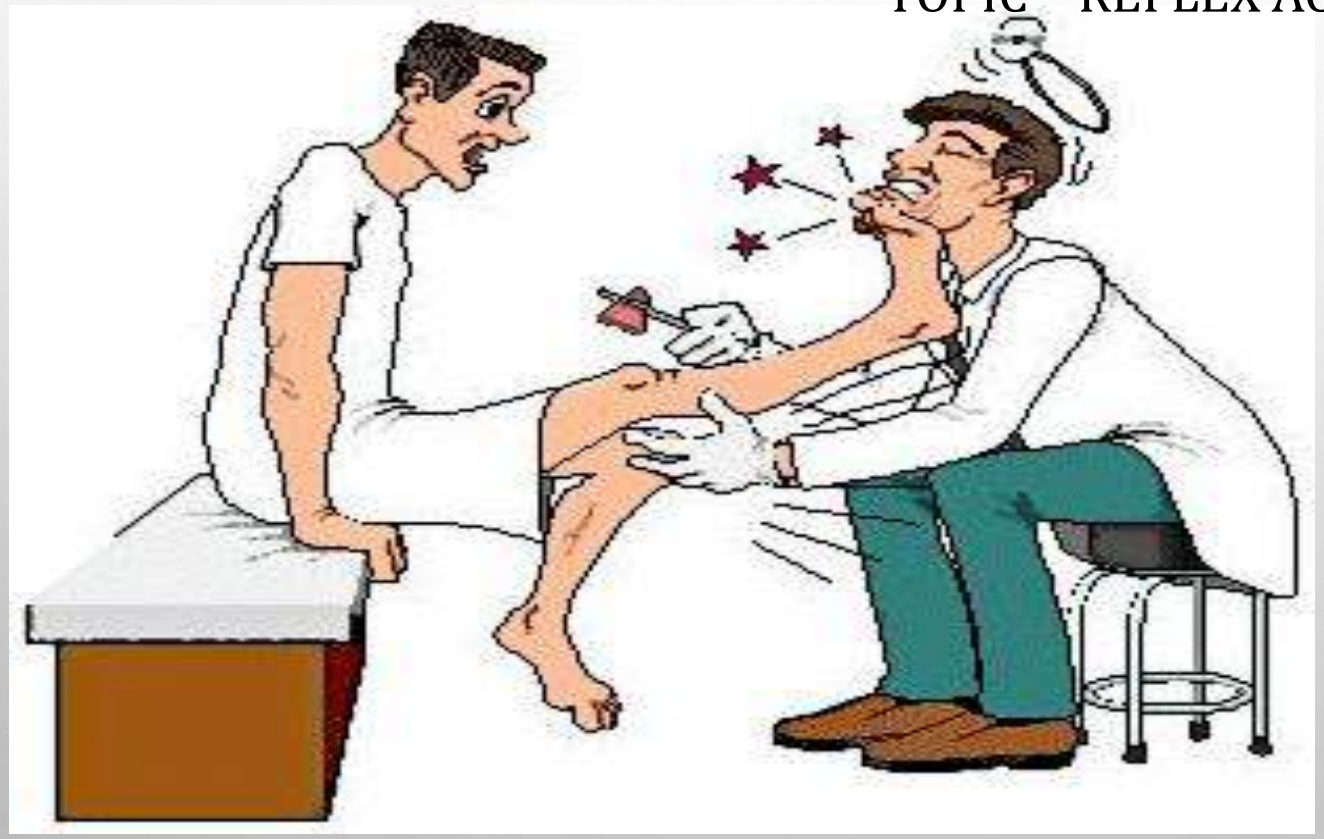
3RD SEMESTER

PAPER – CC7 NERVOUS SYSTEM

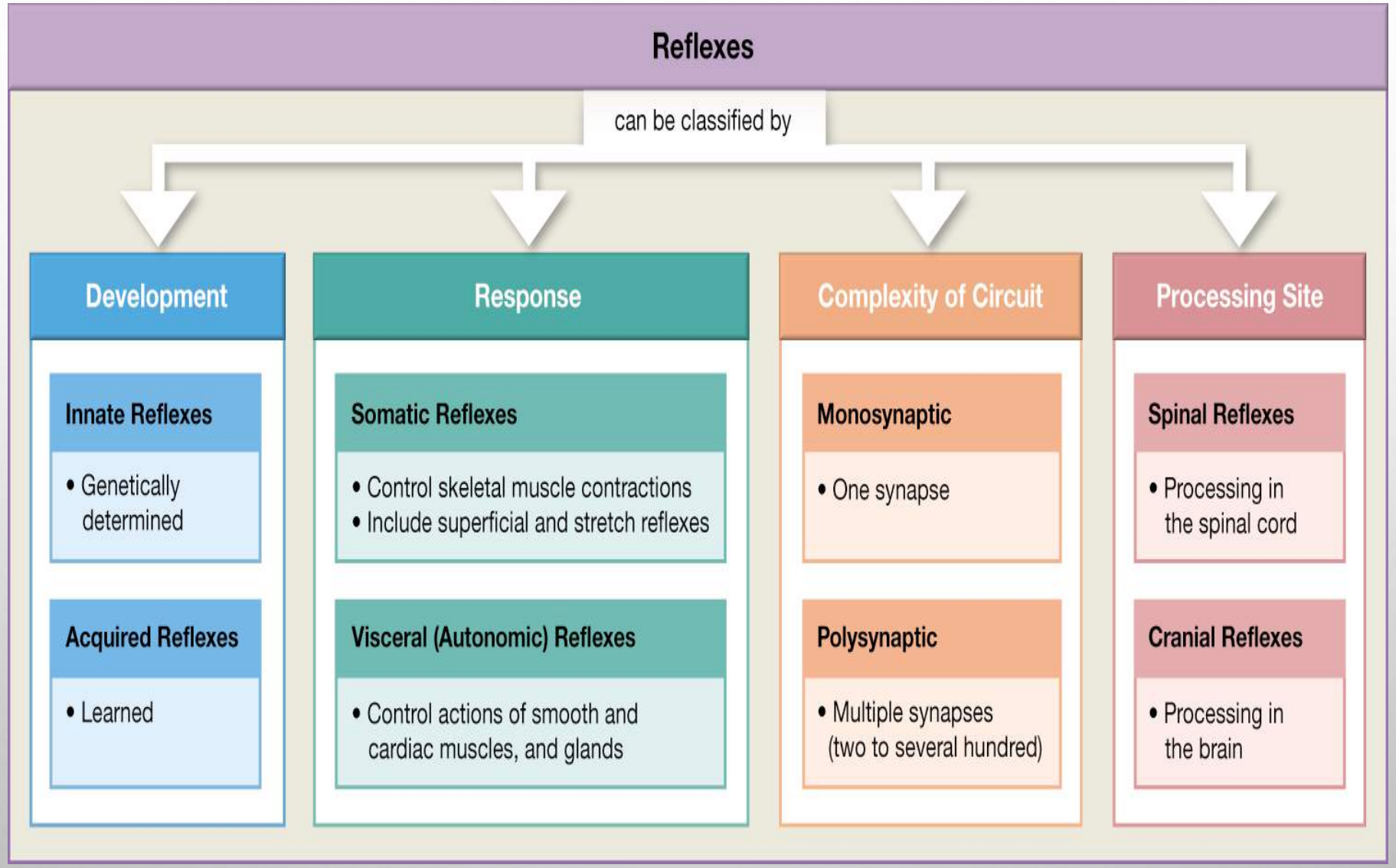
- TOPIC – REFLEX ACTION



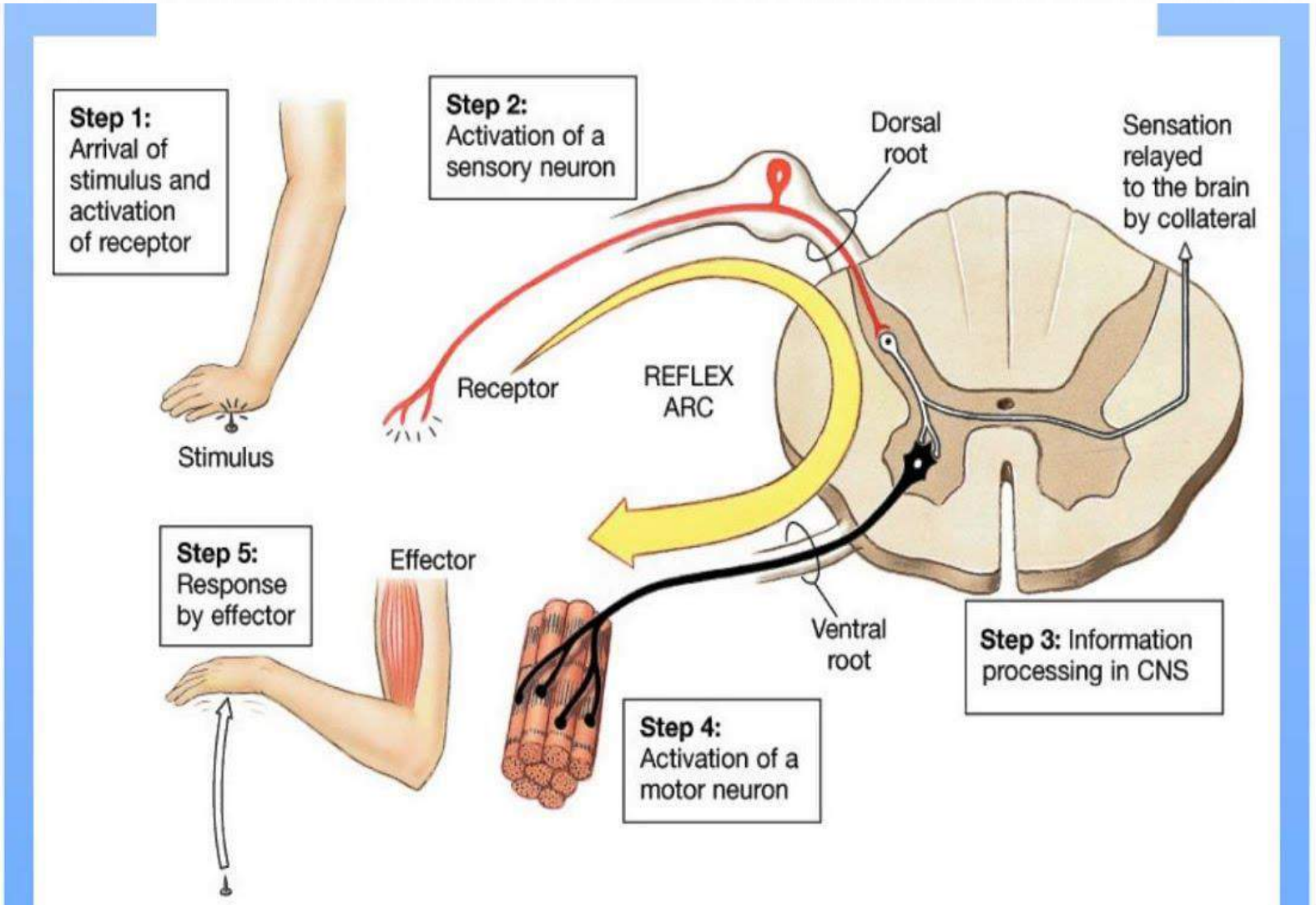
REFLEX ACTION

- A REFLEX ACTION, ALSO KNOWN AS A REFLEX, IS AN INVOLUNTARY AND NEARLY INSTANTANEOUS MOVEMENT IN RESPONSE TO A STIMULUS. WHEN A PERSON ACCIDENTALLY TOUCHES A HOT OBJECT, THEY AUTOMATICALLY JERK THEIR HAND AWAY WITHOUT THINKING. A REFLEX DOES NOT REQUIRE ANY THOUGHT INPUT.
- THE PATH TAKEN BY THE NERVE IMPULSES IN A REFLEX IS CALLED A REFLEX ARC. IN HIGHER ANIMALS, MOST SENSORY NEURONS DO NOT PASS DIRECTLY INTO THE BRAIN, BUT SYNAPSE IN THE SPINAL CORD. THIS CHARACTERISTIC ALLOWS REFLEX ACTIONS TO OCCUR RELATIVELY QUICKLY BY ACTIVATING SPINAL MOTOR NEURONS WITHOUT THE DELAY OF ROUTING SIGNALS THROUGH THE BRAIN, ALTHOUGH THE BRAIN WILL RECEIVE SENSORY INPUT WHILE THE REFLEX ACTION OCCURS.
- MOST REFLEX ARCS INVOLVE ONLY THREE NEURONS. THE STIMULUS, SUCH AS A NEEDLE STICK, STIMULATES THE PAIN RECEPTORS OF THE SKIN, WHICH INITIATE AN IMPULSE IN A SENSORY NEURON. THIS TRAVELS TO THE SPINAL CORD WHERE IT PASSES, BY MEANS OF A SYNAPSE, TO A CONNECTING NEURON CALLED THE RELAY NEURON SITUATED IN THE SPINAL CORD.
- THE RELAY NEURON IN TURN MAKES A SYNAPSE WITH ONE OR MORE MOTOR NEURONS THAT TRANSMIT THE IMPULSE TO THE MUSCLES OF THE LIMB CAUSING THEM TO CONTRACT AND PULL AWAY FROM THE SHARP OBJECT. REFLEXES DO NOT REQUIRE INVOLVEMENT OF THE BRAIN, ALTHOUGH IN SOME CASES THE BRAIN CAN PREVENT REFLEX ACTION.

TYPES OF REFLEX ACTION



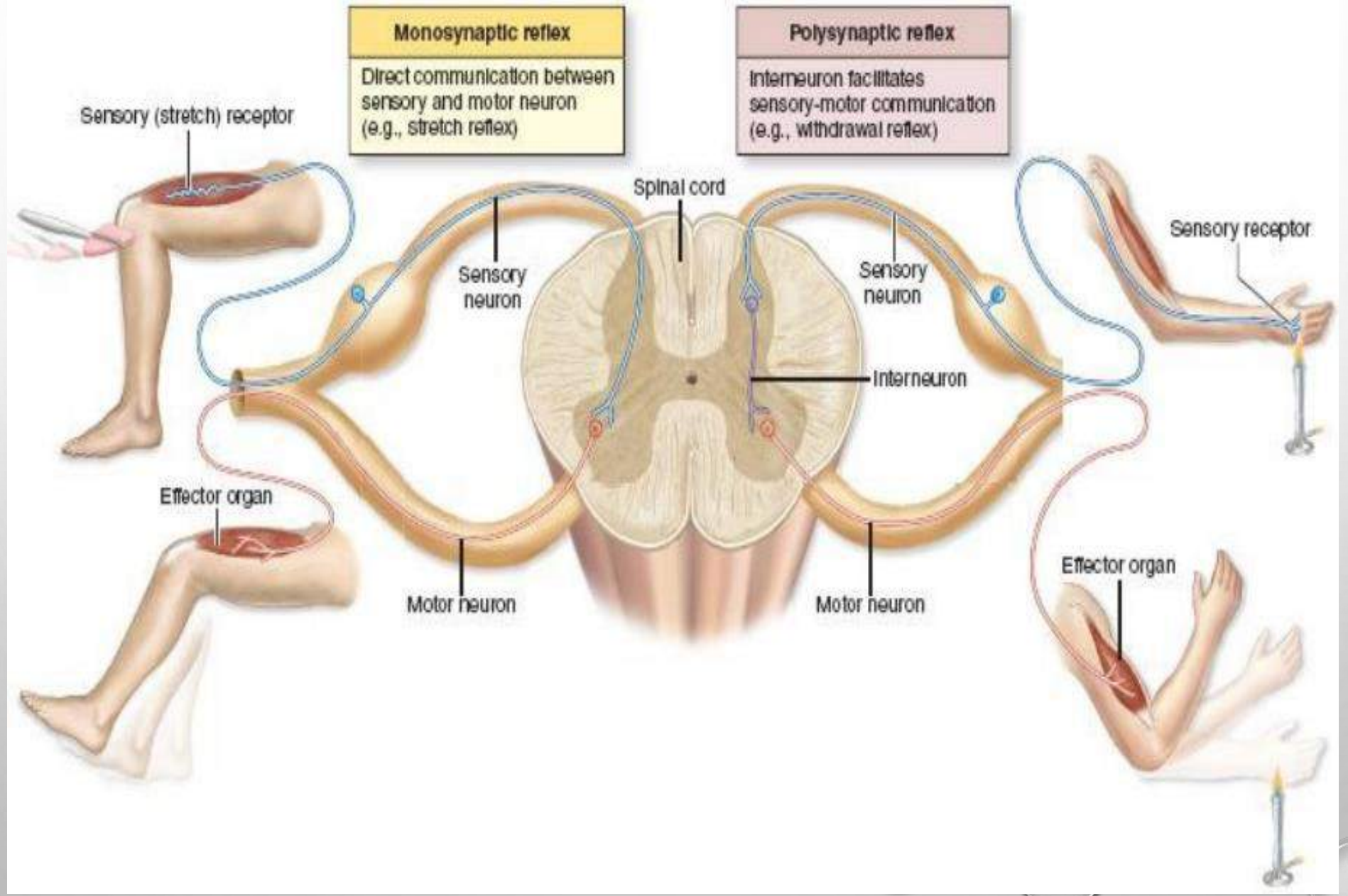
REFLEX ARC


Step 1:
Arrival of stimulus and activation of receptor
Stimulus
Step 2:
Activation of a sensory neuron
Receptor
REFLEX ARC
Dorsal root
Sensation relayed to the brain by collateral
Step 3: Information processing in CNS
Ventral root
Step 4:
Activation of a motor neuron
Effector
Step 5:
Response by effector

MONOSYNAPTIC AND POLYSYNAPTIC REFLEX

- A MONOSYNAPTIC REFLEX, SUCH AS THE KNEE JERK REFLEX, IS A SIMPLE REFLEX INVOLVING ONLY ONE SYNAPSE BETWEEN THE SENSORY AND MOTOR NEURONE.

- BY CONTRAST, IN POLYSYNAPTIC REFLEX ARCS, ONE OR MORE INTERNEURONS CONNECT AFFERENT (SENSORY) AND EFFERENT (MOTOR) SIGNALS.
  FOR EXAMPLE, THE WITHDRAWAL REFLEX (NOCICEPTIVE OR FLEXOR WITHDRAWAL REFLEX) IS A SPINAL REFLEX INTENDED TO PROTECT THE BODY FROM DAMAGING STIMULI. IT CAUSES THE STIMULATION OF SENSORY, ASSOCIATION, AND MOTOR NEURONS.


Monosynaptic reflex
Direct communication between sensory and motor neuron (e.g., stretch reflex)
Polysynaptic reflex
Interneuron facilitates sensory-motor communication (e.g., withdrawal reflex)
Sensory (stretch) receptor
Spinal cord
Sensory neuron
Sensory neuron
Sensory receptor
Interneuron
Effector organ
Motor neuron
Motor neuron
Effector organ

MONOSYNAPTIC- STRETCH REFLEX

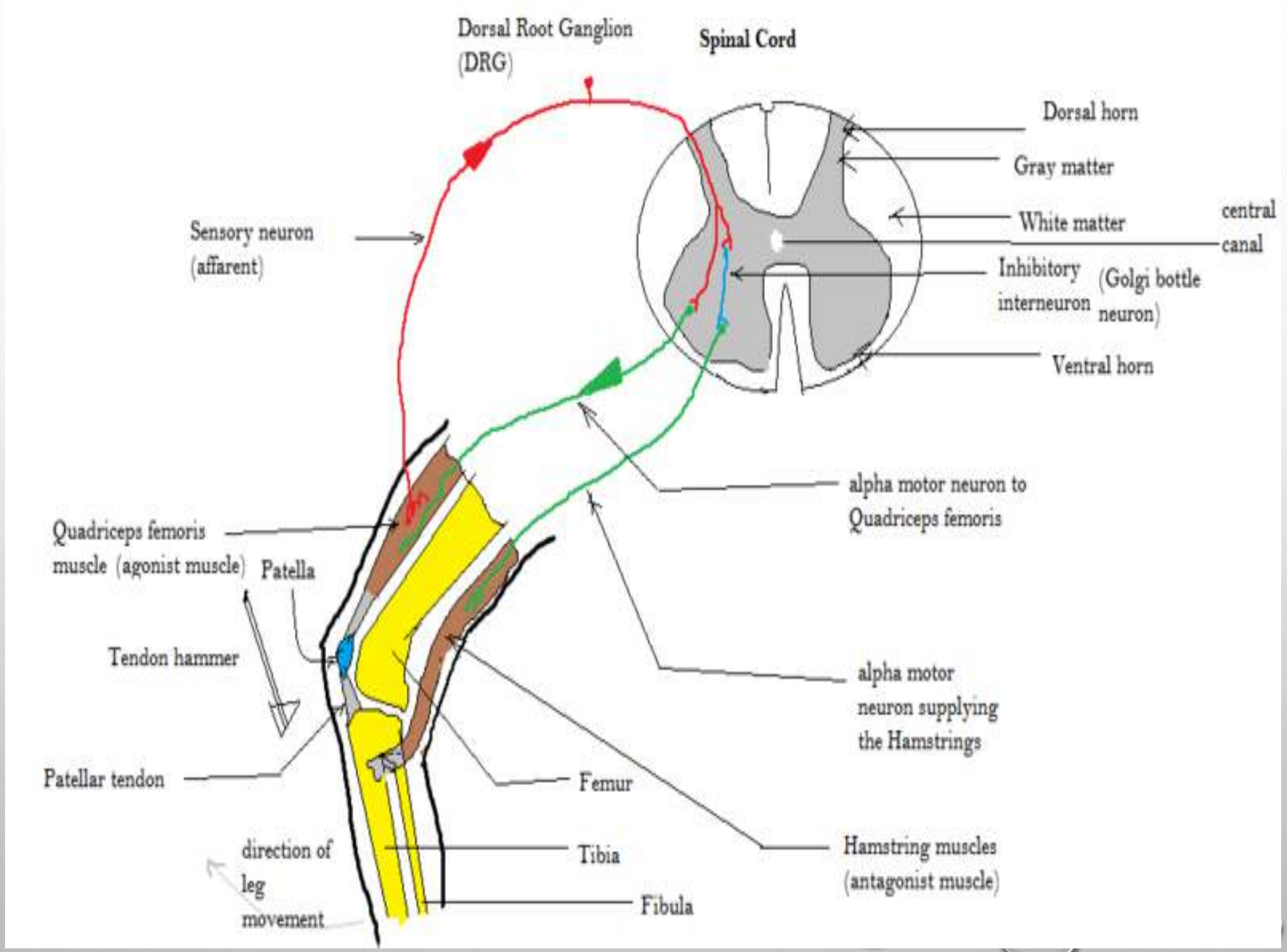
- THE PATHWAY STARTS WHEN THE MUSCLE SPINDLE IS **STRETCHED** (CAUSED BY THE TAP STIMULUS IN THE KNEE JERK REFLEX). THE MUSCLE SPINDLES ARE RESPONSIBLE FOR DETECTING THE LENGTH OF THE MUSCLES FIBRES.
- WHEN A STRETCH IS DETECTED IT CAUSES ACTION POTENTIALS TO BE FIRED BY **IA AFFERENT FIBRES**. THESE THEN SYNAPSE WITHIN THE SPINAL CORD WITH A-MOTONEURONES WHICH INNERVATE EXTRAFUSAL FIBRES. THE ANTAGONISTIC MUSCLE IS INHIBITED AND THE AGONIST MUSCLE CONTRACTS I.E. IN THE KNEE JERK REFLEX THE QUADRICEPS CONTRACT AND THE HAMSTRINGS RELAX.
- THE SENSITIVITY OF THE REFLEX IS REGULATED BY **GAMMA MOTONEURONES** – THESE LEAD TO TIGHTENING OR RELAXING OF MUSCLE FIBRES WITHIN THE MUSCLE SPINDLE. IT IS THOUGHT THAT THIS TAKES PLACE TO ALLOW PRESERVATION OF THE STRETCH REFLEX WHEN MUSCLES ARE CONTRACTED.

MECHANISM OF ACTION- STRETCH REFLEX

- AT REST, THE STRETCH REFLEX CAN BE OBTAINED BY A QUICK STRETCH, SUCH AS BY TAPPING ON A MUSCLE TENDON, WHICH PRODUCES A BURST OF ACTION POTENTIALS IN THE IA SPINDLE AFFERENTS .
- IN THE SPINAL CORD, THE IA AFFERENTS SYNAPSE ON THE MOTOR NEURONS OF THE MUSCLE CONTAINING THE SPINDLE (THE HOMONYMOUS MOTOR NEURONS) AND, TO A LESSER EXTENT, ON MOTOR NEURONS THAT INNERVATE OTHER MUSCLES (HETERONYMOUS MOTOR NEURONS).
- THE RAPID VOLLEY OF GLUTAMATERGIC IA EPSPS CAUSED BY A QUICK STRETCH CAN SUMMATE IN THE MOTOR NEURON, AND IF SUFFICIENT DEPOLARIZATION OCCURS, AN ACTION POTENTIAL OCCURS THAT PRODUCES CONTRACTION OF THE MUSCLE, WITH A JERK OF THE LIMB.
- IF THE STRETCH REFLEX IS ELICITED DURING MOVEMENT, THE IA EPSPS WILL SUMMATE WITH INPUTS FROM OTHER SOURCES SUCH AS CPGS (CENTRAL PATTERN GENERATORS) AND DESCENDING INPUTS.
- STRETCH DURING THE PHASE OF MOVEMENT WHEN THE MUSCLE IS ACTIVE WILL ADD TO OTHER SOURCES OF MOTOR NEURON DEPOLARIZATION, AND THE REFLEX MOTOR RESPONSE WILL ENHANCE THE ONGOING CONTRACTION.

MECHANISM OF ACTION- STRETCH REFLEX

- STRETCH OF THE MUSCLE WHEN IT IS OUT OF ITS ACTIVE PHASE WILL PRODUCE A SMALLER MOTOR RESPONSE, IF ANY. IN THIS WAY, THE SPATIAL SUMMATION OF POSTSYNAPTIC POTENTIALS CONTRIBUTES TO PHASE MODULATION OF THE STRETCH REFLEX.
- ADDITIONALLY, THERE IS MODULATION OF THE STRETCH REFLEX THROUGH PRESYNAPTIC INHIBITION OF THE IA AFFERENTS DURING MOVEMENT (RUDOMIN, 2009).
- THIS PRESYNAPTIC INHIBITION IS PRODUCED BY GABA-ERGIC SPINAL INTERNEURONS THAT SYNAPSE ON THE IA AFFERENT TERMINALS, FORMING AXO-AXONIC SYNAPSES
- PRESYNAPTIC INHIBITION REDUCES THE RELEASE OF GLUTAMATE FROM IA AFFERENTS, LEADING TO SMALLER IA EPSPS IN THE MOTOR NEURON, BUT IT DOES NOT AFFECT THE SIZE OF OTHER INPUTS TO THE MOTOR NEURON.
- THE GABAERGIC INTERNEURONS MEDIATING PRESYNAPTIC INHIBITION ARE STRONGLY ACTIVATED BY ANTAGONIST IA AFFERENTS, THAT IS, FROM SPINDLES OF MUSCLES THAT PRODUCE THE OPPOSITE MOVEMENT, AS WELL AS BY CPGS AND DESCENDING INPUTS.
- THUS, PRESYNAPTIC INHIBITION OF A MUSCLE'S STRETCH REFLEX IS STRONGEST WHEN THE MUSCLE CONTRACTION IS OUT OF PHASE WITH THE MOVEMENT CYCLE, WHEN ITS ANTAGONIST MUSCLE IS CONTRACTING.


Dorsal Root Ganglion
(DRG)
Spinal Cord
Dorsal horn
Gray matter
White matter
central
canal
Sensory neuron
(affarent)
Inhibitory
interneuron
(Golgi bottle
neuron)
Ventral horn
alpha motor neuron to
Quadriceps femoris
Quadriceps femoris
muscle (agonist muscle)
Patella
Tendon hammer
alpha motor
neuron supplying
the Hamstrings
Patellar tendon
Femur
Hamstring muscles
(antagonist muscle)
direction of
leg
movement
Tibia
Fibula

POLYSYNAPTIC- WITHDRAWAL REFLEX

- THE WITHDRAWAL REFLEX IS A SPINAL REFLEX INTENDED TO PROTECT THE BODY FROM DAMAGING STIMULI. IT IS A POLYSYNAPTIC REFLEX, CAUSING STIMULATION OF SENSORY, ASSOCIATION, AND MOTOR NEURONS. IN THIS ARTICLE WE WILL DISCUSS THE BASIC ANATOMY, THE NEURAL PATHWAYS AND ALSO THE CLINICAL RELEVANCE OF THIS REFLEX.

- THE WITHDRAWAL REFLEX IS DEFINED AS AN AUTOMATIC WITHDRAWAL OF AN EXTREMITY (E.G. A HAND) FROM A PAINFUL STIMULUS. UNLIKE DEEP TENDON REFLEX, THE WITHDRAWAL REFLEX IS POLYSYNAPTIC.

MECHANISM OF ACTION- WITHDRAWAL REFLEX

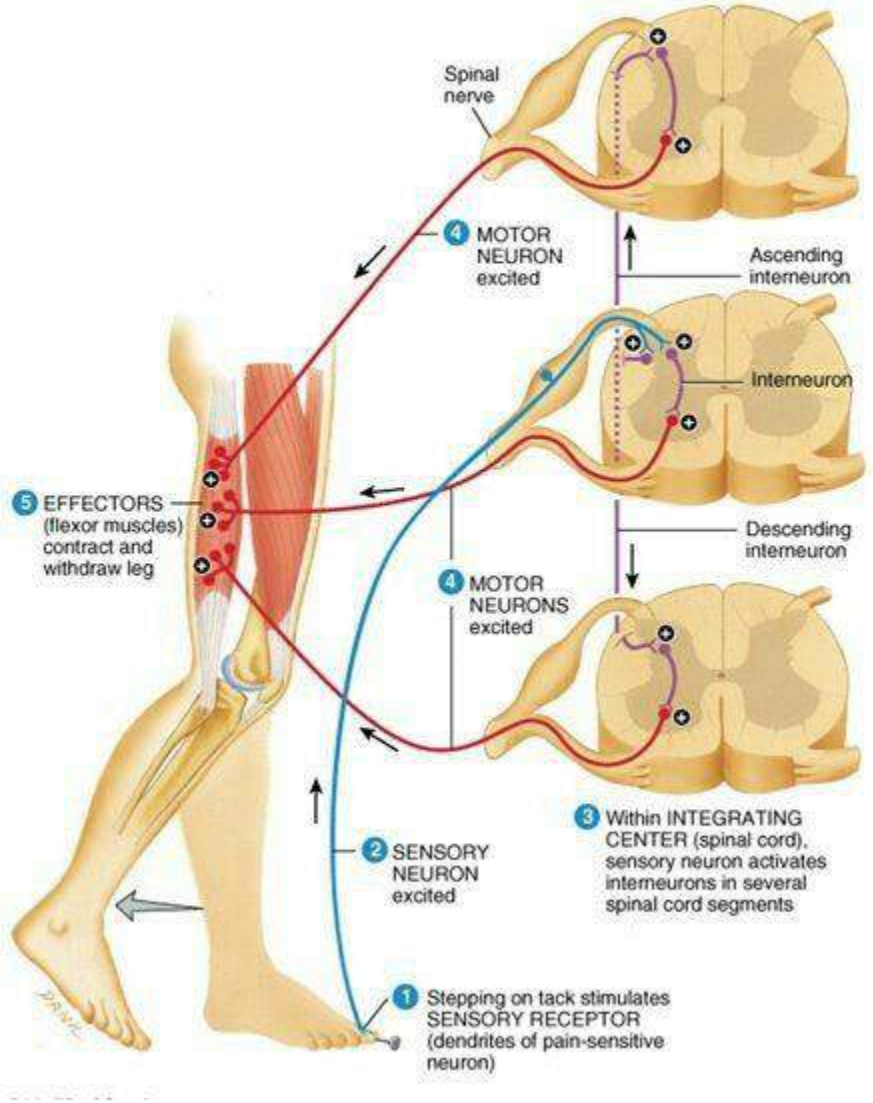
THE BASIC MECHANISM BY WHICH IT WORKS IS THE FOLLOWING:

- A NOXIOUS STIMULUS, SUCH AS HEAT OR PAIN, WILL EXCITE THE SENSORY NOCICEPTOR E.G. A HEAT RECEPTOR ON THE PERSON'S SKIN.
- THE SIGNAL TRAVELS THROUGH A PRIMARY SENSORY NEURON, WHICH WILL ENTER THE DORSAL HORN OF THE SPINAL CORD
- THE NEURON WILL THEN WILL SYNAPSE WITH AN INTERNEURON WITHIN THE SPINAL CORD ITSELF
- NEXT, THE INTERNEURON WILL SYNAPSE WITH AN ALPHA MOTOR NEURON
- SUBSEQUENTLY, THIS WILL LEAVE VIA THE VENTRAL HORN, AND WILL SUPPLY EXCITATORY INPUT TO THE IPSILATERAL (SAME SIDE) FLEXOR MUSCLE GROUP.
- IN PARALLEL, MOTOR NEURONS THAT SUPPLY THE IPSILATERAL EXTENSOR COMPARTMENT WILL RECEIVE SIGNALS FROM INHIBITORY NEURONS AND SUPPLY THE ANTAGONIST MUSCLES. THIS IS KNOWN AS 'RECIPROCAL INHIBITION'. THE OVERALL RESULT WILL CONSIST OF PULLING THE LIMB AWAY FROM THE NOXIOUS STIMULUS WITHIN HALF A SECOND.

MECHANISM OF ACTION- WITHDRAWAL REFLEX

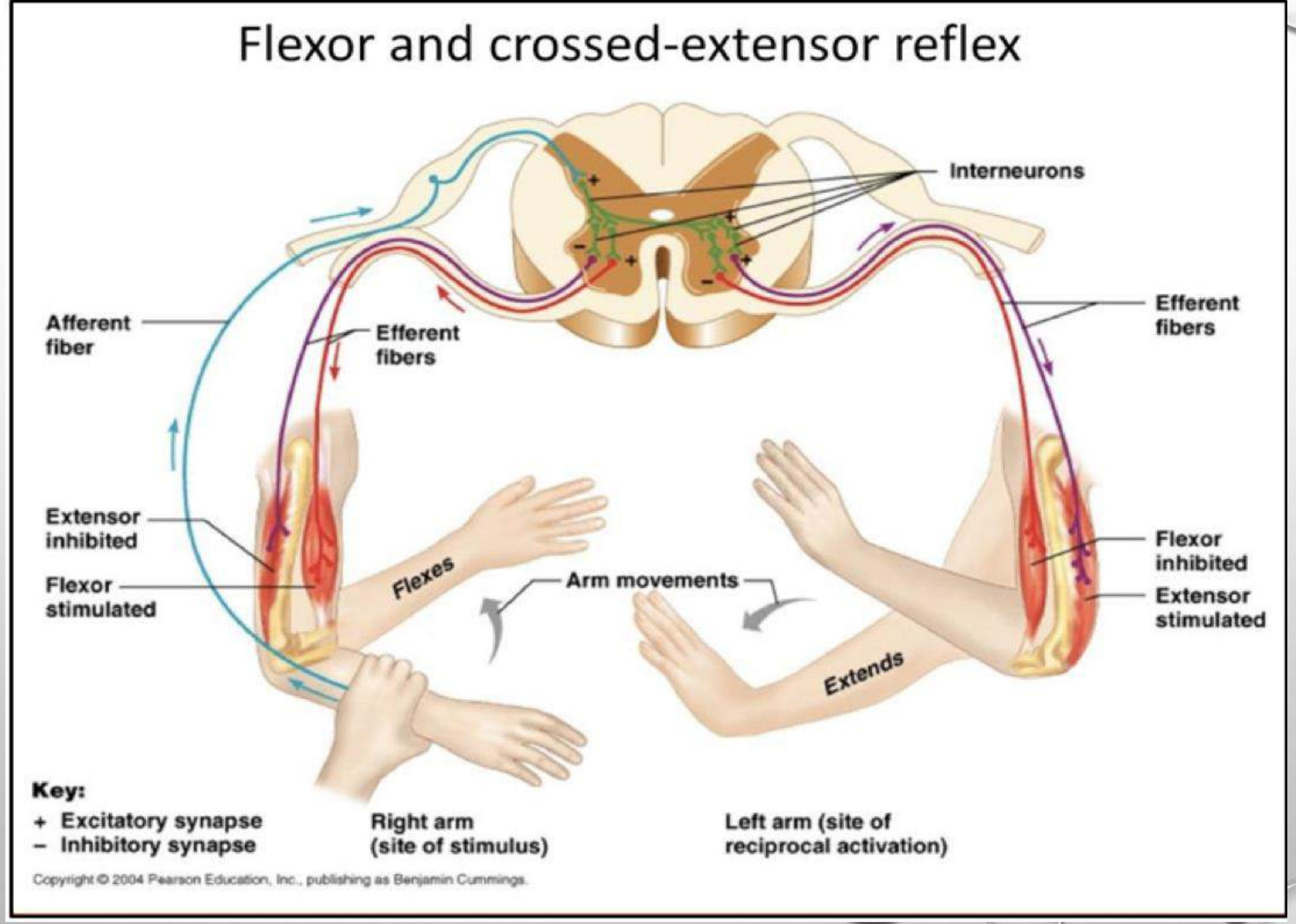
- IT IS WORTH NOTING, THAT AT THE SAME TIME THE SENSORY NEURON SYNAPSES WITH THE IPSILATERAL MOTOR NEURON, IT ALSO SYNAPSES WITH THE CONTRALATERAL MOTOR NEURON. THIS WILL SEND SIGNALS UP THE SPINAL CORD AND CAUSE THE PERSON TO CONTRACT MUSCLES THAT WILL MOVE THE CENTRE OF GRAVITY OF THE PERSON TO PREVENT THEM FALLING ONCE THEY WITHDRAW FROM THE STIMULUS.
- FOR EXAMPLE, IT WILL PREPARE THE CONTRALATERAL LEG IN ORDER TO STABILIZE THE BODY AND PREVENT THE PERSON FALLING. THE STIMULATION OF THE CONTRALATERAL HALF OF THE BODY FOR STABILIZATION IS KNOWN AS THE CROSSED EXTENSION REFLEX.
- UNDER NORMAL CONDITIONS, A NOXIOUS STIMULUS WILL OCCUR BEFORE THE FLEXOR REFLEX WILL OCCUR. HOWEVER, SQUEEZING A LIMB CAN CAUSE THE SAME RESPONSE. THIS SUGGESTS THAT THE SPINAL CORD CAN MODIFY AND MODULATE THE SENSITIVITY OF THE LOCAL CIRCUITRY TO A VARIETY OF SENSORY INPUTS.

Flexor (withdrawal) Reflex



- Step on tack (pain fibers send signal to spinal cord
- Interneurons branch to different spinal cord segments
- Motor fibers in several segments are activated
- More than one muscle group activated to lift foot off of tack

Flexor and crossed-extensor reflex



Properties of reflex arc

(1) Irradiation:

- ☺ If the sensory ***stimulus be too strong***, the impulse would spread on to many neighbouring neurones in the center and produce ***a wider response***.
- ☺ For example, a weak pin prick on the finger will produce a reflex movement of that finger only. But if the prick be too hard, the whole hand will jerk up.
- ☺ Irradiation is due to transmission of the impulse ***through a large number of collaterals*** of the afferent fibers and their interneurones.

(2) Delay:

- ☺ There is a short interval between the application of stimulus and the onset of reflex response. This period is called ***total reflex delay***. This time is lost in crossing the number of synapses in the central nervous system.

Properties of reflex arc

(3) Summation:

- ☺ If the stimulus is subminimal and applied to an afferent nerve there will be liberation of a chemical transmitter which will cause excitatory postsynaptic potential (EPSP), but this EPSP will not be sufficient to produce discharge of impulse from the motoneurones.
- ☺ If ***a number of subminimal stimuli be applied***, their effects will be summated together and the EPSP will be sufficient to induce the motoneurones to discharge impulses and produce the reflex response. This is called summation.

(4) Occlusion:

- ☺ When a reflex contraction is produced ***by simultaneous stimulation of two afferent nerves***, the amount of tension (T) in the muscle is less that the sumtotal of the tensions (t_1+t_2) setup in the same muscle when the two afferent nerves are separately stimulated (*i.e.*, $T<t_1+t_2$).

Properties of reflex arc

(5) Facilitation:

- ☺ The ***passage of a reflex impulse facilitates the transmission of the next impulse*** (by reducing synaptic resistance).
- ☺ If a reflex be elicited repeatedly at proper intervals, the response becomes progressively higher. Each subsequent stimulus seems to exert a better effect than the previous one and makes the passage of the next impulse easier.

(6) Inhibition:

- ☺ In this phenomenon a stimulus diminishes or inhibits the effects of another stimulus.
- ☺ For example, when the ***flexor muscles of a joint*** are stimulated the ***extensor muscles*** are inhibited due to the inhibitory activity exerted by the interneurones.

Properties of reflex arc

(7) Recruitment:

- When muscle fibers are ***stimulated directly through their motor nerve***, ***the tension rises 'very quickly' to the maximum***. But if they are stimulated reflexly through a sensory nerve, the tension in the muscle develops 'gradually' to the peak. After repeated stimulation of the afferent nerves more internuncial neurons are activated and lead to excitation of more number of motoneurons due to recruitment property of reflex.

(8) After discharge:

- After reflex contracton, ***if the stimulation is discontinued, the muscle does not completely relax at once***. It relax gradually. This is due to the fact that ***the center go on discharging motor impulses for a brief period***, even after the sensory stimuli are stopped. So, even after cessation of afferent stimulation, these impulses travel for certain periods.

Properties of reflex arc

(9) Fatigue:

- ☺ If a particular reflex be repeatedly elicited at frequent intervals, the response becomes progressively feebler and finally disappears altogether. This phenomenon is called fatigue.

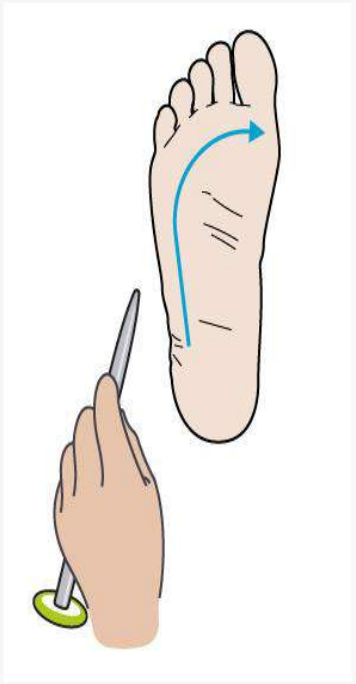
(10) Reciprocal innervation:

- ☺ In a reflex action when ***one group of muscles contracts***, the antagonistic ***group relaxes to some degree***.

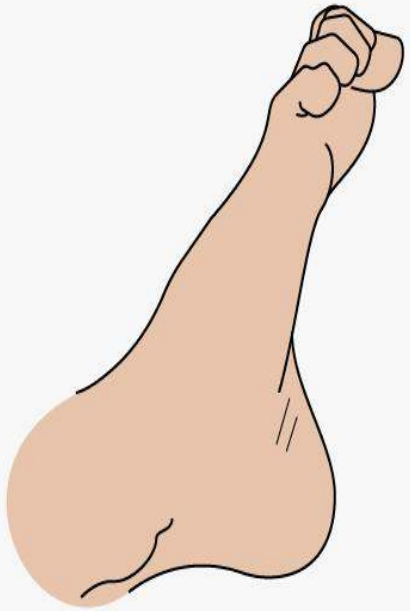
BABINSKI SIGN OR REFLEX

- THE BABINSKI REFLEX TESTS THE INTEGRITY OF THE CORTICOSPINAL TRACT (CST). THE CST IS A DESCENDING FIBER TRACT THAT ORIGINATES FROM THE CEREBRAL CORTEX THROUGH THE BRAINSTEM AND SPINAL CORD. FIBERS FROM THE CST SYNAPSE WITH THE ALPHA MOTOR NEURON IN THE SPINAL CORD AND HELP DIRECT MOTOR FUNCTION.
- DAMAGE ANYWHERE ALONG THE CST CAN RESULT IN THE PRESENCE OF A BABINSKI SIGN.
- STIMULATION OF THE LATERAL PLANTAR ASPECT OF THE FOOT (S1 DERMATOME) NORMALLY LEADS TO PLANTAR FLEXION OF THE TOES (DUE TO STIMULATION OF THE S1 MYOTOME). THE MOTOR RESPONSE WHICH LEADS TO THE PLANTAR FLEXION. THE TOES CURL DOWN AND INWARD. SOMETIMES THERE IS NO RESPONSE TO STIMULATION. THIS IS CALLED A NEUTRAL RESPONSE. THIS RESPONSE DOES NOT RULE OUT PATHOLOGY.
- THE DESCENDING FIBERS OF THE CST NORMALLY KEEP THE ASCENDING SENSORY STIMULATION FROM SPREADING TO OTHER NERVE ROOTS. WHEN THERE IS DAMAGE TO THE CST, NOCICEPTIVE INPUT SPREADS BEYOND S1 ANTERIOR HORN CELLS. THIS LEADS TO THE L5/L4 ANTERIOR HORN CELLS FIRING, WHICH RESULTS IN THE CONTRACTION OF TOE EXTENSORS.
- BABINSKI SIGN OCCURS WHEN STIMULATION OF THE LATERAL PLANTAR ASPECT OF THE FOOT LEADS TO EXTENSION (DORSIFLEXION OR UPWARD MOVEMENT) OF THE BIG TOE (HALLUX). ALSO, THERE MAY BE FANNING OF THE OTHER TOES. THIS SUGGESTS THAT THERE IS BEEN SPREAD OF THE SENSORY INPUT BEYOND THE S1 MYOTOME TO L4 AND L5. AN INTACT CST PREVENTS SUCH SPREAD.

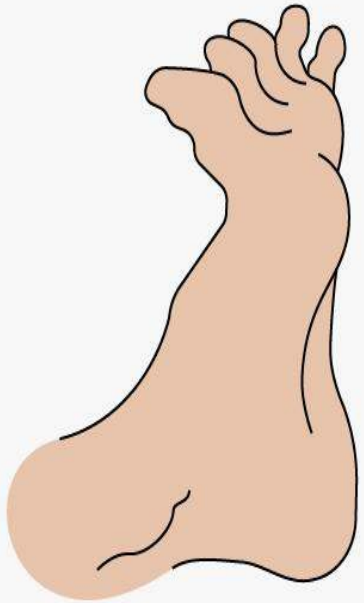
The Babinski Reflex



test



negative



positive

MedicalNewsToday