Electricity within the Body

- **Introduction**

All functions in the body, voluntary and involuntary electricity is involved. So all movements are related to electrical movement.

There are two aspects of electricity and magnetism in medicine:

1. Electrical & magnetic effects generated inside the body.
2. We use electricity & magnetism to measure some of body functions.

The electricity generated inside the body serves for the control and operation of nerves, muscles, and other organs. The nervous system plays an important role in every part of body; the brain receives internal and external signals and usually makes proper response.

- **Nervous System & the Neuron**

Nervous system can be divided into two parts.

1. Central nervous system: consist of brain, spinal cord and the peripheral nerves.

Nerve fibers (neuron): that transmit sensory information to brain or spinal cord are "**Afferent nerves**".

Nerve fibers: that transmit information from brain or spinal Cord to the appropriate muscles and glands are "**Efferent nerves**".

2. Autonomic nervous system: controls various internal organs such as heart, intestines and glands ((the control here is essentially involuntary)).

Neuron: is the basic structure unit of nervous system, which is specialized for reception and transmission of electrical signals.

- **Contents of neuron (nerve cell)**

1. *Cell body*: receives electrical massages from another neurons through contacts called "synapses", which are located on the "dendrites".

   Dendrites: Are the part of the neuron specialized for receiving information from other cells, (or stimuli).

2. *Axon:* (or nerve fibers) this carries the electrical signal to muscles, glands, or other neurons. It's usually covered by myelin sheath, except some parts called **Nodes of Synapse** : permit the transparent of a signal on one direction and prevent it from going back.

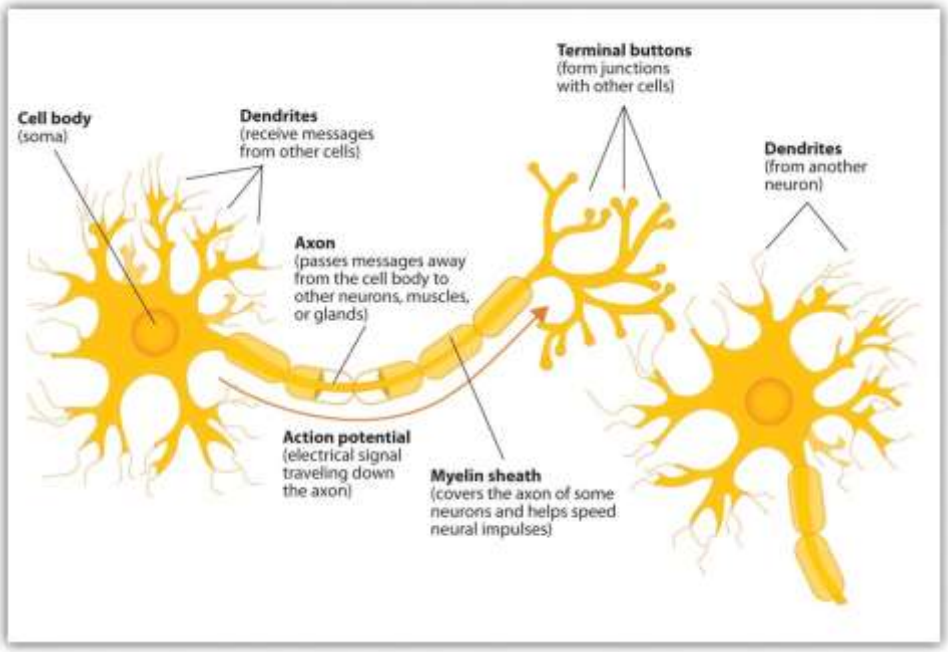


Figure (1). Schematic of a motor neuron.

- **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 the outside.

** A polarization neuron is mostly inside negative than the outside, 60 to 90 mV it is polarized. This potential difference is called "***Resting potential*** "of the neuron. when

the neuron is simulated, a momentary charge will happen from positive to negative, this potential change is called" ***Action potential***".

There are two primary factors affects the velocity of propagation of the action potential:

1. The Resistance within the core of the membrane.
2. The Capacitance (or the charge stored) across the membrane.

A decrease in either will increase the propagation velocity.

- **Electrical Signals from Muscles & EMG**

* The record of potentials from muscles during movement is called EMG (electromyogram).

* A muscle made up of many motor units, each one consist of a single branching neuron from spinal cord.

* Resting potential across the membrane of muscle fibers is similar to that of a nerve fiber.

Muscle Action: is initiated by an action potential that travels along an axon and is transmitted across the motor and plates into the muscle fibers, causing them contraction.

* Single muscle cells are usually not monitored in EMG examination because it is difficult to isolate a single fiber. Therefore, there are two methods for obtaining EMG:-

1. Surface electrode : It attached to the skin measures the electrical signals from many motor units.

2. Concentric needle electrode : It inserted under the skin measures single motor unit activity.

Many times nerve damage may results from decreased in conduction velocity. Typical velocities are 40 to 60 m/sec. velocity blow 10 m/sec would indicate a problem.

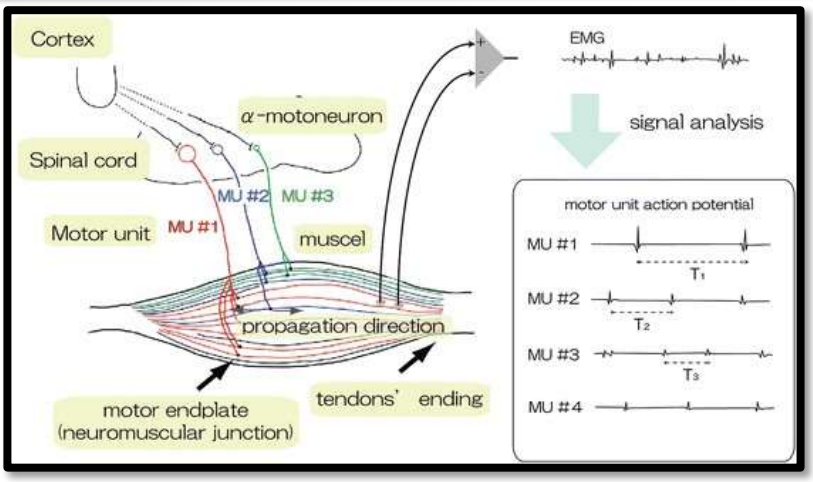


Figure (2). Electromyogram obtained with a concentric needle electrode and surface electrode.

- **Electrical Signal from the heart ECG**

* The action of the heart is controlled by an electrical signal initiated by **"Sinoatrial (SA) Node"** which is spontaneous stimulation of special muscle cells located in the right atrium.

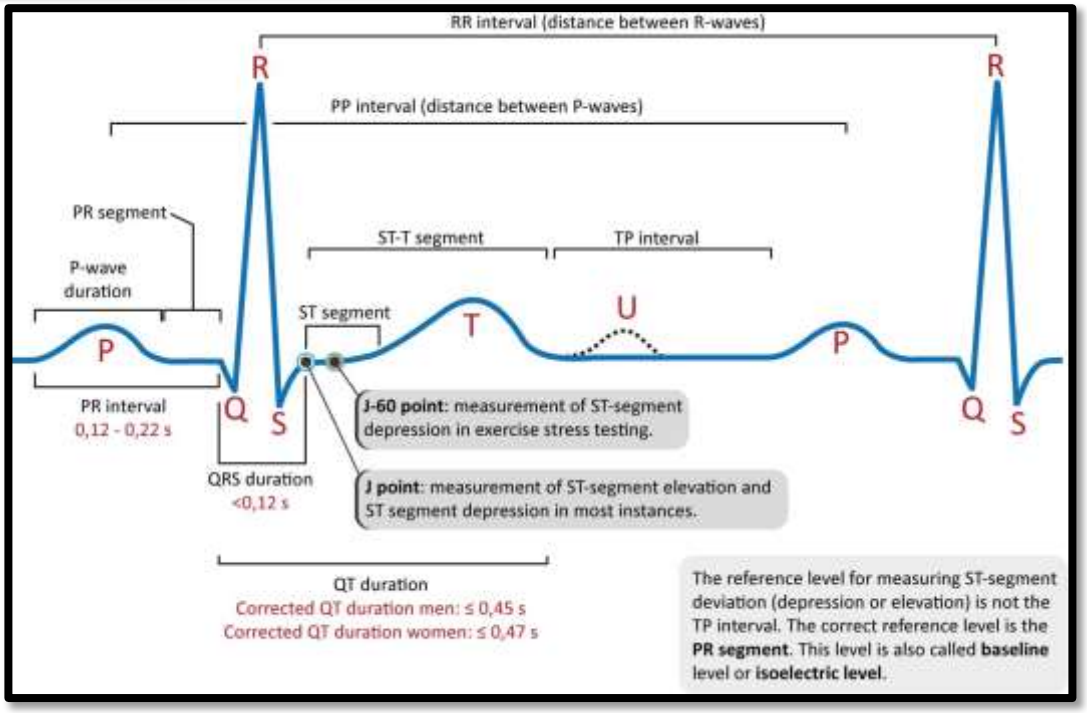
* SA node controls the pulse rate (72 pulse per min), it decreases or increases the pulse rate according to the demands of body to the blood.

* The electrical signal from SA node initiate depolarization of nerves and muscles of both atria, causing the atria to contract and pump blood into ventricles.

Repolarization of atria follows:

Measuring ECG:-

1. The potentials measured on the surface of the body depends on the location of the electrodes.
2. Surface electrodes for obtaining ECG are most commonly located in left arm (LA), right arm (RA) and left leg(LL).
3. ECG graphing contains 12 section:- (6) of them are in the frontal plane, other (6) are in the transverse plane in each section an electrode is located.



The sign of the waveform depends on:

1. direction of negative dipole vector
2. polarity
3. position of electrodes of measuring instrument

- **Electrical Signals from the Brain ECG**

The recording of the signals from the brain is called electroencephalogram or (EEG), which are due to primarily to the electrical activity of the neurons in the cortex of the brain.

* Electrode are small discs made of AgCI, these are attached to the head at locations that depend upon the part of brain to be studied.

* These electrodes out on the head at some areas, we record only the potential difference response to that area.

* The reference electrode is attached to the ear (A1 and A2). As shown in fig. (8), exams 8 to 16 channels are recorded.

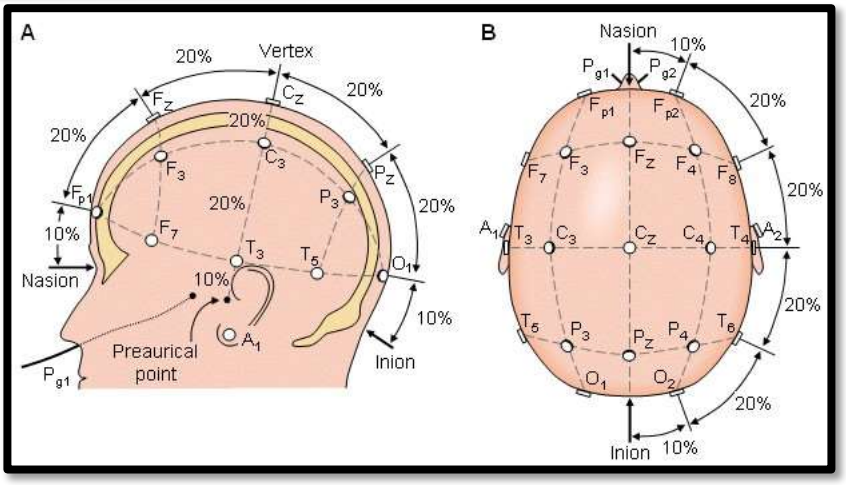


Figure (4). International standard 10-20 system of electrode location of EEGs.

* Asymmetrical activity is often an indication of brain disease the right signals compared to the left one.

* The amplitude of EEG signals is low (50 μV).

* The external noise is controlled, the potentials of muscle activity, such as eye movement, can cause artifacts in the record.

* The frequencies of EEG signals are depend on the metal activity of the subject .e.g. relaxed person frequency is from 8 to 13 Hz (α wave), while frequency of person in action is > 13 Hz (β wave)

Various frequency Bands:

- Delta δ or slow 0.5 to 3.5 Hz deep sleep
- Theta θ or intermediate 4 to 7 Hz light sleep
- Alpha α relaxed 8 to 13 Hz wake (relax)
- Beta β fast >13 in action

ECG advantages:

1. It's most useful in diagnosis of epilepsy and its classification.
2. It aids in confirming brain tumors since electrical activity recorded in the region of a tumor.
3. It's used to monitor in surgery when ECG cannot be used.
4. Also, in surgery for indicating the anesthesia level of the patient during surgery, single channel is monitored.
5. to study the stages of sleep.

- **Magnetic Signals from Heart and Brain**

1. Magneto cardiogram MCG:-

Magnetic field produced by the current in the heart during depolarization and repolarization.

* MCG measures the very weak magnetic fields around heart.
* The recording of the heart's magnetic field is MCG.
* Magnetic field around heart is ~5* 10^{-11} tesla or ~ 1\$10^6$ of earth's magnetic field. (tesla = 10^4 gauss).
* To measure such small field it's necessary to use: magnetically shielded rooms, and very sensitive magnetic detectors.
* Total time involved for each MCG is usually less than 1 min.

MCG advantages:-

1. MCG provides information about heart without the use of electrodes touching the body.
2. It provides information not available in ECG , because it measures magnetic field due to direct current.

2. ***Magneto encephalogram MEG:-***

The recording of magnetic field surrounding brain during α wave magnetic Field from brain is ~ 10^{-3} tesla.

MEG : can measure fields resulting from direct current, it's impossible to obtain this information from EEG.

* Not all measure fields produced within the body are due to ion current, the body can be easily contaminated with magnetic materials .e.g. asbestor workers inhale asbestos fibers which contain iron oxide particles.

ECG MCG

Applications of Electricity and Magnetism in Medicine

- **Electrical Shock:**

When an electrode is connected to each hand & 60 Hz currents of different levels are passed through the body, various reactions are produced.

1. About 50% of adult men feel 60 Hz currents about 1.0 m A.
2. Women feel lower levels, about 0.67 m A.

The perception levels rise as the frequency increases above 100 Hz.

1. As a 60 Hz current is increased above the perception level, it causes a tingling sensation in the hands or body.
2. At currents of 10 to 20 mA, a sustained muscular contraction takes place in the hands & many subjects do not have the ability to control their muscle a cations.
3. As the current is increased still further, pain & in some cases fainting occur.
4. Near the 100 mA level, the portion of the 60 Hz current passing through the heart is

sufficient to cause ventricular fibrillation (rapid irregular & ineffectual, contraction of the ventricles).

The heart is especially vulnerable to fibrillation during one portion of its cycle. This portion is beginning repolarization of the ventricle (the upswing of the T – Wave)

* Current levels of (6A) & above cause sustained muscular contraction of the heart similar to the "Cannot let go" behavior of the hands.

* If a patient has ventricular fibrillation, a brief shock from a defibrillator usually restores normal coordinated pumping in the heart. The defibrillator uses a brief pulse of up 10 KV.

* To treat a patient with atrial fibrillation. In this case, the electrical pulse is applied after the R wave (depolarization of the ventricles) but before the upswing of the T wave (repolarization the ventricles).

Continuous current above (6A) can cause temporary paralysis & serious burns.

The damage depends upon:

1. The individual the dampness of the skin.
2. The contact of the skin with the conductor.

The 60 Hz current level at which 99.5% of a can let go of the electrodes is ~ 9mA. At current 10 – 20 mA a sustained muscular contraction take place in the hand and cannot let go the electrode.

Note: This current is higher at both low and high frequencies.
Marco shock: when the electrical contact is made on the surface of the body and the level of current that cause damage and fibrillation is in mA.
Micro shock: it is the shock, which occurs when the current is applied inside the body. It does not move to pass through the high resistance of the skin.
*ventricular fibrillation can be induced with very much smaller than the current level of macro shock.

It has been estimated 30 μA through human heart would cause ventricular fibrillation.

A patient in tensive care units (ICU) may have apacemaker catheter running through a major vessel & touching the heart muscle to stimulate the heart if its own timing mechanism should fail, some others catheters contain wires or electrically conducting fluids, therefore; provide low resistance electrical paths greatly increase the possibility of micro shock significant factor in fatal accidents in operating rooms & ICU.

- **Types of electricity:**

1. High – frequency electricity (HFE) in Medicine used in:

A. heat therapy: the heating effects of (HFE) is done by using:

1. Short wave & diathermy. 2. Long wave & diathermy. 3. Microwave & diathermy.

B. Electro surgery: uses of (HFE) to:

1. Control hemorrhage during Suring surgery.
2. Sear the wounds.
3. Electro surgery = cut through tissues.
4. Electro cauterizing = coagulate small or moderate- size blood vessels that are too tie.

2. Low frequency electricity (LFE) & magnetism in medicine it is used to:

A. measure the blood flow by electromagnetic methods.

B. Measure the skin resistance by LFE to monitor psychological change.