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.
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 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

\[ \tau \text{ is the amount of time it takes to about } 2/3 \text{ of the way from the rest equilibrium (with 0 external current) to the new equilibrium} \]
Circuit Diagram for a Compartamental Model

$R_m$ = membrane resistance
$R_a$ = specific axial resistance

3 compartments
Voltage Dynamics in Cable Equation

(a) Equilibrium

(b) Current pulse

Equation

$V(x) = V_0 e^{-x/2d}$

$I(t) = \frac{1}{2} e^{-t/\tau}$