PD233: Design of Biomedical Devices and Systems

(Lecture-6 Biopotentials 1)

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Course Website:
http://cpdm.iisc.ac.in/utsaah/courses/

Course Syllabus (2:1)

Softcore

- Medical Device Classification
- Bioethics and Privacy
- Design Control & Regulatory Requirement

- Biocompatibility and Sterilization Techniques
- Design of Clinical Trials

Hardcore

- Biopotential measurement (EMG, EOG, ECG, EEG)
- Medical Diagnostics (In-vitro diagnostics)
- Medical Diagnostics (Imaging)
- Minimally Invasive Devices
- Surgical Tools and Implants
- Medical Records and Telemedicine

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Electric Potentials (Basics)

Electric potential or voltage: Amount of ***electric potential energy one unit charge*** would have if located at a position in space. Electric potential is measured in Volts.

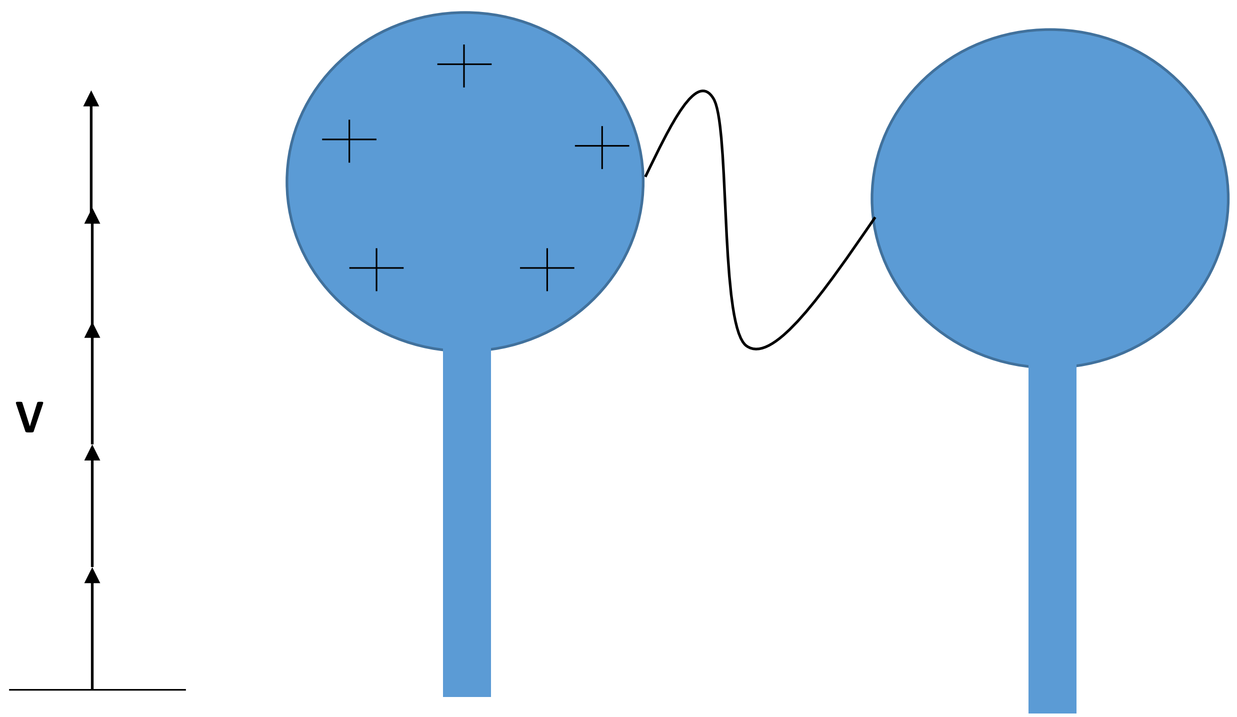
Potential difference between electric potential of two point (again measured in volts).

Potential difference leads to flow of current flow when two points with different electric potential are connected with conducting media.

What is Ohms law?

Voltage

- Accumulation of positive charge leads in increase in electric potential.



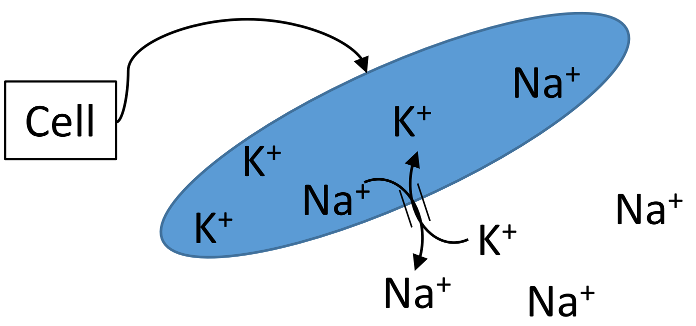
Origin of Biopotentials

- Certain class of biological cells produce electric potentials due to electro-chemical activity

  e.g. i) Nervous cells

  ii) Muscular cells

Resting potential: Most cells maintain steady state electrical potential difference between inside and outside of cells known as resting potential.



Active membrane proteins (***sodium-potassium pumps***) transport sodium ion (Na^+) out of the cell and potassium ion (K^+) into the cell in the ratios of $3Na^+:2K^+$

Membrane Potential

Ionic concentrations

Outside of the cells (extracellular)

Na^+:145 mmol/l K^+ : 4 mmol/l

Cl^- :120mmol/l

concentration

$$E_K = \frac{RT}{nF}\ln\frac{[K^+]_o}{[K^+]_i} = 0.0615\ \log_{10}\frac{[K^+]_o}{[K^+]_i}$$

Nernst equation

R = gas constant, T =temperature

n = valance,

$[K^+]$ = concentration of potassium ions

Inside the cells (intracellular)

Na^+:12 mmol/l K^+:155mmol/l

Cl^- :4mmol/l

$$E = \frac{RT}{F}\ln\frac{\{P_K[K^+]_o + P_{Na}[Na^+]_o + P_{Cl}[Cl^-]_i\}}{\{P_K[K^+]_i + P_{Na}[Na^+]_i + P_{Cl}[Cl^-]_o\}}$$

Resting Potential

Total membrane potential

$P_{k,Na,Cl}$=Permeability coefficient

Action potential:

Resting stage is *polarized* (steady state) ~-80 to -120mV

Depolarization is lessening of polarization magnitude. Once the depolarization crosses a certain threshold it starts a 'action potential' which can travel across the cell ***without attenuation***.

Locally the polarization is recovered in short time (~1ms) but the depolarization wave continue to travel.

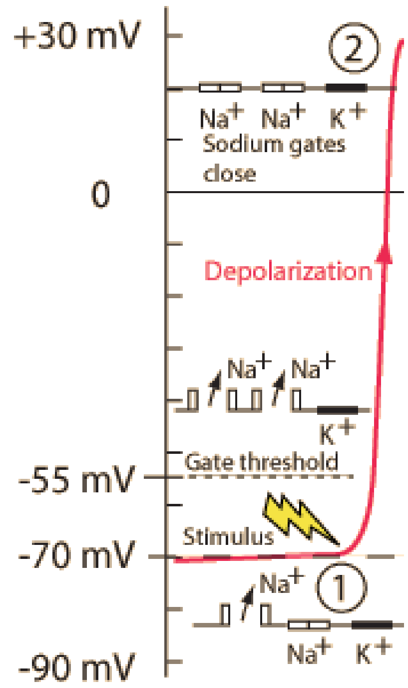
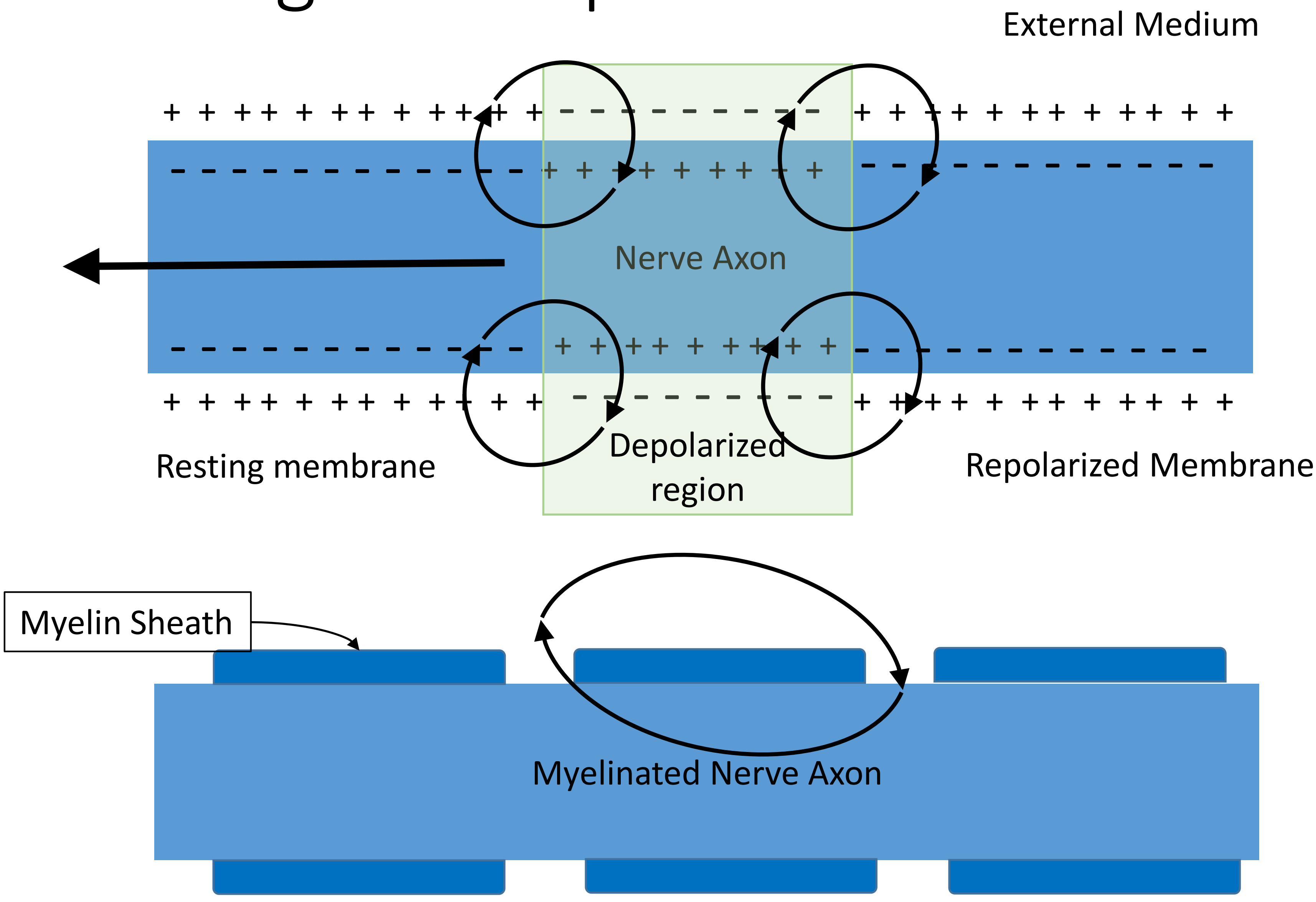
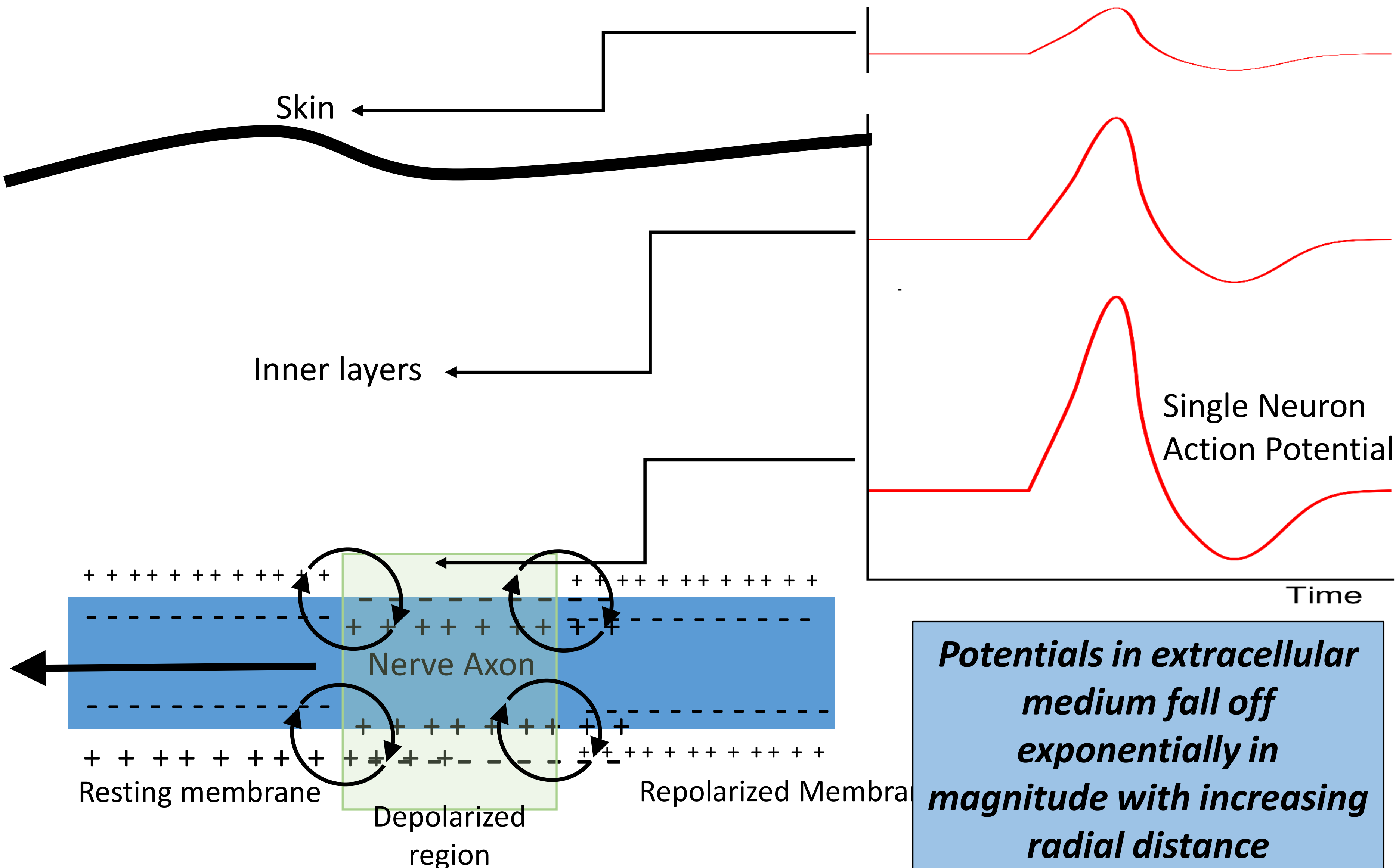


Image credit: http://hyperphysics.phy-astr.gsu.edu/hbase/biology/imgbio/actpot4.gif

Traveling action potential



Clinical Applications?

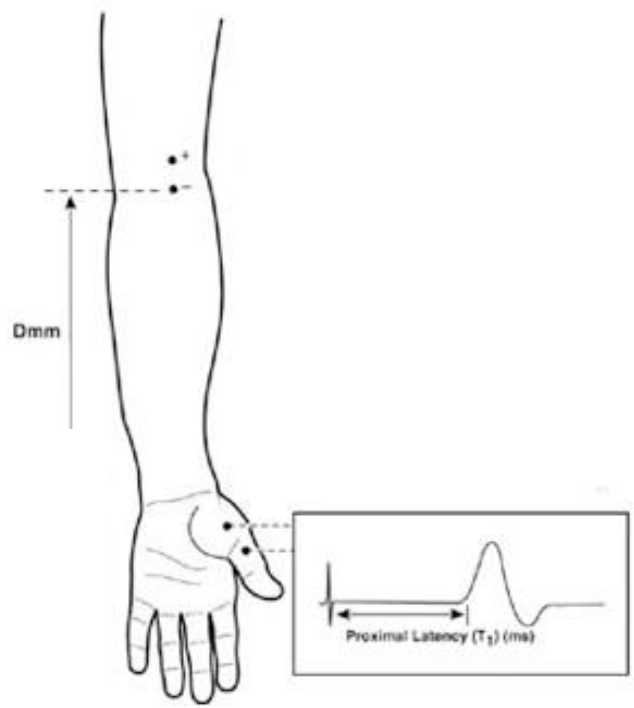


Potentials in extracellular medium fall off exponentially in magnitude with increasing radial distance

Motor Nerve Conduction Velocity

Sensory nerves can be excited by ***intense*** (~100V) ***brief*** (100-300μs) electrical stimuli.

Such pulse do not excite pain nerve fibre or surrounding muscles.



Diabetic Neuropathy

- High level of sugar can damage nerve cells including myelin sheath.
- Nerve conduction might get effected and can be diagnosed with NCV measurements along with other clinical information.