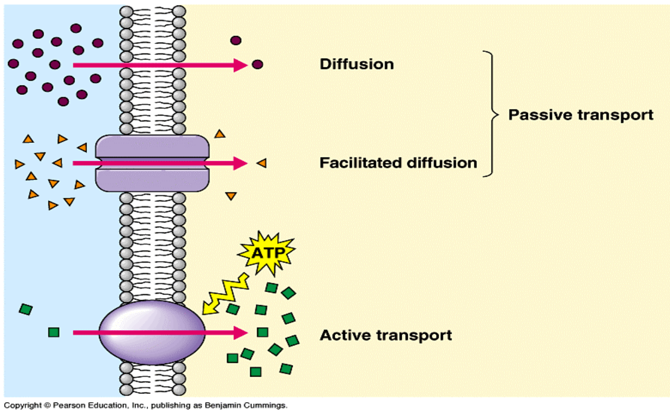
Movement across membranes

Diffusion, Osmosis, Active Transport



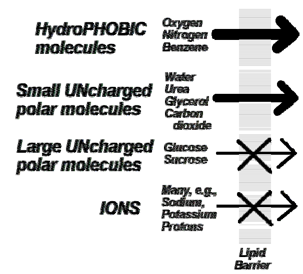
There are **two** ways in which substances can enter or leave a cell:

1) **Passive**
   a) Simple Diffusion
   b) Facilitated Diffusion
   c) Osmosis (**water** only)

2) **Active**
   a) Molecules
   b) Particles

Diffusion

Diffusion is the net passive movement of particles (atoms, ions or molecules) from a region in which they are in higher concentration to regions of lower concentration. It continues until the concentration of substances is uniform throughout.



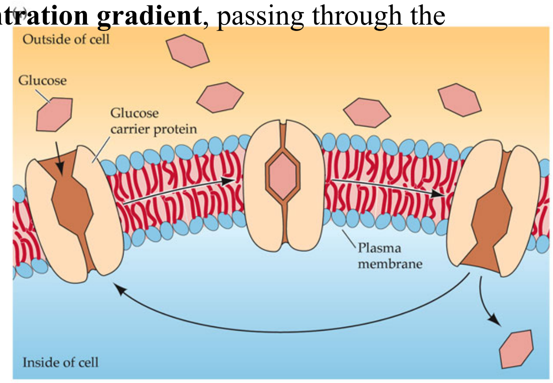
Some major examples of diffusion in biology:

- Gas exchange at the alveoli — oxygen from air to blood, carbon dioxide from blood to air.
- Gas exchange for photosynthesis — carbon dioxide from air to leaf, oxygen from leaf to air.
- Gas exchange for respiration — oxygen from blood to tissue cells, carbon dioxide in opposite direction.
- Transfer of transmitter substance — acetylcholine from presynaptic to postsynaptic membrane at a synapse.
- Osmosis — diffusion of water through a semipermeable membrane.

High Diffusion Rate: short distance, large surface area, big concentration difference (Fick's Law). High temperatures **increase** diffusion; large molecules **slow** diffusion.

Facilitated Diffusion

This is the movement of **specific** molecules **down a concentration gradient**, passing through the membrane *via* a **specific carrier protein.** Thus, rather like enzymes, each carrier has its own shape and only allows one molecule (or one group of closely related molecules) to pass through.
Selection is by size; shape; charge.
Common molecules entering/leaving cells this way include glucose and amino-acids.
It is **passive** and requires no energy from the cell.
If the molecule is changed on entering the cell (glucose + ATP → glucose phosphate + ADP), then the **concentration gradient of glucose** will be kept high, and there will a steady one-way traffic.



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.11 A Carrier Protein Facilitates Diffusion (Part 1)
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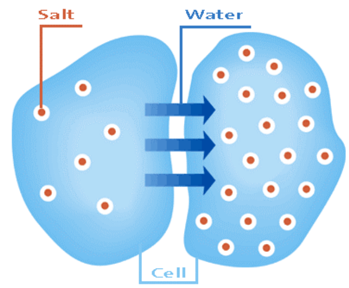
Osmosis

Osmosis is a special example of diffusion. It is the diffusion of water through a partially permeable membrane from a more dilute solution to a more concentrated solution – **down the water potential gradient)**



Note: diffusion and osmosis are both passive, i.e. energy from ATP is **not** used.
A partially permeable membrane is a barrier that permits the passage of some substances but not others; it allows the passage of the solvent molecules but not some of the larger solute molecules.
Cell membranes are described as selectively permeable because not only do they allow the passage of water but also allow the passage of certain solutes. The presence of particular solutes stimulates the membrane to open specific channels or trigger active transport mechanisms to allow the passage of those chemicals across the membrane.

Some major examples of osmosis

- Absorption of water by plant roots.
- Re-absorption of water by the proximal and distal convoluted tubules of the nephron.
- Re-absorption of tissue fluid into the venule ends of the blood capillaries.
- Absorption of water by the alimentary canal — stomach, small intestine and the colon.

Osmoregulation

Osmoregulation is keeping the concentration of cell cytoplasm or blood at a suitable concentration.
(a) *Amoeba*, living in freshwater, uses a contractile vacuole to expel the excess water from its cytoplasm (thus need more respiration/O_2/ATP than isotonic (marine) *Amoebae).*
(b) The kidneys maintain the blood (thus, whole body) at the correct concentration.

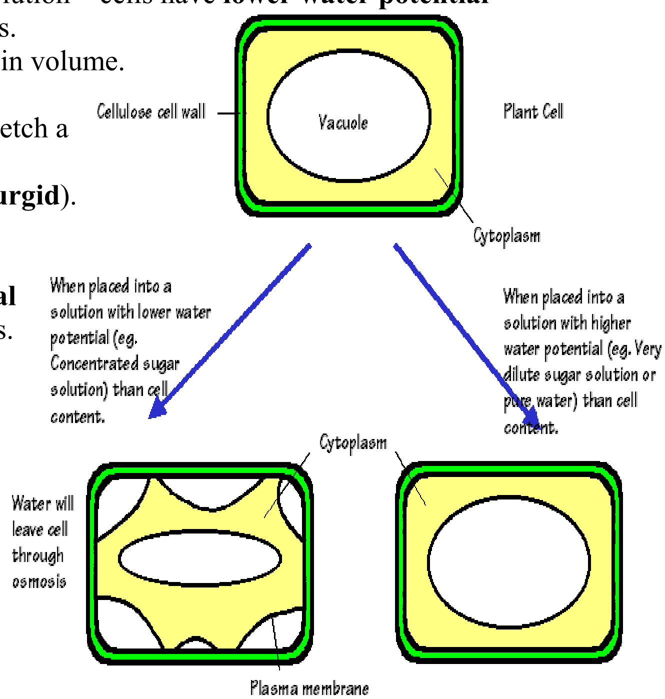
Osmosis and Plant Cells

(a) Plant Cells in a hypotonic (= weaker) solution – cells have **lower water potential**

- the plant cells gain water by osmosis.
- the vacuole and cytoplasm increase in volume.
- the cell membrane is pushed harder against the cell wall causing it to stretch a little.
- the plant tissue becomes stiffer (= **turgid**).

(b) Plant Cells in a hypertonic (=stronger) solution – cells have **higher water potential**

- the plant cells lose water by osmosis.
- the vacuole and cytoplasm decrease in volume.
- the cell shrinks away from the cell wall.
- shrinkage stops when the cell sap is at the same concentration as the external solution.
- the plant tissue becomes **flaccid**, it has shrunk slightly
- may go on to become **plasmolysed.**



Turgor

Turgor is the pressure of the swollen cell contents against the cell wall when the external solution more dilute than the cell sap of the vacuole.

Role of Turgor in Plants

- Mechanical support for soft non-woody tissue, e.g., leaves.
- Change in shape of guard cells forming the stomatal opening between them.
- Enlargement of young immature plant cells to mature size.

Water Potential

- This is the tendency of water to move from one place to another.
- **Values are always negative!**
- Water always **flows downhill** i.e. towards the more negative number.
- Units are pressure (kPa)
- Calculations are **not** set, but this formula may be:

Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)

- Pressure Potential = **the force of the cell wall on the contents**,
- so for animal cells, this is zero, thus, in animals:

Water Potential (ψ) = Solute Potential (ψ_s)

Active Transport

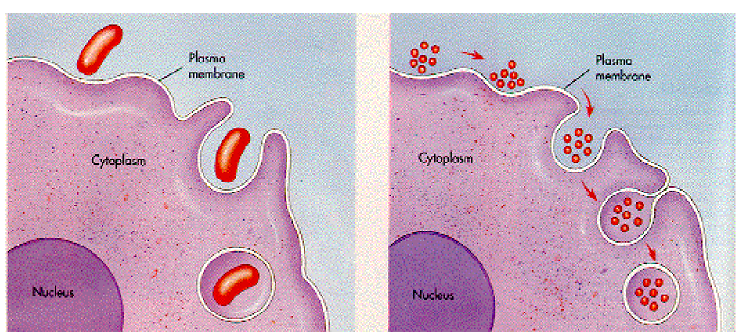
Active transport is the energy-demanding transfer of a substance across a cell membrane **against** its concentration gradient, i.e., from lower concentration to higher concentration.
Special proteins within the cell membrane act as specific protein 'carriers'.
The energy for active transport comes from ATP generated by respiration (in mitochondria).

Major examples of Active Transport

Re-absorption of glucose, amino acids and salts by the proximal convoluted tubule of the nephron in the kidney.
Sodium/potassium pump in cell membranes (especially nerve cells)

Endo/exocytosis

This is the movement of **very large** molecules (or particles, bacteria or other organisms) across the cell membrane. It involves the fusion of vesicles (containing the target/victim) with the cell membrane e.g. bacteria entering **macrophages**. Substances destined for secretion are packaged in the **Golgi body** first.



Pinocytosis *('cell drinking')*
This is the uptake of large molecules (DNA, protein) from **solution**, by a form of endocytosis – the vesicles formed are minute and short-lived.
Phagocytosis *('cell eating')*
This is the uptake of **solid particles** by a cell e.g. *Amoeba* feeding, phagocytes engulfing bacteria.

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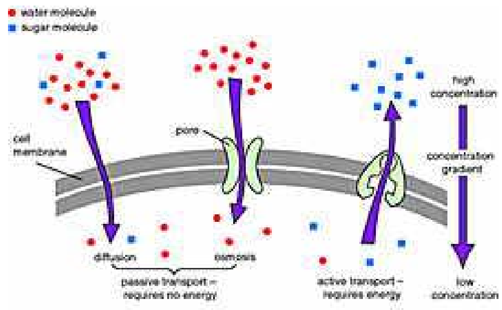
Crossing the Membrane

Generally obey **Fick's Law**: $\frac{\textbf{Surface Area} \times \textbf{Concentration Difference}}{\textbf{Distance}}$

Any tissue designed for absorption has: **maximised SA** (villi/microvilli/alveoli); and will use **active transport out** (to ↑ conc. Diff.); be **thin**, (thus close to blood supply/food/air)



Passive: Molecules move **down the concentration gradient** (high → low)
Simple Diffusion: gases (O_2, CO_2) pass **between molecules** in membrane
Facilitated Diffusion: uses carrier (channel) proteins to cross membrane (glucose, amino-acids etc.)
Osmosis: water **only.** Goes **down the water potential gradient** (less –ve towards more –ve)

Active: Against the concentration gradient; needs ↑ energy (ATP); ↑ **respiration**; ↑ **mitos**.
Ions/small molecules: **sodium pump (Na$^+$ out, K$^+$ in)**. Found in **all cells**
Large molecules: enter through **pinocytosis**; leave through **secretion** (vesicles, Golgi body)
Particles: Enter through **phagocytosis** (WBC's, *Amoeba*)

Tools & Techniques

Cell fractionation: Break open cells with ultrasound/homogeniser;
use ice-cold osmotic buffer (to keep organelles intact); then use
Centrifuging: organelles settle in size order:
nucleus; chloroplasts; mitochondria; lysosomes; e.r./ribosomes; remaining cytoplasm = **supernatant**
Chromatography: chemicals identified by **R_f values**, which remain constant (table of data)
Calculation: distance to **front** of spot ÷ distance moved by **solvent** (= solvent front). **Use mm's!**
Staining: **Gram's** with bacteria (+ve = black, -ve = pink); **Heavy metals** for e-m's
all stains show up (particular) parts of cells – so **name the part**
(nucleus / DNA /chromosomes / starch grains /cell wall)
Squashing: makes cells spread out (and flat), so easier to see
Sectioning: Allows light through, one cell thick; easier to see cells
Food Tests: Sugars - Benedicts; Starch - iodine **solution**; protein – biuret; lipids - ethanol/emulsion
Light microscope: + points: easy to use, portable, colour, movement, (< x 1,000)
Transmission e.m. + points: **high resolution** (due to short wavelength) x 50,000+
Scanning e.m. + points – 3-D images of **surface** of object (with high resolution) x 200-10,000
Magnification calculations: Distance across object (mm) ÷ magnification (1000's) = real size (μm)