NeuroPsychiatry Block

جامعة الملك سعود
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Spinal Cord Functions and Reflexes

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Motor Functions of the Spinal Cord, The cord Reflexes

Chapter 55

(Guyton & Hall)

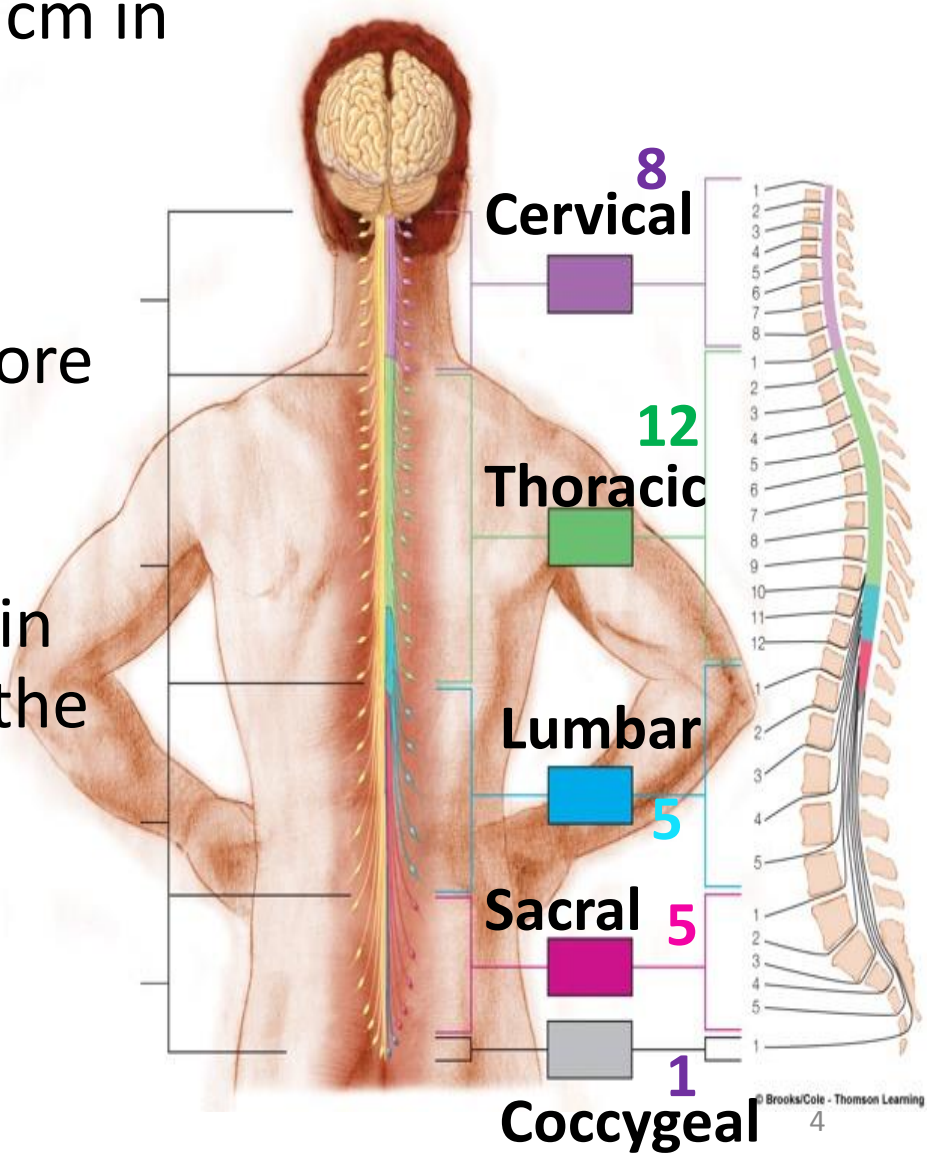
Objectives

By the end of this session students are expected to:

- Appreciate the two-way traffic along the spinal cord
- Describe some characteristics of spinal neuronal circuits
- Classify reflexes and appreciate their clinical importance
- Describe neuronal mechanisms of the withdrawal reflex & crossed extensor reflex

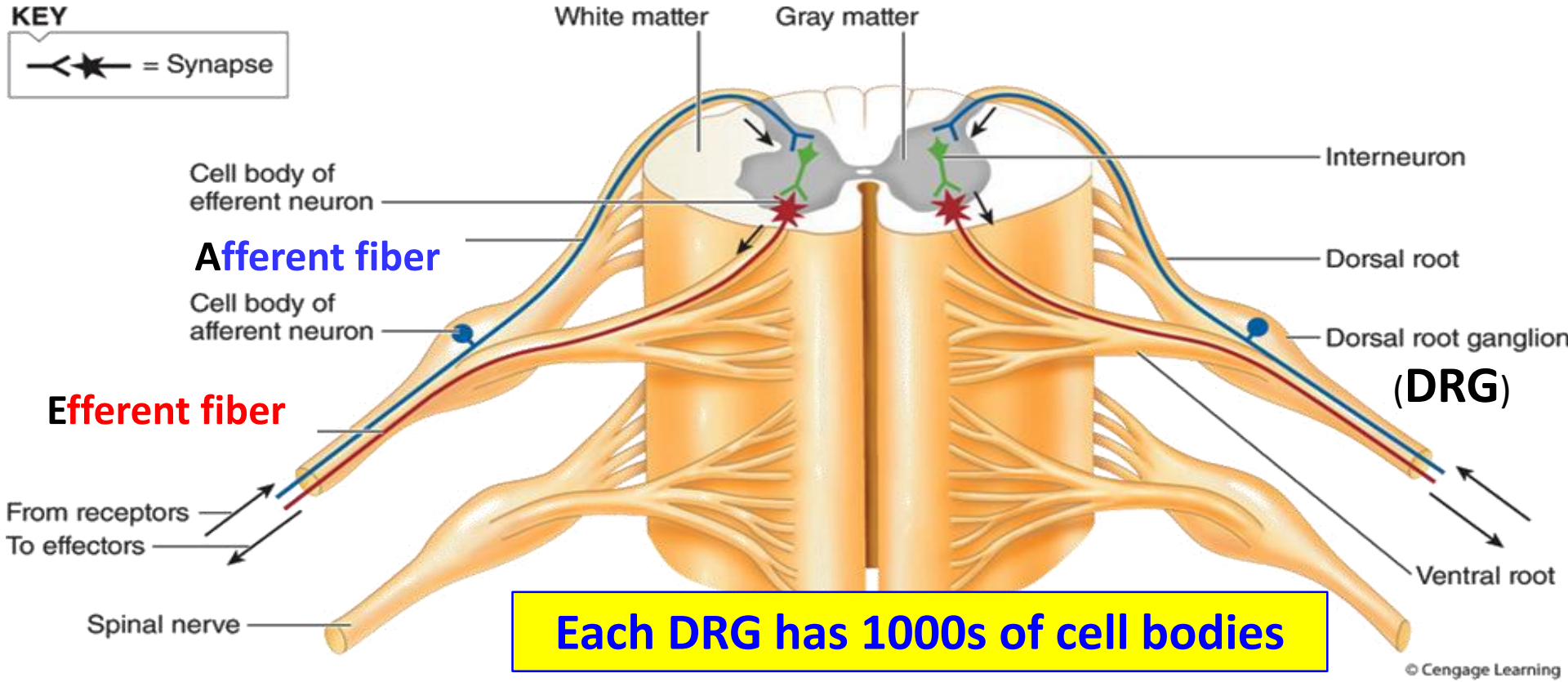
The Spinal Cord (SC)

- It is about 45 cm long and 2 cm in diameter
- It is composed of about 100 million neurons and even more neuroglia
- It is continuous with the brain and together they make up the **CNS**
- **31 pairs** of spinal nerves are connected to it



The Spinal Nerves

- Each spinal nerve has a ventral root and a dorsal root
- The dorsal (**posterior**) root contains **afferent** (sensory) nerve fibers, and their cell bodies are located in **dorsal root ganglion** (DRG).
- The ventral (**anterior**) root carries **efferent** (motor) fibers, and their cells bodies are located in the ventral horn of the spinal cord.



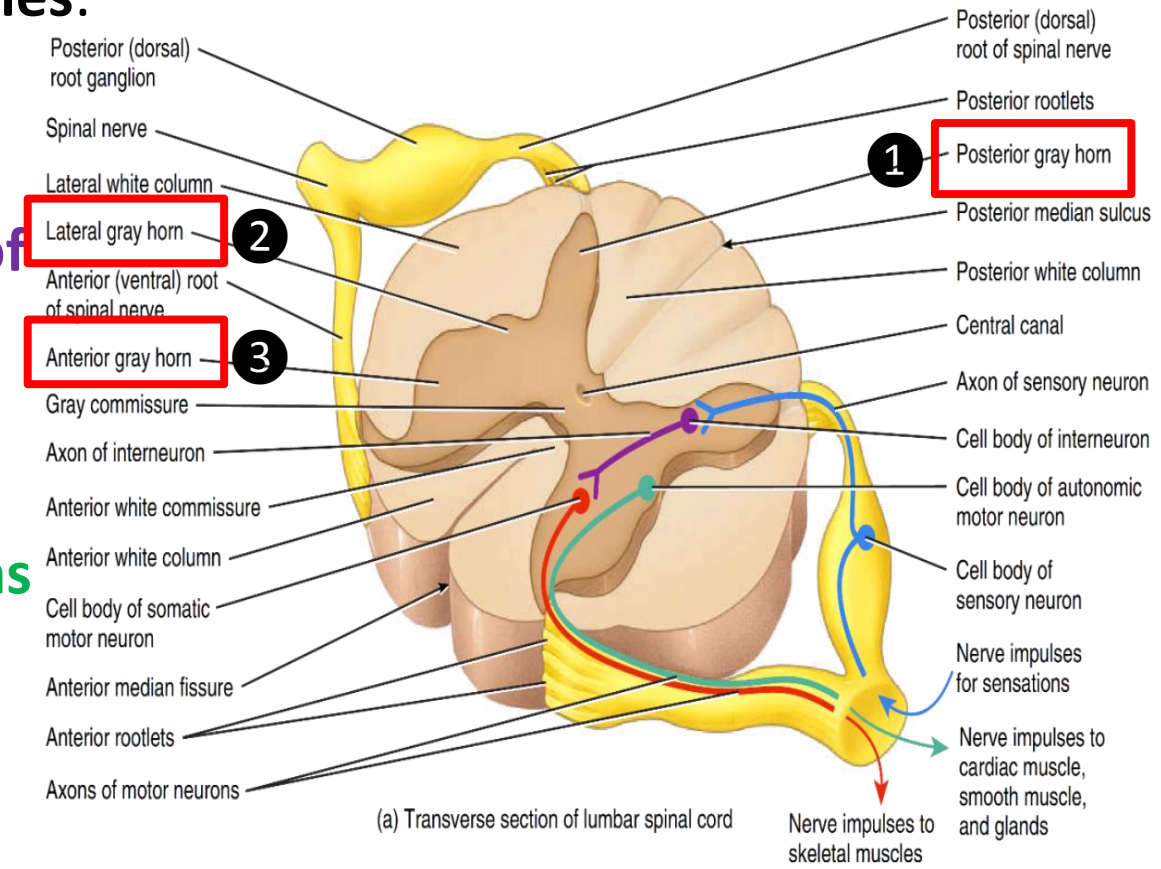
Spinal Cord Organization: 1. The Grey Matter

- **The structural organization of the SC can best be studied in a cross section of the cord which reveals:**
  - An outer band of ***white matter*** surrounding
  - An inner core of **grey matter (H shaped)** which can be divided into **3 functional zones**:

1. The **dorsal** grey horn contains axons of sensory neurons and **cell bodies of interneurons**

2. The **lateral** grey horn contains cell bodies of **autonomic motor neurons**

3. The **anterior** grey horn contains cell bodies of **somatic motor neurons**.

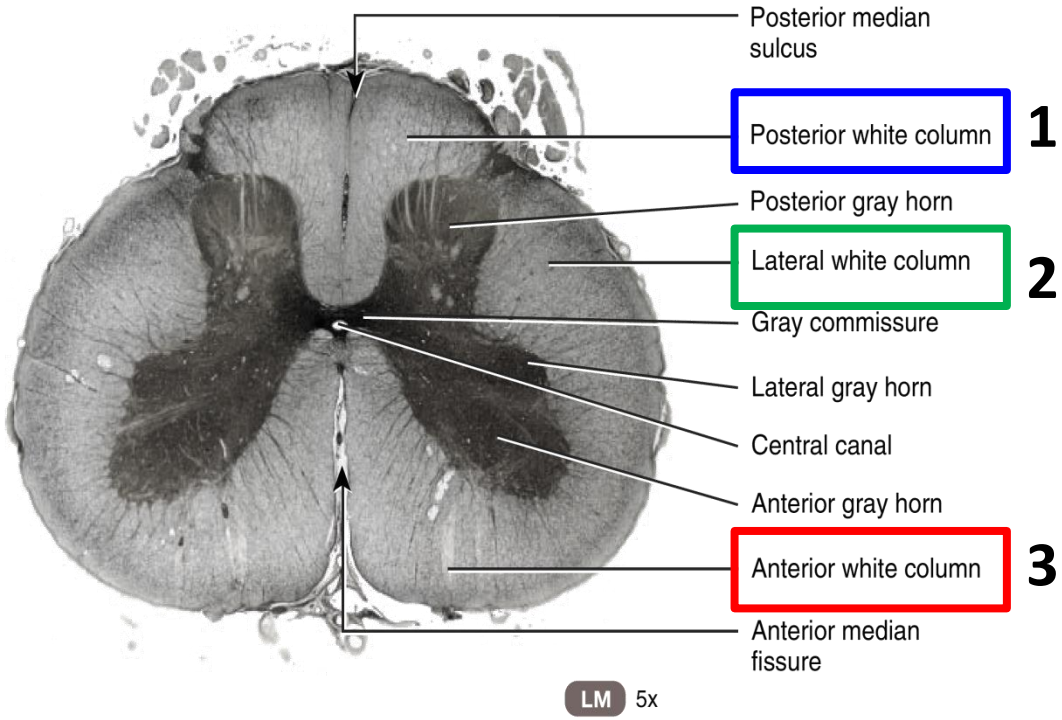


Spinal Cord Organization: 2. The White Matter

- The **white matter** of the SC is divided into **bundles** (**funiculi**)
- Each bundle (**tract**) contains nerve fibers travelling between **SC** and **brain**
- These bundles form the SC **ascending** (**sensory**) and **descending** (**motor**) pathways

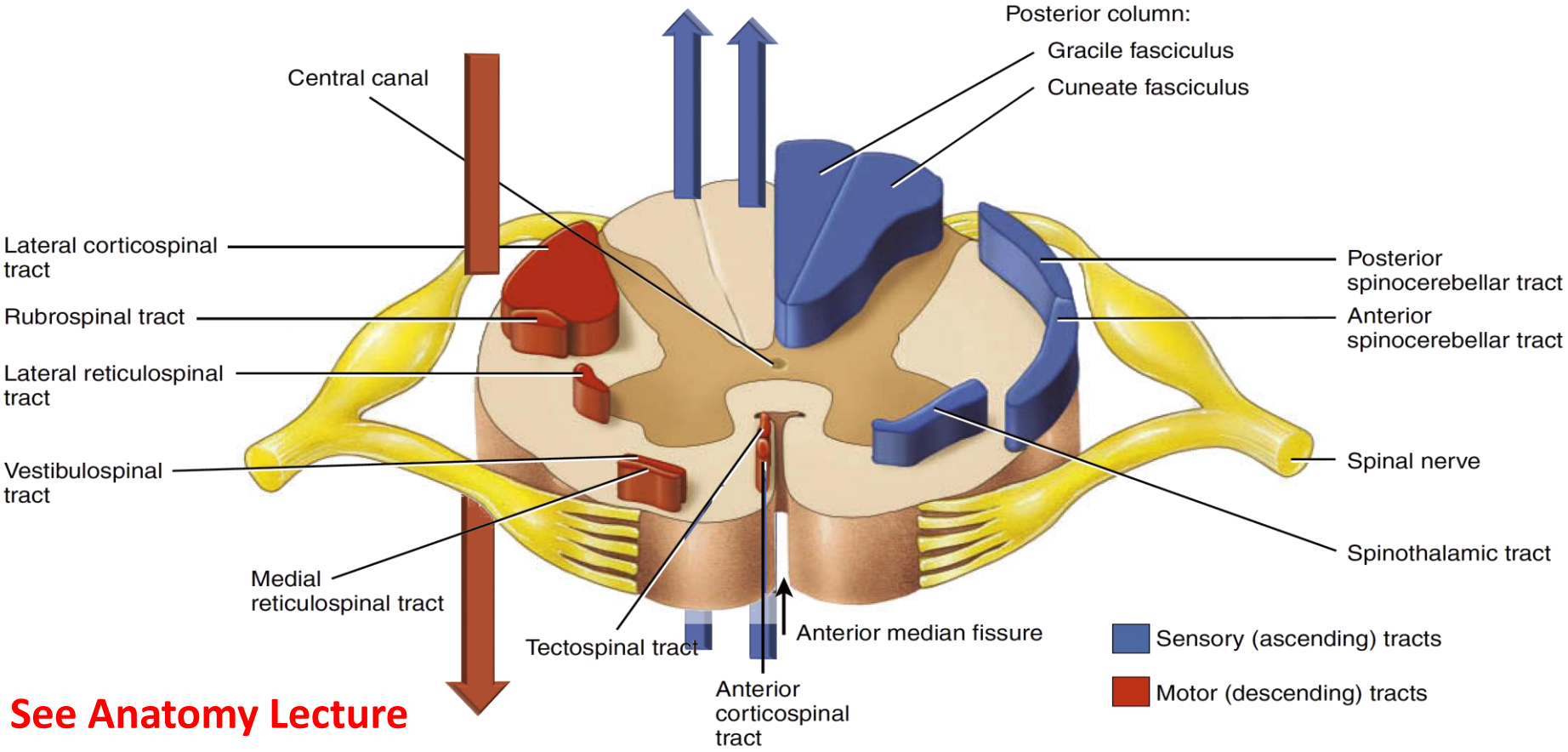
- The white matter on each side is divided into 3 broad areas called **columns:**

1. **The dorsal (posterior)** column
2. **The lateral** column
3. **The *ventral*** (**anterior**) column



The Ascending & Descending Tracts of SC

- **Ascending (sensory) tracts** are the "highways" for conduction of sensory nerve impulses toward the brain
- **Descending (Motor) tracts** are the "highways" for conduction of motor nerve impulses from the brain toward effector tissues



See Anatomy Lecture

Functions of Spinal Cord

The spinal cord serves two basic functions:

1. Two-way nerve center (station) between the periphery and the brain

- All the **sensory signals** are transmitted to higher centers through spinal ascending tracts such as **dorsal column tract** and **spinothalamic tract**.
- All **motor signals** are first communicated to the SC via descending tracts before being sent to skeletal muscles via spinal efferent motor nerves.

2. Generation of reflexes: activates the motor output directly without input from the brain.

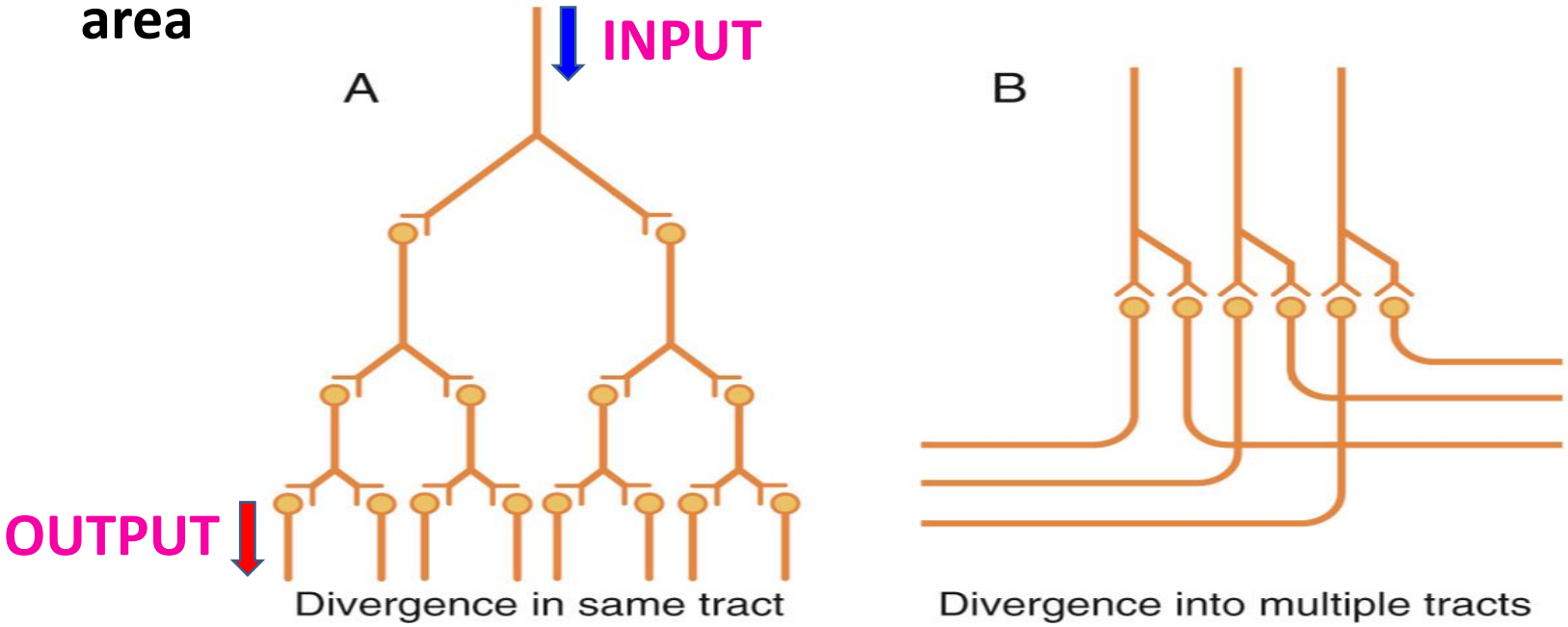
✓ **Objective: Appreciate the two-way traffic along the spinal cord**

Some Important Characteristics of Neuronal Circuits

1. **Divergence** of signals passing through neuronal pools
2. **Convergence** of signals
3. **Reciprocal inhibition:** Neuronal circuit with both **excitatory** and **inhibitory** output signals
4. **Synaptic delay & Reaction time**
5. **Irradiation of stimulus** & **neuronal recruitment**
6. **Signal prolongation**
   - Synaptic Afterdischarge
   - Reverberatory (oscillatory) circuit

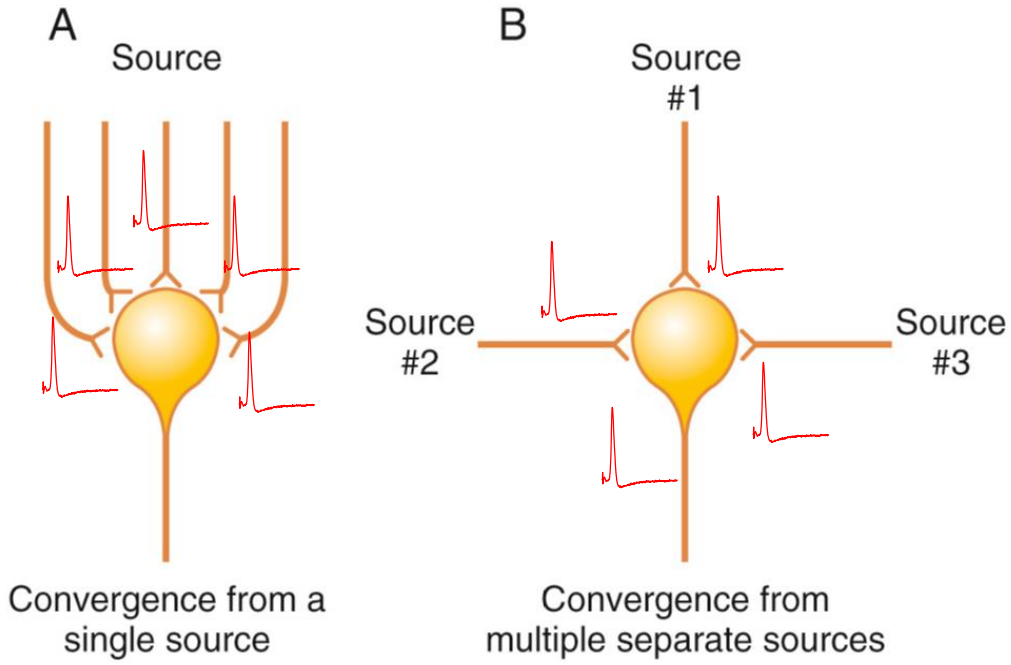
1. Divergence of Signals

- **Diverge means that a signal from a single input spreads to many neurons (many outputs) either:**
  - In the same tract/path **(A)** or
  - In multiple tracts **(B)** (e.g. pain signal can be relayed by different ascending tracts)
- **In the spinal cord, divergence helps a signal to spread to a wide area**



2. Convergence of Signals

- **Convergence means signals from multiple inputs converge to excite or inhibit a single neuron.** The inputs can be:
  - From a single source **(A)** or
  - Multiple separate sources (**excitatory or inhibitory**) **(B)**
- **Convergence allows *summation* of information**



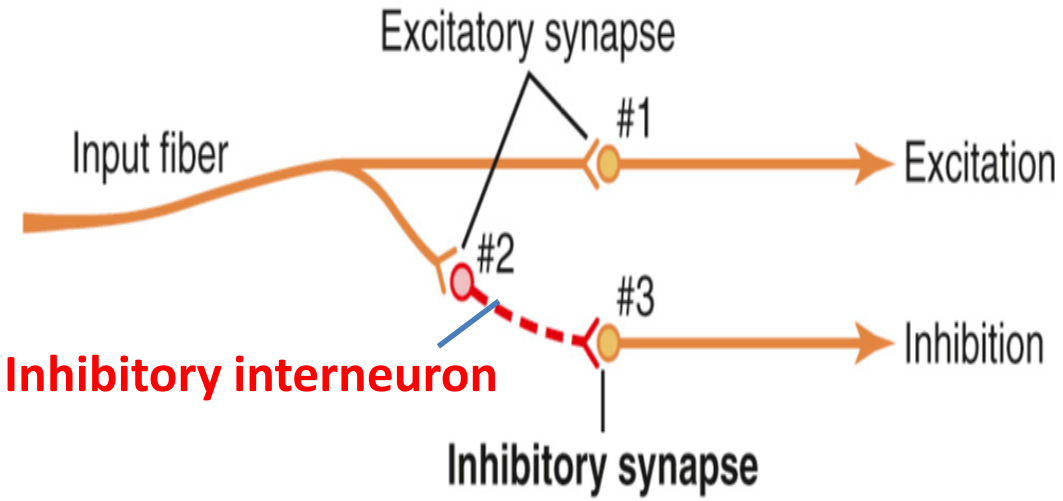
Note

1. Neurons are almost never excited by a single action potential from a single input terminal

2. Temporal or spatial summation is required

3. Reciprocal Inhibition

- Sometimes **an input signal** through an input fiber causes:
  - **An excitatory output** signal in one direction **(ǂ1)** and
  - Simultaneously, **an inhibitory output** signal going elsewhere **(ǂ3)**
  - The inhibitory output is caused by an *inhibitory neuron* (**neuron 2**), which secretes a different type of neurotransmitter
  - This type of circuit (**reciprocal inhibition) & is** characteristic for controlling all **antagonistic** pairs of muscles.



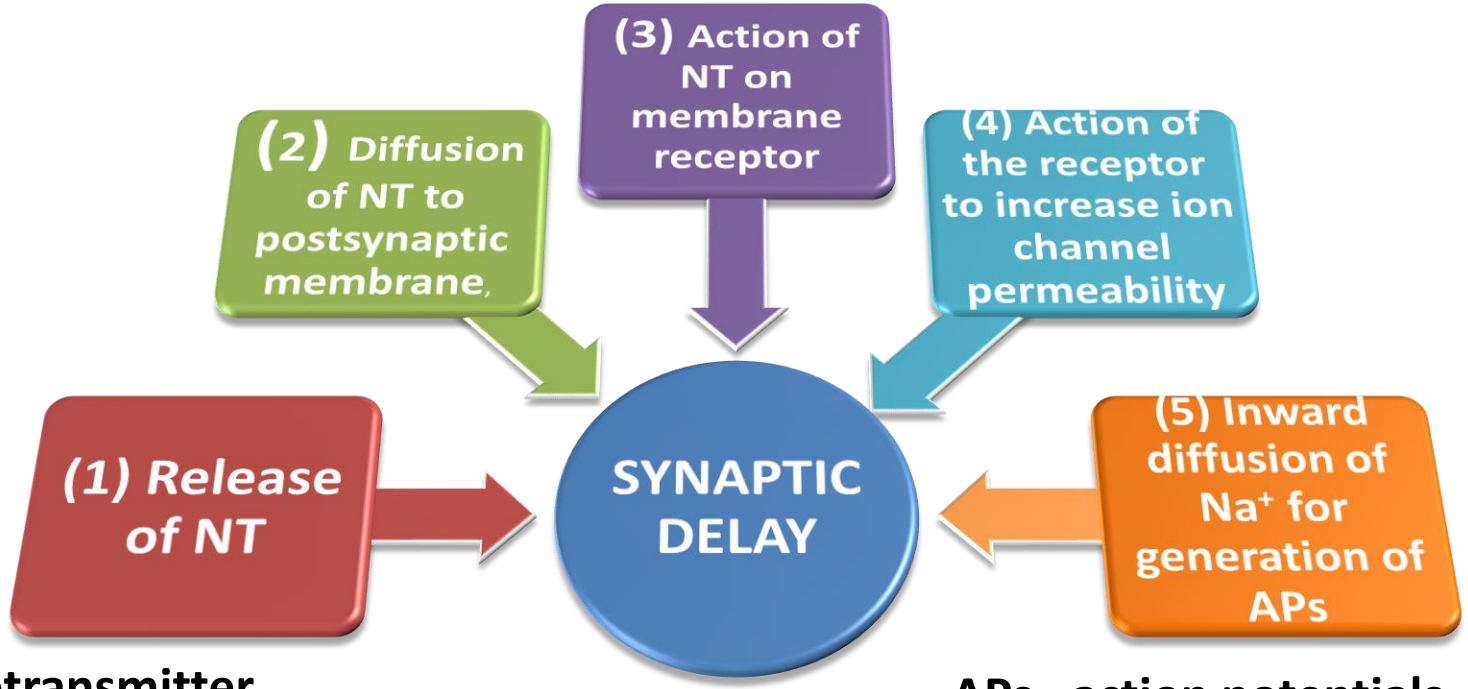
QUESTION

Which neurotransmitter could be released from inhibitory interneuron?

- **GABA** or
- **Glycine**

4. Synaptic Delay& Reaction Time

- **Synaptic delay**: is the minimal period of time required for transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron. Its duration is about **0.5 ms** per synapse
- **Reaction time** = **Reflex Time** = synaptic delay + time spent in conduction of APs though the afferent and efferent nerves.



NT= neurotransmitter

APs= action potentials

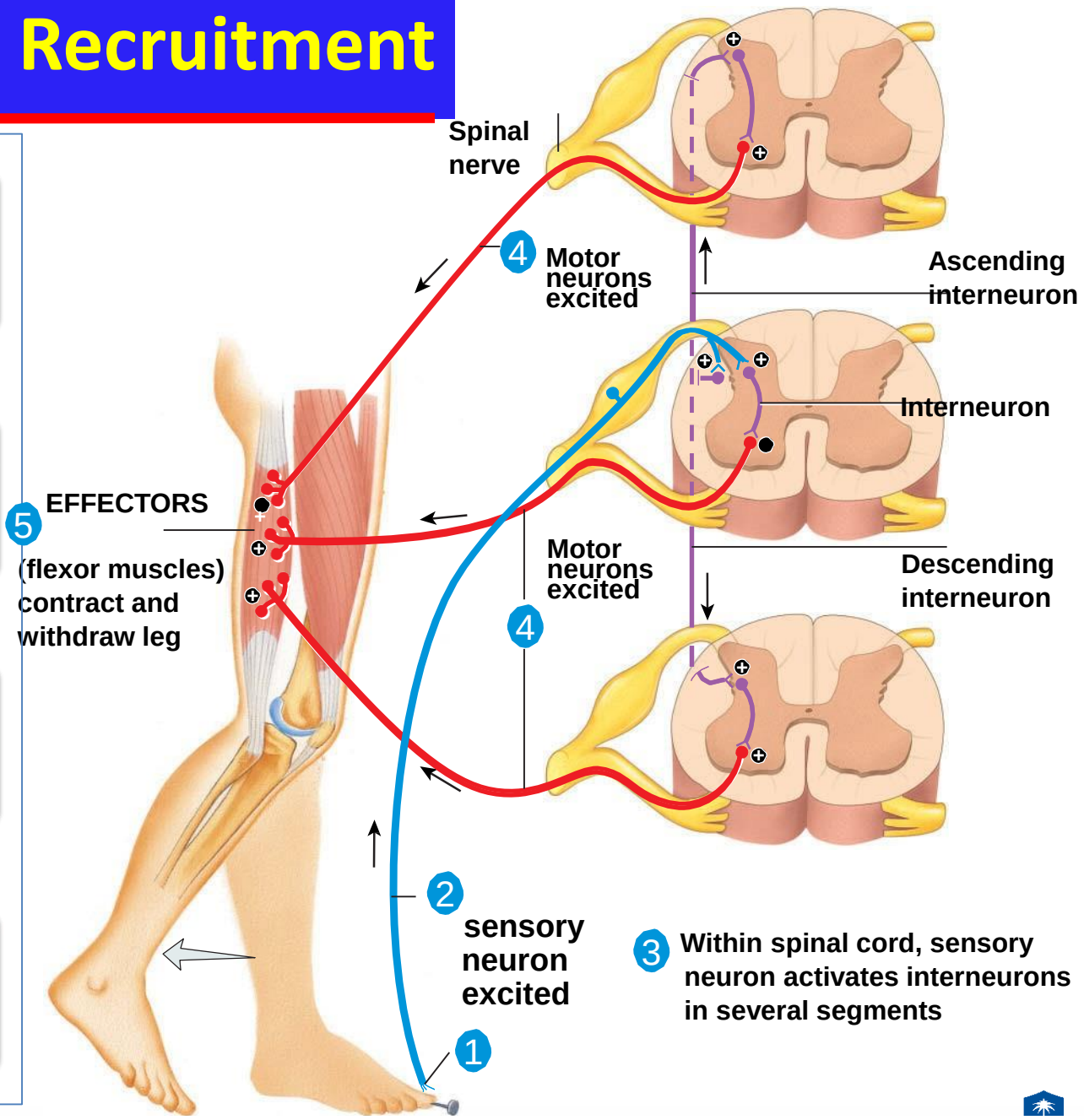
5. Irradiation & Recruitment

Strong stimuli can generate activity in the interneuron pool that spreads

Up and down spinal cord to motor neurons. This is called stimulus **irradiation**

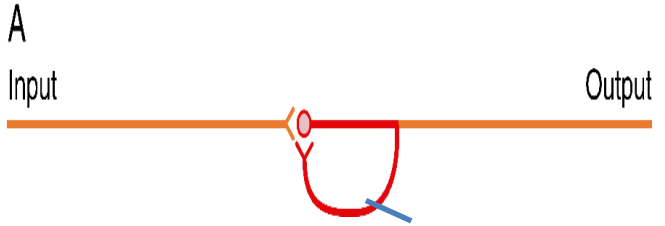
The increase in the number of active motor units is called

Recruitment of motor units



6. Signal Prolongation

- Often the output discharge (initiated by a signal entering a spinal pool) is **prolonged** for a **few milliseconds** or **many minutes** after the incoming signal is over.



- This prolongation is due to:
  - Synaptic afterdischarge
  - Reverberatory (oscillatory) circuit is caused

  by positive feedback within the circuit in which the **output neuron** sends a **collateral nerve fiber** back to input neuron itself making it discharge repetitively for a long time.

- **The signal prolongation prolongs the protective response of reflex**

✓ **Objective: Describe some characteristics of spinal neuronal circuits**

Spinal Reflexes

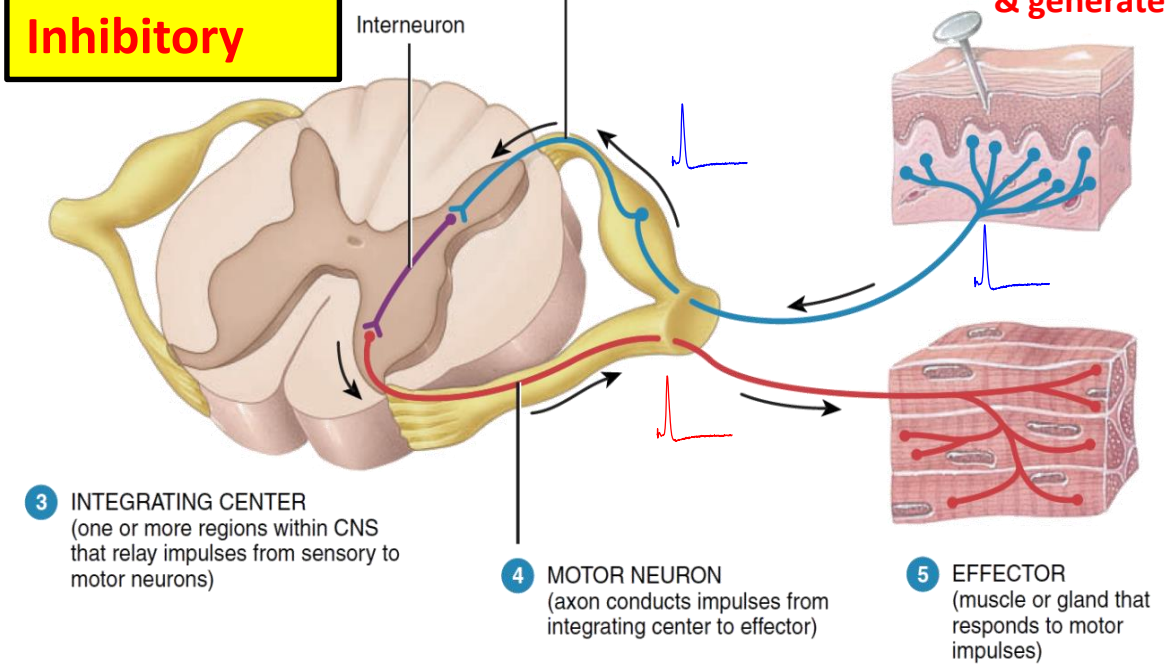
What is a spinal reflex ?

- It is a rapid, automatic (**involuntary**) response to a stimulus (e.g. pinprick causes withdrawal response)
- It is the functional unit of CNS
- **Reflexes** are very important in defending against harmful stimuli and maintaining body support
- It involves **sensory receptors, sensory afferent neurons, spinal cord motorneurons** and **spinal nerves** (**Reflex Arc**).

Components of a Reflex Arc

- Reflex arc (reflex circuit) is the pathway followed by nerve impulses that produce a reflex
- It includes 5 functional components :

Interneurons can be:
Excitatory
Inhibitory



1. Sensory receptor
2. Sensory neuron
3. Integrating center
4. Motor neuron
5. Effector

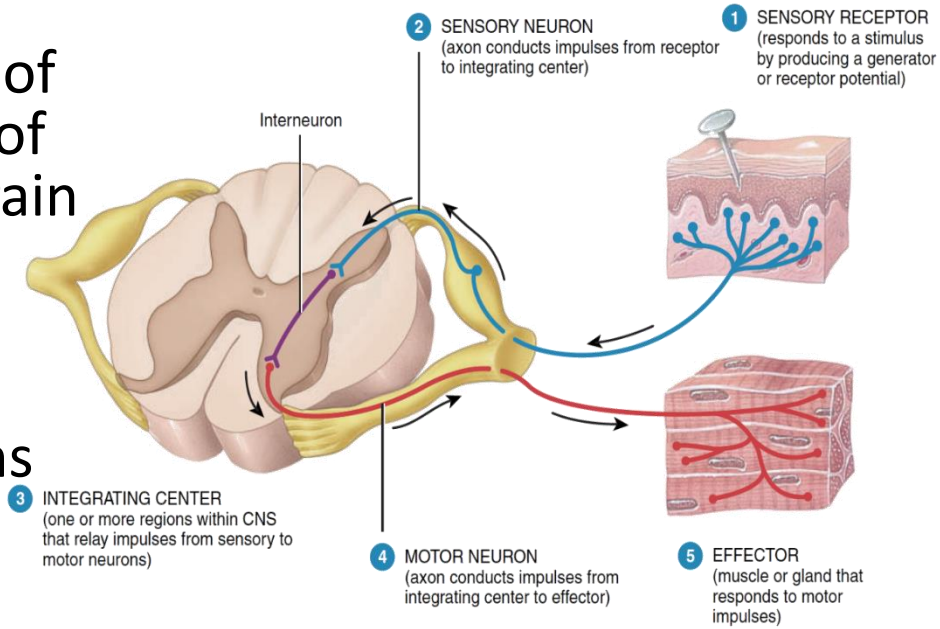
Components of a Reflex Arc-1

1. Sensory receptor:

- Is the distal end of a sensory neuron or an associated structure.
- Responds to a specific stimulus by producing a **generator/receptor** potential (**RP**)
- When the **RP** reaches threshold, it triggers one or more nerve impulses/**action potentials** (**APs**) in the sensory neuron

2. Sensory (afferent) neuron:

- The sensory signal in the form of APs propagate along the axon of the sensory neuron to SC or brain stem.
- The signal is relayed **to brain regions that allows conscious awareness** or to motor neurons **directly** or via **interneurons**



Components of a Reflex Arc-2

3. Integrating center:

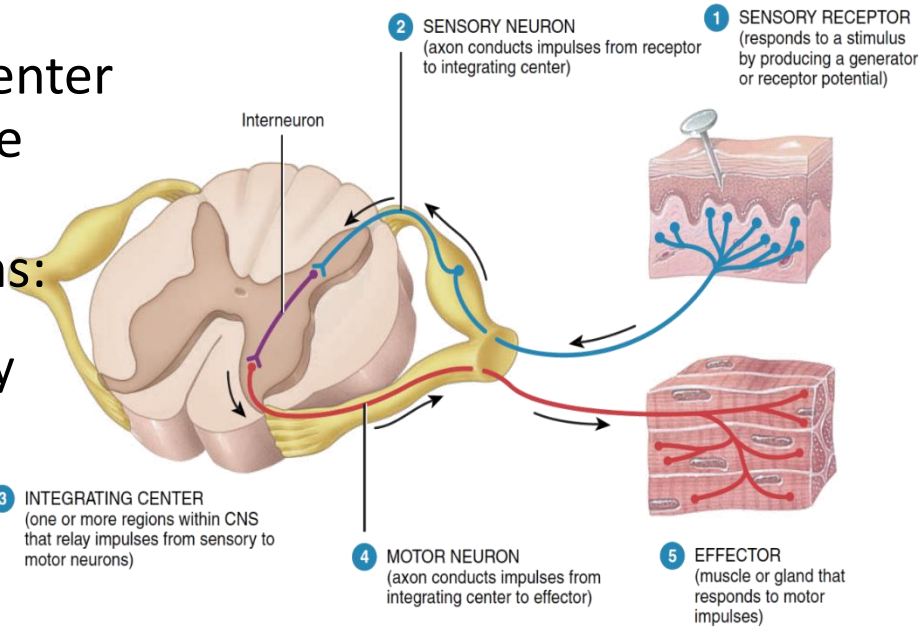
- One or more neurons within the SC acts as an integrating center, depending on whether the reflex is **monosynaptic** (**one synapse**) or **polysynaptic** (**2 or more synapses**)
- SC interneurons are involved in polysynaptic reflexes.
- Interneurons are ~30 times as numerous as the motor neurons

4. Motor (Efferent) neuron:

- APs generated in the integrating center propagate out of the CNS along the efferent axons to the effector.
- There are 2 types of motor neurons:

1. Alpha motor neurons that supply extrafusal muscle fibers

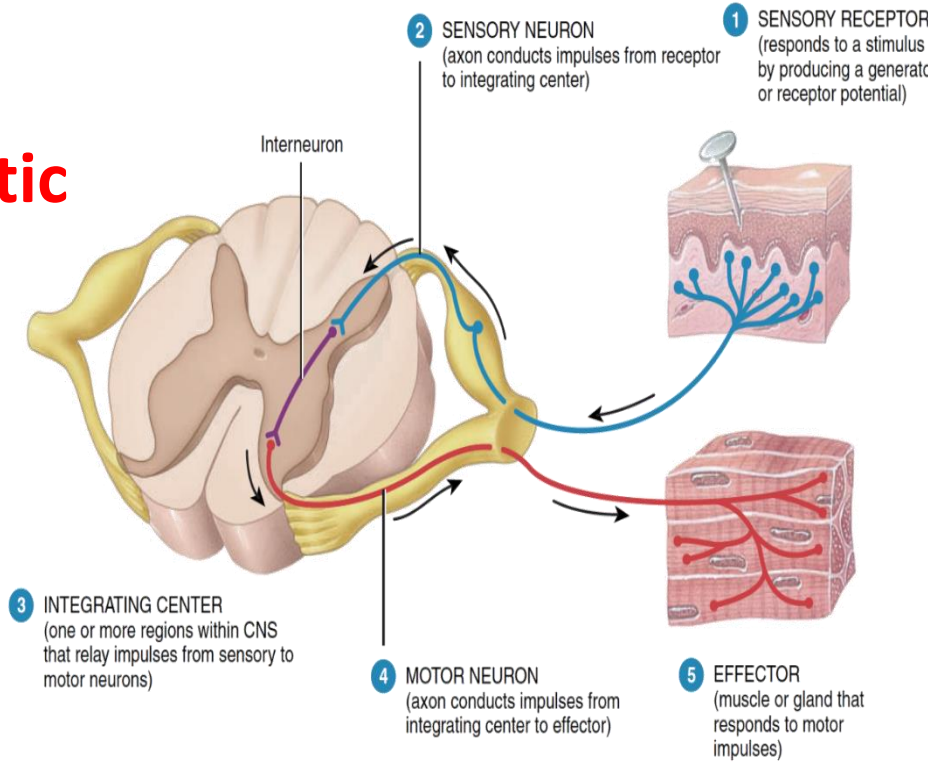
2. Gamma motor neurons that supply intrafusal muscle fibres



Components of a Reflex Arc-3

5. Effector:

- Is the part of the body that responds to the motor nerve impulse, such as a muscle or gland.
- Its response is called a reflex.
- If the effector is **skeletal muscle**, the reflex is a **somatic reflex.**
- If the effector is a **smooth muscle**, cardiac muscle, or a gland, the reflex is an **autonomic** (visceral) reflex.



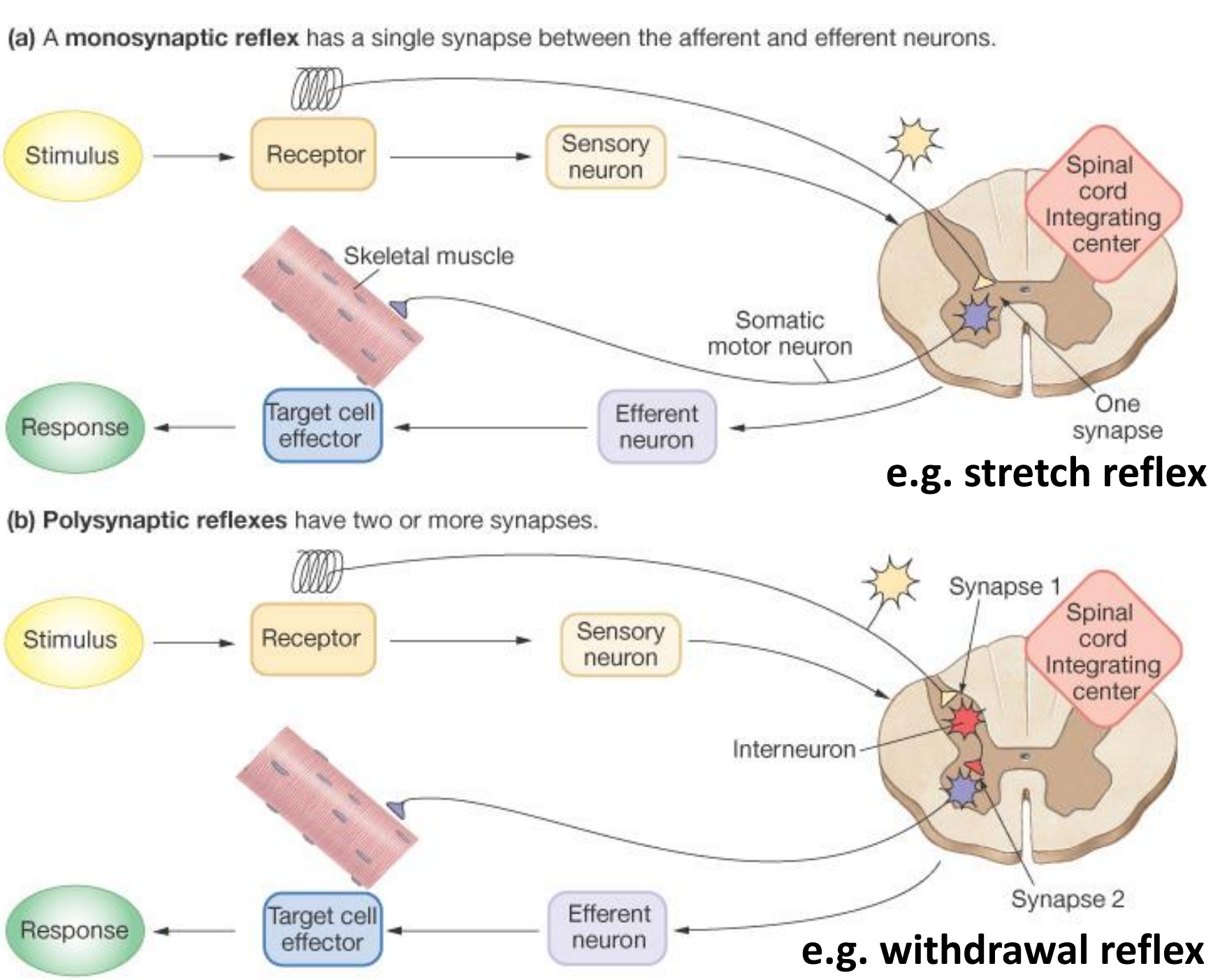
Types of Spinal Reflexes-1

I. According to the number of synapses

- **Monosynaptic** (one synapse): Afferent nerve fibers synapse directly with motor neurons (No interneuron, e.g. stretch reflex)
- **Polysynaptic** (2 or more synapses): e.g. Withdarwal and visceral reflexes)

See next slide

✓ **Objective: Classify reflexes and appreciate their clinical importance**


(a) A monosynaptic reflex has a single synapse between the afferent and efferent neurons.
Stimulus
Receptor
Sensory neuron
Spinal cord Integrating center
Skeletal muscle
Somatic motor neuron
Response
Target cell effector
Efferent neuron
One synapse
e.g. stretch reflex
(b) Polysynaptic reflexes have two or more synapses.
Stimulus
Receptor
Sensory neuron
Synapse 1
Spinal cord Integrating center
Interneuron
Response
Target cell effector
Efferent neuron
Synapse 2
e.g. withdrawal reflex

Types of Spinal Reflexes-2

II. According to site of the sensory receptor:-

A. Deep Reflexes: generated by stimulation of receptors deep in muscle and tendons

- **Stretch Reflexes** (Tendon jerks) such as knee-jerk/patellar reflex
- **Inverse Stretch Reflex** (Golgi Tendon organ reflex)

B. Superficial Reflexes: Are polysynaptic reflexes; the receptors are superficial in the skin

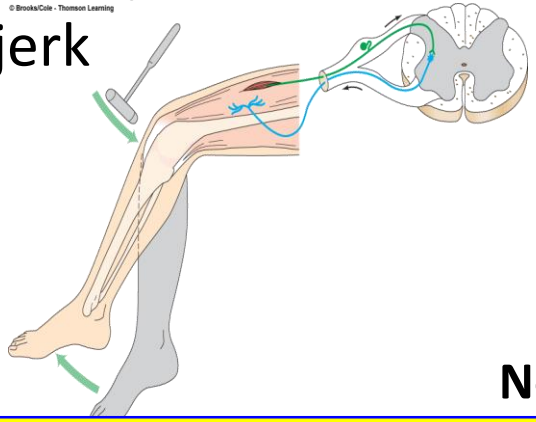
C. Visceral: generated by stimulation of receptors in wall of viscera

- **Urination**
- **Defecation**

Superficial and Deep Reflexes

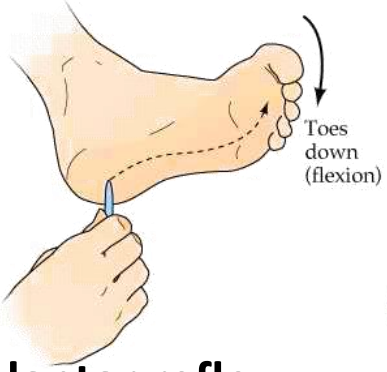
Deep Reflexes

- Generated by stimulation of **receptors deep in muscle and tendons** (muscle spindle and Golgi tendon organ)
- Examples are
  - Stretch reflexes
  - knee-jerk (patellar reflex)
  - Ankle jerk

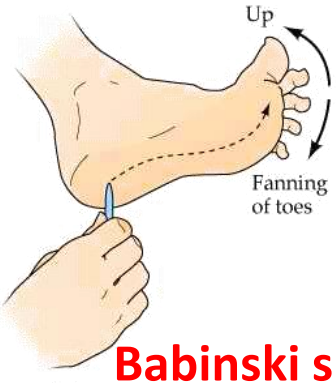


Superficial Reflexes

- Generated by stimulation of superficial **receptors in the skin**
- Examples are
  - Withdrawal
  - Plantar



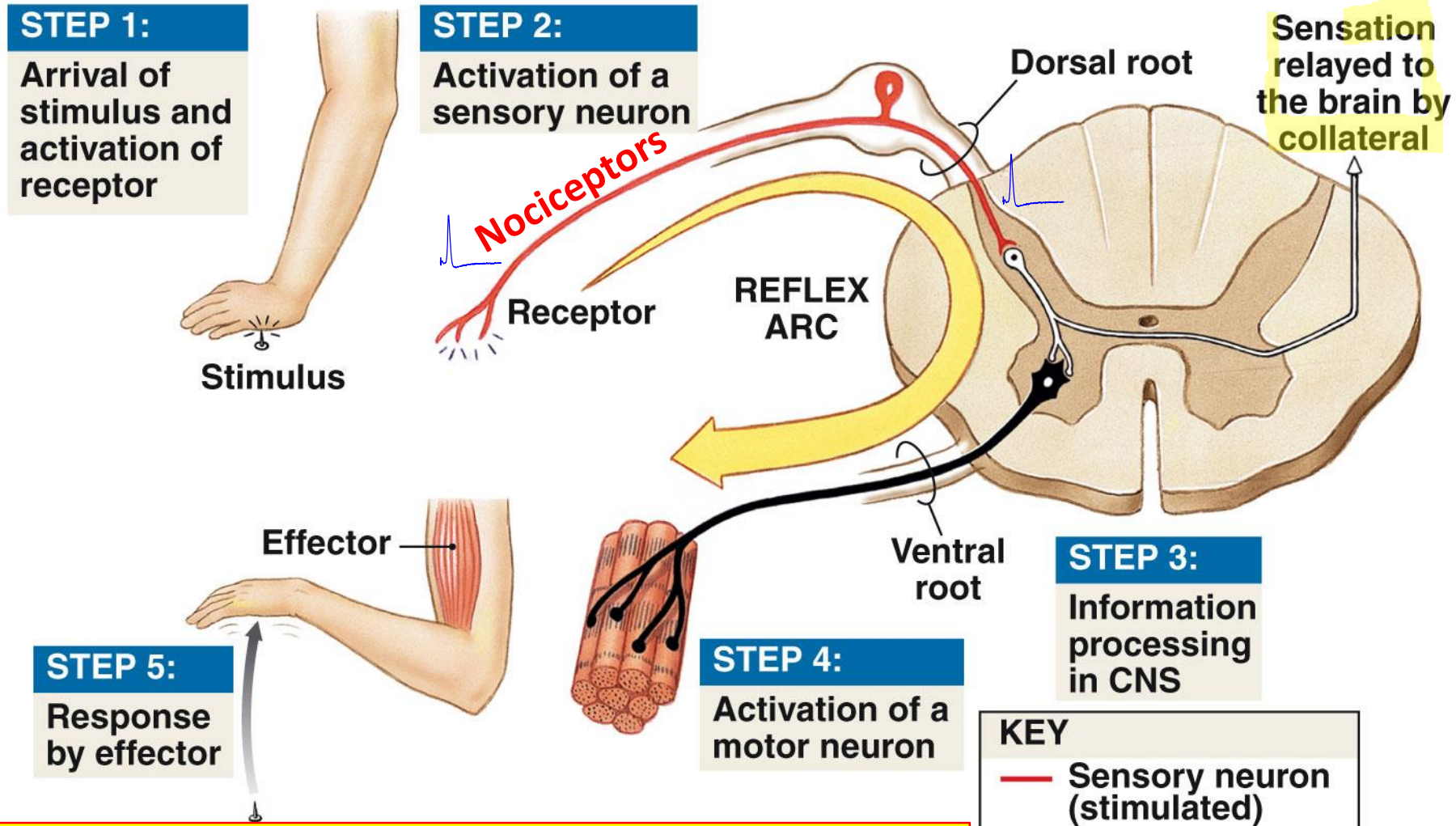
Normal plantar reflex



Babinski sign

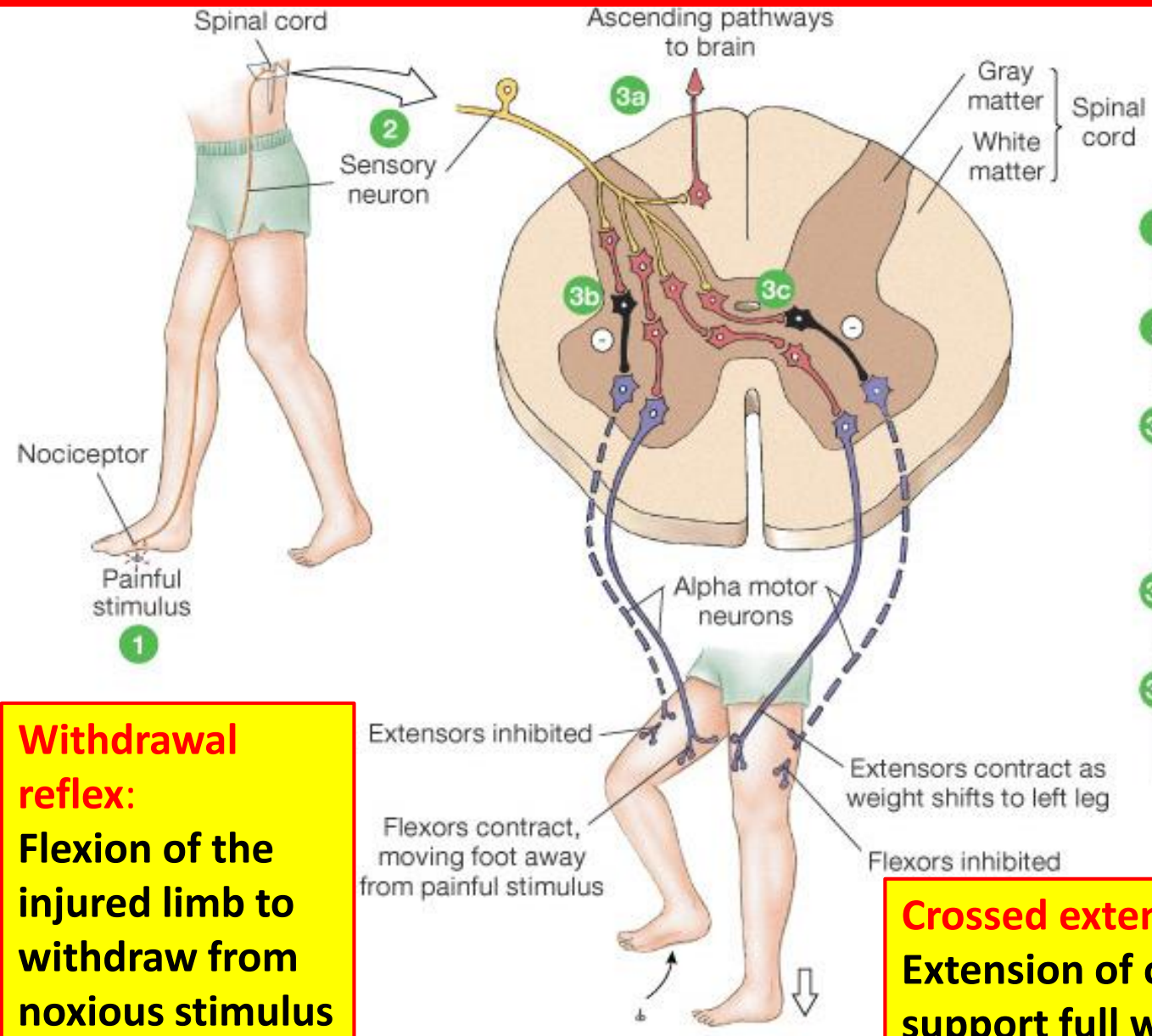
✓ **Objective: Describe withdrawal & crossed extensor reflexes (next)**

Withdrawal Reflex (Polysynaptic)



Mediated by nociceptors (pain receptors).
The response is reflex contraction of the flexor muscles causing withdrawal of the limb from painful stimulus

Crossed Extensor Reflexes



1. Painful stimulus activates nociceptor.
2. Primary sensory neuron enters spinal cord and diverges.
3a. One collateral activates ascending pathways for sensation (pain) and postural adjustment (shift in center of gravity).
3b. Withdrawal reflex pulls foot away from painful stimulus.
3c. Crossed extensor reflex supports body as weight shifts away from painful stimulus.

Withdrawal reflex:
Flexion of the injured limb to withdraw from noxious stimulus

Crossed extensor reflex:
Extension of opposite limb to support full weight of body.


Thank You
Any Questions
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