ELECTRODES

Electrodes are employed to pick up the electrical signals of the body. In presenting a bio electric event to the preamplifier of signal processing circuit, a pair of electrodes plays the role of transducers. Since the electrode are transferring the bioelectric event to the input of the amplifier, the amplifier should be designed such that it accommodates the characteristics of electrodes.

The types of the electrode to be used depends upon the anatomical location of bioelectric event and the dimensions of the bioelectric generator. The electrical characteristics of the electrodes specify the type of preamplifier.

Half cell potential or electrode potential:

The voltage developed at an electrode – electrolyte interface is designated as the half cell potential or electrode potential. In the case of a metal solution interface, an electrode potential results from the difference in rates between two opposing processes. The passage of ions from the metal into the solution and the combination of metallic ions in solutions with electrons in the metal to form atoms of the metal.

Electrodes in which no net transfer of charge occurs the metal electrolyte interface are called as perfectly polarised electrodes. Electrodes in which unhindered exchange of charge is possible across the metal electrolyte interface are called perfectly nonpolarizable electrodes. Real electrodes have properties that lie between these idealised limits.

In many instances the presence of an electrode potential would not be objectionable if it were stable. In practice, it is not a stable and its variations constitute a source of variable noise voltage called artifact. The figure shows the electrical equivalent circuit of a surface electrode when it is in contact with the body surface.

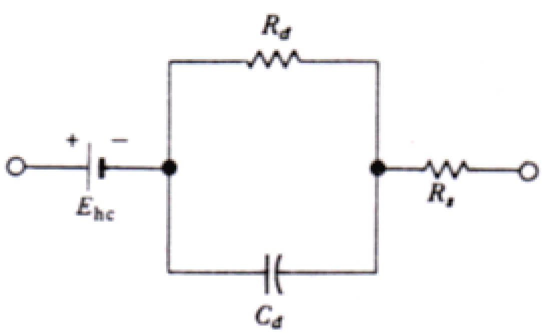

Fig: Surface electrode equivalent circuit

The electrode-electrolyte interface resembles a voltage source having half cell potential 'E_{hc}' which is developed due to charge gradient and a capacitor C_d in parallel with a leakage resistance R_d. The series resistance in the equivalent circuit R_s represents the series electrolyte and skin resistance under equilibrium conditions. The half-cell potential developed can be expressed by the Nearnst equation.

$$E_{hc} = -\frac{RT}{nF} \ln \frac{C_1}{C_2} \cdot \frac{f_1}{f_2} = -2.303 \frac{RT}{nF} \log 10 \frac{C_1 f_1}{C_2 f_2}$$

Where

R=Gas constant = 8.314 kJ/ mol K

T=absolute temperature in kelvin

F=number of coulombs transferred or Faraday constant=96500 coulombs

n=velocity of the iron

C_1, C_2=concentration of the selected ion on the two sides of the membrane

f_1, f_2=activity coefficient of the ion on the two sides of the membrane

Types of electrodes

- Surface Electrodes
- Needle Electrodes
- Microelectrodes

Surface Electrodes:

Generally larger area surface electrodes are used to sense ECG potentials, smaller area surface electrodes are used to sense EEG and EMG potentials. The surface electrodes used to measure the potential available from the surface of the skin and these are used to sense the potential from heart, brain, and nerves.

Types of surface electrode:

Metal plate electrode:

Rectangular (3.5cm x 5cm) and circular (4.5cm) plates from german silver, nickel silver or nickel plates steel are used as surface electrodes in the case of ECG measurement. When these electrodes are applied on the skin with electrode plate, typical d.c resistance values are in the range from 2 to 10 kilo ohms, the high frequency impedance amounts to a few hundred ohms.

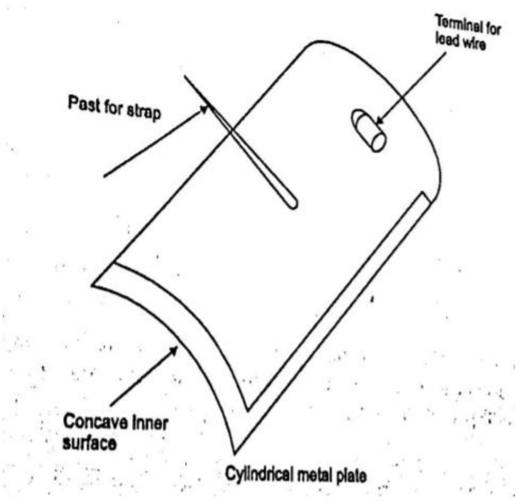

Fig: Cylindrical metal plate surface electrode

Suction cup electrode:

It is more practical and is well suited for attachment to flat surface of the body and to regions where the underlying is soft. Although physically large as shown in figure. This electrode has a small area because only the rim is in contact with the skin.

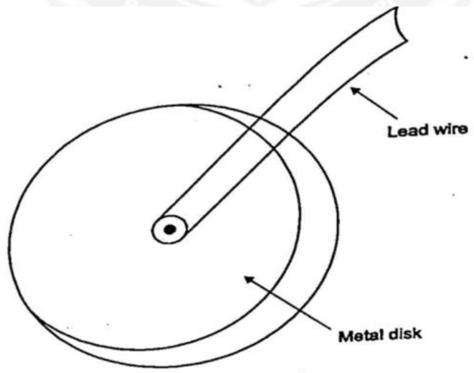

Fig: Circular metal disk surface electrode

Adhesive tape electrode:

The pressure of the surface electrode against the skin may squeeze the electrode paste out. To avoid this problem, adhesive tape electrode is used. It consists of a lightweight metallic screen backed by a pad for electrode paste as shown in figure. The adhesive bucking holds the electrode in place and retards the evaporation of the electrolyte present in the electrode paste.

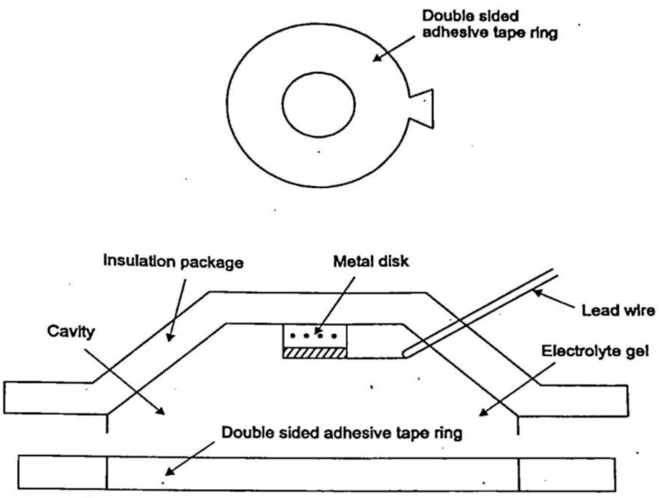

Fig: Adhesive tape electrode

Multipoint electrode:

The multipoint electrode is a practical electrode for ECG measurements, and it contains nearly 1000 fine active contact points. By this a low resistance contact is established with the subject. If the subject has hairs on the regions of interest, then one can use the multipoint electrode without removing the hair. We can use it under any environmental conditions.

Floating electrode:

In the floating electrode, the metal does not contact the subject directly. That is the contact is made via an electrolytic bridge. By means of this electrode movement artifact is eliminated. This is also called as liquid junction electrode.

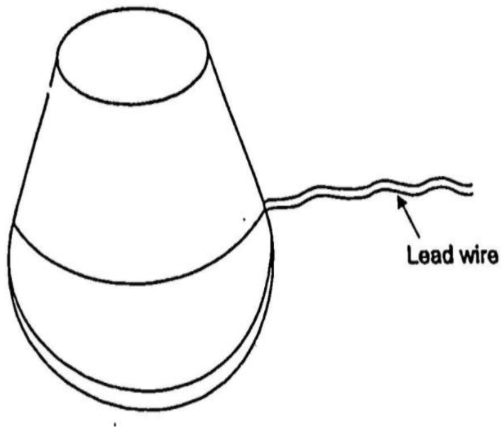

Fig: Floating electrode

During the application of surface electrodes, we are getting signals from a relatively large section of tissue. The activity we see is the total product of millions of nerve or muscle cells working as a team. If it becomes necessary to evaluate the activity of a small section of tissue or of cells themselves, then the surface electrodes are not useful.

During long-term monitoring an exercise testing the surface electrode is an important part of the system. The monitoring or exercise testing the surface electrode is an important part of the system. The pH of the electrode paste should be maintained at 7.0 during measurement and buffered.

Pregelled disposable electrode:

Pregelled, disposable electrodes with the adhesive already in place are now being used regularly, since these devices are ready to be applied to the patient saving a considerable amount of time.

Needle Electrodes:

Generally, needle electrodes are used to record the peripheral nerves action potentials. The needle electrode resembles a medicine dropper hyper dermic needle.

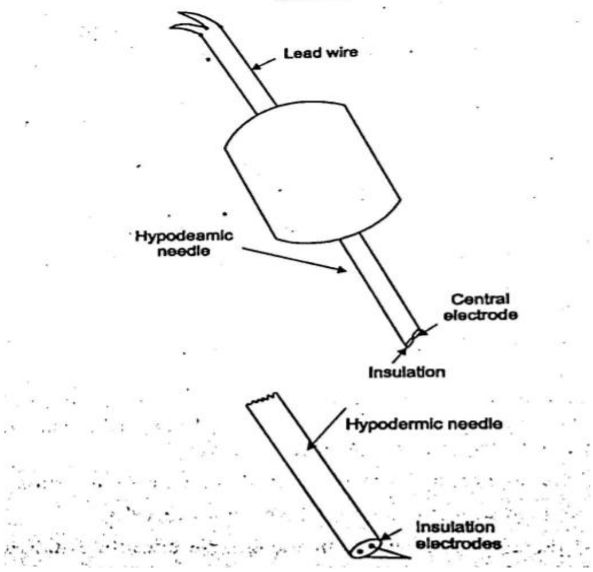

Fig: Needle electrode

A short length of the fine insulated metal wire is bean at its one end and the bent portion is inserted through the lumen of the needle and is advanced into the muscle. The needle is withdrawn, and the bent wire is resting inside the muscle. When the reference electrode is placed on the skin, then the needle electrode, then the two wires constitute bipolar electrode such that one wire is active electrode, and the other wire is reference electrode.

Micro Electrodes:

Micro electrodes are divided into metallic and non-metallic. The microelectrodes should have smaller diameter and during insertion of the electrode into cell, there will not be any damage to the cells. When a microelectrode is used to measure the potential of the cell, it is located within the cell, while the reference electrode is suited outside the cell.

The size of the electrode is determined by the size of the cell. Since the size of the cells is about 50 microns, the diameter of the tip of the microelectrodes is ranging from 0.5 to 5 microns. There are two types of micro electrode,

- Metallic electrode
- Non-metallic electrode

Metal microelectrode:

Metal microelectrodes are formed by electrolytically etching the tip of a fine tungsten or stainless-steel wire to a fine point. This technique is known as electro pointing. The metal electrodes are located almost to the micro tip with an insulating material. To reduce the impedance, some electrolytic processing like chloriding the tip and then developing by the photographic developer can be performed.

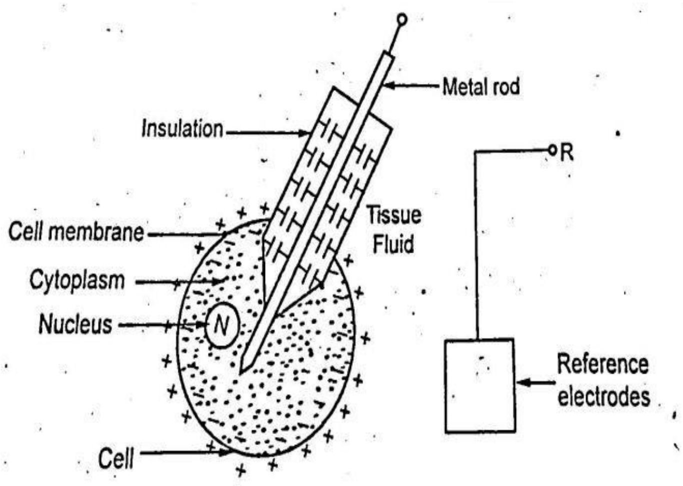

Fig: Portion of Electrode

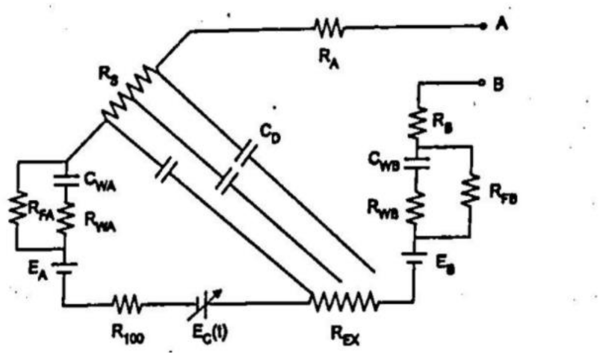

Fig: Electrical equivalent circuit

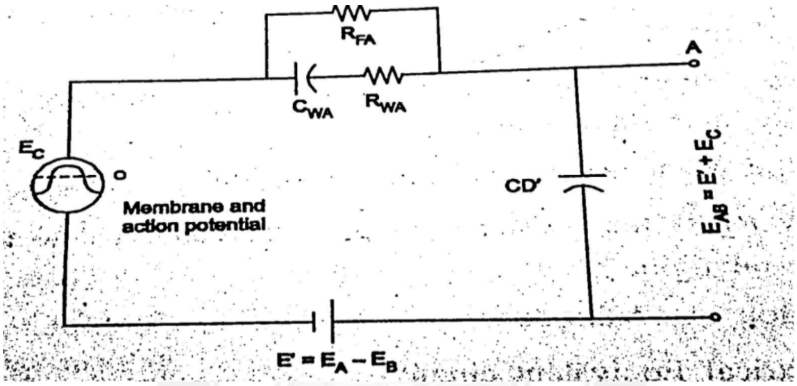

Fig: Metal micro electrode

Since the measurement of bioelectric potential requires two electrodes. The voltage measured is really the difference between the instantaneous potentials of the micro electrode and the reference electrode and it is the sum of three potentials as shown in figure such that

Where

E_A – Metal electrode-electrolyte potential at the microelectrode tip

E_B – Reference electrode-electrolyte potential

E_C – Variable cell membrane potential

N – Nucleus

C – Cytoplasm

The capacitance between the tip of the micro electrode and intra cellular fluid is negligible because the potential difference across it does not change. Since the area of the reference electrode is many times greater than the metal electrodes tip whose area of cross section is very small, its impedance is negligible. The impedance of the micro electrode tip is inversely proportional to the area of the tip and frequency.

When the electrode output is coupled with an amplifier, the low frequency components of the bio electric potential will be attenuated if the input impedance of the amplifier is not high. Thus, when the input impedance of the amplifier is not high enough, it behaves as a high pass filter.

Micropipet:

Non-metallic metro electrode is called micropipet. The non-metallic micropipet is filled with an electrolyte usually 3M KCI which is compatible with the cellular fluids. The non-metallic micropipet consists of a glass micropipet whose tips diameter about 1 micrometer.

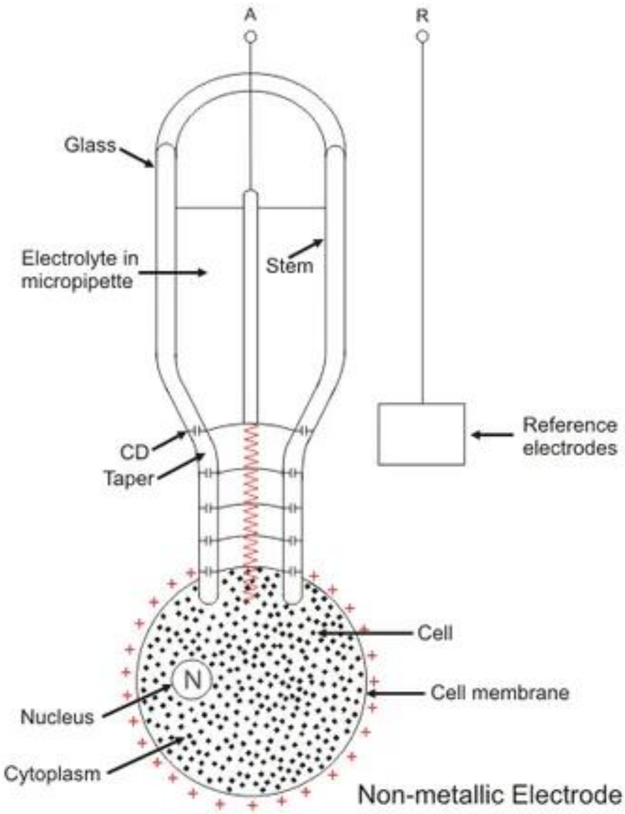

Fig: Micropipet electrode

A thin, flexible metal wire form chloride silver, stainless steel or tungsten is inserted into the stem of micropipet. The friction between the wire and the stem of the micropipet and the fluid surface tension hold the micropipet on the wire. The other end of the metal wire is mounted to a rigid support and the free end of resting on the cell.