Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS

B400U10-1

S18-B400U10-1

BIOLOGY – AS component 1
Basic Biochemistry and Cell Organisation

THURSDAY, 24 MAY 2018 – AFTERNOON

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**6**	
2.	**12**	
3.	**9**	
4.	**21**	
5.	**18**	
6.	**9**	
Total	**75**	

B400U101
01

ADDITIONAL MATERIALS

In addition to this paper you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of quality of extended response (QER) will take place in question **6**.

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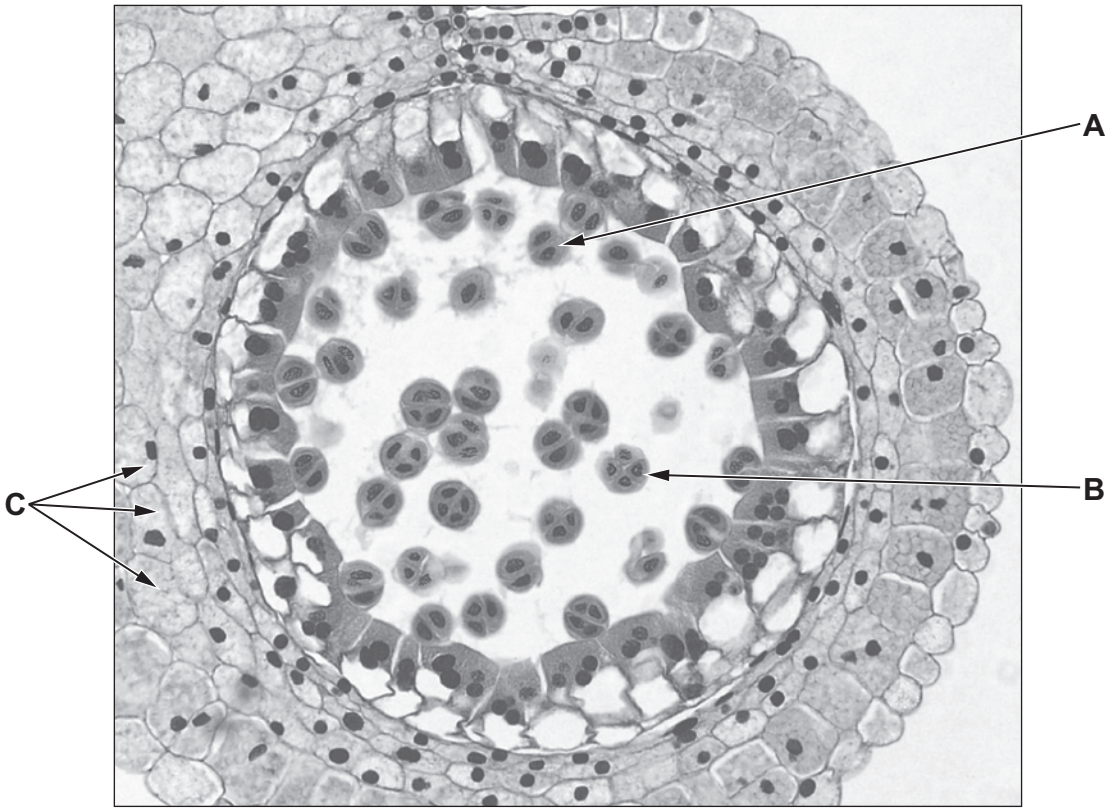
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Answer **all** *questions.*

1. Mitosis and meiosis are both forms of nuclear division. Both types of nuclear division are involved in the production of gametes.

(a) Image **1** below shows a section through part of an anther of *Lilium sp.* showing stages in the production of pollen grains.

Image 1



(i) It was concluded that structure **A** had just completed meiosis I and structure **B** had just completed meiosis II. Explain how you would draw these conclusions from the photomicrograph. [1]

A has two cells (nuclei) so it is the result of one division (meiosis I);

B has four, so it results from two divisions (meiosis II).

(ii) The cells labelled **C** are in interphase. Explain why nuclei are only visible in some cells and, where nuclei are visible, why they appear to be of different sizes. [2]

The plane (angle) of the section may not pass through the nucleus of some cells, so no nucleus is seen.

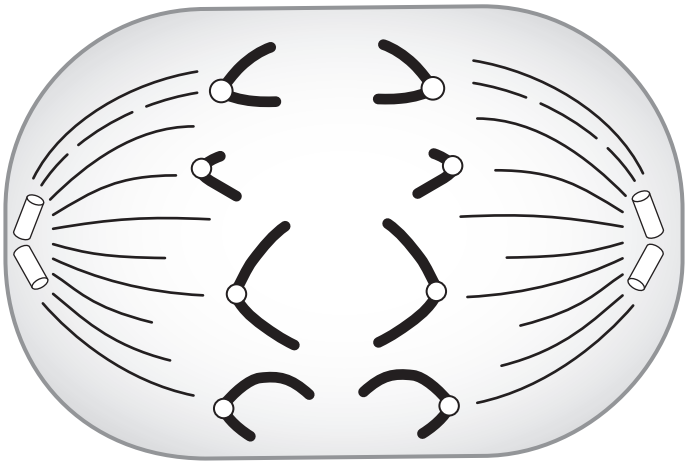
Where nuclei are visible they have been cut at different levels (planes), so they appear to be different sizes.

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(b) A drawing was made of an animal cell during anaphase. The diploid number in this cell is eight.



Deduce whether this cell is undergoing anaphase of mitosis, anaphase I of meiosis or anaphase II of meiosis. Explain your answer. [3]

Anaphase II of meiosis.

There are only four chromosomes moving to each pole, so the resulting cells are haploid (one copy of each chromosome); in mitosis each pole would receive two copies of each chromosome (homologous pairs, 8 chromosomes).

In anaphase I each chromosome would still have two chromatids, but here sister chromatids are being separated, which happens in anaphase II.

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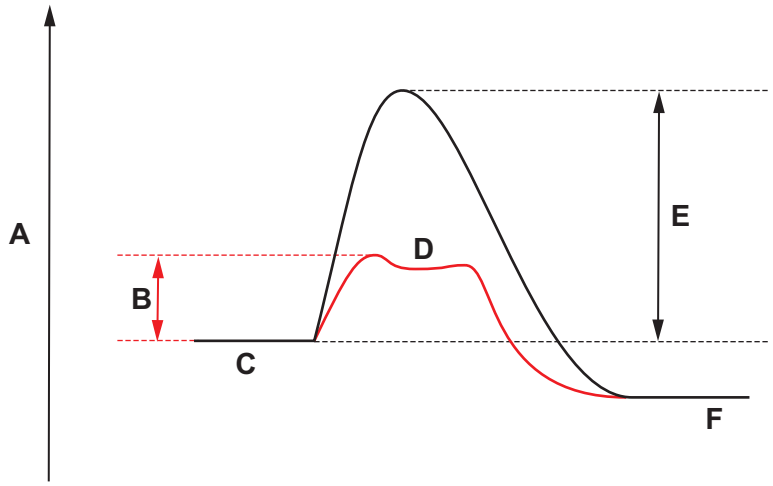
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2. Enzymes catalyse reactions by lowering the activation energy of a reaction. This is shown in the graph below.



(a) Using letters from the graph, identify the following: [2]

- the energy level of the products of an enzyme catalysed reaction ..... F .....
- the activation energy of an enzyme catalysed reaction ..... B .....
- the energy level of an enzyme-substrate complex ..... D .....

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(b) Adenylate kinase (ADK) is a globular protein that acts as an enzyme involved in the regeneration of ATP in muscle. There are several types of this enzyme. One form catalyses the following reaction:

$$2ADP \longrightarrow AMP + ATP$$

(AMP = adenosine monophosphate)

(i) Suggest why the activity of ADK would be an advantage to muscle. [1]

ATP can be regenerated quickly, so more ATP is available for muscle contraction.

(ii) The 'lock and key' model of enzyme action was first proposed in 1894 by Emil Fischer and provides a simple explanation of how enzymes and substrates interact. However, ADK interacts with its substrates by the induced fit mechanism proposed in 1958 by Daniel Koshland.

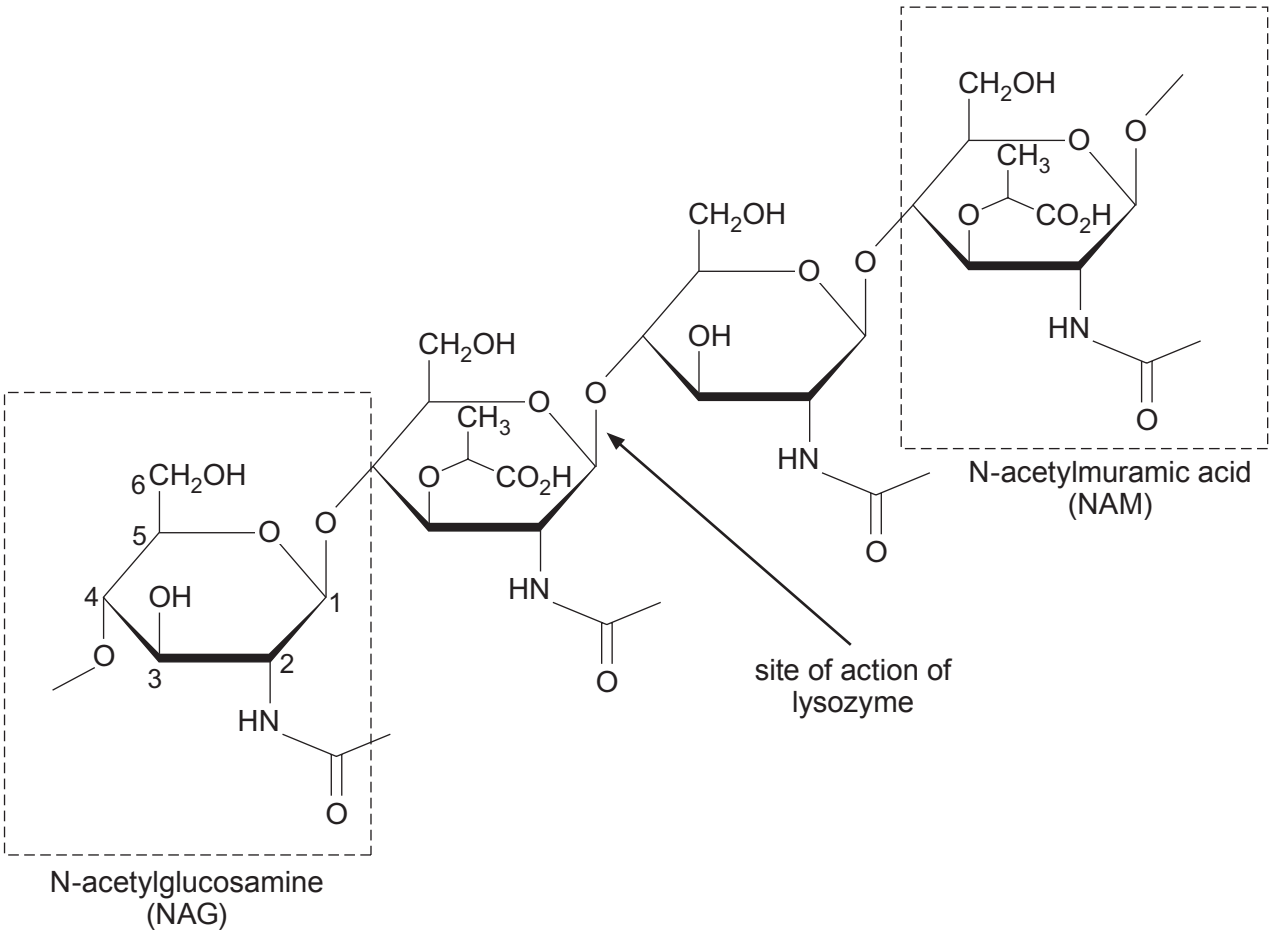
Explain how the induced fit mechanism differs from the lock and key model. [2]

In lock and key the active site shape is already fixed and perfectly complementary; in induced fit the (3D) active site changes shape when the substrate binds.

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(c) Lysozyme is an enzyme which also forms enzyme-substrate complexes through the induced fit mechanism and can function both intra- and extra-cellularly. It catalyses the hydrolysis of a bond in the peptidoglycan component of the cell walls of some bacteria. This is shown in the diagram below. The carbon atoms have been numbered on one molecule of NAG (N-acetylglucosamine).



(i) State the difference between an intra- and an extra-cellular enzyme. [1]

Intracellular enzymes act within a cell; extracellular enzymes act outside the cell.

(ii) The molecule shown in the diagram is a part of a peptidoglycan molecule. Explain why a peptidoglycan cannot be classified as a true polysaccharide. [1]

It contains nitrogen (amine groups); true polysaccharides contain only C, H and O.

(iii) NAG and NAM can exist as alpha or beta isomers. State what is meant by an isomer. [1]

Same molecular formula but a different structural formula (arrangement of atoms).

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(iv) Identify which isomers of NAG and NAM are found in this molecule. Explain your answer. [1]

Beta isomers, because the –O– (glycosidic bond / OH) is above carbon 1 and the H is below C1.

(v) In plant cells, cellulose carries out the same function as the peptidoglycan in bacterial cell walls. Peptidoglycan molecules can be cross-linked by the formation of peptide bonds between NAM molecules in adjacent chains.

Describe how the structure of cellulose molecules enables cross-linking and explain why cross-linking of molecules of the polymer shown in the diagram would result in a stronger cell wall. [3]

In cellulose alternate β-glucose monomers are rotated 180°, forming long straight chains.

This allows hydrogen bonds to form between adjacent parallel chains (cross-linking into microfibrils).

Cross-links between peptidoglycan chains are peptide (covalent) bonds, which are much stronger than hydrogen bonds, so the wall is stronger.

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3. Protein synthesis involves two stages, transcription and translation. Different types of RNA are involved in each stage.

(a) The table below shows the percentages of the different types of RNA present in a rabbit body cell.

RNA	Percentage of total RNA
RNA present in nucleus	11.5
mRNA	3.5
rRNA	69.5
tRNA	15.5

(i) Name the organelle that would contain the greatest percentage of RNA. Explain your answer. [1]

Ribosome, because rRNA (69.5%, the greatest) is ribosomal RNA, a constituent of ribosomes.

(ii) The total mass of RNA in a typical rabbit cell contains about 50 000 000 000 nucleotides.

Calculate the approximate number of nucleotides contained in the tRNA of a typical rabbit cell. **Give your answer in standard form to two significant figures.** [3]

15.5 / 100 × 50 000 000 000

= 7 750 000 000 = 7.75×10^9

Number of nucleotides in tRNA = 7.8×10^9

(iii) Explain why there would be large numbers of different mRNA molecules in a rabbit cell but only a maximum of 64 different tRNA molecules. [3]

A different mRNA codes for every protein (polypeptide): there are many different genes, one gene one polypeptide.

The genetic code is a base triplet code, so there are only $4^3 = 64$ possible triplets (codons).

Each tRNA has an anticodon of three bases complementary to a codon, and each tRNA is specific to one amino acid, so a maximum of 64 tRNAs.

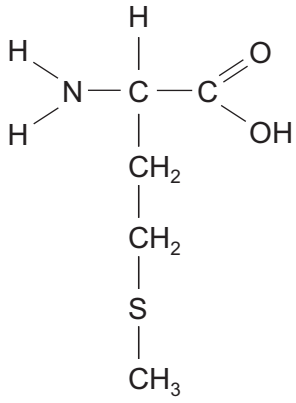
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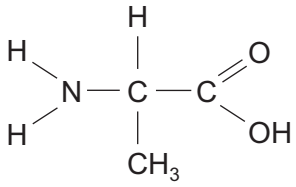
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(b) During translation amino acids can be joined together in different sequences. The drawings below show the structural formulae of the amino acids methionine and glycine.

methionine



glycine



Methionine and glycine can bond together in two different ways:

methionine – glycine	or	glycine – methionine

Name the bond that would join these amino acids and with reference to the structure of the molecules, explain why two different dipeptides could be formed. [2]

Peptide bond.

It forms by a condensation reaction between the amino group of one amino acid and the carboxyl group of the other; the OH can be lost from either methionine or glycine, so either can provide the carboxyl end. Which forms depends on the DNA (mRNA) base sequence.

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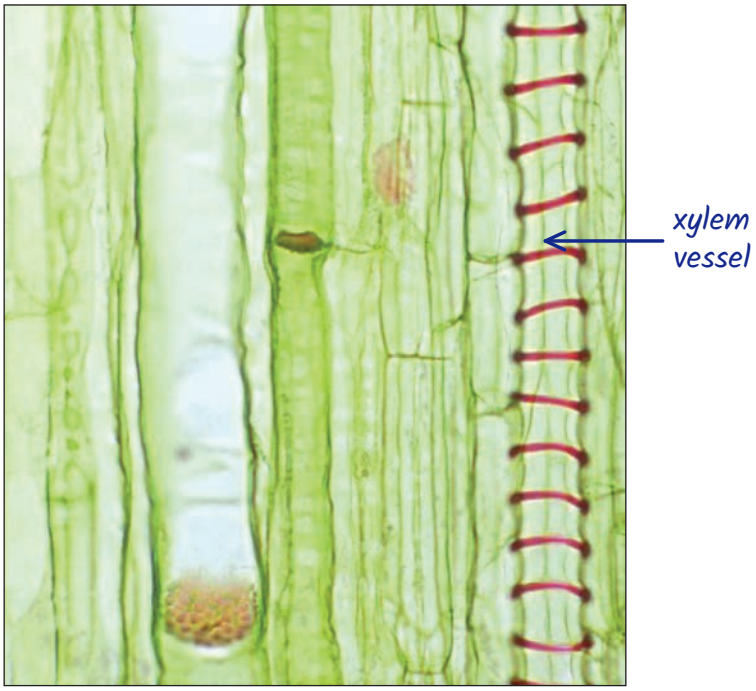
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4. All organisms need certain elements for healthy growth. Plants obtain most of their essential elements by uptake of mineral ions from the soil. The vascular bundles of plants contain xylem vessels that transport water and minerals from the roots to all other parts of the plant.

The photomicrograph below shows a section through the vascular bundle of a plant.



(a) (i) State if this is a transverse or a longitudinal section. Explain your answer. [2]

Longitudinal: the cells appear long and rectangular (cut lengthwise, not round as in TS) and several rings of lignin thickening can be seen.

(ii) **Label a xylem vessel on the photomicrograph above** and explain why a group of xylem vessels form a tissue rather than an organ. [2]

A tissue is a group of similar cells (only one type) aggregated together to perform the same function; an organ contains several different tissues.

(b) The movement of water through xylem vessels partly relies on the polar nature of water molecules.

(i) Explain why water is a polar molecule. [2]

Oxygen is slightly negative (δ−) and the hydrogens are slightly positive (δ+), as electrons are unevenly shared: it is a dipole.

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(ii) With reference to the polar nature of water molecules, explain how the loss of water from leaves enables water to be transported upwards through xylem vessels. [4]

Evaporation of water from the leaves places tension on the water column in the xylem (reduces pressure at the top of the xylem). Water molecules stick together by cohesion, due to hydrogen bonds between δ+ H and δ− O of adjacent molecules. So water is pulled up the xylem as a continuous column: the transpiration stream. Adhesion of water molecules to the xylem walls also helps.

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(c) The table below shows the concentrations of some ions in the xylem and phloem in a plant grown under laboratory conditions.

Substance	Concentration / mmol dm^{-3}	
	Xylem	Phloem
magnesium	1.1	3.7
nitrate	7.1	0.6
phosphate	0.7	6.6

(i) Describe **one** use made by a plant of the ions listed below: [2]

Magnesium Mg^{2+} is needed to make chlorophyll.

Nitrate NO_3^- is a nitrogen source to make amino acids (proteins), nucleic acids and ATP.

(ii) Explain how the data supports the following hypotheses regarding **lateral transport** of ions between xylem and phloem.

Hypothesis 1. Nitrate is transported from xylem to phloem by diffusion through plasmodesmata. [2]

Nitrate is higher in the xylem (7.1) than the phloem (0.6), so it moves down its concentration gradient by diffusion.

Plasmodesmata provide cytoplasmic channels for this.

Hypothesis 2. Phosphate is transported from xylem to phloem by active transport and must cross a cell membrane in the process. [3]

Phosphate is higher in the phloem (6.6) than the xylem (0.7), so it moves against its concentration gradient (needs ATP).

It passes through carrier proteins embedded in cell membranes.

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(d) (i) Fick's Law states that the rate of diffusion of a substance is affected by the surface area, the concentration gradient and the distance the substance travels. His law can be used to calculate the time taken for a substance to diffuse using the formula below:

$$\text{time taken to diffuse} = \text{distance}^2 \times \frac{1}{\text{diffusion coefficient}}$$

Use this formula to calculate the distance (in μm) between a xylem vessel and a phloem sieve tube given that: [3]

time taken to diffuse = 5s
diffusion coefficient (at 20°C) = 5×10^4 $\mu m^2 s^{-1}$

$5 = distance^2 \times 1 / (5 \times 10^4)$

$distance^2 = 5 \times 5 \times 10^4 = 250\ 000\ \mu m^2$

$distance = \sqrt{250\ 000}$

distance = 500 μm

(ii) Explain why an increase in temperature will result in a decrease in time taken to diffuse across a cell membrane. [1]

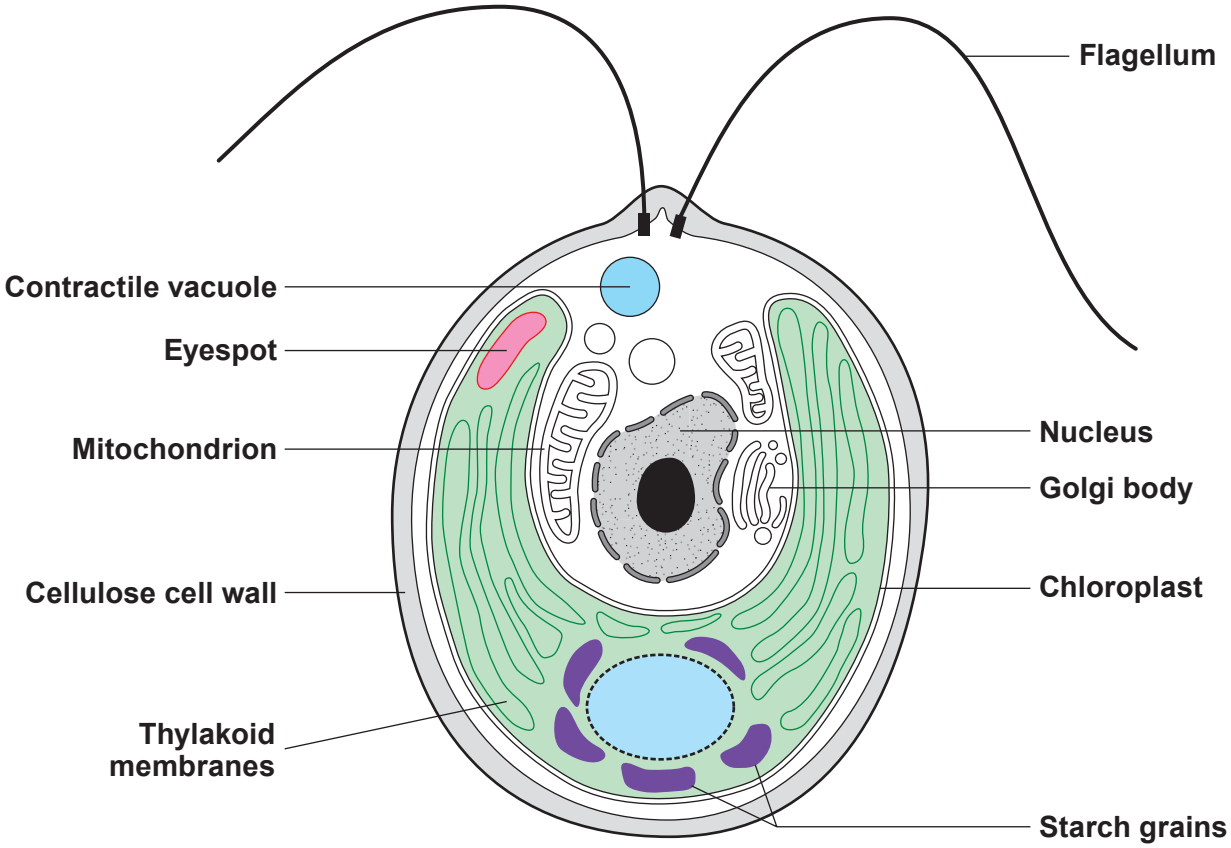
An increase in temperature increases the kinetic energy of the molecules, so they move faster and diffuse across more quickly.

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5. The classification of protoctistan eukaryotes changes frequently. *Chlamydomonas reinhardtii* is now classified as a protoctistan but has previously been classified as an animal and a plant. The diagram below shows the structure of this organism.



(a) With reference to the diagram, explain why this organism has, at different times, been classified as an animal and a plant. [2]

Chloroplasts, a cellulose cell wall and starch grains are plant features (it photosynthesises).

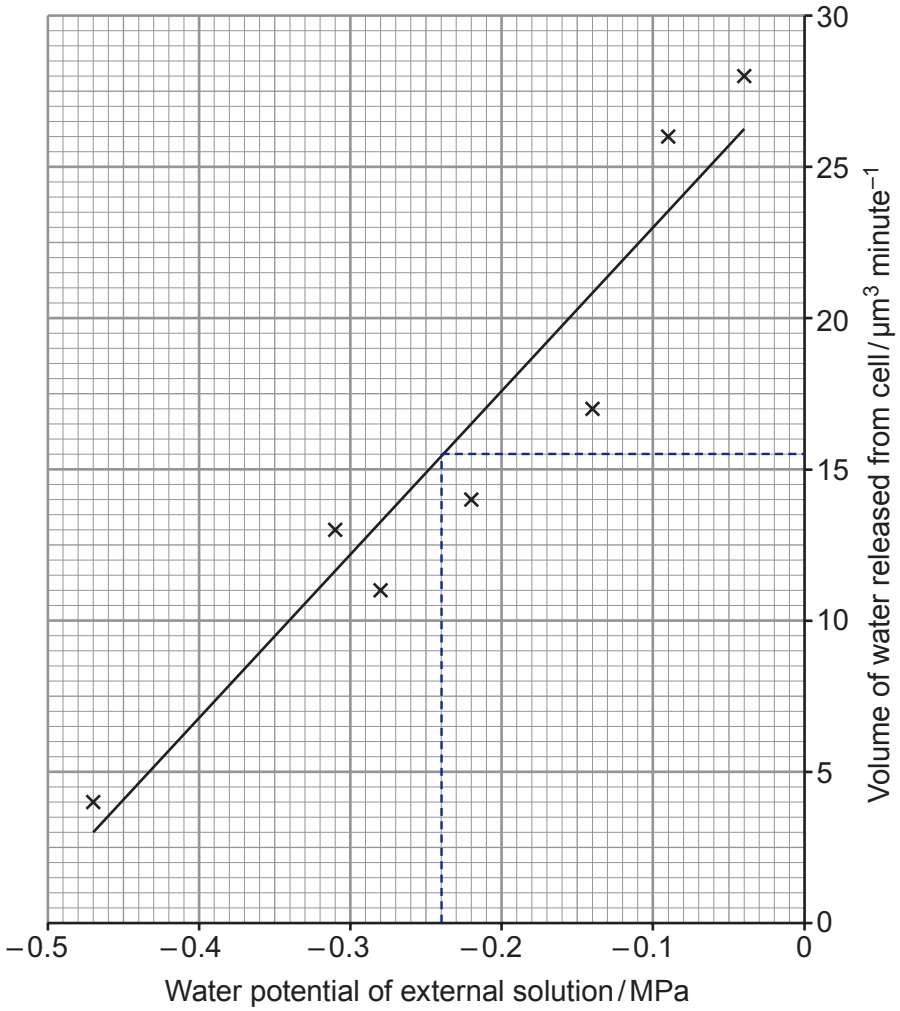
A flagellum (it moves), an eyespot and small (contractile) vacuoles are animal features.

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(b) *Chlamydomonas* lives in freshwater. When viewed under a light microscope, the contractile vacuoles are seen to fill and empty on a regular basis. They are involved in regulating the water content of the cell.
The graph shows the volume of water released from a cell of *Chlamydomonas* per minute at different water potentials of external solution.
A line of best fit is drawn.



(i) The diameter of a contractile vacuole reaches a maximum of 2 µm.
Calculate the volume of a contractile vacuole and use this to calculate the number of times the contractile vacuole fills and empties each minute at an external water potential of –0.24 MPa. **Give your answer to one decimal place.** [3]

volume of sphere = $\frac{4}{3}\pi r^3$;
π = 3.142

volume = 4/3 × 3.142 × 1^3 = 4.189 µm^3

at −0.24 MPa, volume released = 15.5 µm^3 $minute^{-1}$

15.5 ÷ 4.189 = 3.70

Volume of contractile vacuole = ... *4.19 µm^3* .....

Number of times the contractile vacuole fills and empties each minute = ... *3.7* .....

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(ii) Explain why the volume of water released from a cell of *Chlamydomonas* increases as the water potential of the external solution increases. [4]

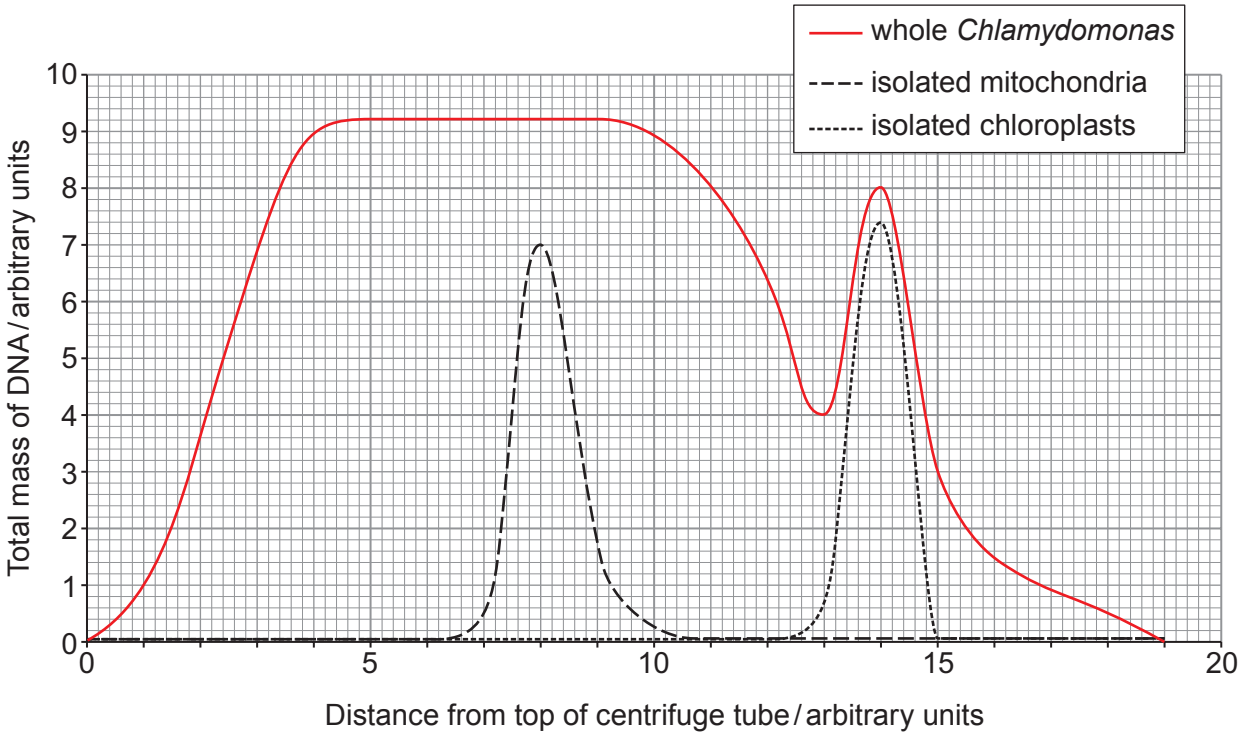
Water enters the cell by osmosis, down a water potential gradient (water potential inside is lower than outside).

As external water potential increases the gradient becomes steeper, so the rate of osmosis increases.

Contractile vacuoles empty more often to remove the excess water.

(c) The nuclear DNA of *Chlamydomonas reinhardtii* contains approximately 120 million base pairs arranged in 17 chromosomes of varying length. The mitochondrial DNA contains nearly 16 000 base pairs and the chloroplast DNA a further 203 000 base pairs.

DNA was extracted from whole *Chlamydomonas* and also from isolated mitochondria and chloroplasts. The samples were spun separately in an ultracentrifuge. The results are plotted on the graph below.



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(i) The cytoplasm of *Chlamydomonas* was found to contain an enzyme that partially digests the chromosomes. Explain how the presence of this enzyme could be a reason for the results obtained for the whole *Chlamydomonas* extract. [2]

The enzyme breaks the chromosomes down into fragments (pieces) of different sizes (masses).

These travel different distances from the top of the tube, giving a broad spread of DNA instead of separate peaks.

(ii) To improve the quality of data obtained using this method, the scientists added an inhibitor of the enzyme that digests the chromosomes of *Chlamydomonas*. Suggest how this change would affect the data obtained. [3]

There would be no (less) digestion of the DNA, so there would be fewer fragments and less variation in distances travelled.

Different separate peaks would be seen, one for each chromosome (17).

(iii) Explain why keeping the whole *Chlamydomonas* extract **on ice** in a **buffer** would also improve the quality of data. [2]

Ice: cold reduces the kinetic energy (activity) of the enzymes, so less DNA is digested.

Buffer: maintains a constant pH.

(iv) Both mitochondria and chloroplasts are believed to have evolved from prokaryotes. What evidence does the graph provide that could support this hypothesis? Explain your answer. [2]

There is a single peak (spike) for the DNA from both the mitochondria and the chloroplasts.

Therefore only one (size of) DNA molecule is present in each organelle.

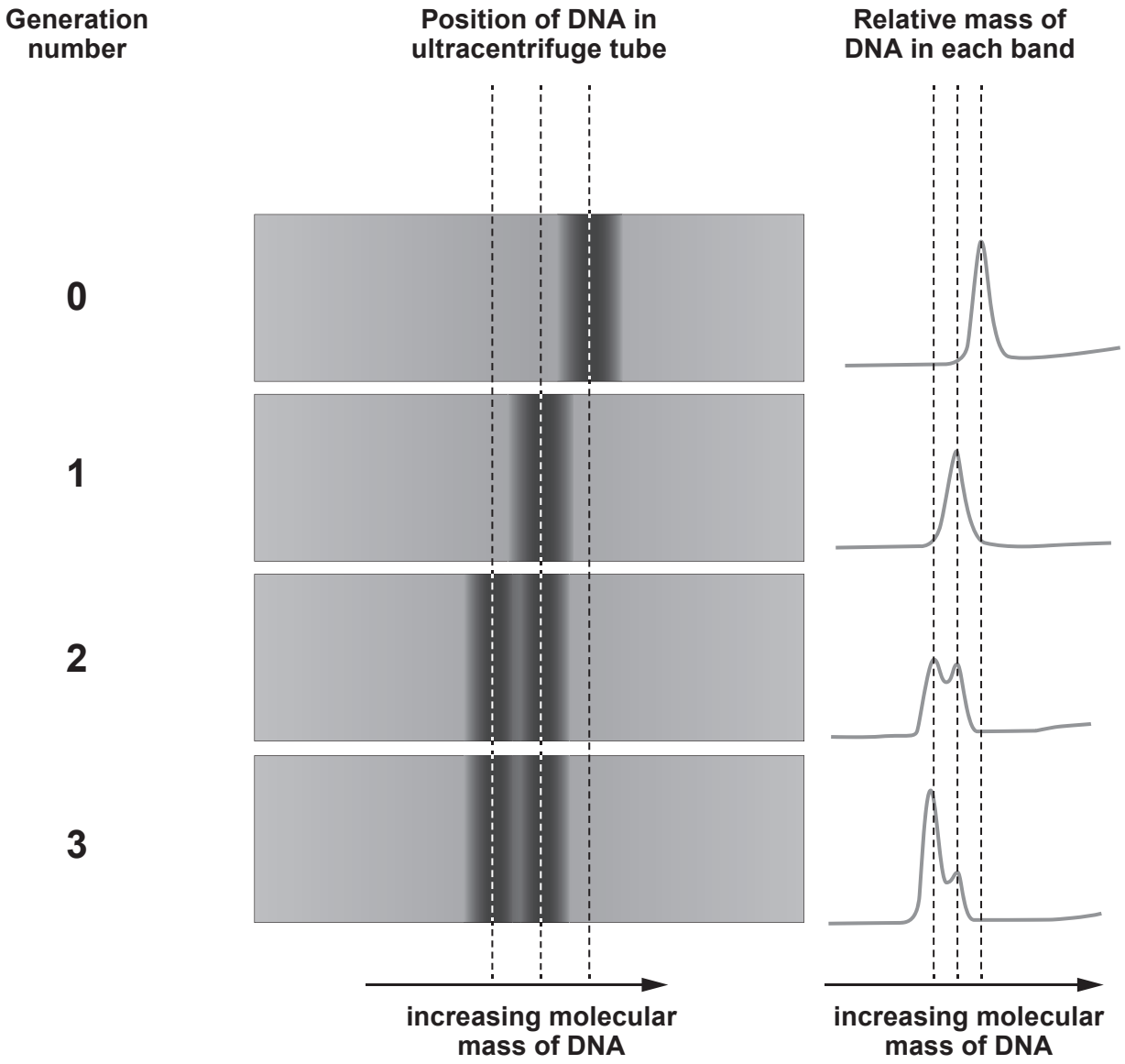
This could be circular DNA (plasmid-like), as found in bacteria (prokaryotes), not linear chromosomes.

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6. In 1958, Matthew Meselson and Franklin Stahl conducted a series of experiments that demonstrated that DNA replication is semi-conservative.

The images below show some of their results.



Other theories of DNA replication included:

- conservative replication, in which the original DNA is retained as a double stranded molecule; and
- dispersive replication, where the original DNA is split into many fragments which are then dispersed throughout the replicated molecules.

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Using your own knowledge of Meselson and Stahl's experiments, explain how their experiment and the results shown in the image supported the theory of semi-conservative replication. Predict how the results would have differed if the other theories had been correct. Explain your answer. [9 QER]

Meselson and Stahl grew E. coli for many generations in a medium containing the heavy isotope of nitrogen, ^{15}N, so that the bases of all their DNA contained ^{15}N (heavy DNA). The bacteria were then transferred to a medium containing the light isotope ^{14}N and allowed to divide; samples were taken after each generation. The DNA was extracted, mixed with caesium chloride solution and spun in an ultracentrifuge, so DNA settled at a position depending on its density (molecular mass).

Generation 0: all the DNA is heavy ($^{15}N/^{15}N$), so there is one band (one peak) in the heavy position.

Generation 1: after one replication in ^{14}N there is a single band at an intermediate position. Each molecule is a hybrid containing one original heavy ^{15}N strand and one new light ^{14}N strand, as each original strand acted as a template.

Generation 2: there are two bands of equal mass, intermediate and light. The hybrid molecules separate; each ^{15}N strand pairs with a new ^{14}N strand (2 intermediate molecules) and each ^{14}N strand pairs with a new ^{14}N strand (2 light molecules), a 1 : 1 ratio.

Generation 3: there are still two bands, but now the light band is larger (3 light : 1 intermediate), because the original heavy strands are retained in only two molecules while all new molecules are light. No heavy band is seen after generation 0, so the results support semi-conservative replication.

Conservative replication: the original heavy DNA would never be split, so there would always be some heavy DNA present (a heavy band in every generation), with no intermediate DNA at all. Generation 1 would show one heavy and one light band (1 : 1) and the mass of light DNA would increase each generation

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(1 : 3 in G2, 1 : 7 in G3). The single intermediate band in generation 1 rules this theory out.

Dispersive replication: the original heavy DNA would be split into fragments shared between all the new molecules, so apart from G0 all the DNA would be of intermediate molecular mass, giving a single band each generation that gets gradually lighter from G1 to G3 but never forms a separate light band. The appearance of two separate bands (intermediate and light) in generation 2 rules this theory out.

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