3. Bioelectric Phenomena

Neurons

- Two classes of neuron
  - Nerve cell
  - Neuroglial cell
- Neuron= nerve cell
- A neuron consists of cell body, axon, dentrite and presynaptic terminals

Four major regions of typical neuron

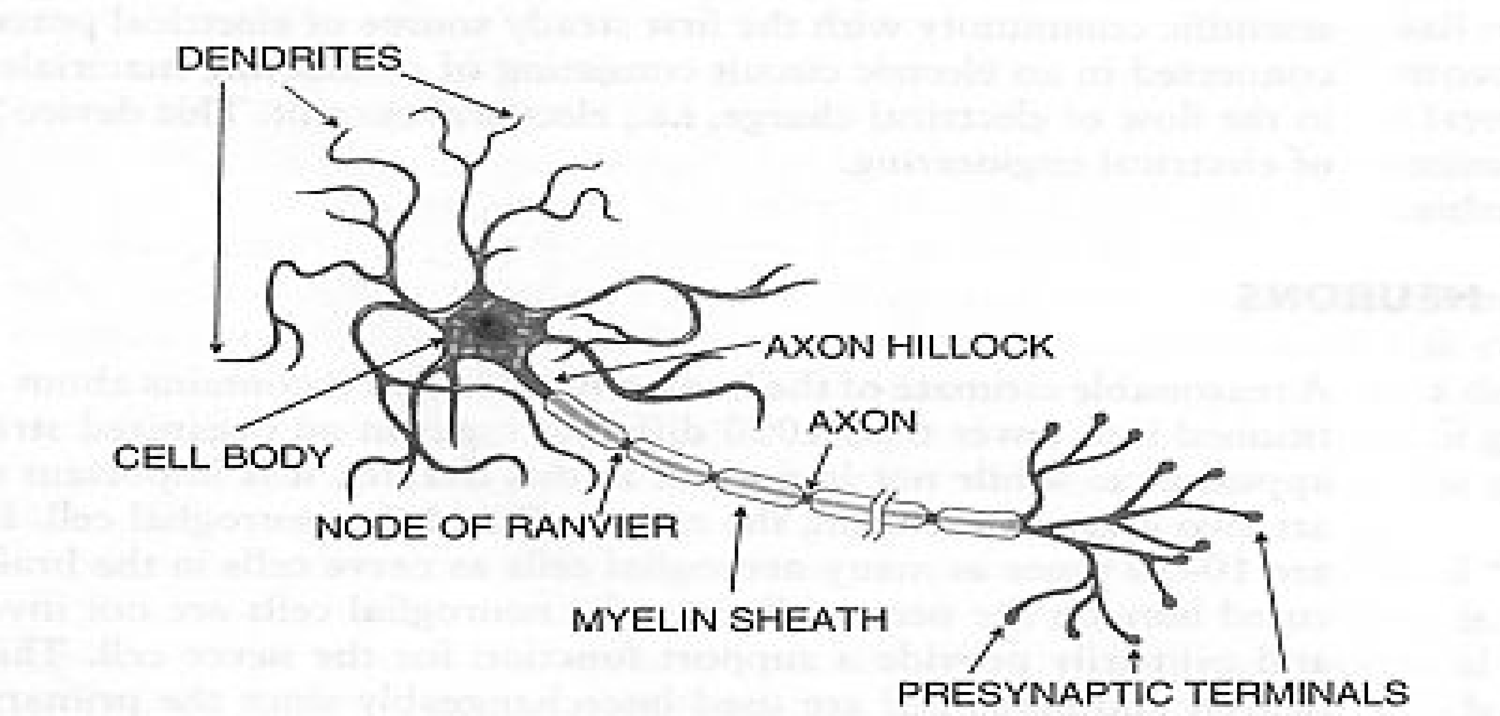
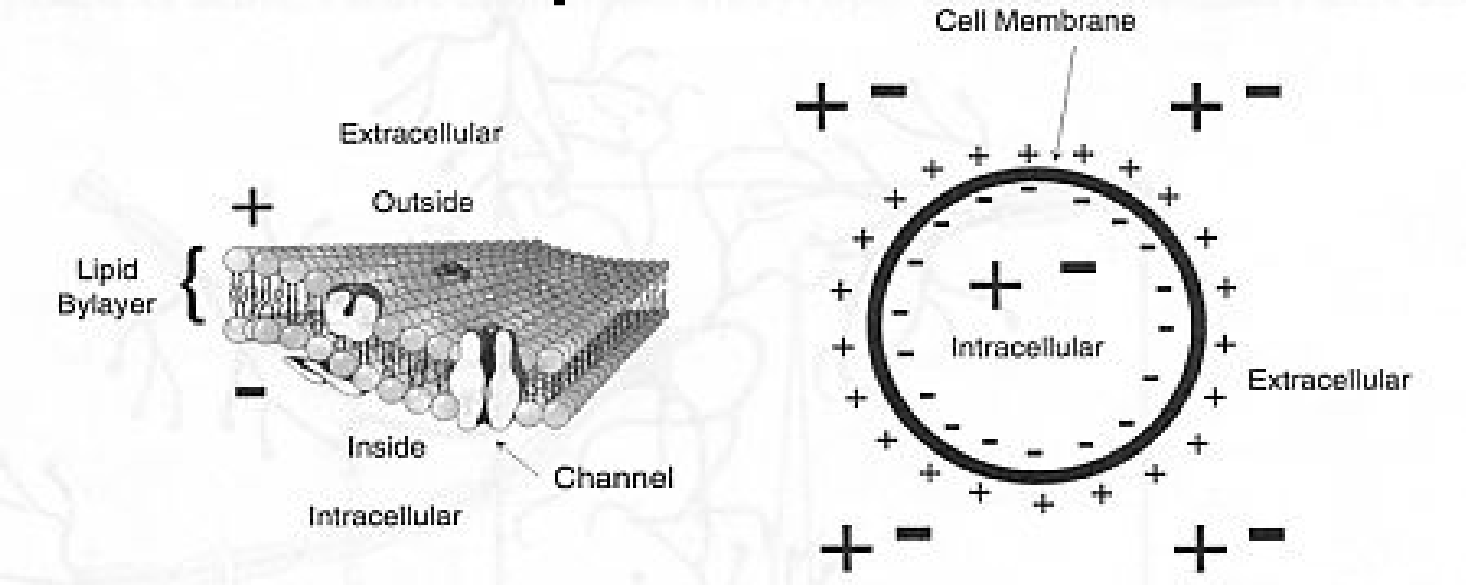


Diagram of a typical neuron

Membrane potentials



Diagrams illustrating separation of charges across a cell membrane. (Left)A cell membrane with positive ions along the outer surface of the cell membrane and negative ions along the inner surface of the cell membrane(Right)The further illustrates separation of charge by showing that only the ions along the inside and outside of the cell membrane are responsible for membrane potential(negative ions along the inside and positive ions along the outside of cell membrane).

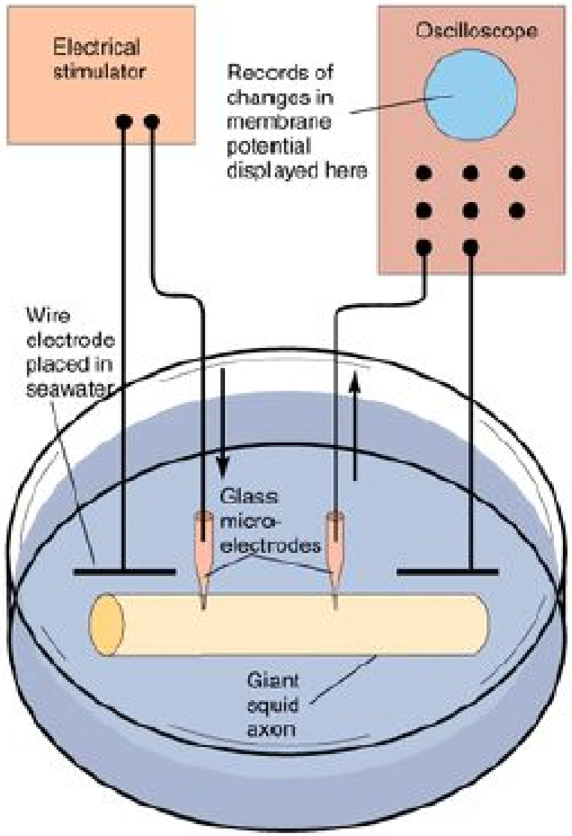
Membrane Potential

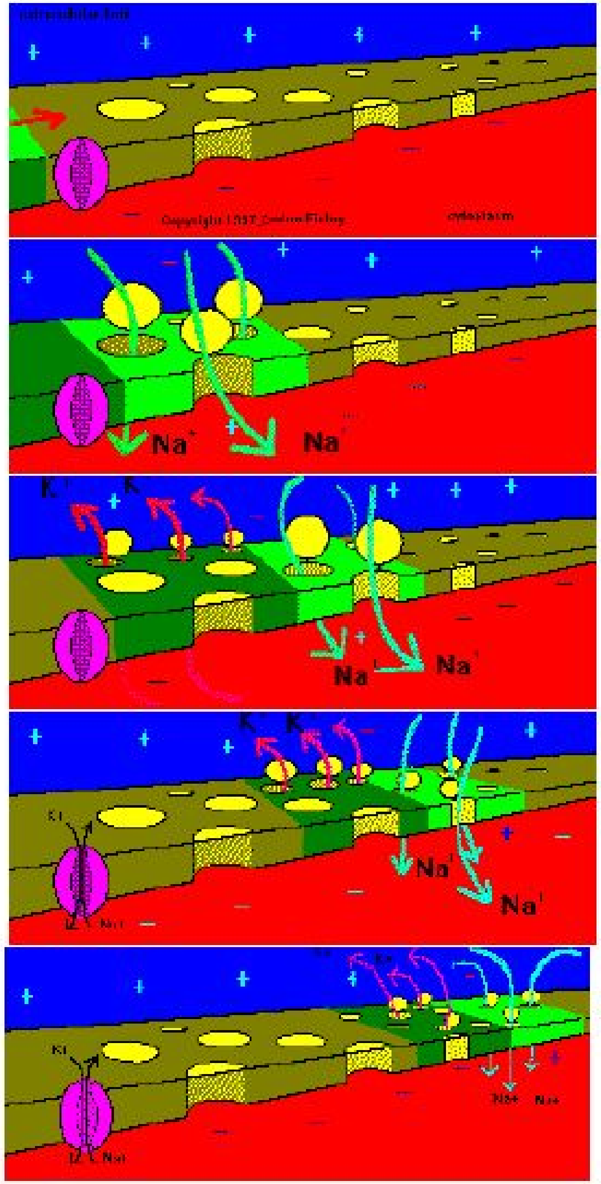
Elsewhere negative and positive ions are approximately evenly distributed as indicated with the large plus/minus symbols for the illustration on the right. Overall, there is a net excess of negative ions inside the cell and a net excess of positive ions in the immediate vicinity outside the cell.

Intracellular Space: E=0
Extracellular Space: E=0
Across the membrane: ~100 KV/cm.

Generation & Measurement of Action Potential

► Stimulation of an Axon While Its Membrane Potential Is Recorded





At rest, the inside of the neuron is slightly negative due to a higher concentration of positively charged sodium ions outside the neuron.

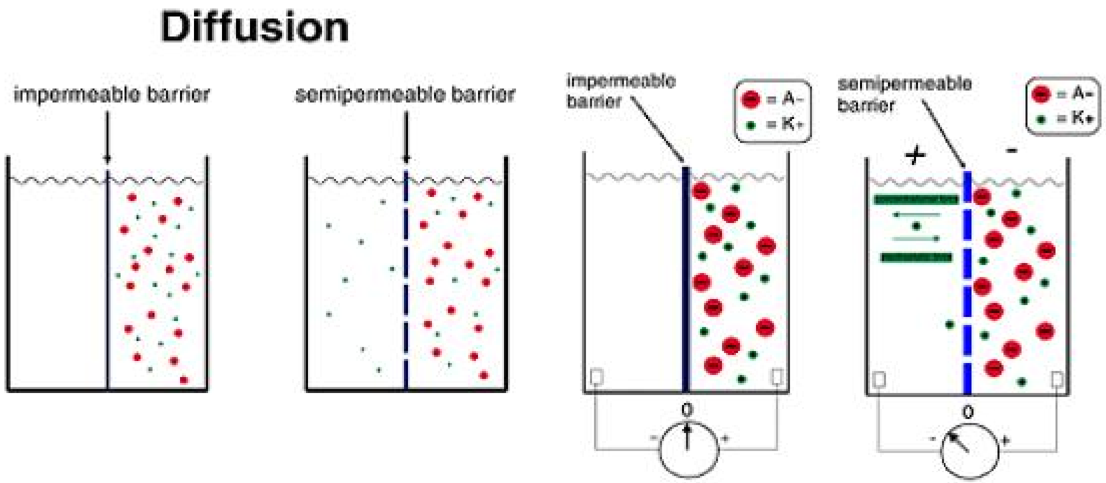
When stimulated past threshold, sodium channels open and sodium rushes into the axon, causing a region of positive charge within the axon.

The region of positive charge causes nearby sodium channels to open. Just after the sodium channels close, the potassium channels open wide, and potassium exits the axon.

This process continues as a chain-reaction along the axon. The influx of sodium depolarizes the axon, and the ourflow of potassium repolarizes the axon.

The sodium/potassium pump restores the resting concentrations of sodium and potassium ions

Nernst Equation



- $V = -2.303(RT/ZF)*\log_{10}(C_{in}/C_{out})$, where R is the gas constant, T is temperature in degrees Kelvin, and F is Faraday's constant.

$$E_{Na} = v_i - v_o = 26 \ln \frac{[Na^+]_o}{[Na^+]_i} \text{mV} \qquad E_{Cl} = v_i - v_o = 26 \ln \frac{[Cl^-]_o}{[Cl^-]_i} = 26 \ln \frac{[Cl^-]_i}{[Cl^-]_o} \text{ mV}$$

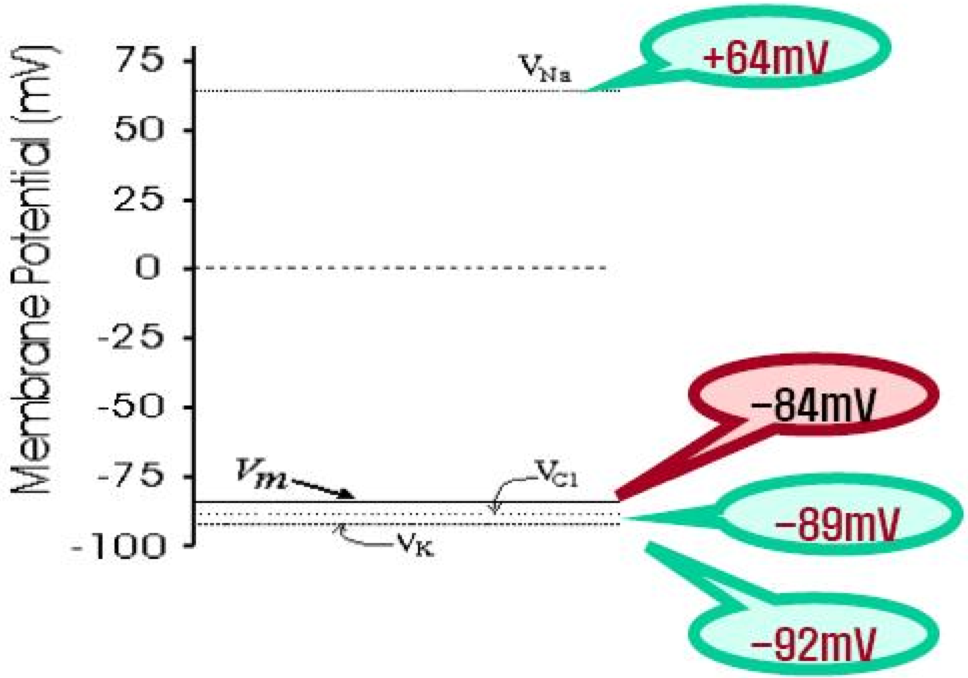
Minus sign here

Equilibrium Membrane Potentials

- If the plasma membrane were permeable only to any single ion of K^+, Na^+, and Cl^-, the Potential Difference across the membrane could be calculated by the *Nernst equation*.

ion	cytoplasm	extracellular	V_{eq}
Na^+	12	140	+64mV
K^+	135	4	−92mV
Cl^-	5	150	−89mV

Resting Membrane Potentials



Goldman-Hodgkin-Katz Equation

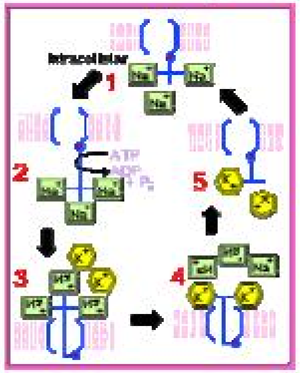
- Because the membrane has a finite permeability to most ionic species, the actual electrical PD at any point in time is a compromise between their combined influence.
- Goldman equation provides a reasonable prediction of the electrical potential difference across the plasma membrane of a cell at rest

Ion	permeability (cm/sec)
Na+	1×10^{-9}
K+	1×10^{-7}
Cl−	1×10^{-8}

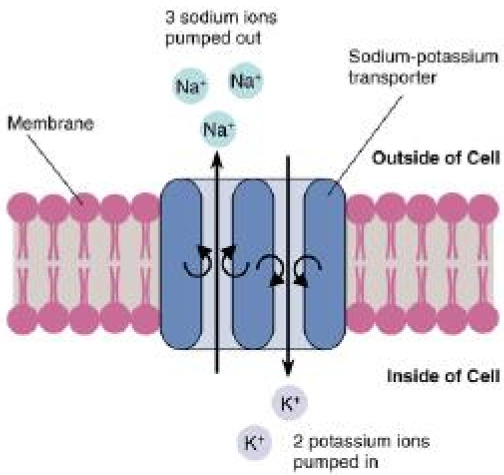
$$V_m \cong -60\text{mV} \log_{10} \frac{P_K[K]_{in} + P_{Na}[Na]_{in} + P_{Cl}[Cl]_{out}}{P_K[K]_{out} + P_{Na}[Na]_{out} + P_{Cl}[Cl]_{in}}$$

Sodium/Potassium Pump

- to maintain the concentration gradients for Na^+ and K^+), there is an energy dependent (ATP-dependent) pump system (**Na^+/K^+-ATPase**) that pumps Na^+ out of the cell and K^+ into the cell.
- Normal operation of this pump is essential for the maintenance of Na^+ and K^+ concentrations across the membrane.

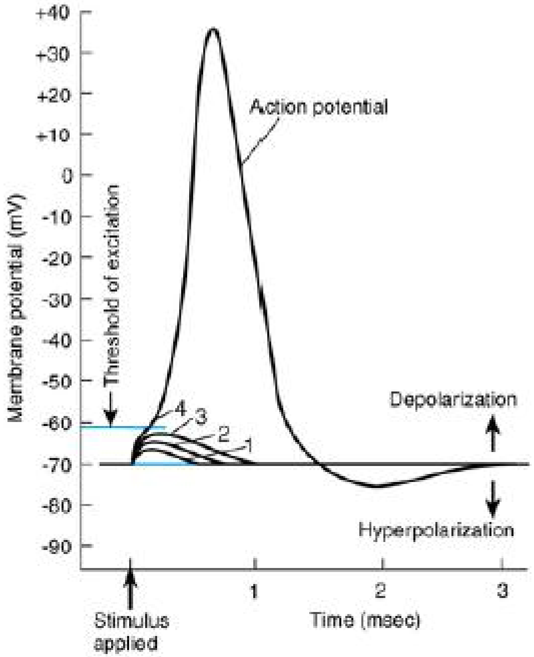


► Sodium-Potassium Transporter in the Cell Membrane



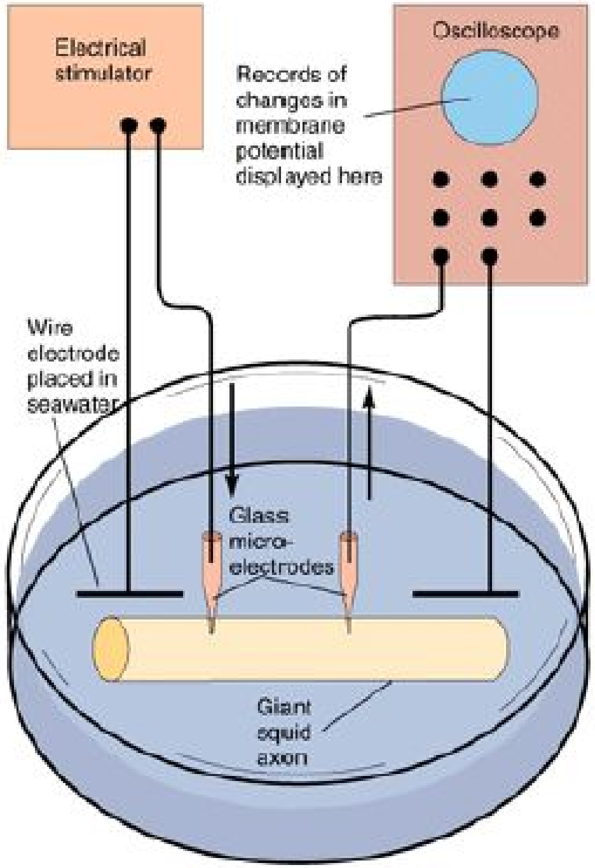
Action Potential

- Brief (about one-thousandth of a second) reversal of electric polarization of the membrane of an excitable cell (neuron or muscle cell)

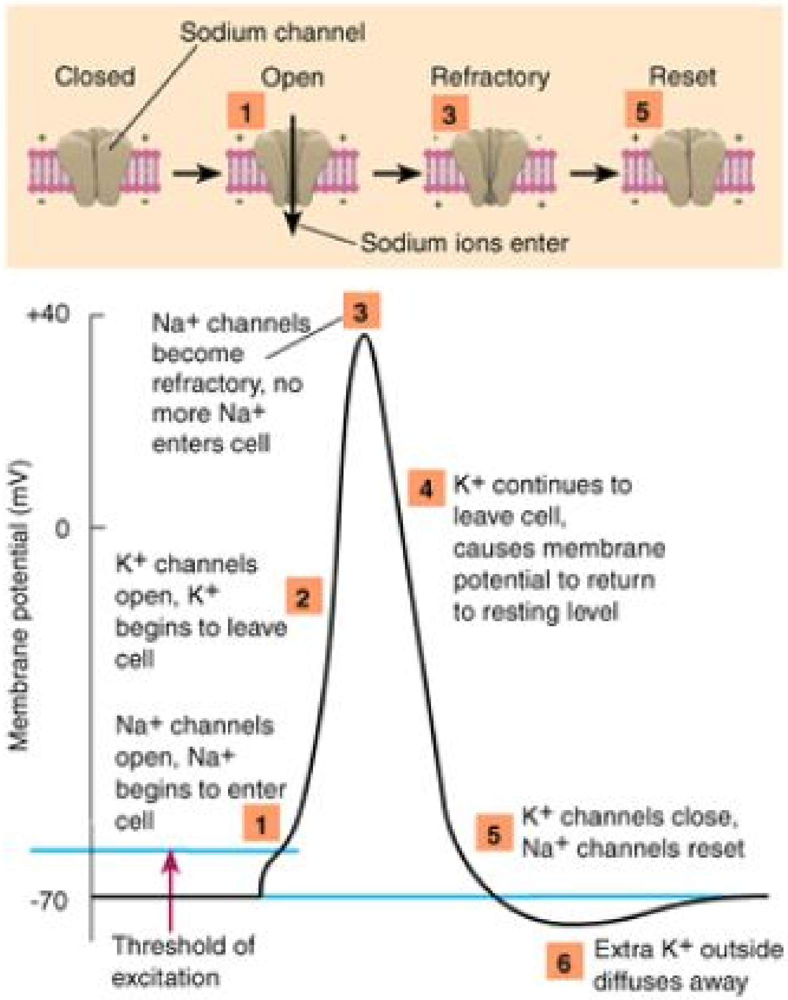


- The refractory period
- The action potential is all-or-none

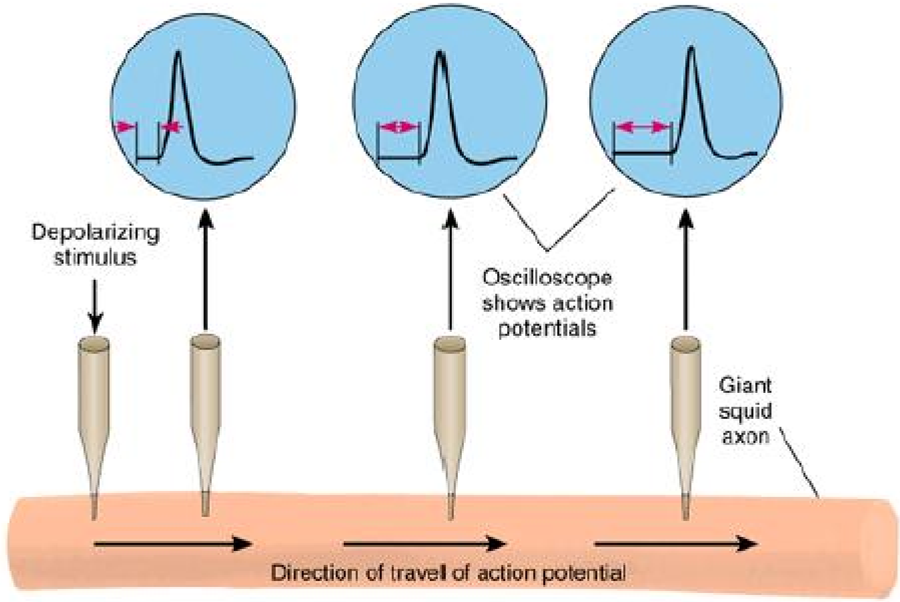
► **Stimulation of an Axon While Its Membrane Potential Is Recorded**



► **The Movements of Ions During the Action Potential**

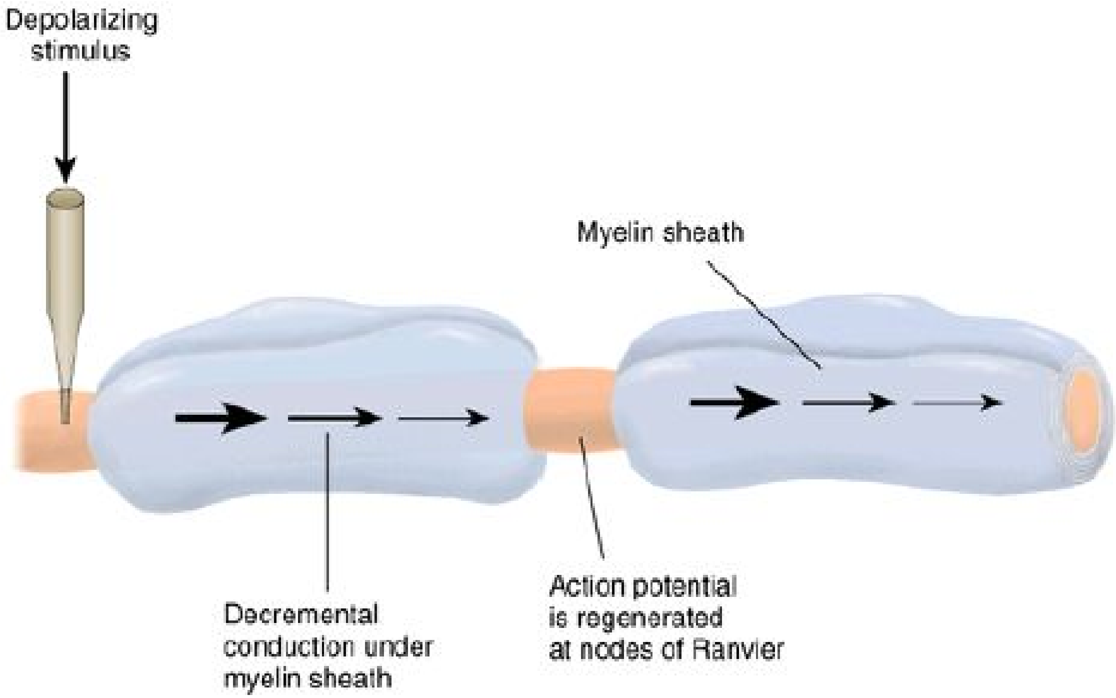


Conduction of Action Potential



- an action potential is conducted at speeds that range from 1 to 100 m (3 to 300 feet) per second, depending on the properties of the fibre and its environment.

► **Saltatory Conduction**



MS (Multiple Sclerosis) is an autoimmune disease that gradually destroys the mylelin sheath

Graded response and Action Potentials

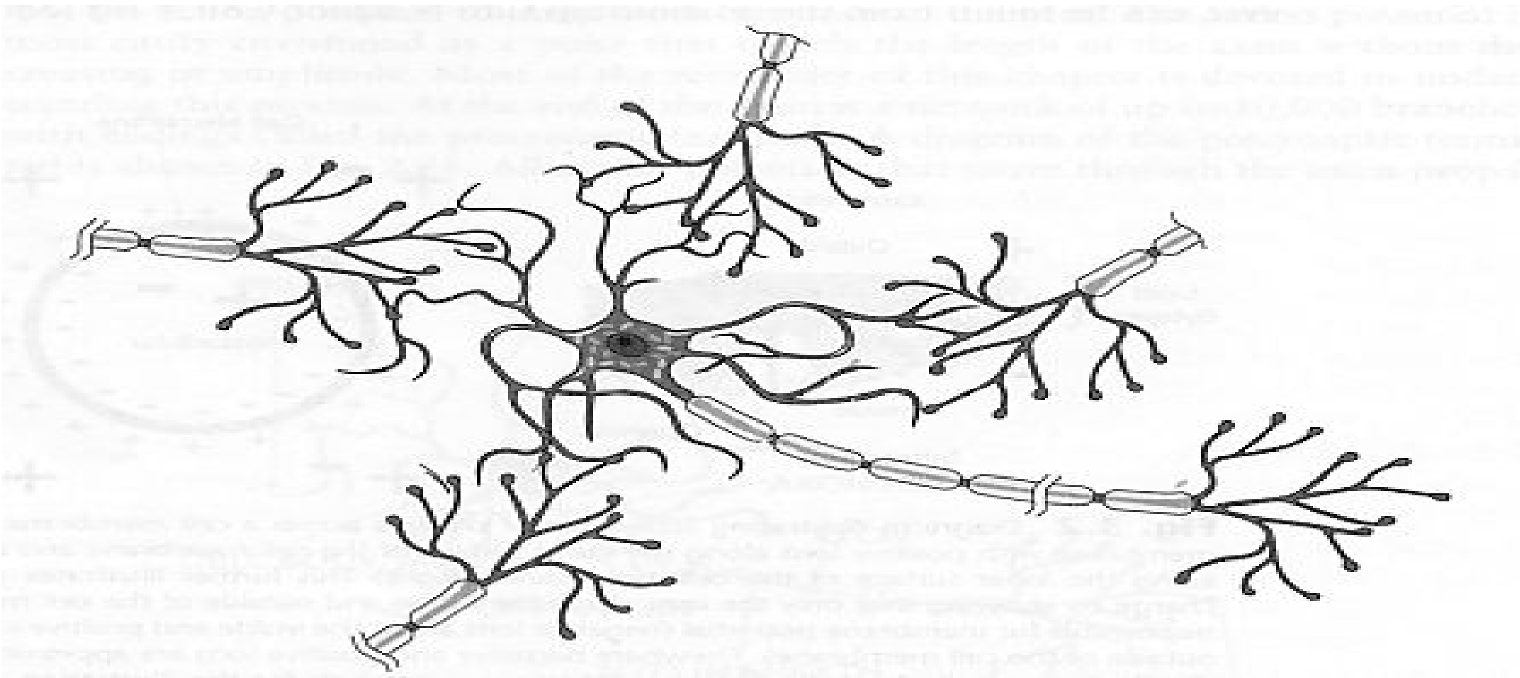
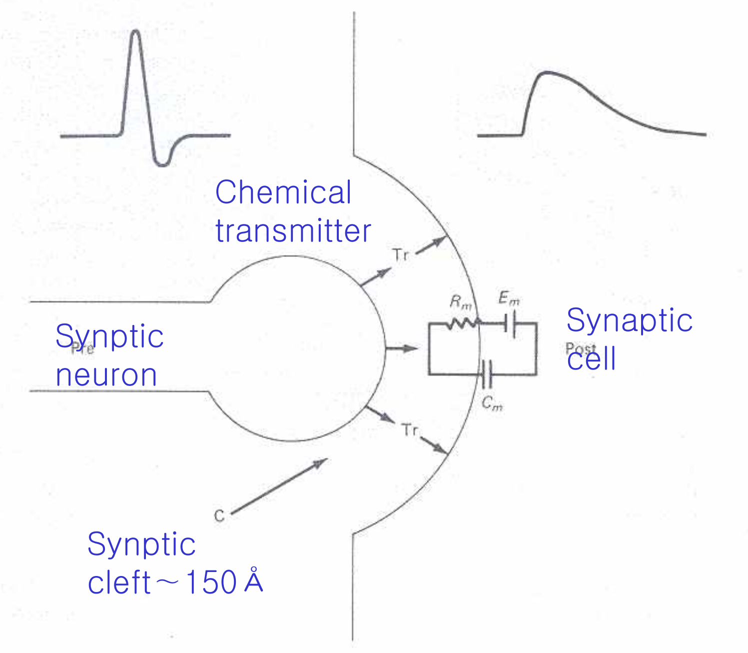


Diagram illustrating a typical neuron with presynaptic terminals of adjacent neurons in the vicinity of its dendrites

Synapses

- EPSP(Excitatory Post synaptic Potential) causes depolarization. Subthreshold EPSP can add to raise potential above Vth.
- IPSP(Inhibiting~) causes hyperpolarization.



Sequence of events in chemical transmission. Circuit diagram shows electrical model of postsynaptic membrane.