The Cell and Action Potentials

The Cell

- Basic building block of human body
- Same funciton grouped to form
- Tissues - Muscles, Nerves, Blood, Bones, Cartilage
- 2+ tissues of dissimilar physiology form organs
- Heart, Lungs, Kidneys, etc.
- Several organs constitute system
- digestive system, respiratory system etc.
- Interstitial fluid
- Provides nourishment to cell
- Removes waste
- Responds to electrochemical impulses

!(images/s2/s2p1.png)

Average Human Cell

- Nearly Spherical
- 20μm diameter
- Semipermeable outer membrane, 100 Angstrom units thick
- Inner fluid, cytoplasm, comprising of organelles and inclusions
- Organelles: Small internal living organs of cell
- Inclusions: Non-living accumulation of metabolites such as fats/carbs
- Inner control unit, nucleus, enclosed by membrane, filled with nucleoplasm
- Includes nucleoli containing RNA and DNA
- Determine specific biochemical characteristics of cell type
- Control metabolic activities

Cell Metabolism: Membrane Transport

- Cell uses 3 processes for nourishment and waste expulsion across membrane:
- Diffusion:
- Movement of substance from regions of high concentration
- Influenced by factors such as:
- Membrane permeability
- Relative concentration of internal and external substances
- Electrical potential inside/outside cell
- Pressure difference across membrane
- Active Transport:
- Carrier transports substance across membrane
- Moves from lower to higher contentration

- Pinocytosis
- Similar to Active Transport
- Carrier not used
- Membrane can engulf certain substances resting on it
- Forms capsule, travels through membrane to cytoplasm

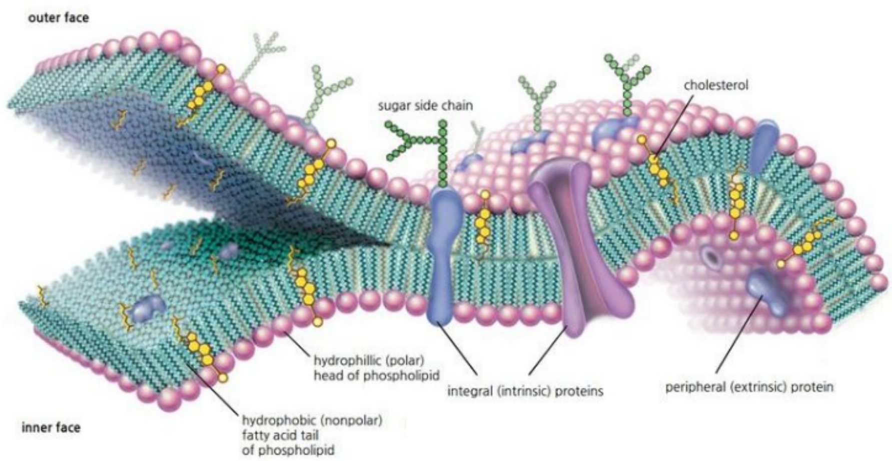

Figure 1:

Resting Potential

- Cell membrane separates interstitial fluid from intracellular fluid, maintaining markedly different concentrations of ions inside/outside cell
- Concentration of Sodium and Chloride ions higher in interstitial fluid
- Concentration of Potassium ions higher in intracellular fluid
- Skeletal muscle cells:
- Insidel cell: Negative potential difference, approx. -90mV, relative to interstitial fluid
- Resting Potential of Cell
- Resting cell membrane:
- Highly permeable to potassium
- Slightly permeable to sodium
- Potassium leaks out as high rate of equilibrium reached when tendency for potassium to defuse out is balanced by resulting electric field
- Metabolic proceses of cell actively transport sodium ions out of cell, potassium ions into cell, opposition to chemical gradient

Action Potential

- Cell receives electrical stimulus above threshold value

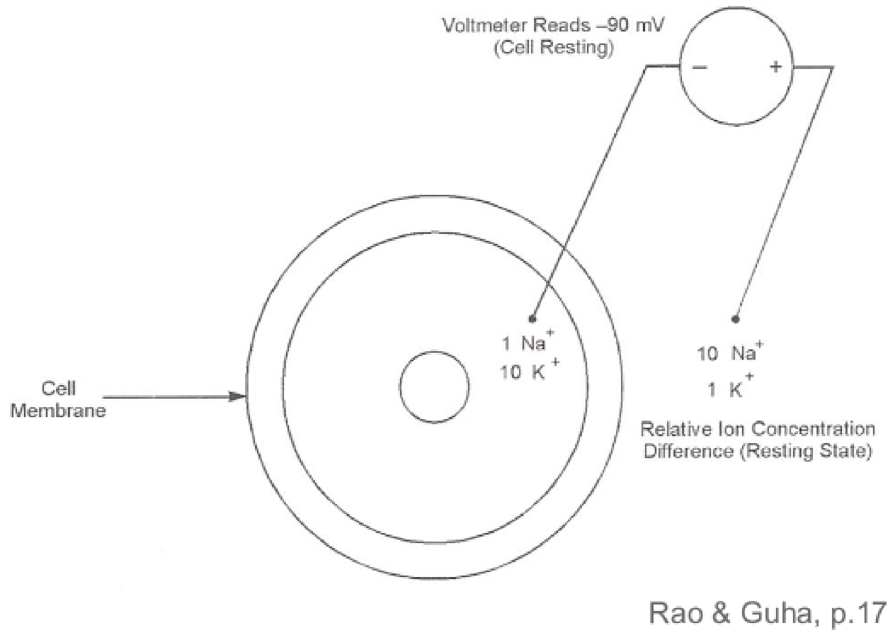
Voltmeter Reads –90 mV
(Cell Resting)
–
+
1 Na+
10 K+
10 Na+
1 K+
Cell
Membrane
Relative Ion Concentration
Difference (Resting State)
Rao & Guha, p.17

Figure 2:

- Electrochemical balance upset
- Cell goes through Action Potential cycle
- Can result in electrochemical impulses transmit from cell to cell
- Results from change in membrane permeability at point of stimulation
- Permeability to sodium ions increased
- Sodium ions flow into cell
- Outer side of cell momentarily more negative than interior
- Depolarisation
- Cell potential changed to approx. +20mV
- Cell returns to resting permeability
- Potassium ions defuse outwards
- Cell returns to resting potential, approx. -90mV
- Repolarization
- Action Potential Timescale
- 1ms in nerve/muscle cells
- 150-300ms in heart cells
- Bioelectronic currents due to + and - ions in conducting fluid
- Finite rise/fall time of cell action potential arises from:
- Mass of ions
- Resistance to movement through fluid/across membrane

- Ionic concentration gradient across membrane maintained by sodium-potassium pump
- Sodium withdrawn from cell against both charge and concentration gradients supported by high-energy phosphate compound ATP
- Rate of pumping proportional to sodium concentration in cell
- Operation of pump delivers potassium ions into cell
- Cell may be stimulated/caused to depolarise/repolarise by subjecting membrane to ionic current above certain min. value
- Stimulus Threshold, typically -60mV
- If stimulus less than threshold/too short duration, cell won't depolarise
- Action potential always same for given cell, irrespective of thresh. intensity of stimulus
- Following generation of action potential, brief period where cell cannot respond to new stimulus
- Absolute Refactory Period - approx. 1ms in nerve cells
- May also have relative refactory period
- Another action potential can be triggered
- Much stronger stimulation needed
- Once thresh. reached, polarisation/depolarisation sequence can't be turned off/changed, regardless of length/further presence of stimulus
- Second stimulus won't have effect while cell in depolarising phase
- Theshold level can be increased/decreased by:
- Altering membrane permeability
- Changing concentration of potassium, sodium, calcium etc
- Introducing other chemicals to fluid around cell

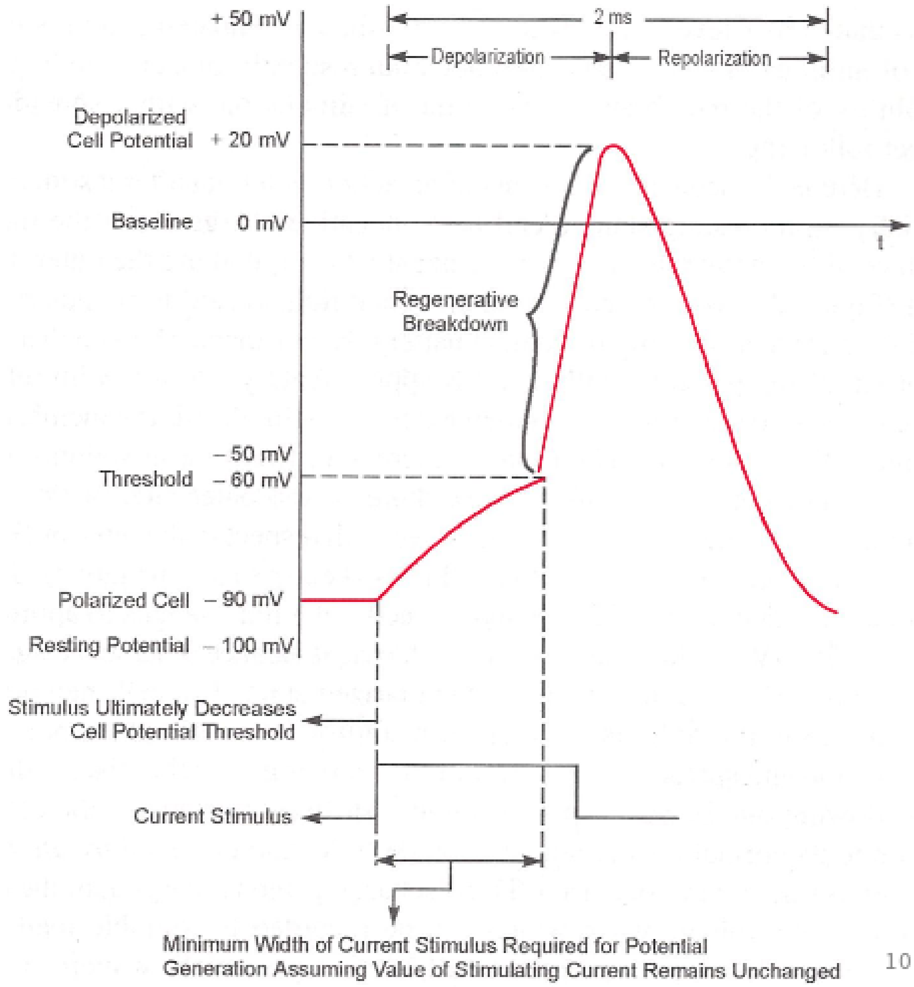
+ 50 mV
2 ms
Depolarization
Repolarization
Depolarized
Cell Potential + 20 mV
Baseline 0 mV
t
Regenerative
Breakdown
– 50 mV
Threshold – 60 mV
Polarized Cell – 90 mV
Resting Potential – 100 mV
Stimulus Ultimately Decreases
Cell Potential Threshold
Current Stimulus
Minimum Width of Current Stimulus Required for Potential
Generation Assuming Value of Stimulating Current Remains Unchanged
10

Figure 3:

Bioelectric Potentials

- Combined effects of coordinated electrochemical action potentials of large groups of cells is basic source of Bioelectric Potentials
- Charge mitigation through body fluids constitute electric current setting up potential differences between various part of body including outer surface
- Can measure potential differences by placing electrodes on outer surface of body, amplifying voltages with sensitive amplifiers

Bioelectric Signal	Spectrum (Hz)	Potential Range (µV)	Sensing Devices Used	Signal Origin
Electrocardiogram (ECG) Vectorcardiogram	0.05 to 100	10 to 5 000 covers fetal range	Surface electrodes are used with jelly. Needle electrodes are less noisy	Heart Muscles
Electroencephalogram (EEG)	0.1 to 100	2 to 200	Surface and needle electrodes	Neuronal activity of brain
Cerebral Potentials (intracranially recorded)	Pulse duration (0.6 ms to 0.1s)	10 to 10 0000	Deep needle electrodes	Cerebrum of the brain
Electromyogram (EMG) (Primary signal)	5 to 2 000	20 to 5 000	Surface or needle electrodes	Skin muscles
Electrogastrogram	0.05 to 0.2	10 to 350	Surface electrodes	Peristaltic movement of the gastro-intestinal tract
Electroretinogram (ERG)	0.01 to 200	0.5 to 1 000	Corneal electrodes	Retina of the eye
Electrooculogram (EOG)	DC to 100	10 to 3 500	Miniature surface electrodes	Corneal-retinal Potential variations

Figure 4: