



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

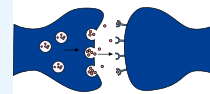


# Motor Function of the Spinal Cord

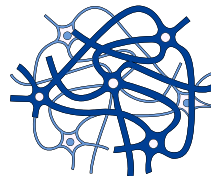
FINAL | Lecture 5

﴿ إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ مَا مِنْ دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا إِنَّ رَبِّي عَلَى صِرَاطٍ مُسْتَقِيمٍ ﴾

**Written by:** Sadeel Al-hawawsheh  
Heba Suliman



**Reviewed by:** Salwa Alawi



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# Motor system-Motor Functions of the Spinal Cord-

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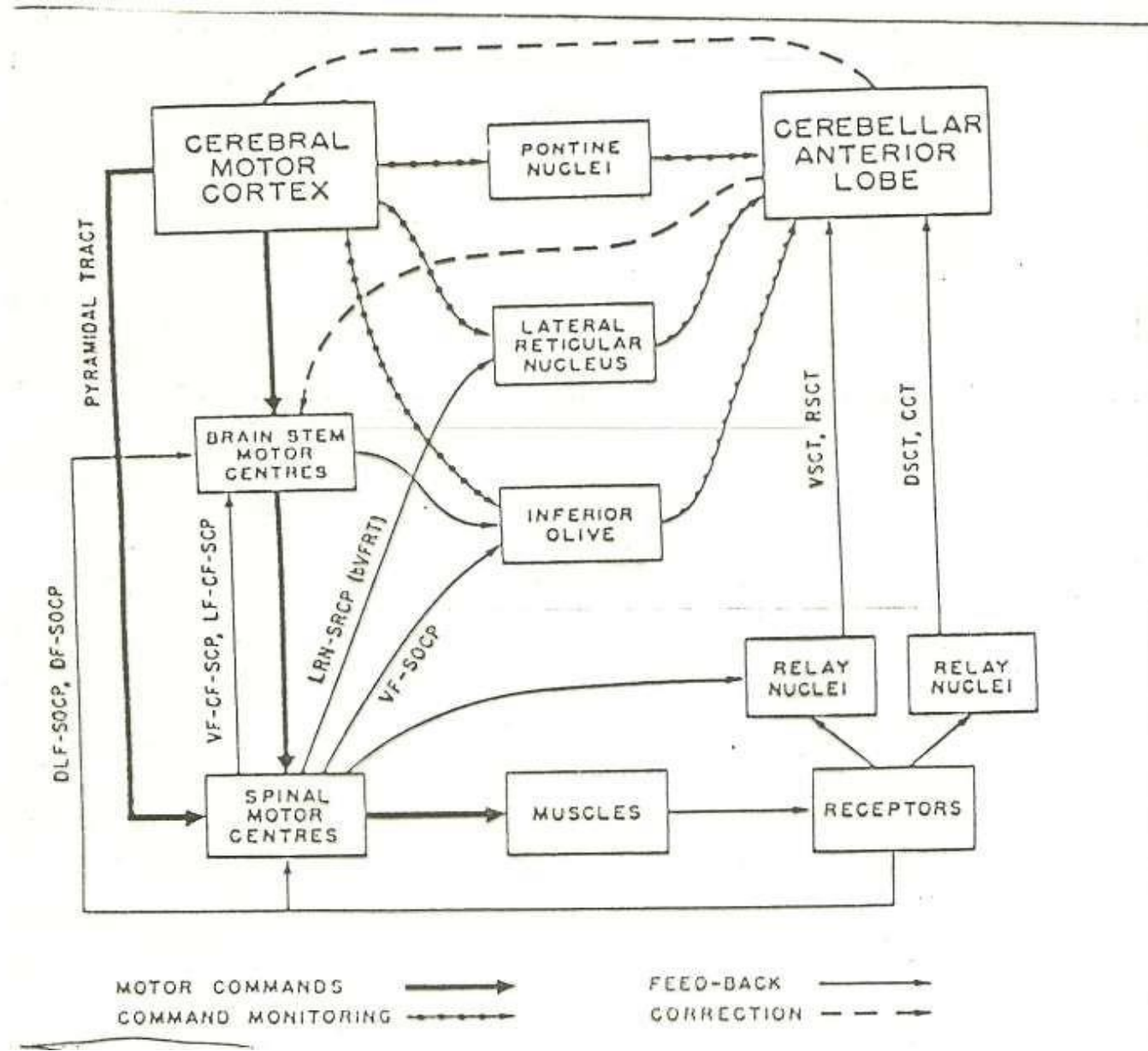
Faisal I. Mohammed, MD, PhD

This lecture may seem a bit long, but with focus it will be clear, Insha'Allah. Say **بِسْمِ اللّٰهِ** and let's get started.

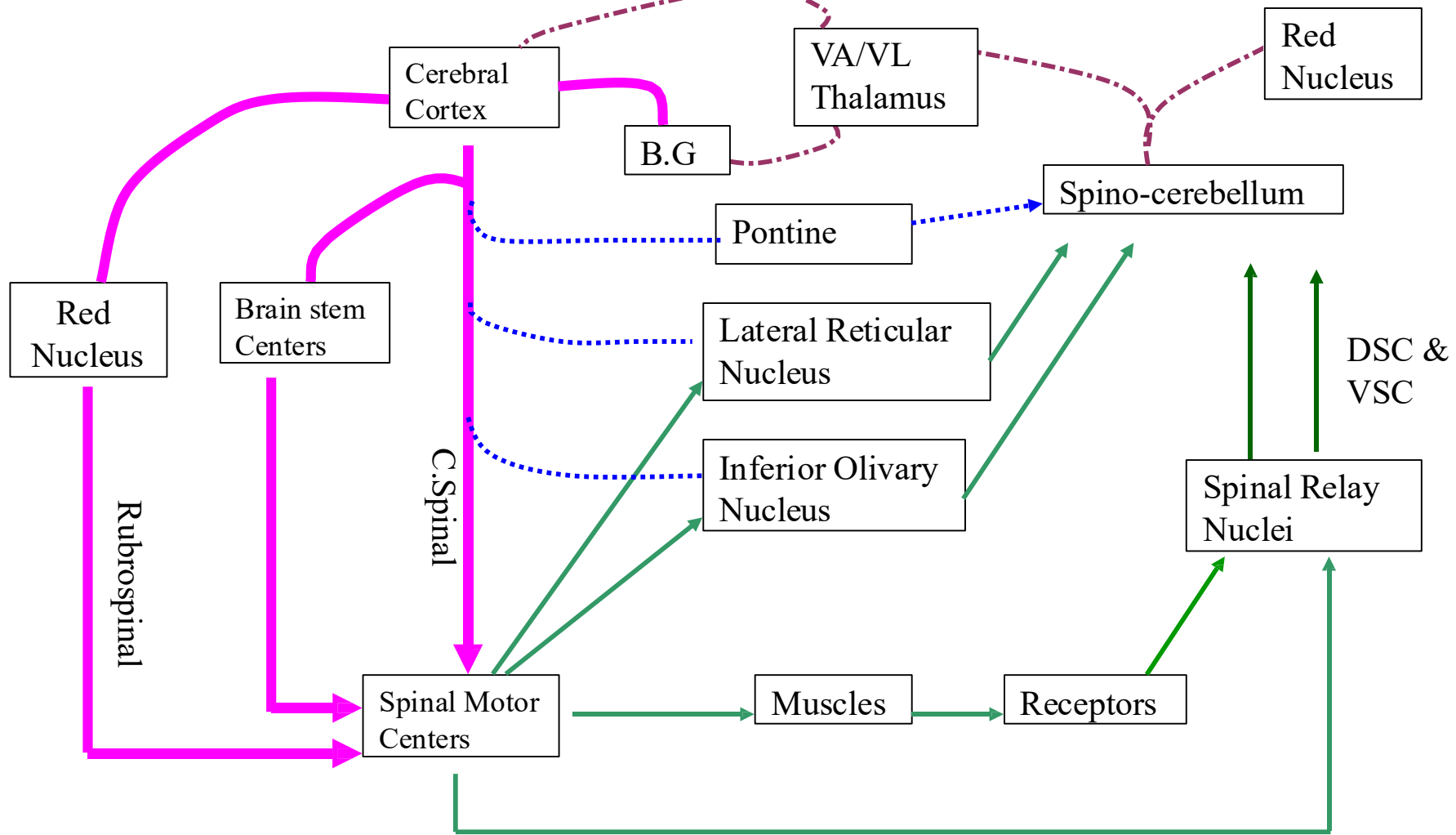
# Objectives





- List the ascending and descending tracts passing through the spinal cord
- Describe the muscle spindle
- Explain the functions and mechanism of action of the muscle spindle system
- Outline the spinal cord reflex mechanism
- Follow up the neural circuitry and function of the spinal reflexes (Stretch reflex e.g knee and Ankle jerks, Flexor and crossed extensor reflexes)
- Demonstrate spinal reflexes
- Interpret the results of spinal reflexes

# Motor System



General sketch of the motor system



-  Motor Command
-  Feed Back
-  Command Monitor
-  Corrective Command

# Motor System

See the next slides for further explanation

# Motor System / Further Explanation

The **motor system** begins with the **motor command** that originates from the **motor cortex**. This command travels through the **corticospinal tract**, which carries signals from the cortex to the spinal cord. This pathway corresponds to the first (**pink**) part of the diagram.

In the **spinal cord**, the corticospinal tract connects with **alpha motor neurons** located in the anterior horn. These neurons represent the **lower motor neurons**, which send signals directly to the **muscles**, causing them to contract and produce movement.

Within the muscles, there are **two** types of receptors: **Muscle spindle & Golgi tendon organs**.

- The **muscle spindle** detects changes in **muscle length**. It is positioned in parallel with the **extrafusal** muscle fibers. It detects two types of changes: **Dynamic** change: the **rate** of change in muscle length OR **Static** change: how much the **length** has changed
- The **Golgi tendon** organ detects changes in muscle tension, meaning the **force** of muscle **contraction**.

# Motor System / Further Explanation

Information from these receptors travels upward through the **spinal relay nuclei** to the **cerebellum** via two tracts: **Dorsal (Posterior) spinocerebellar tract** & **Ventral (Anterior) spinocerebellar tract**.

Both tracts project to a specific region of the cerebellum called the **spinocerebellum**, which receives input from the spinal cord. These pathways provide the cerebellum with **feedback** about what is **actually** happening in the **muscles**.

At the same time, the **cerebellum** receives a copy of the **motor command from the cerebral cortex** through the **corticopontocerebellar tract**. This copy informs the cerebellum about the **intended** movement.

The **spinocerebellum** now receives **two** types of information: **Actual movement** (from sensory feedback) & **Intended movement** (from the cortex). Additionally, the cerebellum receives feedback from the spinal cord through the inferior olivary nuclei and the lateral reticular nuclei.

# Motor System / Further Explanation

Then, the cerebellum compares these two signals. However, they *never match* exactly because the cerebral cortex never sends a perfectly accurate signal to the muscles. The impulses may be more than intended or less than intended.

Because of this mismatch, the cerebellum sends **corrective commands** back to the **cerebral cortex** which does not receive these signals directly. Instead, they pass through the **motor** part of the **thalamus**, specifically: **Ventroanterior (VA) nucleus**, **Ventrolateral (VL) nucleus**.

From the **VA and VL** nuclei, the corrective signals are transmitted to the **cerebral cortex**, which then sends a new **adjusted** motor command.

The corrected command is also **NOT** perfectly accurate. For example:

- If the first impulse was **more** than intended, the correction will be **less**.
- If the correction becomes too **little**, the next correction will be **more**.

This process continues repeatedly, producing a cycle of **more → less → more → less adjustments**.

This small oscillating movement is called **tremor**. Normally, this tremor is very fast and too small to be noticed in everyday life. However, if there is damage to the cerebellum, the tremor becomes visible and recognizable.

# Motor System / Further Explanation

Other important structures in the motor system include:

## Basal Ganglia

- Receives input from the **cerebral cortex**
- Mainly involved in **patterns** of movement
- Send their **corrective** signals through the **VA and VL nuclei** of the **thalamus** back to the **cerebral cortex**

## Brainstem Motor Pathways

Motor signals can also originate from the brainstem, including:

- **Reticular** formation (reticulospinal tract)
- **Vestibular** nuclei (vestibulospinal tract)
- **Red nucleus:** (rubrospinal tract) the red nucleus also receives input from the **cerebellum** (in addition to the cortex) and contributes to motor control.

# The Spinal Cord is More Than Just a Conduit for Nerve Fibers

- The spinal cord serves as a pathway for **ascending** (sensory) and **descending** (motor) tracts.
- Neuronal circuits for walking and various reflexes are contained within the spinal cord.
- Rather than having separate neurons dedicated to specific actions like walking or writing, **the same** neural circuits can be utilized for **multiple** activities.
- Higher brain centers activate and command these circuits.
  - walking
  - maintaining equilibrium

# Internal Anatomy of Spinal Cord

The spinal cord has an H-shaped **gray matter** region, which consists of **cell bodies** and dendrites. Each spinal cord segment is organized into two mirror-image halves, separated by the **anterior median fissure** and the **posterior median sulcus**.

The gray matter divides the spinal cord into regions surrounded by white matter, which is composed of **myelinated fibers**. The white matter is arranged into three columns: **posterior** (dorsal), **lateral**, and **anterior** (ventral).

At the center of the gray matter lies the **central canal**, which is filled with **(CSF)**. From each spinal cord segment, a spinal nerve exits through the **intervertebral foramen**. These spinal nerves are **mixed** nerves, containing both **motor** and **sensory** components.

Sensory neurons carry signals from **receptors** to the cell bodies located in the **dorsal root ganglia**, then enter the **posterior** (dorsal) horn of the spinal cord. They may synapse with **interneurons**, which in turn synapse with **motor neurons** that project to **muscles**. Additionally, the **lateral horn** contains **autonomic** neurons, particularly those of the **sympathetic system**.

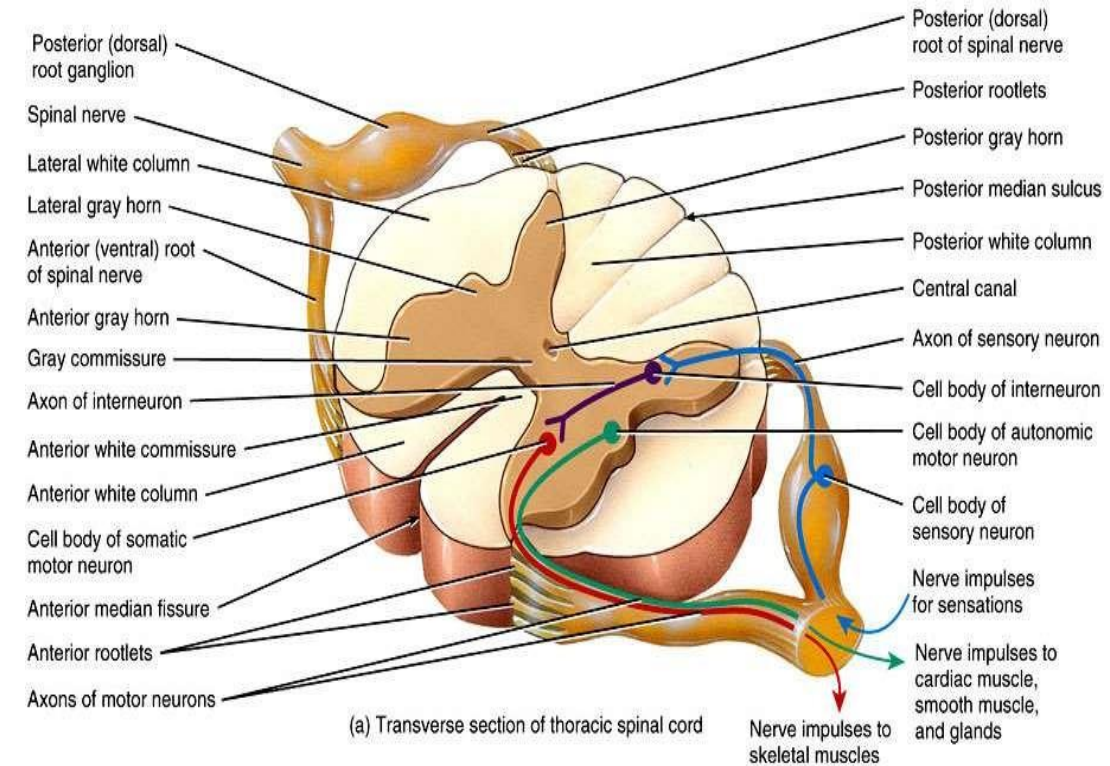
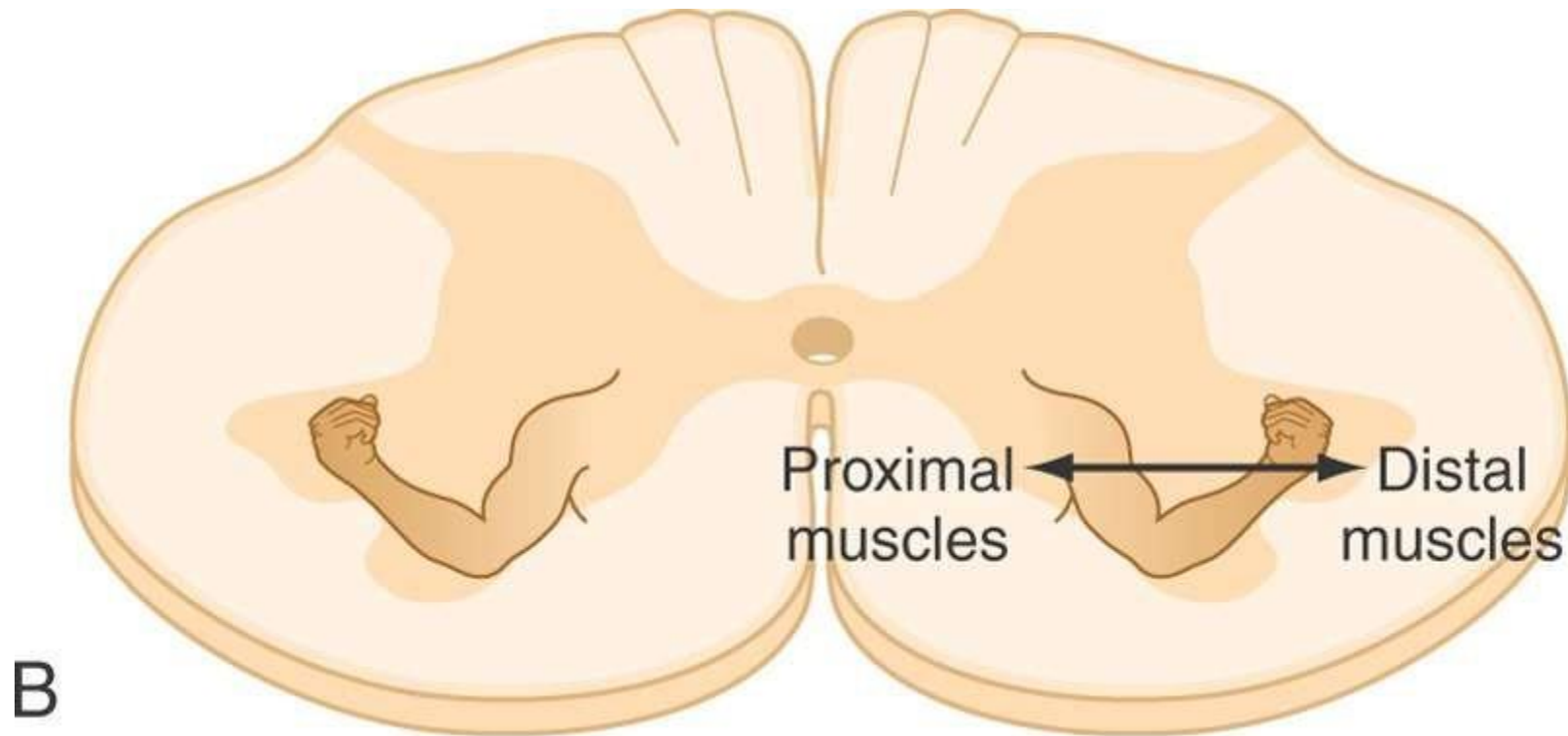


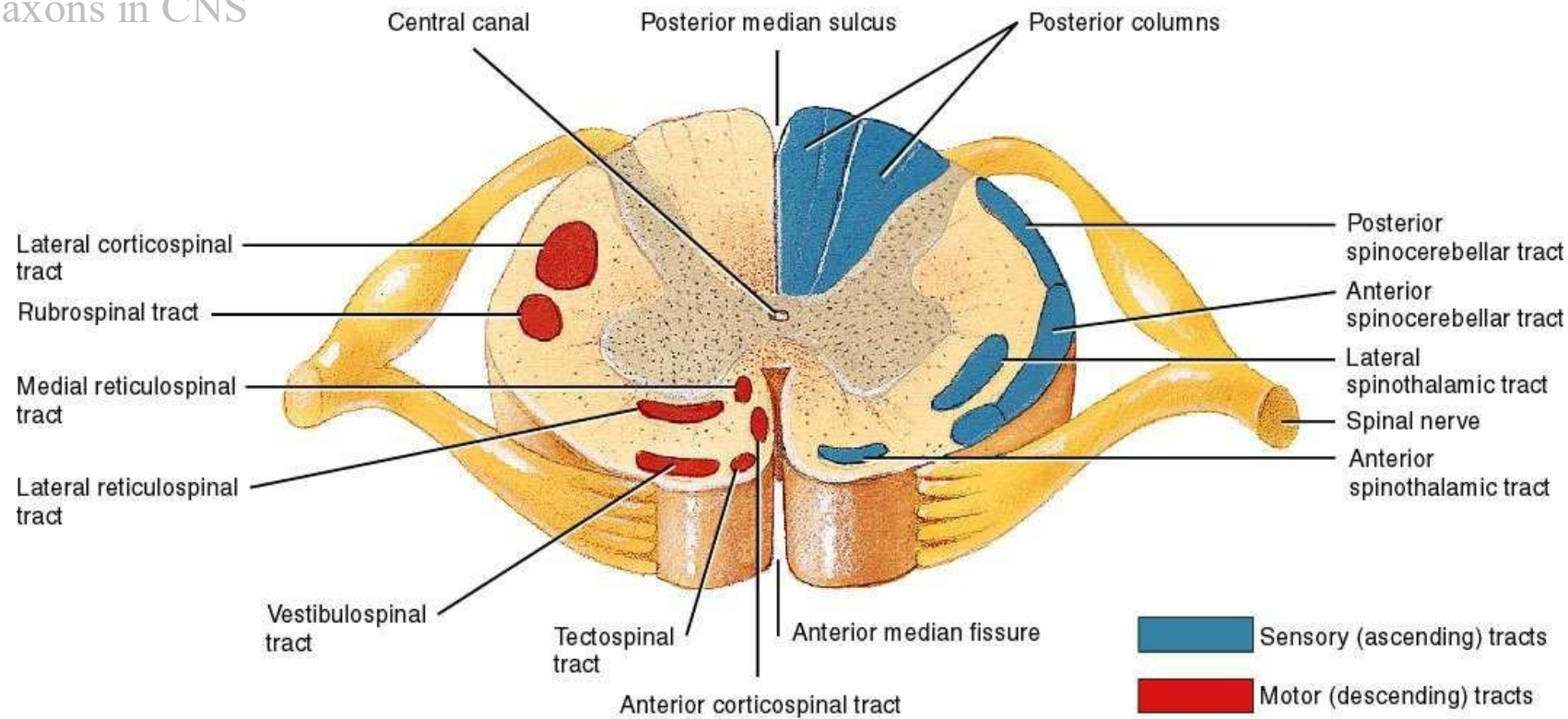
Figure 13.03 Tortora - PAP 12/e  
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(Redrawn from Purves D et al [eds]: Neuroscience, 3rd ed. Sunderland, MA, Sinauer, 2004.)

In every part of the motor system, there is a **topographic organization** of body muscles. This organization is also present in the spinal cord. In the anterior horn, **proximal** muscles are represented **medially**, while **distal** muscles are represented **laterally**. Each muscle has a specific, organized representation rather than a random distribution.

Tract: collection of axons in CNS



13.04

The **right** side shows **sensory** (ascending) tracts, while the **left** side shows **motor** (descending) tracts. The motor pathways include the lateral system pathways including the **lateral corticospinal** and **rubrospinal** tracts, as well as the medial system pathways, including the **reticulospinal**, **vestibulospinal**, and **tectospinal** tracts. Knowing that, in reality, both sides of the spinal cord segments contain both motor and sensory tracts.

# Motor Organization of the Spinal Cord

- Sensory fibers enter the cord and are transmitted to higher centers, or they synapse locally to elicit motor reflexes.
- Motor neurons are located in the anterior portion of the cord.
  - motor neurons are 50 - 100 % bigger than other neurons

# Anterior Motor Neurons

- Neurons are classified into types **A**, **C** or **B** based on myelination: A fibers are myelinated, while C fibers are unmyelinated and B are partially myelinated. They are further subclassified as **alpha** (biggest), **beta**, **delta** (smallest), or numbered **I**, **II**, **III** (myelinated) and **IV** (unmyelinated).
- Within muscles, the muscle spindle fibers are called **intrafusal** fibers, while the main contractile fibers of the muscle are called **extrafusal** fibers (to be discussed).
- Alpha motor neurons
  - give rise to large type A alpha fibers (~14 microns).
  - stimulation can excite 3 - 100 *extrafusal* muscle fibers collectively called a motor unit (**A motor unit consists of a motor neuron and all the muscle fibers it innervates**).
- Gamma motor neurons
  - give rise to smaller type A gamma fibers (~5 microns)
  - stimulation excites *intrafusal fibers*, a special type of sensory receptor

# Interneurons and Propriospinal Fibers

- Interneurons
  - ❑ 30 times as many as anterior motor neurons
  - ❑ serve as connections between motor and sensory neurons, as well as between other neurons.
  - ❑ small and very excitable
  - ❑ comprise the neural circuitry for the motor reflexes
- Propriospinal fibers
  - ❑ travel up and down the cord for 1 - 2 segments
  - ❑ provide pathways for multisegmental reflexes
  - ❑ Pain signals transmitted through sensory fibers can ascend one or two segments via these propriospinal fibers.

# Sensory Receptors of the Muscle

- Muscle Spindle
  - sense muscle length and change in length. That's why they are sometimes referred to as **stretch receptors**.
  - located inside muscles.
  - The **number** of muscle spindles in a muscle depends on its **activity**; **extensor** or **antigravity** muscles contain many **more spindles** than flexor muscles.
  
- Golgi Tendon Organ
  - sense tendon tension and change in tension or the force of contraction.
  - located at the muscle-tendon junction.

# Muscle Spindle

A single muscle spindle has a **central receptor region** containing two types of sensory endings:

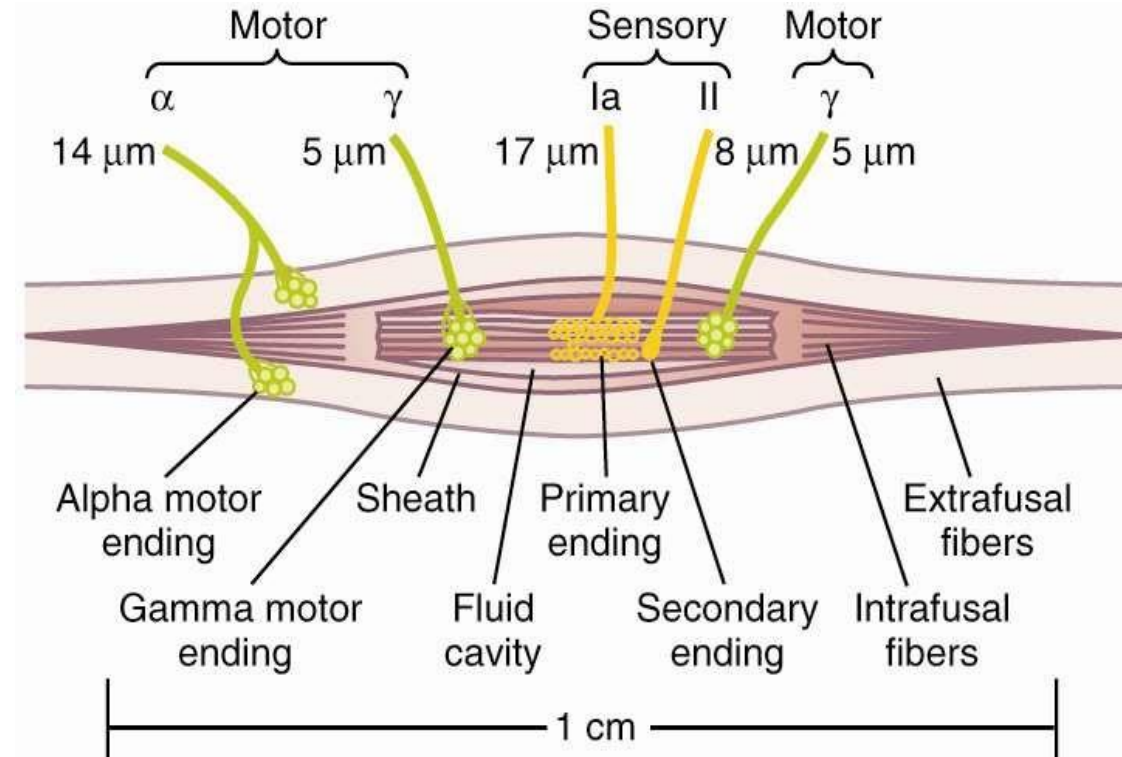
- **Primary ending** (annulospiral, nuclear bag or the dynamic part) – located in a bag-like structure, supplied by **large** myelinated type **Ia** fibers.
- **Secondary ending** (flower-spray, nuclear chain or the static part) – supplied by type **II** sensory fibers.

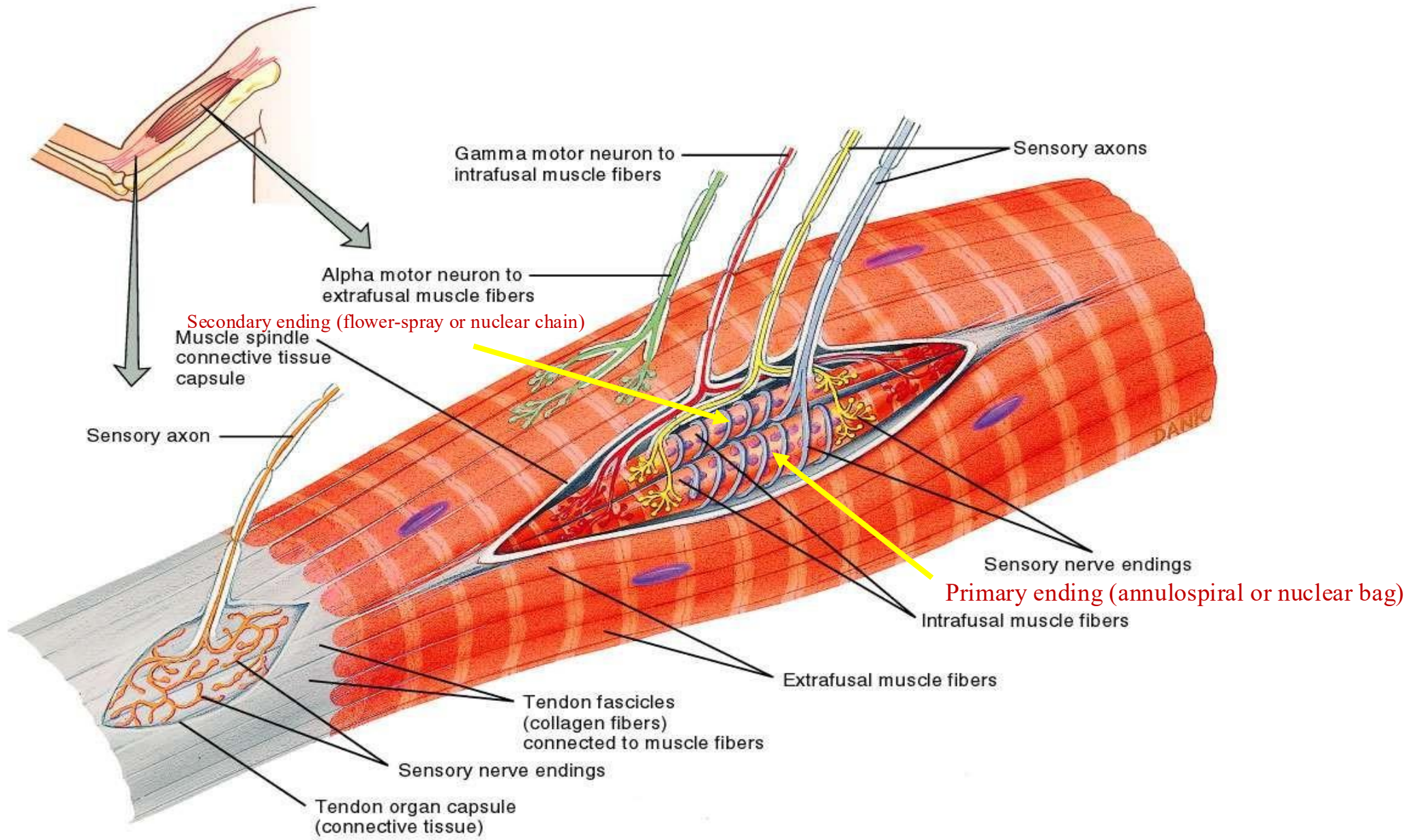
The lateral portions of the muscle spindle contain **intrafusal** fibers, which are innervated by **gamma motor** fibers. These include:

- **Gamma dynamic fibers**
- **Gamma static fibers**

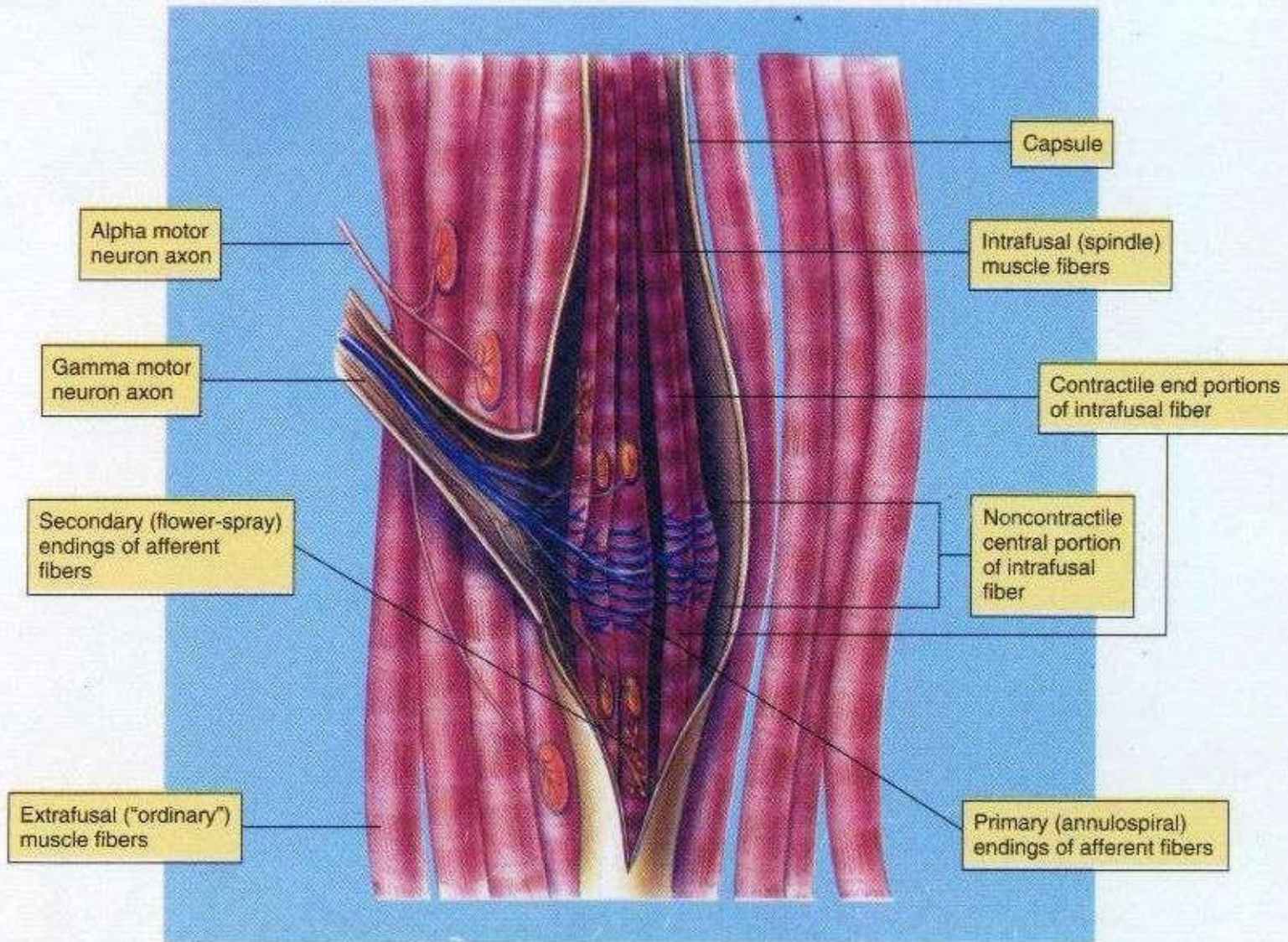
When **intrafusal** fibers contract via **gamma** motor activation, they **shorten laterally**, keeping the **central** receptor region **stretched**, which maintains or **increases** its sensitivity. This ensures that the spindle **continues to detect changes in muscle length**, even when the muscle contracts.

The main contractile muscle fibers surrounding the spindle are called **extrafusal** fibers, supplied by **alpha** motor neurons.





## Muscle Spindle



# Sensory fibers of muscle spindle

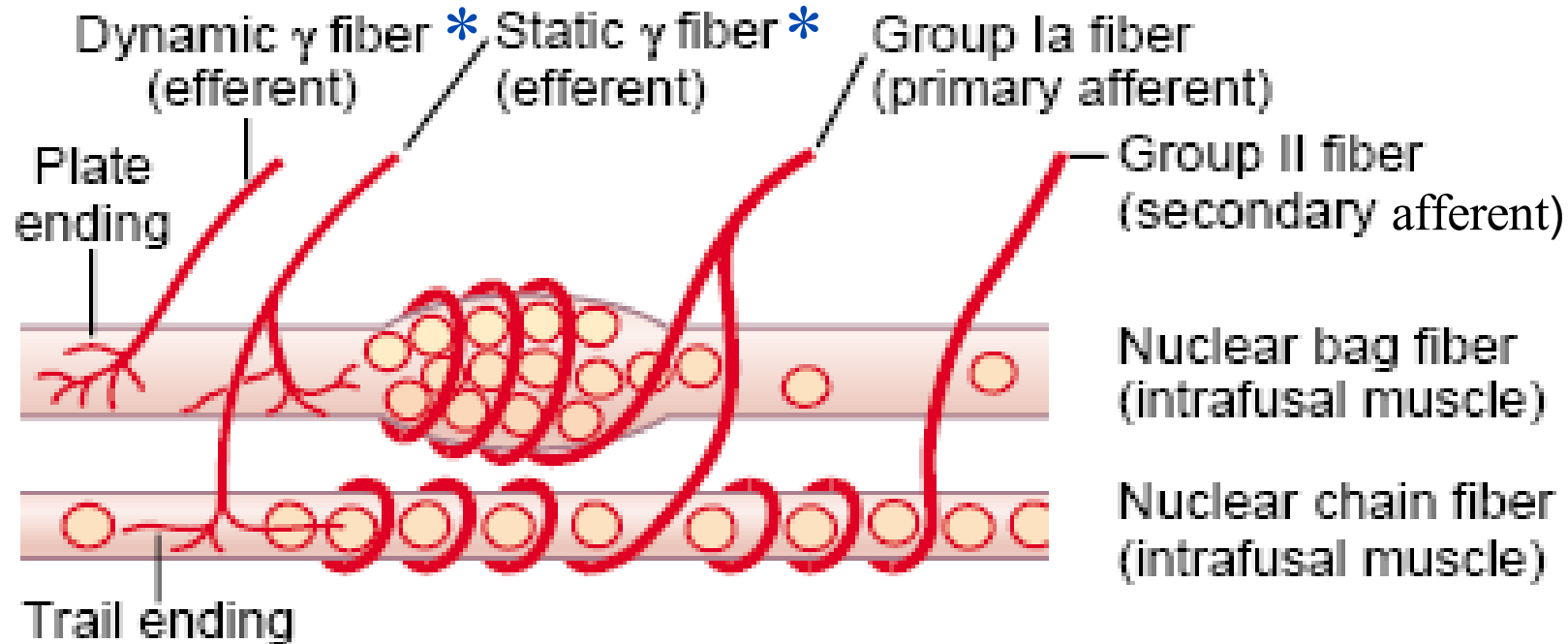


Figure 54-3

Details of nerve connections from the nuclear bag and nuclear chain muscle spindle fibers. (Modified from Stein RB: Peripheral control of movement. *Physiol Rev* 54:225, 1974.)

\*Dynamic gamma fibres supply the nuclear bag intrafusal fibres, while Static gamma fibres supply the nuclear bag (mainly) and the nuclear chain intrafusal fibres.

# Static Response of the Muscle Spindle

- When the center of spindle is stretched *slowly* - the number of impulses generated by the primary and secondary endings increases in proportion to the *degree of stretch*.
- This is the '*static response*'.
- Function of the static nuclear bag and nuclear chain fibers.
- The **static nuclear bag** and **nuclear chain fibers** provide information to the **cerebellum** about the **state** of muscle contraction and the **degree of change** in muscle length.

# Dynamic Response of the Muscle Spindle

- When the center of the spindle is stretched *rapidly* - the number of impulses generated by the primary endings increases in proportion to the *rate of change* of the length.
- This is the '*dynamic response*'.
- Function of the dynamic nuclear bag fiber.
- As the **speed** of contraction **increases**, the **rate of discharge** (firing) from type **Ia** fibers also **increases**.
- These fibers (Ia fibres) are responsible for detecting the **static** as well as **dynamic** aspect of stretch, meaning they signal both the **change** in muscle length and the **rate** of that change.

# Dynamic Response of the Muscle Spindle

- In contrast, **type II** fibers are more **static**; they primarily convey information about the sustained muscle **length** rather than the speed of change.
- This distinction is **important** because sensing the rate of change allows the nervous system to **estimate distance** (since distance is related to speed and time). Based on this, the system subconsciously determines the **time** required to complete a movement, allowing it to **stop accurately at the intended position**.
- Experimental studies have shown that when muscle **spindles** are **damaged**, animals such as monkeys lose this ability. Their movements become poorly controlled, and they **cannot accurately judge distance**, often **overshooting** targets and colliding with objects.

# Physiologic Function of the Muscle Spindle

- Comparator of length between the intrafusal and extrafusal muscle fiber.
- Opposes a change in length of the muscle.
- When the muscle is stretched the spindle returns it to its original length.
- Leads to the stretch reflex.

# Smoothing effect of muscle spindle

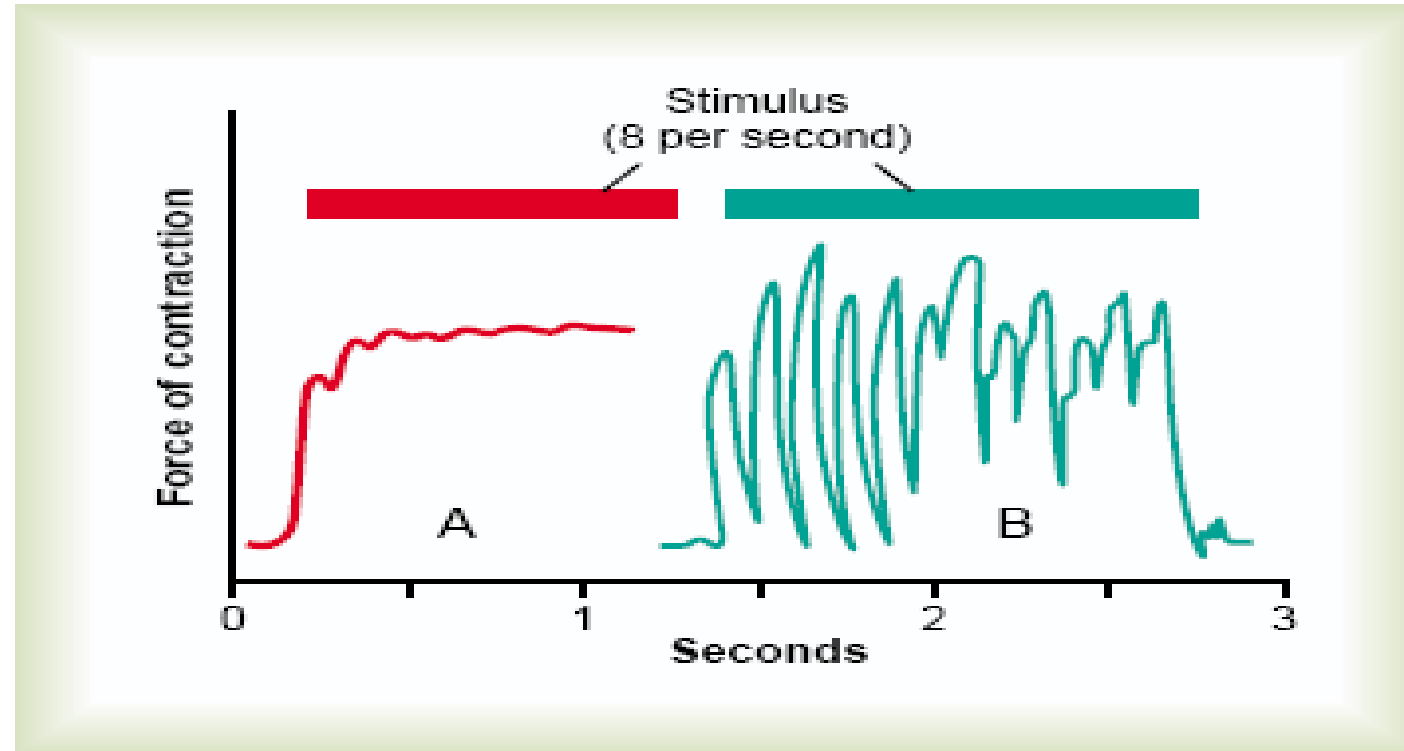


Figure 54-5

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. (Modified from Creed RS, et al: *Reflex Activity of the Spinal Cord*. New York: Oxford University Press, 1932.)

See the next slide for further explanation

# Smoothing effect of muscle spindle

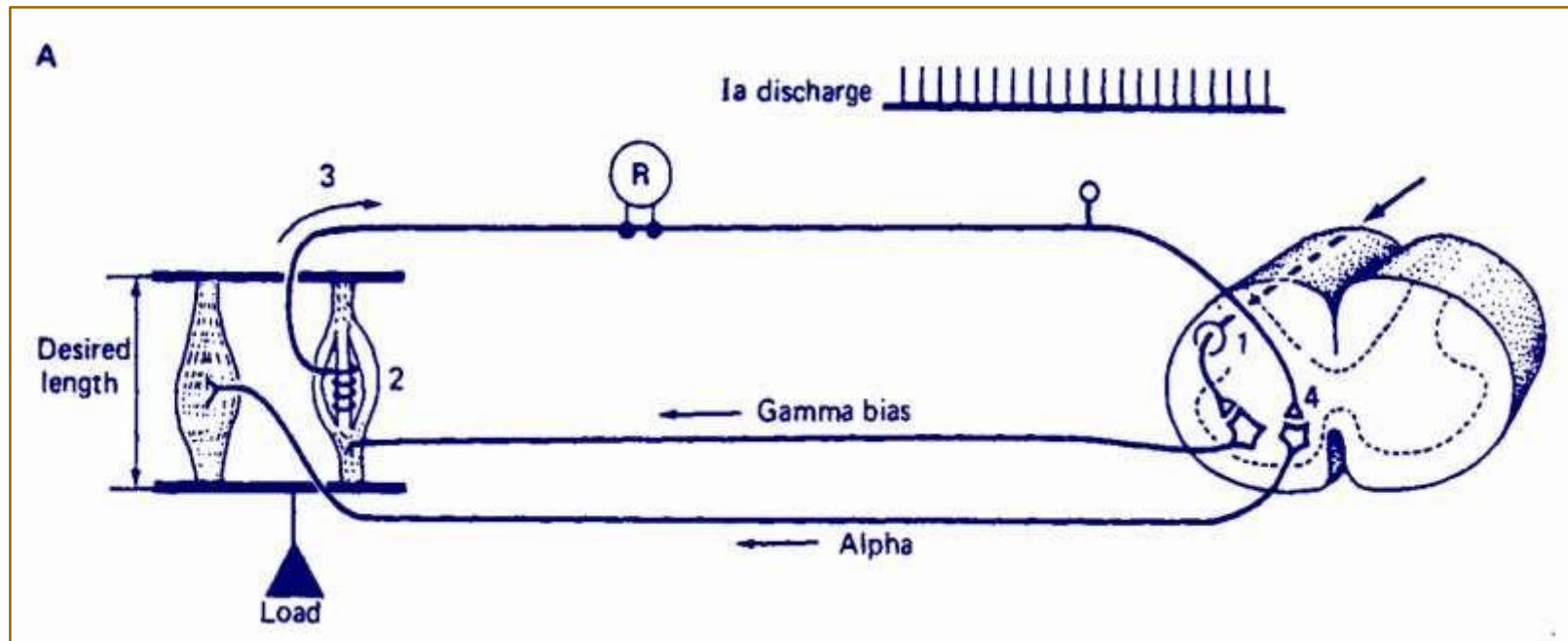
When the muscle spindle **innervation is intact**, we can control the muscle to **maintain tension** through **alpha–gamma coactivation**. Here's how it works:

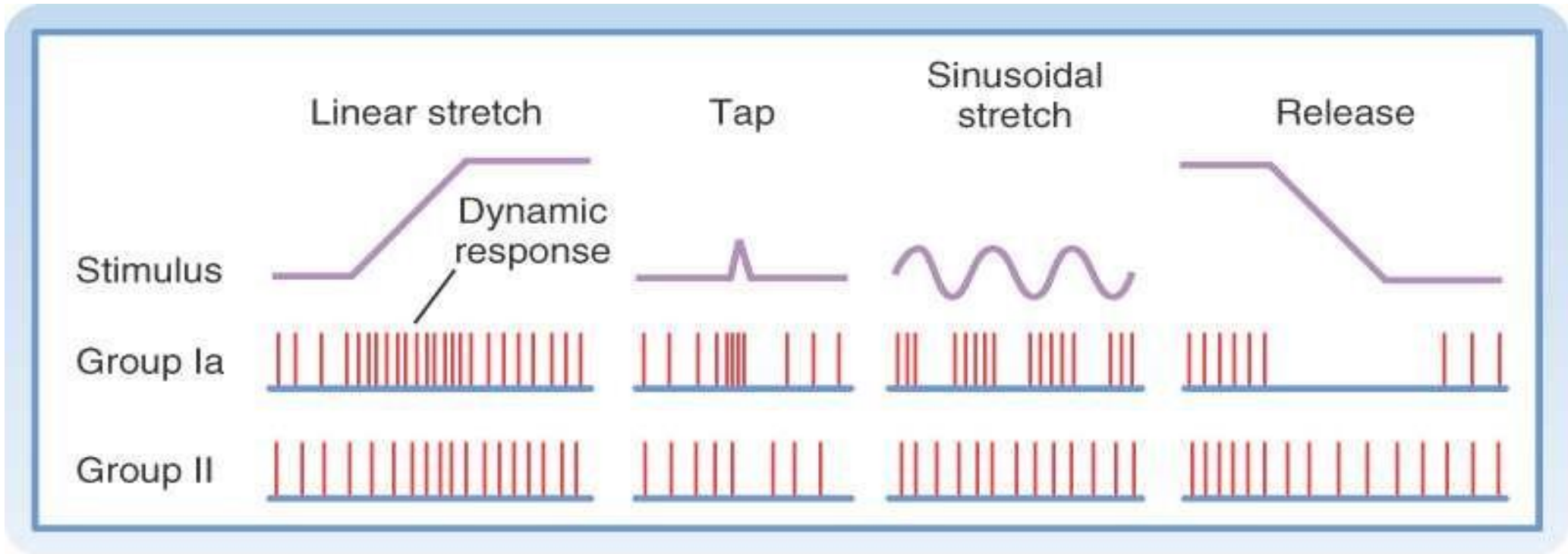
- **Alpha motor neurons** cause contraction of the **extrafusal** muscle fibers, which **shortens** the muscle. This shortening would normally **reduce spindle stretch** and **inhibit spindle firing**.
- **Gamma motor neurons** innervate the **intrafusal** fibers of the muscle spindle. When **activated**, they **contract** the intrafusal fibers laterally, keeping the **central region** (the sensory part) **stretched**, and spindle continues firing (Ia & II fibers) allowing smoothing effect of muscle spindle.

If the **muscle spindle is denervated**, stimulating the muscle causes the **extrafusal** fibers to **shorten**, but the **spindle cannot signal length changes**. As a result, the muscle **cannot** maintain steady **contraction**: it **alternates** between contraction and relaxation. To keep the muscle **continuously** contracted, the muscle spindle must be innervated by **gamma fibers** and receive **feedback** through **Ia** or **II** sensory fibers.

# Function of the Gamma System

- Spindle is normally tonically active as a result of input from higher brain centers. Alpha-gamma co-activation helps maintain muscle contraction
- **Controls the intensity of the stretch reflex.**
- Performs a damping function by adjusting sensitivity.





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See the next slides

# Function of the Gamma System

Muscle spindles are **tonically active** even at **rest**, producing a **basal rate of firing**. This basal firing is crucial: it allows the nervous system to **detect** both **stretch** (increase in firing above basal) and **shortening** (decrease in firing below basal). Without this **baseline**, the system **could not sense** muscle shortening or relaxation. Thus, the basal Ia activity is essential for **both positive and negative feedback** control of muscle length.

During dynamic stretch, the muscle spindle responds differently through its sensory fibers. When the muscle is **stretched**, group **Ia fibers** show a very **high rate of discharge initially** because they are **sensitive to the rate of change** of stretch (velocity). After this initial burst, their firing **decreases** but remains above baseline during sustained stretch.

On the other hand, group **II fibers** increase their discharge **more gradually** and mainly reflect **the degree of stretch** (muscle length) rather than the rate. They maintain a **more steady firing during sustained contraction**.

So, the main difference is that:

- **Ia fibers** detect changes in **rate** (**dynamic** response)
- **II fibers** detect maintained **length** (**static** response)

# Function of the Gamma System

The same concept applies during a tendon **tap** (stretch reflex):

A sudden stretch causes a **strong burst** of discharge in **Ia fibers**.

As the muscle **contracts** and the spindle **shortens**, the firing **decreases**.

In **sinusoidal** (repetitive) stretch, With each cycle of stretch and relaxation:

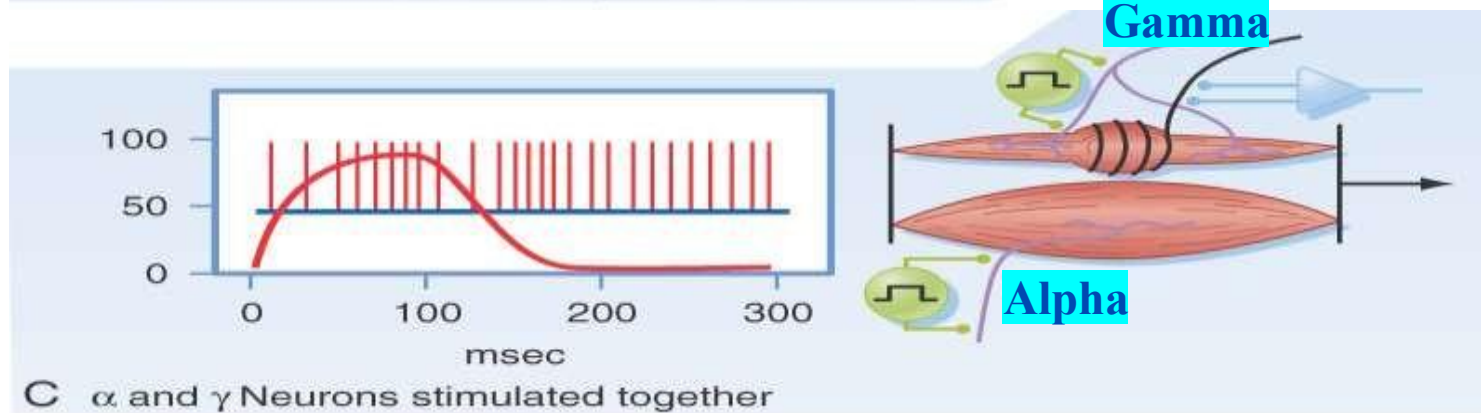
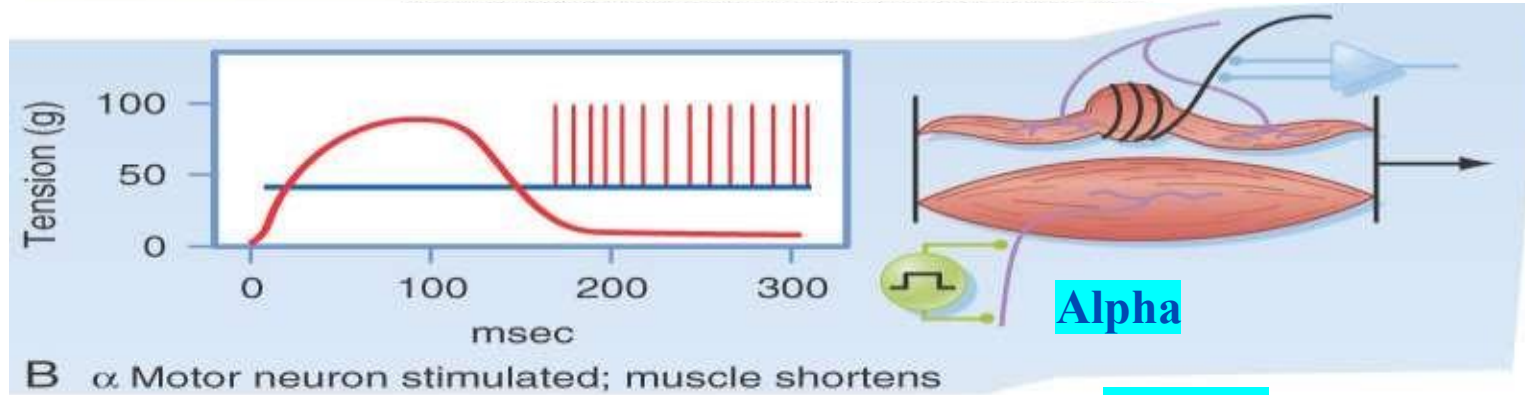
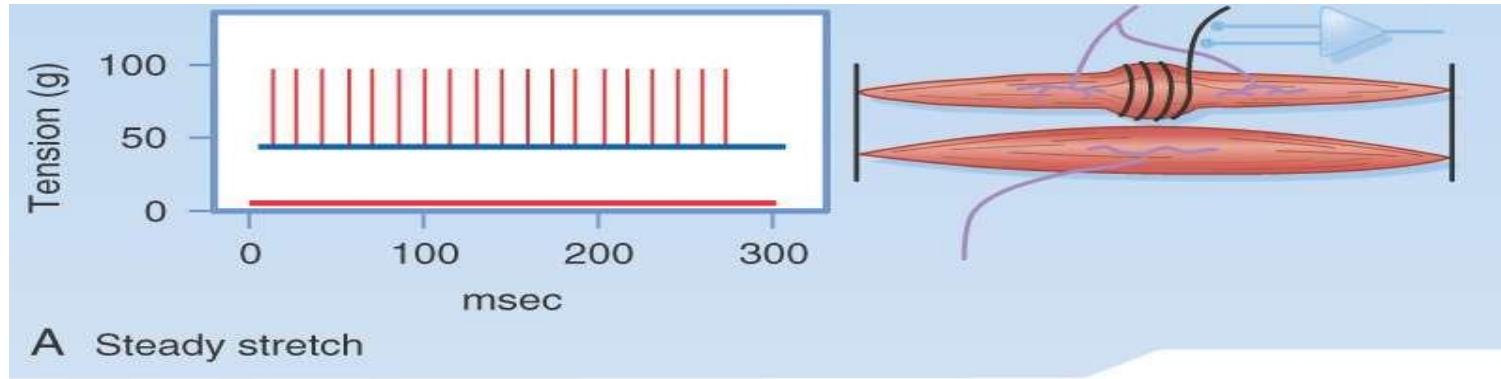
- **Ia fibers** fire **strongly** during the stretch phase.
- Their **activity decreases** during **shortening**.
- This produces a **wave-like** pattern of discharge.

During **release** of stretch:

The discharge of **Ia fibers** **decreases markedly**.

**Group II** fibers also **decrease**, but **less dramatically**, because they **continue to signal muscle length**.

✓ This distinction is why group Ia fibers are called dynamic and group II fibers are called static.



(Redrawn from Kuffler SW, Nicholls JG: From Neuron to Brain. Sunderland, MA, Sinauer, 1976.)

*Examine the figure carefully and read the explanation on the next page.*

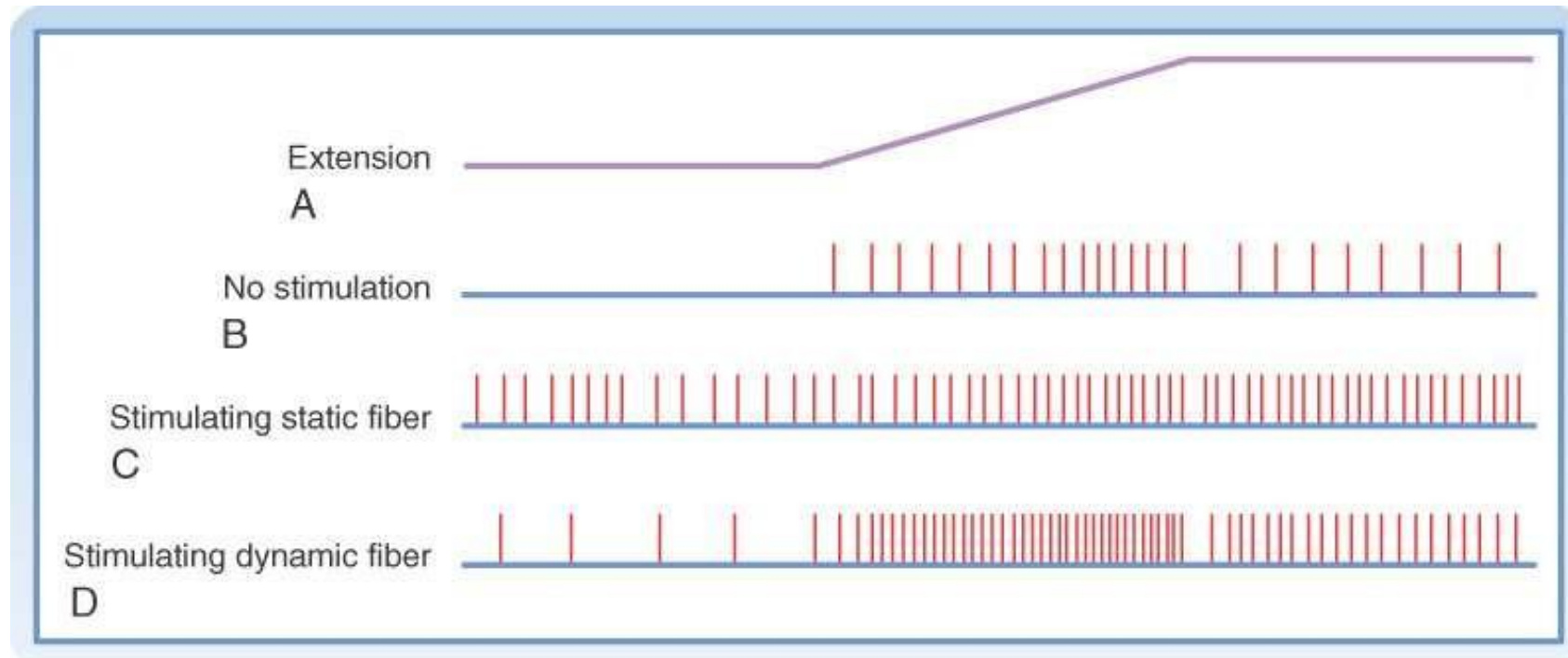
In this experiment:

**A.** When the muscle is **relaxed**, the recording from the 1a fiber shows a basal (resting) rate of firing.

**B.** When the 1a fiber is stimulated, the muscle **contracts**, leading to shortening of the muscle spindle. During this shortening, there is **no discharge**.

**C.** When **both** alpha motor neuron and gamma motor neuron **are stimulated together**, the muscle contracts, but the muscle spindle remains stretched due to gamma fiber stimulation. Therefore, a rate of firing is maintained, which is important for sustaining muscle contraction. This is called ***alpha-gamma co-activation***.

# Effect of gamma motor fibers (Dynamic and static)



(Redrawn from Crowe A, Matthews PBC: J Physiol 174: 109, 1964.)

- We have two types of gamma motor neurons:
  - a. Dynamic gamma.
  - b. Static gamma.
  
- During extension of the muscle, in the absence of stimulation, the muscle spindle maintains a basal rate of firing.
  
- When stretch occurs, the firing rate of static gamma fibers increases, but the main and highest increase in discharge is seen in dynamic gamma fibers.
  
- We conclude that the number of discharges depends on the rate of change; the faster the stretch, the greater the increase in discharge.

# Control of the Gamma Motor System (Fusimotor System)

- Gamma signal excited by the **bulboreticular facilitatory area of the brain stem.**
- Secondarily by areas that send impulses to this area.
  - cerebellum, basal ganglia, cortex
- Little is known about the precise control of this system.

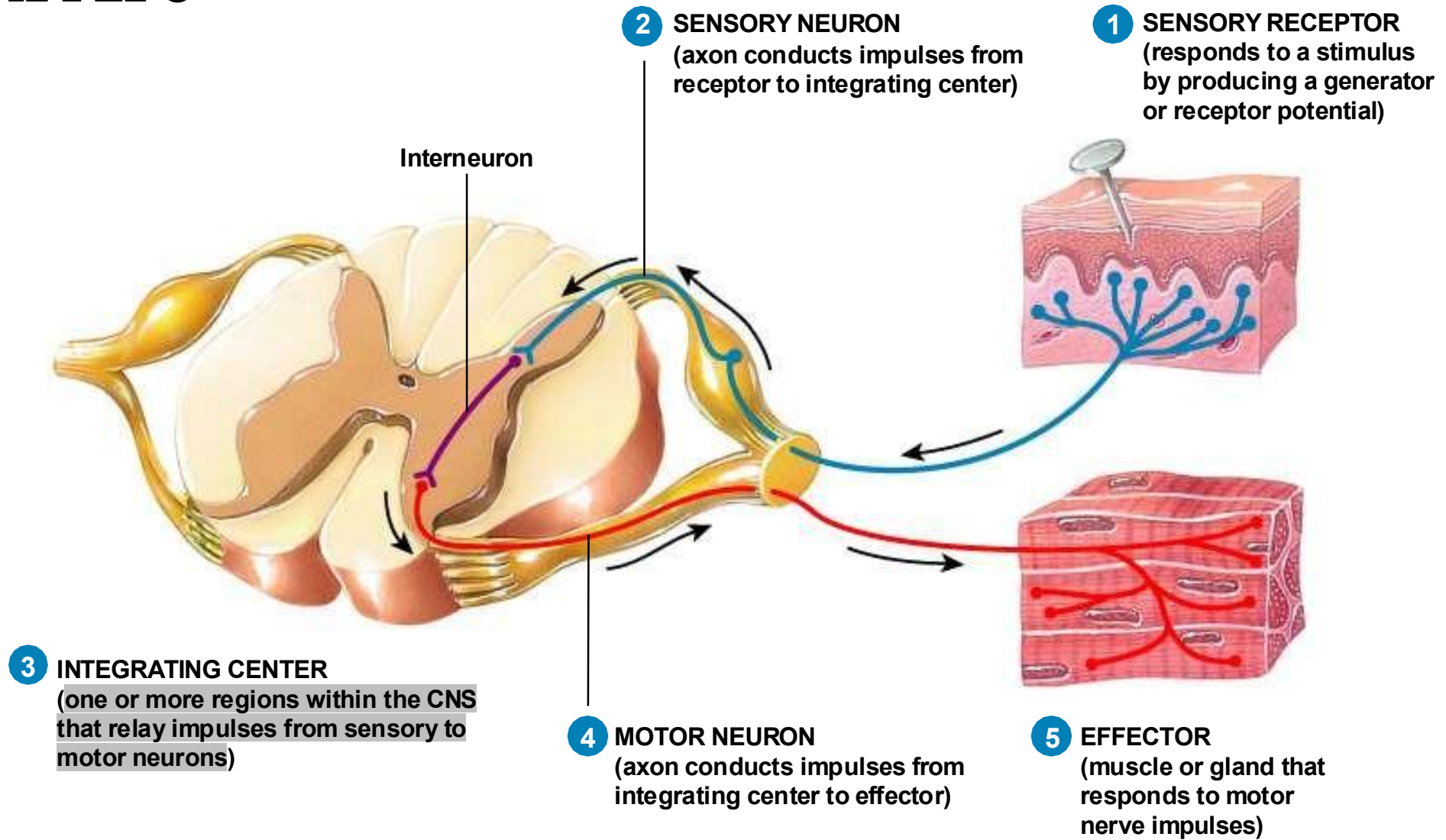
# Clinical Application of the Stretch Reflex

## (Myotatic reflex)

*Reflex: rapid involuntary response to a stimulus.*

- Knee jerk reflex (jerk means sudden movement)
  - striking the patellar tendon with a hammer stretches the quadriceps muscle (an extensor muscle).
  - this initiates a stretch reflex which shortens the muscle and causes the knee to move forward.
- Can be done with almost any muscle. (There are many examples, such as the ankle, biceps, triceps, and so on).
- Index of the facilitation of the gamma efferents.
- Cortical lesions usually increase muscle stretch reflexes.

# Reflex Arc



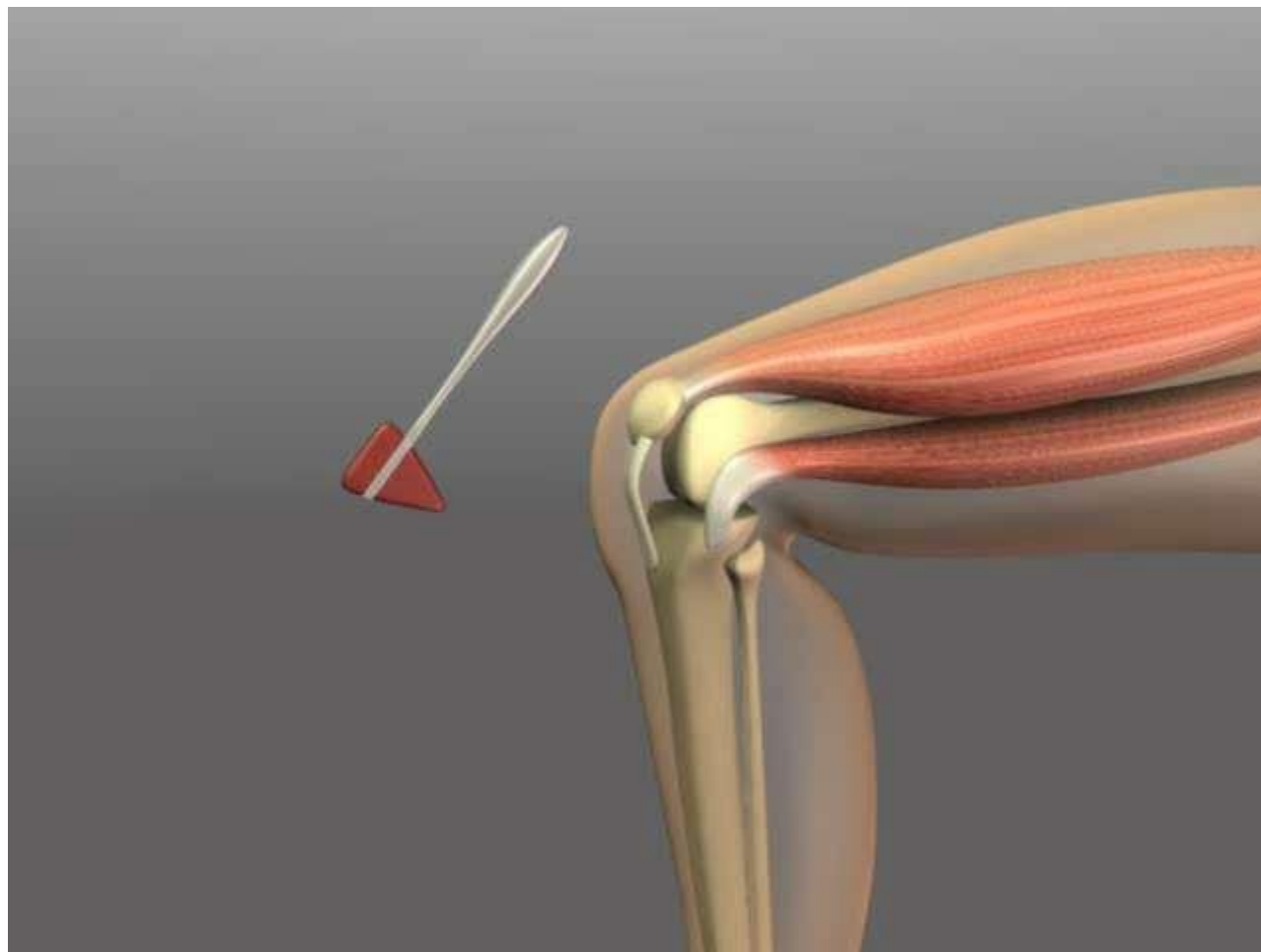
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## Components of a Reflex:

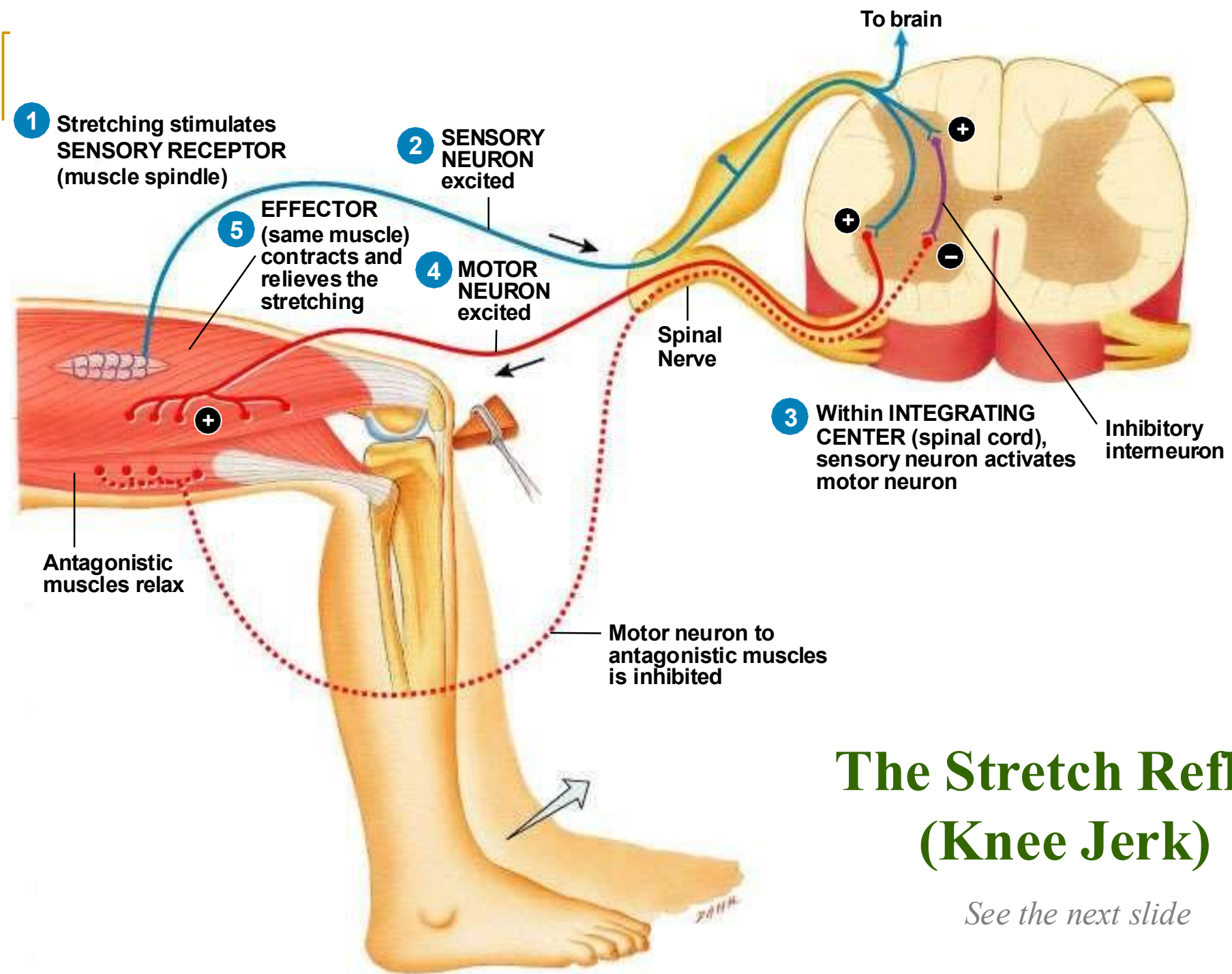
A reflex consists of five main parts:

1. **Receptor:** detects the stimulus.
2. **Sensory neuron:** transmits the signal to the posterior horn (sensory horn) of the spinal cord; its cell body is located in the dorsal root ganglion.
3. **Integrating center:** may involve an interneuron or, in some cases, a direct connection between sensory and motor neurons; this is where information is processed.
4. **Motor neuron:** usually an alpha motor neuron whose axon conducts the response signal.
5. **Effector:** the muscle or gland.

Note: The stimulus itself is **NOT** considered a component of the reflex. It only triggers the reflex and can originate from the receptor, sensory neuron, or even the spinal cord.



*See the next slides*



# The Stretch Reflex (Knee Jerk)

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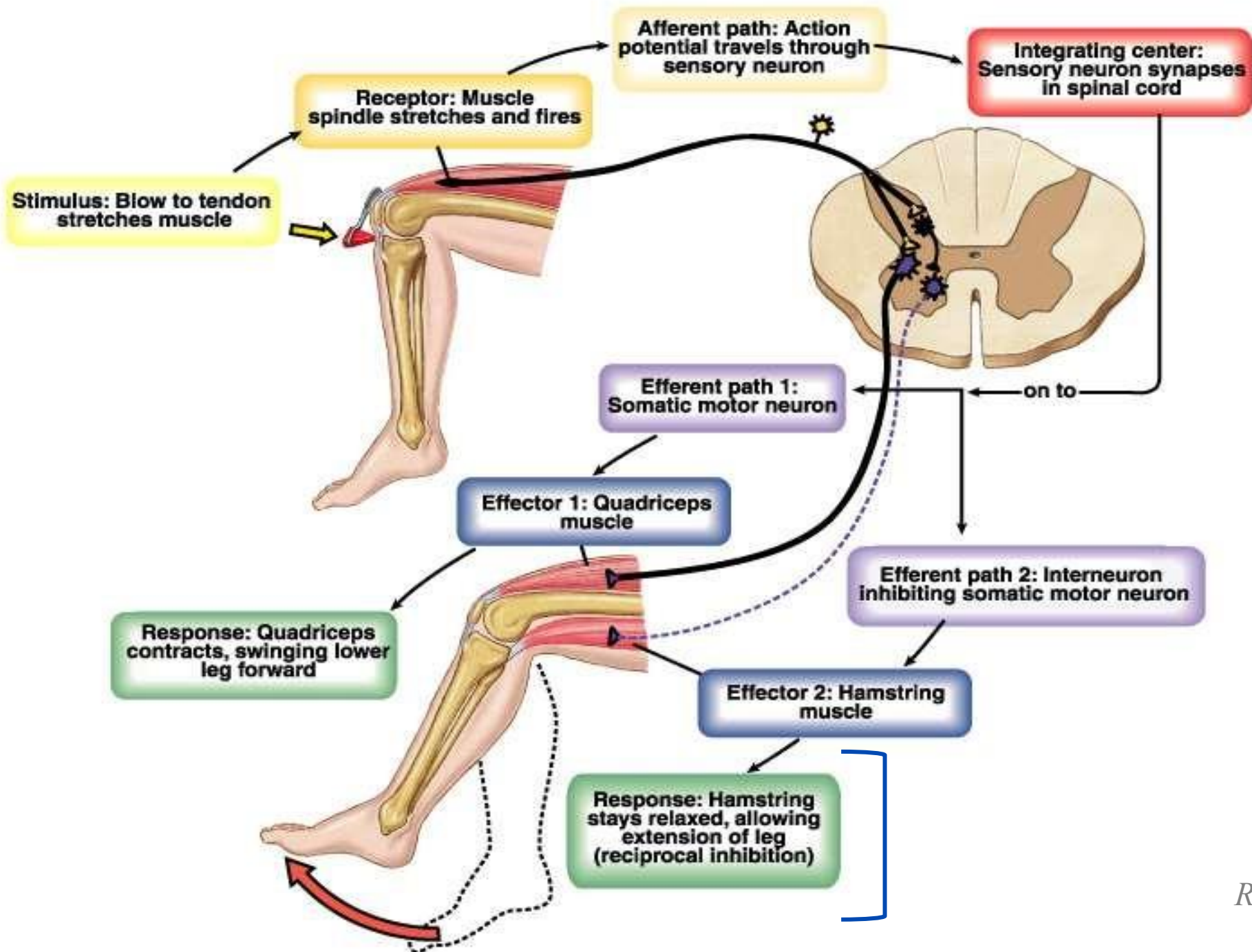
## **Knee-Jerk Reflex (Patellar Reflex):**

In the knee-jerk reflex, the rubber end of the reflex hammer is used to tap the groove between the patella and the tibial tubercle, where the patellar tendon of the quadriceps is located. Striking the tendon stretches the muscle, which in turn stretches the muscle spindle inside. This stimulates the spindle, sending a signal to the spinal cord, where it connects **directly** to an alpha motor neuron. The motor neuron then activates the extrafusal fibers of the quadriceps, **causing the knee to extend**.

The sensory information from the muscle spindle, carried by type **Ia or II** fibers, is also transmitted to the brain. This pathway, including connections to the cerebellum, informs the brain about the actual movement, demonstrating that this circuit contributes not only to reflexes but also to the control of voluntary movement.

### **Characteristics of the Patellar Reflex:**

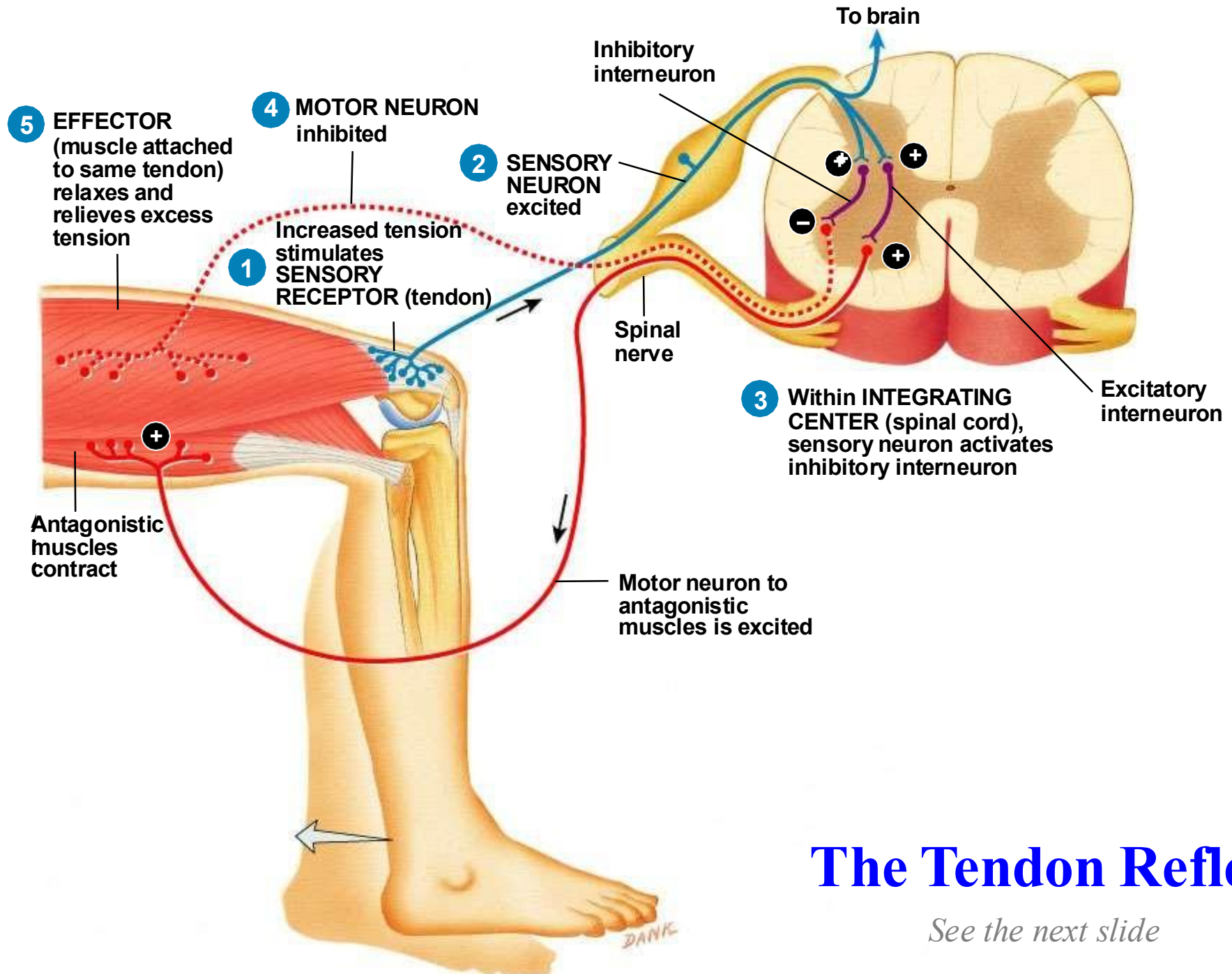
- Monosynaptic.
- Very fast (conducted via type Ia fibers).



*Read it carefully*

# The Stretch Reflex

- ❖ Causes contraction of a skeletal muscle in response to stretching of the muscle.
- ❖ Monosynaptic reflex.
- ❖ Patellar or knee-jerk reflex: Stretching of a muscle → activation of muscle spindles  
→ sensory neuron → spinal cord → motor neuron  
→ muscle contraction. (**Excitatory reflex**)
- ❖ **Ipsilateral.**
- ❖ Receptors are located in the same muscle stimulated by lengthening of muscle (stretch)



# The Tendon Reflex

*See the next slide*

## **Tendon Reflex (Protective Reflex or Inverse Myotatic Reflex):**

Sometimes, if a muscle's stretch reflex is **very intense**, it can produce such a strong contraction of the quadriceps that the tendon could tear. The protective reflex prevents this from happening.

The stronger the muscle contraction, the more the Golgi Tendon Organs (located in the tendon of the same muscle) is stimulated.

If the muscle is **overstretched**, the tendon organ is activated. This signal is carried by type **Ib** fibers, which are slower than the fibers mediating the stretch reflex. The signal enters the posterior horn of the spinal cord and also diverges to the brain, particularly the cerebellum, to convey information about muscle tension.

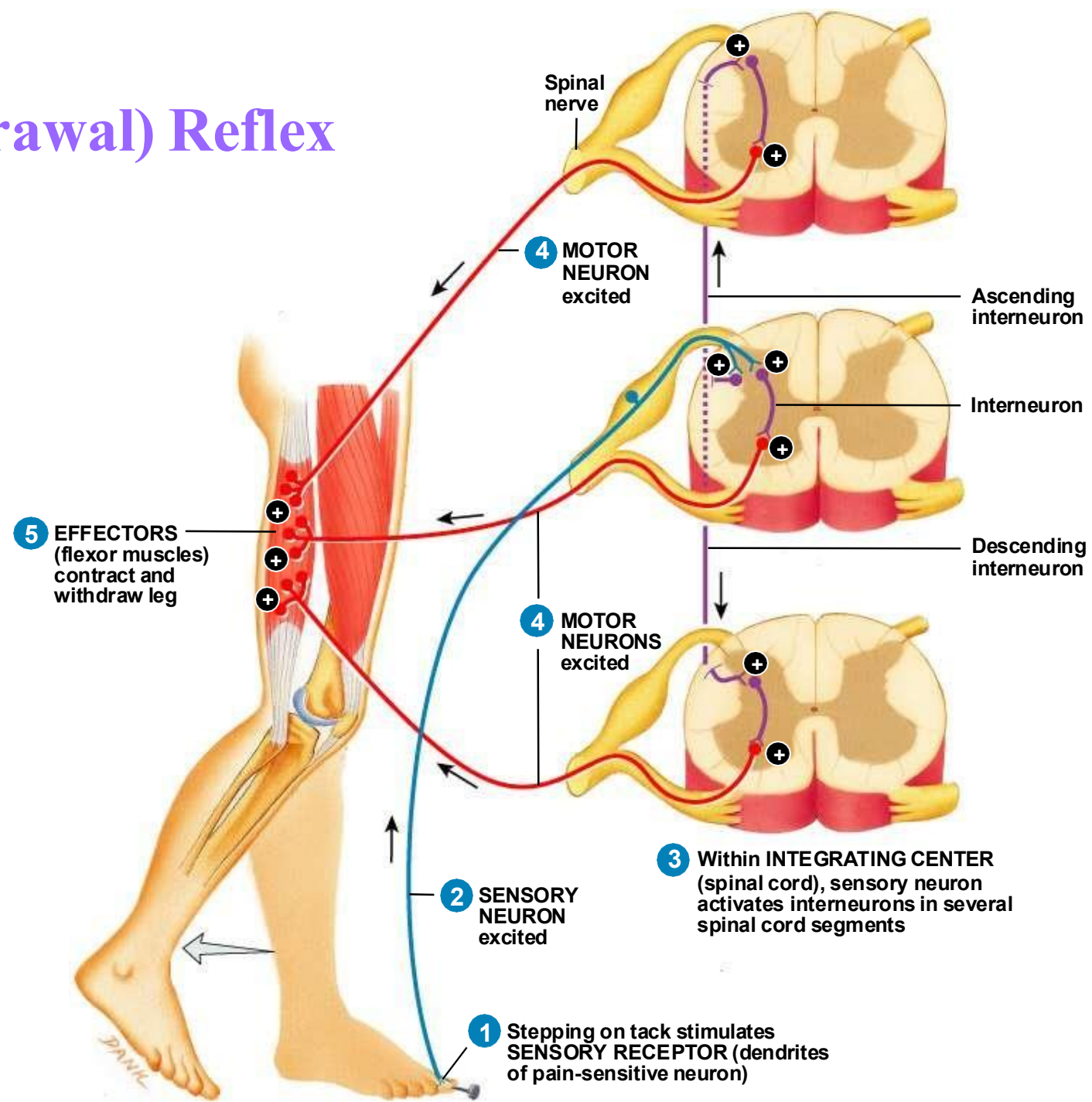
Within the spinal cord, the type Ib fibers synapse with **inhibitory interneurons**, which inhibit the alpha motor neurons of the same muscle, reducing contraction and protecting the tendon.

The Golgi tendon organ has both dynamic and static components, allowing it to respond to changes in muscle tension over time as well as steady tension.

# The Tendon Reflex

- ❖ Polysynaptic reflex. (Di-synaptic)
- ❖ **Control muscle tension by causing muscle relaxation when muscle tension is great.**
- ❖ Sensory receptors- Golgi tendon organs (same muscle stimulated by tension applied on the muscle in series with muscle fibers)
- ❖ **Ipsilateral.**
- ❖ ↑ Tension applied to the tendon → tendon organ stimulation → nerve impulse → spinal cord  
→ motor neuron causes muscle relaxation and relieves tension  
**(inhibitory reflex)**

# Flexor (Withdrawal) Reflex



*See the next slide*

## Flexor Reflex (Withdrawal Reflex):

This reflex is called the withdrawal reflex because, in animals walking on four limbs, flexing a limb withdraws it from danger. The same principle applies to humans.

The stimulus comes from nociceptors, detecting **pain**. The signal is carried to the spinal cord via **A $\delta$  or C** fibers, entering through the posterior horn. From there, it is transmitted through the anterolateral spinothalamic tract. Because fibers in this tract can travel up or down one or more spinal segments, the reflex is **multisegmental**.

In the spinal cord, the afferent fibers synapse with interneurons, which then activate motor neurons controlling groups of flexor muscles. For example, if you step on a glass shard or nail, your leg will automatically lift. This occurs because the hamstring muscles contract, flexing the knee and withdrawing the foot from the harmful stimulus.

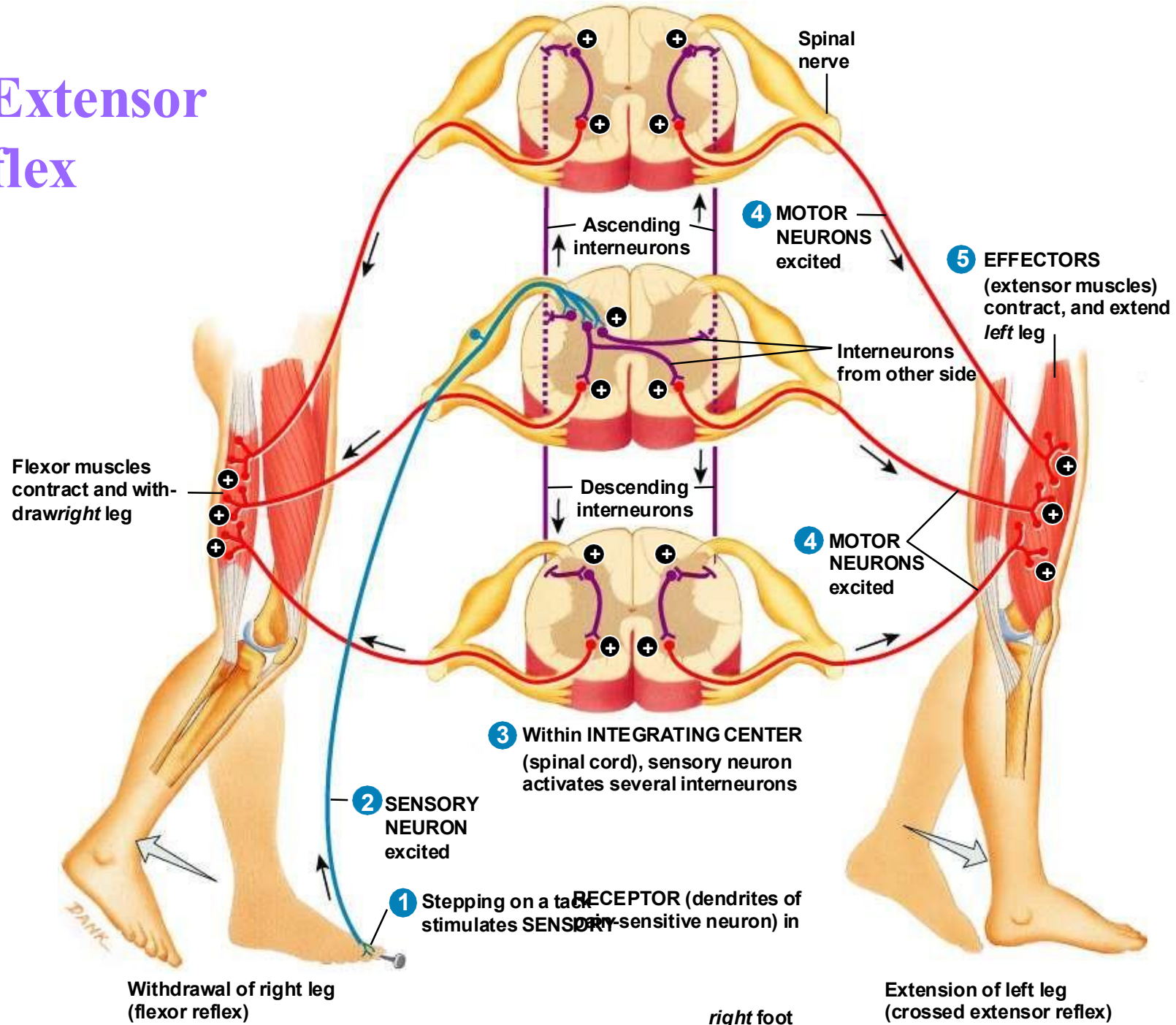
The flexor reflex is slower than the stretch reflex or tendon reflex due to the involvement of multiple interneurons and longer pathways.

# Flexor (Withdrawal) Reflex

- ❖ Polysynaptic reflex
- ❖ **Ipsilateral.**
- ❖ Stepping on a tack (stimulus) → nerve impulse → activation of the interneuron → activation of the motor neuron → muscle contraction → withdrawal of the leg (**excitatory reflex**)
- ❖ There is **reciprocal inhibition** (i.e inhibition of antagonist group of muscles on the same side)

When you lift your leg, the flexor muscles (agonists) contract, while the extensor muscles (antagonists) on the same side are inhibited through **inhibitory interneurons**.

# Crossed Extensor Reflex



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## Crossed Extensor Reflex:

When you flex the leg that steps on a painful stimulus (activating nociceptors), the opposite leg extends to help **maintain balance and prevent falling**.

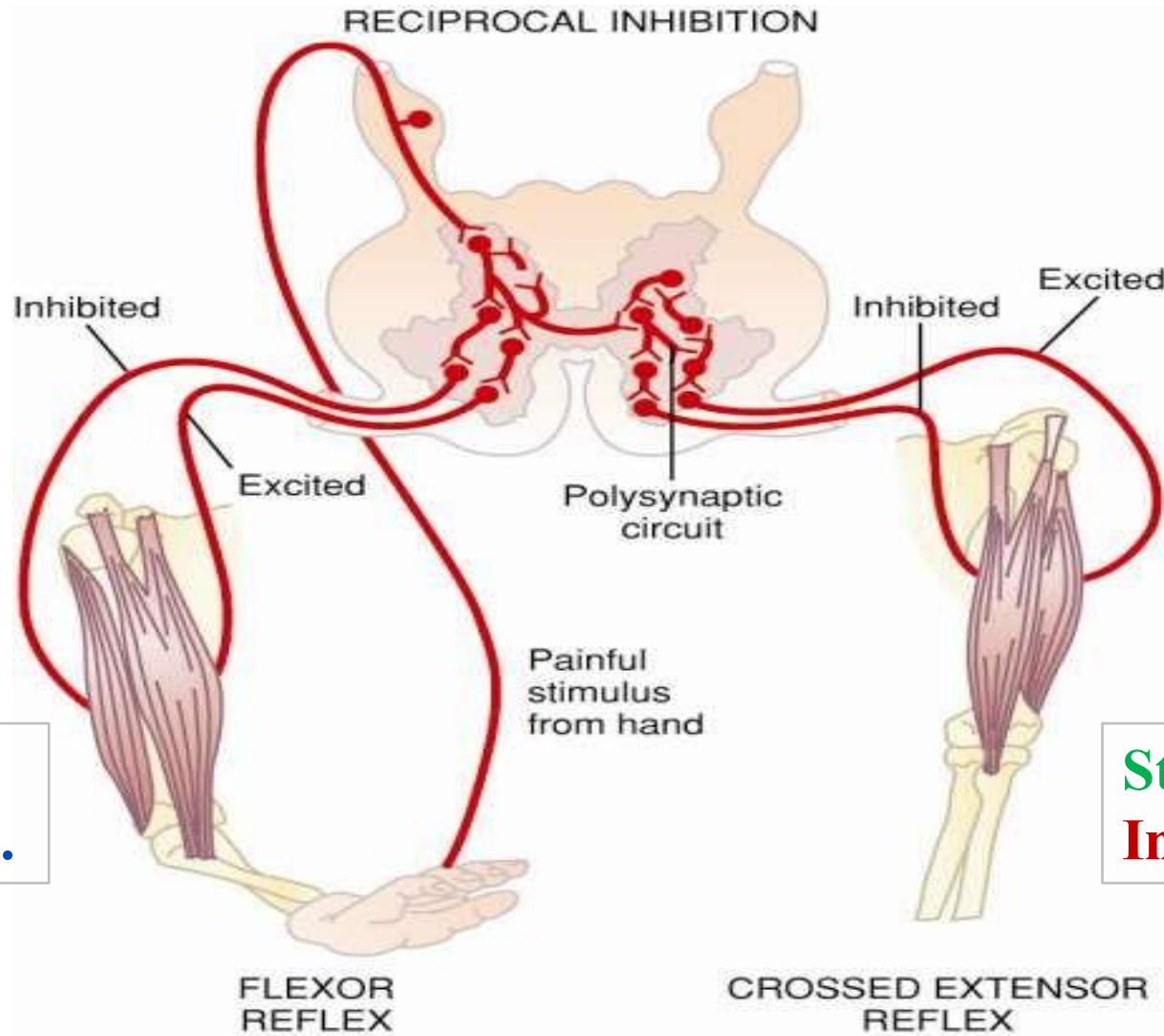
To support yourself, you contract the flexors on the side of the stimulus and contract the extensors on the opposite side. It is called the **crossed extensor reflex** because the signal crosses the midline of the spinal cord and activates extensor muscles on the **contralateral side**.

The pain signal travels to the spinal cord via **A $\delta$  or C** fibers, spreading across multiple segments (usually 2–3 segments) both up and down. On the same side, it activates flexor muscles, while on the opposite side it activates extensor muscles.

This reflex shares the same characteristics as the withdrawal reflex, but it is **contralateral**, involving muscles on the opposite side of the body.

# Neuronal Circuits for Withdrawal and Crossed Extensor Reflex

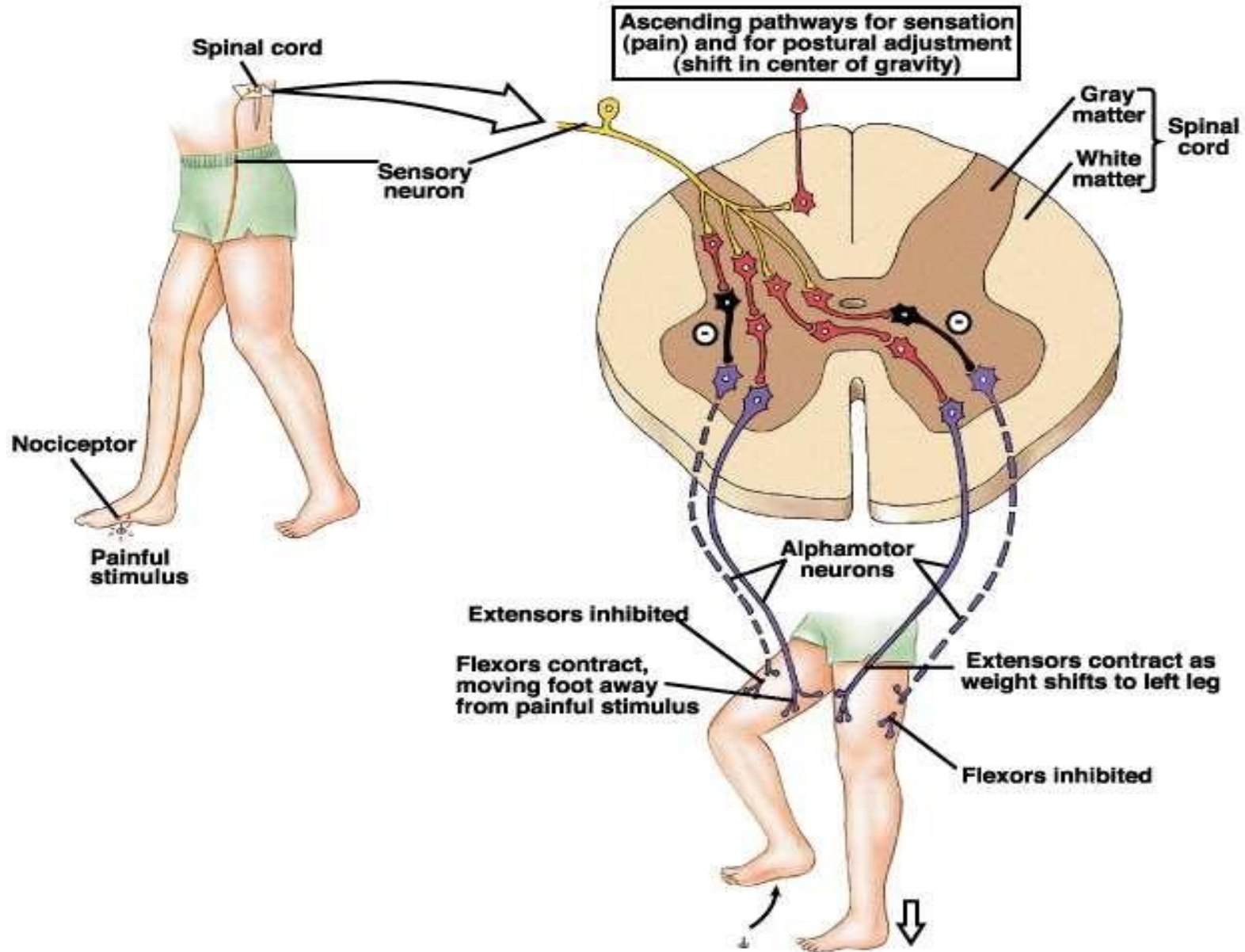
Do not forget the reciprocal inhibition!!



Stimulation of flexors.  
Inhibition of extensors.

Stimulation of extensors.  
Inhibition of flexors.

*We will discuss this concept further when we cover balance.*

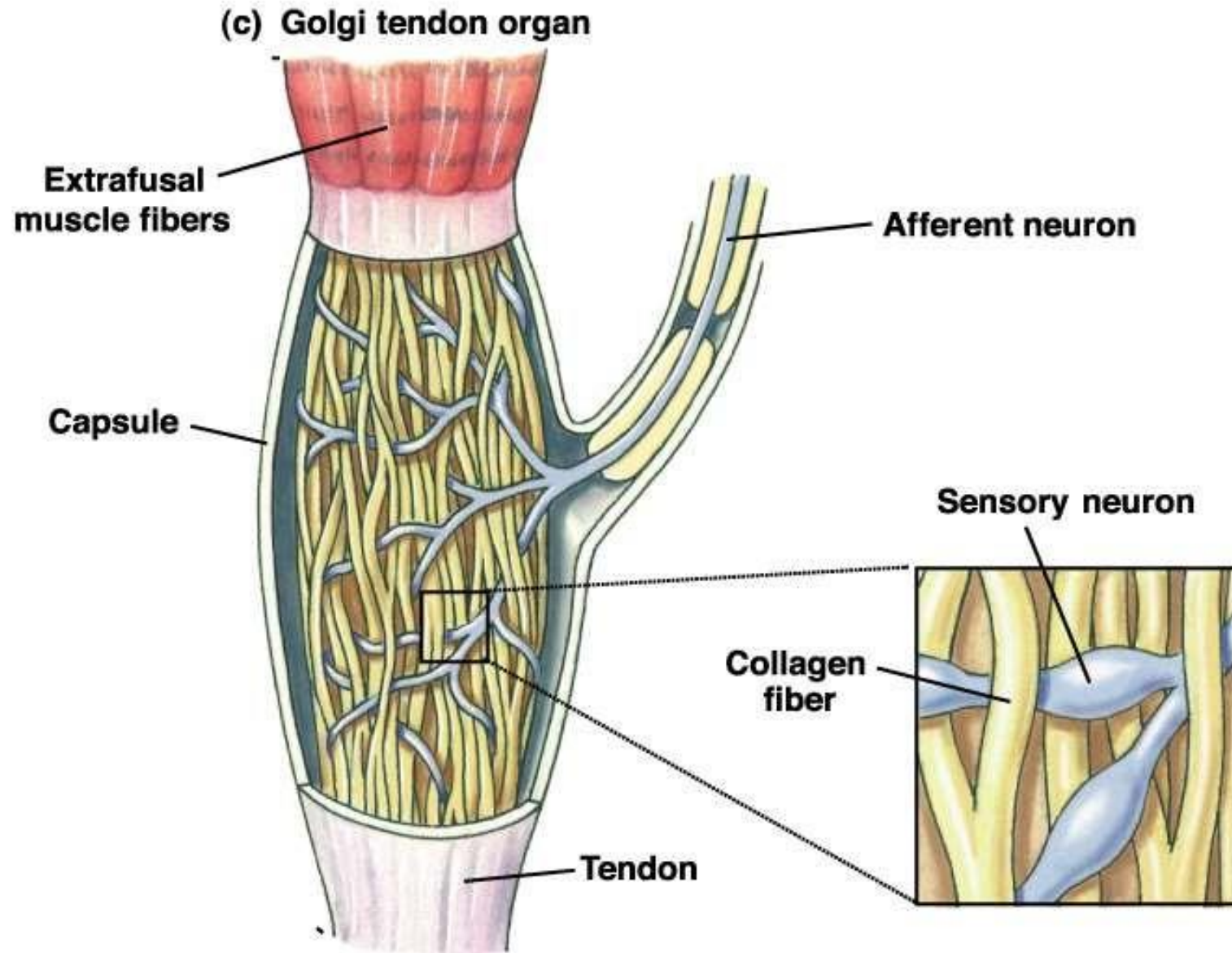


# Crossed Extensor Reflex

- ❖ Polysynaptic reflex.
- ❖ **Contralateral reflex.**
- ❖ Contraction of muscles that extend joints in the opposite limb in response to a painful stimulus.
- ❖ Stepping on a tack (stimulus) → nerve impulse → activation of several interneuron → activation of the motor neurons → muscle contraction causing flexion of the leg stepping on a tack & extension on the opposite side.
- ❖ There is **reciprocal inhibition** (i.e inhibition of antagonist group of muscles on the same side)

# Golgi Tendon Reflex

- Mediated by the golgi tendon organ receptor located in the tendon.
- This receptor responds to tension.
- When the tension becomes too great the reflex inhibits the motor fibers attached to the tendon.
- Function is to equalize force among muscle fibers. (Protective function)
- Has **both** dynamic and static parts.



# Transmission of Stretch Information to Higher Centers

- Muscle spindle and golgi tendon signals are transmitted to higher centers **through dorsal spinocerebellar tract**.
- This informs the brain of the tension and stretch of the muscle.
- Information is transmitted at 120 m/sec **by Ia fiber**.
- Important for feedback control of motor activity.

# The Withdrawal Reflexes

- A painful stimulus causes the limb to automatically withdraw from the stimulus.
- Neural pathways for reflex:
  - nociceptor activation transmitted to the spinal cord.
  - synapses with pool of interneurons that diverge to the muscles for withdrawal, inhibit antagonist muscles, and activate reverberating circuits to prolong muscle contraction.
  - duration of the afterdischarge depends on strength of the stimulus.

Neural pathway for the reflex can be used for other types of movements.

- **Afterdischarge:** This occurs due to a **prolonged receptor potential**. Although the initial stimulus usually lasts for 1 ms or less, it is preceded by a receptor potential that can last 15–20 ms. As a result, a single stimulus can generate a receptor potential that persists longer than the duration of the stimulus itself. If this receptor potential exceeds the threshold, it can trigger multiple action potentials in the neuron—potentially **up to 100 APs from a single stimulus**. Because the receptor potential lasts longer than the stimulus, this phenomenon is called afterdischarge.
- The extent of afterdischarge also depends on the **number of synapses involved**.

# Crossed Extensor Reflex

- Painful stimulus elicits a flexor reflex in affected limb and an extensor reflex in the opposite limb.
- Extensor reflex begins 0.2 - 0.5 milli seconds (**latent period: lag time**) after the painful stimulus.
- Serves to push body away from the stimulus, also to shift weight to the opposite limb.

The latent period of the extensor muscles is **longer** than that of the flexor muscles due to the **greater number** of synapses involved.

# Other Reflexes for Posture and Locomotion

- Pressure on the bottom of the feet cause **extensor reflex**.  
(Babinski reflex; positive in children).
  - more complex than flexor-crossed extensor reflex
- Basic walking reflexes reside in the spinal cord.

# Reflexes that Cause Muscle Spasm

- **Pain signals** can cause reflex activation and spasm of local muscles.
- **Inflammation** of peritoneum can cause abdominal muscle spasm.  
(Called abdominal emergencies)
- **Muscle cramps** caused by painful stimulus in muscle:
  - can be due to cold, ischemia, or overactivity (due to accumulation of lactic acid).
  - reflex contraction increases painful stimulus and causes more muscle contraction. (More ischemia causes more contractions)

# Myograms of flexor and crossed extensor reflexes

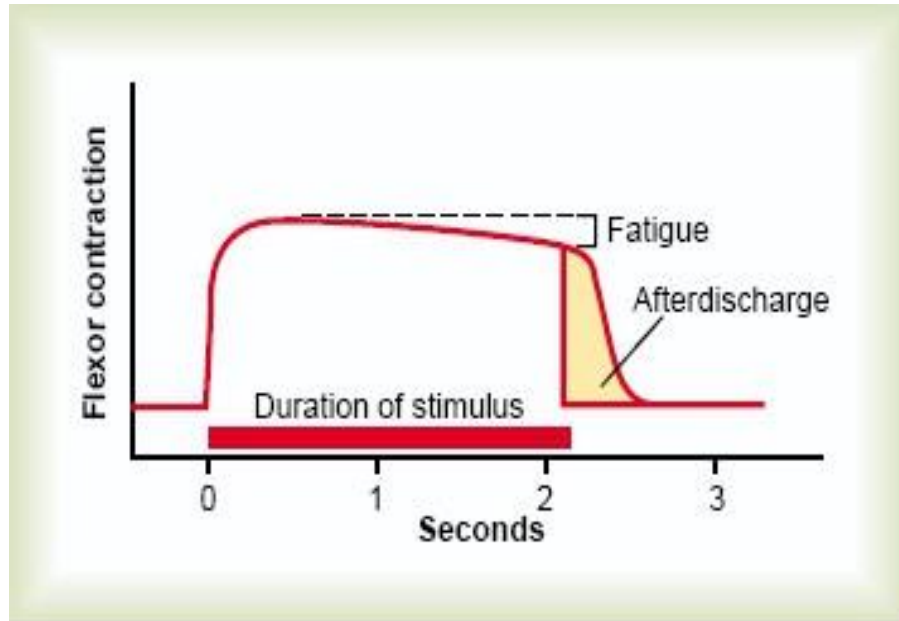


Figure 54-9

Myogram of the flexor reflex showing rapid onset of the reflex, an interval of fatigue, and, finally, afterdischarge after the input stimulus is over.

## The flexor reflex:

- Very *short* latent period.
- *Short* afterdischarge.
- *Less* synapses.

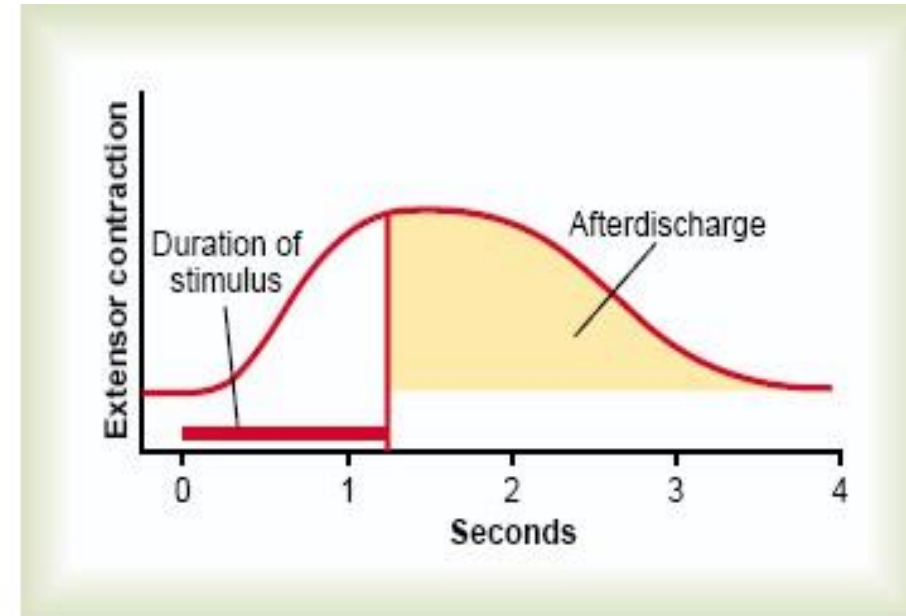


Figure 54-10

Myogram of a crossed extensor reflex showing slow onset but prolonged afterdischarge.

## The extensor reflex:

- *Longer* latency.
- Delayed onset.
- *Prolonged* afterdischarge.
- *More* synapses, resulting in multiple excitatory postsynaptic potentials (EPSPs).

# Spinal Shock

- Definition: Immediate temporary loss of total power and reflexes below the level of injury.
- Usually recover after 24 - 48 hours.
- Trauma causes a **concussion injury to the spinal cord**.
- **Reflexes** in the spinal cord below the level of injury are **lost (Areflexia)**.
- The shock in spinal shock does **not** refer to circulatory collapse.

# Phases of spinal shock

Phase	Time	Physical Exam Findings	Underlying Physiological Event
1	0-1 days	Areflexia	Loss of descending facilitation
2	1-3 days	Initial reflex return	Denervation susceptibility
3	1-4 weeks	Hyperreflexia	Axon-supported synapse growth
4	1-12 months	Hyperreflexia, spasticity	Soma-supported synapse growth

## Phase 1:

- ❑ Complete loss of all reflexes below the level of spinal cord injury.
- ❑ Spinal cord concussion caused the neurons involved in various reflex arcs and the neural input from the brain become hyperpolarized and unresponsive.

## Phase 2:

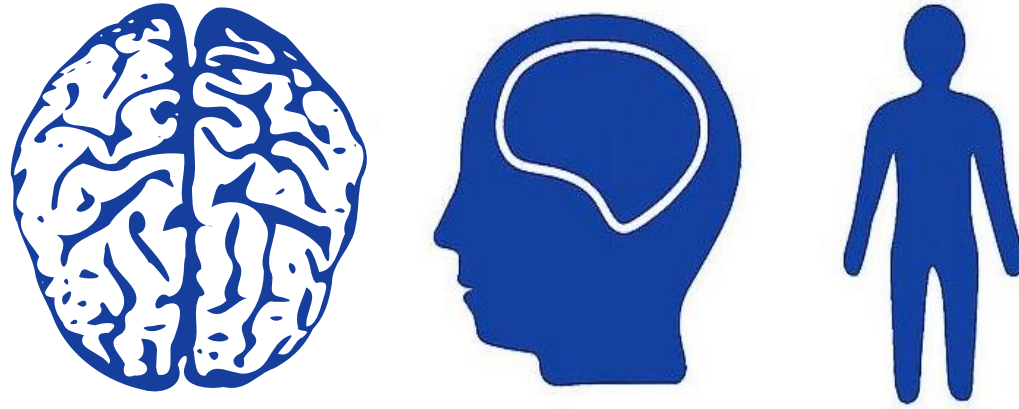
- ❑ The reason reflexes return is the hypersensitivity of reflex muscles following denervation; more receptors are expressed and therefore are easier to stimulate.

# Phase 3 and 4

- ❑ Characterized by hyperreflexia
- ❑ Neurons below the injury attempt to re-establish the synapses.

## Spinal shock Vs. Neurogenic shock

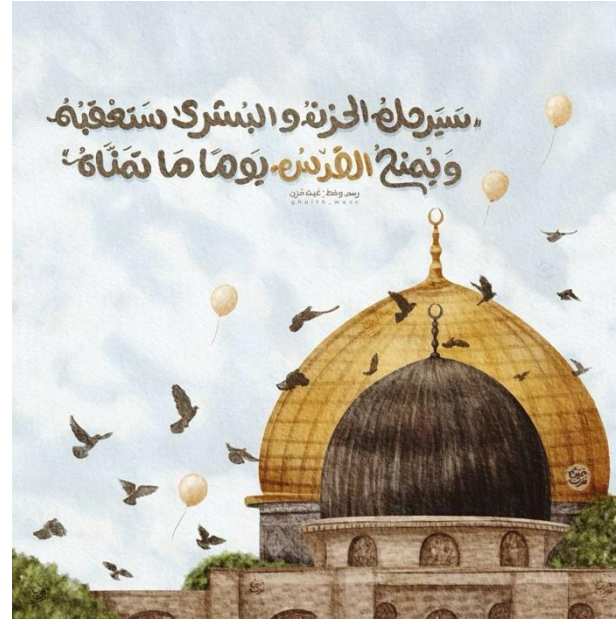
	Spinal shock	Neurogenic shock
Definition		
BP	Hypotension	Hypotension
Pulse	Bradycardia	Bradycardia
Motor	Flaccid paralysis	Variable
Mechanism	Peripheral neurons become unresponsive to brain stimuli	Disruption of autonomic pathways causes loss of sympathetic pathways and vasodilation



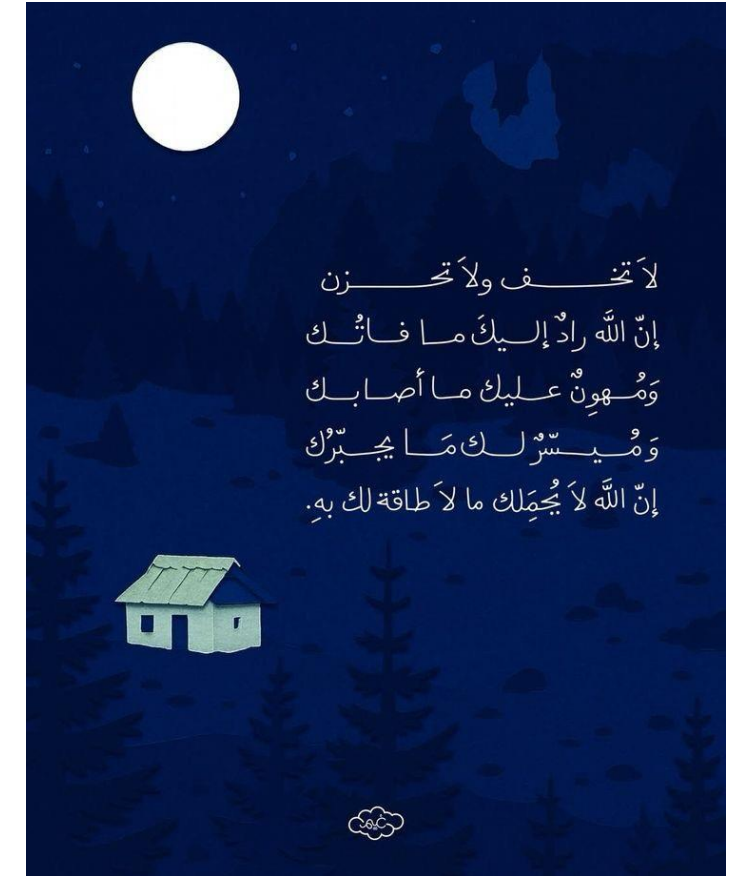
**PHYSIOLOGY  
QUIZ  
LECTURE 5**

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