

# Foundations

## Osmosis and Diffusion

### Learning Outcomes

1. Define and describe osmosis and diffusion
2. Describe what would happen in a hypertonic, isotonic and hypotonic solution

### Fluid Compartments of the Body

There are two main fluid compartments in the body:

- Extracellular fluid includes plasma and interstitial fluid.
  - Plasma
    - Fluid portion of blood
    - Restricted to the circulatory system
    - Contains
      - Dissolved proteins
      - Ions ( $\text{Na}^+$ ,  $\text{Cl}^-$  etc)
  - Interstitial fluid
    - High  $[\text{Na}^+]$ , low  $[\text{K}^+]$
    - Fills the space between cells in the body
    - very similar to plasma
      - Few dissolved proteins
- Intracellular fluid is found inside the cells.
  - High  $[\text{K}^+]$ , low  $[\text{Na}^+]$
  - Fluid inside the cell
  - Cytoplasm
  - Significantly different to ECF

### Barriers Between Fluid Compartments

Each compartment is separated by barriers like the capillary wall and cell membrane, restricting movement of substances between compartments.

- Plasma · interstitial = Capillary wall
- Interstitial · intracellular = Cell membrane

## Diffusion and Osmosis

Diffusion is the movement of molecules from high to low concentration without requiring extra energy.

- The identity of the dissolved particles is relevant.

Osmosis is the movement of water across a semipermeable membrane to equalise the concentration of dissolved particles.

- The identity of the dissolved particles in the water is irrelevant.
  - If on the left of the membrane there were 5 Na<sup>+</sup> ions, and on the right of the membrane there were 5 K<sup>+</sup> ions. There would be no net movement of water across the membrane
- "Water follows salt"

## Cell in Different Solutions

- Cells in hypertonic solutions lose water
- Cells in isotonic solutions maintain equilibrium
- Cells in hypotonic solutions gain water.

## Concentration, Osmolarity, and Tonicity

- Concentration describes the number of a particular molecule dissolved in a volume of solution
  - In biology we are usually describing concentrations on the millimolar (mM) (1/1000 of a M) scale
- **Osmolarity** describes the total number of dissolved particles in a volume of solution
  - **Penetrating** (can cross cell membrane) and **non-penetrating** (can't cross cell membrane)
  - Units = ~~OsM~~ which are Osmol/L
  - In biology this is usually ~~milliOsmolar (mOsM)~~
    - Typically for a cell  $\approx 300\text{mOsM}$
  - Oncotic pressure is osmotic pressure due to large molecules. The significance is that large molecules have disproportionately large osmotic pressure.
- **Tonicity** reflects cell behaviour and depends on the concentration of **only the non-penetrating solute** (cannot cross the semipermeable membrane)
  - Tonicity is a measure of the osmotic pressure gradient between two solutions
  - **Non-penetrating solutes** are the only solutes that **influence the osmotic pressure gradient**
    - Isotonic: same solute/water concentration on both sides of the membrane

# Cellular Membranes, Membrane Potentials, and Gated Ion Channels

## Cellular Membranes and Ion Gradients

Ion concentration gradients across cellular membranes enable cells to perform work.

- The steeper the gradient, the faster the speed of travel.
- Opposite charges attract, like charges repel.
- Membranes have selective permeability to ions like  $K^+$  and  $Na^+$ .
- Selective permeability of the membrane to  $K^+$  allows  $+ve$  charge to leave the cell
  - Ions act as charge carriers
  - Leak channels are specific to  $K^+$ , thus accompanying anion cannot follow  $K^+$  into the extracellular space
  - The membrane is about x40 more permeable to  $K^+$  than  $Na^+$
- Proteins are the most prominent anion inside the cell

## Membrane Potential and Equilibrium

- Membrane potential is the difference in charge across the membrane, measured in millivolts (mV)
- Resting membrane potential (RMP) is when the permeability of the cell is due entirely to "Leak" channels and the membrane is said to be at rest
  - The more permeable the membrane is to  $K^+$ , the more negative the RMP will be.
  - Excitability of a neuron is determined by how close to 0mV the RMP is
- During rest, the  $Na^+/K^+$  ATPase pump actively transports 3  $Na^+$  ions out of the cell and 2  $K^+$  ions into the cell, maintaining the resting membrane potential and ion concentration gradients.
- Depolarization: shifts in membrane potential toward 0mV, repolarization: shifts in membrane potential towards RMP, and hyperpolarization: shifts in membrane potential past the RMP

## Learning Objectives: Equilibrium Potential

1. Understand the term(s) equilibrium/reversal potential
2. Be able to predict the direction of movement of any particular ion based on the cells membrane potential and the reversal potential for that ion

## Equilibrium (Reversal) Potential

- There are two sources of potential energy driving the movement of a specific ion across the cellular membrane
  - Chemical concentration gradient