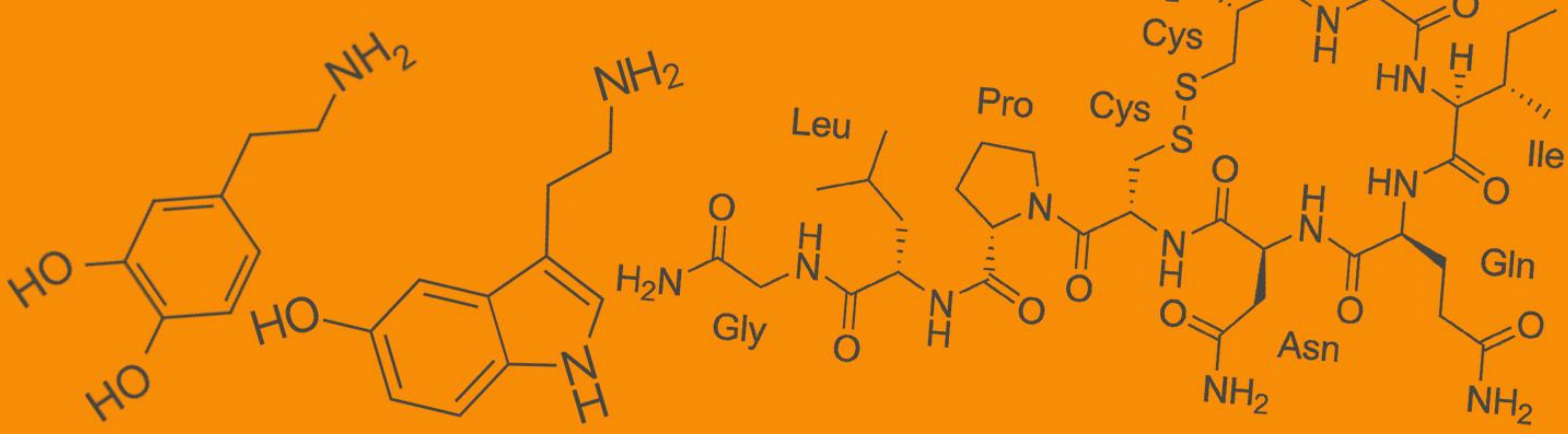
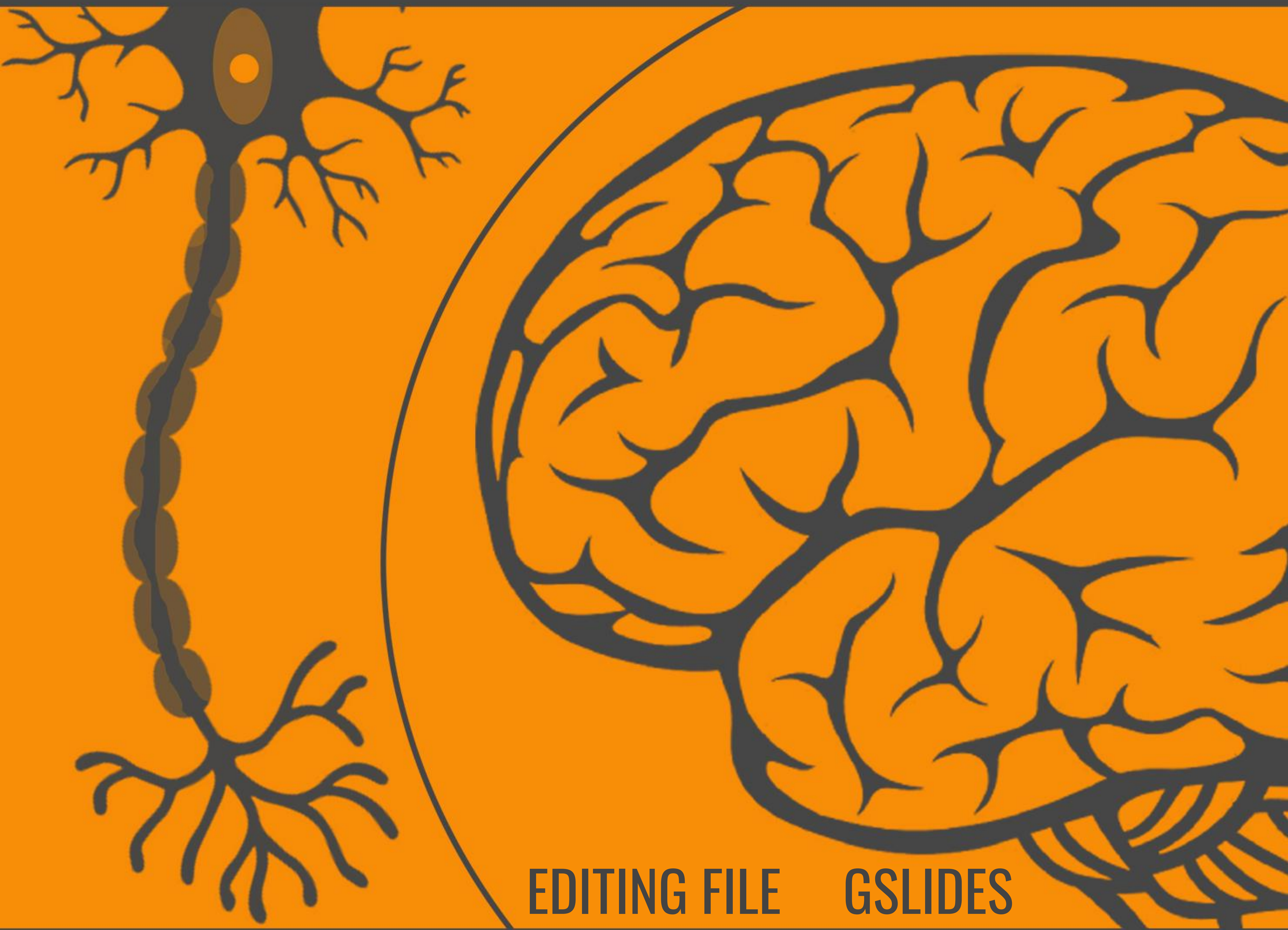


MEDICINE438's
CNS PHYSIOLOGY

LECTURE V: Stretch Reflex and Tendon Jerks



EDITING FILE GSLIDES

IMPORTANT | MALE SLIDES | EXTRA | FEMALE SLIDES | LECTURER'S NOTES

OBJECTIVES

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

STRETCH REFLEX

Stretch Reflex (also known as *myotatic reflex*):
It is a reflex contraction of muscle when it is moderately stretched.

- Monosynaptic Deep reflex (one sensory neuron synapse with one motor neuron)
- it has two components:
  - *Dynamic stretch reflex* (patellar-tendon or knee jerk reflex)
  - *Static stretch reflex* (muscle tone)

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

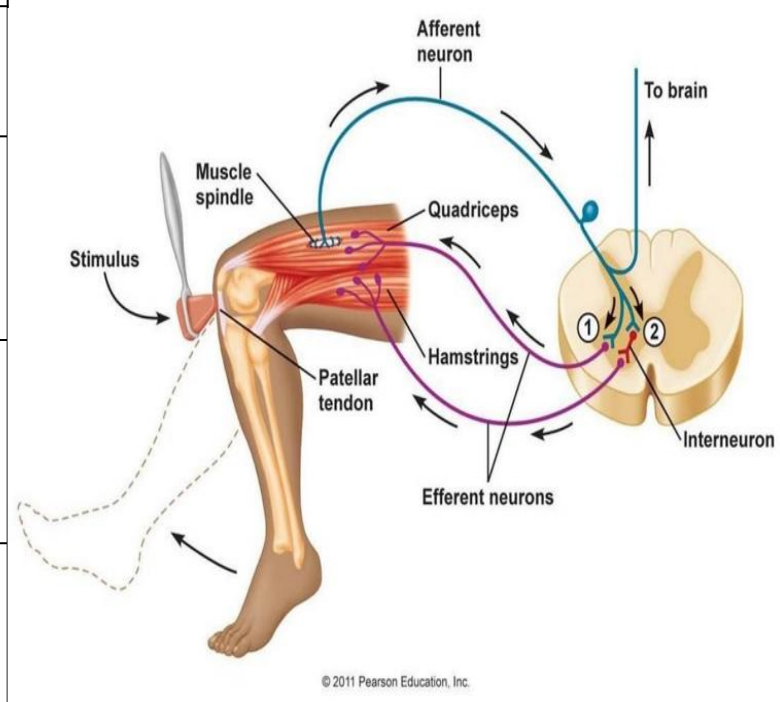


Figure 5-1

Pathway Of the Stretch Reflex

Sensory Receptor	Muscle spindles
Afferent fibers	Group Ia and group II afferents
Integrating center	Spinal cord (Anterior horn cell) • Alpha motor neurons synapse with the afferent sensory neurons in the spinal cord (secrete glutamate)[1]
Efferent fibers	1. alpha motor efferent arise from alpha motor neurons to supply extrafusal muscle fibers. 2. gamma efferent (from gamma motor neurons to supply intra-fusal muscle fibers inside muscle spindle)
Effector	Skeletal muscle

FOOTNOTES

1. Glutamate is released from presynaptic terminals in many sensory pathways, such as the stretch reflex, it is almost always excitatory in function.

BOX 5-1: GUYTON AND HALL

- Skeletal muscles are made of skeletal muscle fibers that extend throughout the length of the muscle, and are then connected to the bones by tendons, each fiber is made of numerous myofibrils which contain 3000 actin and 1500 myosin filaments for contraction, between those myofibrils is the cytoplasm, mitochondria and sarcoplasmic reticulum.
- Intrafusal fibers are mostly contractile at its peripheral ends only. Contraction of the peripheral parts of intrafusal fibers causes stretch of the non contracting central part of intrafusal fibers.

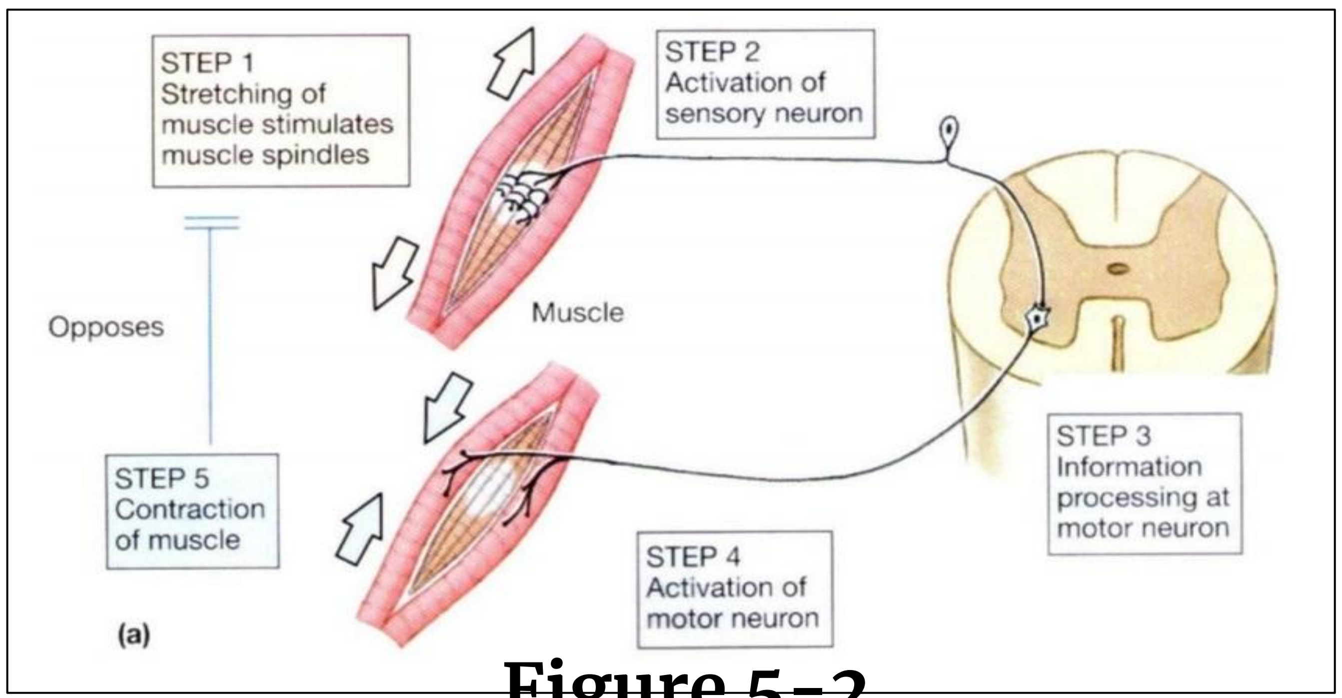


Figure 5-2

MUSCLE SENSORY RECEPTORS

Proprioceptors[1]: muscle spindles and golgi tendon organs

Proper control of muscle function requires:

1. Excitation of the muscle by spinal cord anterior motor neurons
2. Continuous feedback of sensory information from muscle to the spinal cord, indicating the length and tension of the muscle

STRETCH REFLEX RECEPTOR (MUSCLE SPINDLE)

Located inside the muscle and detects changes in muscle length

Structure

- consist of 3-12 small **intrafusal fibers** within a CT capsule.[2]
- each intrafusal fiber has:
  - Central non-contractile area (receptor)
  - Peripheral contractile area on each side of central zone, it has actin & myosin.

Types of intrafusal muscle fibers:

Nuclear bag fibers

- (2 per spindle)
- have a dilated central area filled with nuclei

Nuclear chain fibers

- (About 4 or more per spindle)
- Have nuclei which are arranged as a chain in the receptor area.

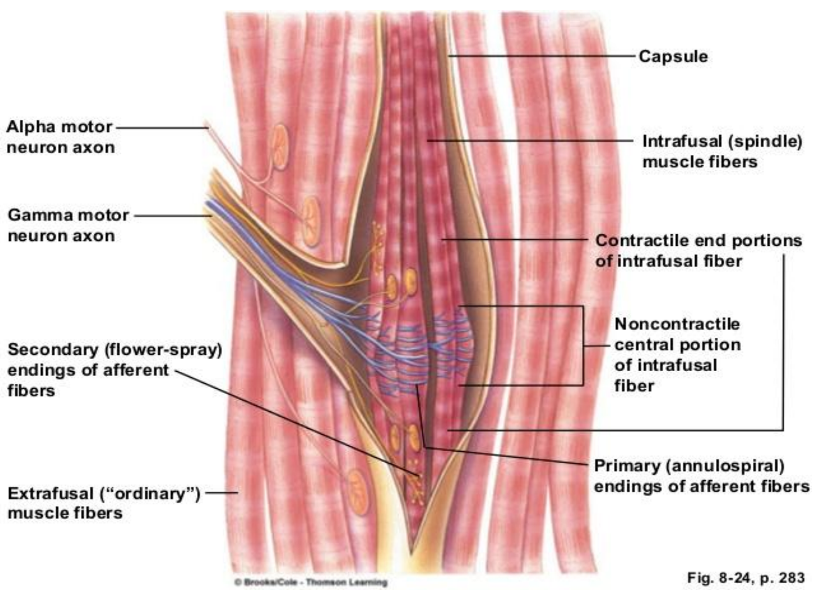
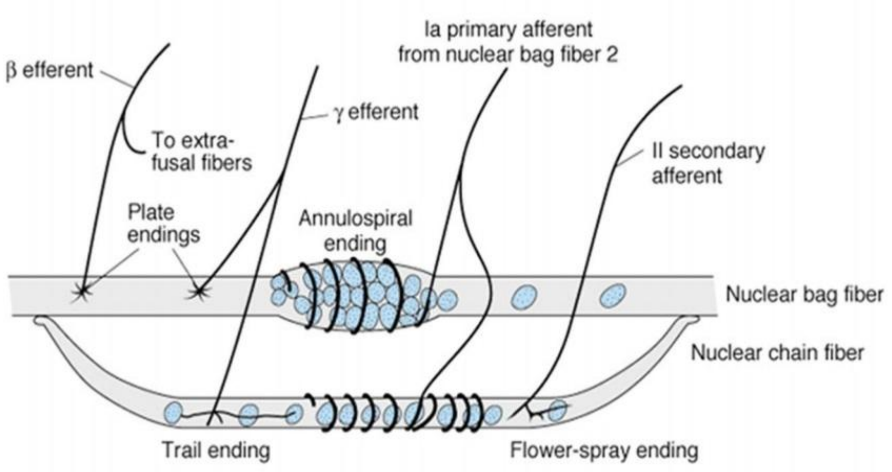


Figure 5-3



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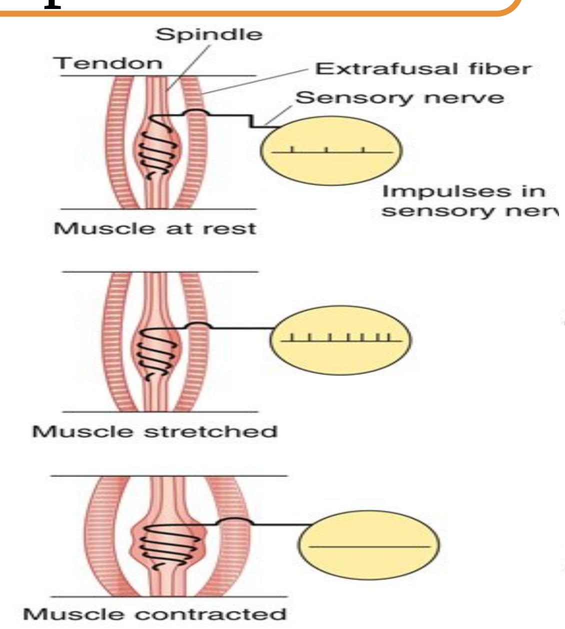


Figure 5-5

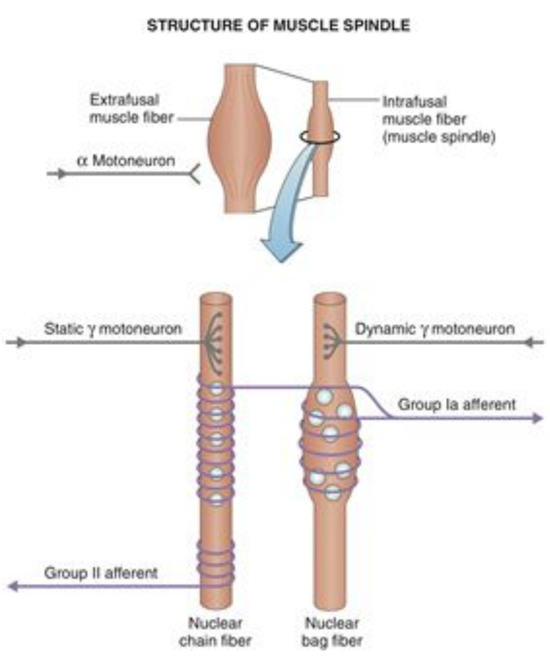


Figure 5-6

FOOTNOTES

1. Guyton & Hall: There are proprioceptive and exteroreceptive sensations, proprioceptive sensations are relayed by proprioceptors, a type of mechanoreceptors, it has to do with the physical state of the body including position sensations, tendon and muscle sensations pressure sensations and even an equilibrium sensation. Exteroceptive sensations are those from the surface of the body.
2. CT layer that contains collagen (a structural protein) and fibroblasts, which function to renew this collagen along with other functions

FUNCTIONS OF MUSCLE SPINDLE

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

BOX 5-2: GANONG'S

TABLE 4–1 Types of mammalian nerve fibers.

Fiber Type	Function	Fiber Diameter (μm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
Aα	Proprioception; somatic motor	12–20	70–120		
Aβ	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
Aγ	Motor to muscle spindles	3–6	15–30		
Aδ	Pain, temperature	2–5	12–30		
B	Preganglionic autonomic	< 3	3–15	1.2	1.2
C, Dorsal root	Pain, temperature	0.4–1.2	0.5–2	2	2
C, Sympathetic	Postganglionic sympathetic	0.3–1.3	0.7–2.3	2	2

Classification of mammalian nerve fibers according to velocity of conduction, and their respective functions.

TABLE 4–2 Numerical classification of sensory nerve fibers.

Number	Origin	Fiber Type
Ia	Muscle spindle, annulo-spiral ending	Aα
Ib	Golgi tendon organ	Aα
II	Muscle spindle, flower-spray ending; touch, pressure	Aβ
III	Pain and cold receptors; some touch receptors	Aδ
IV	Pain, temperature, and other receptors	C

More specific classification of sensory fibers according to velocity of conduction

INNERVATION OF THE MUSCLE SPINDLE

Sensory Afferent fibres

1. Primary (annulospiral) endings (Ia fibres)(refer to BOX 5-2)

- 17 micrometers diameter
- encircle receptor areas of **nuclear bag fibers mainly, but also nuclear chain fibres**
- Fast, transmits sensory signals to the spinal cord at the highest conduction velocity of 70 to 120 m/sec
- Discharge most rapidly if the muscle is suddenly stretched (dynamic response) & less rapidly (or not) during sustained stretch (static response)
- Measure the rate & or velocity of change in muscle length of nuclear bag fibres

2. Secondary (flower-spray) (Group II)

- 8 micrometers in diameter
- innervate the receptor area of the nuclear chain fibres **ONLY**
- Discharge at an increased rate throughout the period of muscle stretch, (sustained stretch) (measure mainly muscle length)
- directly proportional to the degree of stretch.

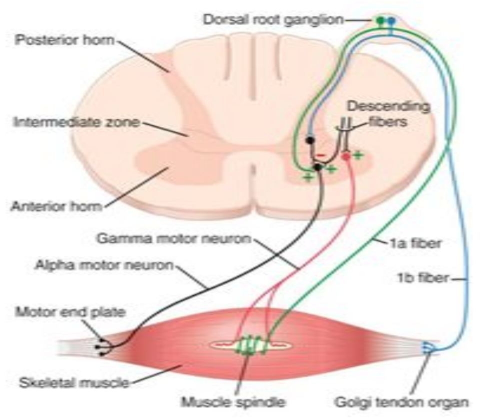


Figure 5-7

Motor Efferent fibres

Gamma (γ) efferent endings terminate on 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)

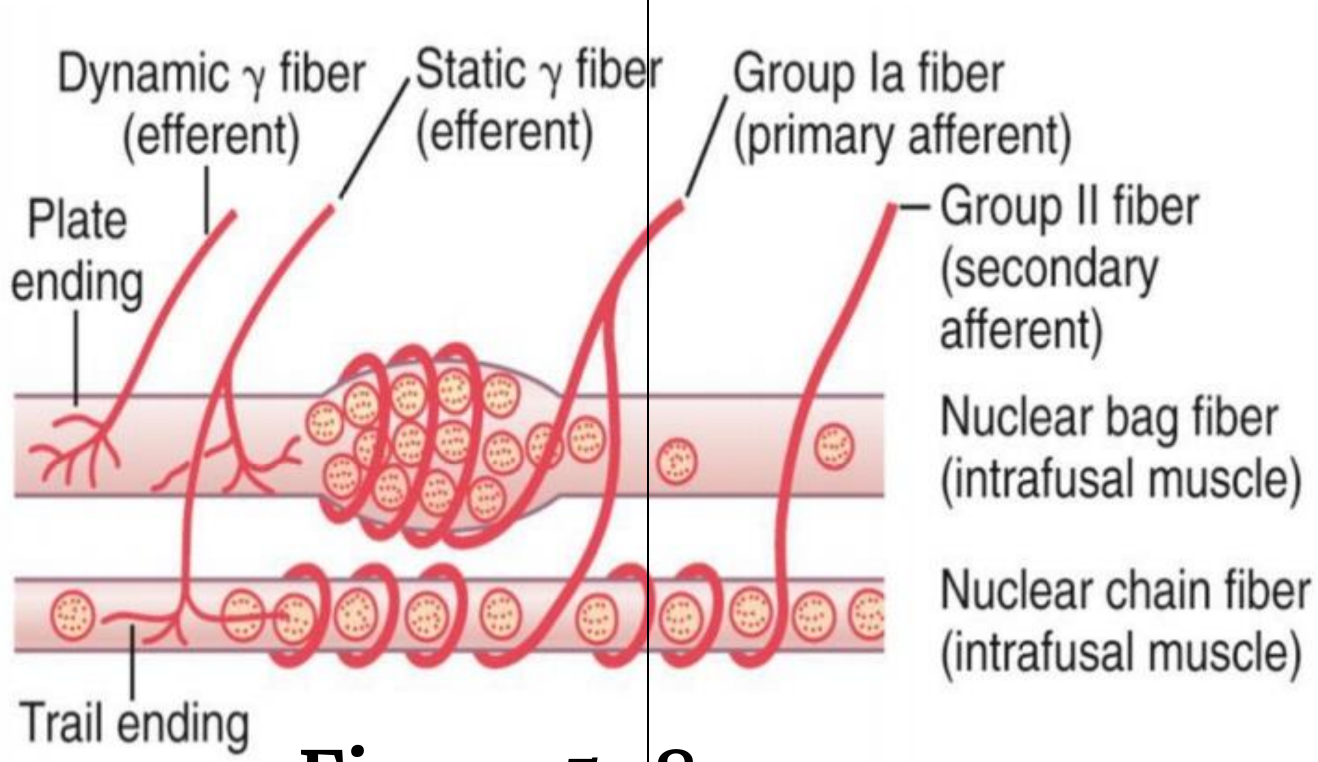


Figure 5-8

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 function of the γ motoneurons (either static or dynamic) is to regulate the sensitivity of the intrafusal muscle fibres. How?
- ↑ γ- motor neurons cause contraction of the peripheral parts of intrafusal fibers → stretch of central parts of muscle spindle → ↑ the sensitivity of the muscle spindle to stretch i.e. muscle spindle needs a small amount of passive stretch to be stimulated

Types of Stretch Reflexes

Dynamic stretch reflex

- *Sudden* (phasic) ***rapid stretch*** of a muscle causing stimulation of **nuclear bag fibers** which respond to velocity of change of receptor length. It causes synchronous strong burst of excitatory discharges in annulospiral afferents to the ***alpha motoneuron***.

This causes the latter to send strong motor excitatory impulses to extrafusal fibers, Causing ***sudden***, ***jerky "brief" muscle contraction***. (jerky movement)

As the muscle shortens, the spindle becomes lax and ceases to discharge

→ no more stimulation of alpha motor neuron → no more excitatory impulses from alpha motor neuron to the extrafusal fibers → ***muscle relaxes***

- This is the basis of ***Tendon Jerks "Dynamic stretch reflexes."***
- ***Role of Dynamic gamma efferent (plate endings):***
  - ***Tapping the tendon, stretch the muscle, so it contracts and shorten, nuclear bag fibres relax during muscle contraction, its sensitivity to stretch decreases.***
  - ***Plate gamma endings which end mainly on the nuclear bag fibres periphery, enhances the dynamic response***

Static stretch reflex

- ***Maintained*** "Tonic" stretch of muscle.
- impulses from ***Nuclear chain fibers*** travel through spindle afferent fibers (mainly along Flower Spray "secondary" ending) to ***alpha motor neuron***, stimulating it to produce muscle contraction.
- Causing ***sustained*** "continuous"***contraction*** of the muscle as long as it is stretched.
- The Static Stretch Reflex is the basis of ***muscle tone***, which is defined clinically as **resistance to muscle stretch.**
- **Static gamma efferent (trail endings): enhances the static response**

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

BOX 5-3: GUYTON AND HALL

Stretch reflexes are crucially important for the control of skeletal **muscle tone.** The term muscle tone refers to the degree of contraction of a muscle or, in other words, the proportion of motor units that are active at any one time. Muscle tone is reflected in the compliance of the muscle on palpation and its resistance to passive stretch/movement. Thus, a muscle with high tone feels firm, or rigid, and resists passive stretch, while a muscle with low tone is soft, or flaccid, and offers little resistance to passive stretch. Since stretch reflexes operate to maintain muscles at a constant length in opposition to imposed stretch, they are important in the control of body posture. By their action, activity is maintained in neck, trunk and lower limb extensor muscles (antigravity muscles) that support an upright body posture against the force of gravity and are stretched when these body parts become fixed.

MUSCLE TONE

- Muscle tone is defined as a state of ***continuous partial*** "mild "***contraction*** of skeletal muscle during **rest.**
- it is present in all skeletal muscle but specially in the ***antigravity muscles:***
  - extensors of LL, back, and neck
  - Flexors of UL
  - Muscles 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.***

Functions of Muscle tone:

- Postural control.
- Help in heat production and maintain of body temperature. [1]
- It helps both the venous return & lymph flow.[2]
- keeps viscera in position.

Damping or smoothing function of Stretch Reflexes

- It Is the stretch reflex ability to prevent oscillation or jerkiness of body movements.
- Motor Signals from the motor area are transmitted to the muscle in an ***unsmooth form***, with increasing or decreasing intensity for few milliseconds.
- This causes ***irregularities*** or ***oscillations*** of movements.
- The signals discharged from the ***muscle spindles*** cause ***partial activity*** of αMNs of the muscle.
- the **motor signals** find αMNs in state of ***partial activity***, so they cause continuous activation of them which will lead to ***smooth muscle contraction.***

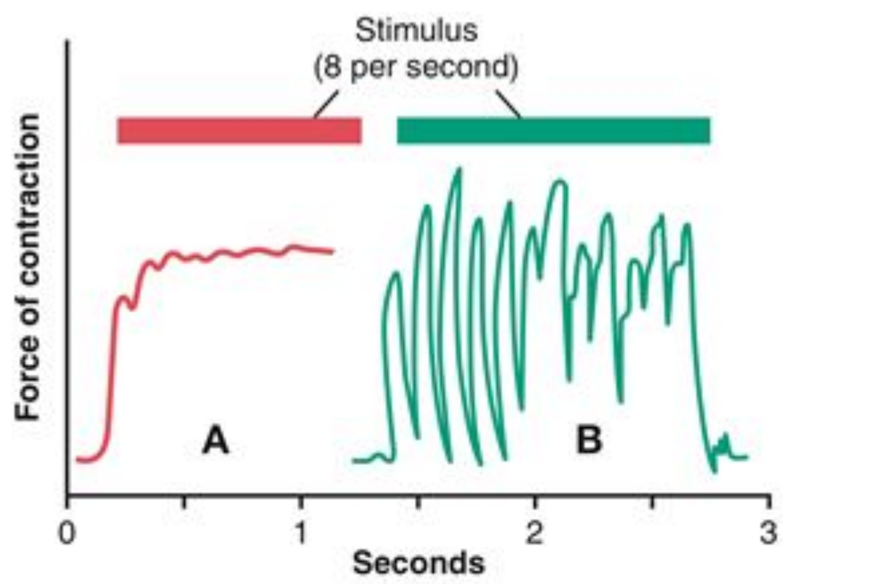


Figure 5-9. Muscle contraction caused by a spinal cord signal under two conditions: ***curve A,*** in a normal muscle, and ***curve B,*** in a muscle whose muscle spindles were denervated by section of the posterior roots of the cord 82 days previously. Note the smoothing effect of the muscle spindle reflex in ***curve A.***

CONSCIOUS AWARENESS

- Axon collaterals of the muscle spindle sensory neuron also relay nerve impulses ***to the brain*** over specific ***ascending pathways,*** to allow conscious awareness that the reflex has occurred.
- In this way, the brain receives input about the ***state of stretch or contraction*** of skeletal muscles to coordinate.

How Muscle Stretch Is detected?

- stretching of the muscle will also stretches the spindle.
- Sensory nerve impulses will be sent to the spinal cord
  - the number of impulses sent are proportional to the stretched length of the muscle.

FOOTNOTES

1. Muscle tone is a state of partial contraction, contraction requires energy in form of ATP, formation of ATP from oxidation of molecules also releases heat, therefore muscle tone can help in maintaining temperature.
2. Venous return through skeletal muscle pump, mostly the calf muscle pump which squeezes the veins in the lower limb to push the blood towards the right atrium, veins contain valves, therefore blood only has the choice of going forward in normal conditions.

How Are Muscle Spindles Stimulated?

1. Passive stretch of the whole muscle

It causes stretch of the muscle spindle which lies parallel to muscle fibers.

2. Activation of the γ-MNs

- by supraspinal centers or reflexively
- it causes contraction of the peripheral part of the intrafusal fibers → stretch of receptor area

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
- Significance of coactivation?
  - Regulate the sensitivity of the spindle by keeping its length constant
  - Oppose sudden changes in muscle length

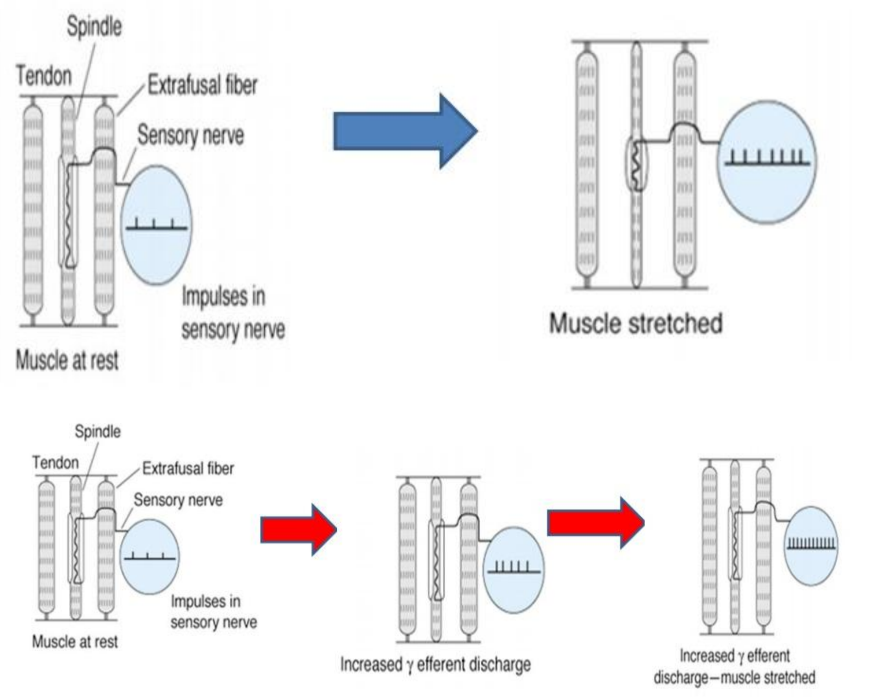


Figure 5-10

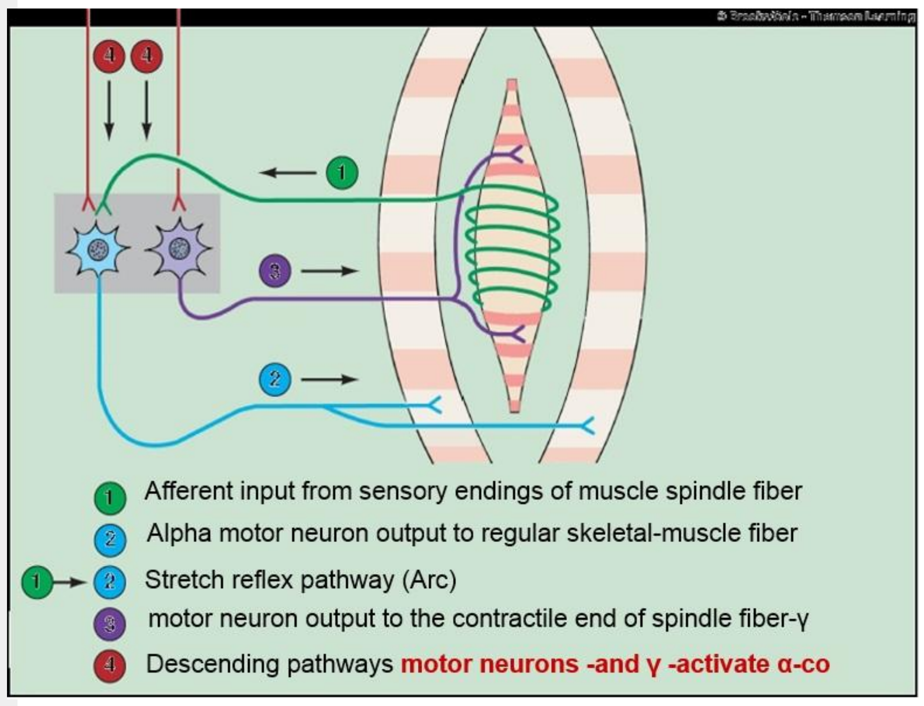


Figure 5-11

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

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

1. **alpha motor neurons (70%)**
   - send impulses to extrafusal ordinary muscle fibres causing muscle contraction.

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

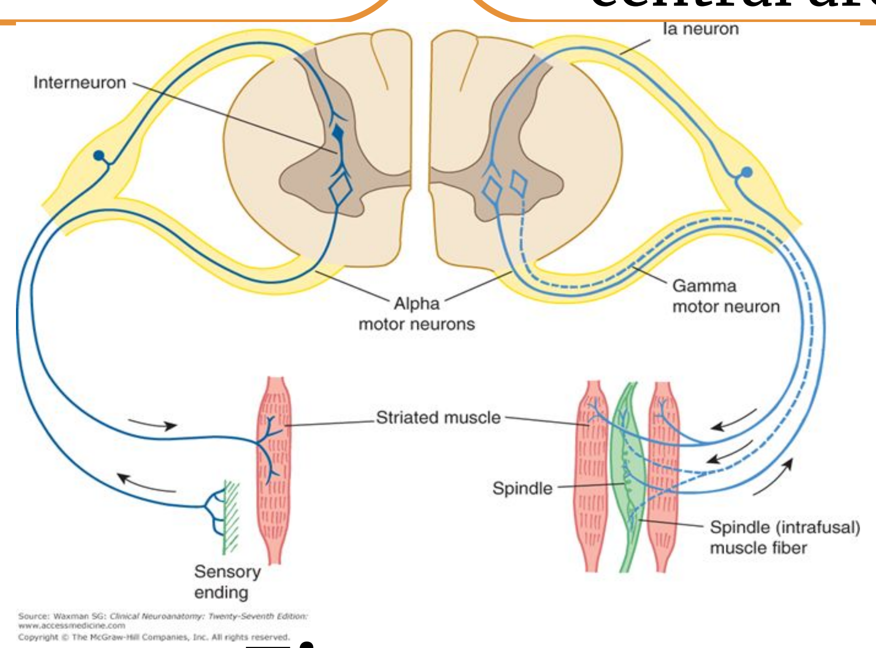


Figure 5-12

BOX 5-4: GANONG'S

It should be noted that a reflex like the stretch reflex is monosynaptic, that is, the sensory signal causes direct stimulation for contraction of a certain muscle through AHCs. However, a collateral from the sensory axon must synapse with an interneuron to inhibit antagonist muscle. Hence, the reflex is monosynaptic, but the whole process is bisynaptic.

Reciprocal inhibition and Reciprocal innervation

BOX 5-5: GUYTON AND HALL

- ❖ The excitation of one group of muscles is often associated with inhibition of another group. For instance, when a stretch reflex excites one muscle, it often simultaneously inhibits the antagonist muscles, which is the phenomenon of ***Reciprocal inhibition.***
- ❖ The neuronal circuit that causes this reciprocal relation is called ***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 reach the spinal cord to cause:
  1. stimulate the motor neurons of the stimulated muscle to contract (by ***glutamate***)
  2. send collaterals to the inhibitory interneurons synapse on the AHCs of the antagonistic muscle & inhibit them (by ***GABA***)
- ◆ Reciprocal innervation prevents conflict between opposing muscles and is vital in coordinating body movements.

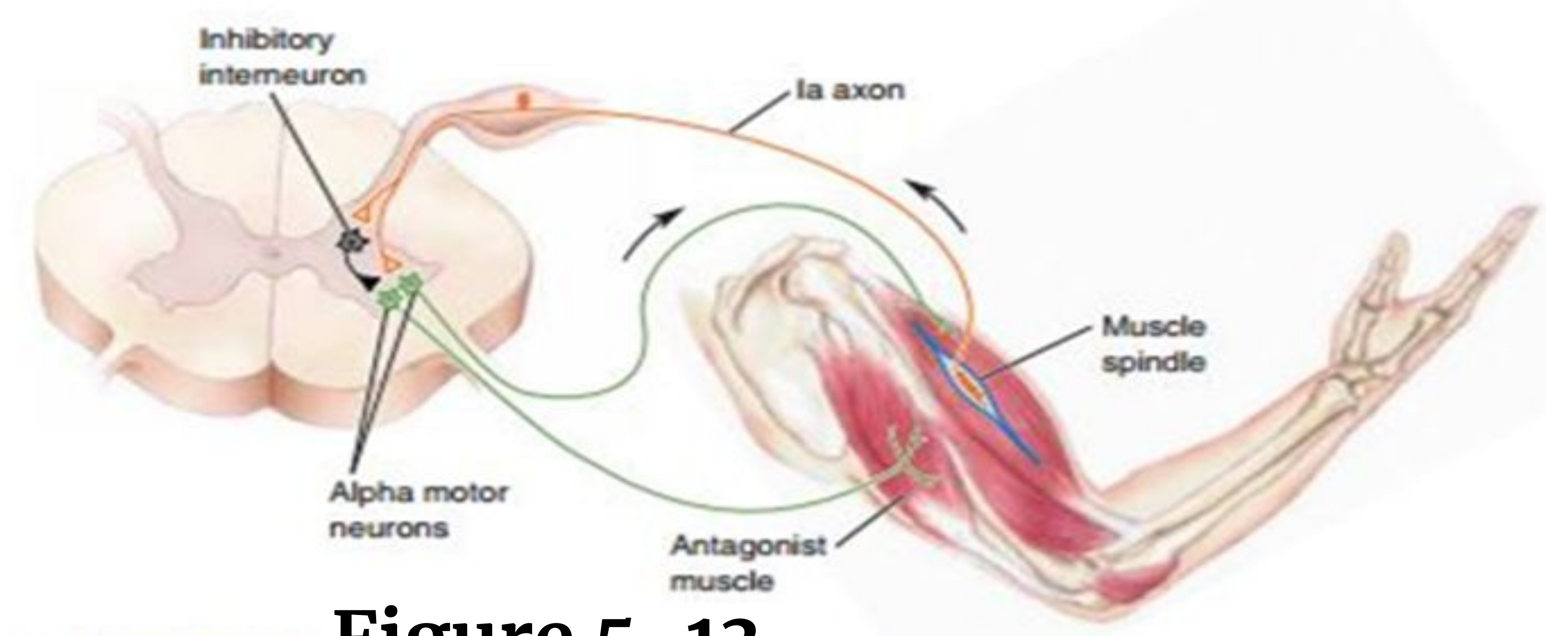


Figure 5-13

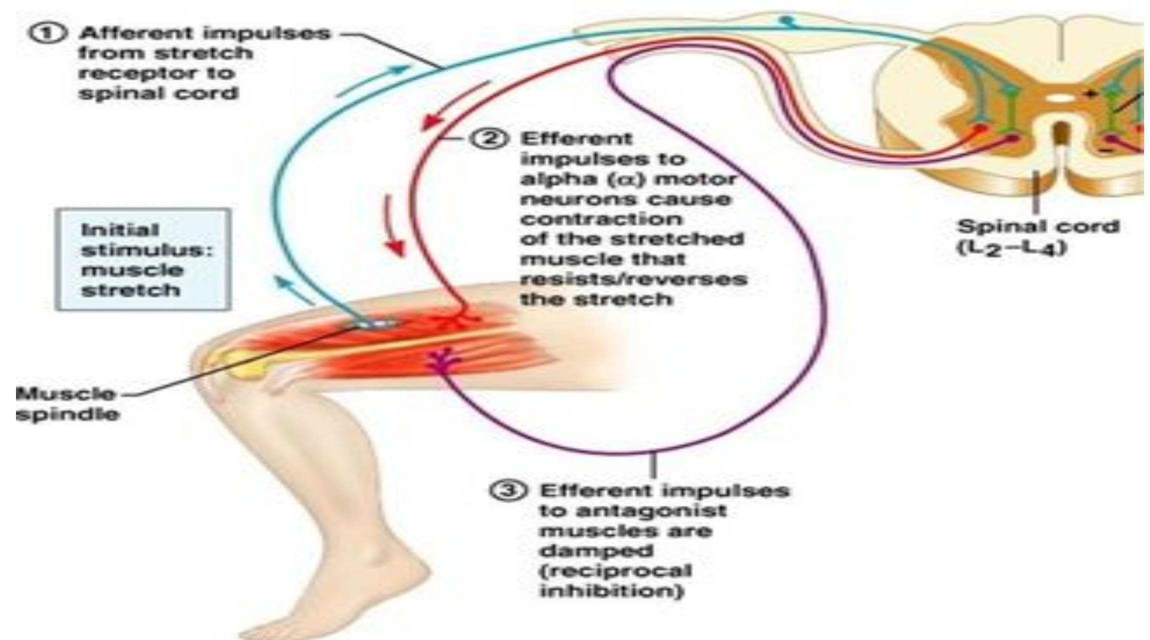


Figure 5-14

Clinical Significance of Tendon Reflexes

- ❖ They are carried out clinically to ***test the integrity of reflex arc.***
- ◆ **Areflexia or hypo-reflexia (hypo-tonia)** indicates that the reflex arc is interrupted at one of its components by:
- ❏ Lesions of lower motor neuron, e.g. poliomyelitis
- ❏ Peripheral nerve lesions e.g. peripheral neuropathy, Diabetic neuropathy
- ❏ Neuromuscular junction disorder e.g. myasthenia gravis
- ❏ Primary muscle disorder e.g. myopathy
- ◆ **Hyper-reflexia (hyper-tonia):** exaggerated deep reflexes.
- ❏ Upper motor neuron lesion.
- ❏ Anxiety

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.

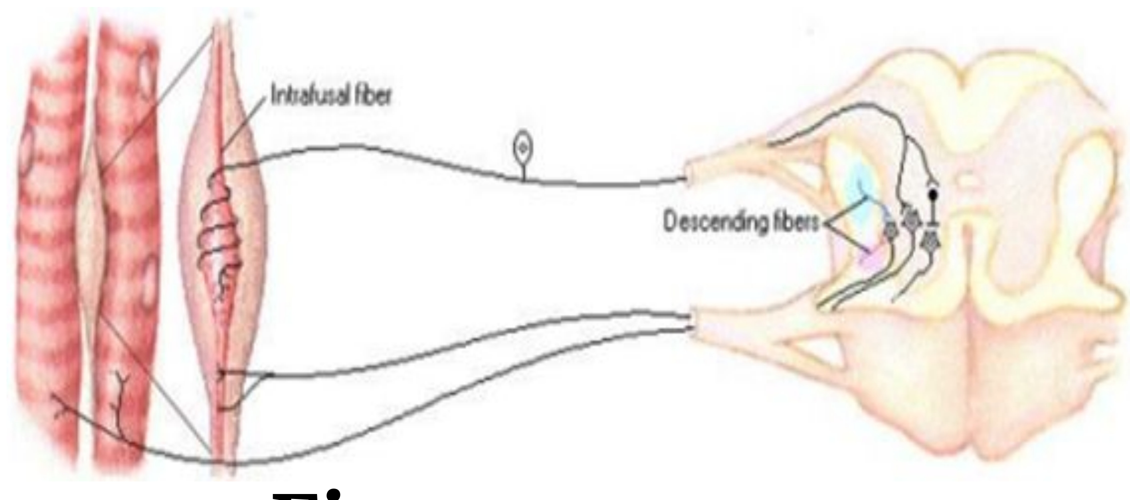


Figure 5-15

Factors that influence stretch reflex
“all act on gamma motor neurons”

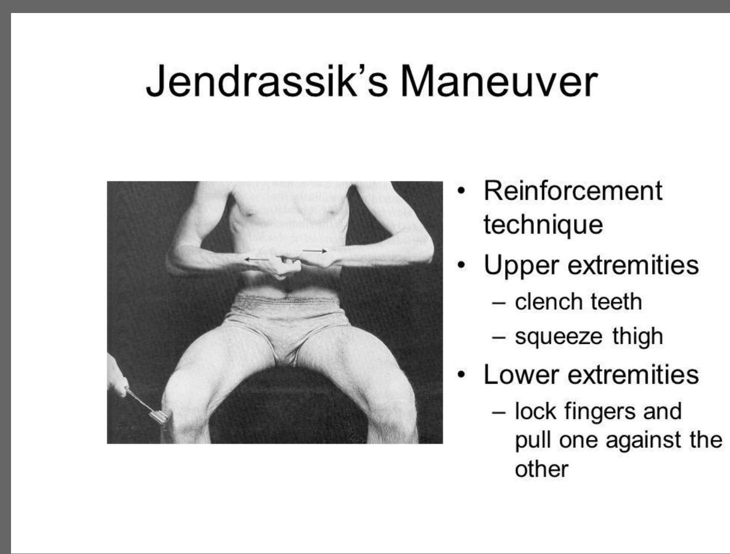
Facilitation	Inhibition
Supraspinal: 1. ***Cortical*** (Primary motor area 4) 2. ***Brainstem mechanisms***: • Vestibular nucleus • Pontine Reticular Formation 3. ***Neocerebellum*** “Cortex”	Supraspinal: 1. ***Cortical*** (motor area 6) 2. ***Extrapyramidal & Brainstem mechanisms***: • Basal ganglia • Red Nucleus • Medullary Reticular formation 3. ***Paleocerebellum*** “Cortex”
❖ Spinal mechanisms: • Noxious painful stimuli ❖ Anxiety ❖ Jendrassik maneuver	❖ Spinal mechanisms: • Excessive muscle stretch (stimulation of golgi tendon organ) • Muscle contraction

BOX 5-6: CLINICAL RELEVANCE

JENDRASSIK MANEUVER

It is well-known that trying to pull the hands apart when flexed fingers are hooked together facilitates the knee jerk reflex, this is called Jendrassik maneuver.

- This is because as the motor cortical centers recruit upper motor neurons to excite the lower motor neurons that excite the flexors of fingers of distal limbs (therefore lateral corticospinal tract), the lower motor neurons become highly excited from the flood of upper motor neurons, therefore when the patellar tendon is hit with a hammer to cause a stretch reflex, the response becomes much faster due to the overflow of upper motor neurons that excite extra lower motor neurons.



INHIBITORY SUPRASPINAL CENTERS TO GAMMA MOTOR NEURONS

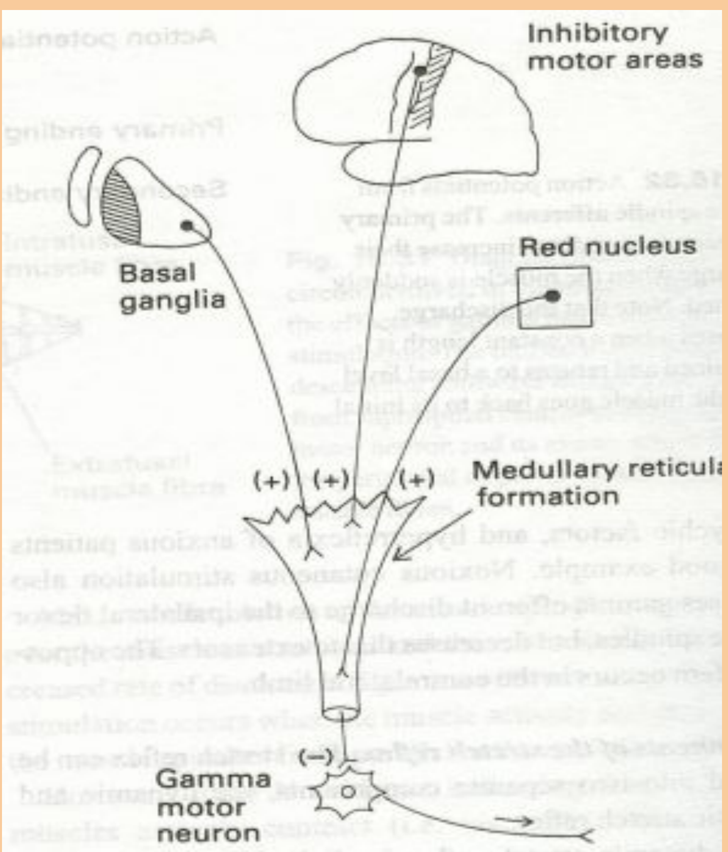


Figure 5-16

FACILITATORY SUPRASPINAL CENTERS TO GAMMA MOTOR NEURONS

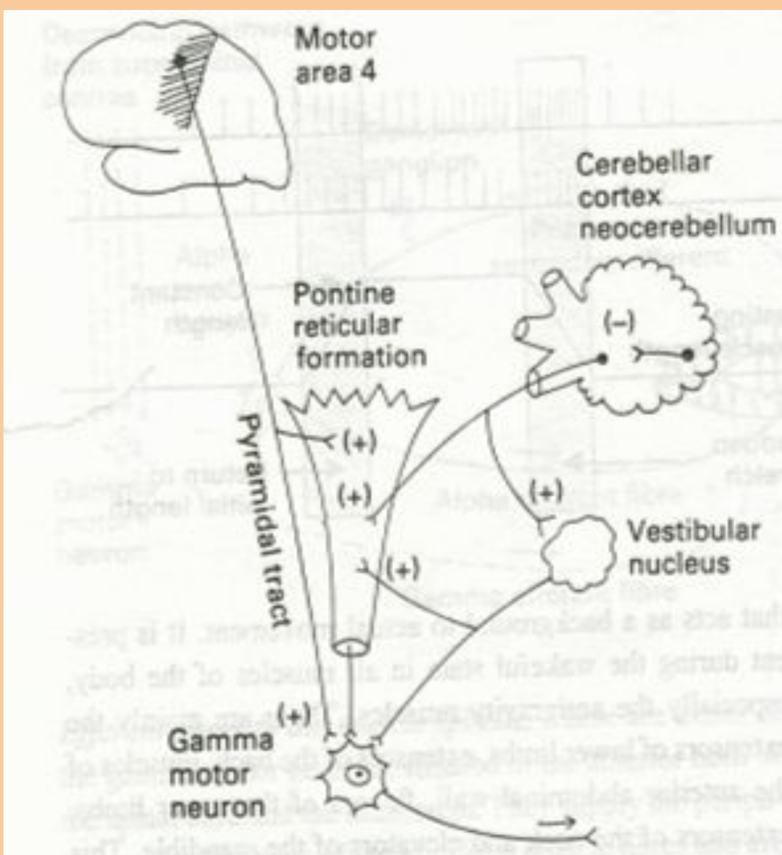


Figure 5-17

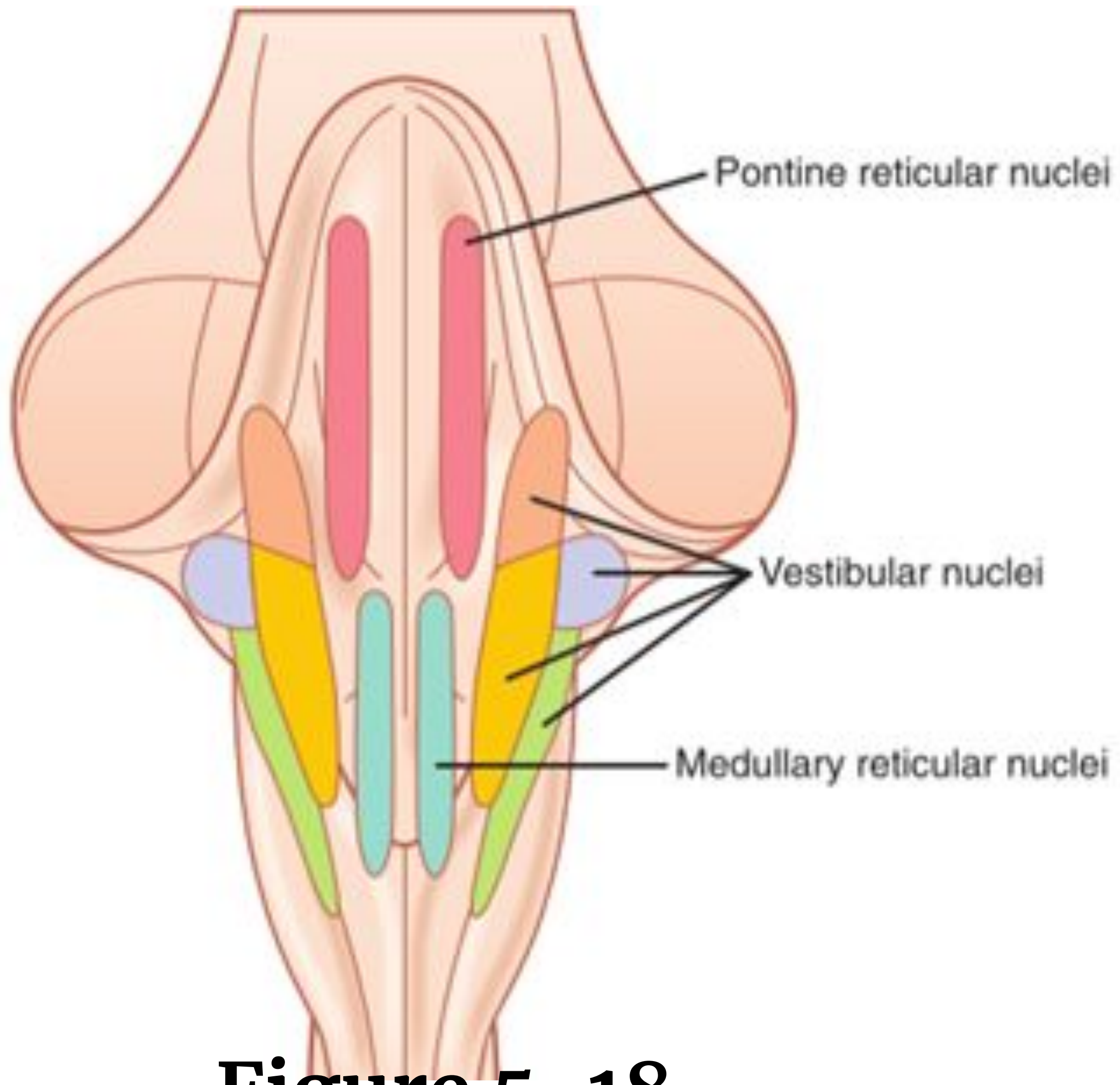


Figure 5-18

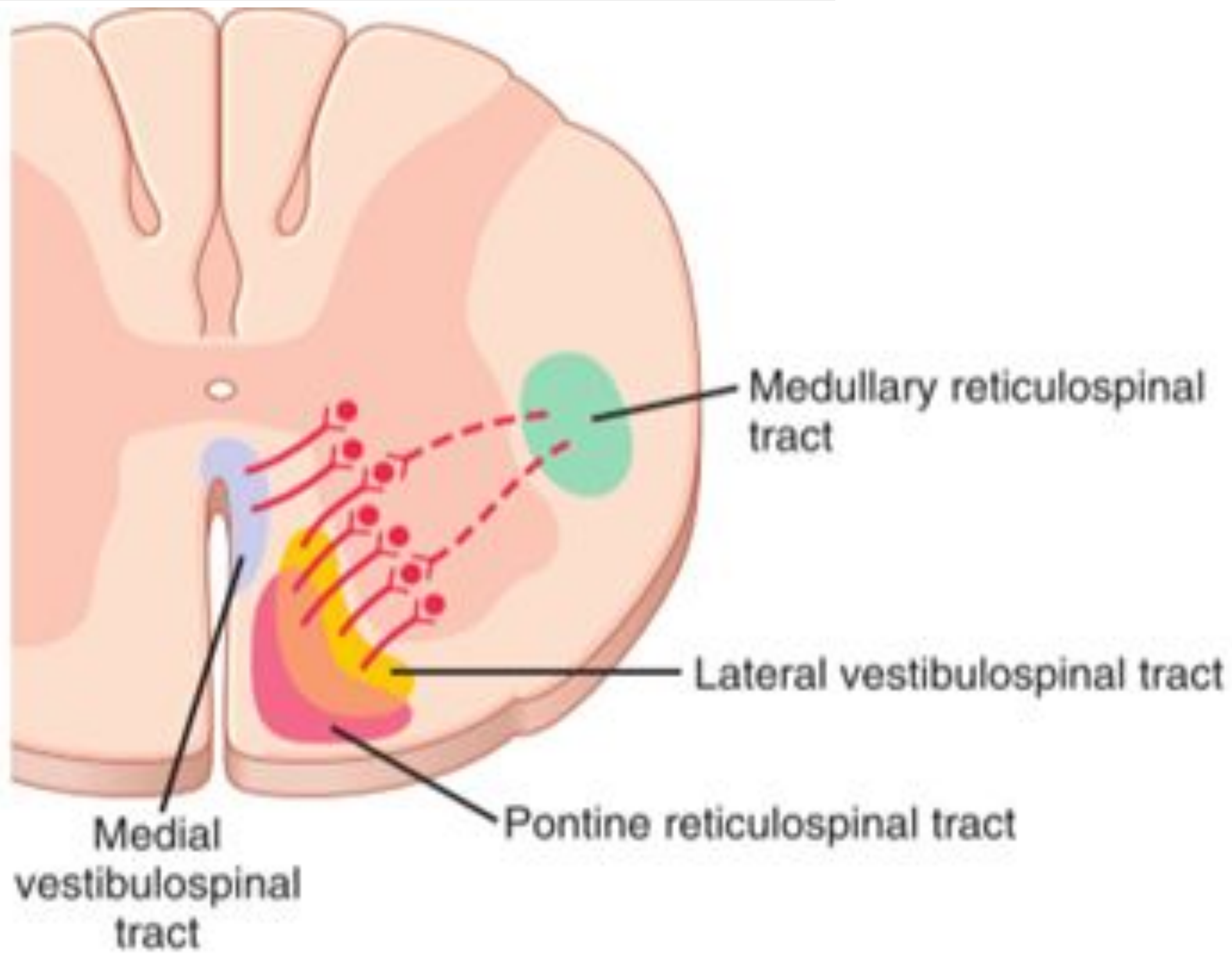


Figure 5-19

Inverse Stretch Reflex (Golgi Tendon Reflex)

- It is a ***deep*** and ***polysynaptic*** reflex in which there is a ***reflex relaxation*** (or lengthening) caused by ***excessive tension*** in the muscle (by passive over-stretch of tendon or severe active muscle contraction)
- Opposite response to stretch reflex

Sensory receptors	*Golgi tendon organs* (3-25)
Clinical test stimulus	increased tension by large force on tendon (pull on muscle when rested)
Function	Protect muscle from rupture & tendon from avulsion and tear

Golgi tendon organs

- They are present in tendons and encapsulated sensory receptors through which muscle tendon fibers pass.
- 6-20 elastic fibers
- About 10 to 15 muscle fibers are usually connected to each Golgi tendon organ
- they transmit information about tendon tension or rate of change of tension

Stimulus:	• passive overstretch or • severe contraction
Innervations:	Type Ib afferent fibres • fast, large and rapidly conducting fibers (16 micrometers in diameter)
Center (spinal cord)	◆ inhibitory interneurons (secrete **Glycine**) → inhibit the α-MNs supplying the same muscle ◆ excitatory interneurons→ excite the α-MNs supplying the antagonistic muscle
Response:	◆ Relaxation of the same muscle ◆ Relaxes synergistic muscles ◆ Contraction of antagonistic group of muscles.

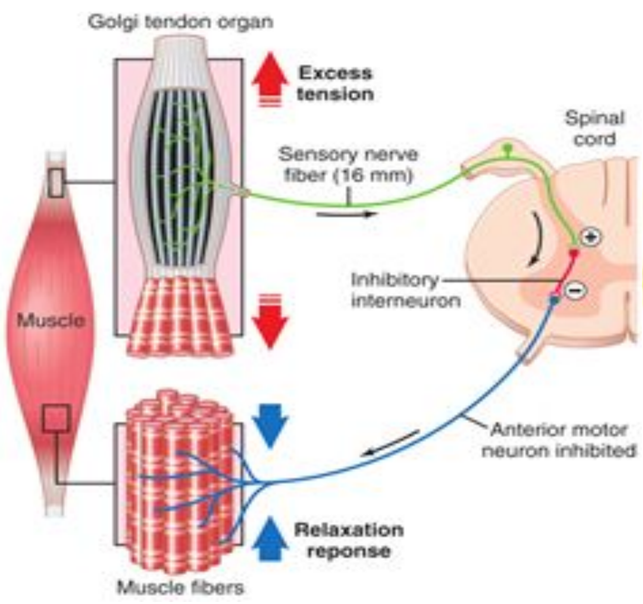


Figure 5-20

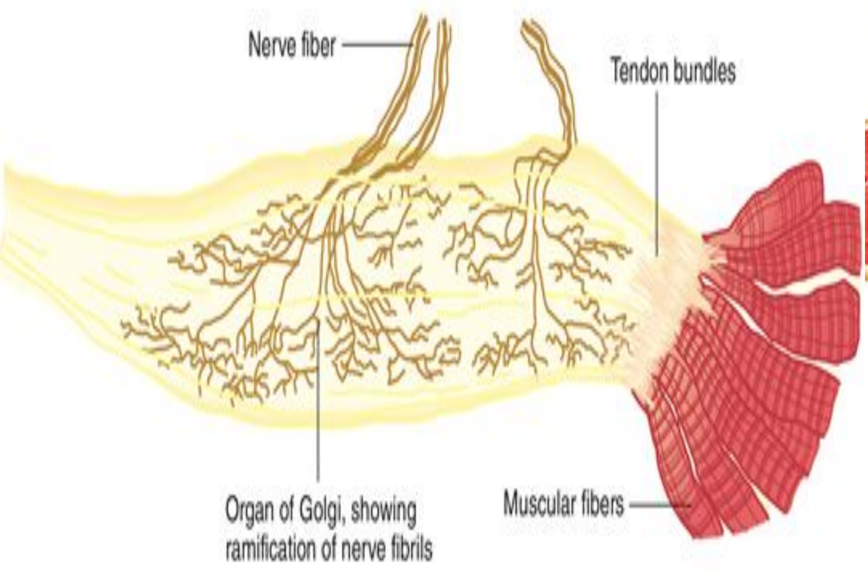


Figure 5-21

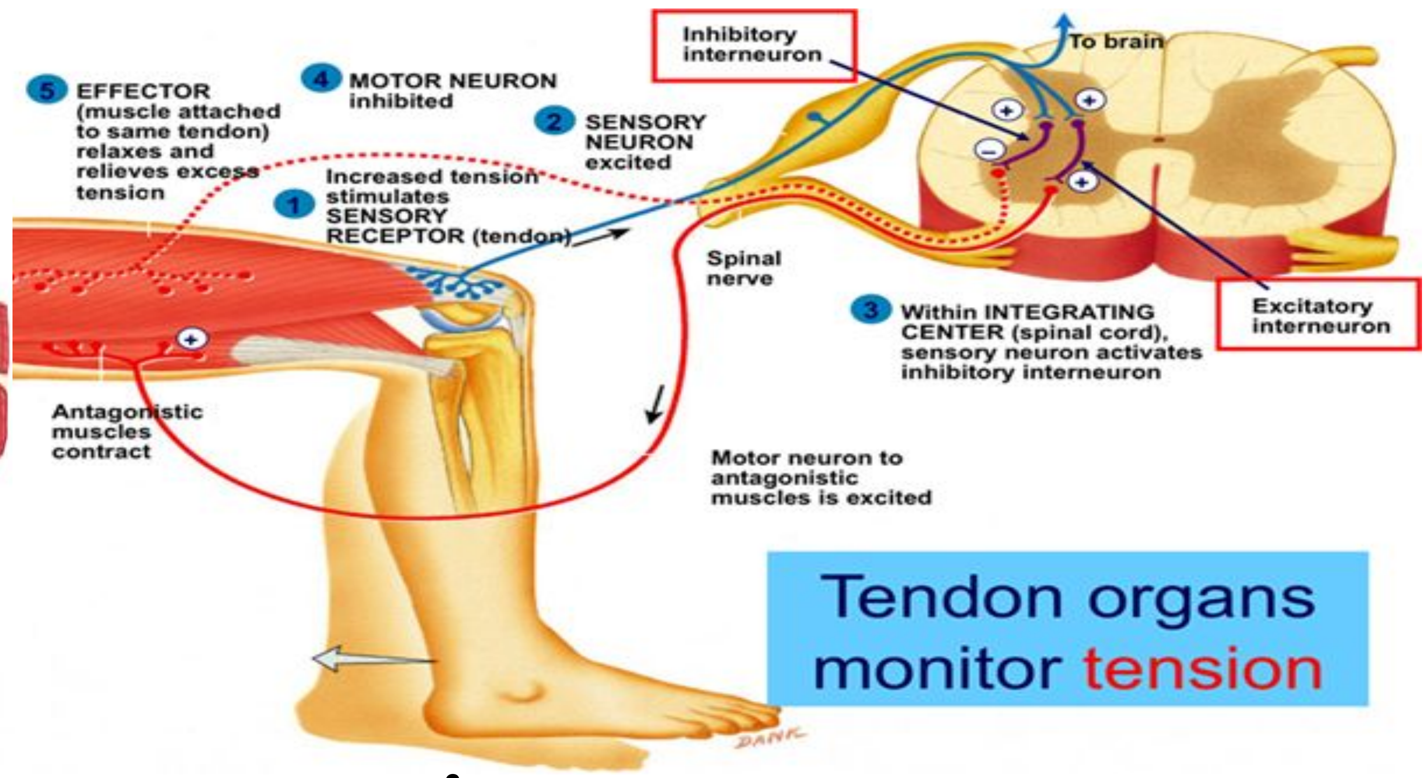


Figure 5-22

Comparison Between Stretch & Inverse Reflexes

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

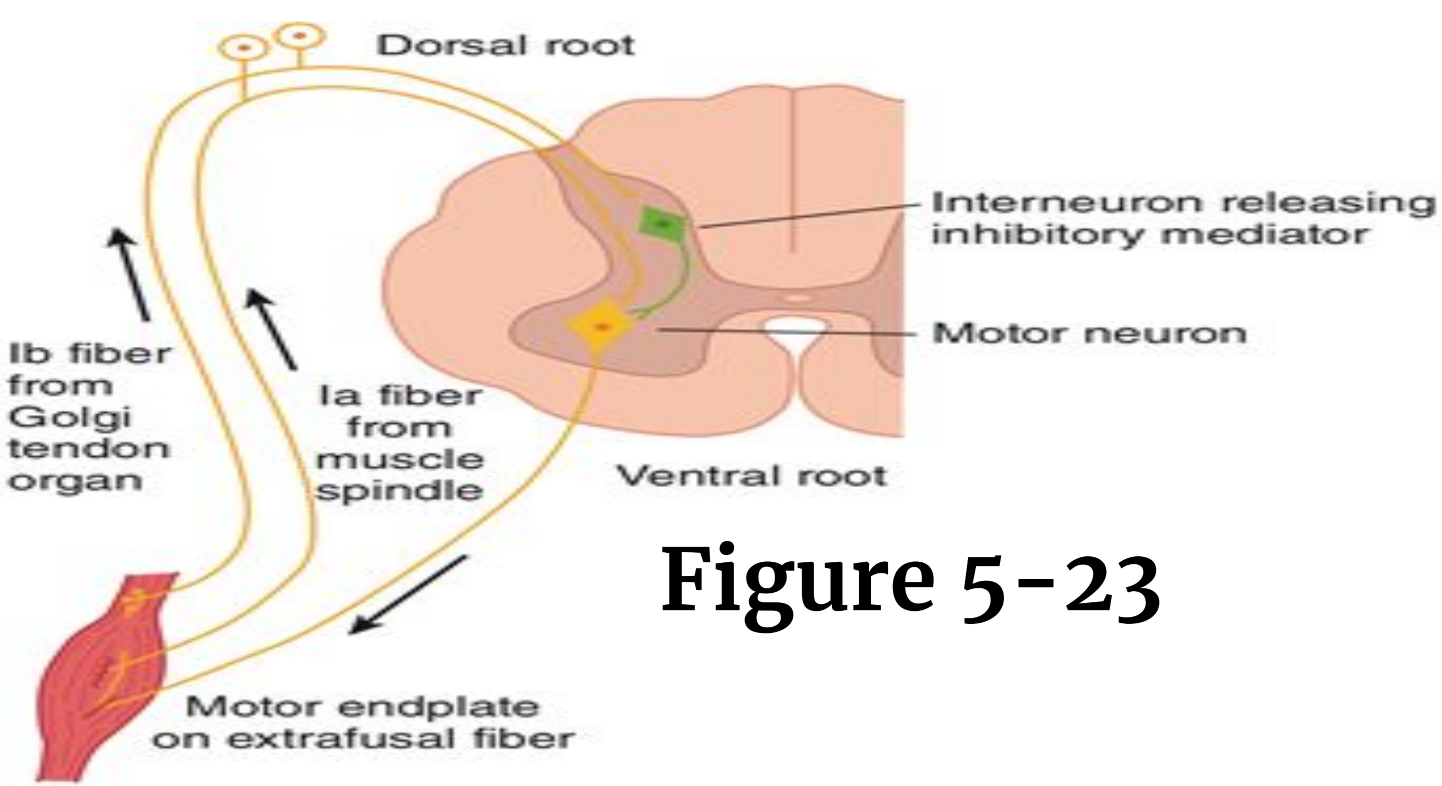


Figure 5-23

QUIZ

MEDICINE438's CNSPHYSIOLOGY

1. A strong rapid stretch of a muscle will cause stimulation of which of the following?
A) Nuclear chain fibers
B) Nuclear bag fibers
C) Trail endings

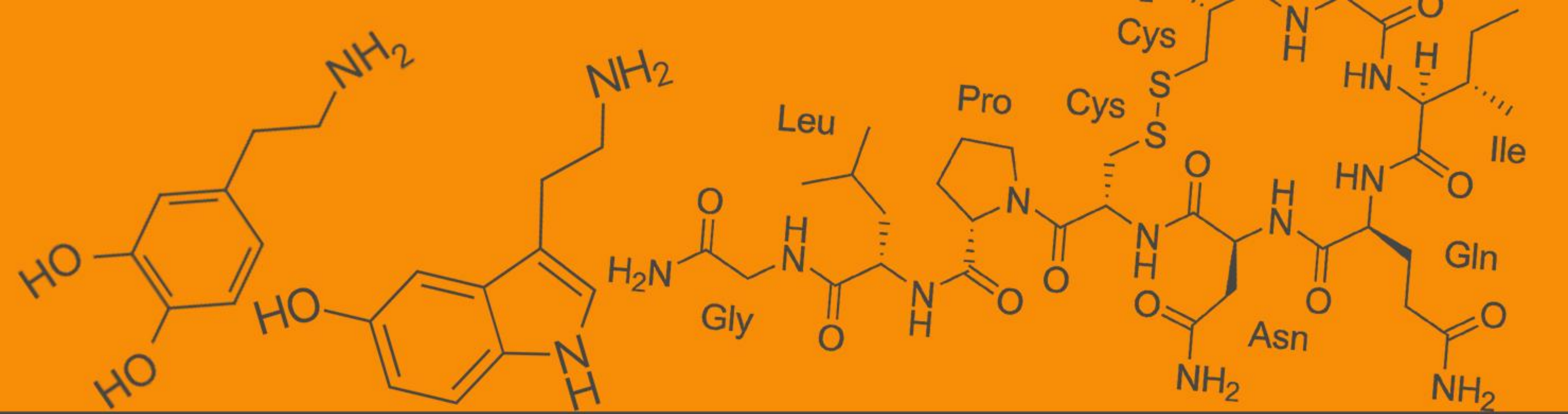
2. Which of the following encircle receptor areas of both nuclear bag and nuclear chain fibers?
A) Primary endings
B) Secondary endings
C) Plate ending

3. Relaxation in response to strong stretch is called?
A) Stretch reflex
B) Withdrawal reflex
C) Inverse stretch reflex

4. Which of the following is considered as an inhibitory center to gamma motor neurons?
A) Motor area 4
B) Red nucleus
C) Pontine reticular formation

5. The afferent fibers for inverse stretch reflex are?
A) Type IA fibers
B) Type II fibers
C) Type Ib fibers

ANSWER KEY: B, A, C, B, C



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- Ganong's Review of Medical Physiology