*Ministry of Higher Education and Scientific Research*
*Al-Mustaqbal University*
*College of Medicine*

# *Medical Physics*

# Electricity within the Body

## First stage

## Lecture 4

**2024-2025**
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# Electricity within the Body

Electricity plays an important role in medicine. The electricity generated inside the body serves for the control and. operation of nerves, muscles, and organs. The nervous system plays a fundamental role in nearly every body function. Basically, a central computer (**the brain**) receives internal and external signals and makes the proper response.

To know how ***cells control electrical currents*** and that is from the ***elements*** in our bodies, like ***sodium***, ***potassium***, ***calcium*** , and ***magnesium***, have a specific ***electrical charge***. Almost all of our cells can use these charged elements, called ***ions***, to ***generate electricity***.

A ***disruption in electrical currents*** can lead to ***illness***. For example, in order for the heart to pump, cells must generate electrical currents that allow the heart muscle to contract at the right time. Doctors can even observe these **electrical** ***pulses*** in the heart using a machine, called an ***electrocardiogram*** or **ECG** Irregular electrical currents can prevent heart muscles from contracting correctly, leading to a heart attack.


**Electrocardiogram** or **ECG**

# The nervous system and the neuron

The nervous system can be divided into *two parts*:

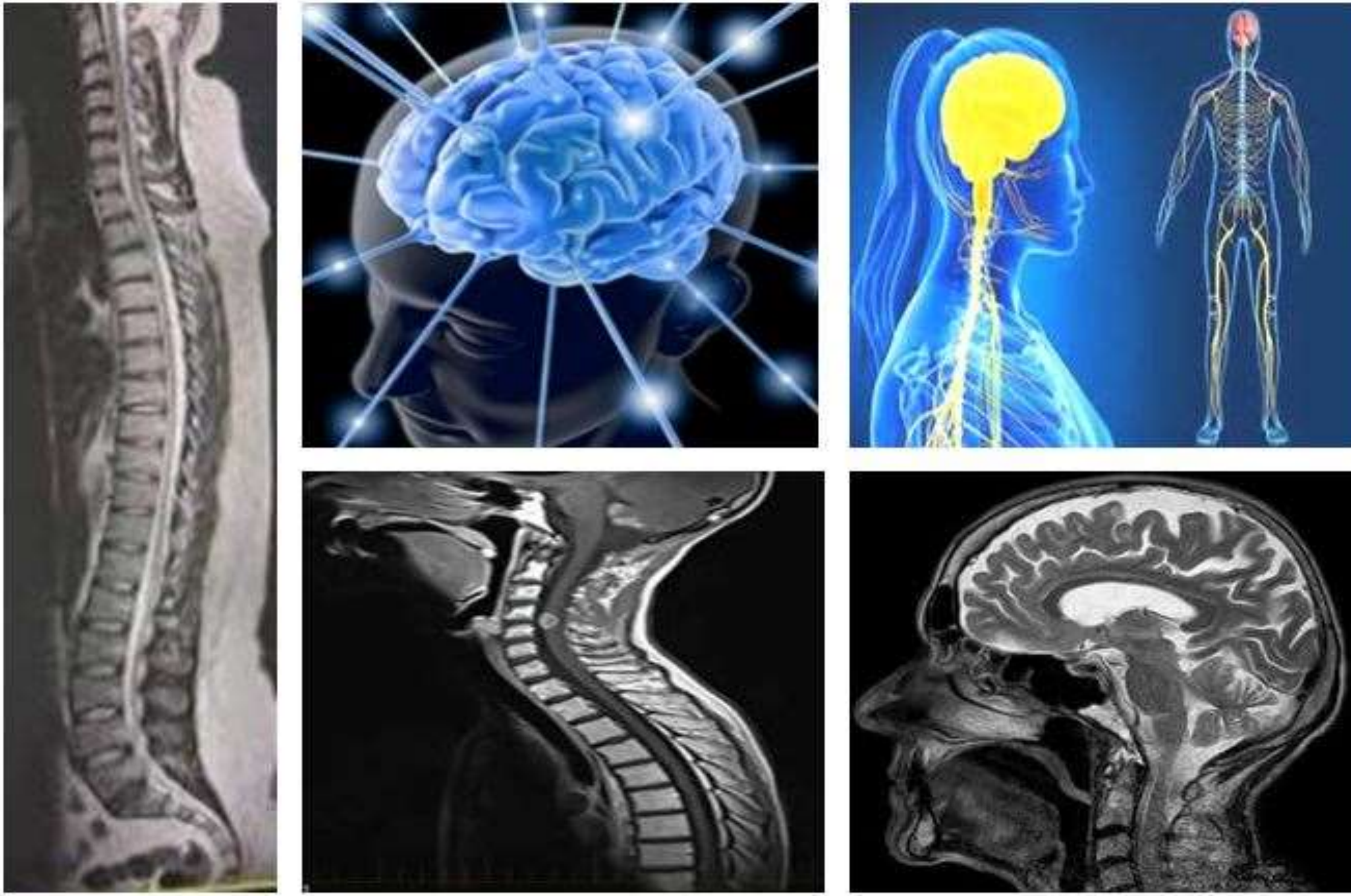
***1- The central nervous system (CNS)***

***2- The autonomic nervous system (ANS)***

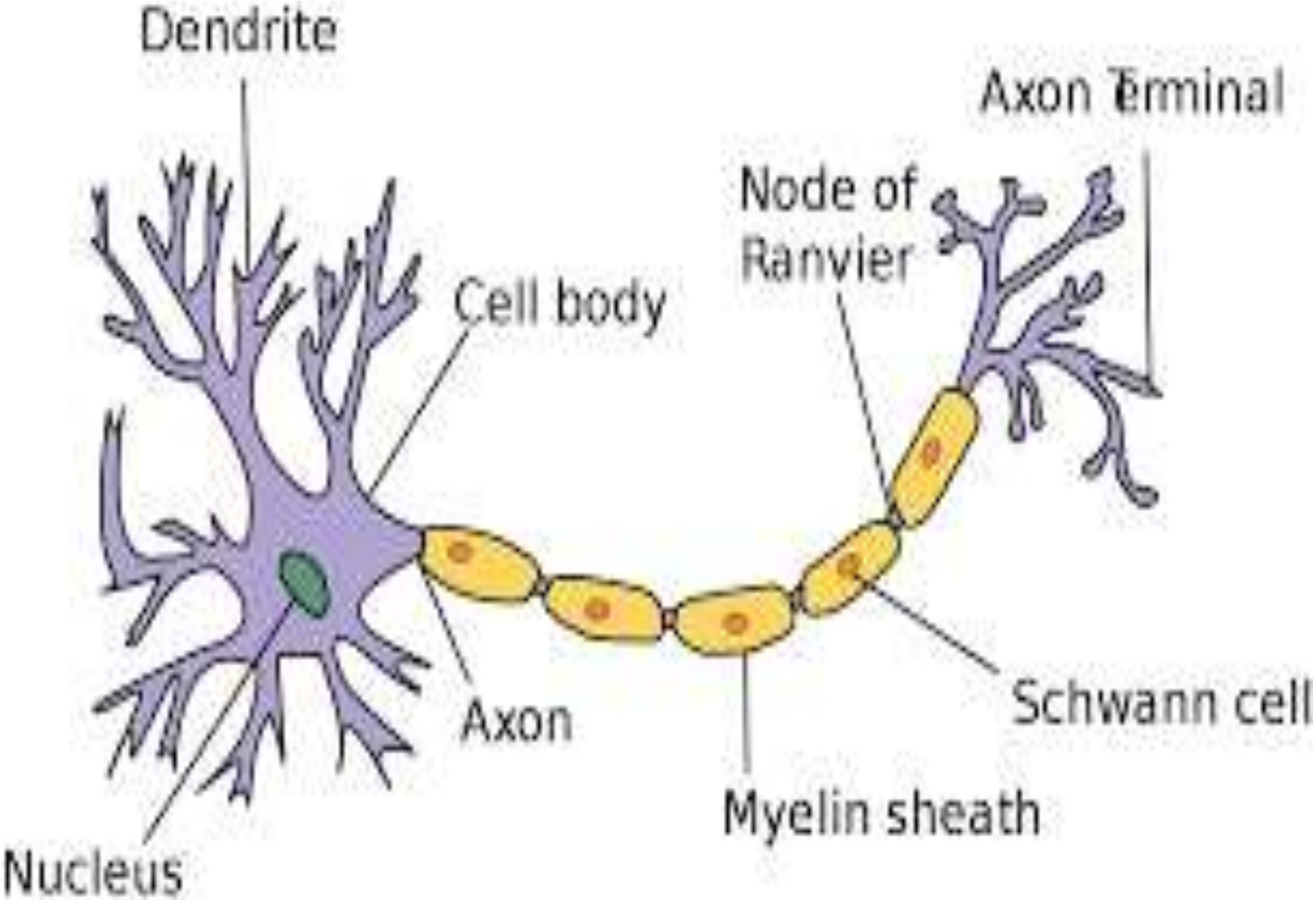
The ***central nervous system*** consists of the ***brain***, the ***spinal cord***, and the ***peripheral nerves-nerve fibers*** (***neurons***) that ***transmit sensory information to the brain*** or ***spinal cord*** (*afferent nerves*) and nerve fibers (neurons) that transmit information from the brain or spinal cord to the appropriate muscles and glands (*efferent nerves*).

The ***autonomic nervous system* controls** varies internal organs such as the heart ,intestines, and glands. The control of the autonomic nervous system is essentially involuntary.

The **basic structural unit of the nervous system** is the neuron, Neurons are special cells which are consist of the cell body (soma), a nucleus, smooth and rough endoplasmic reticulum, Golgi apparatus, mitochondria, and other cellular components. Additionally, neurons have other unique structures such as ***dendrites***, and a ***single axon***. The soma is a compact structure, and the ***axon*** and ***dendrites*** are filaments extruding from the soma. Dendrites typically branch profusely and extend a few hundred micrometers from the soma.



**Brain , Spinal Cord Image**


Dendrite
Axon Terminal
Node of
Ranvier
Cell body
Schwann cell
Axon
Myelin sheath
Nucleus

Its function is specialized for reception, interpretation, and ***transmission of electrical massages*****.**

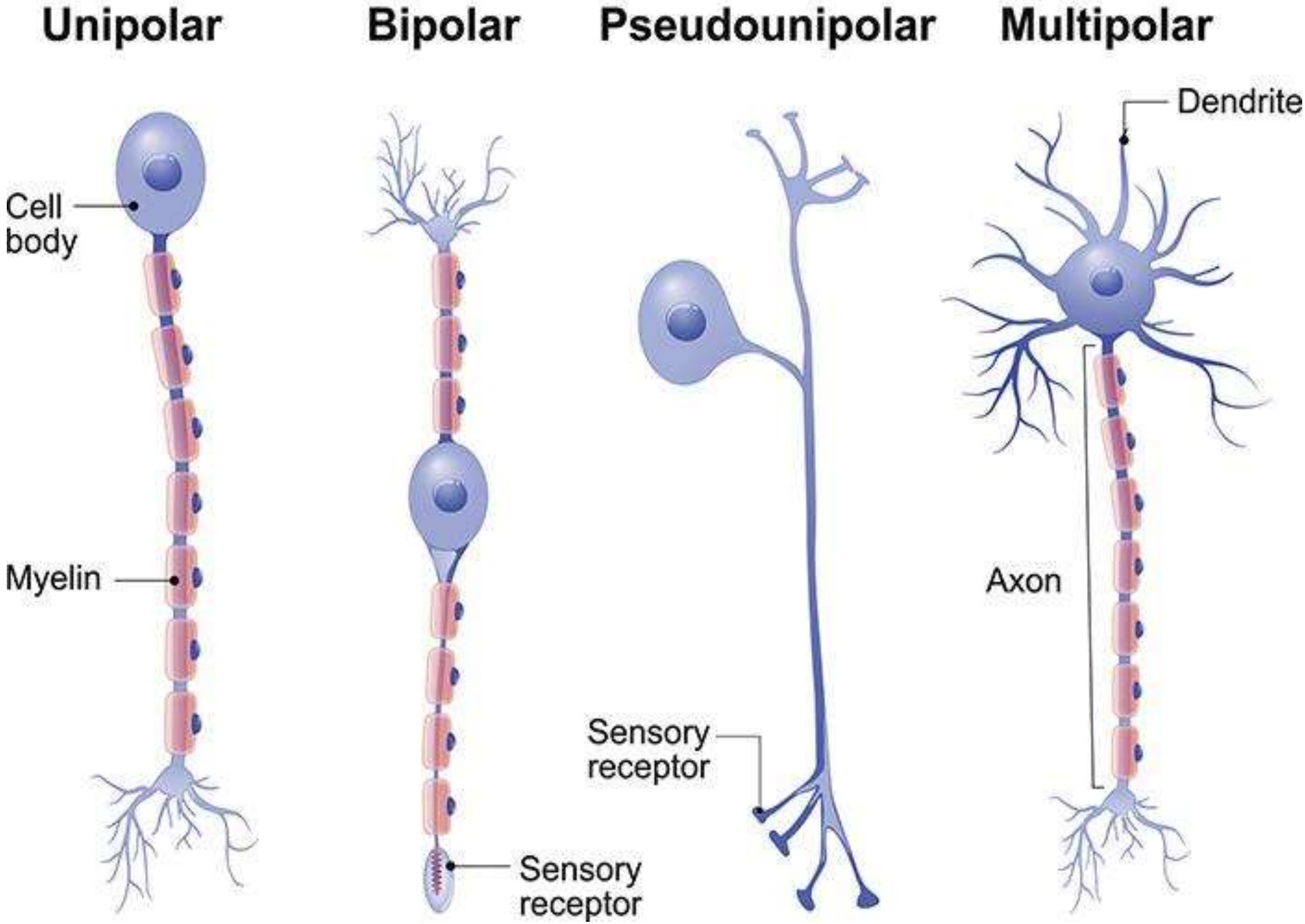
There are **many types** of neurons according to its structure:

**1- Unipolar**: Unipolar cells are exclusively sensory neurons. That is mean their dendrites are receiving sensory information only.

**2 - Bipolar**: 1 axon and 1 dendrite. They are found mainly as a part of the retina.

**3- Multipolar**: 1 axon and 2 or more dendrites.

**4- Pseudounipolar**: This type of neuron contains an axon that has split into two branches.


Unipolar
Bipolar
Pseudounipolar
Multipolar
Cell body
Myelin
Sensory receptor
Sensory receptor
Dendrite
Axon

# Electrical potentials of nerves

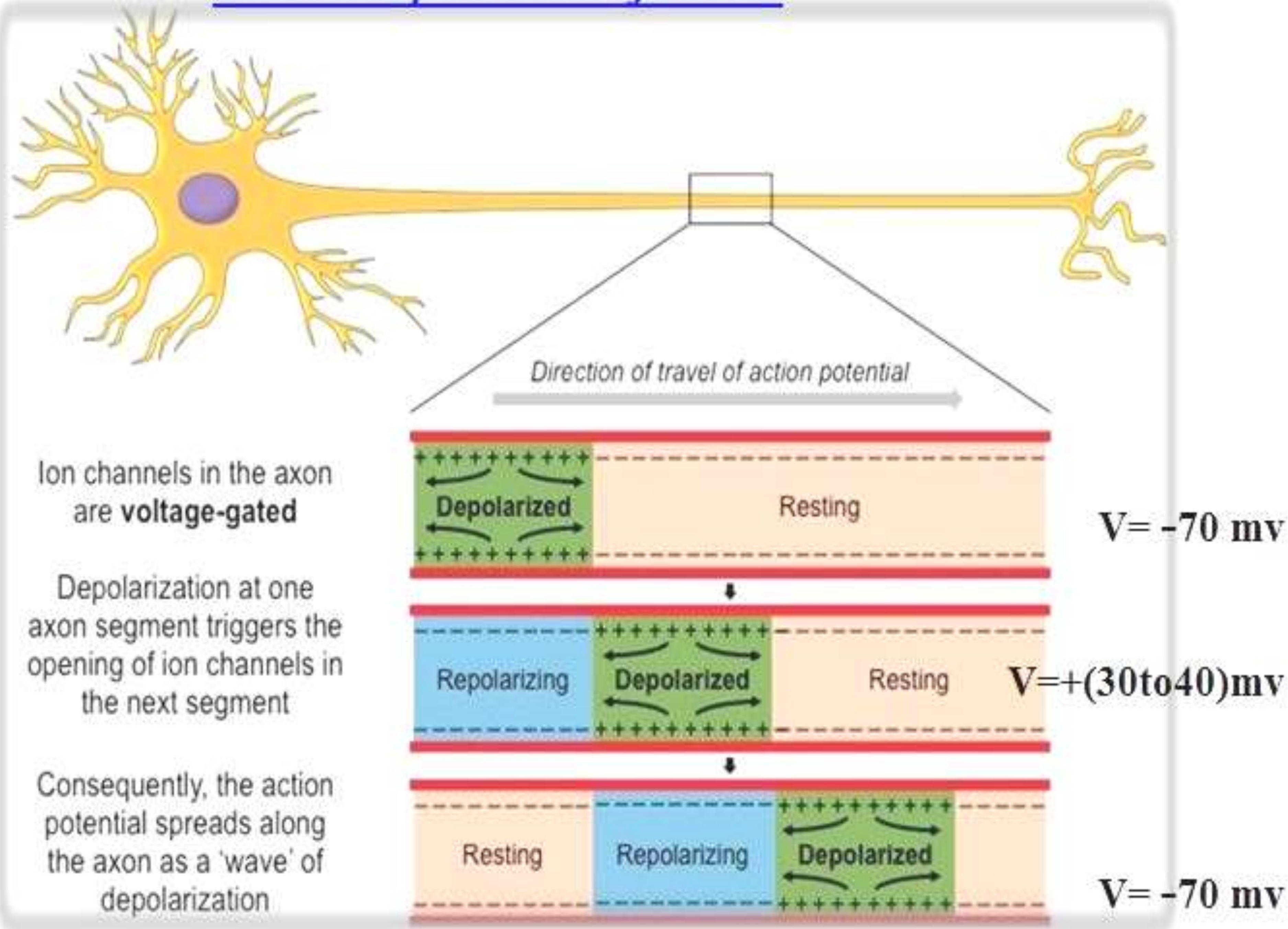
Across the surface or membrane of every neuron is an electrical potential (**voltage**) difference due to the presence of more negative ions **on** the **inside** of the membrane than on the **outside**.

The neuron is said to be polarized. The inside of the cell is typically **60** to **90 mV** more negative than the outside. This potential difference is called the ***resting potential*** of the neuron. When the neuron is stimulated, a large momentary change in the resting potential occurs at the point of ***stimulation***.

This potential change, called the ***action potential***, propagates along the axon. The action potential is the major method of **transmission of signals within the body.**

An axon can transmit in either direction. However, the synapse that **connects** it to another neuron only permits the action potential to move along the axon away from its own cell body.

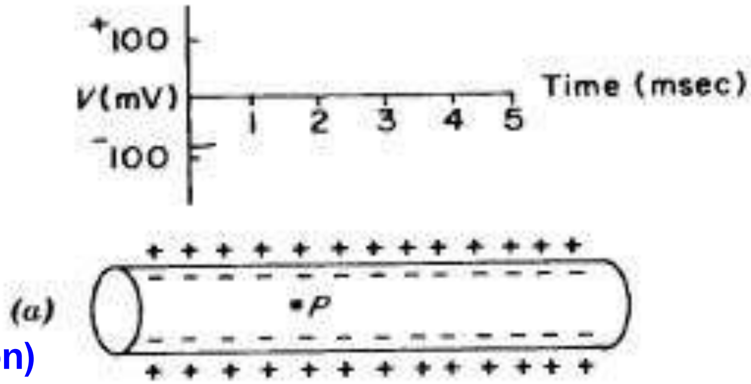
# Electrical potentials of nerves



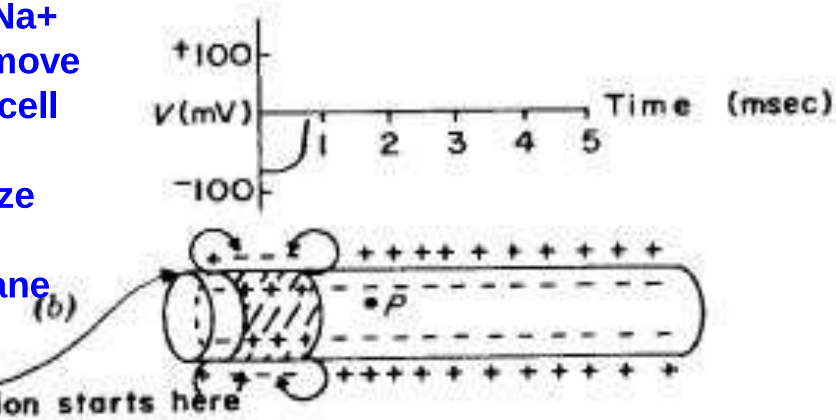
(d and e) mean while K+
**ions move out of the core of the axon and restore the resting potential**
the membrane *depolarize*

The voltage pulse moving along the nerve is the action potential

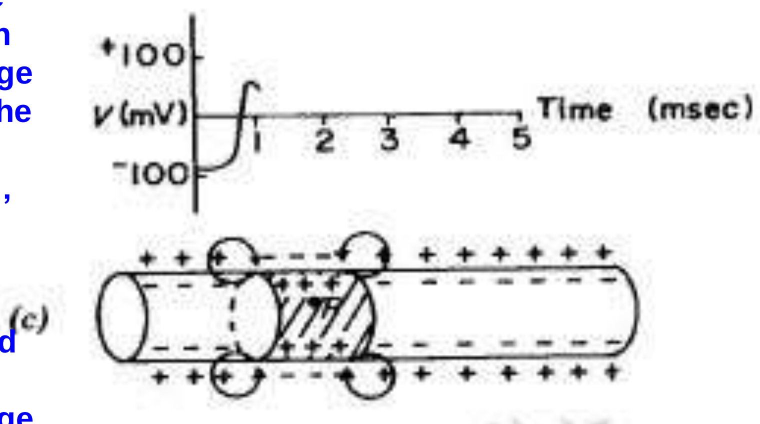
**a)The axon has a resting potential of about (-80mv)**

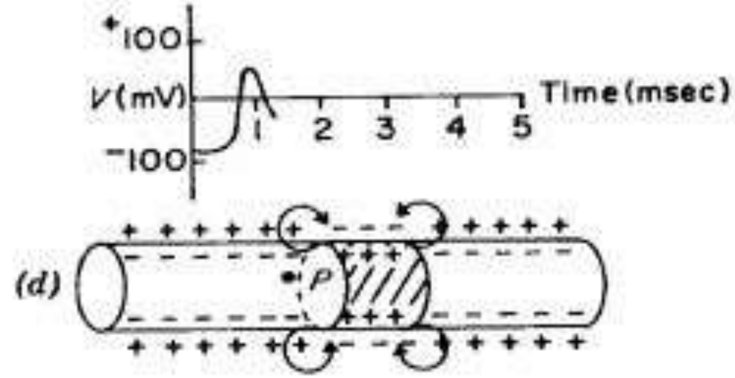


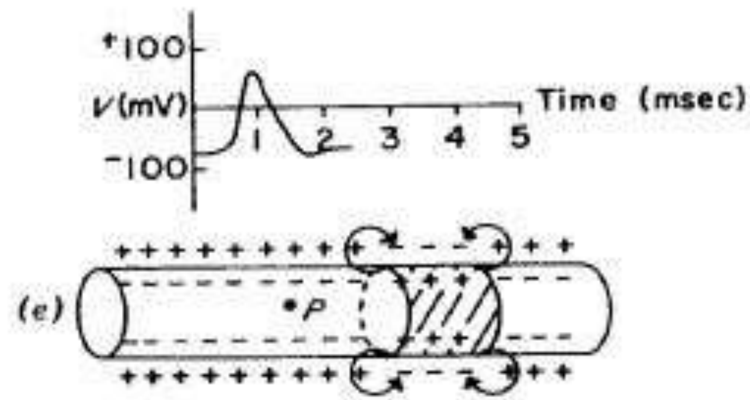

**b)Stimulation) on the left causes Na+ ions to move into the cell and depolarize the .membrane**




**c) The positive current flow on the leading edge ,indicated by the arrows stimulates the , regions to the right so that depolarization takes place and the potential change propagates**



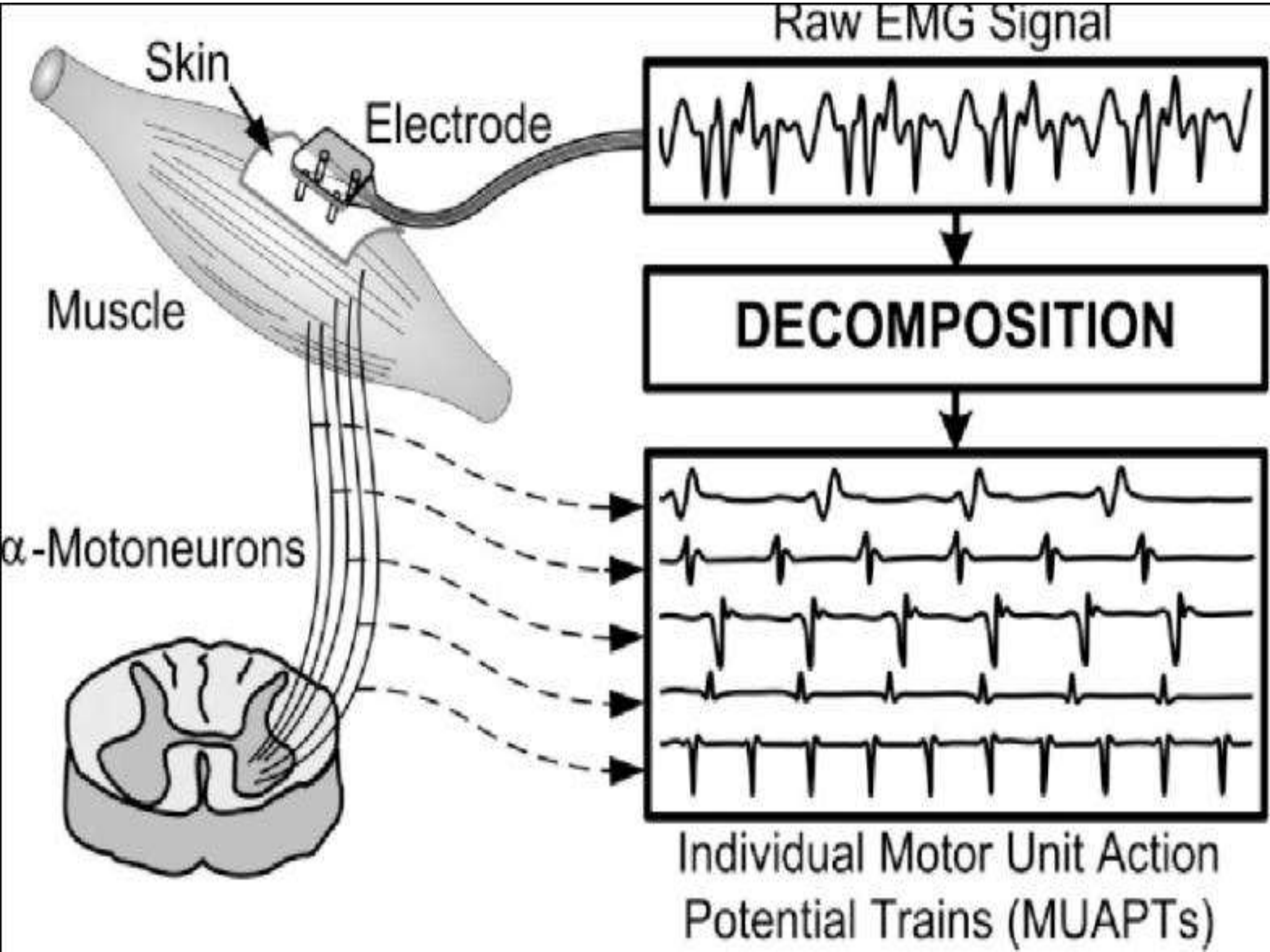
# Electrical signals from Muscle (EMG)

In this section we briefly trace the transmission of the action potential from the axon into the muscle, where it causes muscle contraction. the record of the potentials from muscles during movement is **called** the ***electromyogram*** ***EMG*** .

A muscle is made up of many motor units. motor unit consists of a single branching neuron from the brain stem or spinal cord and ( 25 – 2000) muscle fibers(cells)it connects to via motor end plates

Muscle action is initiated by an action potential that travels along an axon and is transmitted across the motor end plates into the muscle fibers, causing them to contract. The record of the action potential in signal muscle cell

**Surface electrode attached to the skin measures the electrical signal from many motor units**


Raw EMG Signal
Skin
Electrode
Muscle
DECOMPOSITION
α-Motoneurons
Individual Motor Unit Action
Potential Trains (MUAPTs)

# Electrical potential in the Heart (ECG)

The record of the hearts potentials on the skin is called the *electrocardiogram* ***ECG***

The relationship between the pumping action of the heart and the electrical potentials on the skin

the location of the electrodes for obtaining the ECG located on the left arm(LA), right arm (RA), and left leg (LL).

The measurement of the potential between RA and LA is called **Lead I**

The measurement of the potential between RA and LL is called **Lead II**

The measurement of the potential between LA and LL is called **Lead III**

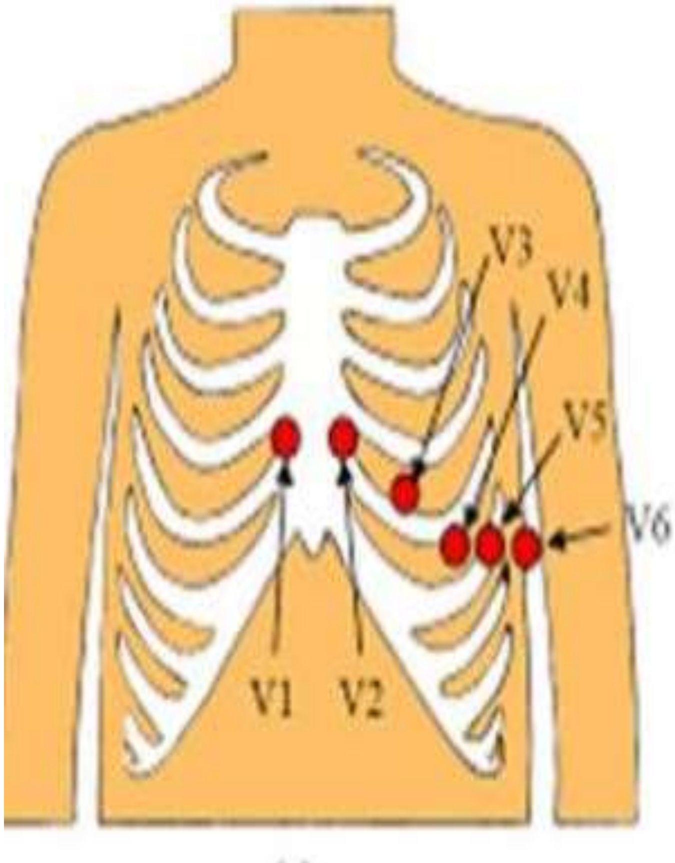
Three augmented lead configurations **,and a VF , a VL, a VR**

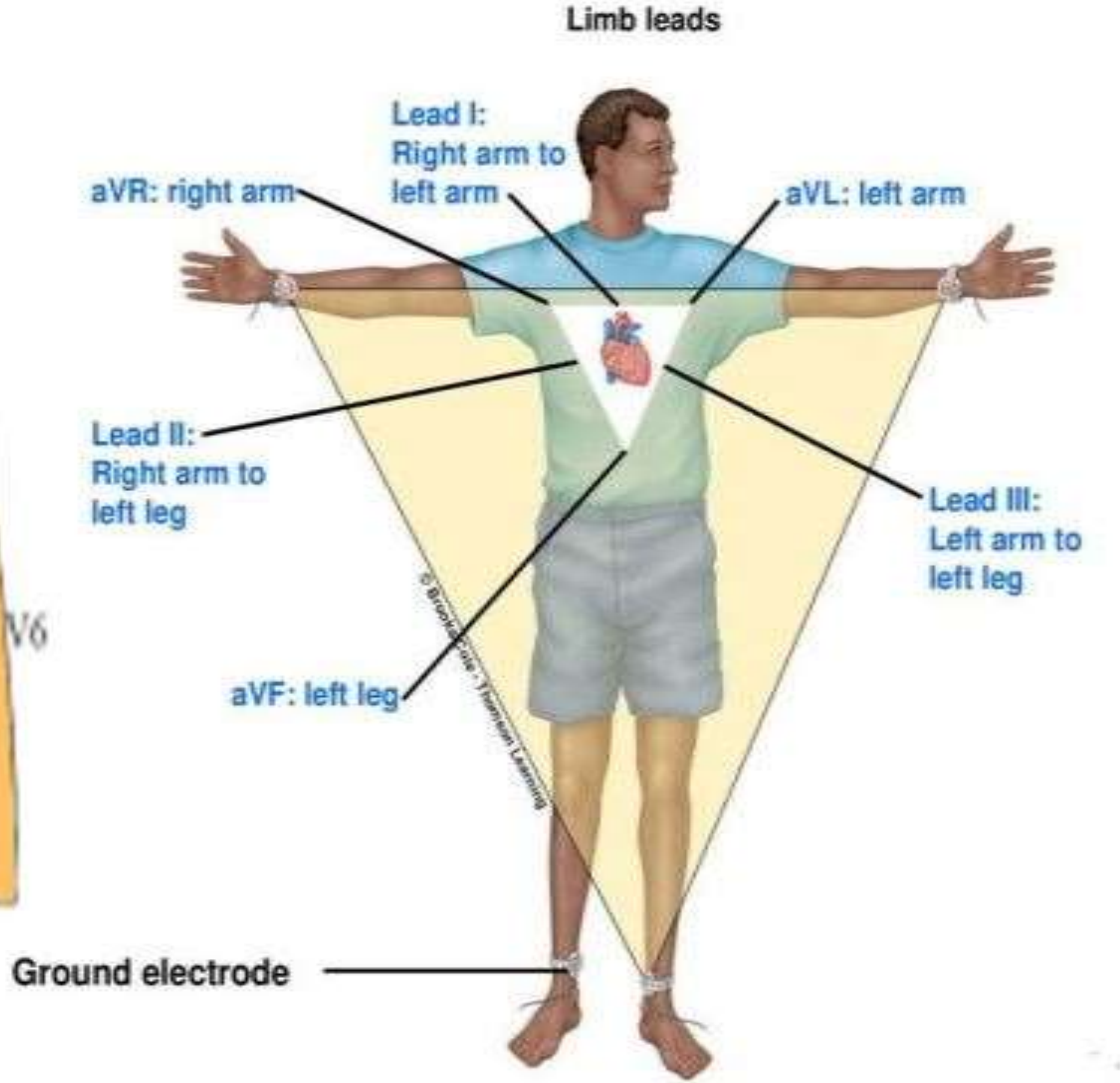
are also obtained in the frontal plane

lead ,one side of the recorder is connected to **RA** for the a VR

and the other side is connected to the center of two resistors connected to **LL** and **LA**

Electrode is moved across the chest wall to the six different positions. (V1,V2,V3,V4,V5,V6)



Each ECG tracing maps out a projection of the electric vector, or the electrical activity of the heart

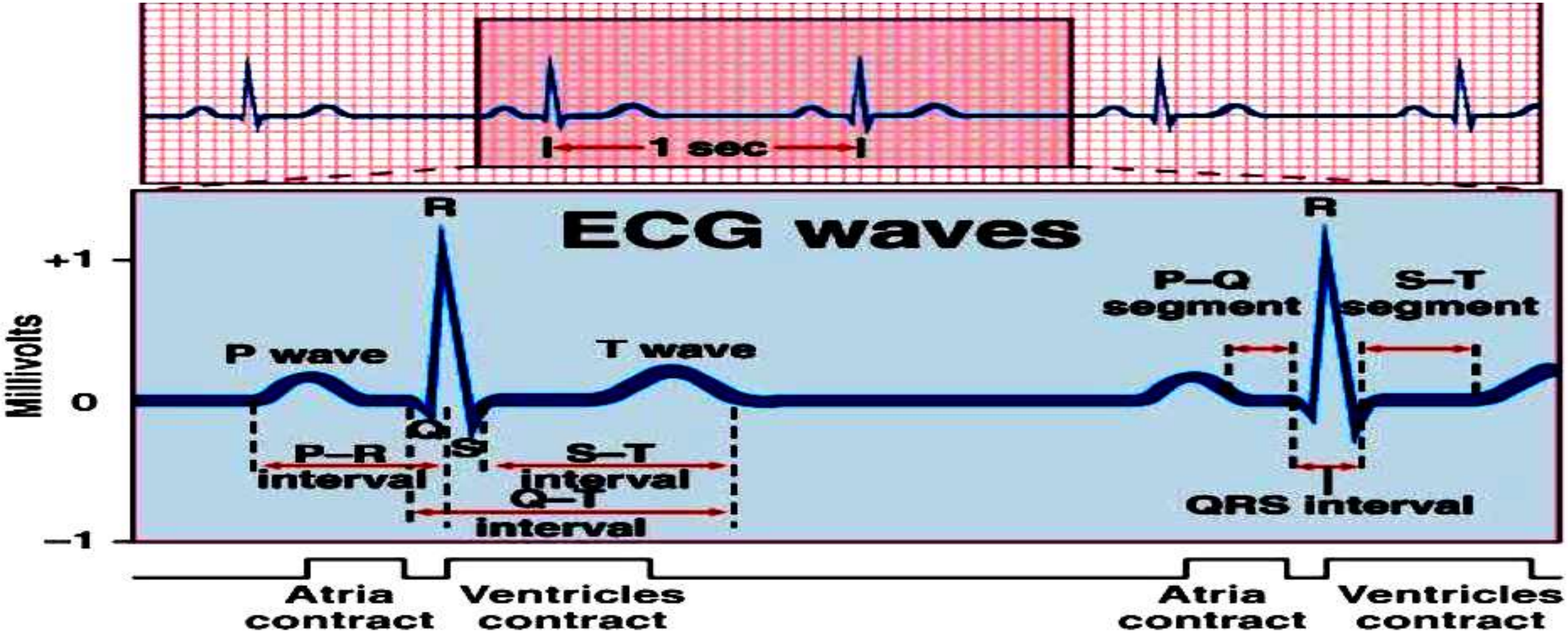
**The major electrical events of the normal heart cycle are:**

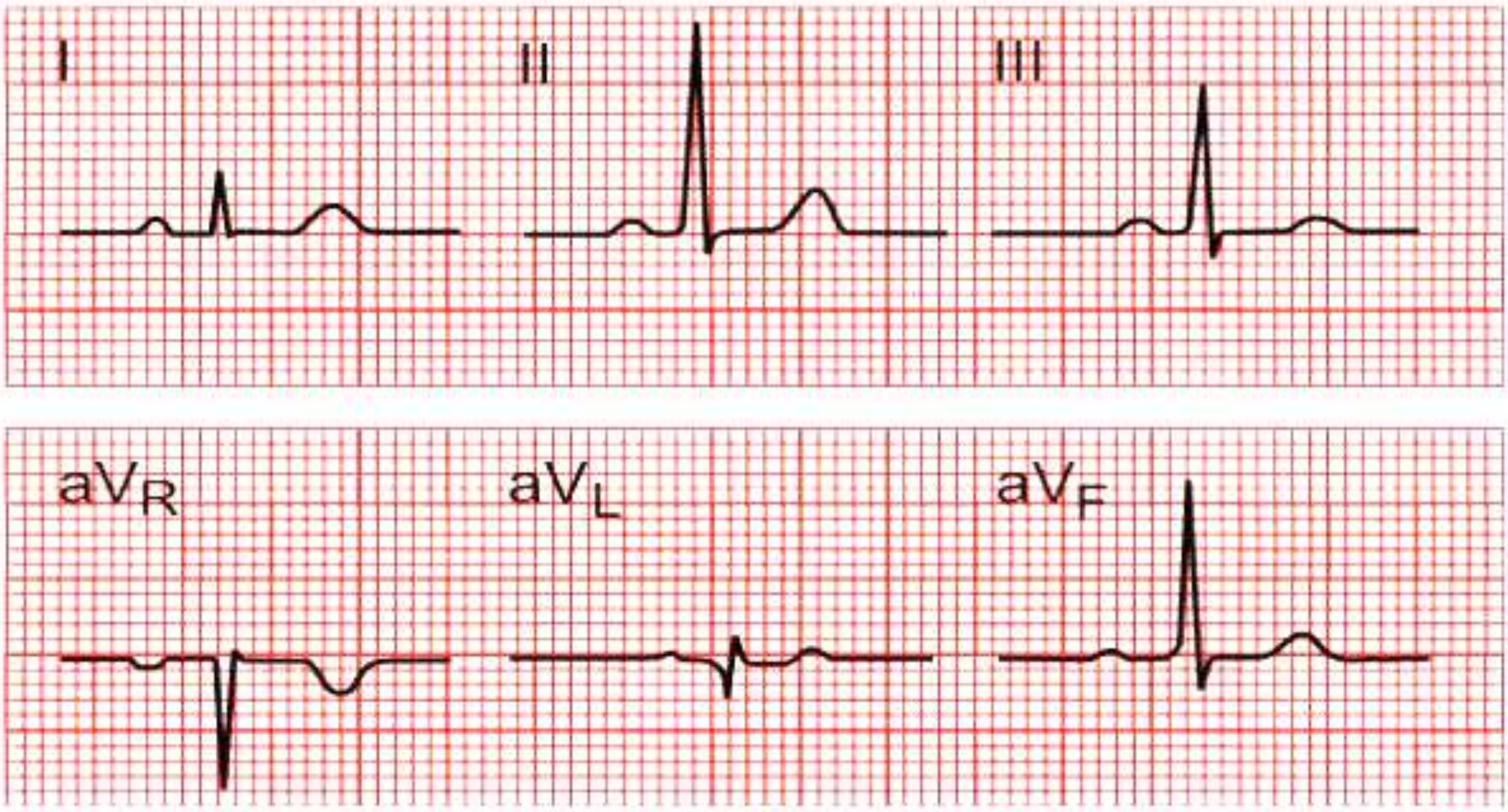
*1-The atrial **depolarization** ,which produces the **P wave**.*

*2-The atrial **repolarization** ,which is rarely seen and is unlabeled. .*

*3-The ventricular **depolarization** ,which produces the **QRS complex**.*

*4-The ventricular **repolarization** ,which produces the **T wave** .*



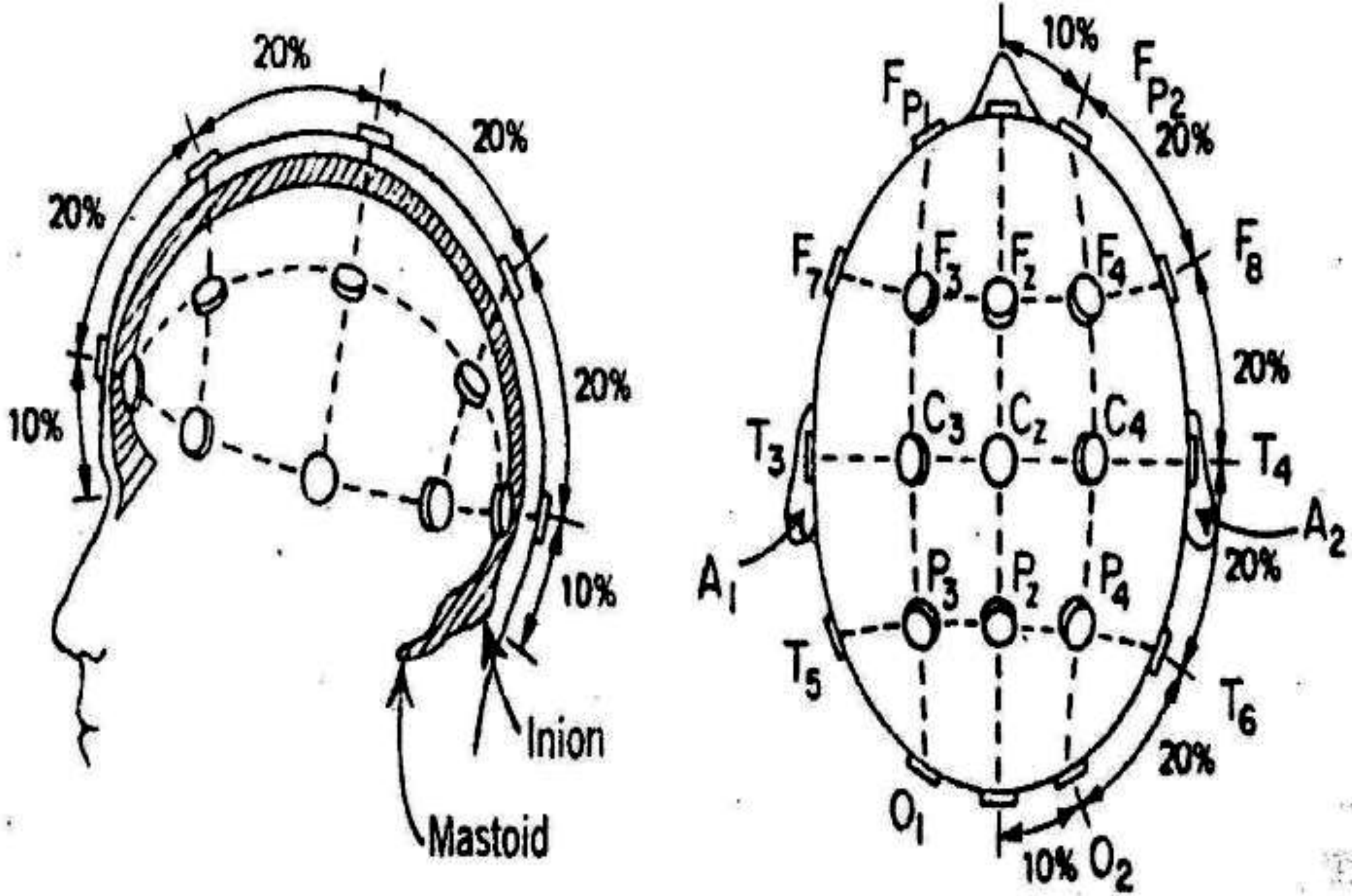



***Six frontal plane ECG, some cases the waveform is .positive and in other cases it is negative***

## Electrical signals from Brain (EEG)

**The recording of the signals from the brain is called the *electroencephalogram EEG***

the EEG is used as an aid in the diagnosis of disease involving the brain Electrodes for recording the signals are They are attached to the often small discs of chloride silver. head at locations that depend upon the part of the brain to be studied. The international standard 10 -20 system of Since asymmetrical activity is often an electrode location. indication of brain disease, the right side signals are often compared to the left side signals




*International standard 10 -20 system of electrode location for EEG*

The ***frequencies*** of the EEG signals seem to be dependent upon the mental activity of the subject ,for example , a relaxed person usually has an EEG signal composed primarily of . *alpha waves* frequencies from **8 to 13 Hz** ,or When a person is more alert higher frequency range , the **beta wave** range **above** 13Hz) ,dominates the EEG signal ,the various **frequency bands** are as follows:

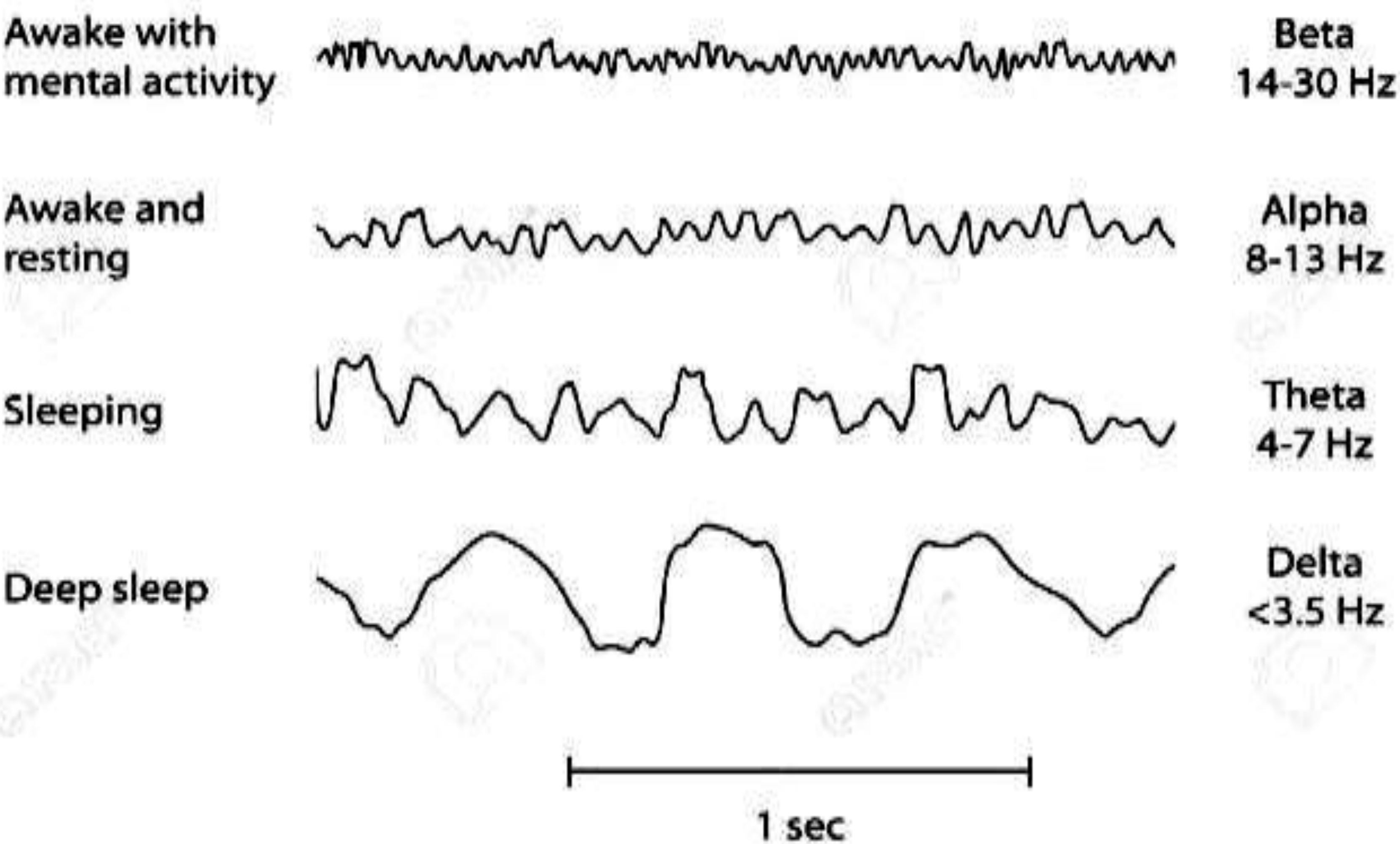
*** Delta ( δ) ,or slow [0.5 to 3.5 Hz]**

*** Theta (θ) ,or intermediate slow [4 to 7 Hz]**

*** Alpha (α ) [8 to 13 Hz]**

*** Beta (β ) ,or fast [greater than 13Hz]**

# Normal Adult Brain Waves



# Electrical signals from the Eye (ERG &EOG)

The recording of potential changes produced by the eye when the retina is exposed to a flash of light is called ***the electroretinogram (ERG)***

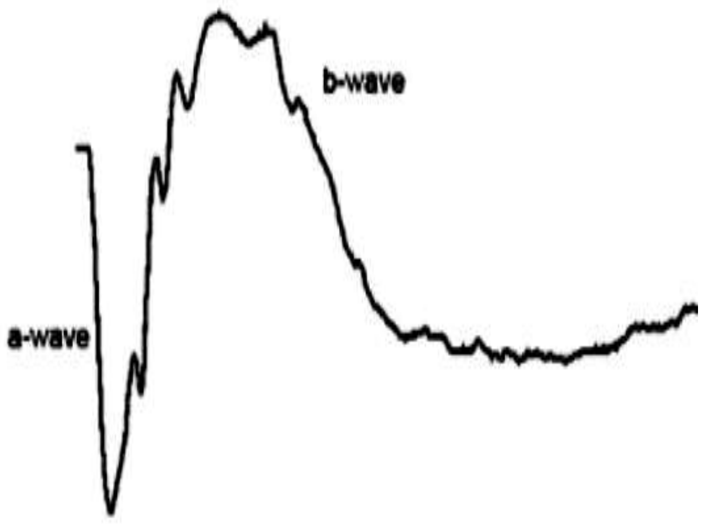
**One electrode** is located in a contact lens that fits over the cornea and the other electrode is attached to the ear or forehead to approximate the potential at the back of the eye

***The electroculogram (EOG)***

is the recording of potential changes due to eye movement. For this measurement.

a pair of electrodes is attached near the eye.

*potential change for horizontal movement of the eyeball*



# magnetic signals from the Heart & Brain (MCG & MEG)

Since a flow of electrical charge produces a **magnetic field**, a magnetic field is produced by the ***current in the heart during depolarization and repolarization***.

***magnetocardiography*** measured these very weak magnetic fields around the heart, the recording of the heart's magnetic field is the **magnetocardiogram MCG.**

**The magnetic field around the heart is about *$5 \times 10^{-11}$ tesla (T)***