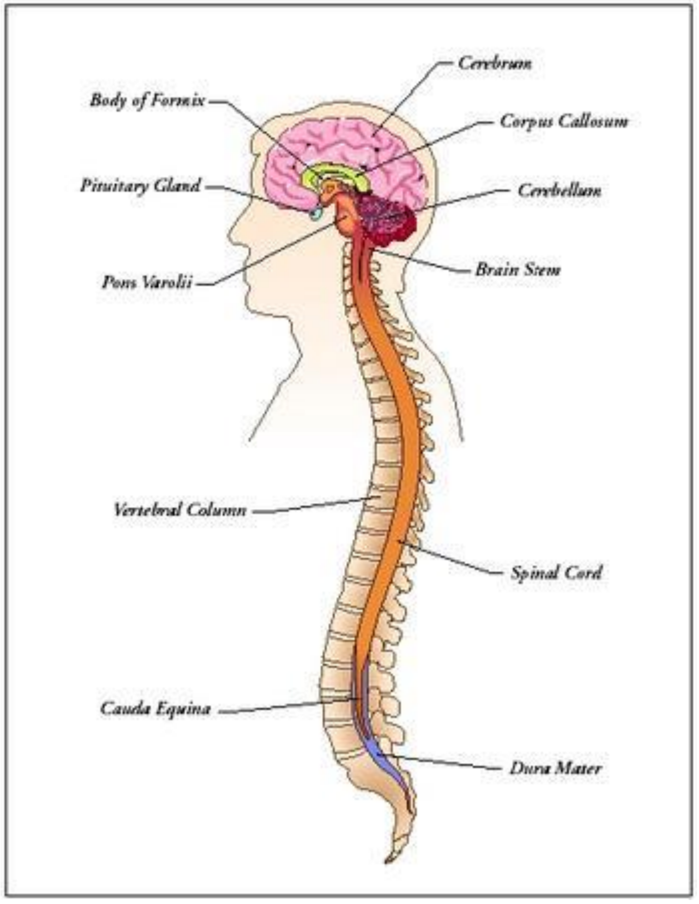
CHAPTER (1)
ELECTRICITY WITHIN THE BODY

- **The nervous system plays a fundamental role in nearly every body function. Basically, a central computer (the brain) receives internal and external signals and (usually) makes the proper response. The information is transmitted as electrical signals along various nerves.**

1.1. The Nervous System and the Neuron:

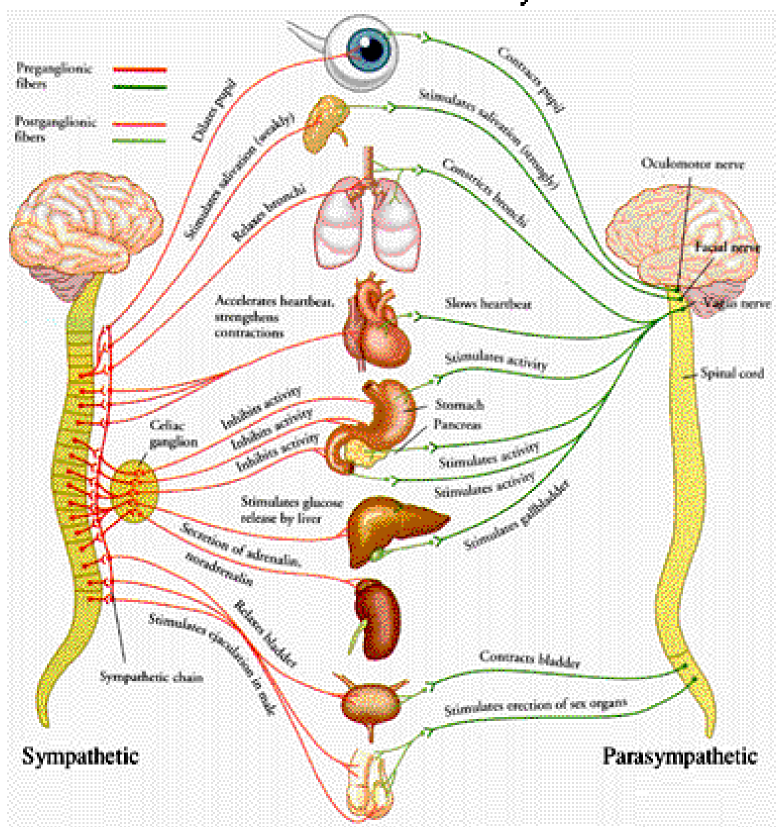
- The nervous system can be divided into two parts:
- The central nervous system consists of the brain, the spinal cord, and the peripheral nerves-nerve fibers (neurons) that transmit sensory information to the brain or spinal cord (afferent nerves) and nerve fibers that transmit information from the brain or spinal cord to the muscles and glands (efferent nerves).
- The autonomic nervous system controls various internal organs such as the heart, intestines, and glands. The control of the autonomic nervous system is essentially involuntary.

Central nervous system

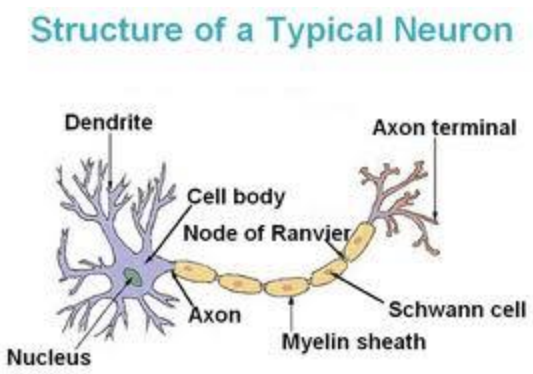


Autonomic nervous system

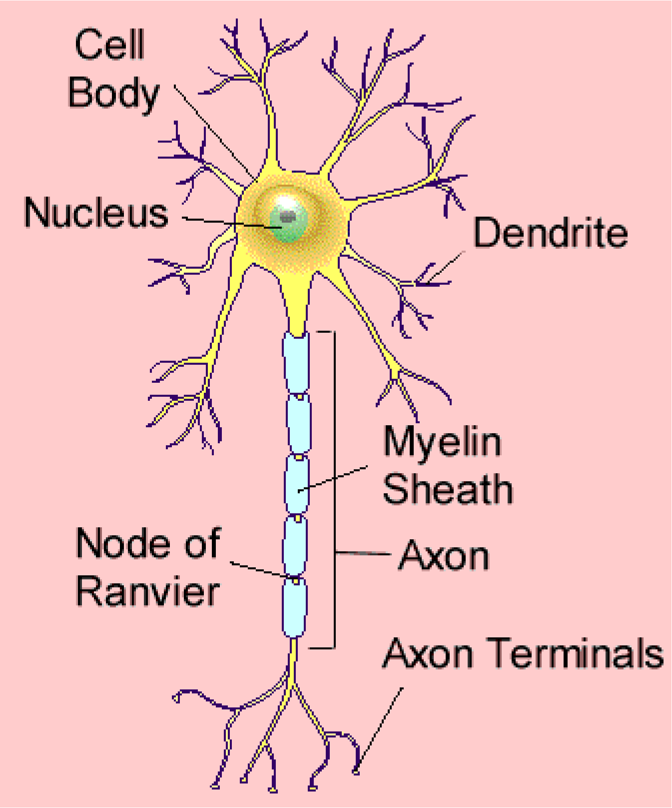
Autonomic Nervous System*



The basic structural unit of the nervous system is the neuron .A neuron consists of a cell body that receives electrical messages from other neurons through contacts called synapses located on the dendrites or on the cell body. The dendrites are the parts of the neuron specialized for receiving information from stimuli or from other cells. If the stimulus is strong enough, the neuron transmits an electrical signal outward along a fiber called an axon.



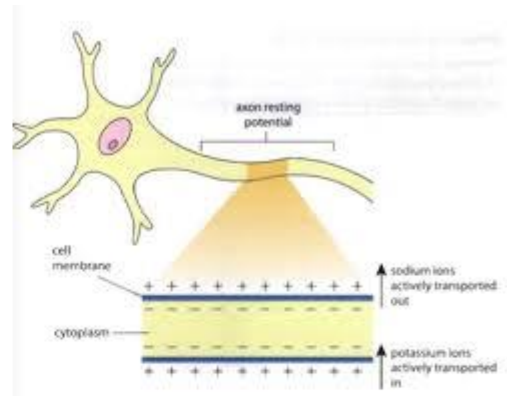
The neuron

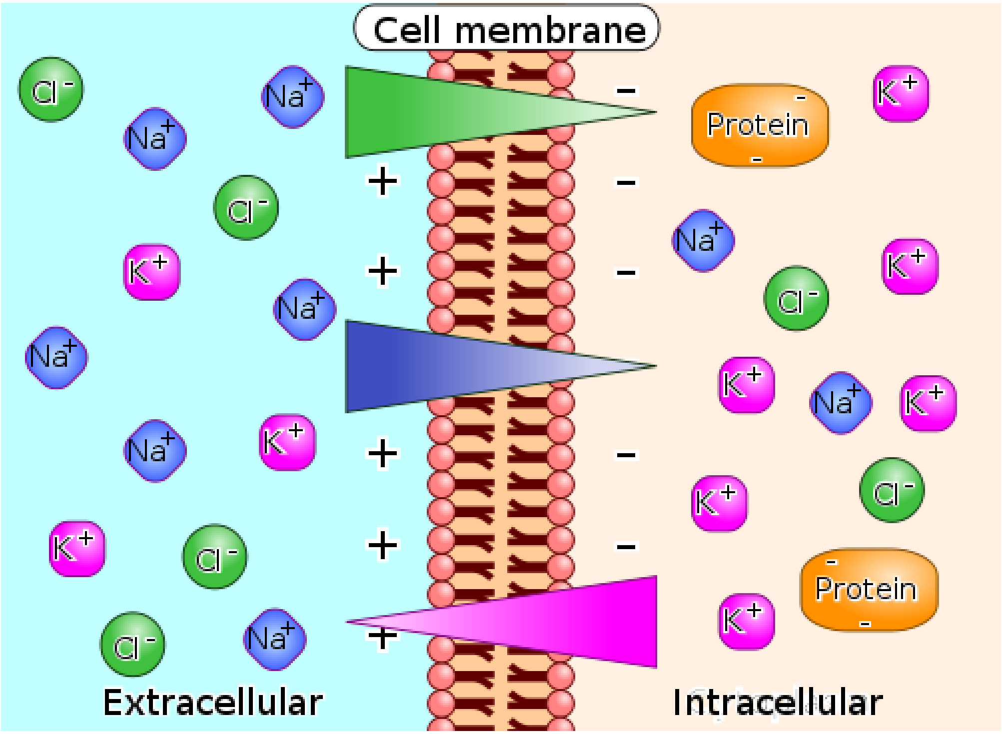


Cell
Body
Nucleus
Dendrite
Myelin
Sheath
Node of
Ranvier
Axon
Axon Terminals

Resting potential

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.



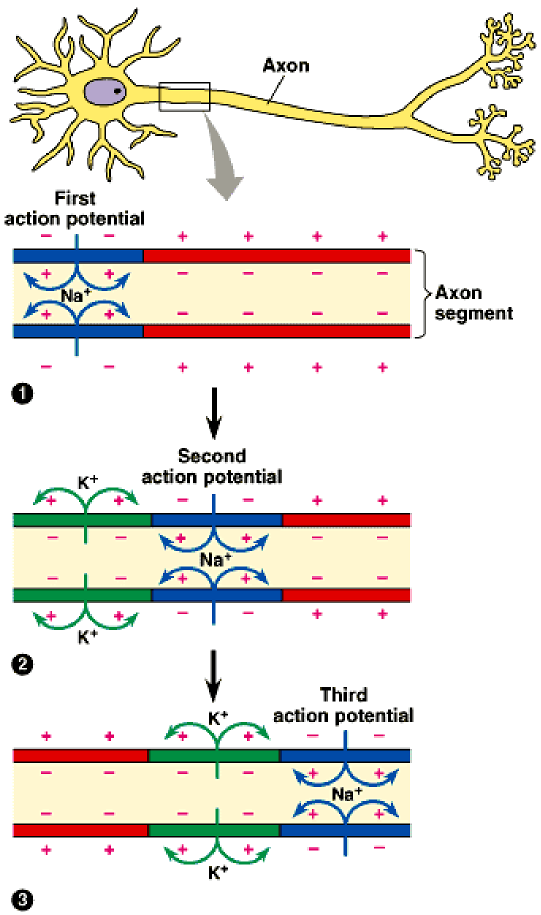

Cell membrane
Extracellular
Intracellular
Cl-
Na+
K+
Protein

Action potential

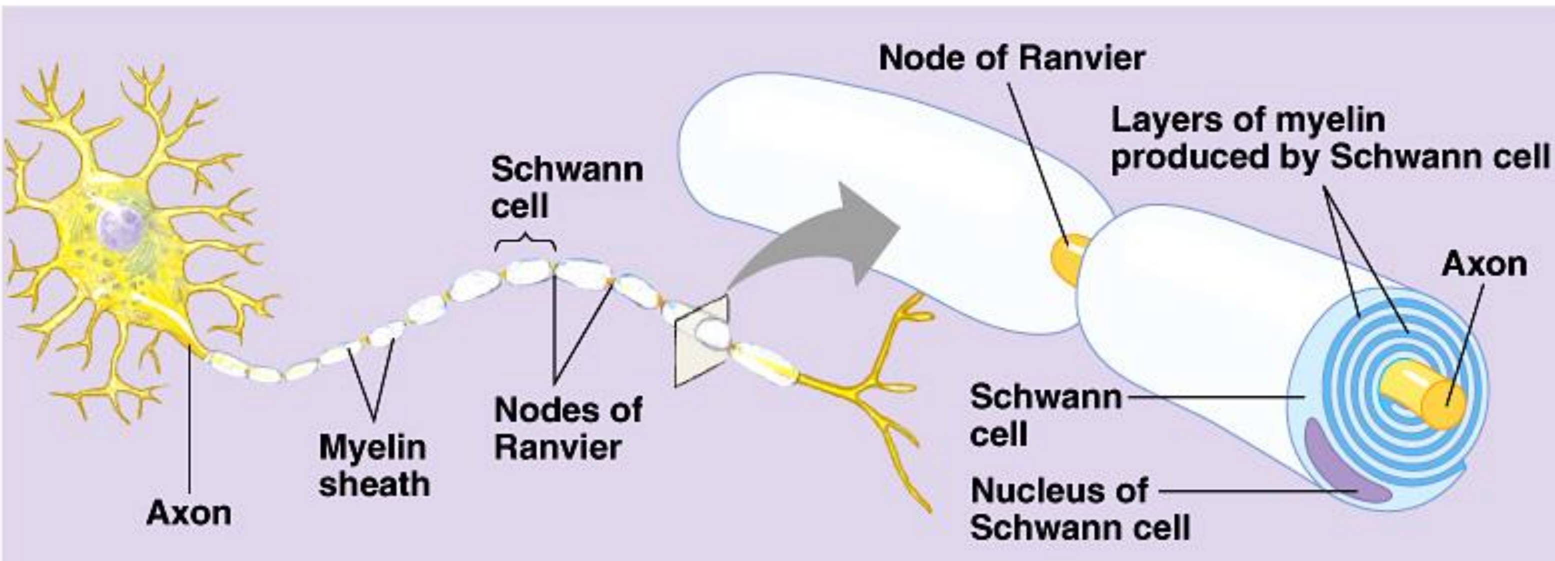
-If the left end of the axon is stimulated, the membrane walls become porous to Na^+ ions and these ions pass through the membrane causing it to **depolarize**. The inside momentarily goes positive to about 50 mV. **The reversed potential in the stimulated region causes ion movement.**

-The positive current flow on the leading edge, stimulates the regions to the right so that depolarization takes place and the potential change propagates

- Meanwhile the point of original stimulation has recovered (repolarized) because K+ ions have moved out to restore the resting potential . The voltage pulse is the action potential.



Myelinated neurons



Types of nerve fibers:

- *- <u>Myelinated nerve fiber:</u>* **They are nerves in which the membranes of axons are covered with a fatty insulating layer called myelin that has small uninsulated gaps called nodes of Ranvier every few millimeters . The myelin sleeve is a very good insulator, and the myelinated segment of an axon has very low electrical capacitance and the action potential seems to jump from one node to the next.**
- *<u>Unmyelinated nerve fiber:</u>* **They are nerves in which the axons have no myelin sleeve (sheath).**
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- **Myelinated axon conducts action potentials much faster than unmyelinated.**
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Two primary factors affect the speed of propagation of the action potential:

- The resistance within the core of the membrane
- The capacitance (or the charge stored) across the membrane.
- A decrease in either will increase the propagation velocity.

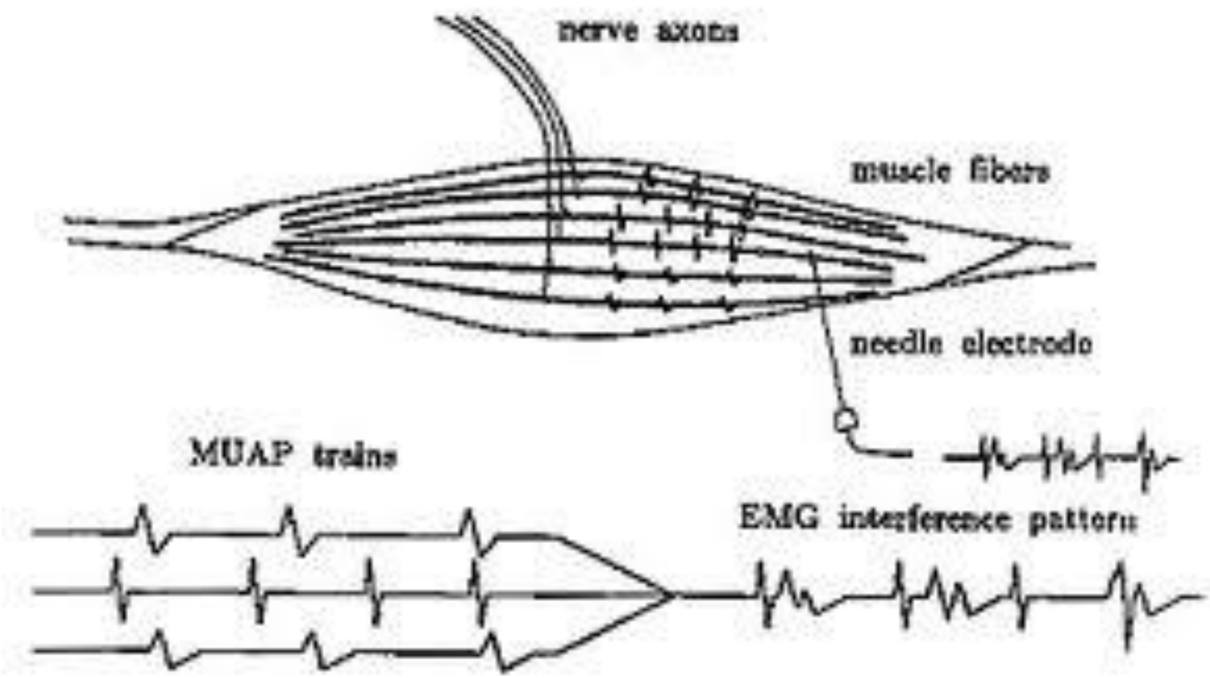
- The internal resistance of an axon decreases as the diameter increases, so an axon with a large diameter will have a higher velocity of propagation than an axon with a small diameter.

Electrical Signals from Muscles – The Electromyogram (EMG)

The transmission of the action potential from the axon into the muscle causes muscle contraction. The record of the potentials from muscles during movement is called the *electromyogram,* or EMG.

EMG

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. Such a measurement is made with a very tiny electrode (microelectrode) thrust through the muscle membrane and the reference electrode is immersed in the fluid surrounding the cell.



Types of recording electrode:

- EMG electrodes usually record the electrical activity from several fibers.
- \- A *surface electrode* attached to the skin measures the electrical signals from many motor units. - A *concentric needle electrode* inserted under the skin measures single motor unit activity by means of insulated wires connected to its point

Response of sensory and motor nerves to different stimulus' length:

- The action potential appears in the EMG after a latency period (the time between stimulation and the beginning of the response).

- **Measurement of the velocity of action potential in motor nerves:**
- The velocity of the action potential in motor nerves can be determined as follows:
- \- Stimuli are applied at two locations, and the latency period for each response is measured .
- \- The difference between the two latency periods **(Δt)** is the time required for an action potential to travel the distance between them **(Δx)**.
- \- **The velocity of the action potential is this distance divided by this time.**

- **Measurement of the conduction velocity for sensory nerves:**
- The conduction velocity for sensory nerves can be measured as follows:
- - Stimulus is applied at one site and recording electrodes are placed at several locations that are known distances from the point of stimulation.
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Electrical Signals from the Heart – The Electrocardiogram (ECG):

[A] General blood circulation of the heart:

- The heart has four chambers ,the two upper chambers, the left and right atria, are synchronized to contract simultaneously, as are the two lower chambers, the left and right ventricles. The right atrium receives blood from the body and pumps it to the right ventricle. This ventricle pumps the blood through the lungs, where it is oxygenated. The blood then flows into the left atrium. The contraction of the left atrium moves the blood to the left ventricle, which contracts and pumps it into the general circulation; the blood passes through the capillaries into the venous system and returns to the right atrium.
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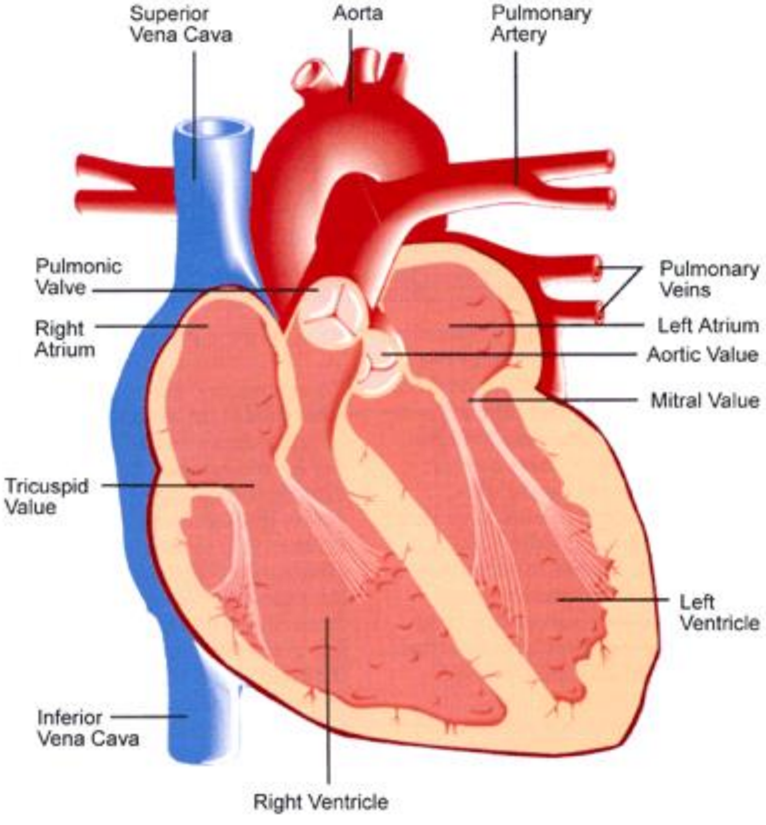
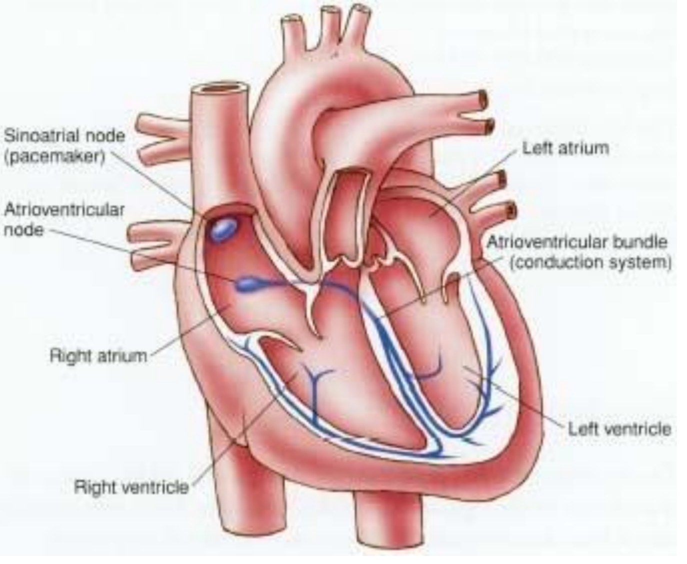
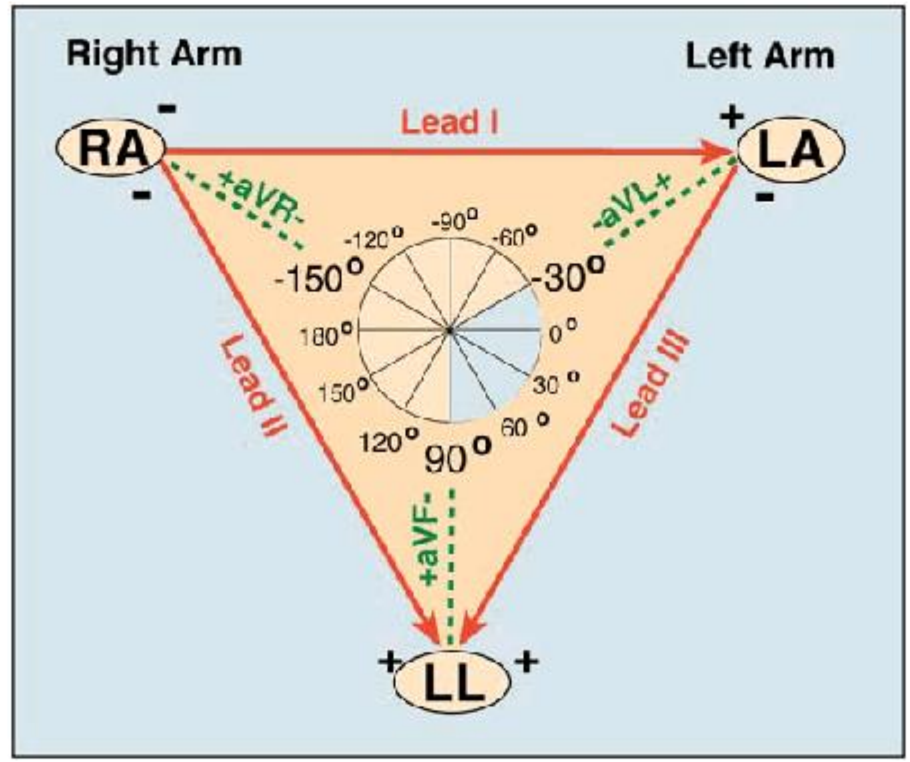

Superior
Vena Cava
Aorta
Pulmonary
Artery
Pulmonic
Valve
Pulmonary
Veins
Right
Atrium
Left Atrium
Aortic Value
Mitral Value
Tricuspid
Value
Left
Ventricle
Inferior
Vena Cava
Right Ventricle

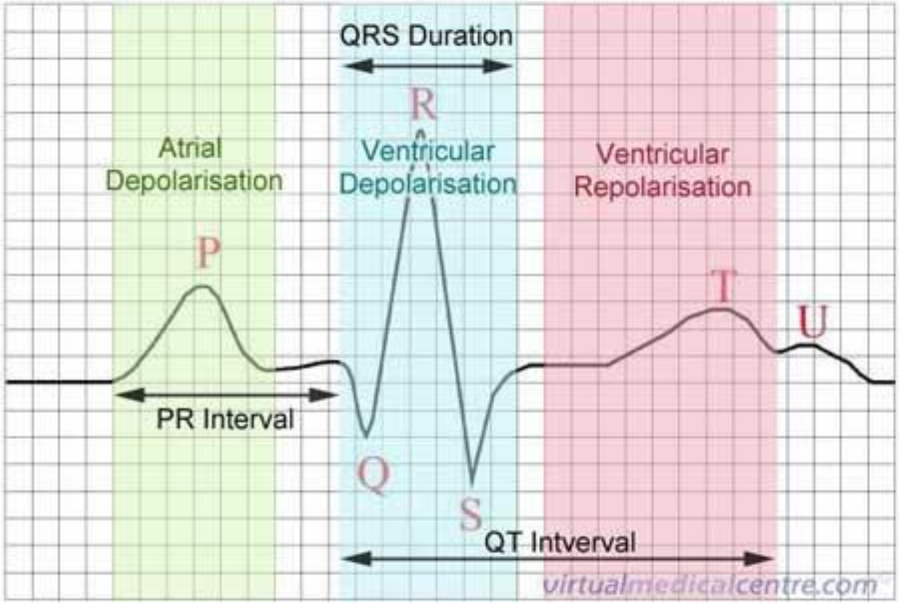

Sinoatrial node
(pacemaker)
Atrioventricular
node
Right atrium
Right ventricle
Left atrium
Atrioventricular bundle
(conduction system)
Left ventricle

Heart as an electrical conductor

The nerves and muscles of the heart can be regarded as sources of electricity enclosed in an electrical conductor, the torso. The surface electrodes for obtaining the ECG are most commonly 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 , that between RA and LL is called Lead II, and that between LA and LL is called Lead III



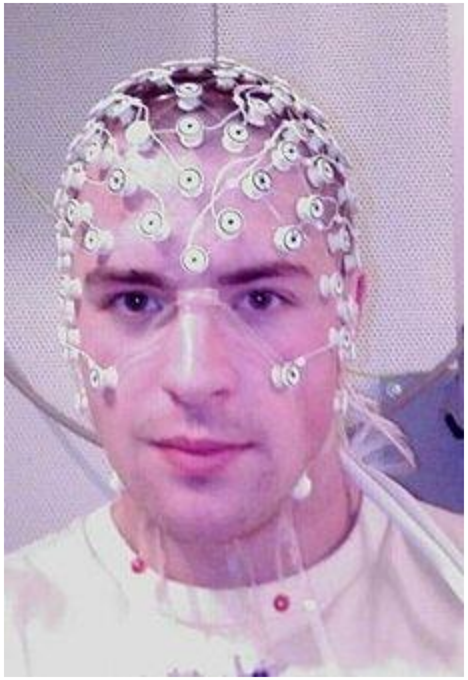
Major electrical event of normal heart



Electrocardiogram-What-Is-an-ECG-Performing-an-EKG-Video-flv[www.savevid.com].flv

Electroencephalography (EEG)

- *Electroencephalography* (EEG) is the recording of electrical activity along the scalp.



- The frequencies of the EEG signals seem to be dependent upon the mental activity of the subject.
- Delta (δ), or slow 0.5 to 3.5 Hz
- Theta (θ), or intermediate slow4 to 7 Hz
- Alpha (α)relaxed 8 to 13 Hz
- Beta (β), or fast (alert)greater than 13Hz

- **Importance of EEG:**
- EEG is used as an aid in the diagnosis of diseases involving the brain. It is most useful in the diagnosis of *epilepsy* and allows classification of epileptic seizures.
- The EEG aids in confirming brain tumors since electrical activity is reduced in the region of a tumor.
- The EEG is useful for indicating the *anesthesia* level of the patient.
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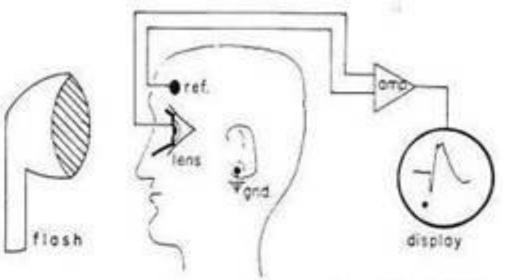
Electroretinogram (ERG)

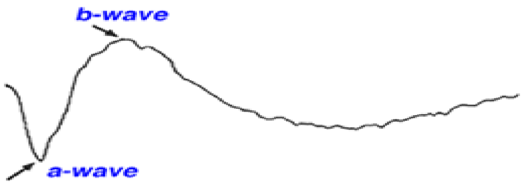
The recording of potential changes produced by the eye when the retina is exposed to a flash of light is called the *electroretinogram* (ERG). One electrode is located in a contact lens that fits over the cornea and the other electrode is attached to the ear or forehead to approximate the potential at the back of the eye



Carr & Siegel, 1990

B wave

The B wave is the most interesting clinically since it arises in the retina. The B wave is absent in the ERG of a patient with inflammation of the retina that results in pigment changes, or *retinitis pigmentosa.*



The basic waveform of the ERG

Electrooculogram (EOG)

The electrooculogram (EOG) is the recording of potential changes due to eye movement. For this measurement, a pair of electrodes is attached near the eye . The EOG potential is defined as zero with the eye in the position fixed on the reference spot labeled 0º.