

Biopotential Electrodes

Introduction

- Electrode
- A conductor in electrical contact with biological tissue or chemical solution (electrolyte)
- Skin, other body tissue act as electrolytic solutions
- Want to measure voltages (biopotentials)
- To do this need to conduct currents
- Function of biopotential electrodes:
- Provide interface between electrical signals of the body and electronic instrumentation system
- i.e. to act as transducers from ionic currents in the body to electrical current in the external system
- Choice of electrodes is important for the recording of bioelectronic signals:
- Should be comfortable for the patient
- convenient to apply
- not produce any artifacts
- None completely achievable, some compromise in each

Redox Reaction (an electrochemical reaction)

- Oxidation Reaction: Metal loses electrons and ion goes into solution
- Called the Anode: $Fe \rightarrow Fe^{2+} + 2e^-$
- Reduction Reaction: Hydrogen/Hydroxyl ions in solution gain electrons
- Called the Cathode: $2H^+ + 2e^- \rightarrow H_2$
- These reactions need to occur in pairs
- Rate of reaction = Rate of oxidation
- Unless current flows from electrode to electrolyte or vice versa
- Assuming Fe is surrounded by weak acid in which H^+ ions are abundant
- Acid called electrolyte
- Provides home for dissolved Fe^{2+}
- Has to be internal movement of electrons through metal
- Corrosion current

Half-Cell Potential

- When metal place in electrolyte solution
- Metal slightly dissolves into solution (same process as corrosion)
- Accompanied by loss of electrons to atoms that remain with parent metal
- Leaving parent metal with net negative charge (excess of electrons)
- And dissolved metal ions with a positive charge

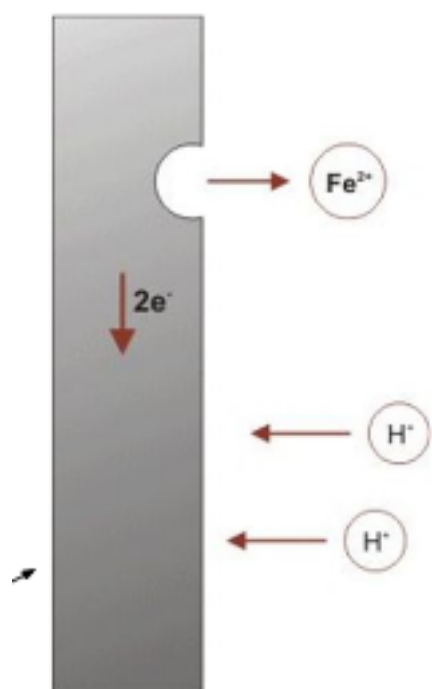


Figure 1:

- Resultant electric field draws dissolved positive metal ions back to vicinity of metal surface
- Without energy required for recombination ions held close to metal surface
- Form region called electrode double layer, and potential called Half-Cell Potential
- Voltage value depends on
 - metal present
 - electrolyte composition
 - temperature
- Note: potential varies across electrolyte

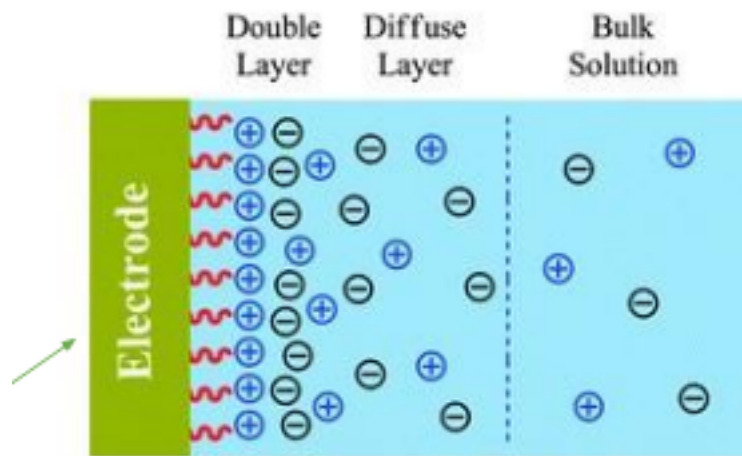


Figure 2:

- To avoid problem of not being able to directly measure an individual half-cell potential electrochemists adopt convention that H electrode has half-cell potential of 0, others measured relative to this
- Values are for 0 current flowing between cell and electrolyte

Polarisation

If current is flowing between electrode and electrolyte - Three factors - 'polarisation of electrode' - can affect observed half-cell potential - Difference between observed half-cell potential with current and equilibrium 0 current half-cell potential known as overpotential - Polarisation potential V_P of electrode given by: $V_P = E^0 + V_r + V_c + V_a - E^0$ is half-cell potential of electrode - V_r is Ohmic overpotential - voltage drops due to finite resistivity of electrolyte - Non-linear with current - More relevant in low concentration electrolytes - V_c is Concentration overpotential - from changes in distribution of ions near electrode-electrolyte interface when

<u>Metal Oxidation Reaction</u>	<u>Half-cell Potentials E^0 (volts)</u>
$\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$	-1.706
$\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$	-0.763
$\text{Cr} \rightarrow \text{Cr}^{3+} + 3\text{e}^-$	-0.744
$\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$	-0.409
$\text{Cd} \rightarrow \text{Cd}^{2+} + 2\text{e}^-$	-0.401
$\text{Ni} \rightarrow \text{Ni}^{2+} + 2\text{e}^-$	-0.230
$\text{Pb} \rightarrow \text{Pb}^{2+} + 2\text{e}^-$	-0.126
$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$	0.000 by definition
$\text{Ag} + \text{Cl}^- \rightarrow \text{AgCl} + \text{e}^-$	+0.223
$2\text{Hg} + 2\text{Cl}^- \rightarrow \text{Hg}_2\text{Cl}_2 + 2\text{e}^-$	+0.268
$\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$	+0.340
$\text{Cu} \rightarrow \text{Cu}^+ + \text{e}^-$	+0.522
$\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$	+0.799
$\text{Au} \rightarrow \text{Au}^{3+} + 3\text{e}^-$	+1.420
$\text{Au} \rightarrow \text{Au}^+ + \text{e}^-$	+1.680

Figure 3:

current is flowing - Oxidation-reduction reaction rates at interface change, altering equilibrium concentration of ions - V_a is Activation overpotential - Due to activation barrier for oxidation or reduction of ions, and will depend on direction of current - Polarizable Electrodes - If activation overpotential v_a is very large, no charge can flow - No conduction current, which is good for high impedance measurements - Electrode behaves like a capacitor - Only displacement current flows - Non-polarizable Electrodes - If activation overpotential V_a is very small and independent of the direction of current - Good for both voltage and current measurements and preferred for bio instrumentation - Electrode behaved like resistor - Conduction current flows across interface - In practice, both mechanisms occur to some extent and the interface impedance has components of resistance and capacitance - Silver/silver chloride electrode: - Deposition of (non-soluble) AgCl on Ag makes good non-polarizable electrode for any biological tissue or biological electrolyte which generally has excess of chlorine ions - Silver base with attached insulated lead wire is coated with layer of AgCl - Only slightly soluble in water - Electrode immersed in electrolyte bath in which principal anion of electrolyte is Cl^- -

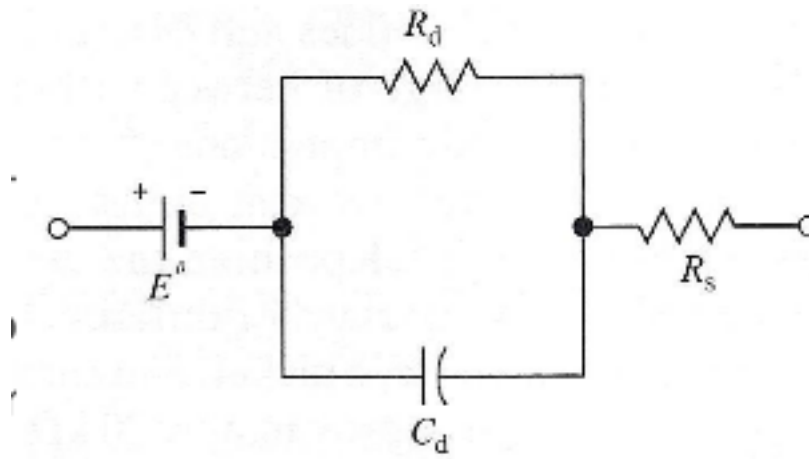


Figure 4:

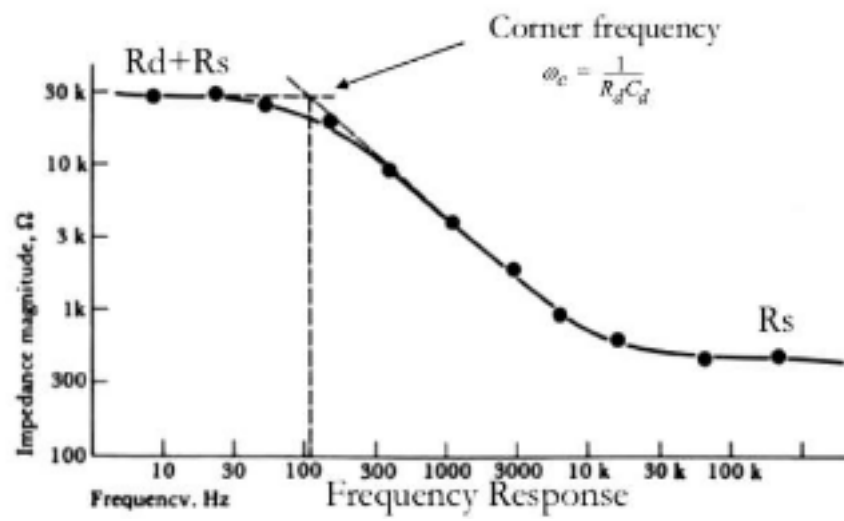


Figure 5:

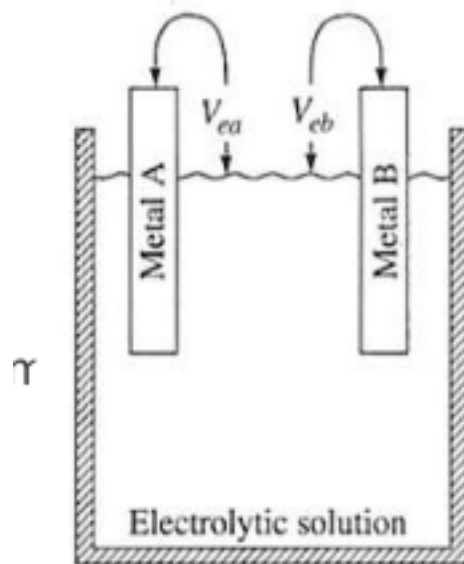


Figure 6:

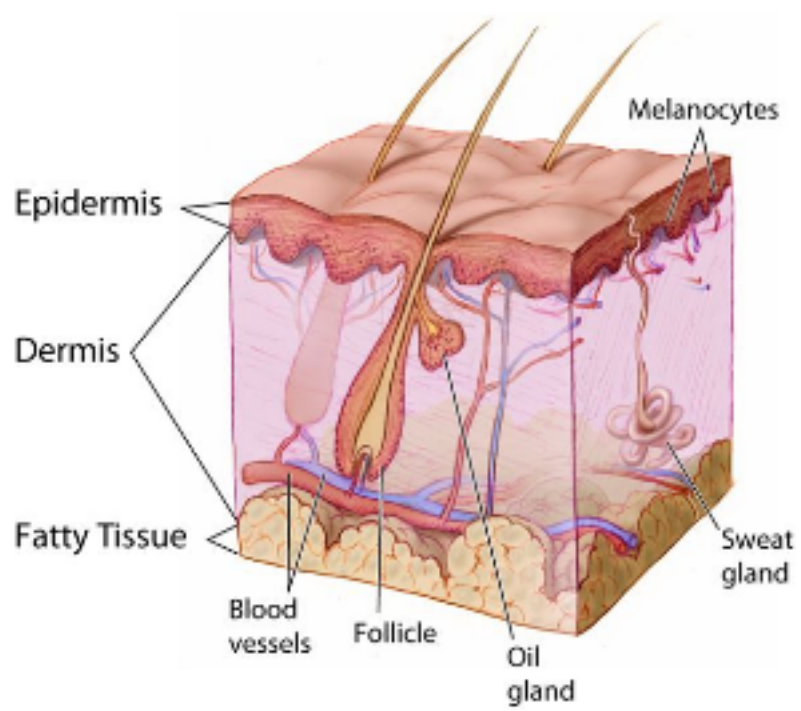


Figure 7:

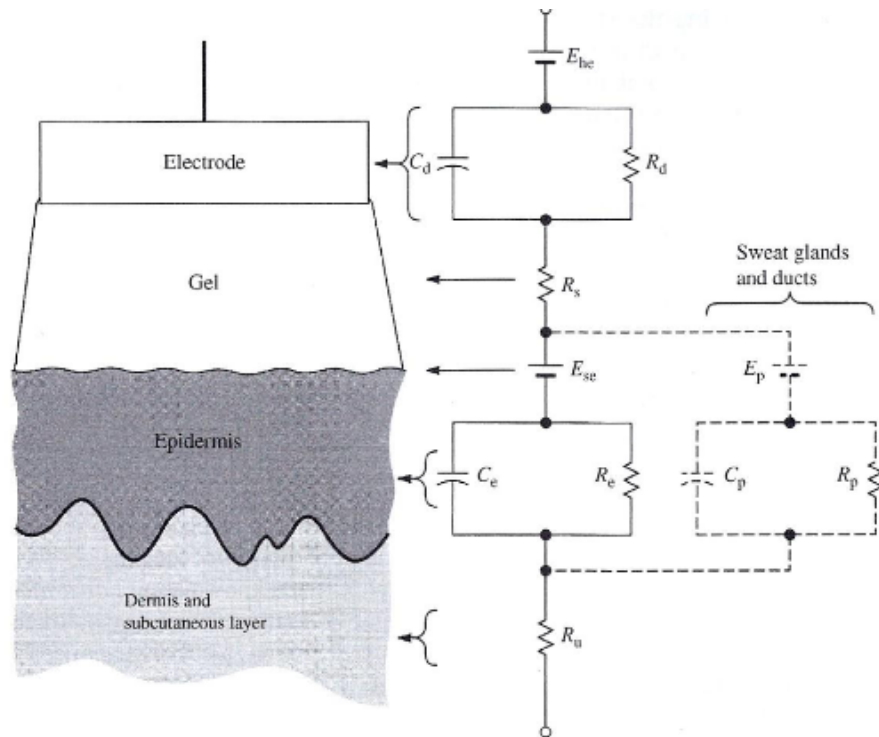


Figure 8:

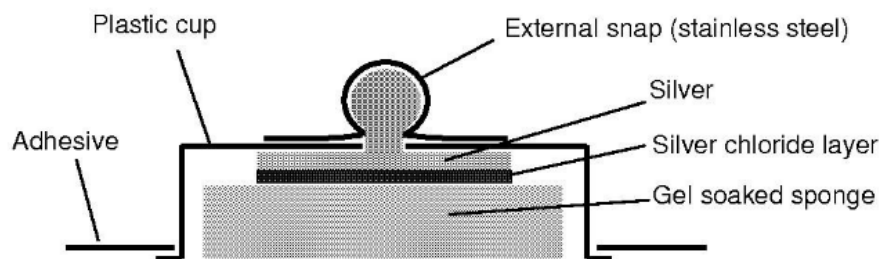


Figure 9:

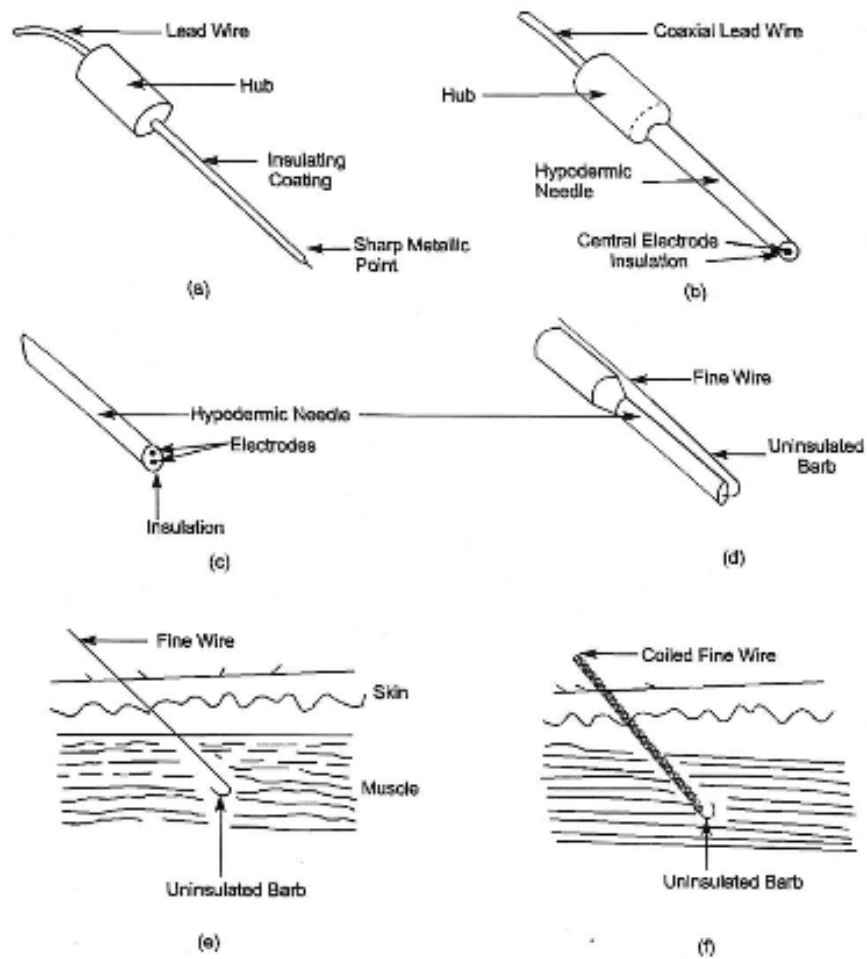


Figure 10:

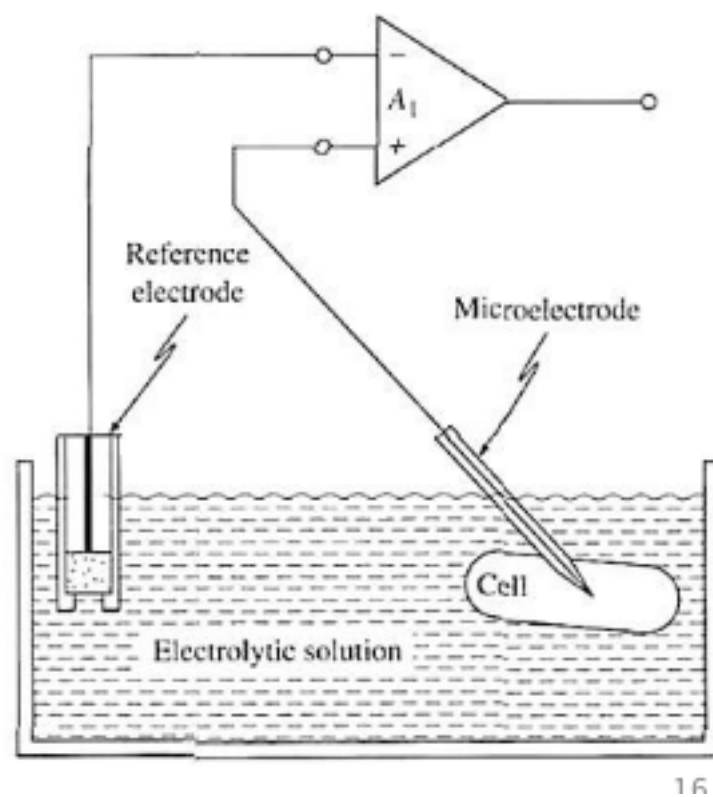


Figure 11:

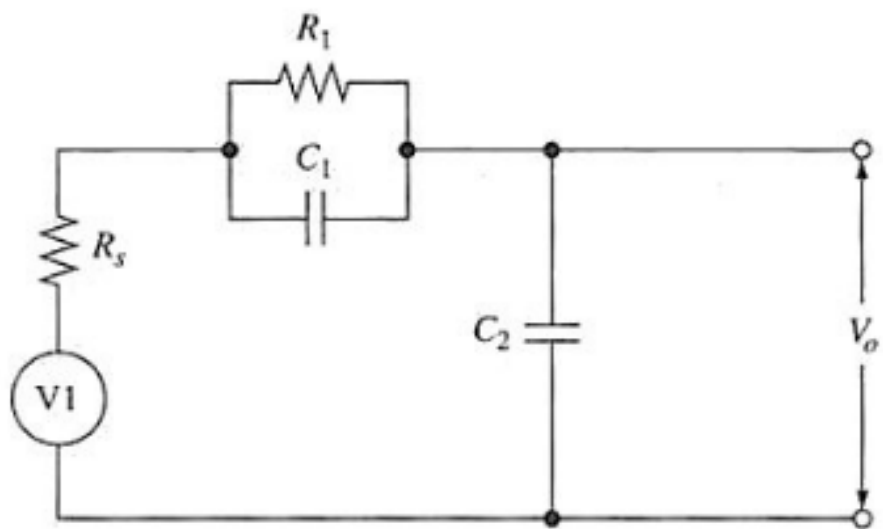


Figure 12:

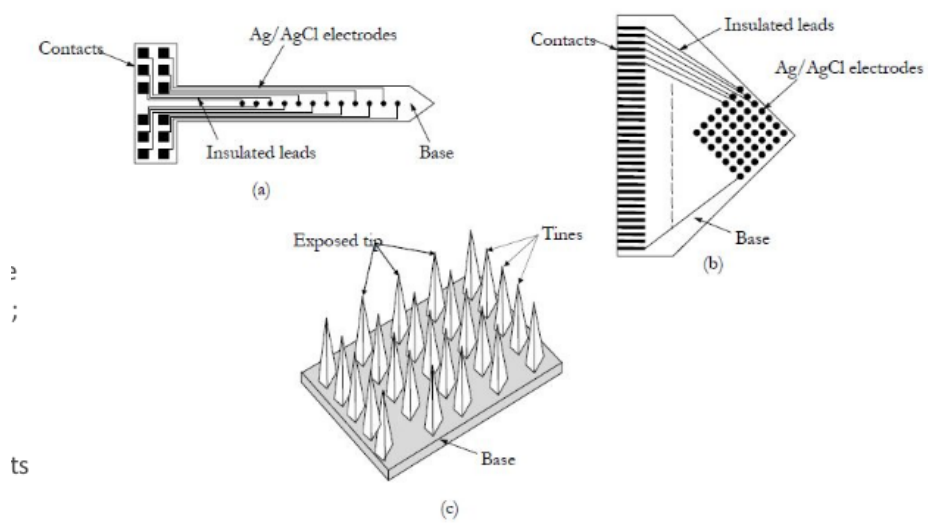


Figure 13: