4. Cell Membranes and Transport

4.2 Movement into and out of Cells

Paper 2

Question Paper

1 In the mesophyll tissue of leaves, products of photosynthesis can be used to synthesise organic compounds, such as the polysaccharide cellulose and some amino acids.

A source of nitrogen for amino acid synthesis can be provided by nitrate ions that have been taken up in the roots and transported to the leaves.

To investigate nitrate uptake, roots can be cut and removed (excised) and placed in a buffered solution containing nitrate ions. The root tissue can be analysed to determine the quantity of nitrate taken up over a set time period.

(d) Excised roots of the crop plant maize, *Zea mays*, were placed in three different concentrations of nitrate solution: 0.2 mmol dm^{-3}, 1.0 mmol dm^{-3} and 5.0 mmol dm^{-3}.

The solutions were maintained at 30 °C and were aerated to provide a continuous supply of oxygen to the root tissue.

Nitrate (NO_3^-) uptake by the root tissue was determined each hour for five hours.

The results are shown in Fig. 4.1.

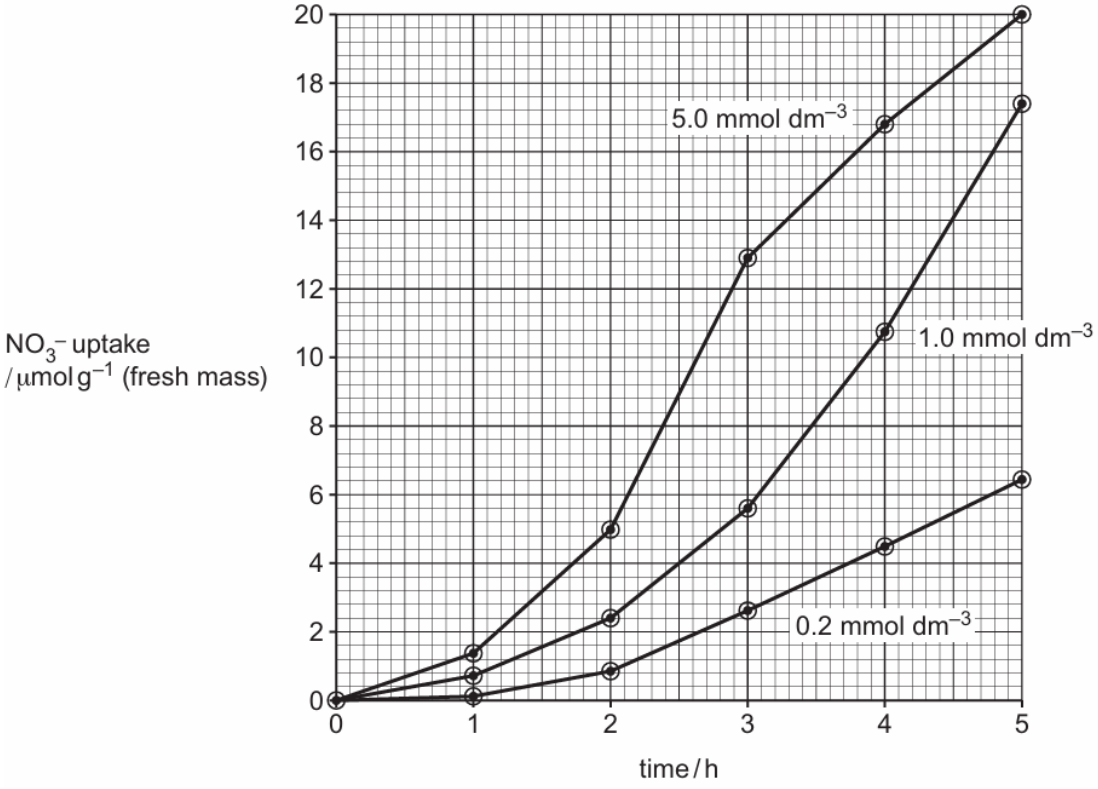


Fig. 4.1

Fig. 4.1 shows that the rate of nitrate uptake is very low initially and then increases for all three concentrations of nitrate solution tested.

(e) The nitrate uptake of excised maize roots was investigated under different conditions.

Table 4.1 shows details and results for a control experiment and four modified experiments, **1**, **2**, **3** and **4**. The same concentration of nitrate solution was used throughout for all the experiments. All the results were taken after a set time period.

Table 4.1

experiment	temperature /°C	aeration	additional substances present in nitrate solution	nitrate uptake / μmol g^{-1} (fresh mass)
1	30	no	nitrogen gas bubbled through instead of oxygen	0.4
2	3	yes	none	0.6
3	30	yes	protein synthesis inhibitor	1.4
4	30	yes	antibacterial compound	10.0
control	30	yes	none	10.9

The results for experiments **1**, **2**, **3** and **4** in Table 4.1 can be compared to the results for the control experiment.

Discuss how comparing each of the results with the control provides information about:

- how nitrate ions are taken up by the root cells
- the factors affecting the uptake of nitrate ions.

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2 The transport of water from the soil solution to the xylem of roots occurs by the apoplast and symplast pathways. Mineral ions can be transported dissolved in water.

(b) Researchers investigated the mechanism of transport used for the uptake of potassium ions (K^+) into root epidermal cells at different concentrations of K^+ in the soil solution.

Complete Table 6.1 to provide information about the two different transport mechanisms that were identified by the researchers.

Table 6.1

net movement of K^+	membrane protein needed (yes or no)	ATP used (yes or no)	name of transport mechanism
against the concentration gradient			
down the concentration gradient			

[3]

3 **(d)** The bladder is the organ in the body used to store urine.

When cells divide uncontrollably in the bladder, a tumour develops. This can lead to bladder cancer.

The BCG vaccine has been used to treat bladder cancer.

The BCG vaccine is introduced into the bladder. The tumour cells take up the weakened pathogens in the vaccine and act as antigen-presenting cells.

(i) Name the process used by the tumour cells to take up the weakened pathogens.

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4 Fig. 2.1 is a photomicrograph of a longitudinal section (LS) through a root tip. Two different regions are visible:

- the root apical meristem
- the root cap.

Cells in the root cap synthesise a gel-like, sticky secretion known as mucilage, which is important in reducing friction between soil and the growing root. It is composed mainly of polysaccharides and also contains some amino acids and enzymes.

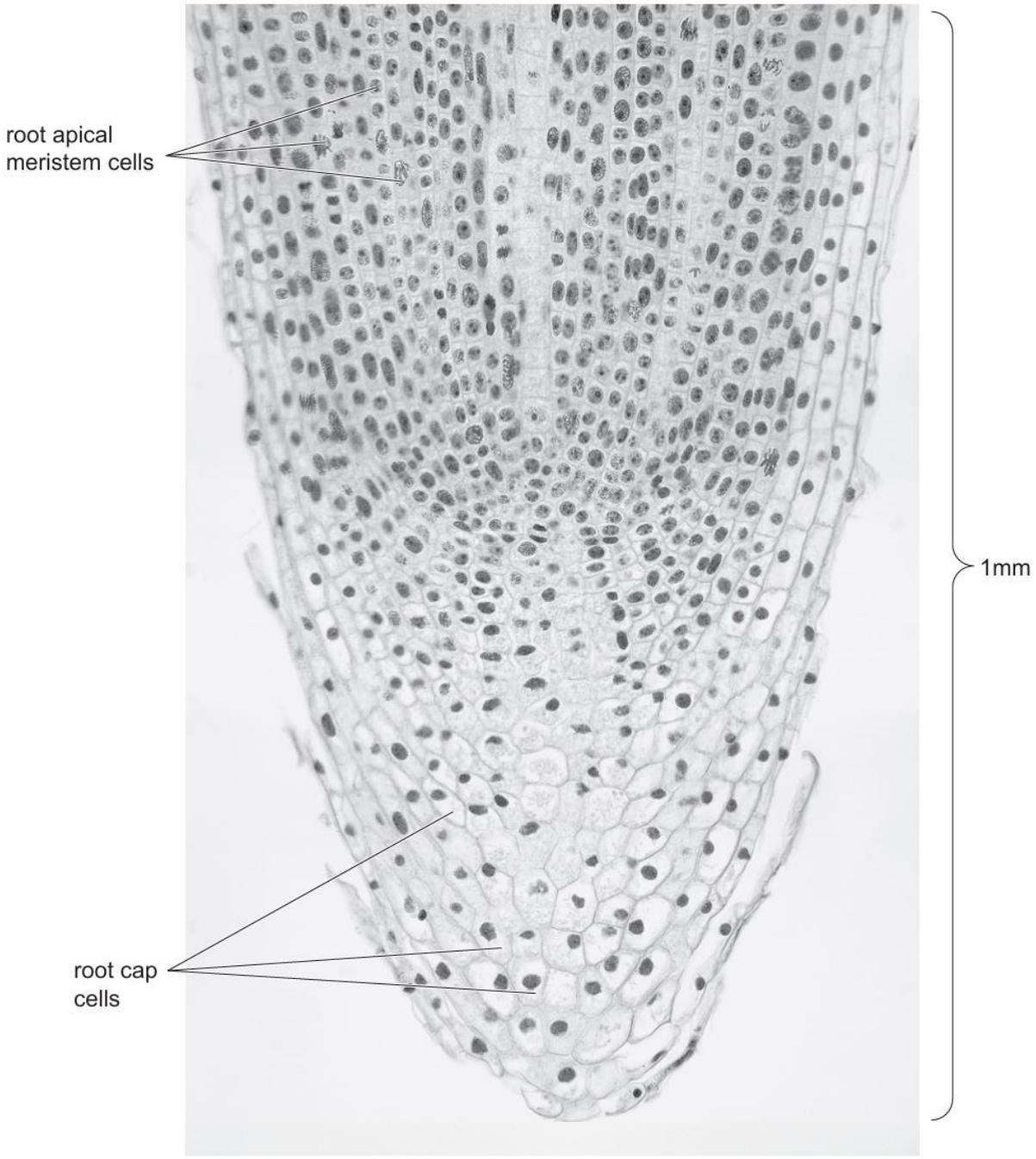


Fig. 2.1

(d) The polysaccharides and amino acids present in the mucilage are a source of nutrients for soil microorganisms that live in the area surrounding the root. Some of these microorganisms can break down soil compounds to release mineral ions.

(iii) Mineral ions are usually present in the soil in very low concentrations. The action of mucilage enzymes and soil microorganisms can help to increase the presence of mineral ions.

Root hair cells are specialised for the uptake of these mineral ions **and** for the absorption of water from the soil.

Suggest **and** explain how the presence of mineral ions in the root hair cell can **increase** the absorption of water by the root hair cells.

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5 Fig. 3.1 shows some fruits (grapes) of the grapevine, *Vitis vinifera*.



Fig. 3.1

Sucrose is transported in the phloem of the grapevine to the fruits. In the fruits, sucrose is hydrolysed by the enzyme sucrase, which is found in cell walls. The glucose and fructose produced by the hydrolysis of sucrose pass through membrane proteins, known as hexose transporters, into the cytoplasm of the fruit cells.

(a) State why membrane proteins are required for the movement of molecules, such as glucose, across cell surface membranes into cells.

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Researchers investigated one type of hexose transporter, known as VvHT1, which is found in the fruit cells of *V. vinifera*. They used a mutant strain of yeast that has very few hexose transporters in its cell surface membranes to investigate the properties of VvHT1. The researchers inserted molecules of VvHT1 into the cell surface membranes of the mutant strain of yeast.

- Equal volumes of mutant yeast cells with VvHT1 were kept in eight different concentrations of glucose solution.
- The rate of uptake of glucose by the yeast cells in each solution was determined.
- All the solutions were kept at the same temperature and pH.

The results are shown in Fig. 3.2.

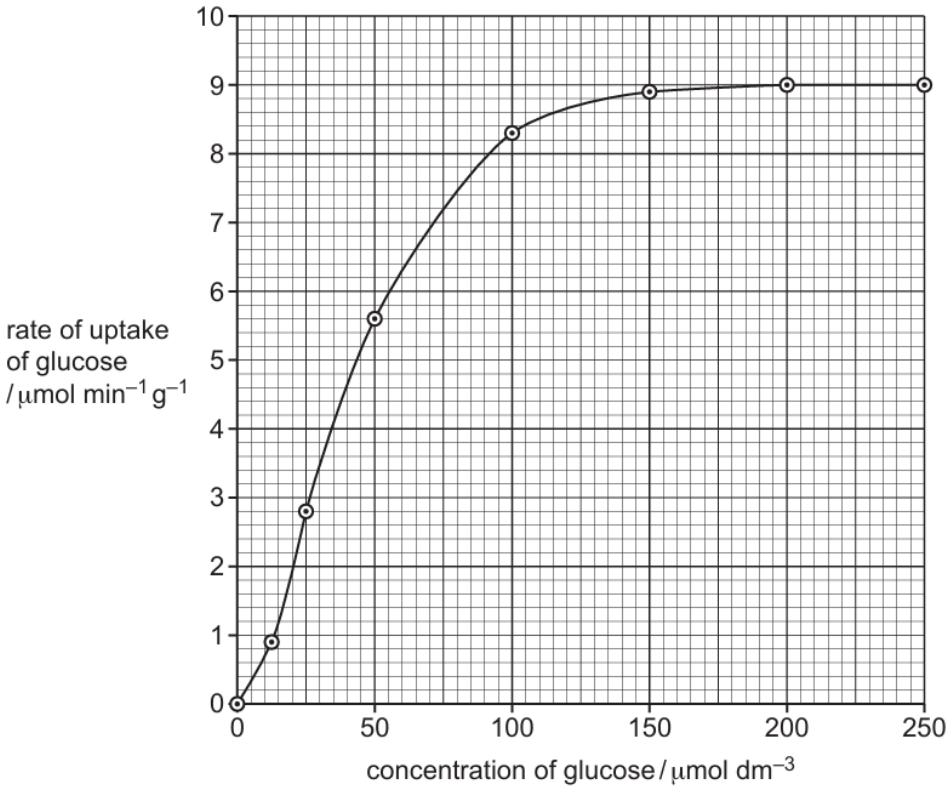


Fig. 3.2

(b) (i) The researchers concluded that VvHT1 is responsible for the facilitated diffusion of glucose into the cells.

Explain how the results in Fig. 3.2 provide evidence to support this conclusion.

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(ii) The researchers thought that grapevines could be modified to have more hexose transporters to increase the size and quality of grapes.

Explain why increasing the number of hexose transporters could be commercially important to growers of grapevines.

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6 The alveoli of the lungs are the main gas exchange surface in humans.

(a) Explain how blood flow through the alveolar capillaries helps to maintain steep diffusion gradients for gas exchange.

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(b) Ventilation of the lungs is the process of inhalation and exhalation. Ventilation helps to maintain steep diffusion gradients.

Explain the role of elastic fibres in the alveolar wall during ventilation.

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(c) Some cells in the alveolar wall are specialised to secrete surfactant to prevent collapse of the alveoli at the end of exhalation. In these cells, surfactant is stored in membrane-bound organelles known as lamellar bodies. Surfactant is a mixture of lipids, mainly phospholipids, and some proteins.

A protein known as ATP-binding cassette transporter A3 (ABCA3) is needed to move surfactant phospholipids into lamellar bodies from the surrounding cytosol (fluid part of cytoplasm).

Suggest **and** explain the features of protein ABCA3 that make it suited to its function.

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7 Scientists measured the concentration of sodium ions and potassium ions in the red blood cells and in the blood plasma of a group of people. The results are shown in Table 1.1.

Table 1.1

	mean concentration of sodium ions / mmol dm^{-3}	mean concentration of potassium ions / mmol dm^{-3}
red blood cells	10	100
blood plasma	100	4

(a) (i) Use the information in Table 1.1 to identify **and** describe the process by which potassium ions enter red blood cells from the blood plasma.

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(ii) Sodium ions and oxygen molecules enter red blood cells.

State **one** similarity and **one** difference between the processes used by sodium ions and oxygen molecules to enter red blood cells.

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difference .....

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(iii) Chloride ions move across the membrane of human red blood cells in a process called the chloride shift.

Explain why the chloride shift is important in the transport of carbon dioxide from respiring tissues.

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(b) Scientists studied the uptake of a substance, **F**, by human red blood cells.

The red blood cells were immersed in a solution of substance **F** for 30 minutes. After this time the scientists recorded two observations:

- the cell surface membrane of the red blood cells showed infoldings (invaginations)
- an increase in the number of vesicles in the cytoplasm.

Identify the process by which substance **F** entered the red blood cells.

..... [1]

8 Epithelial cells in the small intestine have cell structures known as microvilli. The microvilli of these cells are found only on the surface that borders the gut lumen.

Fig. 1.1 shows images of microvilli of intestinal epithelial cells. These images have been obtained using a scanning electron microscope and a transmission electron microscope.

Fig. 1.1**A** is at a different magnification to Fig. 1.1**B**.

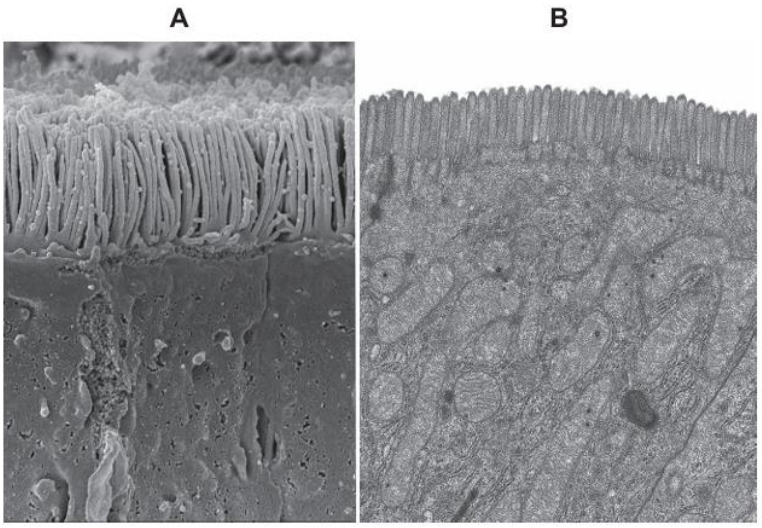


Fig. 1.1

(c) One role of an intestinal epithelial cell is the absorption of glucose from the gut lumen into the circulatory system. This involves different membrane transport proteins.

The events occurring in an intestinal epithelial cell during the absorption of glucose are summarised in Fig. 1.2.

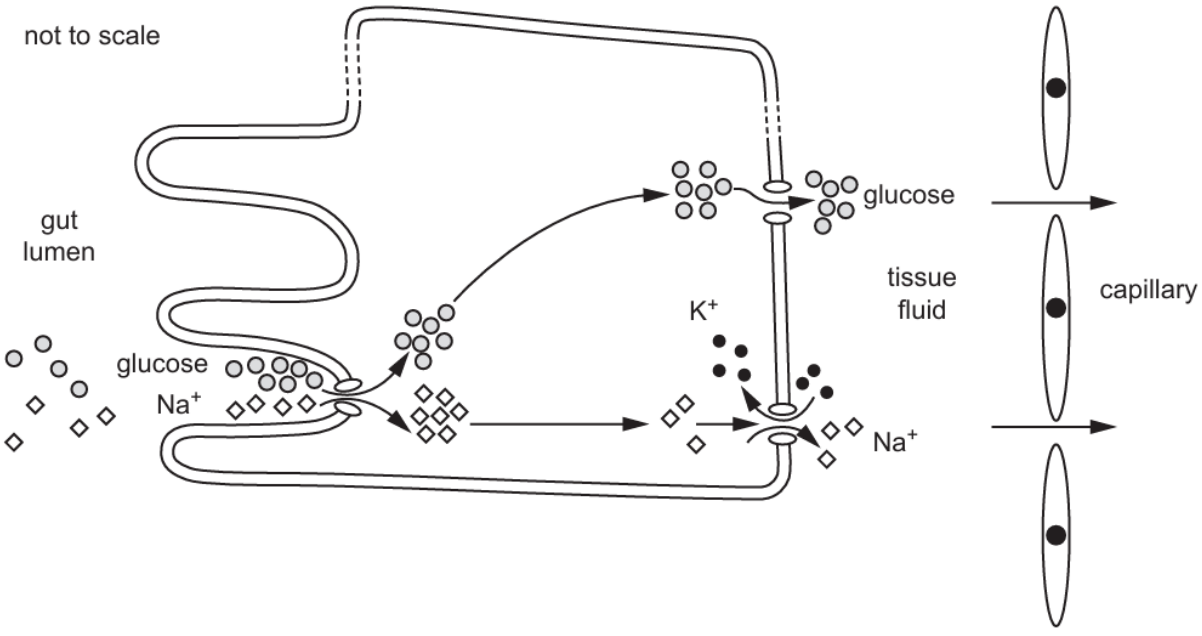


Fig. 1.2

- Sodium ions (Na^+) are removed from the cell by active transport through a transport protein known as a sodium-potassium (Na^+/K^+) pump.
- This decreases the concentration of Na^+ in the cell compared to the gut lumen.
- Glucose molecules are cotransported with Na^+ into the cell from the gut lumen.
- Glucose molecules are transported out of the cell into the tissue fluid down a concentration gradient.

(i) Active transport involves water-soluble substances, such as Na^+ and K^+, and the use of ATP to provide the energy needed for their transport through carrier proteins.

Outline **other** features of active transport.

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(ii) Glucose molecules enter the cell through a membrane protein.

Suggest why glucose molecules need to be cotransported with Na^+ when it enters the cell through the membrane protein.

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(iii) Explain how microvilli increase the uptake of glucose into an intestinal epithelial cell.

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9 The enzyme carbonic anhydrase has been found in a wide range of organisms and acts as a catalyst in many tissues.

Studies have shown that there are differences in the protein structure of the enzyme and differences in the number and organisation of introns and exons of the gene coding for the enzyme.

All carbonic anhydrase enzymes catalyse the same reversible reaction, shown in Fig. 4.1.

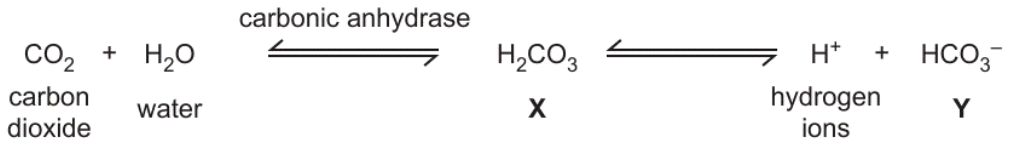


Fig. 4.1

(e) Isoform CA6 forms part of human breast milk. Mammary gland cells package CA6 in Golgi vesicles for release from the cells.

Name the transport mechanism associated with CA6 secretion.

..... [1]

10 B-lymphocytes are activated to form plasma cells during immune responses.

Fig. 2.1 is a drawing of a plasma cell made from a transmission electron micrograph.

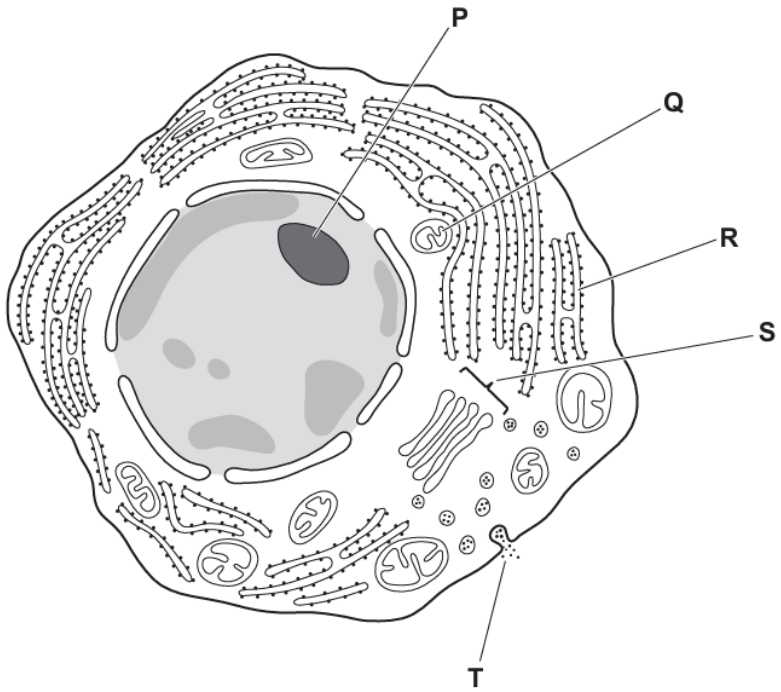


Fig. 2.1

(a) **(i)** State the name of the process that is occurring at **T**.

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11 Fibroblasts are one of the cell types of connective tissue. The cells synthesise and secrete collagen, which forms part of the supporting external cellular environment, known as the extracellular matrix.

(b) After final processing in the Golgi body, collagen is released to the outer surface of the cell by exocytosis.

Complete the passage to describe the process of exocytosis.

After final processing in the Golgi body,

..... [3]

12 **(c)** Scientists have studied the process of cell death that occurs during the development of the cells that become mature xylem vessel elements.

During this development, the tonoplast ruptures (bursts) and releases hydrolytic enzymes contained in the vacuole into the cytoplasm.

(ii) The rupture of the tonoplast during development of xylem vessel elements is due to changes in permeability of the tonoplast.

Suggest how the permeability of the tonoplast changes **and** explain how this change could result in the rupture of the tonoplast.

..... [3]

13 A person who is exposed to tobacco smoke is at greater risk of lung cancer and chronic obstructive pulmonary disease (COPD).

Many people with COPD have both chronic bronchitis and emphysema. These diseases cause changes in the gas exchange system. For example, changes occur in the total lung surface area to volume ratio (SA:V).

(b) A student investigated the effect of SA:V on diffusion.

Agar was prepared with Universal Indicator solution and sodium hydroxide solution. The agar was coloured blue.

Three cubes, **A**, **B**, and **C**, were cut from a solid block of blue agar. Each cube was a different size.

Universal Indicator solution changes to a red colour in the presence of acid.

The student prepared Table 4.1 to show the sizes and SA:V of each cube.

Table 4.1

cube	length of each side / cm	total surface area / cm^2	volume /	SA:V
A	1	6	1	6:1
B	2	24	8	3:1
C	3			2:1

Complete Table 4.1 by:

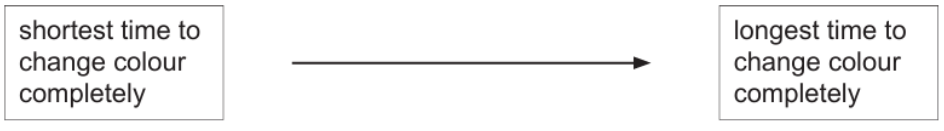
- writing the correct units for volume
- calculating the total surface area, and volume, of cube **C**.

[2]

(c) Cubes **A**, **B** and **C** were placed in a small beaker. At time 0 seconds, dilute hydrochloric acid was added to the beaker to cover the cubes.

The student timed how long it took for each cube to change colour completely.

Complete Fig. 4.1 to show the results that were obtained.



cube ..... → cube ..... → cube .....

[1]

Fig. 4.1

14 Visking tubing can be used to investigate the properties of cell membranes.

A student carried out an experiment to investigate osmosis using Visking tubing. An outline of the investigation is shown in Fig. 3.1.

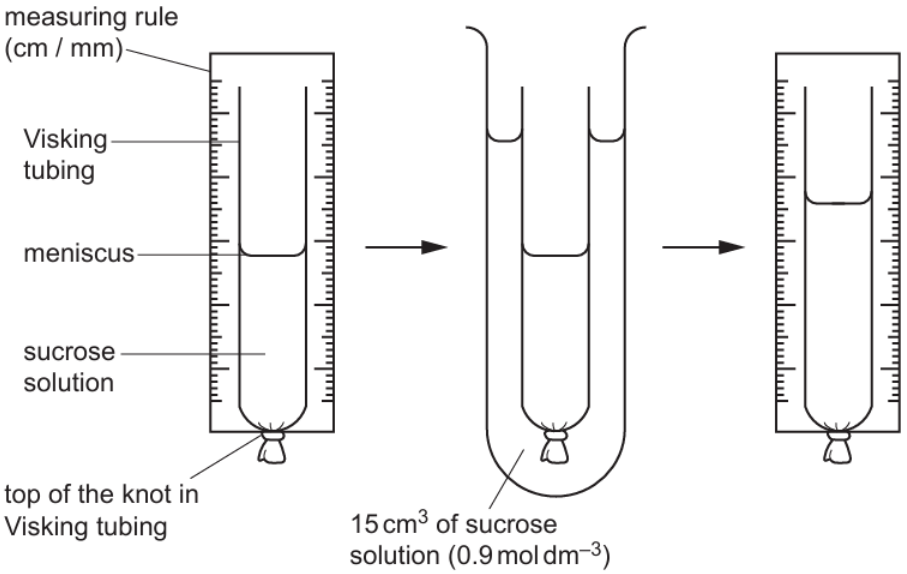


Fig. 3.1

- Six pieces of Visking tubing were filled with 10 cm^3 of different concentrations of sucrose solution: 0.0, 0.4, 0.8, 1.2, 1.6 and 2.0 $mol\,dm^{-3}$.
- The height of the meniscus of each solution in the Visking tubing was measured.
- The pieces of Visking tubing were put into test-tubes containing 15 cm^3 of 0.9 $mol\,dm^{-3}$ sucrose solution.
- After 20 minutes, the pieces of Visking tubing were removed from the test-tubes and the height of the meniscus in each was measured.

The results are shown in Table 3.1.

Table 3.1

concentration of sucrose solution inside Visking tubing / $mol\,dm^{-3}$	difference in height of meniscus after 20 minutes / mm
0.0	–12
0.4	–4
0.8	–2
1.2	+1
1.6	+6
2.0	+11

(a) The Visking tubing used by the student was **not** permeable to sucrose.

Explain the results shown in Table 3.1.

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(b) When red blood cells are placed in water they are destroyed by bursting.

The student also investigated how red blood cells are affected by immersion in solutions of sodium chloride of different concentration. Blood samples of the same volume were added to solutions of sodium chloride in separate test-tubes.

After 10 minutes, the student took 0.1 cm^3 of the blood samples from the test-tubes and estimated the percentage of red blood cells that had burst in each blood sample.

Fig. 3.2 shows the student's results.

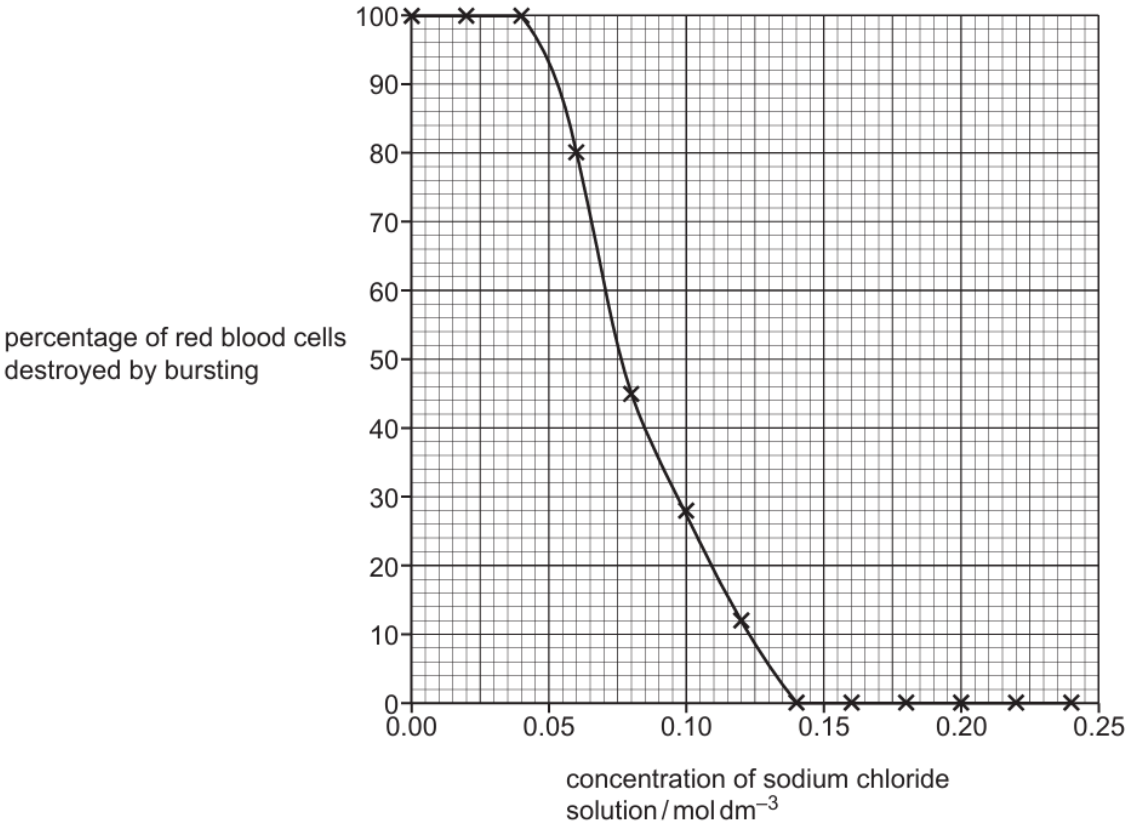


Fig. 3.2

Describe **and** explain the effects on red blood cells of immersion in different concentrations of sodium chloride as shown in Fig. 3.2.

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15 Lysosomes are cell structures that contain enzymes known as acid hydrolases.

Fig. 6.1 shows some processes that occur in animal cells.

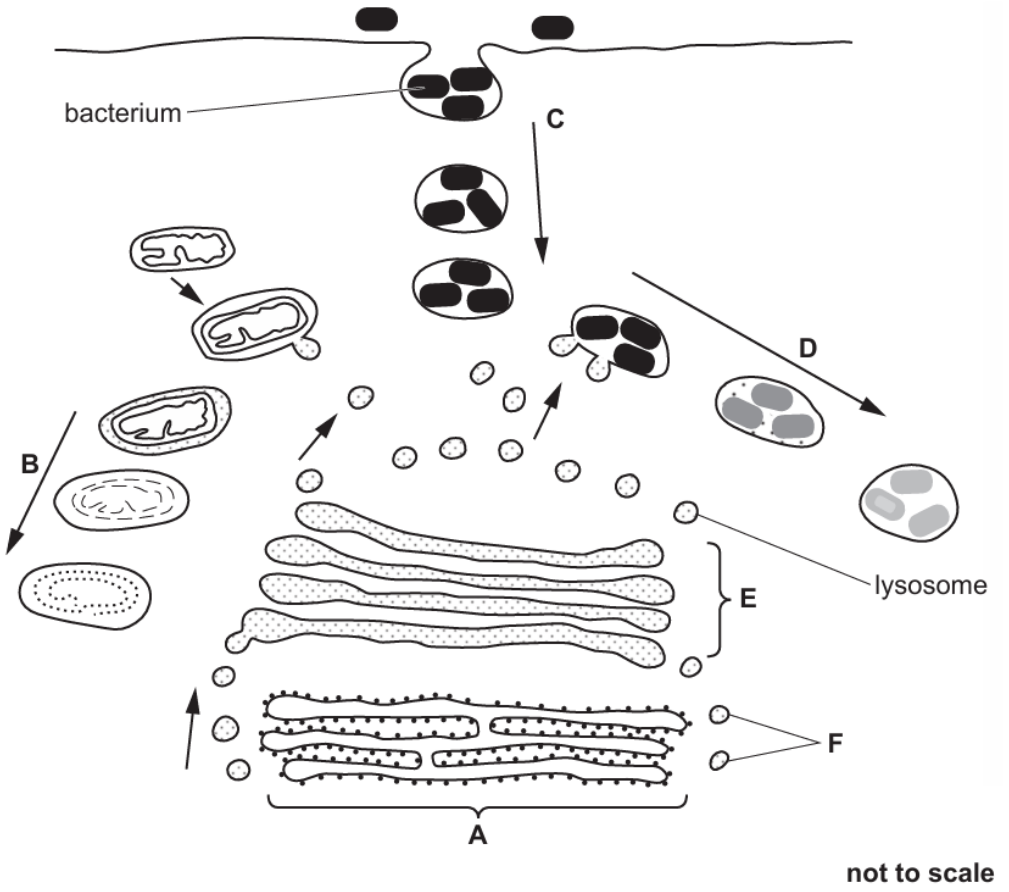


Fig. 6.1

(c) Name the process by which bacteria are taken into the cell at **C**.

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(e) Carrier proteins in the membranes of lysosomes maintain a lower pH than the surrounding cytoplasm by moving hydrogen ions.

Suggest how the carrier proteins maintain the lower pH within the lysosomes.

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16 Picornaviruses are small viruses that are 30 nm in diameter. Picornaviruses are able to enter the cells of mammals and birds and can replicate within these cells.

Fig. 1.1 shows the entry of a picornavirus into its host cell.

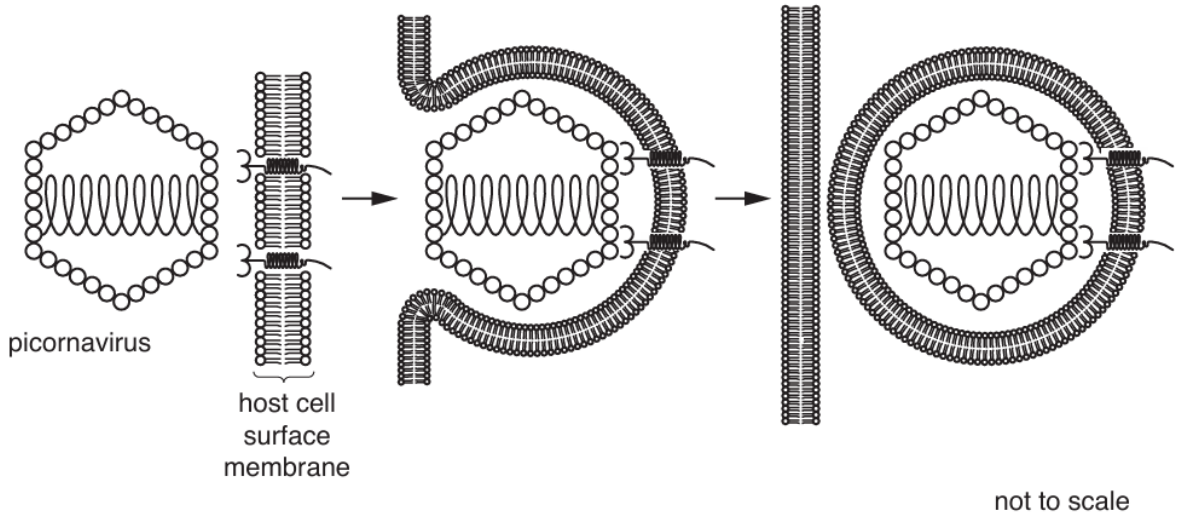


Fig. 1.1

(c) With reference to Fig. 1.1, describe how the picornavirus enters the host cell.

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17 **(b)** Fig. 5.2 is a photograph of two African elephants, *Loxodonta africana*.



Fig. 5.2

(i) Describe the difference in surface area to volume ratio between the adult elephant and baby elephant shown in Fig. 5.2.

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(ii) Suggest why animals such as elephants require a gas exchange system.

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18 Fig. 1.1 is a diagram drawn from a photomicrograph of a transverse section through part of a leaf.

The arrows in Fig. 1.1 show the movement of water through the cells of the leaf after it has left the xylem.

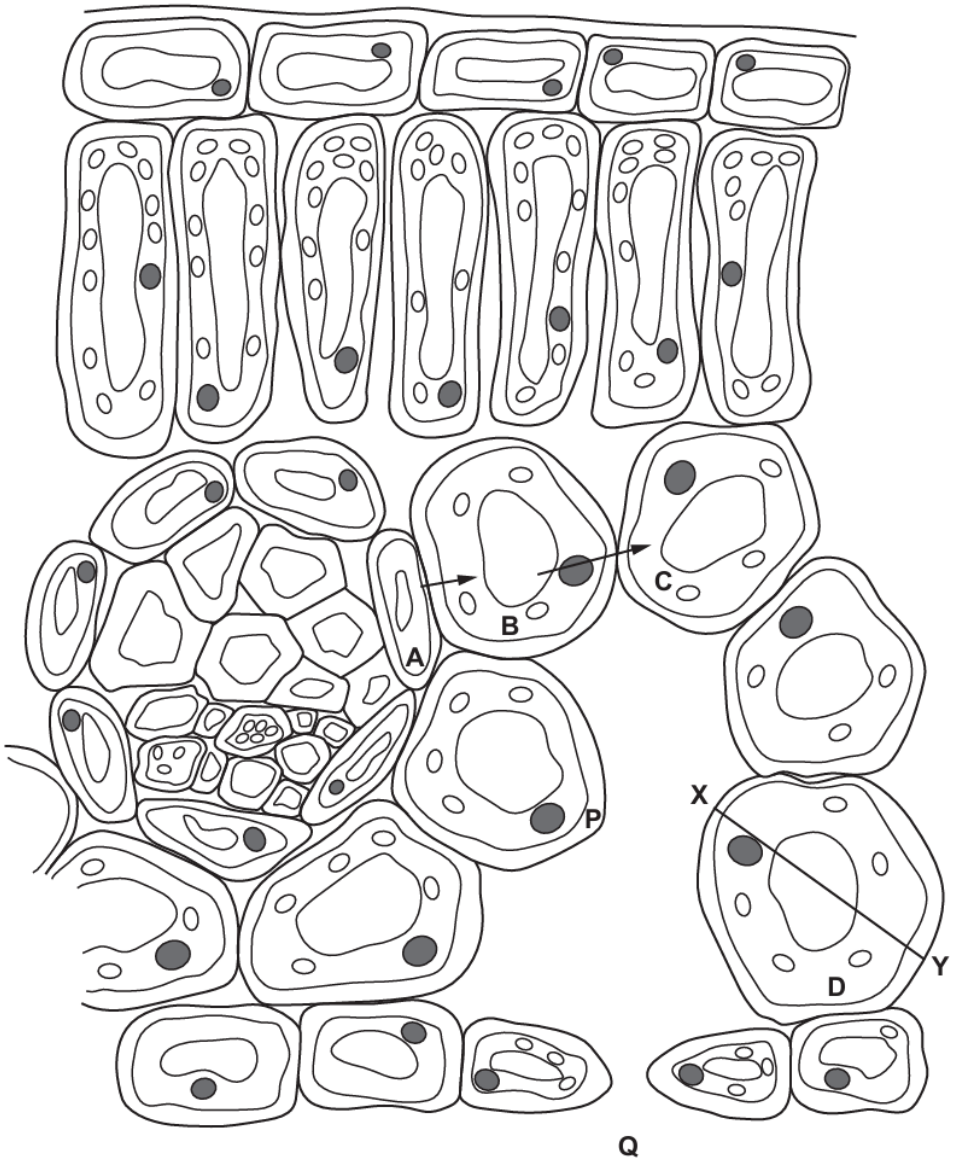


Fig. 1.1

(a) Water from the xylem can enter cell **A** and then moves to cells **B** and **C** without crossing their cell walls.

The cell structures through which water passes from cell **A** to cell **B** are **not** visible in Fig. 1.1.

(ii) Explain what causes water to move from cell **B** to cell **C**.

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19 A student carried out an experiment to investigate the effect of increasing the concentration of sucrose solution on the mass of potato tissue.

- Potato tissue was cut into cylinders of equal length and diameter.
- The mass of each cylinder was recorded.
- Each cylinder was put into a solution of sucrose, as shown in Fig. 3.1.

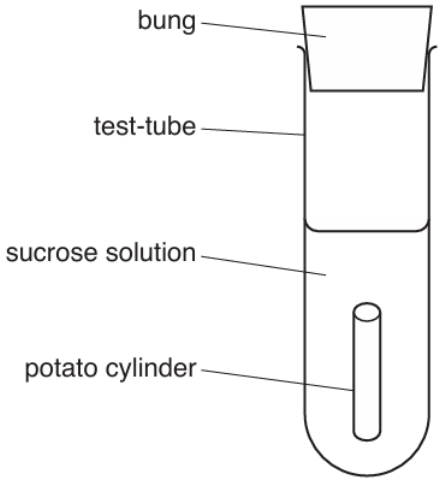


Fig. 3.1

- After one hour each cylinder was removed, blotted dry and reweighed.
- The percentage change in mass of each cylinder was calculated.
- The experiment was repeated three times.
- The mean percentage change in mass of the potato cylinders in each sucrose solution was calculated.

Fig. 3.2 shows the results of this investigation.

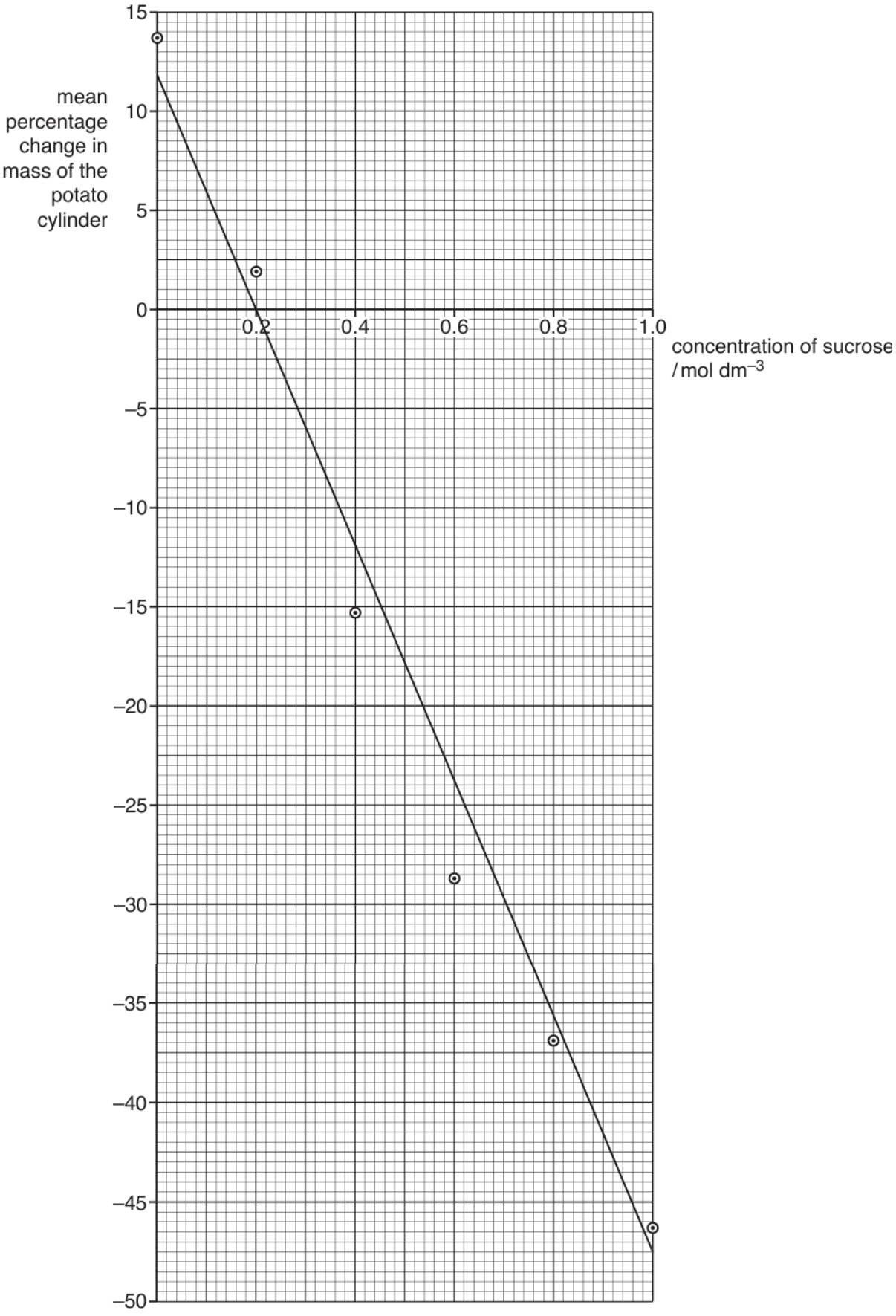

mean percentage change in mass of the potato cylinder
15
10
5
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
0.2
0.4
0.6
0.8
1.0
concentration of sucrose /mol dm−3

Fig. 3.2

(a) With reference to Fig. 3.2, describe the effect of increasing the concentration of sucrose solution on the mass of the potato cylinders.

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(b) Explain why there was a change in mass for the potato cylinders in 0.6 mol dm^{-3} sucrose solution.

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20 A red blood cell goes through a number of stages in the bone marrow before it is released into the circulation to carry out its role of oxygen transport.

Fig. 3.1 is a transmission electron micrograph of developing red blood cells in the bone marrow. Each cell is known as an erythroblast.

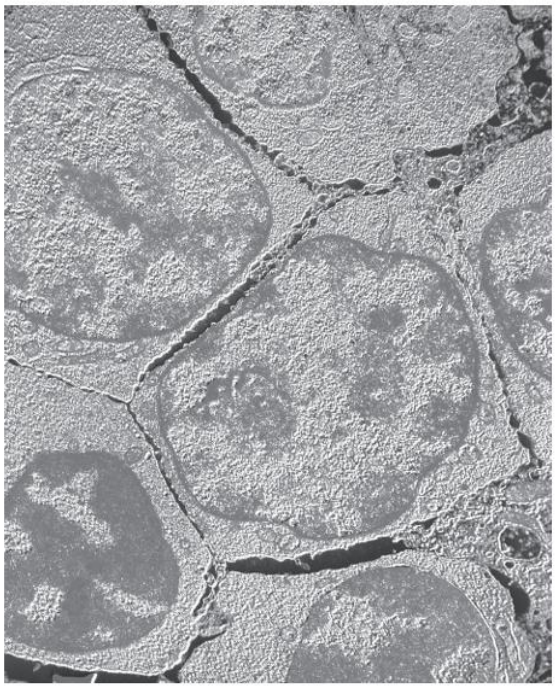


Fig. 3.1

(e) Increases in the water potential of the blood plasma have greater effects on red blood cells in people with spherocytosis type 2 than on normal red blood cells.

Compare **and** explain the effects of an **increase** in the water potential of blood plasma on spherocytosis type 2 red blood cells and normal red blood cells.

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21 Some tissues of the gas exchange system include cells that are able to produce and secrete mucins. Mucins are stored in vesicles in these cells, ready for secretion. Once outside the cell, mucins adsorb water to form mucus.

(d) Chloride ions move out of the mucin-producing cells at the same time as mucin is secreted.

Suggest **and** explain how the exit of chloride ions helps the formation of mucus from mucin.

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22 Fig. 3.1 is a photomicrograph of human blood cells from a healthy individual who lives at sea level. The cells labelled **C**, **D** and **E** are white blood cells.

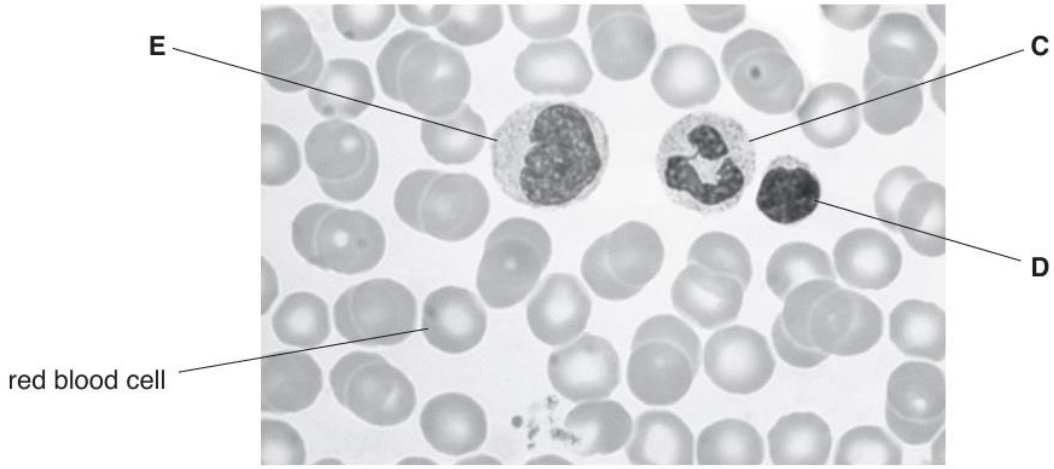


Fig. 3.1

(c) Most of the oxygen that enters the mammalian circulatory system is transported by red blood cells.

(i) Describe **and** explain the passage of oxygen across the cell surface membrane of the red blood cell.

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23 Bacteria may be classified according to differences in cell wall structure. The differences are shown by using the Gram stain.

- A Gram-positive bacterium has a cell wall mainly composed of a thick layer of peptidoglycan (murein).
- A Gram-negative bacterium has a more complex cell wall. This wall is composed of a much thinner layer of peptidoglycan and an outer layer known as the outer membrane.

Escherichia coli is a Gram-negative bacterium.

Fig. 3.1 is a diagram through the cell surface membrane **and** the cell wall of *E. coli*.

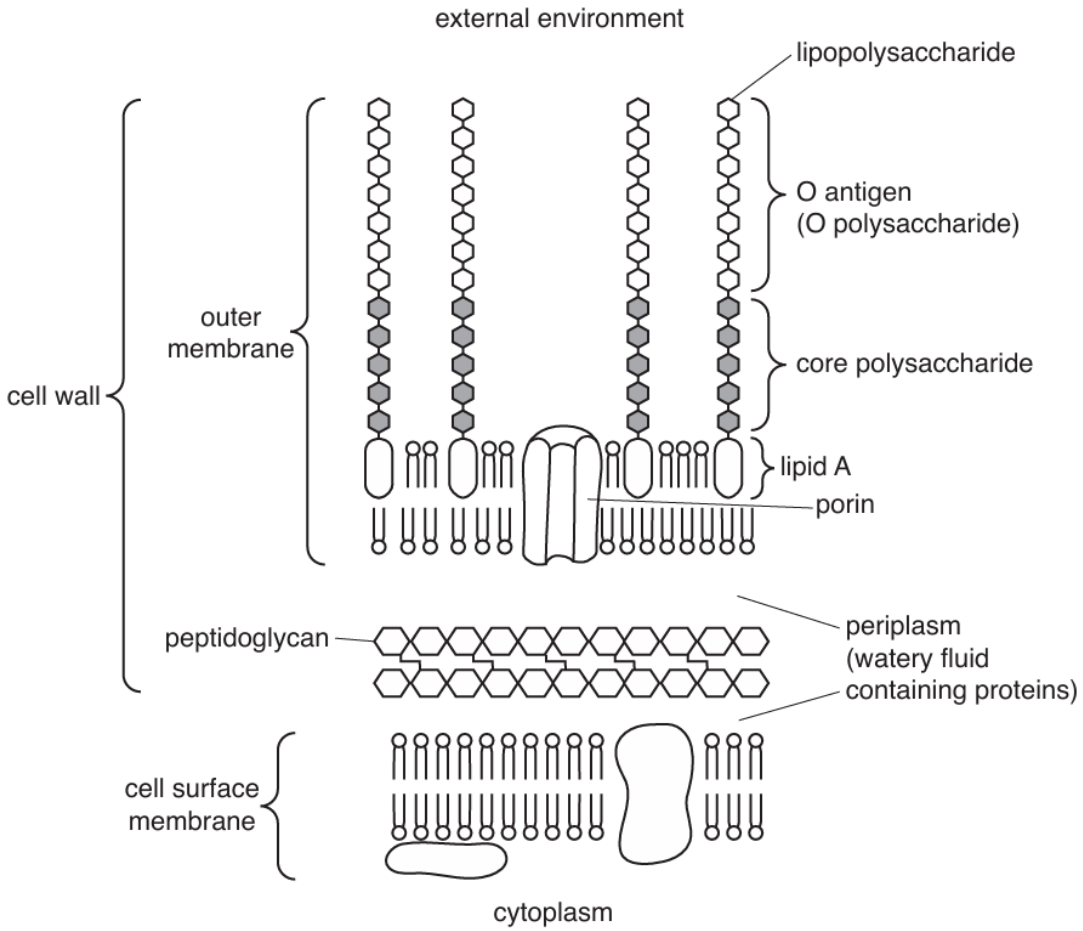


Fig. 3.1

(b) The outer membrane contains transport proteins called OmpF porins. These porins allow the passive movement of water, ions and small, polar molecules across the outer membrane. Each OmpF porin is formed from three identical polypeptides.

(i) Explain what is meant by the term *passive*.

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24 Water absorbed by plant roots travels by different pathways from root hairs to the xylem.

Fig. 6.1 shows these pathways in the root of *Ranunculus acris*.

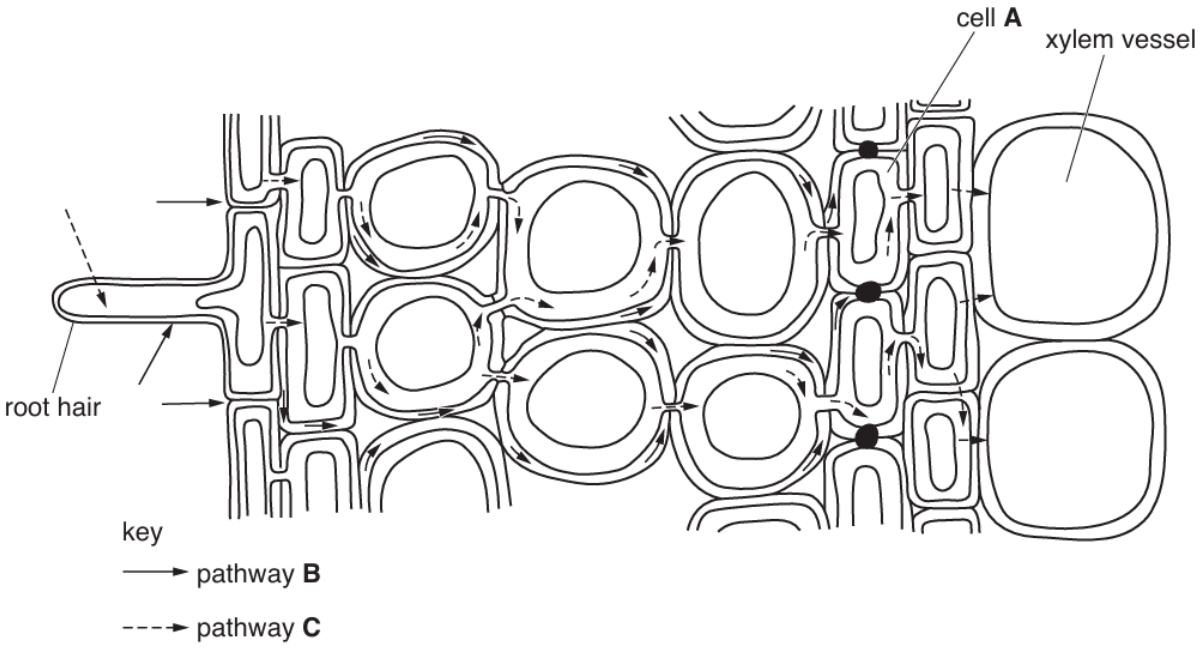


Fig. 6.1

(d) Ions are taken up by root hair cells using active transport and facilitated diffusion.

Describe **two** ways in which facilitated diffusion differs from active transport.

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2 .....

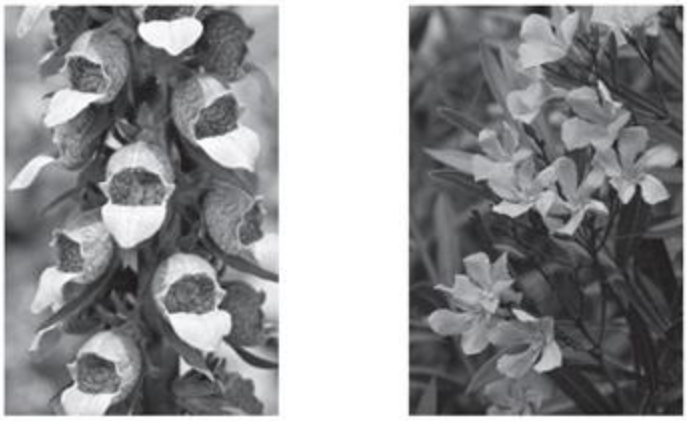
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[2]

25 Woolly foxglove, *Digitalis lanata*, shown in Fig. 2.1**A**, and common oleander, *Nerium oleander*, shown in Fig. 2.1**B**, are plants grown for the attractive flowers that they produce.

Both plants are poisonous, as their leaves produce toxic organic compounds known as cardiac glycosides. Cardiac glycosides have a powerful effect on the action of cardiac muscle.



A B

Fig. 2.1

Cardiac glycosides have an effect on the movement of ions into and out of cardiac muscle cells. The outcome is an increased ability for the cells to contract.

(c) Investigations into the action of the cardiac glycoside oleandrin, extracted from *N. oleander*, have shown that it acts to prevent the correct functioning of Na/K-ATPase, a membrane transport protein.

Na/K-ATPase has a role as an enzyme **and** as a transport molecule.

- ATPase is an enzyme that catalyses the hydrolysis of ATP to ADP and inorganic phosphate.
- Energy released from this hydrolysis is used to transport sodium ions (Na^+) out of cardiac muscle cells and potassium ions (K^+) into the cells.

(ii) Name the type of transport mechanism involved in the transport of Na^+ and K^+ across the cell surface membrane of cardiac muscle cells.

..... [1]

26 Fig. 2.1 shows the disaccharide lactose, which is found in milk.

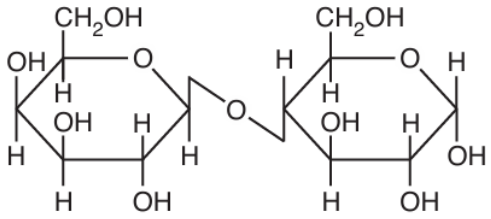


Fig. 2.1

(b) The enzyme lactase catalyses the breakage of the bond between the two monosaccharides in lactose.

(ii) Some people do not produce the enzyme lactase, so cannot digest lactose.

The presence of lactose in the lumen of the intestine reduces the volume of water absorbed into the blood, resulting in diarrhoea.

Suggest why the presence of lactose in the intestine reduces the volume of water absorbed.

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..... [2]