1.8 Movement Across Cell Membranes

Diffusion, osmosis and active transport over cell membranes

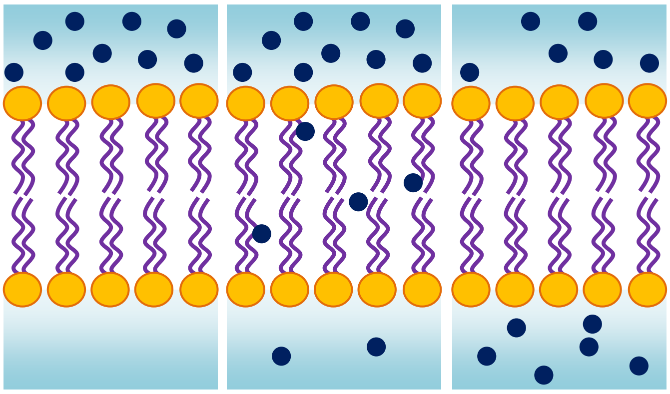
In order to survive, cells need a supply of nutrient molecules; and most cells also need an oxygen supply for aerobic respiration. Also, the reactions within living cells (collectively known as **metabolism**) generate waste products which need to be removed from the cell. Any molecule needs to cross a membrane to move in or out of a cell.

Diffusion

Passive Processes - processes which rely on the kinetic energy in molecules

In a fluid (gas or liquid), the molecules or ions move around freely, even if it is not mixed or stirred, this is because the molecules are not held together like in a solid, they possess **kinetic energy** that keeps them moving. Processes such as diffusion that depend only on this energy are termed as **passive processes**.

The process of **diffusion** is the evening out of molecules across an area. It is the **net movement** of particles from an area of high concentration to an area of lower concentration; which continues until the concentration of the particles is consistent throughout.



The diagram shows a phospholipid bilayer (cell membrane) with carbon dioxide molecules on one side of it in the first stage. In the second stage, the carbon dioxide molecules are travelling through the bilayer because they are small enough to pass between the phospholipids. The molecules move through to the other side of the membrane. Diffusion stops when the amount of molecules on both sides is even. This is an example of diffusion as would happen with photosynthesis with the gas exchange.

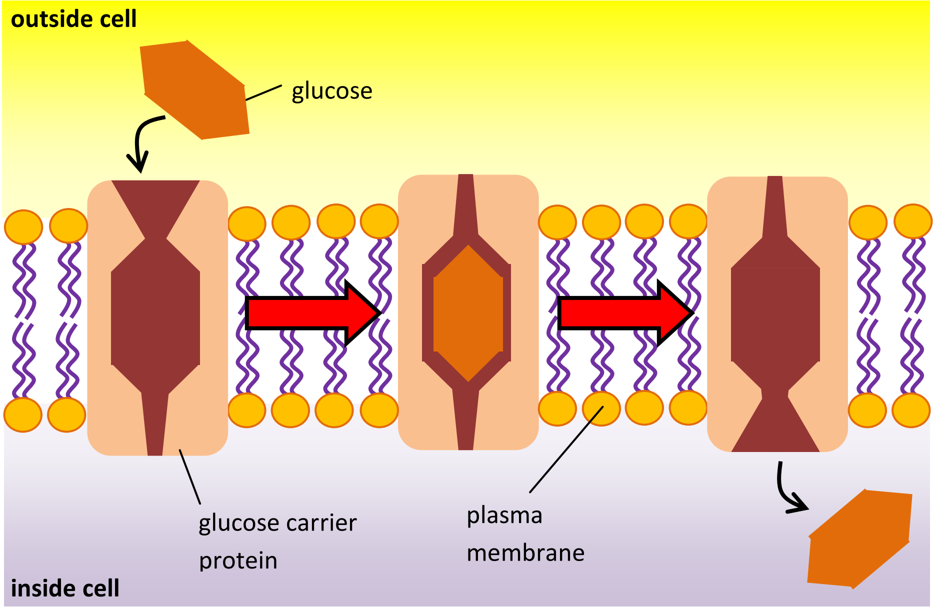
Even when the molecules have been distributed evenly via diffusion, movement doesn't stop completely. The molecules still move around, but not in any one particular direction – because they still have this kinetic energy. We refer to this state as **equilibrium**, when there is no net movement.

Factors affecting the rate of diffusion are:

- ✓ **temperature** – an increase in temperature means an increase in kinetic energy, so the rate of random movement of the molecules increases as does the rate of diffusion
- ✓ **concentration gradient** – having more molecules on one side of the membrane increases the concentration gradient and so increases the rate of diffusion
- ✓ **size of molecules** – smaller molecules diffuse more quickly than larger ones
- ✓ **thickness of membrane** –diffusion is slowed down by thick membranes as molecules have to cross large distances
- ✓ **surface area** – diffusion occurs more quickly when there is a larger surface area to diffuse across

There is a second type of diffusion, called **facilitated diffusion**, which is the movement of a specific molecule down a concentration gradient, passing through the membrane via a specific protein carrier. The two types of protein are:

1. the **channel protein** forms pores in the membrane, which are usually shaped only to allow the one type of molecule or ion through – and many are also *gated*, meaning they can be opened and closed
2. the **carrier protein** is shaped so that a specific molecule (e.g. glucose in the diagram on the following page) can fit into the protein at the membrane surface, and when the molecule fits, the protein changes shape to allow the molecule to pass through to the other side



The diagram shows a glucose molecule entering a carrier protein which is shaped to specifically hold that molecule. When it is securely in there, the carrier protein changes shape to allow the glucose molecule to travel through the protein and out through the other end. Glucose molecules are too big to diffuse through the phospholipids, so they have to use these proteins instead.

OSMOSIS

A special type of diffusion is **osmosis**, which is specifically concerned with water molecules across a partially-permeable membrane. Water molecules are also free to move from areas of a high water concentration, to areas of low water concentration. Having a substance dissolved in the water will affect the number of free water molecules, and this *decreases* the water concentration.

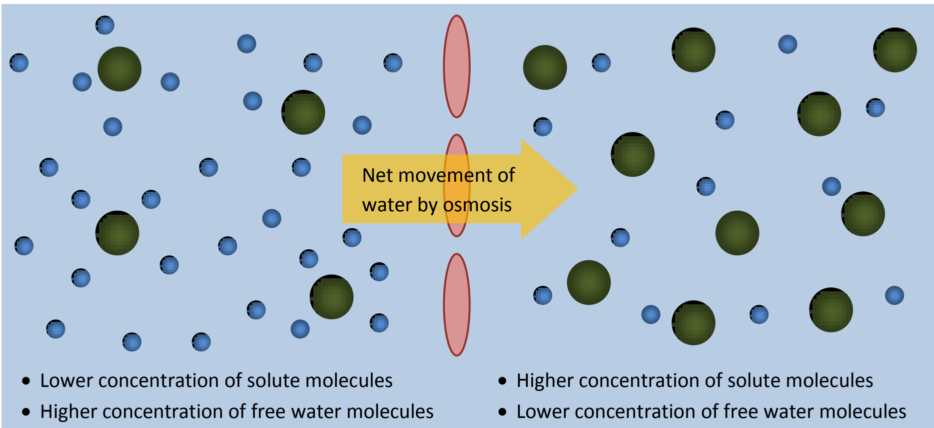
The measure of the tendency of water molecules to move from one place to another is called **water potential** (**ψ**). Water always moves from an area of high water potential to an area of low water potential, i.e. from areas with lots of these "free" water molecules to areas with fewer water molecules.

As with diffusion, net movement of molecules occurs until the concentrations are evened out, so osmosis will occur until the water potential is the same on both sides of the membrane.

solute molecule

water molecule

partially-permeable membrane



The water potential of cells is lower than that of pure water, because of all the sugars, salts and other substances dissolved in the cytoplasm. The water potential of pure water is zero, which is in fact the *highest* water potential. Everything else has a water potential lower than that of pure water, which is measured using negative numbers. The unit of measurement for water potential is **kilopascals** (**kPa**). The larger the negative figure, the more solute dissolved and the lower the water potential (e.g. -14kPa has a lower water potential than -3kPa).

Highest water potential	0kPa	Pure water	No solute dissolved
Lower water potential	-10kPa	Dilute solution	Small amount of solute dissolved
Very low water potential	-500kPa	Concentrated solution	Large amount of solute dissolved

The cell membrane is a partially permeable membrane. Placing plant or animal cells in pure water, or in any solution with a water potential *higher* than the cell contents, means there is a water potential gradient from outside to inside the cells. Water molecules will move down the water potential gradient into the cells by osmosis. The cells will swell. In the case of *animal* cells, the cell will eventually burst open – it is **haemolysed**. In a *plant* cell, the swelling vacuole and cytoplasm will push the membrane against the cell wall. It will not burst because the wall will eventually stop the cell getting any larger. Osmosis will then stop at this point, even if the concentration gradient remains. The cell is **turgid**.

Placing animal or plant cells in a salt or sugar solution (with a water potential *lower* than the cell contents) means there is a water potential from insider to outside the cells, so water molecules move out of the cells by osmosis. The cells will shrink, and in the case of *animal* cells, the cell contents will shrink and the membrane will wrinkle up – the cell has **crenated**. With *plant* cells, the cytoplasm and vacuole will shrink as they lose water, the cell surface membrane will pull away from the cell wall – this is called **plasmolysis**.

ACTIVE TRANSPORT

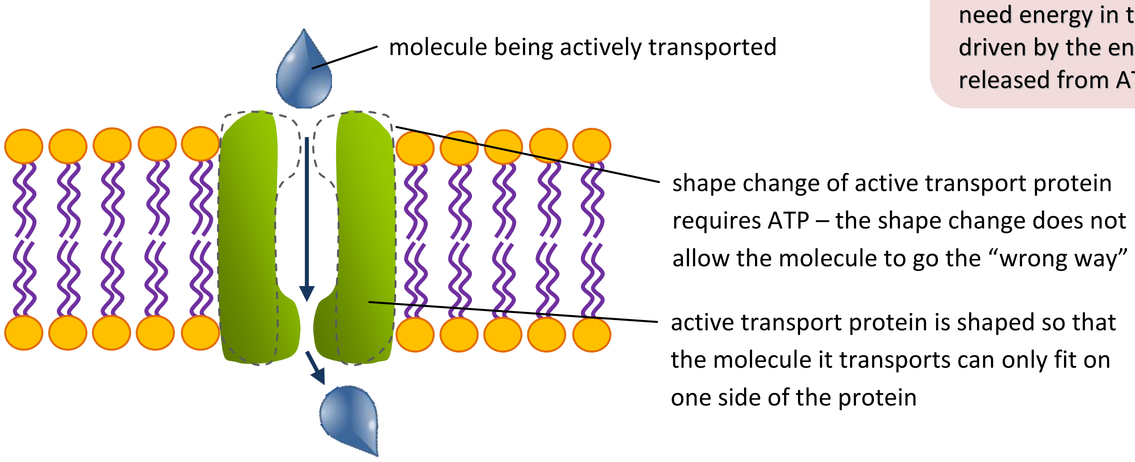
A cell cannot get everything it needs via diffusion and osmosis. Sometimes a cell will need more of a particular substance than there is outside of the cell; or in other cases, it may just be that the cell needs to get a particular substance inside the cell quicker than simple diffusion allows. This would obviously require energy to drive the process.

Active Transport - the movement of molecules across membranes using ATP to drive the proteins used

Some of the carrier proteins found in membranes act as "pumps." These proteins are similar to the carrier proteins used for facilitated diffusion. They are shaped in a way that is complementary to the molecules they carry. They carry larger or charged ions through membranes. These are the molecules that cannot pass through the lipid bilayer using diffusion. These protein pumps differ significantly from the proteins used in facilitated diffusion:

- they carry specific molecules one way across the membrane
- in carrying molecules across the membrane, they use energy in the form of **ATP**
- they can carry molecules *against* the concentration gradient (from low to high)
- they can carry molecules at a much faster and more efficient rate than diffusion

ATP - (adenosine triphosphate) produced during respiration, almost all activities that need energy in the cell are driven by the energy released from ATP



The energy which is used in the active transport process is used to change the shape of the transport protein. The shape change means that specific molecules to be transported fit into the protein on *one* side of the membrane only. As the molecule is carried through, the carrier uses the energy from ATP to chane shape so that the molecule being carried across now leaves the carrier protein. The molecule cannot enter the transport protein, because the protein is now a different shape and so it will not fit.