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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

NAME OF THE SUBJECT : BASIC OF BIOMEDICAL INSTRUMENTATION

SUBJECT CODE :OMD551

REGULATION :2017

UNIT I- BIO POTENTIAL GENERATION AND ELECTRODES TYPES

SYLLABUS

OMD551 BASICS OF BIOMEDICAL INSTRUMENTATION L T P C 3 0 0 3

UNIT I BIO POTENTIAL GENERATION AND ELECTRODES TYPES

Origin of bio potential and its propagation. Types of electrodes - surface, needle and micro electrodes and their equivalent circuits. Recording problems - measurement with two electrodes

UNIT II BIOSIGNAL CHARACTERISTICS AND ELECTRODECONFIGURATIONS

Bio signals characteristics – frequency and amplitude ranges. ECG – Einthoven's triangle, standard 12 lead system. EEG – 10-20 electrode system, unipolar, bipolar and average mode. EMG– unipolar and bipolar mode.

UNIT III SIGNAL CONDITIONING CIRCUITS

Need for bio-amplifier - differential bio-amplifier, Impedance matching circuit, isolation amplifiers, Power line interference, Right leg driven ECG amplifier, Band pass filtering

UNIT IV MEASUREMENT OF NON-ELECTRICALPARAMETERS

Temperature, respiration rate and pulse rate measurements. Blood Pressure: indirect methods - Auscultatory method, direct methods: electronic manometer, Systolic, diastolic pressure, Blood flow and cardiac output measurement: Indicator dilution, and dye dilution method, ultrasound blood flow measurement.

UNIT V BIO-CHEMICAL MEASUREMENT

Blood gas analyzers and Non-Invasive monitoring, colorimeter, Sodium Potassium Analyzer, spectrophotometer, blood cell counter, auto analyzer (simplified schematic description).

TEXT BOOKS: 1. Leslie Cromwell, "Biomedical Instrumentation and measurement", Prentice hall of India, New Delhi, 2007.

2. John G. Webster, "Medical Instrumentation Application and Design", John Wiley and sons, New York, 2004. (Units I, II &

REFERENCES:

. Myer Kutz, "Standard Handbook of Biomedical Engineering and Design", McGraw Hill Publisher, 2003.

2. Khandpur R.S, "Handbook of Biomedical Instrumentation", Tata McGraw-Hill, New Delhi, 2003.(Units II & IV)

3. Joseph J. Carr and John M. Brown, "Introduction to Biomedical Equipment Technology", Pearson Education, 2004.

ONLINE SOURCES

O1. www.nptel.ac.in.

O2. Internet Source

Unit-1.

Biopotential Generation and electrode types.

Origin of biopotential:

Bioelectric potential:

The chemical activity in the nerves and muscles of the body generates bioelectric signals.

* For example heart and brain produce some voltage variation.
* Bioelectric potential generated at each cell. So each cell act as a minute voltage generator.
* In the normal resting state of the cell its interior is negative with respect to outside.
* Under excitation state the outside of the cell becomes negative with respect to inside.
* After a short time the cell regains normal state. Again the inside cell becomes negative and outside cell become positive.

This discharging and recharging of a cell known as depolarisation and repolarisation. This action produces voltage waveforms.

Biosignal characteristics.

Bioelectric signal.	Frequency range	Voltage range	Electrode used	Origin
1. Electrocardiogram (ECG)	0.05 to 100.	10 to 5000	surface electrode used.	heart
2. Electroencephalograph. EEG	0.1 to 100	2 to 200.	surface and needle electrode	Brain.
3. Electromyograph	5 to 2000	20 to 5000	surface or needle electrode	skin muscles.
4. Electroretinogram	0.01 to 200	0.5 to 1000	Corneal electrodes.	Retina of the eye.

Measurement of biopotentials with two electrode.

→ A wide variety of electrode used to measure bioelectric potentials.

The electrodes are classified into three types.

1. Microelectrodes.
2. Skin (or) surface electrodes.
3. Needle electrode.

1. Microelectrodes :

Electrodes are used to measure bio electric potentials near or within a single cell.

2. Skin , surface electrode :

Electrodes used to measure ECG, EEG, EMG potentials from the surface of the skin.

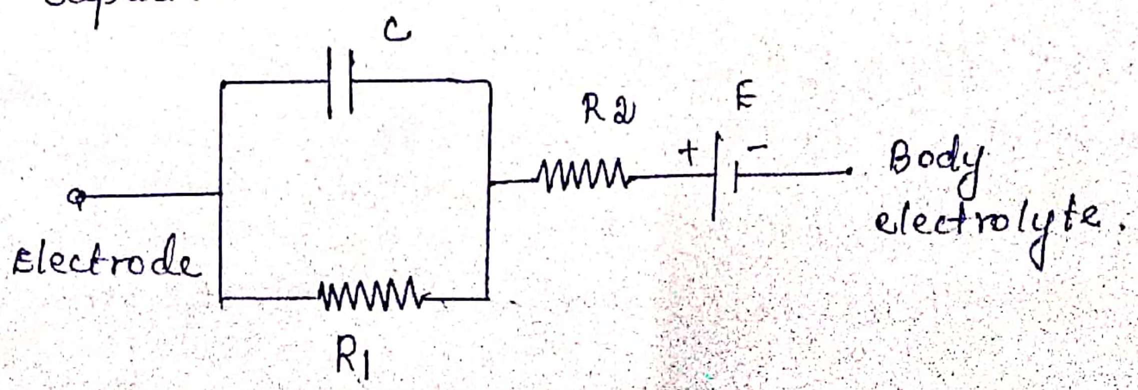
3. Needle Electrodes :

Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG potentials from a specific group of muscles.

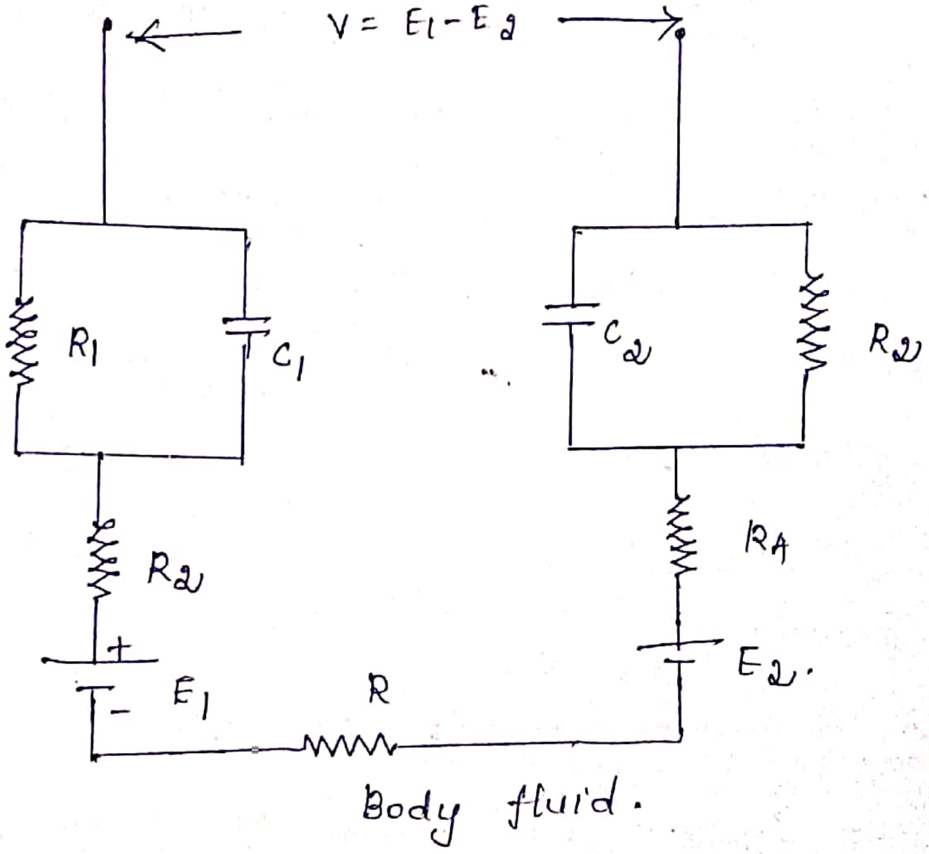
Normally electrode made up of metal. It is placed to measure biopotential. There is a interface between metal and body electrolyte. There is a exchange of ions between metal and body electrolyte.

The electrode potential developed across metal and body electrolyte. This potential proportional to the exchange of ions between metal and electrolyte. It will act as a capacitor.

The equivalent circuit of a biopotential electrode contact with a body consists of voltage in series with a resistance - capacitance network.



The measurement of biopotential requires two electrodes. The voltage is measured is the difference between the instantaneous potentials of the two electrode.



→ If the two electrodes of same type, the difference is small. It depends on the ionic between two points of the body.

→ If the two electrode are different they produce dc offset voltage. This voltage causes current flows through the electrode. This dc offset voltage is called electrode.

offset voltage.

→ Even the two electrodes of the same material ~~they~~ p may produce a small electrode offset voltage.

→ The chemical activity within the electrode produce Voltage fluctations. This fluctations appear as noise on bioelectric signal.

This noise can be reduced by proper choice of materials. Coating the electrodes by some electrolyte improves stability.

Silver - silver chloride electrolyte very stable.

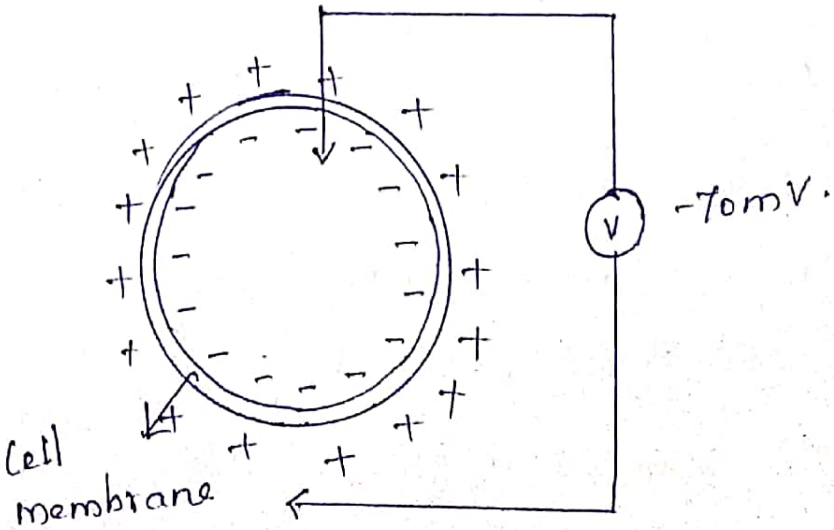
x ———— x

Resting and Action potentials:

→ Nerve and muscle cells are encased in a semipermeable membrane. It permits some substances to pass through the membrane while others are kept out.

→ The body fluids surrounds the cells of the body. These fluids are conductive solutions containing charged atoms (ions). The principal ions are sodium (Na^+), potassium and chloride. The cell membrane readily permits the entry of potassium (K+) and chloride (Cl-) ions but blocks the entry of sodium ions. (Na+) These ions form a balance between the inside and outside of the cell.

Now the concentration of sodium ions less in inside of the cell and higher is the outside cell. So the outside of the cell becomes more positive. It is called resting potential.



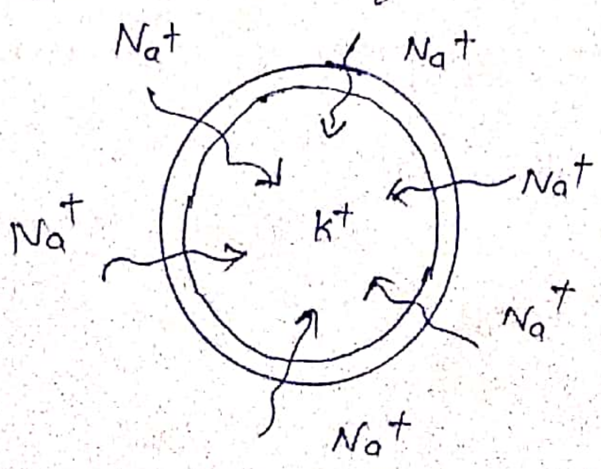
The resting potential is maintained until some kind of disturbance upsets the equilibrium. The membrane potential is measured from inside the cell with respect to the body fluids.

→ The resting potential of the cell is given as negative.

Resting potentials ranging from -60 to -100mV. The cell in its resting state is said to be polarized.

→ When the cell membrane is excited by the ionic current the sodium ions enter into the cell. The movement of the sodium ions increases the ionic current. The increased ionic current reduces barrier of the membrane. So sodium ions rush into the cell because of the avalanche effect. At the same time potassium ions try to leave the cell. Potassium ions are unable to move outside the cell.

So the outside of the cell becomes positive and inside of the cell becomes negative.



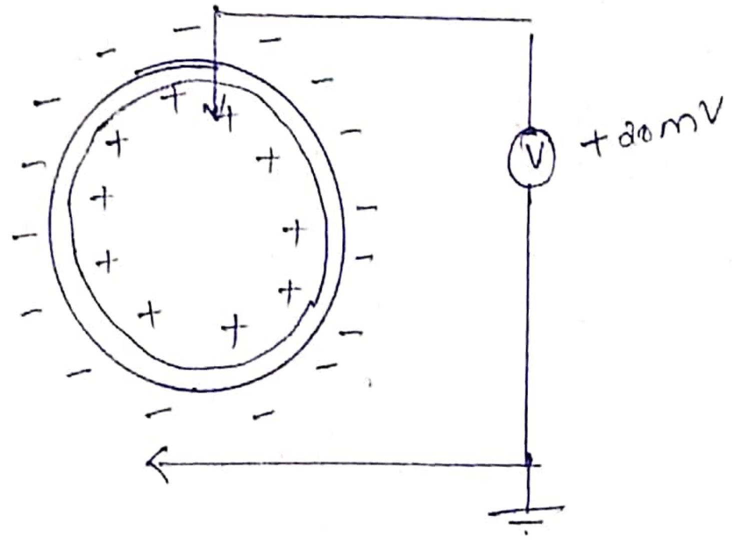


Fig. Depolorized cell during action potential.

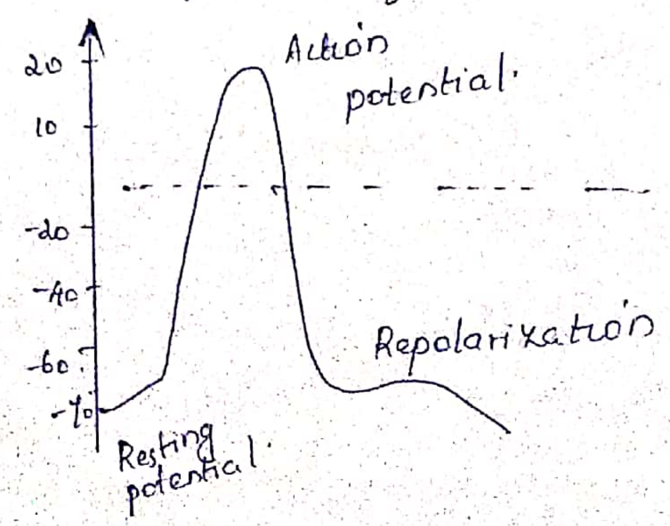
Sodium Pump:-

Sodium pump is used to transport sodium ions from the inside of the cell to outside.

The cell again polarized and assumes its resting potential. This process is called repolarization.

The rate of pumping is directly proportional to the sodium concentration in the cell.

Waveform of the action potential.



It is beginning at the resting potential, depolarizing and returning to the resting potential after repolarization

→ In nerves and muscle cells repolarization occures so rapidly. In heart muscle cell repolarizes much more slowly.

Depolarization means the cell changes from resting to action potential.

Repolarization means the cell changes from action to resting potential.

All or nothing law:

Regardless of the method by which the cell is excited or the intensity of the stimulus, the action potential is always same for any given cell.

Absolutely refractory period:

Following the generation of action potential the cell cannot respond to any new stimulus. It is called absolutely refractory period. It is about 1ms.

Relative refractory period:

During this period strong simulation

is applied another action potential can be triggered.

→ Normally relative refractory period is about several milliseconds.

Propogation of action potential:

The rate at which an action potential is propogated from cell to cell is called propogation rate.

→ In nerve fibre the propogation rate is called the nerve conduction velocity. Nerve conduction velocity varies from 20 to 140m/s.

→ propogation through heart is slower. Propogation rate is from 0.2 to 0.4 m/sec.

x. ———————— x

Electrodes:

→ Electrodes convert ionic potentials into electric potentials are called electrodes.

Nernst Equation:-

$$E = \frac{-RT}{nF} \ln \frac{C_1 f_1}{C_2 f_2}$$

An equation relating the potential across the membrane and the two concentrations of the ion is called Nernst equation.

R = Gas constant.

T = Absolute temperature degrees kelvin

n = Valence of the ion.

F = Faraday constant.

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

f_1, f_2 = Respective activity coefficients of the ion.

Biopotential Electrodes:-

→ A wide variety of electrodes can be used to measure biopotentials.

Electrodes can be classified into three types

1. Micro electrodes.
2. skin surface electrodes.
3. Needle electrodes

Microelectrodes:-

Electrodes used to measure bioelectric potentials near or within a single cell.

Skin surface Electrodes:-

Electrodes used to measure ECG, EEG, and EMG potentials from the surface of the skin.

Normally Larger electrodes are used for ECG. Smaller electrodes are used for EEG and EMG measurements.

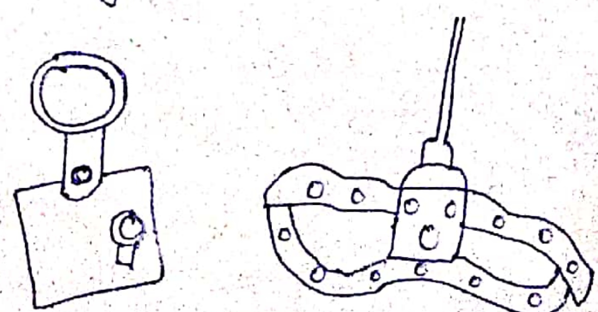
Types of surface electrodes

1. plate Electrodes.
2. Suction cup electrodes.
3. Floating electrodes.
4. Disposable electrodes.

1. plate Electrodes:-

→ plate electrode is the improvement from the immersion electrode. plate electrodes were seperated from the patient skin by cotton or saline soaked pads. Later cotton or soaked pads replaced by jelly. Metal contacts the skin through a thin coat of jelly. plate electrodes are used still today.

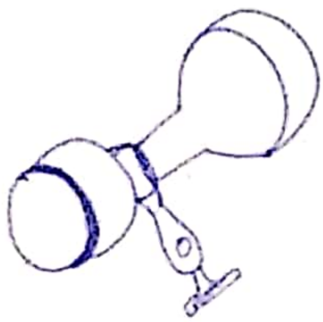
Fig. Metal plate electrodes



8. Suction cup Electrode:

It is the old type of electrode. In this electrode rim actually contacts the skin.

one of the difficulty while using this electrode is the possibility of electrode slippage or movement. If the electrode movement occures it changes the thickness of electrolyte between the metal and the skin this changes the electrode potential.

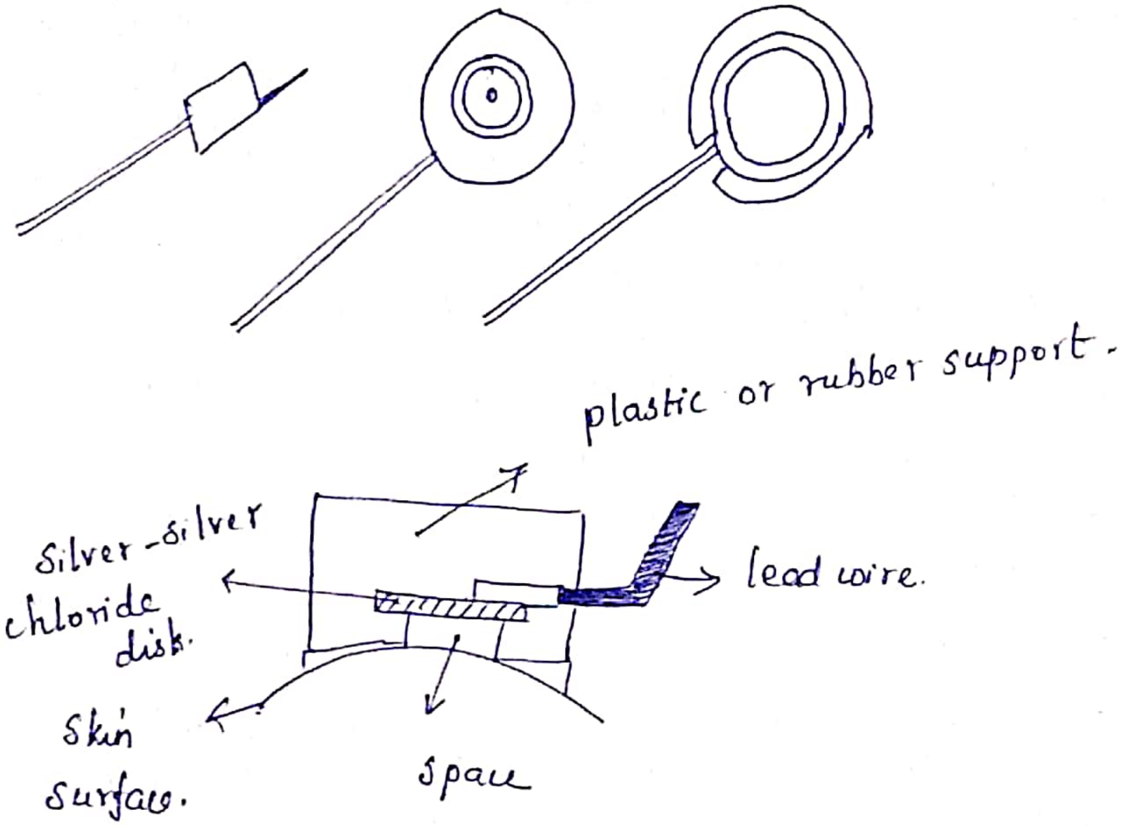


9) Floating Electrode:

→ This type of electrode avoid direct Contact of the metal with the skin. The conductive path between metal and skin is the electrolyte jelly or paste.

→ The floating electrodes are attached to the skin by the two sided adhesive collars.

Fig. floating skin surface electrode

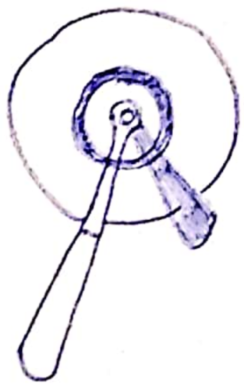


4) Disposable Electrodes:

This electrode eliminate the requirement of cleaning and care after each use. This electrode is also used for monitoring ECG, EEG and EMG as well.

Disposable electrodes are of floating type. Snapconnectors by which the reusable leads are connected. Some disposable electrodes can be reused several times, their cost is low.

fig. disposable electrodes



Several types of surface electrodes have been developed for other applications.

For example a special ear-clip electrode is used as a reference electrode for EEG measurements. Scalp surface electrodes also used for EEG measurements. Scalp electrodes are usually small disks about 7mm is diameter.

Fig. Ear-clip electrode

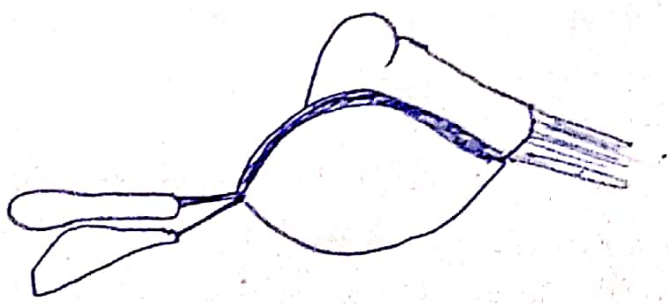
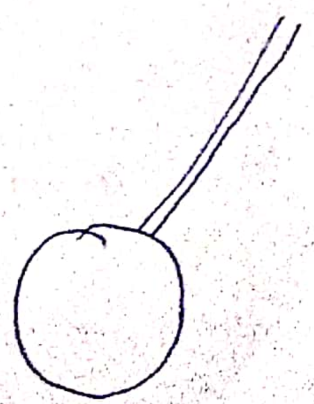


Fig. EEG scalp Surface el



Needle electrodes :-

Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG potentials from a specific group of muscles.

Micro Electrode:

→ Measure biopotential near or within a single cell.

→ Microelectrode have small tips to penetrate into a single cell without damaging the cell.

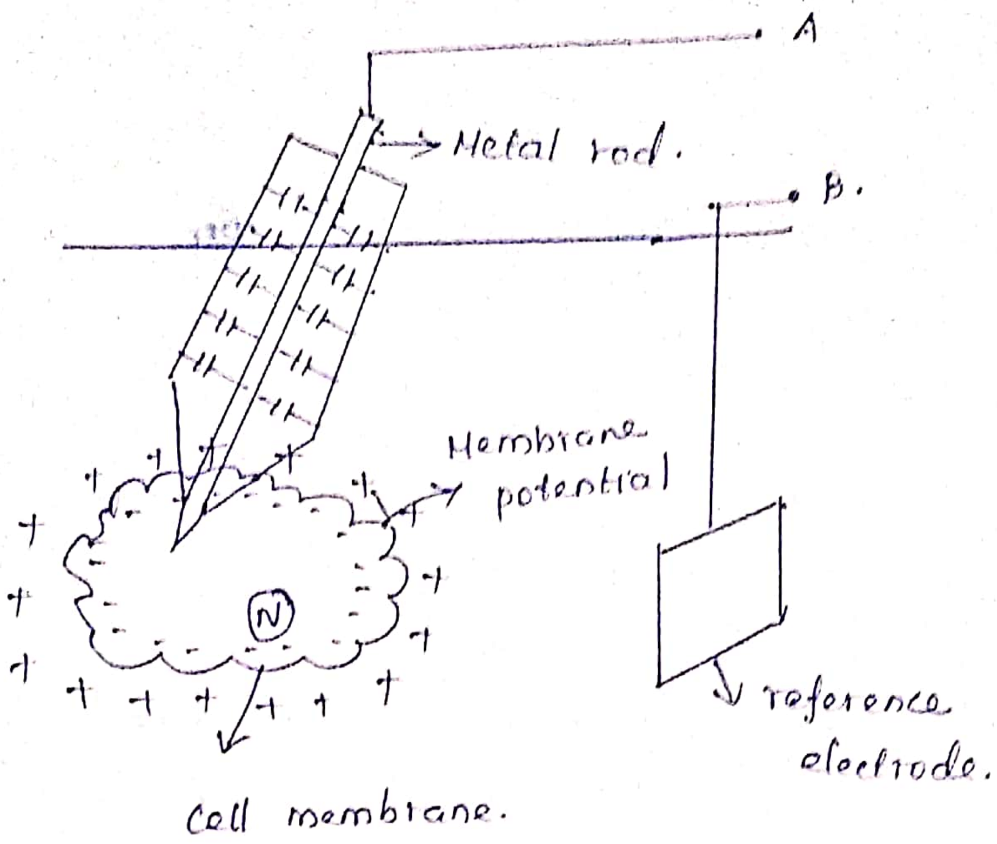
Microelectrode are generally two types.

1. Metal.
2. Micropipet.

Metal Electrode:

In metal electrodes the tips are etched with the tungsten or stainless steel wire.

Then the wire is coated with insulating material. Metal ion interface takes place when the metal tip is inserted in the electrolyte inside or outside the cell.



The biopotential is measured by two electrodes. The bioelectric potential is the difference between potential of the microelectrode and the reference electrode.

Biopotential is the sum of the three potential

Let

E_A = Metal electrode - electrolyte potential.

E_B = Reference electrode - electrolyte potential.

E_C = Variable cell membrane potential.

R_A = Resistance of the connecting wire

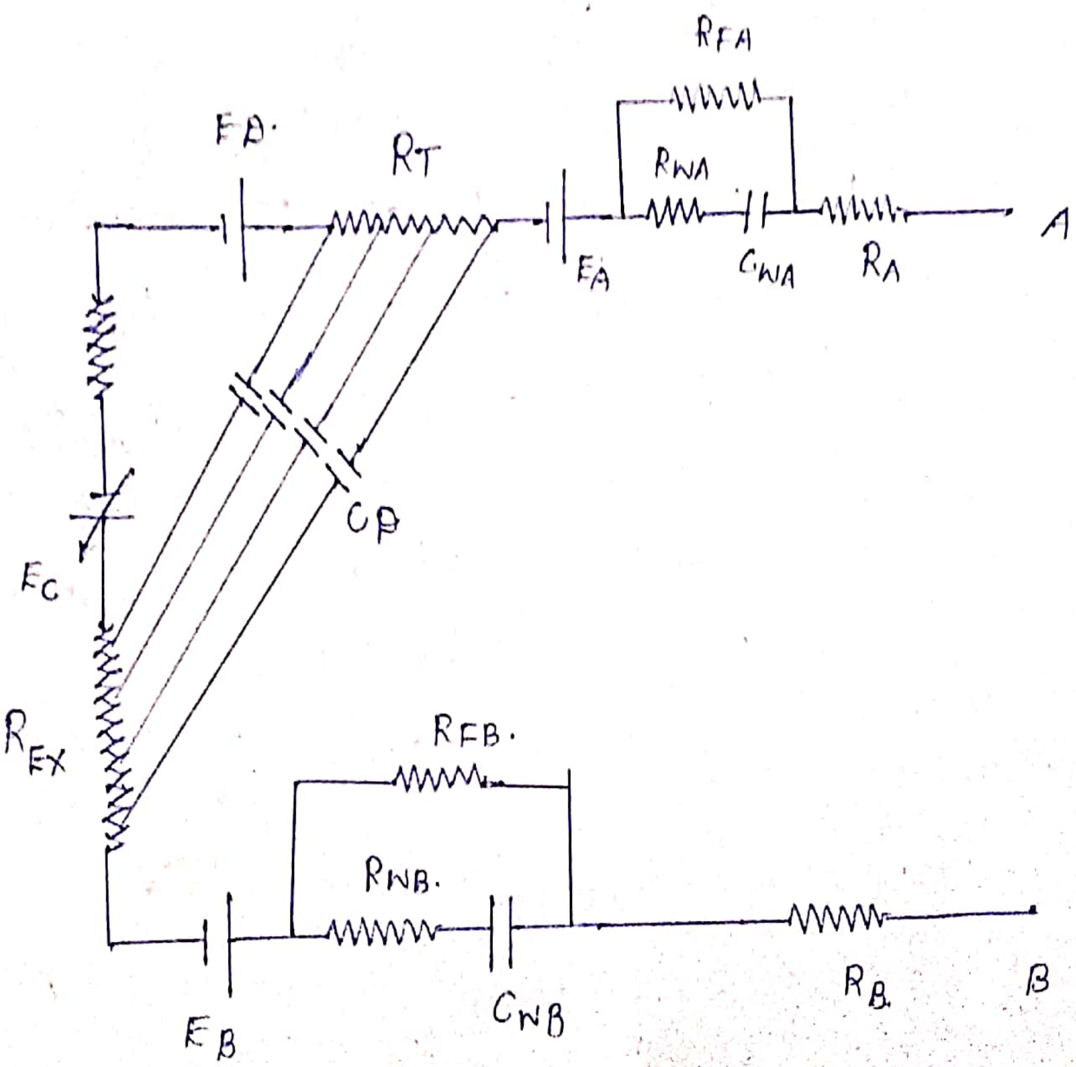
R_S = Resistance of the shaft of the microelectrode.

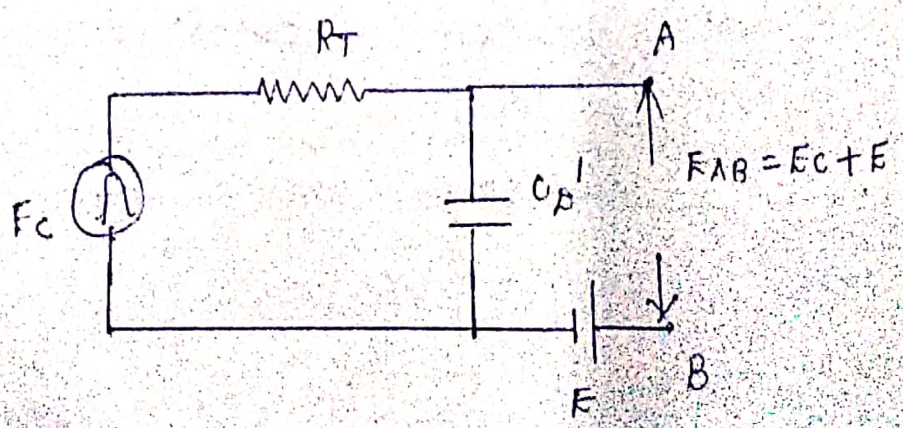
R_{FA}, R_{WA}, C_{WA} = Impedence of the ~~wire connected to the reference electrode.~~ microelectrode tip intracellular fluid interface.

E_C : Variable cell membrane potential

E_D : Potential existing at the tip due to different electrolytes present in the pipet & the cell.

$E = E_A + E_B + E_D$.





R_A = Resistance of the connecting wire.

R_{EA}, R_{WA}, C_{WA} - Impedence of the electrode-electrolyte interface in the stem of the micropippet.

R_T = Resistance of the electrolyte filling the tip of the micropipet.

R_{IN}, R_{EX} - Resistance of the electrolyte inside the cell and outside the cell.

R_{EB}, R_{WB}, C_{WB} : Impedence of the reference electrode - electrolyte.

R_B : Resistance of the wire connected with reference electrode

C_D = Equivalent distributed capacitances

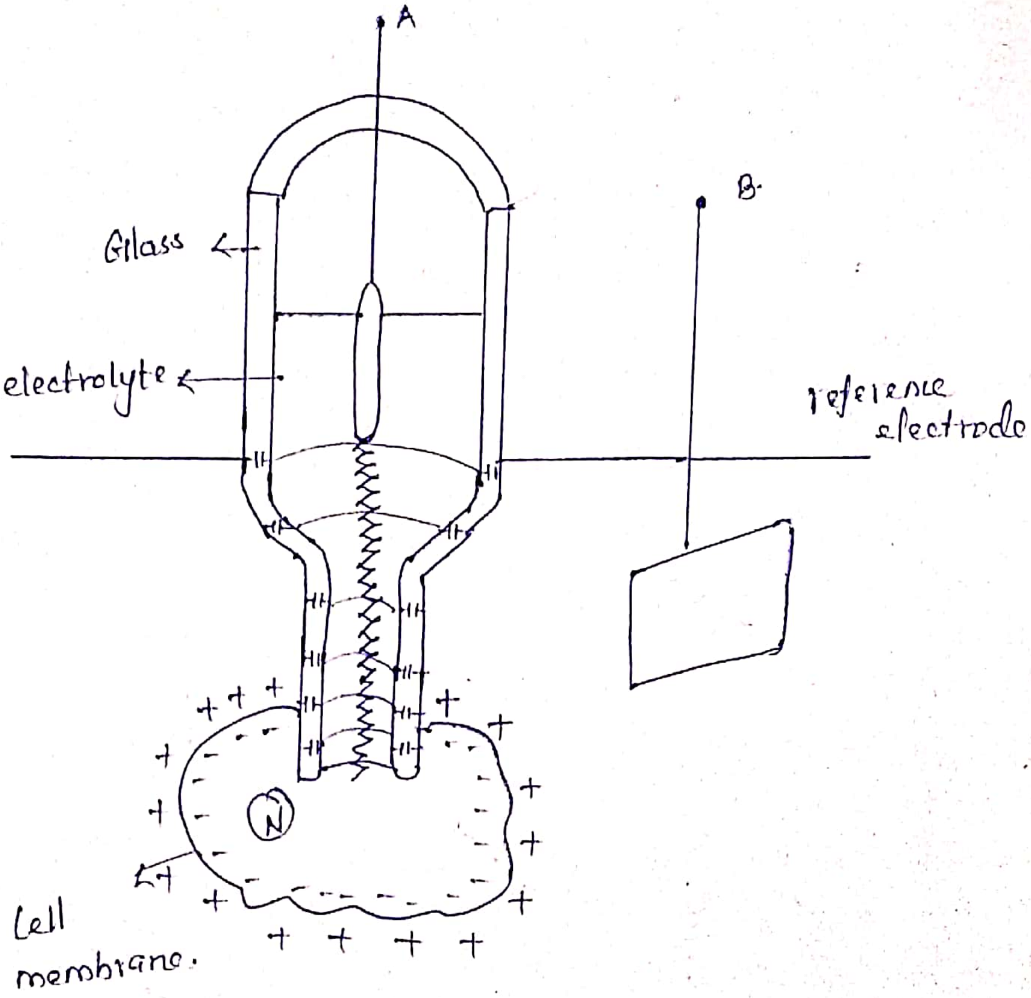
Surface electrodes :-

→ It is used to obtain bioelectric potential from the surface of the body.

Surface electrodes are found in many sizes and forms. Any type of surface electrode can be used to sense ECG, EEG or EMG potential.

Micropippet :-

Micropippet is a glass microelectrode.



This type of microelectrode has a dual interface. one interface in consists of metal wire contact with electrolyte solution inside the micropippet while the pipet and fluids outside the cell.

Equivalent circuit

Here E_A = potential between the metal wire and electrolyte filled in the pippet.

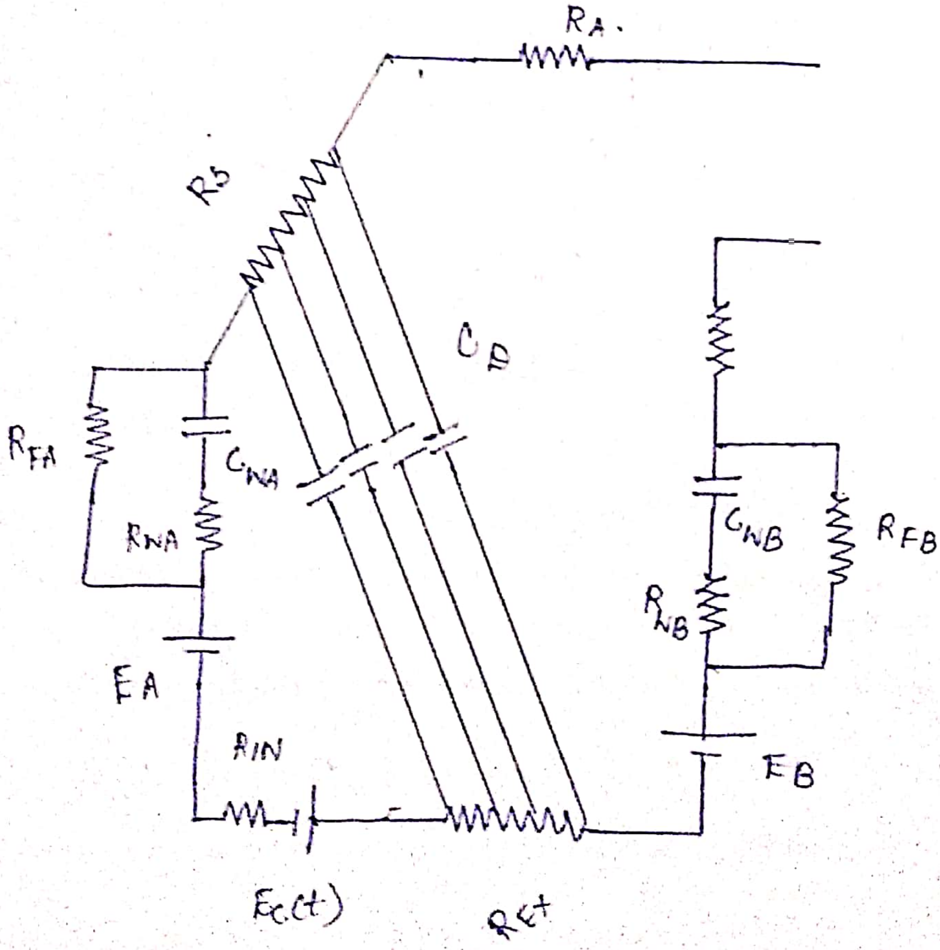
E_B = Potential between the reference electrode and extracellular fluid.

R_{IN} = Resistance of the intracellular fluid.

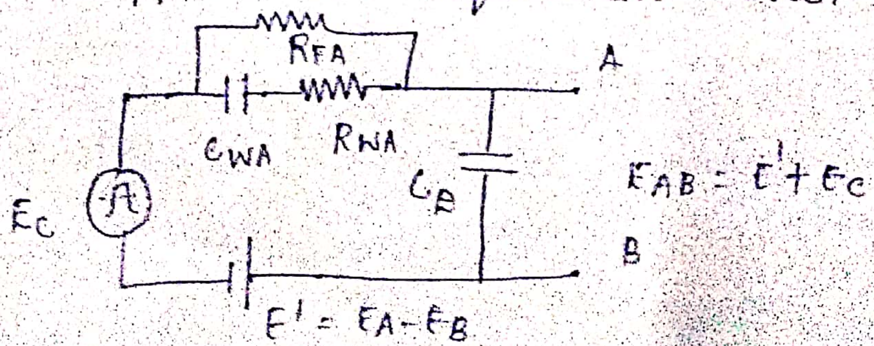
R_B = Resistance of the wire connected to the reference electrode.

R_{EX} = Resistance of the extracellular fluid.

C_D = Distributed capacitance between shaft of the microelectrode and the extracellular fluid.



Approximate Equivalent circuit.



Needle Electrode:-

To reduce interface impedence and movement artifacts in EEG measurement needleelectrode used. Needle electrode penetrated into the scalp. Needle electrode are not inserted into the brain, they penetrate the skin

In animal research long needles are usually inserted into the brain to obtain the potentials of the brain. This requires longer needles located in map or atlas of the brain.

Stereotaxic instrument is used to hold the animals head and guide the placement of electrodes.

In some applications simultaneous measurements from various