AS LEVEL

4 Cell membranes and transport

4.1 Fluid mosaic membranes

Every cell is surrounded by a cell membrane. There are also many membranes within cells. The membrane around the outside of a cell is called the cell surface membrane.

Structure of a cell membrane

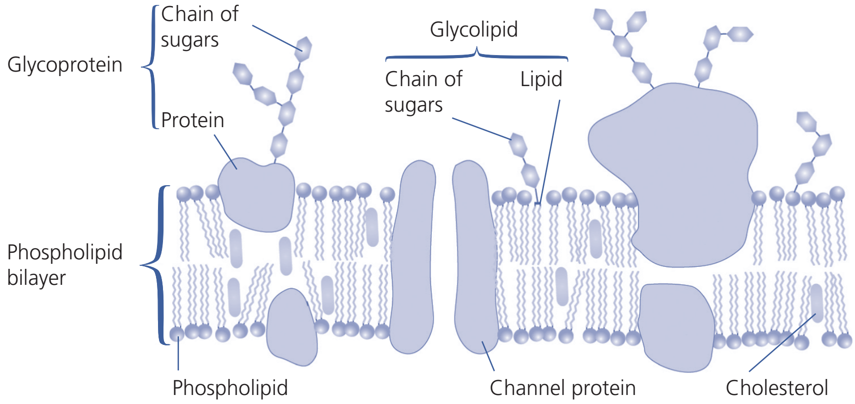
REVISED

A cell membrane has several structural features and components:

- The basic structure is a double layer of **phospholipid** molecules (p. 27). This structure arises because in water a group of phospholipid molecules arranges itself into a **bilayer**, with the hydrophilic heads facing outwards into the water and the hydrophobic tails facing inwards, therefore avoiding contact with water.
- There are also **cholesterol** molecules among the phospholipids.
- **Protein** molecules float in the phospholipid bilayer.
- Many of the phospholipids and proteins have short chains of carbohydrates attached to them, on the outer surface of the membrane. They are known as **glycolipids** and **glycoproteins**. There are also other types of glycolipid with no phosphate groups.

The model for the cell membrane structure is called the **fluid mosaic model** of membrane structure (Figure 4.1):

- 'Fluid' because the molecules within the membrane can move around within their own layers.
- 'Mosaic' because the protein molecules are dotted around within the membrane.
- 'Model' because no-one has ever seen a membrane looking like the diagram – the molecules are too small to see even with the most powerful microscope. The structure has been worked out because it explains the behaviour of membranes that has been discovered through experiment.



▲ **Figure 4.1 The fluid mosaic model of membrane structure**

The roles of the components of cell membranes are outlined in Table 4.1.

▼ Table 4.1

Component	Roles
Phospholipids	Form the fluid bilayer that is the fundamental structure of the membrane Prevent hydrophilic substances – such as ions and some molecules – from passing through
Cholesterol	Helps to keep the cell membrane fluid
Proteins and glycoproteins	Provide channels that allow hydrophilic substances to pass through the membrane; these channels can be opened or closed to control the substances' movement Actively transport substances through the membrane against their concentration gradient, using energy derived from ATP Act as receptor molecules for substances such as hormones, which bind with them; this can then affect the activity of the cell Cell recognition – cells from a particular individual or a particular tissue have their own set of proteins and glycoproteins on their outer surfaces
Glycolipids	Cell recognition and adhesion to neighbouring cells to form tissues

REVISION ACTIVITY

Make a large diagram of a cell membrane. Label the phospholipids, channel proteins, receptor proteins, cholesterol, glycoproteins and glycolipids. Annotate your diagram to give the functions of all the parts.

Cell signalling

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Cells can communicate with one another using chemicals that interact with cell membranes. There are key stages in cell signalling:

- Cells secrete specific chemicals, known as ligands. These ligands can be substances such as hormones and growth factors that instruct other cells to undergo cell division or alter their activity.
- The ligands are then transported to target cells. The ligands may simply diffuse to cells that are close, or be transported in transport fluids such as blood to cells that are further away.
- The ligands then bind to receptor molecules in the cell surface membrane of the target cells. Like enzymes, these receptors are specific, only accepting one type of ligand. This means that the signalling molecule can only affect cells that have its receptor in their cell surface membrane.

For example, the hormone insulin is a protein that fits into receptors in the cell surface membrane of liver cells. When insulin is bound to the receptor, this brings about changes in the cell that result in an increase of transporter proteins for glucose in the cell surface membrane, causing the cell to take up glucose.

NOW TEST YOURSELF

TESTED

1 Suggest why some pharmaceutical drugs have the same shapes as cell signalling molecules.

4.2 Movement of substances into and out of cells

The cell surface membrane controls what enters and leaves cells. Substances can be transported across membranes both passively and actively.

Passive transport through cell membranes

REVISED

Molecules and ions are in constant motion. In gases and liquids they move freely. As a result of their random motion, each type of molecule or ion tends to spread out evenly within the space available. This is **diffusion**. Diffusion results in the net movement of ions and molecules from a high concentration to a low concentration.

KEY TERMS

Diffusion is the net movement of molecules or ions down a concentration gradient, as a result of the random movement of particles.

Diffusion across a cell membrane

- Some molecules and ions are able to pass through cell membranes by simple diffusion. The membrane is permeable to these substances.
- Some substances cannot pass through cell membranes, so the membranes are said to be partially permeable.
- An example of simple diffusion is the movement of oxygen into cells:
  - Oxygen is often at a higher concentration outside a cell than inside, because the oxygen inside the cell is being used up in respiration.
  - The random motion of oxygen molecules inside and outside the cell means that some of them 'hit' the cell surface membrane.
  - More of them hit the membrane on the outside than on the inside, because there are more of them outside.
  - Oxygen molecules are small and do not carry an electrical charge, so they are able to pass freely through the phospholipid bilayer.
  - Oxygen therefore diffuses from outside the cell, through the membrane, to the inside of the cell, down its concentration gradient.
  - This is passive transport, because the cell does not do anything to cause the oxygen to move across the cell membrane.

SKILLS FOCUS

Investigating the effect of surface area on diffusion rate

In general, large objects have a smaller surface area-to-volume ratio than small objects. You can use blocks of agar jelly to investigate how the rate of diffusion is affected by surface area-to-volume ratio.

Method

- Make up some agar jelly using a little universal indicator solution. If the water used to dissolve the agar is slightly acidic, then the jelly will be red.
- Decide on the shapes and sizes of jelly to cut, thinking about keeping the volume of each piece constant, but varying the surface area.
- Immerse your pieces of jelly in a dilute alkali (e.g. sodium hydrogencarbonate solution).
- As the alkali diffuses into the jelly, the indicator will change colour. You can time how long it takes for the whole piece of jelly to change colour.

Calculating surface area-to-volume ratios

- You need to be able to calculate surface area-to-volume ratios for simple shapes such as cuboids and cylinders.
- For example, to calculate the surface area-to-volume ratio for an agar cube with side length of 2 cm, we do the following:

  Step 1: calculate the surface area of the cube:

  $\text{surface area} = 6 \times l^2$

  where l is the length of a side.

  $\text{surface area} = 6 \times 2^2 = 24\,\text{cm}^2$

  Step 2: calculate the volume of the cube:

  $\text{volume} = l^3 = 2^3 = 8$

  Step 3: calculate the ratio of surface area to volume:

  $$\text{ratio} = \frac{\text{surface area}}{\text{volume}} = \frac{24}{8} = 3$$

Therefore, the surface area-to-volume ratio for this cube is 3:1.

Exam-style questions and answers

This practice paper comprises structured questions similar to those you will meet in the exam.

You have 1 hour and 15 minutes to do the paper. There are 60 marks on the paper, so you can spend just over 1 minute per mark. If you find you are spending too long on one question, then move onto another that you can answer more quickly. If you have time at the end, then come back to the difficult one.

Some of the questions require you to recall information that you have learned. Be guided by the number of marks awarded to suggest how much detail you should give in your answer. The more marks there are, the more information you need to give.

Some of the questions require you to use your knowledge and understanding in new situations. Do not be surprised to find something completely new in a question – something you have not seen before. Just think carefully about it, and find something that you do know that will help you to answer it.

Do think carefully before you begin to write. The best answers are short and relevant – if you target your answer well, you can get a lot of marks for a small amount of writing. Do not say the same thing several times over, or wander off into answers that have nothing to do with the question. As a general rule there will be twice as many answer lines as marks. So you should try to answer a 3-mark question in no more than six lines of writing. If you are writing much more than that, you almost certainly have not focused your answer tightly enough.

Look carefully at exactly what each question wants you to do. For example, if it asks you to 'Explain', then you need to say *how* or *why* something happens, not just *describe* what happens. Many students lose large numbers of marks by not reading the question carefully.

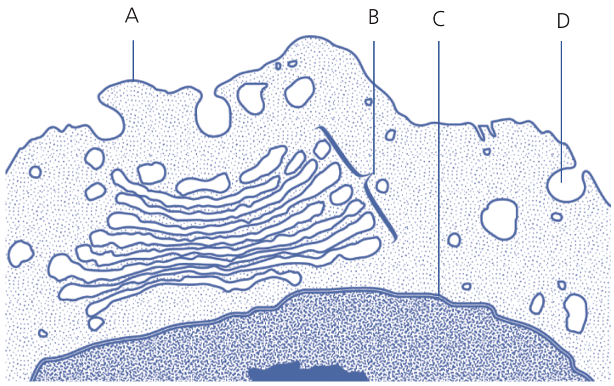
Following each question in this practice paper, there is an answer that might get a C or D grade, followed by expert comments (shown by the icon ⓔ). Then there is an answer that might get an A or B grade, again followed by expert comments. You might like to try answering the questions yourself first, before looking at these.

Notice that there are sometimes more ticks on the answers than the number of marks awarded. This could be because you need two correct responses for 1 mark (e.g. Q1 a i) or because there are more potential marking points than the total number of marks available (e.g. Q1 a ii). Even if you get four or five ticks for a 3-mark question, you cannot get more than the maximum 3 marks.

Exemplar paper

QUESTION 1

a The photograph shows a small part of a cell, as seen using an electron microscope.



i Name the parts labelled A to D. [2]

ii Describe how part B is involved in the formation of extracellular enzymes. [3]

b Give two reasons, other than the presence of part B, why the cell in the diagram cannot be a prokaryotic cell. [2]

Total: 7

ANSWER A

a i A = plasma membrane ✓, B = Golgi ✓, C = nucleus ✗, D = phagocyte ✗

ⓔ C is the nuclear envelope (or membrane), not the nucleus itself. A phagocyte is a cell – perhaps the student is thinking of a phagocytic vesicle. Mark: 1/2

ii First, the enzymes are made by protein synthesis on the ribosomes. Then they go into the endoplasmic reticulum. Then they are taken to the Golgi ✓, where they are packaged. Then they go in vesicles ✓ to the cell membrane where they are sent out by exocytosis.

This student has not really thought about exactly what the question is asking, and has wasted time writing about events that take place before and after the involvement of the Golgi apparatus. There is, however, a mark for the idea that the Golgi apparatus receives proteins that have been in the RER, and another for packaging them into vesicles. Mark: 2/3

b It has a nucleus. ✓ And it has Golgi apparatus. ✗

The Golgi apparatus is part B, and this has been excluded by the question. Mark: 1/2

ANSWER B

a i A = cell surface membrane ✓, B = Golgi apparatus ✓, C = nuclear envelope ✓, D = vesicle ✓

All correct. Mark: 2/2

ii Proteins made in the RER are transported to the convex face ✓ of the Golgi apparatus in vesicles. The vesicles fuse ✓ with the Golgi and the proteins inside are modified ✓ by adding sugars to make glycoproteins ✓. They are packaged inside membranes ✓ and sent to the cell membrane.

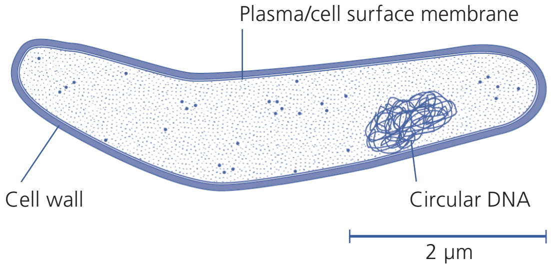
All correct. Mark: 3/3

b If it was a prokaryotic cell it would not have a nucleus ✓ and it would have a cell wall ✓.

Correct. Mark: 2/2

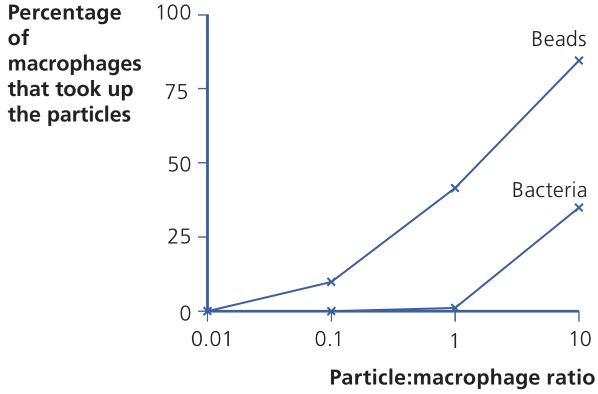
QUESTION 2

The diagram shows the bacterium *Mycobacterium tuberculosis*, which causes tuberculosis (TB).



a *M. tuberculosis* is taken up by macrophages and multiplies inside them.
Suggest how this strategy could help to protect *M. tuberculosis* from the immune response by B cells. [3]

b In an experiment to investigate how *M. tuberculosis* avoids destruction by macrophages, bacteria were added to a culture of macrophages obtained from the alveoli of mice. At the same time, a quantity of small glass beads, equivalent in size to the bacteria, were added to the culture. The experiment was repeated using increasing quantities of bacteria and glass beads.
After 4 hours, the macrophages were sampled to find out how many had taken up either glass beads or bacteria. The results are shown in the graph. The *x*-axis shows the initial ratio of bacteria or glass beads to macrophages in the mixture. Discuss what these results suggest about the ability of macrophages to take up *M. tuberculosis*. [3]



c When *M. tuberculosis* is present inside a phagosome of a macrophage, it secretes glycolipids that accumulate in lysosomes and prevent the lysosomes fusing with the phagosome.
Explain how this prevents the macrophage from destroying the bacterium. [3]

Total: 9

ANSWER A

a It stops the B cells seeing them, so they do not make antibodies ✓ against them.

This is not a clear answer. B cells do not 'see', so this is not a good term to use. The 'they' in the second half of the sentence could refer to either B cells or the bacteria. Mark: 1/3