Cambridge OL

Biology

CODE: (5090)

Chapter 03 and chapter 04

Movement into and out of cells and Biological Molecules

Substances may pass through the cell membrane either passively by **diffusion** or actively by some form of **active transport**.

Key definitions

Diffusion is the net movement of particles from a region of their higher concentration to a region of their lower concentration (i.e. down a **concentration gradient**), as a result of their random movement.

Diffusion

The molecules of a gas like oxygen are moving about all the time. So are the molecules of a liquid or a substance like sugar dissolved in water. As a result of this movement, the molecules spread themselves out evenly to fill all the available space (Figure 3.1)

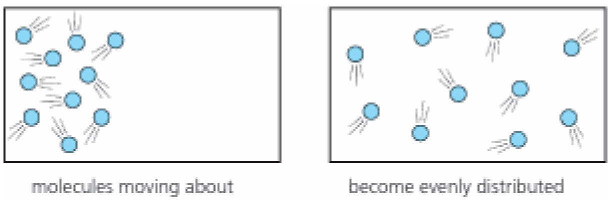


Figure 3.1 Diffusion

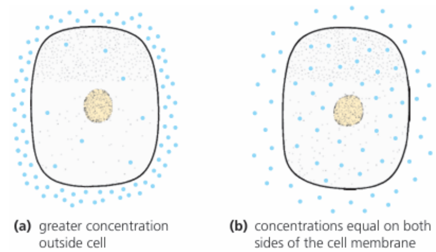


Figure 3.2 Molecules entering a cell by diffusion

Some substances move by diffusion. Figure 3.2(a) is a diagram of a cell with a high concentration of molecules (e.g. oxygen) outside and a low concentration inside. The effect of this difference in concentration is to make the molecules diffuse into the cell until the concentration inside and outside is the same, as shown in Figure 3.2(b).

Diffusion balances the concentration of small molecules like water, carbon dioxide, and oxygen inside and outside a cell. When oxygen is used for aerobic respiration, oxygen molecules diffuse into the cell until it reaches a higher concentration. Carbon dioxide is released during tissue respiration, increasing its concentration inside the cell.

The importance of diffusion of gases and solutes

Gases

Small animals with a large surface area to volume **ratio** may get oxygen through their body surface. Larger animals need gas exchange organs like lungs or gills, which provide a large surface area for **gas exchange.**

Photosynthetic plants need carbon dioxide for making their food. This diffuses through the **stomata** in the leaves into the air spaces in the mesophyll, before reaching the palisade cells.

Solutes

Scientists think that some mineral ions in solution, like nitrates and magnesium, diffuse across the tissues of plant roots, but that most are absorbed into the roots by active transport.

In the **ileum**, water-soluble vitamins like vitamin C are absorbed into the bloodstream by diffusion.

In the kidneys, some solutes, like **urea** and mineral ions, pass back into the bloodstream by diffusion. At first, **glucose** is reabsorbed by diffusion, but active transport is also involved.

Rates of diffusion

Molecules and ions in liquids and gases move around randomly using **kinetic energy** (energy from movement).

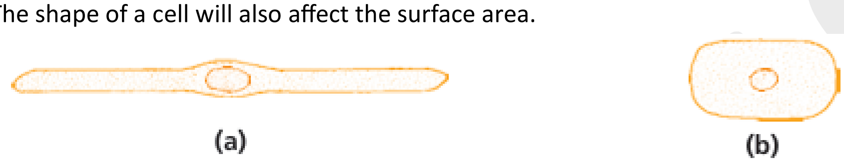
The speed with which a substance diffuses through a cell wall or cell membrane will depend on many conditions, including:
» The surface area across which the diffusion is happening
» The temperature
» The difference between its concentration inside and outside the cell
» The distance it diffuses.

▲ **Figure 3.3** Microvilli

Surface area

Cells which are involved in rapid **absorption**, like those in the kidney or the intestine, often have their exposed surface membrane formed into hundreds of tiny projections called **microvilli** (see Figure 3.3). These increase the absorbing surface to make diffusion faster.

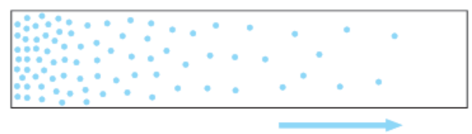
The shape of a cell will also affect the surface area.



▲ **Figure 3.4** Surface area

Temperature

An increase in temperature gives molecules and ions more kinetic energy. This allows them to move faster, so the process of diffusion speeds up.



▲ **Figure 3.6** Concentration gradient

Concentration gradient

When oxygen molecules enter a red blood cell they combine with a chemical (**haemoglobin**), which takes them out of solution. So, the concentration of free oxygen molecules inside the cell is kept very low and the concentration gradient for oxygen stays the same.

Distance

Cell membranes are all about the same thickness (approximately 0.007 µm), but plant cell walls vary in their thickness and **permeability** (how easily materials pass through them).

When oxygen diffuses from the alveoli of the lungs into red blood cells, it travels through the cell membranes of the **alveoli**, the blood capillaries and the red blood cells, as well as the cytoplasm of each cell.

Osmosis

> **Key definitions**
> **Osmosis** is the net movement of water molecules from a region of higher **water potential** to a region of lower water potential through a partially permeable membrane.

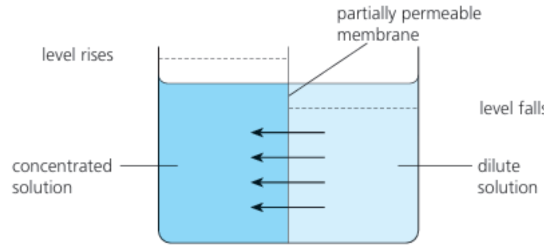
Roles of water

Blood is made up of cells and a liquid called **plasma**. This plasma is 92% water and is a way of transporting many dissolved substances, like carbon dioxide, urea, digested food and **hormones**.

Diffusion of water

If a dilute solution is separated from a concentrated solution by a partially permeable membrane, water diffuses across the membrane from the dilute to the concentrated solution. This is called osmosis and is shown in Figure 3.10

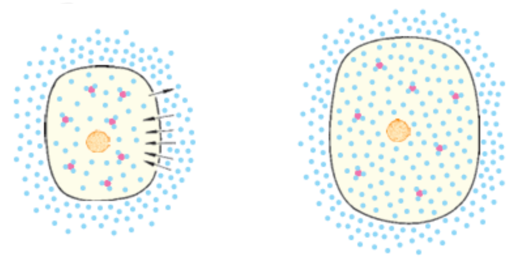
A partially permeable membrane allows water to pass more rapidly than dissolved substances. In living cells, the cell membrane is partially permeable, allowing water to diffuse into cells by osmosis if surrounded by a weak solution, or by osmosis if surrounded by a stronger solution.



▲ **Figure 3.10** Osmosis. Water will diffuse from the dilute solution to the concentrated solution through the partially permeable membrane. As a result, the liquid level will rise on the left and fall on the right

Animal cells

Figure 3.11 illustrates a cell surrounded by pure water, with a 100% concentration of water molecules. The concentration of free water molecules outside the cell is greater than inside, allowing water to diffuse into the cell through osmosis. The cell membrane allows water to move in or out, but the concentration of substances inside the cell is not enough to diffuse freely.



(a) There is a higher concentration of free water molecules outside the cell than inside, so water diffuses into the cell.

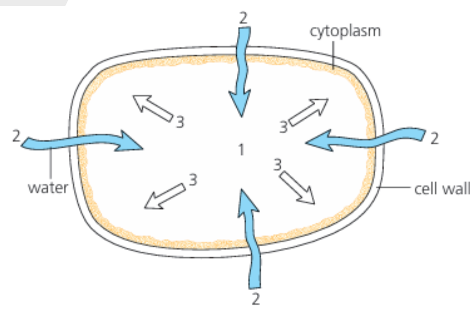
(b) The extra water makes the cell swell up.

▲ **Figure 3.11** Osmosis in an animal cell

Plant cells

Plant cells contain mineral ions, sugars, and proteins in their cytoplasm and cell sap, reducing water concentration. The cell wall is partially permeable to water and dissolved substances, but water can pass into the vacuole through osmosis. The mature cell's inelastic wall limits water inflow.

Plant cells become rigid when they absorb maximum water through osmosis, supporting stems and leaves. If water loss occurs, the pressure on cell walls dissipates, causing the plant to become limp and **wilt**.



1 there is a lower concentration of water in the cell sap
2 water diffuses into the vacuole
3 and makes it push out against the cell wall

▲ **Figure 3.12** Osmosis in a plant cell

Water potential

Water potential measures the likelihood of water molecules losing or gaining from another solution. Dilute solutions have a higher water potential due to a higher proportion of free water molecules. Pure water has the highest potential, as water molecules can flow to any aqueous solution. When sap cells have different water potentials, water moves from dilute to concentrated solutions.

(a) plant wilting **(b)** plant recovered after watering

The importance of water potential and osmosis in plants

A plant cell with the vacuole pushing out on the cell wall is **turgid** (it is swollen because the cell has taken up water) and the vacuole is exerting **turgor pressure** on the inelastic cell wall.

If the vacuoles lose water for any reason, the cells will lose their turgor (a process called **plasmolysis**) and become **flaccid.**

Root hair cells touch water between soil particles, allowing water to enter cells through osmosis. However, too much chemical fertilizer or irrigation can lower soil water potential, leading to wilting and death of plants. This can also occur in hot countries due to irrigation side effects. Salt applied to roads can also cause water loss from roots, causing plants to wilt and die. Therefore, proper water uptake and irrigation are crucial for plant health and survival.

▲ **Figure 3.14** An irrigation furrow

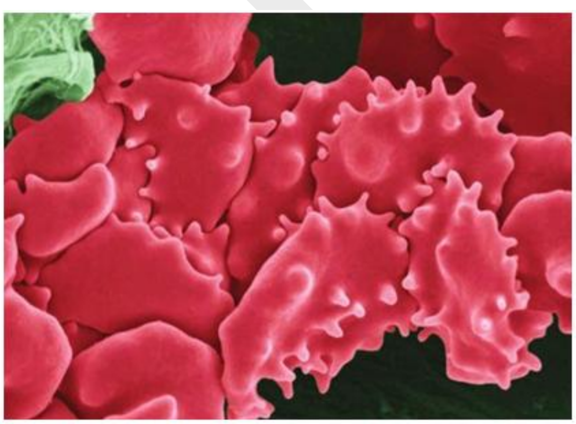
▲ **Figure 3.15** Salt gritter at work to prevent ice formation on a road

The importance of water potential and osmosis in animal cells and tissues

Animal cells require fluid with the same water potential as their contents to prevent water from escaping. If the bathing fluid has a higher water potential, it can cause cell swelling and eventually burst. Single-celled animals like Amoeba have a contractile vacuum to control water content. Surgeons use a saline solution when rinsing wounds, as pure water would enter cells and cause cell burst.

During physical activity, the body may sweat to keep a steady temperature. If liquids are not drunk to make up for water loss through **sweating**, the body can become dehydrated.

Sports drinks, isotonic with water, salts, and glucose, are used by athletes to replace lost fluids and provide energy without causing osmotic issues. However, prolonged use can lead to weight gain.



▲ **Figure 3.16** Plasmolysed red blood cells

▲ **Figure 3.17** People may use isotonic sports drinks

Active transport

Cells have control over the movement of substances, as diffusion is the only way they can take in substances. However, the cell membrane has a significant role in controlling what enters and leaves the cell. Active transport, such as in plants, allows root hair cells to absorb mineral ions from dilute solutions against a concentration gradient. This process requires energy from respiration, as any interference with respiration, like oxygen or glucose shortage, stops active transport. Examples include epithelial cells in the small intestine absorbing glucose against a concentration gradient, and kidney tubule cells reabsorbing glucose into the bloodstream.

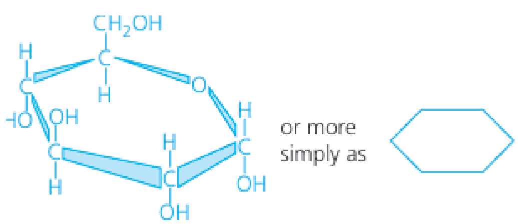
Chapter 04 - Biological molecules

Carbon is a key element in all biological molecules, which can form chains or ring structures, and are often monomers. Other elements include oxygen, hydrogen, and occasionally nitrogen. Examples are **polysaccharides** (chains of single sugar units like glucose), proteins (chains of amino acids) and DNA (chains of units called **nucleotides**,)

Carbohydrates

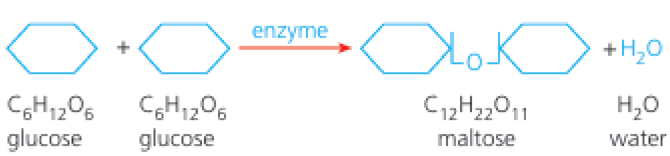
These may be simple, soluble sugars or complicated materials like starch and cellulose, but all carbohydrates contain carbon, hydrogen and oxygen only. A common simple sugar is glucose, which has the chemical formula $C_6H_{12}O_6$.

The glucose molecule is often in the shape of a ring, shown as:

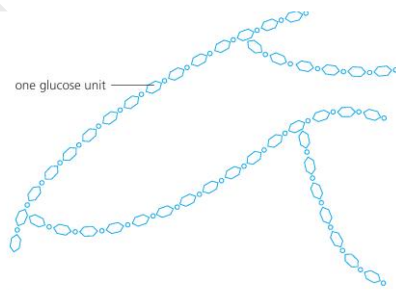


▲ **Figure 4.1** Glucose molecule showing ring structure

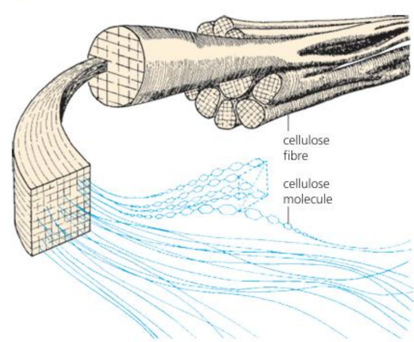
Two molecules of glucose can be joined to make a molecule of **maltose**, $C_{12}H_{22}O_{11}$ (Figure 4.2).



▲ **Figure 4.2** Formation of maltose

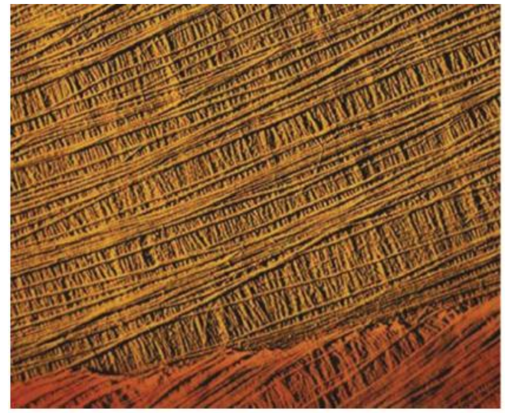


▲ **Figure 4.3** Part of a glycogen molecule



▲ **Figure 4.4** Cellulose. Plant cell walls are made of long, interconnected cellulose fibres. These are large enough to be seen with the electron microscope. Each fibre is made up of many long-chain cellulose molecules

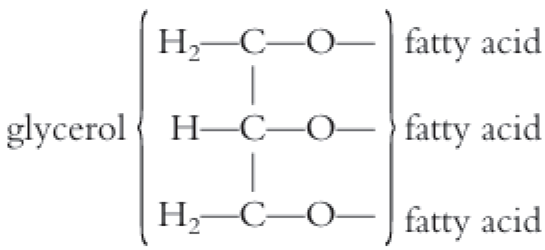
Cellulose is made of even longer chains of glucose molecules. The molecules in the chain are grouped together to make microscopic **fibres**, which are laid down in layers to make the cell wall in plant cells (Figures 4.4 and 4.5). Glycogen, starch and cellulose are not very soluble in water.

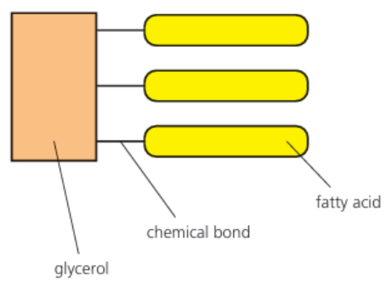


▲ **Figure 4.5** Scanning electron micrograph of a plant cell wall (×20 000) showing the cellulose fibres

Lipids

Lipids are fats and oils. Fats are a solid form of this group of molecules. When lipids are liquid they are known as oils. Lipids are made from carbon, hydrogen and oxygen only. A molecule of lipid is made up of three molecules of an organic acid, called a **fatty acid**, joined with one molecule of **glycerol**.

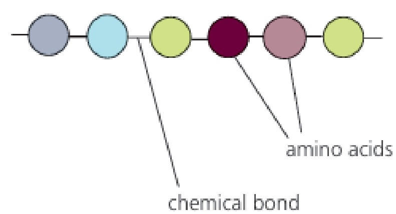




▲ **Figure 4.6** Lipid molecule

Proteins

Proteins are found in cell structures like membranes, mitochondria, ribosomes, and chromosomes, and enzymes control chemical reactions. All proteins contain carbon, hydrogen, oxygen, nitrogen, and sulfur, and are made up of long chains of amino acids.



▲ **Figure 4.7** Protein molecule (part of)

DNA

A DNA molecule contains the elements carbon, hydrogen, oxygen, nitrogen, phosphorus and sometimes sulfur. It is made up of long chains of nucleotides, formed into two strands. A nucleotide is made up of a 5-carbon sugar molecule joined to a phosphate group ($-PO_3$) and an organic base

▼ **Table 4.1** Summary of the main nutrients

Nutrient	Elements present	Examples	Sub-units
carbohydrate	carbon, hydrogen, oxygen	starch, glycogen, cellulose, sucrose	glucose
lipid	carbon, hydrogen, oxygen (but lower oxygen content than carbohydrates)	vegetable oils, e.g. olive oil; animal fats, e.g. cod liver oil, waxes	fatty acids and glycerol
protein	carbon, hydrogen, oxygen, nitrogen, sometimes sulfur or phosphorus	enzymes, muscle, haemoglobin, cell membranes	amino acids (about 20 different forms)

Revision questions

1. Some students investigated osmosis in raw potato sticks.
(a) Define the term osmosis.

(b) The students measured the mass of four of the potato sticks using an electronic balance.

Fig. 4.1 shows an electronic balance.

Fig. 4.1

The students left each potato stick in one of four different liquids for 5 hours:

- distilled water
- 0.1 mol per dm^3 sodium chloride solution
- 0.5 mol per dm^3 sodium chloride solution
- 1.0 mol per dm^3 sodium chloride solution.

After 5 hours they measured the mass again and calculated the change in mass.

(i) Predict which of the liquids would cause the largest decrease in mass of a potato stick.

(ii) The students dried the potato sticks with paper towels before putting them on the electronic balance. Suggest why.

(c) After the experiment the students noticed that the potato stick with the lowest mass was soft and floppy. Explain why the potato stick had become soft and floppy.

(d) The students followed the same experimental procedure with boiled potato sticks and found no overall change in mass in any of the solutions.
Suggest why the mass of the boiled potato sticks remained the same.

2. A student investigated the diffusion of substances through Visking tubing, an artificial membrane which has some of the properties of cell membranes.

The student made a bag of Visking tubing as shown in Fig. 4.1.

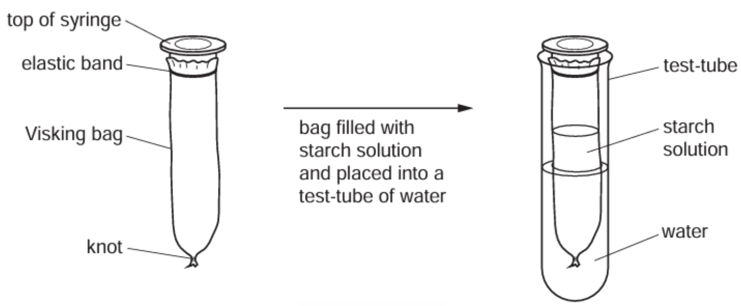


Fig. 4.1

The student added some iodine solution to the water in the test-tube.

After 30 minutes at room temperature, the contents of the Visking bag were stained blue-black, but the water outside remained a yellow colour.

(a) **(i)** Explain these results.

(ii) State three factors that influence the movement of molecules through membranes

(b) Fig. 4.2 is an electron micrograph of a red blood cell within a capillary.

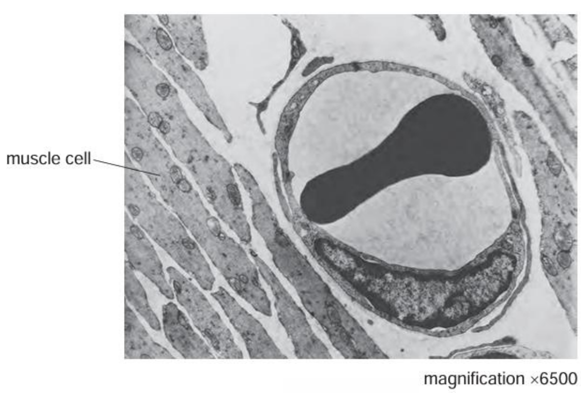


Fig. 4.2

(i) Molecules of carbon dioxide that are produced in muscle cells are transported to the blood.

Describe the pathway taken by these molecules of carbon dioxide.

(ii) Explain how capillaries are adapted for their functions.

(c) Mammals have a transport system for carbon dioxide. Plants absorb carbon dioxide from their surroundings to use in photosynthesis.
Explain how a molecule of carbon dioxide from the atmosphere reaches the site of photosynthesis in a leaf.

3. Some plants can be grown in water using the technique of hydroponics. The roots are in water and supplied with the ions that they need at the concentrations that support maximum growth. Some ions can be absorbed both by diffusion and by active transport.
(a) (i) State two features of diffusion that do not apply to active transport.

(ii) Explain how roots are adapted to absorb ions.

A group of students investigated the effect of soaking small onion bulbs in different concentrations of sodium chloride solution. They peeled off the outer papery leaves of the onion bulbs and divided the onions into 6 batches, each with 10 onions.

The onions were surface dried with paper towels and weighed. The mean mass of the onions in each batch was calculated. The onions were then left in sodium chloride solutions for three hours.

After three hours the students surface dried the onions and weighed them again. Their results are given in Table 2.1.

Table 2.1

concentration of sodium chloride solution / $g\,dm^{-3}$	mean mass of onions / g		percentage change in mass
	before soaking	after soaking for 3 hours	
0	147	173	+17.7
25	153	165	+7.8
50	176	172	–2.3
100	154	149	–3.2
150	149	142	–4.7
200	183	175	

(b) (i) Calculate the percentage change in mass of the onions that were in the most concentrated solution of sodium chloride. Show your working. Write your answer in Table 2.1.

(ii) Explain why the students calculated the percentage change in mass of the onions.

(c) The students plotted a graph of the results as shown in Fig. 2.1.

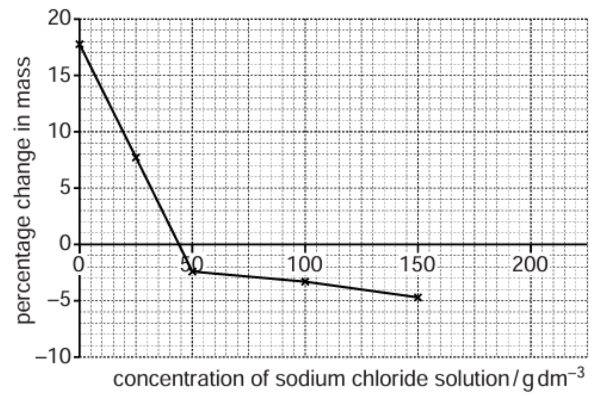


Fig. 2.1

(i) Complete the graph using your answer to (b)(i).

(ii) Use the graph in Fig. 2.1 to estimate the concentration of the sodium chloride solution that has the same water potential as the onions.

(d) Using the term water potential, explain why the onions:
gained mass when soaked in dilute solutions of sodium chloride
lost mass when soaked in concentrated solutions of sodium chloride.

4. Fig. 6.1 shows the changes in glucose concentration of the blood.

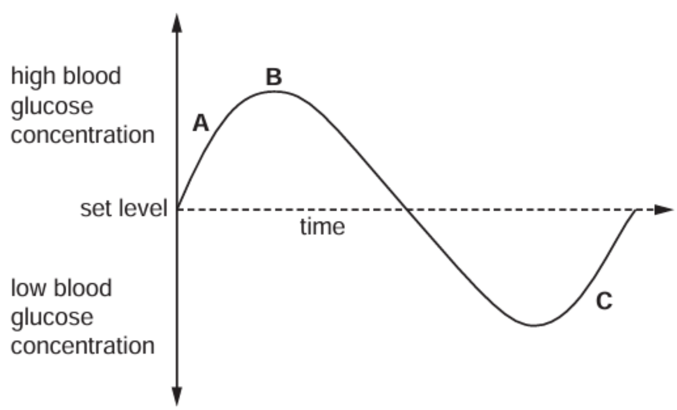


Fig. 6.1

(a) Name the process that maintains blood glucose concentration within set limits.

(i) Name the hormone that would be secreted in response to the increasing blood glucose concentration at A in Fig. 6.1.

(ii) Name an organ that is responsible for the decrease in blood glucose concentration after B in

(iii) Name the compound that is converted to glucose at C in Fig. 6.1.

5. Fig. 2.1 shows part of the nitrogen cycle.

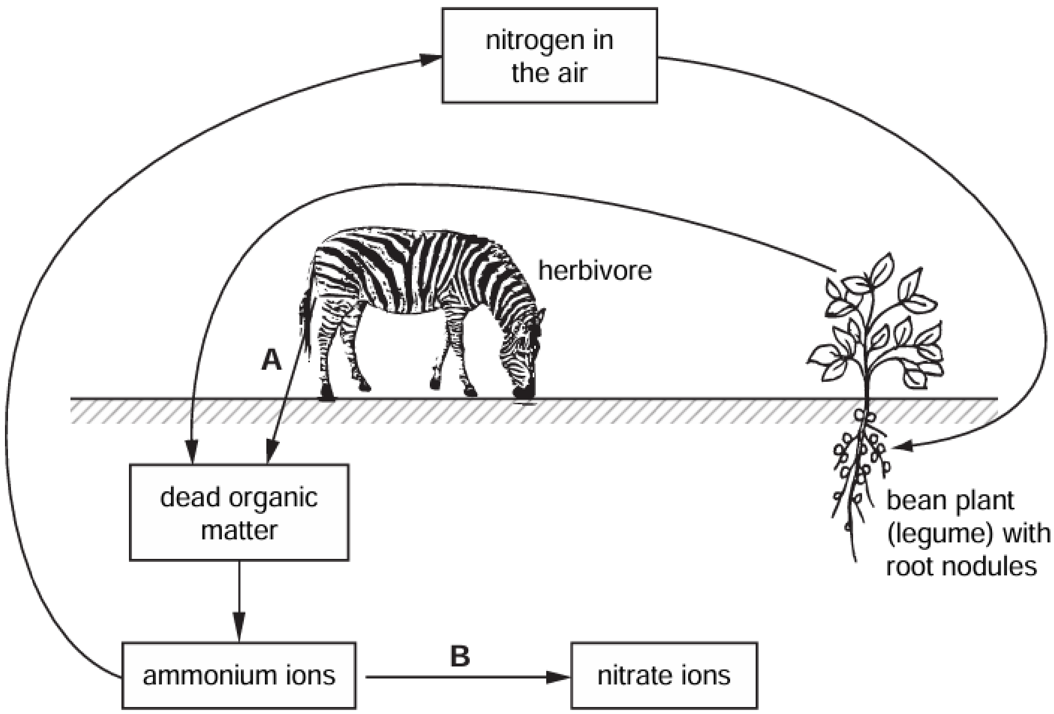


Fig. 2.1

(a) Name the processes A and B shown in Fig. 2.1.

(b) Fig. 2.1 shows that legumes have root nodules.
Explain why these root nodules are important in the nitrogen cycle.

(c) Proteins and DNA are important nitrogen-containing compounds in cells.

Describe the roles of proteins and DNA in cells.

(d) Many inorganic fertilisers contain compounds of nitrogen. If crop plants do not absorb the fertilisers they can be lost from the soil and pollute freshwater ecosystems, such as lakes and rivers.
Describe how fertilisers may affect freshwater ecosystems.

6. (i) Explain the term balanced diet.

(ii) State three factors that influence a person's nutritional needs.

(b) Glucose is absorbed in the small intestine and transported in the blood. The kidneys filter the blood and reabsorb the glucose.

If the blood contains more than 180 mg of glucose per 100 cm3, the kidney cannot reabsorb it all and some is present in the urine. This figure is called the renal threshold.

A doctor suspects that a patient has diabetes because a urine test is positive for glucose.
The patient takes a glucose tolerance test by drinking a solution of glucose. The doctor records the patient's blood glucose concentration at 30-minute intervals for five and a nair nours.

The results are plotted on Fig. 2.1.

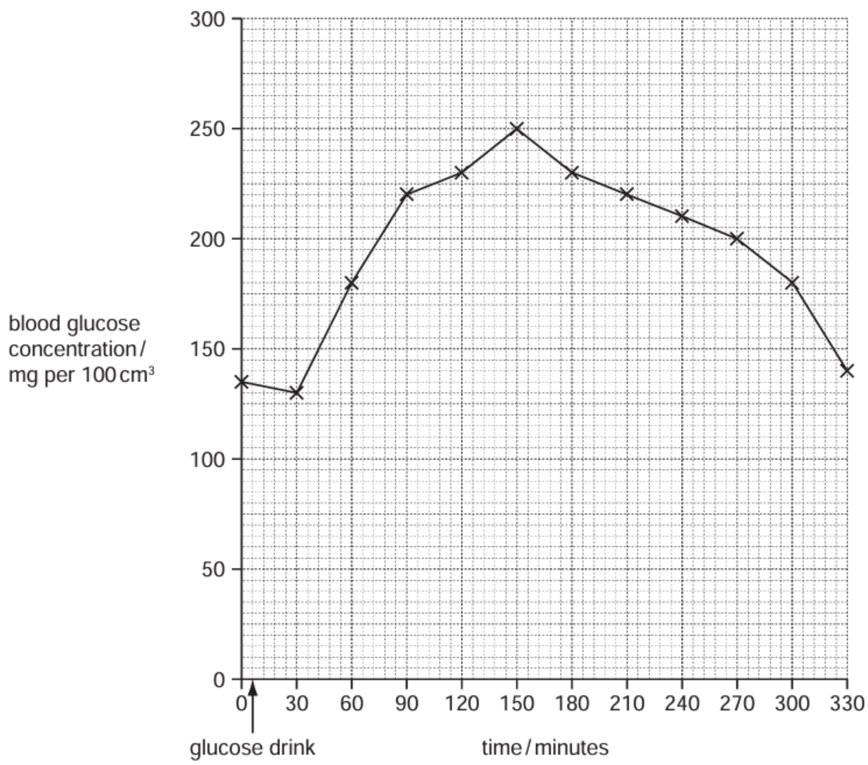


Fig. 2.1

(i) Draw a horizontal line on Fig. 2.1 to show the renal threshold.

(ii) State the time period when the kidney will produce urine containing glucose.

(iii) Sketch on Fig. 2.1 the blood glucose concentrations that the doctor might expect if he repeated this test on someone who does not have diabetes.

(c) People who do not have diabetes maintain their blood glucose concentration below 180 mg per 100 cm3. Explain how the body does this.