



**Physiology Team**



# Lecture : 2

Spinal Cord Functions & Spinal Reflexes

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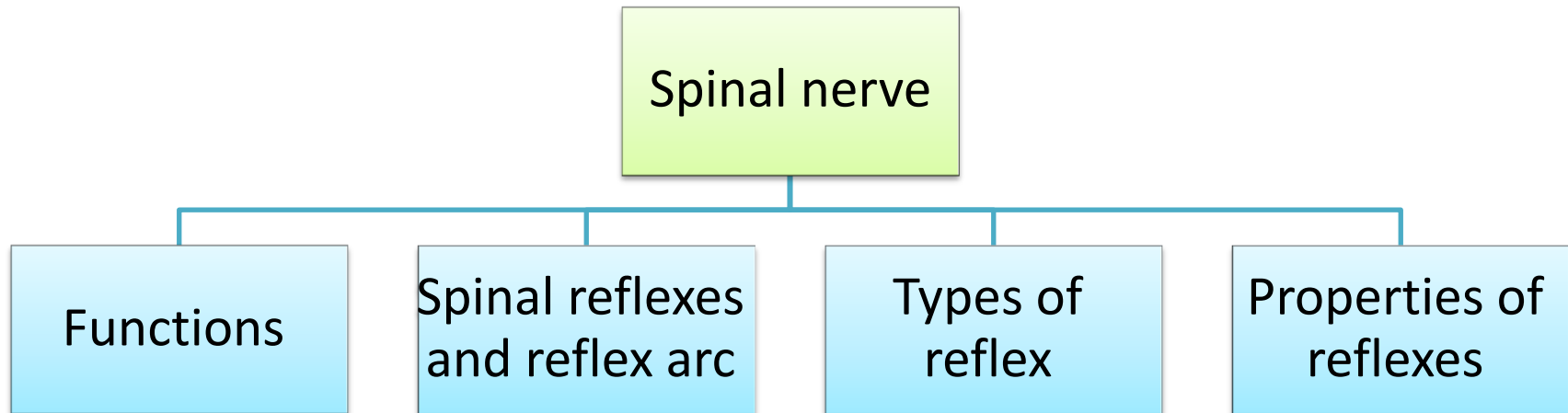
**Reviewed By: Mohammed Jameel**

# OBJECTIVES

**At the end of this lecture, student should be able to describe:**

- ❖ Describe **the functions** of spinal cord .
- ❖ Understand **the physiological role** of the spinal cord as a pathway for tracts.
- ❖ Explain functional role of **tracts** pass in spinal cord .
- ❖ Describe the definition of a **spinal reflex** and **reflex arc components** .
- ❖ Describe the most important types of spinal cord reflexes as **withdrawal reflex** & **crossed extensor reflex** .
- ❖ Describe properties of spinal cord reflexes as **irradiation**, **recruitment** , **synaptic delay** and **after discharge** .

# MIND MAP



■ Slides

■ Important

■ Doctor's Notes

■ Explanation

■ Boy's Slides

# Spinal Nerves

Spinal Nerves : ❖ The spinal cord has **31 pairs** of spinal nerves  
(• 8 cervical / • 12 thoracic / • 5 lumbar / • 5 sacral / • 1 coccygeal )

❖ Each spinal nerve has:

Afferent fibers

- Carrying **Sensory information** from receptor of skin , muscles and joints to the CNS .

Efferent fibers

- Carrying **Motor commands** from CNS to muscles .

❖ The spinal cord has:

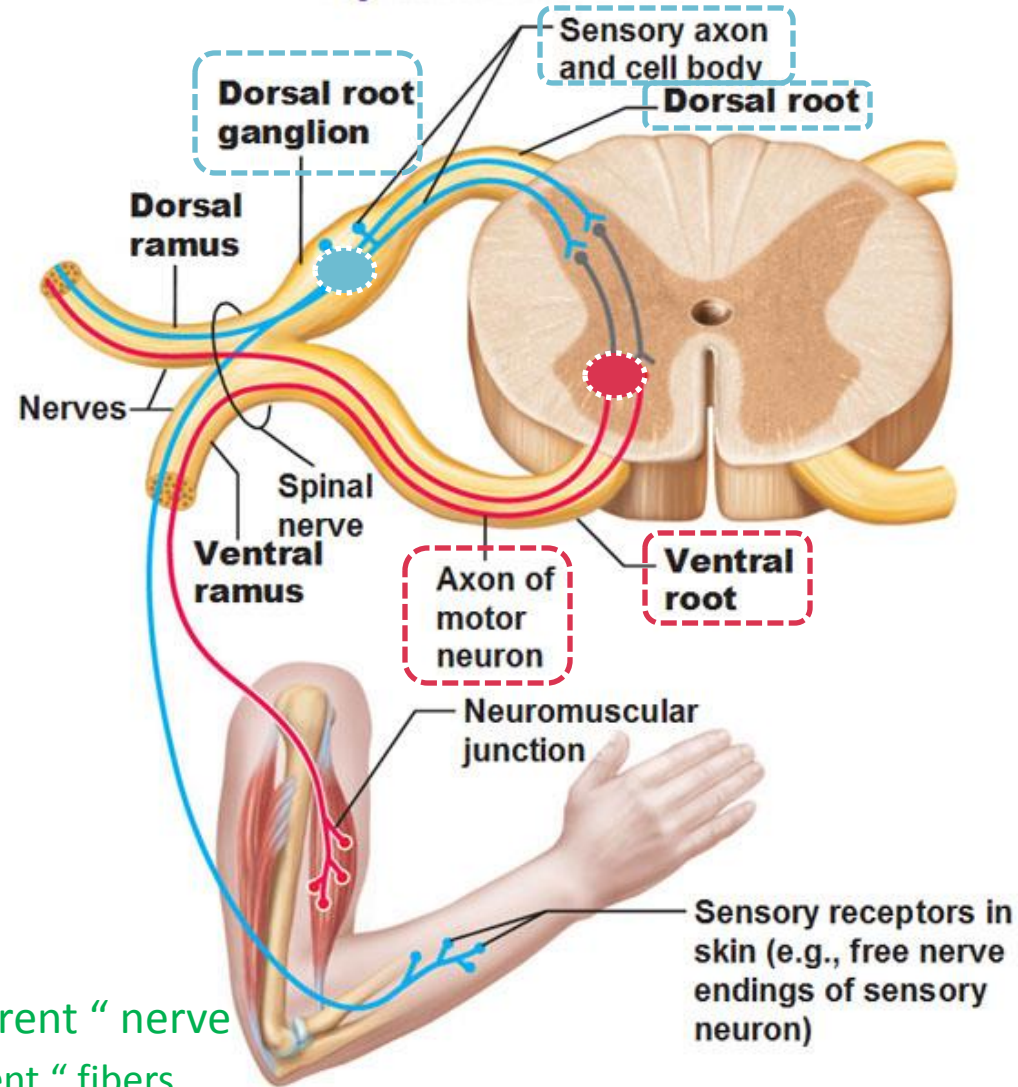
## The Dorsal (Posterior) root

- Contains **Afferent (Sensory)** nerves coming from receptors .
- The cell body of these neurons located in **dorsal posterior root ganglion (DGR)** .

## The ventral (Anterior) root

- Carries **Efferent (Motor)** fibers
- The cell body is located in **the ventral (anterior) horn** of spinal cord .

# Spinal Nerves



## Keys :

 Afferent fibers

 Efferent fibers

 The cell body of Efferent fibers

 The cell body of Afferent fibers

\* Ganglion just in Sensory “ Afferent “ nerve  
 There is **no** ganglion in motor “ Efferent “ fibers

# Functions of spinal cord

**Executing brain motor commands**  
 “Descending motor tracts ➤ spinal efferent motor nerves ➤ skeletal muscles “

**Carrying sensory information**  
 “ Receptor ➤ Spinal afferent sensory nerves ➤ ascending sensory tracts ➤ Brain “

**Generating Spinal Reflexes**

Carrying tracts Reaching Conscious  
 Brain Level “ **cerebral cortex** “

- 1- **Dorsal Column Tracts** ( Gracile & Cuneate )  
 Fine discriminative touch , vibration , position senses , proprioception & stereognosis
- 2- **Lateral Spinothalamic Tract**  
 for pain and temperature .
- 3- **Anterior Spinothalamic Tract**  
 for crude touch , pressure .

Carrying tracts Not reaching Conscious  
 Brain Level “ subconscious level “

- 1- **Spinocerebellar Tracts** carry fibers to cerebellum for proprioceptive information ( sense of joint position & movements) for **posture control & coordination of movement**

Fine discrimination = اللمس الدقيق  
 Crude touch = الاهتزاز / اللمس الغير دقيق كالقطنه  
 Proprioception = الاحساس بأماكن الجسم بالنسبة لبعضها البعض  
 stereognosis = التعرف على شيء عن طريق حاسة اللمس

# Spinal reflexes and Reflex arc

**What is a reflex?** = Functional unit of CNS -automatic ,involuntary response to a stimulus ( **Doesn't reach conscious level** ) ...

e.g : pinprick causes withdrawal. انسحاب القدم لا إراديا وبسرعة عند المشي على الإبرة

**Reflex Arc :** ( **the pathway of reflex** ) .The **basic unit** of a reflex is the **reflex arc**

\* It is the pathway of **Sensory information** to spinal cord to cause spinal reflex, it is formed of :

1-Sense organ (**receptor**).



2-An **afferent sensory neuron**.



3- Center/ending of the afferent sensory neuron within the spinal cord on one or more synapses (interneurons “ **in gray matter** “ in S.C located in one or more spinal cord segments ).

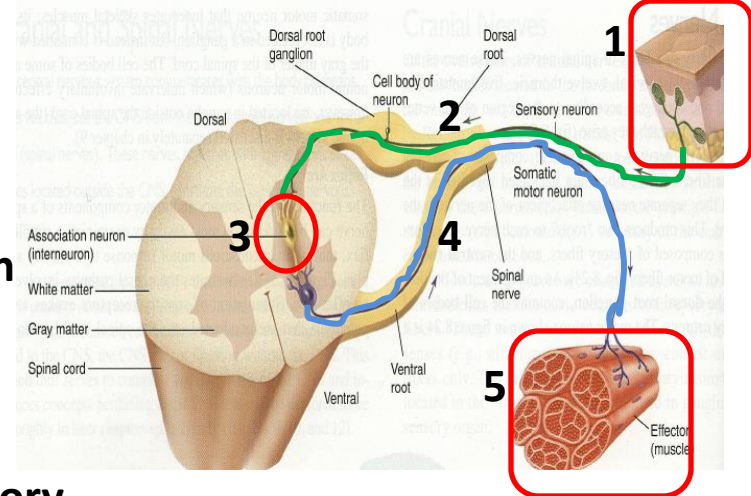
- Such interneurons can be excitatory or inhibitory .



4-An **efferent somatic motor neuron** ( **ventral horn = anterior horn cells** ) .



5-An **effector organ** ( skeletal muscle).



# Components of reflex arc

## Afferent neuron

Sensory afferent enter spinal cord via dorsal (posterior) root, ends at **same segment** or **ascend to higher segments**

Afferent neurons undergo :

- 1- **Divergence** to help to spread a single stimulus to a wide area of the spinal cord,
- 2- **Convergence** to help the process of spatial summation .(multiple stimuli summate & collect together at the same time “ **concentration of information=strong response** “)

## Interneurons

are small cells in grey matter of spinal cord **connecting afferent to efferent** (excitatory or inhibitory).

Two types of circuits formed by inter neurons

- 1- **parallel**: **afferent & efferent are parallel** .
- 2- **reverberating circuits** : Impulse from one neuron feed back to re-stimulate itself for long time as the fibers turn back on the same neurons  
-What is its Value? Prolong discharge of same neuron by single stimulation .

## Efferent neuron

-Anterior Horn Cells (Motor neurons) of spinal cord supplying skeletal muscle:

1. **alpha motor neurons** :- **large cells**, with large **myelinated fibers** (axons) form **70%** of ventral root – supply **Extrafusal muscle fibers**
2. **Gamma motor neurons** :- **smaller cells**- with small axons form **30 %** of ventral root – supply **intrafusal ms fibers = muscle spindle**



## The Alpha Motoneurons are called:- **the Final Common Pathway** “ final station that gave us the final discharge “

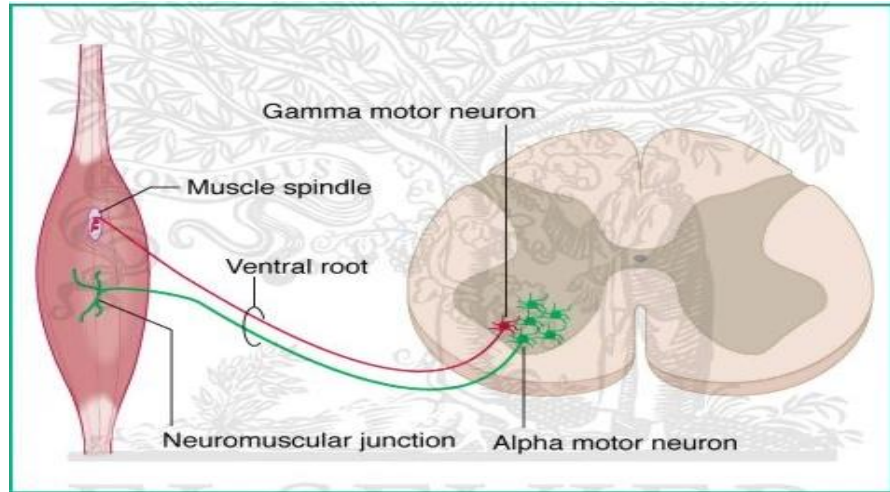
-inputs come from spinal & superspinal centers converge on them( up to 10000 synapses can be present on one alpha motorneuron )

They receive signals from:

1-excitatory and inhibitory signals from **same segment of S.C**

2-excitatory and inhibitory signals from **other segments of S.C**

3-supraspinal descending tracts from **brainstem** and **cerebral cortex**



\* all these signals are integrated **at the Alpha Motoneurons** then they send integrated activity to muscles to adjust: **posture , voluntary activity & coordinate actions of muscle.**

-What is Motor Unit ? = **motor neuron + the group of skeletal muscle fibers it controls**

# Types of reflexes

According to **number** of neurons:-

## Monosynaptic

Sensory axon (afferent) synapse **directly** with anterior horn cell- Ex. **Stretch reflex**  
 “Directly with alpha motor neurons , there are no interneurons” It is produced by co-activation of alpha & gamma motorneurons

## Polysynaptic

Sensory axon (afferent) synapse with **one or more interneuron**  
 Ex. **Withdrawal** - **abdominal reflexes** - **visceral**

-According to **site** of the receptor:-

### (A) Deep Reflexes

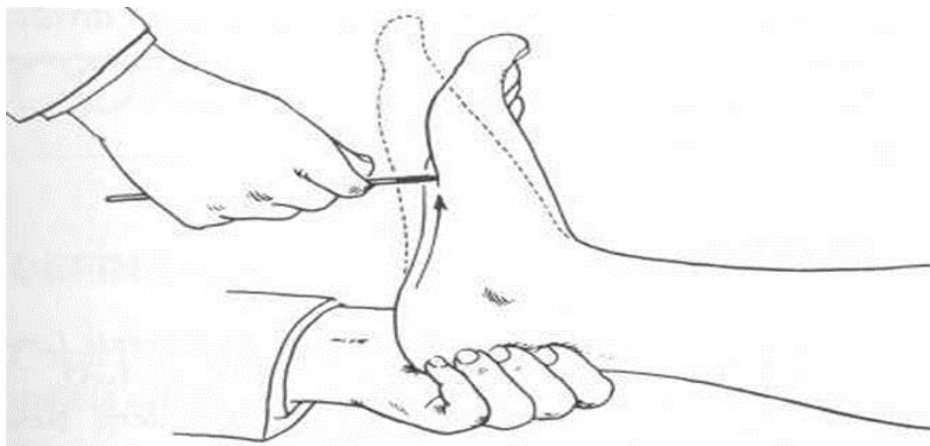
(1) **Stretch Reflexes (Tendon jerks)** “not in tendon! In muscle” ,they are *monosynaptic* : such as knee-jerk ( patellar reflex ) and ankle jerk . The receptor for all these is **the muscle spindle** “is located deep within **the muscle itself**”  
 (2) **Inverse Stretch Reflex ( Golgi Tendon organ reflex )** , *polysynaptic* : The receptor is called Golgi Tendon Organ present deep in the **muscle tendon**

### B) Superficial Reflexes

**polysynaptic reflexes** . The receptor are **superficial in the skin** .  
 Examples are :  
 -Withdrawal  
 -abdominal reflexes  
 -plantar reflex

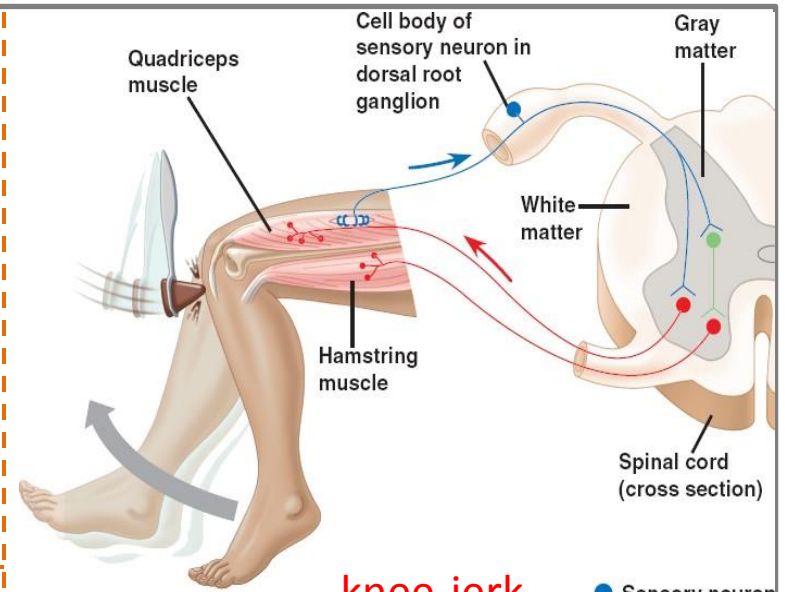
### C) Visceral

by stimulation of receptors in wall of **viscera** As :  
**Micturition, defecation**



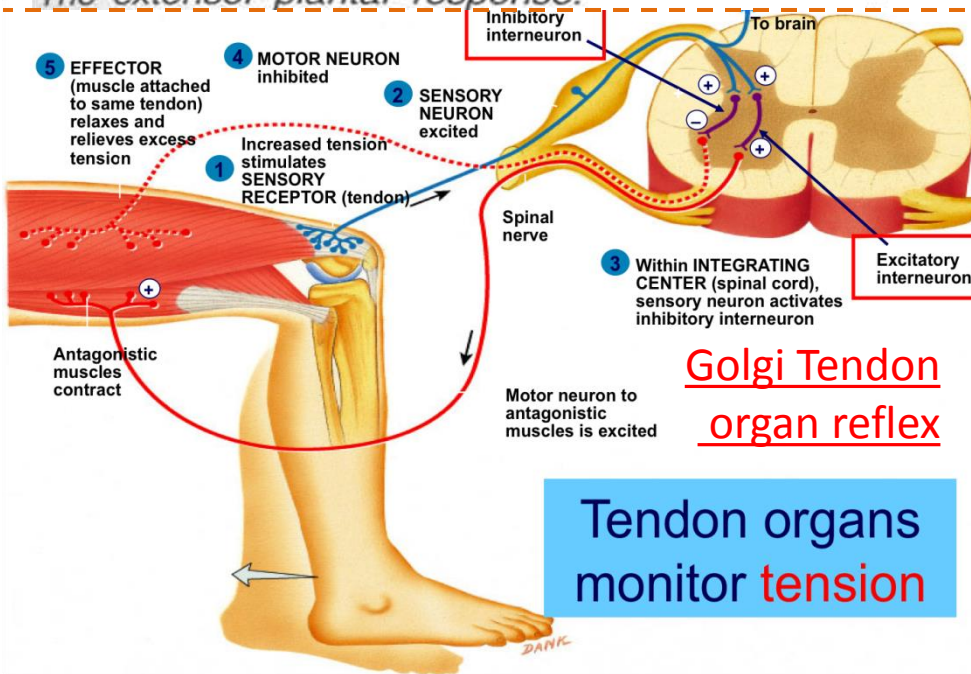
**Figure 1-35**  
*The extensor plantar response.*

plantar reflex

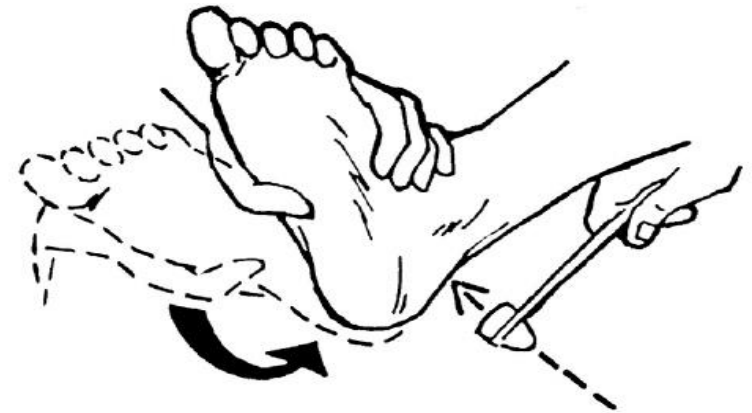


knee-jerk

- Sensory neuron
- Motor neuron
- Interneuron



ankle jerk



■ Slides

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# Withdrawal reflex

Properties of reflexes : 1-Reciprocal inhibition 2-Irradiation  
3-Recruitment 4-After discharge 5-central delay & reflex time

Withdrawal reflex(flexor reflex): -A **superficial-polysynaptic-spinal** reflex .

Stimulation of **pain** receptors of hand

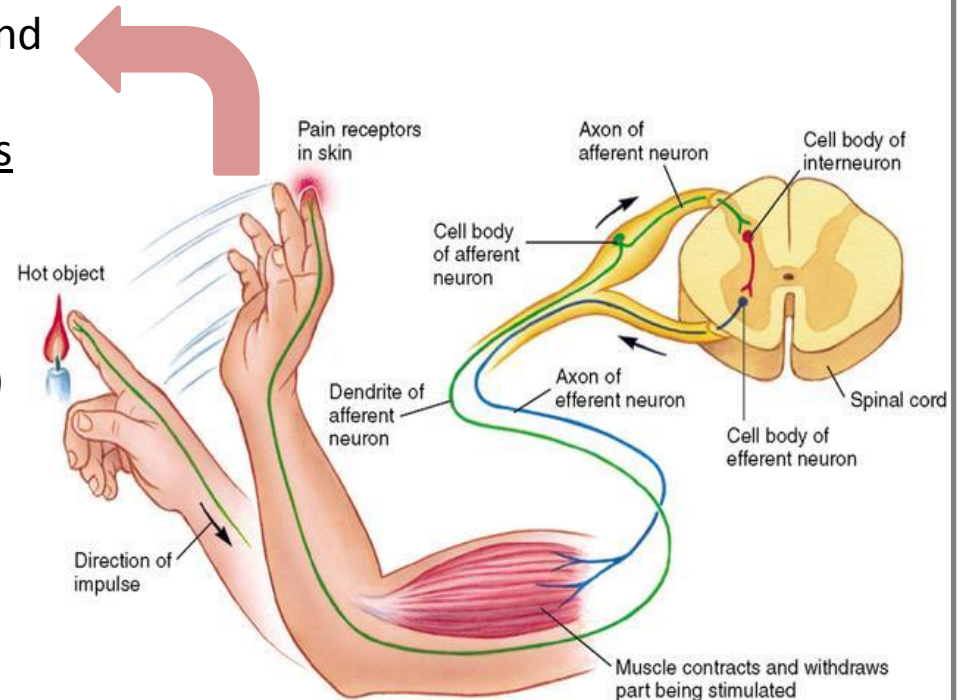
↓  
impulses to SC in A delta or C fibers  
( types of sensory afferent that varies according to pain type )

↓  
interneurons ( =polysynaptic) )

↓  
anterior horn cells

↓  
stimulate hand flexor muscles

↓  
move the hand away from the injurious stimulus.



# Withdrawal reflex

characterized by :\_

## 1-Reciprocal inhibition or reciprocal innervation)

stimulation of **flexors muscle** accompanied by **inhibition of extensor through inhibitory interneurons**

“Reflex contraction of an agonist muscle is accompanied by inhibition of the antagonist”

## 2- Crossed extensor reflex

Flexion and withdrawal of the stimulated limb > extension of the opposite limb ( to become a supporter )  
occurs with **strong stimulus**,  
Because it depends on the **intensity of stimulus** .

-**Reciprocal innervations** occurs also in crossed extensor reflex. (**excitation of flexors accompanied with inhibition of extensors**)  
it is an **Antigravity Reflex**

## 3- IRRADIATION

**spread of impulses up & down to different segments and motor neurons in the S.C**

A **strong stimulus** in sensory afferent irradiate to many segments of S.C due to **divergence** .

The extent of the response in a reflex depends on the intensity of the stimulus.

-Weak stim- weak flexion of limb  
- Strong stim-withdrawal of affected limb & extension of opposite limb.  
(as in crossed extensor reflex)

# Withdrawal reflex

characterized by :\_

## 4- RECRUITMENT

Gradual activation "by **single stimulus**" of more number of motor neurons (AHCs) on stim of afferent nerve in a reflex arc by maintained, repetitive stimulus

**Cause** / 1-different **conduction velocities of afferents**  
2-different **number of interneurons** with short & long pathways to the motor neurons (AHCs)

(impulses **do not** reach AHCs at **same time** but reach them **gradually**, so maintained stimulation allow more neurons to be stimulated )

## 5- After-discharge

It means **prolonged discharge of AHCs after stoppage of afferent stimulation**. "**neurons continue to sent impulses**" (this cause maintained reflex action & response continue for some time after cessation of stimulus )

cause by: reverberating circuits

Value : prolong the response

مثال : قرص بعض الحشرات يستمر تأثيره لفترة . "itching"

## 6- Central delay

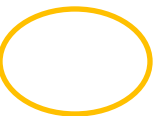
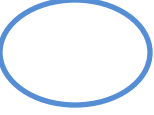
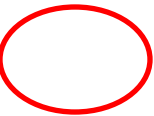

"**center=interneurons**" :  
**time of reflex to pass through neurons of CNS(S.C)**  
-equals **0.5 ms/synapse**  
(SO it is long in polysynaptic R)  
-> **2 ms** in the **withdrawal R**

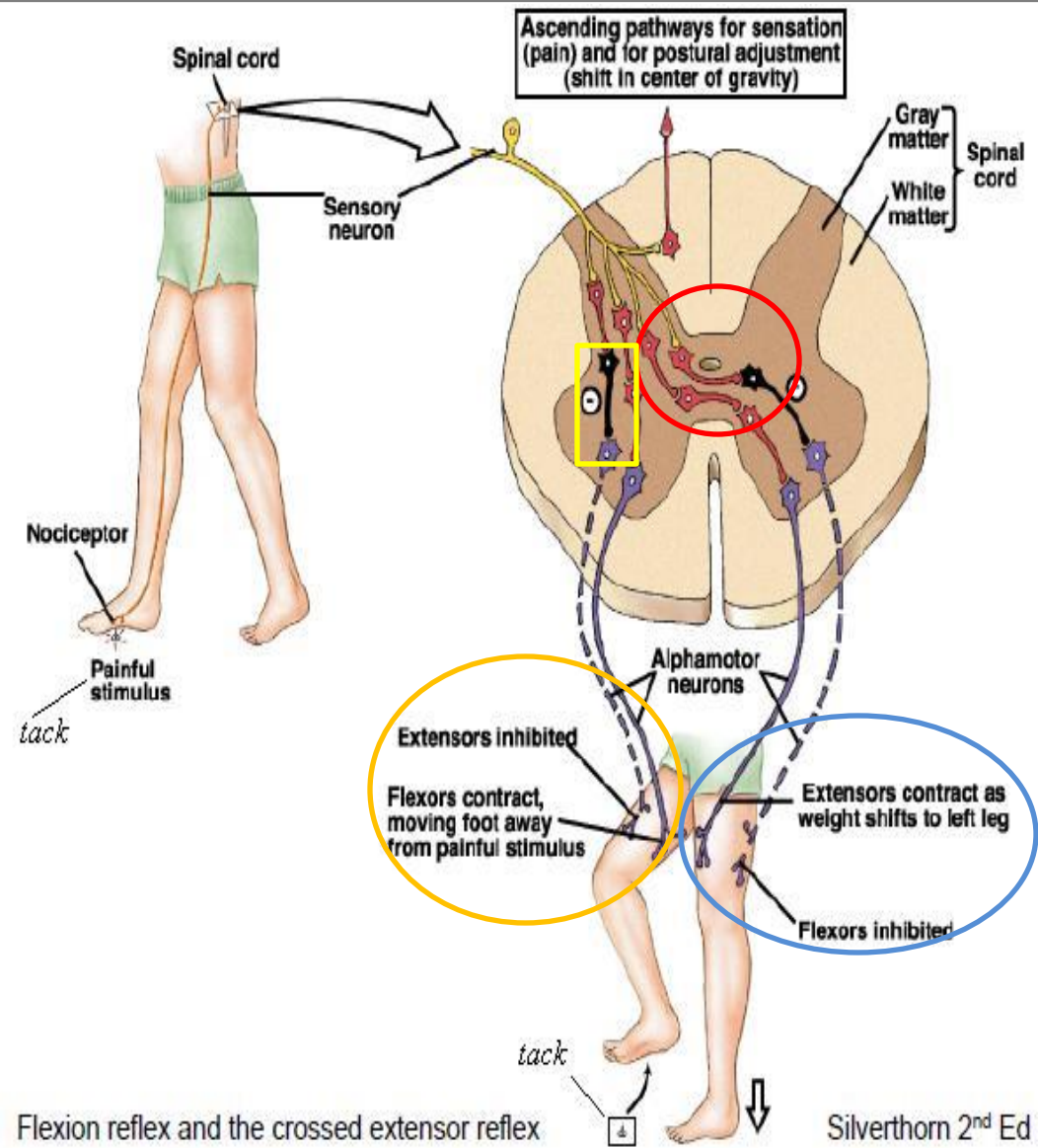
\*\*If it was *20 ms* , how many neurons/synapses passed ?  
=20/0.5 = 4

-**Number of synapses= central delay /0.5ms**

-**Reflex Time =**

**Central Delay + Time spent in conduction of impulses along the afferent and efferent nerves**

-  Reciprocal inhibition
-  Crossed extensor reflex
-  Irradiation
-  Central delay



# SUMMARY

- ❖ The spinal nerve has **afferent “sensory”** & **efferent “motor”** fibers .
  - ❖ S.C has 3 functions: **execution motor command/carrying sensory info/generating spinal reflexes** .
  - ❖ **Reflex** is functional unit of CNS, automatic ,involuntary response to a stimulus .
  - ❖ **Reflex arc** is the basic unit of a reflex “ pathway “ **its component** : **Afferent n** ( Difergence & convergance) **interneurons** (parallel-reverberating circuits) -**efferent n** (Alpha & gamma m.n)
  - ❖ Types of reflexes \***number of n**\* : **Monosynaptic&Polysynaptic** .. \*Site\*: **Deep R/Superficial R /Visceral**
  - ❖ Deep R : **Knee-jerk & Ankle jerk** \***monosynaptic (in muscle spindle)** --- **Golgi T.O.R** \***polysynaptic (muscle tone)**
  - ❖ Properties of reflexes : **1-Reciprocal inhibition \* flexor ms & inhibition of extensor\***  
**2-Irradiation \*strong stim \*** **3-Recruitment \*gradual activation of motor neurons\***  
**4-After discharge \*prolong discharge after stoppage of afferent stim \***  
**5-central delay \* 0.5 ms/synapse \* ...**
- Reflex time** = **central delay + afferent & efferent time** .

Reflex arc – 3D video

<https://www.youtube.com/watch?v=wLrhYzdbbpE>

**Take a look !**

Very helpful website contain many tests for some physiology and anatomy lectures .

[http://highered.mcgraw-](http://highered.mcgraw-hill.com/sites/0072351136/student_view0/chapter12/chapter_quiz.html)

[hill.com/sites/0072351136/student\\_view0/chapter12/chapter\\_quiz.html](http://highered.mcgraw-hill.com/sites/0072351136/student_view0/chapter12/chapter_quiz.html)

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# QUESTIONS

1/B – 2/B – 3/C -4/D -5/D

**1-Which of the following reflexes inhibits skeletal muscle contraction :**

- A- stretch reflex .
- B- Golgi tendon reflex .
- C- crossed extensor reflex.
- D- withdrawal reflex .

**2-Inhibitory interneurons are involved in Which of the following spinal reflexes :**

- A- knee-jerk reflex.
- B- Golgi tendon reflex .
- C- stretch reflex .
- D- withdrawal reflex .

**3-You are walking bare foot and step on a tack with your right foot. All of the following will occur EXCEPT :**

- A- flexor muscles in your right thigh and leg contract to remove your foot
- B- reciprocal innervation inhibits extensor muscles in the same limb
- C- collaterals of sensory neurons stimulate alpha motor neurons that cause extension in the opposite limb
- D- collaterals of interneurons stimulate a crossed extensor reflex

**4-Excitatory interneurons are involved in Which of the following spinal reflexes :**

- A- knee-jerk reflex.
- B- Golgi tendon reflex .
- C- stretch reflex .
- D- withdrawal reflex .

**5- The reflex arc contains a**

- A- sensory reception
- B- sensory neuron
- C- motor neuron
- D- All of the above.

## 6-Stretch reflexes :

- A) cause muscles to contract in response to a stretching force being applied to them.
- B) involve a sensory receptor (muscle spindle).
- C) involve sensory neurons that directly synapse with motor neurons in the spinal cord.
- D) help maintain posture.
- E) all of the above

## 7-The withdrawal reflex :

- A) includes the Golgi tendon organs.
- B) includes the synapse of sensory neurons directly with alpha motor neurons.
- C) helps to protect the body from painful stimuli.
- D) is a response to increased tension at a tendon.
- E) all of the above

## 8-The Golgi tendon reflex :

- A) involves the synapse of sensory neurons from the Golgi tendon organs with stimulating interneurons at the spinal cord.
- B) prevents contracting muscles from applying excessive tension to tendons.
- C) involves the stimulation of alpha neurons leading back to the muscles that are stretching tendons.
- D) results in increased tension at tendons.

**THE END**

**If there are any Problems or Suggestions,  
Feel free to contact:**

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**THANK YOU**