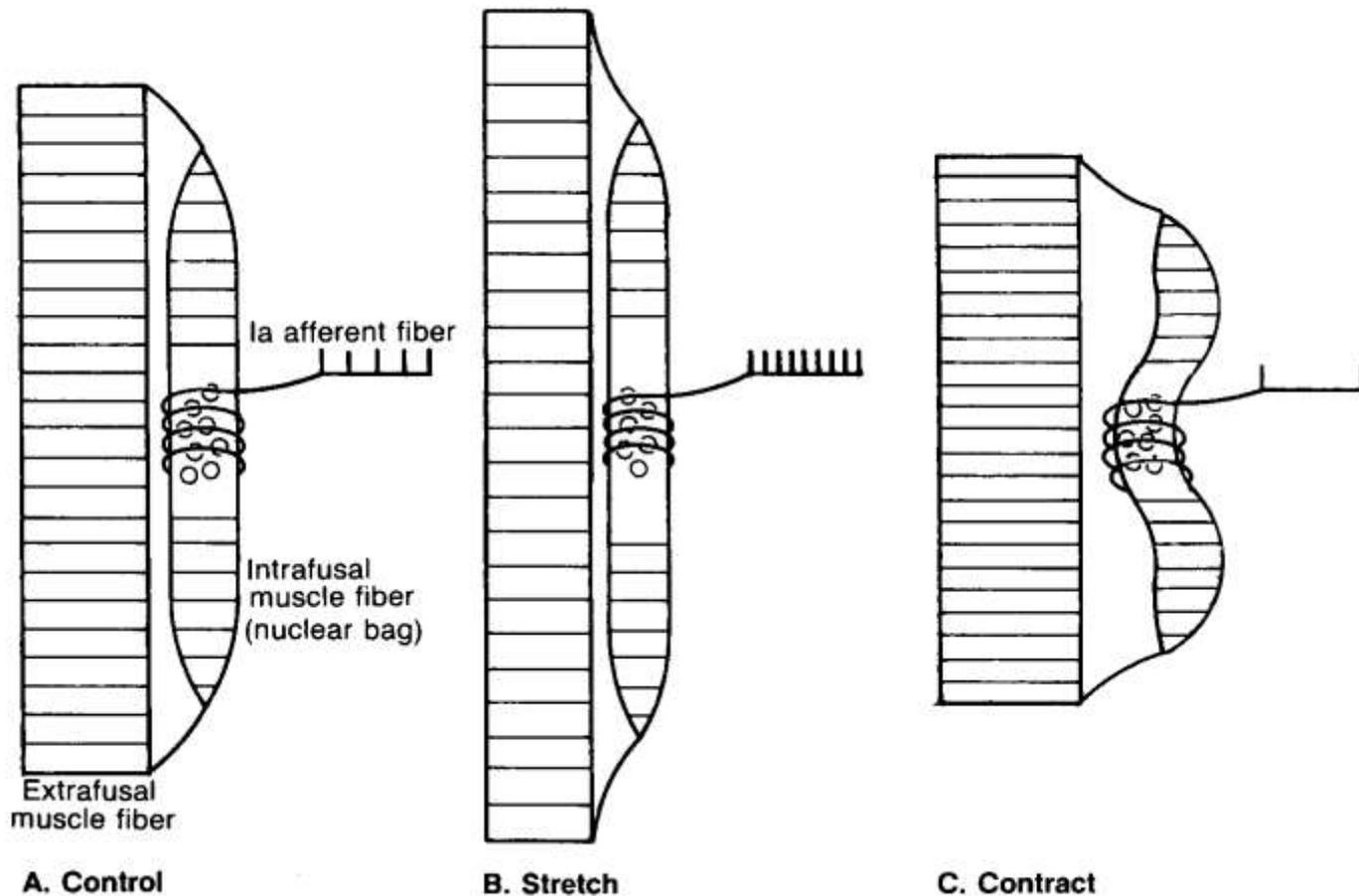
Time →

Functional significance of gamma impact on spindle activity

- The tension of intrafusal fibers is maintained during active contraction by gamma activity.
- The system is informed about very small changes in muscle length.



The reduction of firing that occurs during muscle contraction, called **unloading**, is functionally disadvantageous because the CNS stops receiving information about the rate and extent of muscle shortening.

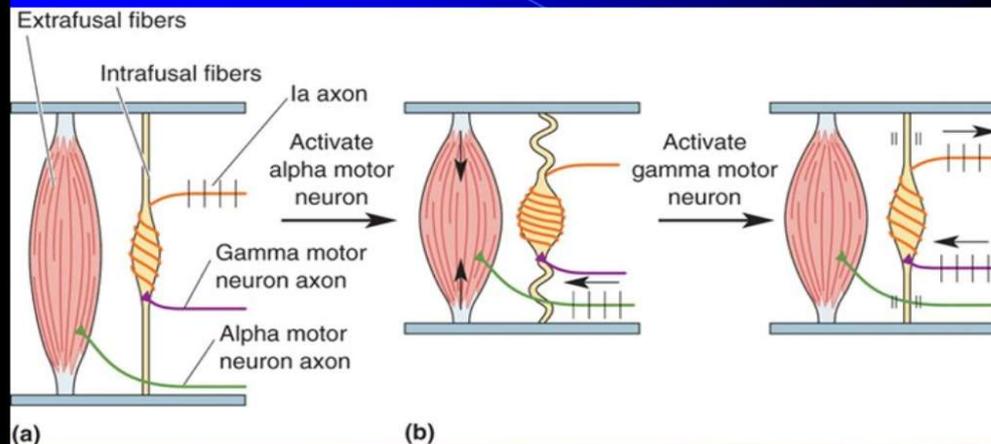


Role of the stretch reflex in the control of movement. The stretch reflex is used by the motor control system to aid in the performance of a movement. During activity generated by the motor command system, the Ia fibers from the muscle spindle inform the motor control system about the changes in muscle length and provide the alpha motoneuron with a source of excitatory input in addition to that coming from higher centers.

During a normal movement, the motor command system **coactivates** both the alpha and gamma motoneurons. This diminishes the amount of unloading that occurs during muscle contraction, allowing the CNS to determine if its motor commands are being carried out.

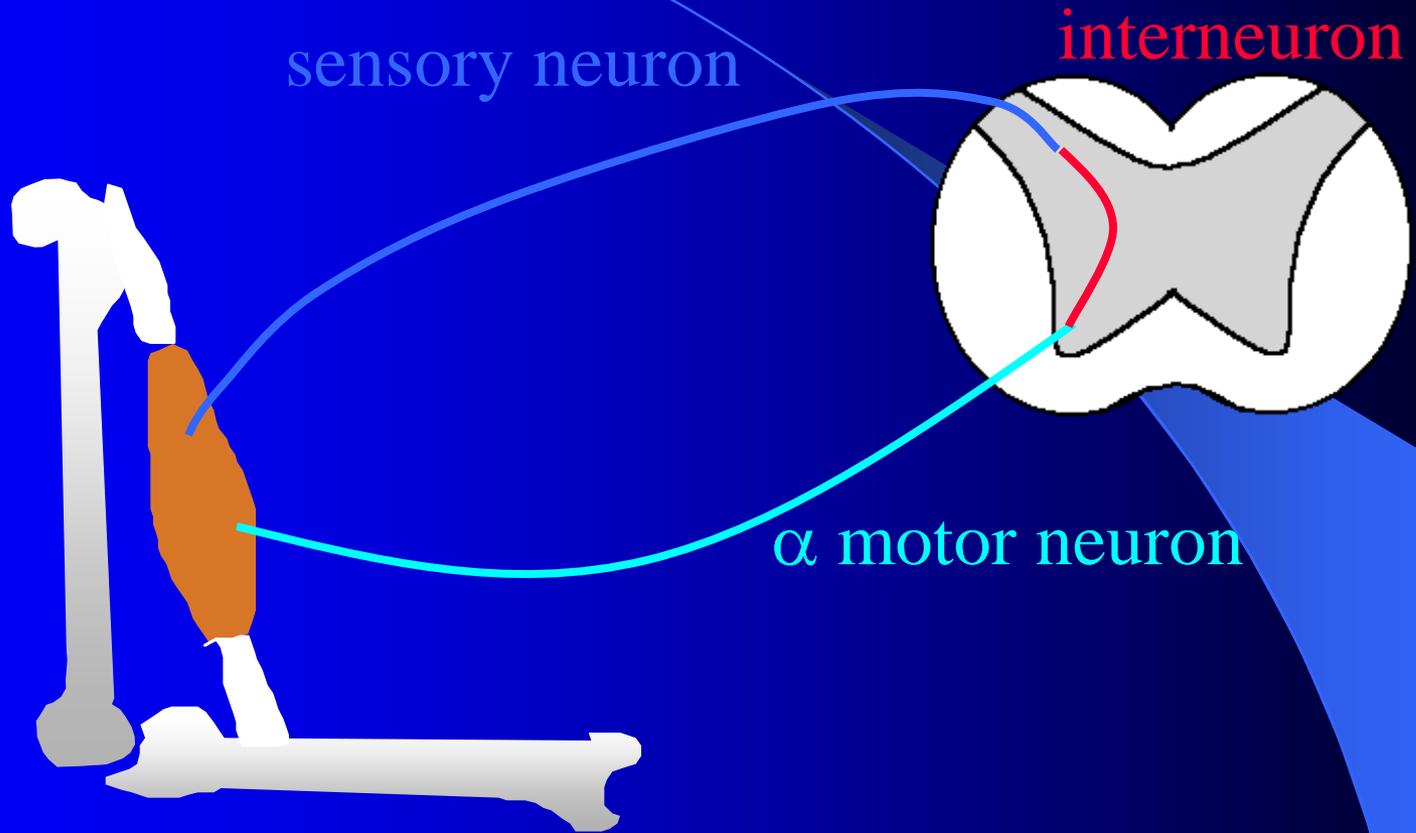
For example, when the motor control system issues a command to lift a weight, the alpha and gamma motoneurons are coactivated.

- (1) As the extrafusal muscle fiber shortens, the intrafusal muscle fiber sarcomeres also shorten.
- (2) If the two muscle fibers shorten at the same rate, then the central region of the intrafusal fiber is neither compressed nor lengthened, thus keeping Ia activity at a constant level.
- (3) The constant level of Ia input to the CNS during a movement indicates that the motor command is being carried out.

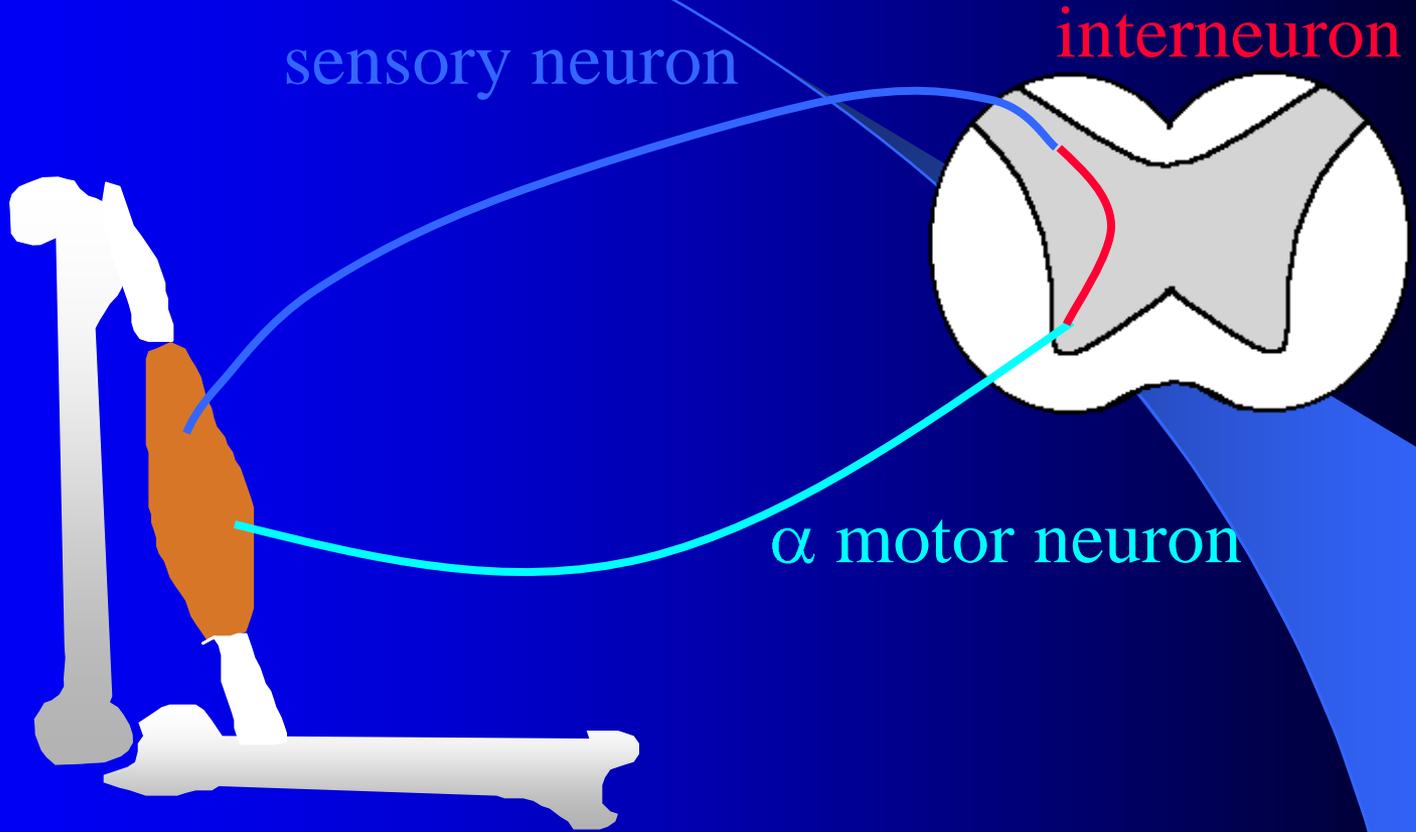


Innervation of a Skeletal Muscle

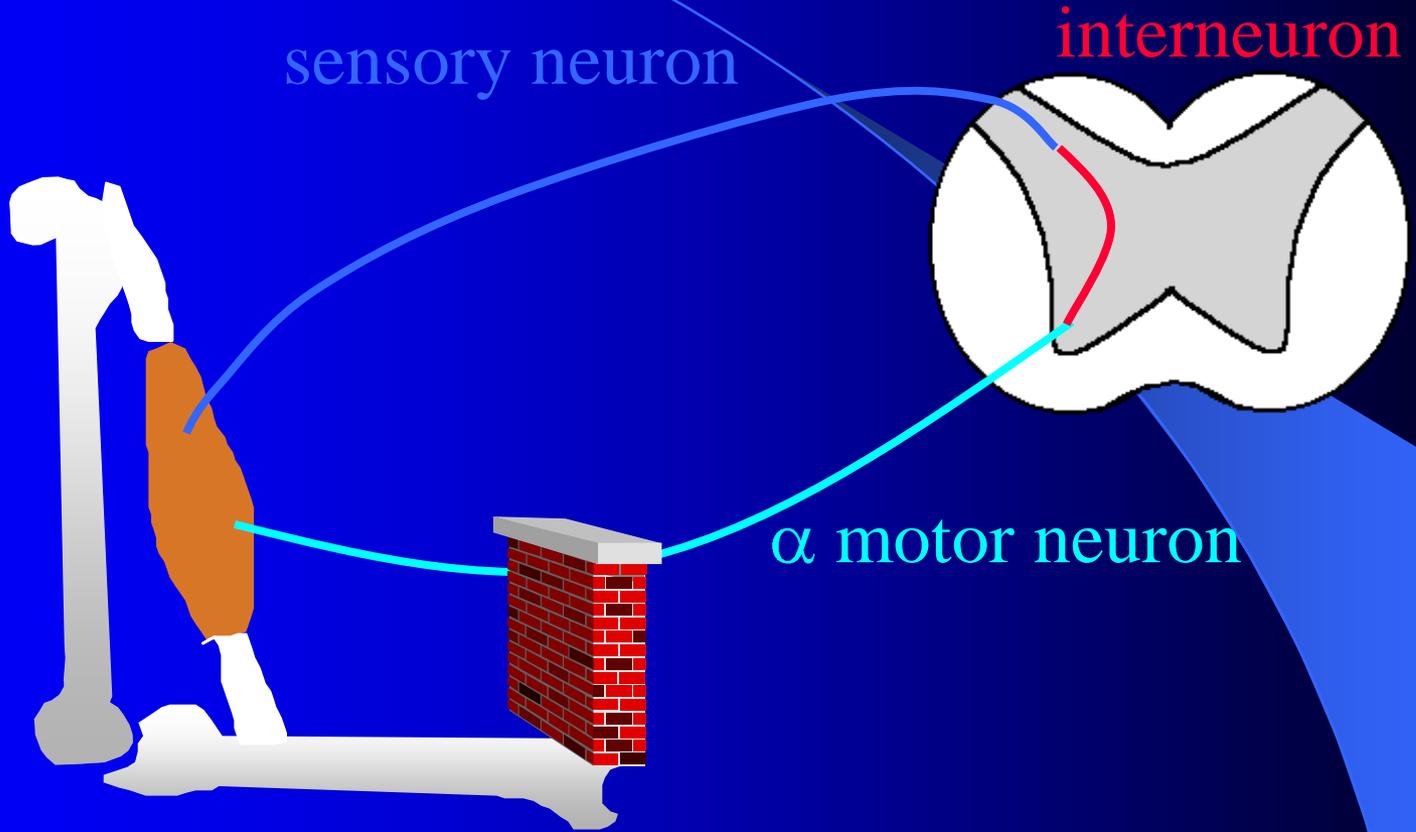
The arm is commanded to a particular position.



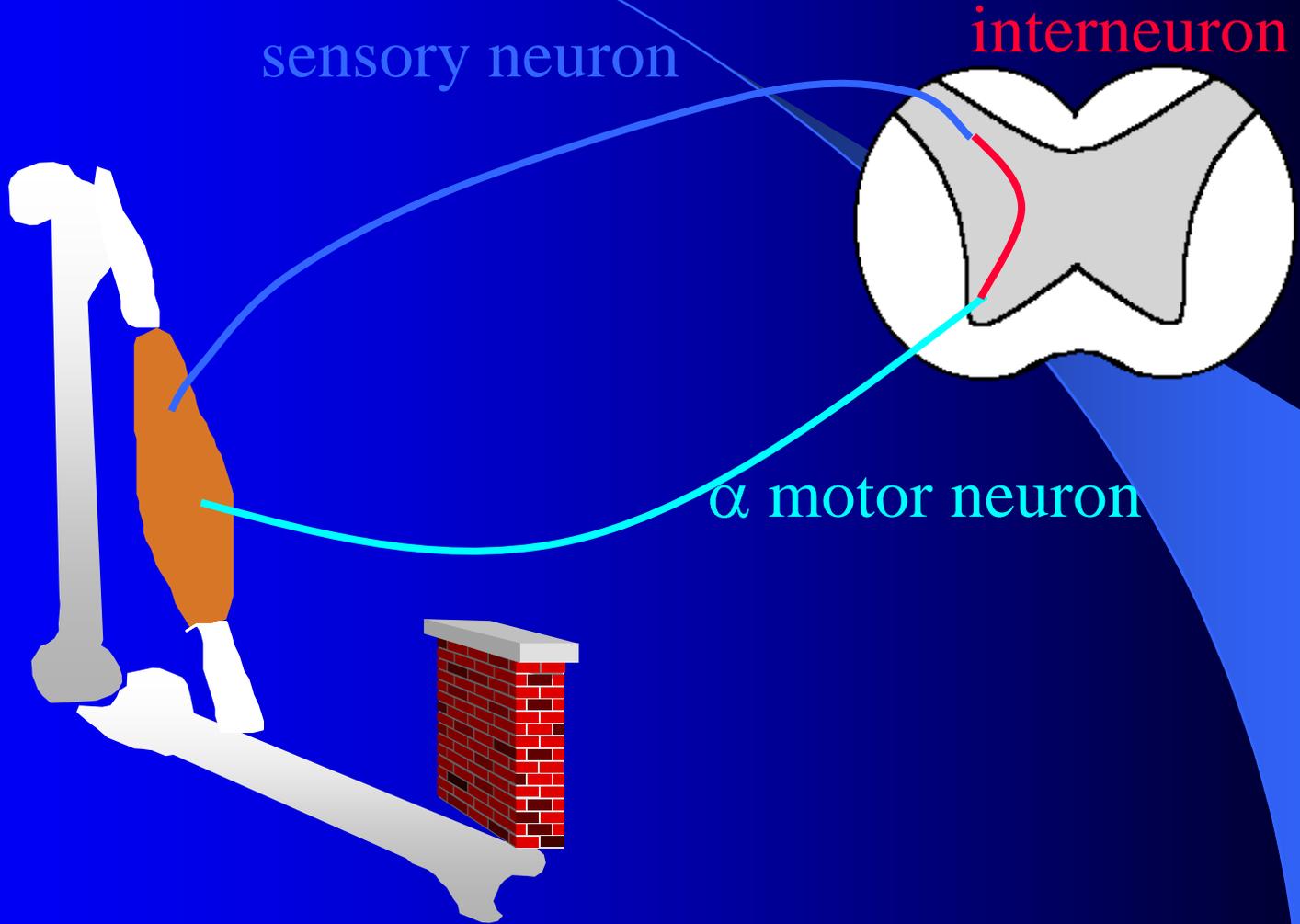
A weight is applied to the arm.



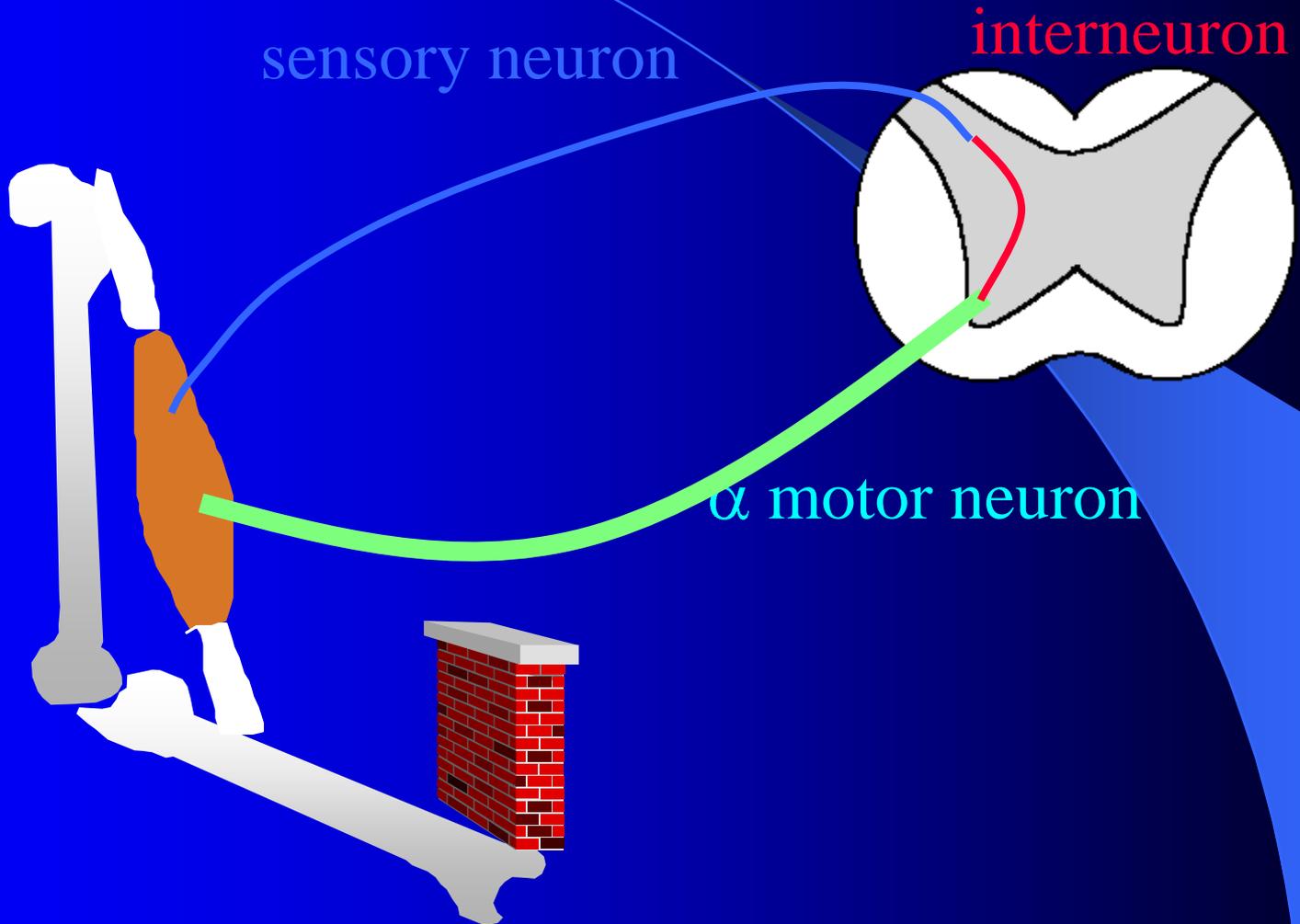
A weight is applied to the arm.



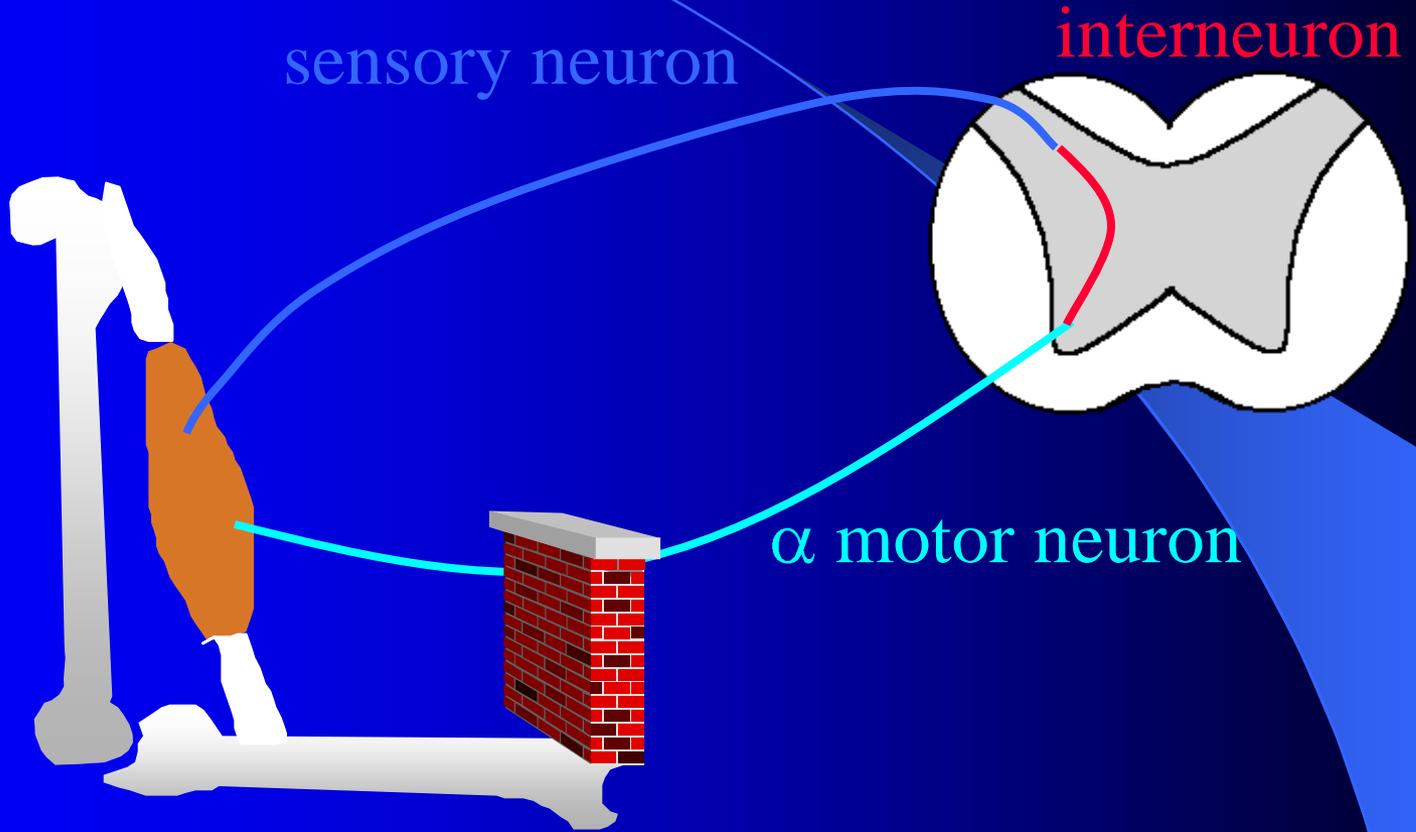
This weight pushes down the arm which stretches the muscle.

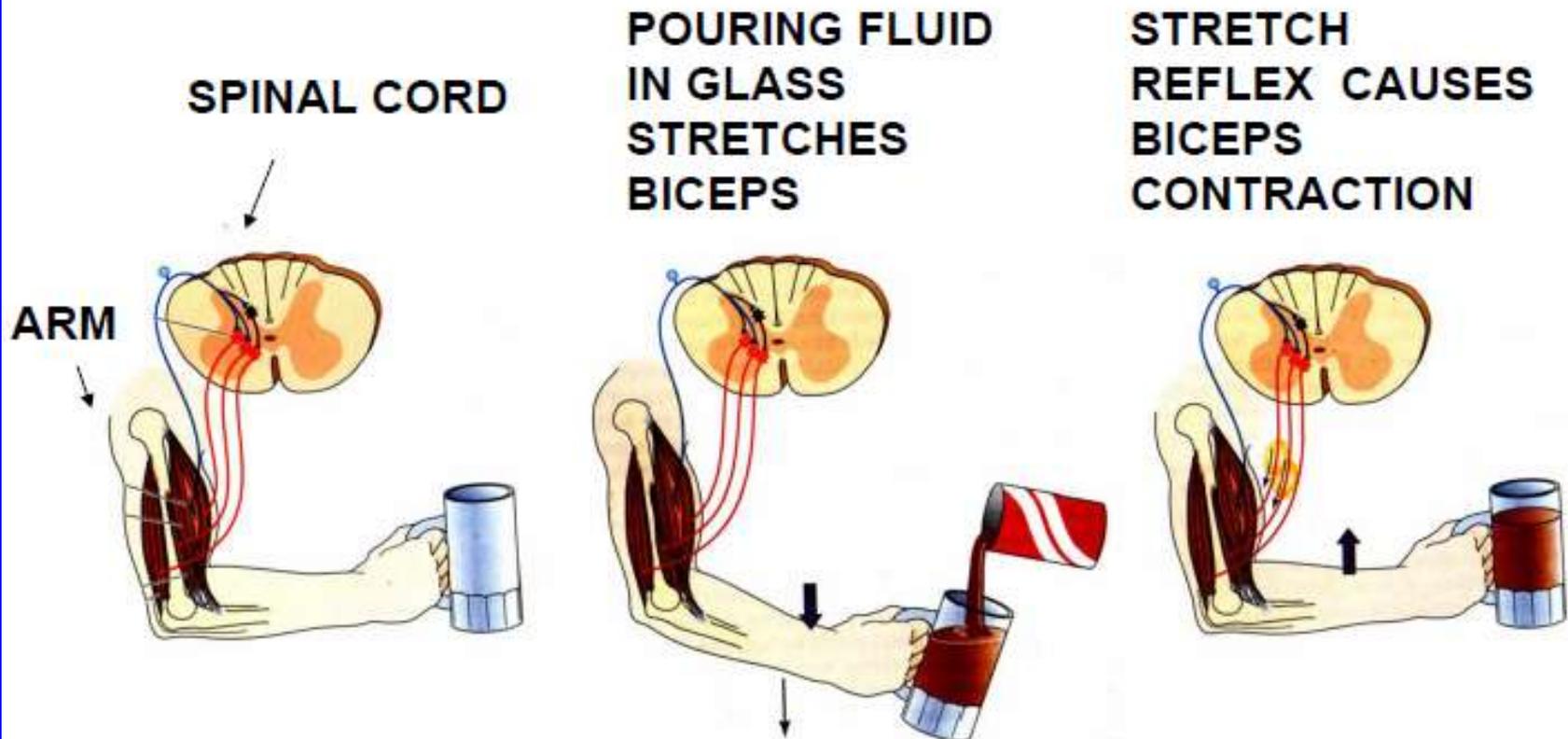


A command to further contract the muscle is sent out the alpha motor neuron.



The arm is returned to its commanded position.





When stretch reflexes are active, unexpected perturbations that lead to stretch of any skeletal muscle will cause muscle to contract.
Example from text: pouring fluid into glass increases weight, stretches biceps muscle.

If the weight to be lifted is underestimated by the CNS, the motor command system does not activate a sufficient number of alpha motoneurons to lift the weight. Thus, the extrafusal muscle fibers do not shorten.

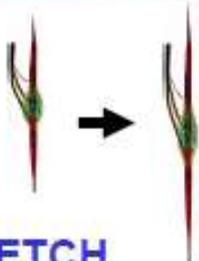
- (1) However, the intrafusal muscle fibers do shorten. But, because the tendon ends of the muscle cannot move, the central portion of the intrafusal fiber lengthens.
- (2) Stretching the central region of the fiber causes Ia activity to increase, indicating that the motor command is not being carried out. The CNS uses this information to readjust its command to the spinal cord.
- (3) Even before the CNS responds to the information provided by the Ia fibers, the Ia activity is used at the spinal cord level to adjust the alpha motoneuron activity to meet the unexpectedly high load.
 - (a) Since the Ia fiber synapses on the alpha motoneuron, its activity increases the excitability of the alpha motoneuron.
 - (b) The increase in excitability leads to an increase in the frequency of action potential generation and an increase in muscle force development.

FUNCTION OF STRETCH REFLEX: MAINTAINING BALANCE WHEN STANDING



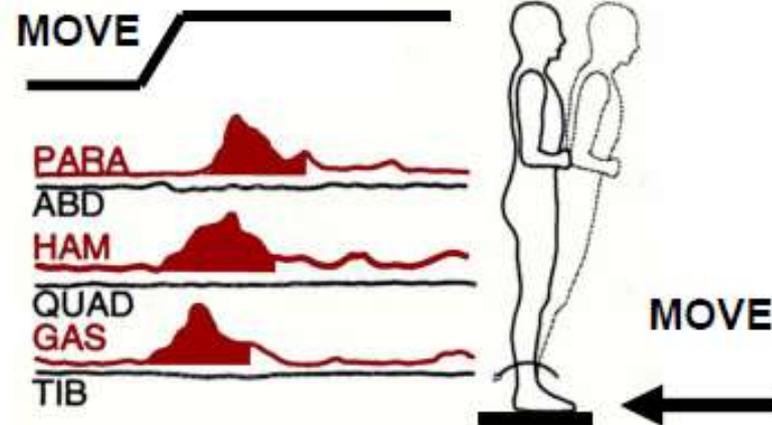
1) tilting forward stretches muscles on back of leg

2) muscles rapidly contract



STRETCH MUSCLE SPINDLES

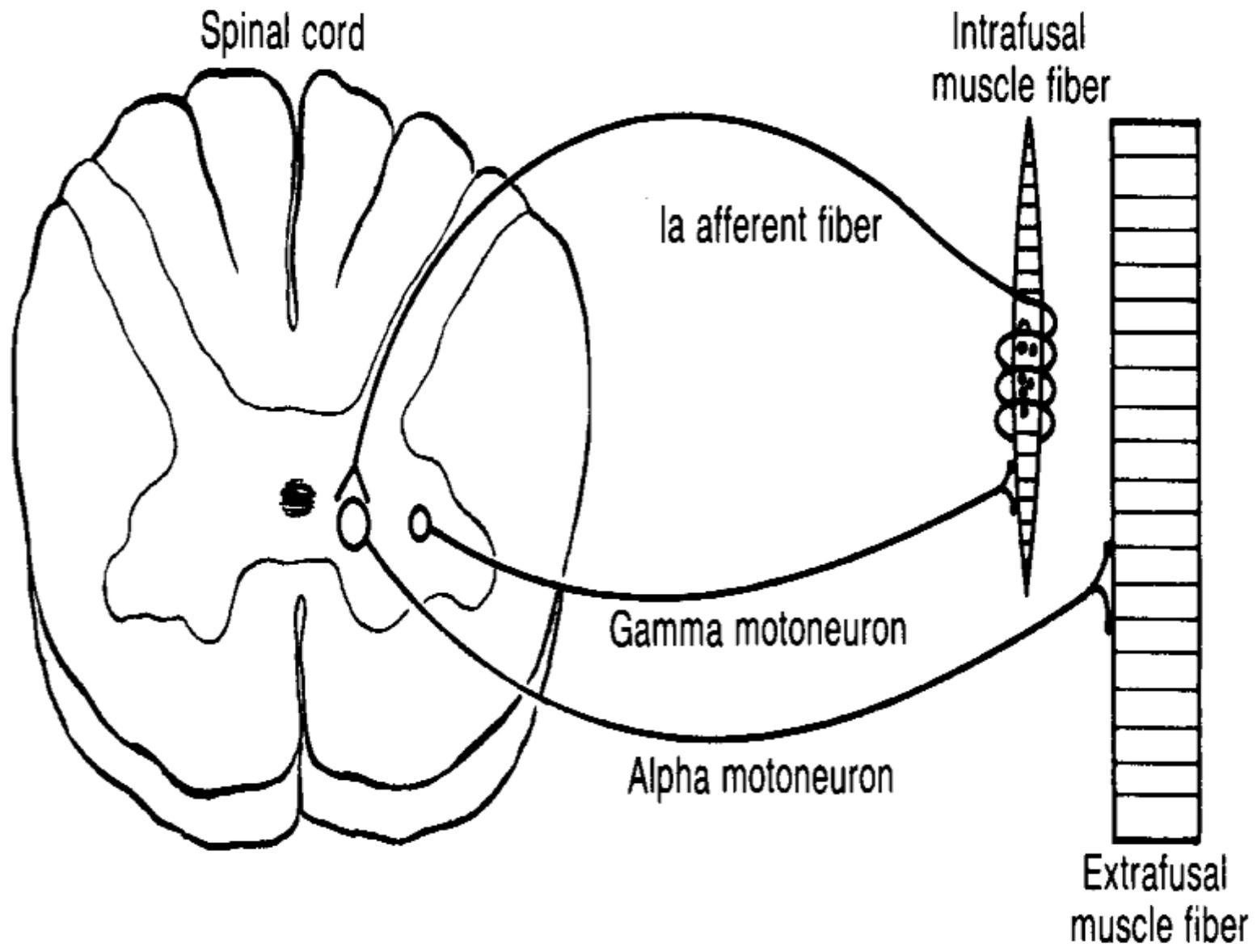
TEST: STAND ON MOVING PLATFORM



Gastrocnemius excited first (consistent with monosynaptic reflex)

However, responses

- 1) are longer in duration than stretch reflex
- 2) activate extensor muscles of back
- 3) change when wearing a backpack; influenced by other sensory inputs.



Gamma loop. The CNS is theoretically capable of initiating movements directly by stimulating just the gamma motoneurons, using a pathway called the **gamma loop** (Figure 1-55).

- a. Increasing gamma motoneuron activity causes the intrafusal muscle fiber sarcomeres to shorten, which, in turn, leads to stretching of the central portion of the intrafusal fiber and activation of the Ia fiber. Firing the Ia fibers causes alpha motoneuron activity to increase, which results in an increased amount and force of skeletal muscle activity.
- b. Although the gamma loop can elicit movement on its own, it normally does not do so. However, because of coactivation, the gamma loop is activated during all movements and thus contributes to the excitability and firing rate of the alpha motoneurons.

Muscle Tone

Muscle tone can be defined as the resistance of skeletal muscle to stretch

Muscle Tone

- Muscle tone is due both to the viscoelastic properties of the muscles and joints and to whatever degree of alpha motor neuron activity exists

Abnormal Muscle Tone

- Abnormally high muscle tone, called *hypertonia*,
- The increased resistance is due
- to a greater-than-normal level of alpha motor neuron
- activity, which keeps a muscle contracted despite the
- individual's attempt to relax it. Hypertonia is usually
- found when there are disorders of the descending
- pathways that result in decreased inhibitory influence
- exerted by them on the motor neurons.

upper motor neuron disorders.

- Clinically, the descending pathways—primarily
- the corticospinal pathways—and neurons of the motor
- cortex are often referred to as the “upper motor
- neurons” (a confusing misnomer because they are not
- really motor neurons at all). Abnormalities due to their
- dysfunction are classed, therefore, as *upper motor neuron*
- *disorders.*

- Thus, hypertonia indicates an upper motor
- neuron disorder.
- *Spasticity is a form of hypertonia in which the muscles do not develop increased tone until they are stretched a bit, and after a brief increase in tone, the contraction subsides for a short time.*
- *Rigidity is a form of hypertonia*
- in which the increased muscle contraction is
- continual and the resistance to passive stretch is constant.

Clasp-knife reflex, an exaggerated form of the Golgi tendon reflex, can occur with **disease of the corticospinal tracts** (hypertonicity or spasticity).

- **For example**, if the arm is hypertonic, the increased sensitivity of the muscle spindles in the extensor muscles (triceps) causes resistance to flexion of the arm. Eventually, tension in the triceps increases to the point at which it activates the Golgi tendon reflex, causing the triceps to relax and the arm to flex closed like a jackknife.

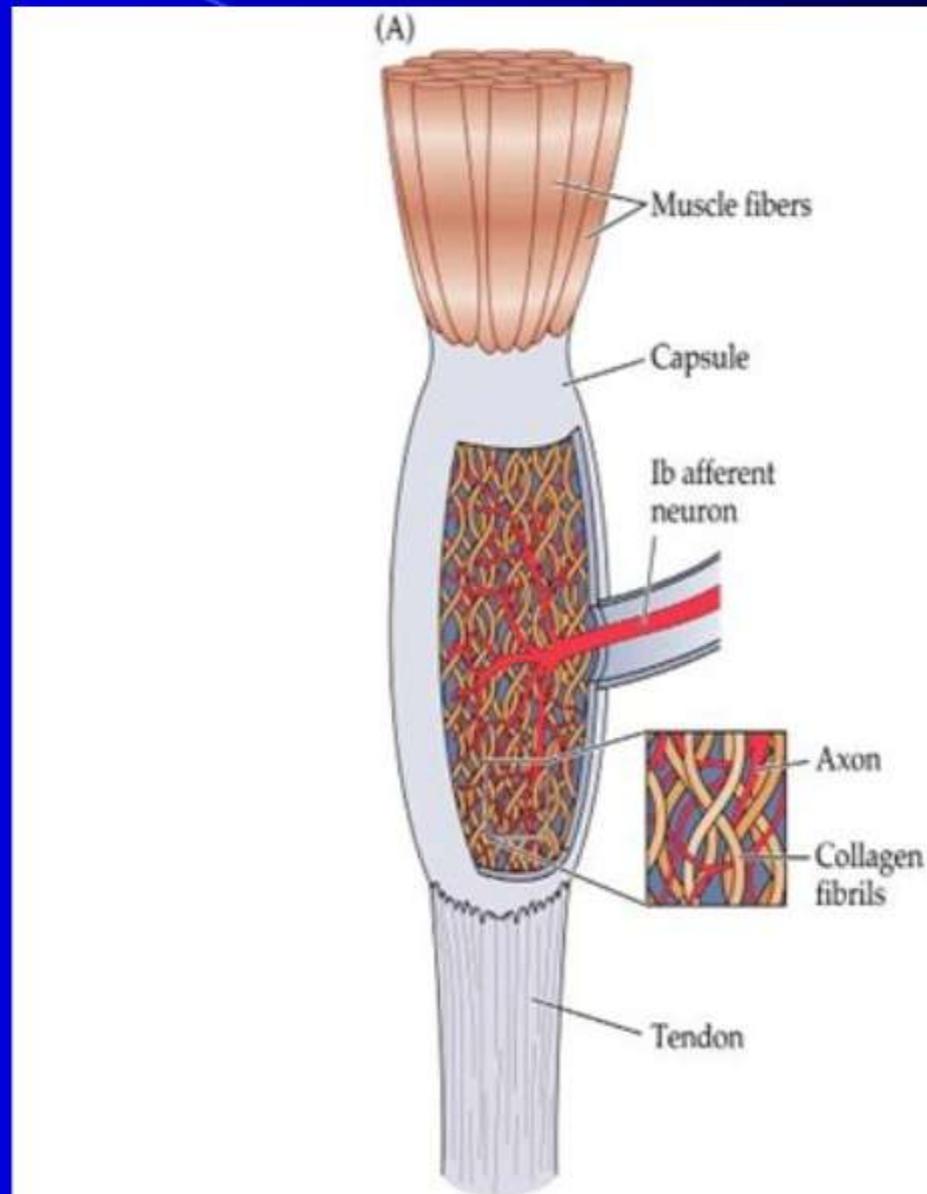
- When the muscles are hypertonic, the sequence of moderate stretch muscle contraction, strong stretch muscle relaxation is clearly seen. Passive flexion of the elbow, for example, meets immediate resistance as a result of the stretch reflex in the triceps muscle. Further stretch activates the inverse stretch reflex. The resistance to flexion suddenly collapses, and the arm flexes. Continued passive flexion stretches the muscle again, and the sequence may be repeated. This sequence of resistance followed by give when a limb is moved passively is known as the **clasp-knife effect** because of its resemblance to the closing of a pocket knife. It is also known as the **lengthening reaction** because it is the response of a spastic muscle to lengthening.

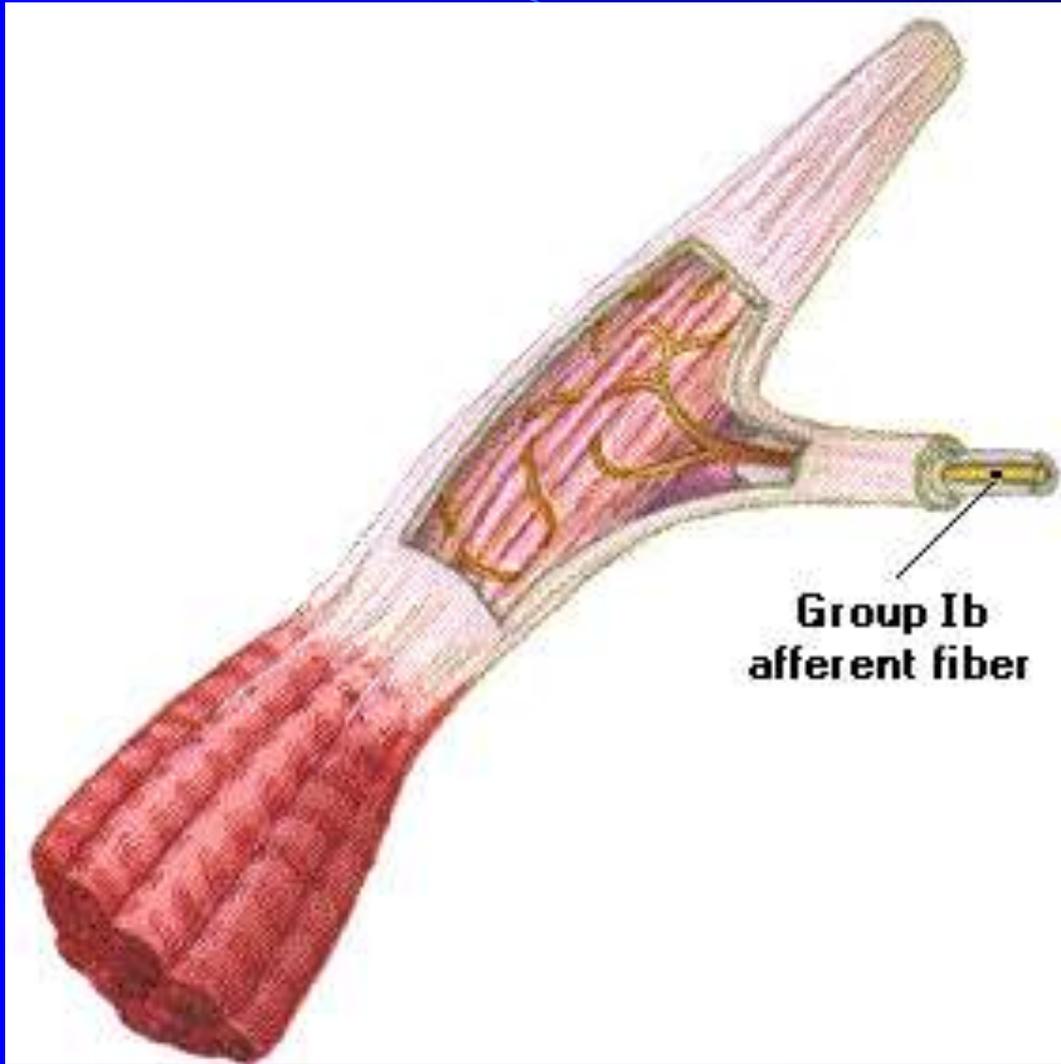
Hypotonia

- *Hypotonia is a condition of abnormally low muscle* tone, accompanied by weakness, atrophy (a decrease in muscle bulk), and decreased or absent reflex responses.
- It more frequently accompanies disorders of the alpha motor neurons (“lower motor neurons”), neuromuscular junctions, or the muscles themselves.

Golgi tendon organ: structure

- Located in the muscle tendon junction.
- Connective tissue encapsulating collagen fibers and nerve endings.
- Attached to 10-20 muscle fibers and several MUs.
- Ib afferent fiber.
- sensitive to **tension**

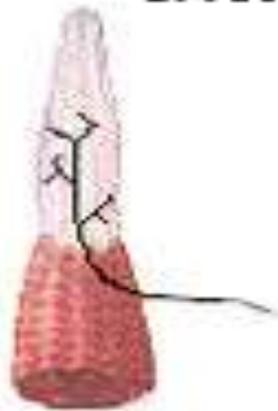




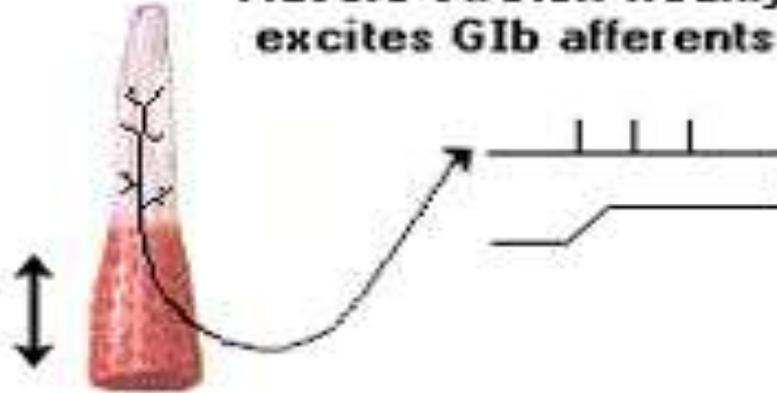
**Group Ib
afferent fiber**

Golgi Tendon Organ

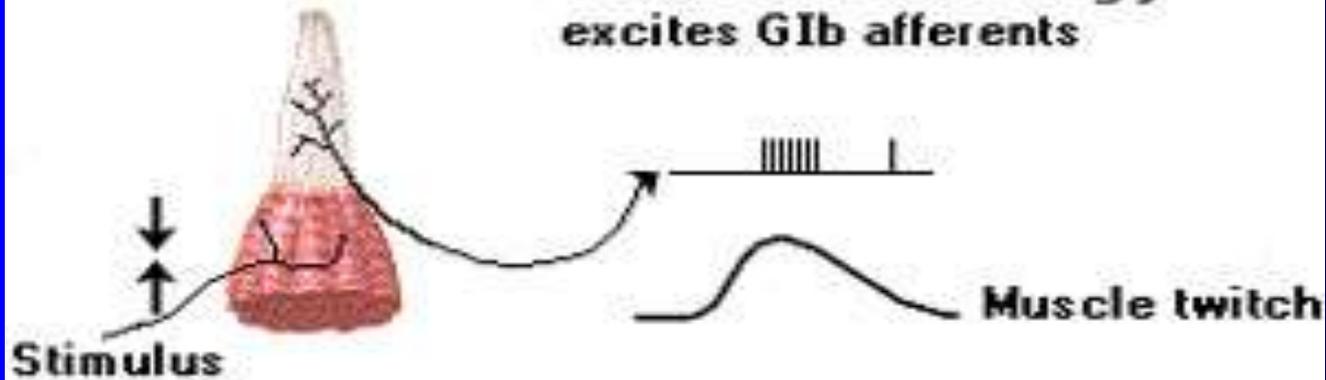
at rest...



Muscle stretch weakly excites G1b afferents



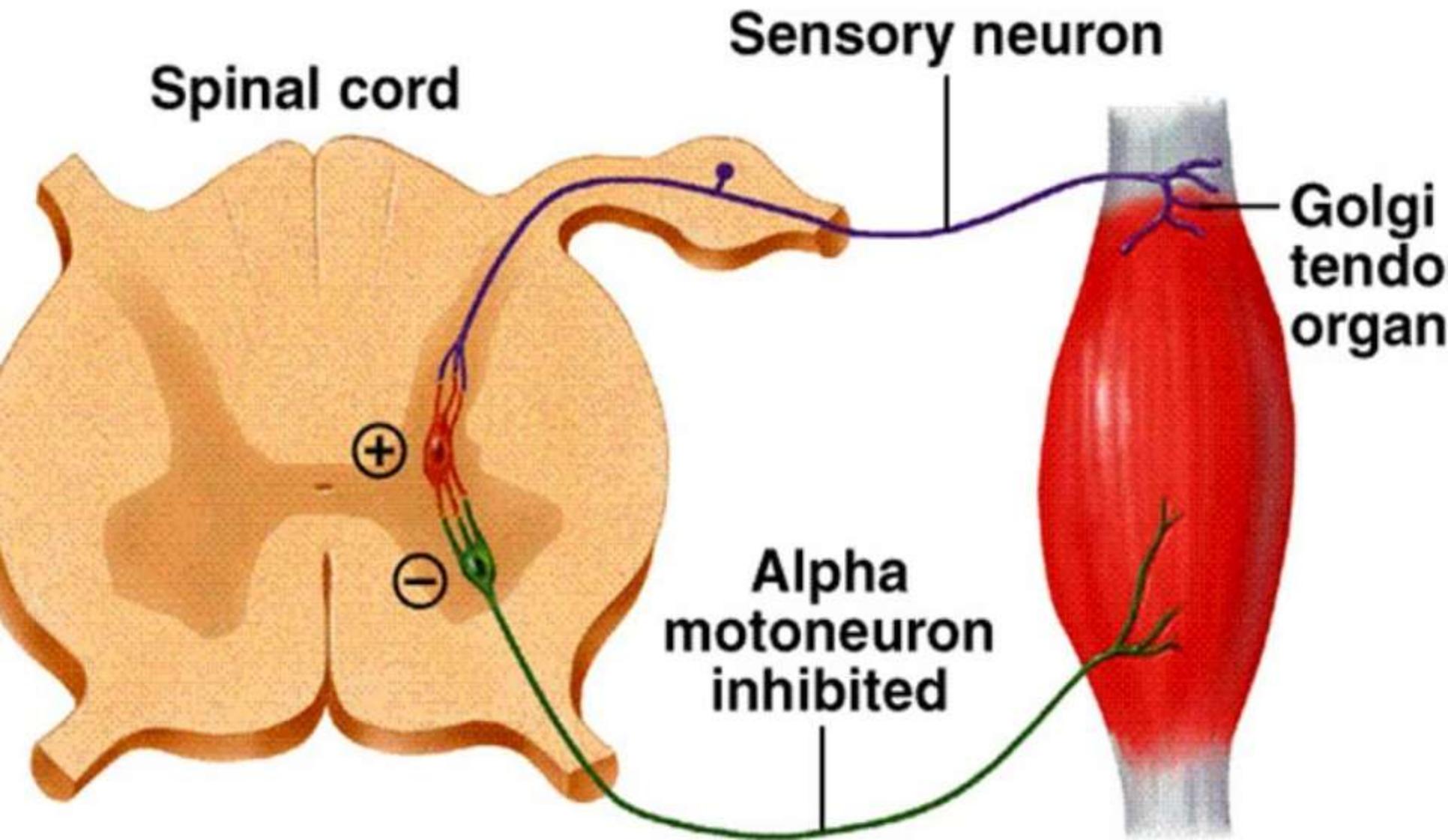
Muscle contraction strongly excites G1b afferents



Golgi Tendon Reflex

- Opposite of Stretch Reflex
 - Contracting Muscle Activates Golgi Tendon Organs
 - Afferent Golgi Tendon Neurons Stimulated
 - Neurons Inhibit Contracting Muscle
 - Antagonistic Muscle Activated
 - Contracting Muscle Relaxes
 - Antagonist Contracts

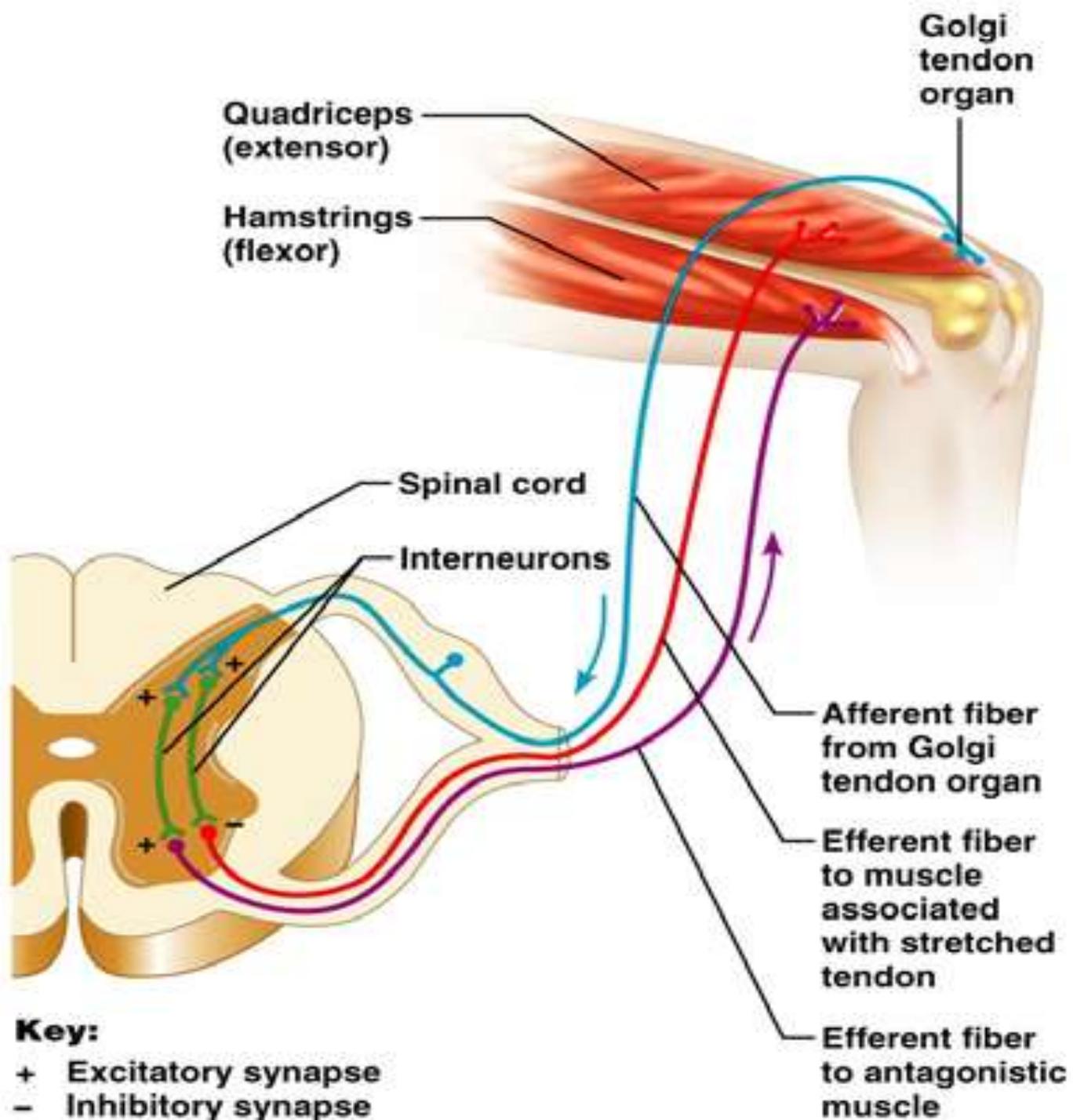
Action of Golgi Tendon Organ (Disynaptic Reflex)



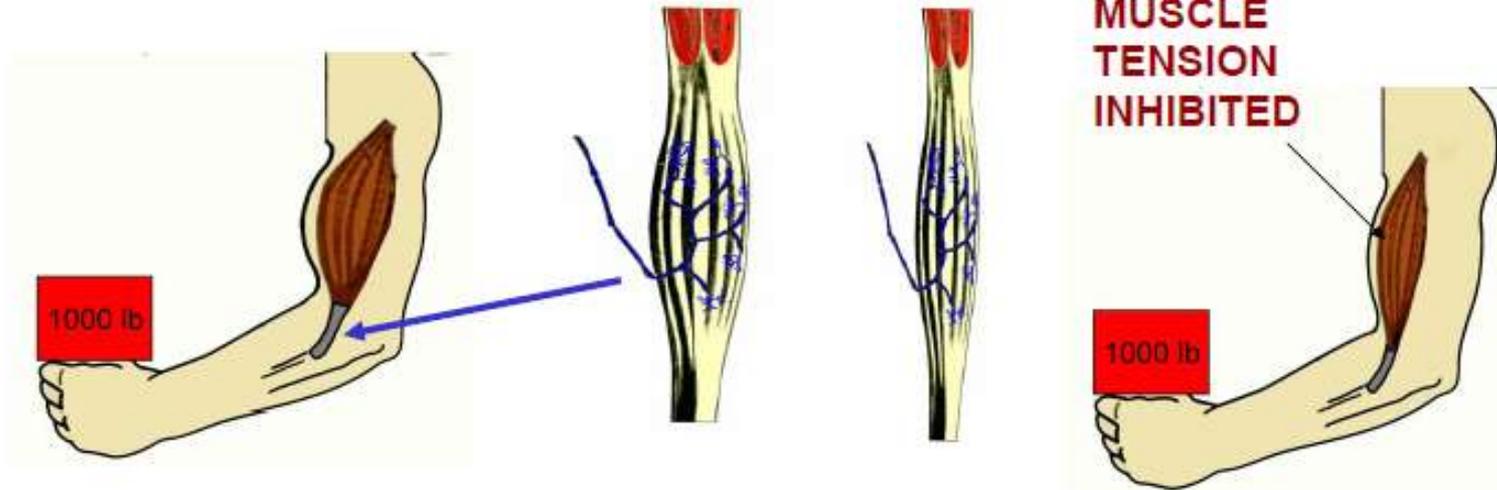
Golgi tendon reflex (inverse myotatic)

- is **disynaptic**.
- is the opposite, or inverse, of the stretch reflex.
 - a. *Active muscle contraction* stimulates the Golgi tendon organs and group Ib afferent fibers.
 - b. The group Ib afferents stimulate **inhibitory interneurons** in the spinal cord. These interneurons **inhibit α -motoneurons** and cause relaxation of the muscle that was originally contracted.
 - c. At the same time, antagonistic muscles are excited.

GTO Rx



AUTOGENIC INHIBITION

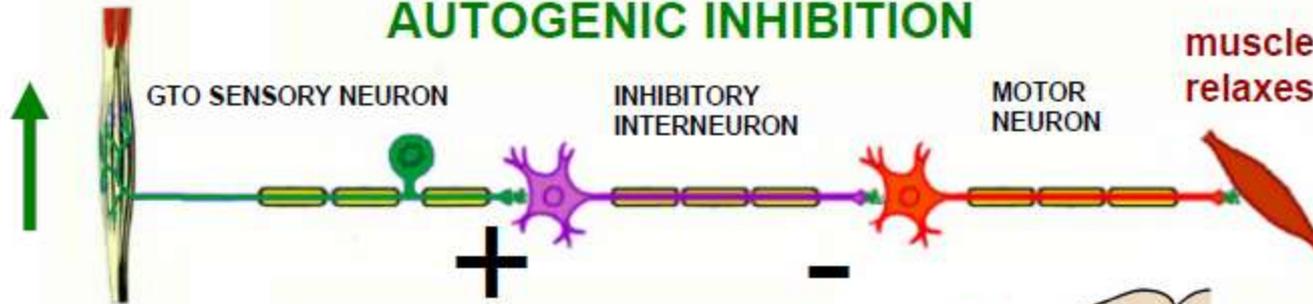


1) Stimulus -
Large force
exerted on
muscle tendon

**2) Sense organ
excited -**
Golgi tendon
organs

**3) Primary
response -**
muscle
attached to
tendon relaxes

AUTOGENIC INHIBITION



PRIMARY RESPONSE

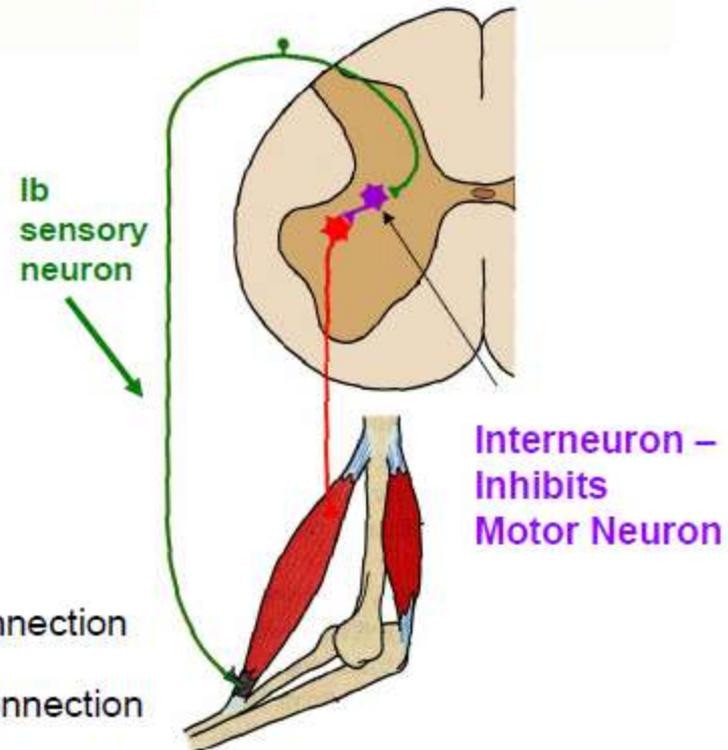
Synapses - polysynaptic

1) Ib sensory neuron (GTO) makes excitatory synapse onto interneuron

2) Interneuron makes inhibitory synapse onto motor neuron;
Motor neuron decreases firing

+ note: plus indicates excitatory connection

- note: minus indicates inhibitory connection



AUTOGENIC INHIBITION

Other effects

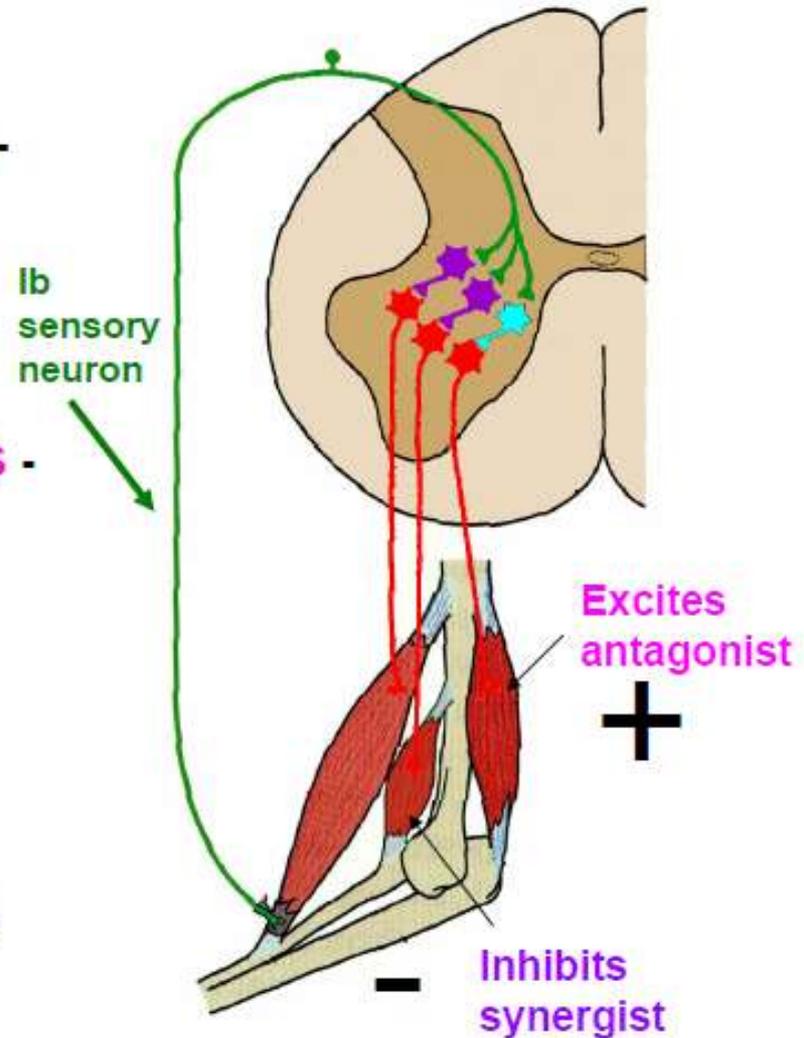
a. Inhibits synergist muscles -

GTO makes excitatory synapse on interneuron; interneuron makes inhibitory synapse on motor neurons to synergist muscle

b. Excites antagonist muscles -

GTO makes excitatory synapse on interneuron; interneuron makes excitatory synapse on motor neurons to antagonist muscles

CLASPED KNIFE REFLEX: in Upper motor neuron lesions, tonus increases, resistance to stretch increases; if sufficient force is applied, limb resistance suddenly decreases (like pocket knife snapping shut)



AUTOGENIC INHIBITION AND FORCE REGULATION

1- **Regulating muscle tension** - forces developed by contractions of muscles are automatically controlled so that they do not cause damage to tendons (ex. lifting heavy object).



2- **Regulation of force during other behavior is more complex** (ex. walking) –

Connections for autogenic inhibition may be inactivated during walking

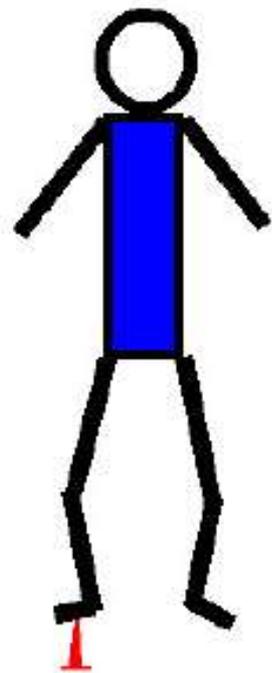
Effects of Golgi tendon organs can then become excitatory via other interneurons



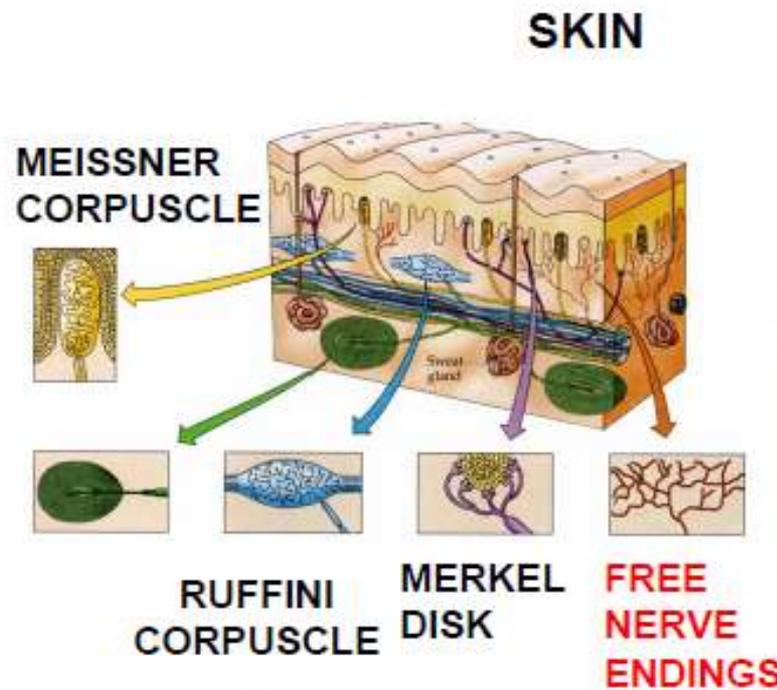
Flexor & Crossed Extensor Reflexes

- Flexor Reflex Initiated by Painful Stimulus
(Actual or Perceived) → Automatic
Withdrawal of Threatened Body Part
- Crossed Extensor Reflex - 2 Parts
 - Stimulated Side Withdrawn
 - Contralateral Side Extended

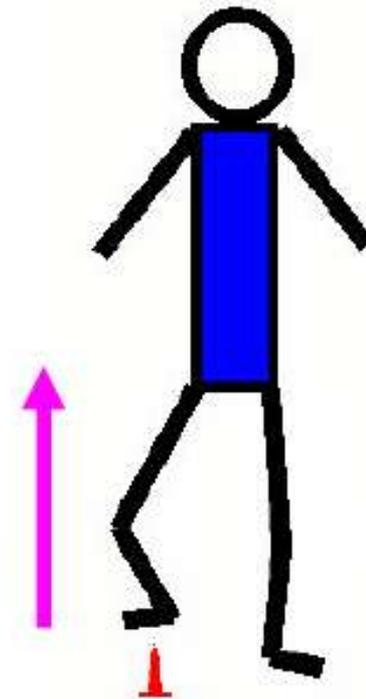
FLEXOR REFLEX



1) Stimulus - painful or noxious stimulus (stepping on nail)



2) Sense organ excited - Cutaneous receptors, Pain receptors (nociceptors)

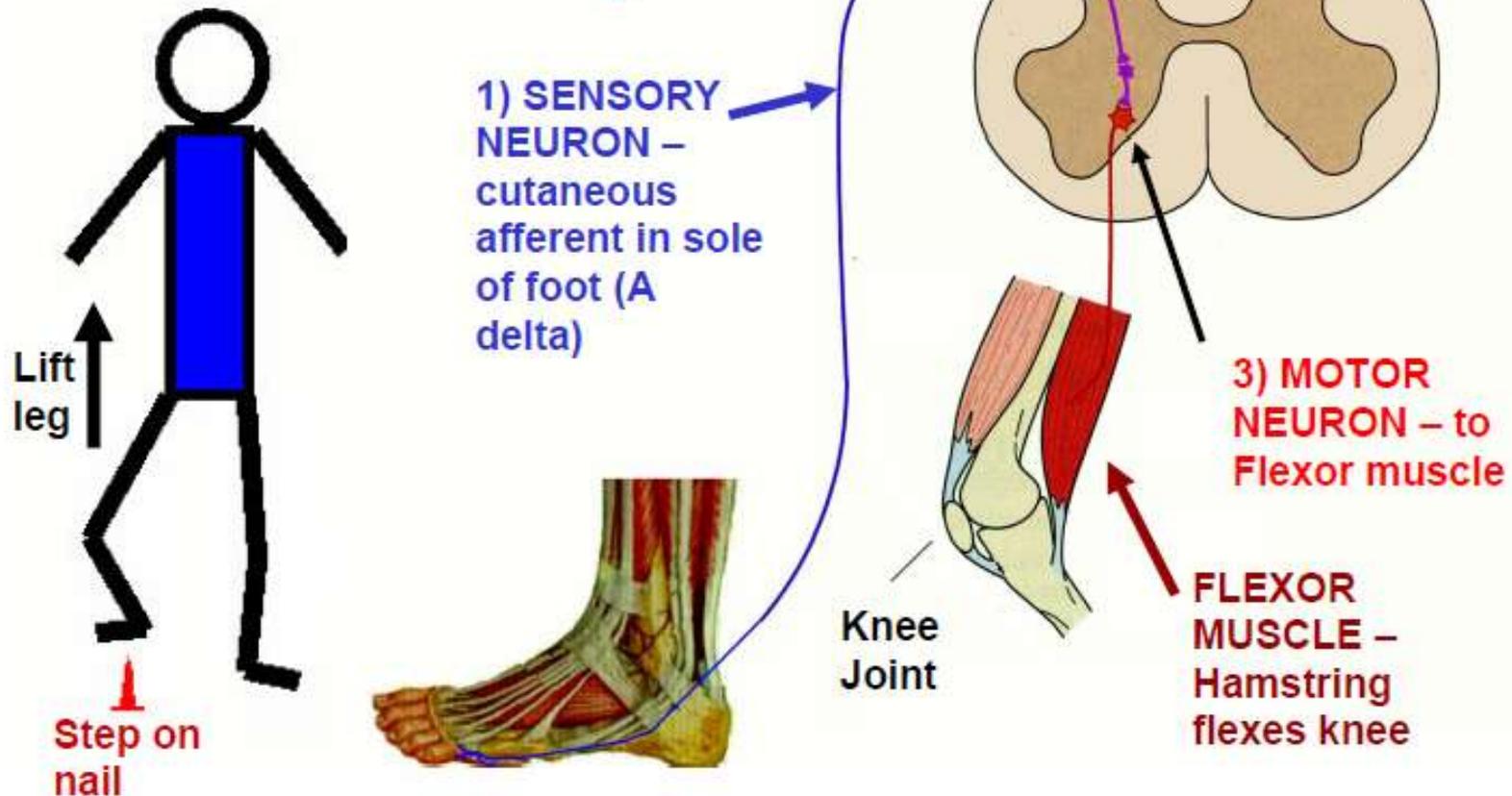


3) Primary response - Protective withdrawal of limb

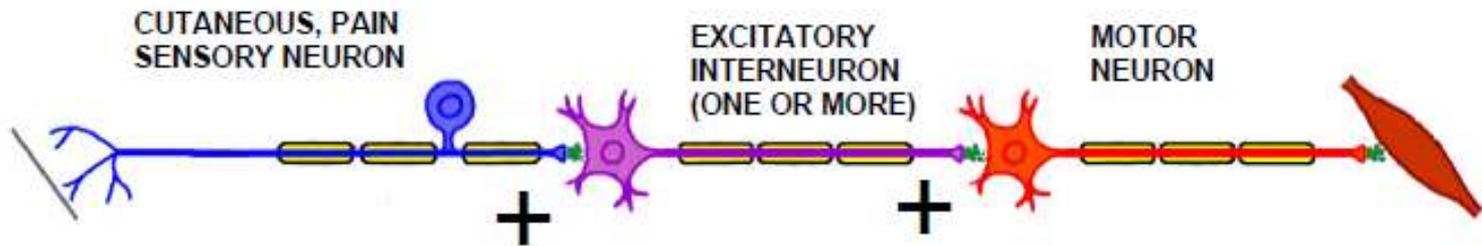
TYPICAL REFLEX

Example: FLEXOR REFLEX –
SENSORY STIMULUS - Stepping
on nail causes pain
MOTOR RESPONSE - Lift leg

2) INTERNEURON(S)



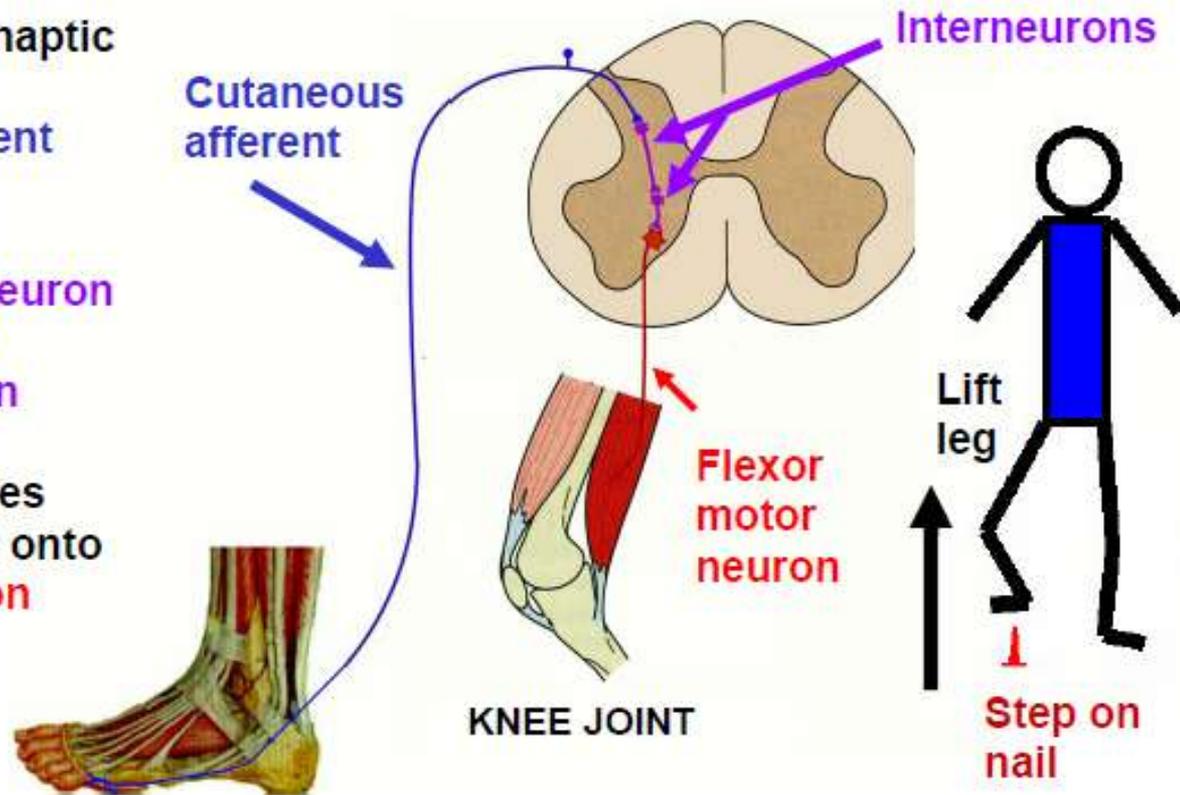
FLEXOR REFLEX: PATHWAYS



Synapses - Polysynaptic

1) Cutaneous afferent makes excitatory synapse onto Interneuron; Interneuron can synapse upon another interneuron

2) Interneuron makes excitatory synapse onto Flexor motor neuron



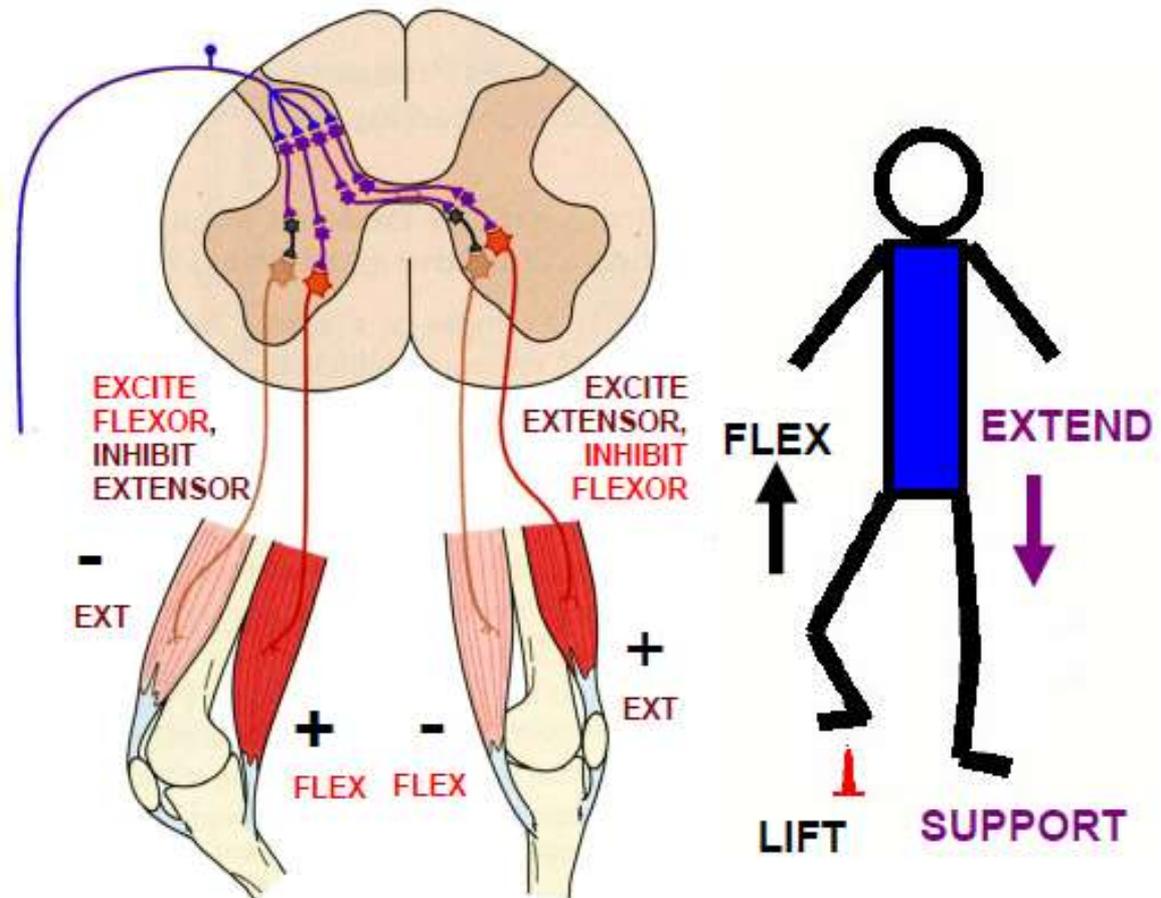
FLEXOR REFLEX: OTHER EFFECTS

ALL ARE POLYSYNAPTIC BY INTERNEURONS

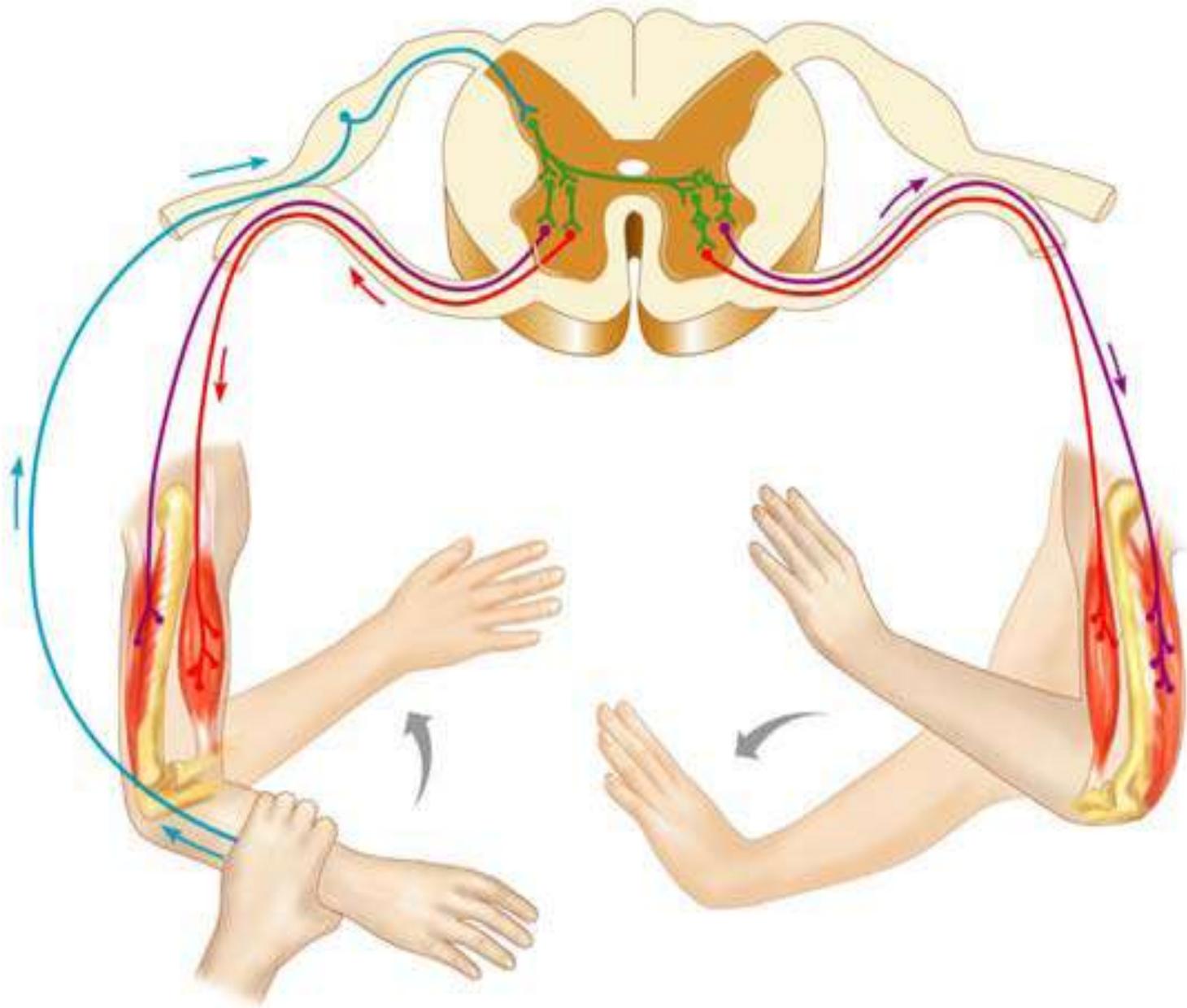
1) Excite synergist muscles - **excite other flexors in same leg** (other joints)

2) Inhibit antagonist muscles - **inhibit Extensors in same leg**

3) **CROSSED EXTENSION REFLEX - EXCITE EXTENSORS AND INHIBIT FLEXORS IN OPPOSITE LEG**

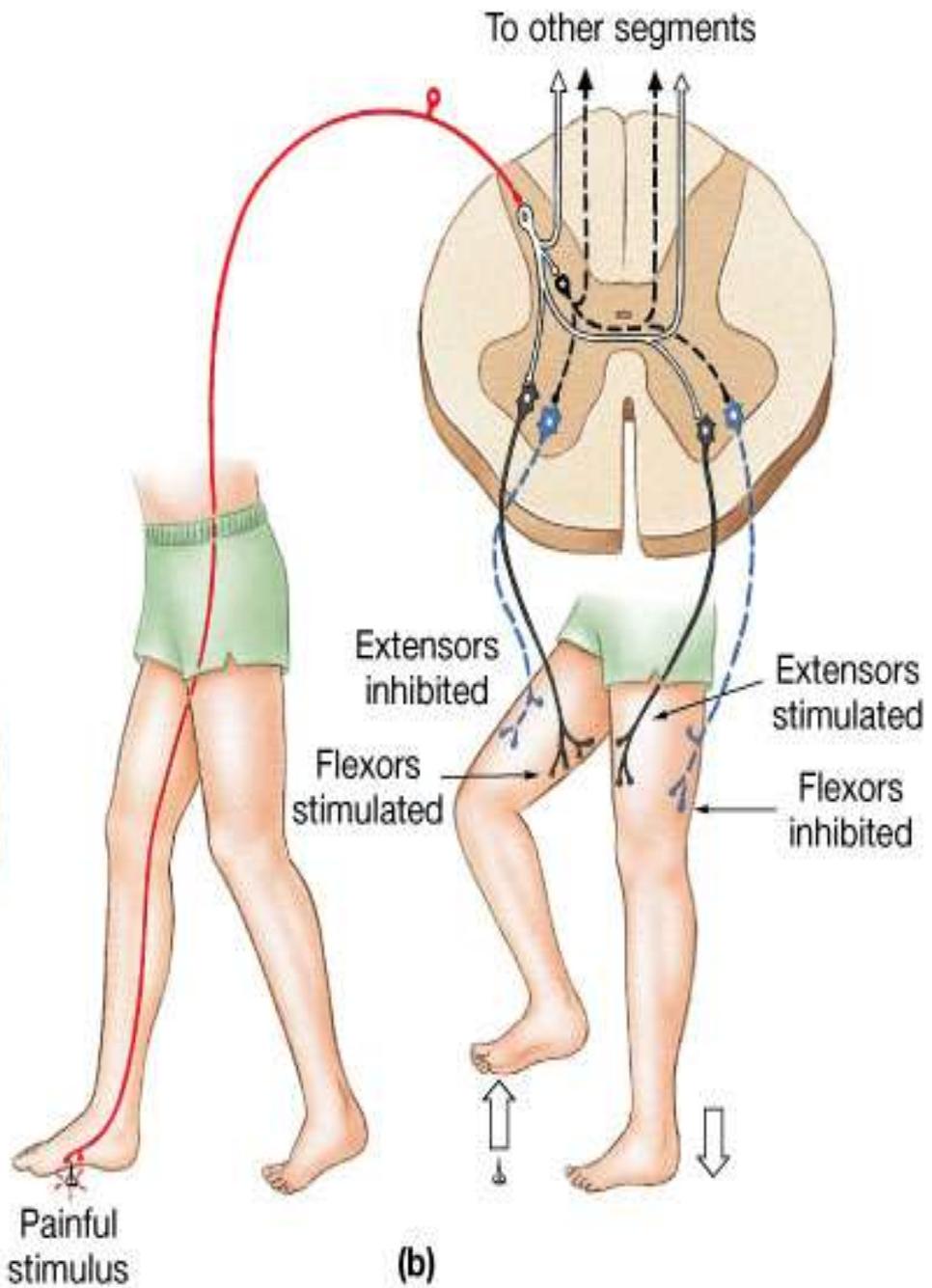
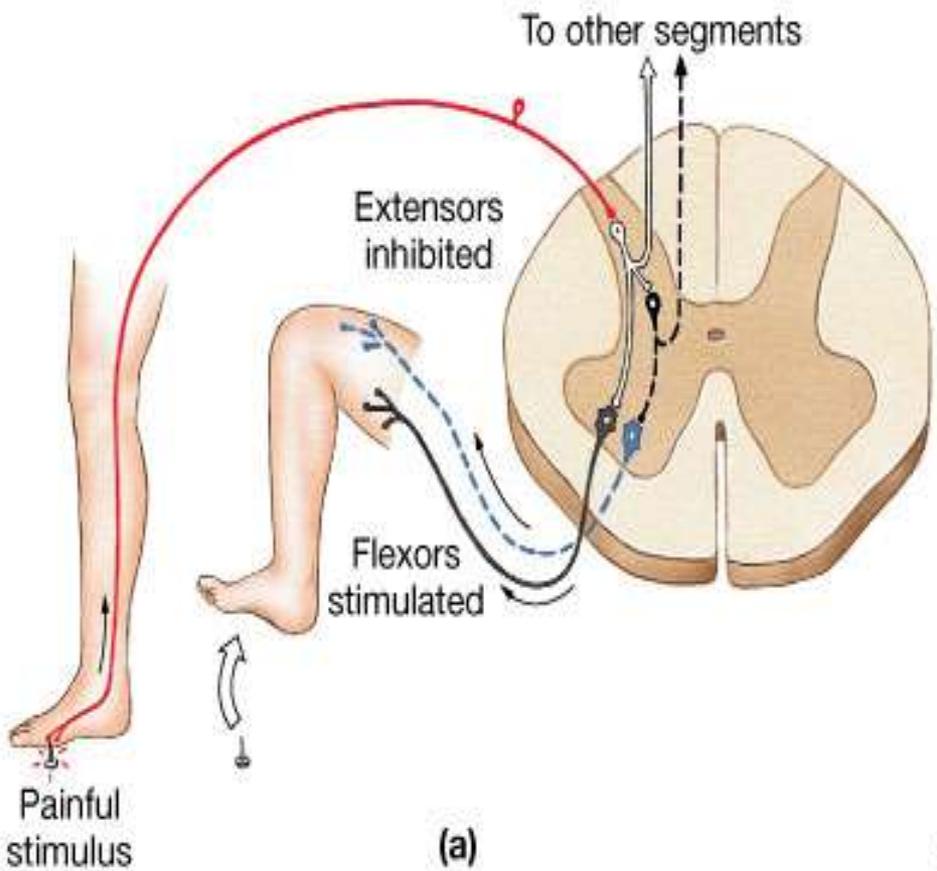


FUNCTION: OTHER LEG PROVIDES SUPPORT WHEN FIRST LEG IS LIFTED



KEY

- Sensory neuron (stimulated)
- - - Motor neuron (inhibited)
- Excitatory interneuron
- - - Inhibitory interneuron
- Motor neuron (stimulated)



Flexor withdrawal reflex

- is **polysynaptic**.
- results in **flexion on the ipsilateral side** and **extension on the contralateral side**.
- Somatosensory and pain afferent fibers elicit withdrawal of the stimulated body part from the noxious stimulus.

- a. **Pain** (e.g., touching a hot stove) stimulates the flexor reflex afferents of **groups II, III, and IV**.
- b. The afferent fibers synapse polysynaptically (via interneurons) onto motoneurons in the spinal cord.
- c. On the **ipsilateral side** of the pain stimulus, flexors are stimulated (they contract) and extensors are inhibited (they relax), and the arm is jerked away from the stove. On the **contralateral side**, flexors are inhibited and extensors are stimulated (**crossed extension reflex**) to maintain balance.
- d. As a result of persistent neural activity in the polysynaptic circuits, an **after-discharge** occurs. The afterdischarge prevents the muscle from relaxing for some time.

3. The Crossed Extensor Reflex

- The reflex occur when you step on a sharp object
- There is a rapid lifting of the affected foot (ipsilateral withdrawal reflex),
- while the contralateral response activates the extensor muscles of the opposite leg (contralateral extensor reflex)
- support the weight shifted to it

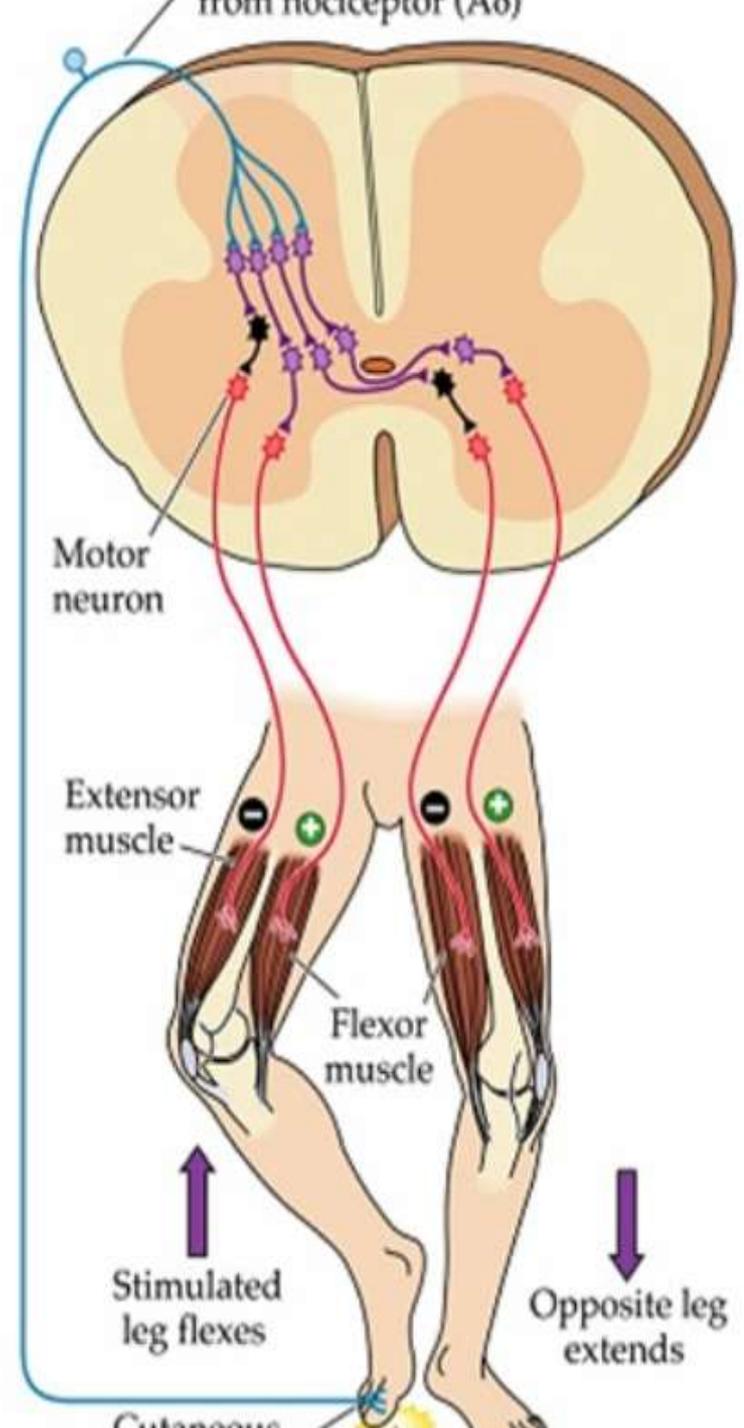


TABLE 2-8

Summary of Muscle Reflexes

Reflex	Number of Synapses	Stimulus	Afferent Fibers	Response
Stretch reflex (knee-jerk)	Monosynaptic	Muscle is stretched	Ia	Contraction of the muscle
Golgi tendon reflex (clasp-knife)	Disynaptic	Muscle contracts	Ib	Relaxation of the muscle
Flexor-withdrawal reflex (after touching a hot stove)	Polysynaptic	Pain	II, III, and IV	Ipsilateral flexion; contralateral extension

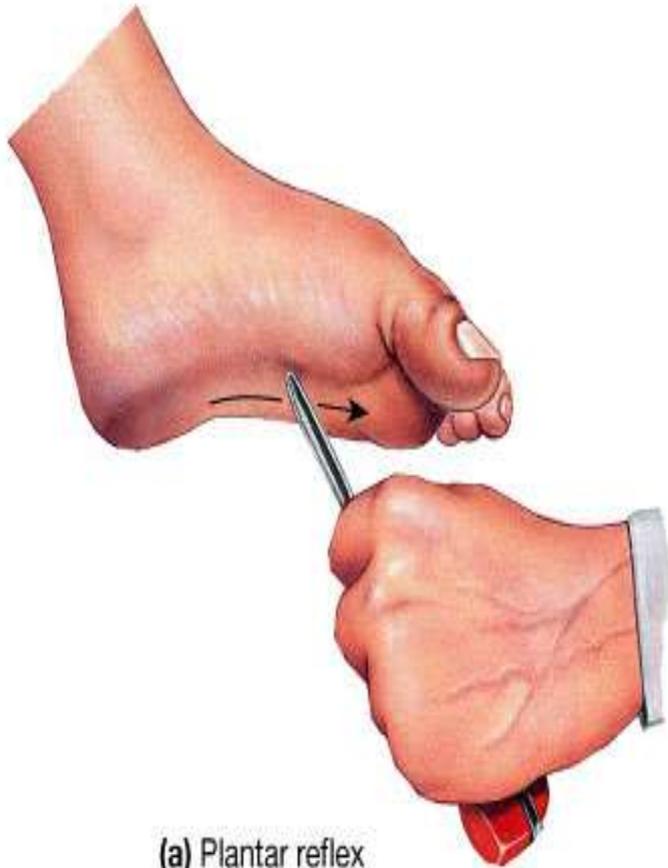
4. Superficial Reflexes

- Superficial reflexes are elicited by gentle cutaneous stimulation
- These reflexes are dependent upon functional upper motor pathways and spinal cord reflex arcs
- Babinski reflex

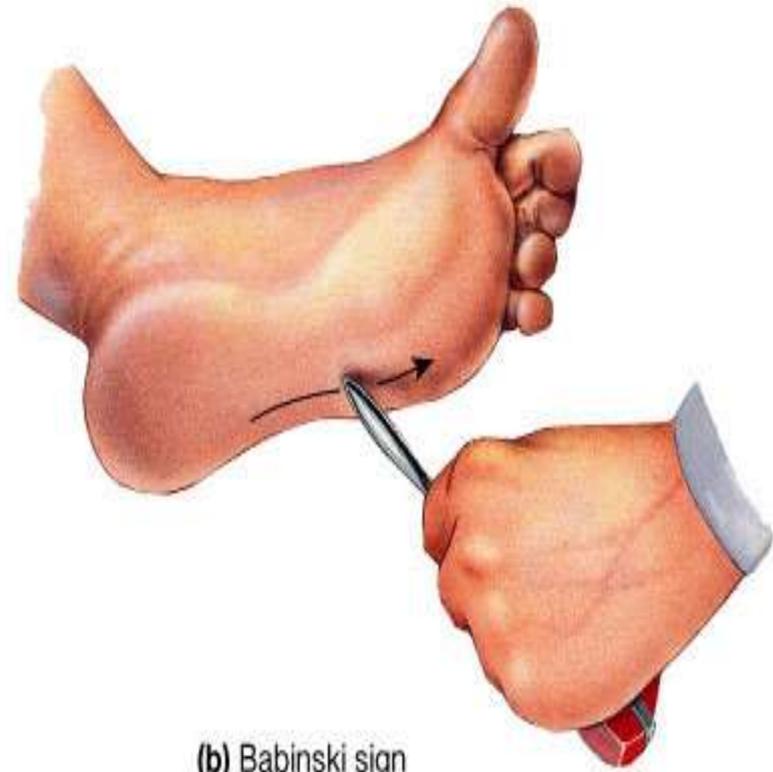
Superficial Reflexes

- Initiated by Gentle Cutaneous Stimulation
 - Plantar Reflex Initiated by Stimulating Lateral Aspect of Sole of Foot
 - Response Downward Flexion of Toes
 - Indirectly tests for Proper Corticospinal Tract Functioning
- Babinski's Sign
 - Abnormal Plantar Reflex
 - Corticospinal Damage
 - Great toe Dorsiflexes Smaller Toes Fan Laterally

Babinski's Sign



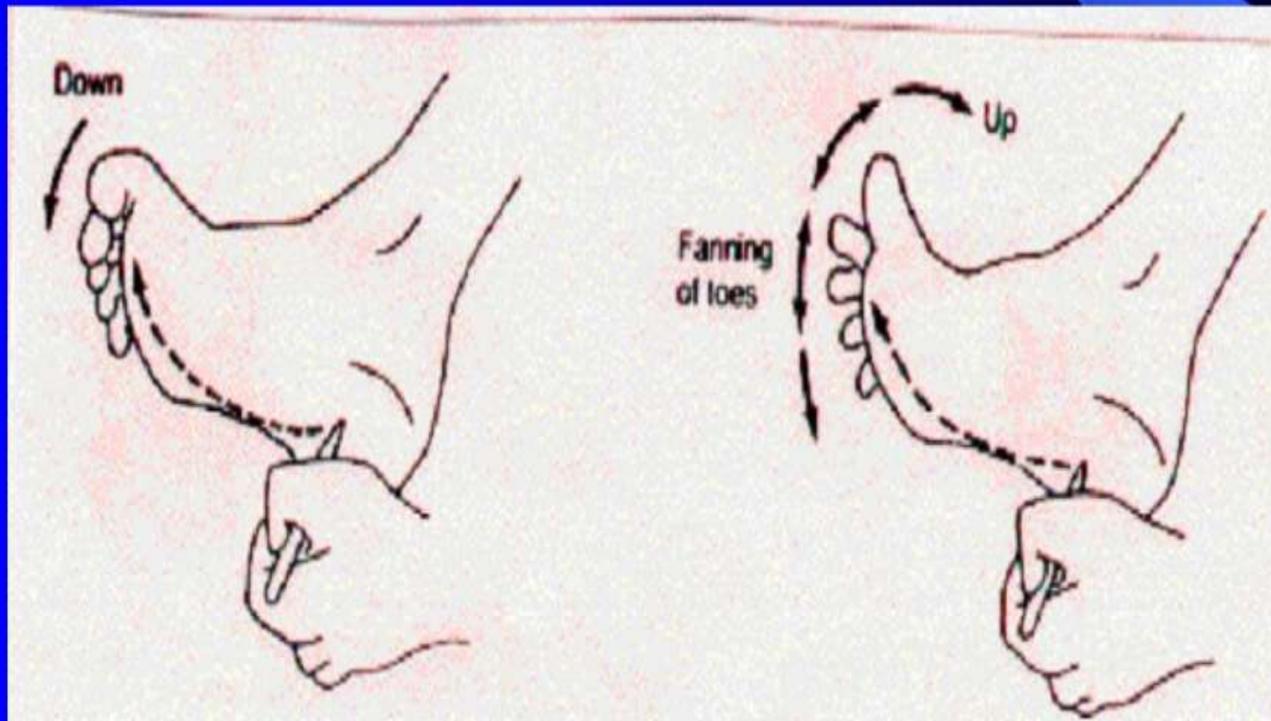
(a) Plantar reflex



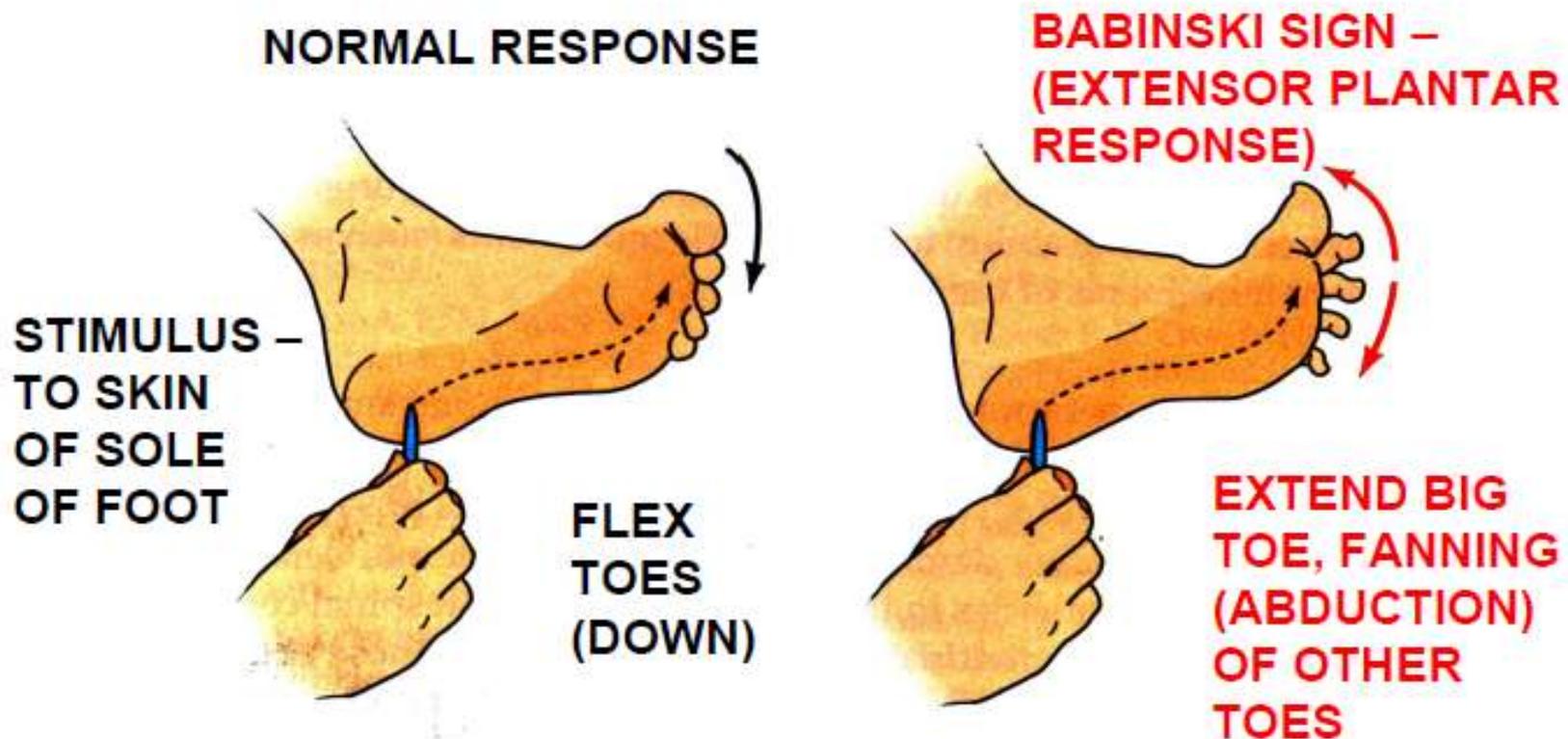
(b) Babinski sign

Babinski reflex - an UMN sign

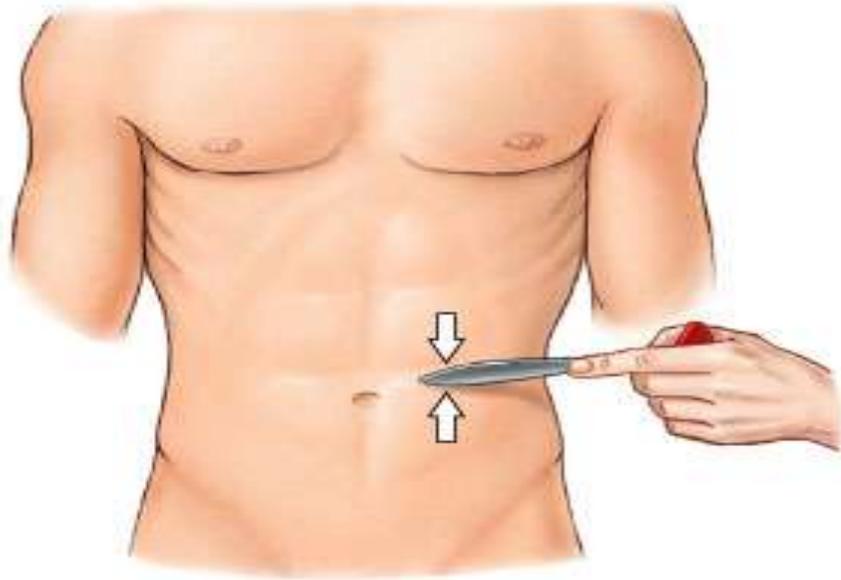
- Adult response - plantar flexion of the big toe and adduction of the smaller toes
- Pathological (Infant) response - dorsoflexion (extension) of the big toe and fanning of the other toes
- Indicative of upper motor neuron damage



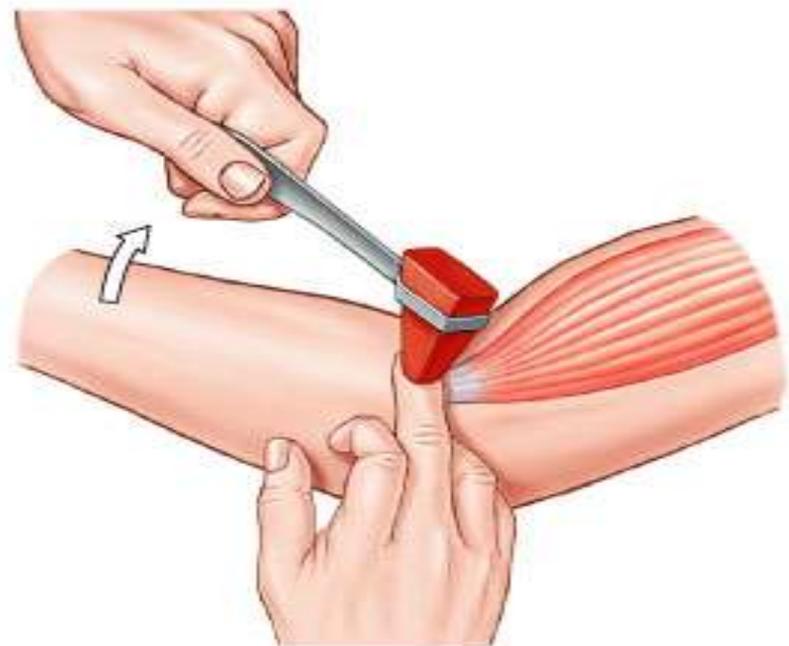
REFLEXES ARE MODULATED: SOME FLEXOR REFLEXES CAN CHANGE AFTER LESIONS, DISEASE PROCESSES



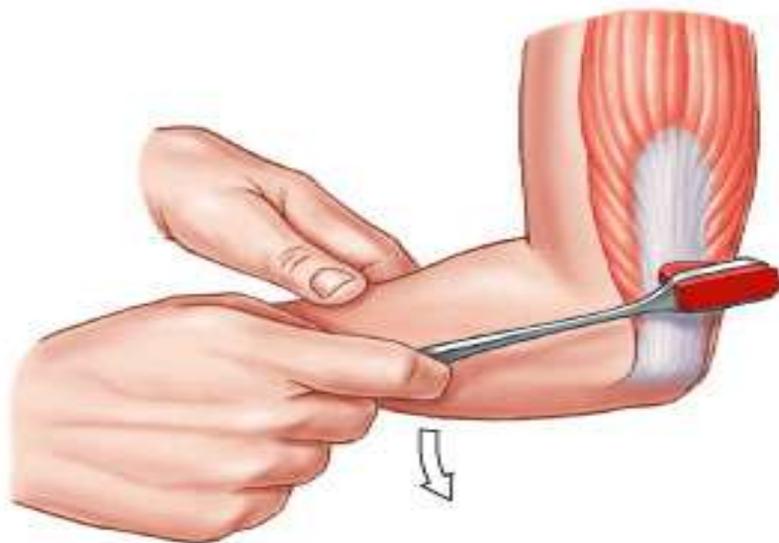
Babinski sign - seen after **Upper Motor neuron lesion**
-direction of movement **changes from flexing toes to extending and fanning (abductin) toes**



(a) Abdominal reflex



(b) Biceps reflex



(c) Triceps reflex



(d) Ankle jerk

Testing for Clonus



Testing for the Babinski Sign



Testing Muscle Tone

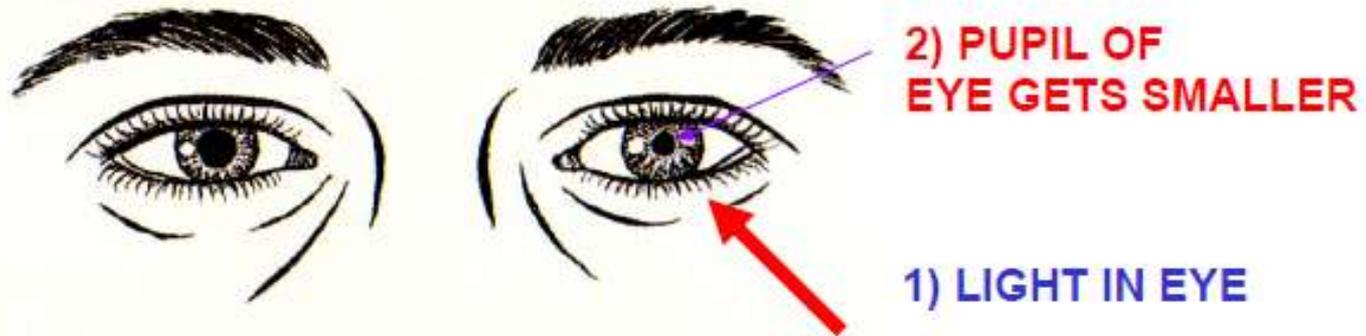


Testing the Clasp Knife Reflex



SOME REFLEXES ARE CONSTANT

PUPILLARY LIGHT REFLEX - SHINE LIGHT IN EYE causes **PUPILLARY CONSTRICTION**; protective reflex that limits light entering eye.



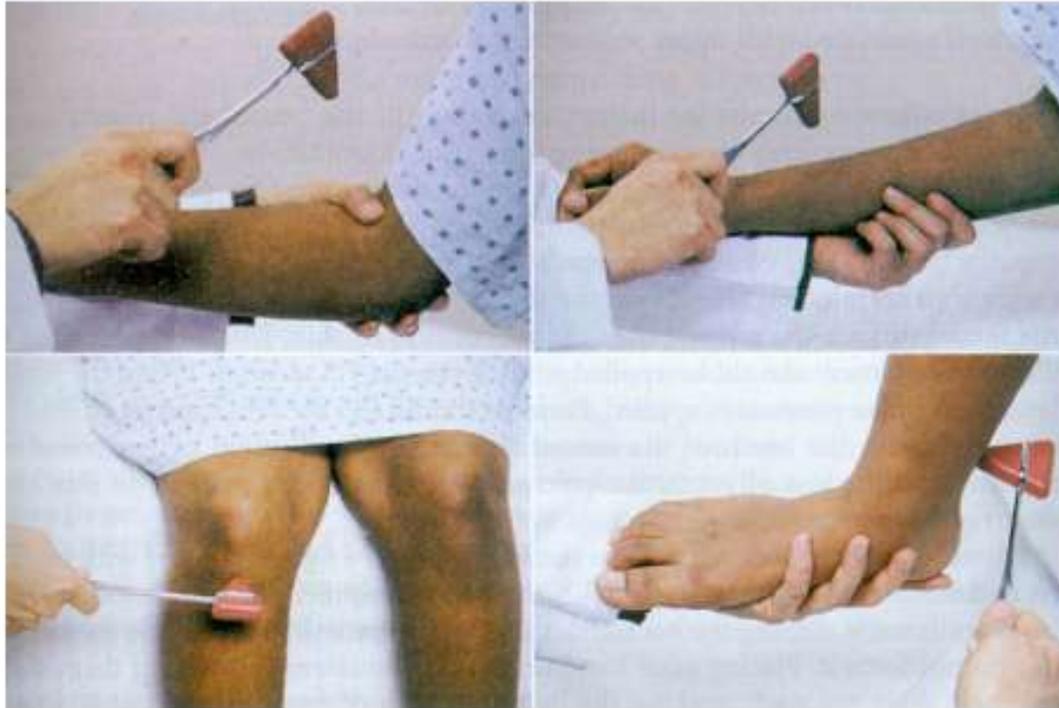
1) **STIMULUS (AFFERENT ARM) - OPTIC NERVE (CRANIAL NERVE II)** detects light

2) **RESPONSE (EFFERENT ARM) - OCULOMOTOR NERVE (CRANIAL NERVE III)** innervates pupillary constrictor muscle

PROTECTIVE REFLEXES - limit amplitude of sensory stimulus, amount of light entering eye; connection is functional and present at all times.

SOME REFLEXES ARE CONSTANT UNDER SAME CIRCUMSTANCES

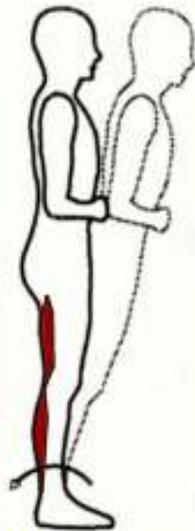
DEEP TENDON REFLEXES - stretch reflex activates muscle spindles



Patient positioned correctly, told to relax; focus patient's attention elsewhere (ex. tell patient to clench hands and try pulling apart). Reason: reflexes can be modulated by neural activities in CNS.

SPINAL REFLEXES FORM PART OF AUTOMATIC REACTIONS AND ADJUSTMENTS

1) **Maintaining balance** when standing and walking



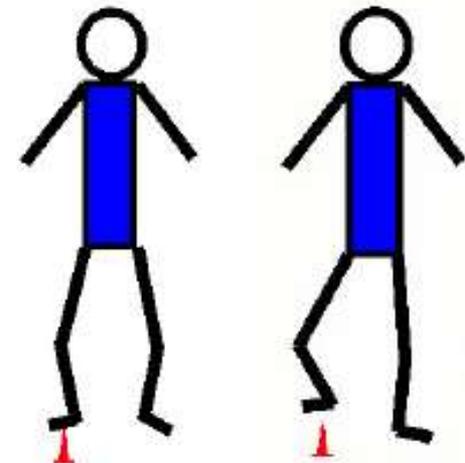
Muscle spindles

2) **Regulating muscle tensions** - not damage muscles or insertions



Golgi tendon organs

3) Stepping on a nail - **avoid painful stimuli**



Cutaneous, nociceptive (pain) receptors

Note: Automatic reactions differ from reflexes in duration, complexity and can be influenced by different types of sensory inputs.

Three basic reflexes:

- 1) Stretch reflex - produced by activating muscle spindles - contributes to maintaining postural stability, countering sudden loads
- 2) Autogenic inhibition - produced by activating Golgi tendon organs - aids in regulating muscle tension, prevents damage to tendon, bone
- 3) Flexion reflex - produced by activating cutaneous, pain afferents - avoid obstacle or painful stimulus (stepping on nail)

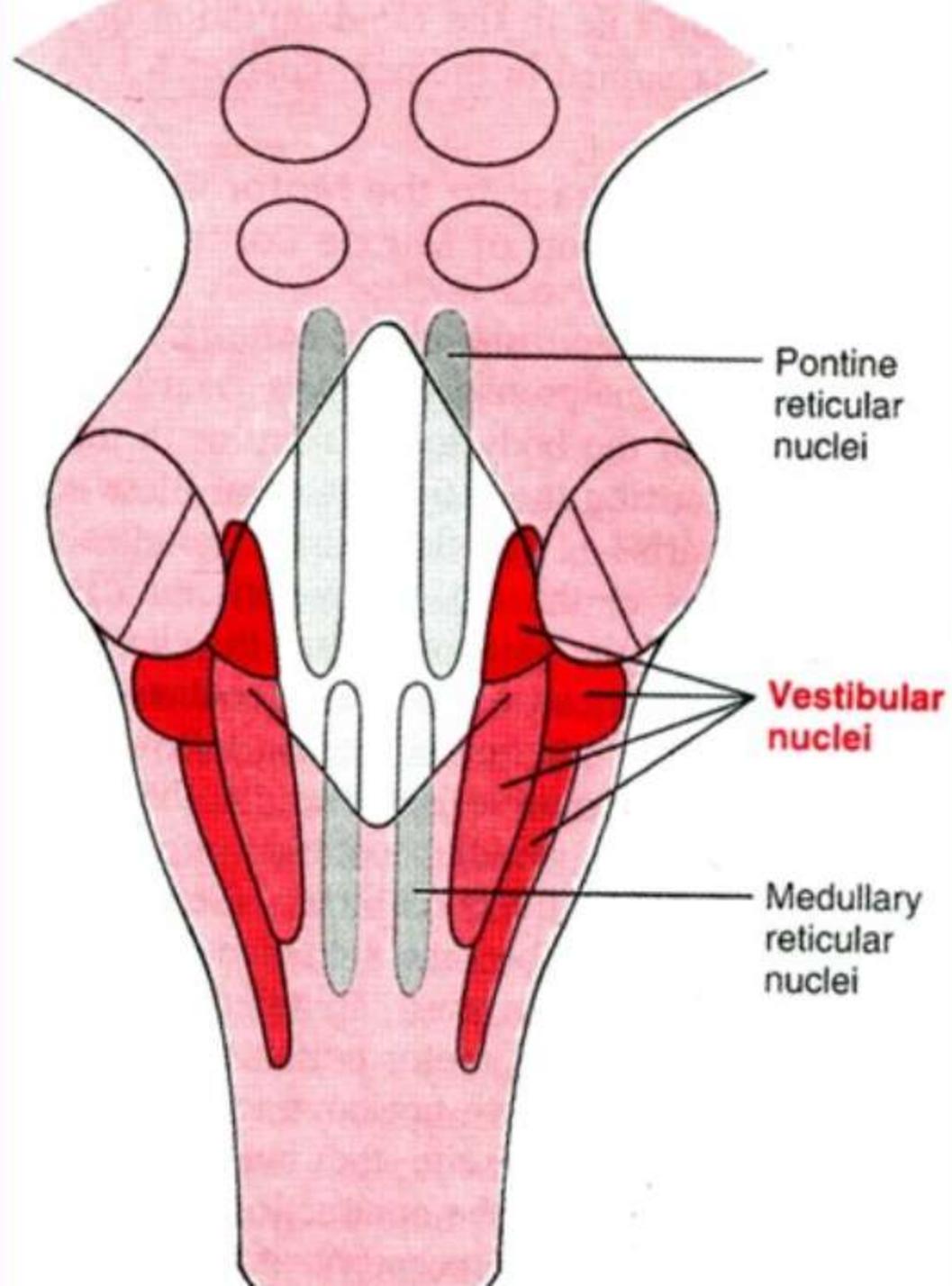
SUMMARY OF SPINAL REFLEXES

REFLEX	STIMULUS (CLINICAL TEST)	RESPONSE	SENSORY RECEPTOR	SYNAPSES	EFFECT ON MUSCLE	OTHER EFFECTS	FUNCTION
Stretch (Myotatic) Reflex	Rapid Stretch of muscle (test: tap on muscle tendon)	Stretched muscle contracts rapidly (ex. knee jerk)	Muscle Spindle Primary (Ia) and Secondary (II) sensory neurons	Ia: Mono-synaptic II: Mono-synaptic (weak) and Poly-synaptic	Excite Homonymous (same muscle)	Also Excite synergist muscles; Inhibit antagonist muscles (Reciprocal Inhibition)	Aid in maintaining posture, counter sudden loads
Autogenic Inhibition (Inverse Myotatic Reflex)	Large force on tendon (pull on muscle when resisted)	Muscle tension decreases (Clasped knife reflex)	Golgi Tendon Organ (Ib)	Poly-synaptic (via interneuron)	Inhibit Homonymous (same muscle)	Also Inhibit synergist muscles; Excite antagonist muscles	Protective, prevent damage to tendon
Flexor Reflex	Sharp, painful stimulus (as in stepping on nail)	Limb is rapidly withdrawn from stimulus	Cutaneous (skin) and pain receptors	Poly-synaptic (via interneuron)	Excite Flexor muscle	Also Inhibit extensor muscle of same limb; Excite extensor muscles and Inhibit flexors of opposite limb (Crossed Extensor Reflex)	Protective, withdraw from painful stimulus; Cross extension aids in maintaining posture when leg is lifted

Spinal reflexes are important tools; behaviors are more complex and can incorporate, change and adapt reflex connections

III. Role of the brain stem:

Support of the Body Against Gravity –
Roles of the Reticular and Vestibular
nuclei



Facilitated and inhibitory area

Motor cortex

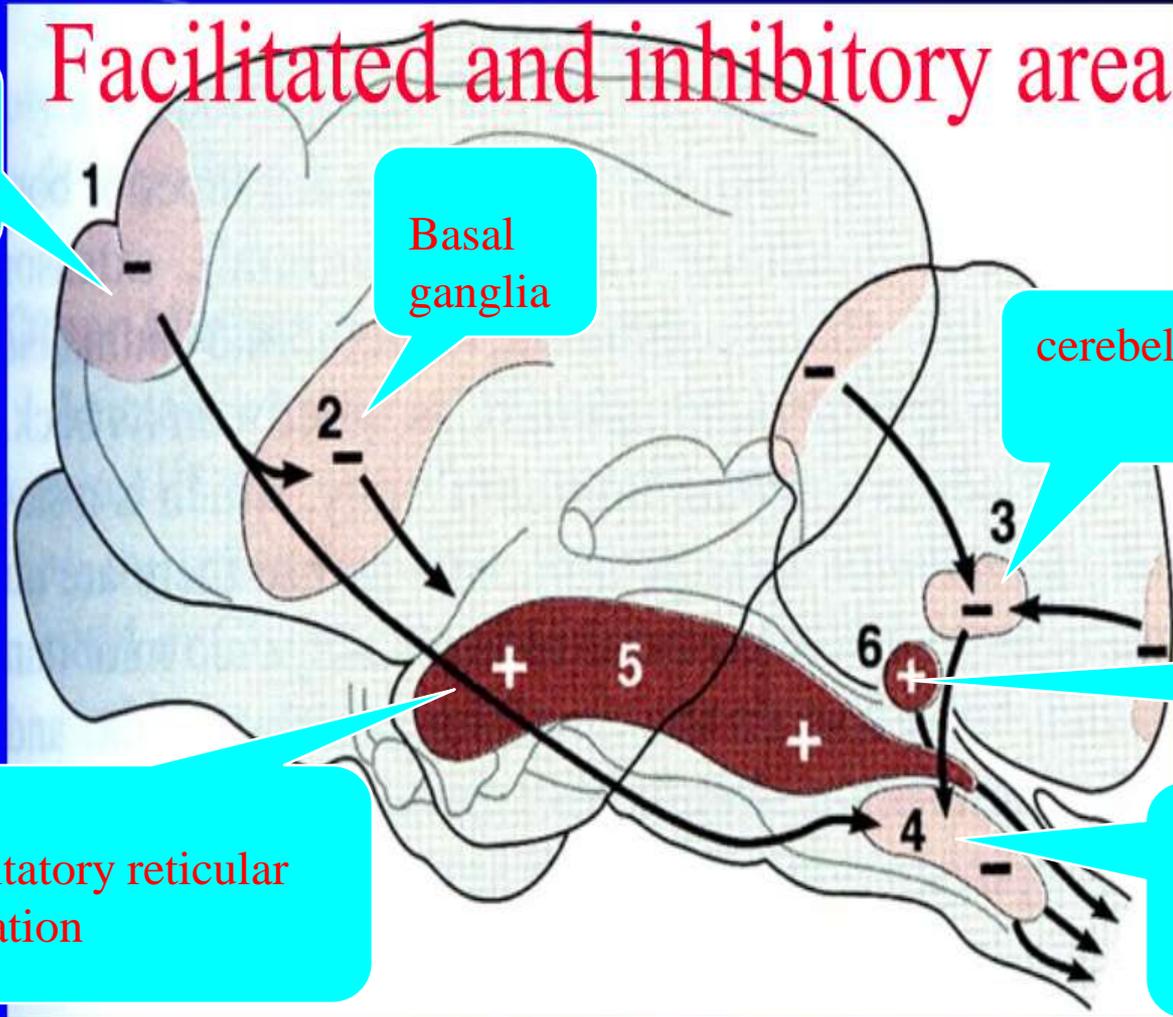
Basal ganglia

cerebellum

Vestibular nucleus

Facilitatory reticular formation

Inhibitory reticular formation



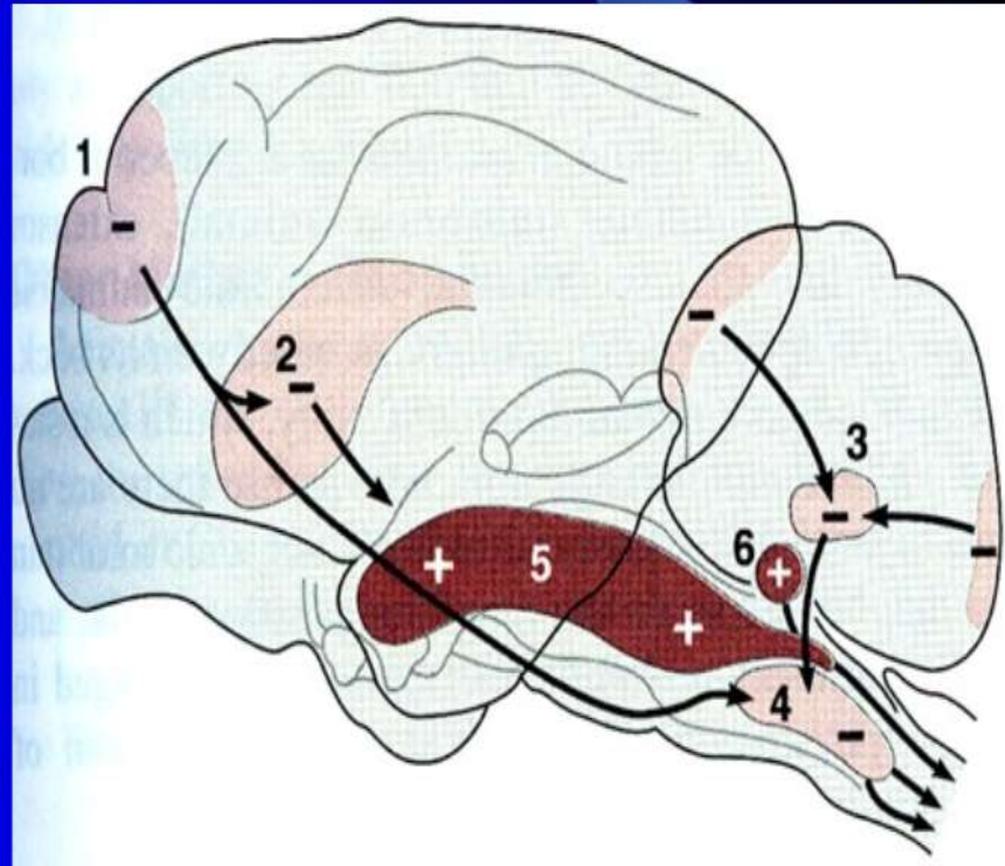
Areas in the cat brain where stimulation produces facilitation (+) or inhibition (-) of **stretch reflexes**. 1. motor cortex; 2. Basal ganglia; 3. Cerebellum; 4. Reticular inhibitory area; 5. Reticular facilitated area; 6. Vestibular nuclei.

1. Facilitated area—roles of the reticular and vestibular nuclei. :

(1) The pontine reticular nuclei

- Located slightly posteriorly and laterally in the pons and extending to the mesencephalon,
- Transmit excitatory signals downward into the cord (the pontine reticulospinal tract)

1. motor cortex;
2. Basal ganglia;
3. Cerebellum;
4. Reticular inhibitory area;
5. Reticular facilitated area;
6. Vestibular nuclei.



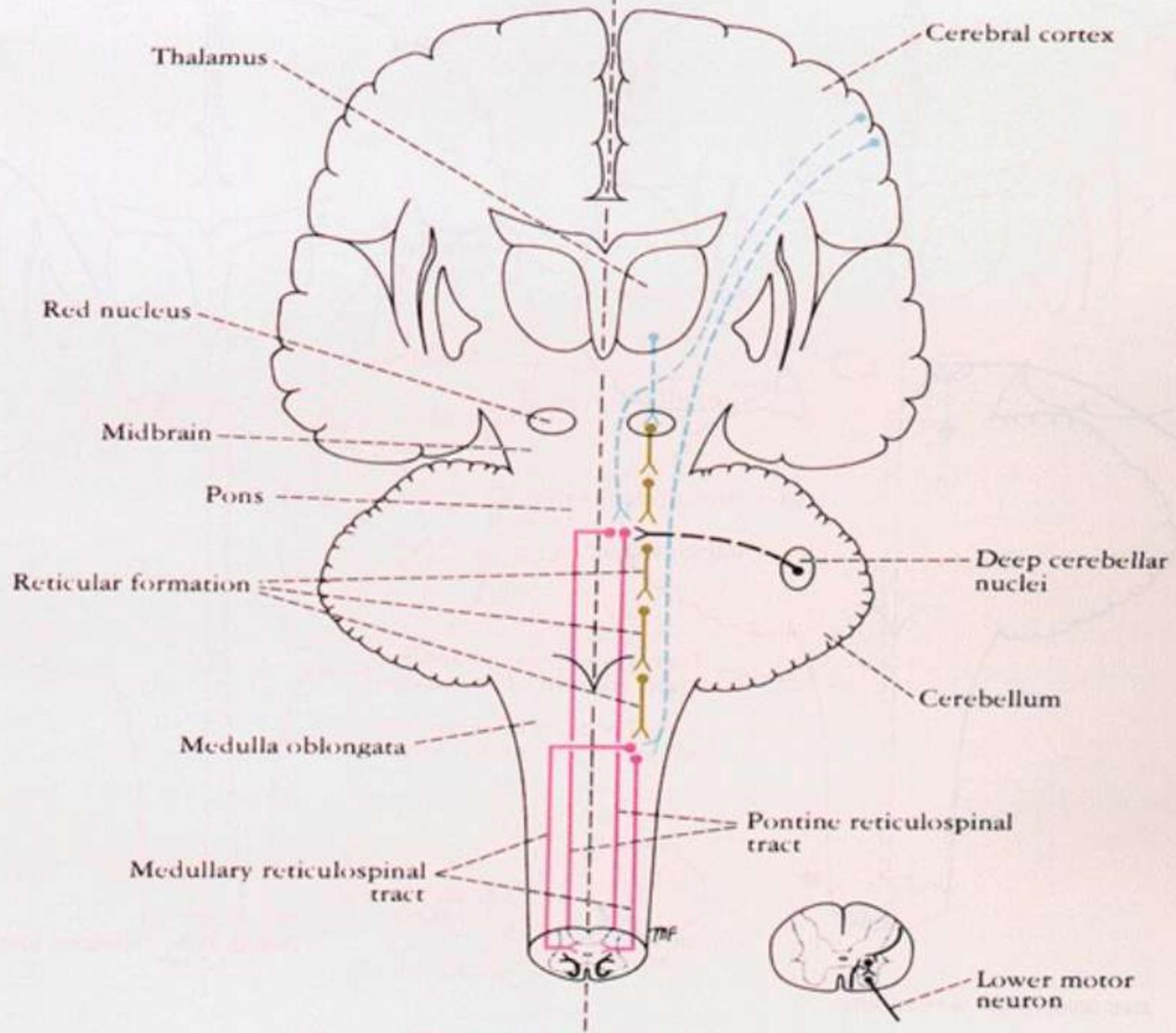
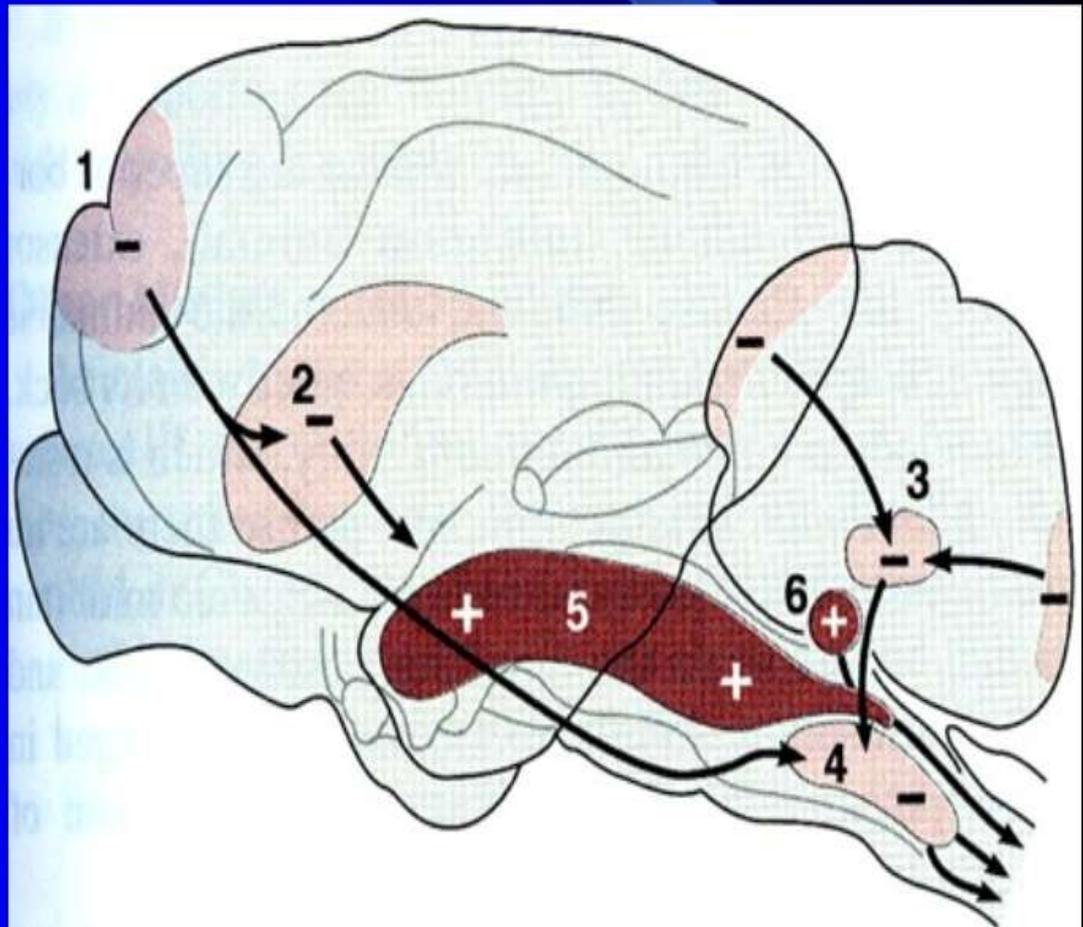


FIGURE 21-4 Reticulospinal tracts

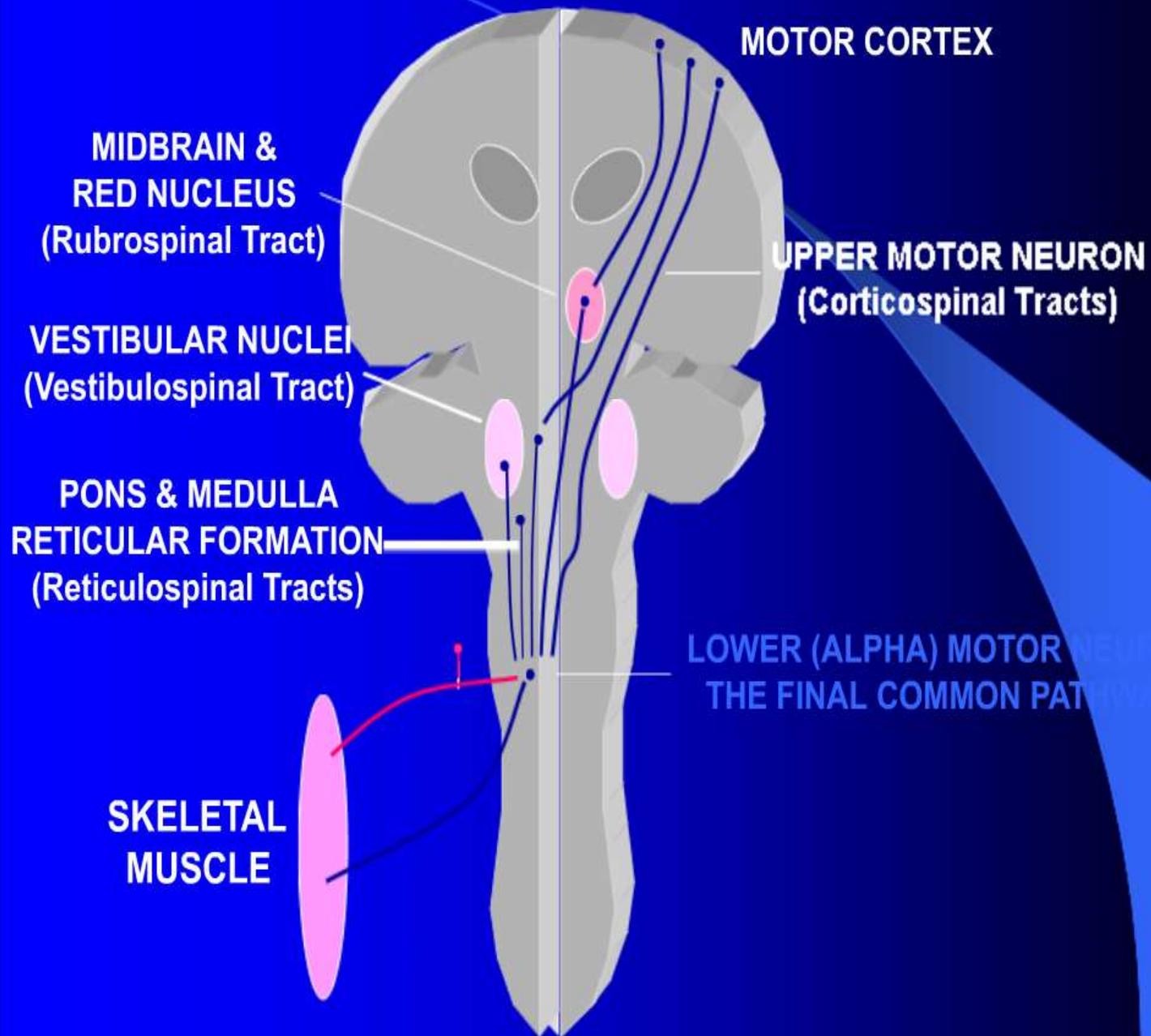
(2) The vestibular nuclei

□selectively control the excitatory signals to the different antigravity M. to maintain equilibrium in response to signals from the vestibular apparatus.

1. motor cortex;
2. Basal ganglia;
3. Cerebellum;
4. Reticular inhibitory area;
5. Reticular facilitated area;
6. Vestibular nuclei.



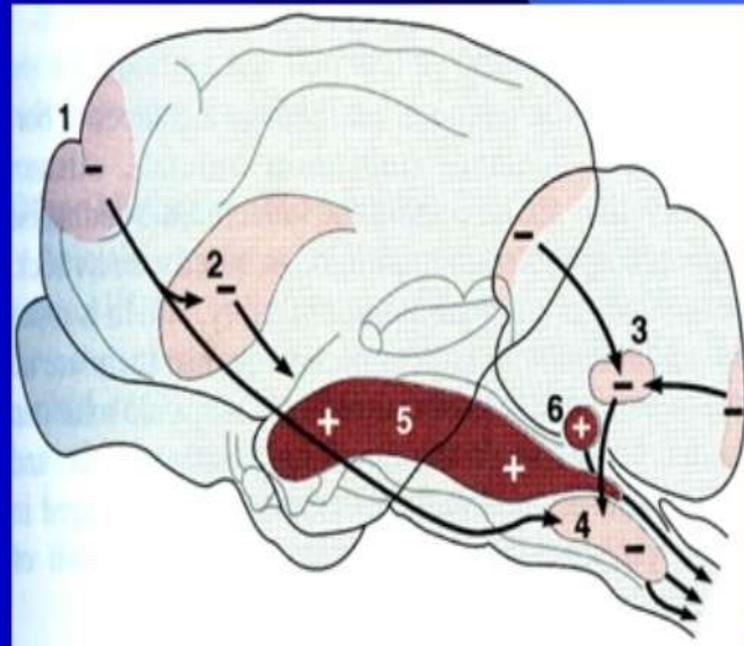
MOTOR TRACTS & LOWER MOTOR NEURON



Properties of the Facilitated Area

- Terminate on the motor neurons that exciting antigravity M. of the body (the M. of vertebral column and the extensor M. of the limbs).
- Have a high degree of **natural (spontaneous) excitability**.
- Receive especially strong excitatory signals from vestibular nuclei and the deep nuclei of the cerebellum.
- Cause powerful excitation of the antigravity M throughout the body (facilitate a standing position), supporting the body against gravity.

1. motor cortex; 2. Basal ganglia; 3. Cerebellum; 4. Reticular inhibitory area; 5. Reticular facilitated area; 6. Vestibular nuclei.

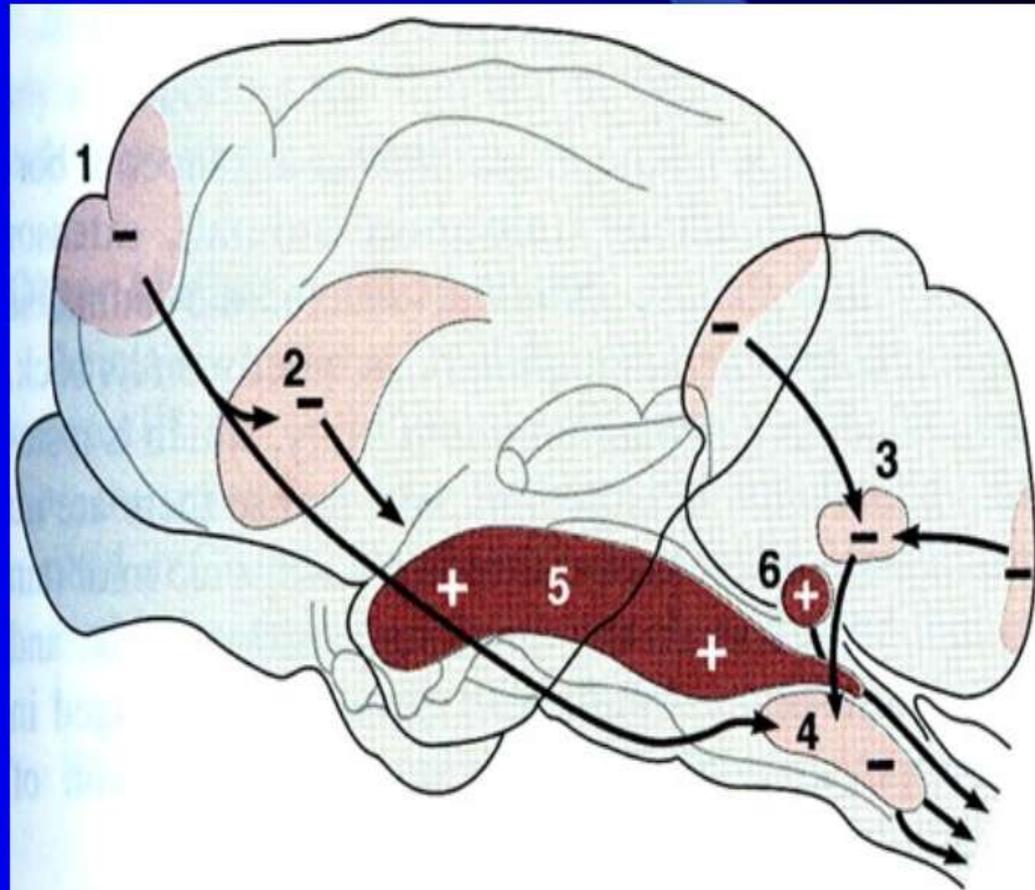


2. Inhibitory area –medullary reticular system

(1) Extend the entire extent to the medulla, lying ventrally and medially near the middle.

(2) Transmit inhibitory signals to the same antigravity anterior motor neurons (medullary reticulospinal tract).

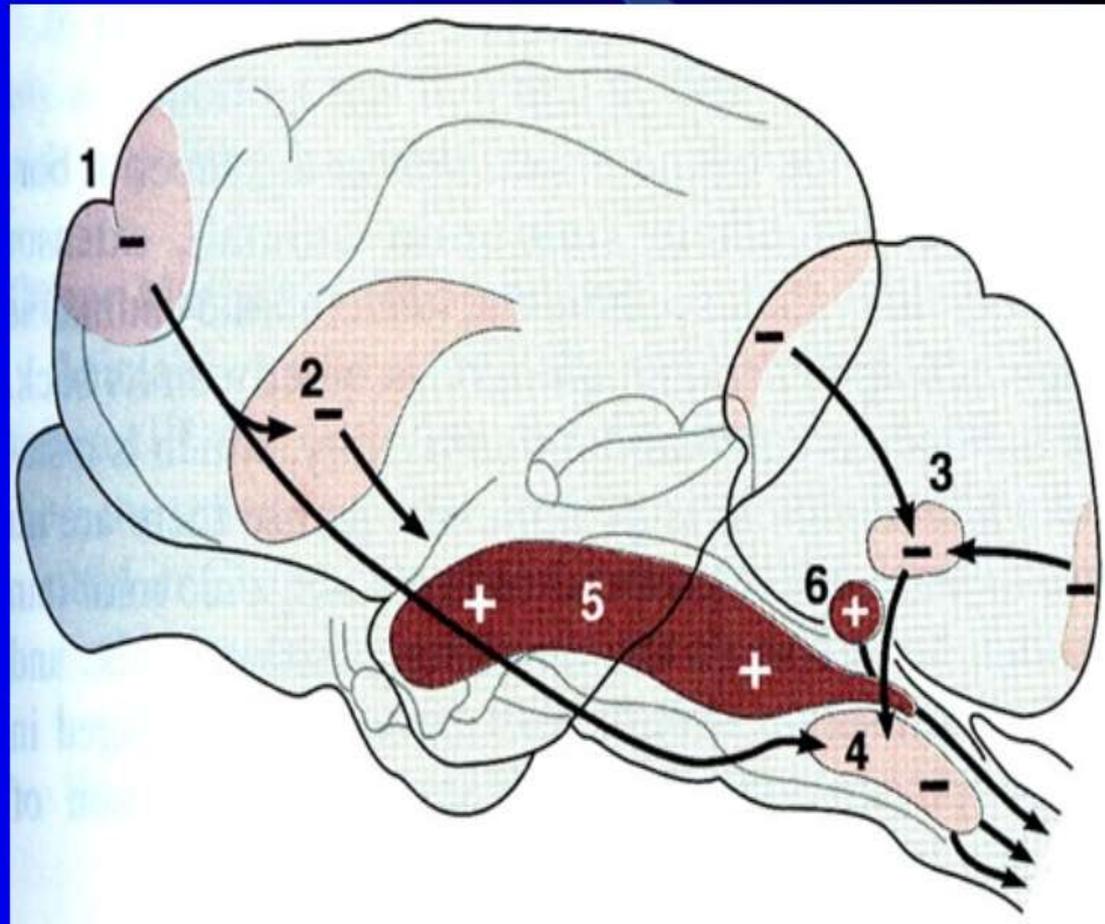
1. motor cortex;
2. Basal ganglia;
3. Cerebellum;
4. Reticular inhibitory area;
5. Reticular facilitated area;
6. Vestibular nuclei.

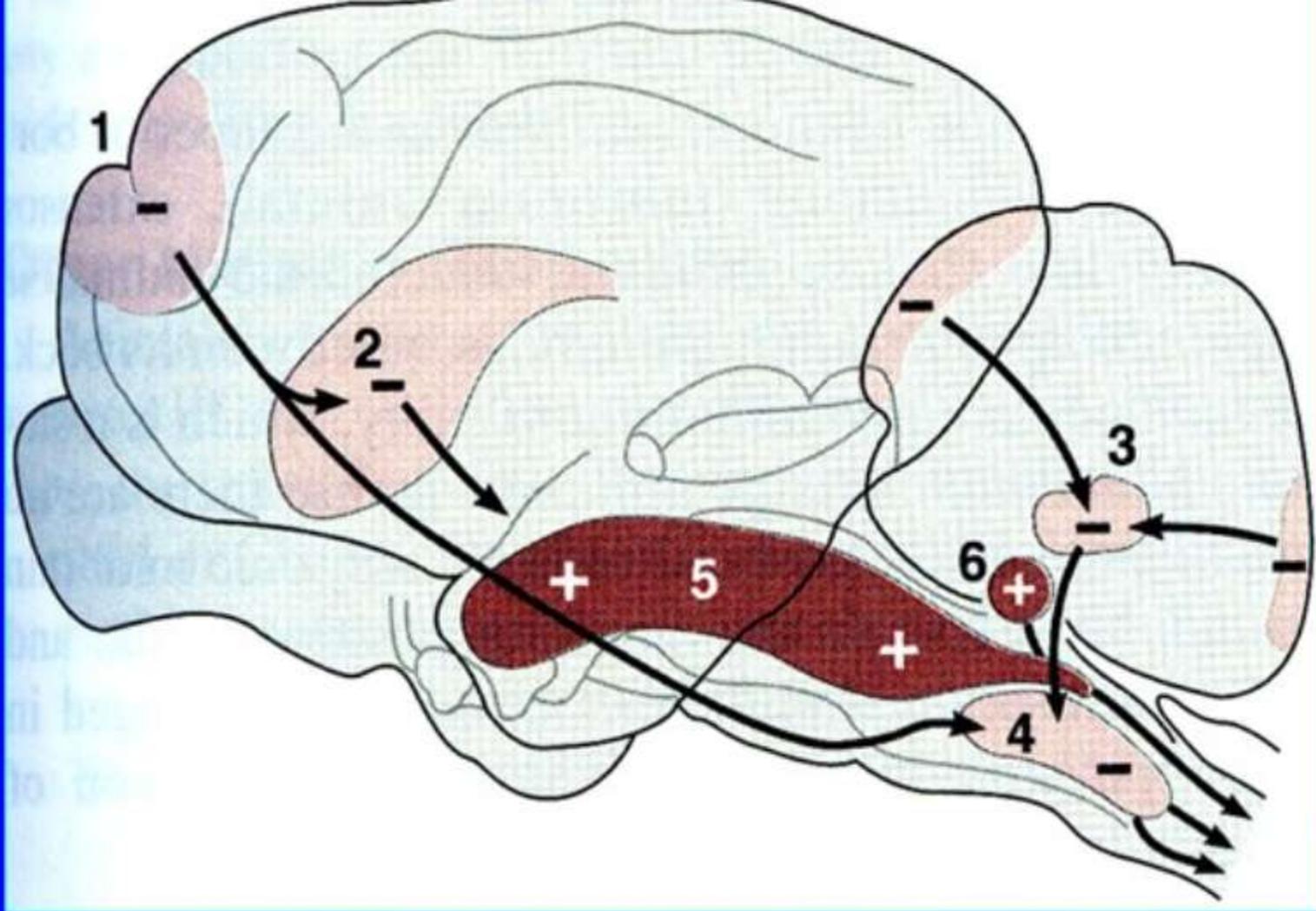


(3) Receive collaterals from the corticospinal tract; the rubrospinal tracts; and other motor pathways.

These collaterals activate the medullary reticular inhibitory system to balance the excitatory signals from the P.R.S., so that under normal conditions, the body M. are normally tense.

- 1. motor cortex;**
- 2. Basal ganglia;**
- 3. Cerebellum;**
- 4. Reticular inhibitory area;**
- 5. Reticular facilitated area;**
- 6. Vestibular nuclei.**

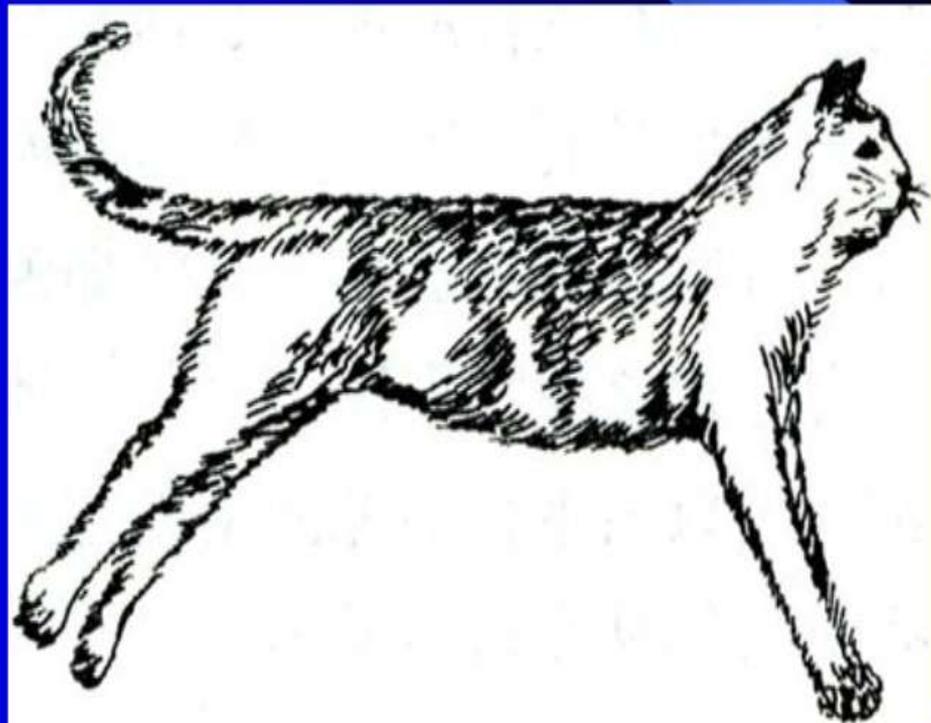
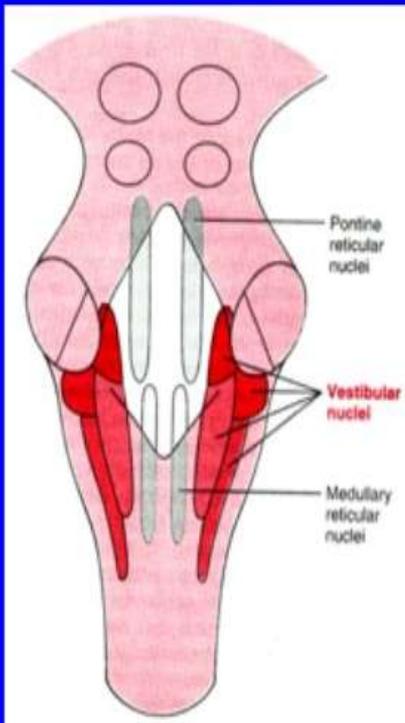




Areas in the cat brain where stimulation produces facilitation (+) or inhibition (-) of stretch reflexes. 1. motor cortex; 2. Basal ganglia; 3. Cerebellum; 4. Reticular inhibitory area; 5. Reticular facilitated area; 6. Vestibular nuclei.

Decerebrate Rigidity

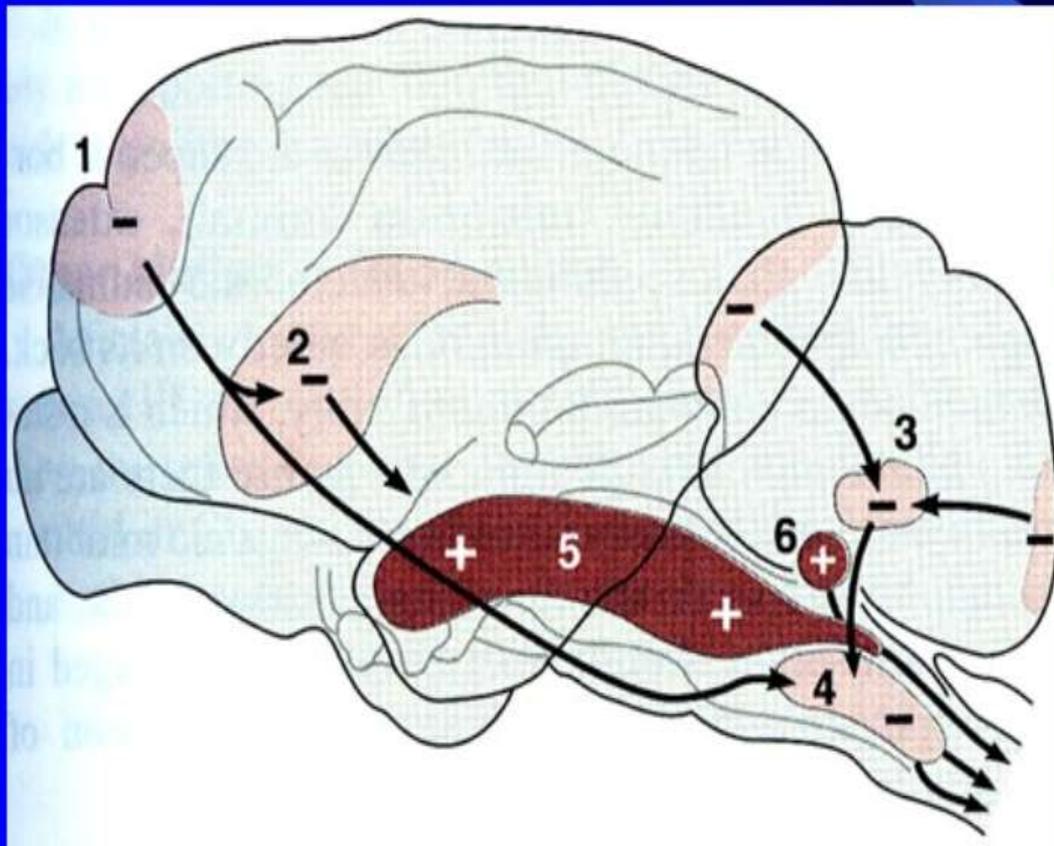
- Decerebrate Rigidity: transection of the brainstem at midbrain level (above vestibular nuclei and below red nucleus)
- Symptoms include:
 - extensor rigidity or posturing in both upper and lower limbs



- Results from:

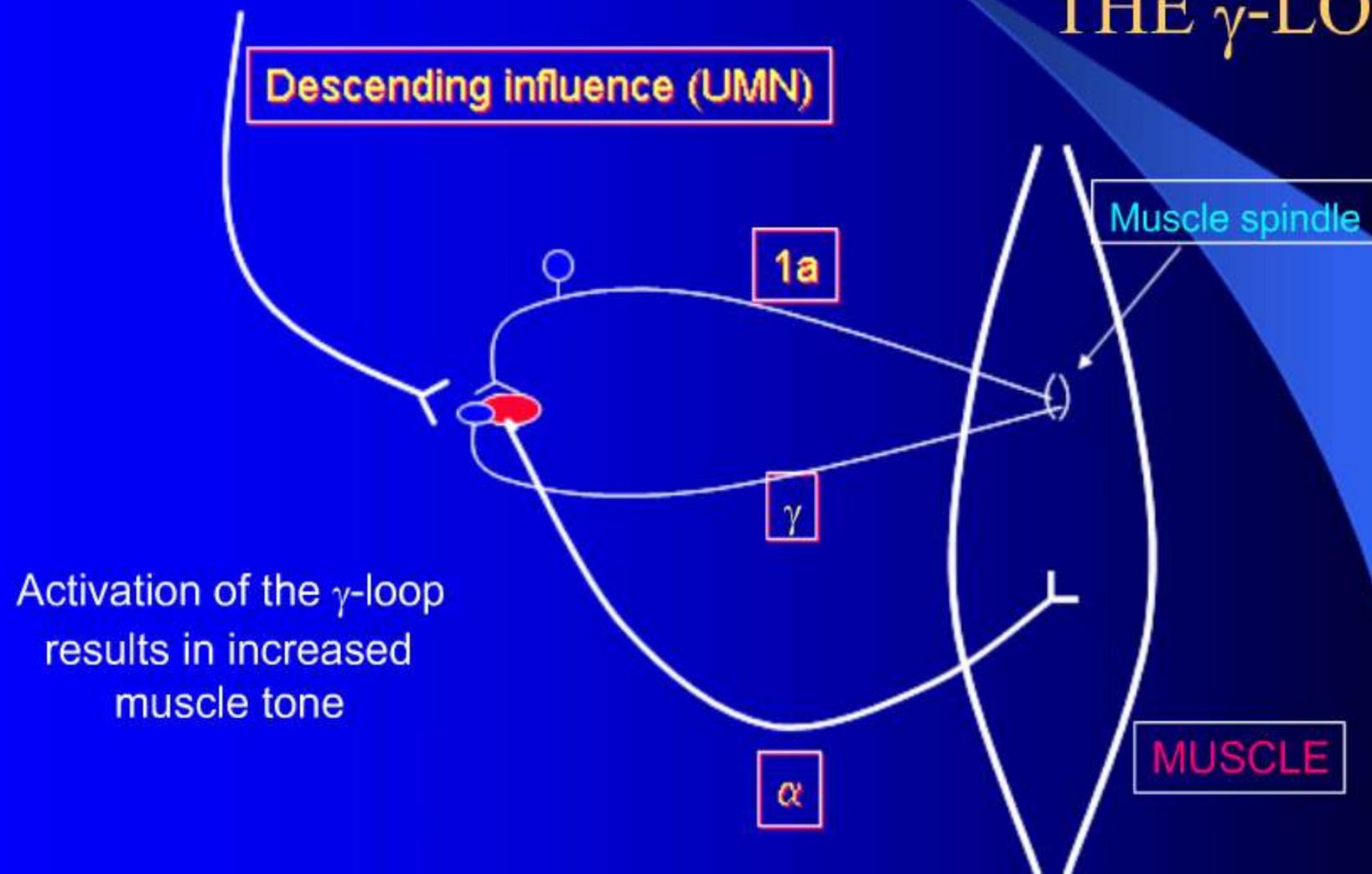
- loss of input from inhibitory medullary RF (activity of this center is dependent on input from higher centers).

- active facilitation from pontine RF (intrinsically active, and receives afferent input from spinal cord).



- The extensor rigidity is γ -loop dependent
 - section the dorsal roots interrupts the γ -loop, and the rigidity is relieved. This is γ -rigidity.

THE γ -LOOP?



General Properties of Reflexes

- Adequate Stimulus
- The stimulus that triggers a reflex is generally very precise. This stimulus is called the **adequate stimulus** for the particular reflex

- **Final Common Path**

- The motor neurons that supply the extrafusal fibers in skeletal muscles are the efferent side of many reflex arcs. All neural influences affecting muscular contraction ultimately funnel through them to the muscles, and they are therefore called the **final common paths**.

- **Central Excitatory & Inhibitory States**
- the spinal cord also shows prolonged changes in excitability, possibly because of activity in reverberating circuits or prolonged effects of synaptic mediators.
- When the central excitatory state is marked, excitatory impulses irradiate not only to many somatic areas of the spinal cord but also to autonomic areas.

- In chronically paraplegic humans, for example, a mild noxious stimulus may cause, in addition to prolonged withdrawal-extension patterns in all four limbs, urination, defecation, sweating, and blood pressure fluctuations (**mass reflex**).

THANK YOU