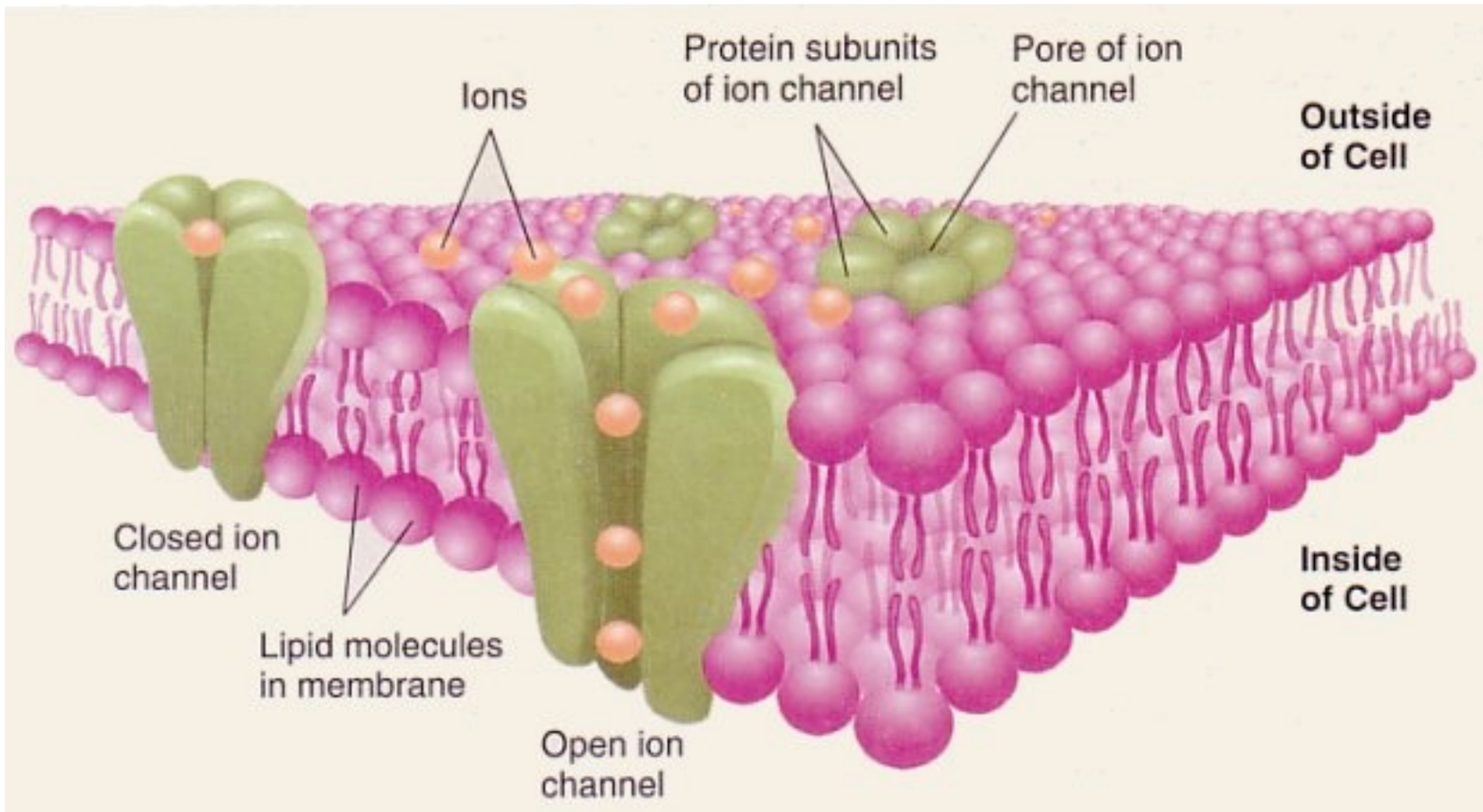
Single Neuron Dynamics

— point neuron model


Ions
Protein subunits of ion channel
Pore of ion channel
Outside of Cell
Closed ion channel
Lipid molecules in membrane
Open ion channel
Inside of Cell

What determines the resting potential of a neuron?

$$[K^+]_{outside} = [K^+]_{inside} P(E > -qV_K)$$

$$p(E)dE = \frac{1}{Z}\exp\left(-\beta E\right)dE \qquad Z = 1/\beta = k_B T$$

$$P(E > -qV_K) = \int_{-qV_K}^{\infty} p(E)dE = \exp\left(\frac{qV_K}{k_B T}\right)$$

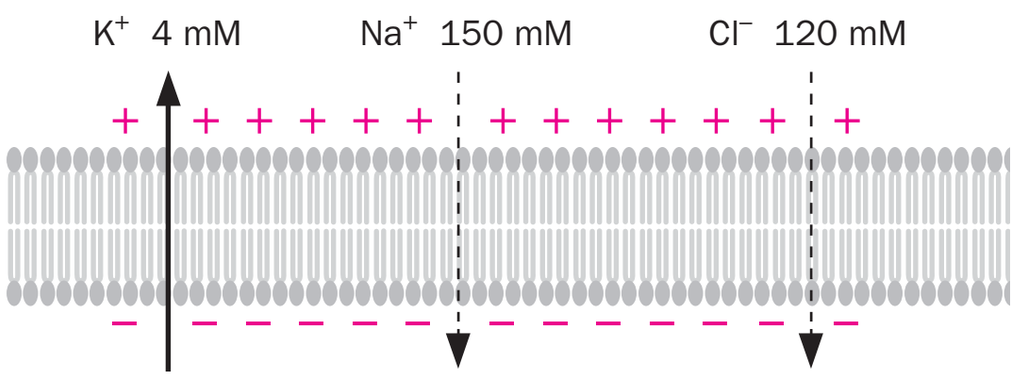
$$[K^+]_{outside} = [K^+]_{inside} \exp(qV_K/k_B T)$$

$$V_K = \frac{k_B T}{q} \ln \frac{[K^+]_{outside}}{[K^+]_{inside}}$$

$$E_A = \frac{k_B T}{q} \ln \frac{[A]_{outside}}{[A]_{inside}}$$

$$V = \frac{k_B T}{e} \ln \left(\frac{\sum_{i=1}^{N} P_{M_i^+} [M_i^+]_{out} + \sum_{j=1}^{N} P_{A_j^-} [A_j^-]_{in}}{\sum_{i=1}^{N} P_{M_i^+} [M_i^+]_{in} + \sum_{j=1}^{N} P_{A_j^-} [A_j^-]_{out}} \right)$$

(A)



$$E_K = -70mV$$

$$E_{Cl} = -60mV$$

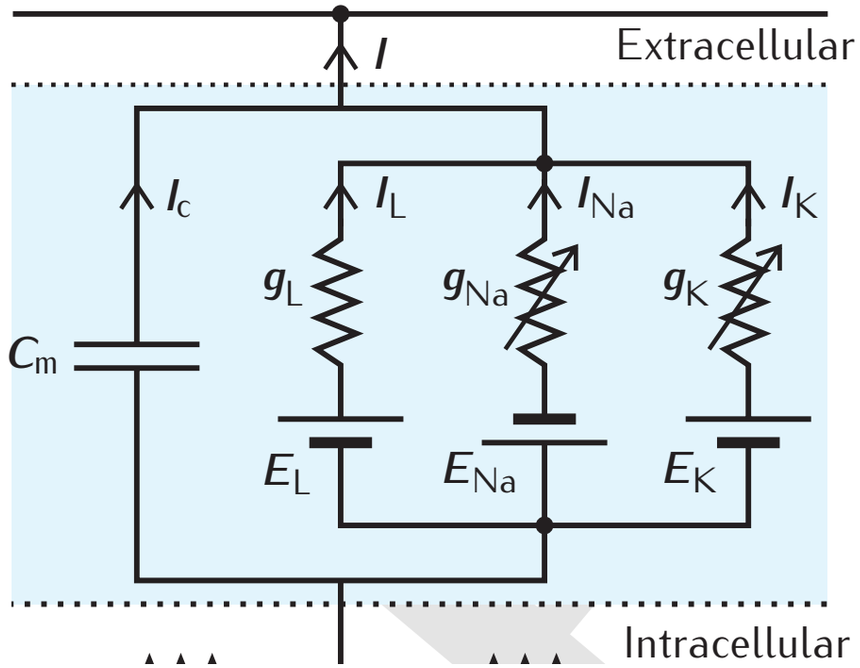
$$V_{rest} = -60mV$$

$$E_{Na} = +40mV!$$

$$I_{Na} = g_{Na}(V - E_{Na})$$

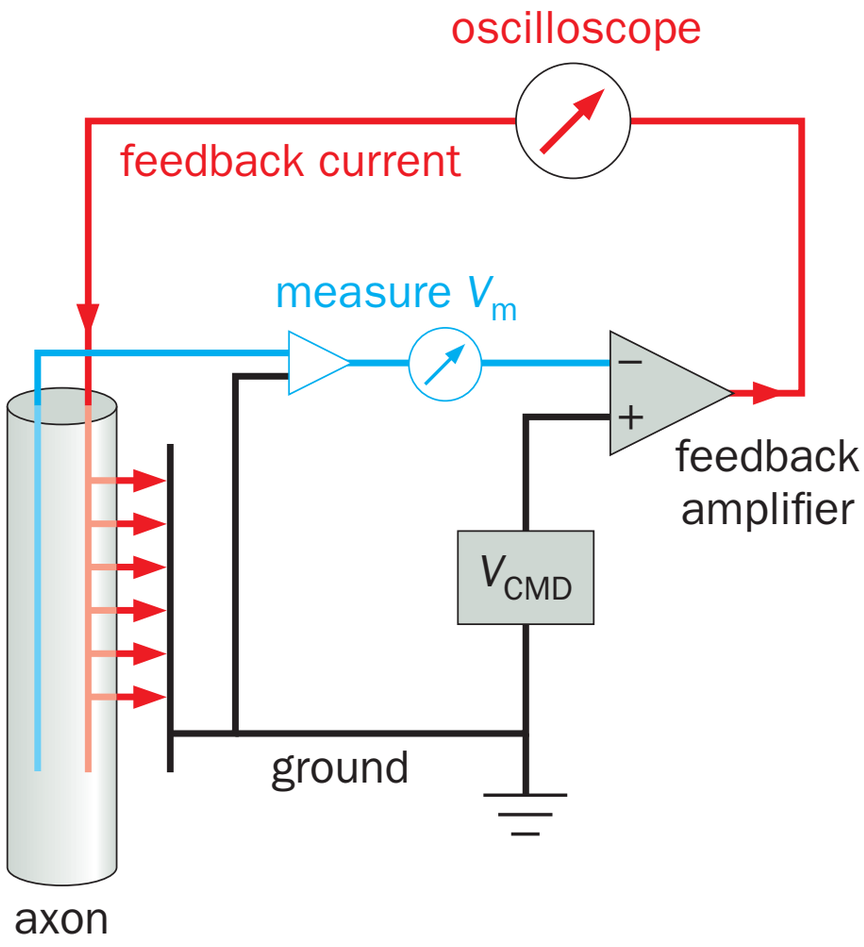
$$I_K = g_K(V - E_K)$$

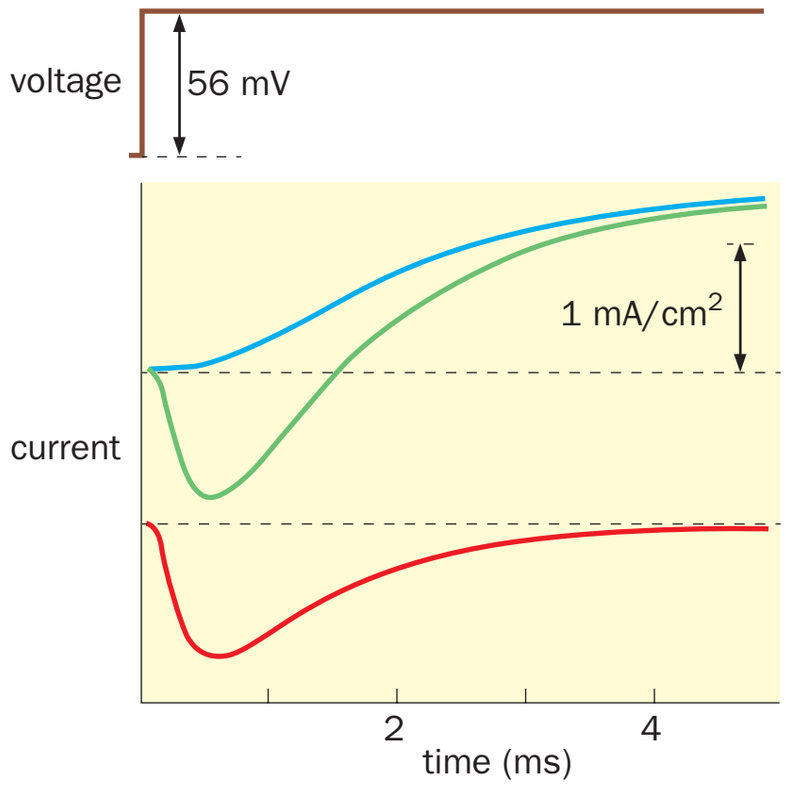
The Equivalent Electronic Circuit of a Neuron



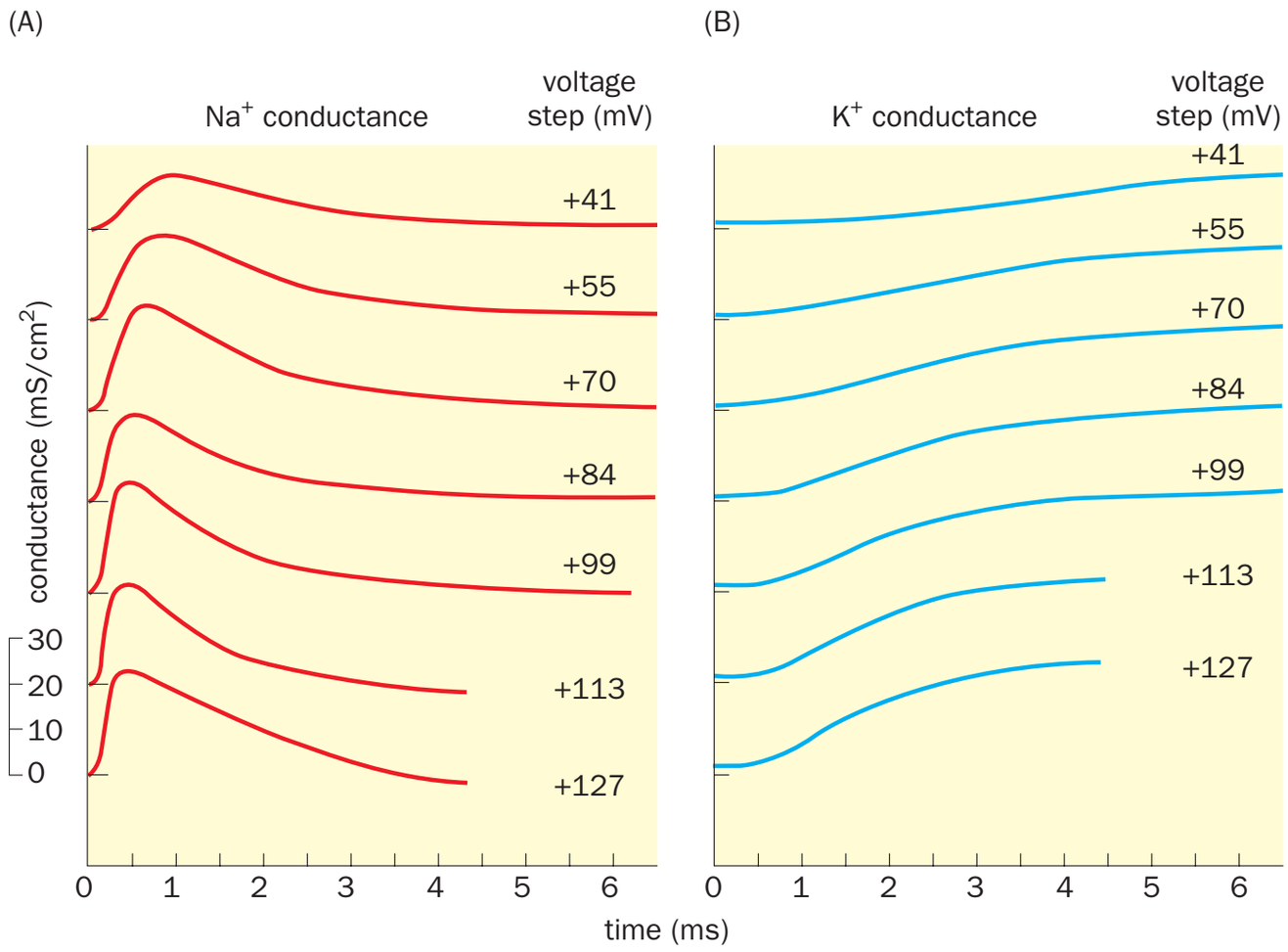
$$C_m \frac{dV}{dt} = -\sum_i g_i(V)(V - E_i) - \bar{g}_L(V - E_L) + I_e$$

Voltage Clamp Recording

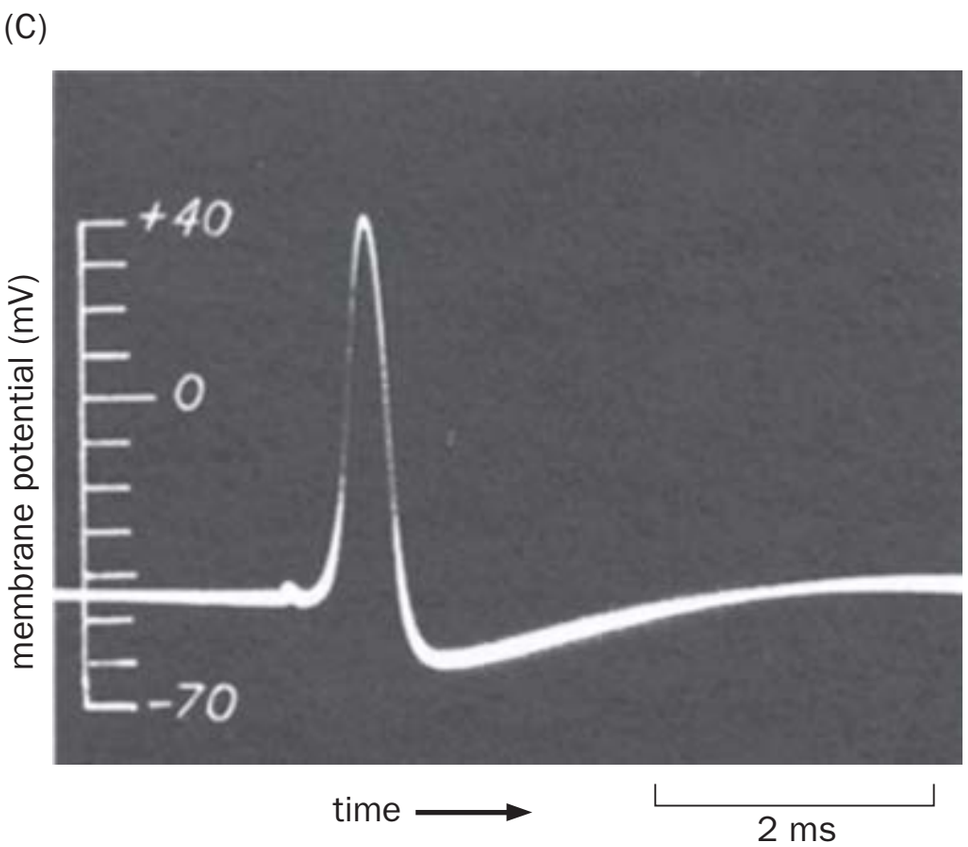


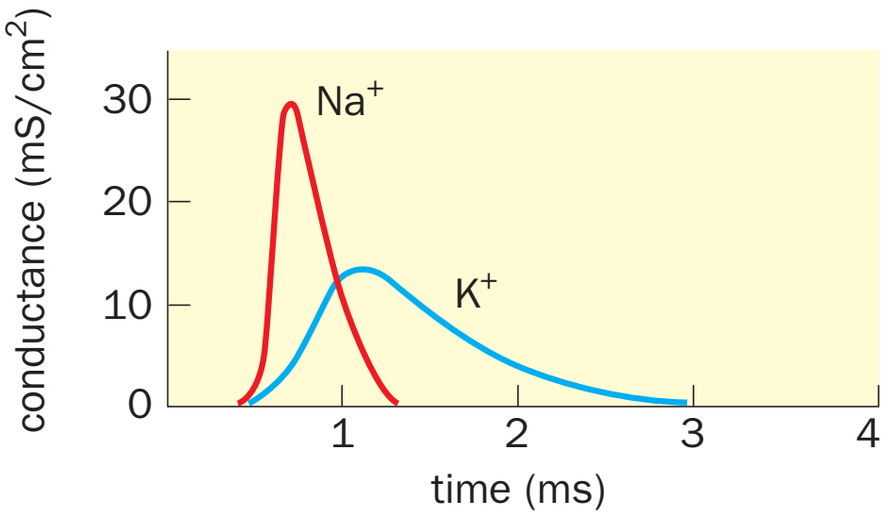


Voltage-gated Conductance

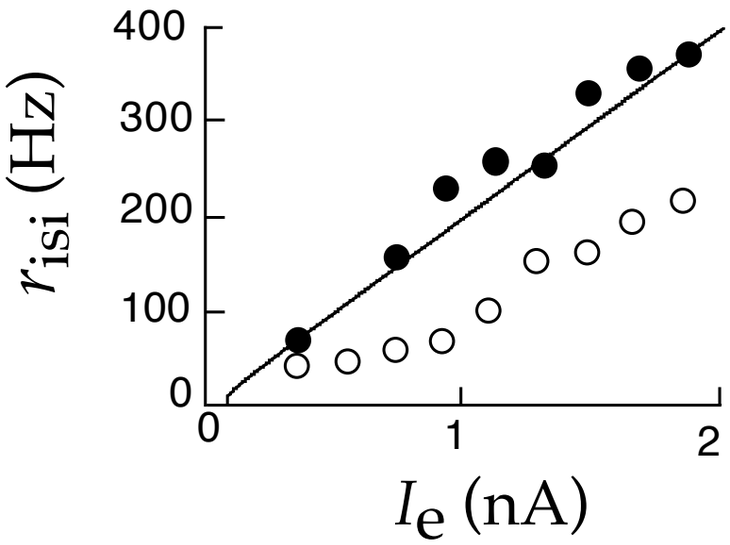


Qualitative explanation of action potential generation





A



B