

Answer ALL questions.

Some questions must be answered with a cross ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

- 1 (a) Plants take up magnesium ions and nitrate ions from the soil. These inorganic ions are dissolved in the water in the soil.
- (i) Magnesium ions and nitrate ions are incorporated into molecules made by the plant.

Which row in the table shows the molecules that incorporate these ions?

(1)

	amino acids	chlorophyll	nucleotides
☐ A	magnesium ions	nitrate ions	magnesium ions
☐ B	magnesium ions	nitrate ions	nitrate ions
☒ C	nitrate ions	magnesium ions	nitrate ions
☐ D	nitrate ions	magnesium ions	magnesium ions

- (ii) Explain why these ions dissolve in water.

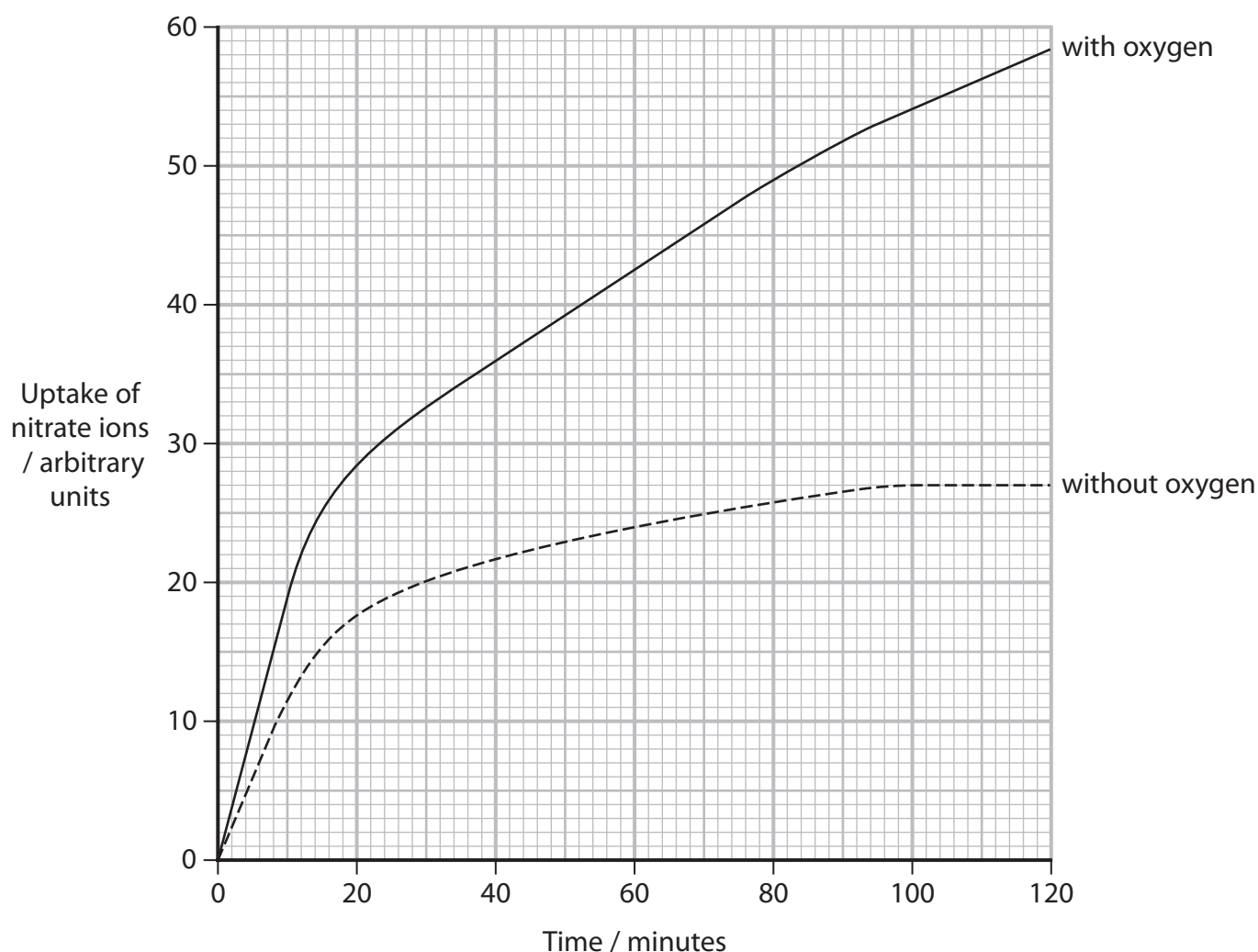
(2)

Water is a polar (dipolar) solvent: the oxygen atom is slightly negative (δ^-) and the hydrogen atoms are slightly positive (δ^+).

The charged ions form electrostatic attractions with the water molecules: Mg^{2+} is attracted to the δ^- oxygen and NO_3^- to the δ^+ hydrogens, so the ions become surrounded by water molecules and dissolve.



(b) The graph shows the uptake of nitrate ions by a plant in the presence and absence of oxygen.



Analyse the data to describe **two** conclusions that can be made about the uptake of nitrate ions by this plant.

(2)

- 1 *More nitrate ions are taken up, and they are taken up faster, in the presence of oxygen (about 58 compared with 27 arbitrary units at 120 minutes).*
- 2 *With oxygen, nitrate ions are taken up by diffusion and active transport (using ATP from aerobic respiration); without oxygen they are only taken up by diffusion, so uptake levels off.*

(Total for Question 1 = 5 marks)



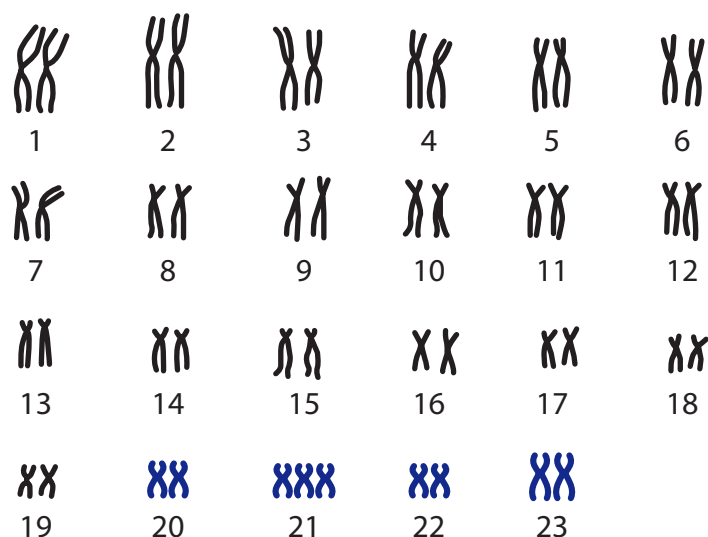
P 7 4 4 7 4 A 0 3 2 8

2 Chromosome mutations include non-disjunction and translocation.

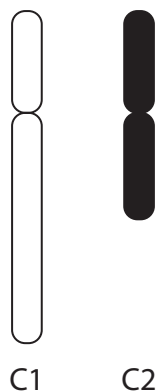
(a) The diagram shows part of a karyotype from a female with Down's syndrome.

Complete the diagram to show the full karyotype of a female with Down's syndrome.

(2)

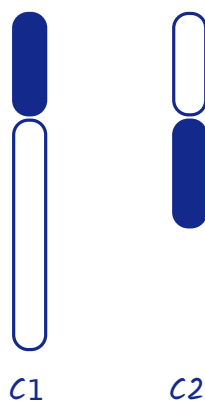


(b) The diagram shows two chromosomes, C1 and C2, before translocation.



Draw a diagram to show the appearance of these two chromosomes after translocation has occurred.

(1)



- (c) The table shows some features of a control group of females without Turner's syndrome and a group of females with Turner's syndrome.

Feature	Control group n = 11	With Turner's syndrome n = 37
Mean mass / kg $\pm$ SD	45.2 $\pm$ 19.3	36.7 $\pm$ 14.8
Mean height / cm $\pm$ SD	146.3 $\pm$ 21.3	134.8 $\pm$ 20.0
Body mass index (BMI)	21.1	20.2

- (i) Complete the table to show the BMI for the control group, using the formula:

$$\text{BMI} = \text{mass in kg} \div (\text{height in metres})^2$$

$$45.2 \div 1.463^2 = 45.2 \div 2.140 = 21.1 \quad (2)$$

- (ii) Analyse the data to comment on the conclusions that could be made about the effect of Turner's syndrome on these features.

(4)

Females with Turner's syndrome have a lower mean mass (36.7 kg compared with 45.2 kg), a lower mean height (134.8 cm compared with 146.3 cm) and a slightly lower BMI (20.2 compared with 21.1) than the control group.

However, the standard deviations are large and the mean $\pm$ SD ranges overlap, so there may be no significant difference in mass or height; more data (a statistical test) is needed.

No standard deviation is given for BMI, so we cannot tell if the difference in BMI is significant.

The sample sizes are small (only 11 in the control group and 37 with Turner's syndrome), so the results may not be reliable or representative.

(Total for Question 2 = 9 marks)



P 7 4 4 7 4 A 0 5 2 8

3 *Bacillus subtilis* and *Pseudomonas aeruginosa* are two types of bacteria.

(a) (i) Which pair of structures is found in these bacteria?

(1)

- ☒ A nucleoid and 70S ribosomes
- ☐ B nucleoid and 80S ribosomes
- ☐ C nucleus and 70S ribosomes
- ☐ D nucleus and 80S ribosomes

(ii) Name **three other** structures that are surrounded by the cell wall of bacteria.

(2)

1 *cytoplasm*

2 *plasmid*

3 *cell (surface) membrane*

(b) A scientist determined the thickness of the cell wall of these bacteria.

The thickness of the cell wall of *B. subtilis* is 55.4 nm and the thickness of the cell wall of *P. aeruginosa* is 2.4 nm.

(i) Calculate the ratio of the thickness of the cell wall of *B. subtilis* to that of *P. aeruginosa*.

Give your values to **two** significant figures.

(1)

$$55.4 \div 2.4 = 23.08$$

$$\text{ratio} = 23 : 1.0$$

Answer *23 : 1.0*



- (ii) Some antibiotics affect only Gram positive bacteria.

Explain which of *B. subtilis* or *P. aeruginosa* will be affected by these types of antibiotics.

(2)

B. subtilis, because it is Gram positive: its cell wall is thick (55.4 nm), so it has a thick peptidoglycan cell wall, while *P. aeruginosa* has a thin wall (2.4 nm) and is Gram negative.

These antibiotics (e.g. penicillin) inhibit the formation of peptidoglycan cross-links in the cell wall, so the wall is weakened and the cell bursts (osmotic lysis).

- (c) *Bacillus subtilis* was grown in a culture. At the start the culture contained 6×10^3 cells and after two hours the culture contained 1.7×10^5 cells.

Calculate the mean rate of increase in the number of bacteria in this culture.

Give your answer in cells per minute.

(2)

$$\text{increase} = 1.7 \times 10^5 - 6 \times 10^3 = 170\,000 - 6000 = 164\,000 \text{ cells}$$

$$2 \text{ hours} = 120 \text{ minutes}$$

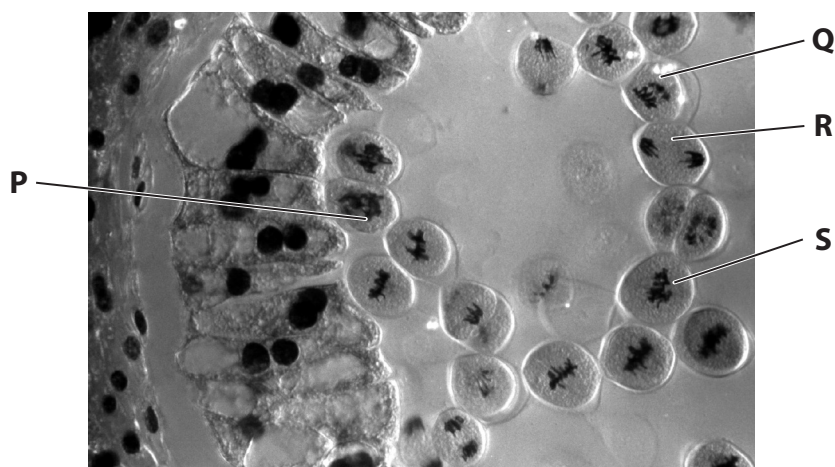
$$\text{rate} = 164\,000 \div 120 = 1366.67$$

Answer 1367 cells per minute

(Total for Question 3 = 8 marks)

4 Sexual reproduction occurs in flowering plants.

(a) The photograph shows meiosis in a bluebell plant.



(Source: SCIENCE PICTURES LTD/SCIENCE PHOTO LIBRARY)

(i) Which cell is in the latest stage of meiosis?

(1)

- ☐ A P
- ☐ B Q
- ☒ C R
- ☐ D S

- (ii) Devise a practical procedure to determine the total percentage of cells in both metaphase I and metaphase II in a bluebell.

(5)

Remove the anthers from a young bluebell flower bud, as these contain cells undergoing meiosis.

Place the anthers in hydrochloric acid in a water bath at about 60 °C for 5 minutes, then rinse in water.

Put them on a microscope slide and add a stain such as acetic orcein to stain the chromosomes.

Tease the cells apart (macerate) with a mounted needle, place a coverslip on top and gently squash the preparation.

View under a light microscope at high power. Count the total number of cells in the field of view, and count the number of cells in metaphase I and in metaphase II.

Repeat for several fields of view and slides.

Percentage = (number of cells in metaphase I + metaphase II) ÷ total number of cells × 100.

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(b) Explain how meiosis results in genetic variation in a flowering plant.

(3)

Independent assortment of homologous chromosomes in meiosis I: the pairs line up randomly at the equator, so different combinations of maternal and paternal chromosomes go into each gamete.

Crossing over between non-sister chromatids of homologous chromosomes (at chiasmata) exchanges sections of DNA.

So the gametes (pollen nuclei and egg cells) have different combinations of alleles, and the offspring are genetically different.

(Total for Question 4 = 9 marks)



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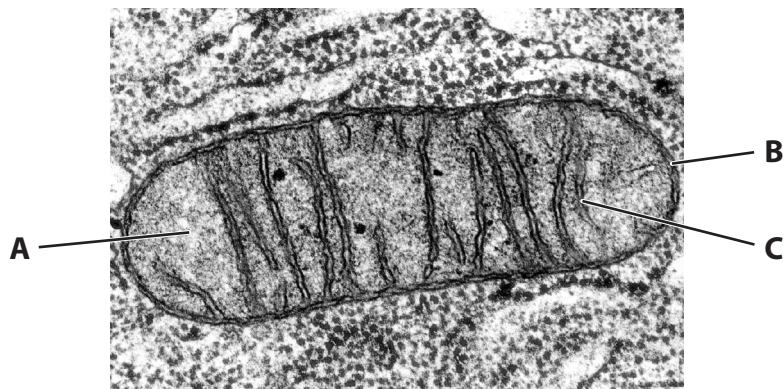
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- 5 The photograph shows a mitochondrion, as seen using an electron microscope.



(Source: © CNRI/SCIENCE PHOTO LIBRARY)

- (a) Name the parts labelled **A**, **B** and **C**.

(2)

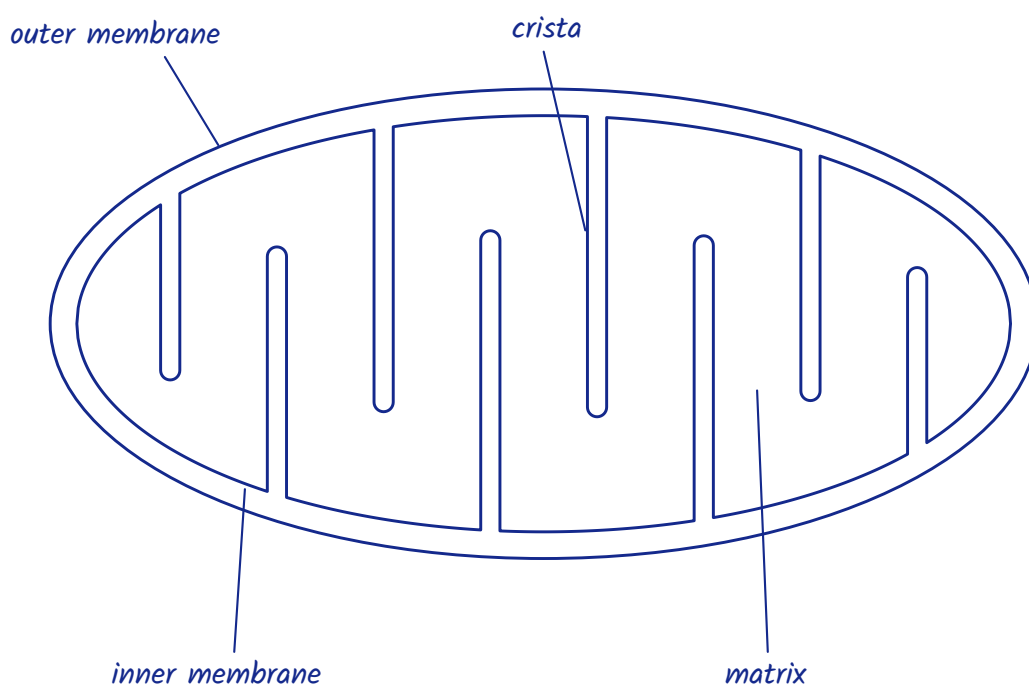
A *matrix*

B *outer membrane (envelope)*

C *cristae (folded inner membrane)*

- (b) Draw a diagram of this mitochondrion.

(2)



(c) The actual length of this mitochondrion is $0.9\text{ }\mu\text{m}$.

(i) What is the magnification of this photograph?

(1)

- ☐ A $\times 1200$
☐ B $\times 8200$
☐ C $\times 12\,000$
☒ D $\times 82\,000$

(ii) The magnification of this photograph can be shown as a scale bar.

Complete the 1 cm scale bar for this photograph.

(1)

$0.12\text{ }\mu\text{m}$
 1 cm scale bar 

$$1\text{ cm} = 10\,000\text{ }\mu\text{m}; \quad 10\,000 \div 82\,000 = 0.12$$

Answer 0.12 μm

(d) Explain why specimens have to be stained with coloured dyes when viewed using a light microscope and not when using an electron microscope.

(2)

Most specimens (cells) are colourless or transparent, so a stain is needed to give contrast and make the structures visible in light.

An electron microscope uses a beam of electrons, not light, so colour is not seen; the image depends on electron-dense areas (stained with heavy metals) scattering electrons, so coloured dyes are not needed.

(Total for Question 5 = 8 marks)



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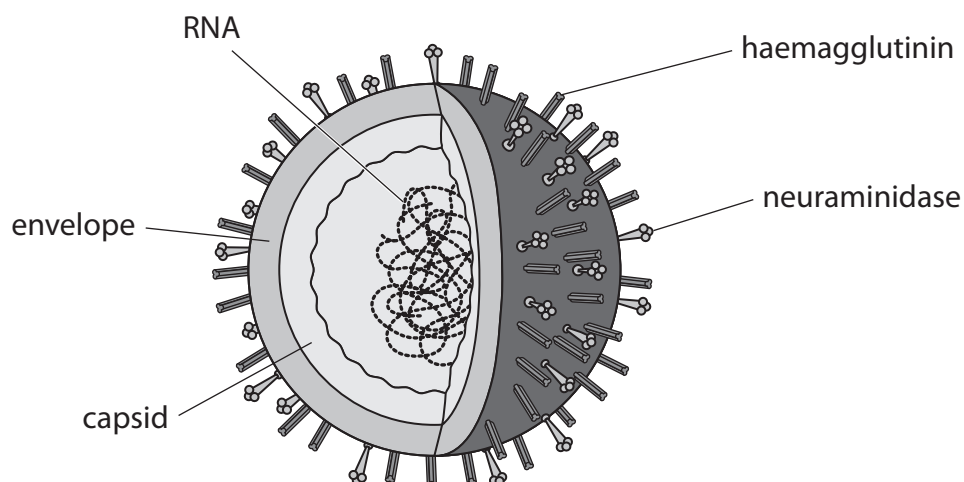
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6 The diagram shows the structure of the influenza virus.



(a) The influenza virus has a helical capsid.

Which virus also has a helical capsid and an envelope?

(1)

- ☒ **A** Ebola
- ☐ **B** human immunodeficiency virus
- ☐ **C** λ (lambda) phage
- ☐ **D** tobacco mosaic virus

(b) Neuraminidase is an enzyme.

Describe the structure of an enzyme.

(3)

An enzyme is a globular protein with a specific tertiary (3D) structure.

The polypeptide chain is folded and held in shape by hydrogen bonds, ionic bonds, disulfide bridges and hydrophobic interactions between the R groups of the amino acids.

Hydrophobic R groups are on the inside and hydrophilic R groups are on the outside, so it is soluble.

It has an active site with a specific shape that is complementary to its substrate.

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.....

*(c) The host cells of the influenza virus are the cells lining the airways. These cells are coated in mucus.

Neuraminidase and haemagglutinin are glycoproteins present in the envelope of the influenza virus.

Neuraminidase and haemagglutinin are important in the lytic cycle of this virus.

Neuraminidase breaks bonds between sialic acid groups and other molecules.

Sialic acid is found on glycoproteins present in the cell membrane, mucus and the envelope of the virus.

Haemagglutinin is a glycoprotein that binds to sialic acid groups.

The lytic cycle of the influenza virus includes the following steps:

- 1 the virus attaches to a cell
- 2 the virus moves until it attaches to the correct cell surface receptor
- 3 new virus particles are made inside the host cell
- 4 new virus particles bud from the host cell
- 5 new virus particles are attached to the outside of the host cell membrane and to each other
- 6 new virus particles infect new host cells.



Explain the importance of neuraminidase and haemagglutinin in the spread of infection of the influenza virus in the body.

(6)

Haemagglutinin binds to sialic acid groups on the glycoproteins of the cell membrane, so the virus attaches to a host cell. However, it can also bind to sialic acid in the mucus or on the wrong cells.

Neuraminidase breaks the bonds between haemagglutinin and the sialic acid groups, so it breaks down the mucus and frees the virus, allowing it to move until it attaches to the correct cell surface receptor.

The virus enters the host cell and its RNA is released and replicated. Viral proteins, such as capsid proteins, haemagglutinin and neuraminidase, are made by the host cell and new virus particles are assembled.

The new virus particles bud out of the host cell, taking cell membrane as their envelope. As the envelope and membrane contain sialic acid, haemagglutinin makes the new particles stick to the host cell membrane and to each other.

Neuraminidase cleaves the sialic acid groups, separating the new virus particles from the host cell membrane and from each other, and releasing them from the mucus.

So the new particles are free to attach to and infect new host cells, and the infection spreads through the airways.

(Total for Question 6 = 10 marks)

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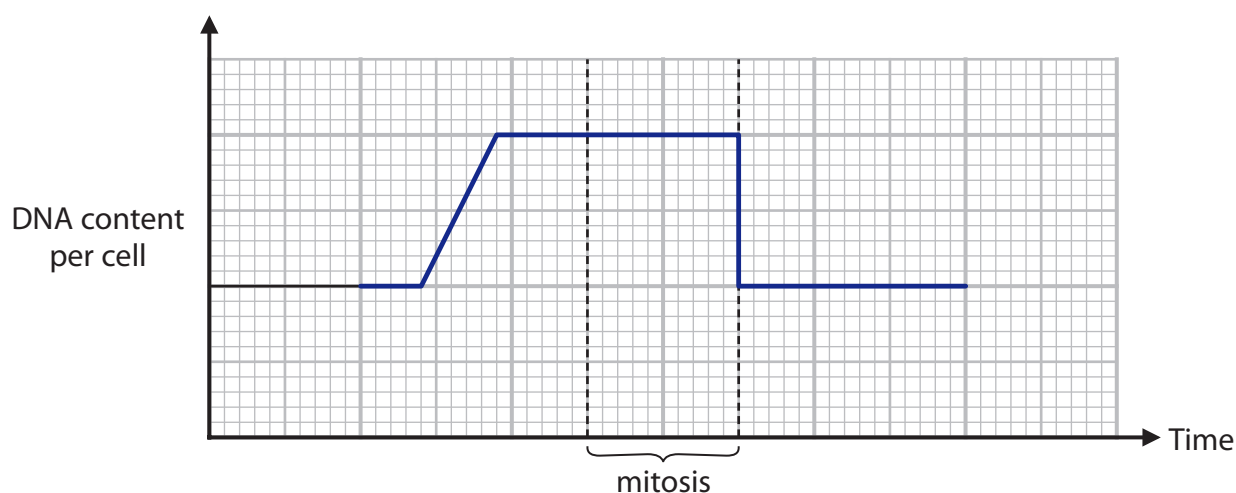
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7 The synthesis of DNA takes place during the cell cycle.

- (a) Sketch a graph to show how the DNA content of a cell changes during one cell cycle that includes mitosis.

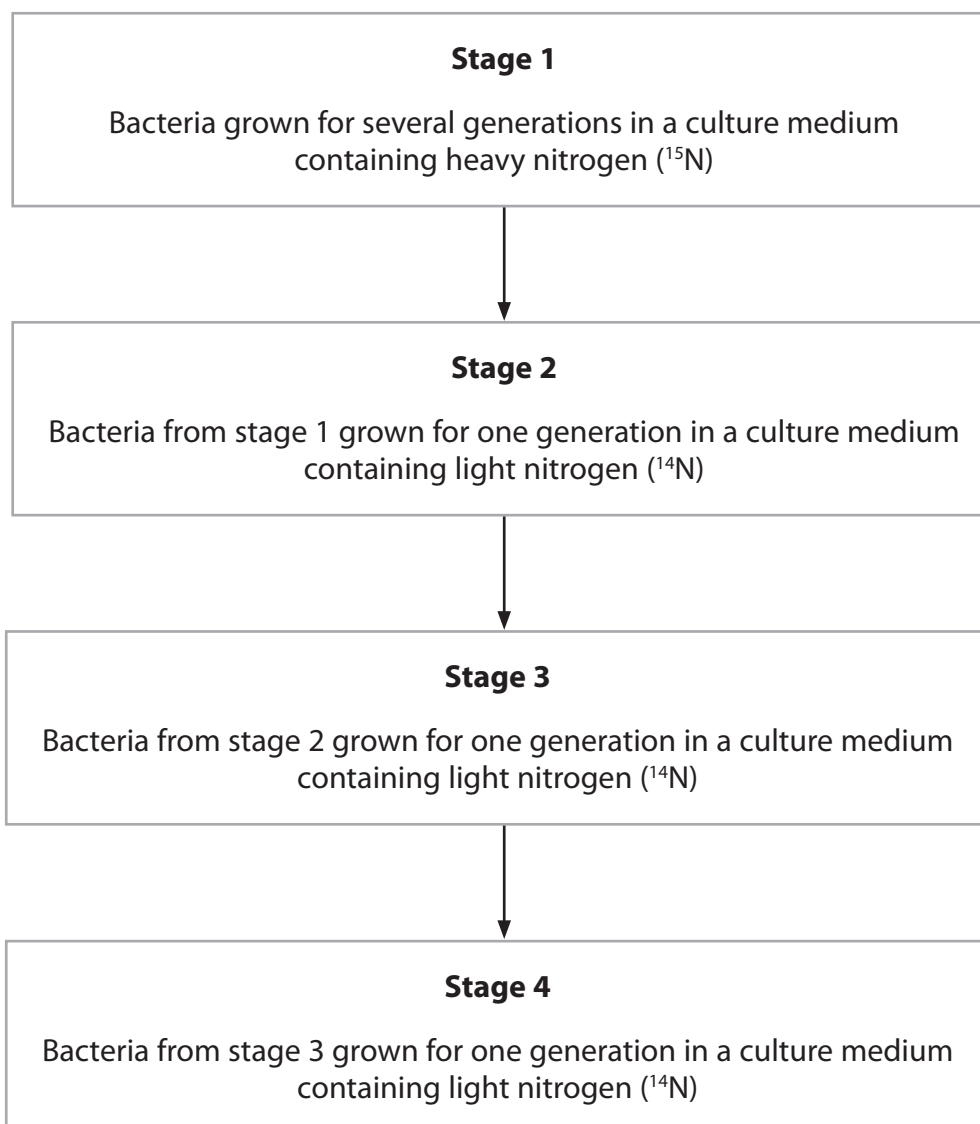
(3)



DNA content doubles when DNA replicates (S phase) before mitosis, stays doubled throughout mitosis, then halves back to the starting level when the cell divides at the end of mitosis.

*(b) The experiments of Meselson and Stahl contributed to our current understanding of DNA replication.

The diagram shows the stages involved in one experiment.



After each stage, a sample of DNA was taken from the bacteria and the DNA molecules separated using a density gradient in a tube.

The heavier DNA molecules form bands lower down the gradient than lighter DNA molecules.

The size of each band is proportional to the percentage of DNA molecules in the sample.

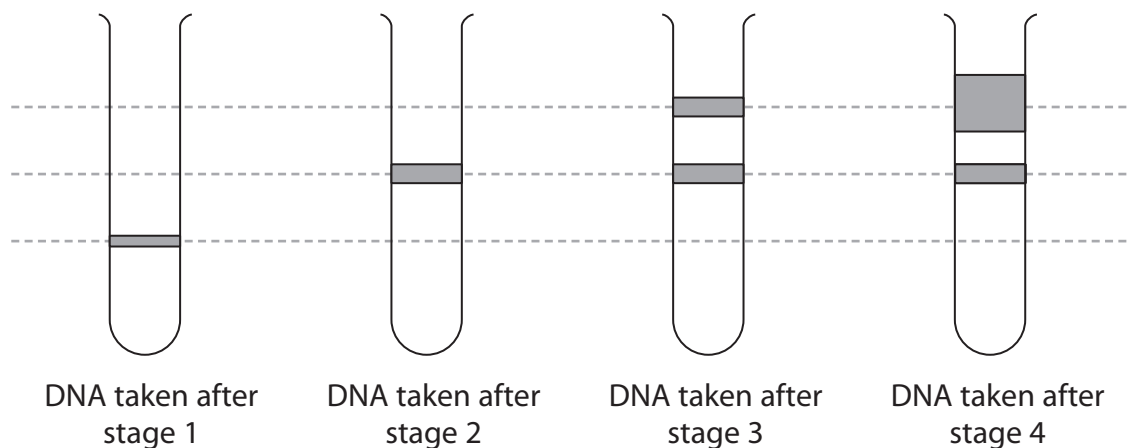
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The diagram shows the results of this experiment.



Analyse the data to explain the results of this experiment and how it contributed to our current understanding of DNA replication.

(6)

Stage 1: all the bases contain heavy nitrogen (^{15}N), so there is only one band, near the bottom of the tube.

Stage 2: replication uses light nitrogen (^{14}N), so the new strands contain ^{14}N . There is one band, higher up than stage 1, as every molecule has one heavy (old) strand and one light (new) strand.

Stage 3: ^{15}N strands pair with new light strands to form medium-weight DNA (band in the same position as stage 2), and the ^{14}N strands from stage 2 pair with new light strands to form the lightest DNA, higher up the tube. The bands are equal in width, as stage 2 DNA had equal numbers of light and heavy strands.

Stage 4: two bands in the same positions, but the light band is wider (ratio 3 : 1), as stage 3 DNA had more light strands than heavy strands. The number of molecules doubles each time, so the total band width doubles.

This showed that replication is semi-conservative: helicase breaks the hydrogen bonds, each strand acts as a template for complementary base pairing, and DNA polymerase joins the nucleotides, so each new molecule has one old and one new strand.

(Total for Question 7 = 9 marks)

- 8 Carbohydrates can be classified as monosaccharides, disaccharides, or polysaccharides.

- (a) The table gives some information about polysaccharides.

For each polysaccharide, put **one** cross in the appropriate box, in each row, to show the type of glycosidic bond present.

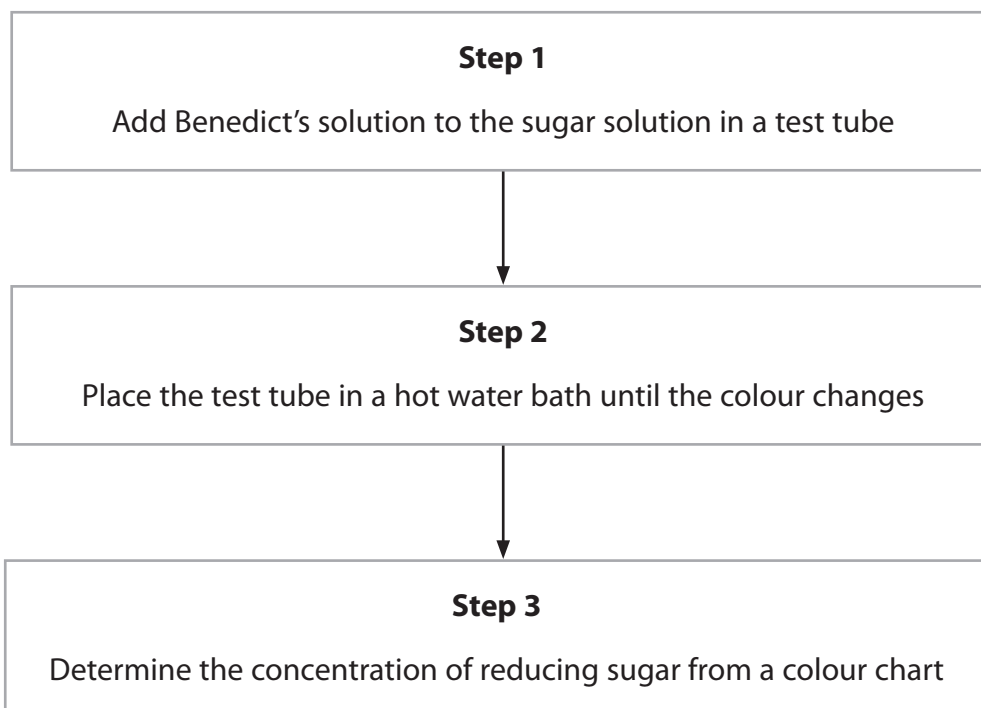
(3)

Polysaccharide	Type of glycosidic bond			
	both 1-4 and 1-6	1-4 only	1-6 only	neither 1-4 nor 1-6
cellulose	☐	☒	☐	☐
glycogen	☒	☐	☐	☐
starch	☒	☐	☐	☐

- (b) Monosaccharides and disaccharides are either reducing sugars or non-reducing sugars.

The presence of a reducing sugar, such as glucose, can be identified using the Benedict's test. The method can be used to determine the concentration of the reducing sugar.

The diagram shows the steps involved in the Benedict's test.



The table shows the colour chart.

Colour after heating	blue	green	yellow	orange	red
Concentration of reducing sugar / mg dm^{-3}	0	<1000	1000 to 1500	1500 to 2000	>2000

- (i) Describe **two** limitations of using this method for determining the concentration of reducing sugars.

(2)

- 1 *Deciding on the colour is subjective: people judge colours differently and it is hard to distinguish between similar colours, e.g. yellow and orange.*
- 2 *The concentrations are given as ranges (semi-quantitative), so an exact concentration cannot be determined, e.g. 1500 mg dm^{-3} could be yellow or orange.*



- (ii) This method can be modified to determine the concentration of non-reducing sugars.

Non-reducing sugars, such as sucrose, must be heated in acid before step 1.

A student was given a solution containing both glucose and sucrose.

Devise a method, using the Benedict's test, to determine the concentration of each of these sugars in this solution.

(4)

Take a known volume (e.g. 2 cm^3) of the solution, add the same volume of Benedict's solution and heat in a water bath (test for reducing sugar). Use the colour chart to find the concentration of glucose.

Take a second sample of the same volume of the solution and heat it with dilute hydrochloric acid to hydrolyse the sucrose into glucose and fructose.

Neutralise with sodium hydrogencarbonate, then add the same volume of Benedict's solution, heat and use the colour chart to find the total concentration of reducing sugar.

Subtract the glucose concentration from the total concentration to find the concentration of sucrose.

(Total for Question 8 = 9 marks)



9 The membranes of cells and organelles contain many types of lipids.

(a) Phospholipids are one type of lipid found in cell membranes.

(i) Explain the role of phospholipids in the cell membrane.

(3)

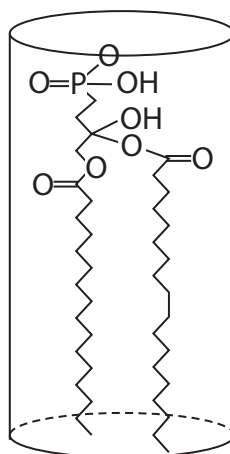
Phospholipids form a bilayer, which is the basic structure of the membrane.

The phosphate heads are polar (hydrophilic), so they face the aqueous environment inside and outside the cell.

The fatty acid tails are non-polar (hydrophobic), so they face inwards and form a hydrophobic barrier.

So the bilayer controls the movement of substances: lipid-soluble molecules can pass through, but polar, charged or water-soluble molecules cannot move freely into or out of the cell.

(ii) The diagram shows a phospholipid drawn inside a cylinder.



The cross-sectional area of this cylinder is 0.3 nm^2 .

Calculate the number of phospholipid molecules in $1 \mu\text{m}^2$ of a phospholipid bilayer.

Give your answer in standard form.

(3)

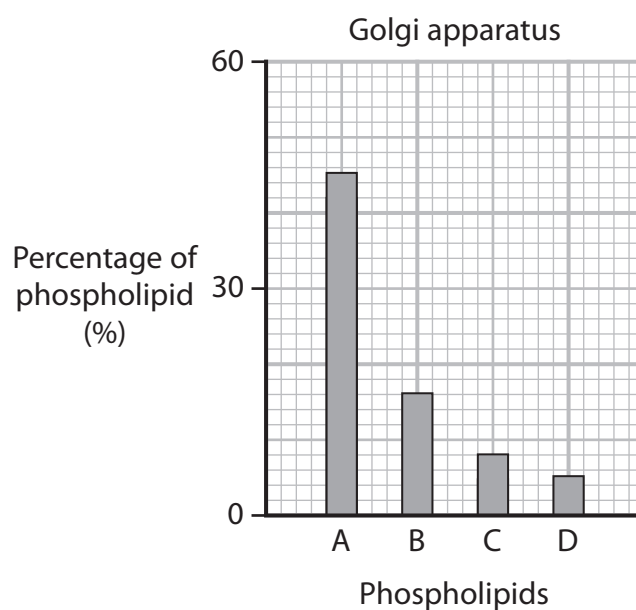
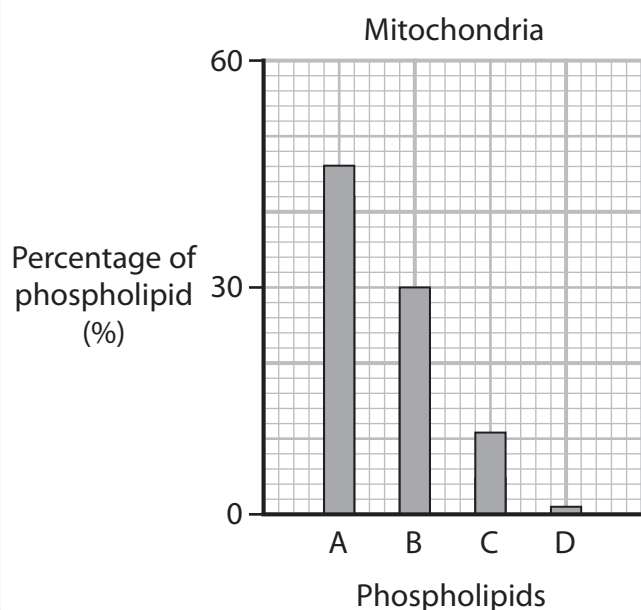
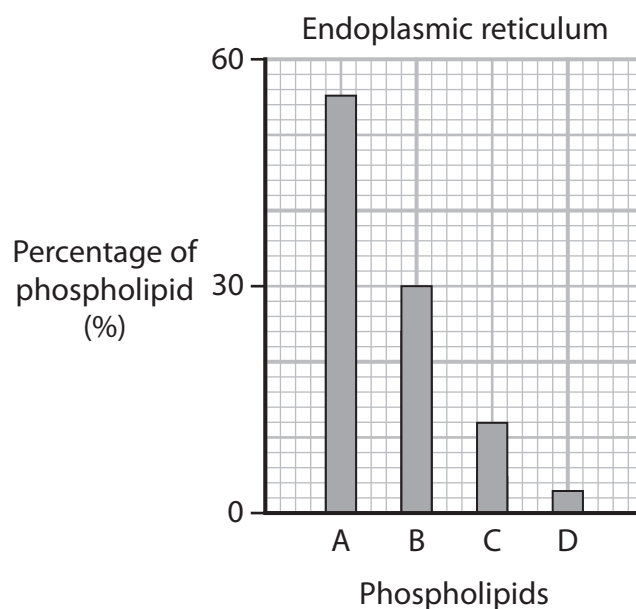
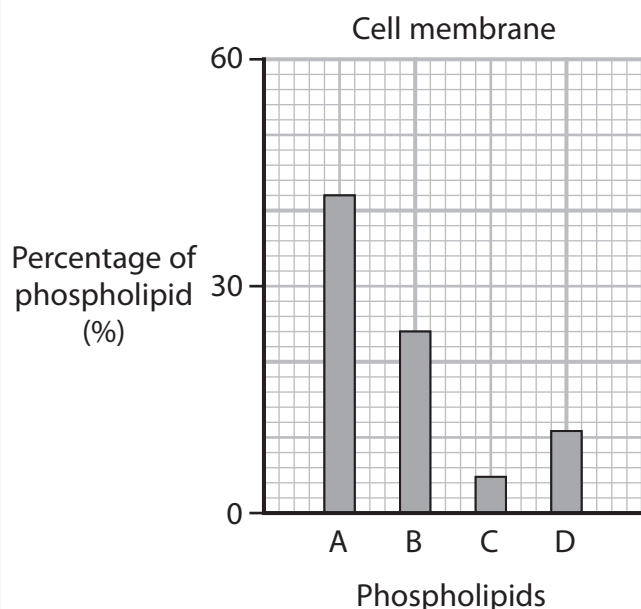
$$1 \mu\text{m}^2 = 1000 \text{ nm} \times 1000 \text{ nm} = 1\,000\,000 \text{ nm}^2$$

$$\text{one layer: } 1\,000\,000 \div 0.3 = 3\,333\,333$$

$$\text{bilayer: } 3\,333\,333 \times 2 = 6\,666\,667$$

Answer 6.7×10^6

- (b) The graphs show the percentage of four types of phospholipid, A, B, C and D, in the cell membrane and in the membranes of endoplasmic reticulum, mitochondria and Golgi apparatus.



- (i) Describe how the structure of one type of phospholipid can be different from the structure of another type of phospholipid.

(2)

The fatty acid tails can have different lengths (different numbers of carbon and hydrogen atoms).

The tails can have different numbers of C=C double bonds, so some are saturated and some are mono- or polyunsaturated.

- (ii) Compare and contrast the phospholipid content of these membranes.

(3)

Similarities: all four membranes contain all four types of phospholipid; A is the most common in all of them (42 to 55%) and B is the second most common in every membrane.

Differences: each membrane has a different percentage of each phospholipid, e.g. the ER has the most A (55%). In the cell membrane C is the lowest (5%) and D is higher (11%), but in the other three membranes D is the lowest, so the order of B, C and D is different in the cell membrane.

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- (iii) The scientists who produced the data did not expect the phospholipid content in the membranes of the endoplasmic reticulum and the Golgi apparatus to be different.

Explain why these scientists did not expect there to be a difference in the phospholipid content in the membranes of these two organelles.

(2)

Vesicles containing proteins (and lipids) pinch off from the endoplasmic reticulum, move to the Golgi apparatus and fuse with it, where the proteins are modified.

So the membrane of the Golgi apparatus comes from the membrane of the endoplasmic reticulum, and would be expected to have the same phospholipid content.

(Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 80 MARKS

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