NeuroPsychiatry Block
Spinal Cord Functions & Spinal Reflexes

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Objectives:

Upon completion of this lecture, students should be able to:

- Appreciate the two-way traffic along the spinal cord .

-- Describe the organization of the spinal cord for motor functions(anterior horn cells& interneurons & neuronal pools)

- Describe the physiological role of the spinal cord in spinal reflexes & reflex arc components

--Classify reflexes into superficial and deep; monosynaptic & polysynaptic

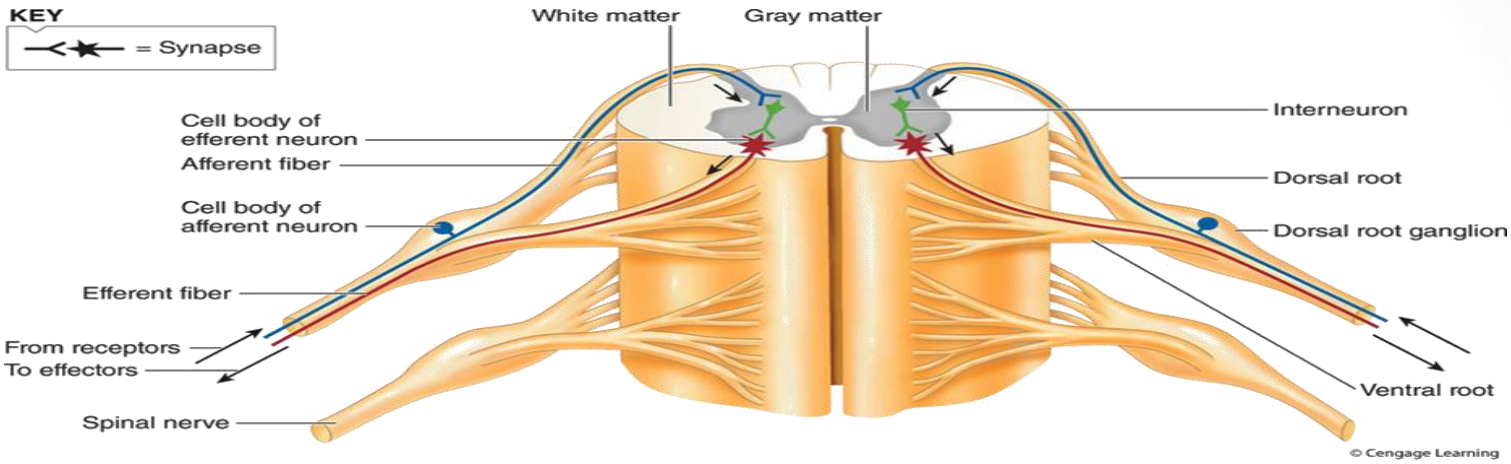
-Describe withdrawal reflex & crossed extensor reflex

--Recognize the general properties of properties of spinal cord reflexes

-Reference book/**Chapter 55 (Guyton & Hall)**

- Review of Human physiology by Ganong (last edition)

THE SPINAL CORD



The spinal cord has 31 pairs of spinal nerves

Each spinal nerve has has ventral & dorsal roots :

- The dorsal(posterior) root contains afferent (sensory) nerves coming from receptors .
- The cell body of these neurons is located in dorsal (posterior) root ganglion (DRG)
- The ventral(anterior) root carries efferent (motor) fibers
- The cell-body of these motor fibres is located in the ventral (anterior) horn of the spinal cord

Functions of the Spinal Cord

1- The two-way traffic along the spinal cord

A-Sensory signals from receptors enter the cord through the sensory (posterior) roots, then every sensory signal travels to two separate destinations:

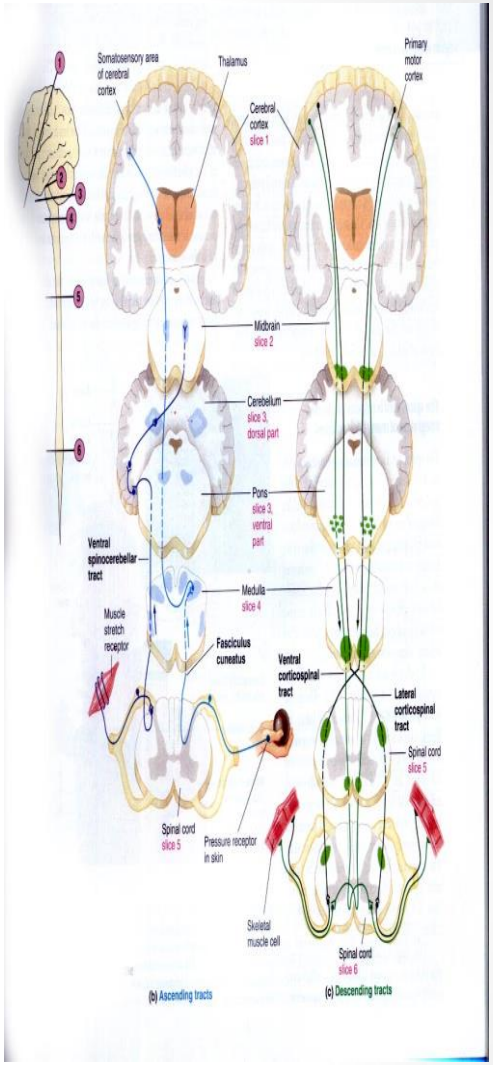
1-One branch of the sensory nerve terminates in the gray matter of the cord and elicits local segmental cord reflexes

2-Another branch transmits signals to higher levels in the cord , or to the brain stem, or even to the cerebral cortex through:-

A- spinal ascending sensory tracts as:

- **Dorsal Column Tracts (Gracile &Cuneate)**
- **Lateral & Anterior Spinothalamic Tract.**
- **Spinocerebellar Tracts**

B- Spinal decending motor tracts:-Motor signals & brain motor commands pass through descending motor tracts & then to spinal efferent motor nerves to skeletal muscles to execute motor functions



2- Initiate spinal reflexes

As withdrawal & stretch reflex

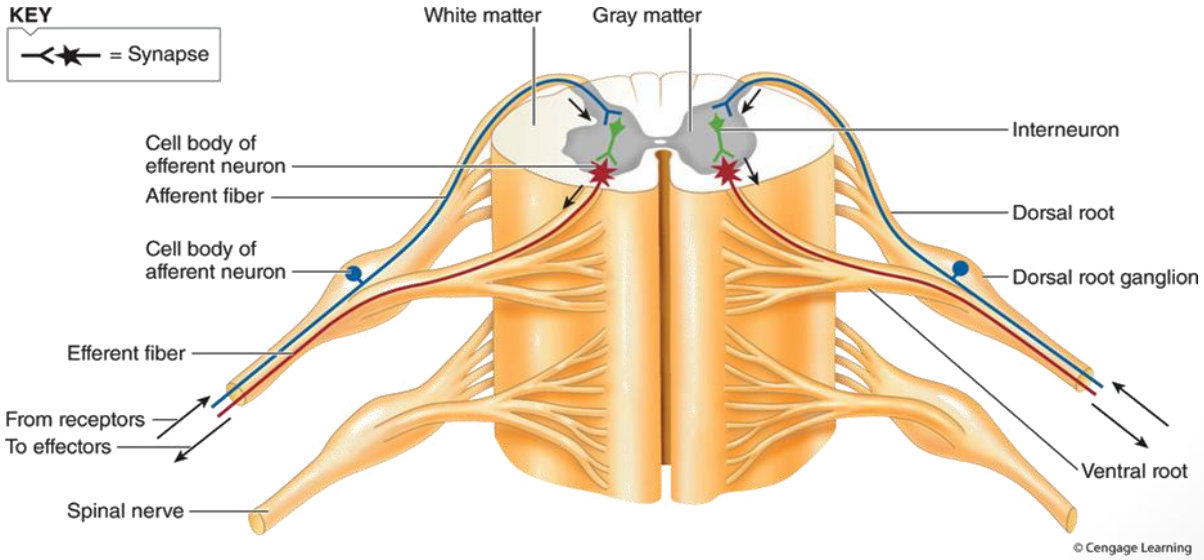
The organization of the spinal cord for motor functions (anterior horn cells& interneurons& neuronal pools)

Located in each segment of the anterior horns of the cord gray matter , several thousand neurons that are 50 to 100 percent larger than others *neurons* .They give rise to the nerve fibers that leave the cord in the ventral roots and directly innervate the skeletal muscle fibers.

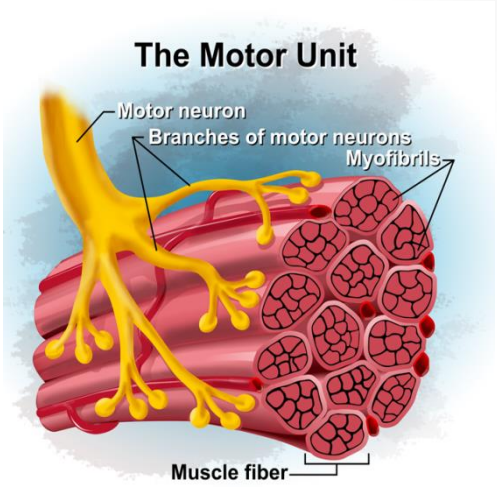
- ***1-Alpha motor neurons*:**
- -They give rise to large type A alpha motor nerve fibers,
- ***2-Gamma motor neurons:-***

-smaller *gamma motor neurons*

-They transmit impulses through much smaller type A gamma motor nerve fibers



Q-What is the motor unit ?



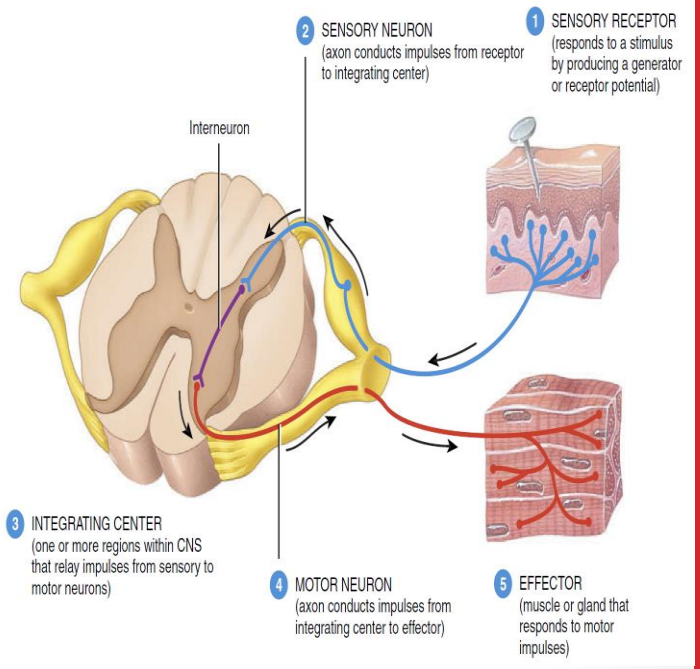
Spinal reflexes

What is a reflex?

-Functional unit of CNS, rapid, automatic ,

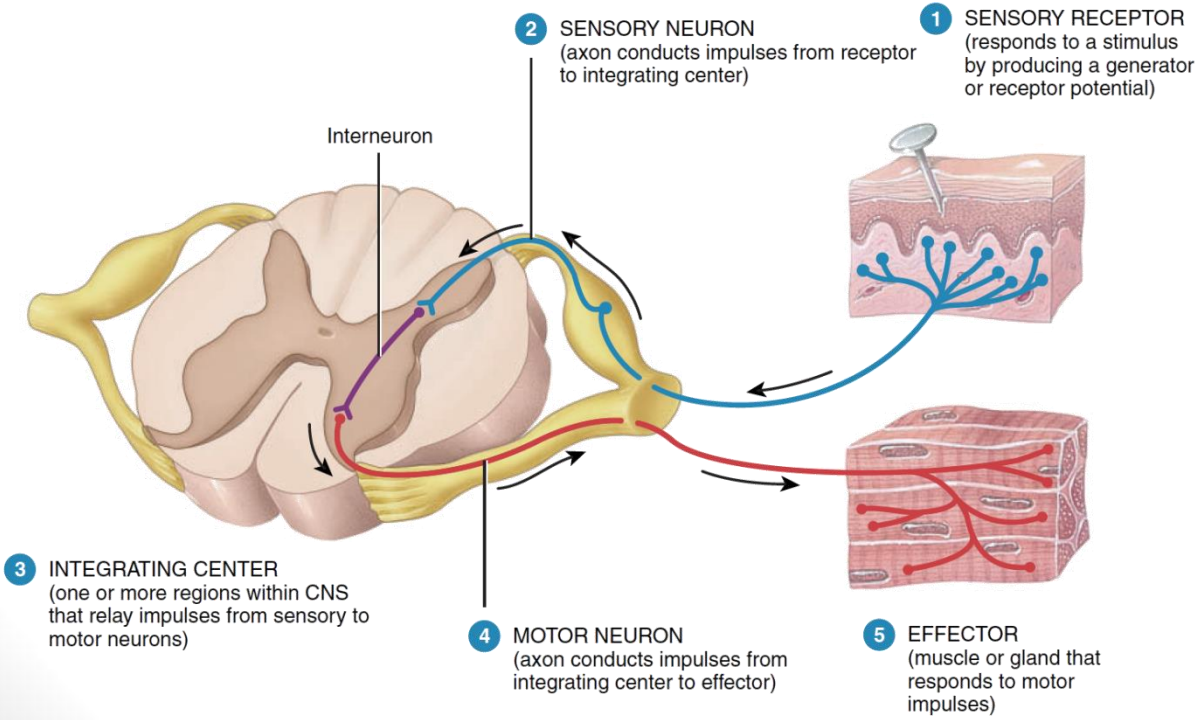
involuntary response to a stimulus that involve spinal neurons only

-example/pinprick causes withdrawal. R



Components of the reflex arc

REFLEX ARC IS THE PATHWAY FOLLOWED BY NERVE IMPULSES THAT PRODUCE A REFLEX IS A REFLEX ARC (REFLEX CIRCUIT)



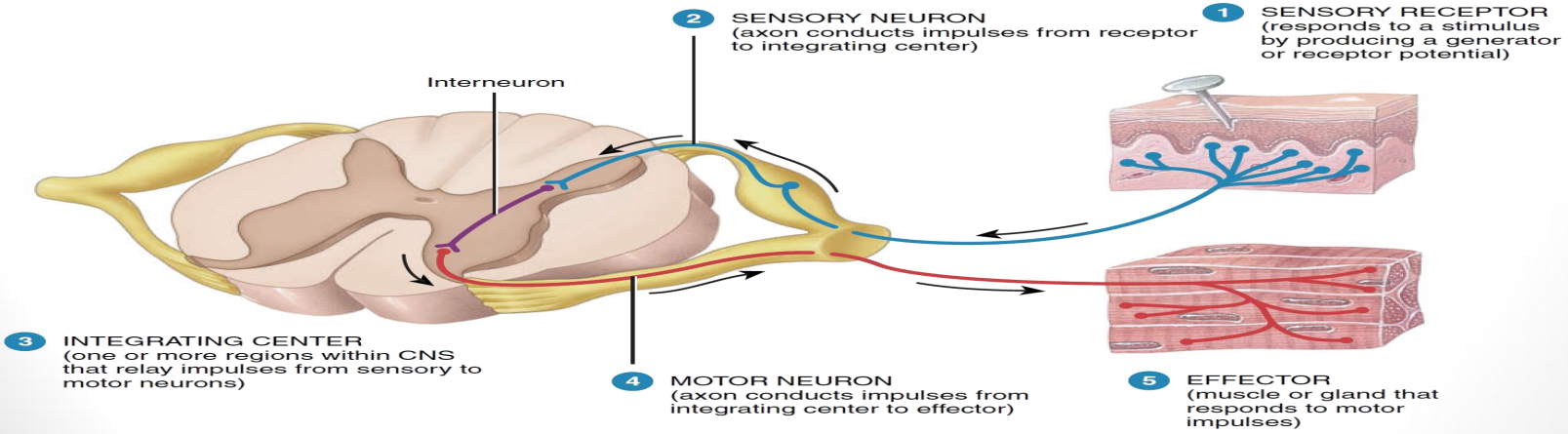
A REFLEX ARC INCLUDES FIVE FUNCTIONAL COMPONENTS

- SENSORY RECEPTOR
- SENSORY NEURON
- INTEGRATING CENTER
- MOTOR NEURON
- EFFECTOR

SENSORY RECEPTOR |1|

IT RESPONDS TO A SPECIFIC STIMULUS—A CHANGE IN THE INTERNAL OR EXTERNAL ENVIRONMENT—BY PRODUCING A GRADED POTENTIAL CALLED A GENERATOR (OR RECEPTOR) POTENTIAL

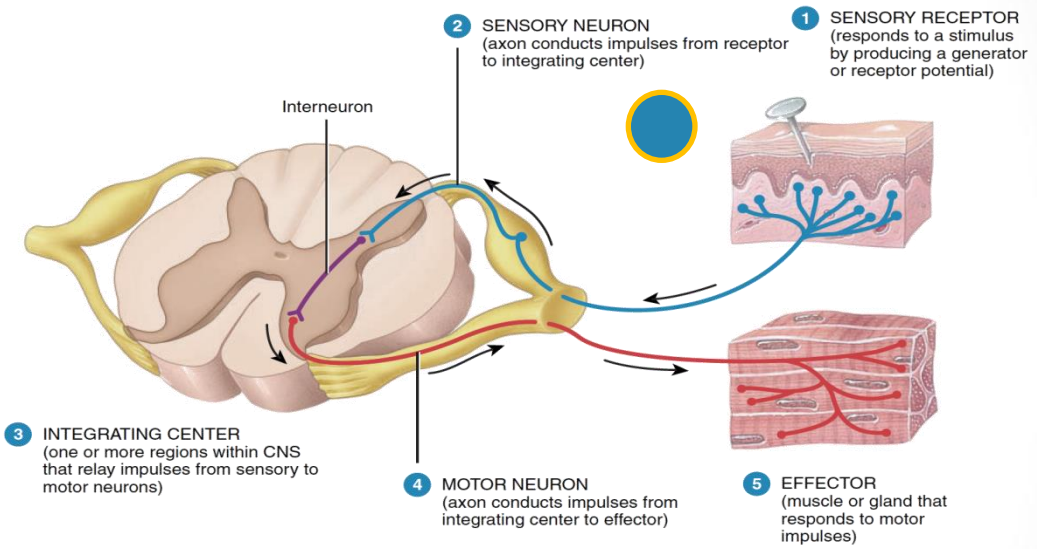
IF A GENERATOR POTENTIAL REACHES THE THRESHOLD LEVEL OF DEPOLARIZATION, IT WILL TRIGGER ONE OR MORE NERVE IMPULSES IN THE SENSORY NEURON



SENSORY NEURON |2|

THE NERVE IMPULSES PROPAGATE FROM THE SENSORY RECEPTOR ALONG THE AXON OF THE SENSORY NEURON TO THE AXON TERMINALS, WHICH ARE LOCATED IN THE GRAY MATTER OF THE SPINAL CORD OR BRAIN STEM.

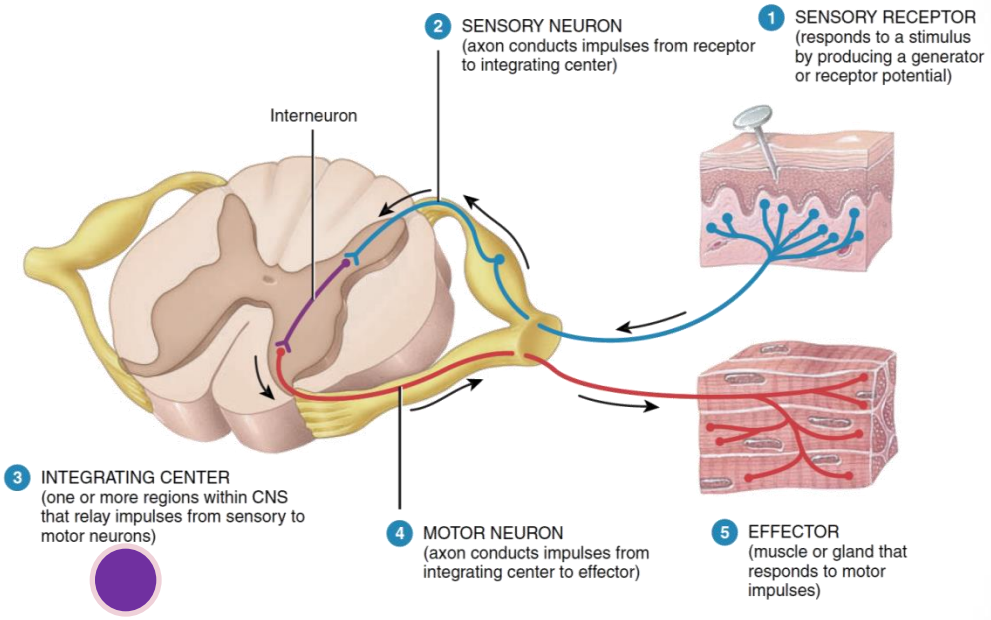
RELAY NEURONS SEND NERVE IMPULSES TO THE AREA OF THE BRAIN THAT ALLOWS CONSCIOUS AWARENESS THAT THE REFLEX HAS OCCURRED.OR IT SEND TO MOTOR NEURON OR INTERNEURON



INTEGRATING CENTRE|3|

IN THE SIMPLEST TYPE OF REFLEX, THE INTEGRATING CENTER IS A SINGLE SYNAPSE BETWEEN A SENSORY NEURON AND A MOTOR NEURON TERMED MONOSYNAPTIC REFLEX ARC.

A POLYSYNAPTIC REFLEX ARC INVOLVES MORE THAN TWO TYPES OF NEURONS AND MORE THAN ONE CNS SYNAPSE.



- Interneurons & interneuron pool

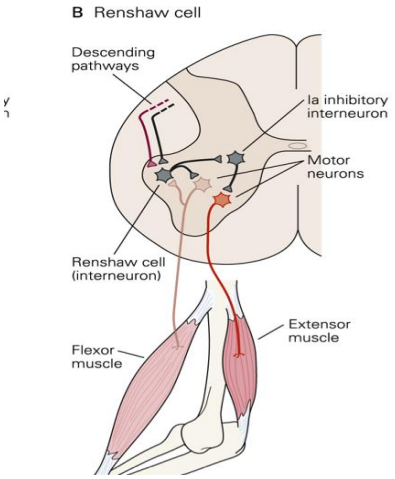
- **Interneurons** are present in the gray matter in the dorsal horns, the anterior horns, and the intermediate areas between them.
- -30 times as numerous as the anterior motor neurons, small and highly excitable, often exhibiting spontaneous activity

- Different types of neuronal circuits are found in the interneuron pool **(parallel and reverberating circuits).**

- **Have** diverging, converging, and repetitive-discharge

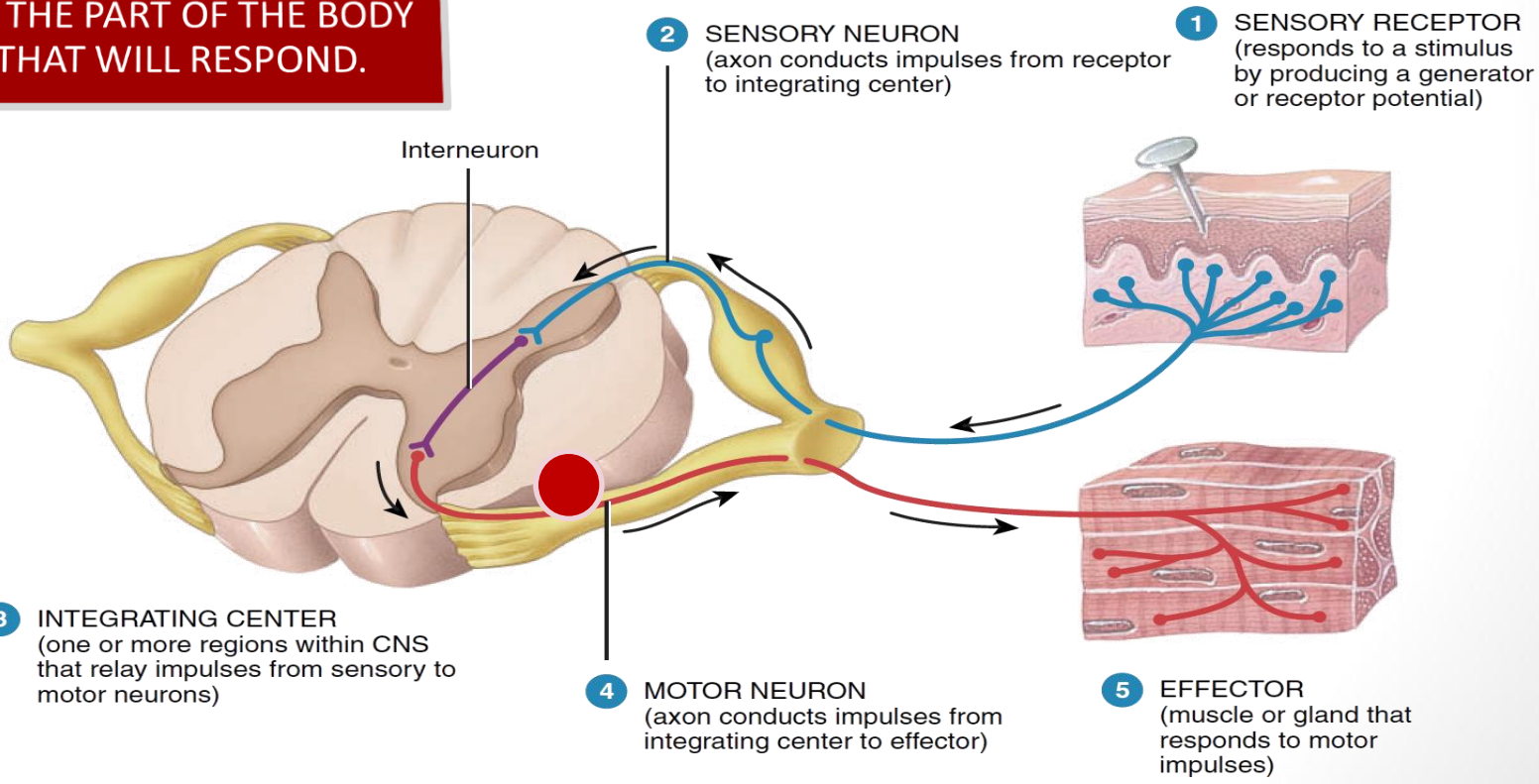
- They are **(excitatory or inhibitory).**

- **Renshaw Cells :-**
- - As the anterior motor neuron axon leaves the body of the neuron, sends collateral branches to adjacent Renshaw cells.
- - These are **inhibitory cells** that transmit inhibitory signals to the surrounding motor neurons BY **Lateral inhibition**/ So stimulation of one motor neuron tends to inhibit adjacent motor neurons .
- -This lateral inhibition helps to focus or sharpen the signals from each excited motor neuron
- allow transmission of the primary signal in the desired direction& suppressing the tendency for signals to spread laterally)



-Efferent neuron

IMPULSES TRIGGERED BY THE INTEGRATING CENTER PROPAGATE OUT OF THE CNS ALONG A MOTOR AXON TO THE PART OF THE BODY THAT WILL RESPOND.



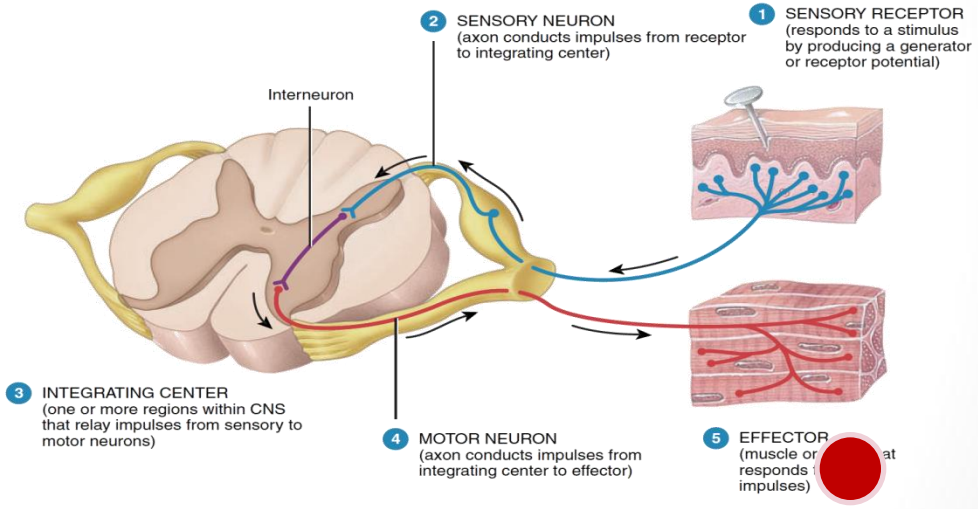
- **MOTOR NEURON|4|(Efferent neurons)**
- **Anterior Horn Cells (Motor neurons) of spinal cord supplying skeletal muscle:**

1. **alpha motor neurons :- large cells, with large mylinated fibres (axons) form 70% of ventral root - supply extrafusal muscle fibres (2/3 Of skeletal muscle fibers)**
2. **Gamma motor neurons :- smaller cells- with thiner axons form 30 % of ventral root - supply intrafusal muscle fibres (muscle spindles=1/3 Of skeletal muscle fibers)**

EFFECTOR|5|

THE PART OF THE BODY THAT RESPONDS TO THE MOTOR NERVE IMPULSE, SUCH AS A MUSCLE IS THE EFFECTOR.

IF THE EFFECTOR IS SKELETAL MUSCLE, THE REFLEX IS A SOMATIC REFLEX.



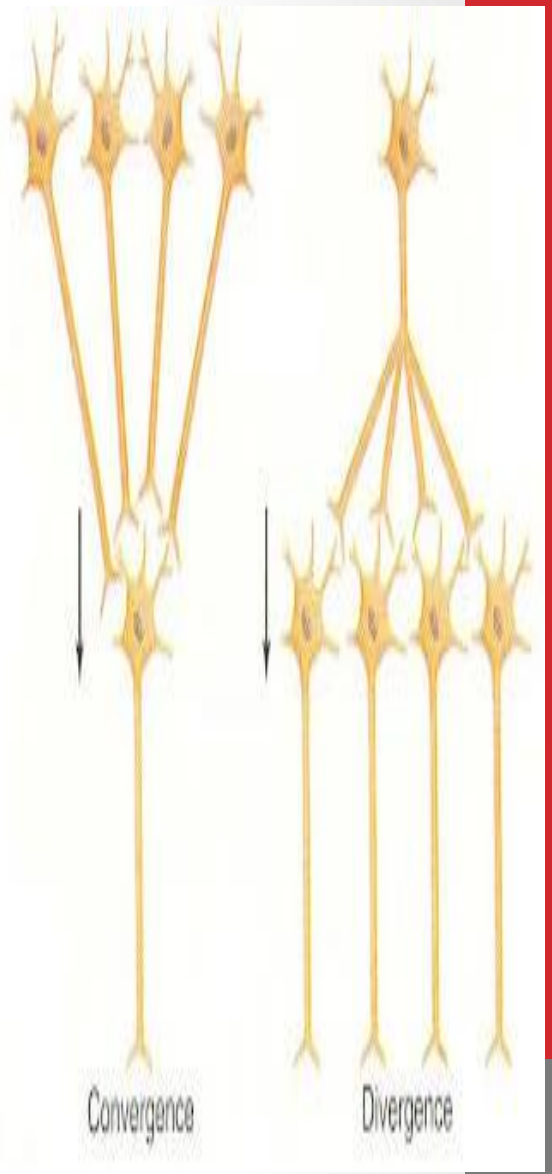
DESCRIBE THE GENERAL PROPERTIES OF REFLEXES AND THEIR NEURONAL POOLS SUCH AS

- CONVERGENCE
- DIVERGENCE
- IRRADIATION
- RECRUITMENT
- REVERBERATING CIRCUITS
- AFTER-DISCHARGE
- MINIMAL SYNAPTIC DELAY
- CENTRAL DELAY

- Sensory afferent enter spinal cord via dorsal(posterior) root, as they enter the neuronal pool undergo:

1- **Divergence** help to spread a single stimulus to a wide area of the spinal cord(amplification of signal)

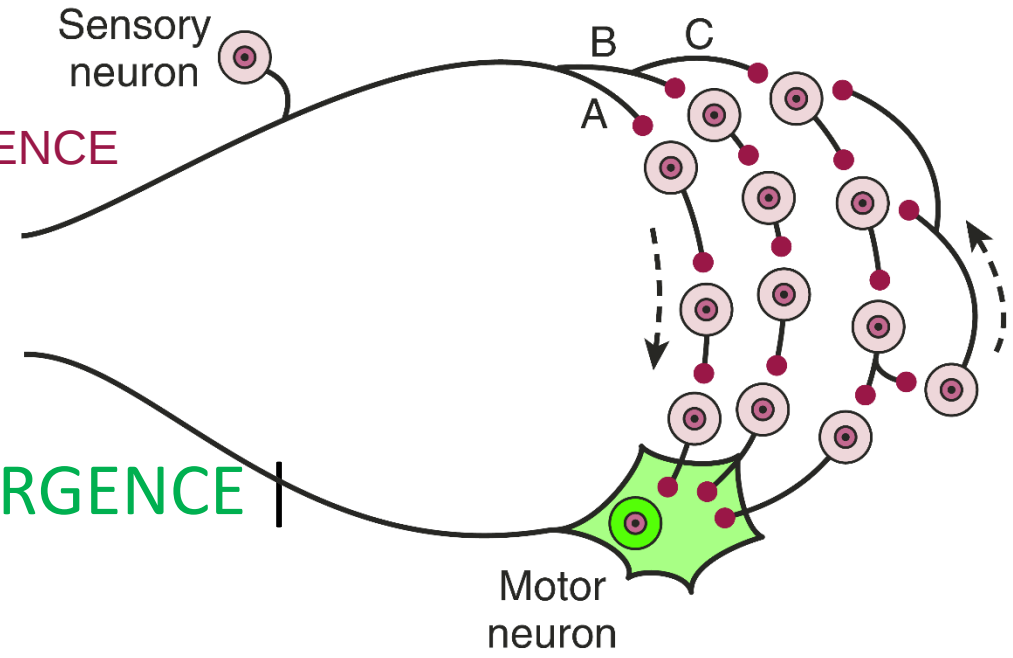
- it is important for weak signals to excite far greater numbers of nerve fibers leaving the pool.



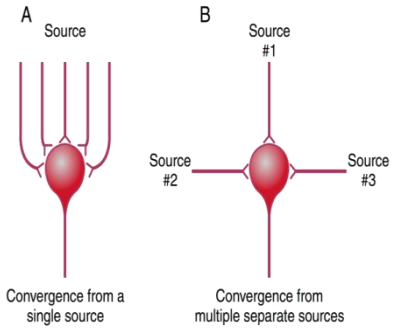
2-**Convergence** :- signals from multiple inputs unit to excite a single neuron

-multiple action potentials converging on the neuron provide enough spatial summation to bring the neuron to the threshold required for discharge.

- (multiple stimuli summate & collect together at the same time)



- CONVERGENCE



OUTPUT FROM ONE NEURON ONTO MANY.

EACH POSTSYNAPTIC NEURON RECEIVES INPUT FROM THE SAME PRESYNAPTIC NEURON, BUT MAY REACT TO IT DIFFERENTLY.

IN A DIVERGENT NEURAL CIRCUIT, THE AXON OF ONE NEURON BRANCHES TO SEND INFORMATION TO MULTIPLE TARGET NEURONS.

DIVERGENT OUTPUT ALLOWS THE SAME SIGNAL TO REACH MANY DIFFERENT NEURONS.

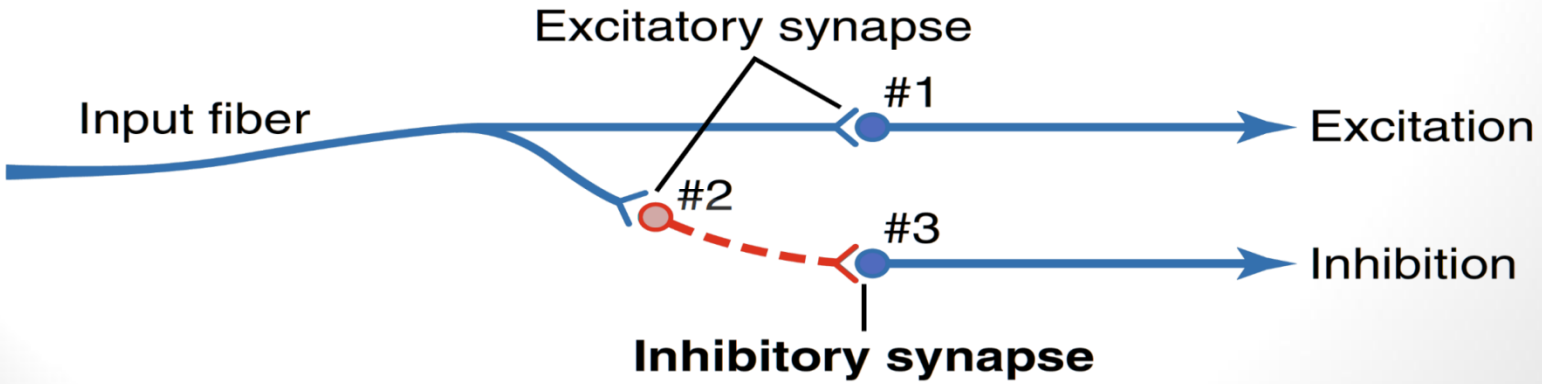
3-Reciprocal inhibition circuits

-Stimulation of flexors muscle accompanied by inhibition of extensors through inhibitory interneurons , the neuronal circuit that causes this reciprocal relation is called reciprocal innervation

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

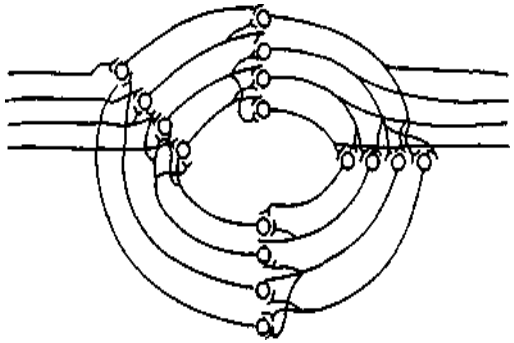
-the input fibre directly excites the excitatory output pathway, but it stimulates an intermediate *inhibitory neuron* (neuron 2), which secretes a different type of transmitter substance to inhibit the second output pathway from the pool. (3)

-Value/ preventing over activity in many parts of the spinal cord.

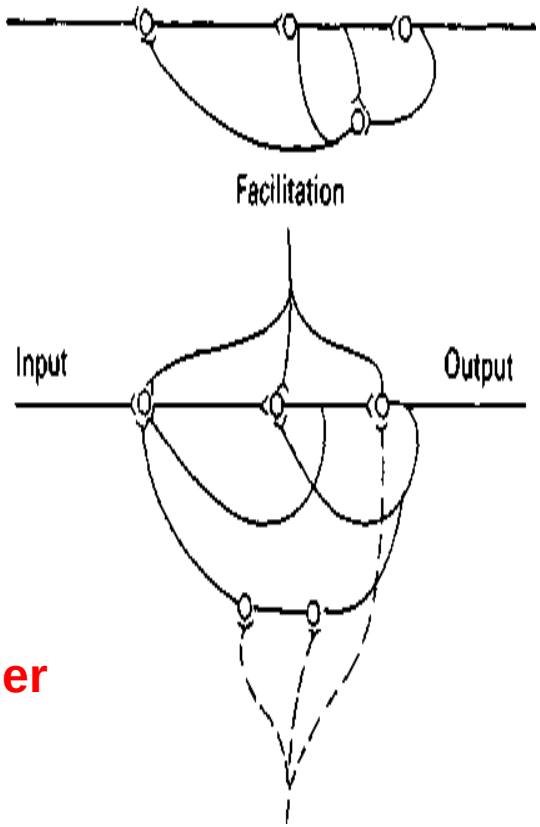


Neuronal pool circuits

1- Parallel



2-Reverbrating



1-Parallel circuits //afferent and efferent are parallel to each other (input parallel to output)

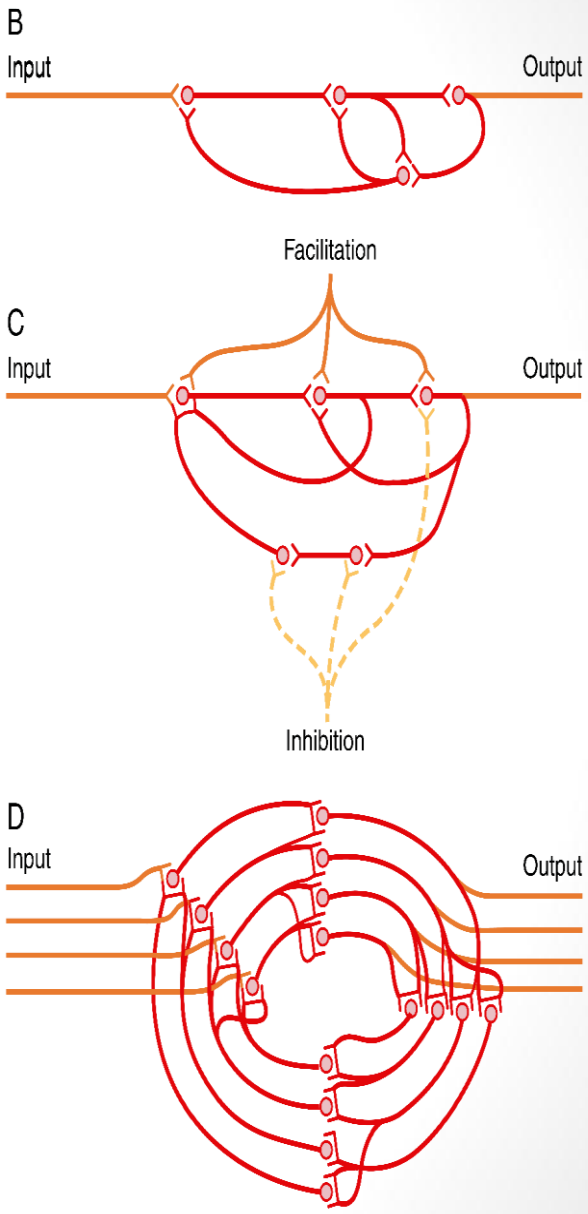
- **4-Reverberatory (Oscillatory) Circuit**
- **1-The simplest reverberatory circuits involves only a single neuron**
- **-the output neuron sends a collateral nerve fiber back to its own dendrites or soma to restimulate the input neuron itself & so the circuit may discharge repetitively for a long time and causes signal prolongation (Allow prolonged discharge of the same motor neurons by a single stimulus**
- **- Amore complex circuits in which both facilitatory and inhibitory fibers involved on the reverberating circuit.**
- **A facilitatory signal enhances the intensity and frequency of reverberation, whereas an inhibitory signal depresses or stops the reverberation.**
- **- Most reverberating pathways are constituted of many parallel fibers**

B SHOWS A FEW ADDITIONAL NEURONS IN THE FEEDBACK CIRCUIT, WHICH CAUSES A LONGER DELAY BETWEEN INITIAL DISCHARGE AND THE FEEDBACK SIGNAL.

C SHOWS A STILL MORE COMPLEX SYSTEM IN WHICH BOTH FACILITATORY AND INHIBITORY FIBRES INTERACT IN THE REVERBERATING CIRCUIT.

- A FACILITATORY SIGNAL ENHANCES THE INTENSITY AND FREQUENCY OF REVERBERATION,
- AN INHIBITORY SIGNAL DEPRESSES OR STOPS THE REVERBERATION.

D SHOWS THAT MOST REVERBERATING PATHWAYS ARE CONSTITUTED OF MANY PARALLEL FIBRES.



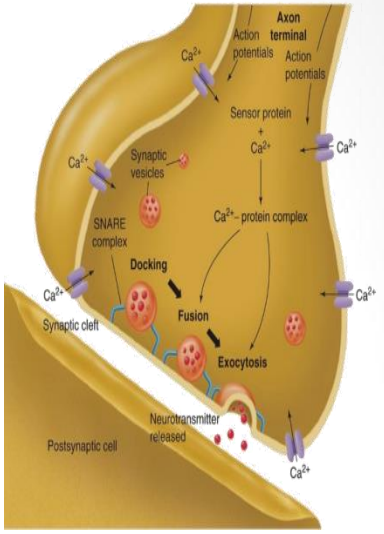
5-After-discharge:-

- **A prolonged maintained output discharge of AHCs called after -discharge, lasting a few milliseconds or many minutes after the incoming signal is over.**

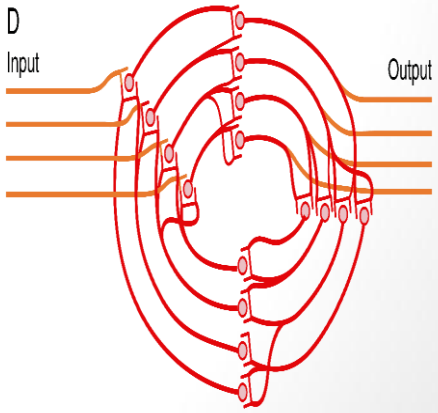
- **After- discharge occurs due to the following:-**

- **1-Synaptic After-discharge.**

When excitatory synapses discharge on the surfaces of dendrites or soma of a neuron, a postsynaptic electrical potential (PSP)develops in the neuron and lasts for milliseconds. As long as this potential lasts, it can continue to excite the neuron to transmit (a series of continuous repetitive discharges) .



- **2- Reverbrating circuits**
- **Presence of reverberating circuit restimulate AHCs**



6-SYNAPTIC DELAY (central delay)

-Is the time of reflex to pass through neurons of the spinal cord

-

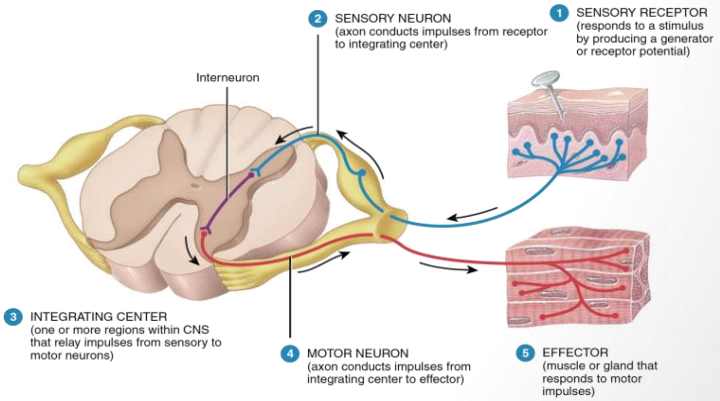
-The minimal period of time required for transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron, is SYNAPTIC DELAY.

-Equals 0.5 ms /synapse (it is long in polysynaptic Reflex).

- It is > 2 ms in the withdrawal R (polysynaptic Reflex)

-Number of synapses in a reflex = central delay / 0.5ms

-for knee jerk it equals 0.6 msc = one synapse



Types of spinal reflexes

-According to number of neurons:-

- **Monosynaptic**
  - Sensory axon (afferent)synapse directly with anterior horn cell- (No interneuron)

  Ex.Stretch reflex
- **Polysynaptic**
  - Sensory axon (afferent)synapse with one or more interneuron

  Ex.Withdarwal,abdominal reflexes, visceral

Types of reflexes

-According to site of the receptor:-

(A)Deep Reflexes:- by stimulation of receptors deep in muscle and tendons

(1) Stretch Reflexes (Tendon jerks) ,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

Are polysynaptic reflexes . The receptor are superficial in the skin . Examples are

Withdrawal, abdominal reflexes and plantar reflex

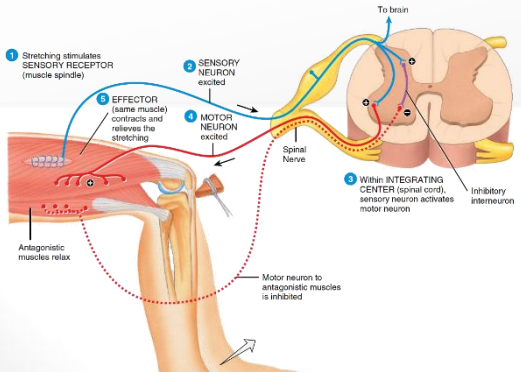
©Visceral:-by stimulation of receptors in wall of viscera

As Micturition, defecation

SUPERFICIAL AND DEEP REFLEXES

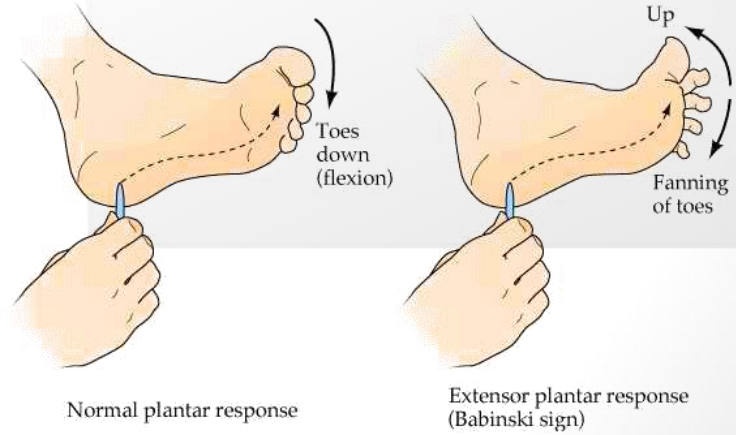
DEEP REFLEXES

- BY STIMULATION OF RECEPTORS DEEP IN MUSCLE AND TENDONS
- EXAMPLES ARE
  - STRETCH REFLEXES (TENDON JERKS)
  - KNEE-JERK (PATELLAR REFLEX)
  - ANKLE JERK .
- THE RECEPTORS FOR THESE ARE THE MUSCLE SPINDLE AND GOLGI TENDON ORGAN REFLEX



SUPERFICIAL REFLEXES

- THE RECEPTORS ARE SUPERFICIAL IN THE SKIN .
- EXAMPLES ARE WITHDRAWAL, ABDOMINAL REFLEXES AND PLANTAR REFLEX



Withdrawal reflex(flexor reflex) (Nociceptive Reflex)

-A **superficial polysynaptic** reflex

Stimulation of pain receptors of hand(a pin- prick, heat, or a wound)>>>>>> **impulses to SC in A delta or C fibres** >>>>>>> **interneurons pool >> motor neurons >> stimulate hand flexor muscles >>move the hand away from the injurious stimulus.**

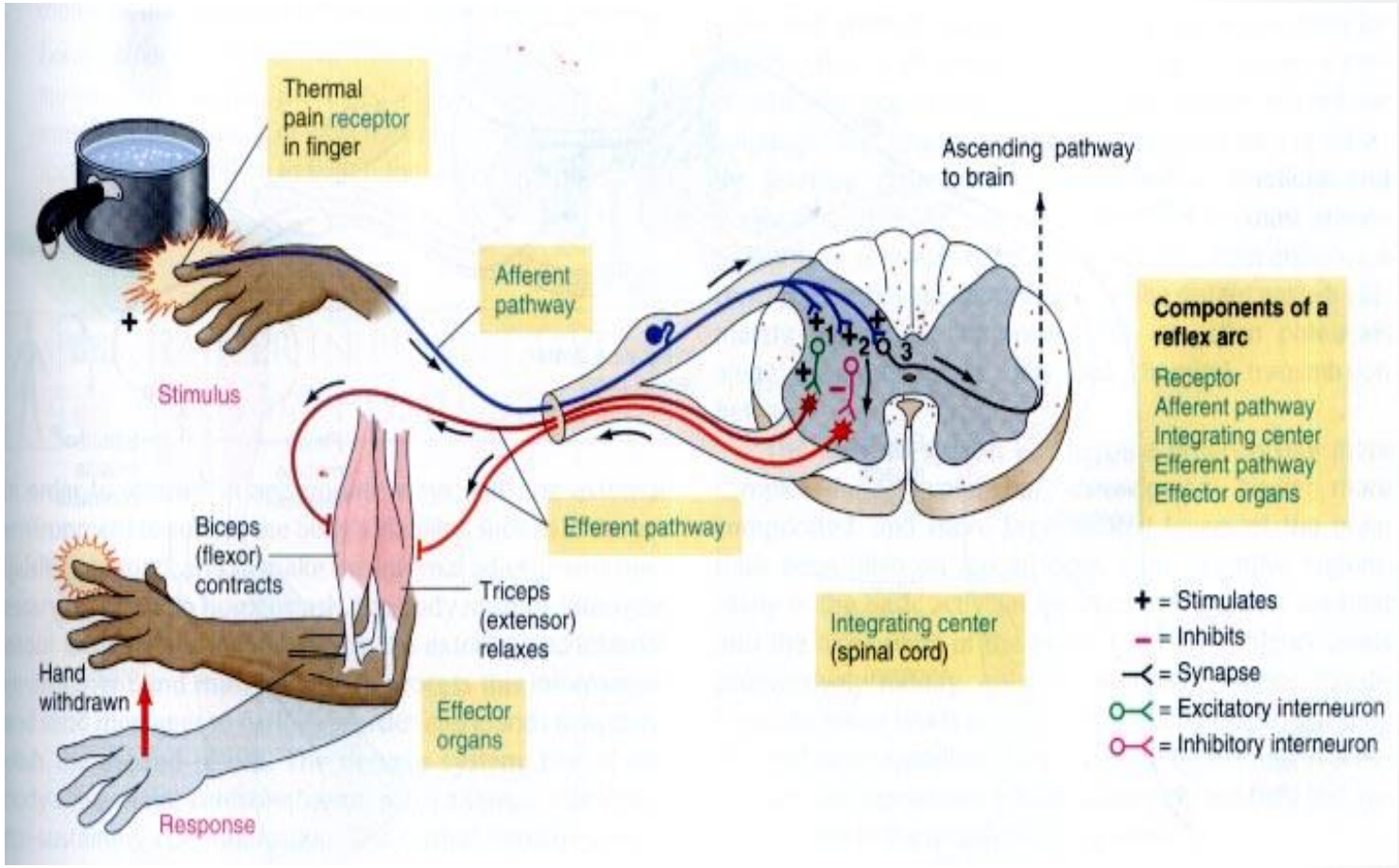
characterised by :

1- diverging circuits to spread the reflex to the necessary muscles for withdrawal

(2) **reciprocal inhibition circuits**

Circuits to inhibit the antagonist muscles

-Stimulation of flexors muscle accompanied by inhibition of extensors through inhibitory interneurons

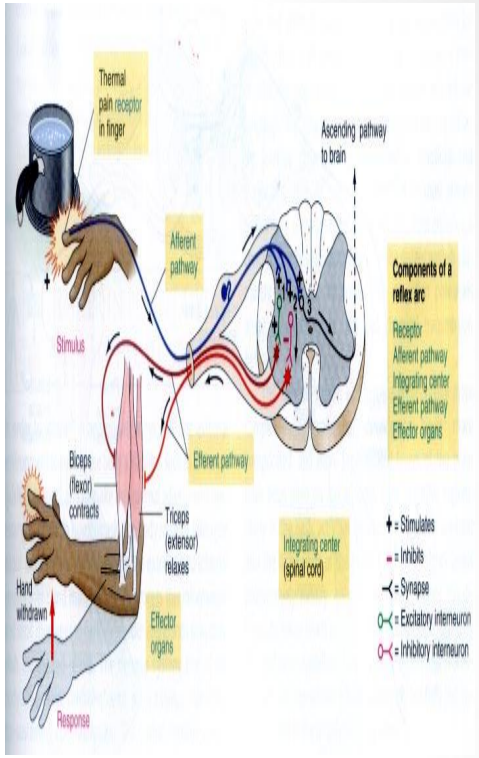

Thermal pain receptor in finger
Ascending pathway to brain
Afferent pathway
Components of a reflex arc
Receptor
Afferent pathway
Integrating center
Efferent pathway
Effector organs
Stimulus
Efferent pathway
Biceps (flexor) contracts
Triceps (extensor) relaxes
Integrating center (spinal cord)
+ = Stimulates
− = Inhibits
= Synapse
= Excitatory interneuron
= Inhibitory interneuron
Hand withdrawn
Effector organs
Response

3- RECRUITMENT :

- **Gradual** activation 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 some are slowly &others are rapidly conducting fibres

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)



Motor unit recruitment :

If a repetitive &stronger stimulus is maintained, there will be gradual increase in the force of the muscle contraction until the maximum force is reached , due to gradual recruitment/activation of more and more motor neurons

4- After-discharge CIRCUITS:-

Circuits to cause afterdischarge lasting many fractions of a second after the stimulus is over.

-The duration of after-discharge depends on the intensity of the sensory stimulus that elicited the reflex

Cause/
-Presence of reverberating circuit restimulate AHCs

-Value /prolong the protective response of reflex

5- IRRADIATION :- - spread of impulses up & down to different segments and motor neurons in the S.C

A strong stim 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.**

- The more intense the stimulus >>>> greater spread of activity in the spinal cord >>>involving more & more motor neurons>>>more response

- Weak stim-----irradiates to small number of neurons ,
  so it causes weak flexion of limb

- Strong stim---- irradiates to large number of neurons ,
  so it causes withdrawal of affected limb &
  extension of opposite limb.(as in crossed extensor reflex)

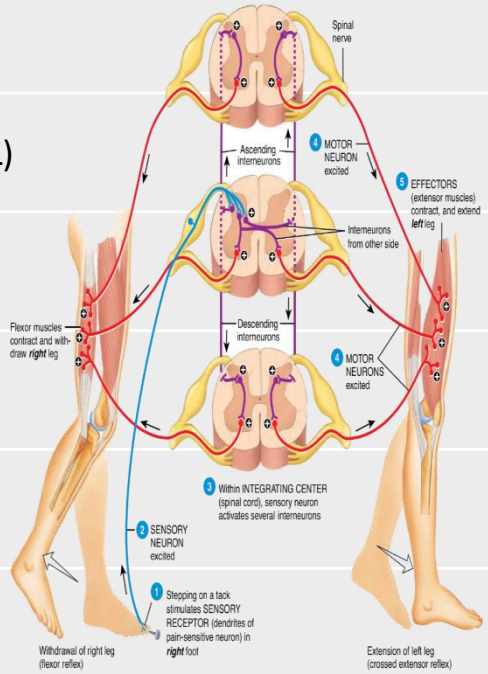
- **6- "local sign" Pattern of Withdrawal.**

The pattern of withdrawal that results when the flexor reflex is elicited depends on which sensory nerve is stimulated.

- - Thus, a pain stimulus on the inward side of the arm elicits not only contraction of the flexor muscles of the arm but also contraction of abductor muscles to pull the arm outward.
- This is called the principle of "**local sign"**

THE WITHDRAWAL REFLEX |

REFLEX	FLEXOR REFLEX OR WITHDRAWAL REFLEX	
CLINICAL TEST | STIMULUS	SHARP PAINFUL STIMULUS (STEPPING ON NAIL)	
RESPONSE	LIMB IS RAPIDLY WITHDRAWN	
SENSORY RECEPTOR	CUTANEOUS SKIN AND PAIN RECEPTORS	
SYNAPSES INVOLVED	POLYSYNAPTIC (VIA INTERNEURON)	
EFFECTS ON MUSCLE	CONTRACTS FLEXOR MUSCLE	
OTHER EFFECTS	RELAXES (-) EXTENSOR MUSCLE OF SAME LIMB	REVERSE EFFECT ON OPPOSITE LIMB (CROSS EXTENSOR REFLEX)
FUNCTION	PROTECTIVE – WITHDRAWAL FROM PAINFUL STIMULUS	CROSS EXTENSOR AIDS IN MAINTAINING POSTURE WHEN OPPOSING LEG IS LIFTED



https://musom.marshall.edu/anatomy/grosshom/allppt/pdf/Spinalreflexes.pdf

Crossed Extensor Reflex:-

Crossed extensor reflex supporting the body weight against gravity While pushing the body away from the injurious agent by withdrawal R ,the Flexion and withdrawal of the stimulated limb >> extension of the opposite limb

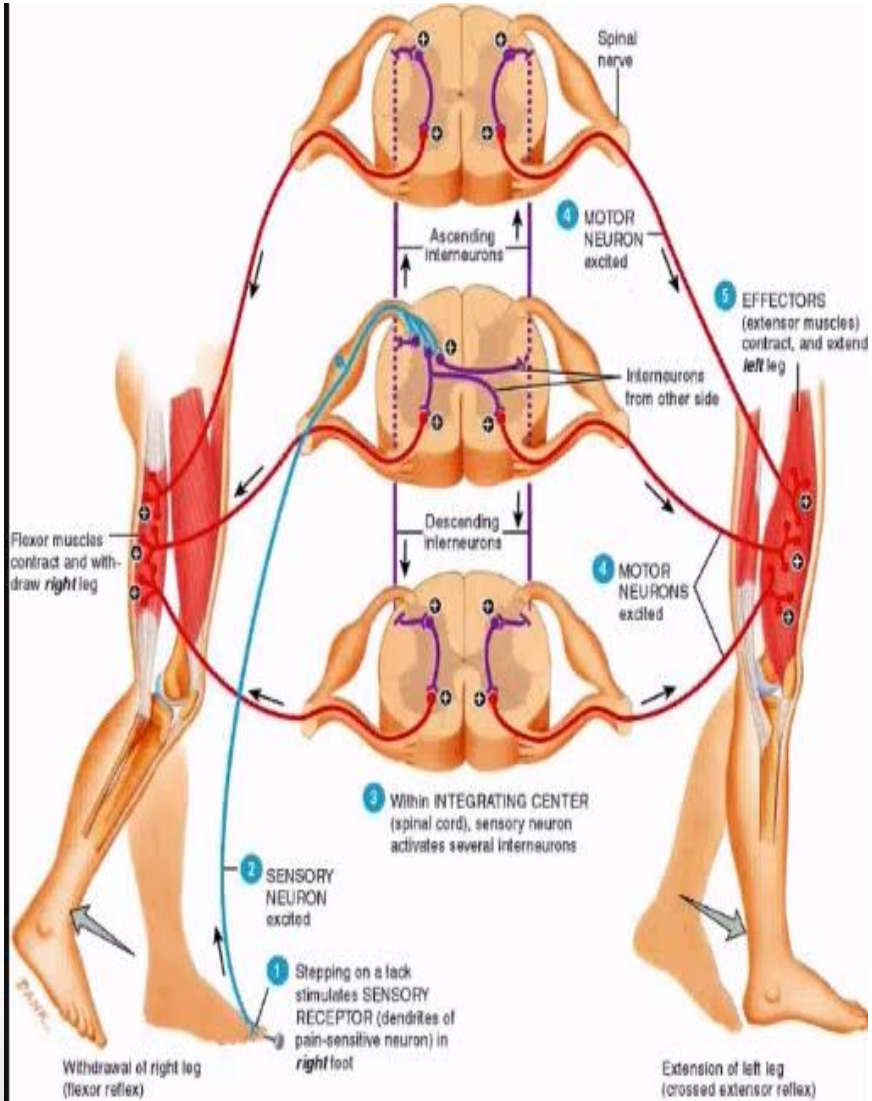
- Occurs with strong stimulus only. why?

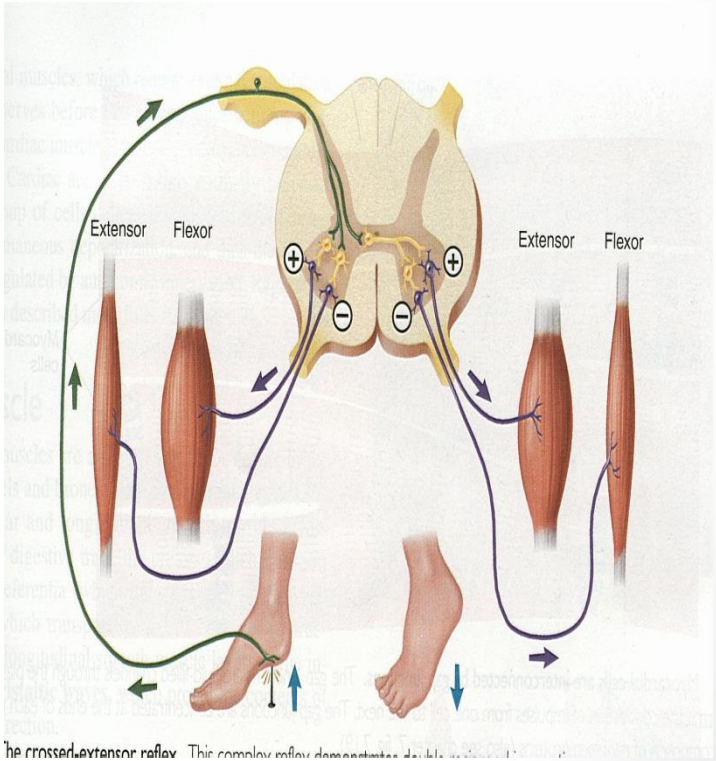
Signals from sensory neurons cross to the opposite side of the cord to excite extensor muscles motor neurons.
-It does not begin until 200 to 500 milliseconds after onset of the initial pain stimulus, because many interneurons are involved in the circuit between the incoming sensory neuron and the motor neurons of the opposite side of the cord
-After the painful stimulus is removed, the crossed extensor reflex has an even longer period of afterdischarge, results from reverberating circuits among the interneuronal cells.
The prolonged afterdischarge is of benefit in holding the body away from the painful object

- Mostly in the lower limb to support balance.

- It has reciprocal innervations occurs also in crossed extensor reflex. How?
-flexors in the opposite limb are inhibited while extensors are excited supporting the body weight against gravity during withdrawal .R

Crossed extensor reflex





he crossed-extensor reflex. This complex reflex demonstrates double