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 physiological role of the spinal cord as an initiator of spinal reflexes.
-- Describe the organization of the spinal cord for motor functions(anterior horn cells& interneurons & neuronal pools)
-Describe the spinal reflex and reflex arc components
--Classify reflexes into superficial and deep; monosynaptic & polysynaptic
-Describe the most important types of spinal cord reflexes as withdrawal reflex & crossed extensor reflex
--Describe THE GENERAL PROPERTIES OF properties of spinal cord reflexes such as convergence, divergence ,irradiation, recruitment , after discharge, recruitment, reverberating circuits, , minimal synaptic delay, central delay and reflex time .

Reference book/Gyton chapter 54&46 and Review of Human physiology by Ganong (last edition)

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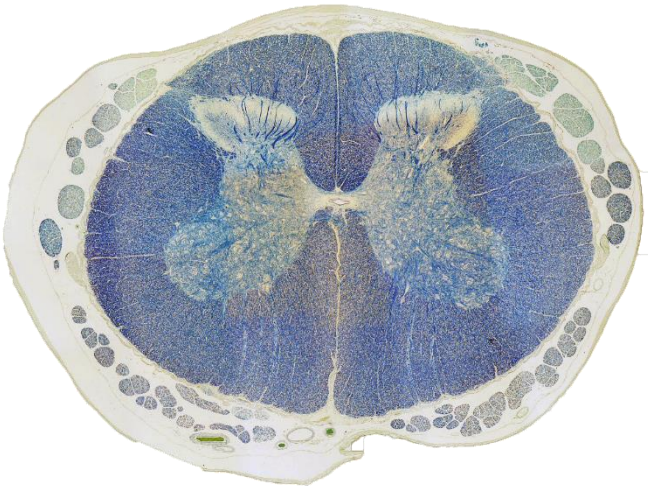
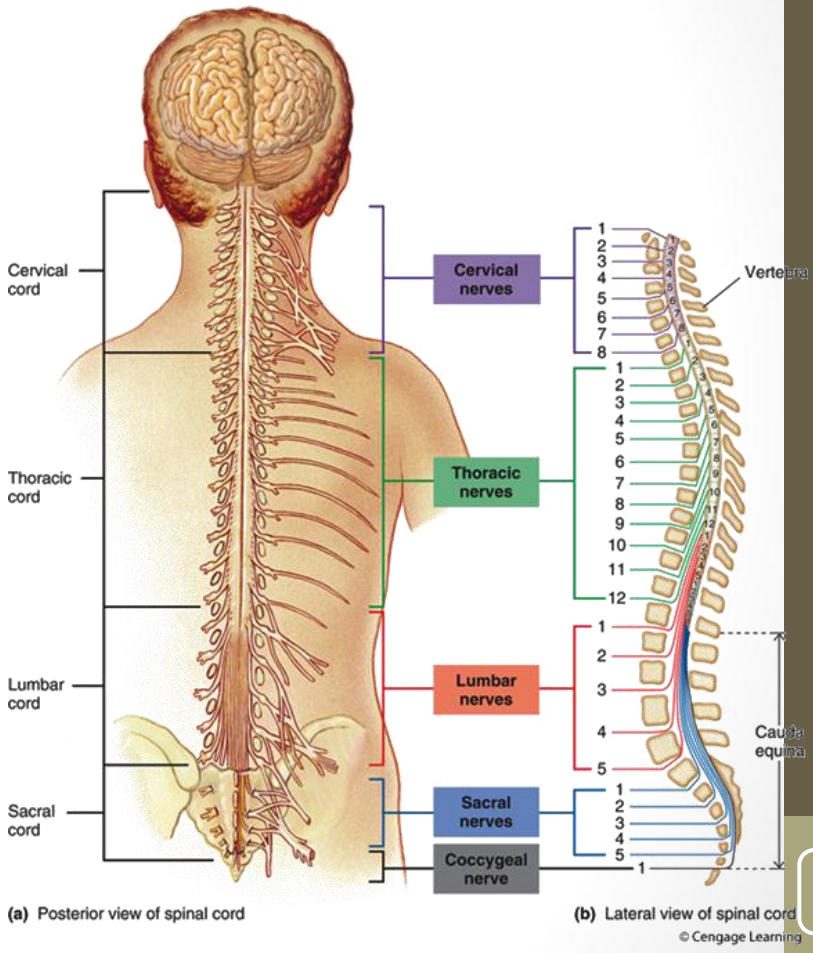
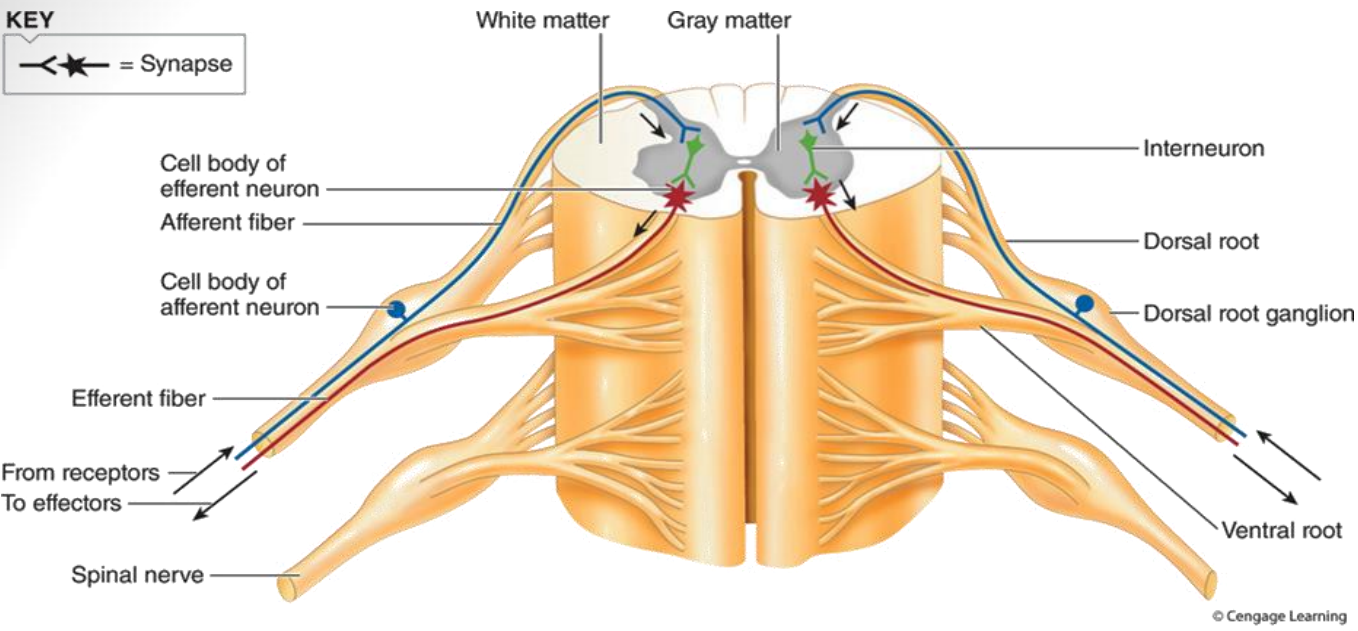
THE SPINAL CORD



ABOUT 100 MILLION NEURONES AND EVEN MORE NEUROGLIA COMPOSE THE **SPINAL CORD**

THE SPINAL CORD IS CONTINUOUS WITH THE BRAIN AND TOGETHER THEY MAKE UP THE CENTRAL NERVOUS SYSTEM (CNS)





The spinal cord has 31 pairs of spinal nerves

Each spinal nerve has has ventral & dorsal roots :

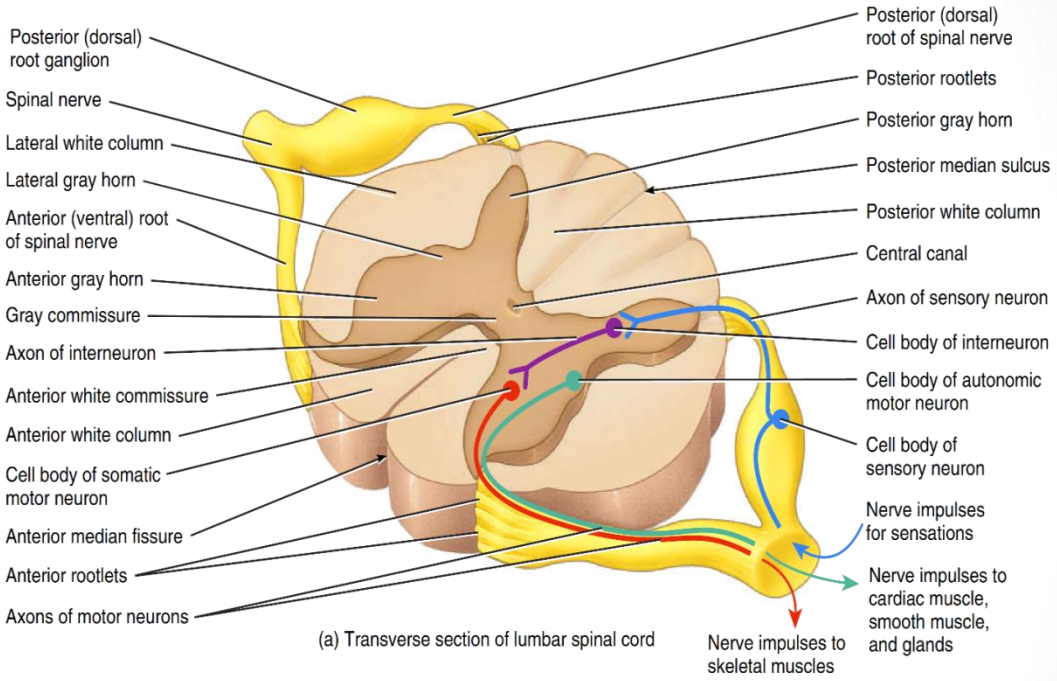
- The dorsal(posterior) root contains afferent (sensory) nerves coming from receptors .
- The cell body of these neurons is located in dorsal (posterior) root ganglion (DRG)
- The ventral(anterior) root carries efferent (motor) fibers
- The cell-body of these motor fibres is located in the ventral (anterior)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

GREY MATTER | NUCLEI

IN THE GREY MATTER OF THE SPINAL CORD AND BRAIN, CLUSTERS OF NEURONAL CELL BODIES FORM FUNCTIONAL GROUPS CALLED NUCLEI

SENSORY NUCLEI RECEIVE INPUT FROM RECEPTORS VIA SENSORY NEURONS

MOTOR NUCLEI PROVIDE OUTPUT TO EFFECTOR TISSUES VIA MOTOR NEURONS



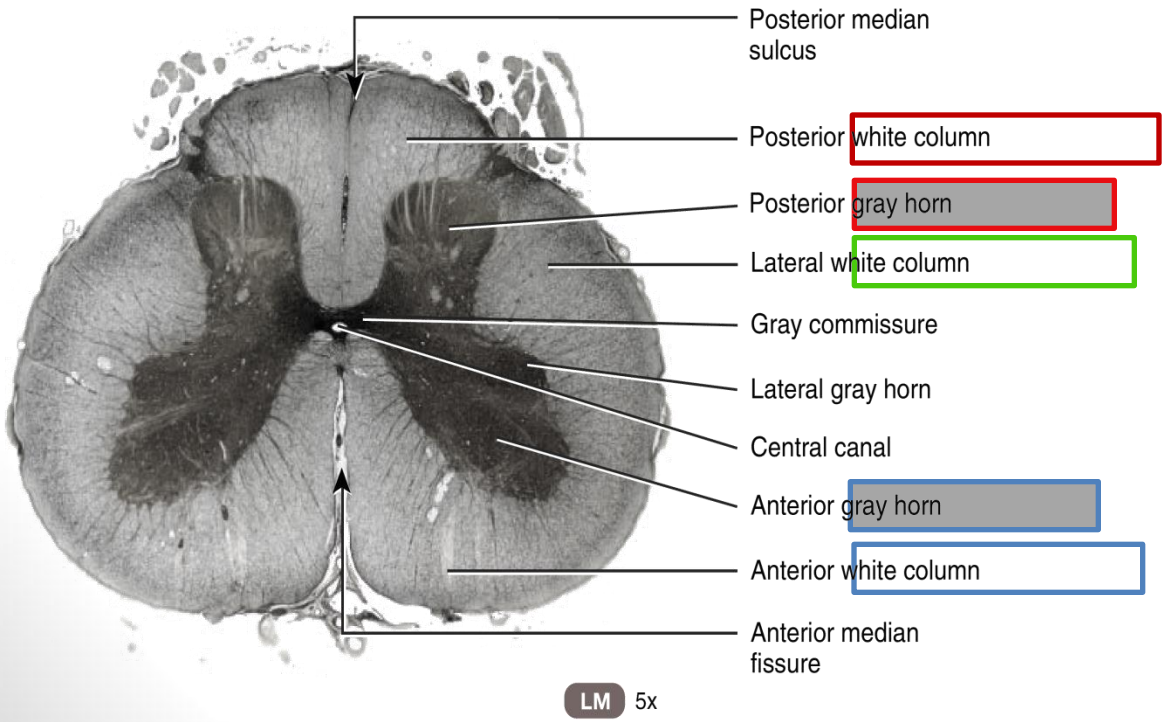
THE POSTERIOR GREY HORN CONTAINS AXONS OF SENSORY NEURONS AND CELL BODIES OF INTERNEURONS

THE LATERAL GREY HORN CONTAINS CELL BODIES OF AUTONOMIC MOTOR NEURONS;

THE ANTERIOR GREY HORN CONTAINS CELL BODIES OF SOMATIC MOTOR NEURONS.

WHITE MATTER

- The white matter of the spinal cord, like the grey matter, is organized into regions.
- The anterior and posterior grey horns divide the white matter on each side
- White matter is divided into three broad areas called **columns:**
  - **anterior** (*ventral*) **white columns,**
  - **posterior** (*dorsal*) **white columns,**
  - **lateral white columns**



EACH COLUMN IN TURN CONTAINS DISTINCT BUNDLES OF AXONS HAVING A COMMON ORIGIN OR DESTINATION AND CARRYING SIMILAR INFORMATION.

THESE BUNDLES, WHICH MAY EXTEND LONG DISTANCES UP OR DOWN THE SPINAL CORD, ARE CALLED **TRACTS.**

RECALL THAT TRACTS ARE BUNDLES OF AXONS IN THE CNS, WHEREAS NERVES ARE BUNDLES OF AXONS IN THE PNS.

SENSORY (*ASCENDING*) **TRACTS** CONSIST OF AXONS THAT CONDUCT NERVE IMPULSES TOWARD THE BRAIN.

TRACTS CONSISTING OF AXONS THAT CARRY NERVE IMPULSES FROM THE BRAIN ARE CALLED **MOTOR** (*DESCENDING*) **TRACTS.**

SENSORY AND MOTOR TRACTS OF THE SPINAL CORD ARE CONTINUOUS WITH SENSORY AND MOTOR TRACTS IN THE BRAIN.

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:

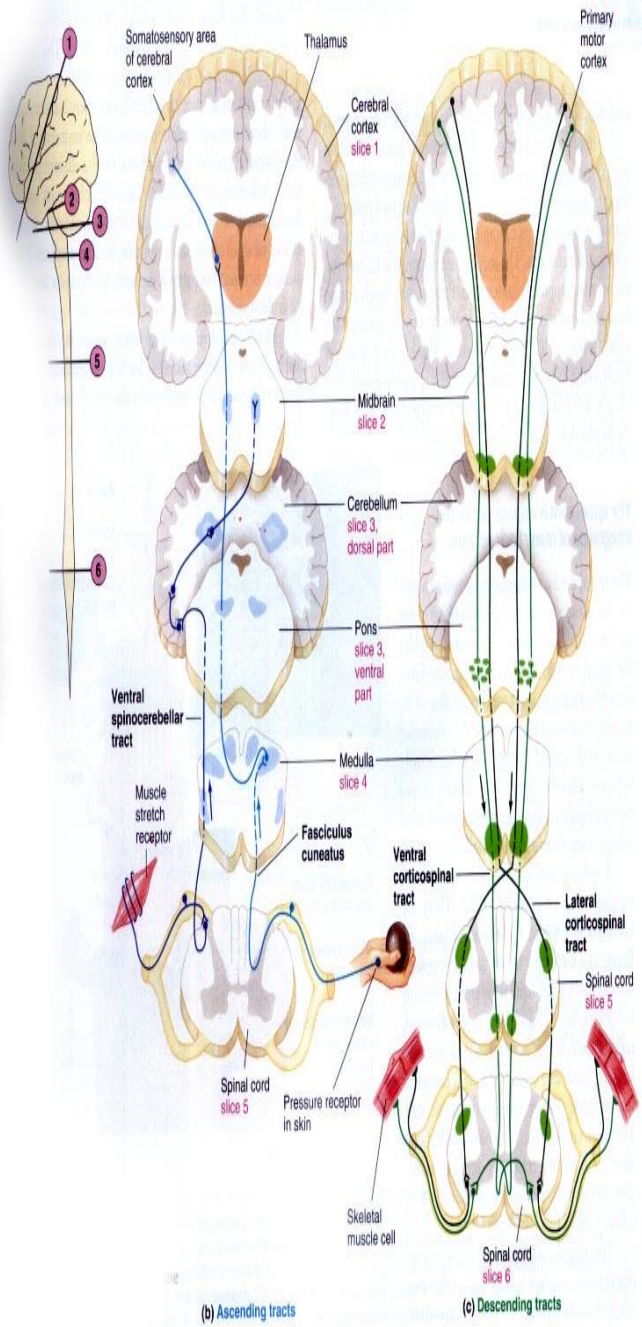
1-One branch of the sensory nerve terminates in the gray matter of the cord and elicits local segmental cord reflexes

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

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

B- Motor signals & brain motor commands pass through descending motor tracts & spinal efferent motor nerves to skeletal muscles to excute motor functions

(2) Generating Spinal Reflexes



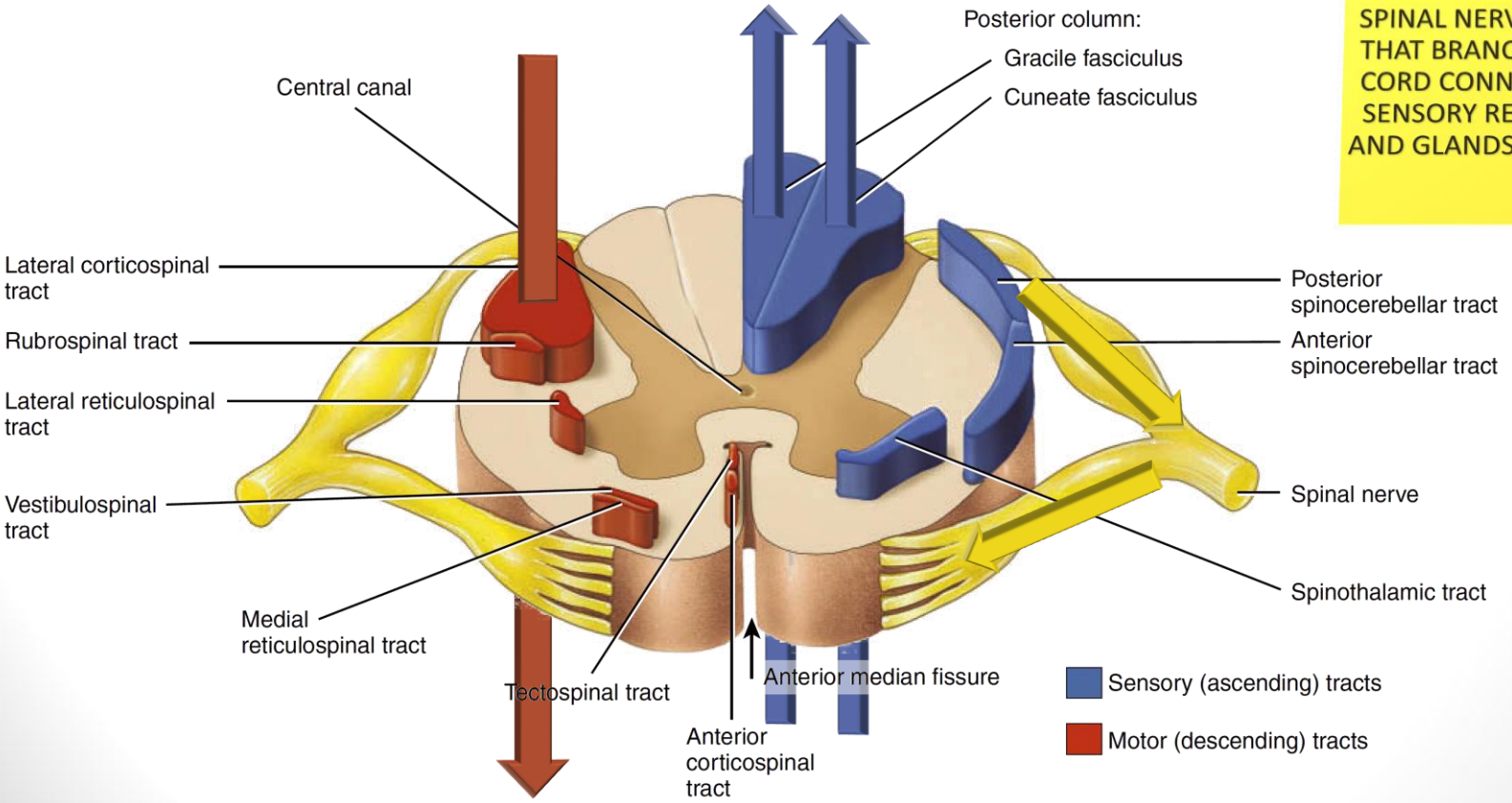
OBJECTIVE: APPRECIATE THE TWO-WAY TRAFFIC ALONG THE SPINAL CORD

THE WHITE MATTER OF THE SPINAL CORD CONTAINS SENSORY AND MOTOR TRACTS

SENSORY TRACTS ARE THE "HIGHWAYS" FOR CONDUCTION OF SENSORY NERVE IMPULSES TOWARD THE BRAIN

MOTOR TRACTS ARE **THE "HIGHWAYS" FOR CONDUCTION OF MOTOR NERVE IMPULSES FROM THE BRAIN TOWARD EFFECTOR TISSUES**

SPINAL NERVES AND THE NERVES THAT BRANCH FROM THE SPINAL CORD CONNECT THE CNS TO THE SENSORY RECEPTORS, MUSCLES, AND GLANDS IN ALL PARTS OF THE BODY.



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

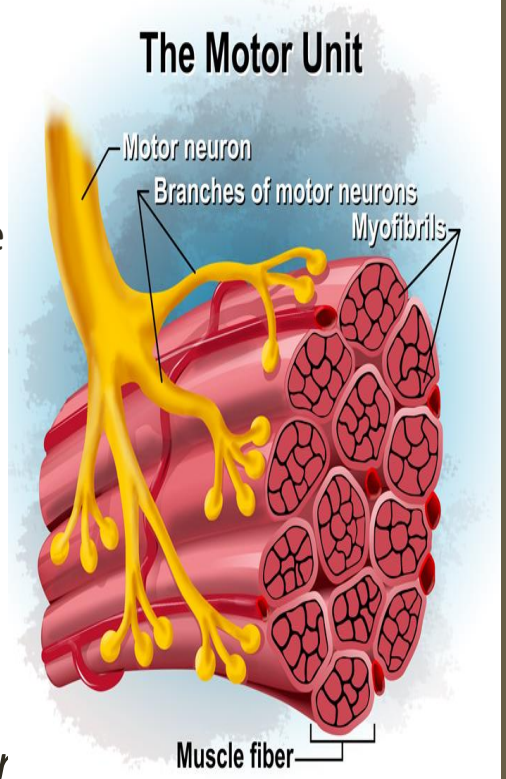
- Anterior Horn Cells:-***alpha motor neurons*** and ***gamma motor neurons.***
- Located in each segment of the anterior horns of the cord gray matter , several thousand neurons that are 50 to 100 percent larger than others *neurons .*
- -They give rise to the nerve fibers that leave the cord in the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

- ***1-Alpha motor neurons:***
- -They give rise to large type A alpha (Aa) motor nerve
- fibers, 14 micrometers in diameter; branch in the muscle

and innervate the large skeletal muscle fibers.

-Stimulation of a single alpha nerve fiber excites from three to several hundred extrafusal fibers skeletal muscle fibers.

-Q-What is the motor unit?



2-Gamma motor neurons:-

Along with the alpha motor neurons,are smaller *gar*

-They transmit impulses through much smaller type A gamma motor nerve fibers, 5 micrometers in diameter, which go to special skeletal muscle fibers called intrafusal fibers

Spinal reflexes

What is a reflex?

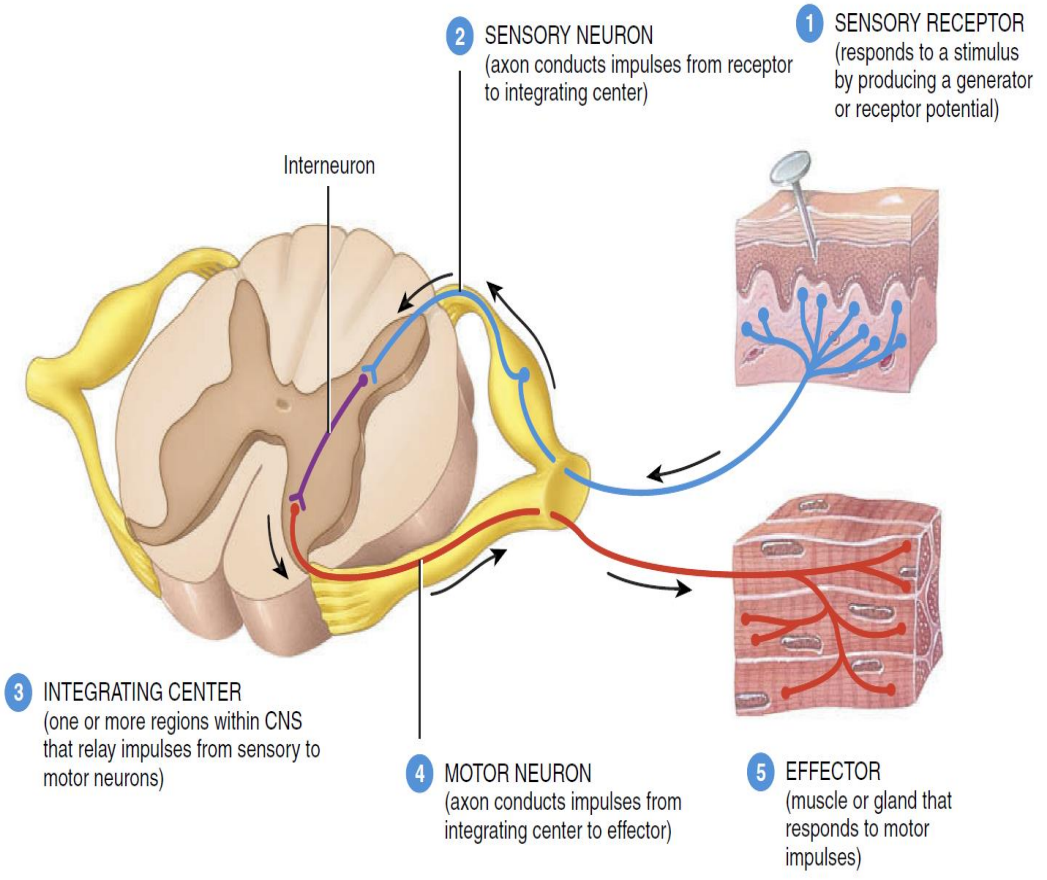
-Functional unit of CNS, rapid, automatic , involuntary response to a stimulus

-example/pinprick causes withdrawal. R

SPINAL REFLEXES

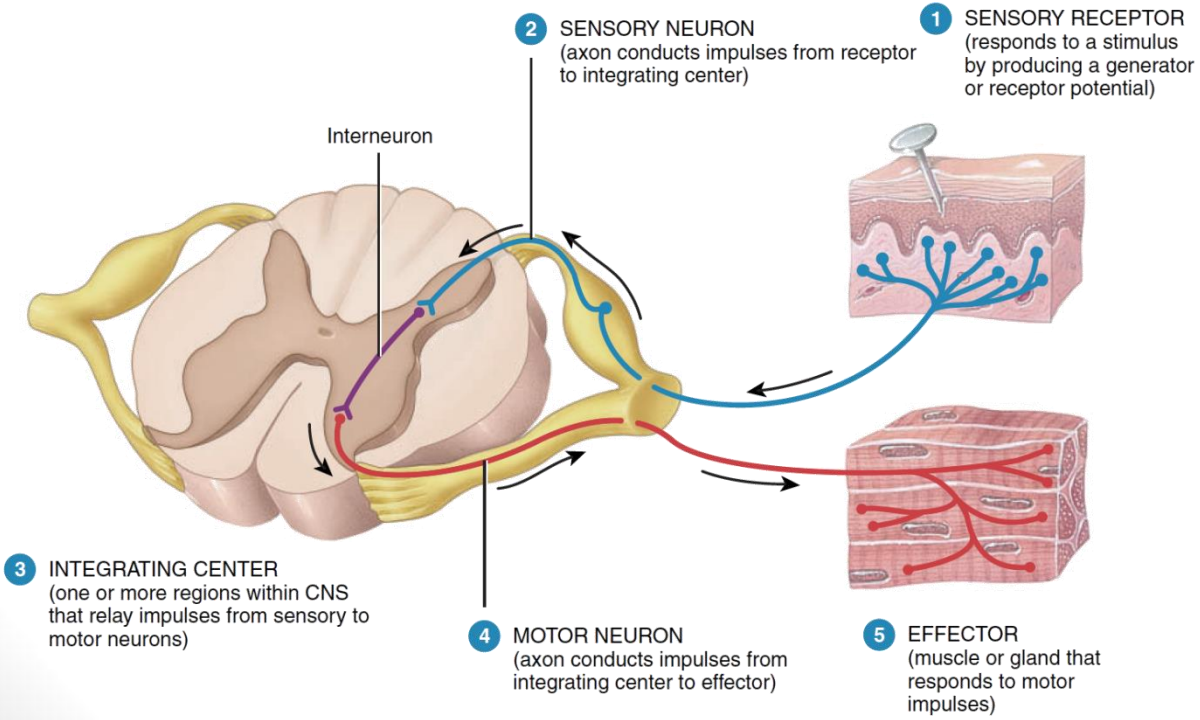
THE SPINAL CORD AND ITS ASSOCIATED SPINAL NERVES CONTAIN NEURAL CIRCUITS THAT CONTROL REFLEXES

A SPINAL REFLEX IS A RAPID, AUTOMATIC RESPONSE TO CERTAIN KINDS OF STIMULI THAT INVOLVES NEURONS ONLY IN THE SPINAL NERVES AND SPINAL CORD.



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

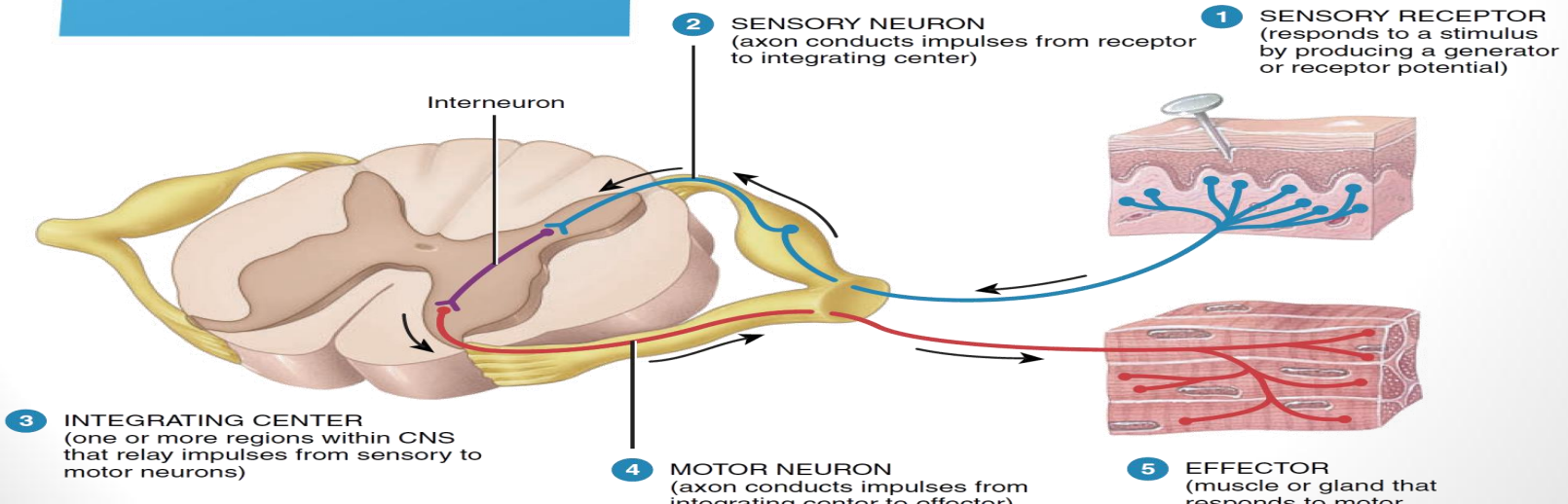
- SENSORY RECEPTOR
- SENSORY NEURON
- INTEGRATING CENTER
- MOTOR NEURON
- EFFECTOR

SENSORY RECEPTOR |1|

THE DISTAL END OF A SENSORY NEURON (DENDRITE) OR AN ASSOCIATED SENSORY STRUCTURE SERVES AS A SENSORY RECEPTOR.

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

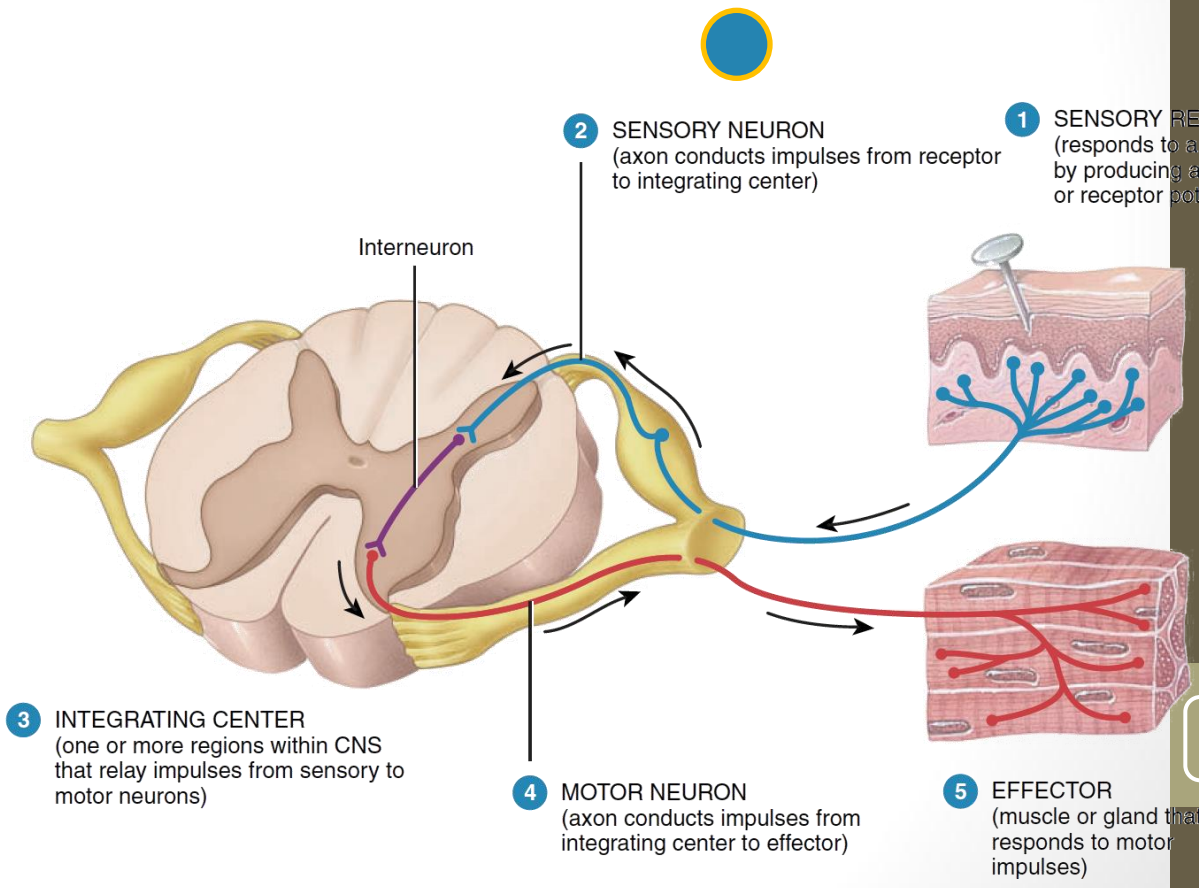
IF A GENERATOR POTENTIAL REACHES THE THRESHOLD LEVEL OF DEPOLARIZATION, IT WILL TRIGGER ONE OR MORE NERVE IMPULSES IN THE SENSORY NEURON



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|

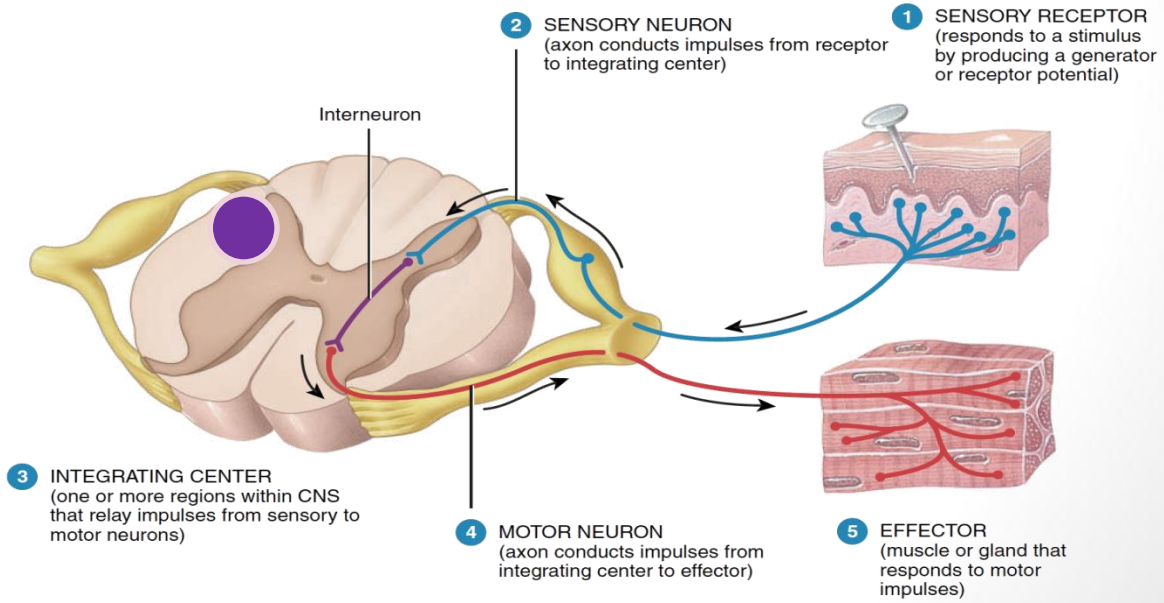
ONE OR MORE N EURONS GRAY MATTER WITHIN THE SPINAL CORD ACTS AS AN INTEGRATING CENTER.

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

A REFLEX PATHWAY HAVING ONLY ONE SYNAPSE IN THE CNS IS TERMED A MONOSYNAPTIC REFLEX ARC

MORE OFTEN, THE INTEGRATING CENTER CONSISTS OF ONE OR MORE INTERNEURONS, WHICH MAY RELAY IMPULSES TO OTHER INTERNEURONS AS WELL AS TO A MOTOR NEURON.

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 ante rior horns, and the intermediate areas between them.
- -These cells are about 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).**

-*diverging, converging, and repetitive-discharge*

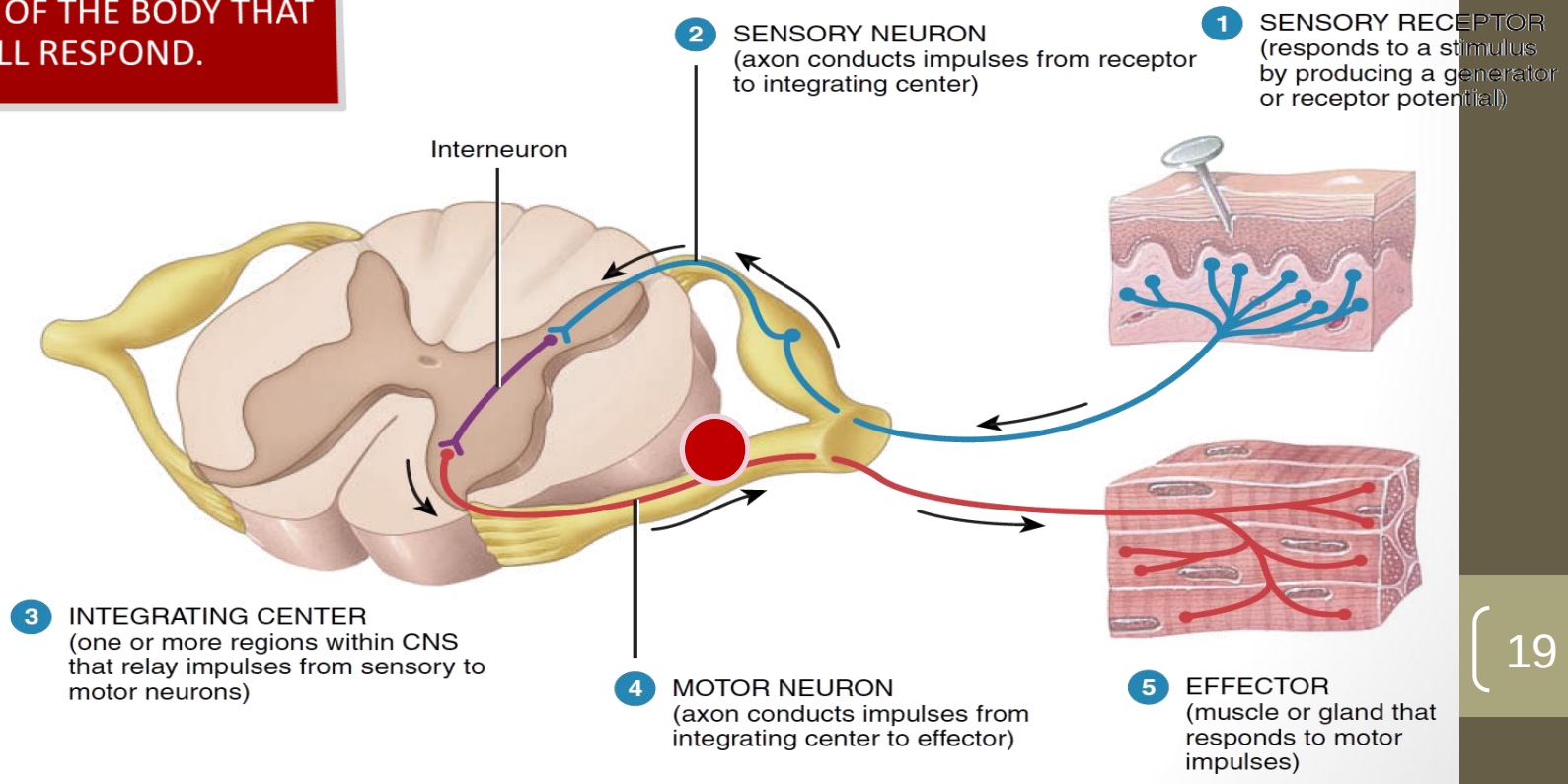
- They are **(excitatory or inhibitory).**

- **Renshaw Cells :-**
- - Small neurons located in the anterior horns of the spinal cord, in close association with the motor neurons.
- - 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**/ stimulation of each motor neuron tends to inhibit adjacent motor neurons .
- -This lateral inhibition helps to focus or sharpen the signals from each motor neuron
- (allow transmission of the primary signal in the desired direction while suppressing the tendency for signals to spread laterally)

MOTOR NEURON|4|

-Efferent neuron

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



-These are Anterior Horn Cells (Motor neurons)

of spinal cord supplying skeletal muscle:

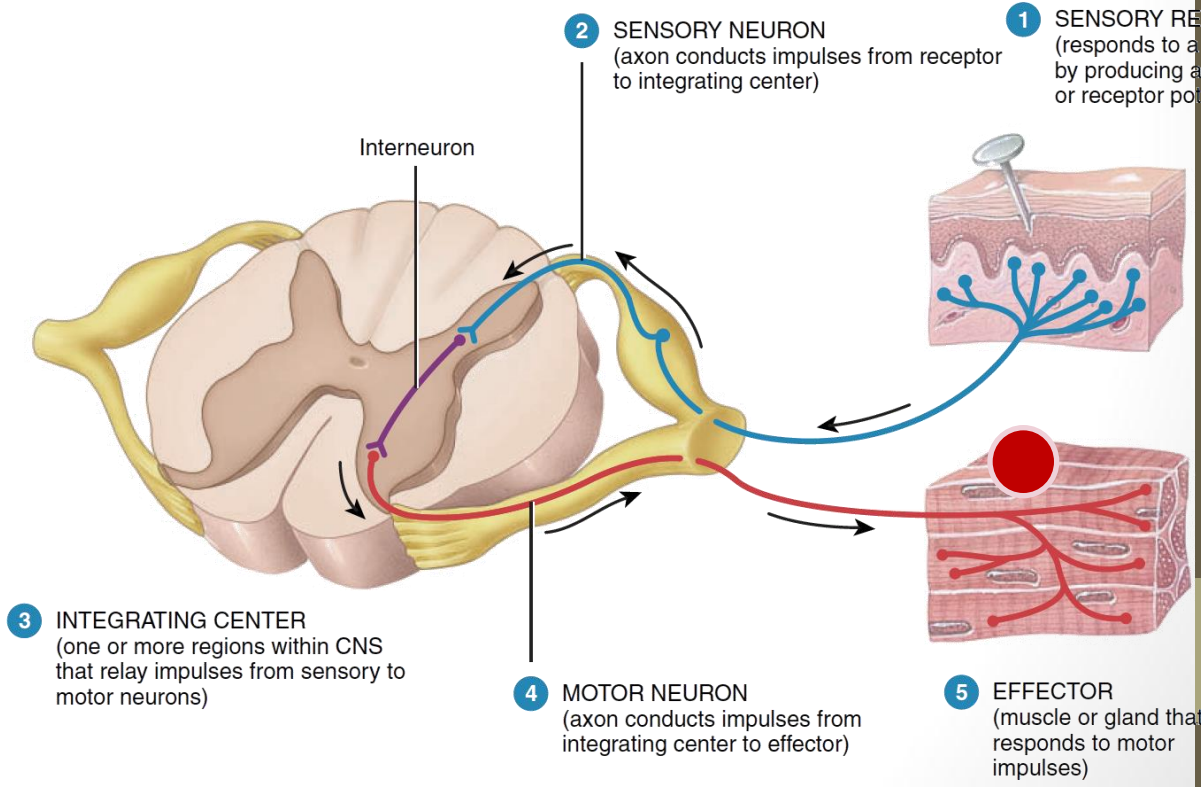
1. **alpha motor neurons** :- large cells, with large mylinated fibres (axons) form 70% of ventral root - supply extrafusal muscle fibres (2/3 Of skeletal muscle fibers)
2. **Gamma motor neurons** :- smaller cells- with small axons form 30 % of ventral root - supply intrafusal muscle fibres (muscle spindles=1/3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

EFFECTOR|5|

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

ITS ACTION IS CALLED A REFLEX.

IF THE EFFECTOR IS SKELETAL MUSCLE, THE REFLEX IS A SOMATIC REFLEX. IF THE EFFECTOR IS SMOOTH MUSCLE, CARDIAC MUSCLE, OR A GLAND, THE REFLEX IS AN AUTONOMIC (VISCERAL) 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	REFLEX TIME

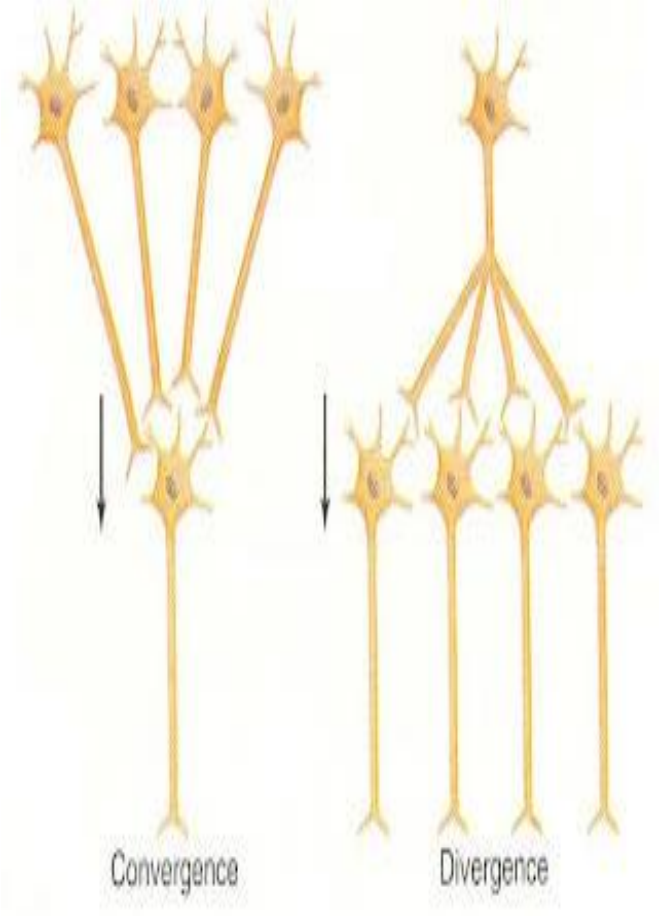
- Sensory afferent enter spinal cord via dorsal(posterior) root, ends at same segment , or ascend to higher segments, as they enter the neuronal pool undergo:

1- **Divergence** help to spread a single stimulus to a wide area of the spinal cord, it is important for weak signals entering a neuronal pool to excite far greater numbers of nerve fibers leaving the pool.

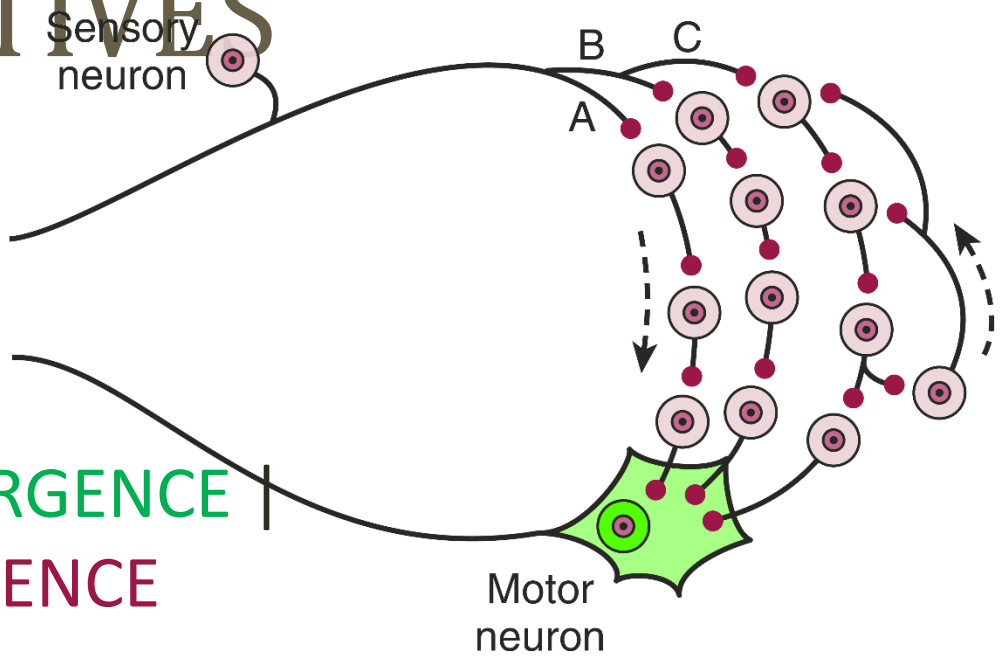
2-**Convergence :-** signals from multiple inputs uniting to excite a single neuron multiple action potentials converging on the neuron from multiple terminals provide enough spatial summation to bring the neuron to the threshold required for discharge.

- The neurons are almost never excited by an action potential from a single input terminal.

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



GLORIOUS LEARNING OBJECTIVES



- CONVERGENCE
  DIVERGENCE

OUTPUT FROM MANY NEURONS ONTO ONE.

MANY DIFFERENT PRESYNAPTIC NEURONES PROVIDE INPUT TO A SINGLE POSTSYNAPTIC NEURON.

THESE INPUTS MAY BE EXCITATORY OR INHIBITORY, AND MAY BE ACTIVE AT DIFFERENT TIMES

IN A CONVERGENT NEURAL CIRCUIT, THE AXONS OF MULTIPLE NEURONS ALL SEND INFORMATION TO A SINGLE TARGET NEURON.

CONVERGENT OUTPUT ALLOWS DIFFERENT SIGNALS TO REACH ONE NEURON FOR COMPARISON OR INTEGRATION.

OUTPUT FROM ONE NEURON ONTO MANY.

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

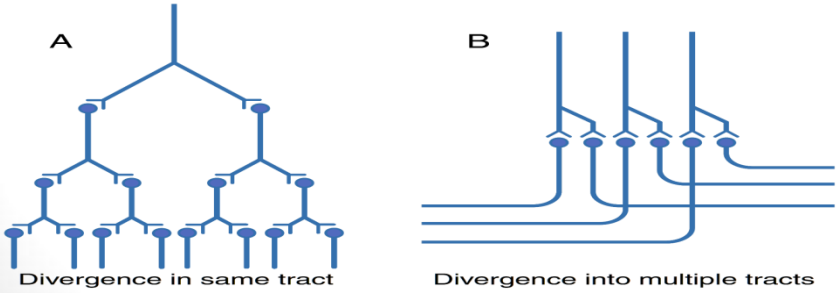
IN A DIVERGENT NEURAL CIRCUIT, THE AXON OF ONE NEURON BRANCHES TO SEND INFORMATION TO MULTIPLE TARGET NEURONS.

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

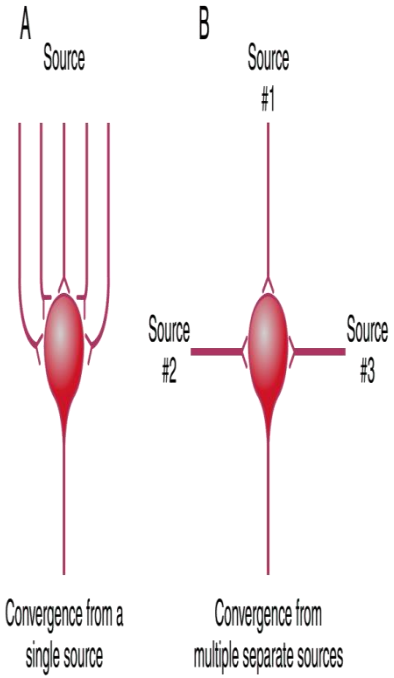
1-DIVERGENCE

A | DIVERGENCE WITHIN A PATHWAY TO CAUSE AMPLIFICATION OF THE SIGNAL

B | DIVERGENCE INTO MULTIPLE TRACTS TO TRANSMIT THE SIGNAL TO SEPARATE AREAS.



2-CONVERGENCE



CONVERGENCE OF MULTIPLE INPUT FIBRES ONTO A SINGLE NEURON.

A | MULTIPLE INPUT FIBRES FROM A SINGLE SOURCE

B | INPUT FIBRES FROM MULTIPLE SEPARATE SOURCES

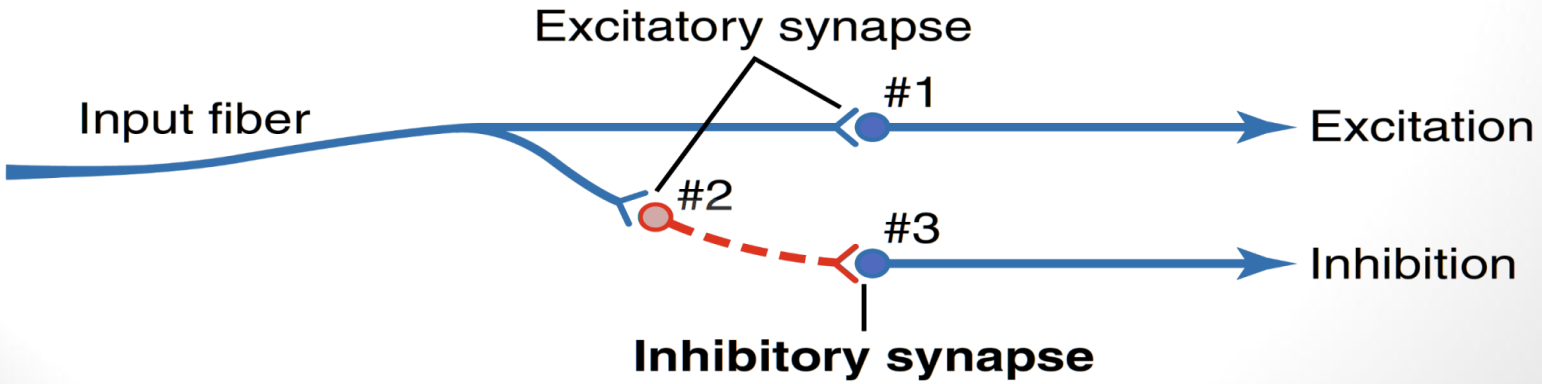
3-Reciprocal inhibition circuits

-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.

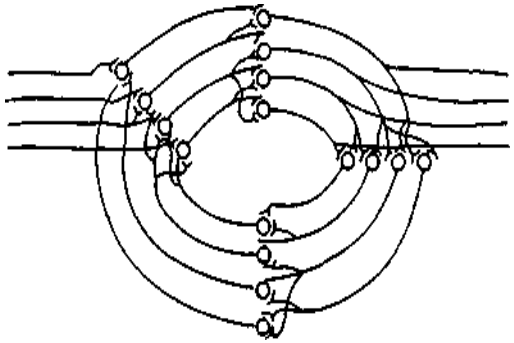
-the input fibre directly excites the excitatory output pathway, but it stimulates an intermediate *inhibitory neuron* (neuron 2), which secretes a different type of transmitter substance to inhibit the second output pathway from the pool.

-preventing over activity in many parts of the brain.

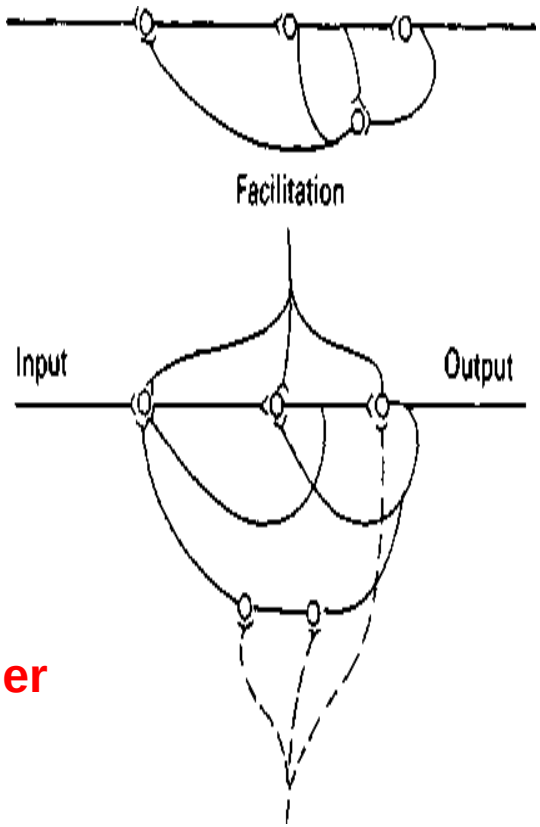


Neuronal pool circuits

1- Parallel



2-Reverbrating



1-Parallel circuits //afferent and efferent are parallel to each other

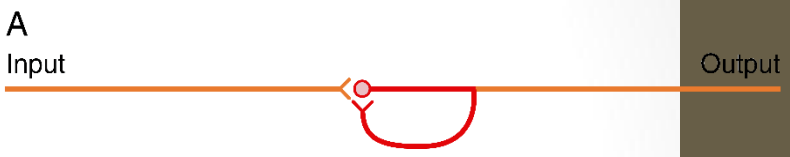
- **4-Reverberatory (Oscillatory) Circuit**
- **-.The simplest reverberatory circuits , involves only a single neuron, the out put neuron sends a collateral nerve fiber back to its own dendrites or soma to restimulate the input neuron itself & once the neuron restimulated,, the circuit may discharge 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 & can beweak or strong, depending on how many parallel nerve fibers are involved in the reverberation**

REVERBERATORY (OSCILLATORY) CIRCUIT AS A CAUSE OF SIGNAL PROLONGATION

SUCH CIRCUITS ARE CAUSED BY POSITIVE FEEDBACK WITHIN THE NEURONAL CIRCUIT THAT FEEDS BACK TO RE-EXCITE THE INPUT OF THE SAME CIRCUIT.

CONSEQUENTLY, ONCE STIMULATED, THE CIRCUIT MAY DISCHARGE REPETITIVELY FOR A LONG TIME.

SEVERAL POSSIBLE VARIETIES OF REVERBERATORY CIRCUITS ARE FOUND | THE SIMPLEST, INVOLVES ONLY A SINGLE NEURON



THE SIMPLEST, INVOLVES ONLY A SINGLE NEURON | THE OUTPUT NEURON SIMPLY SENDS A COLLATERAL NERVE FIBRE BACK TO ITS OWN DENDRITES OR SOMA TO RESTIMULATE ITSELF.

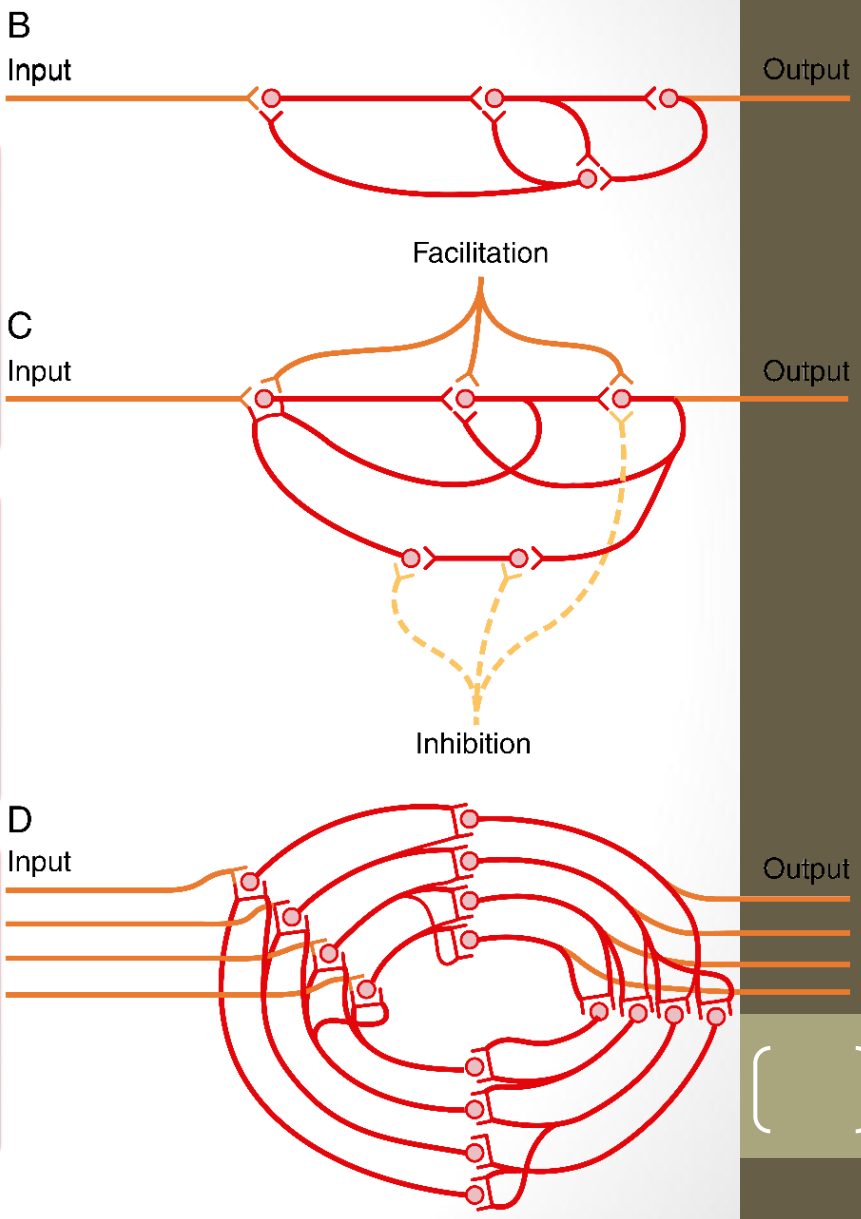
B SHOWS A FEW ADDITIONAL NEURONS IN THE FEEDBACK CIRCUIT, WHICH CAUSES A LONGER DELAY BETWEEN INITIAL DISCHARGE AND THE FEEDBACK SIGNAL.

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.

- IN SUCH A SYSTEM, THE TOTAL REVERBERATING SIGNAL CAN BE EITHER WEAK OR STRONG, DEPENDING ON HOW MANY PARALLEL NERVE FIBRES ARE MOMENTARILY INVOLVED IN THE REVERBERATION.



Characteristics of signal prolongation from a reverberatory circuit & fatigue

-The intensity of the output signal increases to a high value early in reverberation and then decreases to a critical point & suddenly ceases due to **fatigue** of synaptic junctions , this lowers the stimulation of the next neuron& the circuit feedback is suddenly broken.

-

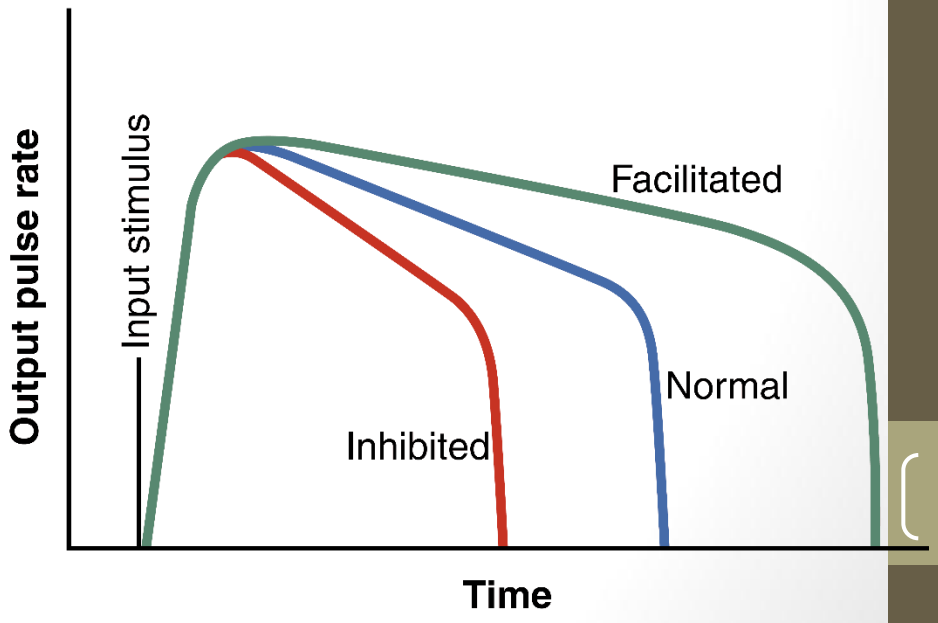
THE INPUT STIMULUS MAY LAST ONLY 1 MILLISECOND OR SO, AND YET THE OUTPUT CAN LAST FOR MANY MILLISECONDS OR EVEN MINUTES

THE FIGURE DEMONSTRATES THAT THE INTENSITY OF THE OUTPUT SIGNAL USUALLY INCREASES TO A HIGH VALUE EARLY IN REVERBERATION AND THEN DECREASES TO A CRITICAL POINT, AT WHICH IT SUDDENLY CEASES ENTIRELY

THE CAUSE OF THIS SUDDEN CESSATION OF REVERBERATION IS FATIGUE OF SYNAPTIC JUNCTIONS IN THE CIRCUIT

FATIGUE BEYOND A CERTAIN CRITICAL LEVEL LOWERS THE STIMULATION OF THE NEXT NEURON IN THE CIRCUIT BELOW THRESHOLD LEVEL SO THAT THE CIRCUIT FEEDBACK IS SUDDENLY BROKEN

THE DURATION OF THE TOTAL SIGNAL BEFORE CESSATION CAN ALSO BE CONTROLLED BY SIGNALS FROM OTHER PARTS OF THE BRAIN THAT INHIBIT OR FACILITATE THE CIRCUIT



FATIGUE OF SYNAPTIC TRANSMISSION

WHEN EXCITATORY SYNAPSES ARE REPETITIVELY STIMULATED AT A RAPID RATE, THE NUMBER OF DISCHARGES BY THE POSTSYNAPTIC NEURON IS AT FIRST VERY GREAT, BUT THE FIRING RATE BECOMES PROGRESSIVELY LESS

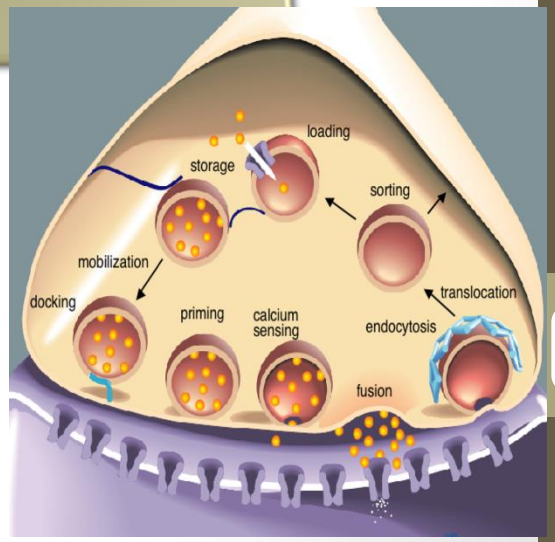
THIS IS CALLED FATIGUE OF SYNAPTIC TRANSMISSION.

FATIGUE IS AN EXCEEDINGLY IMPORTANT BECAUSE WHEN AREAS OF THE NERVOUS SYSTEM BECOME OVEREXCITED, FATIGUE CAUSES THEM TO LOSE THIS EXCESS EXCITABILITY AFTER A WHILE.

FATIGUE IS PROBABLY THE MOST IMPORTANT WAY BY WHICH THE EXCESS EXCITABILITY OF THE BRAIN DURING AN EPILEPTIC SEIZURE IS FINALLY SUBDUED SO THAT THE SEIZURE ENDS.

THUS, THE DEVELOPMENT OF FATIGUE IS A PROTECTIVE MECHANISM AGAINST EXCESS NEURONAL ACTIVITY.

-A reverberating circuit that does not fatigue enough to stop reverberation is a source of continuous impulses



FATIGUE OF SYNAPTIC TRANSMISSION - CAUSES

EXHAUSTION OR PARTIAL EXHAUSTION OF THE STORES OF TRANSMITTER SUBSTANCE IN THE PRESYNAPTIC TERMINALS.

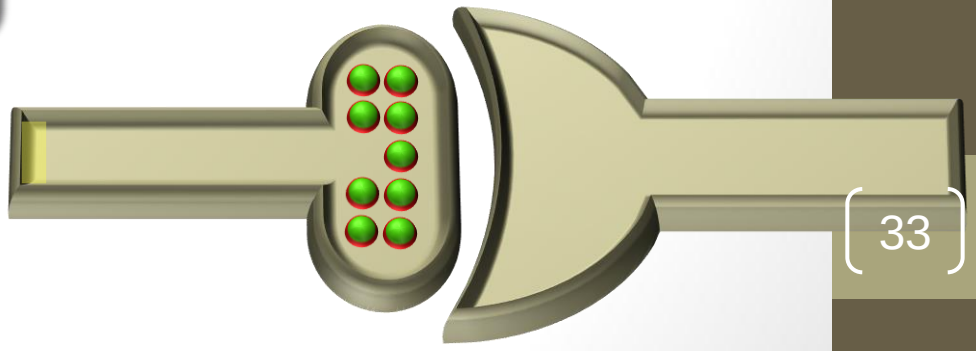
PROGRESSIVE INACTIVATION OF MANY OF THE POSTSYNAPTIC MEMBRANE RECEPTORS

SLOW DEVELOPMENT OF ABNORMAL CONCENTRATIONS OF IONS INSIDE THE POSTSYNAPTIC NEURONAL CELL.

TERMINALS ON MANY NEURONS CAN STORE ENOUGH TRANSMITTER TO CAUSE ONLY ABOUT 10,000 ACTION POTENTIALS,

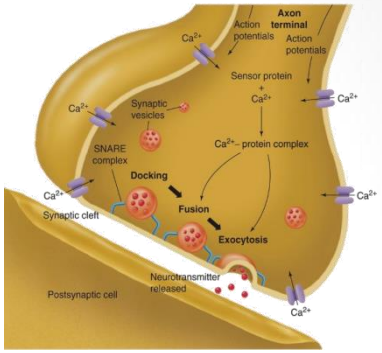
AND THE TRANSMITTER CAN BE EXHAUSTED IN ONLY A FEW SECONDS TO A FEW MINUTES OF RAPID STIMULATION.

IT TAKES TIME TO REPLENISH THE RESERVES OF NEUROTRANSMITTER – IF ACTIVITY IS TOO HIGH SYNAPTIC VESICLES CAN BECOME DEPLETED



5-After-discharge:-

- A signal entering a pool causes a prolonged out- put discharge of AHCs called *afterdischarge*, lasting a few millisec-onds to as long as many minutes after
- the incoming signal is over, after- discharge occurs due to the following:-

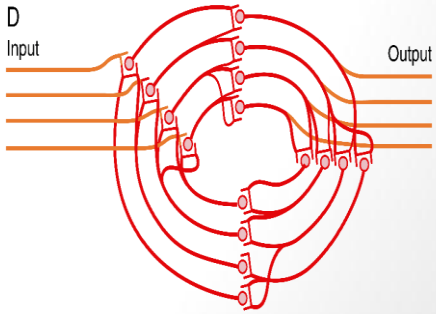


- 1-Synaptic Afterdischarge.

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 many milliseconds. As long as this potential lasts, it can continue to excite the neuron, causing it to transmit a continuous train of output impulses.

- Thus, it is possible for a single input signal to cause a sustained signal output (a series of repetitive discharges) .(this cause maintained reflex action & response continue for some time after cessation of stimulus



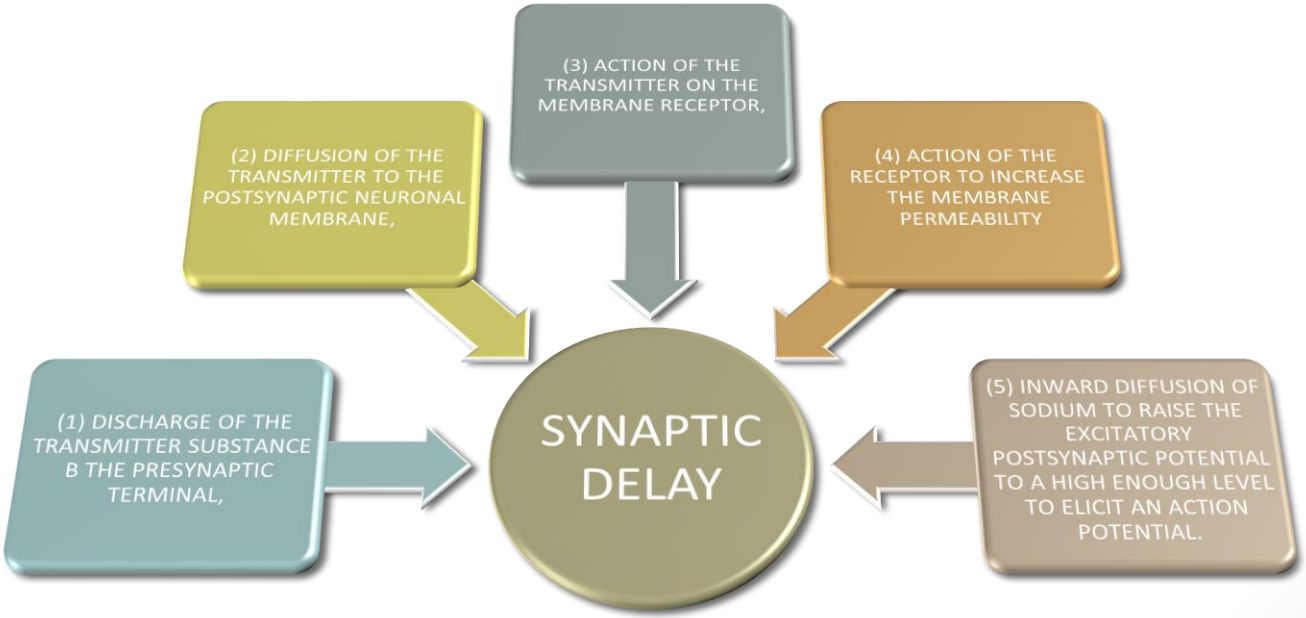
- 2- Reverbrating circuits

- Presence of reverberating circuit restimulate AHCs

6-SYNAPTIC DELAY (central delay)

-Is the time of reflex to pass through neurons of the spinal cord ,
-equals 0.5 ms/synapse (it is long in polysynaptic R).
-It is > 2 ms in the withdrawal R
-Number of synapses = central delay / 0.5ms
-for knee jerk it equals 0.6 msc= one synapse

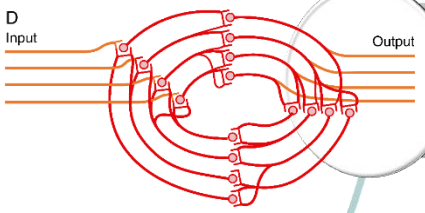
-The minimal period of time required for transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron, is **SYNAPTIC DELAY**,.



SYNAPTIC DELAY

THE MINIMAL PERIOD OF TIME REQUIRED FOR ALL THESE EVENTS TO TAKE PLACE, EVEN WHEN LARGE NUMBERS OF EXCITATORY SYNAPSES ARE STIMULATED SIMULTANEOUSLY, IS ABOUT 0.5 MILLISECOND.

THIS IS CALLED THE SYNAPTIC DELAY.



NEUROPHYSIOLOGISTS CAN MEASURE THE MINIMAL DELAY TIME BETWEEN AN INPUT VOLLEY OF IMPULSES INTO A POOL OF NEURONS AND THE CONSEQUENT OUTPUT

FROM THE MEASURE OF DELAY TIME, ONE CAN THEN ESTIMATE THE NUMBER OF SERIES NEURONS IN THE CIRCUIT.

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

THE TIME BETWEEN THE APPLICATION OF THE STIMULUS AND THE RESPONSE IS CALLED THE **REACTION TIME**

IN HUMANS, THE REACTION TIME FOR A STRETCH REFLEX SUCH AS THE KNEE JERK IS 19–24 MS.

THE CONDUCTION VELOCITIES OF THE AFFERENT AND EFFERENT FIBRE TYPES ARE KNOWN AND THE DISTANCE FROM THE MUSCLE TO THE SPINAL CORD CAN BE MEASURED

- THIS IS RESPONSIBLE FOR MOST OF THE REACTION TIME

CENTRAL DELAY

CENTRAL DELAY

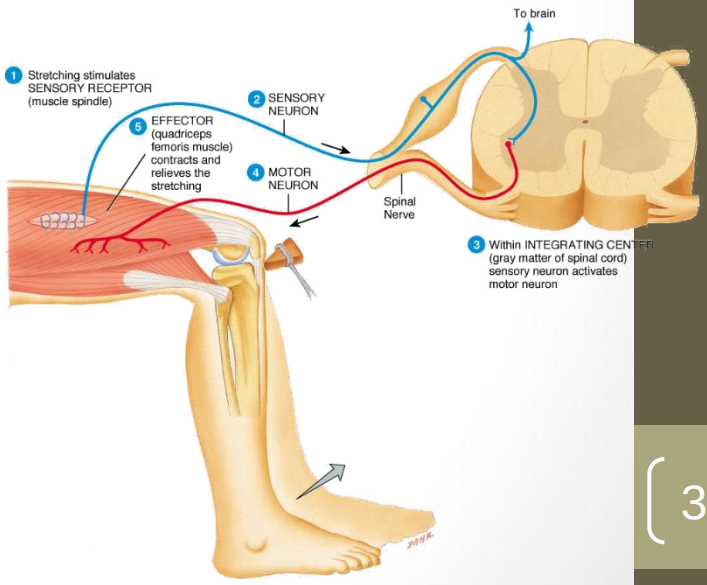
IT IS POSSIBLE TO CALCULATE HOW MUCH TIME WAS TAKEN UP BY CONDUCTION TO AND FROM THE SPINAL CORD.

WHEN THIS VALUE IS SUBTRACTED FROM THE REACTION TIME, THE REMAINDER, CALLED THE CENTRAL DELAY ,

THIS IS THE TIME TAKEN FOR THE REFLEX ACTIVITY TO TRAVERSE THE SPINAL CORD.

THE CENTRAL DELAY FOR THE KNEE JERK REFLEX IS 0.6–0.9 MS

BECAUSE THE MINIMUM SYNAPTIC DELAY IS 0.5 MS, ONLY ONE SYNAPSE COULD HAVE BEEN TRAVERSED



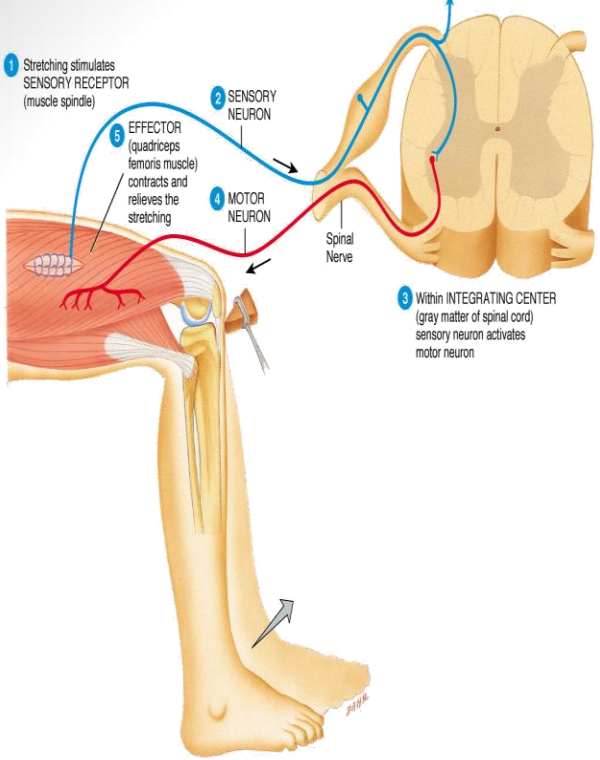
Types of spinal reflexes

-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



MONOSYNAPTIC REFLEX

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

WHEN A REFLEX ARC CONSISTS OF ONLY TWO NEURONS IN AN ANIMAL (ONE SENSORY NEURON, AND ONE MOTOR NEURON), IT IS DEFINED AS MONOSYNAPTIC.

IN THE CASE OF PERIPHERAL MUSCLE REFLEXES (PATELLAR REFLEX, ACHILLES REFLEX), BRIEF STIMULATION TO THE MUSCLE SPINDLE RESULTS IN CONTRACTION OF THE AGONIST OR EFFECTOR MUSCLE

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

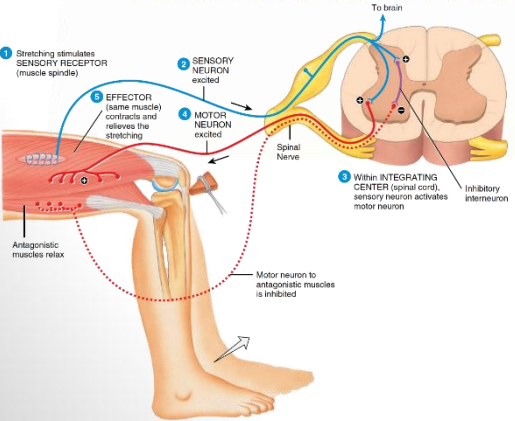
©Visceral:-by stimulation of receptors in wall of viscera

As Micturition, defecation

SUPERFICIAL AND DEEP REFLEXES

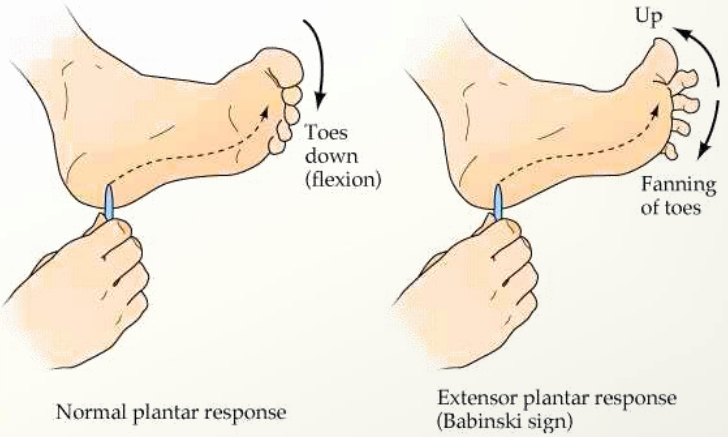
DEEP REFLEXES

- *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*



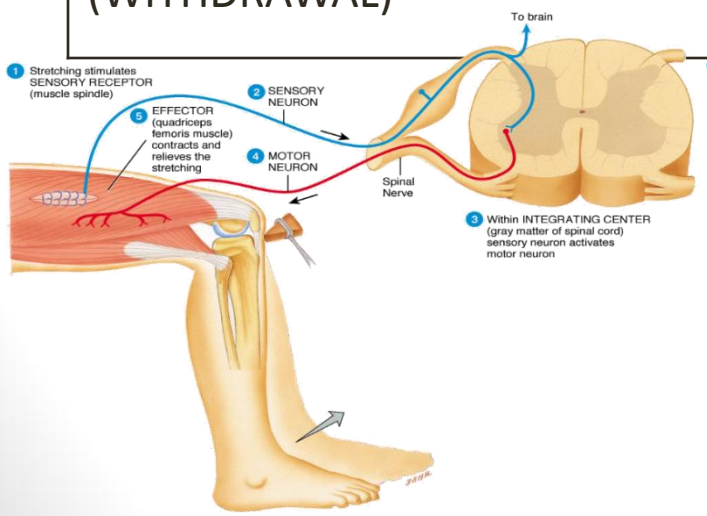
SUPERFICIAL REFLEXES

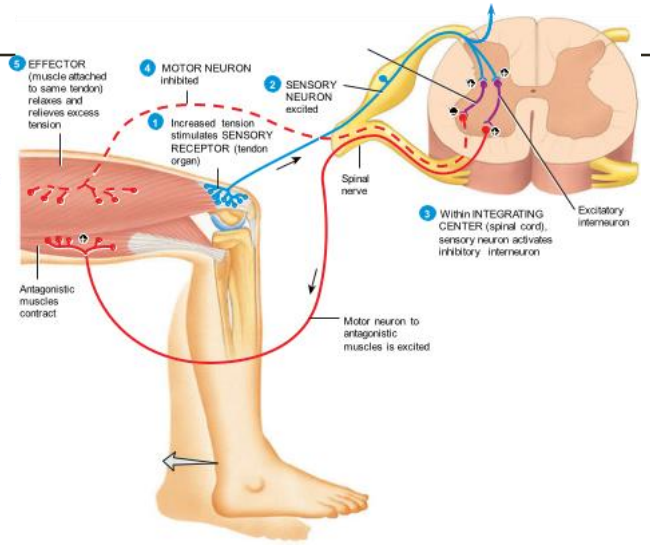
- THE RECEPTORS ARE SUPERFICIAL IN THE SKIN .
- EXAMPLES ARE WITHDRAWAL, ABDOMINAL REFLEXES AND PLANTAR REFLEX

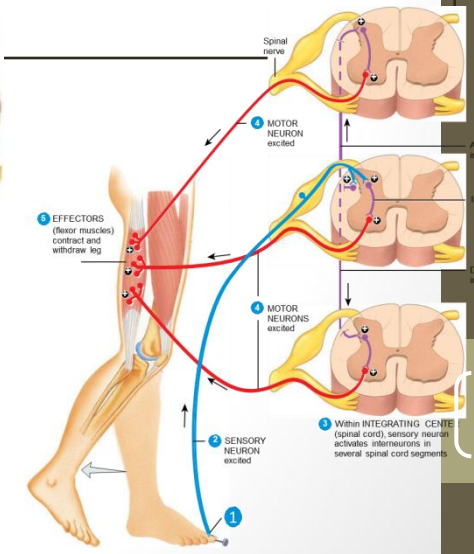


TYPES OF SPINAL REFLEX

REFLEX	STIMULUS	CLINICAL TEST
STRETCH (MYOTACTIC) REFLEX	RAPID STRETCH OF MUSCLE	TAP ON MUSCLE TENDON
INVERSE STRETCH REFLEX (AUTOGENIC INHIBITION)	LARGE FORCE ON TENDON	PULL ON MUSCLE WHEN RESTED
FLEXOR REFLEX (WITHDRAWAL)	SHARP PAINFUL STIMULUS	NONE – STEPPING ON NAIL







Withdrawal reflex(flexor reflex) (Nociceptive Reflex)

-A superficial polysynaptic reflex

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

characterised by :

- It involve the following basic types of circuits:

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

(2) circuits to inhibit the antagonist muscles, called *reciprocal inhibition circuits*

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

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

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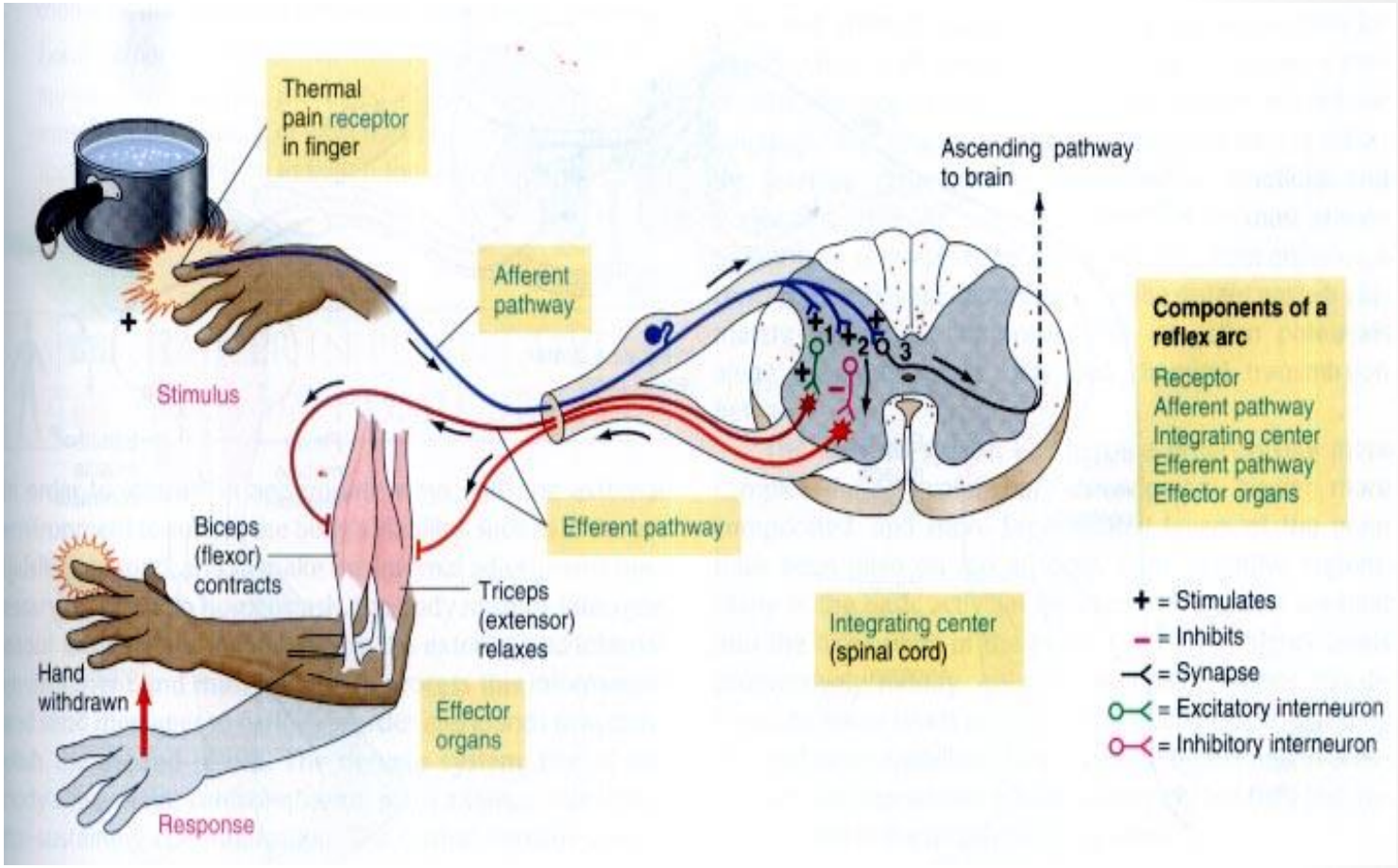

Thermal pain receptor in finger
Ascending pathway to brain
Afferent pathway
Stimulus
Components of a reflex arc
Receptor
Afferent pathway
Integrating center
Efferent pathway
Effector organs
Efferent pathway
Biceps (flexor) contracts
Triceps (extensor) relaxes
Integrating center (spinal cord)
Hand withdrawn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

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 afterdischarge depends on the intensity of the sensory stimulus that elicited the reflex

- It results from repetitive discharge circuits.

-Further, because of afterdischarge, the reflex can hold the irritated part away from the stimulus for 0.1 to 3 seconds after the irritation is over.

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

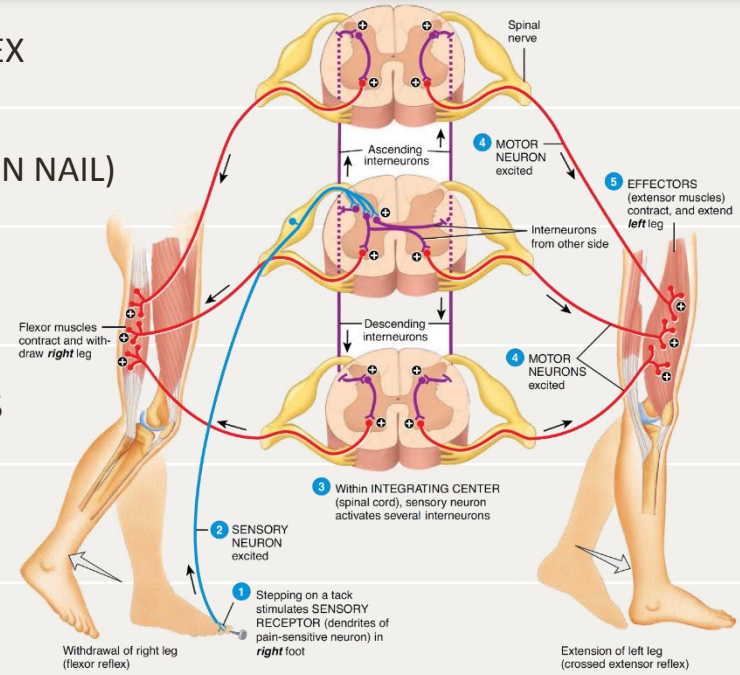
- Weak stim-----irradiates to small number of neurons ,
  so it causes weak flexion of limb

- 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-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



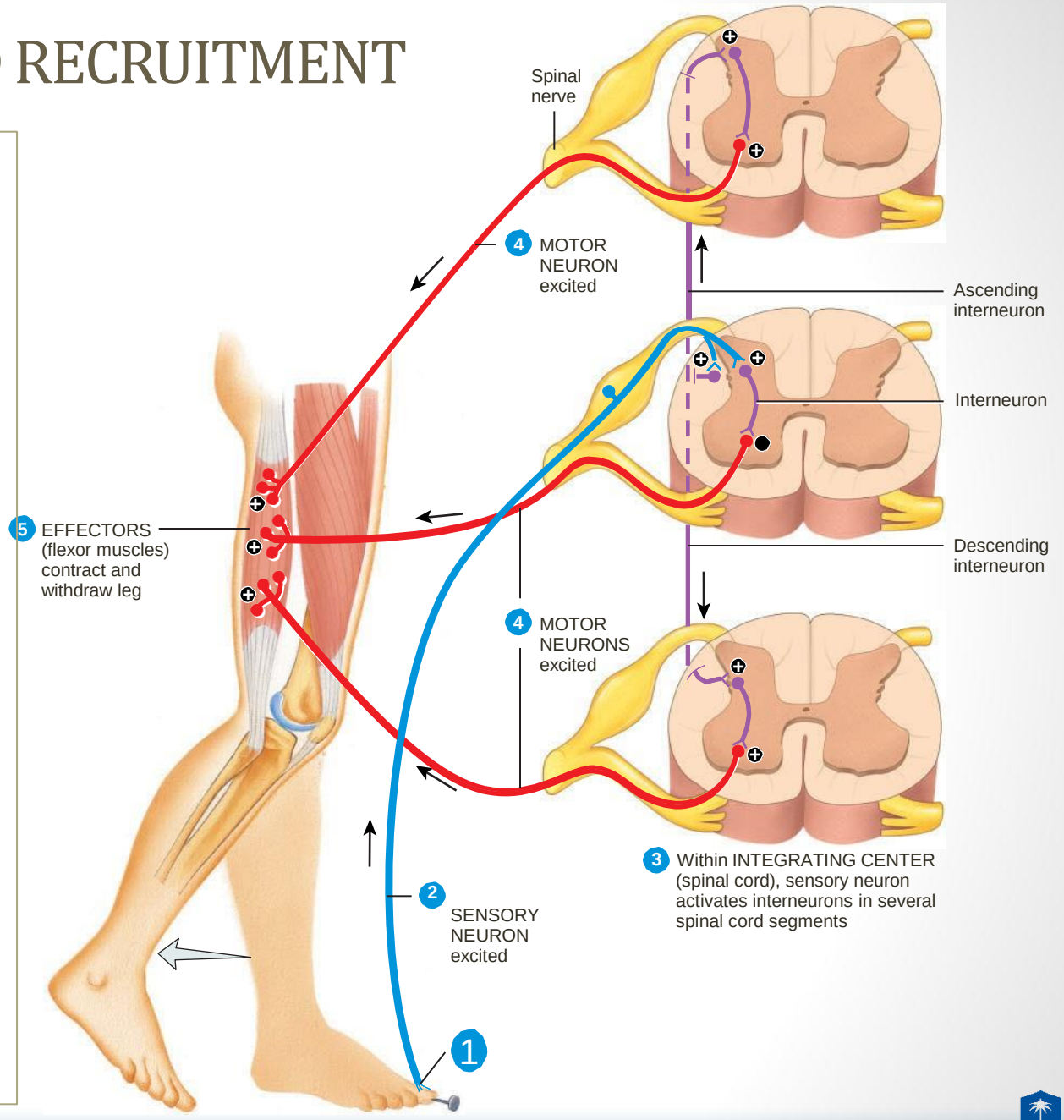
https://musom.marshall.edu/anatomy/grosshom/allppt/pdf/Spinalreflexes.pdf

IRRADIATION AND RECRUITMENT

STRONG STIMULI CAN GENERATE ACTIVITY IN THE INTERNEURON POOL THAT SPREADS

THIS SPREAD OF EXCITATORY IMPULSES UP AND DOWN THE SPINAL CORD TO MORE AND MORE MOTOR NEURONS IS CALLED **IRRADIATION** OF THE STIMULUS

THE INCREASE IN THE NUMBER OF ACTIVE MOTOR UNITS IS CALLED **RECRUITMENT** OF MOTOR UNITS



Crossed extensor reflex:-

Flexion and withdrawal of the stimulated limb >> extension of the opposite limb >> occurs with strong stimulus why?

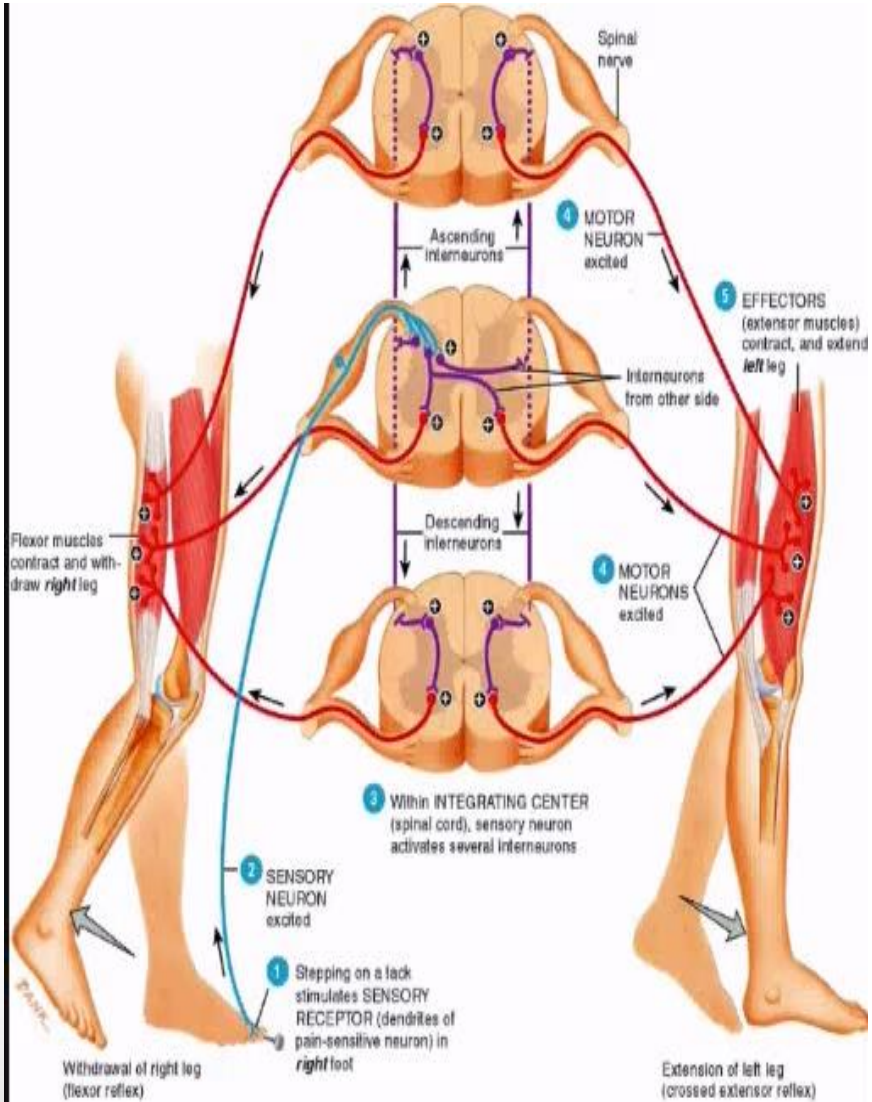
- Signals from sensory nerves cross to the opposite side of the cord to excite extensor muscles. –
- -It does not begin until 200 to 500 milliseconds after onset of the initial pain stimulus, because many interneurons are involved in the circuit between the incoming sensory neuron and the motor neurons 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 pained area of the body away from the painful object

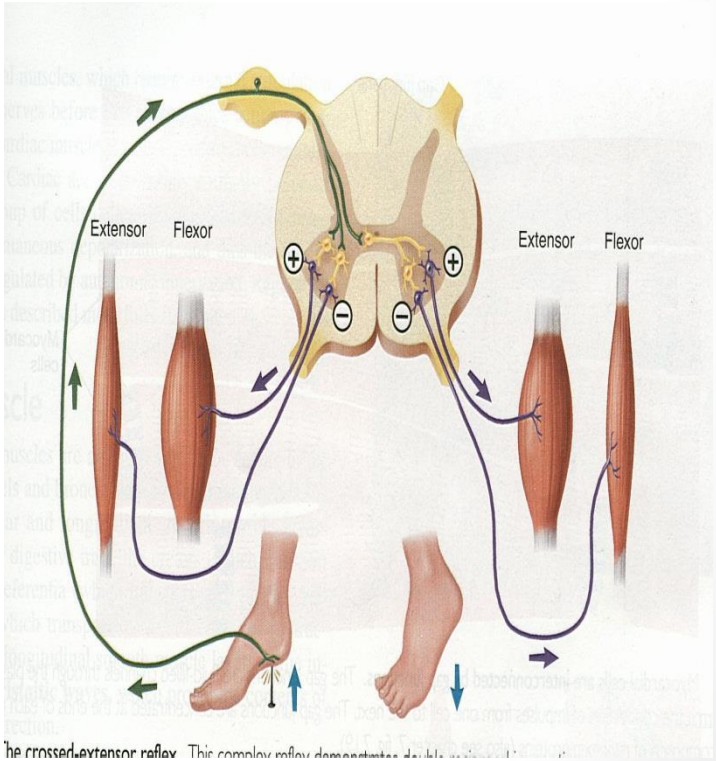
- Mostly in the lower limb to support balance.

-Reciprocal innervations occurs also in crossed extensor reflex. How?

-flexors in the opposite limb are inhibited while extensors are excited because while pushing the body away from the injurious agent by withdrawal R ,the crossed extensor reflex supporting the body weight against gravity

Crossed extensor reflex





he crossed-extensor reflex. This complex reflex demonstrates double