

# 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
- .....

# Electric Potentials (Basics)

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

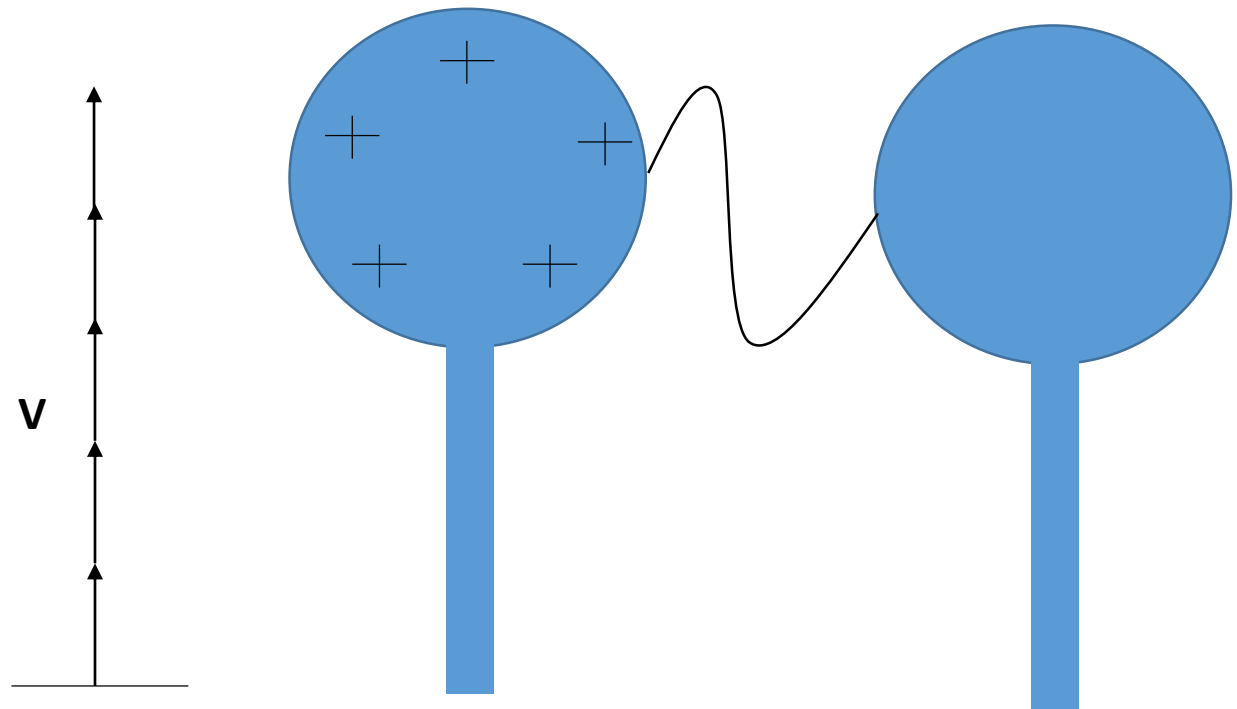
*Potential difference* between electric potential of two point (again measured in volts).

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

Ohms law?

# Voltage

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



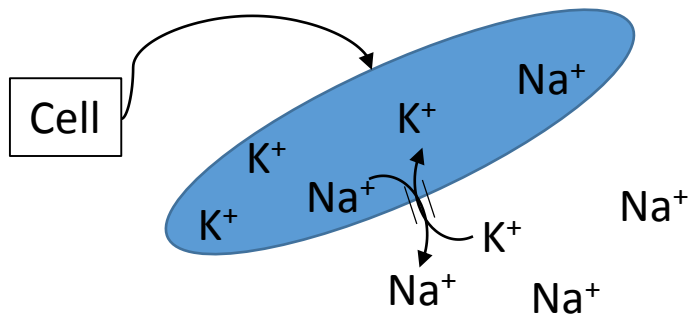
# Origin of Biopotentials

- 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<sup>+</sup>:145 mmol/l    K<sup>+</sup>: 4 mmol/l

Cl<sup>-</sup>:120mmol/l

concentration  
→

Inside the cells (intracellular)

Na<sup>+</sup>:12 mmol/l    K<sup>+</sup>:155mmol/l

Cl<sup>-</sup>:4mmol/l

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

Nernst equation

R = gas constant, T = temperature

n = valance,

[K<sup>+</sup>] = concentration of potassium ions

***Resting Potential***

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

Total membrane potential

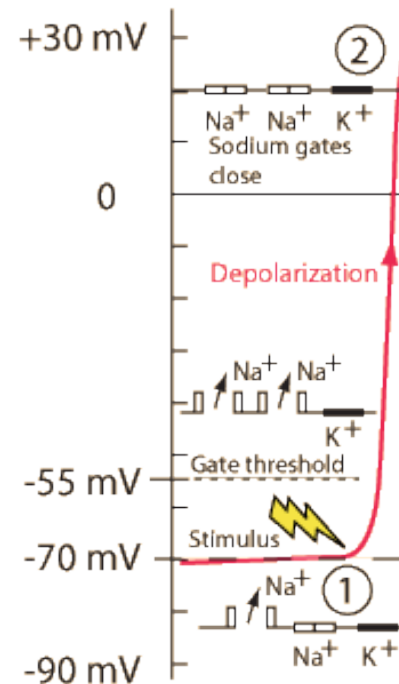
P<sub>k,Na,Cl</sub>=Permeability coefficient

# Action potential:

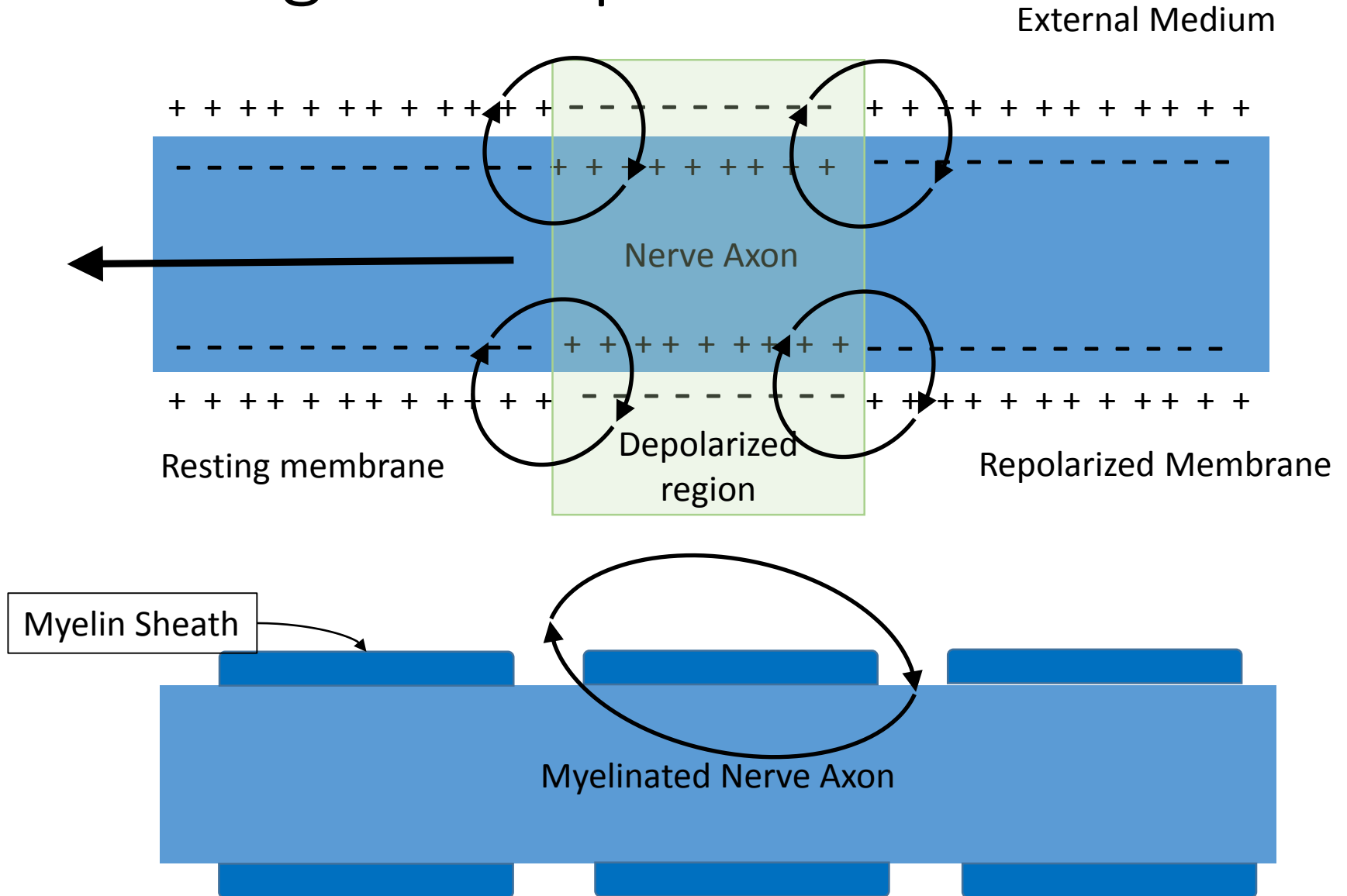
Resting stage is *polarized* (steady state)  $\sim -80$  to  $-120\text{mV}$

*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 ( $\sim 1\text{ms}$ ) but the depolarization wave continue to travel.

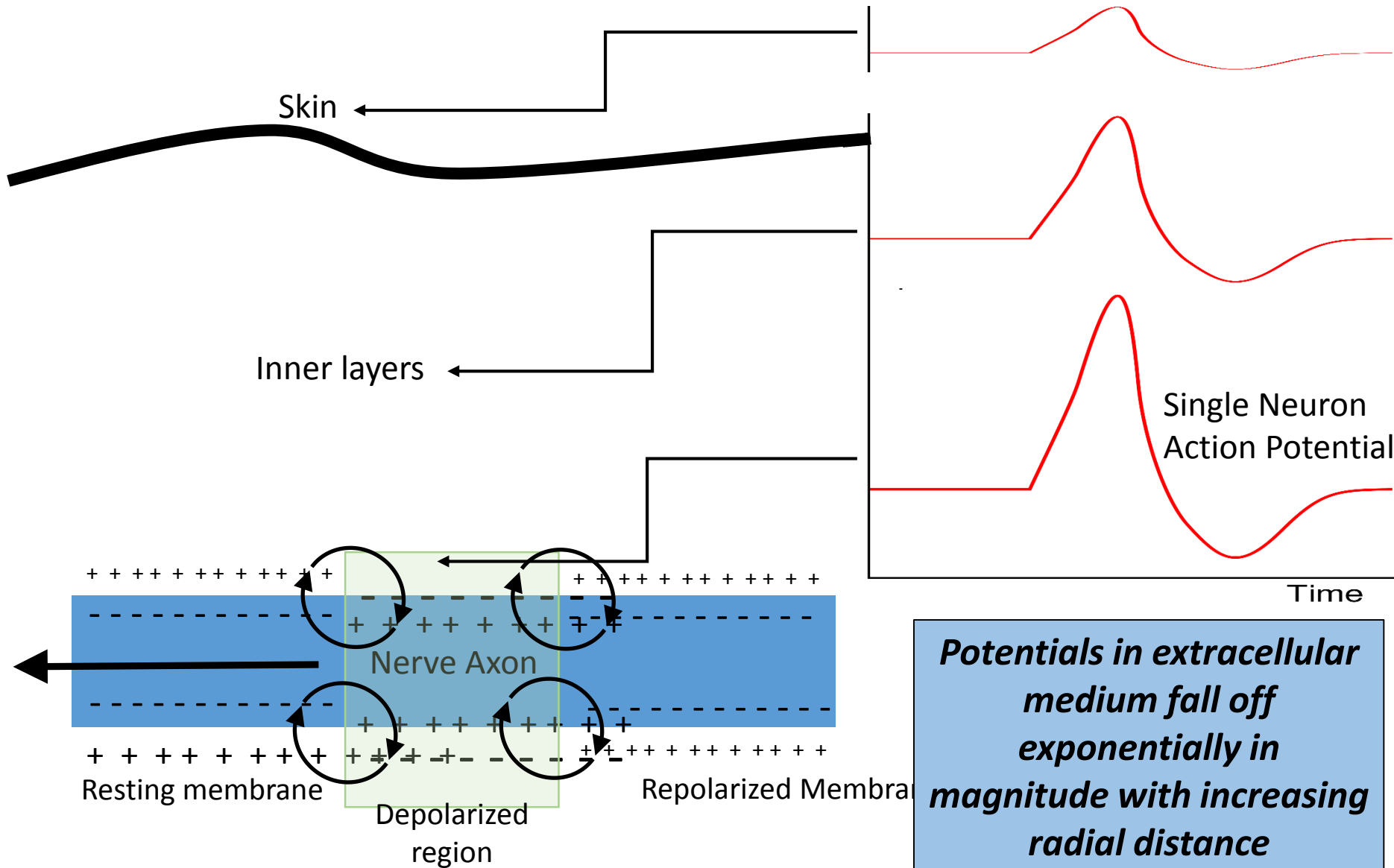


# Traveling action potential





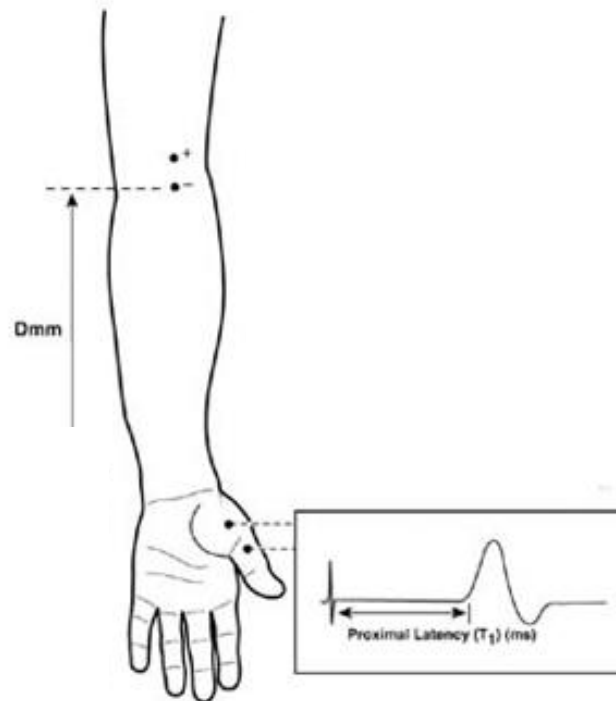
# Clinical Applications?



# Motor Nerve Conduction Velocity

Sensory nerves can be excited by **intense** ( $\sim 100\text{V}$ ) **brief** ( $100\text{--}300\mu\text{s}$ ) 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.