Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Two steps with a microscope

ANSWER A · 4

i. Length = 30 mm ÷ 15,000 = 0.002 mm = **2 µm**. Width = 12 mm ÷ 15,000 = 0.0008 mm = **0.8 µm**.
ii. 60 µm ÷ 2 µm = **30 mitochondria**.
iii. 5 mm = 5,000 µm = 5,000,000 nm. Magnification = 5,000,000 nm ÷ 25 nm = **200,000×**.
iv. 60 µm × 200,000 = 12,000,000 µm = 12,000 mm = **12 m**. Not on any ordinary poster: he can show the ribosome or the whole cell at one scale, not both.

MARKING SCHEME

✓ Real size 2 µm by 0.8 µm.
✓ 30 mitochondria.
✓ Magnification 200,000×.
✓ 12 m across, so it can't fit: the two sizes are too far apart for one scale.

2 A flat cell and a cube

ANSWER A · 4

i. Volume of P = 60 × 60 × 1 = **3,600 µm³**. Side of Q = $\sqrt[3]{3{,}600}$ = **15.3 µm**.
ii. Surface of P = 2 × (60 × 60 + 60 × 1 + 60 × 1) = 2 × 3,720 = 7,440 µm², so its ratio = 7,440 ÷ 3,600 = **2.07 per µm**. For Q, ratio = 6 ÷ a = 6 ÷ 15.3 = **0.39 per µm**.
iii. **P**, by about 2.07 ÷ 0.39 = **5 times**.
iv. In a flat cell nothing inside is far from the surface, so food and oxygen coming in through the surface can reach every part, however wide the cell is. It is the short distance from surface to middle that counts.

MARKING SCHEME

✓ 3,600 µm³ and side 15.3 µm.
✓ Ratios 2.07 and 0.39 per µm.
✓ P, about 5 times.
✓ Every part of a flat cell is close to the surface.

3 Cut one big cell into small ones

ANSWER A · 3

i. Volume 10^3 = 1,000 µm³ and each small cell is 1 µm³, so **1,000 cells**.
ii. Before: 6 × 10^2 = **600 µm²**. After: 1,000 × 6 × 1^2 = **6,000 µm²**, ten times as much.
iii. The same amount of living material has ten times the surface to take in food and oxygen and let out wastes, so none of it starves.

MARKING SCHEME

✓ 1,000 cells.
✓ 600 µm² before and 6,000 µm² after.
✓ The same volume has far more surface to supply it.

4 Predict, then explain

ANSWER

	E. coli	**a yeast cell**	**a human cell**
A drug that stops peptidoglycan being made	harmed	not harmed	not harmed
A drug that jams 70S ribosomes	harmed	harmed only in part (its mitochondria)	harmed only in part (its mitochondria)

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Peptidoglycan is found only in bacteria: a yeast's wall is chitin and a human cell has no wall. The 80S ribosomes in the cytoplasm of yeast and human cells carry on, but their mitochondria have 70S ribosomes, so the second drug can harm them there, which is the reason for some antibiotics' side effects. A · 4

MARKING SCHEME

- ✓ First row: only *E. coli* harmed.
- ✓ Second row: *E. coli* harmed; eukaryotic cells' cytoplasmic ribosomes not affected.
- ✓ Yeast's wall is chitin and human cells have no wall, so they don't need peptidoglycan.
- ✓ Mitochondria have 70S ribosomes, so the eukaryotic cells can be harmed there.

5 Reading an experiment

ANSWER HA · 4

(The numbers are made up, in the pattern of George Palade's experiment described in the unit.)

i. Rough ER → Golgi body → vesicles (and then out of the cell).

ii. At 3 minutes 85% of the protein is already in the rough ER, when the Golgi body has only 10%. As the Golgi body's share rises, the rough ER's falls (85% to 40%), so the protein is being passed on to the Golgi body from the rough ER, where it was made.

iii. The nucleus: the gene must first be copied into messenger RNA, which goes out to the ribosomes on the rough ER.

iv. So that only the protein made in those few minutes is labeled, and it can be followed as one batch. If they were fed all the time, new labeled protein would keep appearing in the rough ER and would hide the movement.

MARKING SCHEME

- ✓ Rough ER, then Golgi body, then vesicles.
- ✓ Claim wrong: the rough ER already has 85% at 3 minutes, and its share falls as the Golgi body's rises.
- ✓ The nucleus, which sends out the RNA copy of the gene.
- ✓ A short feed labels one batch, which can be followed.

6 What if?

ANSWER A · 4

i. The enzyme is made in the rough ER but isn't finished, packed or sent out, so it can't be secreted.

ii. New lysosomes can't be made, since the Golgi body makes them, so the bacterium stays undigested.

iii. No vesicles gather across the middle, so no cell plate forms and no new wall separates the two daughter cells.

iv. No acrosome forms, so the sperm lacks the cap of enzymes with which it enters the egg.

MARKING SCHEME

- ✓ Enzyme not packed or secreted.
- ✓ No new lysosomes, so no digestion of the bacterium.
- ✓ No cell plate, so no new wall.
- ✓ No acrosome, so the sperm can't enter the egg.

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7 Which explanation fits the evidence?

ANSWER HA · 3

i. A smooth disc cap, the cap of the base's species. The nucleus is in the base, so this supports **Reshma**.
ii. A single graft could have been a quirk of one species, for example if disc caps always won. The other way round, a disc-cap stalk on a rayed-cap base finally grew a rayed cap, so it is the nucleus's species that decides each time, whichever it is.
iii. Substances sent out into the cytoplasm, which we now know as RNA.

MARKING SCHEME

✓ A disc cap, the base's species: Reshma's explanation.
✓ The reverse graft gives a rayed cap, so the result follows the nucleus, not one species.
✓ RNA.

8 Correct the misconceptions

ANSWER U · 4

1. Bacteria do have ribosomes (70S), and make proteins with them. What they lack are membrane-bound organelles.
2. Plant cells have both chloroplasts and mitochondria, and every living cell respires day and night.
3. The wall is fully permeable. The cell membrane, which is selectively permeable, decides what enters.
4. Chlorophyll is in the thylakoid membranes of the grana, where light is trapped. The stroma is where sugar is made.

MARKING SCHEME

✓ Bacteria have 70S ribosomes; only membrane-bound organelles are missing.
✓ Plant cells have mitochondria too and respire day and night.
✓ The wall is fully permeable; the membrane decides.
✓ Chlorophyll is in the thylakoids, not the stroma.

9 Weigh up the evidence

ANSWER HA · 3

Two membranes alone prove little. A mitochondrion also has its own circular DNA and 70S ribosomes like a bacterium's, is about a bacterium's size, and divides by splitting. The nucleus's DNA is in several straight chromosomes wound round histones, and it has no 70S ribosomes of its own, so the case for it is much weaker. A lysosome is no better: it has one membrane and no DNA, and it is made by the Golgi body.

MARKING SCHEME

✓ Two membranes alone aren't enough; the theory rests on several pieces of evidence together.
✓ The nucleus lacks the circular DNA and 70S ribosomes that a mitochondrion has.
✓ A lysosome is no better: a single membrane, no DNA, made by the Golgi body.

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10 Design a fair test

ANSWER A · 4

i. She changes the temperature of the water (for example about 20, 40, 60 and 80 °C) and compares how red the water turns.
ii. Any three: the size of the cubes; the same beetroot; the same amount of water; the same time in the water (10 minutes); the same rinsing.
iii. Cutting breaks open some cells, and their pigment would color the water whatever the temperature. Rinsing removes it, so any color that comes later has leaked through the membranes of whole cells.
iv. The hotter the water, the redder it turns after the same time.

MARKING SCHEME

✓ Changes the temperature; compares the color of the water.
✓ Any three things kept the same.
✓ Rinsing removes pigment from cut cells, which would spoil the comparison.
✓ The water gets redder as the temperature rises.

11 Estimate it

ANSWER A · 3

Cell: $2 \times 0.8 \times 0.8 = 1.28\ \mu m^3$.
One ribosome: 25 nm = 0.025 µm, so $(0.025)^3 = 1.56 \times 10^{-5}\ \mu m^3$.
All of them: $20{,}000 \times 1.56 \times 10^{-5} = 0.31\ \mu m^3$.
Fraction = $0.31 \div 1.28 \approx 0.24$, **about a quarter**. Yes, it is fair: a quarter of the cell's space is taken by one kind of part. (This is only an estimate: the shapes are rough.)

MARKING SCHEME

✓ Volumes $1.28\ \mu m^3$ and $1.56 \times 10^{-5}\ \mu m^3$ (25 nm as 0.025 µm).
✓ 20,000 ribosomes fill about $0.31\ \mu m^3$.
✓ About a quarter, so "packed" is fair.

12 Think

ANSWER HA · 3

i. No. Division starts with the nucleus copying its DNA, and it has neither nucleus nor DNA.
ii. Only from the first step of respiration, the splitting of glucose in the cytoplasm (glycolysis), which needs no mitochondria and gives far less ATP.
iii. Ribosomes make proteins by reading messenger RNA, the copies of genes sent out from the nucleus. With no nucleus, no new copies come, so it lives only as long as its parts last.

MARKING SCHEME

✓ Can't divide: no nucleus, no DNA to copy.
✓ ATP only from glycolysis in the cytoplasm, much less than with mitochondria.
✓ No nucleus, so no new messenger RNA for the ribosomes to read.

13 Make your own

ANSWER HA · 3

For example: much **smooth ER**, which makes steroid hormones; many **mitochondria**, for the ATP that making and swimming need; a **flagellum** with a basal body from a centriole, for swimming. It can do with little rough ER, since its product is a lipid, not a protein to be secreted. (Accept any answer that fits a part to its job as the unit describes; a Golgi body to send the product out is also good.)

MARKING SCHEME

✓ Smooth ER for steroids.
✓ Mitochondria for ATP, and a flagellum for swimming.
✓ Little rough ER (or another sensible part), with a reason.

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See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Animal Cell Model** (exhibit): Find the nucleus and the mitochondria, each inside its own membrane: this is a eukaryotic cell. A bacterium, a prokaryote, has neither.
- **Plant Cell Model** (exhibit): Find the cell wall outside the cell membrane, and the chloroplast; then check which of the two cell models has centrioles.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	4	26	16	**46**

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