2 Organization of the Nervous System and Motor unit

- Very important
- Extra information
- Terms

Strength and growth come only through continuous effort and struggle!

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Objectives

- Diagnose the organization of the Nervous System.
- Appreciate differences between both central nervous system (CNS) and peripheral nervous system (PNS).
- Identify motor unit.
- know the function & recruitment of motor unit.
- Appreciate effect of motor units number on motor action performance.

Organization of the nervous system

Nervous system

Central nervous system (CNS)

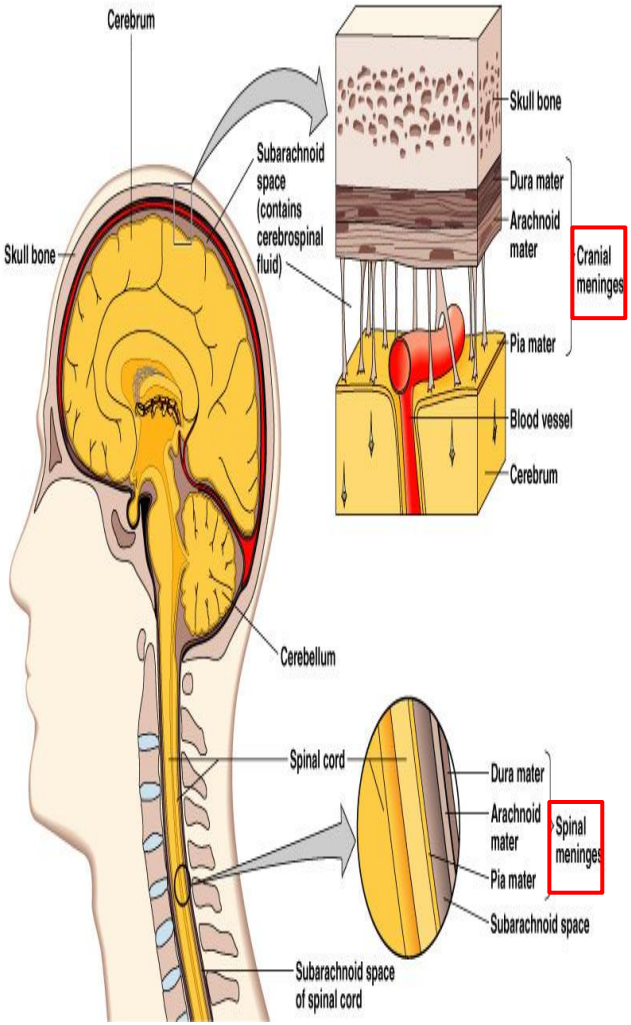
Peripheral nervous system (PNS)

it is the part that integrates the sensory information that is receives from different parts of body and coordinates the activity of all parts of the body.

Consists of :

- The brain and it protected by the **skull** .
- The spinal cord and it protected by the **vertebrae** .

both of them are enclosed in the meninges.



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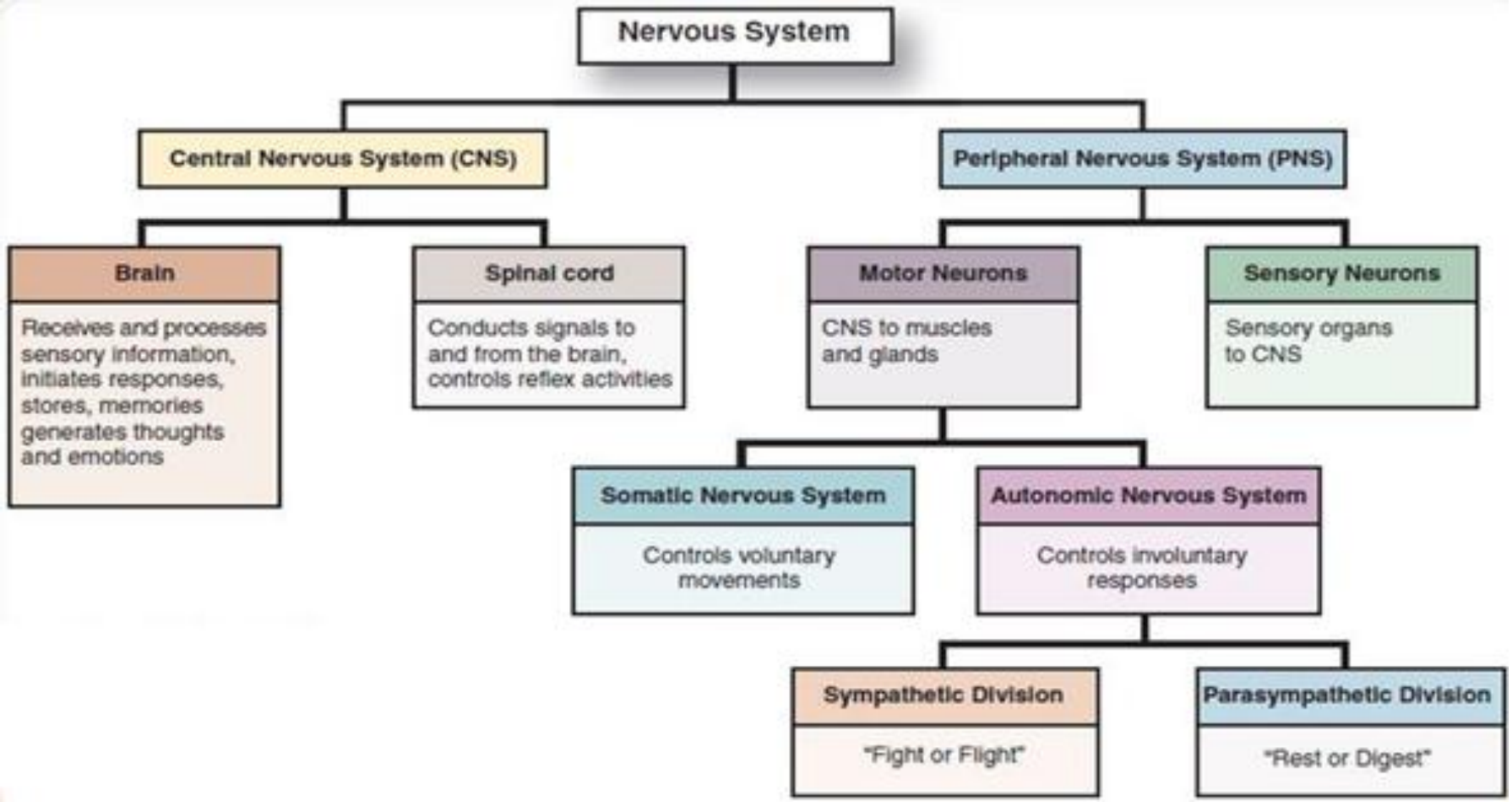

Video / Video2

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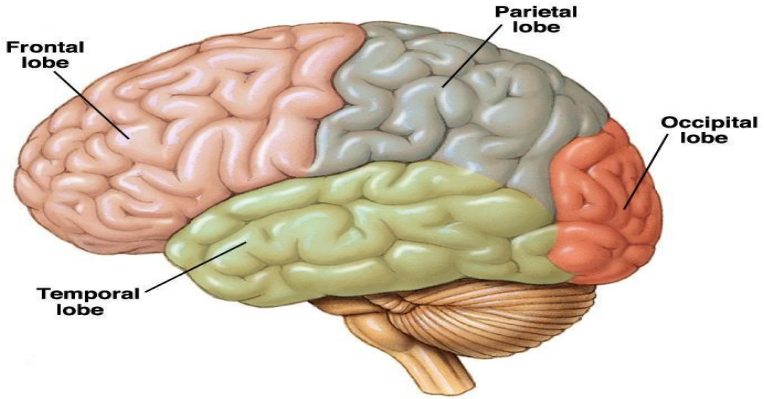
Brain consists of :

- 2 Cerebral hemispheres
  - connected together by corpus callosum
  - frontal
  - parietal
  - temporal
  - occipital lobes
- Cerebral cortex
  - sulci
  - gyri
  - To increase brain surface area.
- Brain stem
- Cerebellum
- Deep white matter
  - has groups of nuclei as basal ganglia and others.



المخ ليس أملساً بل يحتوي على sulci & gyri لزيادة مساحة السطح مما يعني أن هنالك مجال أكبر ليكون لدينا عدد أكبر من الـ neurons في هذه المنطقة.

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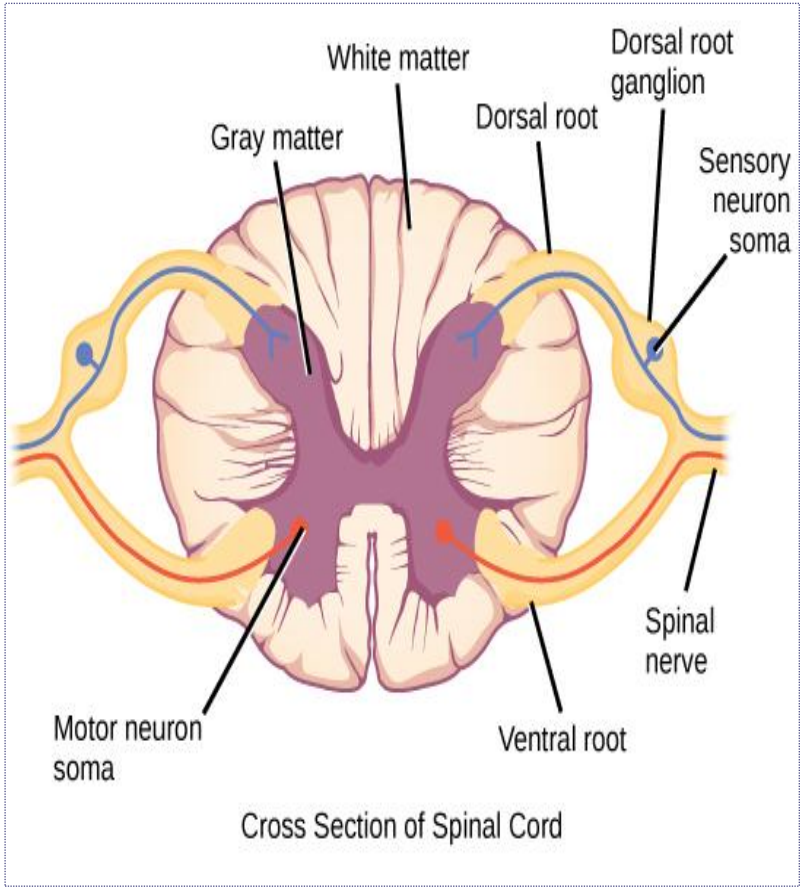
Central nervous system

Spinal cord :

- Consists of H shape grey matter formed of neurons (nerve cells) :

1- **Dorsal** horn has **Sensory** neurons.
2- **Ventral** horn has **Motor** neurons.

- Surrounded by white matter of nerve fibers (ascending and descending tracts).



Cross Section of Spinal Cord

Spinal nerves contain both sensory afferent (bring information to the spinal cord) and motor efferent (send information to periphery)

video

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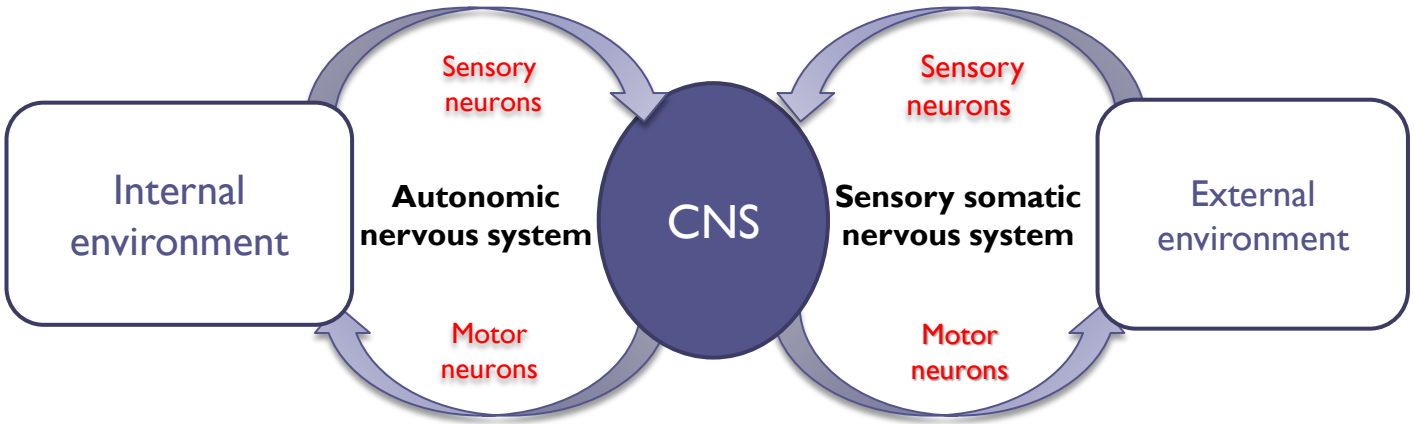
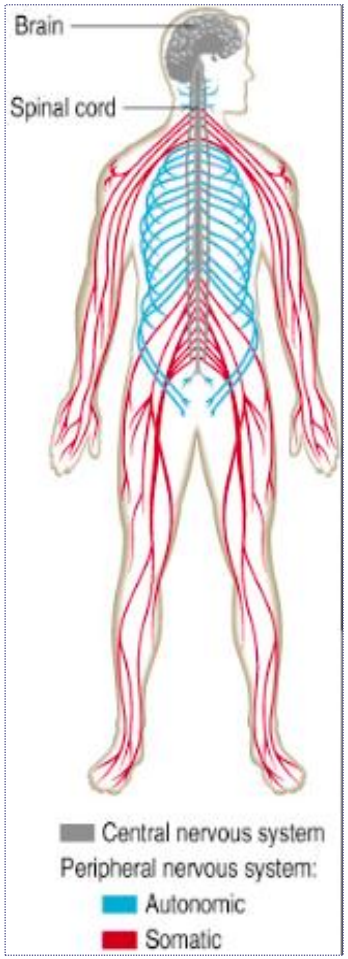
Peripheral nervous system

- **Peripheral nervous system**
  - **Somatic Nervous System**
  - **Autonomic Nervous System**
    - Sympathetic Nervous system
    - Parasympathetic Nervous system





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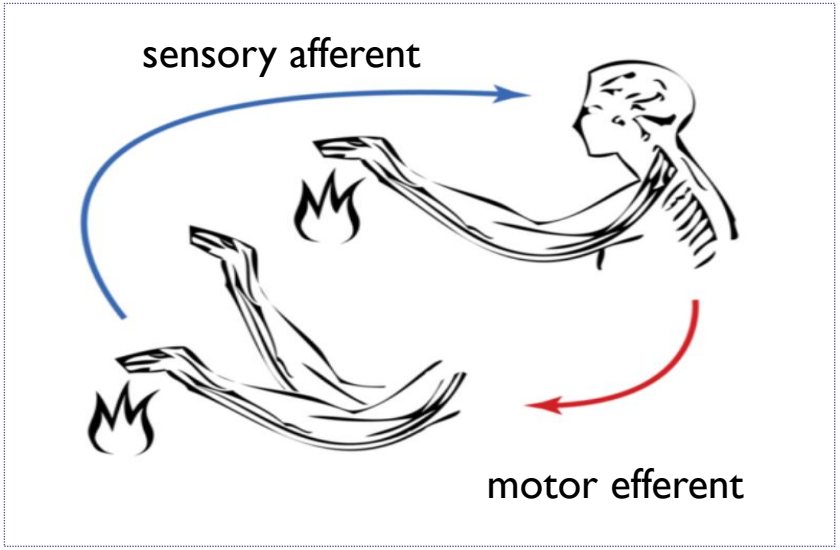
Sensory-somatic nervous system

- The actions of the Sensory-Somatic nervous system are largely voluntary .
- The Sensory-Somatic Nervous System is concerned with all our conscious awareness of the external environment and all our motor activity to cope with it .

The sensory-somatic system consists of :

- **12** pairs of cranial nerves
- **31** pairs of spinal nerves

(All has sensory afferent & motor efferent)



Remember the word "SAME" : Sensory Afferent, Motor Efferent.
Afferent = Arrive / Efferent = Exit.

Video

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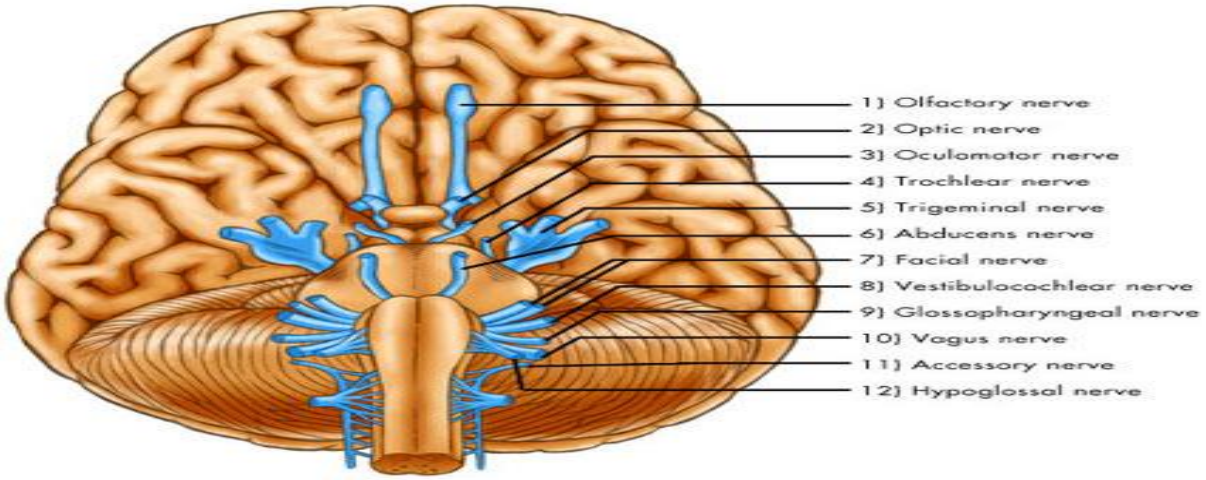
Cranial nerves

They are 12 pairs :

10 cranial nerve originate from the brainstem nuclei

1st (olfactory) and
2nd (optic) lie in the forebrain and thalamus

They control the function of all structures of Head & Neck with some exception



All cranial nerved originate from brain stem except olfactory and optic.

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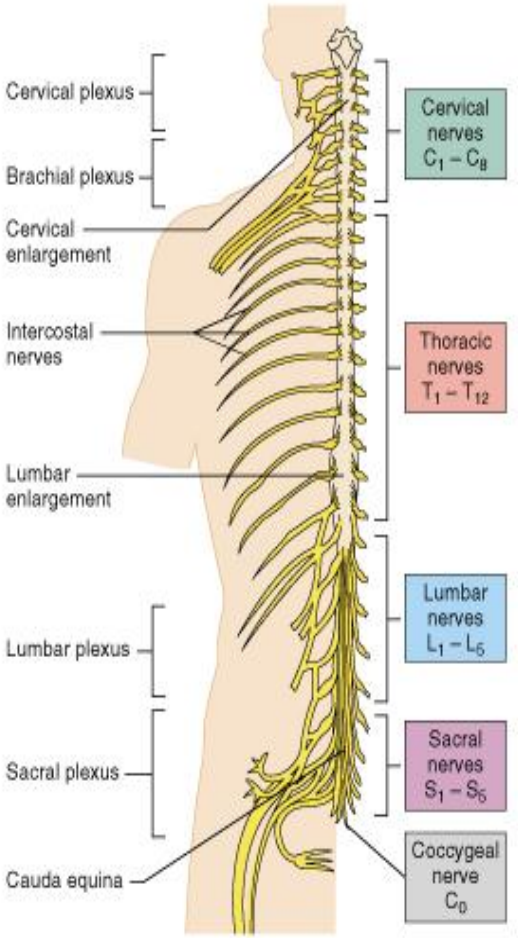
Spinal nerves

- They take their origins from spinal cord.
- They are 31 pairs :
  - * 8 cervical
  - * 12 thoracic
  - * 5 lumber
  - * 5 sacral
  - * 1 coccygeal
- They control the function of all parts of the body (except head & neck).
- All of spinal nerve are mixed {contain both sensory afferent(sensations) and motor efferent (commands) neurons (pass in dorsal & ventral root) }.



Remember : we have 7 cervical vertebrae but 8 cervical nerves

Video

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Sensory afferent & motor efferent

The Sensory Neurons	The Motor Neurons
▪ The sensory neurons are afferent neurons, running from stimulus receptors to relay sensory impulses toward the CNS to inform it about all types of sensations. (pain, touch) [pass in the dorsal root]	▪ The motor neurons are efferent neurons which relay motor impulses away from the CNS to periphery (skeletal muscles, or gland) to take action. [pass in the ventral root]

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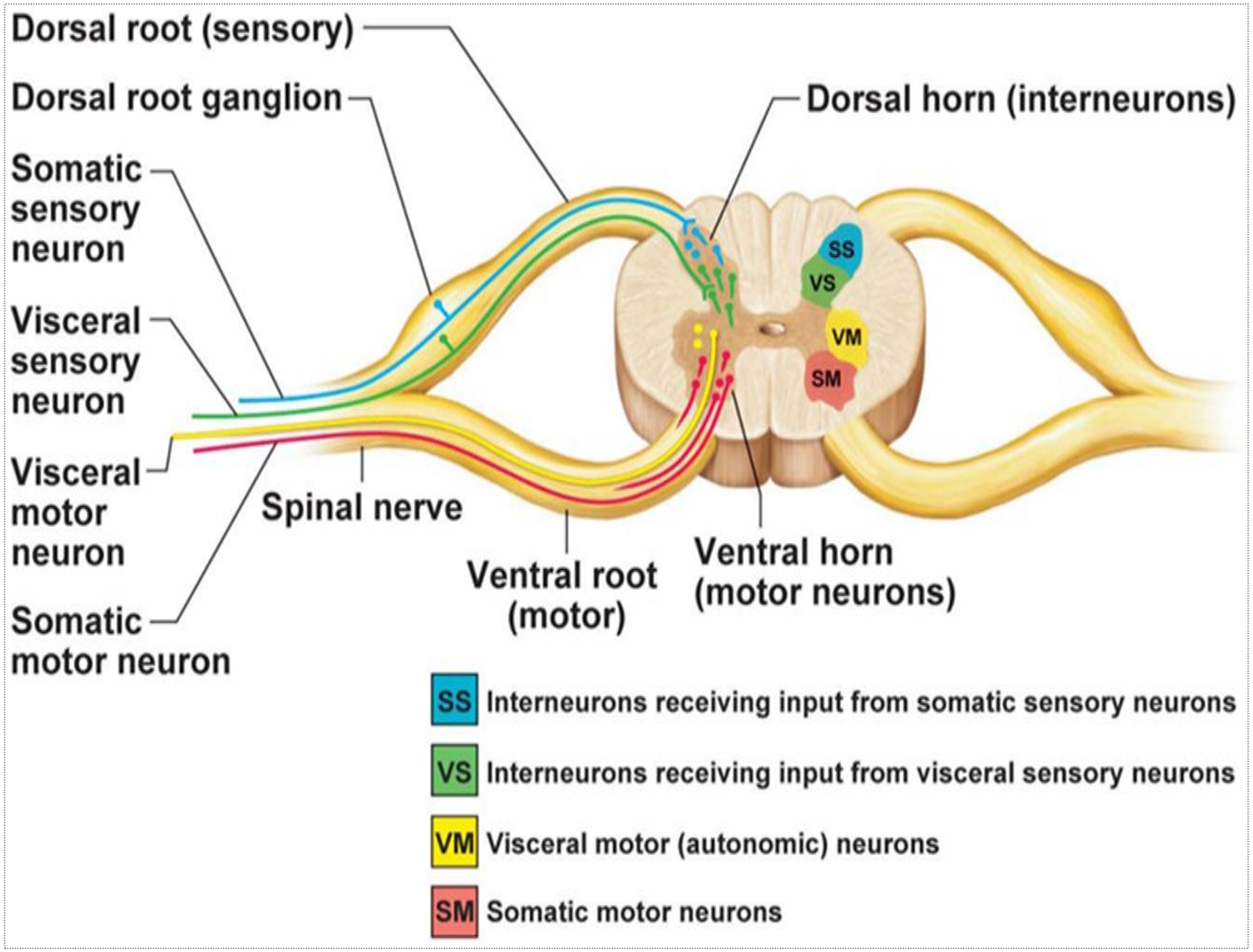
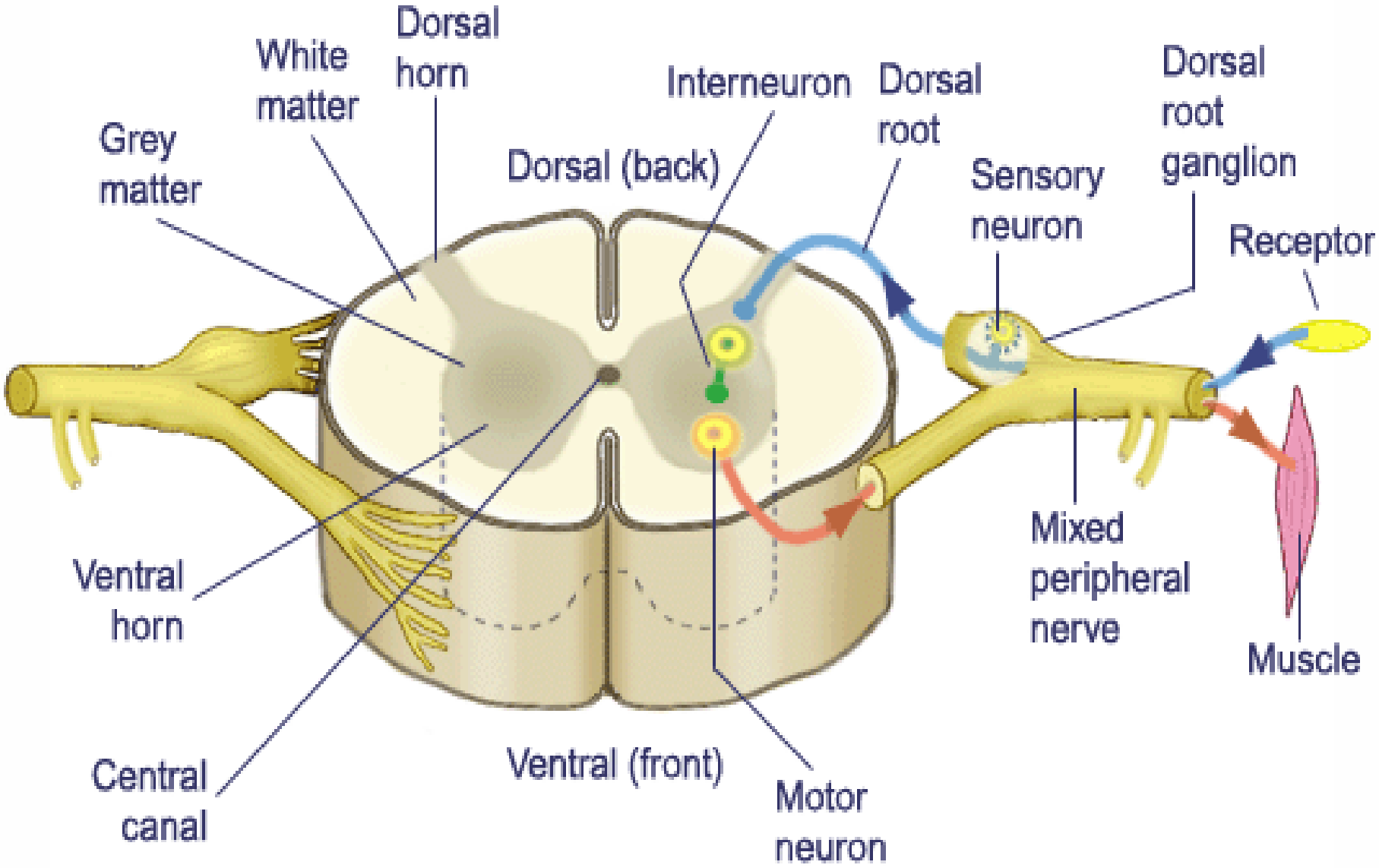


1- Sensory neuron (hold the afferent sensations) will pass from the Dorsal root to reach the Dorsal horn of spinal cord.

2- in the Dorsal horn there are some of the sensations will go up to the brain (CNS), and the rest will complete the cycle by turn to commands which hold by motor neurons and pass the ventral root.

- Dorsal horn = posterior horn = sensory neurons.
- Ventral horn = Anterior horn = Motor neurons.
- AHC = Anterior horn cells.



The Autonomic Nervous System

The autonomic nervous system consists of neurons that run between the central nervous system (especially the hypothalamus and medulla oblongata) and various internal organs such as the: heart ,lungs ,viscera , glands

It is responsible for monitoring conditions in the internal environment and bringing about appropriate changes in them.

The actions of the autonomic nervous system are largely involuntary

The contraction of both smooth muscle and cardiac muscle is controlled by the autonomic system.

Video

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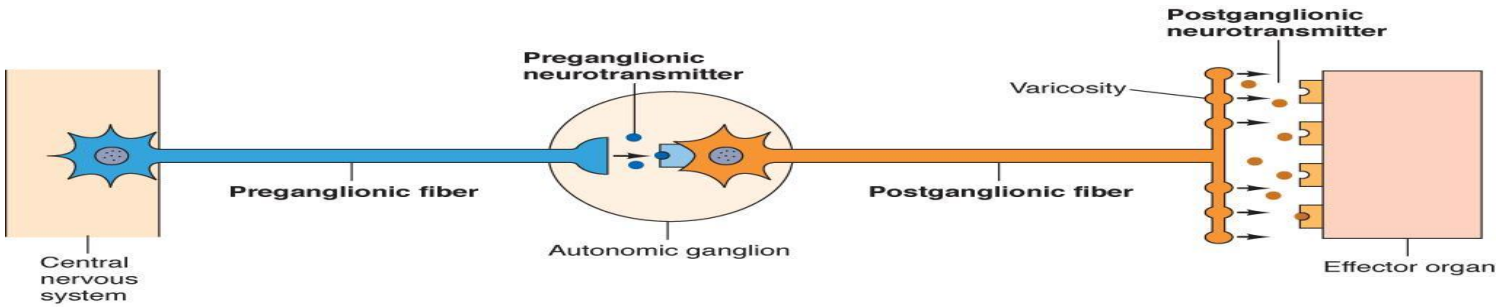
The Autonomic Nervous System

The preganglionic neurons, arise in the CNS and run to a ganglion , here they synapse with postganglionic neurons, which run to the effector organ

(cardiac muscle, smooth muscle, or a gland).



The autonomic nervous system has two subdivisions :

- sympathetic nervous system
- parasympathetic nervous system.

Video

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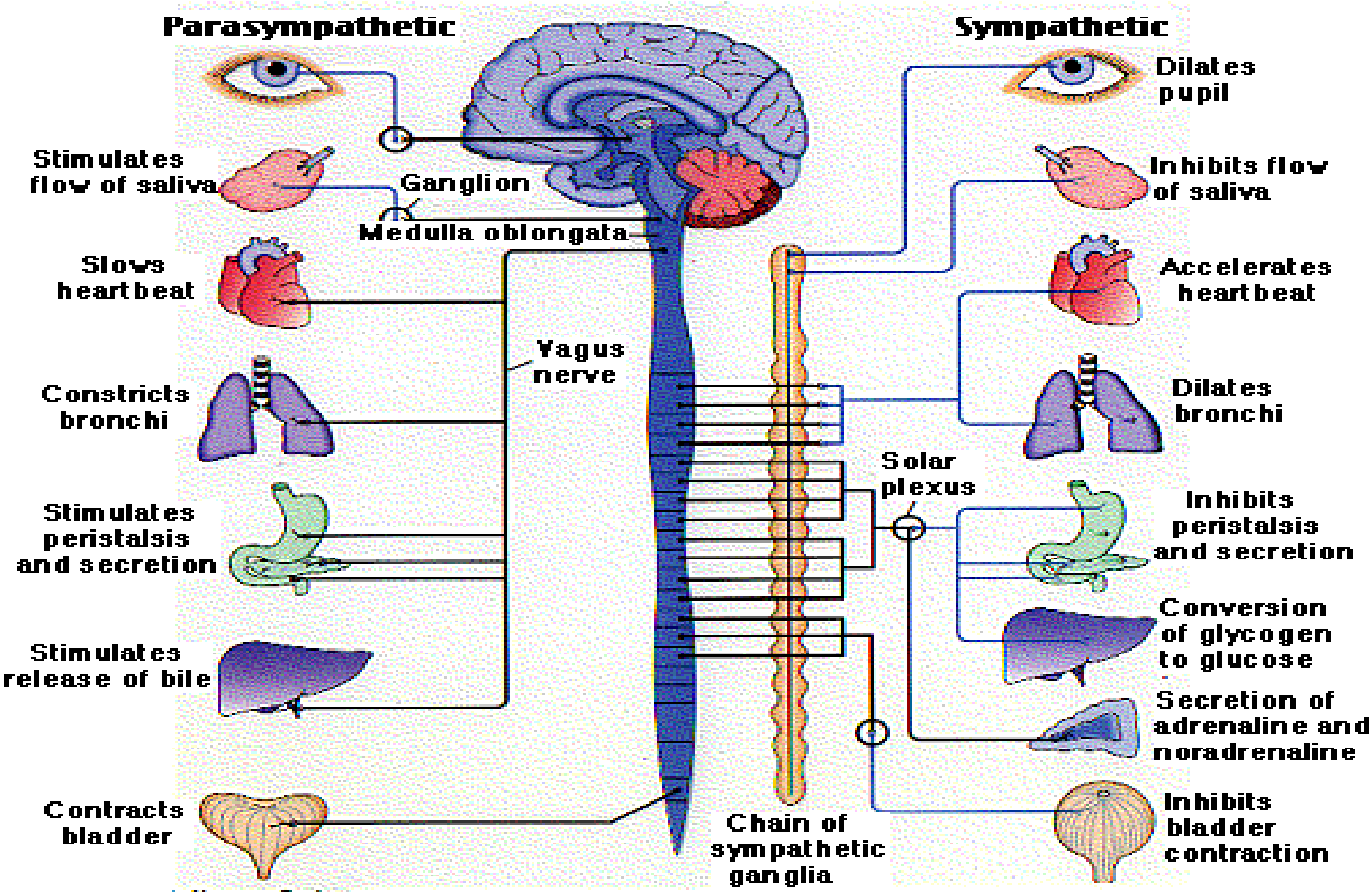


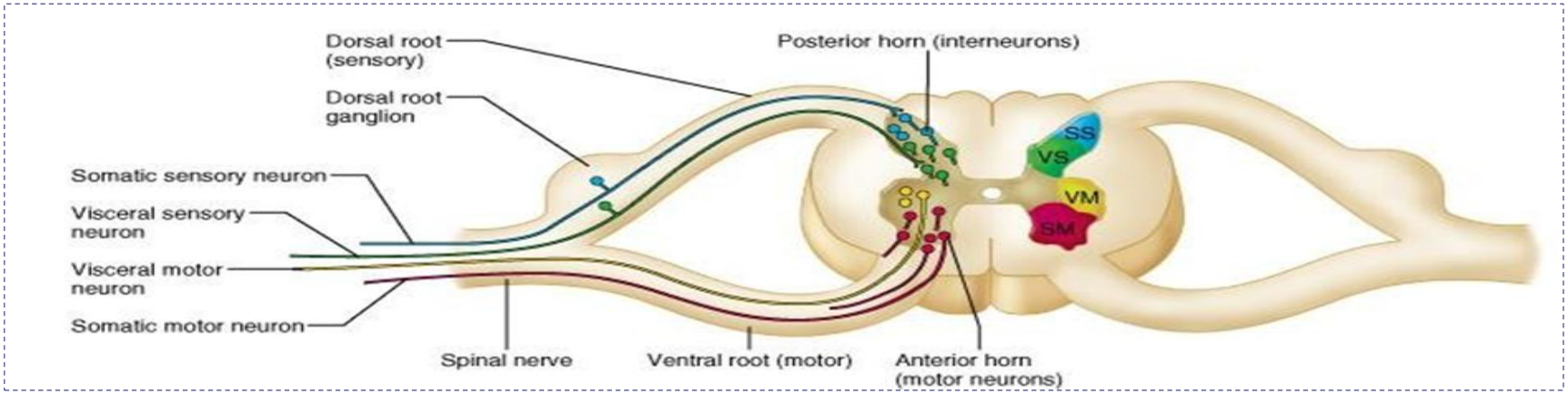
Motor unit

Neuron :

Building unit of function of the central nervous system, Either sensory or motor.

- Motor neuron is mostly anterior horn cell (AHC) in the spinal cord supply skeletal muscle (alpha motor neuron).
- AHC is the motor nerve that controls the skeletal muscle cell contraction.

- **Alpha(α) motor neuron** is an **anterior horn cells** (AHCs)
- A nerve is made of a group of axons of motor neurons



We said that :

- Dorsal horn = posterior horn = sensory neurons.
- Ventral horn = Anterior horn = Motor neurons.

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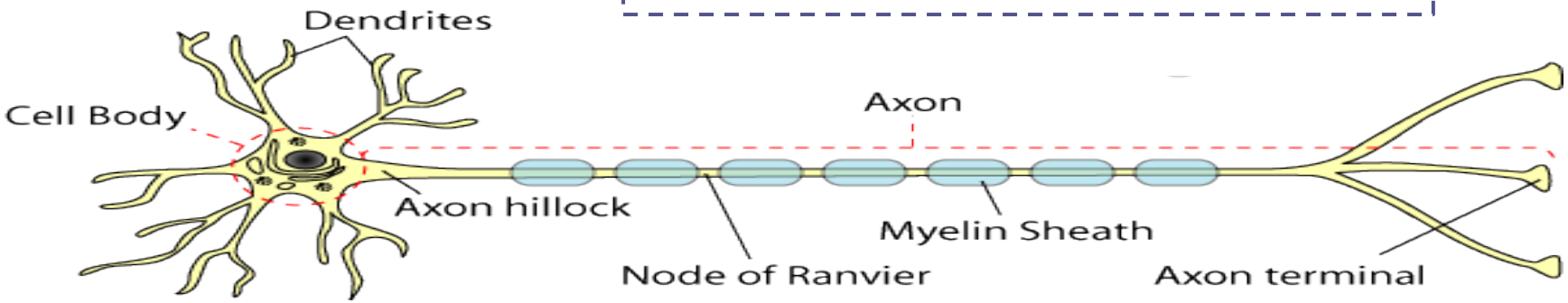
Motor neuron parts and their functions

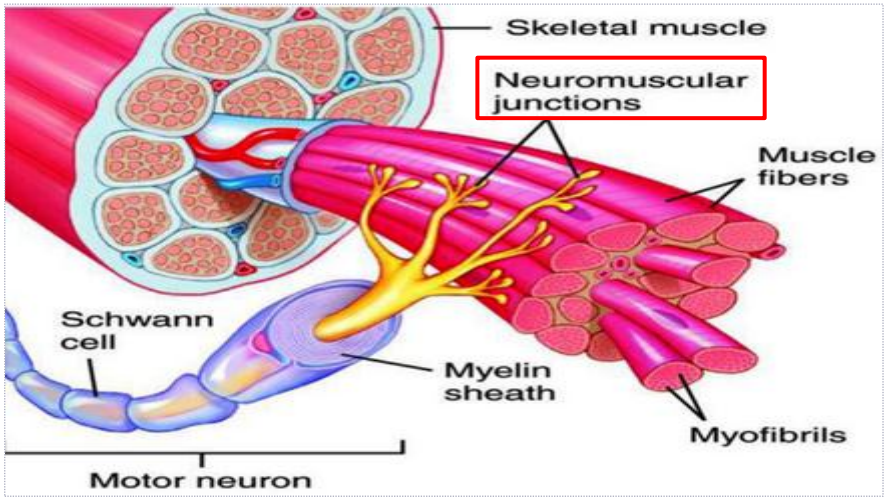
Parts of motor neuron

- **Soma (cell body)**
- **Dendrites** — Carry nerve impulses from surroundings to the soma
- **Axon hillock** — at which nerve impulses begin & pass in one direction from soma to the axon (nerve fiber) then to axon terminal
- **Axon and axon terminal**
  - Nerve cell axons are very thin, about 1 micrometer in diameter, myelinated
  - Axon and axon terminal end on skeletal muscle via neuromuscular junction
  - For many motor neurons the axon is over a meter long, extending from the spinal column to a muscle cell.



Neuromuscular Junction (NMJ)

- **Neuromuscular junction (NMJ):**
  It is the place where the axon terminal contacts the muscle cell.



- Acetylcholine (ACh) is the chemical transmitter released by the axon of the motor nerve.

AHC = Anterior Horn Cell / ACh = Acetylcholine

Motor unit

A motor unit is a single alpha -motor neuron and all of the corresponding muscle fibers it innervates.

(all skeletal muscle fibers innervated by that motor neuron's axonal terminals).

Note: each muscle cell is supplied by only one AHC ,

AHC through the branches of its axon , supplies several muscle cells .

all of these muscle fibers will be of the same type

(either fast twitch fibers or slow twitch)

When a motor unit is activated, all of its muscle fibers contract.

A single muscle is supplied with groups of motor neurons.

So Groups of motor units often work together to coordinate the contractions of a single muscle .

all of the motor units that subserve a single muscle are considered a motor unit pool.

Motor unit = motor neurons & their terminal axons + the muscle fiber which will be innervated.

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Motor unit

- In general, the number of muscle fibers innervated by a motor unit is a function of a muscle's need for refined precise motion.
- Groups of motor units often work together to help the contractions of a single muscle.
- Muscles needed to perform highly precise refined movements generally consist of :
  - large number of **motor units**
  - few **muscle fibers** in each motor unit (Hand and eye muscles).
- The Less precise big movements are carried out by muscles composed of :
  - fewer **motor units**
  - many **muscle fibers per unit** (Trunk muscles).
- Ratio of **muscle fibers** to **motor neurons** affects the precision of movement."دقة الحركة"

The single muscle consists of millions of motor units, which consist of neurons that innervate a number of muscle fibers by their axon terminals "لحد ما تشمل كل العضلة"
استحالة الـ motor unit تغذّي عضلة كاملة ! وإنما تغذي عدد معين من الألياف العضلية.

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- **The number of muscle fibers within each motor unit can vary according to type of muscle movements :**

Fine precise movement	Gross movement
• need motor units have small number of muscle fibers. • A single motor unit for eye muscle controlling eye movements may trigger fewer than 10 muscle fibers – from 7 to10 muscle fiber-. • Muscles needed to perform highly precise movements generally consist of a large number of motor units and few muscle fibers in each motor unit (Hand and eye muscles).	• need motor units have large number of muscle fibers. • A single motor unit for a muscle like the gastrocnemius (calf) muscle may include 1000-2000 muscle fibers. • Thigh muscles can have a thousand fibers in each motor unit. • Muscles needed to perform Less precise movements are carried out by muscles composed many fibers of fewer motor units with per unit (Trunk muscles).

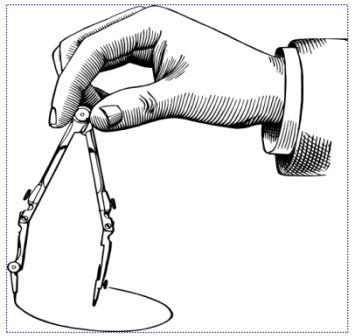
Extra

- The number of muscle fibers within each muscle vary according to the type of muscle movement :

if we have a motor unit that innervates only 3 or 4 muscle fibers that means it is very precise motion.

On the other hand, if we have a motor unit that innervates 100-100 0 or even more muscle fibers that means if is a gross movement (حركة غير دقيقة).
كلما قل عدد الألياف العضلية في وحدة الحركة كلما زادت الدقة.

Gross movement



Fine precise movement

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Motor unit

- **The force of muscle contraction:**

The two ways the nervous system increases the muscle contraction force production is through:

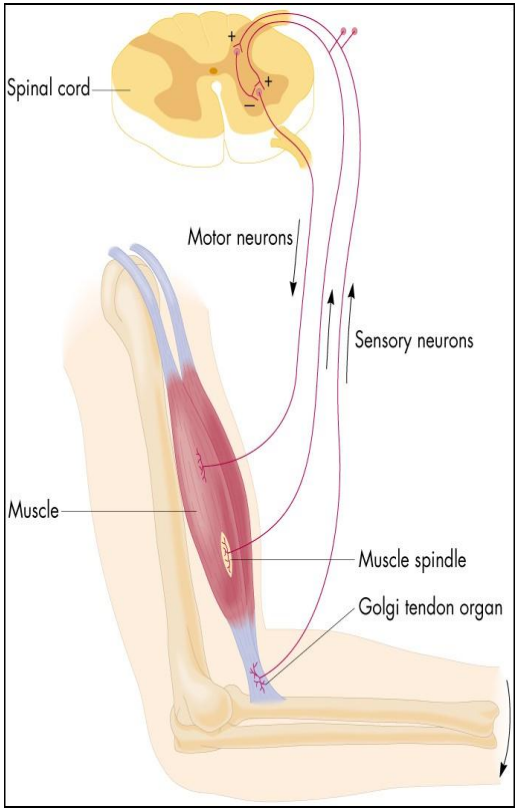
1-Recruitment "تجنيد أو توظيف" **of new motor units.**

By gathering more motor units to work together successively, in order to give it more strength.

(more motor unites = more powerful contraction of muscle = Force)

2- Increasing stimulation frequency rate coding.

Rate coding = Controlling the frequency of nerve impulse in the muscle.



Keep in mind: preciseness **does not** mean force.
Preciseness depends on: number of muscle fibers in the motor unit.

What determines the force that is produced by a single motor unit?

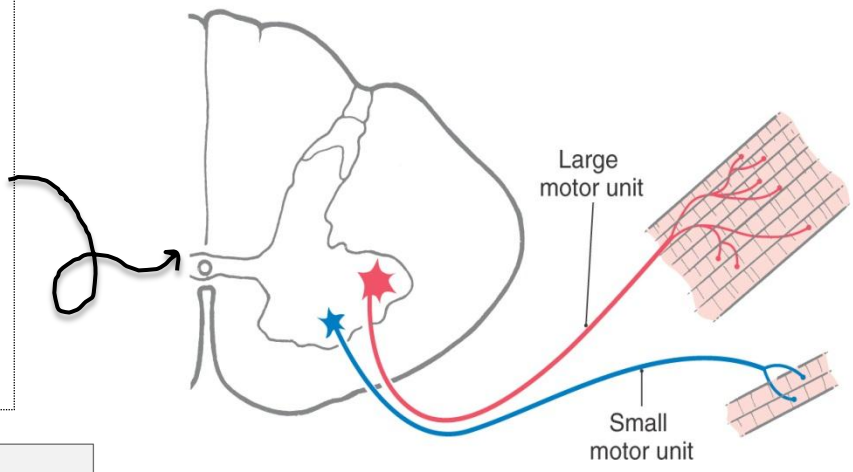
1. The numbers of muscle fibers in the unit (more muscle fibers means more force). "علاقة طردية".

2. How frequent those muscle fibers are stimulated by the innervating axon (The more they're used the stronger the force) " Rate coding " "علاقة طردية"

Small motor units = Low stimulus threshold

Larger motor units = Higher stimulus threshold

Largest motor units = Highest stimulus threshold



The larger the motor unit the more it is stimulated.
low stimulation threshold = weak contraction.
Higher stimulation = innervate more number of muscle fibers = strong contraction.

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Motor Unit Recruitment (MUR)

❖ Motor unit recruitment :

Is the progressive activation of a muscle by successive recruitment of more motor units to accomplish increasing grades of contractile strength force.

- All muscles consist of a number of motor units each one has its own muscle fibers belonging to it.
- When a motor neuron is activated, all of the muscle fibers innervated by this motor neuron are stimulated and contract.
- The activation of one motor neuron (motor unit) will result in a weak muscle contraction.
- The activation of multiple motor units will result in more muscle fibers being activated, and therefore a stronger muscle contraction.

The higher the recruitment of motor units the stronger the force of muscle contraction

It is a measure of how many motor neurons are activated in a particular muscle. That means, it is a measure of how many muscle fibers are activated in that muscle.

When the recruitment of motor units is high we get stronger force for muscle contraction because nerve fibers increase in number. When does it stop? When muscle fatigue happens you're forced to relax your muscles.

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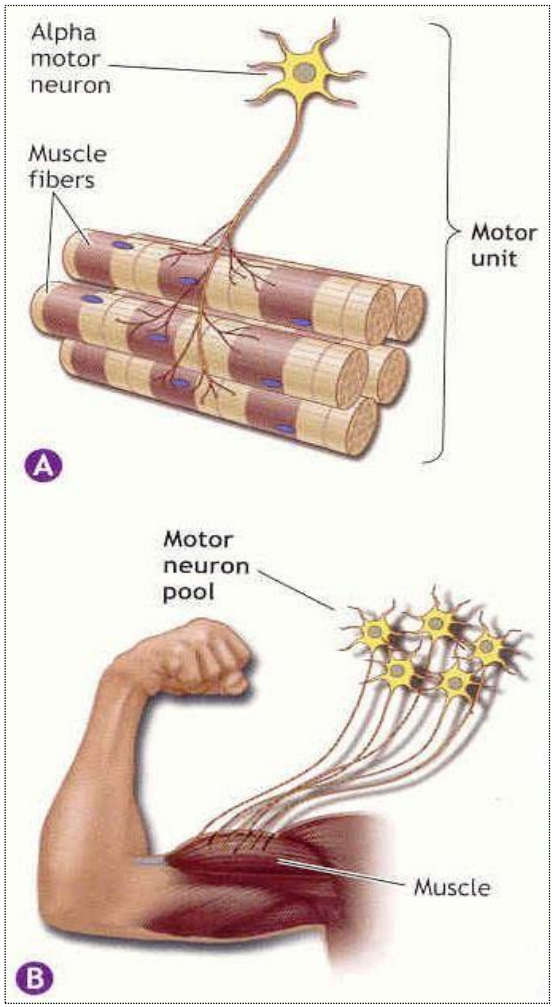
Extra



كلما زاد عدد الـmotor units كلما زاد عدد الـ Muscle fibers
التي يحدث لها انقباض بالتالي تمنح العضلة قوة أكبر لتعطي انقباضاً أقوى

مثال :

- If we have 5 motor units , each unit innervates 5 muscle fibers 5x5 = 25 muscle fibers.
- If we have 20 motor units , each unit innervates 5 muscle fibers 20x5 = 100 muscle fibers = strong contraction.

بالتالي نستنتج :

The higher the recruitment the stronger the force of contraction.

Video

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Motor Unit Firing Rate

❖ Firing Rate :

The rate at which the nerve impulses arrive from motor neurons to muscle fibers.

The rate varies from :

High frequencies firing rate	Low frequencies firing rate
▪ Means its enough to produce a **fused tetanic contractions** "contraction without relaxation"	▪ Means its enough to produce a series of single twitch muscle contractions.
▪ How does it happen? When the Anterior Horn Cell fires at very fast rates →motor unit potentials will be at fast rate → the force of muscle contraction is strong.	▪ How does it happen? When the Anterior Horn Cell (AHC) fires at slow rates →motor unit potentials will be at slow rate → the force of muscle contraction is weak.

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Motor Unit Firing Rate

- In general :

The motor unit firing rate (The firing of nerve impulses) of each individual motor unit will increases with increasing muscular effort until a **maximum rate** is reached.

"That means, nerve impulses from each motor unit will keep on coming when there is increased demand by muscles until it reaches its maximum rate".

"Motor neurons send nerve impulses to muscle fibers, the time it takes nerve impulses to arrive to the muscle fibers is the Motor Unit Firing Rate"

Our brain decides if the weight we lifted requires motor units firing rate. Thus, our motor units condition themselves according to our brains.

بما معناه، هو يختلف من شخص لآخر ومن طبيعة جسم لأخرى وبحسب قدره تحمل العضل في الجسم يقوم المخ باتخاذ القرار اللازم حتى يتمكن الجسم من حمل الأثقال بصورة جيدة

For example:

-if you lifted a 5 kg box your brain would decide that there is no need for motor units firing rate.

-But when you lift 10 kg, your brain will decide it's necessary.

If we gave high frequency to muscle fibers they will become hyper active. Thus, they will cause hyper contraction of muscles to the limit where they become so contracted they cannot relax until you put the 10 kg box down or your muscles fatigue so you're forced to put it down.

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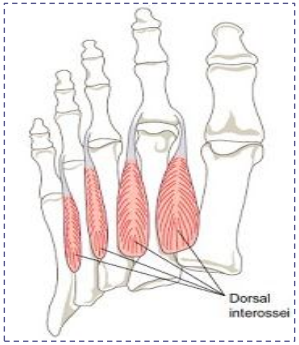
Rate Coding

❖ Rate Coding :

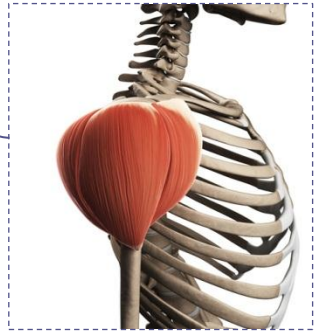
Increasing stimulation frequency "Motor neuron firing rate of nerve impulses" (rate coding) causes that Active motor units can discharge at higher frequencies to **generate greater tensions**. (greater tension = greater contraction = greater force)

To increase force of contraction:

- Smaller muscles → First dorsal interossei rely more on **rate coding**



- Larger muscles → Deltoid rely more on **recruitment**



"Increasing stimulation frequency = Motor neuron firing rate of nerve impulses=rate coding".

- Small muscles have a small number of motor units so how can we increase the force in these small muscle ? By increasing the frequency of Action potential.
- Large muscle posses enough number of muscle fibers and motor units so they will not depend on firing rate, instead they will recruit more and more motor units for stronger contraction.

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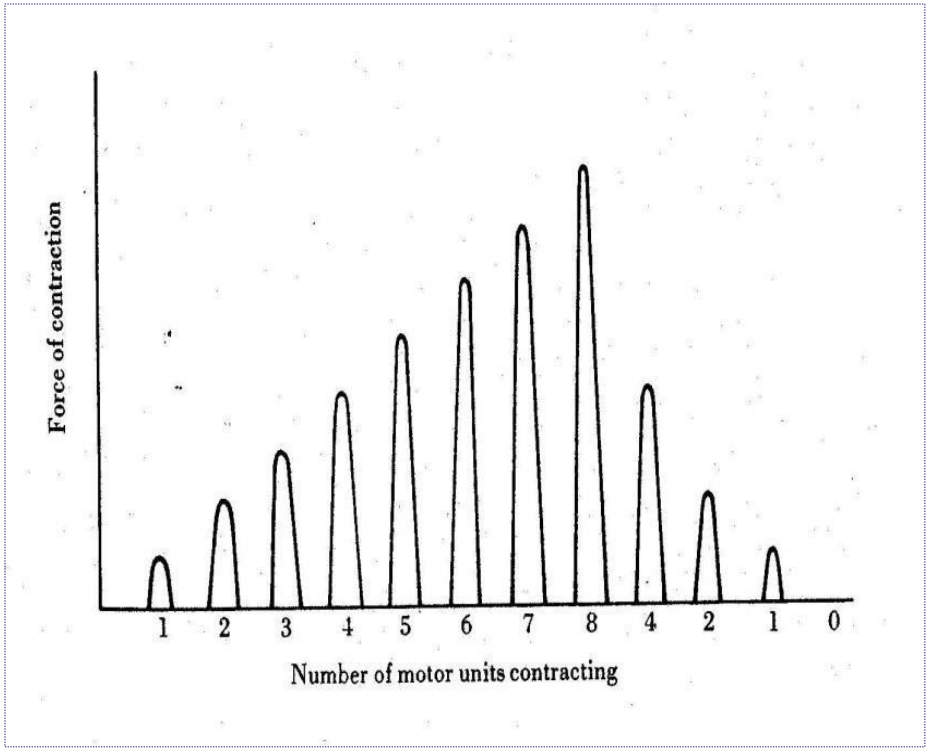
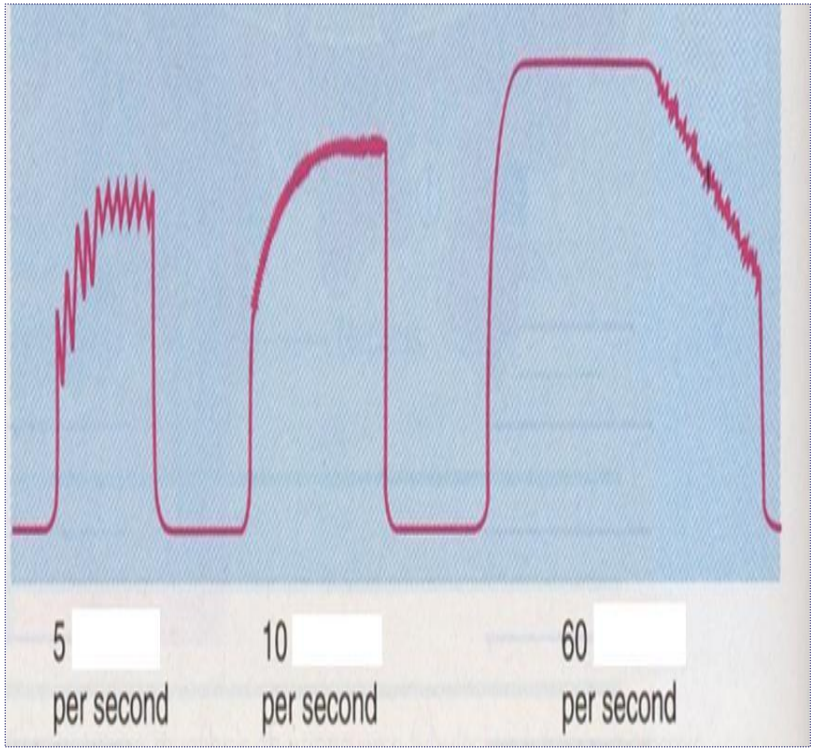
Rate Coding





- Increasing frequency of action potentials resulting in stronger force of contraction.

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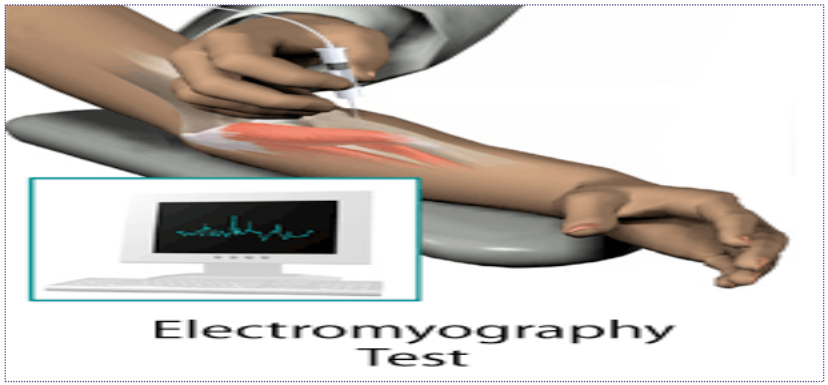
To test motor unit stimulation

1- Electrodes are placed on the skin.
2- An intramuscular stimulation is applied.
3- After the motor unit is stimulated, its pulse is then recorded by the electrode.
4- The pulses are displayed as **motor unit action potential** (MUAP).
"an action potential for the muscle".

- In medical Electrodiagnostic testing for a patient with **muscle weakness** careful analysis of the **motor unit action potential** (MUAP) size, shape, and recruitment pattern can help in distinguishing a Myopathy from a Neuropathy.



Video 1
Video 2

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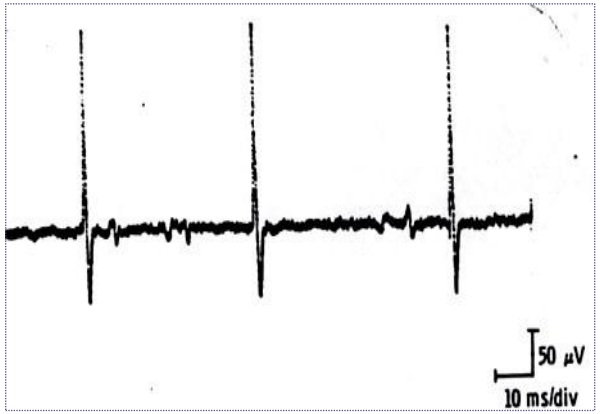
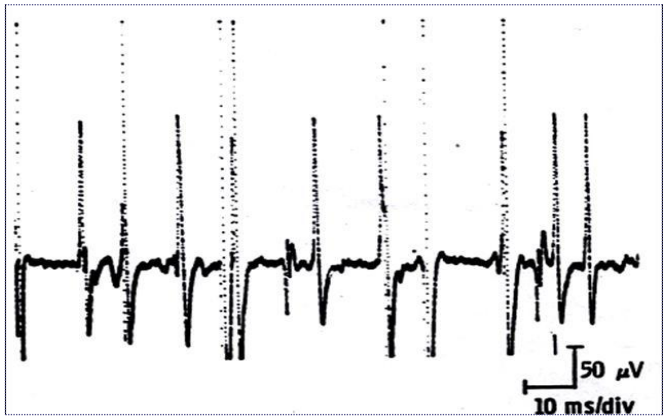
To test motor unit stimulation

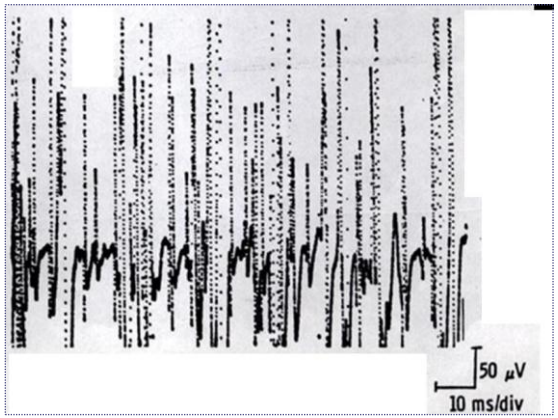


During Mild Effort



During Moderate Effort

" Note recruitment of additional motor neurons"



During Full Voluntary Effort .
There is full recruitment
(you can not see the baseline)

Myopathy

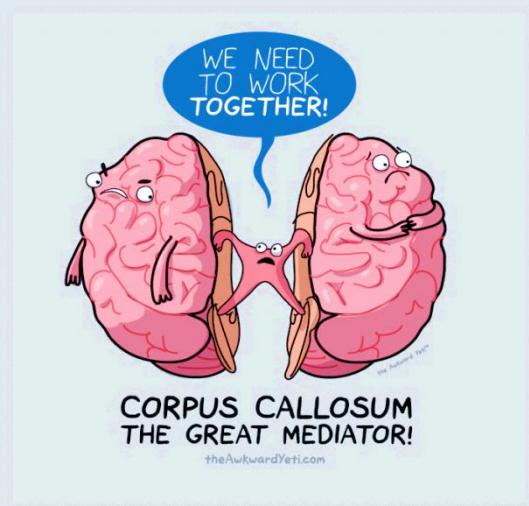
Neuropathy

عندما يشتكي المريض من تنميل في قدميه أو يديه يُجرى له اختبار سرعة توصيل العضلات عن طريق وضع إلكترود على سطح الجلد وإدخال إبرة مباشرة في العضلة وهنا ستظهر نتائج على الشاشة توضح الـ action potential للوحدة الحركية القريبة من الإبرة ، هذه النتائج تسمى :
Motor unit potentials (MUPs)
نطلب من المريض أن يزيد من انقباض عضلاته كل مرة لتحديد نوع المشكلة والمرض الذي يعاني منه.

If it is not clear, zoom it :)

Physiology team

QUIZ



- خولة العماري
- الهنوف الجلعود
- إلهام الزهراني
- رغد النفيسة
- ملاك الشريف
- نورة القحطاني
- منيرة الحسيني
- منيرة السلولي
- فتون الصالح
- أفنان المالكي
- ربى السليمي
- منيرة العمري
- عائشة الصباغ
- شهد الدخيل
- نوف التويجري
- لينة الشهري
- روان الضويحي

- عمر العتيبي
- رواف الرواف
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