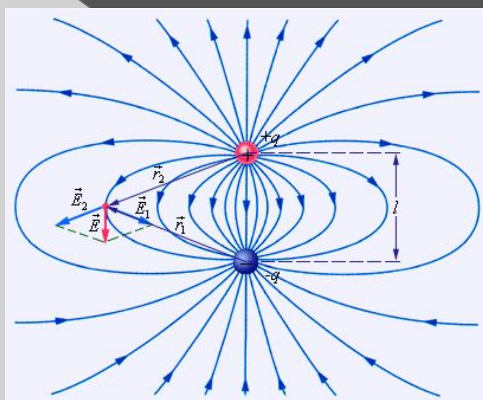
ELECTRICAL POTENTIALS OF THE CELL

Electric field. Coulomb's law.

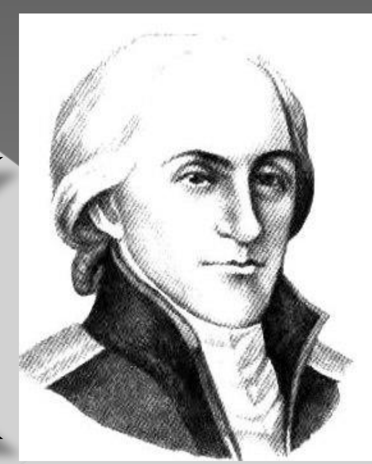
Electric field is the kind of matter by means of which the charged objects interact with each other.



Coulomb law defines the value of electric force *F* acting between the two electric charges q_1 and q_2

Here *k* is the constant determined by the measure units chosen and is the distance between the charges.

$$\vec{F} = k \cdot \frac{q_1 \cdot q_2}{r^2}$$

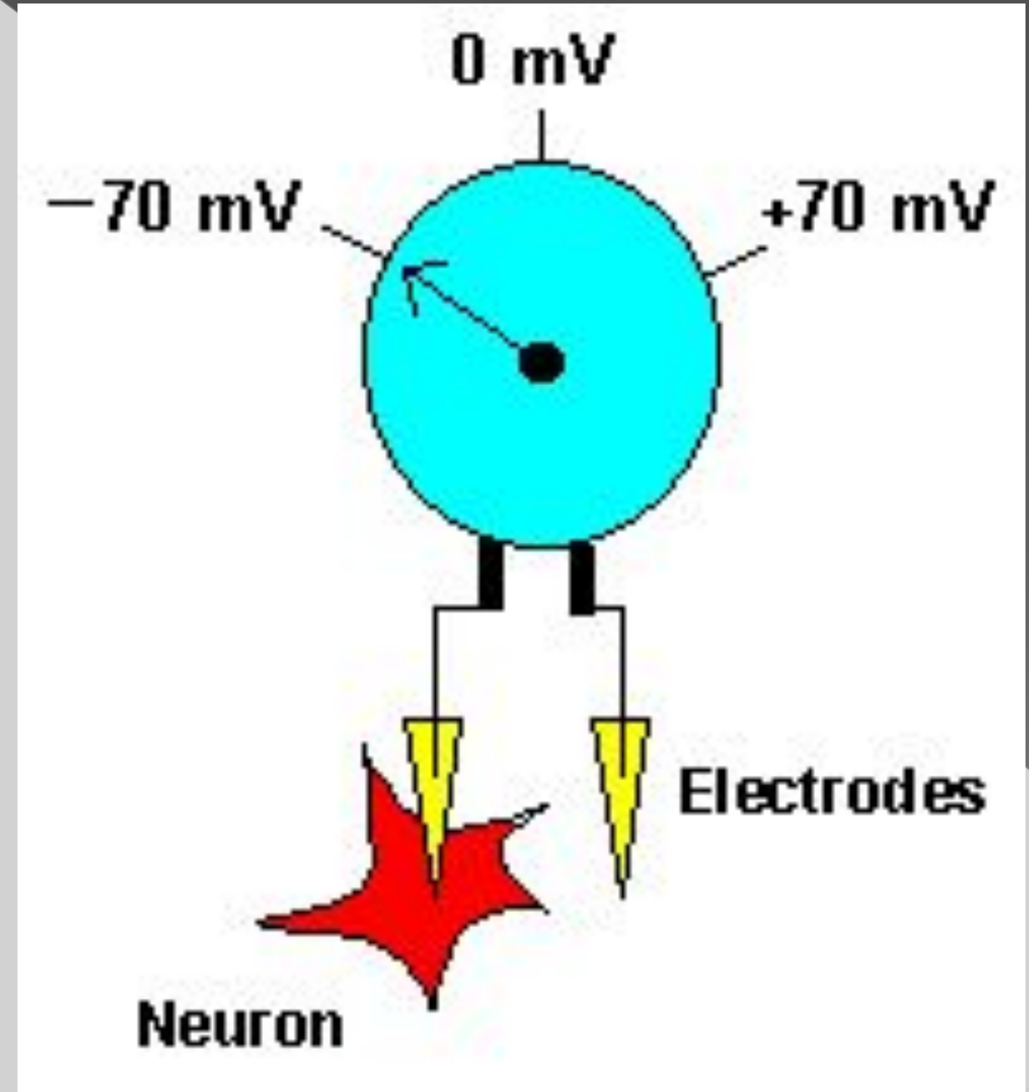


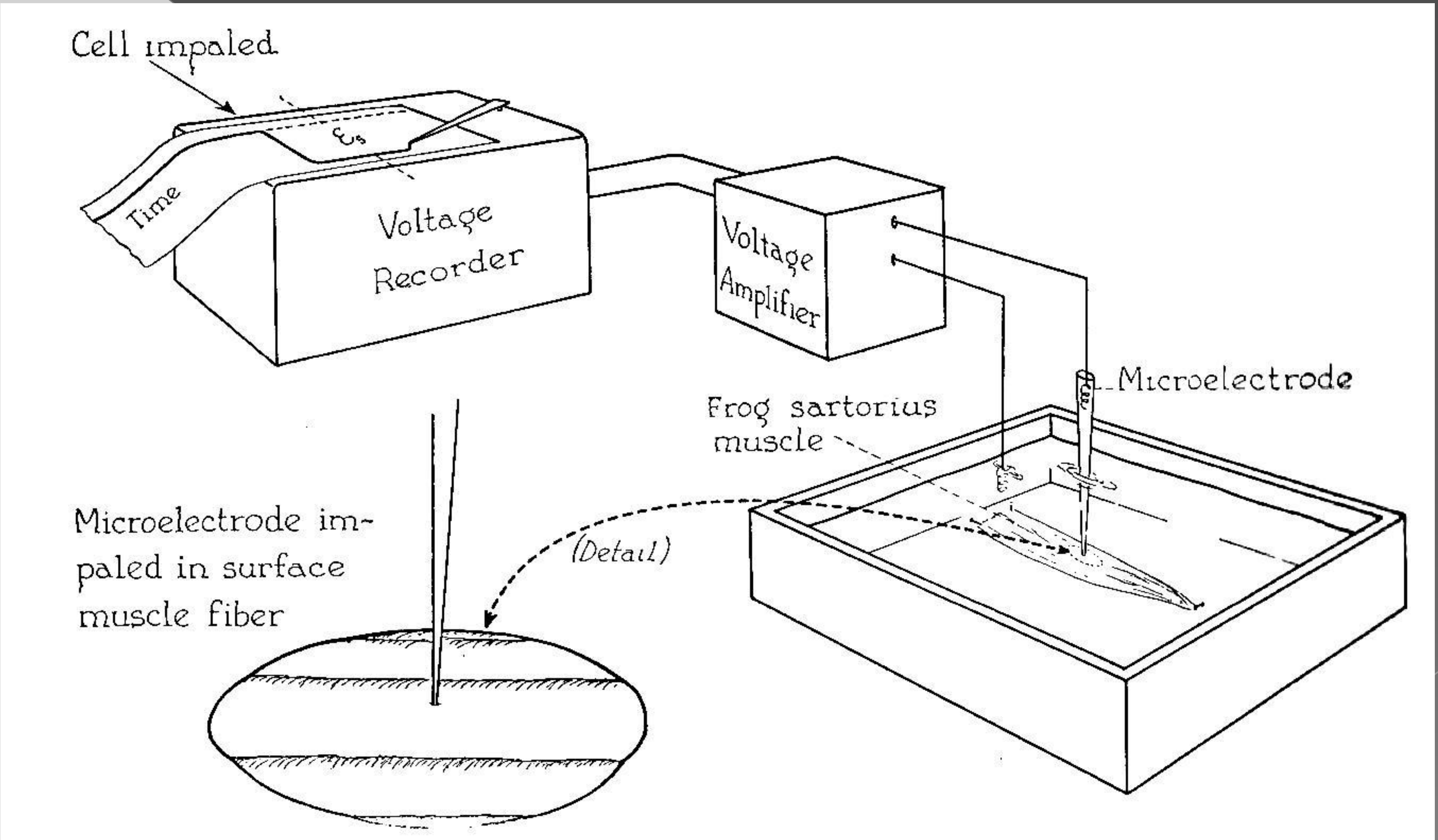
The electric field intensity E at any point is defined as the electric force F that would be exerted on the unit positive charge q placed at this point

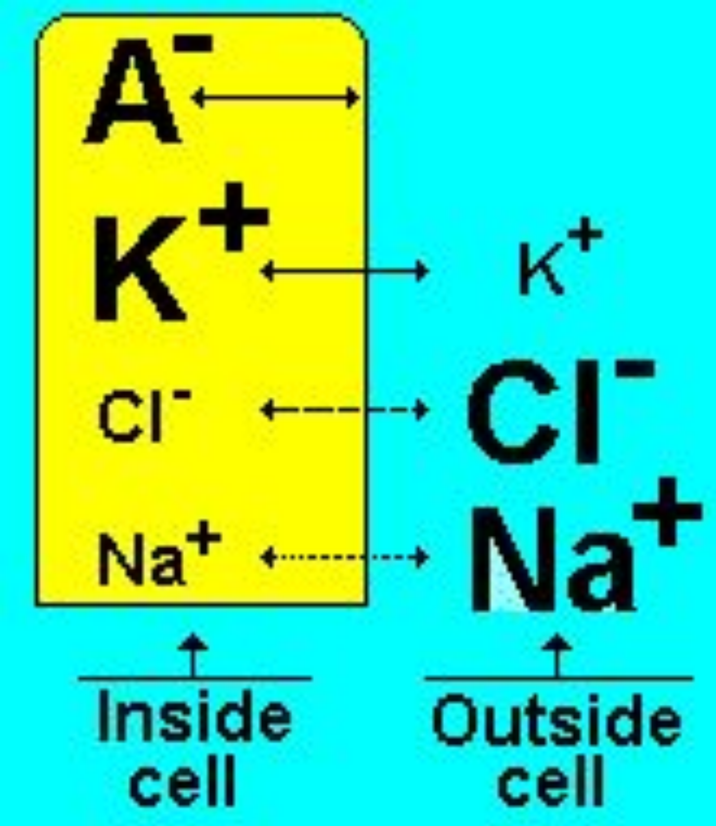
$$E = \frac{F}{q}$$

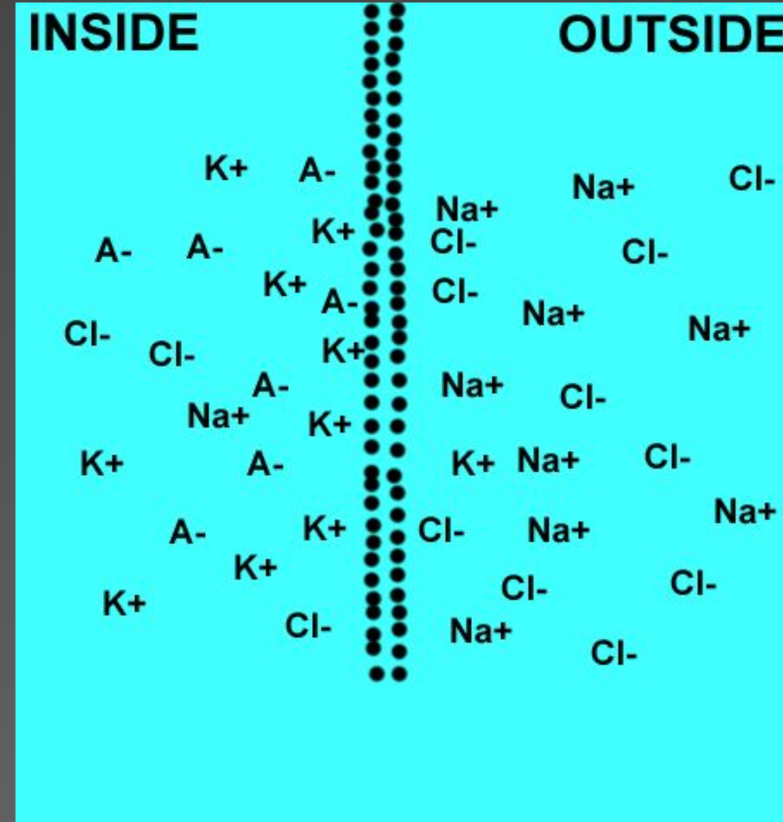
The electric potential ϕ (voltage) at any point equals the electrostatic potential energy W_p that the unit positive charge q would have at this point

$$\varphi = \frac{W_p}{q}$$


0 mV
−70 mV
+70 mV
Electrodes
Neuron


Cell impaled
Time
Voltage Recorder
Voltage Amplifier
Microelectrode
Frog sartorius muscle
(Detail)
Microelectrode impaled in surface muscle fiber





With no channels,
there is no diffusion force.

Kind of ions		Cell protoplasm	Extracellular fluid
Cations	Sodium	12	145
	Potassium	155	4
	Others	-	5
Anions	Chloride	4	120
	Bicarbonate	8	27
	Others (A^-)	155	7

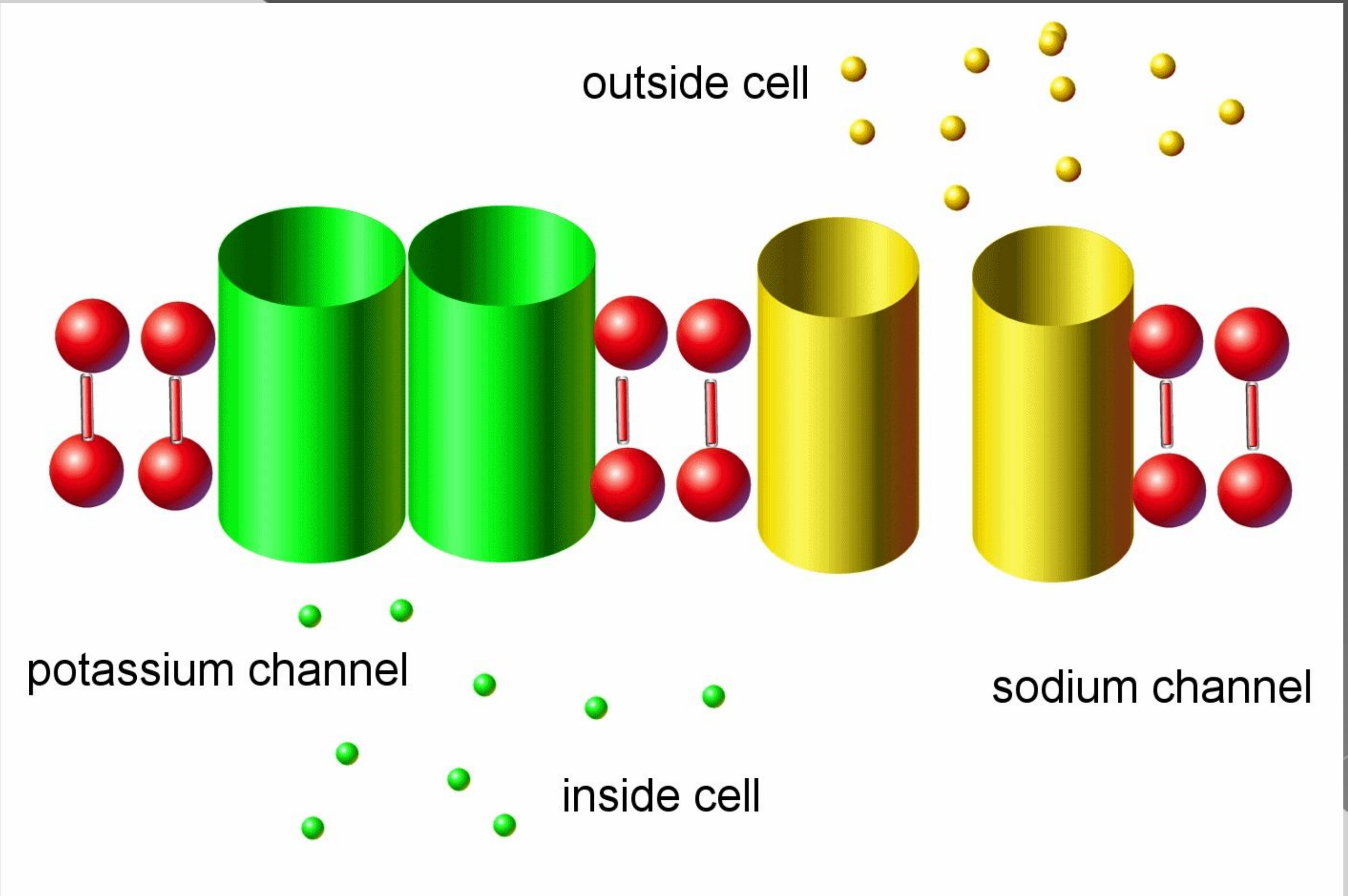
$$E = -\frac{RT}{zF}\ ln\frac{P_K[K^+]i + P_{Na}[Na^+]i + P_{Cl}[Cl^-]o}{P_K[K^+]o + P_{Na}[Na^+]o + P_{Cl}[Cl^-]i}$$

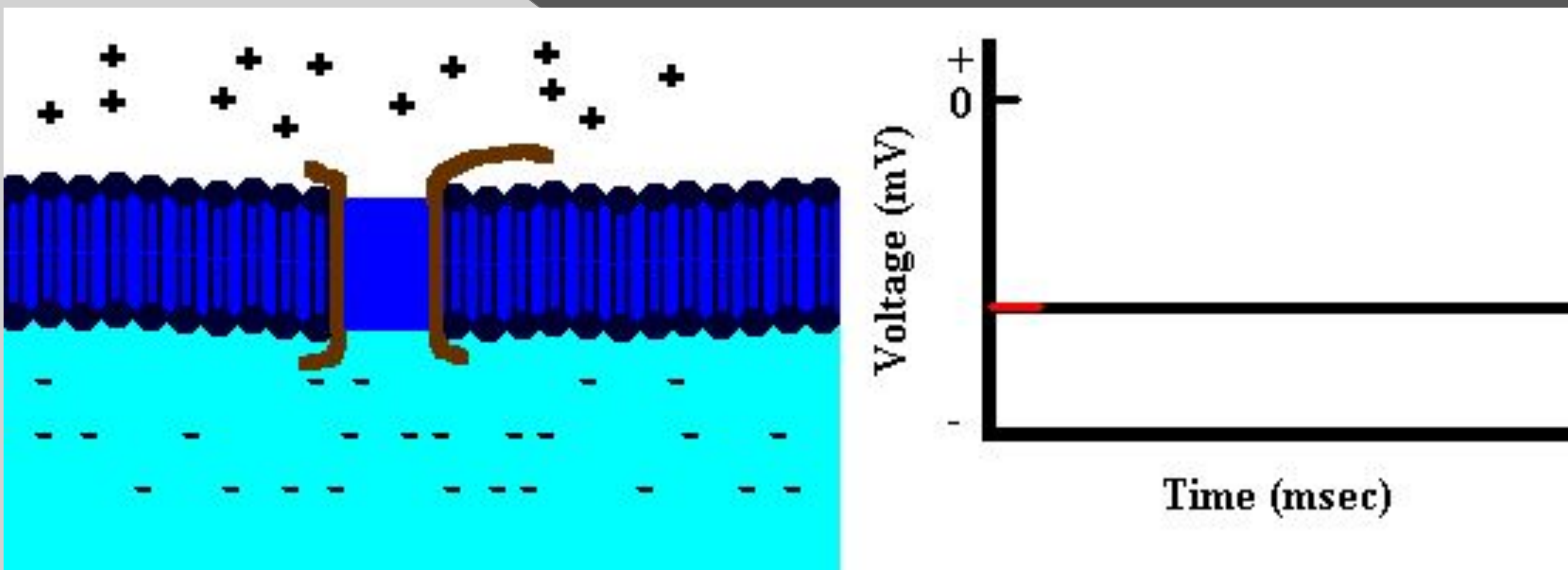
Goldman-Hogkin equation for membrane potential

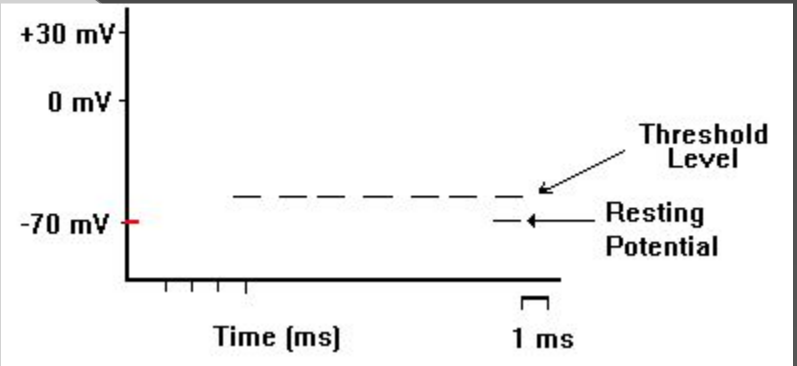
Nernst equation for membrane potential

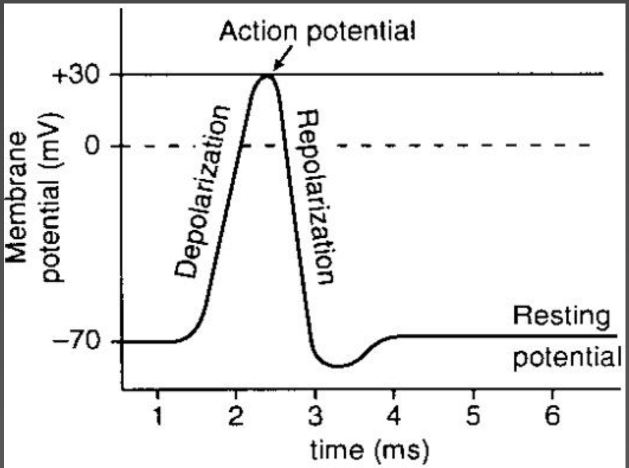
$$E = -\frac{RT}{zF}\ ln\frac{[K^+]i}{[K^+]o}$$

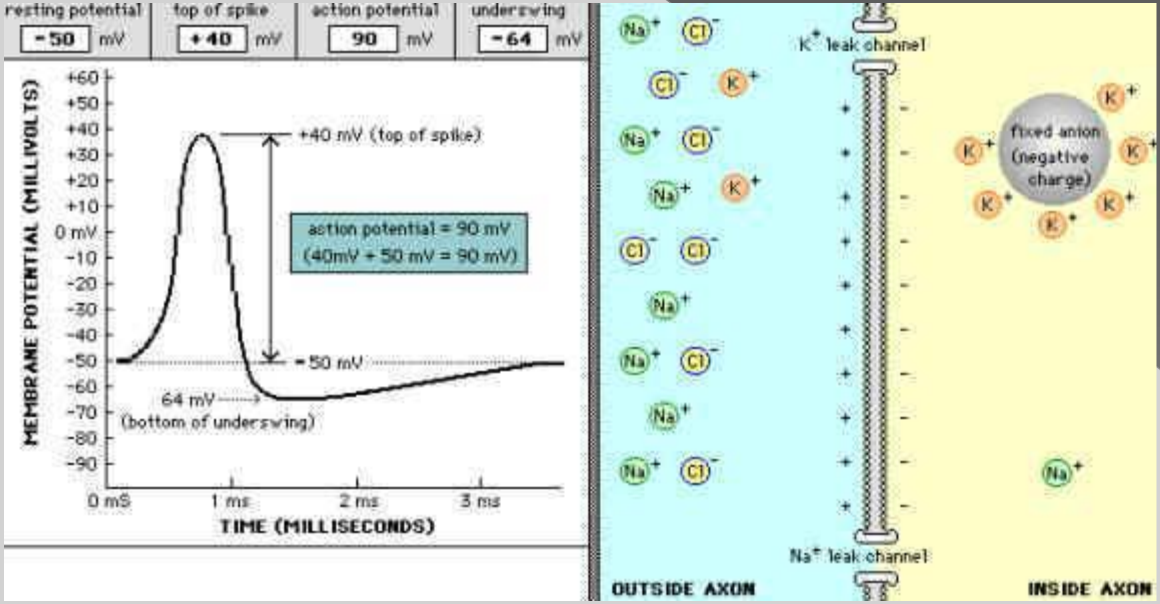
$$E_m = \frac{RT}{\mathbf{z}F} \ln \left(\frac{P_{\mathrm{K}}[\mathrm{K}^+]_{\mathrm{out}} + P_{\mathrm{Na}}[\mathrm{Na}^+]_{\mathrm{out}} + P_{\mathrm{Cl}}[\mathrm{Cl}^-]_{\mathrm{in}}}{P_{\mathrm{K}}[\mathrm{K}^+]_{\mathrm{in}} + P_{\mathrm{Na}}[\mathrm{Na}^+]_{\mathrm{in}} + P_{\mathrm{Cl}}[\mathrm{Cl}^-]_{\mathrm{out}}} \right)$$

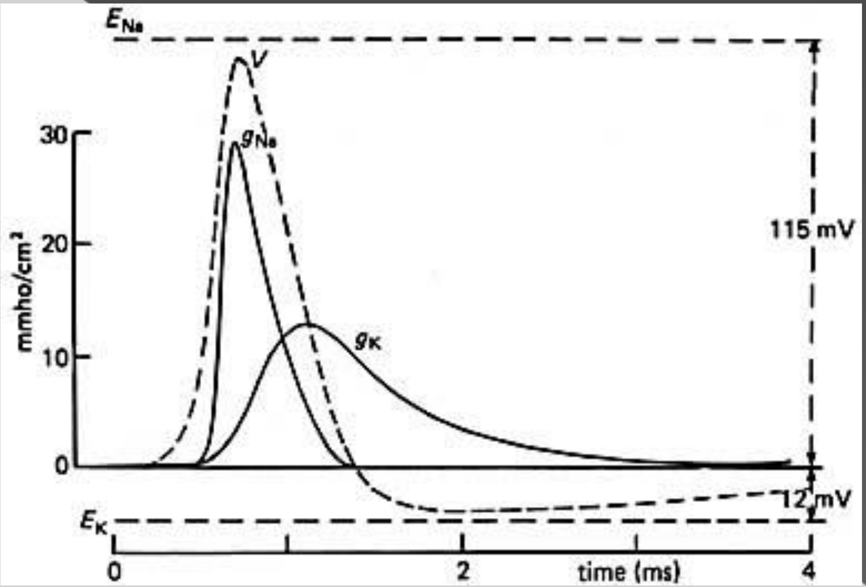


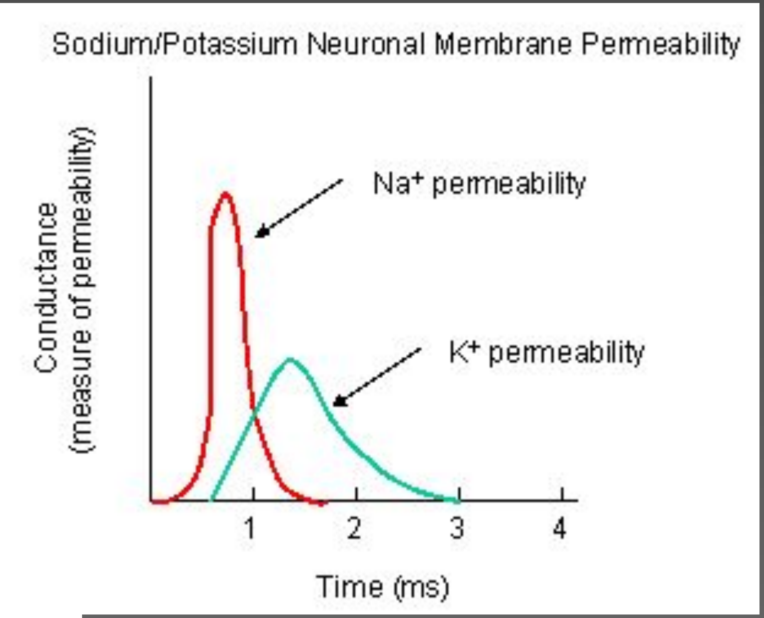

+
0
Voltage (mV)
-
Time (msec)

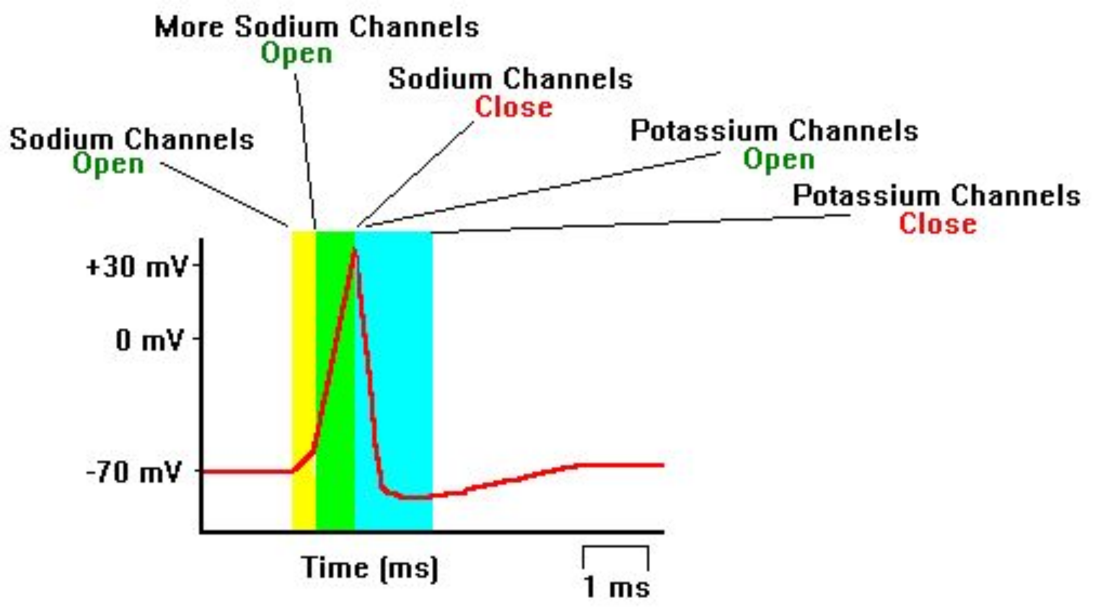

+30 mV
0 mV
Threshold Level
-70 mV
Resting Potential
Time (ms)
1 ms

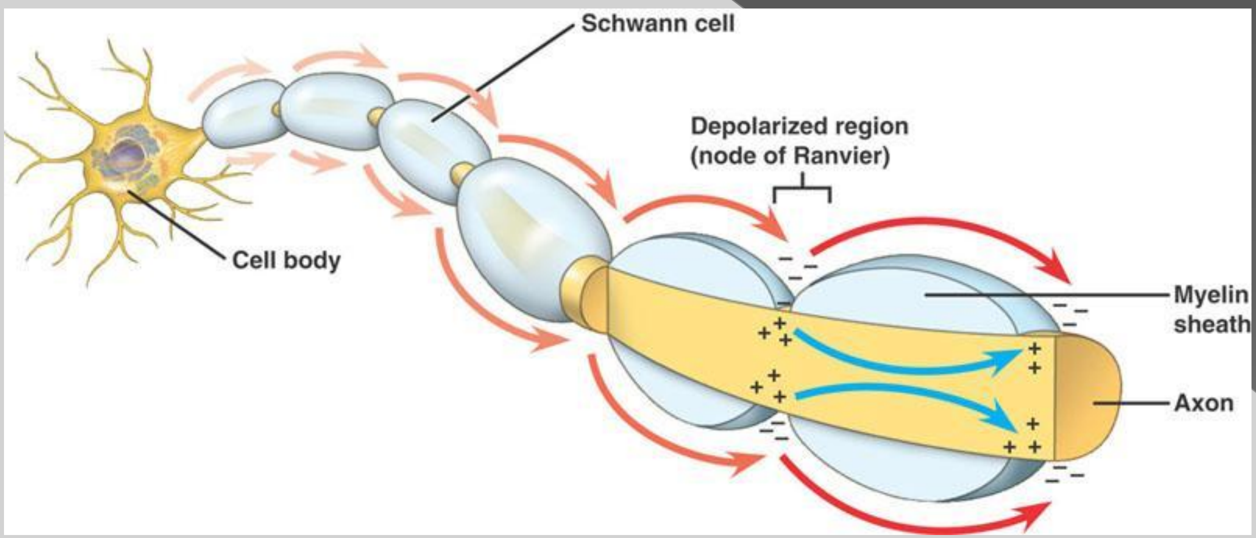

Action potential
+30
0
Membrane potential (mV)
Depolarization
Repolarization
–70
Resting potential
1 2 3 4 5 6
time (ms)

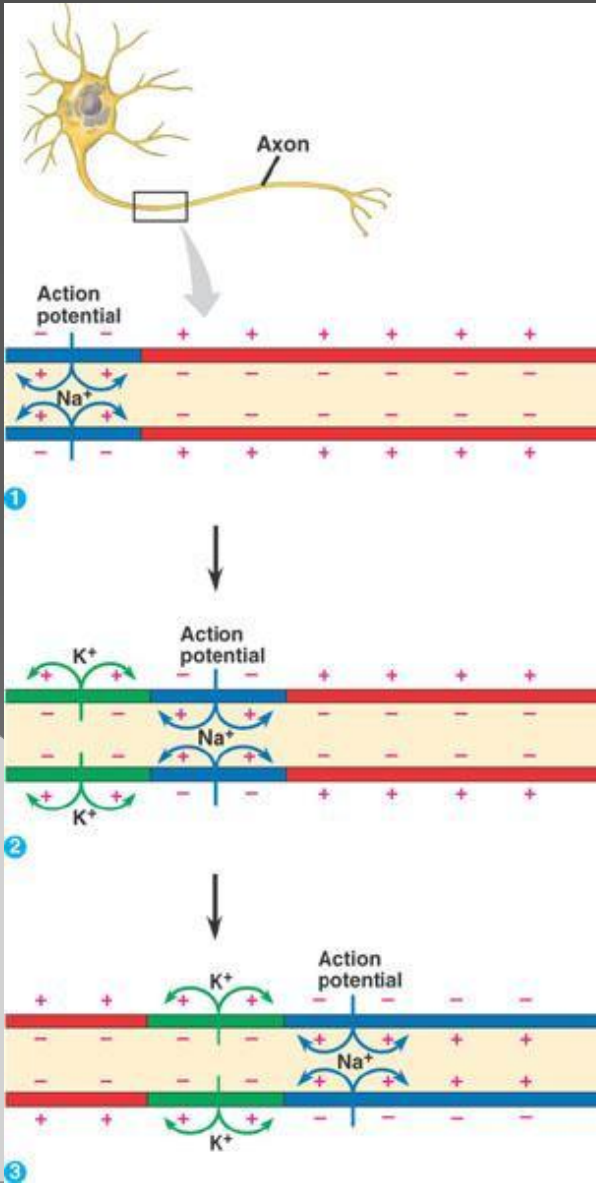

resting potential -50 mV
top of spike +40 mV
action potential 90 mV
underswing -64 mV
MEMBRANE POTENTIAL (MILLIVOLTS)
+40 mV (top of spike)
action potential = 90 mV
(40mV + 50 mV = 90 mV)
-50 mV
64 mV
(bottom of underswing)
0 mS 1 ms 2 ms 3 ms
TIME (MILLISECONDS)
K+ leak channel
fixed anion (negative charge)
Na+ leak channel
OUTSIDE AXON
INSIDE AXON


E_{Na}
V
g_{Na}
g_K
mmho/cm²
30
20
10
0
115 mV
12 mV
E_K
0
2
time (ms)
4


Sodium/Potassium Neuronal Membrane Permeability
Conductance (measure of permeability)
Na⁺ permeability
K⁺ permeability
1
2
3
4
Time (ms)


More Sodium Channels Open
Sodium Channels Close
Sodium Channels Open
Potassium Channels Open
Potassium Channels Close
+30 mV
0 mV
-70 mV
Time (ms)
1 ms


Schwann cell
Depolarized region
(node of Ranvier)
Cell body
Myelin
sheath
Axon


Axon
Action
potential
Na+
1
K+
Action
potential
Na+
K+
2
K+
Action
potential
Na+
K+
3