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Chapter 1
Cell structure

Chapter outline

The questions in this chapter cover the following topics:

- the structure of animal, plant and bacterial cells, and of viruses
- the use of light microscopes and electron microscopes to study cells
- drawing and measuring cell structures
- the variety of cell structures and their functions
- the organisation of cells into tissues and organs

Exercise 1.1 Units for measuring small objects

Cells are small, and the organelles that they contain are sometimes very, very small. In this exercise, you will practise converting between the different units that we use for measuring very small objects. You will also make sure that you are able to write numbers in standard form.

1 The units that we use when measuring cells are millimetres (mm), micrometres (µm) and nanometres (nm).

Copy and complete:

a 1 µm = 1000 nm = $10^{......}$ nm

b 1 nm = ... µm = $10^{......}$ µm

c 1 nm = ... mm = $10^{......}$ mm

TIP

1 mm = 1000 µm
= 10^3 µm
So 1 µm = 1/1000 mm
= 10^{-3} mm

Standard form is a way of writing down large or small numbers simply. The rules are:

- Write down the digits as a number between 1 and 10.
- Then write × $10^{\text{power of the number}}$.

To work out the correct power, imagine moving the decimal point to the right or left, until you get a number between 1 and 10. Count how many moves you have to make, and that is the power of ten you should write.

For example, if your number is 4297, you would move the decimal point like this:

4.297

So we write this number as 4.297×10^3.

Here are some examples of writing large numbers in standard form:
$6000 = 6 \times 10^3$
$6248 = 6.248 \times 10^3$
$82\,910 = 8.291 \times 10^4$
$547.5 = 5.475 \times 10^2$

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2 Write these numbers in standard form:

a 5000

b 63

c 63 000

d 63 497

e 8521.89

Here are some examples of writing small numbers in standard form:

$0.678 = 6.78 \times 10^{-1}$

$0.012 = 1.2 \times 10^{-2}$

$0.0057 = 5.7 \times 10^{-3}$

3 Write these numbers in standard form:

f 0.1257

g 0.0006

h 0.0104

4 A cell measures 0.094 mm in diameter.

a Convert this to micrometres.

b Express this value in standard form.

5 A cell organelle is 12 nm long.
Express this value in µm, in standard form.

6 A mitochondrion is 1.28×10^{2} µm long.
Express this value in nm.

7 A chloroplast is 2.7×10^{3} nm in diameter.
Express this value in µm.

Exercise 1.2 Magnification calculations

This exercise will help you to gain confidence in doing magnification calculations, as well as providing further practice in using different units and converting numbers to standard form. You will also need to think about selecting a suitable number of significant figures to give in your answers. In general, you should use the same number of significant figures as there are in the value with the smallest number of significant figures that you used in your calculations.

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$

TIP
Remember – magnification has no units.

1 A light micrograph of a plant cell shows the cell to be 5.63 cm long. The real size of the cell is 73 µm. Follow the steps to find the magnification of the micrograph.

Step 1 Convert 5.63 cm to µm.

Step 2 Substitute into the magnification equation:

magnification = ――――――

Step 3 Calculate the magnification. Write the answer as ×................

2 An electron micrograph of a nucleus shows it to be 44 mm in diameter. The actual diameter of the nucleus is 6 µm. Calculate the magnification of the electron micrograph.

3 An electron micrograph of a **mitochondrion** shows its diameter as 28 mm. The magnification of the image is given as ×22 700. Follow the steps to find the actual diameter of the mitochondrion.

Step 1 Convert 28 mm to μm.

Step 2 Rearrange the magnification equation, and then substitute into it:

$$\text{actual size} = \frac{\text{image size}}{\text{magnification}}$$

$$= \underline{\hspace{3cm}}$$

Step 3 Calculate the actual diameter of the mitochondrion. Remember to give your answer to the same number of significant figures as the value with the smallest number of significant figures that you used in your calculation.

4 An image of a **chloroplast** in an electron micrograph is 36 mm long. The magnification of the micrograph is ×1285. Calculate the actual length of the chloroplast.

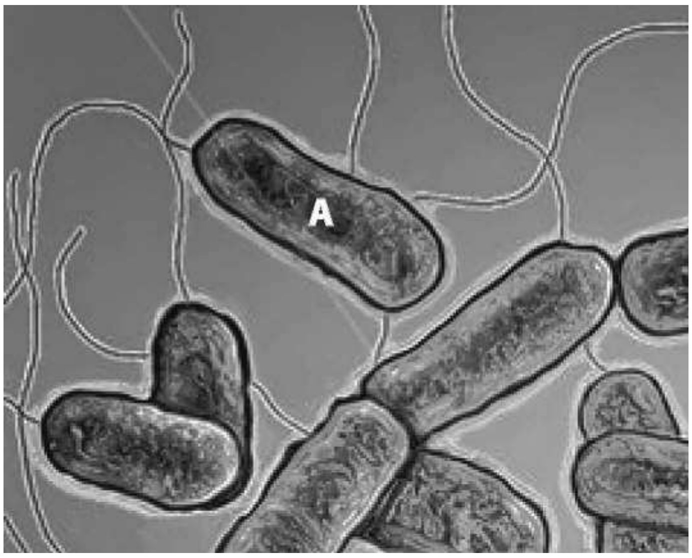

Figure 1.1 Micrograph of *Legionella* bacteria.

5 The micrograph shows a group of *Legionella* bacteria. The image has been magnified ×980.

a Measure the maximum length of bacterium **A**.

b Calculate the actual length of this bacterium. Show all the steps in your working.

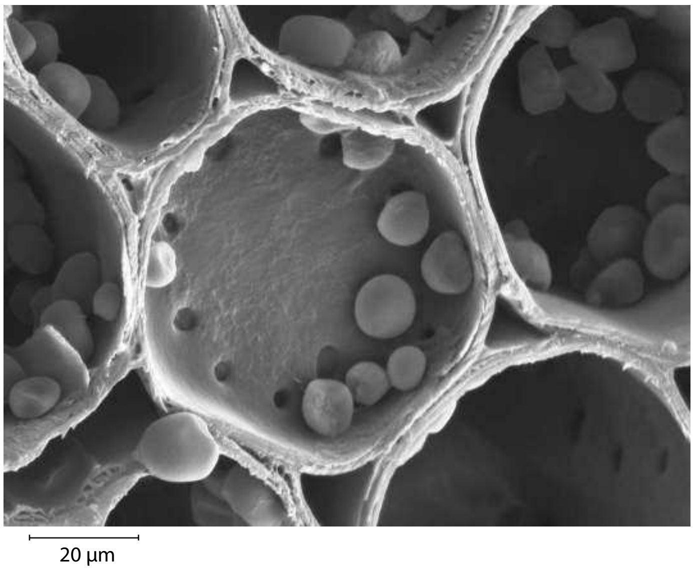

Figure 1.2 Micrograph of plant cells with starch grains.

6 The micrograph shows some plant cells containing starch grains. There is a scale bar beneath the image.

a Measure the length of the scale bar in mm.

b Convert this measurement to μm.

c Use this image size of the scale bar, and the actual size that we are told it represents, to calculate the magnification of the image.

d Measure the maximum diameter of the central cell in the micrograph.

e Use the value of the magnification you have calculated to find the actual diameter of this cell.

7 The micrograph shows a cell from the **pancreas** of a mammal. Several mitochondria are visible.

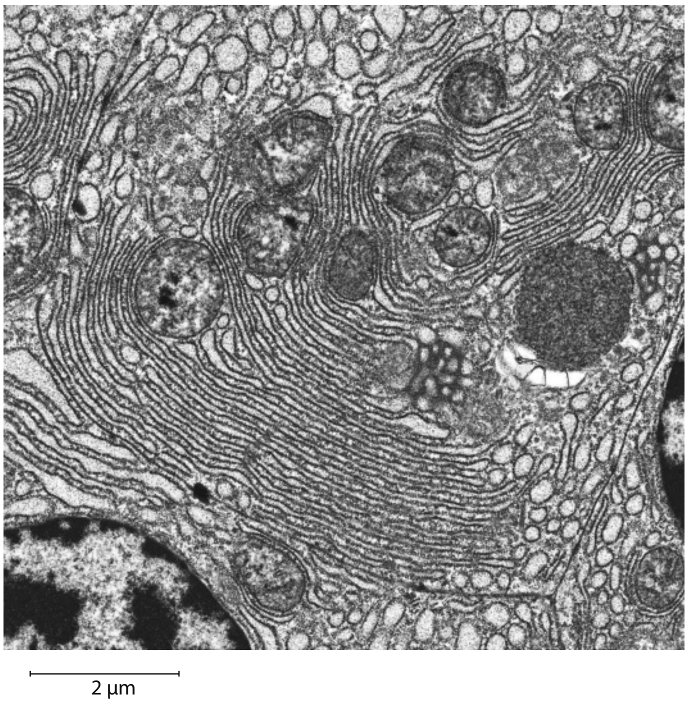

Figure 1.3 Micrograph of a cell from the pancreas.

Use the scale bar to calculate the actual diameter of the largest mitochondrion.

Exercise 1.3 Drawing from light micrographs

Being able to draw good diagrams from micrographs, or from what you can see when using a microscope, is nothing to do with being good at art. Your task as a biologist is to make a clear, simple representation of what you can see. Use a sharp, medium hard (e.g. HB) pencil and have a good eraser to hand. Each line should be clean and not have breaks in it – unless there really are breaks that you want to represent.

1 This drawing was made by a student from the electron micrograph of the plant cells shown in the micrograph Figure 1.2 in Exercise 1.2.6.

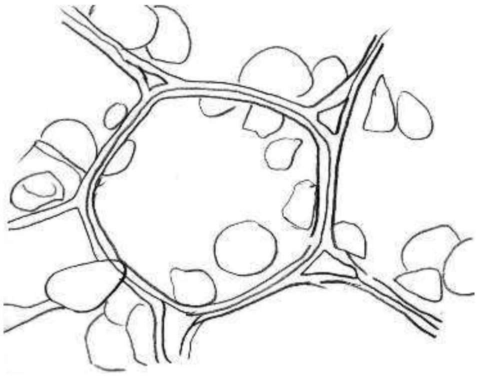

Figure 1.4 Student's drawing of plant cells.

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a Use these criteria to assess the quality of the student's drawing. Copy the table, and put a tick in one box in each row. You could also add a brief comment explaining why you made each decision.

Feature	Done very well	Done fairly well	Poorly done
suitably large diagram – makes good use of space available but does not extend over any text			
clean, clear, continuous lines			
overall shape and proportions look approximately correct			
correct number of starch grains shown, each carefully drawn the right shape and size			
relative sizes of starch grains and cell size correctly shown			
no shading has been used			
good and correct detail of cell walls shown			

b Now make your own drawing of the cells shown in the same electron micrograph, Figure 1.2, taking care to meet all of the criteria fully.

2 The micrograph in Figure 1.5 shows a **lymphocyte**, a type of white blood cell found in mammals.

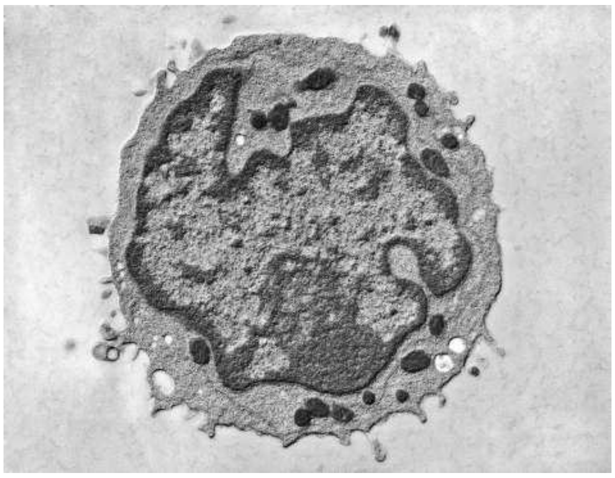

Figure 1.5 Micrograph of lymphocyte.

a Make a drawing of the lymphocyte.

b Construct a list of criteria for your drawing, using the criteria from 1.3.1a as a guide.

c Assess the standard of your drawing against your criteria. Alternatively, or as well, you could exchange your drawing with a partner, and assess each other's drawings.

d The magnification of the micrograph of the lymphocyte is ×4750.

Calculate the actual diameter of the lymphocyte. Give your answer in µm, using standard form.

e Use your answer to **d** to calculate the magnification of your drawing.

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Exercise 1.4 Electron microscopes and optical (light) microscopes

The micrographs in this chapter have been made using different kinds of microscopes. In this exercise, you will practise identifying features that distinguish images taken with different types of microscope, and then summarise the differences between what we can see using optical (light) microscopes and electron microscopes.

1 Copy and complete this table. In the 'type of microscope' column, choose from optical microscope, transmission electron microscope or scanning electron microscope.

Micrograph	Type of microscope used to produce the micrograph	Reason for your decision
Figure 1.2		
Figure 1.3		
Figure 1.5		

2 Copy and complete this table, to compare what can be seen in typical animal cells and plant cells using optical microscopes and electron microscopes. Put a tick or a cross in each box.

Organelle	Visible in plant cells		Visible in animal cells	
	Visible using optical microscope	Visible using electron microscope	Visible using optical microscope	Visible using electron microscope
nucleus				
mitochondrion				
membranes within mitochondrion				
Golgi body				
ribosomes				
endoplasmic reticulum				
chloroplast				
internal structure of chloroplast				
centriole				

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Exercise 1.5 Using an eyepiece graticule and stage micrometer

An eyepiece graticule, calibrated using a stage micrometer, enables you to work out the actual size of objects you can see using a microscope. This exercise provides practice in this technique, and also involves decisions about how many significant figures to give in your answers.

An eyepiece graticule is a tiny piece of glass or plastic that you can put into the eyepiece of a microscope.

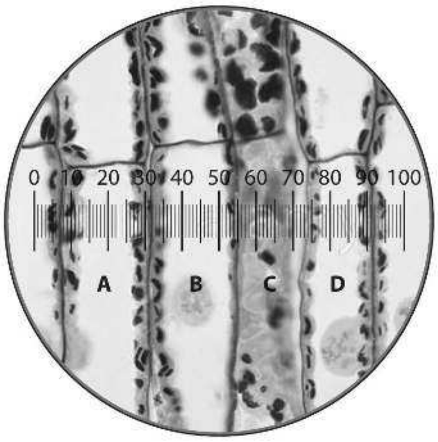

Figure 1.6 Micrograph of palisade cells seen using an eyepiece graticule.

Figure 1.6 shows a group of palisade cells, as they look through a light microscope with an eyepiece graticule. The highest power objective lens of the microscope is being used.

The small divisions on the graticule scale can be referred to as 'graticule units'. Measure the total width of the four palisade cells **A**, **B**, **C** and **D** in graticule units.

> **TIP**
> When you are doing this using your own microscope, you will need to swivel the eyepiece and/or move the slide, so that your eyepiece graticule scale lies neatly over the thing you want to measure.

In order to find out the true size represented by one eyepiece graticule unit we now need to calibrate the eyepiece graticule using a stage micrometer. This is a slide that is accurately marked off in small divisions of 0.01 mm.

Figure 1.7 shows what is seen when the slide with the palisade cells is replaced on the microscope stage by a stage micrometer.

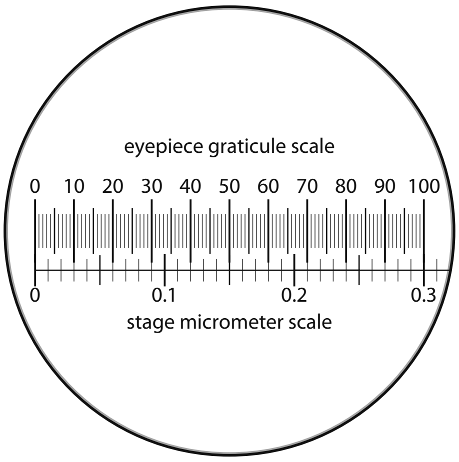

Figure 1.7 Stage micrometer seen using an eyepiece graticule.

> **TIP**
> It's essential to use the same objective lens – the one that you used when you measured the palisade cells in eyepiece graticule units. Again, you may need to swivel the eyepiece, and move the slide on the stage, to get them lined up against one another.

1 **a** Look for a good alignment of marks on the two scales, as far apart as possible. The 0s of both scales match up, and there is another good match at 80 small divisions on the eyepiece graticule.

How many small divisions on the micrometer equal 80 small divisions on the eyepiece graticule?

b Remember that one small division on the micrometer is 0.01 mm. Use your answer to **a** to calculate how many micrometres (μm) are represented by one small division on the eyepiece graticule.

c Use your answer to **b** to find the total width of the four palisade cells in the micrograph.

d Now calculate the mean width of a palisade cell.

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2 Explain why it is not possible to see both the palisade cells and the stage micrometer scale at the same time.

3 Figure 1.8 shows a light micrograph of some villi in the small intestine, seen using an eyepiece graticule.

Figure 1.9 shows the same eyepiece graticule, using the same objective lens, but this time with a stage micrometer on the microscope stage.

Use the two images to calculate the length of the villus that can be seen beneath the eyepiece graticule. Show each step in your working.

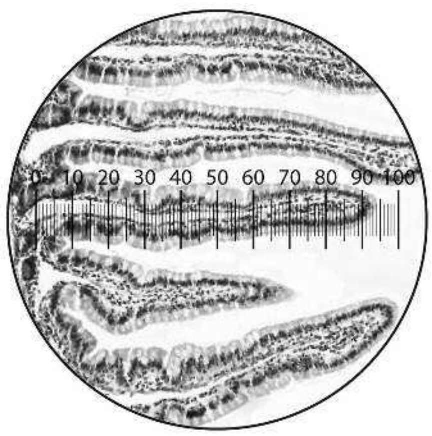

Figure 1.8 Light micrograph of villi seen using an eyepiece graticule.

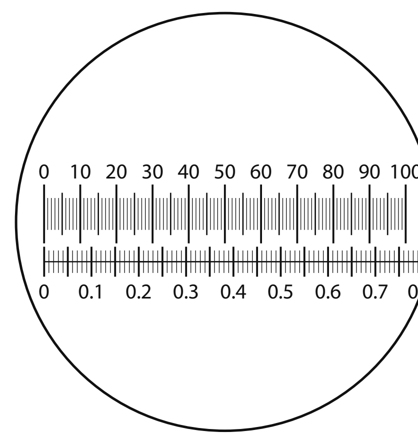

Figure 1.9 Stage micrometer seen using an eyepiece graticule.

Exercise 1.6 Membranes in different types of cells

Most cells in multicellular organisms become specialised for a particular set of functions. In this exercise, you will consider data relating to the membranes in two different types of cell, and use your biological knowledge to suggest explanations for patterns that you can pick out in these data.

All cells are surrounded by a **cell surface membrane**, and also contain many other membranes within them. Researchers estimated the total quantity of membranes in 20 liver cells and 20 exocrine pancreas cells, and then calculated the percentage of these membranes in all the different membrane-containing structures in the cells. Their results are shown in the table.

Source of membrane	Mean percentage of all membranes	
	Liver cells	Exocrine pancreas cells
cell surface membrane	1.8	4.7
mitochondrial membranes	39.4	22.3
nuclear membrane	0.5	0.7
rough endoplasmic reticulum	33.4	61.9
smooth endoplasmic reticulum	16.3	0.1
Golgi apparatus	7.9	10.3
lysosomes	0.4	0
other small vesicles	0.3	0

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1 Explain why we *cannot* use these results to draw the conclusion that the mean quantity of cell surface membrane in liver cells is less than that in exocrine pancreas cells.

2 Which of the sources of membranes listed in the table are made up of two membranes (an envelope)?

3 Using the data in the table, state the organelle that contains the greatest mean percentage of membrane in:

a liver cells

b pancreas cells.

4 Liver cells have a wide variety of functions in metabolism, including synthesising proteins, breaking down toxins, synthesising cholesterol and producing bile. Exocrine pancreas cells have a single main role, which is the production and secretion of digestive enzymes.

Use this information to suggest explanations for the differences between the percentages for mitochondria and rough endoplasmic reticulum in the liver cells and the pancreas cells.

Exercise 1.7 Command words

In examinations, you will only rarely see a question that ends with a question mark. Almost all questions start with a word that tells you what to do. These are called command words. It is extremely important that you identify the command word in each question part, and understand what it means. If you don't do what the command word asks, you are likely to get few, or perhaps no, marks for your answer.

1 Some of the command words used in examination questions are listed below:

describe	**explain**	**discuss**	**list**	**suggest**
outline	**name**	**state**	**deduce**	**define**

Match each description with the correct command word:

a Give a concise answer, with no supporting argument.

b Give a formal statement, possibly one that you have learnt by heart.

c Write an account to help someone else to 'see' something you are looking at, e.g. a graph; or give a step-by-step account of a structure or process.

d Work out an answer from information you have been given.

e Give the technical term, e.g. for a structure or a process.

f Give a brief account, picking out the most important points and omitting detail.

g Give reasons; use your knowledge of biology to say why or how something happens.

h State points on both sides of an argument, e.g. reasons for and against a particular viewpoint, or how a set of results could be interpreted to support or reject a hypothesis.

i Use information provided, and your biological knowledge, to put forward possible answers; there is often more than one possible correct answer.

j State, very briefly, a number of answers to the question; if a particular number is asked for, you should give exactly that number of answers.

Exam-style questions

This is a straightforward question that relies on your recall of facts and concepts. You could answer part **b** either in words, or by using a labelled diagram. Note that the command word for **b** is 'outline'.

1 The table below lists some features of prokaryotic and eukaryotic cells.

Feature	Prokaryotic cell	Eukaryotic cell
cell surface membrane		
nucleus		
ribosomes		
mitochondria		
chloroplasts		

a Copy and complete the table. If a feature can be present in the cell, write a tick in the box. If it cannot be present, write a cross. You should write either a tick or a cross in each box. [5]

b Viruses are not usually considered to be living organisms and are not made of cells. Outline the key features of the structure of a virus. [2]

[Total: 7 marks]

This question asks you to identify structures within an animal cell. You should find this relatively straightforward, although you may have to think carefully about part **b**.

2 The diagram is a drawing of a cell from the body of a mammal.

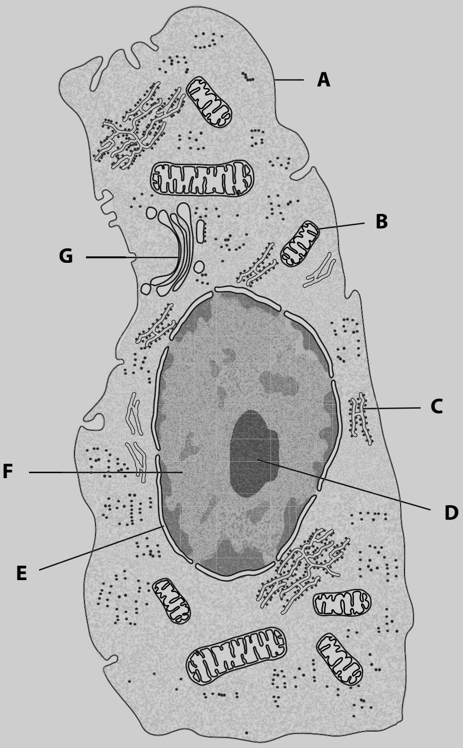

Figure 1.10 Diagram of a micrograph of a mammalian body cell.

a State the type of microscope that would be used to allow this amount of detail to be seen in the cell. [1]

b List the letters of the structures in the drawing which are made up of, or are surrounded by, phospholipid membranes. [3]

c Describe the functions of :

i structure **B** [2]

ii structure **E** [2]

iii structure **G**. [2]

[Total: 10 marks]

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3 The diagram shows a method for separating the different components of cells. This technique is called ultracentrifugation.

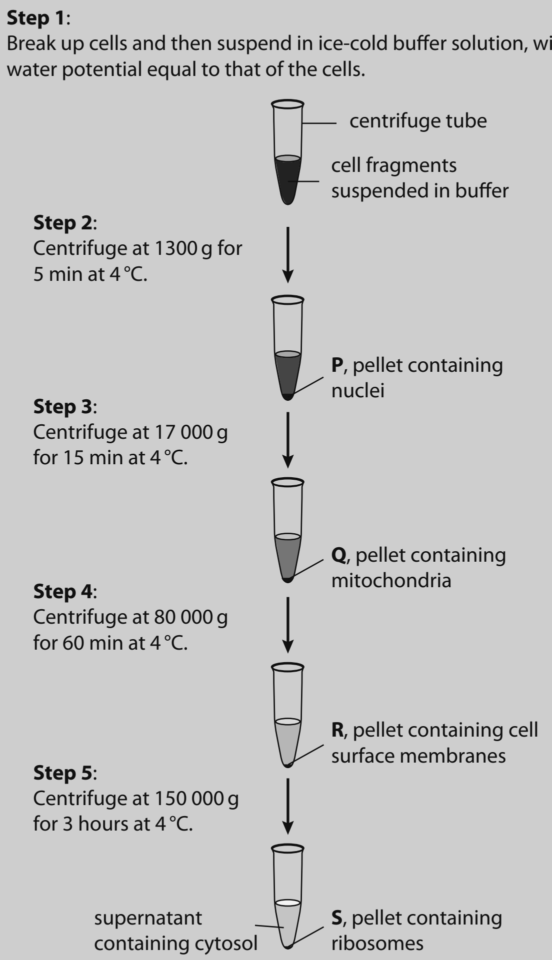

Figure 1.11 Ultracentrifugation.

a Suggest why the solution in which the broken-up cells were suspended:

i was ice-cold [1]

ii contained a buffer [2]

iii had the same water potential as the cells. [2]

b Suggest why ribosomes do not collect in the pellet until the final stage of the ultracentrifugation. [1]

c Give the letter of the component or components in which you would expect to find:

i DNA [1]

ii phospholipids. [1]

d If this process were carried out using plant cells, which other cell organelles might you expect to find in the pellet containing mitochondria? Explain your answer. [2]

[Total: 10 marks]

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Examination questions often contain something new, such as an unfamiliar micrograph. But a combination of your own knowledge and the information in the question should help you work out suitable answers. Look carefully at the mark allocations, which guide you in how detailed an answer you need to give.

4 The photograph shows a micrograph of parts of two cells from the small intestine of a mammal. The structures along the facing surfaces of the two cells are microvilli.

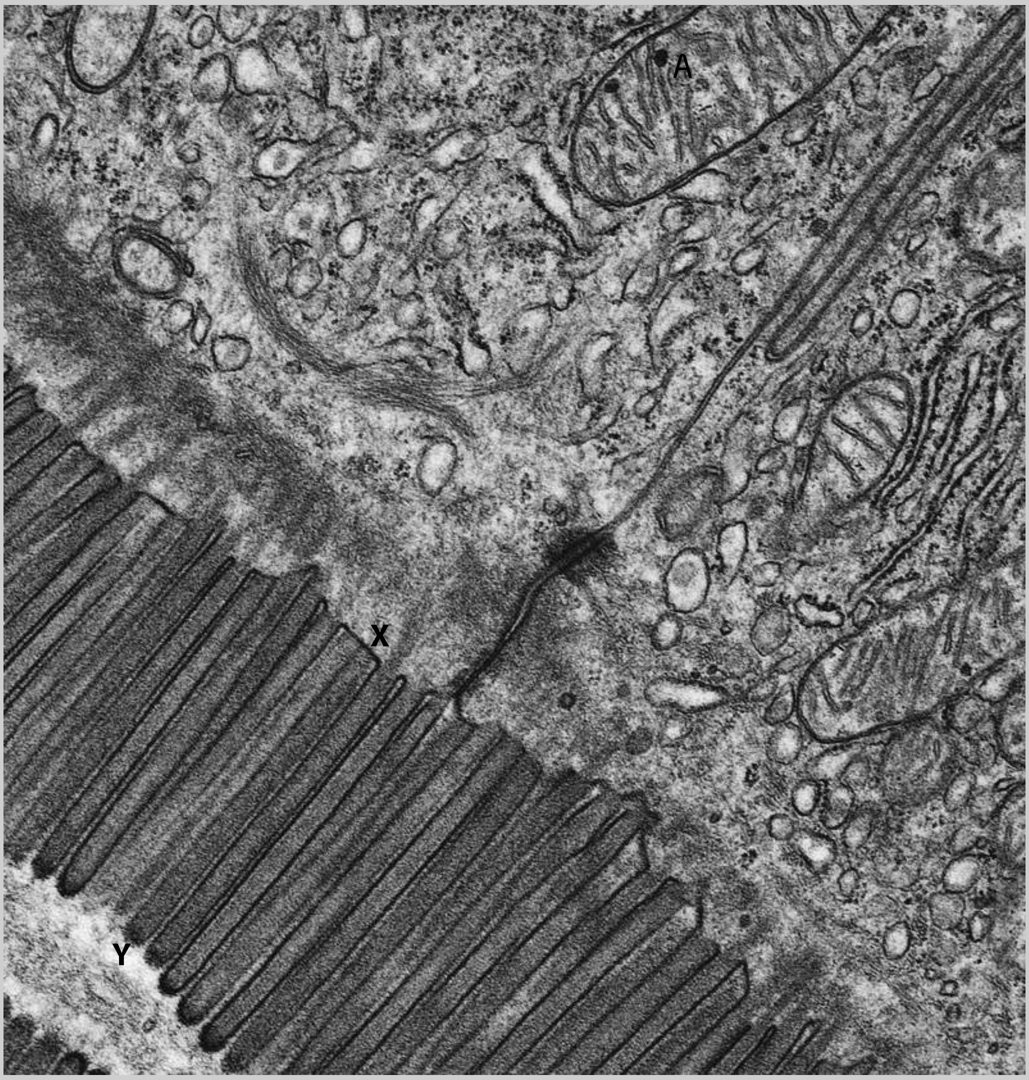

Figure 1.12 Micrograph of cells from the small intestine.

a State the type of microscope that was used to obtain this micrograph. Give a reason for your answer. [2]

b Identify organelle **A**. [1]

c **i** The magnification of the micrograph is × 12 500. Calculate the length of the microvillus between points **X** and **Y**. Show your working. [3]

ii Microvilli greatly increase the surface areas of the cells. Suggest why the cells lining the small intestine have microvilli. [2]

[Total: 8 marks]

