Physiology Team 439

MED439
KING SAUD UNIVERSITY

Revised & Approved
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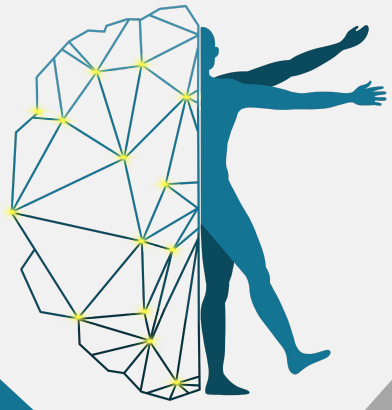


Spinal cord function and Reflexes

Objectives:

- Describe the physiological functions of the spinal cord.
- Describe the organization of the spinal cord for motor functions.
- Identify the spinal reflex and reflex arc components.
- Classify reflexes (superficial ,deep, monosynaptic & polysynaptic).
- Describe withdrawal reflex & crossed extensor reflex.
- Recognize the general properties of spinal cord reflexes.

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note
- Extra information.

Editing File

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)
FIBERS 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.

found in male slides

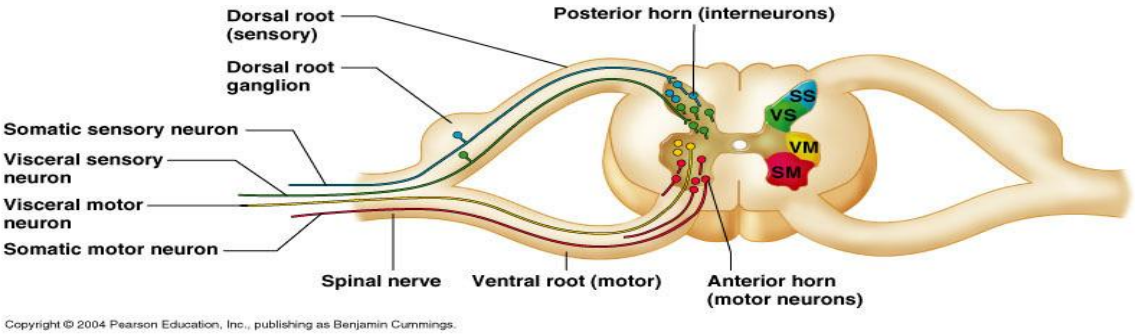
HIGHER BRAIN OR CORTICAL LEVEL	Control all lower centers, thought processes, memory
LOWER BRAIN OR SUBCORTICAL LEVEL	Subconscious activities of the body are controlled in the lower areas of the Brain; the medulla, pons, mesencephalon, hypothalamus, thalamus, cerebellum, and basal ganglia.
SPINAL CORD LEVEL	walking reflexes , withdrawal reflexes, anti-gravity reflexes, Reflexes that control of blood vessels, gastrointestinal, urinary/defecation.

Grey matter (nuclei)

- In the grey matter of the spinal cord and brain, clusters of neuronal cell bodies from functional groups called **nuclei**.
-**Sensory nuclei** receive input from receptors via sensory neurons.
-**Motor nuclei** provide output to effector tissue via motor neurons.

FEATURES:

1. The posterior 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**.



Functions of spinal cord

1. Gateway and conduction pathway for all tracts . Ascending sensory tracts and descending motor tracts
2. Center of Spinal Cord Reflexes(Somatic & Autonomic)
3. Gateway for Pain control systems not only conduct but also regulates the conduction

1-Gateway and conduction pathway for all tracts (The two-way traffic pathways 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 sensory neurons of the gray matter of the **dorsal horn** 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:
i. Dorsal Column Tracts (Gracile & Cuneate)
ii. Lateral & Anterior Spinothalamic Tract
iii. Spinocerebellar Tracts

B- **Motor signals & brain motor commands** pass through descending motor tracts & motor neurons to spinal efferent motor nerves to skeletal muscles to execute motor functions.

White matter

The white matter of spinal cord contains **sensory** and **motor tracts**.
1-**Sensory tracts** are the "highways" for conduction of sensory nerve impulses toward the brain.
2-**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

Located in each segment of the anterior horns gray matter , thousands neurons that are 50 to 100 percent larger than others neurons , they send motor fibers to innervate the skeletal muscle

1. Alpha Motor Neurons
- They give rise to large type A alpha (Aa) (refer to BOX 1-3) motor nerve fibers.
- 14 micrometers in diameter.
- Innervate the large skeletal muscle fibers called extrafusal fibers.

2. Gamma Motor Neurons
- Smaller gamma motor neurons, along with alpha motor neurons.
- They transmit impulses through much smaller type A gamma motor nerve fibers.
- 5 micrometer in diameter.
- Go to special skeletal muscle fibers called intrafusal fibers.

What is the motor unit? A motor unit is made up of a motor neuron and the skeletal muscle fibers innervated by that motor neuron's axonal terminals.

SPINAL REFLEX

-Functional unit of CNS, rapid,automatic ,involuntary response to a stimulus.
-example: pinprick causes withdrawal reflex.

Terms to remember: Reflex Arc, ipsilateral, contralateral, monosynaptic, polysynaptic and reciprocal innervation

The Reflex Arc & its components

L2

REFLEX ARC Reflex arc is the pathway followed by nerve impulses that produce a reflex (reflex circuit).

INCLUDES FIVE FUNCTIONAL COMPONENTS:

Girls slides

1. 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 the generator potential reaches the threshold level of depolarization, it will trigger one or more nerve impulses in the sensory neuron.

2. SENSORY NEURON

The nerve impulses propagate from the sensory receptor along the axon of the sensory neuron to the axon terminals, which are located in the grey matter to relay neurons which 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.

3. INTEGRATING CENTRE

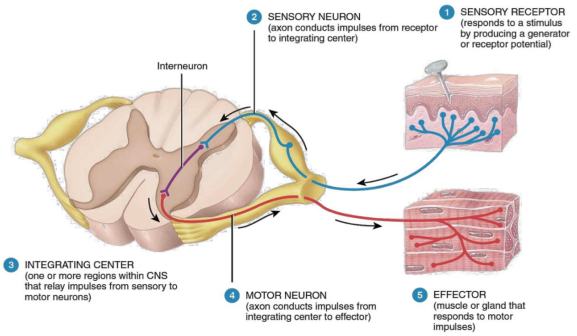
One or more neuron in the gray matter within spinal cord acts as an integrating center. the integrating centre may be a single synapse between a sensory neuron and a motor neuron.

4. MOTOR NEURON (Efferent Neurons)

Impulses triggered by the integrating center propagate out of the spinal cord along motor axons to the part of the body that will respond as skeletal muscle,

5. EFFECTOR

The part of the body that responds to the motor nerve impulse, such as a muscle 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, or a gland, the reflex is an autonomic (visceral) reflex.



Visceral reflex the effector will be gland or organ
Somatic reflex the effector will be skeletal muscle

Types of integrating center: Girls slides

A reflex pathway having only one synapse in the CNS is termed a monosynaptic reflex arc.

A polysynaptic reflex arc involves more than two types of neurons and more than one CNS synapse.(has interneuron)

Interneurons & interneuron pool:

Girls slides

-Interneurons are present within the gray matter in
the dorsal & anterior horns, and the intermediate areas between them.
-They are 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). Recoiling - دوائر متشابكة
- They are (excitatory or inhibitory).
-found only with polysynaptic.

Renshaw Cells :

most important inhibitory interneuron

Small interneurons located in the anterior horns of the spinal cord, in close association with the motor neurons.
- AHCs 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 .**
- This lateral inhibition helps to focus or sharpen the signals from each motor neuron.

The original signal from AHC

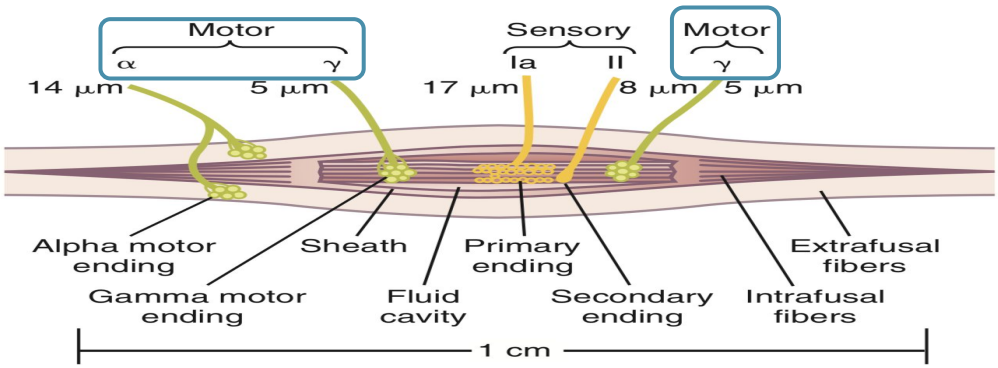
Anterior Horn Cells (Motor neurons)

Alpha motor neurons

- Large cells
- Large myelinated fibres (axons) form 70% of ventral root
- supply extrafusal muscle fibres (2/3 Of skeletal muscle fibers)

Gamma motor neurons

- Smaller cells
- small axons form 30 % of ventral root
- supply intrafusal muscle fibres (muscle spindles=1/3 Of skeletal muscle fibers)



General Properties Of Reflexes And Their Neuronal Pools so important for the reflex to work

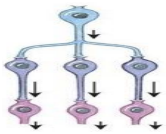
L2

1-Divergence 2-Convergence 3-Reciprocal inhibition circuits

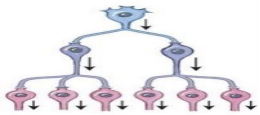
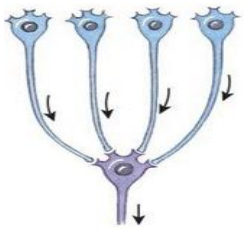
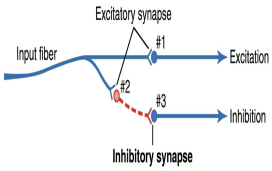
4- Reverberating circuits 5-After-Discharge 6-Central deley

7-Reflex time 8-Recruitment 9-Irradiation 10-minimal synaptic delay

Types of neuronal pool circuits:
1-Parallel: afferent and efferent are parallel to each other (input parallel to output)
2-Reverberating 3-**Divergence** 4-**Convergence**

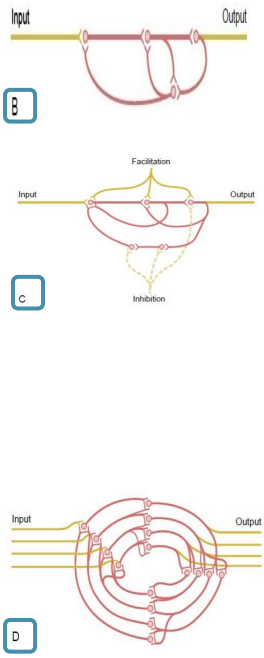
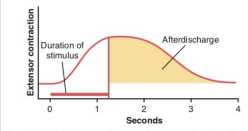
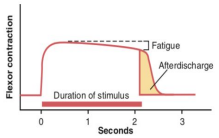


Sensory afferent enter spinal cord & as they enter the neuronal pool undergo: Divergence or Convergence

Property	Explanation Girls slides	Illustration
Divergence	help to spread a **single stimulus** to a wide area of the spinal cord, so weak signals entering a neuronal pool excite greater numbers of nerve fibers leaving the pool.	
Convergence	Signals from **multiple inputs** unit 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. (multiple stimuli summate & collect together at the same time) *Excitatory potentials from many neurons trigger threshold point	
Reciprocal (عكسي) **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 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 (neuron#3).	

General Properties Of Reflexes And Their Neuronal Pools so important for the reflex to work

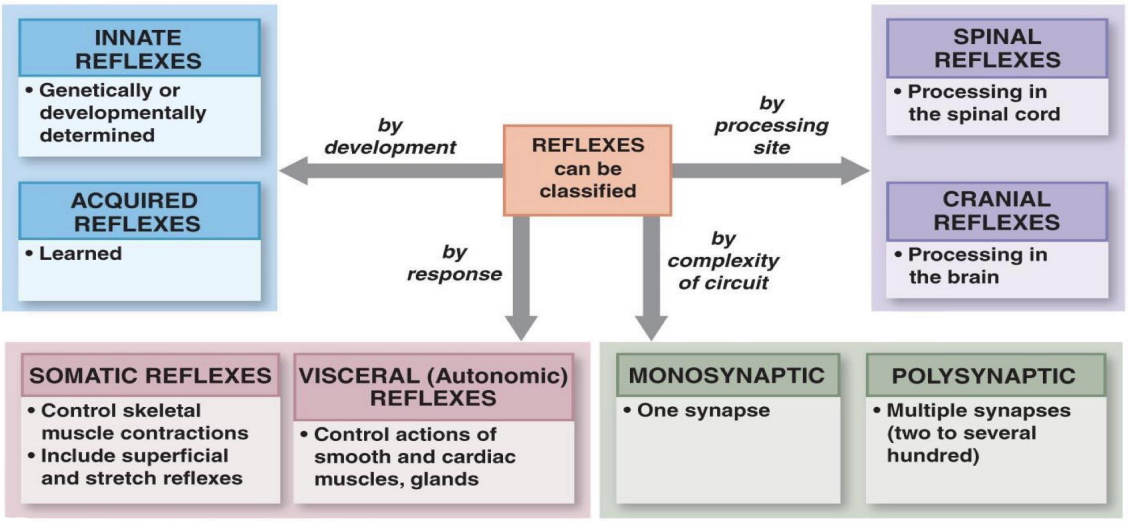
L2

Property	Explanation Girls slides	Illustration
Reverberatory Circuit	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 re-stimulate the input neuron itself & so the circuit may discharge repetitively for a long time and causes signal prolongation. **(B)** A more 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. **(C)** Most reverberating pathways are constituted of many parallel fibers. (**D)**	
After-Discharge	-A signal entering a pool causes a prolonged output discharge of AHCs (anterior horn cell) called afterdischarge, lasting a few milliseconds to 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 many milliseconds. And Continue to excite the neuron to transmit repetitive discharges, this cause maintained response continue for some time after cessation of stimulus. Short term afterdischarge is produced by successive depolarization of the membrane of the neuron after prolonged rhythmic stimulation Prolonged after discharge results from recurrent pathways that initiate oscillation in reverberating interneuron circuits stimulating AHCs **2-Reverberating circuits restimulate AHCs**	 **Figure 55-11.** Myogram of a crossed extensor reflex showing slow onset but prolonged afterdischarge.  **Figure 55-10.** Myogram of the flexor reflex showing rapid onset of the reflex, an interval of fatigue, and, finally, afterdischarge after the input stimulus is over.

General Properties Of Reflexes And Their Neuronal Pools so important for the reflex to work

Property	Explanation
SYNAPTIC DELAY (CENTRAL DELAY)	-Is the time of reflex to pass through neurons of the spinal cord. -Is the minimal period of time required for transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron -Equals 0.5 ms /synapse (it is longer in polysynaptic reflex). - it is > 2 ms in the withdrawal reflex (polysynaptic reflex) **-Number of synapses in a reflex = Central delay / 0.5 msc** for knee jerk it equals 0.6 msc = one synapse(0.6/0.5 ≈1)
Reaction time (reflex time)	-Is the time between the application of the stimulus and the response - Reflex time = central delay + time spent in conduction of impulses along the afferent and efferent nerves -In humans the reaction time for a stretch reflex such as the knee jerk is 19-24ms. -The conduction velocities of the afferent and efferent fiber 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)
RECRUITMENT توظيف أكبر عدد من النيورونز عشان يخدموني في الريفلكس	-Maintained repetitive stimulation of afferent nerve causes **Gradual** activation of more number of motor neurons (AHCS) the contraction is maintained for long period Cause: 1-different conduction velocities of afferents 2-different number of interneurons with short & long pathways to the motor neurons (AHCs)
IRRADIATION	-spread of impulses up & down to different segments of motor neurons in the S.C (spinal cord) -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**

Classification of reflexes



Types of spinal reflexes

According to number of neurons

Monosynaptic:

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

Ex.Stretch reflex
(Bicep jerk tricep jerk, supinator jerk knee jerk, ankle jerk)

Polysynaptic:

Sensory axon (afferent) synapse with one or more interneuron.
These reflexes are mediated by the spinal cord, but influenced by higher centers.

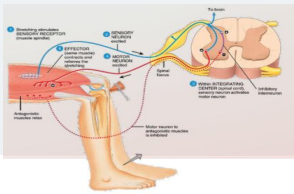
Ex.Withdrawal,abdominal reflexes,
visceral,planter reflex

Classification of reflexes
(according to site of receptor) :

A) Deep Reflexes

BY STIMULATION OF RECEPTORS DEEP IN MUSCLES AND TENDONS

1- *Stretch reflex (tendon jerk)*, 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
Stretch —>Maintain Muscle Tone in



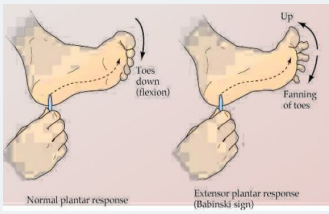
Also there are
-Extensor Standing/Posture/Stepping ▪ Rhythmic Walking/Scratching

B) Superficial Reflexes

Are **polysynaptic** reflexes . The receptor are superficial in the skin or mucous membrane.

Examples are:
- Withdrawal
- Abdominal reflexes and plantar reflex
- Corneal and conjunctival reflexes.

the receptors for the abdominal wall reflex are found on the skin of the anterior abdominal wall



C) Visceral (autonomic)

Are the reflexes where at least one part of the reflex arc is **autonomic nerve**. Stimulation receptors in viscera as micturition, and defecation

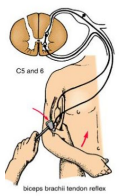
Examples are:
- Pupillary reflex
- Carotid sinus reflex

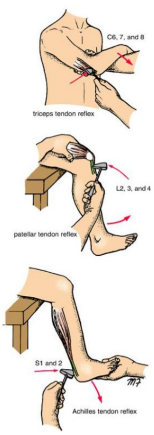
Monosynaptic Reflexes:
As knee reflex

In the simplest type of Reflex, the integration center is a single synapse between a sensory neuron and a motor neuron

When a reflex arc consist of only two neuron in an animal
(One sensory neuron, and one motor neuron)
It is defined as MONOSYNAPTIC

Reflex	Cord level
Biceps (elbow)	C5,6
Brachioradialis	C5,6
Triceps	C6,7
Long finger flexors	C8-T1
Hip Abductors	L2,3,4
Quadriceps (knee)	L2,3,4
Gastrocnemius-soleus (ankle)	S1,2





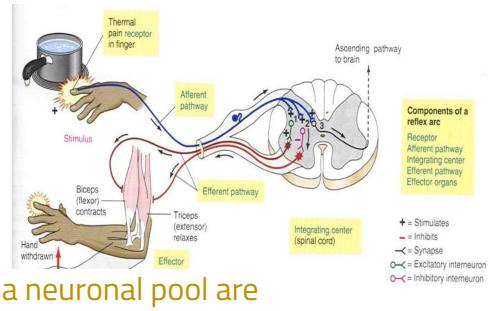
Withdrawal Reflex (Flexor reflex)

L2

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

also called nociceptive reflex

Characterized by: Girls slides only



1

Diverging circuits

to spread the reflex to the necessary muscles for withdrawal. In divergence weak signals entering a neuronal pool are amplified

2

Reciprocal inhibition circuits

stimulation of flexors muscle (agonist) accompanied by inhibition of extensors (antagonist) through inhibitory interneurons

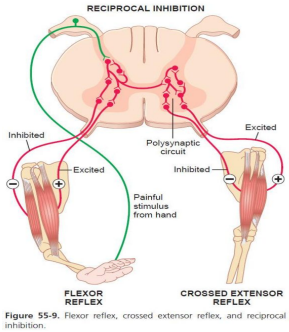


Figure 55-9. Flexor reflex, crossed extensor reflex, and reciprocal inhibition.

3

Recruitment

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

like you keep your hands away from fire after the reflex has occurred

Circuits to cause after discharge 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. The ability of neurons to rhythmically discharge impulses for a relatively longer time after cessation
of the stimulus'

Cause : Presence of reverberating circuit & synaptic after-discharge restimulate AHCs

Value : Prolong the protective response of reflex

5

Irradiation

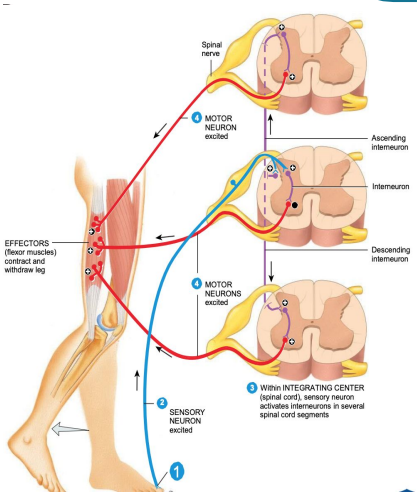
Spread of impulses up & down to different segments and motor neurons in the S.C.
A strong stim in sensory afferent irradiate to many segments of S.C due to divergence

***The extent of the response in a reflex depends on the intensity of the stimulus.**

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

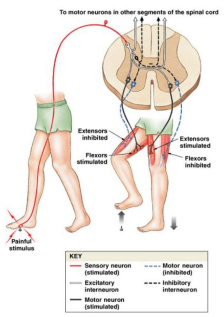
Strong stim: irradiates to large number of neurons , so it causes strong withdrawal of affected limb & extension of opposite limb.(as in crossed extensor reflex)

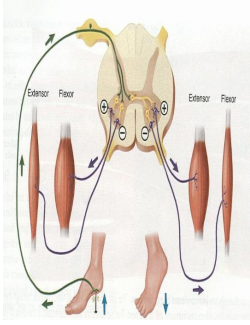
	The Withdrawal Reflex	
Reflex	Flexor reflex or withdrawal reflex	
Clinical Test | Stimulus	Sharp painful stimulus (stepping on nail)	
Response	Limb is rapidly withdrawn	
Sensory Receptor	Cutaneous skin and pain receptors	
Synapses Involved	Polysynaptic (via interneuron)	
Effects On Muscle	Contracts flexor 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



Crossed Extensor Reflex:

Explanation from **Girls slides**





- With strong stimulus while pushing the body away from the injurious agent by - withdrawal R ,the crossed extensor reflex in the other limb supporting the body weight against gravity.

- Flexion and withdrawal of the stimulated limb will lead to extension of the opposite limb >> why?
  - Signals from sensory neurons that activates withdrawal reflex in the stimulated limb, cross to the opposite side of the cord by irradiation & divergence to ***excite excitatory interneurons*** to activate motor neurons of ***extensor muscles neurons*** & send collaterals to inhibitory interneurons to inhibit motor neurons of the flexors(in the other limb)

  - It takes 200 to 500 milliseconds after onset of the initial pain stimulus, because many ▪ interneurons are involved in the circuit between the input sensory neuron and the motor neurons of the opposite side of the cord

  - After the painful stimulus is removed, the crossed extensor reflex has a prolonged after-discharge, results from reverberating circuits .

  - Mostly in the lower limb to support balance.

  - Reciprocal innervations occurs in crossed extensor reflex. **How?**
  Flexors in the opposite limb are inhibited while extensors are excited ,the crossed extensor reflex supporting the body weight against gravity

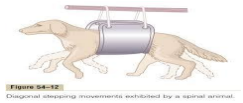
Examples of reflexes

Reflex of Posture and Locomotion

- Positive Supportive Reaction
- Cord "Righting" Reflex

Stepping and walking movements

- Rhythmical Stepping Movements of a Single Limb.
- Reciprocal Stepping of Opposite Limbs.
- Diagonal Stepping of All Four Limbs—"Mark Time"Reflex.
- Galloping reflex



Scratch reflex

- Position sense that allows the paw to find the exact point of irritation on the surface of the body and
- A to-and-fro scratching movement.

Spinal cord reflexes that cause muscle spasm

- Muscle Spasm Resulting From a Broken Bone.
- Abdominal Muscle Spasm in Persons with Peritonitis.
- Muscle Cramps.

Segmental autonomic reflexes (integrated in the Spinal Cord)

- changes in vascular tone resulting from changes in local skin heat
- sweating, which results from localized heat on the surface of the body
- intestinointestinal reflexes that control some motor functions of the gut
- peritoneointestinal reflexes that inhibit gastrointestinal motility in response to peritoneal irritation
- evacuation reflexes for emptying the full bladder

Mass reflex

In a spinal animal or human being, sometimes the spinal cord suddenly becomes excessively active, causing massive discharge in large portions of the cord by painful stimulus

MCQ & SAQ:

Q1: Renshaw cells found:

A. Between 2 motor neurons
B. Between motor and sensory neurons
C. Between 2 sensory neurons
D. None of the above

Q2: which of the following is axon conducts impulses from integrating center to effector:

A. sensory neuron
B. motor neuron
C. effector
D. integrating center

Q3: Involves only a single neuron, the output neuron sends a collateral nerve fiber back to its own soma

A. Divergence circuit
B .Convergence circuit
C. Parallel circuit
D. Reverberatory Circuit

Q4: Stretch reflex considered as

A. polysynaptic
B. monosynaptic
C. Both
D. None of the above

Q5: Pain receptors send impulses to spinal cord in pain fibers as:

A. A alpha
B. A beta
C. A delta
D. A gamma

Q6: Defecation is considered

A. Visceral / monosynaptic
B. Visceral / polysynaptic
C. Deep / monosynaptic
D. Deep / polysynaptic

answer key:
1: A
2: B
3: D
4: B
5: C
6: B

1- Enumerate the component of reflex arc.

2- Explain Reciprocal inhibition circuits?

3- What are the classification of reflexes according to receptors? give an example to each.

A1: Slide 6

A2: Slide 8

A3: 1. Deep (ex: knee jerk), 2. Superficial (ex: planter reflex) 3. Visceral (ex: carotid sinus reflex)

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