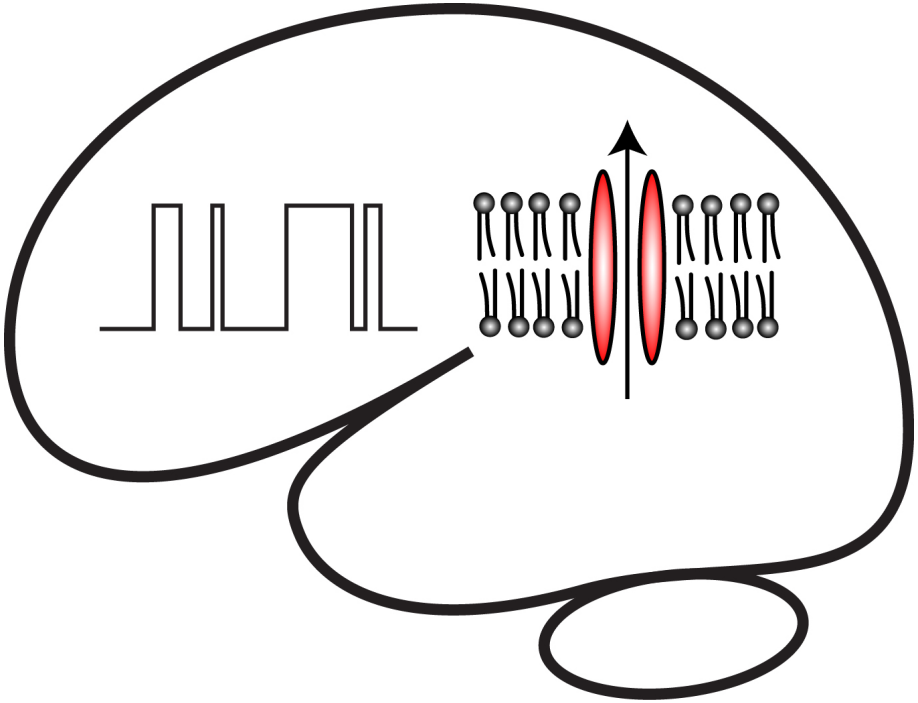
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE



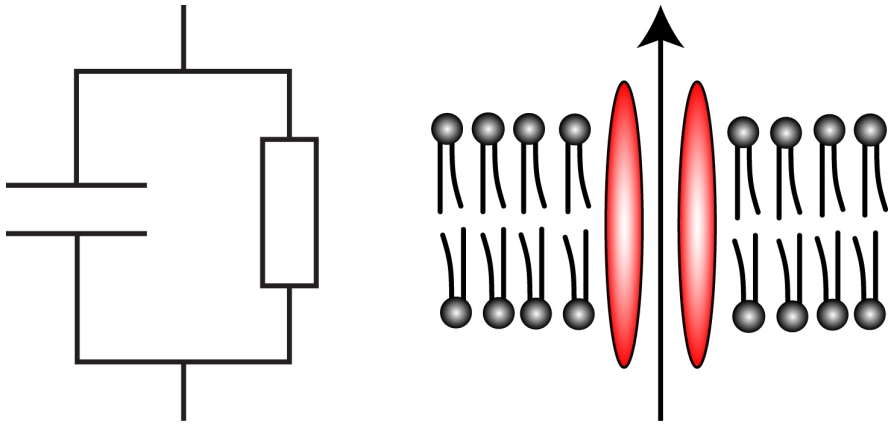
1.3 Ion channels

Cellular Mechanisms of Brain Function

Prof. Carl Petersen

Ion movement across the cell membrane

Ion channels



Ion channels are transmembrane proteins

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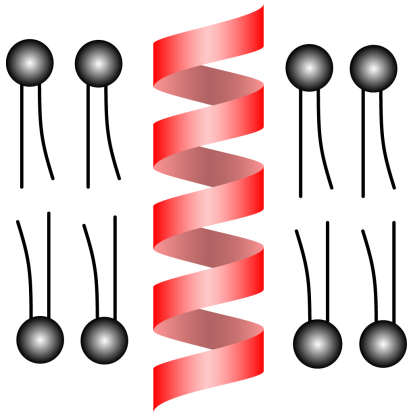
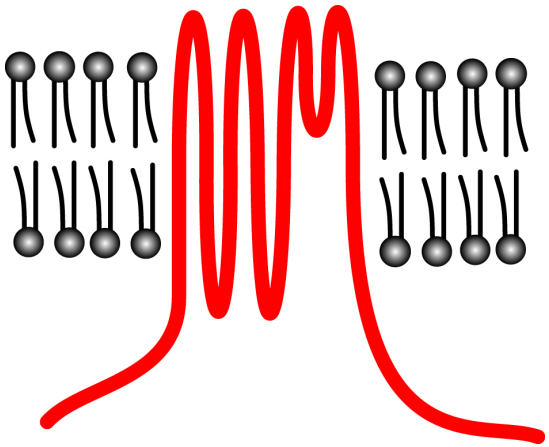
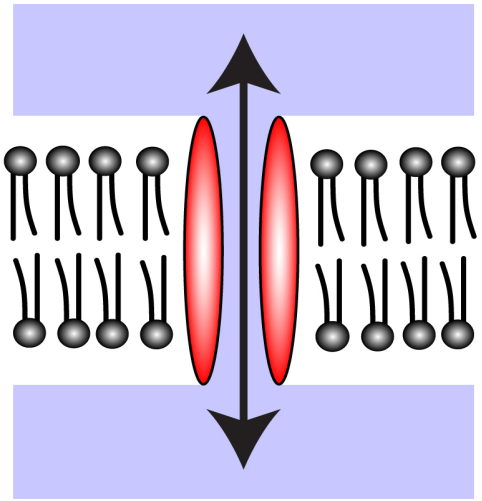
Alpha helix



Hydrophobic transmembrane domains



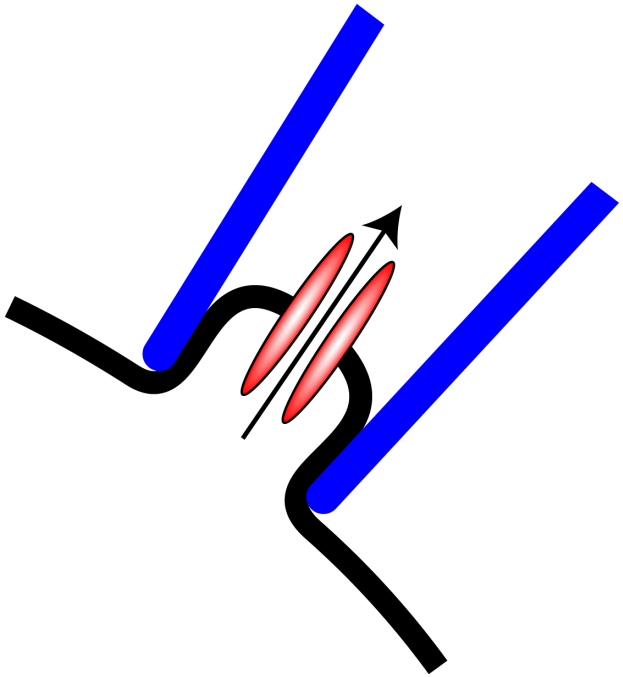
Aqueous pore

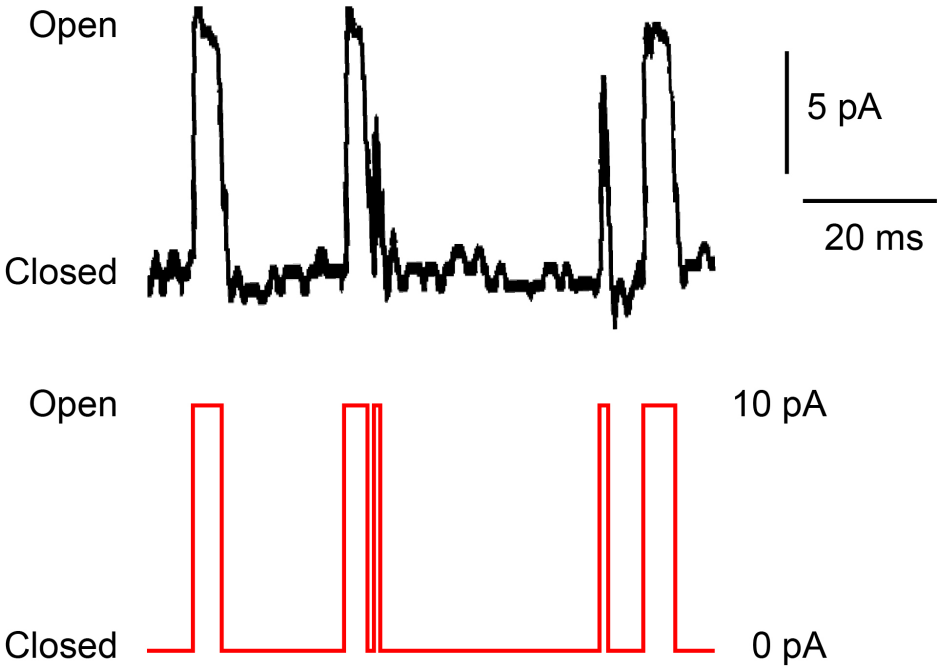


Patch-clamp recordings of single channels

Erwin Neher and Bert Sakmann developed the patch-clamp recording technique allowing measurement of single channel currents (Nobel prize 1991).

Single channel currents

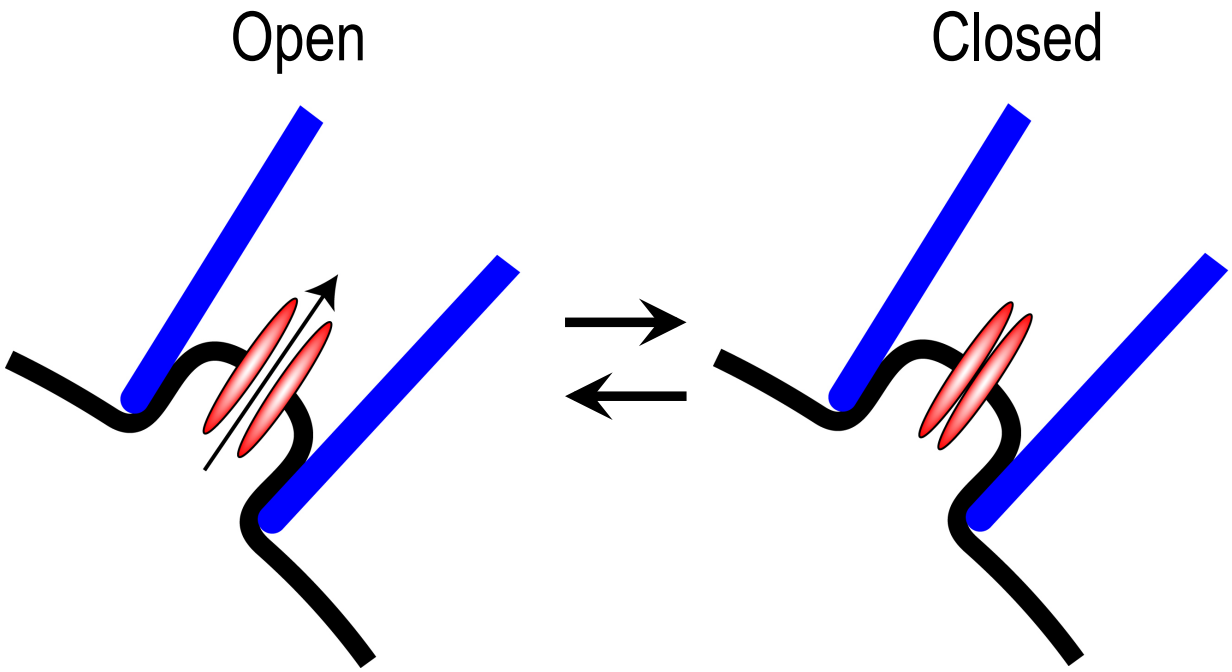




Suzuki, Petersen & Petersen, 1985

Open and closed states

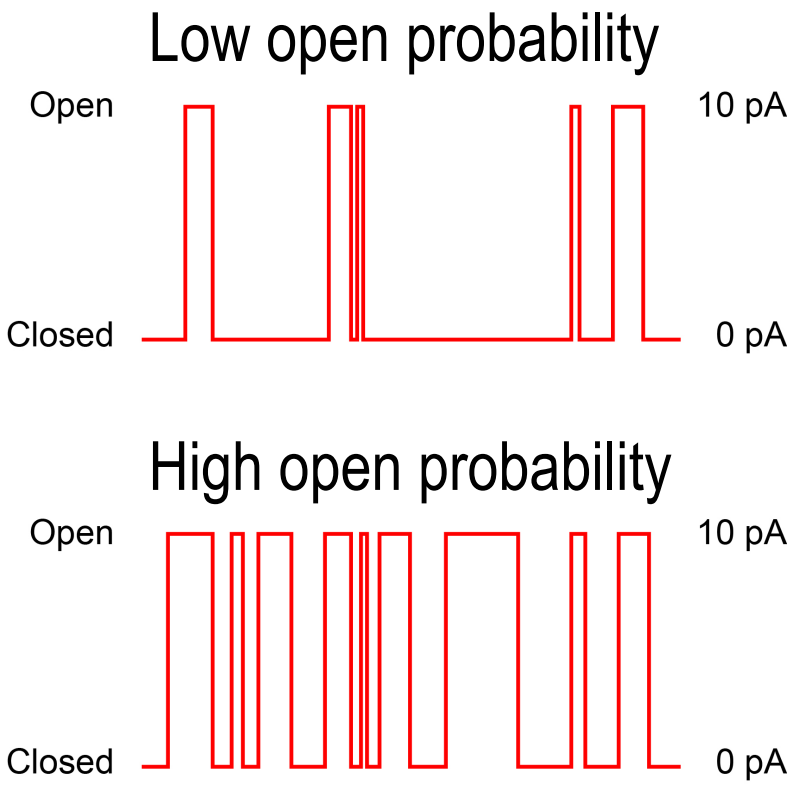
Single ion channels rapidly change protein conformation between open and closed states.



Open probability

The probability of being in the open state is one of the key features of ion channel function that is highly regulated.

$$\text{Open probability} = \frac{\text{Time open}}{\text{Time open + closed}}$$



Ion selectivity

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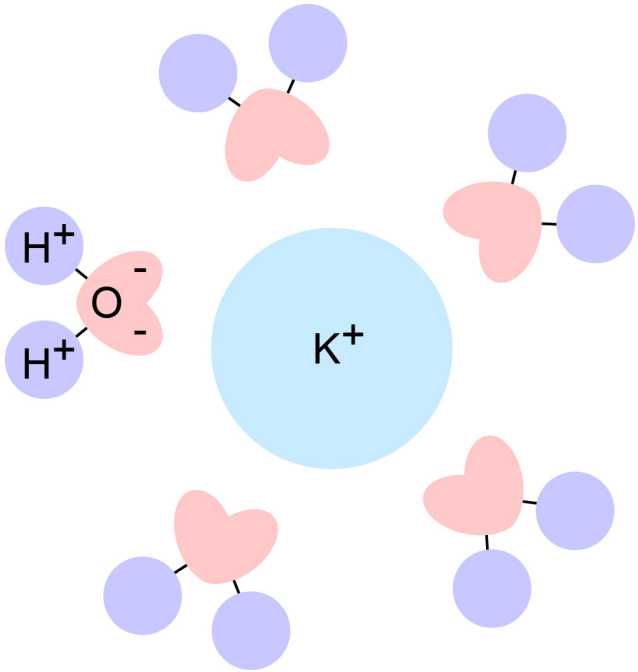
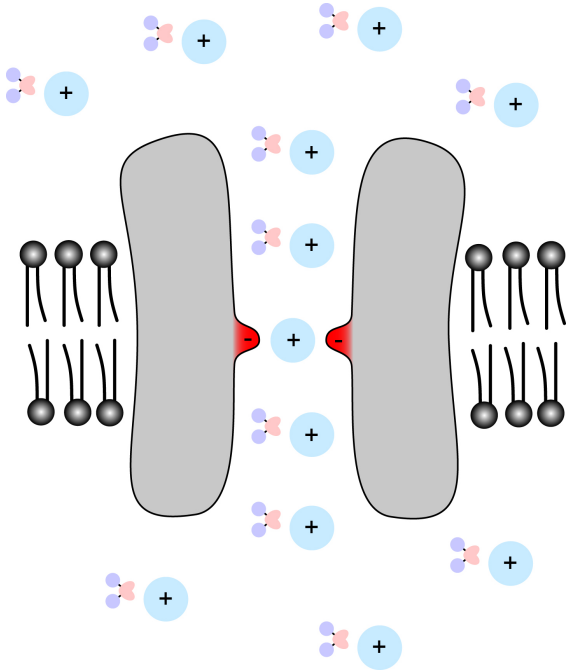
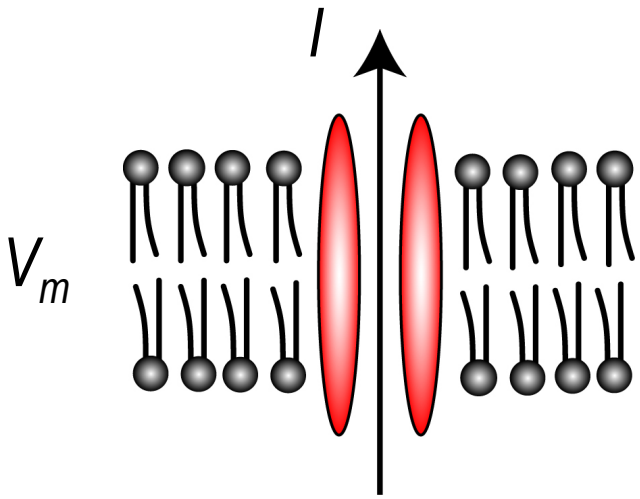
Hydrated ion

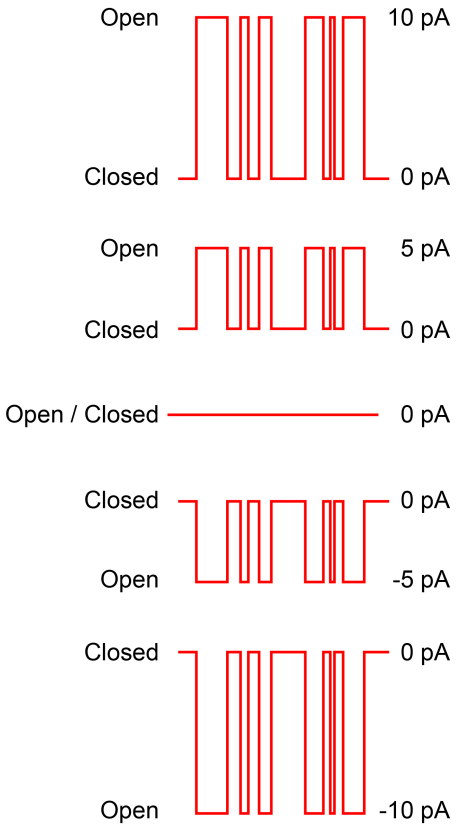


Selectivity filter



Single channel conductance





V_m = 100 mV

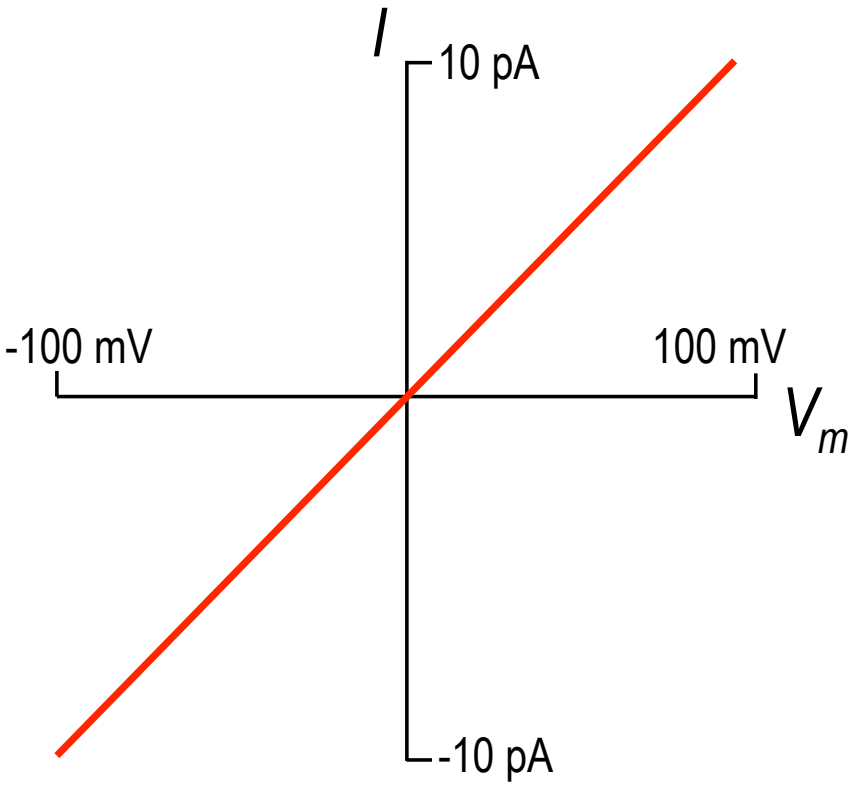
V_m = 50 mV

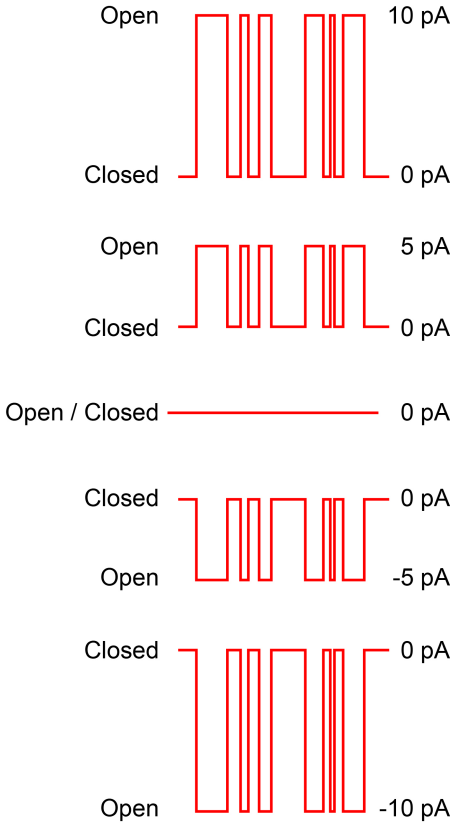
V_m = 0 mV

V_m = -50 mV

V_m =-100 mV

Single channel conductance





V_m = 100 mV

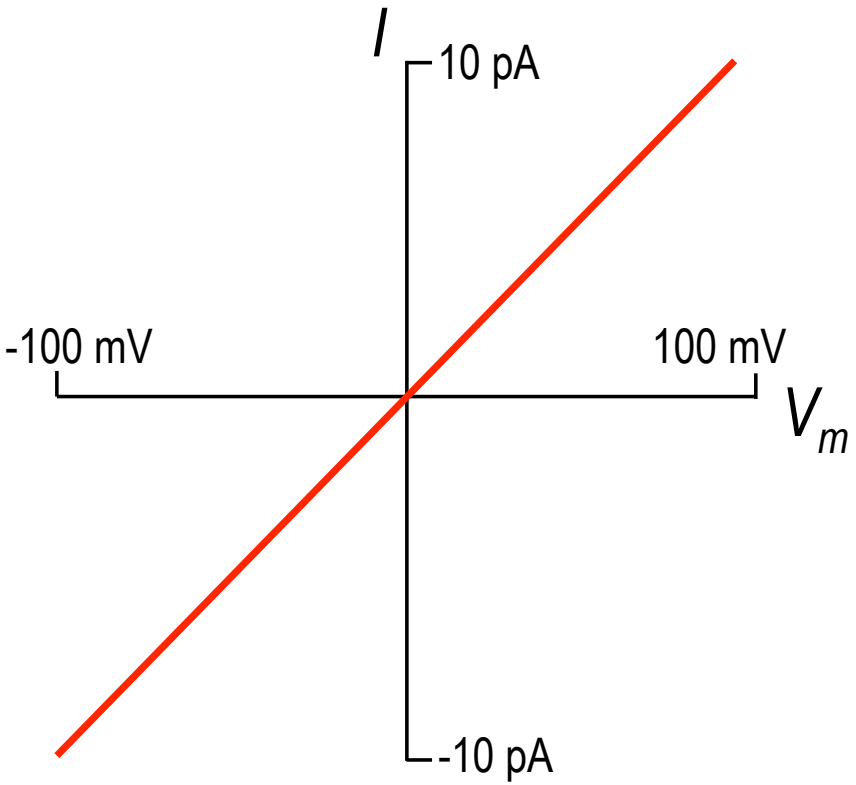
V_m = 50 mV

V_m = 0 mV

V_m = -50 mV

V_m =-100 mV

Single channel conductance



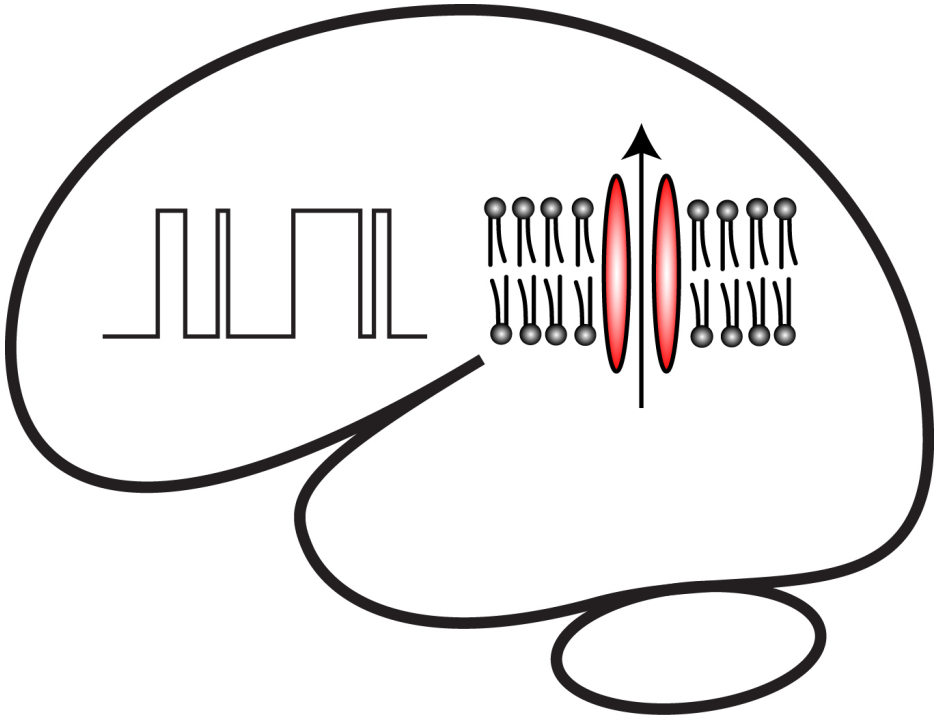
Ohm's law

$$V = I \times R$$
$$I = V \times G$$

V, potential; I, current;
R, resistance; G, conductance
G = 1 / R

G = 10 pA / 100 mV = 100 pS

Transmembrane currents through ion channels



Some numbers – single channel conductance

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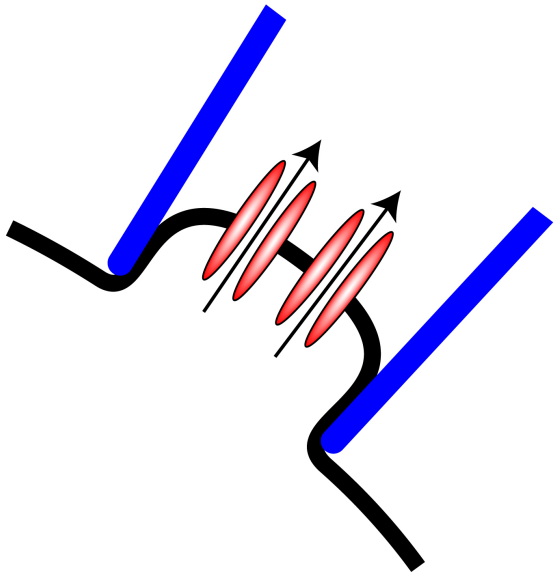
A typical ion channel has
a conductance between
1 pS and 100 pS.

How many ions are
transported per second?

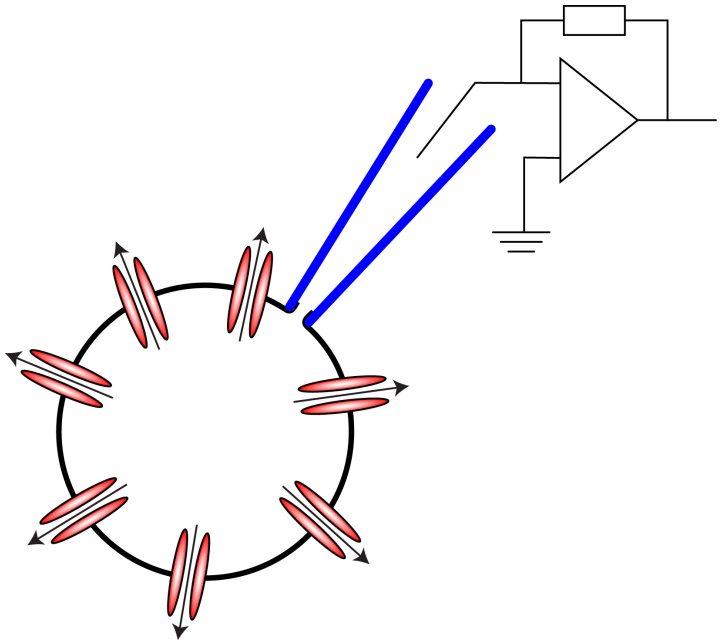
Some numbers – many channels

A typical patch of membrane
contains multiple ion channels.

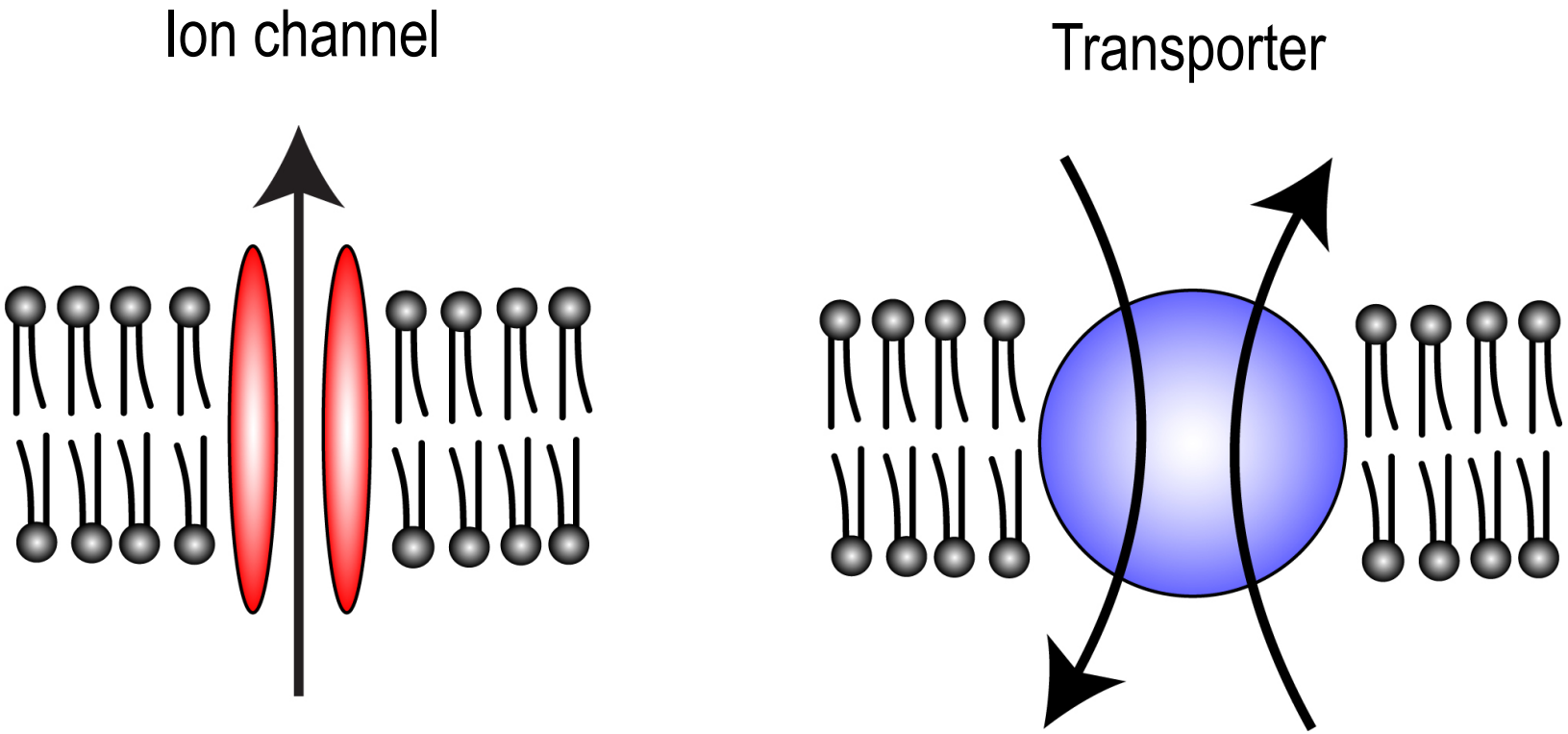


Some numbers – whole-cell currents

The membrane of a cell
contains many ion channels.



Ion channels and transporters



Ion channels

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- Whereas the lipid membrane acts as a capacitor, protein transmembrane ion channels are conductors.

- Ion channels are selectively permeable to specific ions and transition between open and close states.