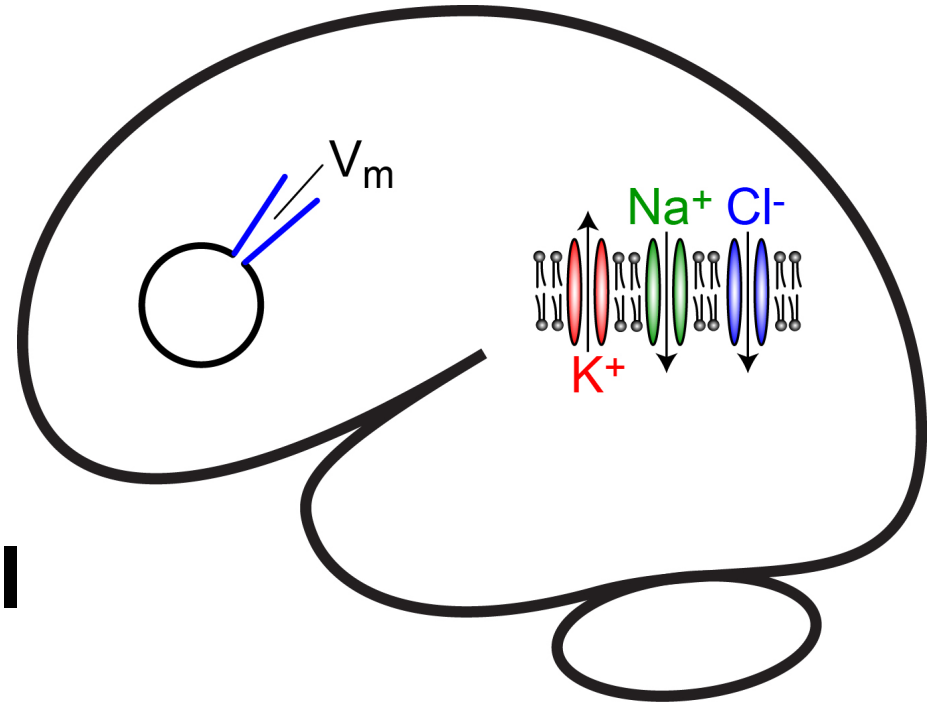
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE



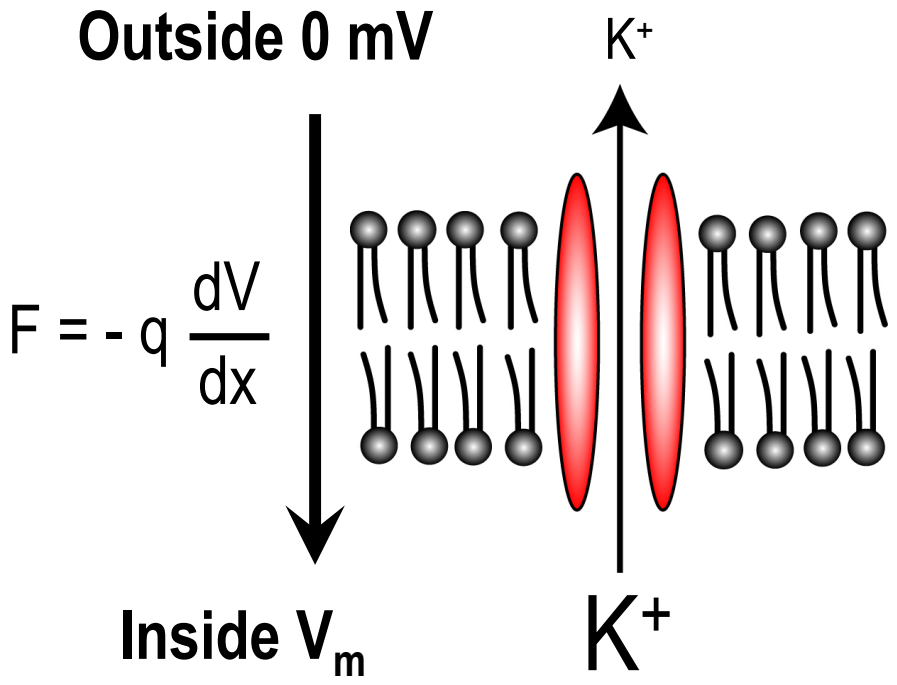
1.4 Membrane potential

Cellular Mechanisms of Brain Function

Prof. Carl Petersen

Membrane potential

Electrochemical diffusion

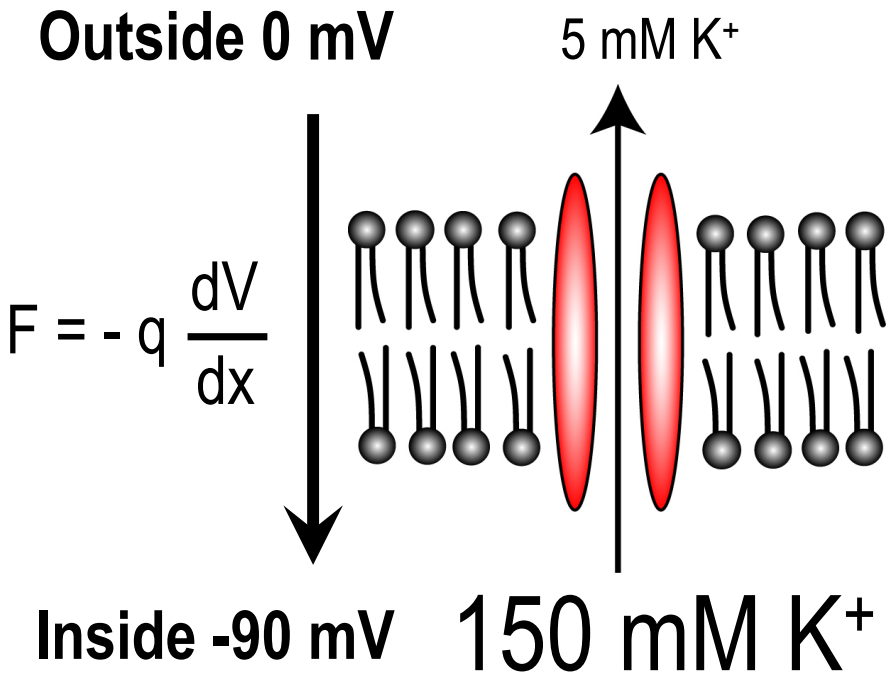


Nernst equilibrium potential

$$E_{K^+} = \frac{RT}{zF} \ln \frac{[K^+]_o}{[K^+]_i}$$

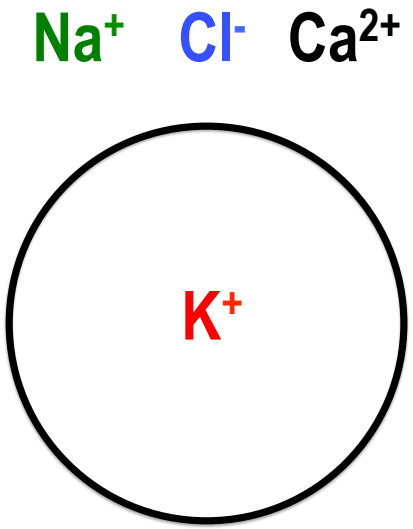
$$E_{K^+} = 61.5 \log_{10} \frac{5}{150}$$

$$E_{K^+} = \sim -90 \text{ mV}$$



Ion concentrations

Ion	Intracellular	Extracellular
K^+	150 mM	4 mM
Na^+	12 mM	145 mM
Cl^-	5 mM	120 mM
Ca^{2+}	100 nM	1 mM



Equilibrium potentials

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Ion	Intracellular	Extracellular	E_{ion}
K^+	150 mM	4 mM	-97 mV
Na^+	12 mM	145 mM	+67 mV
Cl^-	5 mM	120 mM	-85 mV
Ca^{2+}	100 nM	1 mM	+123 mV

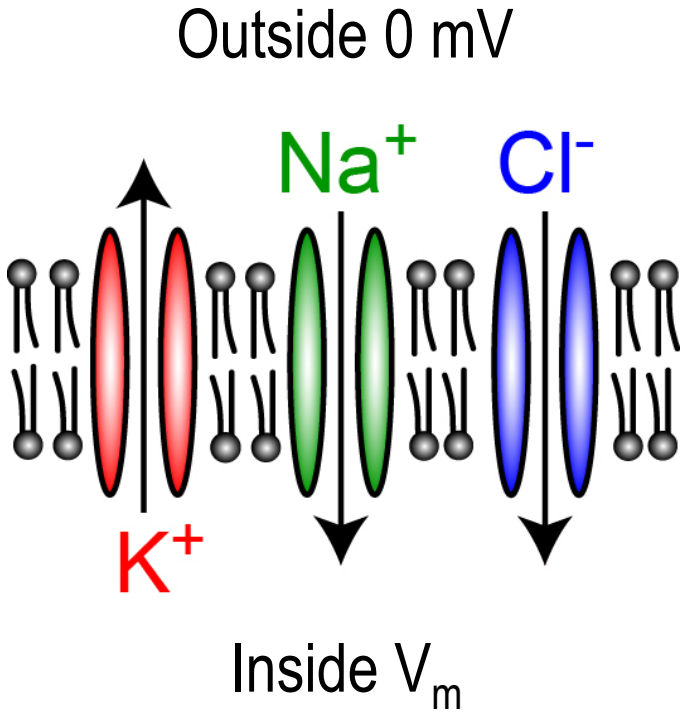
Goldman-Hodgkin-Katz (GHK) equation

$$V_m = \frac{RT}{zF} \ln \frac{P_{K^+}[K^+]_o + P_{Na^+}[Na^+]_o + P_{Cl^-}[Cl^-]_i}{P_{K^+}[K^+]_i + P_{Na^+}[Na^+]_i + P_{Cl^-}[Cl^-]_o}$$

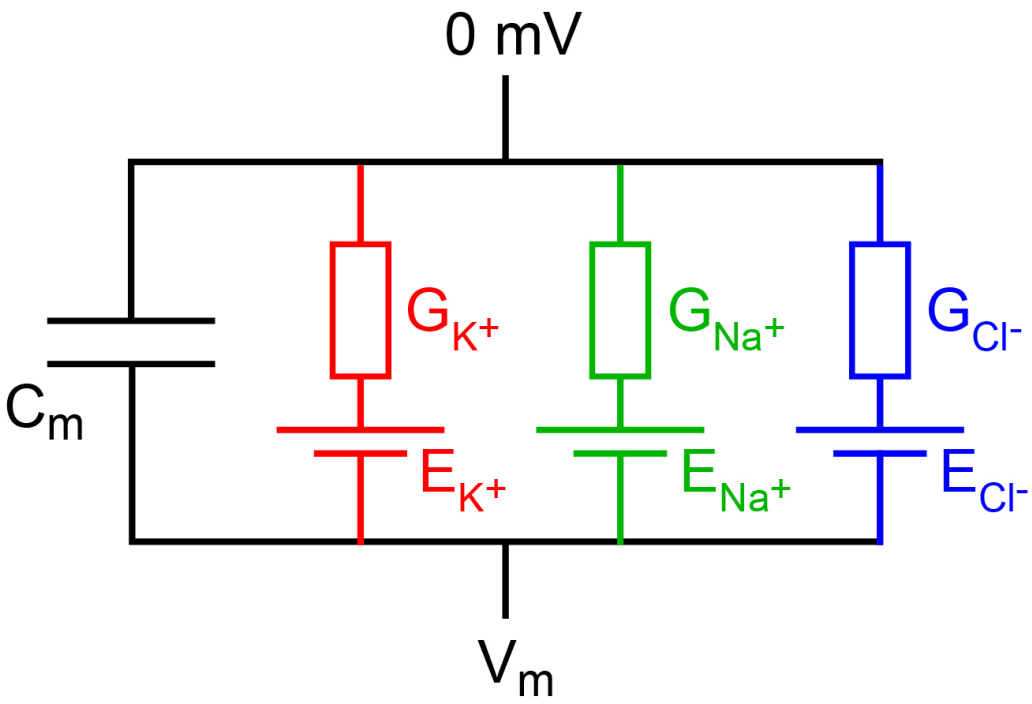
$$P_{K^+} : P_{Na^+} : P_{Cl^-} = 1 : 0.04 : 0.45$$

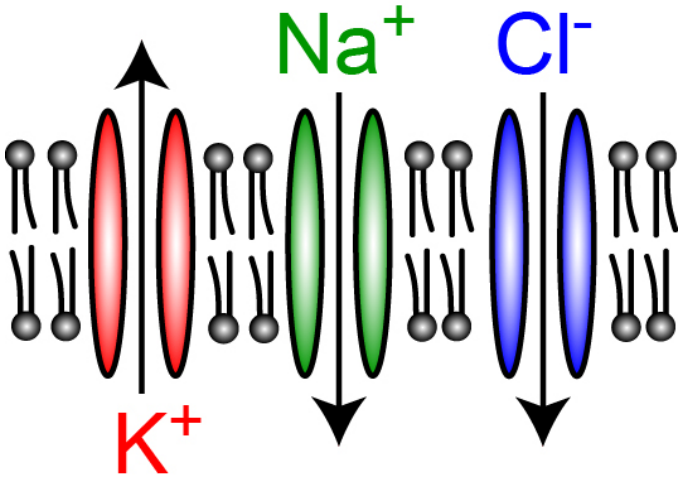
$$V_m = 61.5 \log_{10} \frac{4 + 5.8 + 2.25}{150 + 0.48 + 54}$$

$$V_m = -76 \text{ mV}$$

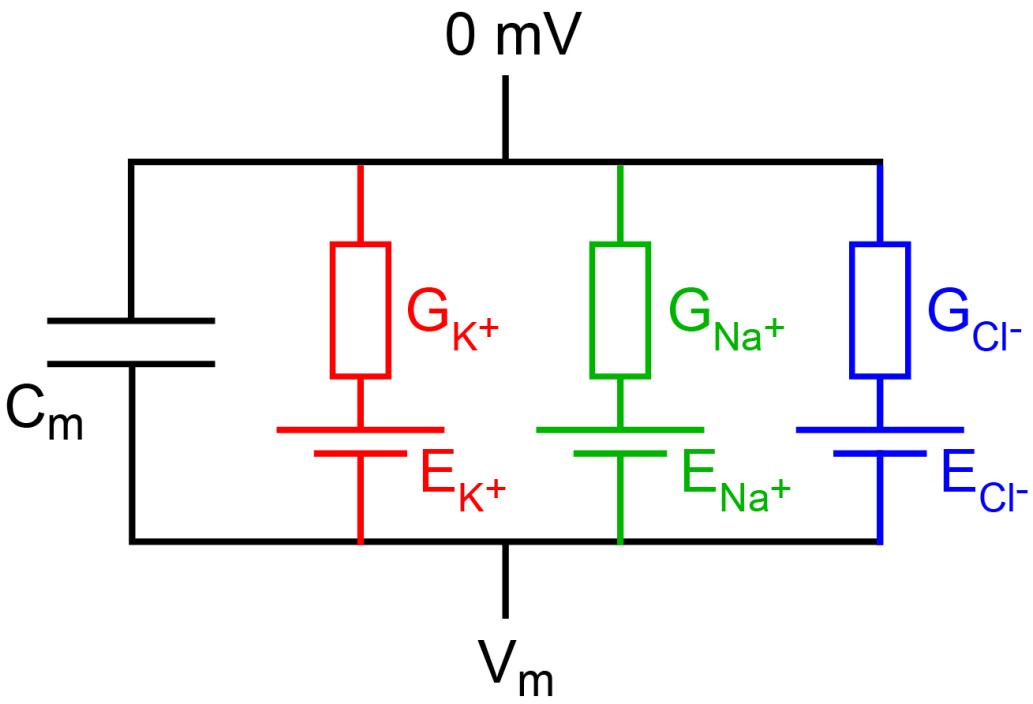


Electrical equivalent of a cell





Electrical equivalent of a cell



Ohm's law:

$V = I R$

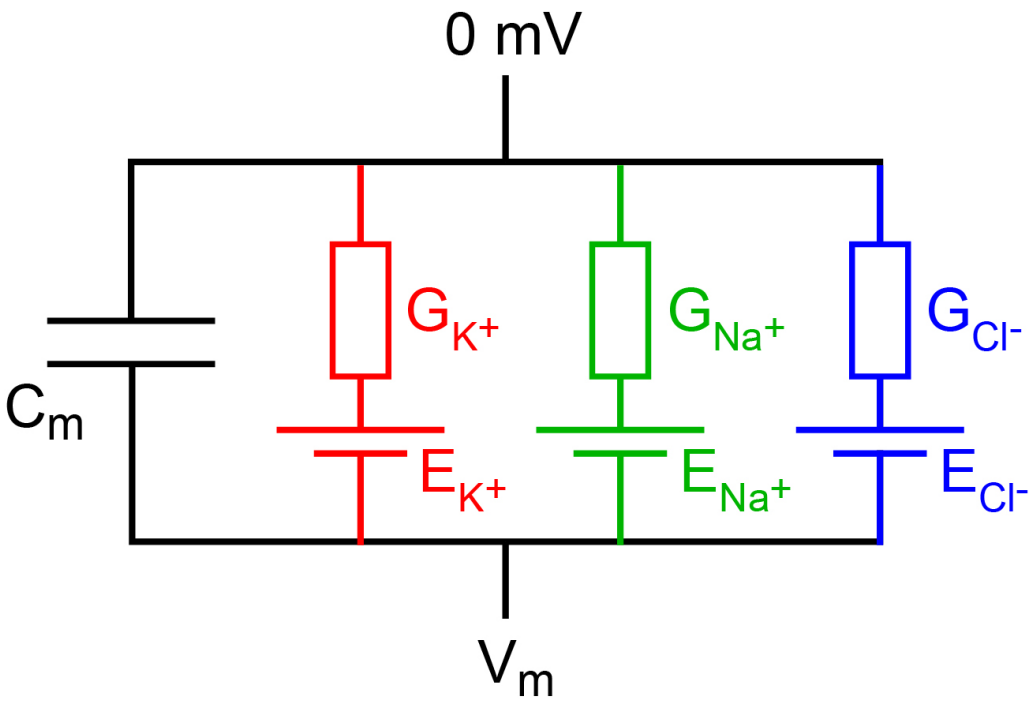
$I = V G$

Capacitance:

$Q = C V$

$I = C \, dV/dt$

Electrical equivalent of a cell



$$I_m = I_C + I_{K^+} + I_{Na^+} + I_{Cl^-}$$

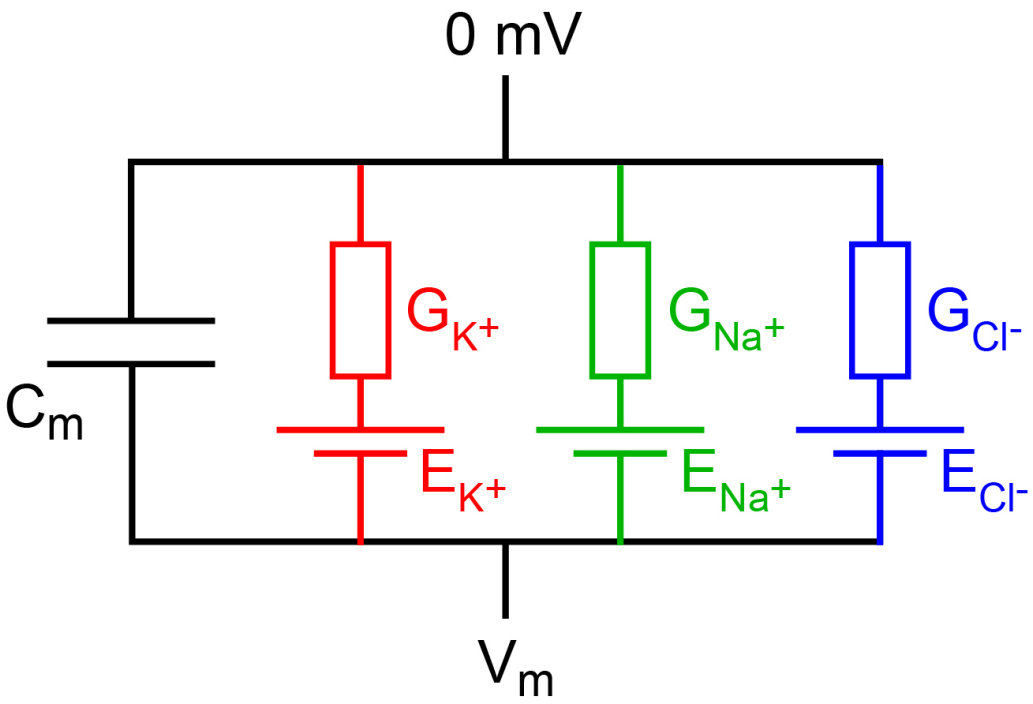
$$I_C = C_m \, dV_m/dt$$

$$I_{K^+} = (V_m - E_{K^+}) \, G_{K^+}$$

$$I_{Na^+} = (V_m - E_{Na^+}) \, G_{Na^+}$$

$$I_{Cl^-} = (V_m - E_{Cl^-}) \, G_{Cl^-}$$

Ion conductances determine V_m

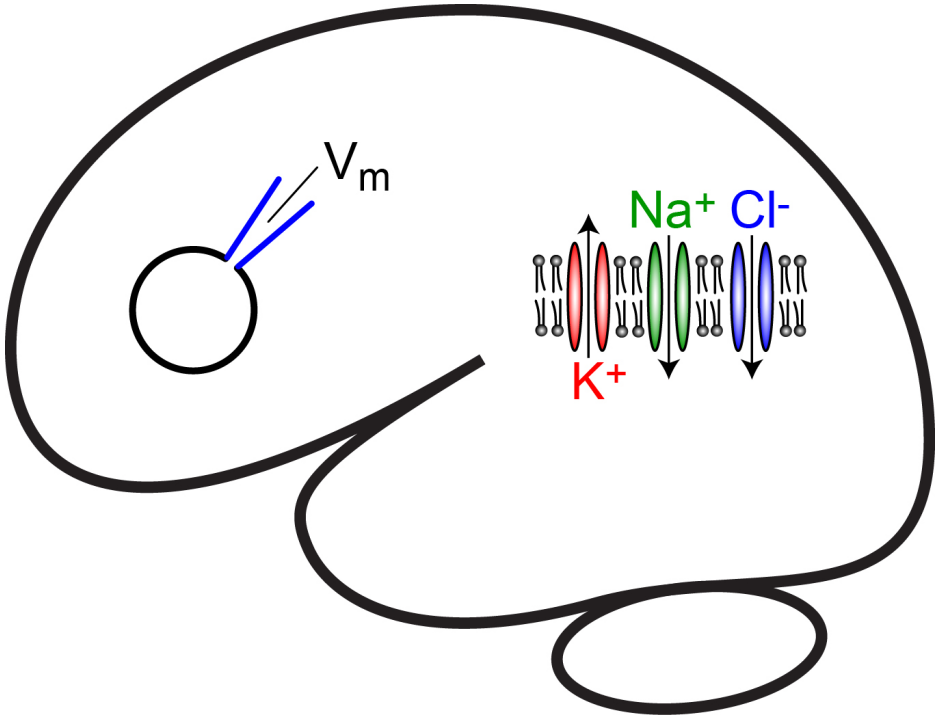


Solving for steady state V_m
($I_m = 0$ and $dV_m/dt = 0$)

$$G_{Total} = G_K + G_{Na} + G_{Cl}$$

$$V_m = \frac{G_K}{G_{Total}} E_K + \frac{G_{Na}}{G_{Total}} E_{Na} + \frac{G_{Cl}}{G_{Total}} E_{Cl}$$

Membrane potential - V_m



Some numbers – K^+ conductance and V_m

What happens to V_m if K^+ channels increase their open probabilty?

Some numbers – K^+, Na^+, Cl^- conductances and V_m

What happens to V_m if :

i) G_{K+} increases

ii) G_{Na+} increases

iii) G_{Cl-} increases

Membrane potential

- Electrochemical diffusion describes ion flow through ion channels and defines Nernst equilibrium potentials.
- Independently regulated ion channel conductances with selective permeability control membrane potential.