Physiology 435 team

SPINAL CORD FUNCTIONS & SPINAL REFLEXES

Objectives:

- Appreciate the **two-way traffic** along the spinal cord and Distinguish between the functional role of gray matter and white matter.
- Describe the structure and the physiological role of the spinal cord as an **initiator of spinal reflexes** and Describe the **spinal reflex** and **reflex arc** components.
- Describe the **organization** of the spinal cord for motor functions (anterior horn cells & interneurons & neuronal pools).
- **Classify reflexes** into superficial and deep; monosynaptic & polysynaptic.
- Describe the most important types of spinal cord reflexes and contrast their features.
- Describe the **general properties of spinal cord reflexes** such as convergence, divergence ,irradiation, recruitment , after discharge, recruitment, reverberating circuits, minimal synaptic delay, central delay and reflex time.
- Appreciate the clinical importance of reflexes (their use as a diagnostic tool for assessment of nervous system function).

Done by:

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Color index: Important - Further explanation - Doctors Notes - Numbers.

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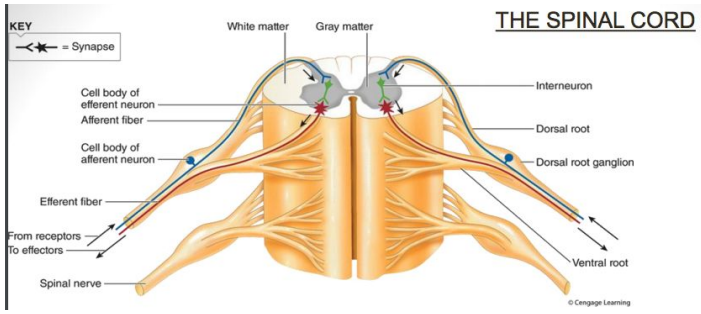
The Spinal Cord



- The spinal cord has 31 pairs of spinal nerves.
- Each spinal nerve has has ventral & dorsal roots :
    - **1- 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).
    - **2- 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.

1- Grey matter / nuclei :

- In the gray 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 tissue via motor neurons.
- The grey matter divided into :

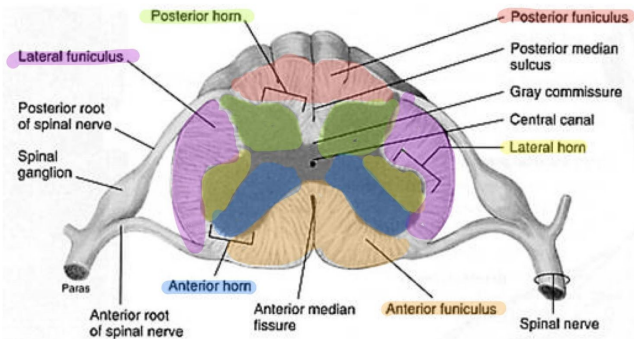
The posterior (dorsal) grey horn	The anterior (ventral) grey horn	The lateral grey horn
Contains **axons of sensory** neurons and **cell bodies of interneurons.**	Contains cell **bodies of somatic** motor neurons.	Contains **cell bodies** of **autonomic motor** neurons.

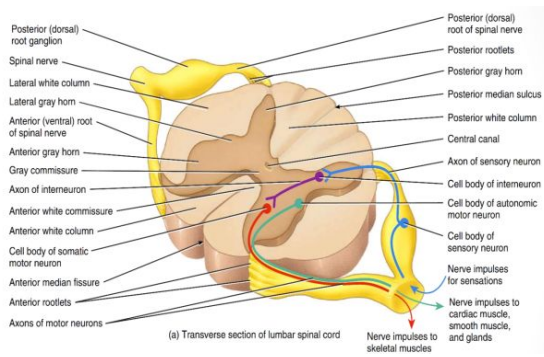
2- The white matter:

- 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 **COLUMN or FUNICULUS[1]:**
  - **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 distance up or down the spinal cord, are called **TRACTS :**
  - **Sensory (ascending) tract**:consist of axons that conduct nerve impulses toward the brain.
  - **Motor (descending) tract:** consist of axons that carry nerve impulses from the brain.
- Both sensory and motor tract of the spinal cord are **continuous** with the sensory and motor tract in the brain.

  ** **RECALL**: that tracts are bundles of axon in the CNS, whereas nerves are bundles of axon in PNS.

White matter and grey matter regions:





Functions of the Spinal Cord

1- The two-way traffic along the spinal cord:

[1] Funiculus:الحبل العصبي

- **First Way:** **Sensory** signals from receptors enter the cord through the **sensory (posterior) roots**, then every sensory signal travels to two separate destinations:
    - **One branch of the sensory nerve terminates in the gray matter** of the cord and elicits **local segmental** cord reflexes
    - **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 Or Cuneate).**
        - **Spinothalamic Tracts (Anterior and lateral).**
        - **Spinocerebellar Tracts.**

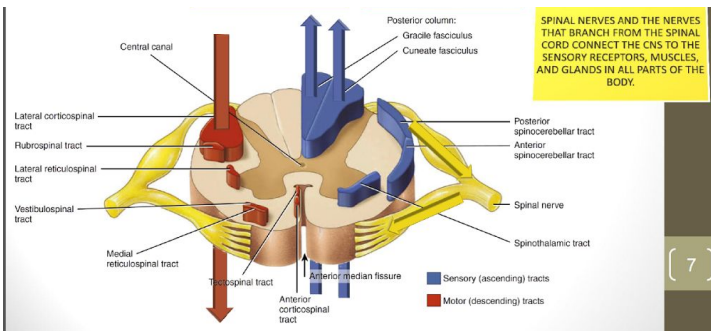
** All sensory signals are transmitted to higher centers through spinal ascending tracts such as dorsal column tract and spinothalamic tract.

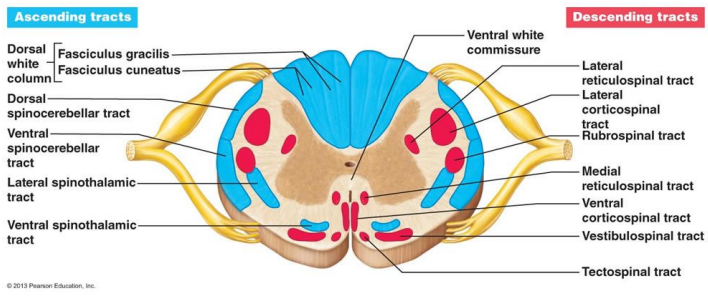
- **Second Way:** **Motor** signals & brain motor commands pass through descending motor tracts & spinal efferent motor nerves to **skeletal** muscles to execute motor functions.

** All motor signals are first communicated to the Spinal Cord via descending tracts before being sent to skeletal muscles via spinal efferent motor nerves.

2-Generating Spinal Reflexes:

Activates the motor output **directly without** input from the brain. (an example of that is when you put your hand on a hot place, directly you will remove it without going to the conscious level). (Involuntary response)





According to the picture:

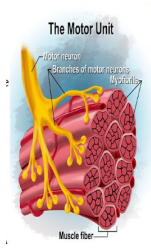
- **The red colour**: **motor** tracts are the “highways” for conduction of motor nerve impulses from the brain toward effector tissue.
- **The blue colour**: **sensory** tracts are the “highways” for conduction of sensory nerve impulses toward the brain.

- **The gold colour:** 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 (Ventral) 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 **(somatic).**

1- Alpha motor neurons:	2- Gamma motor neurons:
They give rise to **large type A alpha (Aa) motor nerve** fibers, branch in the muscle and innervate the large skeletal muscle fibers. 	Along with the alpha motor neurons, are smaller gamma motor neurons. They transmit impulses through much **smaller type A gamma motor nerve fibers** ز
Stimulation of a single alpha nerve fiber excites from three to several hundred **extrafusal fibers** [2]skeletal muscle fibers, which are collectively known as "**Motor unit**".	go to special skeletal muscle fibers called **intrafusal fibers**[3].
14 micrometers in diameter	5 micrometers in diameter

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. Groups of motor units often work together to coordinate the contractions of a single muscle; all of the motor units within a muscle are considered a motor pool.

[2] **Extrafusal muscle fibers** are the skeletal standard muscle fibers that are innervated by alpha motor neurons and generate tension by contracting, thereby allowing for skeletal movement.
[3] **Intrafusal muscle fibers** are skeletal muscle fibers that serve as specialized sensory organs (proprioceptors) that detect the amount and rate of change in length of a muscle.

Alpha & gamma motor neurons (Duration 3:10)

Spinal reflexes

❖ What is a reflex?

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

❖ Spinal reflexes

- Rapid, automatic response to certain kind of stimuli that involves neurons only in the **spinal nerves and spinal cord.**
- The spinal cord and its associated spinal nerves contain neural circuits that control reflexes.
  - **Example:** Pinprick causes withdrawal reflex.

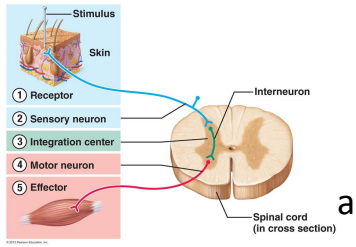
Reflex arc (REFLEX CIRCUIT):

Reflex arc (Duration 1:05)

❖ Definition: The pathway followed by nerve impulse that produce a reflex.

❖ Components:

1-SENSORY RECEPTOR:



- 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.

The stimulus must be strong enough to take the resting membrane potential to threshold.

2-SENSORY NEURON:

- The nerve impulses propagate(transmit) 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 brainstem.
- 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.
- صنع القرار بخصوص ردة الفعل الدماغ ماله دخل، خلاص تلمس شي حار على طول تبعد يدك بدون يقرر المخ حاجة، لكن أنت لما تبعد يدك تستوعب إنك أبعدتها كيف؟ لأن الدماغ توصله نسخ من الإحساس مثل العجوز اللي تقعد عند الباب تبي تعرف من رايح ومن جاي.

3-INTEGRATING CENTRE:

- **Location:** Group of neurons are located in the grey matter of the spinal cord.

monosynaptic reflex ARC:	polysynaptic reflex ARC:
- It Is a reflex pathway having **only one synapse** in the CNS. in which a single synapse between a sensory neuron and a motor neuron takes place. Monosynaptic reflexes (Duration 4:21)	- It Is the pathway having **more than two types** of neuron and more than one synapses in the CNS. - Impulses are transmitted to a motor nerve and neighboring interneurons.
- It is the simplest type of reflexes	- It is more common.

- **Interneurons & interneuron pool:**
  - Interneurons are present in the **gray matter** in the dorsal horns, the anterior horns, and the intermediate areas between them. (in all horns of the grey matter)
  - These cells are about 30 times as numerous **(high numbers)** as the anterior motor neurons, **small** and **highly excitable**, often exhibiting **spontaneous**(عفوي او تلقائي) activity (They don't need signals from the brain to be active)

- Different types of neuronal circuits are found in the interneuron pool (parallel and reverberating circuits).
  - They have the same properties of the synapse like: diverging, converging, and repetitive-discharge.
  - They are either (excitatory or inhibitory) interneurons.

- **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. لما يطلع الموتر نيورون من الحبل الشوكي يرسل بعض من نهايات الأكسون حقه للبودي قاردز (خلايا رنشو)

  • These are **inhibitory** cells that transmit inhibitory signals to the surrounding motor neurons BY **Lateral inhibition**. So the stimulation of each motor neuron tends to inhibit adjacent motor neurons . حنا قلنا الإنترنورونز إما تستثير أو تثبط، خلايا رنشو بودي قارد الموتر نيورون تجي مثبطة

  • This lateral inhibition helps to **focus or sharpen the signals** from each motor neuron (allowing transmission of the primary signal in the desired direction while suppressing the tendency for signals to spread laterally).

  - خلايا رينشو نوع من الإنترنورونز لكنه مصاحب الأنتيريور موتر نورونز يعني تتوقعون وين موجودين؟ أكيد بالأنتيريو هورن .. هذي الخلايا مثل البودي قارد .. تخيل الموتر نيورون يتكلم بالجوال ويبغى يركز تجي هذي الخلايا تبعد الناس اللي حوله بحيث صار الحين يمشي بطريق معين ويكلم بجواله بكل دقة. lateral inhibition

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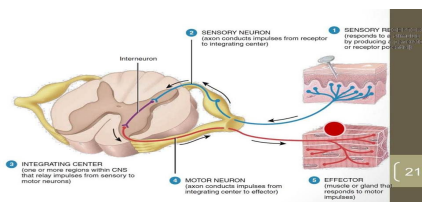
4-MOTOR (Efferent) NEURON:



- impulses triggered by the integrating center propagate out of the CNS along a motor neuron to the part of the body that will respond.
- **Also called the anterior horn cells.**
  (Motor=efferent=AHC)
- Motor neurons which are supplying skeletal muscles are:

	alpha motor neurons	.Gamma motor neurons
Cells Size	**Large** cells	**Small** cells
Axon size	large myelinated fibres form 70% of ventral root	Small axons form 30 % of ventral root مو عندنا 2 روتس يطلعون من الحبل الشوكي بعدين يتحدون ويعطوننا trunk؟ الفينترل روت موتر نقي ونيورونات قاما تشكل 30% من الموتر فيه.
Supply	**Extrafusal muscle fibres**	**Intrafusal muscle fibres**
Muscle spindle	2/3 Of skeletal muscle fibers	1/3 Of skeletal muscle fibers

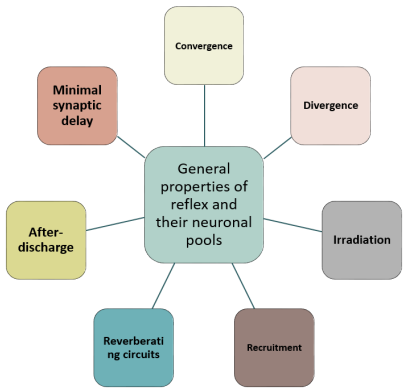
- **Note:** Alpha and gamma motor neurons run in the same nerve (70% alpha and 30% gamma)

5-EFFECTOR:

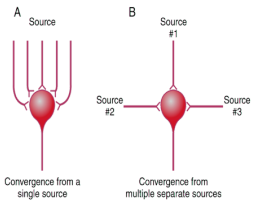
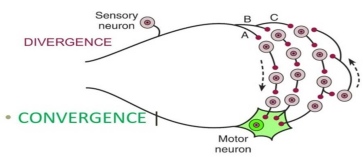
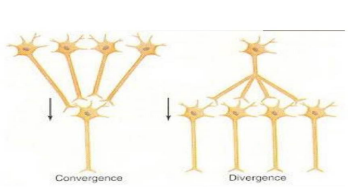
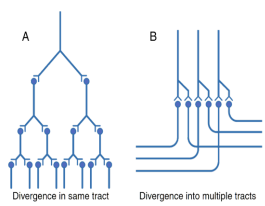
- **Definition:** It is the **part of the body that responds** to the motor nerve impulse, such as muscle or gland. its action is called **reflex**.
  - If the effector is **skeletal** muscle, the reflex is a **somatic reflex**.
  - If the effector is **smooth** muscle, **cardiac** muscle or **gland**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

Important Characteristics of Neuronal Circuits "Properties of Spinal Cord Reflexes"

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



1,2 Convergence and Divergence:

Convergence	Divergence
Signals from multiple inputs (neurons) **unite** to excite a single neuron's multiple action potentials. هذي الفكرة كلها، الكلام تحت تكرار كتبناه لأنه موجود بالسلايدز	Helps to **spread** a single stimulus to a wide area of the spinal cord,.
This will provide enough **spatial summation**[4] to bring the neuron to the threshold required for discharge. ***The neurons are almost never excited by an AP from a single input terminal.**	it is important for weak signals entering a neuronal pool to excite far greater numbers of nerve fibers leaving the pool
Output from many neurons onto **one input** neuron.	Output from one neuron to **many** neurons..
The axons of multiple neurons all send information to a **single** target neuron.	The axon of one neuron branches to send information to **multiple** target neurons
Allows **different signals** to reach **one** neuron for comparison or integration.	Allows the **same signal** to reach **many** different neurons.
Many different presynaptic neurons provide input to a single postsynaptic neuron.	Each postsynaptic neuron receives input from the same presynaptic neuron, but may react to it differently.
These inputs may be excitatory or inhibitory, and may be active at different times	ترا الفكرة سهلة بس بغينا نحط كل الكلام عند الطلاب والطالبات، الدايفرجنس واحد يوزع الشغل على الجماعة.
A: multiple input fibers from a single source. B: input fibers from a single source. **(It can be from a single source of multiple neurons or from different sources)**  	A: divergence within a pathway to cause **amplification** of the signal. B: divergence multiple tracts to transmit the signal to separate areas. **(it can spread in the same tract or in multiple tracts (e.g. pain signal can be relayed by different ascending tracts)**  

[4] **Spatial Summation** الجمع المكاني: At any given moment, a neuron may receive postsynaptic potentials from thousands of other neurons. Whether or not threshold is reached, and an action potential generated, depends upon the spatial (i.e. from multiple neurons) summation of all inputs at that moment.

Convergence: هي جمع الاشارات العصبيه من أكثر من خلية عصبية في خلية عصبية واحدة فقط.
After uniting multiple signals from neurons to a single neuron (convergence), threshold is reached and an action potential is generated because of the **spatial summation.**(الجمع المكاني)
Divergence: وهنا العكس تماما الخلية العصبيه تتفرع لأكثر من خلية عصبيه واحدة
"Divergence to stimulate multiple motor neurons and that help in different muscle movement"

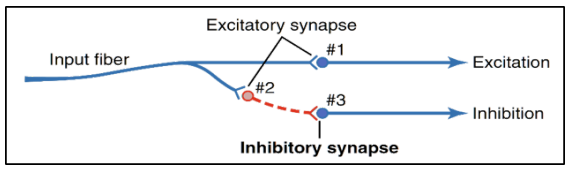
3- Reciprocal inhibition[5] circuits:

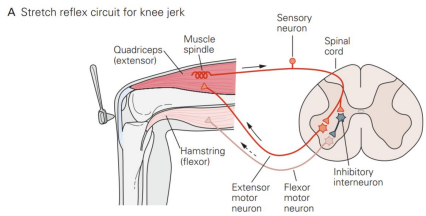
- **Definition:**
  - Stimulation of *flexors muscle* accompanied by **inhibition** of ***extensors*** through **inhibitory interneurons** (antagonism) **by GABA or Glycine neurotransmitters**.
  - The neuronal circuit that causes this reciprocal relation is called **reciprocal innervation**.
- **The objective is:**

- to **prevent** over activity in many parts of the brain.
  - **Example:** Reciprocal inhibition to **brake the lung's elastic recoil** and make respiration smooth. And **stretch reflex** of muscles.

- **Process:**

- The input fiber directly **excites** the excitatory output pathway, but it stimulates an intermediate inhibitory neuron (neuron 2), which secretes a different type of neurotransmitter substance to **inhibit** the second output pathway from the pool.
- **Result:** reflex contraction of an agonist muscle is accompanied by inhibition of the antagonist.

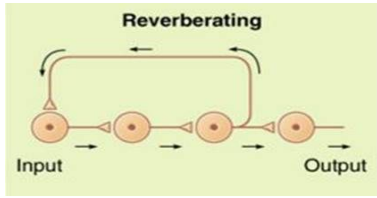




❖ Neuronal pool circuits :

1- Parallel circuits :

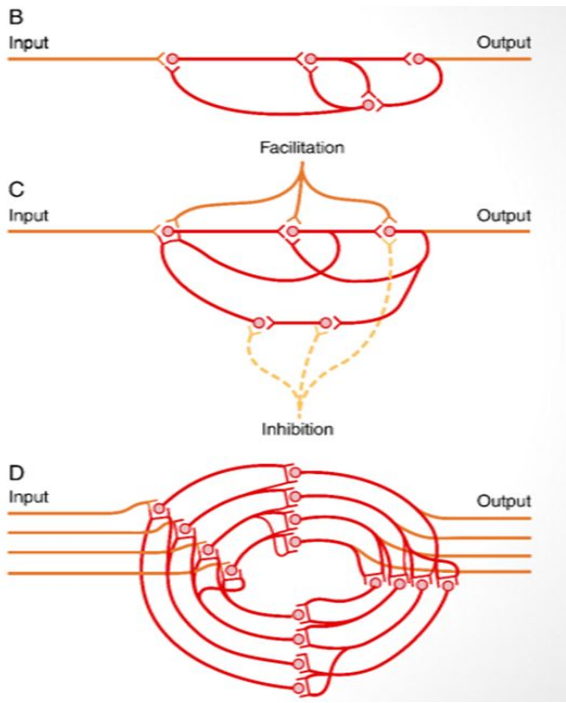
- afferent and efferent are parallel to each other (input parallel to output).



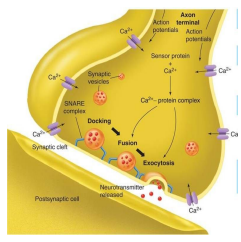
2-Reverberatory (Oscillatory) Circuit : (متذبذب)

[5] Reciprocal(تبادلي) inhibition: عملية تحدث للعضلة بتحفيز الرووت لانقباضها ومنع الرووت المؤدي لانقباض العضلة المقابلة

- 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).
- 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.
- Most reverberating pathways are constituted of many parallel fibers.
- الصور هذي فكرتها وحدة (بالأحمر) رغم كلامها الكثير لكن حطيناها للذمة والضمير :)

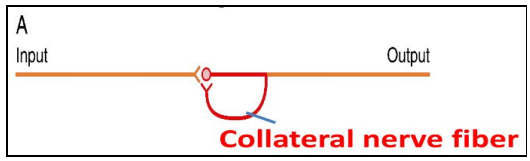
B shows a few additional neurons in the feedback circuit , which causes a longer delay between initial discharge and the feedback signal.	
C shows a still more complex system in which both facilitatory and inhibitory fibers interact in the reverberating circuit. **A facilitatory signal enhances the intensity and frequency of reverberating.** **An inhibitory signal depresses or stops the reverberation.**	
D shows that the most reverberating pathways are constituted of many parallel fibers. In such a system, the total reverberating signal can be either weak or strong, depending on how many parallel nerve are momentarily in the reverberation.	

4- Signal prolongation (Afterdischarge)



- A signal entering a pool causes a **prolonged output discharge of AHCs1** (MOTOR) even if the stimulus is over.
- **Duration:**
  - lasts a few milliseconds-minutes after the incoming signal is over.
  - **Depends on the intensity of the sensory stimulus** that elicited the reflex. كلما زادت شدة المؤثر كلما طالت مدة الإشارة العصبية (إذا انضربت بقوة بتتألم وقت أطول) على سبيل المثال.

- **Importance\Value:** The signal prolongation **prolongs the protective** response of reflex.
- **Causes Of Signal Prolongation:**
    - **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 causes maintained reflex action & response continue for some time after cessation of stimulus.



    - **Reverberatory (oscillatory) circuit:**
    - They **restimulate** AHCs.
    - Positive feedback within the circuit in which the output neuron sends a collateral nerve fiber **back to input neuron itself** making it discharge repetitively for a long time.

Example: لمن ناموسة تقرصك بتحكين القرصة وبعدها بشوي بترجعلك الحكة مره ثانية, ليش؟عشان يكون عندك أفتر ديششارج و النيورونز قاعدة تطلع neurotransmitters

Ganong: A weak stimulus causes one quick flexion movement; a strong stimulus causes prolonged flexion and sometimes a series of flexion movements. This prolonged response is due to prolonged, repeated firing of the motor neurons. The repeated firing is called after-discharge **(Signal prolongation)** and is due to continued bombardment of motor neurons by impulses arriving by complicated and circuitous polysynaptic paths.

5- Synaptic (Central) delay & Reaction time

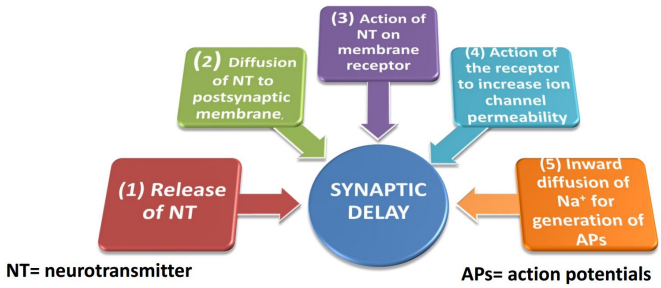
- **Synaptic delay:**

- **Definition**: is the minimal period of **time** required for **transmission** of a neuronal signal from a **pre**synaptic neuron to a **post**synaptic neuron. تخيل البري والبوست لاعبين كورة طائرة، السينابتك ديلاي هي الوقت اللي تمر فيه الكورة من بري للبوست.
- **Duration**: 0.5 ms per synapse.
- Explanation from the boys' slides: When an impulse reaches the presynaptic terminals, an interval of at least 0.5 ms, the synaptic delay, occurs before a response is obtained in the postsynaptic neuron. **it's the time for the synaptic mediator to be released and to act on the membrane of the postsynaptic cell.** Because of it, conduction along a chain of neurons is slower if many synapses are in the chain than if there are only a few. it's possible to determine whether a given reflex pathway is monosynaptic=0.5ms or polysynaptic=2ms by measuring the delay in transmission.

GENERAL RULE: Number of synapses = central delay / 0.5ms

- **Reaction time (Reflex time):**

- **Definition:** The time between the application of the stimulus and the response is called the reaction time.
- **How RT is calculated?** = **synaptic (central) delay + time spent in conduction of APs** through the afferent and efferent nerves. (Reflex time = synaptic duration + conduction duration)



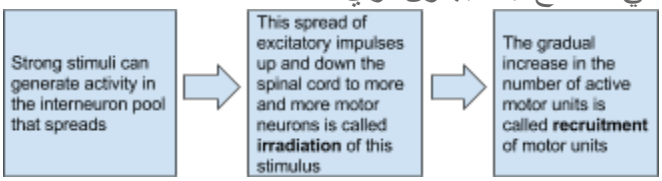
- **Examples of reaction times in humans:** a stretch reflex such as the **knee jerk** is 19–24 ms & the **central delay for the knee jerk** is 0.6–0.9 m.

6- Irradiation of Stimulus

- **Definition**: The **spread** of excitatory impulses up and down the spinal cord to more and more motor neurons in the spinal cord.
- A strong stimulation in sensory afferent irradiate to many segments of the spinal cord 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) .

- كل ما المحفز كان قوي كل ما بيرسل التأثير لأماكن كثير يعني الشعاع تبعه بيكون قوي.



Weak stimulus	Strong stimulus
Irradiation to **small number** of neurons.	Irradiation to **large number** of neurons.
Causes **weak** flexion of limb.	Causes **withdrawal of affected limb** and extension of opposite limb **(as in crossed extensor reflex).**

7- Neuronal Recruitment

- **Definition:** The **Gradual** activation (increase) of motor neurons (AHCS) on stim of afferent nerve in a reflex arc by **maintained, repetitive stimulus.**
- **Causes of recruitment:**
  - **Different conduction velocities of afferents** some are slowly & others are rapidly conducting fibres.
  - 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 neurons 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.

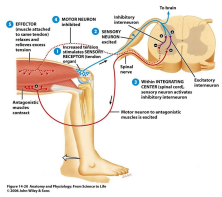
8- Pattern of withdrawal:

- 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.

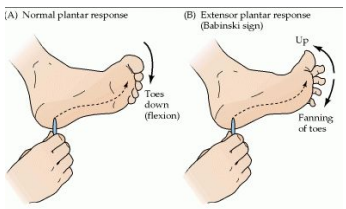
- This is called the principle of **"local sign".**
- نمط ردة الفعل نفسها يختلف من مكان لآخر (من عضلة مثلًا يغذيها عصب مختلف) عن غيرها، يعني لو فيه دبوس جاء على يدك حركتك بتكون غير عن لو جاء كاحلك

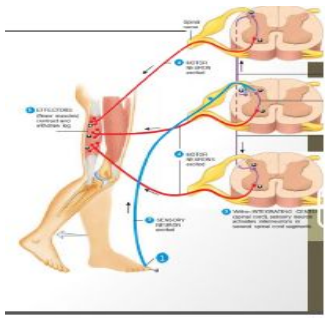
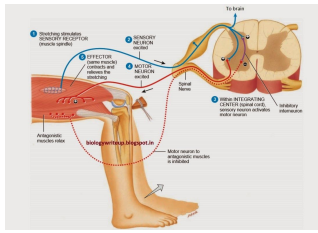
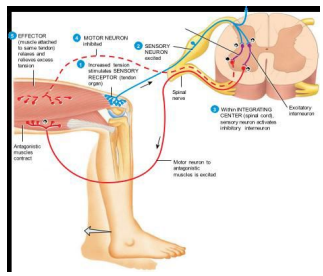
Types of spinal reflexes

❖ According to number of neurons:

Monosynaptic:	Polysynaptic:
The integrating centre is a **single direct synapse** between a Sensory axon (afferent) with a motor neuron (anterior horn cell).	Sensory axon (afferent)synapse with one or more interneurons.
Simplest type of reflex **(No interneurons)**	Interneurons are present.
Example: Stretch reflex. 	**Example: Withdrawal,abdominal reflexes, visceral, inverse stretch reflex (golgi tendon organ reflex)**

❖ According to site of the receptor:

Type	Visceral	Superficial Reflexes	Deep Reflexes	
Types examples	-		**Stretch Reflexes** = **Tendon jerks** = myotatic reflex.	**Inverse Stretch Reflex** =Golgi Tendon organ reflex = Autogenic inhibition.
Number of neurons		**Polysynaptic**	**Monosynaptic**	**Polysynaptic**
Location Of receptor	Wall of viscera (organs)	Superficial in the **skin**	the **muscle spindle** (is located deep within the muscle itself.	**Golgi Tendon Organ** present deep in the muscle tendon.
Example	Micturition, defecation	Withdrawal, abdominal reflexes and plantar reflex	knee-jerk (patellar reflex) and ankle jerk	
Stimulus		**For Withdrawal reflex (flexor reflex)**:	Rapid stretch of muscle.	Large force on tendon.

		Sharp painful stimulus.		
Clinical Test		**For Withdrawal reflex (flexor reflex)**: None-Stepping on nail	Tap on muscle tendon.	Pull on muscle when rested.
				

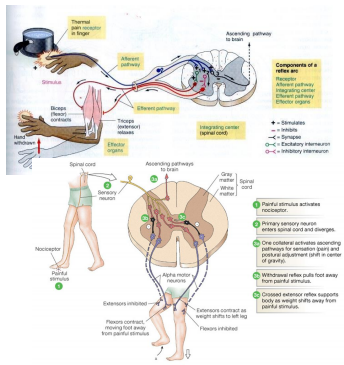
❖ Withdrawal reflex(flexor reflex) (Nociceptive Reflex)

➢ **Type: superficial, polysynaptic reflex.**

➢ Stimulation of **pain receptors (nociceptors)** of hand (like a pin- prick, heat, or a wound) → **A delta or C fibres** (sensory) transmit impulses to the spinal cord → interneurons pool → motor neurons → stimulate hand **flexor** muscles → move the hand **away** from the injurious stimulus.

➢ **characterised by** (It involves the following basic types of circuits):

- **Diverging circuits** to spread the reflex to the necessary muscles for withdrawal. ليه يحتاج هالخاصية؟ ردة الفعل لازم تكون سريعة بما أنها تحمي الجسد من المؤثر الضار، التفرق تساعد بهذا الشيء، بالإضافة إلى أن العضلة غالبًا بتكون كبيرة.
- circuits to inhibit the antagonist muscles, called **reciprocal inhibition circuits.** They result in **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.)



Withdrawal (flexor) reflex (Duration 3:03)

❖ (RECAP) The withdrawal reflex

reflex	Flexor reflex of 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)

Effect on muscle	Contracts flexor muscle
Other effects	1-Relax inhibit extensor muscle of same limb 2-reverse effect on opposite limb (cross extensor reflex)
function	1-protective - withdrawal from painful stimulus. 2-cross extensor aids in maintaining posture when opposing leg is lifted.

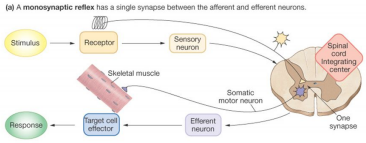
❖ Crossed extensor reflex:

- While pushing the body away from the injurious agent by withdrawal reflex, the **crossed extensor reflex supports the body weight against gravity.**
- Flexion and withdrawal of the stimulated limb → extension of the opposite limb (occurs with strong stimulus).
- **Mostly occurring in:** the **lower limb** to support balance. (عشان نحافظ على توازن الجسم وما نطيح)
- **Initiation time:** It does not begin until 200 to 500 milliseconds **after onset of the initial pain stimulus,** because many interneurons are involved of the opposite side of the cord.
- Signals from sensory nerves **cross the opposite side** of the cord to excite extensor muscles.
- **What happens after the painful stimulus is removed?** the crossed extensor reflex has an even **longer period of afterdischarge, result from reverberating circuits** among the interneuronal cells.
- **Importance of the prolonged afterdischarge:** holding the pained area of the body away from the painful object.
- **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** is supporting the body weight against gravity.

Crossed extensor reflex (Duration 5:53) GOOD EXPLANATION!

(a) A **monosynaptic reflex** has a single synapse between the afferent and efferent neurons.



(b) Polysynaptic reflexes have two or more synapses.