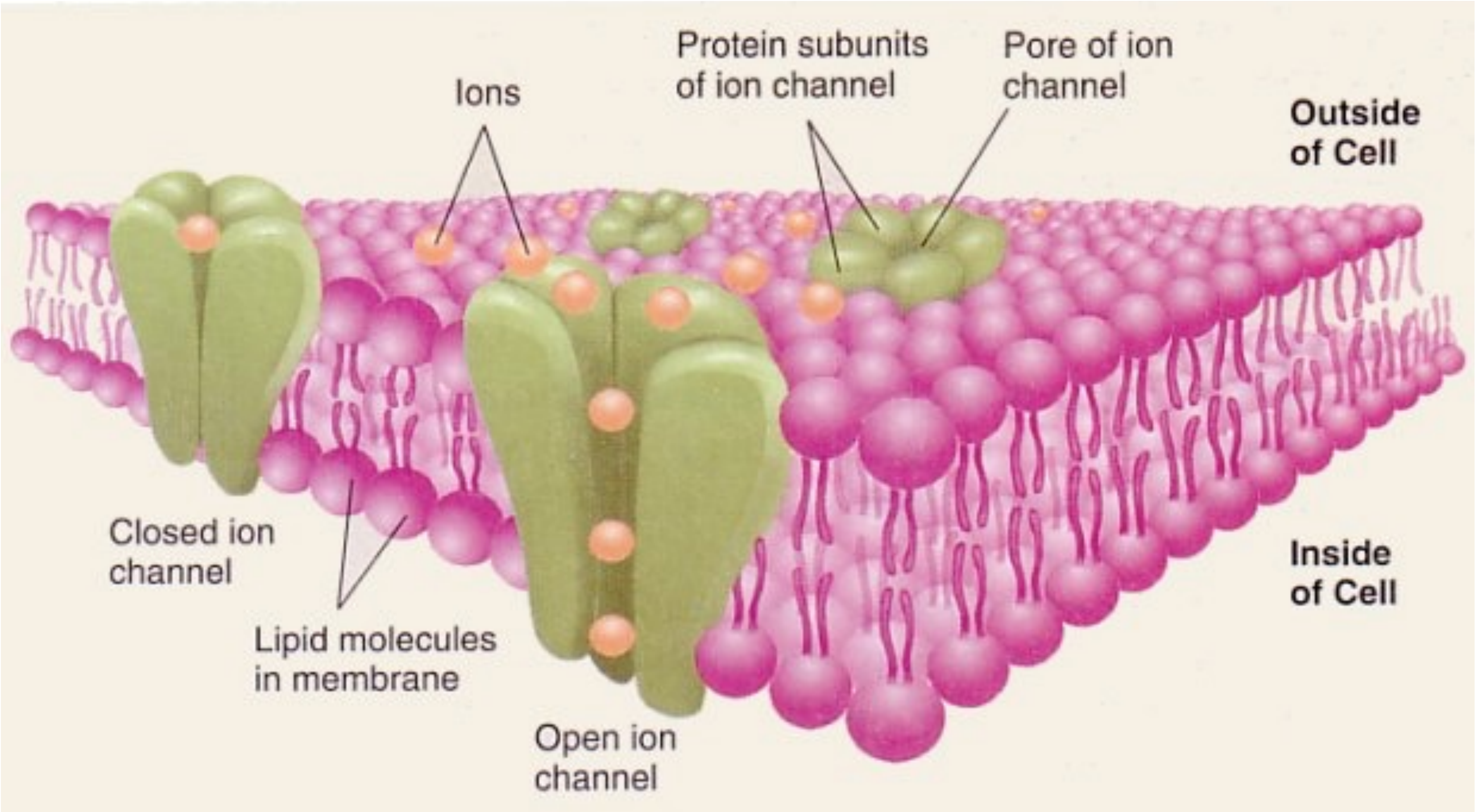
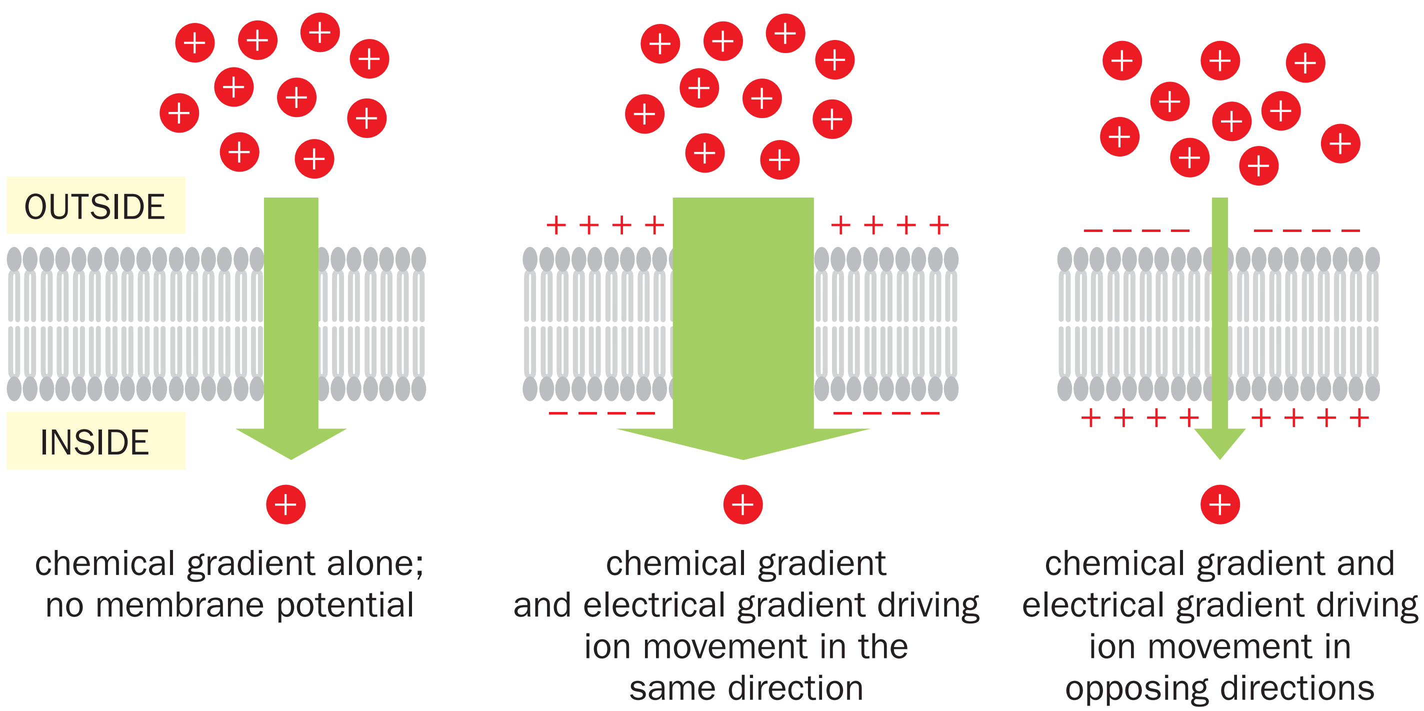
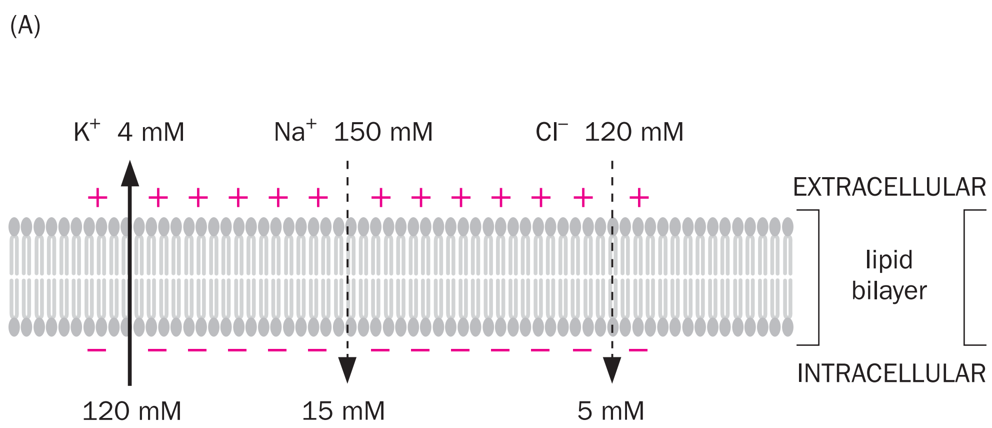
Single Neuron Dynamics


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

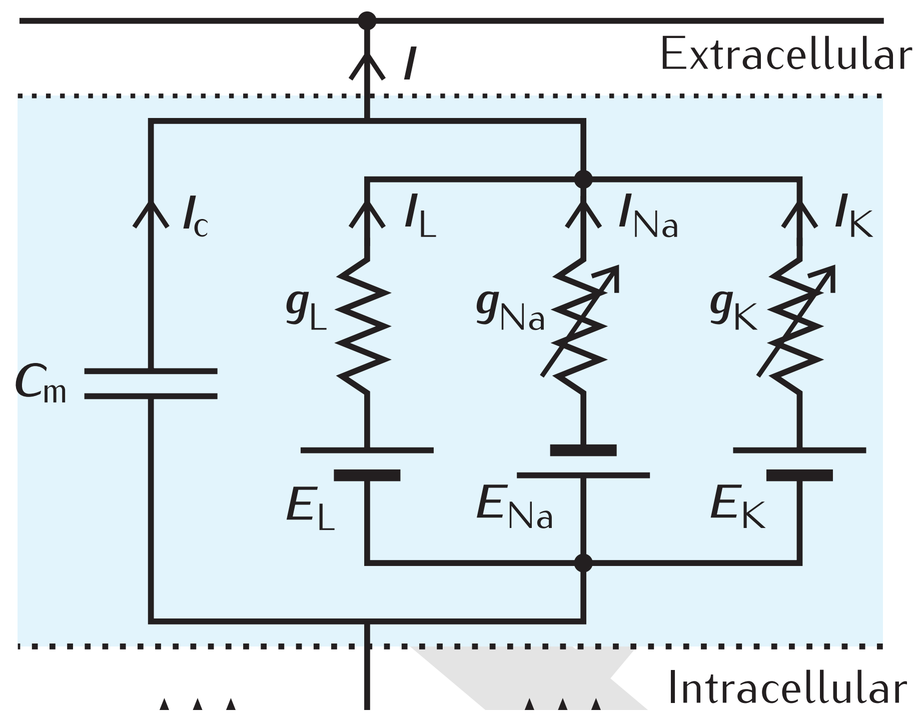
What determines the resting potential of a neuron?



Ion pump

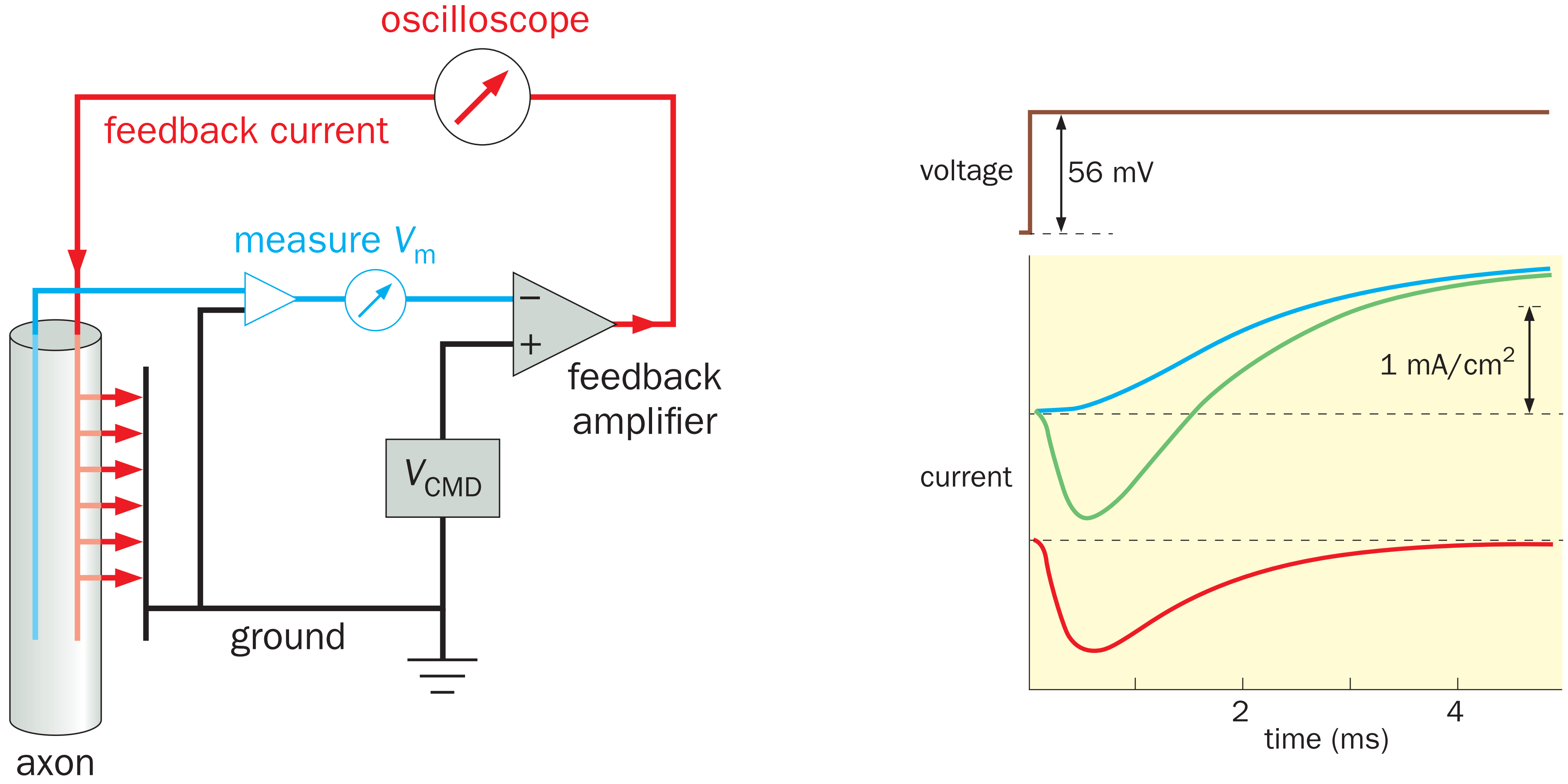

(A)
K+ 4 mM
Na+ 150 mM
Cl− 120 mM
EXTRACELLULAR
lipid
bilayer
INTRACELLULAR
120 mM
15 mM
5 mM

The Equivalent Electronic Circuit of a Neuron

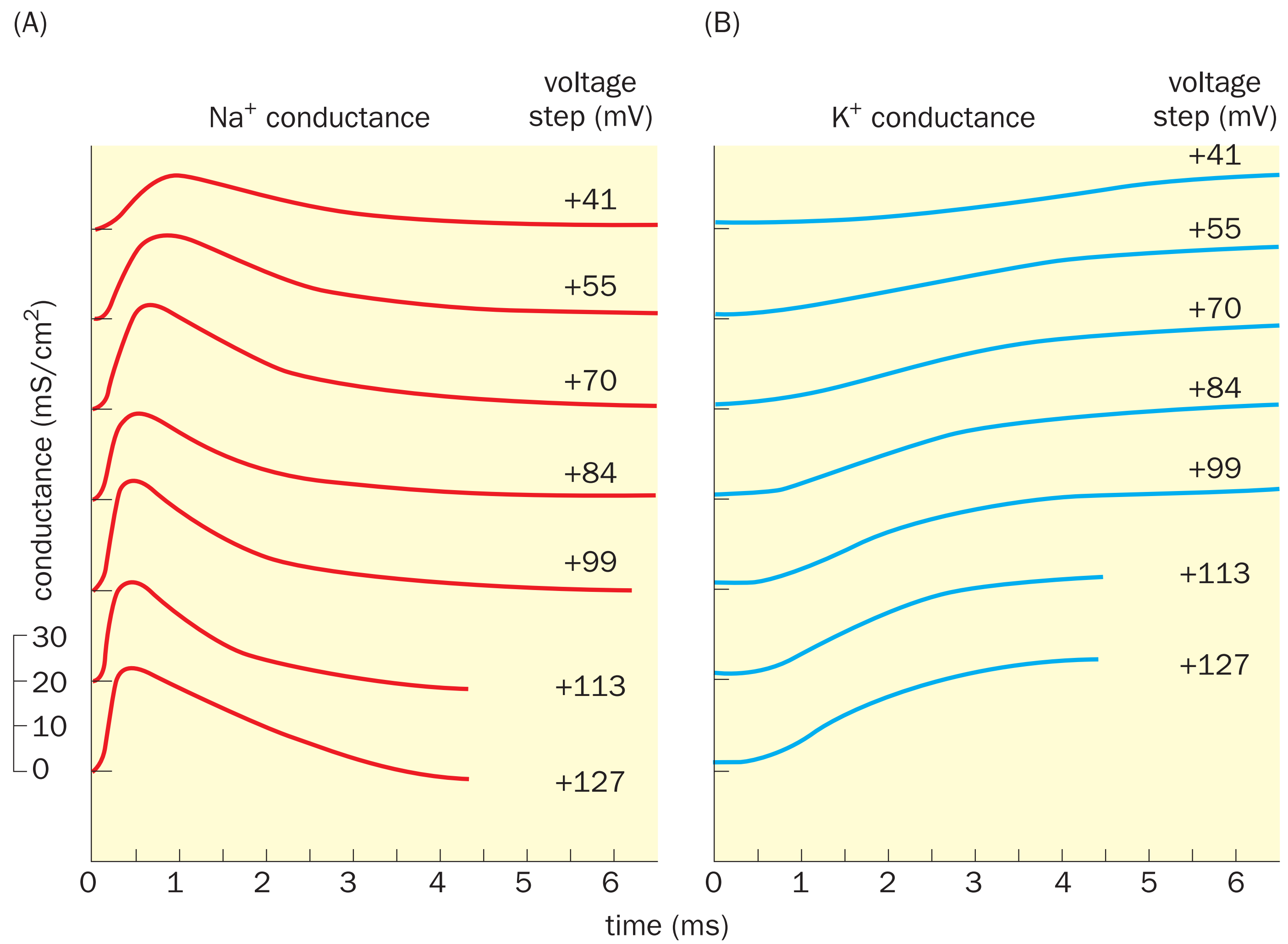


$$C_m \frac{dV}{dt} = -\sum_i g_i(V)(V - E_i) - \bar{g}_L(V - E_L) + I_e$$

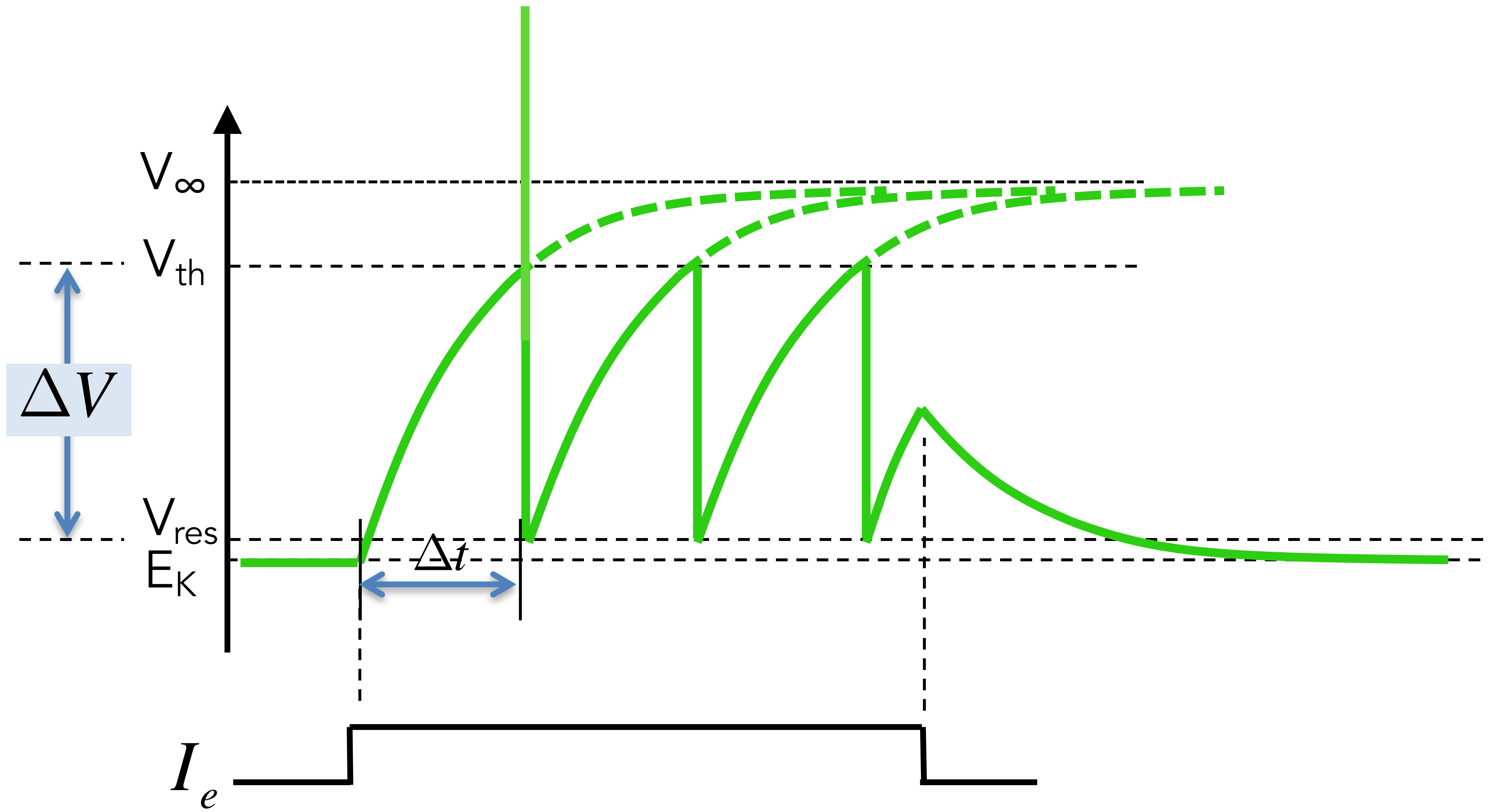
Voltage Clamp Recording



Voltage-gated Conductance



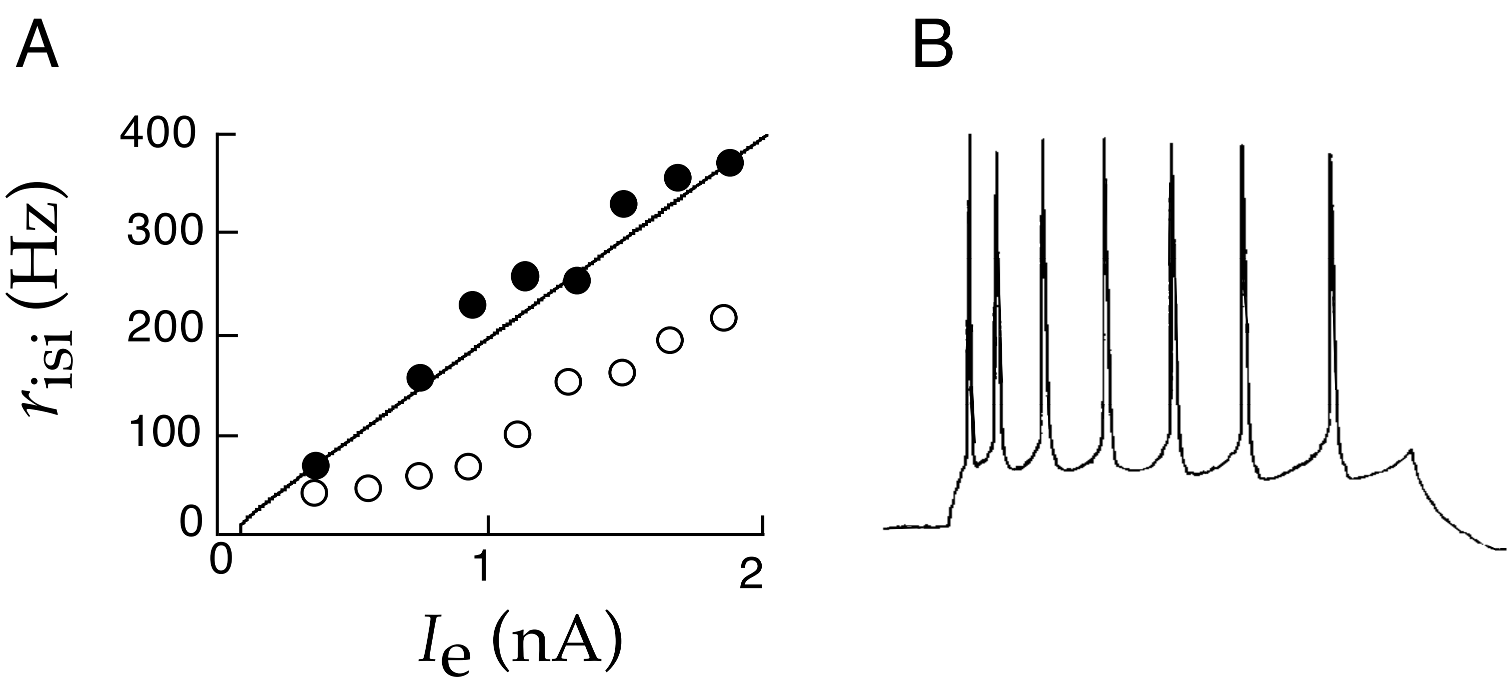
Integrate-and-Fire model



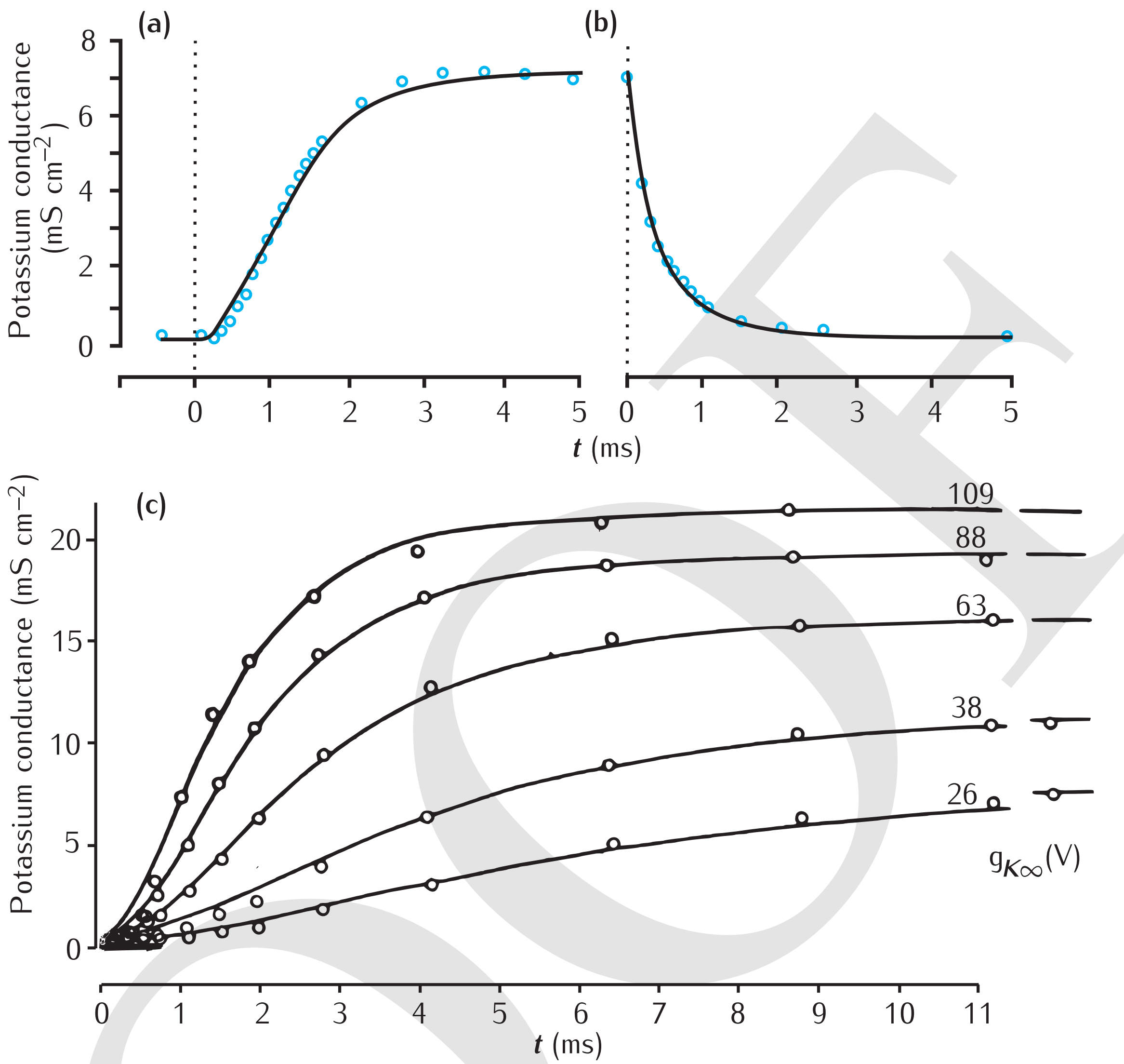
$$C\frac{dV}{dt} = -g(V - E_K) + I_e$$

$$V(t_{spike}^{-}) = V_{th}$$

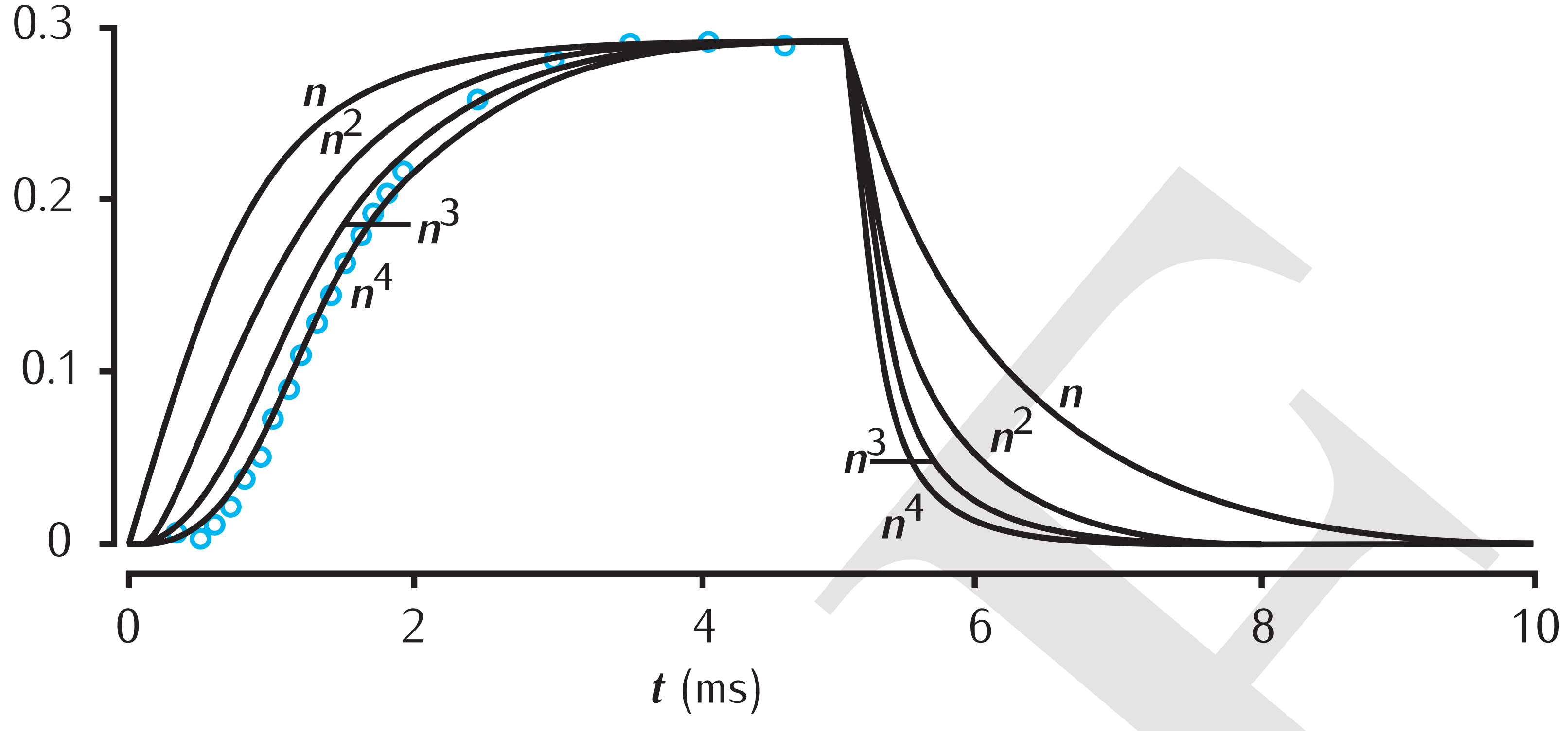
$$V(t_{spike}^{+}) = V_{res}$$


A
B
400
300
200
100
0
r_{isi} (Hz)
0
1
2
I_{e} (nA)

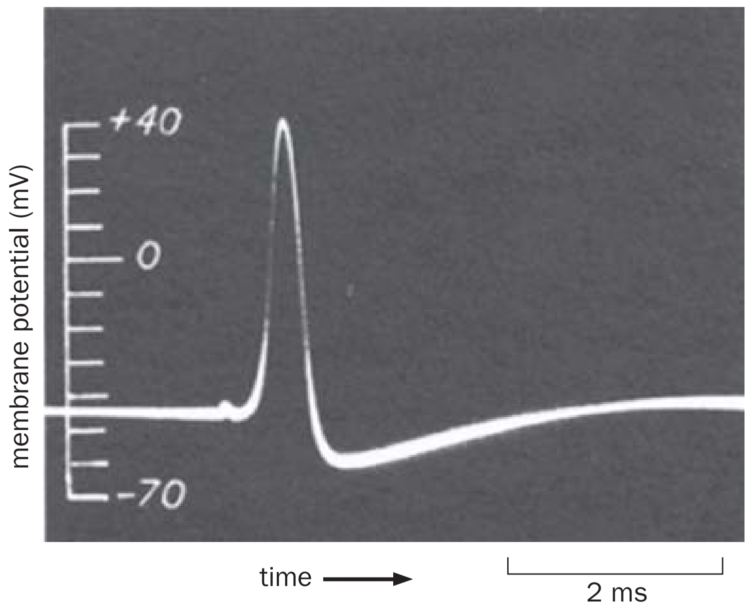
Voltage-gated Conductance of K^+

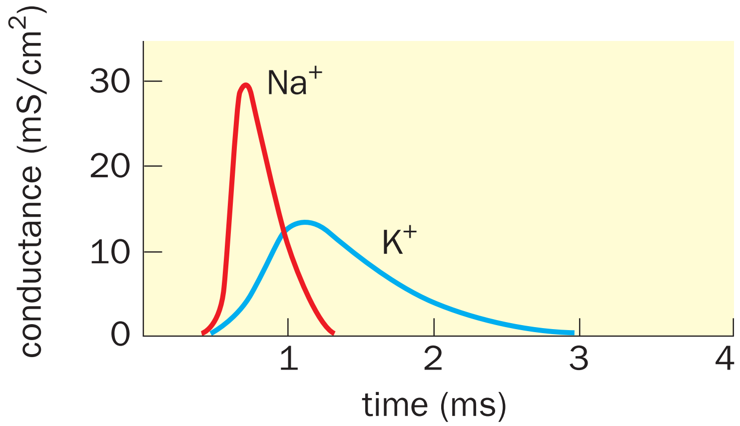


Voltage-gated Conductance of K+



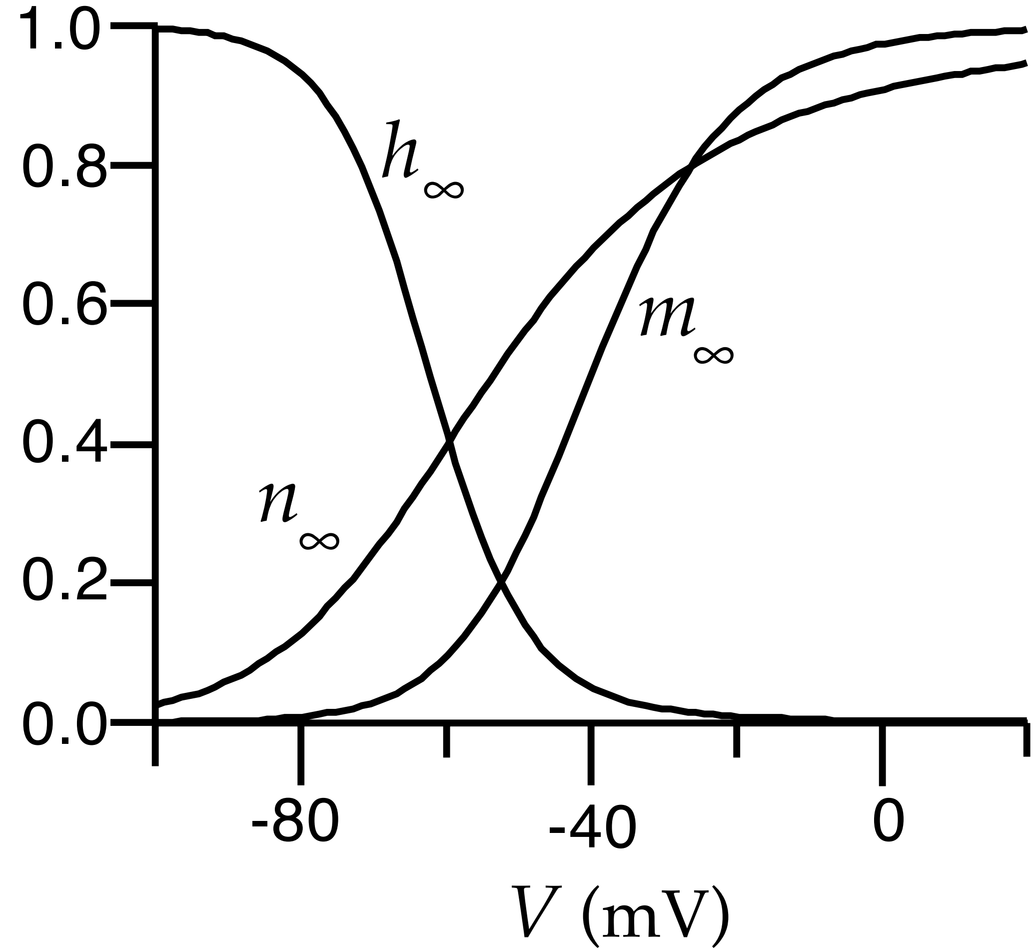
(C)

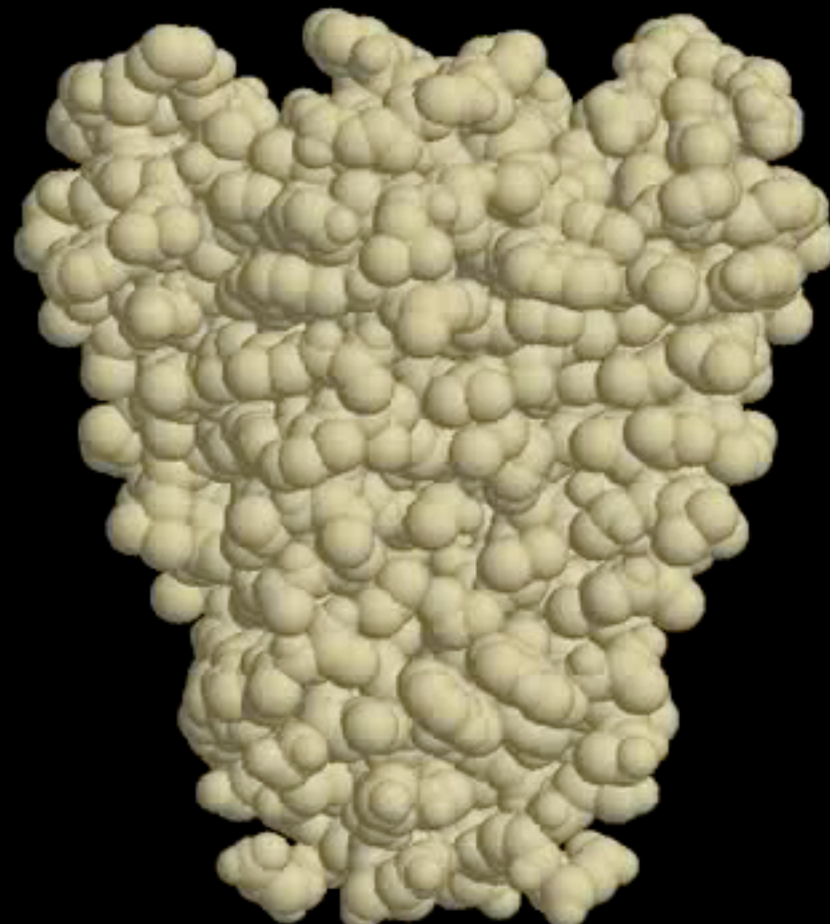




$$C\frac{dV}{dt} = -g_K n^4 (V - E_K) - g_{Na} m^3 h (V - E_{Na}) - g_L (V - E_L) - I_e$$

Transient Na^+ channel conductance





Squid Giant Axon

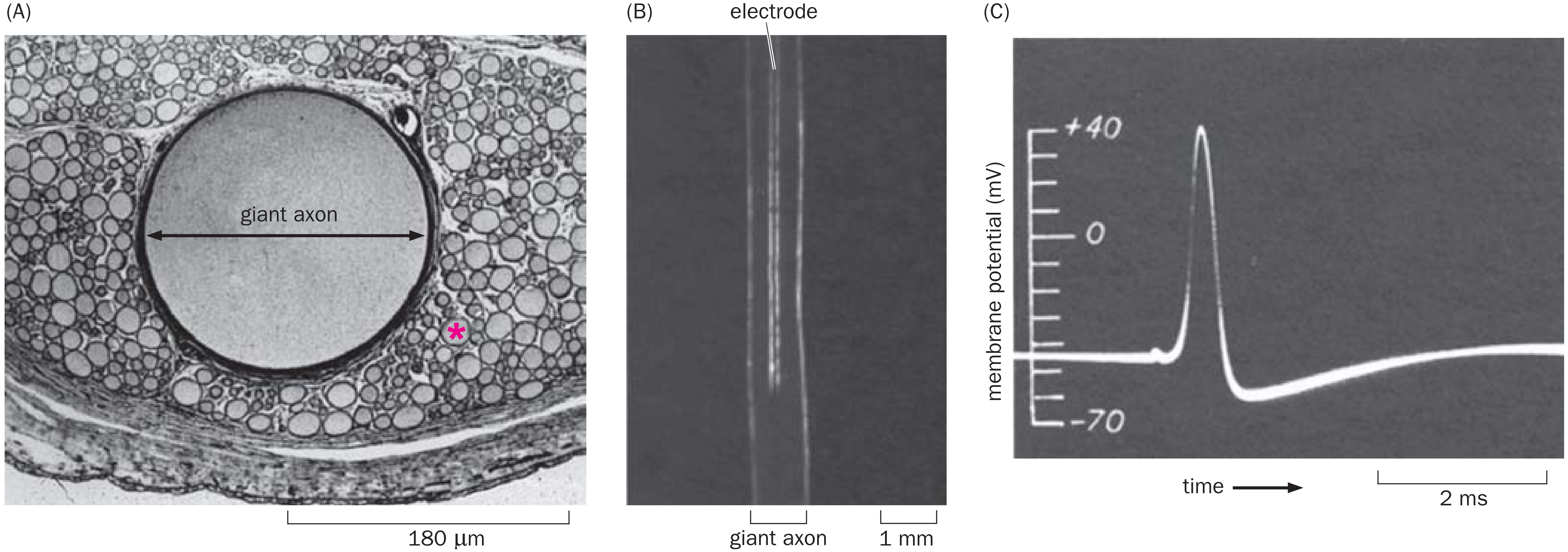
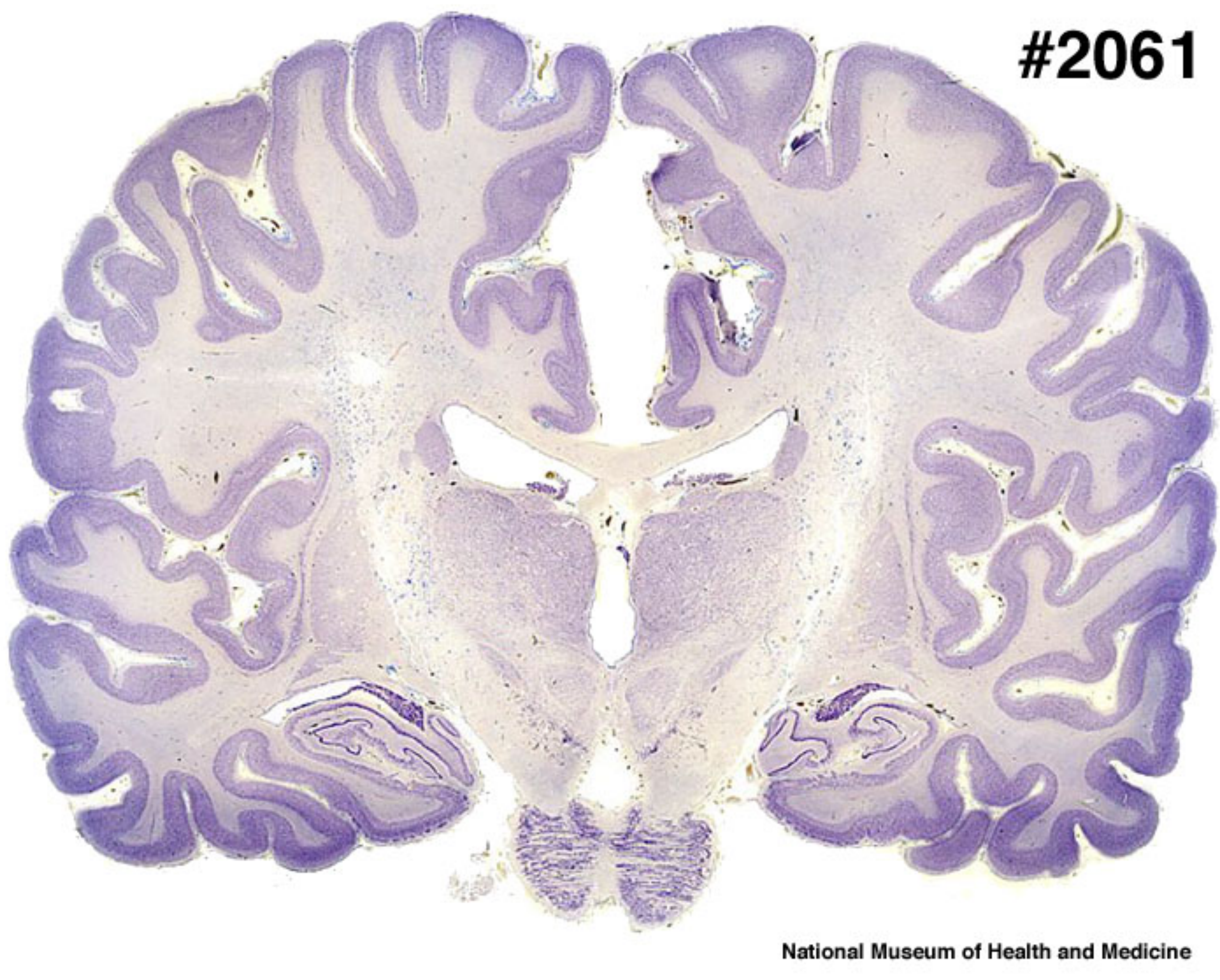


Figure 2–19 Studying action potentials in the squid giant axon. (A) Electron micrograph of a cross section of a squid giant axon showing its large diameter (~180 µm for this sample) as compared to neighboring axons (for example, the axon indicated by *). **(B)** Photograph of an electrode inserted inside a squid giant axon whose diameter is close to 1 mm. **(C)** An action potential recorded from the squid giant axon. (A, courtesy of Kay Cooper and Roger Hanlon; B, from Hodgkin AL & Keyes RD [1956] *J Physiol* 131:592–616; C, from Hodgkin AL & Huxley AF [1939] *Nature* 144:710–711. With permission from Macmillan Publishers Ltd.)

Gray and White Matter



Myelinated axons