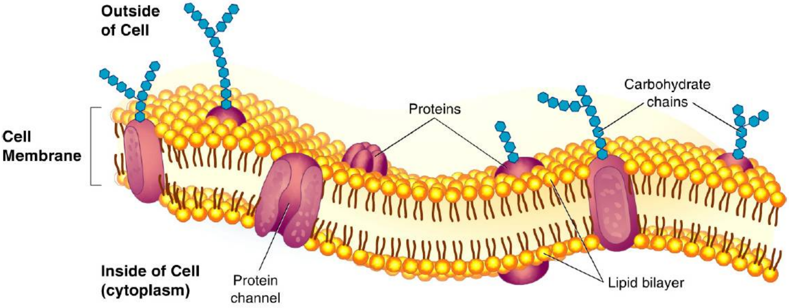
Neuroinformatics 2016

March 3, 2016

Membrane potential and conductance-based model

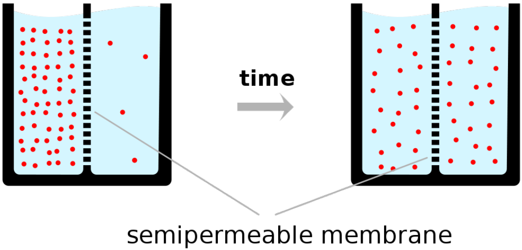
Cell membrane

- Phospholipidic bilayer
- Ion channels

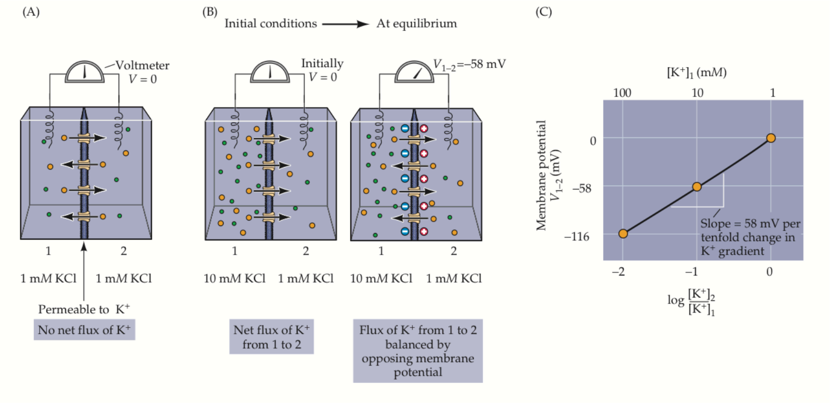


Membrane potential: Diffusion

- Permeable membrane + 2 solutions with different ion concentration
- Ions diffuse until equilibrium is achieved (concentration + electrical)



Nernst potential



Calculation of Nernst potential

- Nernst calculation for one ion

$$V = \frac{RT}{zF} \log \frac{[c_{out}]}{[c_{in}]}$$

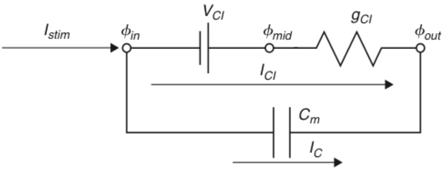
V - membrane potential $[V = J/C]$
$[cin]$ - concentration inside the cell $[mol/m^3]$
$[cout]$ - concentration outside the cell $[mol/m^3]$
R - gas constant $[J/K/mol]$
T - temperature $[K]$
F - Faraday's constant $[C/mol]$

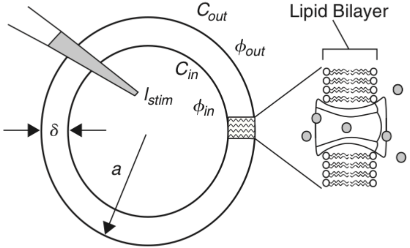
Membrane simulation

$$I_C(t) = C_m \frac{dV}{dt}(t)$$

$$\tau \frac{dV}{dt} = V_{Cl} - V(t) + \frac{I_{stim}(t)}{A g_{Cl}}$$

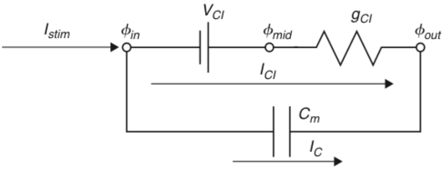
$$\tau = \frac{C_m}{g_{Cl}}$$

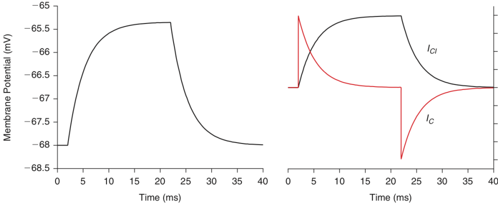




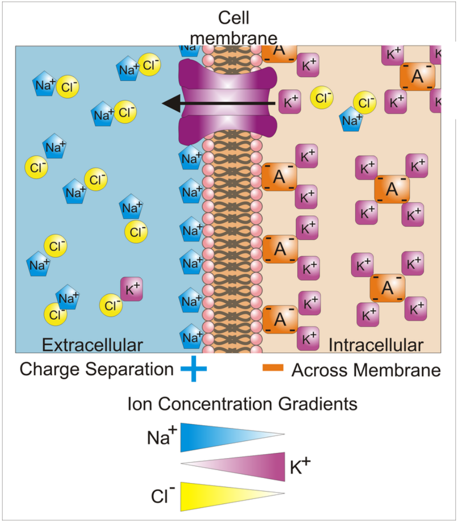
Membrane simulation

$$
\begin{aligned}
I_C(t) &= C_m \frac{dV}{dt}(t) \\
\tau \frac{dV}{dt} &= V_{Cl} - V(t) + \frac{I_{stim}(t)}{A g_{Cl}} \\
\tau &= \frac{C_m}{g_{Cl}}
\end{aligned}
$$





Real membrane: multiple ions



Ion concentrations

Ion	Intracellular c.	Extracellular c.	Equilibrium Potential
Na+	15 mM	**145 mM**	$V_{Na} = +60mV$
K+	**150 mM**	4 mM	$V_K = -97mV$
Cl	10 mM	110 mM	$V_{Cl} = -64mV$
Ca2+	70 nM	2 mM	$V_{Ca} = +137mV$
H+	63 nM (pH 7.2)	40 nM (pH 7.4)	$V_{H+} = -12mV$

Multiple ions: Goldman equation

$$V = \frac{RT}{zF} \log\left(\frac{P_{Na}[Na^+]_{out} + P_K[K^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_{Na}[Na^+]_{in} + P_K[K^+]_{in} + P_{Cl}[Cl^-]_{out}}\right)$$

V - membrane potential $[V = J/C]$
$[M]_{in}$ - concentration of ion M inside the cell $[mol/m^3]$
$[M]_{out}$ - concentration of ion M outside the cell $[mol/m^3]$
$[P]_M$ - Membrane permeability for ion M $[m/s]$

Further Readings

Mark F. Bear, Barry W. Connors, and Michael A. Paradiso (2006), **Neuroscience: exploring the brain**, Lippincott Williams & Wilkins , 3rd edition.

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C. T. Tuckwell (1988), **Introduction to theoretical neurobiology**, Cambridge University Press.

Hugh R. Wilson (1999) **Spikes, decisions and actions: dynamical foundations of neuroscience**, Oxford University Press. See also his paper in J. Theor. Biol. 200: 375–88, 1999.