# Absorption from the small intestine: pathways and mechanisms

## Key concepts you must understand

- Glucose is absorbed from the small intestine by a mechanism that involves the co-transport (simultaneous transport) of sodium ions.
- The transport protein carries a glucose molecule with a sodium ion into the epithelial cell by facilitated diffusion.
- Facilitated diffusion only works if there is a diffusion gradient. This is maintained by the active transport of sodium ions out of the base of the epithelial cell; glucose molecules pass out by facilitated diffusion.
- Absorption is efficient because:
  - microvilli increase the surface area of the epithelial cells for absorption
  - the distance from the lumen of the intestine to the capillaries is short
  - there is always a concentration gradient between the lumen of the small intestine and the epithelial cells
- For the process of simple diffusion, the relationship between the above points is expressed in the formula:

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{difference in concentration}}{\text{thickness of exchange surface (diffusion distance)}}$$

- For facilitated diffusion, this formula is modified to:

$$\text{rate of diffusion} \propto \frac{\text{number of transport proteins} \times \text{difference in concentration}}{\text{thickness of exchange surface (diffusion distance)}}$$

**examiner tip**

You *must* remember to write 'rate of diffusion' on the left-hand side of the 'is proportional to' sign in the formula.

## Key facts you must know and understand

Figure 33 shows the location of some transport proteins and outlines the mechanism of the uptake of sodium ions and of glucose.

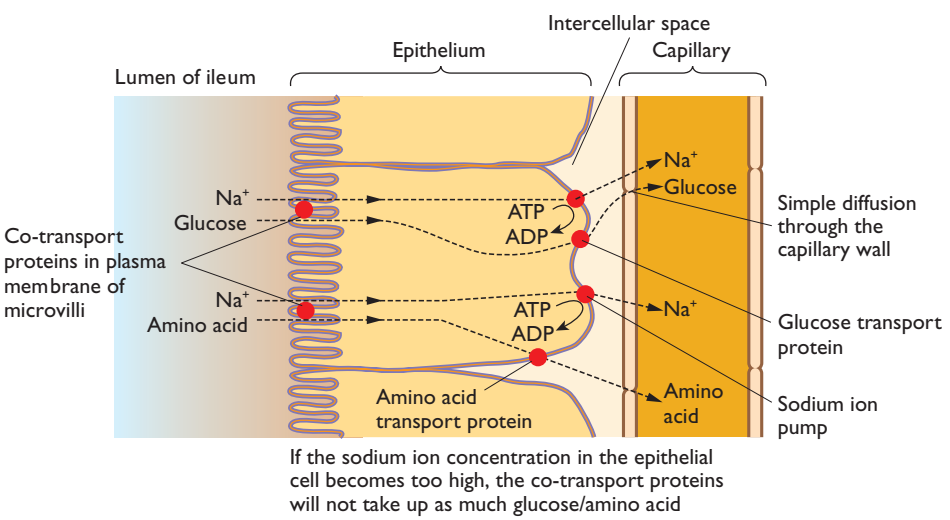



**Figure 33** Absorption in the small intestine involves diffusion, active transport and co-transport

**Knowledge check 17**

In addition to glucose, Figure 33 shows the absorption of amino acids from the small intestine. You are not required to recall the absorption of amino acids. Test your ability to interpret a diagram by using Figure 33 to describe how amino acids are absorbed.

**Knowledge check 18**

The transport proteins shown in Figure 33 are specific to either glucose or amino acids. Explain how.

## The biological basis of related disease

### *Cholera*

Cholera is a bacterial disease that affects absorption from the small intestine. Figure 34 shows that, like all bacteria, the bacterium that causes cholera has a prokaryotic cell. Prokaryotic cells differ from the eukaryotic cells of animals, plants and fungi.

- They are usually much smaller.
- They do not have a true nucleus (the DNA is not contained within a nuclear envelope).
- They do not have membrane-bound organelles (i.e. they do not have lysosomes, mitochondria and chloroplasts).
- They have circular DNA (the DNA forms a closed loop rather than being a linear molecule).
- They have 'naked' DNA (the DNA is not associated with proteins in chromosomes).
- They have plasmids (very small circular pieces of DNA).
- The cell wall is made of peptidoglycan (not cellulose like a plant cell wall or chitin like a fungal cell wall).
- Some bacteria have a 'capsule' outside the cell wall.

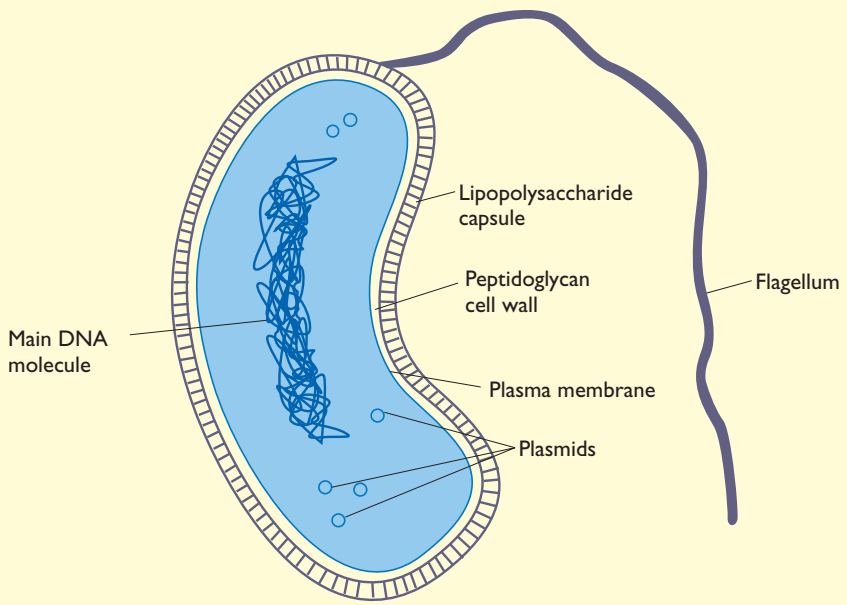
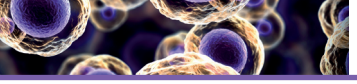



**Figure 34** The cholera bacterium (*Vibrio cholerae*)

The cholera bacterium (*Vibrio cholerae*) causes disease in the following way.

- It is transmitted in polluted water.
- In the small intestine, the bacterium anchors itself to the epithelial cells, multiplies and produces a toxin.
- The toxin affects transport proteins in the plasma membrane of the epithelial cells.





- Sodium and chloride ions pass out of the epithelial cells and create a salt-water environment with a low water potential in the lumen of the small intestine. This is ideal for the cholera bacterium, which occurs naturally in salty water.
- Water is lost by osmosis from the cells (and then from the blood) to the lumen of the small intestine, causing:
  - diarrhoea (the production of very watery faeces)
  - massive dehydration
- If not treated in time, the dehydration can be fatal.

Most deaths from cholera occur as a result of dehydration. Oral rehydration therapy (ORT) aims to reverse dehydration and so give the patient time to mount an effective immune response against the bacterium. The aim is to put back into the blood and cells the water and mineral ions lost due to the action of the cholera toxin. It involves giving the patient a solution that contains mainly glucose and sodium ions (as sodium chloride and sodium citrate).

- For ORT, the patient drinks a commercially pre-prepared powder dissolved in water. The glucose and sodium ions in the solution are taken up by co-transport proteins in the plasma membranes of epithelial cells. This increases the concentration of solutes in the cells and in the blood plasma, lowering their water potential. Water follows by osmosis, rehydrating the patient. The sheer volume of liquid drunk during ORT means that the diarrhoea may last for some time, but the dehydration is prevented.
- As an alternative, an intravenous rehydration 'drip' can be used to add water, glucose and sodium ions directly into the plasma. Its effect is faster than ORT.

Both methods treat the symptoms but not the cause of the infection. However, by reversing the dehydration, most people are then able to make an effective immune response.

ORT has saved millions of lives because it is easy to administer. In the 1970s, after finding out that glucose and ions could still be reabsorbed by the small intestine of cholera sufferers, doctors working in Pakistan and Bangladesh experimented with administering the solutions to patients orally (by mouth). Subsequently, it has been found that, in the absence of commercial ORT mixes, a solution of one teaspoon of salt and four teaspoons of sugar in one litre of water is almost as effective.

Were the doctors justified in experimenting on humans? They may have saved millions, but what about the people who were the 'guinea pigs'?

Since the development of the original oral rehydration solution, researchers have found that:

- reducing the glucose and salt concentrations slightly and drinking slightly less is just as effective in rehydrating the patient; it also reduces the diarrhoea more quickly
- including amino acids in the mixture helps in rehydration because amino acids help the absorption of sodium ions through the amino acid–sodium co-transport protein

**Knowledge check 19**

Why must ORT solutions contain both sodium chloride and glucose?

Summary

After studying this topic, you should be able to:

- explain the terms magnification and resolution
- use your understanding of optical and electron microscopes to explain the advantages and limitations of their use
- calculate the actual size of specimens when given information about magnification
- recognise and describe the function of cell organelles
- apply your understanding of cell fractionation and ultracentrifugation to identify organelles
- apply your knowledge of cell organelles to explain how eukaryotic cells are adapted for their functions
- use the fluid-mosaic model to explain the properties of the plasma membrane
- explain the differences between diffusion, facilitated diffusion and active transport
- use your knowledge of osmosis to identify the movement of water between cells and between cells and solutions
- use your understanding of co-transport of glucose with sodium ions to explain the symptoms of cholera and how ORT reduces these symptoms

# The lungs, breathing and gas exchange

## Key concepts you must understand

### The mechanism of breathing

Air moves into and out of the lungs because of pressure differences. Air moves from a region of high pressure to a region of low pressure.

Breathing movements create pressure differences.

- Inhaling creates a lower pressure in the lungs than in the atmosphere and so air moves in.
- Exhaling creates a higher pressure in the lungs than in the atmosphere and so air moves out.

The amount of air we inhale in one minute is the **pulmonary ventilation rate**. It depends on:

- how much air is inhaled in each breath (the **tidal volume**)
- the ventilation rate (number of breaths taken per minute, i.e. breathing rate)

$$\text{pulmonary ventilation rate} = \text{tidal volume} \times \text{ventilation rate}$$

**examiner tip**

Think of gas coming out of a gas tap; it does so because the pressure in the gas pipe is greater than air pressure.

**Knowledge check 20**

If you know the pulmonary ventilation rate and the breathing rate, how would you find the tidal volume?

### Gas exchange in the alveoli

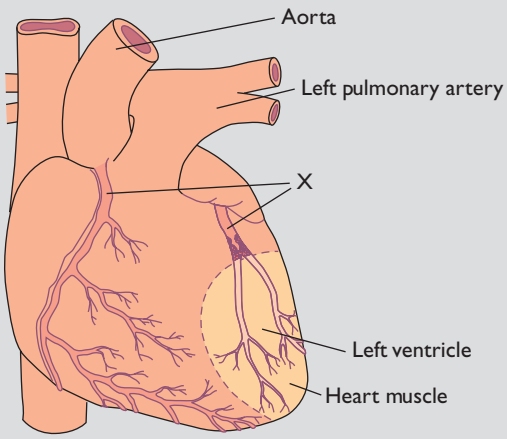
Concentration gradients allow oxygen to diffuse from the air in the alveoli into the red blood cells and carbon dioxide to diffuse from the blood plasma into the alveoli.

The high rate of diffusion of gases between the blood and the alveoli can be explained using the formula:

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{difference in concentration}}{\text{thickness of exchange surface (diffusion distance)}}$$

# Question 1 Heart disease and risk factors

**The diagram shows an external view of the heart.**




**(a) (i) Name the structures labelled X.** (1 mark)

**(ii) What is the function of the structures labelled X?** (3 marks)

**(b) List three factors that increase the risk of developing coronary heart disease. For each factor you name, explain how it brings about the increased risk.** (3 marks)

**Total: 7 marks**

This question tests recall with understanding (AO1). Even if you cannot recall the name of X in (a)(i), it is still possible to gain 3 marks by describing its function in (a)(ii). Part (b) clearly requires you to identify a risk factor *and* explain how it increases the risk for each single mark.

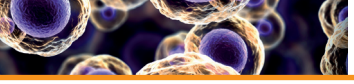
## Student A

**(a) (i)** X is the cardiac artery **a**.

**(ii)** The cardiac arteries carry blood to the heart **b** so that it can have oxygen.

**(b)** Smoking increases cholesterol **c** levels, as can your genes **d**. If you eat too much fatty food you will have high cholesterol levels **e**.

**2/7 marks awarded** **a** The student has not recalled the name and fails to gain an easy mark. **b** It is important to write that these arteries carry blood to heart *muscle*. **c** This is wrong — smoking is not directly linked to high cholesterol levels. **d,e** These factors and their explanations are correct and score 2 marks.





## Student B

**(a) (i)** Coronary artery **a**

**(ii)** They carry blood rich in oxygen to the cardiac muscle **b** so that it can release energy **c** for contraction **d**.

**(b)** Stress can lead to higher blood pressure.
Hypertension (sustained high blood pressure) can increase atherosclerosis.
A diet high in saturated fat can increase atherosclerosis **e**.

**6/7 marks awarded** **a** This answer gains 1 mark. Note that this student has not wasted time writing 'The name of the structure labelled X is the…'. **b,d** These statements are correct and gain 1 mark each. **c** Naming respiration as the process releasing energy would have earned the third mark. **e** The student has correctly identified three risk factors and gone on to explain clearly the nature of each risk, thus gaining all 3 marks.

**This is a quite straightforward question and you should be able to score at least 5 of the 7 marks allocated. For student A to score only 2 marks (grade U) shows a lack of preparation. Student B scores 6 marks (grade A) simply because he/she had learnt some straightforward biology.**