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SECONDARY 3 · BIOLOGY · CELL STRUCTURE AND ORGANISATION

Cell Structure and Organisation

Theory and worked examples

Cells: the basic unit of life

All living things are built from cells, the basic structural and functional unit of life. An organism such as an amoeba is unicellular: a single cell carries out every life process by itself. Most plants and animals are multicellular, built from many cells of different kinds working together. Cells are very small; a typical plant or animal cell can be seen with a light microscope, but some of the smaller structures inside a cell can be seen only with a more powerful electron microscope.

KEY IDEA

Every living thing is made of one or more cells; cells are the smallest level at which life's processes happen.

- Overarching idea for this topic: the structure of a cell or organelle is correlated with its function.
- At the O-Level, 'organelle' includes membrane-bound structures (nucleus, mitochondrion) and non-membrane structures (ribosome).

WORDS TO KNOW

cell	the basic structural and functional unit of life
organelle	a structure inside a cell, often surrounded by its own membrane, that carries out a particular job
unicellular	made of a single cell, which carries out every life process (e.g. an amoeba)
multicellular	built from many cells, often of different kinds, working together (e.g. a human, a flowering plant)

TRY THIS

Is an amoeba unicellular or multicellular? Explain what your answer means for how it survives.

Answer: Unicellular: its single cell must carry out every life process (e.g. feeding, movement) by itself.

Looking at cells: the light microscope and the electron microscope

A light microscope uses light and glass lenses to magnify a specimen; it is used with prepared slides or with fresh material a student has prepared. Most cell structures are almost colourless, so a temporary stain is often added to colour particular structures and give them contrast. A thin piece of onion epidermis is commonly stained with iodine solution, which colours the cell wall and nucleus so that the outline of each cell shows up clearly; cells scraped from the inside of the cheek are commonly stained with methylene blue, which colours the nucleus blue against the paler cytoplasm. A light microscope can show the cell wall, cell membrane, cytoplasm, nucleus, vacuole and chloroplasts, but it cannot show much smaller structures such as the endoplasmic reticulum, Golgi body, mitochondria and ribosomes. These are revealed only by an electron microscope, which uses a beam of electrons instead of light and has a far higher magnification and resolution; a photograph taken with an electron microscope is called an electron micrograph.

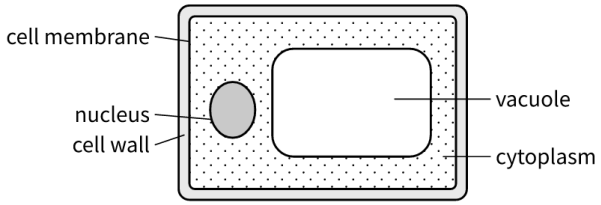
KEY IDEA

A temporary stain gives a cell structure colour contrast; an electron microscope has a far higher magnification and resolution than a light microscope, revealing structures a light microscope cannot.

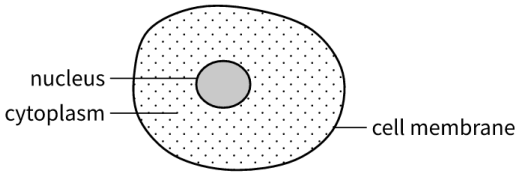
- Onion epidermis + iodine solution: stains the cell wall and nucleus.
- Cheek cells + methylene blue: stains the nucleus, so it stands out against the cytoplasm.
- A light microscope cannot show the endoplasmic reticulum, Golgi body, mitochondria or ribosomes; an electron microscope can.

WORDS TO KNOW

light microscope	an instrument using light and lenses to magnify a specimen so that cells and their larger structures can be seen
temporary stain	a dye added just before a specimen is viewed, to give certain structures colour contrast; it is not permanent
electron microscope	an instrument using a beam of electrons to magnify a specimen; much higher magnification and resolution than a light microscope
electron micrograph	a photograph taken with an electron microscope, showing detail too small for a light microscope to resolve
resolution	the ability of a microscope to show two very close points as two separate points, rather than one blur



onion epidermis cell



cheek cell

WORKED EXAMPLE

A student at a polyclinic health talk is shown a prepared slide of onion epidermis stained with iodine solution. Explain why the stain was added before the slide was viewed.

1. What is given: a prepared slide of onion epidermis stained with iodine solution, about to be viewed under a light microscope.
2. Biology idea: most cell structures are almost colourless, so they are hard to see or tell apart without added colour.
3. Iodine solution is a temporary stain that colours the cell wall and the nucleus, giving these structures contrast against the rest of the cell.

Iodine solution is a temporary stain. Most structures in fresh onion epidermis are almost colourless; the stain colours the cell wall and nucleus, so the outline of each cell and its nucleus are easier to see under the light microscope.

TRY THIS

Name a structure that is invisible under a light microscope but can be seen with an electron microscope.

Answer: Any one of: endoplasmic reticulum, Golgi body, mitochondrion, ribosome.

Calculating magnification

The image of a cell, seen under a microscope or drawn from it, is much larger than the actual (real) size of the cell. Magnification tells us how many times larger the image is than the actual object: magnification = size of image ÷ actual size of object. Image size is usually measured in millimetres (mm) with a ruler on a printed photograph or drawing; the actual size of a cell is usually given in micrometres (μm), because cells are so small. Always convert both sizes to the same unit before dividing; remember that 1 mm = 1000 μm.

KEY IDEA

Magnification = image size ÷ actual size, with both sizes in the same unit.

- Magnification = image size ÷ actual size.
- Actual size = image size ÷ magnification.
- Image size = actual size × magnification.
- Convert the image size and the actual size to the same unit before dividing.

WORDS TO KNOW

magnification	how many times larger an image is than the actual object: image size ÷ actual size, both in the same unit
micrometre (μm)	a unit of length equal to one-thousandth of a millimetre (1 mm = 1000 μm); used for the actual size of a cell

WORKED EXAMPLE

A palisade mesophyll cell from a leaf collected at the Gardens by the Bay community garden has an actual length of 60 µm. A student's drawing of this cell, made at a magnification of ×500, is to be checked. (a) Calculate the expected length of the drawing, in mm. The student's drawing actually measures 35 mm. (b) State, with a reason, whether the student's drawing is an accurate size.

1. (a) Image size = actual size × magnification = 60 × 500 = 30 000 µm.
2. Convert to mm: 30 000 ÷ 1000 = 30 mm.
3. (b) Biology idea: compare the expected image size with the size the student actually drew.
4. The student's drawing (35 mm) is larger than the expected 30 mm, so it is not drawn accurately to the stated magnification.

(a) Image length = 60 × 500 = 30 000 µm = 30 mm. (b) No; the expected length at ×500 is 30 mm, but the student drew 35 mm, so the drawing is too large for the magnification stated.

TRY THIS

A student's drawing of a cell measures 42 mm from end to end, while the real cell is only 70 µm long. Work out the magnification used for the drawing.

Answer: 42 mm = 42 000 µm. Magnification = 42 000 ÷ 70 = ×600.

Structures found in both plant and animal cells

Every plant and animal cell has a cell membrane and cytoplasm, and most have a nucleus. The cell membrane surrounds the cytoplasm and is partially permeable: it controls which substances can move into and out of the cell. The cytoplasm is a jelly-like substance filling most of the cell; it is the site of many chemical reactions, and the organelles are suspended within it. The nucleus controls the activities of the cell and contains the genetic material (DNA), which is passed on when the cell divides.

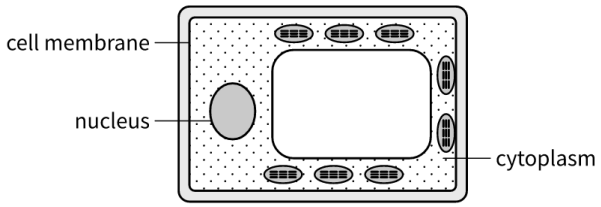
KEY IDEA

Cell membrane, cytoplasm and (in most cells) a nucleus are found in both plant and animal cells.

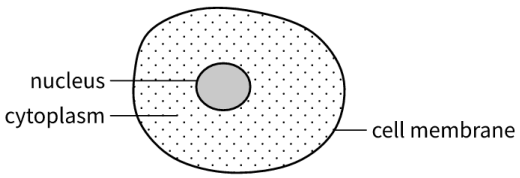
- A mature red blood cell is unusual: it loses its nucleus (covered later in this chapter).
- The nucleus is usually the largest structure easily seen under a light microscope.

WORDS TO KNOW

cell membrane	a thin, partially permeable structure surrounding the cytoplasm; controls the movement of substances into and out of the cell
cytoplasm	the jelly-like material filling the cell, in which the organelles are suspended and many chemical reactions take place
nucleus	the structure that controls the activities of the cell and contains the genetic material (DNA)



plant cell



animal cell

WORKED EXAMPLE

While viewing a partly damaged specimen under a light microscope, a laboratory assistant cannot make out a cell wall, a vacuole or chloroplasts anywhere in it. Name two other structures that should still be identifiable in this cell.

1. What is given: a cell with its plant-only structures not visible.
2. Biology idea: the cell membrane, cytoplasm and nucleus are present in (almost) every plant and animal cell, so they do not depend on the damaged structures.
3. Name two of these three structures.

The cell membrane (or its outline) and the nucleus (accept any two of cell membrane, cytoplasm, nucleus).

TRY THIS

If you set aside the cytoplasm, which other structure would you expect to find in both a plant cell and an animal cell?

Answer: Cell membrane (or nucleus).

CHAPTER 1

Practice Questions

Part 2: Cell Structure and Organisation



In the practice questions

23 questions, 75 marks. For each multiple-choice question, write the letter of the correct option (A, B, C or D) in the brackets. Write your other answers on the lines given. The answers are on page 353.

- Section A: Multiple-Choice Questions: 15 questions, 15 marks
- Section B: Structured Questions: 6 questions, 40 marks
- Section C: Free-Response Questions: 2 questions, 20 marks

Name: _____ Class: _____ Date: _____

SECONDARY 3 · BIOLOGY · CELL STRUCTURE AND ORGANISATION

Cell Structure and Organisation

INSTRUCTIONS

- 23 questions, 75 marks in total.
- Answer all questions in the spaces provided.
- For MCQs, write the letter (A, B, C or D) in the brackets.
- Write your other answers on the lines given, in full sentences.

Section A: Multiple-Choice Questions

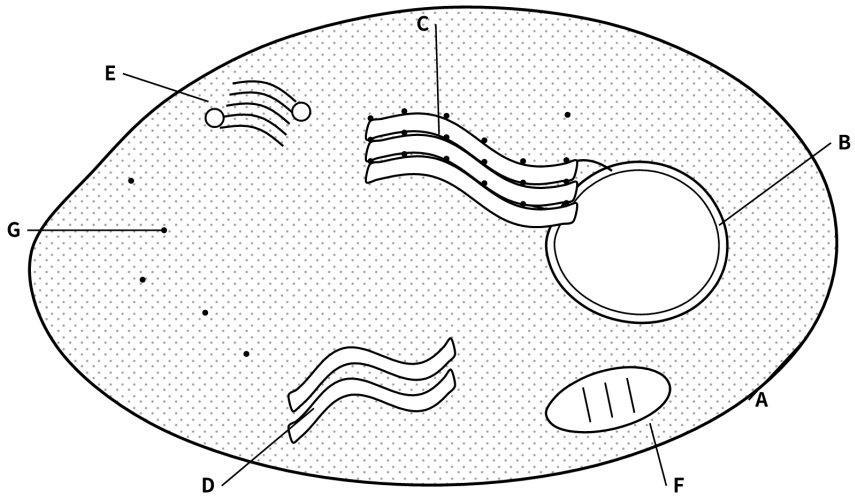
1 A certain structure inside a cell holds its DNA and directs everything the cell does. What is this structure called? ( ) [1]

(A) cytoplasm (B) cell membrane (C) nucleus (D) Golgi body

2 Water can cross a certain boundary around the cytoplasm much more easily than large dissolved substances can. Name this boundary and the term for this kind of permeability. ( ) [1]

(A) cell membrane; partially permeable (B) cell wall; rigid
(C) Golgi body; selective (D) vacuole; permeable

3 Four letters label organelles in the electron micrograph below. Identify the letter for the organelle that modifies, packages and secretes proteins in vesicles. ( ) [1]



Ⓐ B Ⓑ C Ⓒ F Ⓓ E

4 Under a microscope, a cell with an actual length of 20 μm produces an image 14 mm long. Work out the magnification used. ( ) [1]

Ⓐ ×7 Ⓑ ×700 Ⓒ ×70 Ⓓ ×7000

5 A cheek cell's nucleus is almost colourless until a certain dye is applied, after which it stands out clearly under a light microscope. Which dye is this? ( ) [1]

Ⓐ methylene blue Ⓑ iodine solution
Ⓒ Benedict's solution Ⓓ biuret solution

6 The table below shows four attempts by different lab groups to record one cell feature correctly for both a plant cell and an animal cell. Exactly one attempt is fully correct. Which row is it? ( ) [1]

Row	Feature	Plant cell	Animal cell
A	Large permanent vacuole	Absent	Present
B	Chloroplast	Absent	Present
C	Cell wall	Present	Absent
D	Nucleus	Absent	Present

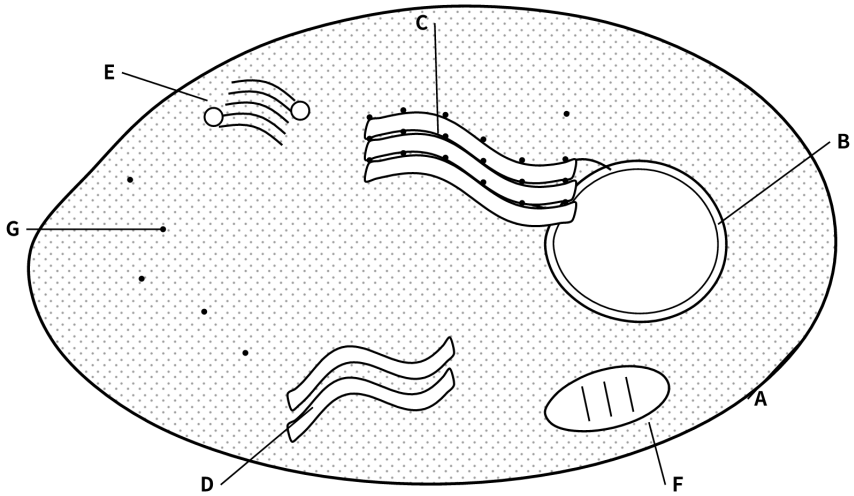
7 Which statements about the rough endoplasmic reticulum are correct?
1 studded with ribosomes
2 makes fats and is involved in detoxification
3 makes and transports proteins ( ) [1]

Ⓐ 1 and 2 only Ⓑ 1 and 3 only Ⓒ 2 and 3 only Ⓓ 1, 2 and 3

8 Compared with an ordinary epidermal cell, a root hair cell has one extra feature that speeds up its uptake of water and mineral salts. What is this feature? ( ) [1]

Ⓐ many mitochondria Ⓑ a thick cell wall
Ⓒ many chloroplasts Ⓓ a long, narrow extension of the cell

9 In the electron micrograph below, one organelle has no ribosomes on its surface and makes fats (lipids). Which letter labels it? ( ) [1]



Ⓐ C Ⓑ A Ⓒ D Ⓓ G

10 A specialised cell needs an unusually large number of mitochondria to release enough energy for repeated contraction. Which cell is this? ( ) [1]

Ⓐ muscle cell Ⓑ xylem vessel Ⓒ red blood cell Ⓓ root hair cell