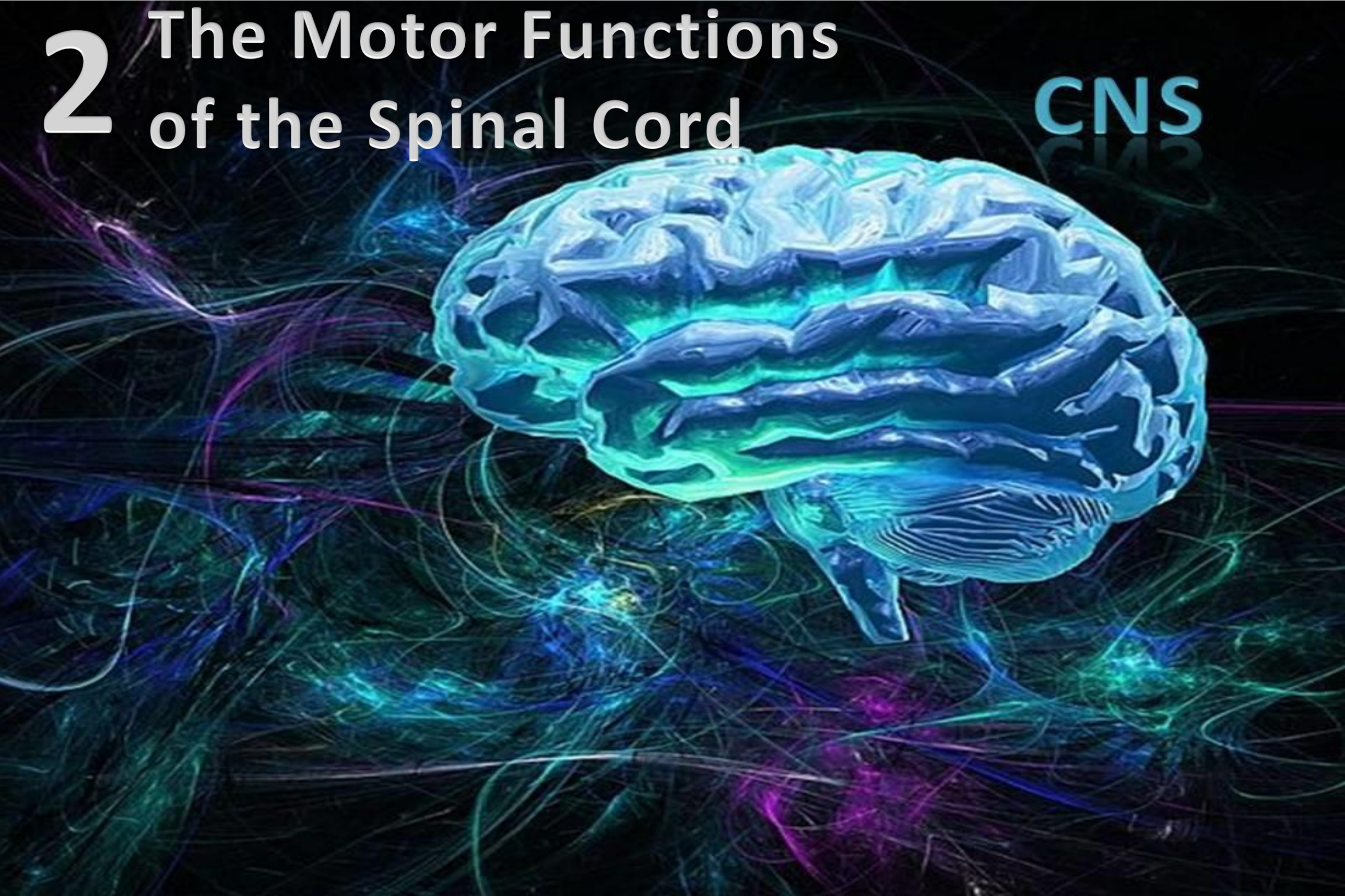
# 2 The Motor Functions of the Spinal Cord



# Objectives

(1) Describe the functions of spinal cord
(2) Understand the physiological role of the spinal cord as a  pathway for tracts.
(3) Explain functional role of tracts pass in spinal cord
(4) Describe the definition of a spinal reflex and reflex arc components
(5) Describe the most important types of spinal cord
reflexes as withdrawal reflex & crossed extensor reflex
(6) Describe properties of spinal cord reflexes as irradiation,
recruitment ,synaptic delay and after discharge

# Abbreviations

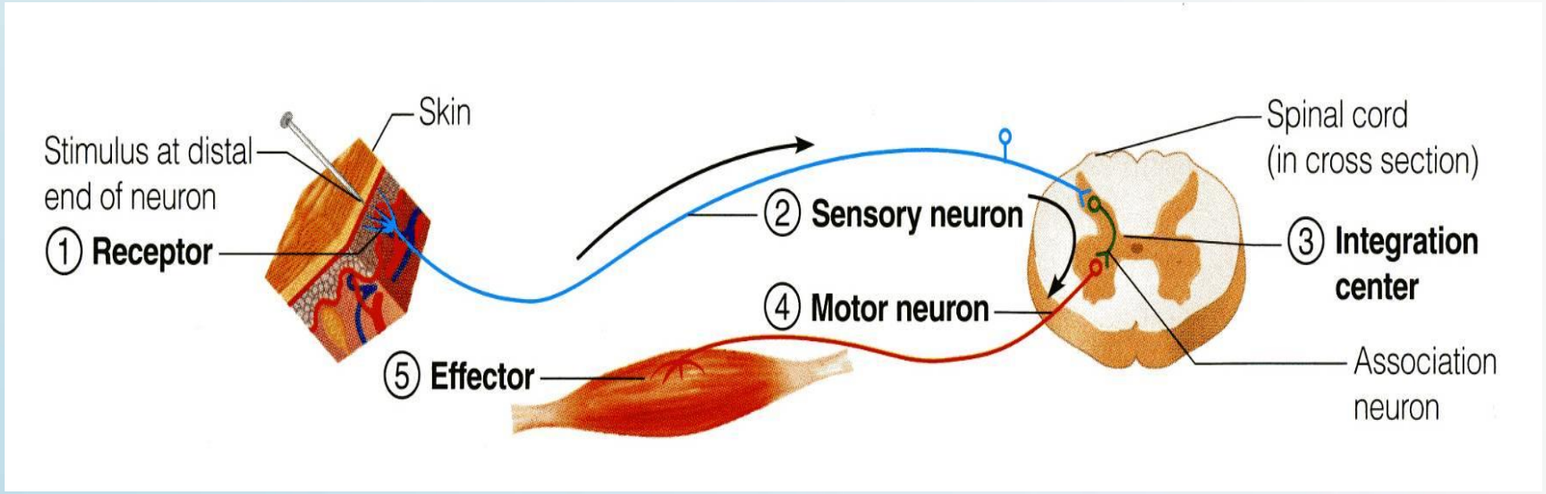
Upper motor neuron ( UMN)
Lower motor neuron (LMN)
Dorsal root ganglion (DRG)
Anterior horn cells (AHCs)
Spinal cord (S.C)

# Functions of the Spinal Cord

(1) Carrying sensory information **from the receptors** **to the brain**
( via spinal afferent/sensory nerves & ascending/sensory tracts )

(2) Executing brain motor commands "Carrying information **from CNS** **to effector organs**"
( via descending/motor tracts & spinal efferent/motor nerves)

(3) **Spinal Reflexes** : Spinal centers serve to receive incoming sensory information , integrate it and respond to it by pre-programmed spinal reflexes .




As you can see here, in the spinal reflex the impulse does not reach the brain to make the decisions.
I.E; its like when you put your hands on fire automatically you will remove your hand so the whole process will happen in the spinal cord without reaching the brain .

## Location of cell bodies and nerves

- **The dorsal root** contains **afferent (sensory) nerves**

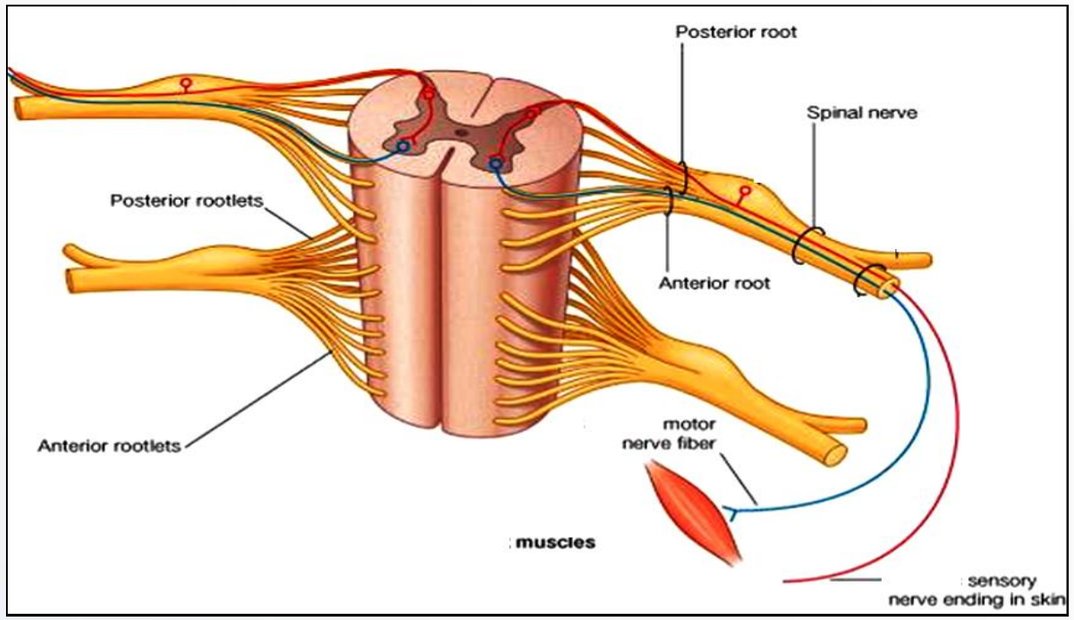
And **The cell body** of these sensory neurons

is located in **dorsal root ganglion ( DRG)**

- **The ventral root** carries **efferent (motor) fibers**

And **The cell body of** these motor fibers (AHC, LMN)

is located in **the anterior horn of the spinal cord .**




## Types of Muscle Fibers

| Extrafusal fibers | Intrafusal fibers |
|---|---|
| Are the contractile units of the muscle , which constitute the muscle bulk | Are tiny microscopic fibers |
| responsible **for the actual shortening and force generation by the muscle** | Present within **the muscle spindle ( the muscle length detector** ) |
| Innervated by **Alpha motor neurons .** | Innervated by **Gamma motor neurons** |

## Spinal Reflex

It is **automatic ,involuntary response** to a stimulus

## Reflex Arc

It is **the basic unit of a reflex** which is **the pathway of Sensory information to spinal cord to cause spinal reflex**

## Components of Reflex Arc

(1) **Sense organ** (receptor)

(2) **Afferent** ( sensory ) neuron. **"Which undergo to Divergence and Convergence"**

(3) **Interneurons** which are small cells in grey matter of spinal **cord connecting afferent to efferent**

*** (Two types circuits formed by inter neurons (parallel and reverberating circuits).**

* Such **interneurons** can be **excitatory or inhibitory .**

(4) **Efferent** ( Motor ) neuron , in the anterior horn of spinal cord → Hence the spinal motor neuron ( or homologous cranial nerve motor neuron ) is called **Anterior Horn Cell** (AHC) or **Lower Motor Neuron** ( LMN)

(5) **Effector organs**

## Types of AHC :

(1) **Large cells 70% of ventral root** , called Alpha motor neurons → **supply extrafusal fibers**

Also called Lower Motor Neuron ( LMN)

(2**) Small cells 30% of ventral root** , called Gamma motor neurons → **supply intrafusal fibers**

## Inputs to the AHC ( LMN)

**(the pulses that came to the LMN to distributed to the body)**

3 sources of Inputs to AHC:

(1) Primary Afferent ( sensory ) neurons

(2) Spinal interneurons

(3) Upper motor neurons ( UMN) , **( from Brain )**

## Final Common Pathway

It is the Alpha motor neuron, all spinal & supraspinal influences converge on the AHC

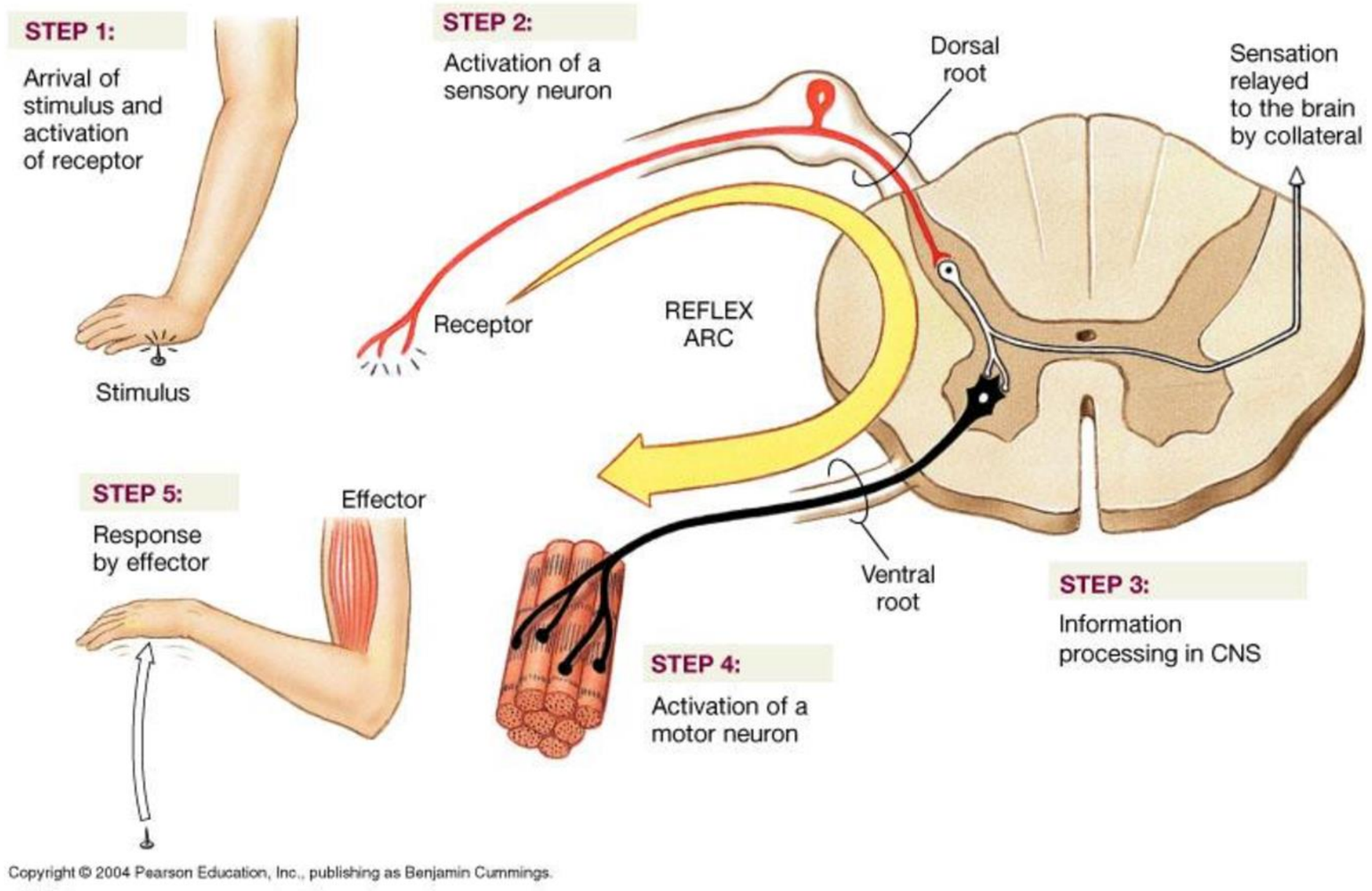
→ **up to 10000 synapses** can be present on **one alpha motor neuron**

## Motor Unit

Motor unit composed of :

**(1) Alpha Motor neuron ( LMN) (2) All muscle fibers it innervates**

# Review of reflex arc.




As you can see here, the impulse doesn't go up to the brain in the condition of Reflex Arc, in the example there is no time to think if you should remove your hand away from the pain because if there was a time to think you would get hurt before making a decision .

## Classification of Reflexes According to the Number of Synapses Present in the Reflex Arc:-

### (1) Monosynaptic Reflexes:

Simple reflex that consist of one synapse, therefor they **don't contain interneurons**

**Example: Stretch Reflex**

### (2) Polysynaptic Reflexes:

Have more than one synapse, therefore **they have interneurons** between the afferent nerve and AHC.

**Examples: Withdrawal reflex, Abdominal reflexes and Planter response.**

## Classification of Reflexes According to the Location of the Receptor

### (A) Superficial Reflexes:

Are **polysynaptic reflexes** . The receptor is in the skin .

**Examples : Withdrawal reflex, abdominal reflexes and plantar reflex.**

### (B) Deep reflexes:

The receptor is located in **muscle or tendon**

### (C) Visceral

by stimulation of receptors in wall of viscera

**Examples: Micturition, defecation**

# Examples of Superficial Reflexes

## (1) Withdrawal reflex (flexor reflex/response )

**A superficial-polysynaptic-spinal reflex .**

Stimulation of pain receptors of hand then → impulses to SC In **A Delta** or **C Fibers** ( types of sensory afferent that varies according to pain type ) → Interneurons → Anterior horn cells → Stimulate hand flexor muscles move the hand away from the injurious stimulus

**Stimulation of flexors muscle** accompanied by **inhibition of extensors** via inhibitory interneurons. This called **Reciprocal Inhibition,** based on Reciprocal Innervation

## (2) Crossed extensor reflex (Antigravity 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** .

The later response is called **Crossed Extensor Reflex :**

(1) Pushing the entire body away from the injurious agent

(2) supporting the body weight against injurious agent and gravity → it is called **Antigravity Reflex**

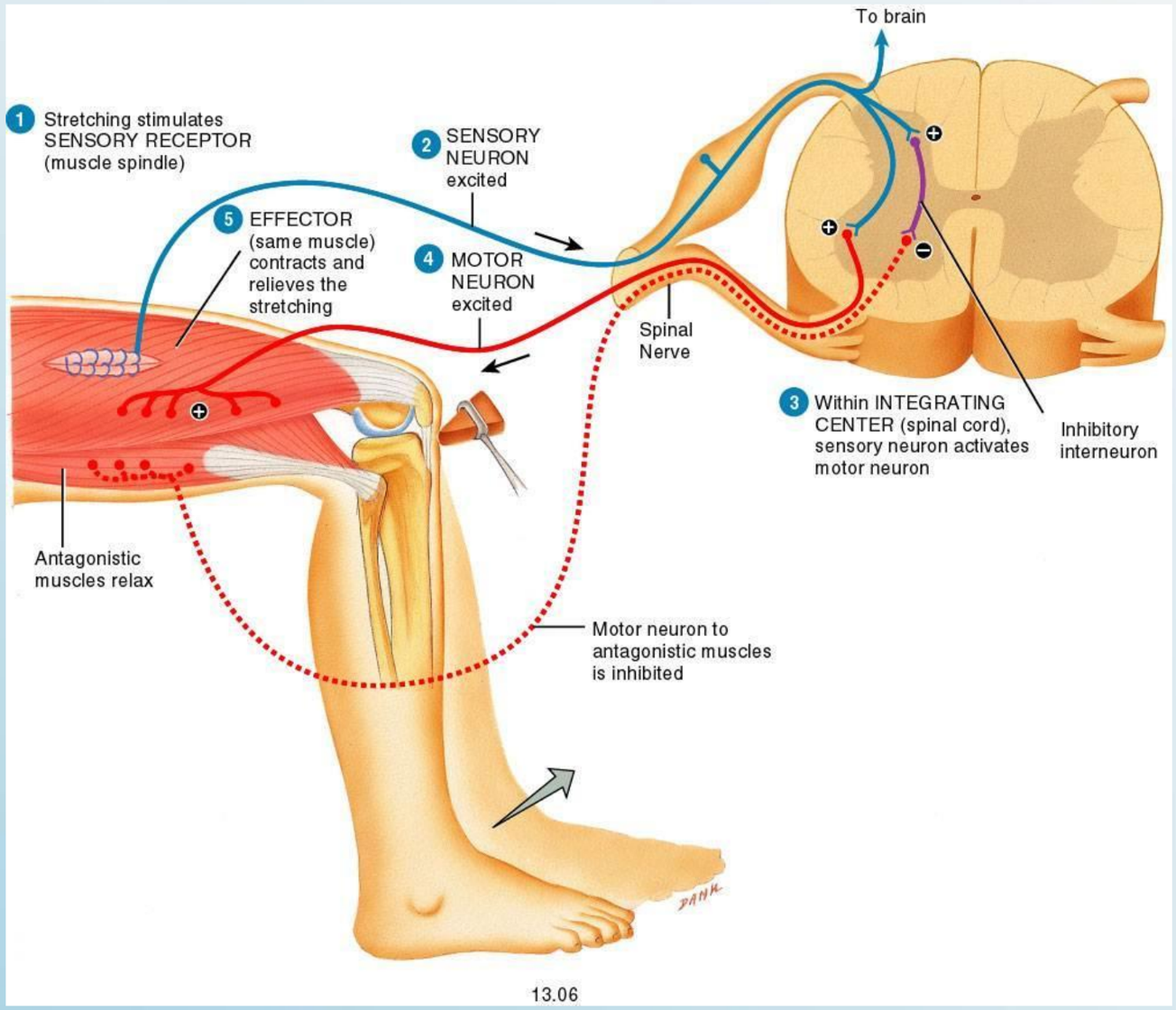
**Reciprocal innervations** occurs also in extensor reflex**: flexors in the opposite limb are inhibited** while **extensors are excited**

# Examples of deep reflexes

## (1) Stretch Reflexes (Tendon jerks)

**monosynaptic**: such as 1- **knee-jerk (patellar reflex) 2- ankle jerk** .

The receptor for all these is **the muscle spindle (which is located within the muscle itself).**




**Explanation:**

In the stretch reflex of patellar reflex, there is a stretch receptor called muscle spindle, it's a sensory receptor that excited with stretching in a particular muscle.

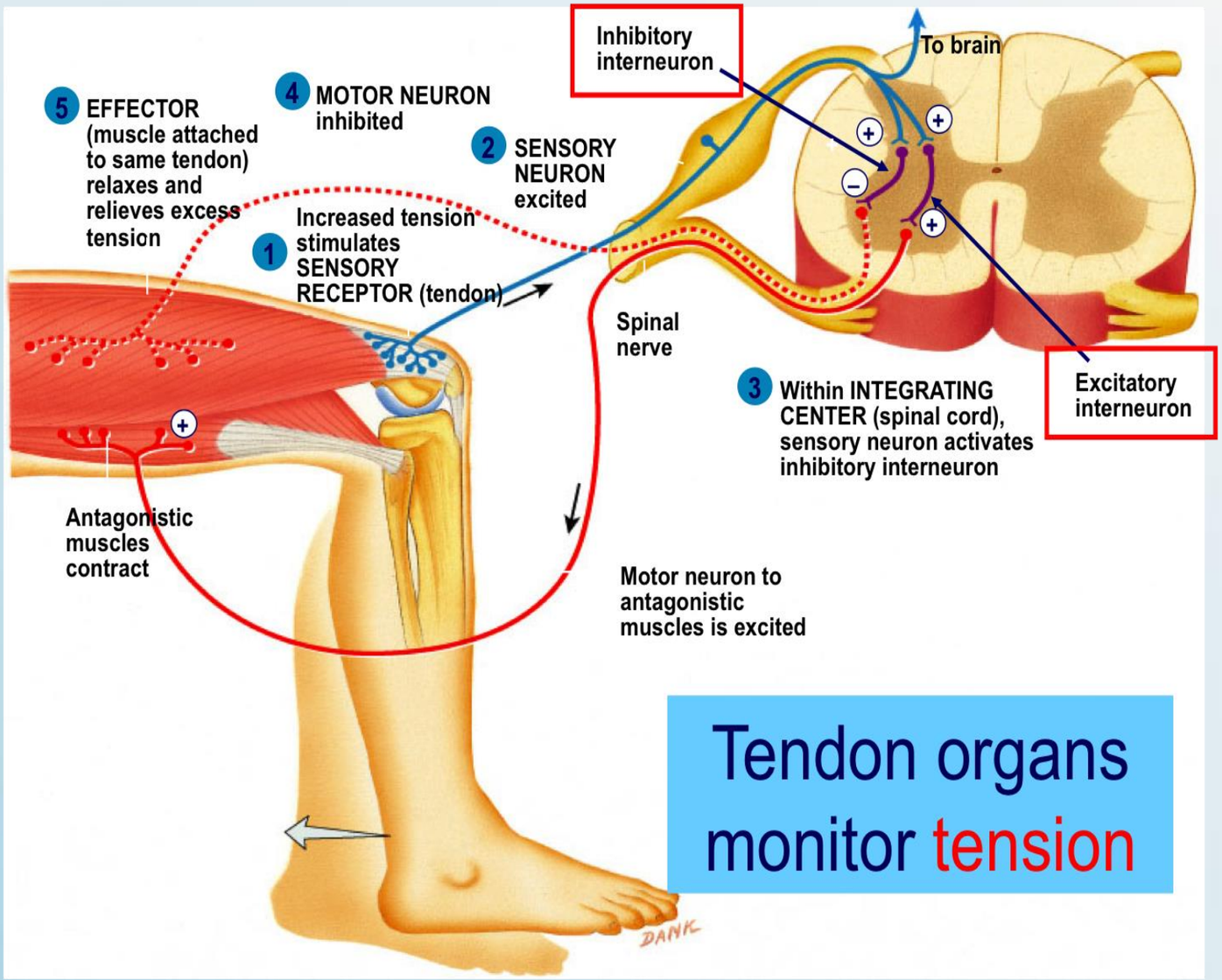
- when a muscle stretched with a reflex hammer it will create a stretching in the muscle that would stimulate the receptors which will create an impulse through the sensory neuron and will travel from the femoral nerve and will go back to spinal nerve into the dorsal root ganglion and dorsal root of spinal nerve
- then into the spinal cord and it will do the synapse with the motor neuron , motor neuron will take the impulse out from the spinal cord through ventral root and go back to the same muscle and will stimulate it to contract , look at the picture.

## (2) Inverse Stretch Reflex ( Golgi Tendon organ reflex) :

**polysynaptic**

the receptor is called **Golgi Tendon Organ** , and is present in **the muscle tendon**

**Instead of responding to excessive stretching the muscle, its response to excessive contraction resulting in a relaxation " inhibitory " .**




**Explanation:**

- In the tendon reflex, the quadriceps muscle its already contracted excessively then it will stimulate the sensory receptors and the impulse will go to the dorsal root ganglion and into the dorsal root and synapse with interneuron in the grey matter " that's why its polysynaptic"
- then the interneuron will synapse with motor neuron of the same muscle and it will do Inhibitory post synaptic potential resulted of " hyperpolarization " so its difficult to stimulate action potential " then it will result in relaxing the muscle , look at picture.

# Properties of reflexes

## (1) Reciprocal Inhibition

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

## (2) Irradiation

spread of impulses up or down to different segments and motor Spinal cord
The extent of the response in a reflex depends on **the intensity of the stimulus.**
( A strong stimulus in sensory afferent lead to irradiate to many segments of S.C due **to divergence**)

**-Weak stimulus → weak flexion of limb**
**-Strong stimulus → withdrawal of affected limb & extension of opposite limb**
**(as in crossed extensor reflex )**

## (3) Recruitment

**Gradual activation** of more number of motor neurons (AHCS) 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 neurones to be stimulated)**

## (4) After Discharge

It means **prolonged discharge of AHCs** after stoppage of afferent stimulation this **cause maintained reflex action & response continue for some time** after cessation of Stimulus

## (5) Central Delay

**Central Delay : Time taken in spinal cord synapses which equal 0.5 ms/synapse**

**(So, it's longer in Polysynaptic reflex and more than 2 ms /synapse in withdrawal reflex)**

**Central Delay = Total Reflex time –Time spent in conduction of impulses along the afferent and efferent nerves.**

**Reflex Time: Time that elapses between application of the stimulus and appearance of the response**

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

**Number of synapses = Central Delay /0.5 ms**

*** If it was 20 ms, how many neurons/synapses passed ?**

**=20/0.5 = 4**

# Summary

**Q1: what is the functions of the Spinal Cord ?**
1- Carrying sensory information from the receptors to the brain  2- Executing brain motor commands  3- Spinal Reflexes

**Q2: where are the cell-bodies of the motor fibers located?**
anterior horn of the spinal cord

**Q3: which type of muscle fibers innervated by Gamma motor neurons?**
Intrafusal fiber

**Q4: what is the sources of the pulses that came to the LMN?**
1- Primary Afferent neurons  2- Spinal interneurons  3- Upper motor neurons

**Q5: what are the kinds of classifications of the reflexes?**
1- According to the Number of Synapses  2- According to the Location of the Receptor

**Q6: what is the simple mechanism of the Withdrawal reflex?**
First: Stimulation of pain receptors
Then: the impulses will go to the SC (Afferent)(posterior horn cell)
After that: it synapse with interneuron
Then: it will synapse with the anterior horn cell to give the motor order(Efferent) to the affected area

**Q7: what is the Reciprocal Inhibition?**
It is inhibition of the antagonist muscle  of the reflex process

**Q8: how many synapses if the central delay was 35 ms?**
synapses 35/0.5 = 70

**Q9: what is the later response of the Crossed Extensor Reflex?**
1- Pushing the entire body away from the pain source  2- Supporting  the body weight against injurious agent and gravity

**Q10: What is the value of After-Discharge or Reverberating circuits?**
To prolong the response

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# CNS Block