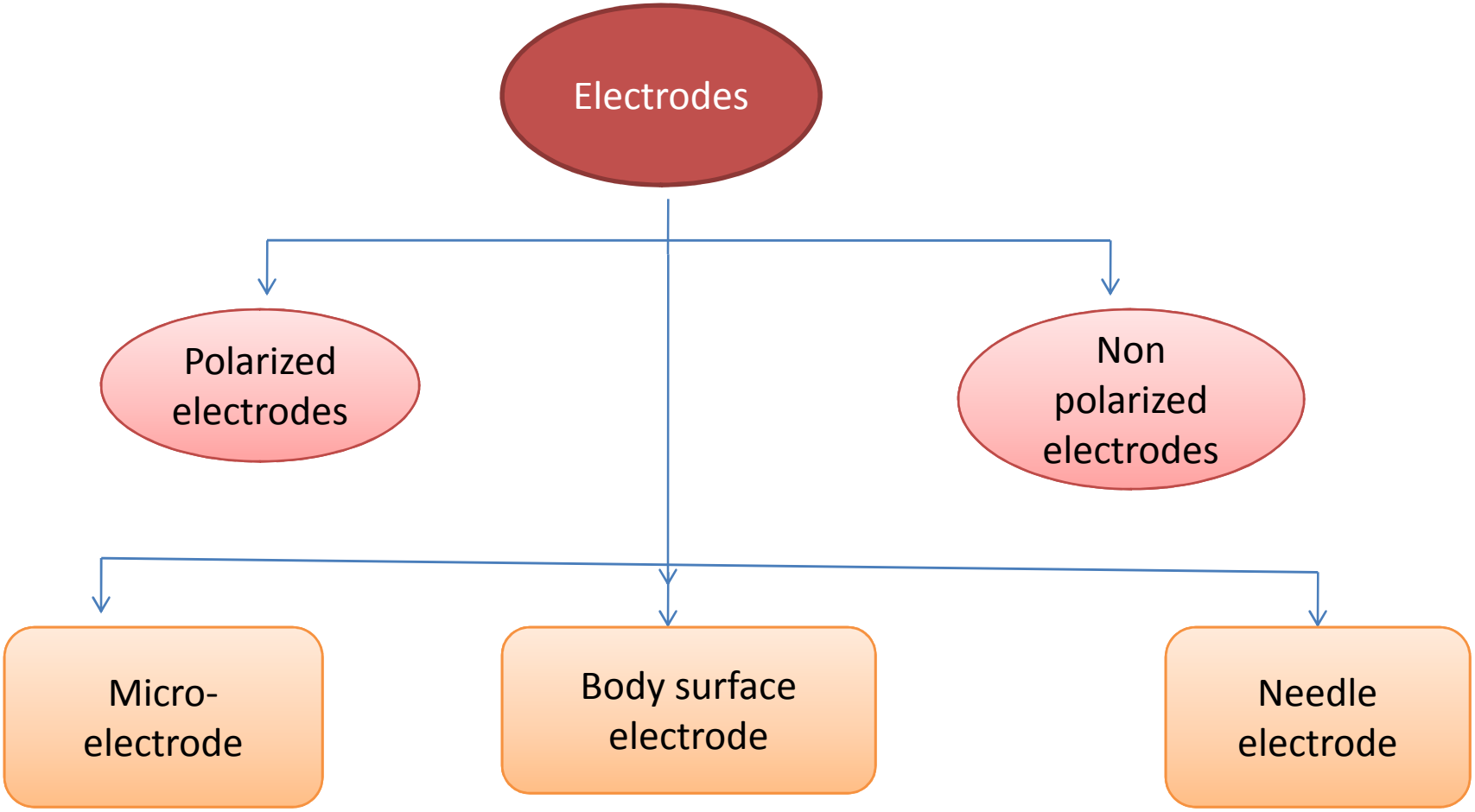
Electrodes in biomedical instrumentation

Definition

- **Electrodes** are devices that convert ionic potentials into electronic potentials. The type of electrode used for the measurements depends on the anatomical location of the bioelectric event to be measured. In order to process the signal in electronic circuits, it will be better to convert ionic conduction into electronic conduction.

Electrodes classifications



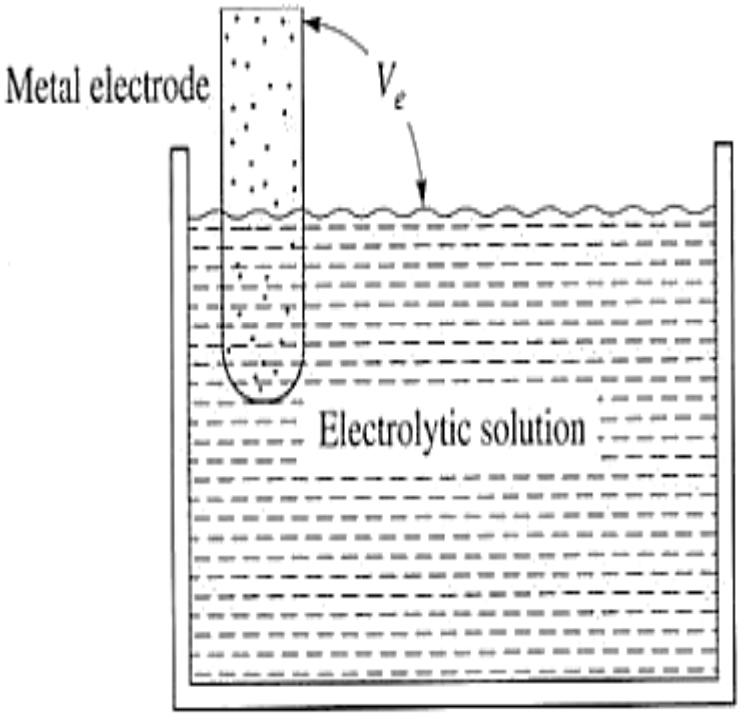
Electrode or Half Cell Potential

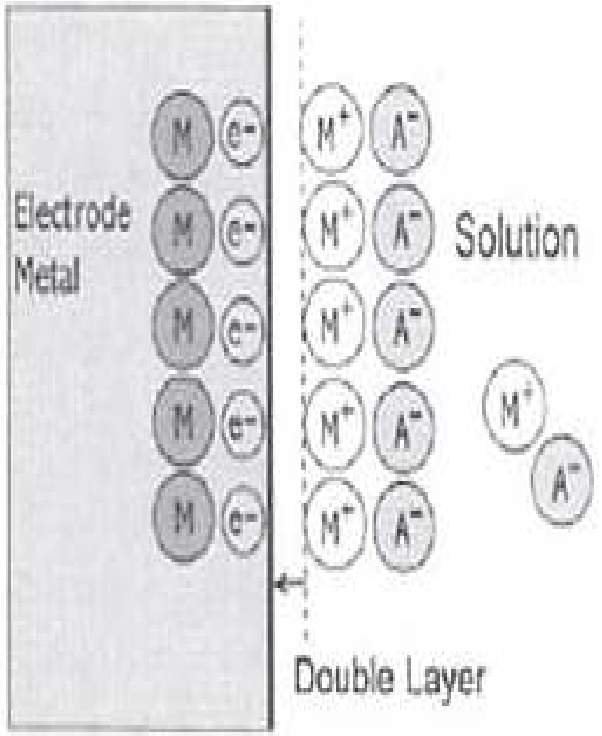
- The skin and other tissues of higher-order organisms, such as humans, are electrolytic and so can be modeled as an Electrolytic Solution.
- Imagine a metallic electrode immersed in an electrolytic solution.
- Immediately after immersion, the electrode will begin to discharge some metallic ions into the solution, while some of the ions in the solution start combining with the metallic electrodes.
- A gradient charge build up, creating a potential difference, or electrode potential and half cell potential.

Cont..

- A complex phenomenon is seen at the interface between the metallic electrode and the electrolyte.
- Ions migrate toward one side of the region or another, forming two parallel layers of ions of opposite charge.
- This region is called the electrode double layer and its ionic differences are the source of the electrode or half-cell potential.

Half Cell Potential





Polarizable and Non-Polarizable Electrode

I. Perfectly Polarizable Electrodes

- Perfectly polarizable electrodes are those in which no actual charge crosses the electrode–electrolyte interface when a current is applied.
- Of course, there has to be current across the interface and the electrode behaves as though it were a ***capacitor***

II. Perfectly Polarizable Electrodes or Perfectly Reversible

- Perfectly non-polarizable electrodes are those in which current passes freely across the electrode–electrolyte interface, requiring no energy to make the transition.
- Thus, for perfectly non-polarizable electrodes there are no over-potentials.
- Electrode interface impedance is represented as a ***resistor***.

A.Microelectrodes

- Microelectrodes are electrodes with tips having tips sufficiently small enough to penetrate a single cell in order to obtain readings from within the cell.
- The tips must be small enough to permit penetration without damaging the minute cell.
- The main functions of microelectrodes are potential recording and current injection.
- Microelectrodes are having high impedances in mega ohn range because of their smaller size.

Types

Metal microelectrode

- Metal microelectrodes are formed by electrolytic ally etching the tip of fine tungsten to the desired size and dimension.
- Then the wire is coated almost to the tip with any type of insulating material.
- The metal-ion interface takes place where the metal tip contacts the electrolyte.
- The main features of metal microelectrodes are
  1. Very good S/N ratio
  2. Strong enough to penetrate
  3. High biocompatibility

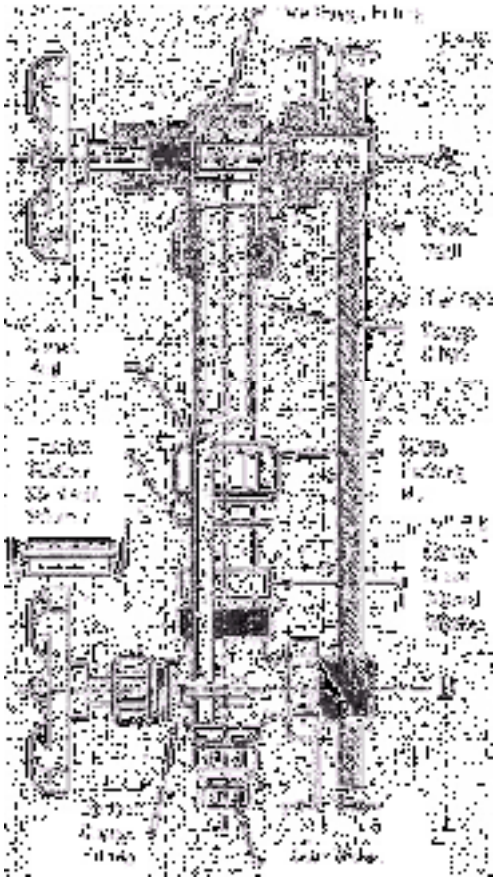
Micropipette

- The micropipette type of microelectrode is a glass micropipette with its tip drawn out to the desired size.
- The micropipette is filled with an electrolyte which should be compatible with the cellular fluids.
- A micropipette is a small and extremely fine pointed pipette used in making microinjections.

B. Body Surface Electrodes

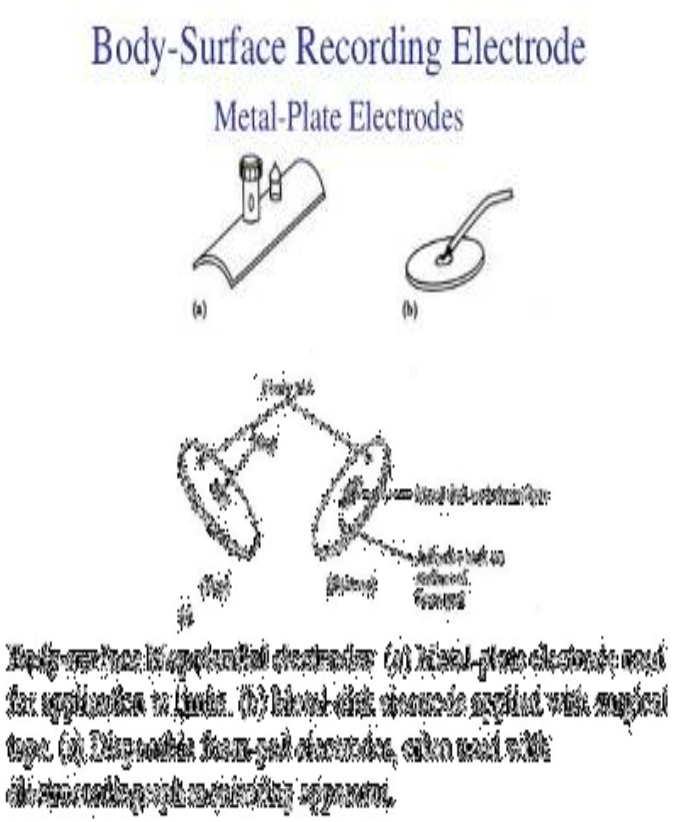
- Surface electrodes are those which are placed in contact with the skin of the subject in order to obtain bioelectric potentials from the surface.
- Body surface electrodes are of many sizes and types. In spite of the type, any surface electrode can be used to sense ECG, EEG, EMG etc.

1. **Immersion electrodes:**



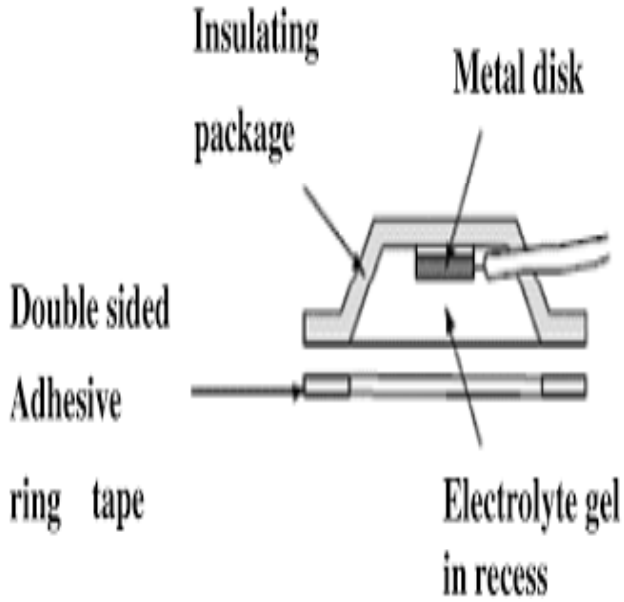
- They are one of the first type of bioelectric measuring electrodes.
- Immersion electrodes were simply buckets of saline solution in which the subject placed his hands and feet.
- So it was not a comfortable type of measurement and hence it was replaced with plate electrodes.

2. **Plate electrodes**:



- These electrodes were separated from subject's skin by cotton pads socked in a strong saline solution.
- The plate electrodes have generally smaller contact area and they do not totally seal on the patient.
- The electrode slippage and displacement of plates were the major difficulties faced by these type of electrodes because they have a tendency to lose their adhesive ability as a result of contact with fluids on or near the patient.
- Since these types of electrodes were very sensitive, it led to measurement errors

3. **Floating electrodes**

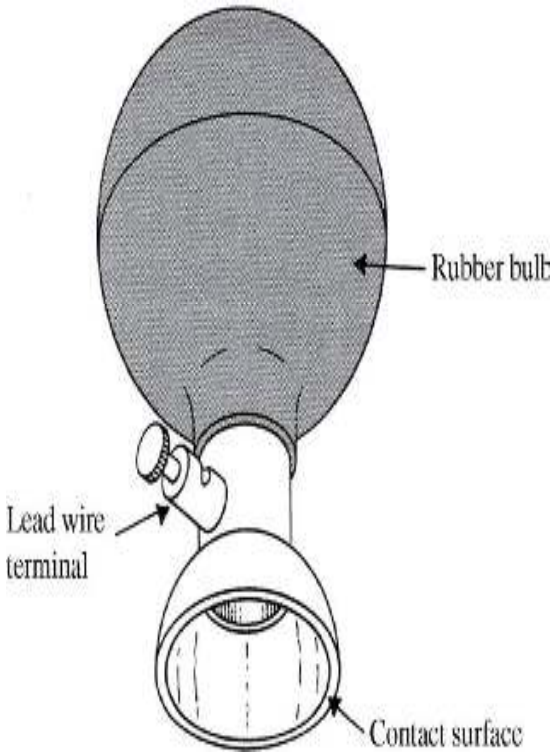


- These types of electrodes can eliminate the movement errors (called artifacts) which is a main problem with plate electrodes.
- This is done by avoiding any direct contact of the metal with the skin.
- So the main advantage of floating electrodes is mechanical reliability.
- Here the conductive path between the metal and the skin is the electrolyte paste or jelly.

4. **Disposable electrodes:**

- Normally plate electrodes, floating electrodes etc can be used more than one time.
- This requires the cleaning and cares after each use.
- We can use disposable electrodes which can be used only once and be dsposed after the use.
- These types of electrodes are now widely used.

5. Suction electrodes:



- These type of electrodes are well suited for the attachment to flat surfaces of body and to regions where the underlying tissue is soft, due to the presence of contact surface.
- An advantage of these type of electrodes is that it has a small surface area.
- These types of electrodes are mainly used for the measurement of ECG.
- Suction electrodes used a plastic syringe barrel to house suction tubing and input cables to an AC amplifier

6. Ear clip & Scalp electrodes:

- These type of electrodes are widely used in the measurement of EEG exclusively.
- Scalp electrodes can provide EEG easily by placing it over bare head. A typical ear clip electrode is shown in figure below.
- The most common method for EEG measurement is 10 – 20 electrode placement system and here we use scalp electrode usually.
- They can avoid measurement errors and movement errors. During labour internal monitoring may be needed and is usually in the form of an electrode placed under the baby's scalp.
- It is called fetal scalp electrode which is used to monitor baby's heartbeat while still in uterus

C. Needle Electrodes:

- To reduce the interface and noise (artifact) caused due to electrode movement, during the measurement of EEG, EMG etc we can use small sub-dermal needle electrodes which penetrate the scalp.
- Actually the needle electrodes are not inserted into the brain. They nearly penetrate the skin. Generally they are simply inserted through a small section of the skin just beneath the skin parallel to it.

Cont..

- The needle electrodes for EMG measurement consist of fine insulated wires placed in such a way that their tips are in contact with the muscle, nerve or other tissues from which the measurement is made. The needle creates the hole necessary for insertion and the wires forming the electrodes are carried inside it.

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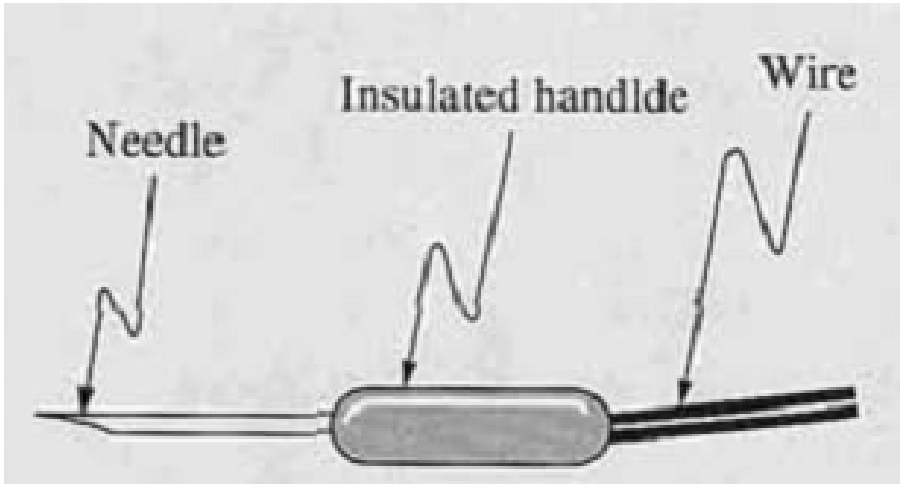
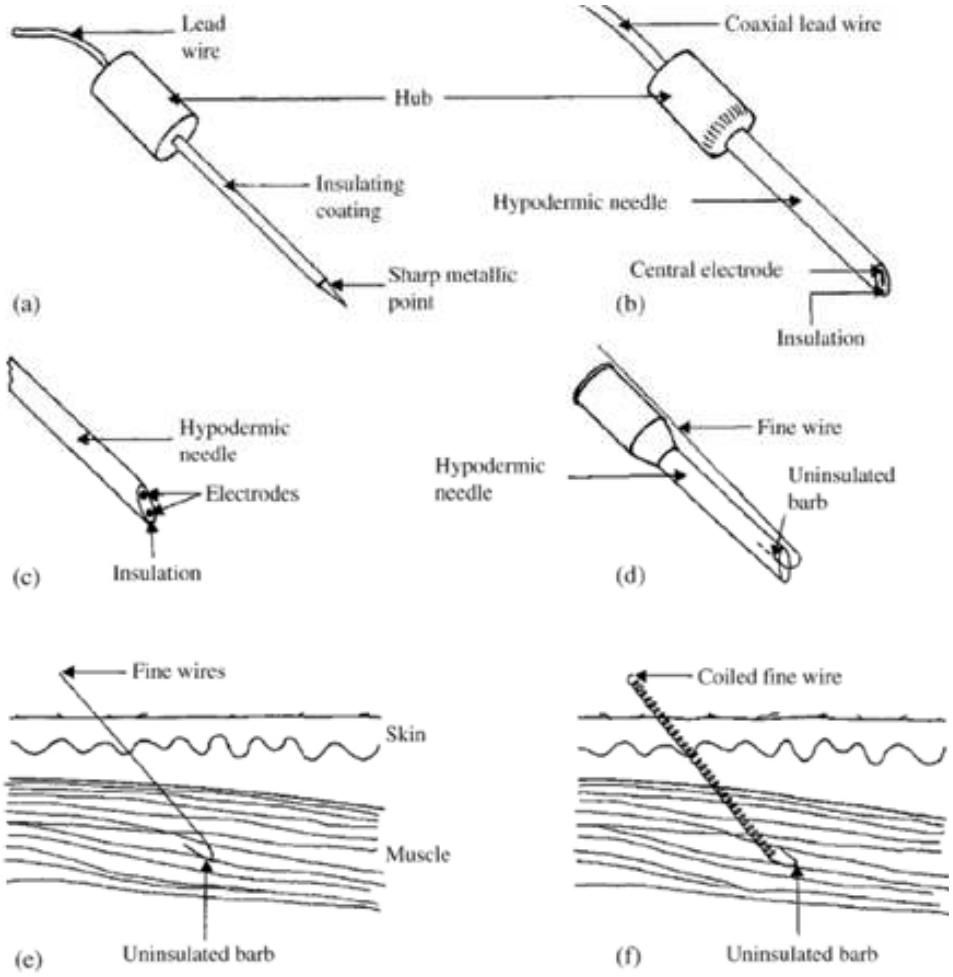

Needle
Insulated handlde
Wire


Lead wire
Hub
Insulating coating
Sharp metallic point
(a)
Coaxial lead wire
Hypodermic needle
Central electrode
Insulation
(b)
Hypodermic needle
Electrodes
Insulation
(c)
Hypodermic needle
Fine wire
Uninsulated barb
(d)
Fine wires
Skin
Muscle
Uninsulated barb
(e)
Coiled fine wire
Uninsulated barb
(f)

- One of the main advantage of needle electrodes is that they are less susceptible to movement errors than surface electrodes.
- Also the needle electrodes have lower impedances when compared to surface electrodes as it makes direct contact with the sub-dermal tissues or intracellular fluid.