

Spinal Cord Functions & Spinal Reflexes

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صطلحات طبيّة هامة

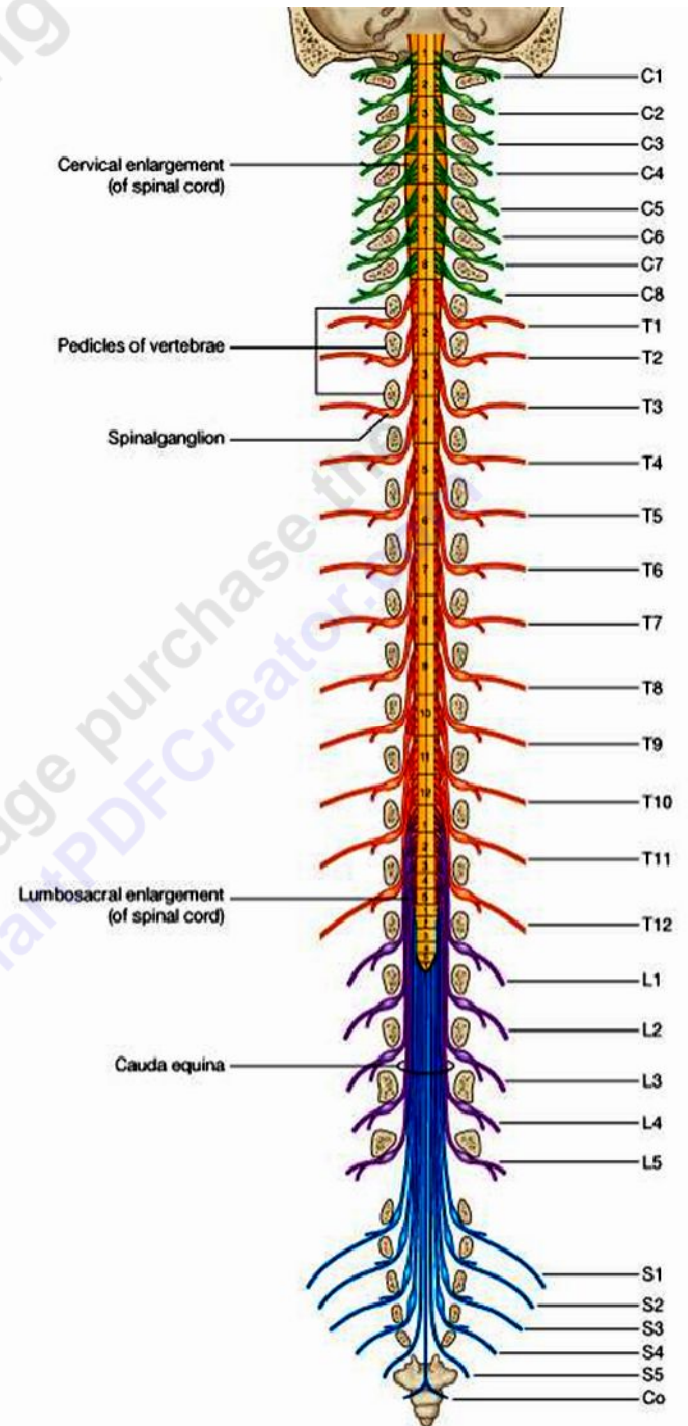
- Spine / Spinal cord النخاع/ الحبل الشوكي
- Neuron/ Nerve fiber (one nerve cell) عصبون
- Nerve : عصب
العصب يتكون من عشرات الآلاف أو مئات الآلاف من العصبونات
e.g., Sciatic nerve , median nerve , ulnar nerve
- Motor Functions of the Spinal Cord المهام الحركية للنخاع الشوكي
- Spinal Reflexes منعكس الفعل النخاعي (أو باختصار :المنعكس النخاعي)
- Afferent (sensory) neuron :
العصبون الحسّي \الوارد إلى الجهاز العصبي المركزي
- Efferent (Motor) neuron :
العصبون الحركي (الأمر لعضلة لتتقبض) و هو الخارج من الجهاز العصبي المركزي

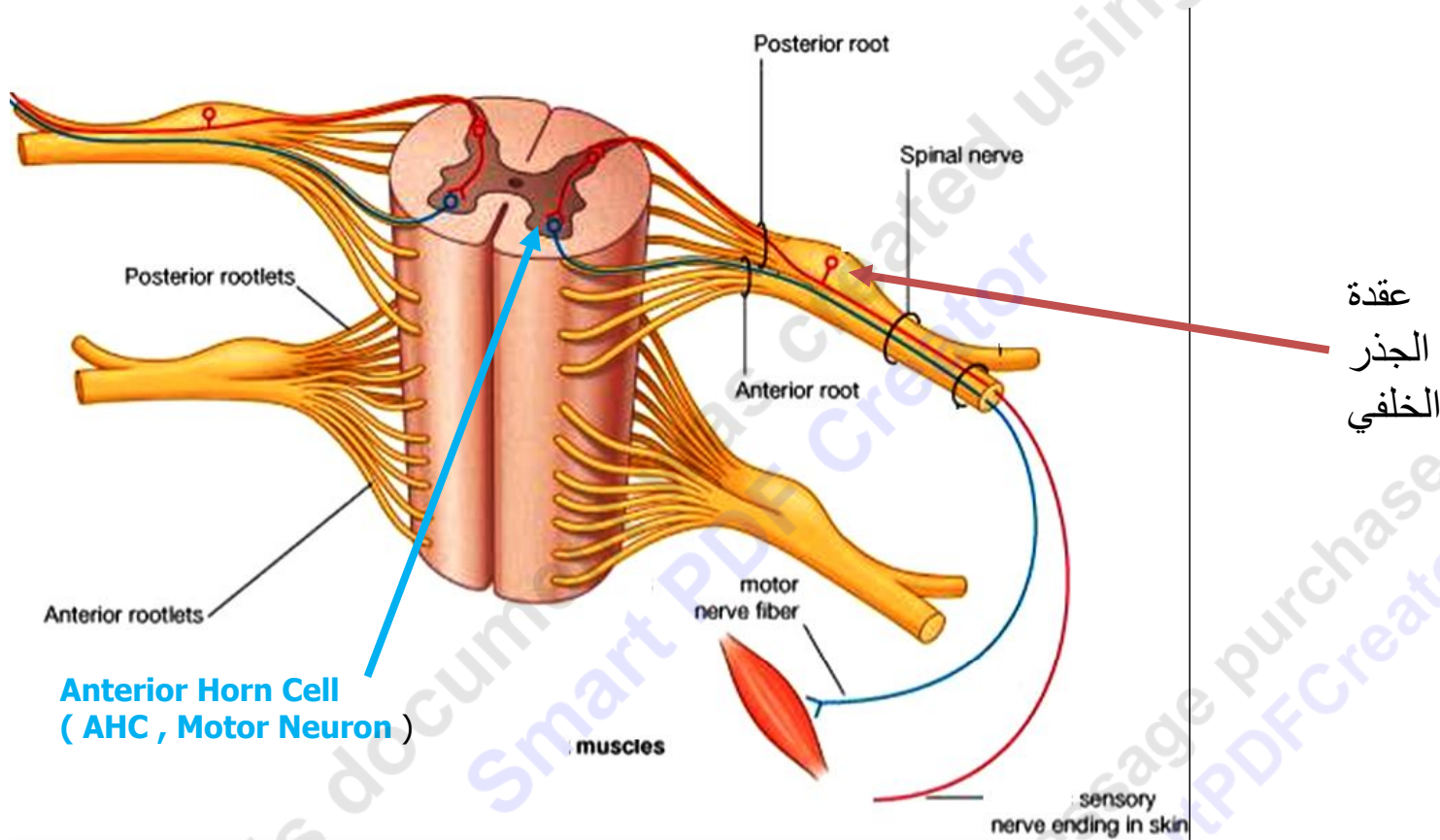
- Innervation (Nerve Supply) : تعصيب
- Synapse : مشبك
- Monosynaptic reflex : منعكس فعل أحادي المشبك
- Polysynaptic reflex : منعكس فعل متعدد المشابك
- Upper motor neuron (UMN) : العصبون الحركي العلوي
- Lower motor neuron (LMN) : العصبون الحركي السفلي
- Spasticity : شنج (بضم الشين) : فرط التوتر التشنجي
- Spastic : شنجي ، تشنجي
- Rigidity : صلابة
- Rigid : صلب
- Muscle tone : درجة التوتر العضلي
- Hypotonia : نقص التوتر ، الرخاوة
- Hypertonia : فرط التوتر
- Flaccid : رخو و ضعيف

- منعكس الشد ، الأنتفاضة العضلية Stretch reflex = Tendon jerk
- (muscle spindle و مستقبله المغزل العضلي)
- منعكس قولجي الوتري (و مستقبله عضو قولجي الوتري Golgi tendon Reflex
- الباحة الحركية Motor area
- الباحة الحركية الأولية Primary motor area
- الباحة الحسية Sensory area
- السبل الصاعدة (حسية) Ascending tracts
- السبل النازلة (حركية) Descending tracts

Spinal Nerves

- The spinal cord has 31 spinal nerves on each side .
- They contain →
- (1) Afferent fibers bringing to the CNS sensory information from receptors skin , muscles & joints ; and
- (2) Efferent fibers carrying motor commands from the CNS to muscles .
- The spinal nerves are 31 pairs →
- 8 cervical,
- 12 thoracic,
- 5 lumbar,
- 5 sacral and
- 1 coccygeal.

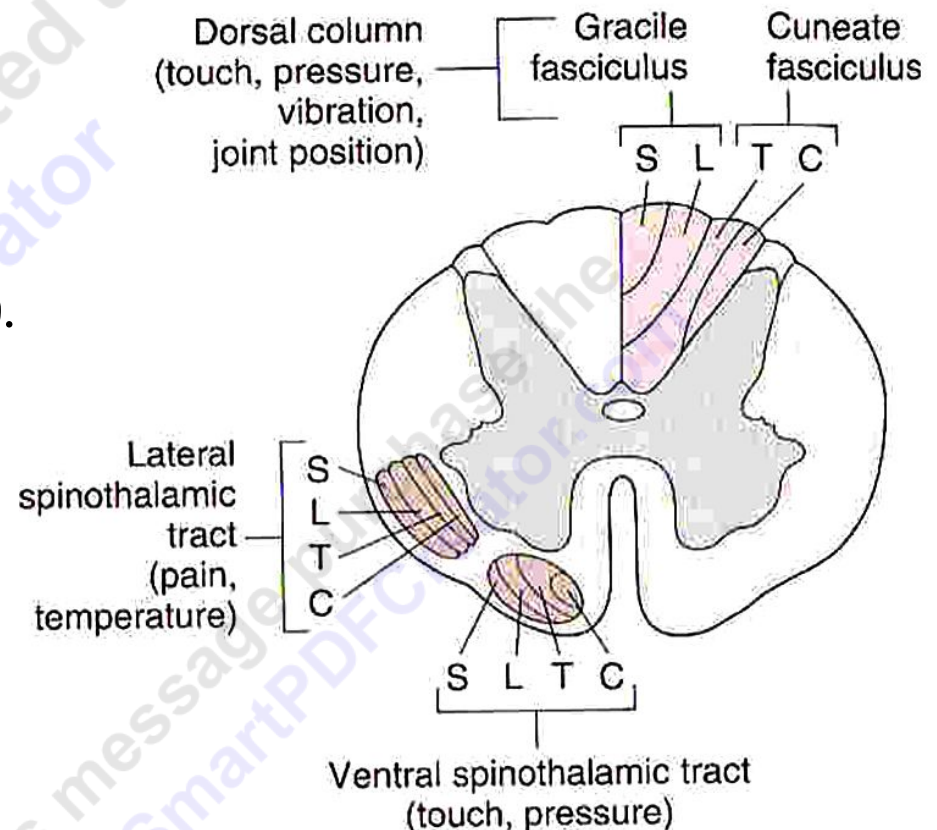




- The spinal cord has ventral & dorsal roots :
- The dorsal root **العقدة الجذرية الخلفية** contains afferent (sensory) nerves coming from receptors .
- The cell body **جسم الخلية** of these neurons is located **موجود** in dorsal (posterior) root ganglion (DRG) **العقدة الجذرية الخلفية**
- The ventral root **الجذرية الأمامية** carries efferent (motor) fibers **أعصاب أمرة حركية**
- The cell-body of these motor fibers is located in the ventral (anterior) horn of the spinal cord .

Functions of the Spinal Cord (1)

- Involves
- (1) Carrying sensory information from the receptors to the brain
- (through spinal afferent/sensory nerves & ascending/sensory tracts).
- I/ Tracts Reaching Conscious Brain Level :
- Dorsal Column Tracts (Gracile & Cuneate) → Fine , discriminative touch , vibration & position senses
- Lateral Spinothalamic Tract → pain and temperature .
- Anterior Spinothalamic Tract → crude touch , pressure .
- I/ Tracts Not Reaching Conscious Level (Functioning at Subconscious Level) :
- Spinocerebellar Tracts → carry proprioceptive fibers to the cerebellum for posture control & coordination of movement

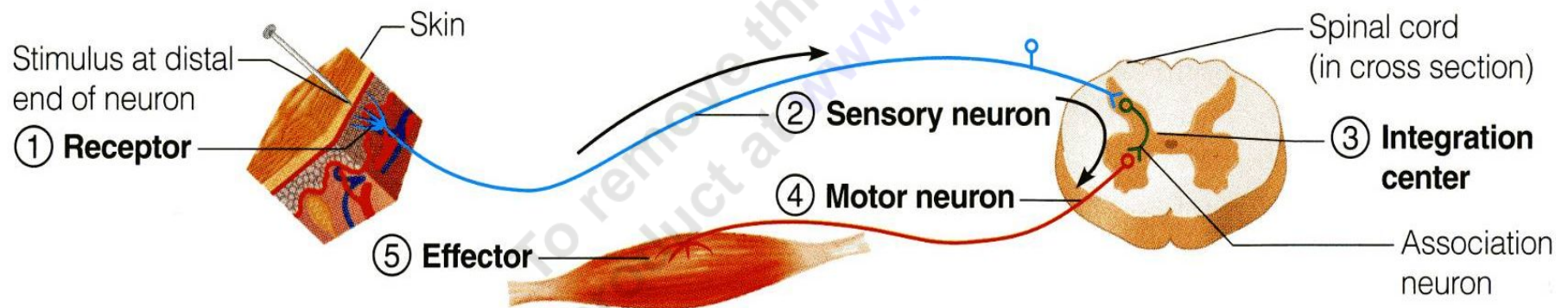


Functions of the Spinal Cord (2)

- (2) Executing brain motor commands (through descending/motor tracts & spinal efferent/motor nerves)
- (3) Generating Spinal Reflexes

What is a spinal reflex ? ما هو منعكس الفعل النخاعي

- A spinal reflex is an inborn (inherited) , automatic , involuntary neuromuscular action elicited by a defined , adequate , specific stimulus
- The basic unit of a reflex is the reflex arc . قوس المنعكس أو قوس الفعل الأنعكاسي
- The controlling " center " of the spinal reflex is located in one or more spinal cord segments .

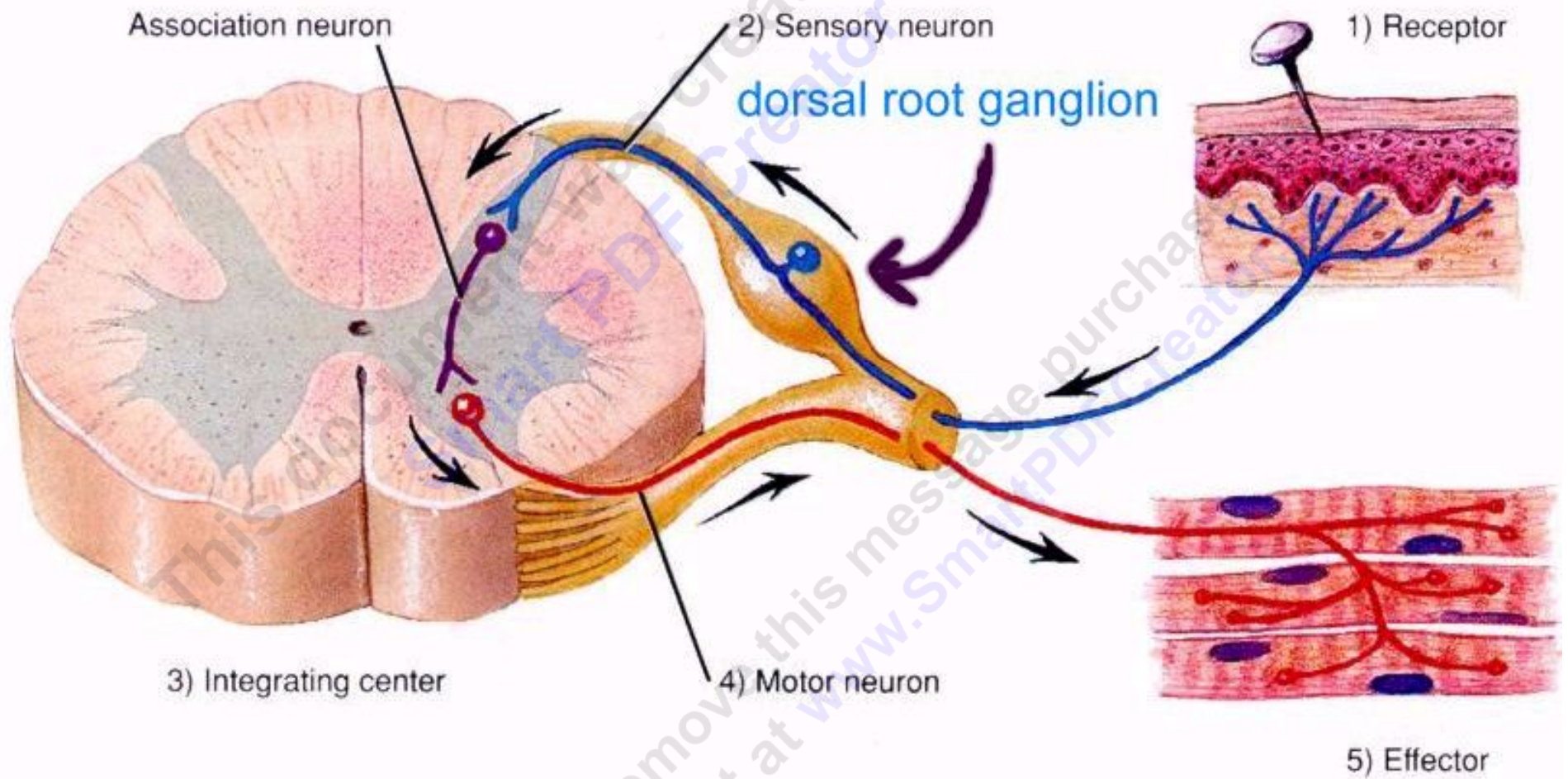


The Reflex Arc

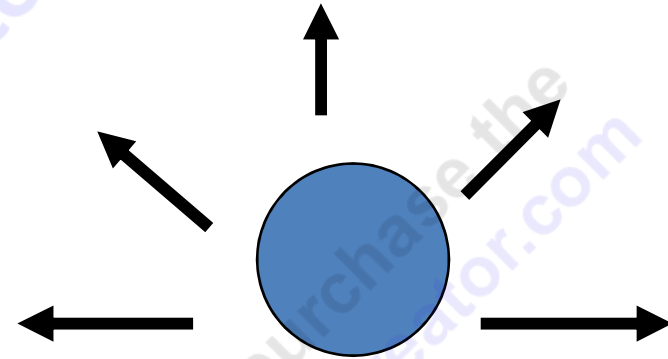
قوس الفعل الانعكاسي

Consists of :

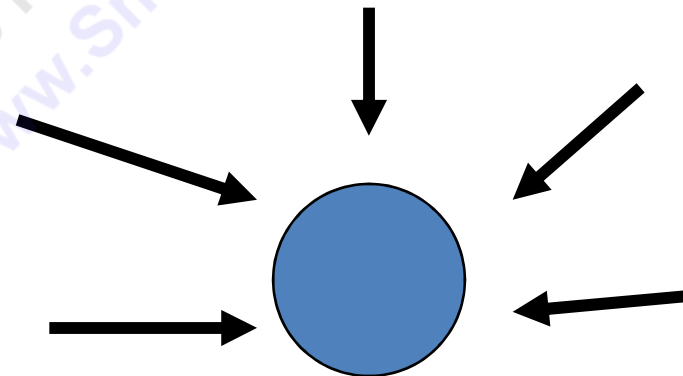
1. Sense organ (receptor). مستقبل ، مستشعر
2. Afferent (sensory) neuron. عصبون وارد (حسيّ)
3. One or more connector (association neuron , interneuron) , that is situated between the afferent & efferent neurons , is present in polysynaptic reflex arcs .
 - Such interneurons can be excitatory or inhibitory .
 - ✓ The “ centre ” of a spinal reflex consists of ending of the afferent nerve within the spinal cord + the motor neuron + in case of polysynaptic reflexes , thr related interneurons
4. Efferent (motor) neuron



- Afferent neurons can undergo:
 - Divergence : to spread the effect of a single stimulus to more motoneurons in the same spinal segment , or to adjacent segments,



- Convergence : (e.g. on a motoneuron)to facilitate spatial summation.



Types of Anterior Horn Cells (Motoneurons)

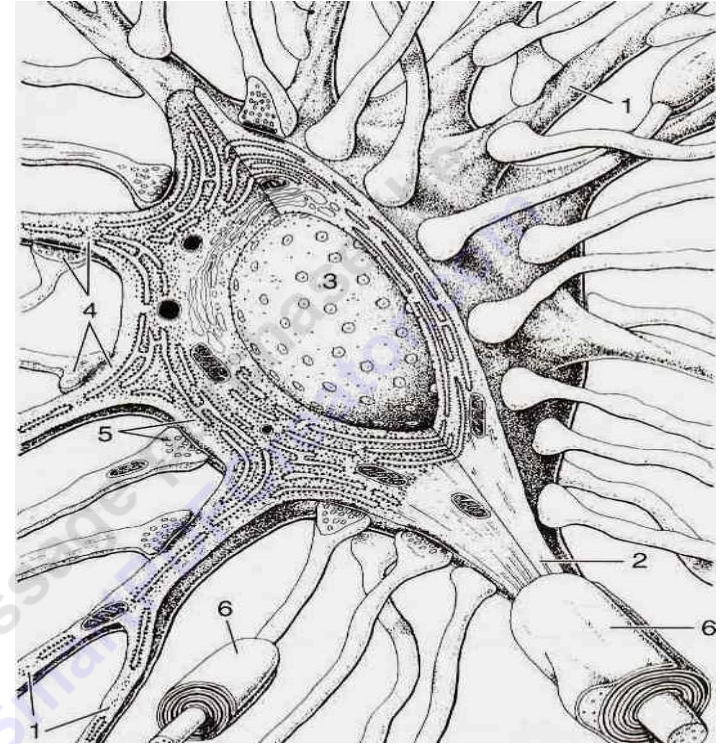
- 2 types :
- (1) Large ones , called Alpha motor neurons
- (2) Small ones , called Gamma motor neurons
- There are also 2 types of muscle fibers in the skeletal muscle :
- (1) Extrafusal fibers : are the contractile units of the muscle , which constitute the muscle bulk , and which are responsible for the actual shortening and force generation by the muscle

- (2) Intrafusal fibers : are tiny , microscopic fibers that are present within the muscle spindle , which is the muscle length receptor
- Extrafusal fibers are innervated by the Alpha Motoneurons , & intrafusal fibers are innervated by the Gamma Motoneurons .

The Alpha Motoneuron is also called the Final Common Pathway

(The one sole/only output for CNS motor commands to muscle)

- The alpha motoneuron synapses directly on the muscle , therefore it directly controls muscle movement , & only through it muscle movement is controlled .
- All spinal & supraspinal influences converge on it (up to 10000 synapses can be present on one alpha motoneuron)
- → hence only through it , all the resultant , final , integrated sum output of spinal and supraspinal influences must pass through it to the muscle .
- That is why it is called The Final Common Pathway to muscle
- Each lower motor neuron + the group of skeletal muscle fibers it controls are together called a "Motor Unit"
- (remember musculoskeletal block lectures).



Convergence of many neurons the
Final Common Pathway
(Alpha Motoneuron)

Input to Alpha Motor Neurons

- 3 sources ثلاثة مصادر
 1. Afferent neurons
 - sensory neurons
 2. Upper motor neurons
 3. Spinal interneurons : that can be excitatory or inhibitory

Classification of Reflexes According to the Location of the Receptor

(A) Superficial Reflexes :

Are polysynaptic reflexes . The receptor is in the skin . Examples are abdominal reflexes and plantar reflex ,

(B) Deep reflexes : The receptor is located in muscle or tendon Examples :

(1) Stretch Reflexes (Tendon jerks منعكسات الوتر), monosynaptic : such as knee-jerk (patellar reflex) and ankle jerk .

The receptor for all these is the muscle spindle (which is located within the muscle itself .

(2) Inverse Stretch Reflex (Golgi Tendon organ reflex منعكس قولجي الوتري), polysynaptic : The receptor is called Golgi Tendon Organ , and is present in the muscle tendon .

Classification of Reflexes According to the Number of Synapses Present in the Reflex Arc

(A) Monosynaptic Reflexes المنعكسات أحادية المشبك:

- have one synapse only : The sensory (afferent) axon synapse directly on the anterior horn cell.
- Therefore , the reflex arc does not contain interneurons .
- Examples : The Stretch reflex منعكس الشد (also called Tendon Jerk).

(B) Polysynaptic reflexes المنعكسات متعددة المشابك:

- Have more than one synapse , therefore contain interneuron(s) between the afferent nerve & AHC .
- Examples : Abdominal Reflexes , withdrawal reflex , Plantar response .

Example of a Superficial ,
Polysynaptic Reflex :
Withdrawal reflex (flexor
reflex/response)

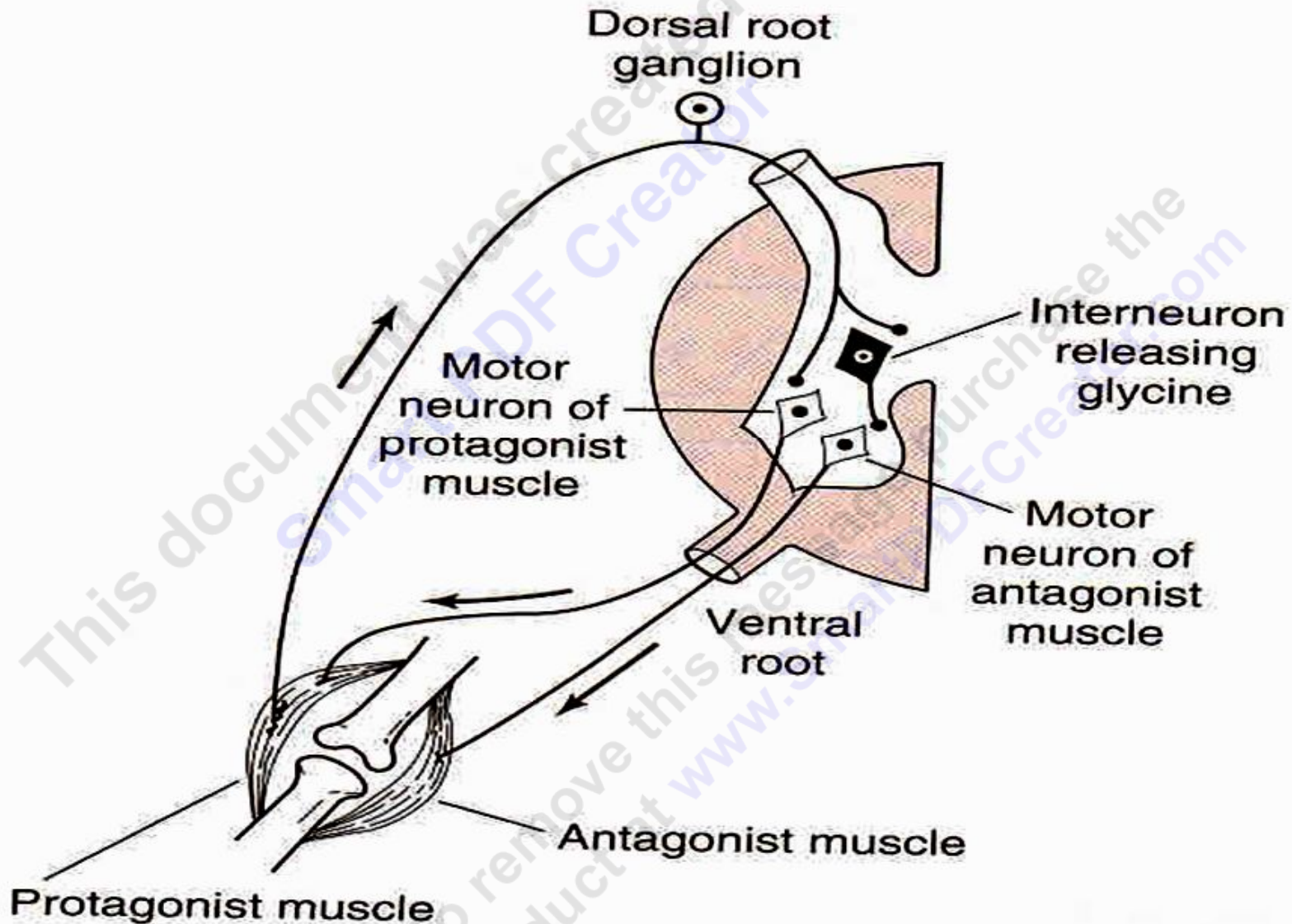
منعكس السحب

Withdrawal reflex (Flexor Reflex/Response)

منعكس السحب

- It is a protective reflex
- Stimulation of pain receptors in a limb (e.g., hand or sole of foot) →
- impulses to spinal cord via A or C fibres →
- interneurons →
- anterior horn cells stimulate limb flexor muscles
- → withdrawal of limb (moving it away from the injurious agent) .
- stimulation of flexors muscle accompanied by inhibition of extensor through inhibitory interneurons (Reciprocal Inhibition).

Reciprocal innervation (Reciprocal Inhibition)



The Crossed Extensor Reflex

- If a stronger stimulus (than that needed to elicit the Withdrawal Reflex is delivered →
- Flexion withdrawal of the stimulated limb will be accompanied by extension of the opposite limb →
- the latter response is called Crossed Extensor Reflex
- Reciprocal innervations occurs in extensor reflex : flexors in the opposite limb are inhibited while extensors are excited →
- pushing the entire body away from the injurious agent and supporting the body weight against gravity → hence it is an Antigravity Reflex

Crossed Extensor Reflex (2)

- Withdrawal reflex Withdrawal reflex is characterized by after discharge المستمر بعد نهاية the response and further enhances the protective role of the reflex. يطيل و يقوي الأستجابة التحفيز
- These reflexes show the properties of reciprocal innervation , motor unit recruitment , irradiation and after-discharge .

Recruitment (of alpha motor neurons

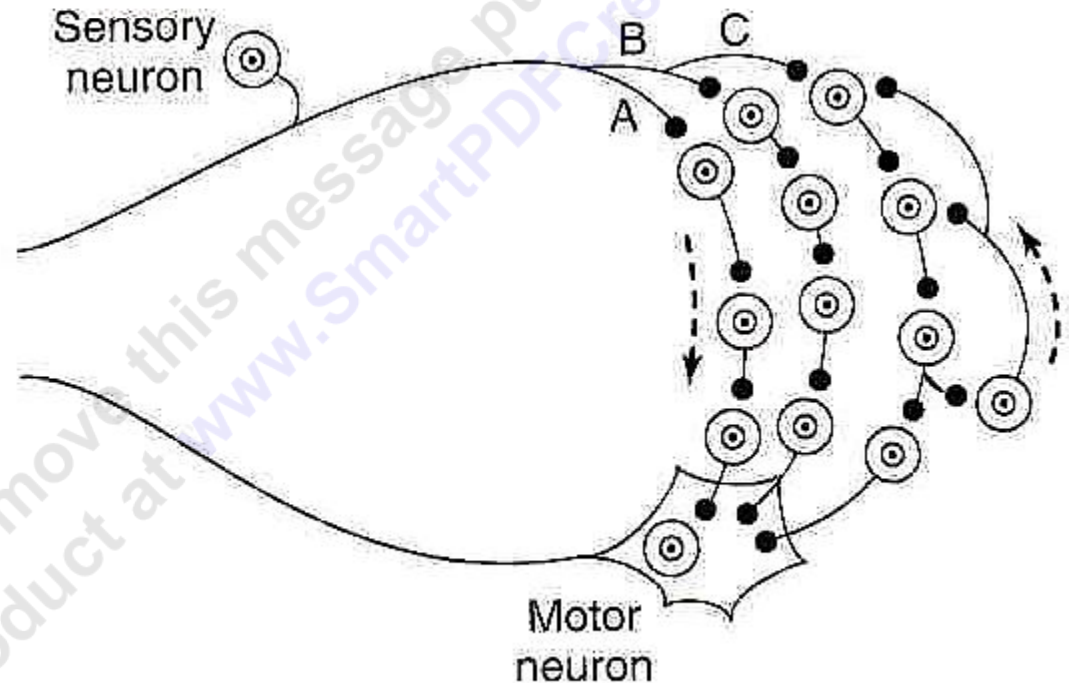
- The extent of the response (strength of muscle contraction) in a reflex depends on the intensity (strength) of the stimulus.
- Motor unit recruitment : If a repetitive & stronger stimulus is maintained, there will be gradual increase in the force of the muscle contraction until the maximum force is reached .
- The slow build-up in force of muscle contraction is due to gradual recruitment/activation of more and more motor neurons (Motor Unit Recruitment).

Irradiation

- The extent of the response (strength of muscle contraction) in a reflex depends on the intensity (strength) of the stimulus.
- The more intense the stimulus is, the greater is the spread (irradiation) of activity in adjacent & other spinal cord segments
→ recruiting more and more other related motor neurons .
- Example : when the sole of the foot is stimulated by a weak painful stimulus, only the big toe is flexed.
- A stronger stimulus will cause reflex flexion of the big toe , other toes , plus the ankle.
- The strongest stimulus will cause withdrawal of the whole leg by causing reflex flexion of the big toe, ankle, knee and hip .
- Impulses may also cross to the other side of the spinal cord to cause extension of the other leg.

After-discharge

The reflex response (muscle contraction) may continue some time (a brief period of time) after cessation of the stimulus, due to after-discharge, which is due to sustained activity in reverberating circuit .



تعريفات هامة Important Definitions

- Reflex Time زمن الأستجابة: Time that elapses between application of the stimulus and appearance of the response .
- الزمن الذي إنقضي بين إعطاء التحفيز و ظهور الأستجابة
- و طبعا هو مجموع التأخير في العصبونين (الوارد و الخارج) + Central Delay التأخير داخل المشابك
- يعني الوقت الذي استغرقته الرحلة في العصبونات زائدا الوقت الذي استغرقه التأخير داخل المشابك (التي هي بين العصبونات)
- Central Delay :التأخير داخل مجموع المشابك Time taken in spinal cord synapses

- i.e., Reflex Time = Central Delay + Time spent in conduction of impulses along the afferent and efferent nerves.
- Minimal Synaptic delay : (التأخير داخل المشبك الواحد : time taken in one synapse) ~ 0.5 ms.
- Central Delay = Total Reflex time – Time spent in conduction of impulses along the afferent and efferent nerves.
- لأنه لو طرحنا الوقت الذي استغرقته الرحلة في العصبونات من كل وقت التأخير المركزي نتوصل إلى التأخير داخل المشبك التي هي بين العصبونات
- Number of synapses = $\frac{\text{Central Delay}}{0.5 \text{ ms}}$