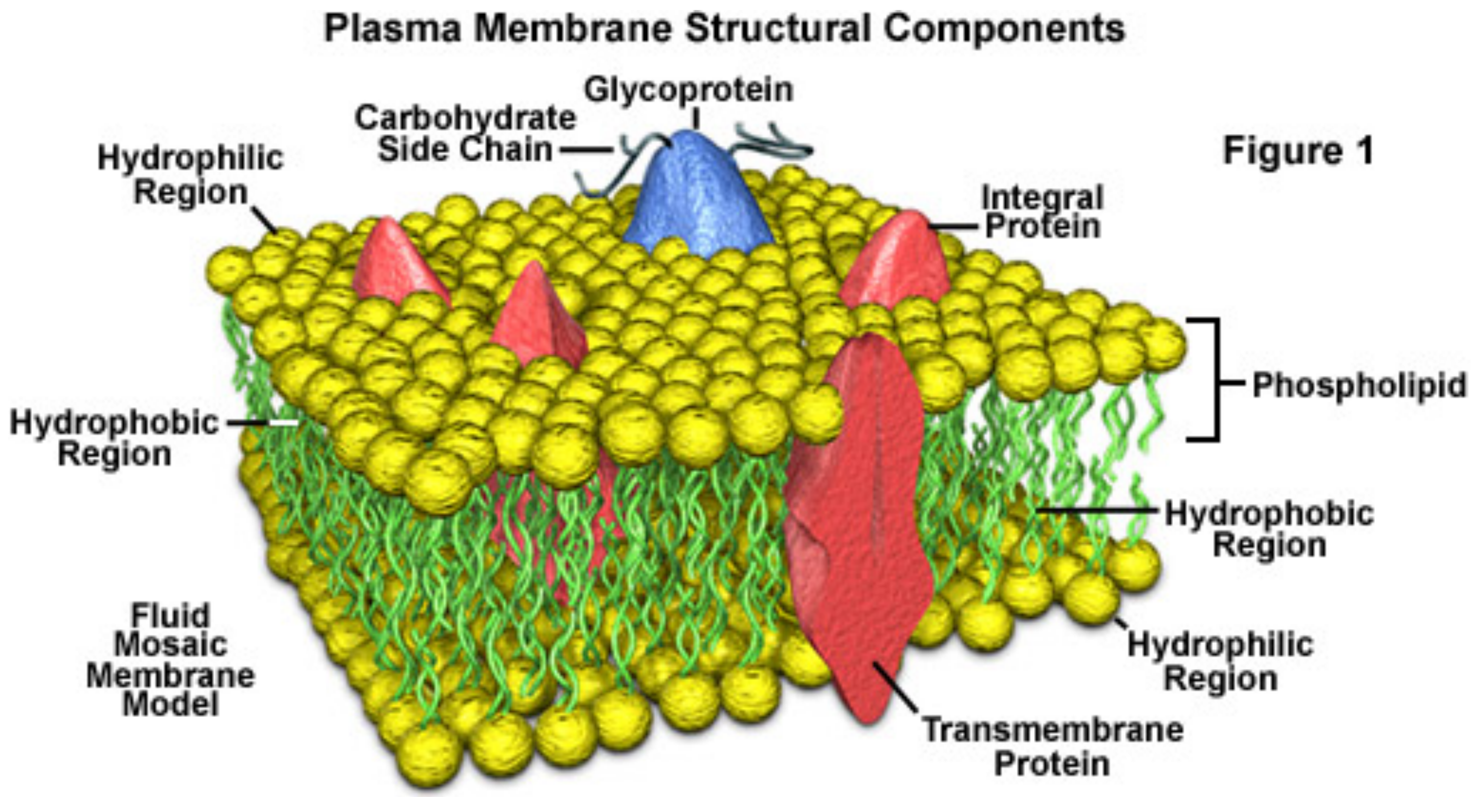
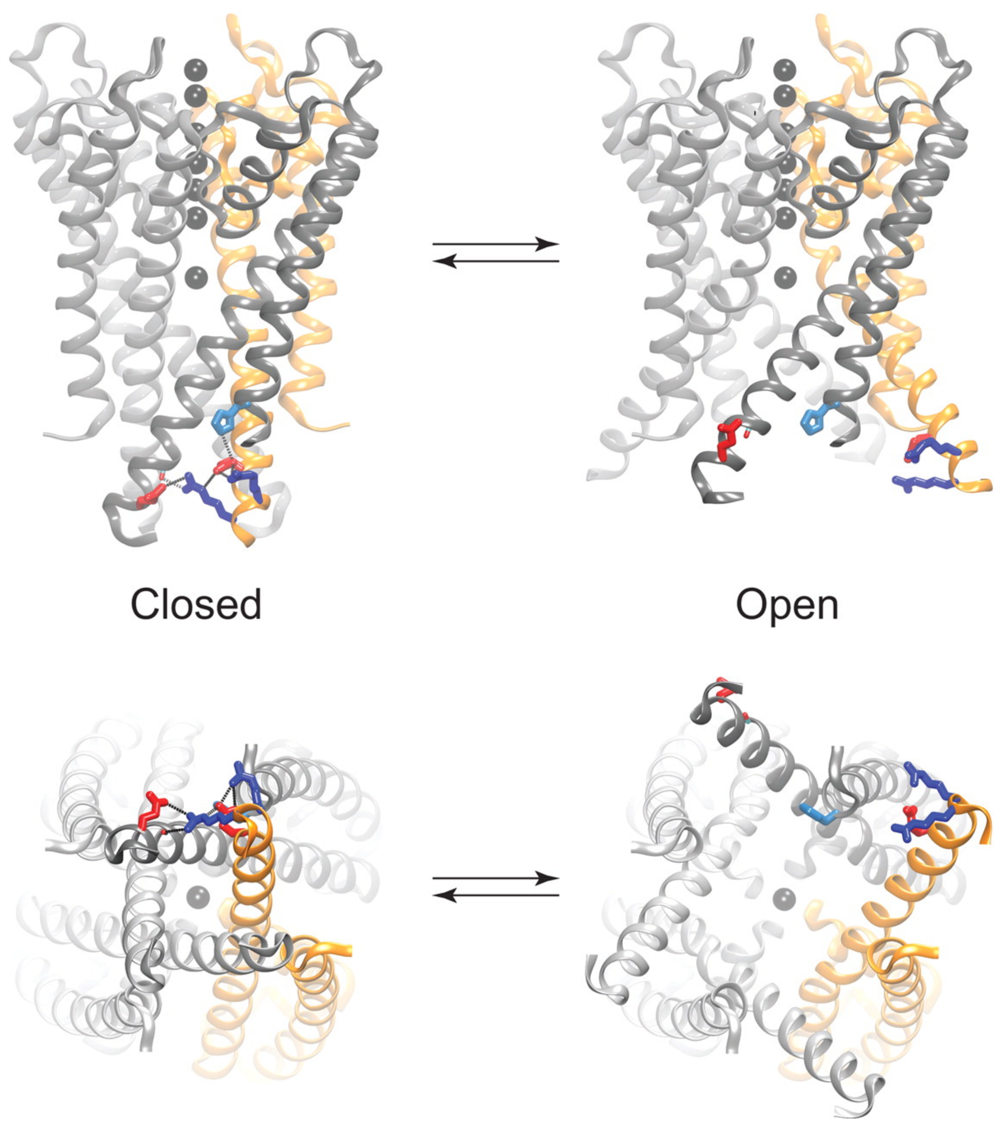
The Basis of Electrical Activity in the Neuron

The Neuronal Membrane



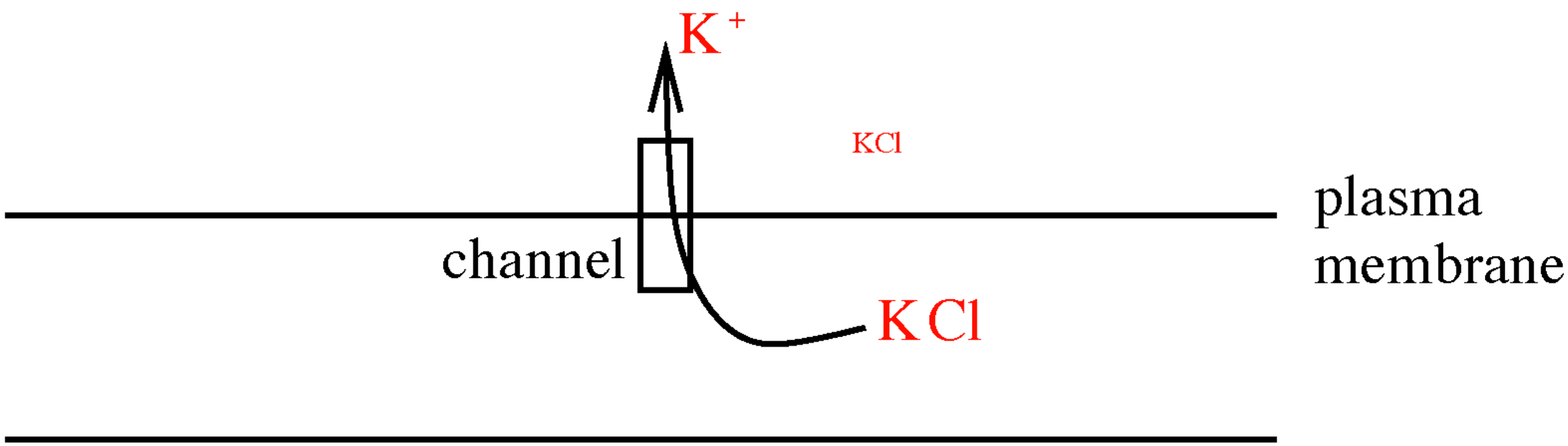
A phospholipid bilayer that does not allow charged particles to cross. There are transmembrane proteins that allow or force the flux of ions between the inside and outside of the cells. These are ion channels and ion pumps and exchangers.

Atomic Model of an Ion Channel



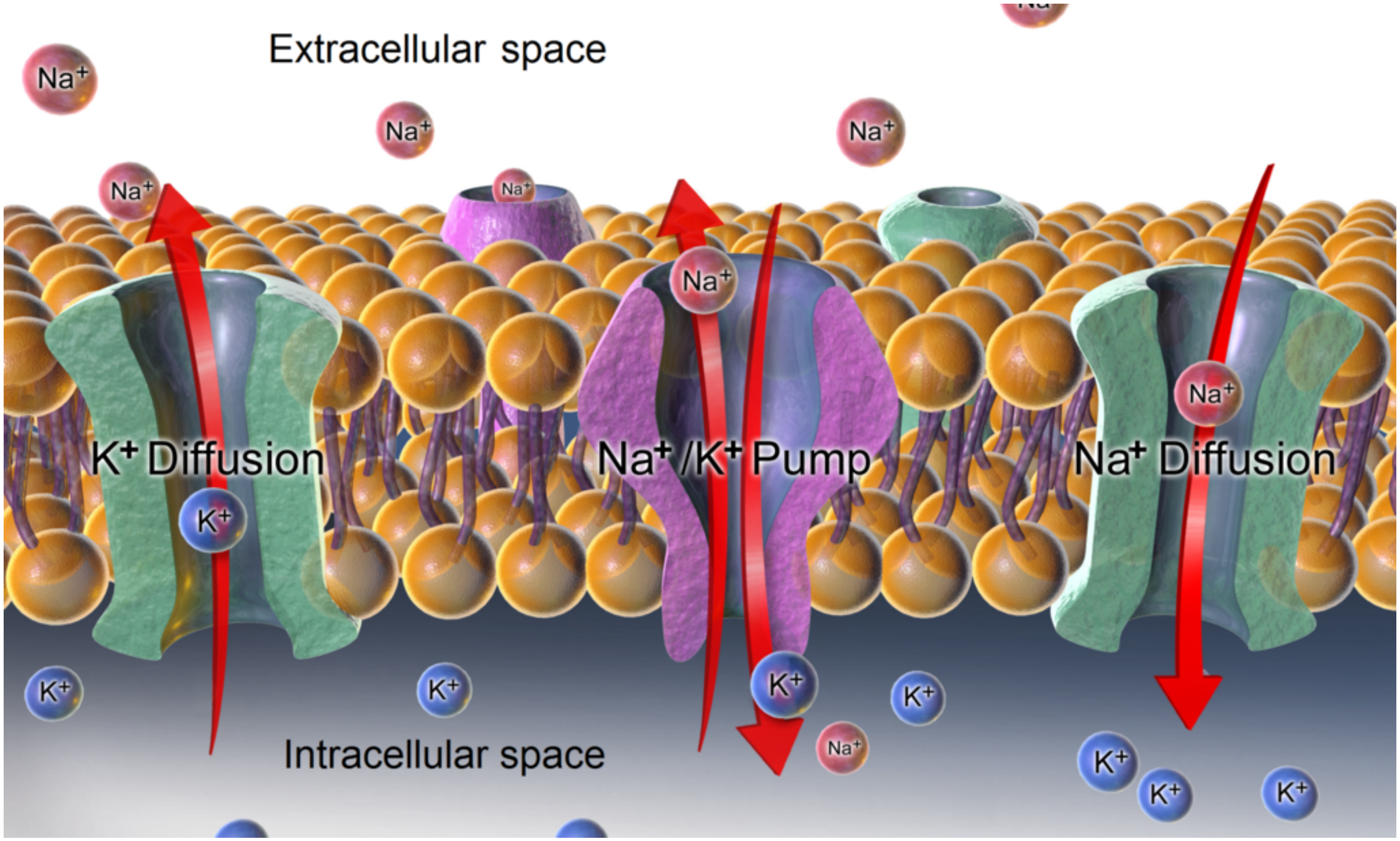
The bacterial KcsA K^+ channel

Ion Flow Through an Ion Channel



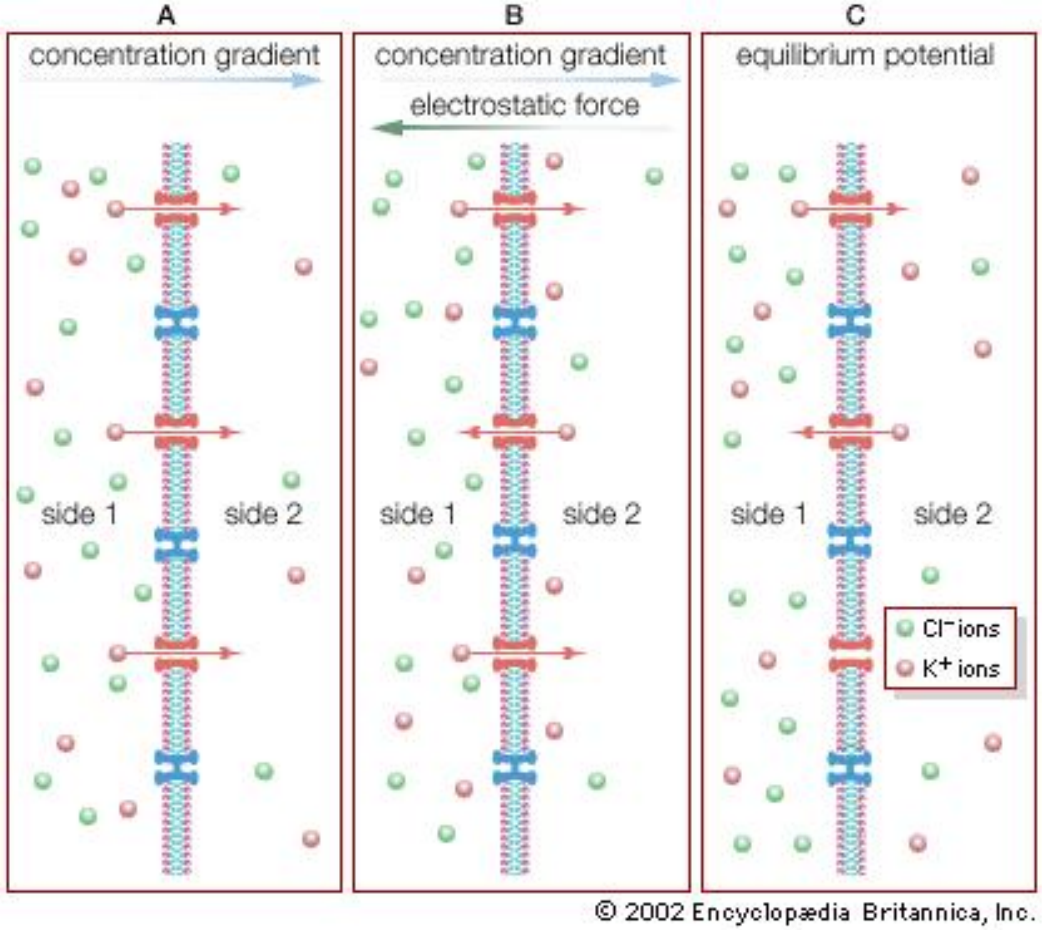
Only the K^+ ions get through, the Cl^- stays put. The membrane acts as a semipermeable membrane.

Ion Flow Through an Ion Exchanger



Na^+/K^+ exchangers move 2 K^+ into the cell for every 3 Na^+ it pumps out. These are going against the ion concentration gradients and therefore require energy. This is provided by the hydrolysis of ATP. Also, it generates an electrical current, and the exchanger is therefore said to be electrogenic.

Electrodiffusion Through a Semipermeable Membrane



Diffusion – flow of atoms down the K^+ concentration gradient

Electrical drift – flow of ions due to electrical potential

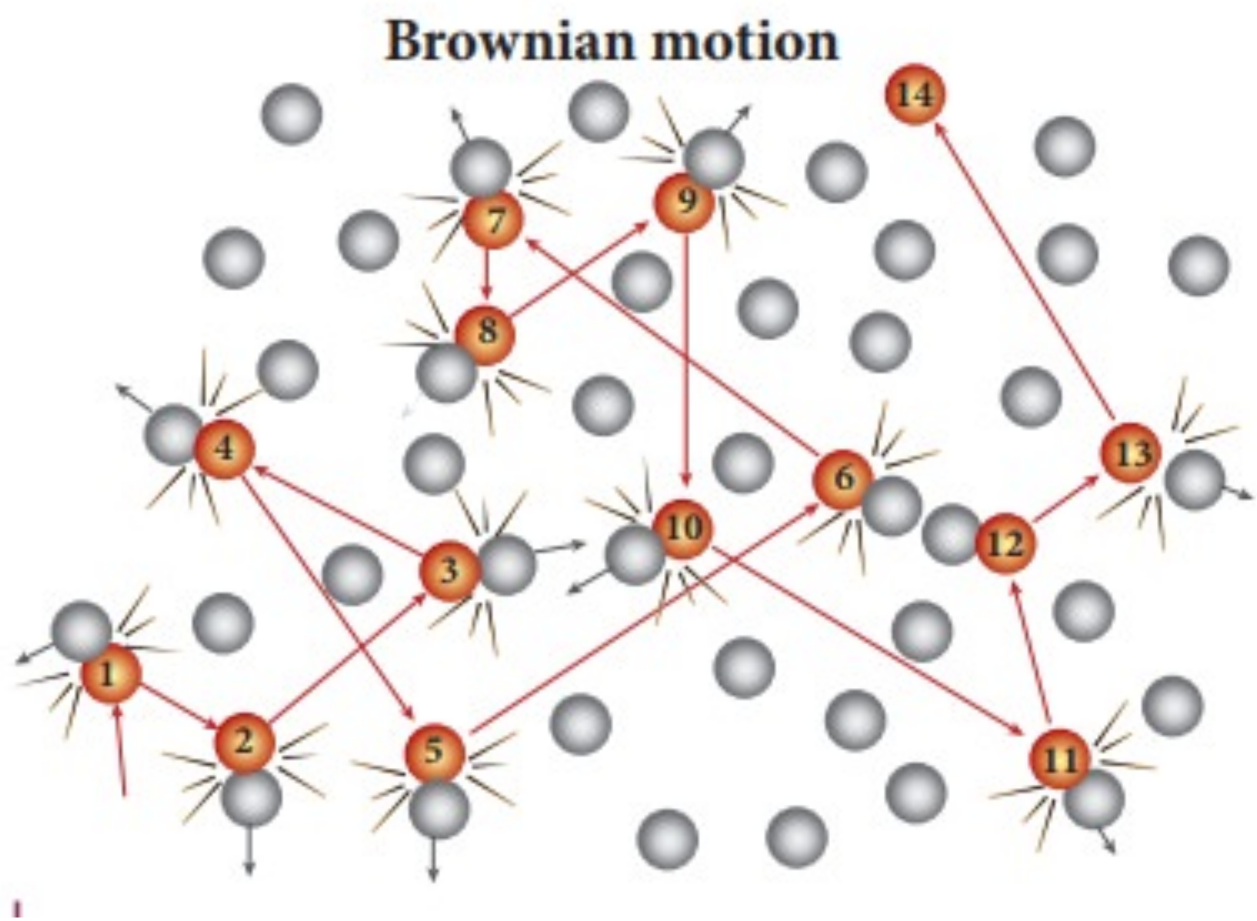
Electrodiffusion – flow of ions due to combination of diffusion and electrical drift

Electrodiffusion Through a Semipermeable Membrane

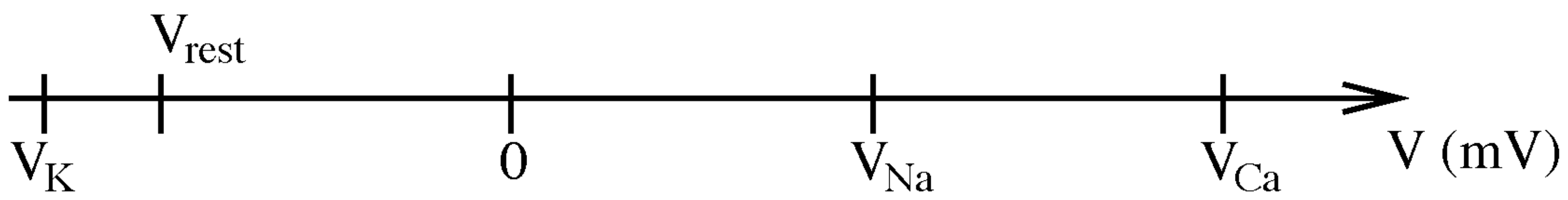
The diffusion of charged ions from one side of the membrane to the other creates an electrical field. The difference in the potential energy per unit charge between any two points in the field is called the potential difference, denoted as V and measured in volts.

When the membrane is a cell's plasma membrane, the potential difference is called the membrane potential, and is defined as the potential inside the cell minus the potential outside the cell.

Diffusion is a Macroscopic Description of Brownian Motion

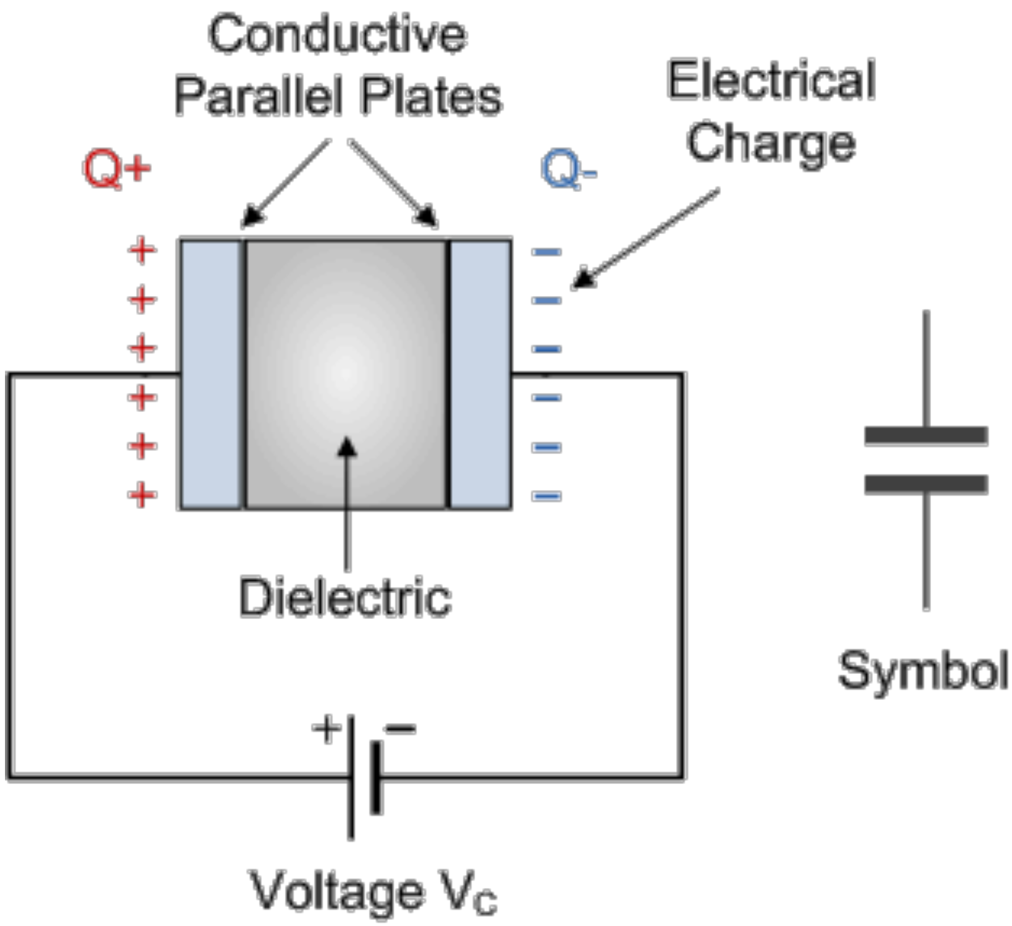


Nernst Potentials



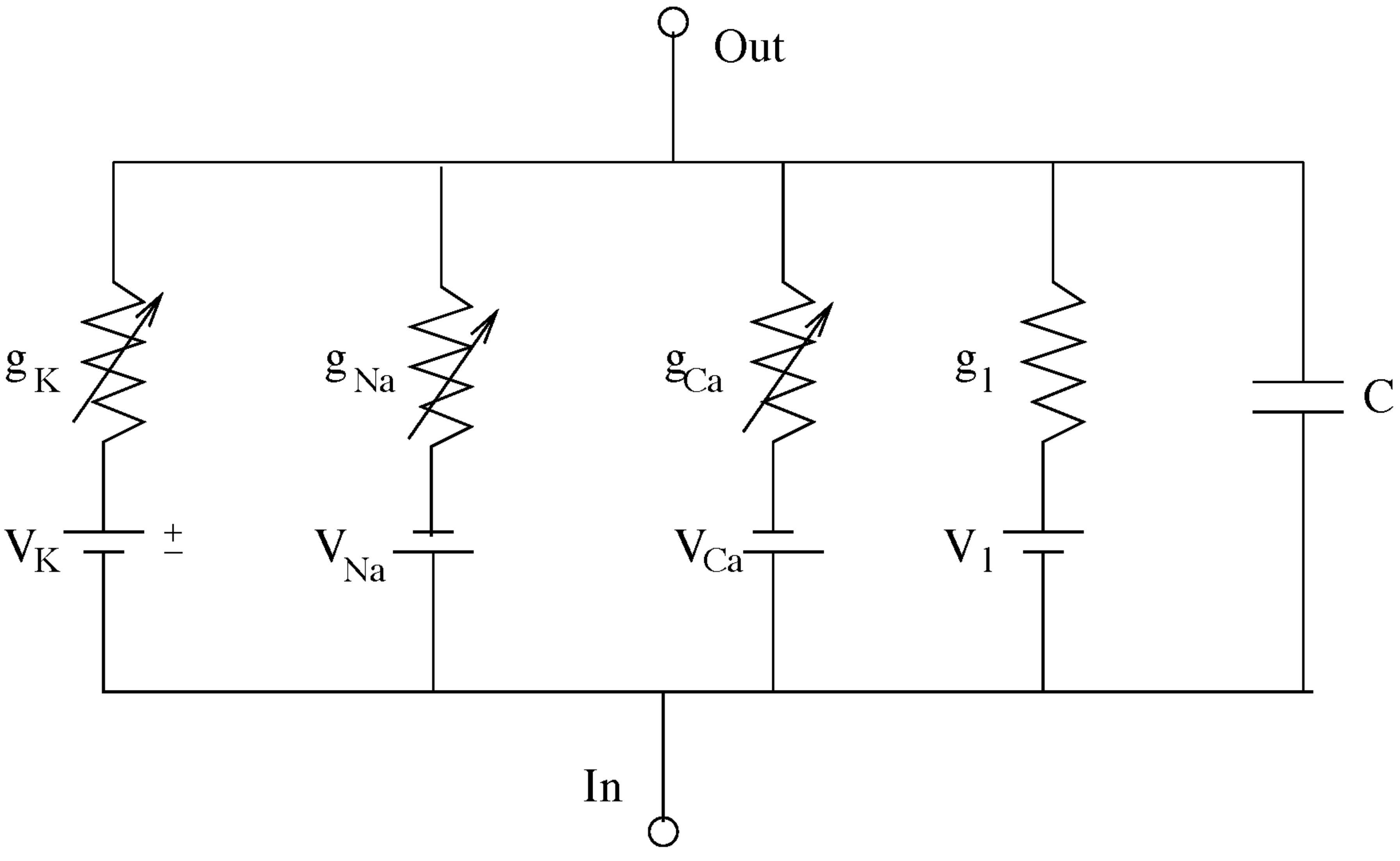
Relative locations of Nernst and resting potentials

A Capacitor

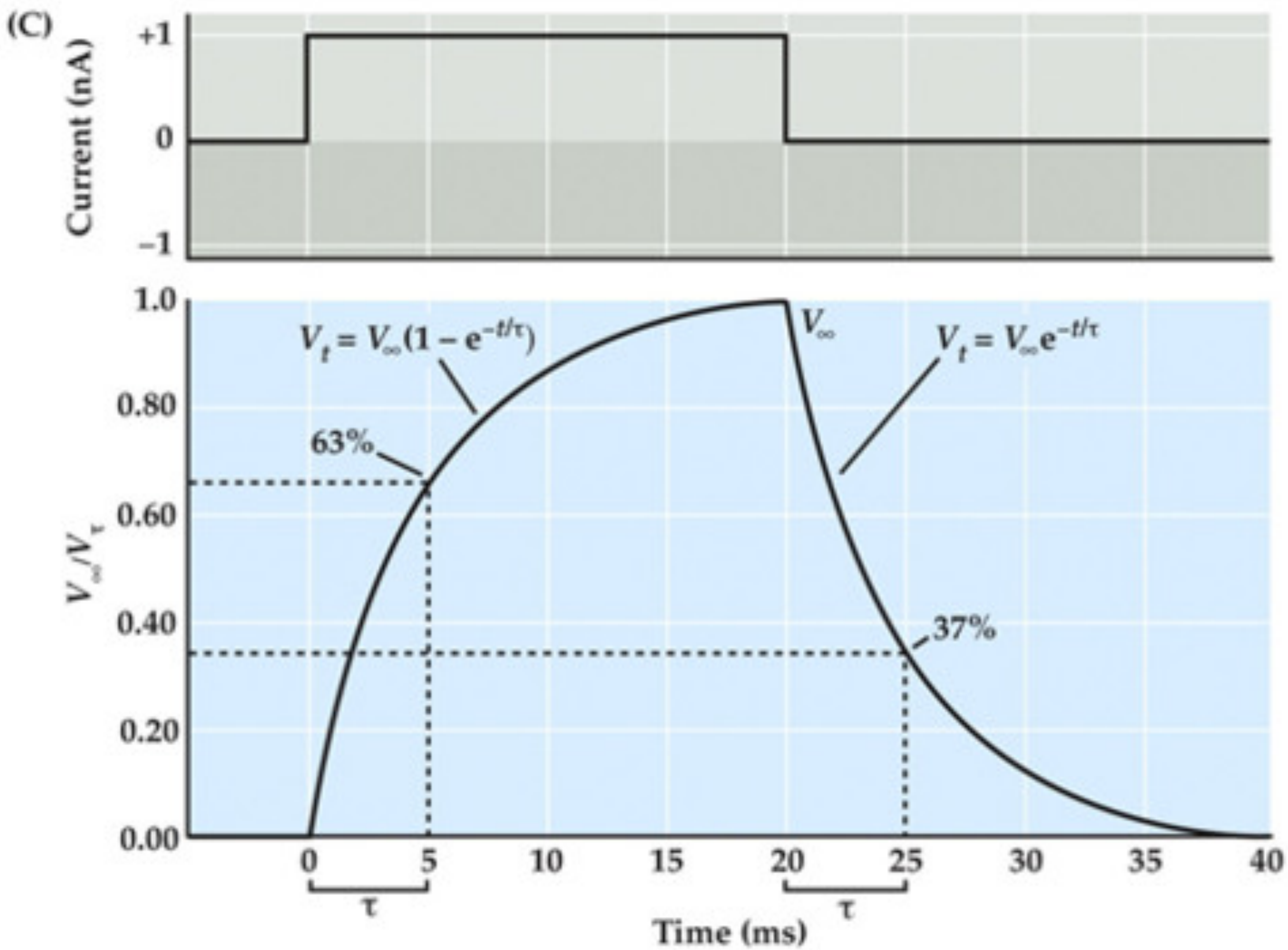


A capacitor is like a moat surrounding a castle: it separates inside from outside. In the membrane, the dielectric reflects the lipids.

An Equivalent Circuit

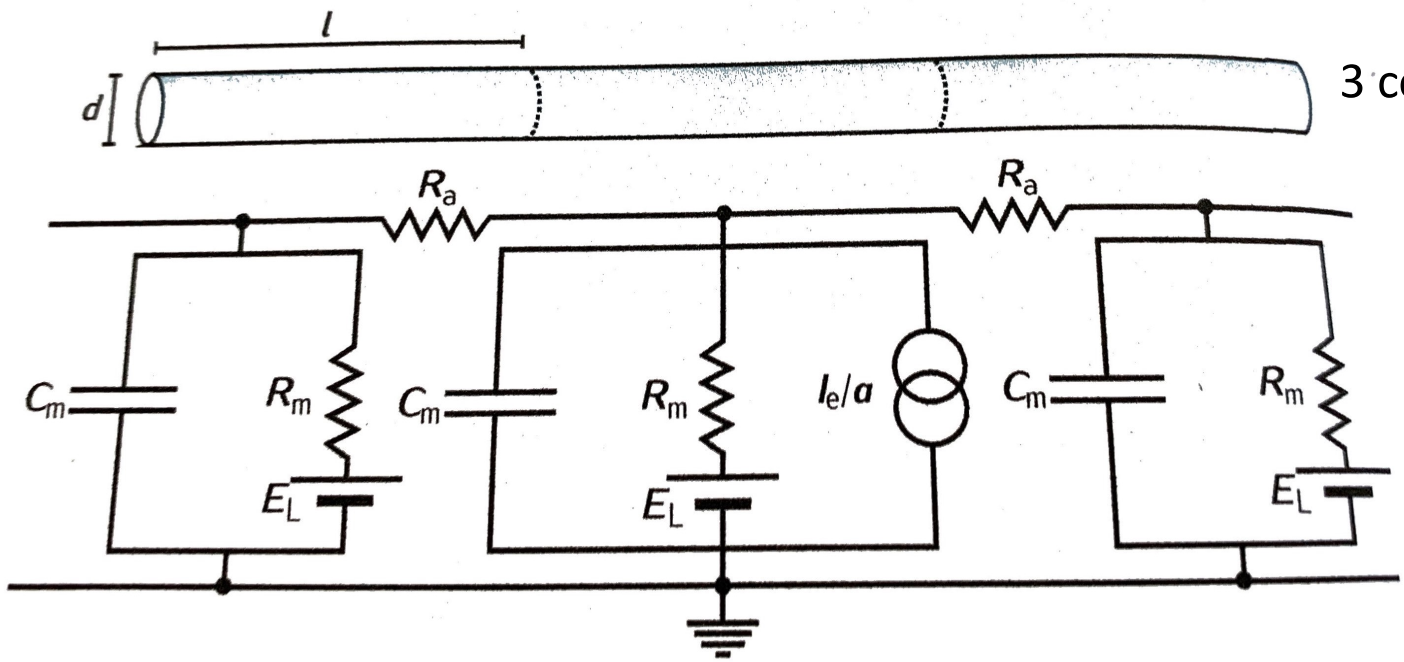


Membrane Time Constant



τ is the amount of time it takes to about 2/3 of the way from the rest equilibrium (with 0 external current) to the new equilibrium

Circuit Diagram for a Compartmental Model



3 compartments

R_m = membrane resistance
R_a= specific axial resistance

Voltage Dynamics in Cable Equation