Spinal Cord Functions & Spinal Reflexes

Dr. Taha Sadig Ahmed,

• Objectives

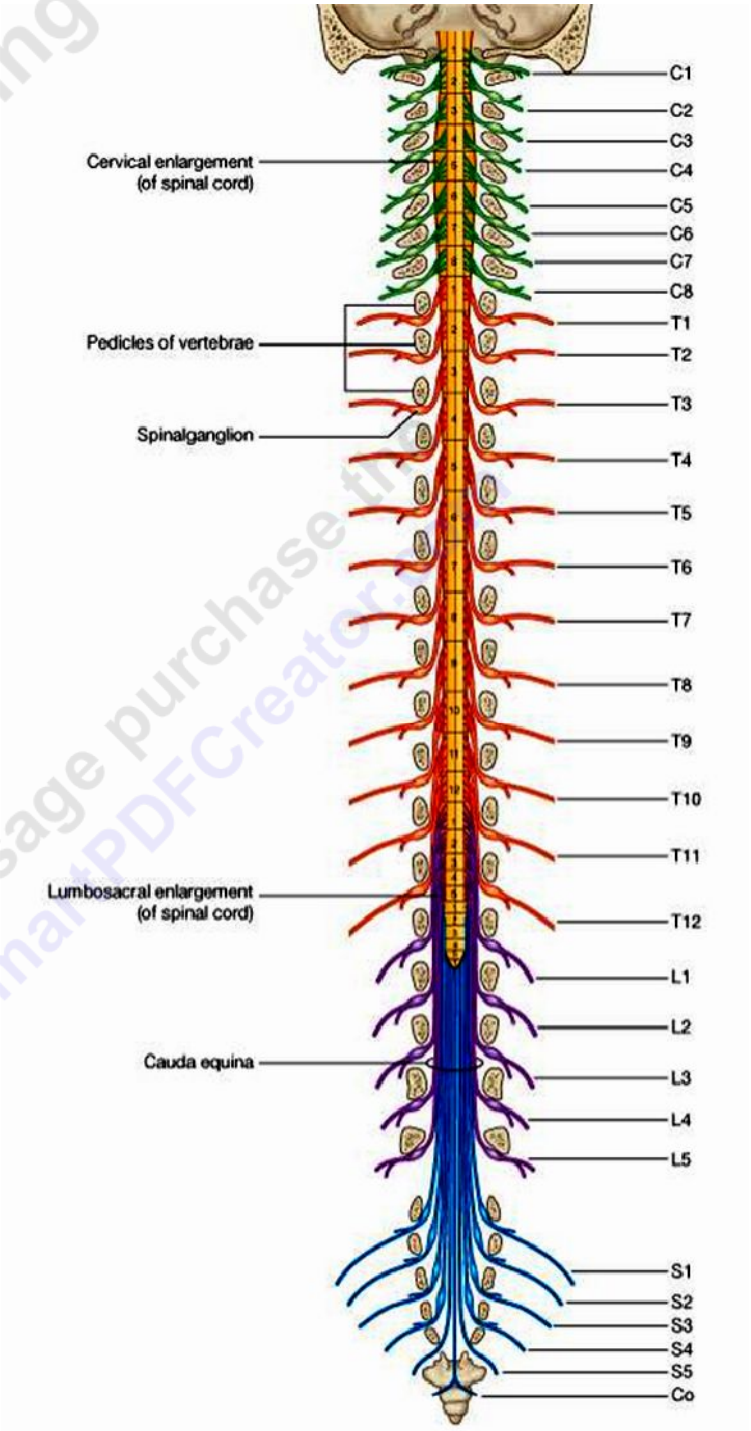
- At the end of this lecture the student should :
- (1) appreciate the two-way trafiic along the spinal cord .
- (2) describe the reflex arc .
- (3) classify reflexes into superficial and deep ; monosynaptic & polysynaptic , give examples of them , and show how they differ from each other .
- (4) describe the general properties of reflexes and their synaptic pools such as convergence , divergence , irradiation , recruitment , reverberating circuits ,after-discharge , minimal synaptic delay, central delay and reflex time .,
- (5) be able to describe the spinal centers of biceps , triceps , knee , ankle , abdominal and plantar reflexes .

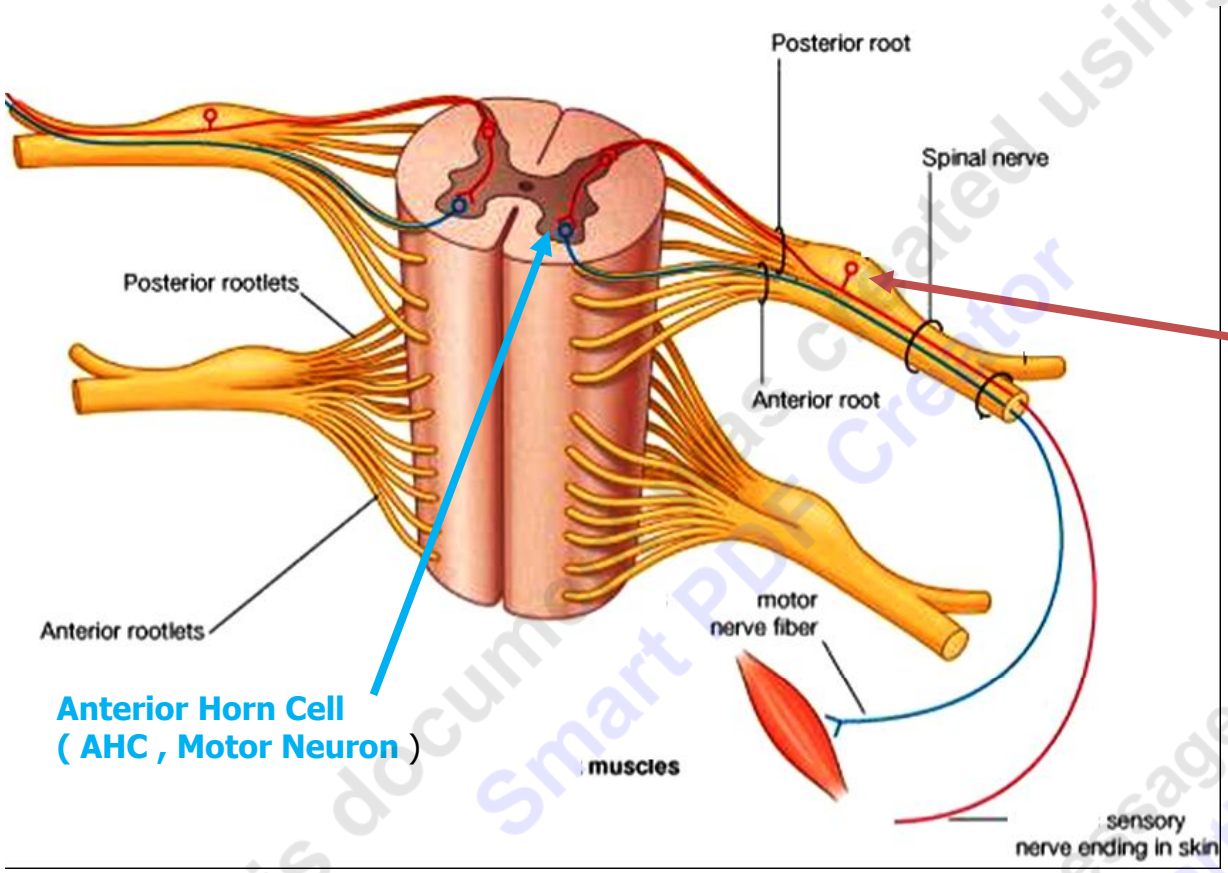
Reference Book

- Ganong's Review of Medical Physiology , 23rd edition . Barrett KE, Barman SM, Boitano S, Brooks HL , edotors . Mc Graw Hill, Boston 2010 .
- Pages 157-165 .

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.



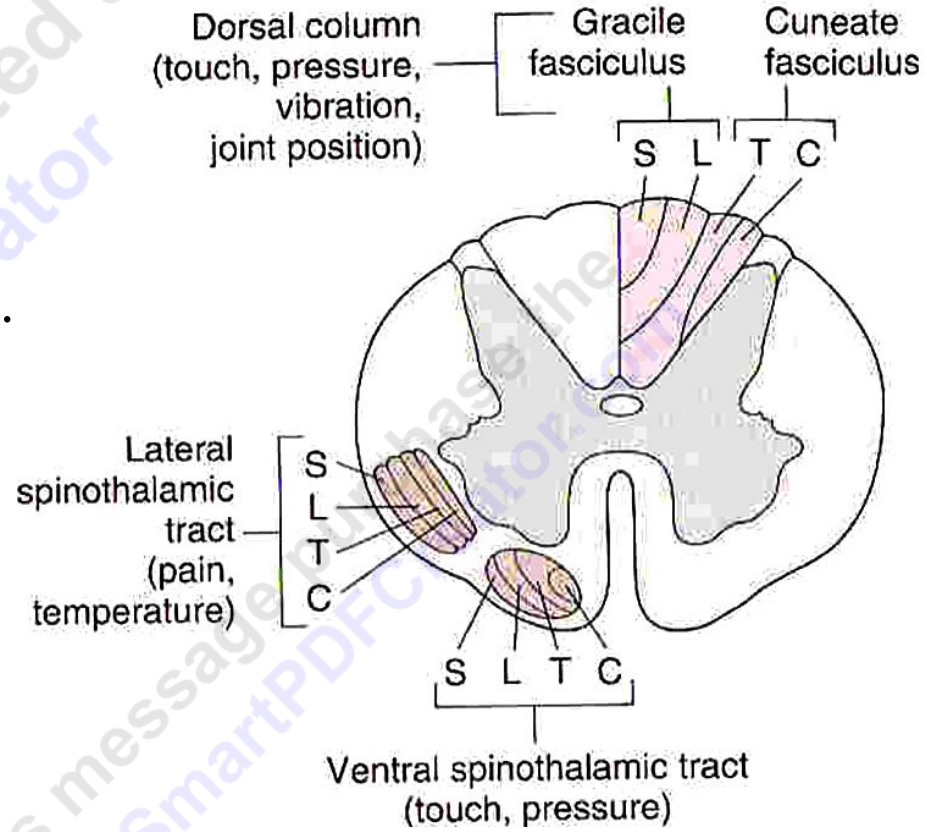


عقدة
الجذر
الخلفي

- The spinal cord has ventral & dorsal roots :
- The dorsal root الجذر الخلفي contains afferent (sensory) nerves coming from receptors .
- The cell body جسم الخلية of these neurons is located موجود in dorsal (posterior) root ganglion (DRG) عقدة الجذر الخلفي
- The ventral root الجذر الأمامي carries efferent (motor) fibers أعصاب آمرة 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 .



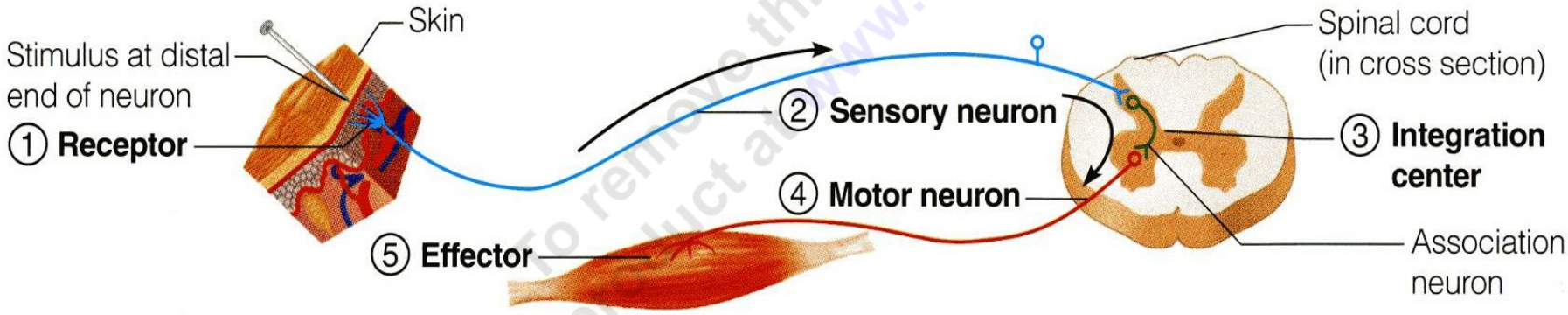
- Anterior Spinothalamic Tract → crude touch , pressure .
- I/ Tracts Not Reaching Conscious Level (Functioning at Subconscious Level) :
- Spinocerebellar Tracts → carry proproceptive fibers to the cerebellum for posture control & coordination of movement

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 الأنعكاسي

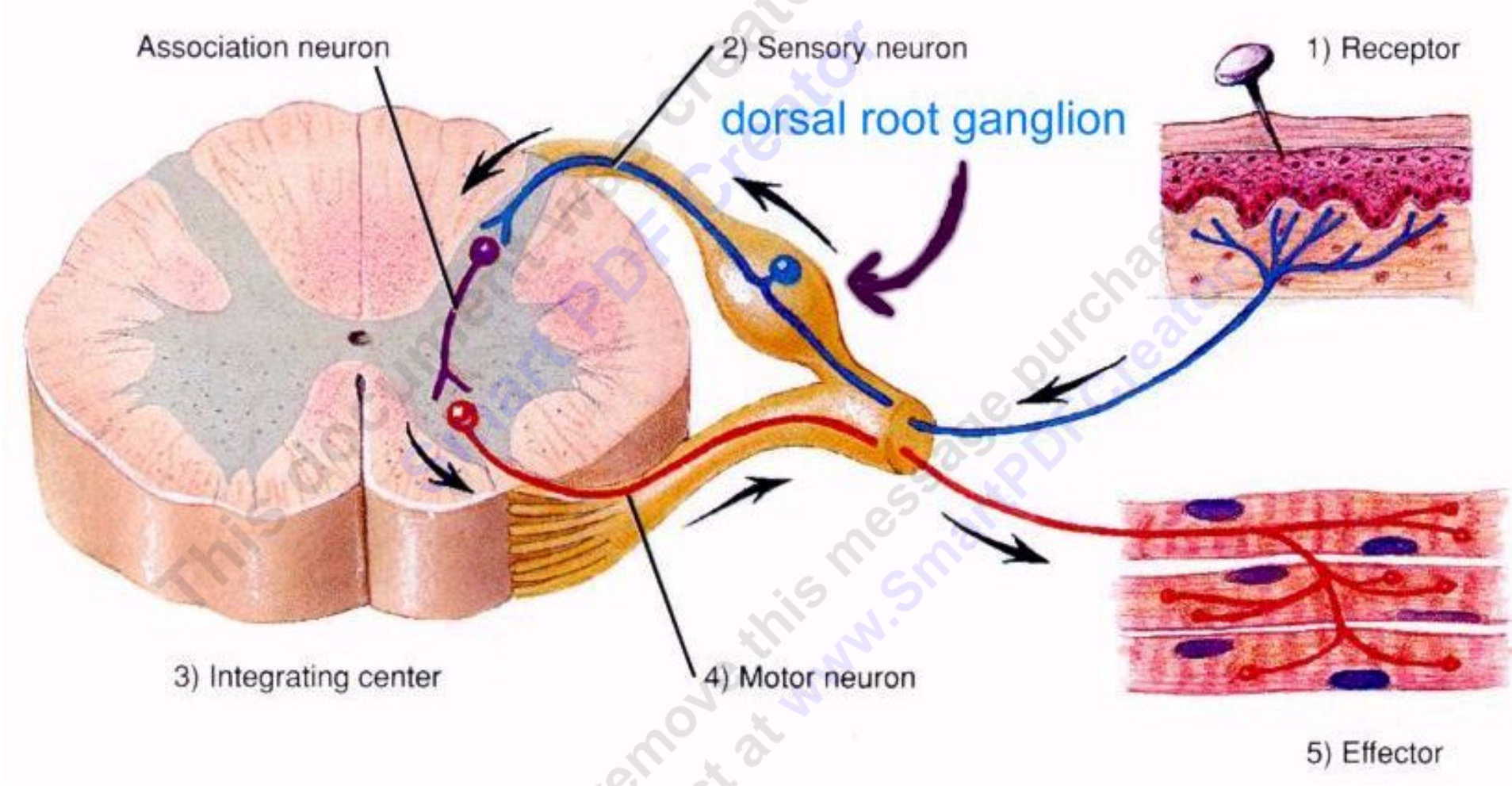
Consists of :

1. Sense organ (receptor). مستقبل ، مستشعر
2. Afferent (sensory) neuron. (حسيّ) عصبون وارد
3. One or more connector (association neuron , interneurn) , that is situated between the afferent & efferent neurons , is present in polysynaptic reflex arcs .

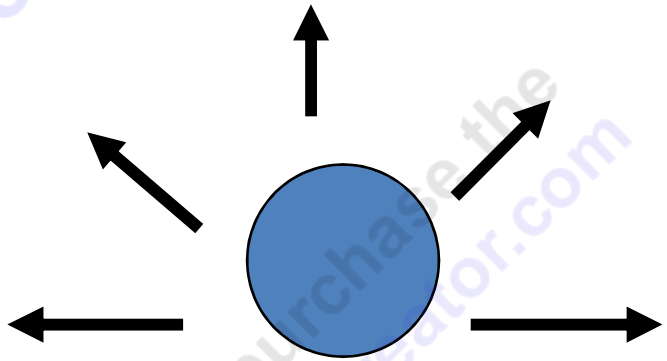
- Such interneurons can be excitatory or inhibitory .

✓ 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

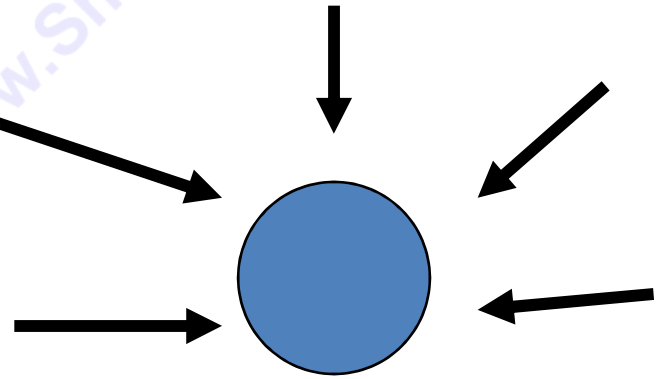
4. Efferent (motor) neuron



- 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)

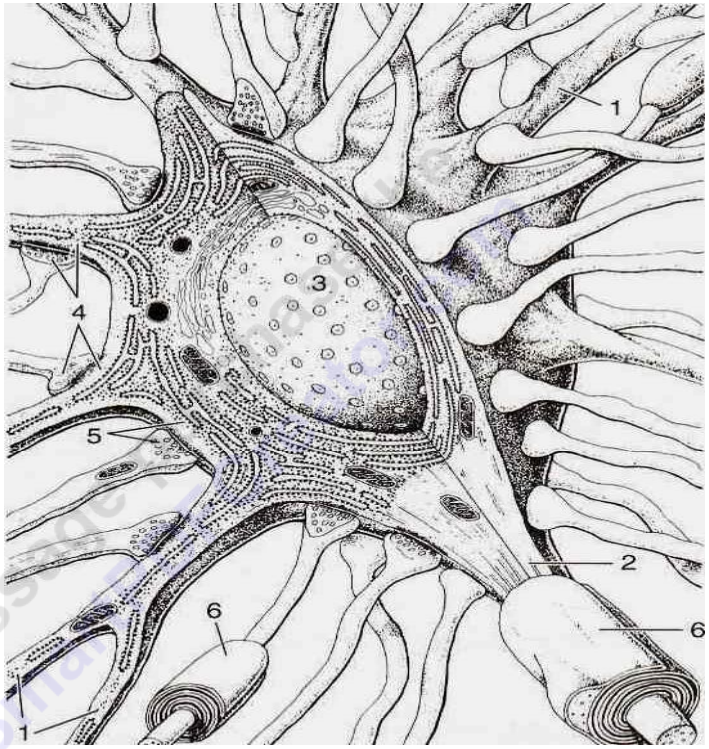
- 2 types :
- (1) Large ones , called Alpha motor neurons
- (2) Small ones , called Gamma motor neurons
- There are also 2 types of muscle fibers in the skeletal muscle :
- (1) Extrafusal fibers : are the contractile units of the muscle , which constitute the muscle bulk , and which are responsible for 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 lenght 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 bock lectures).



Convergence of many neurons the Final Common Pathway
(Alpa 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 reflxes المنعكسات متعددة المشابك:

– Have more than one synapse , therefore contain interneuron(s) between the afferent nerve & AHC .

–Examples : Abdominal Reflexes , withdarwal reflex , Plantar response .

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

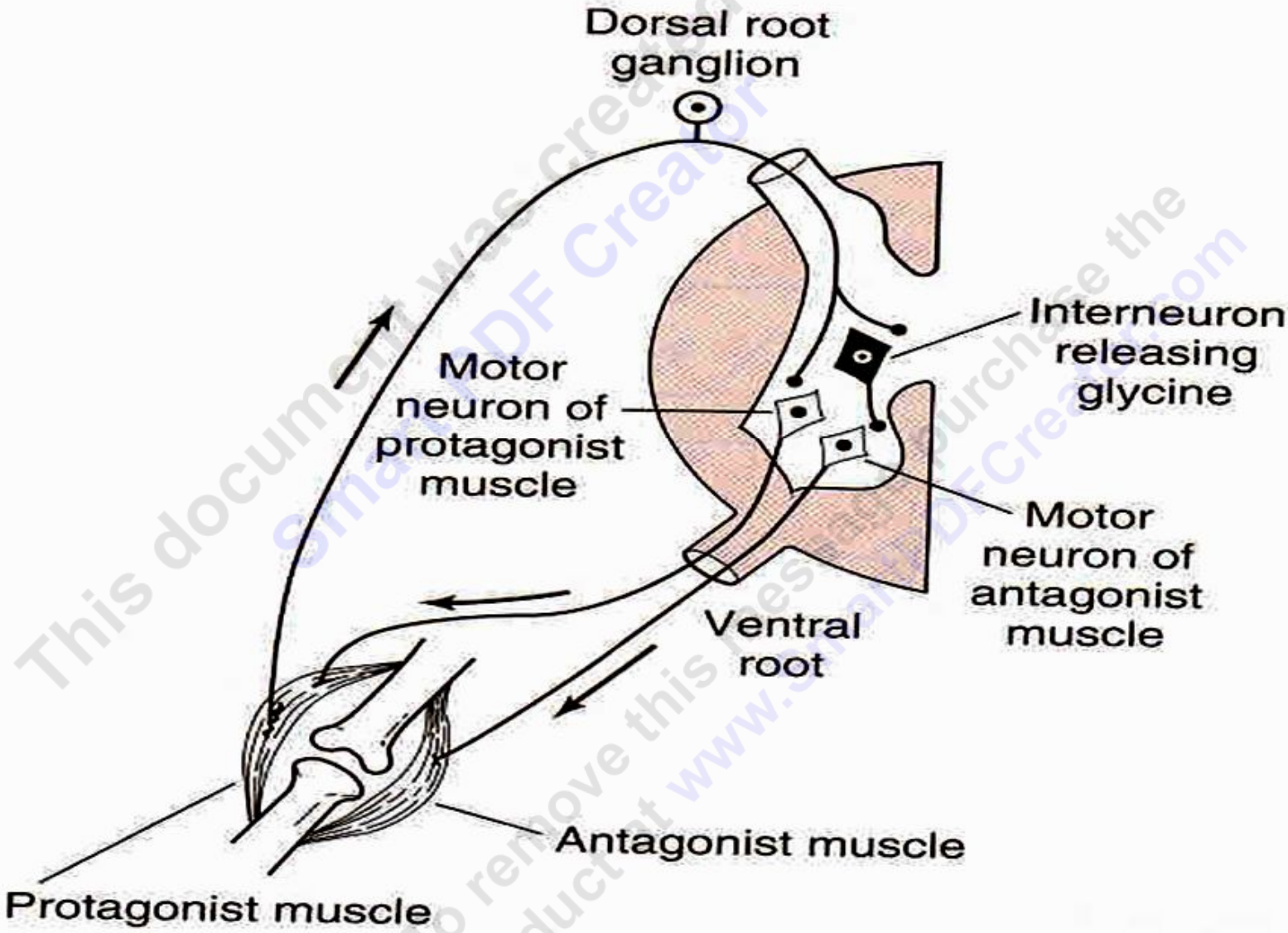
منعكس السحب

Withdrawal reflex (Flexor Reflex/Respnse)

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 imb away from the injurious agent) .
- stimulation of flexors muscle accompanied by inhibition of extensor through inhibitory interneurons <u>(Reciprocal Inhibition).</u>

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 esponse is called <u>Crossed Extensor Reflex</u>
- <u>Reciprocal innervations</u> occurs in extensor reflex : flexors in the opposite limb are inhibited while extensors are excited →
- pushingthe entire body away from the injurious agent and supporting the body weight against gravity → hence it is an <u>Antigravity Reflex</u>

Crossed Extensor Reflex (2)

- Withdrawal reflex Withdrawal reflex is characterized by after discharge المستمر بعد نهاية التحفيز , which prolongs يطيل و يقوّي الأستجابة the response and further enhances the protective role of the reflex.
- 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.

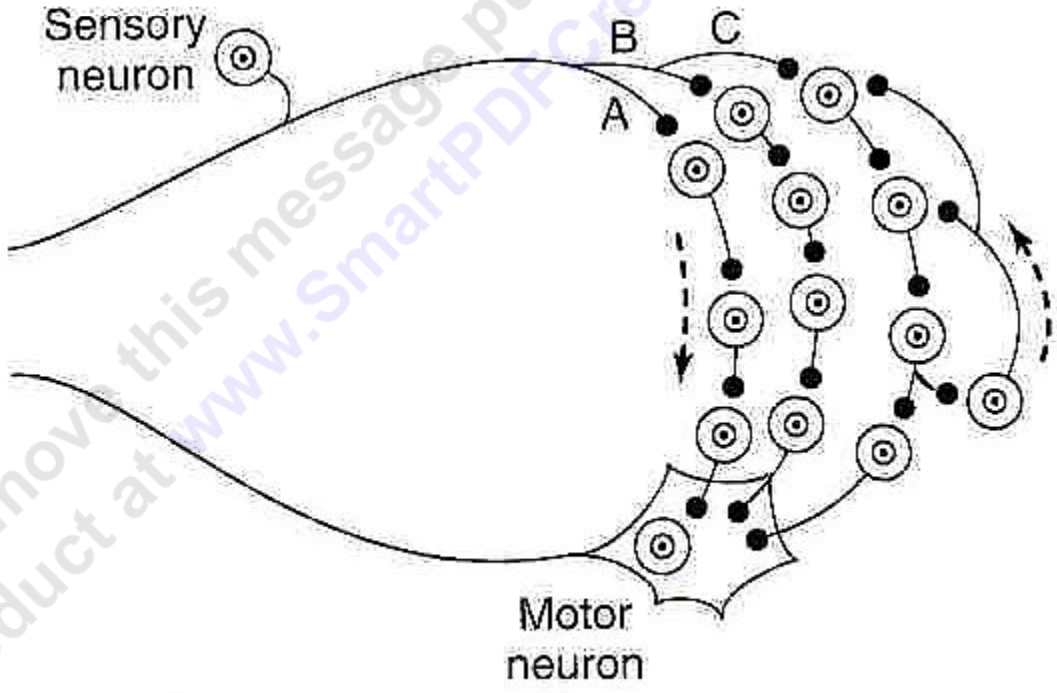
– A stronger stimulus will cause reflex flexion of the big toe , other toes , plus the ankle.

– 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 .



Important Definitions تعريفات هامة

- 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) + التأخير داخل المشابك Central Delay
- 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 Dealy = 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 إلي التأخير داخل المشابك التي هي بين العصبونات
- Number of synapses عدد المشلبك = $\text{Central Delay} \,/_{0.5}$ ms

- End