

Please check the examination details below before entering your candidate information

Candidate surname

StemUp Model Solution

Other names

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Pearson Edexcel Level 3 GCE

Thursday 5 June 2025

Afternoon (Time: 1 hour 45 minutes)

Paper
reference

9BI0/01

Biology B

Advanced

**PAPER 1: Advanced Biochemistry, Microbiology
and Genetics**

You must have:

Scientific calculator, HB pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- In question(s) marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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P 7 4 4 5 9 R A 0 1 3 6


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Answer ALL questions.

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

1 Active transport is one type of cell transport mechanism.

(a) What happens during active transport?

(1)

- ☒ **A** ATP is hydrolysed releasing energy
- ☐ **B** ATP is hydrolysed using energy
- ☐ **C** ATP is phosphorylated releasing energy
- ☐ **D** ATP is phosphorylated using energy

(b) Which substance is transported against a concentration gradient by active transport?

(1)

- ☒ **A** hydrophilic molecule
- ☐ **B** large hydrophobic molecule
- ☐ **C** small hydrophobic molecule
- ☐ **D** water

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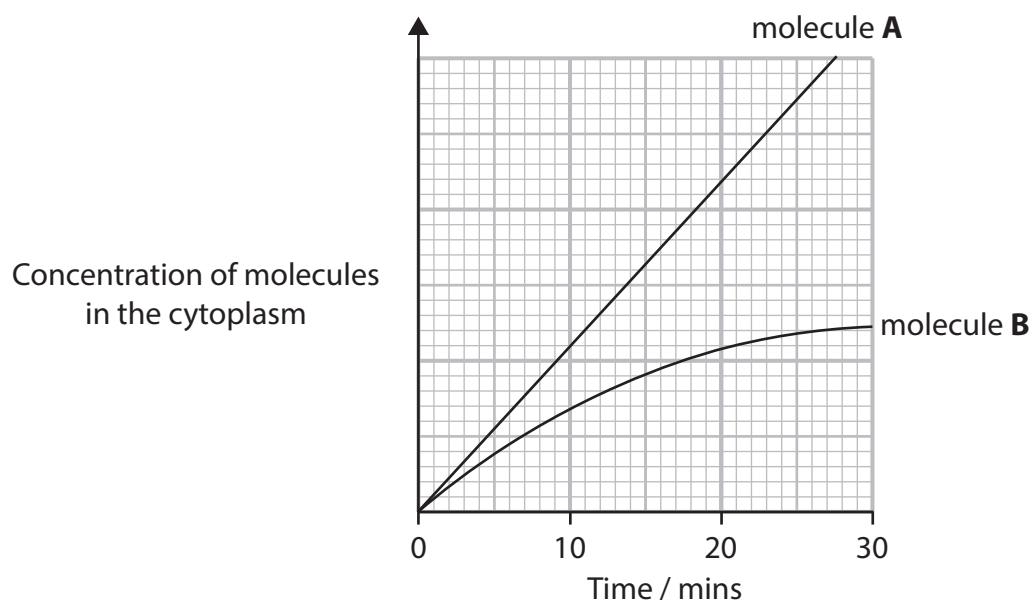
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- (c) The graph shows the change in concentration of molecule **A** and molecule **B**, as they are transported into the cytoplasm of a cell.



Explain the differences in the changes in concentration of molecule **A** and molecule **B** between 0 and 10 minutes and between 20 and 30 minutes.

(2)

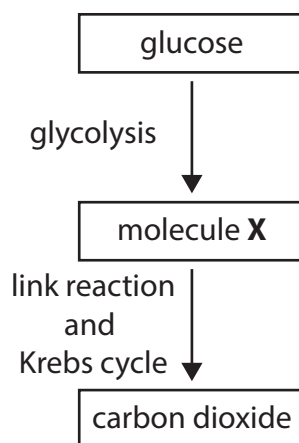
Between 0 and 10 minutes the concentration of molecule A increases faster than that of molecule B, because A is moved by active transport, which is faster than diffusion;

B enters by (facilitated) diffusion.

Between 20 and 30 minutes the concentration of B levels off because there is no longer a concentration gradient (equilibrium: concentration equal inside and outside), whereas A keeps increasing as it is actively transported against the gradient.

(Total for Question 1 = 4 marks)

2 The diagram shows part of cellular respiration.



(a) Which is molecule **X**?

(1)

- ☐ **A** glycerate 3-phosphate
- ☐ **B** glycogen
- ☐ **C** lactate
- ☒ **D** pyruvate

(b) Which row of the table shows the locations of glycolysis, the link reaction and the Krebs cycle in eukaryotic cells?

(1)

	Glycolysis	Link reaction	Krebs cycle
☐ A	cytoplasm	cytoplasm	cytoplasm
☒ B	cytoplasm	mitochondria	mitochondria
☐ C	mitochondria	cytoplasm	cytoplasm
☐ D	mitochondria	mitochondria	mitochondria



(c) Cellular respiration yields 36 molecules of ATP per molecule of glucose.

(i) The oxidation of one glucose molecule yields 2 870 224 Joules.

The free energy stored in one ATP molecule is 30 566 Joules.

Calculate the efficiency of energy transfer in the formation of ATP.

Give your answer to **two decimal places**.

(2)

$$\text{energy in 36 ATP} = 30\,566 \times 36 = 1\,100\,376 \text{ J}$$

$$\text{efficiency} = 1\,100\,376 \div 2\,870\,224 \times 100$$

$$= 38.337... \%$$

Answer **38.34** %

(ii) State why this process is not 100% efficient.

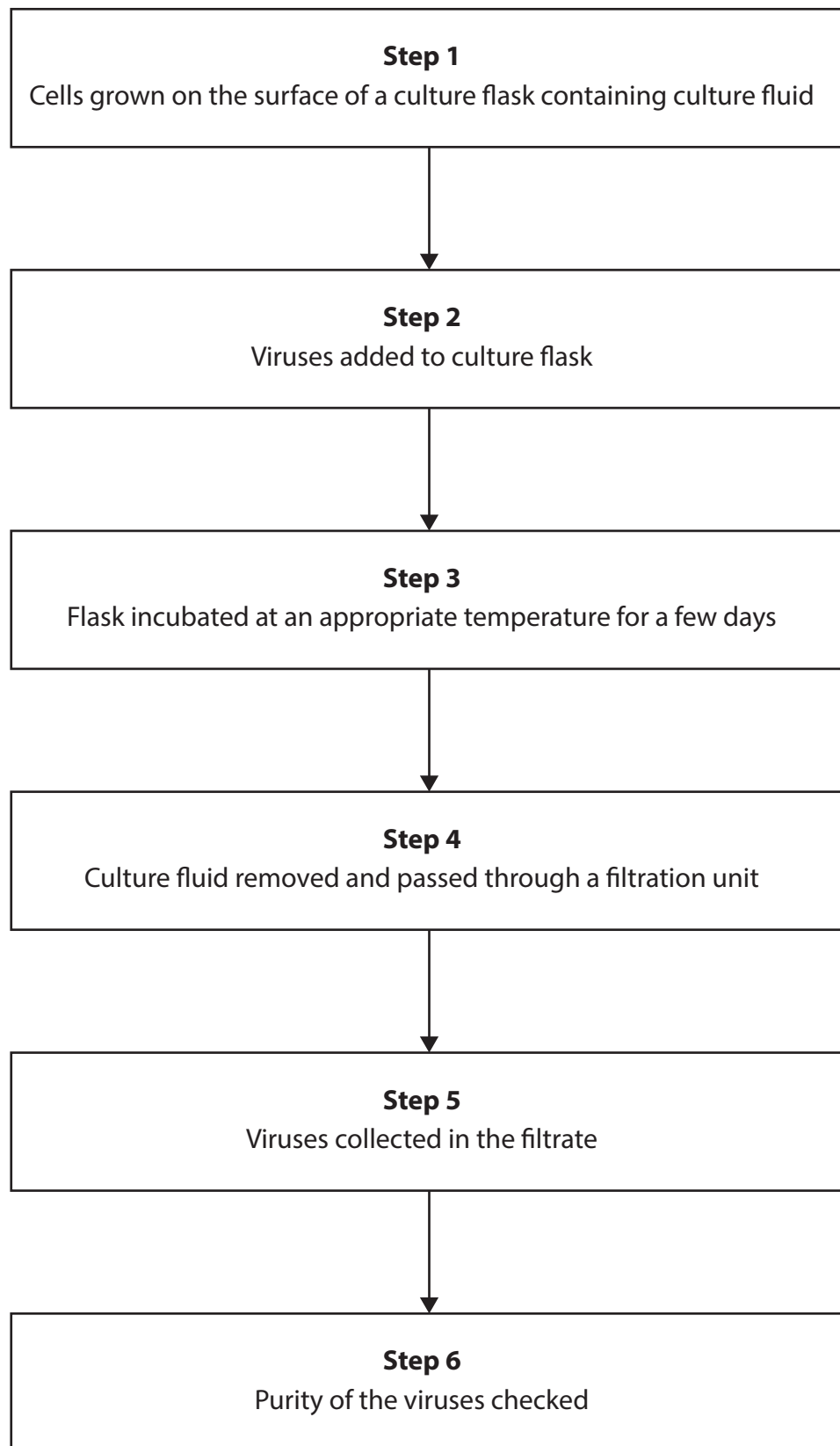
(1)

Some of the energy is lost as heat (thermal energy) during the reactions of respiration.

(Total for Question 2 = 5 marks)

3 Viruses can be cultured and isolated in a laboratory.

The diagram shows the steps involved in culturing and isolating viruses.



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(a) State why specifically-selected cell types have to be grown in **Step 1**.

(1)

Viruses can only attach to and infect specific host cells; viruses are not living, so they can only replicate inside host cells.

(b) Explain why the flask has to be incubated at an appropriate temperature for a few days in **Step 3**.

(2)

The temperature must be suitable for the enzymes of the host cells to function, so the enzymes do not denature and the cells can be used to make new viruses.

A few days are needed to allow enough time for viral replication (the lytic cycle), so that many viruses are released by lysis of the cells.

(c) Explain why the viruses and not the cells will be present in the filtrate in **Step 5**.

(3)

During the lytic cycle the viruses burst out of their host cells (lysis) into the culture fluid.

Most of the host cells stay attached to the surface of the culture flask, so few cells are removed with the culture fluid.

A filter is selected with pores that allow the small viruses through but not the cells, as the cells are too big to pass through the filtration unit.

(Total for Question 3 = 6 marks)



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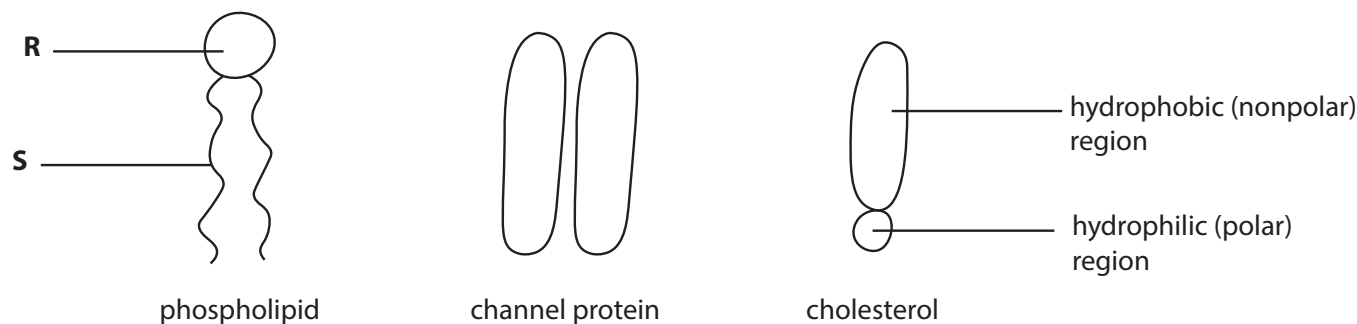
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- 4 The permeability of the cell surface membrane to a particular molecule depends on a number of factors, including the properties of the membrane and the properties of the molecule moving through it.

(a) The diagram shows some of the components of the cell surface membrane.



- (i) Which row in the table describes parts R and S of the phospholipid?

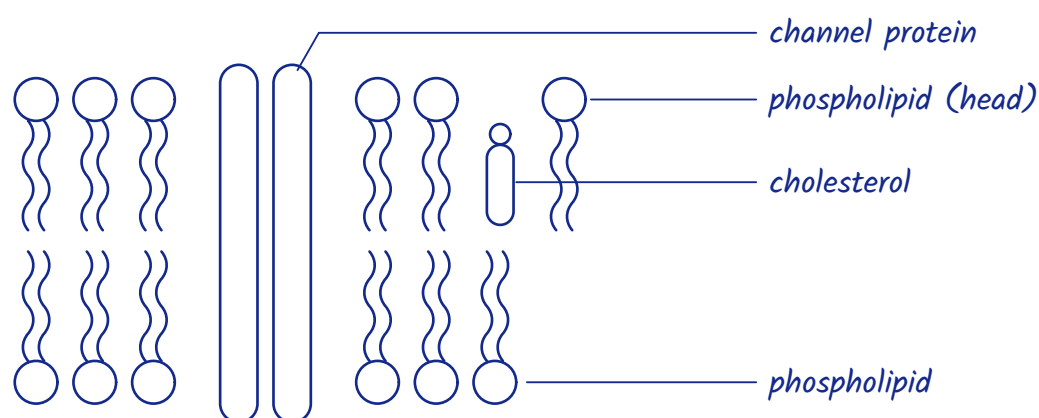
(1)

	Part R	Part S
☐ A	hydrophilic fatty acid	hydrophobic phosphate
☒ B	hydrophilic phosphate	hydrophobic fatty acid
☐ C	hydrophobic fatty acid	hydrophilic phosphate
☐ D	hydrophobic phosphate	hydrophilic fatty acid

- (ii) Draw part of a cell surface membrane that has twelve phospholipids, one channel protein and one cholesterol molecule.

Use the components shown in the diagram.

(2)

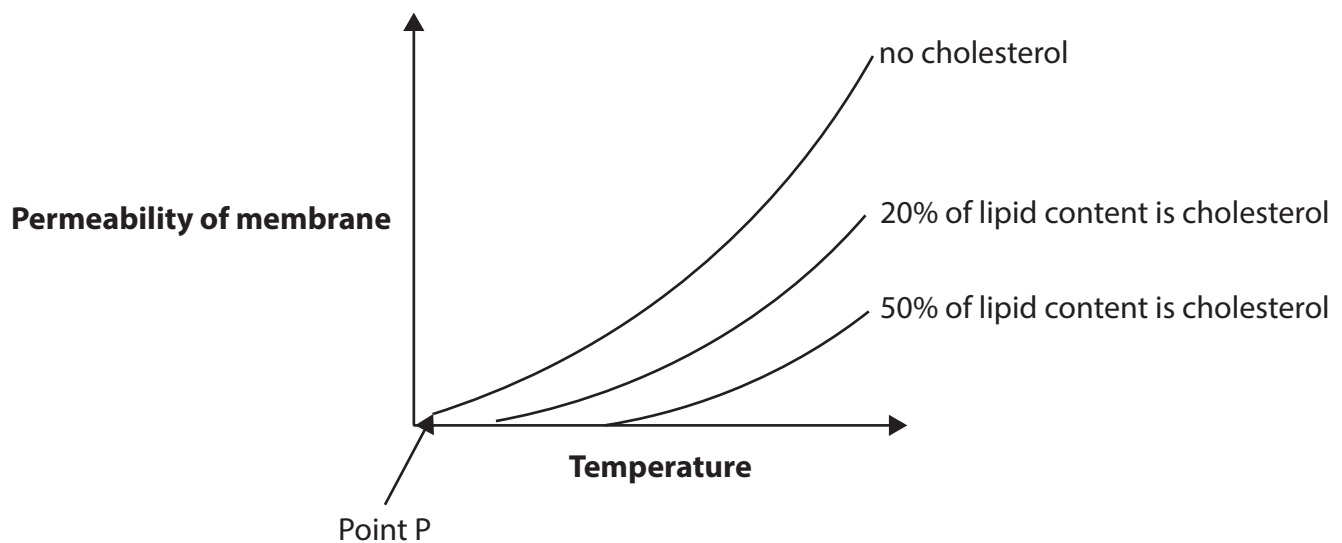


(iii) Describe the role of channel proteins in cell transport.

(2)

Channel proteins span the bilayer and provide a hydrophilic channel through the membrane, allowing hydrophilic (polar or charged) molecules and ions to pass through. They allow facilitated diffusion: passive movement down a concentration gradient, with no ATP needed.

(b) The graph shows the effect on the permeability of membranes of temperature and the proportion of cholesterol in the membrane.



(i) Analyse the data to give **two** conclusions that can be made from this graph.

(2)

As temperature increases, the permeability of the membrane increases.

The presence of cholesterol decreases permeability: the higher the proportion of cholesterol, the lower the permeability at a given temperature, so a membrane with no cholesterol is the most permeable.



(ii) Explain the effect of temperature on membrane permeability at point P.

(2)

At point P the temperature is low, so the phospholipids have very little kinetic energy.

The phospholipids hardly move, so the membrane is less fluid and molecules are not able to pass through it; there is a low rate of diffusion, so the permeability is very low for all three membranes.

(Total for Question 4 = 9 marks)



5 Turner's syndrome (TS) results from a chromosome mutation.

People with TS are at a higher risk of developing autoimmune disorders than people without TS.

An autoimmune disorder results when a person's immune system attacks their own body.

(a) Which of the following describes the chromosome mutation that causes TS?

(1)

- ☒ A non-disjunction leading to monosomy
- ☐ B non-disjunction leading to polysomy
- ☐ C translocation leading to monosomy
- ☐ D translocation leading to polysomy

(b) There were 613 936 babies born in the UK in 2020.

The ratio of baby boys to baby girls is 1.05 : 1.

The incidence of TS is between 1 in 2 000 and 1 in 2 500 in baby girls.

Calculate the **minimum** number of baby girls born with TS in the UK in 2020.

(2)

$$\text{number of girls} = 613\,936 \div 2.05 = 299\,481$$

$$\text{minimum incidence} = 1 \text{ in } 2500$$

$$299\,481 \div 2500 = 119.8$$

Answer 120



(c) Scientists studied a group of girls with TS and a group of girls without TS.

They recorded physical features and immunological markers such as antibodies and lymphocytes.

(i) Girls who had recently been vaccinated were excluded from this study.

Explain why these girls were excluded.

(3)

The vaccine contains antigens, which stimulate a primary immune response in these girls.

So there will be a higher number of lymphocytes (B cells, T cells, plasma cells and memory cells) and antibodies in their blood than normal.

The immunological markers measured would be raised by the vaccination, not by TS, giving false-positive results and making the results of the study invalid (skewed).



(ii) The table shows some of the physical features of the two groups of girls.

Physical features	Mean value $\pm$ SD for each group of girls	
	With TS	Without TS
Age / years	11.9 ± 4.1	12.5 ± 4.0
Mass / kg	36.7 ± 14.8	45.2 ± 19.3
Height / cm	134.8 ± 20.0	146.3 ± 21.3
Standardised height score	-2.16 ± 0.95	-0.41 ± 0.50
Body mass index (BMI)	19.2 ± 3.3	19.7 ± 4.6

Only one of these features was significantly different between the two groups of girls.

Explain which was the significantly different feature.

(2)

The standardised height score.

It is the only feature where the standard deviations do not overlap: the largest value for girls with TS is $-2.16 + 0.95 = -1.21$, which is lower than the smallest value for girls without TS, $-0.41 - 0.50 = -0.91$.



- (iii) The table shows the levels of four immunological markers in the blood of each group of girls.

Immunological marker	Mean value $\pm$ SD for each group of girls	
	With TS	Without TS
IgA antibody / g dm ⁻³	1.08 $\pm$ 0.39	1.15 $\pm$ 0.42
IgG antibody / g dm ⁻³	9.14 $\pm$ 2.10	11.15 $\pm$ 3.29
CD4 lymphocytes / cells per μ l	656.3 $\pm$ 227.3	817.3 $\pm$ 350.1
CD8 lymphocytes / cells per μ l	597.6 $\pm$ 272.6	494.8 $\pm$ 188.3

Analyse the data to describe the conclusions that can be made about the immunological markers in girls with TS.

(2)

Girls with TS have lower mean levels of IgA and IgG antibodies and fewer CD4 lymphocytes, but more CD8 lymphocytes, than girls without TS.

However, the standard deviations overlap for all four markers, so there is no significant difference in the levels of antibodies and lymphocytes.



- (iv) The scientists also determined the number of a type of cell called T regulatory cells in the blood of these two groups of girls.

They found that the numbers of these cells were very similar.

People with autoimmune diseases have been shown to have a decreased number of T regulatory cells.

Explain how this study could be modified to show that a decreased number of T regulatory cells is linked to the risk of autoimmune disease in girls with TS.

(2)

Divide the girls from both groups into those with an autoimmune disease and those without, so one group has TS and autoimmune disease and one group has TS and no autoimmune disease.

Then compare the numbers of T regulatory cells in these groups.

(Total for Question 5 = 12 marks)

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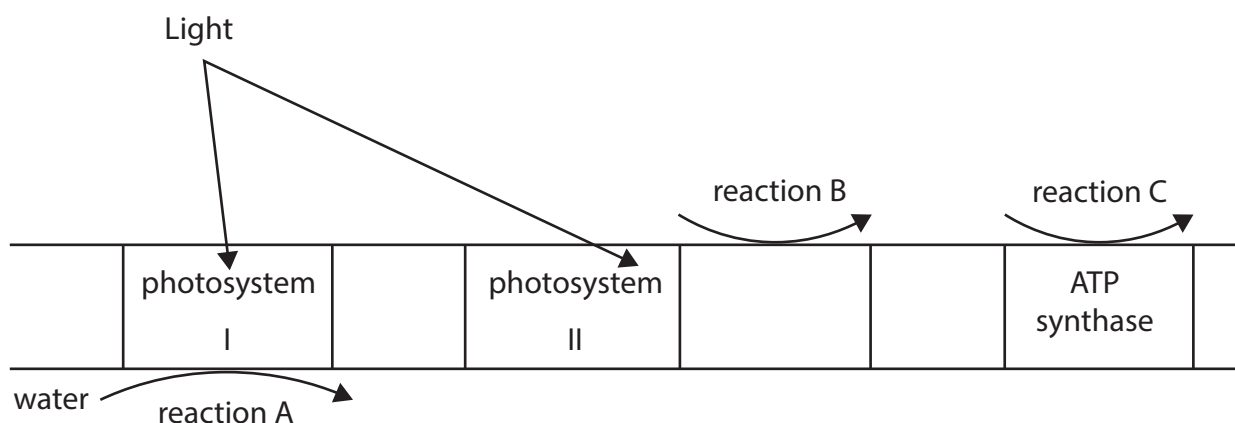
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6 *Chlorella* are single-celled photosynthetic algae.

(a) The diagram shows part of a membrane in a chloroplast from *Chlorella*.



(i) Which membrane is shown in this diagram?

(1)

- ☐ A crista
- ☐ B inner
- ☐ C outer
- ☒ D thylakoid

(ii) Name reaction A.

(1)

Photolysis (of water)

(iii) What occurs in reaction B?

(1)

- ☐ A reduced NADP is broken down by gaining an electron
- ☐ B reduced NADP is broken down by losing an electron
- ☒ C reduced NADP is produced by gaining an electron
- ☐ D reduced NADP is produced by losing an electron

(iv) Write the equation for reaction C.

(1)

$ADP + P_i \rightarrow ATP$



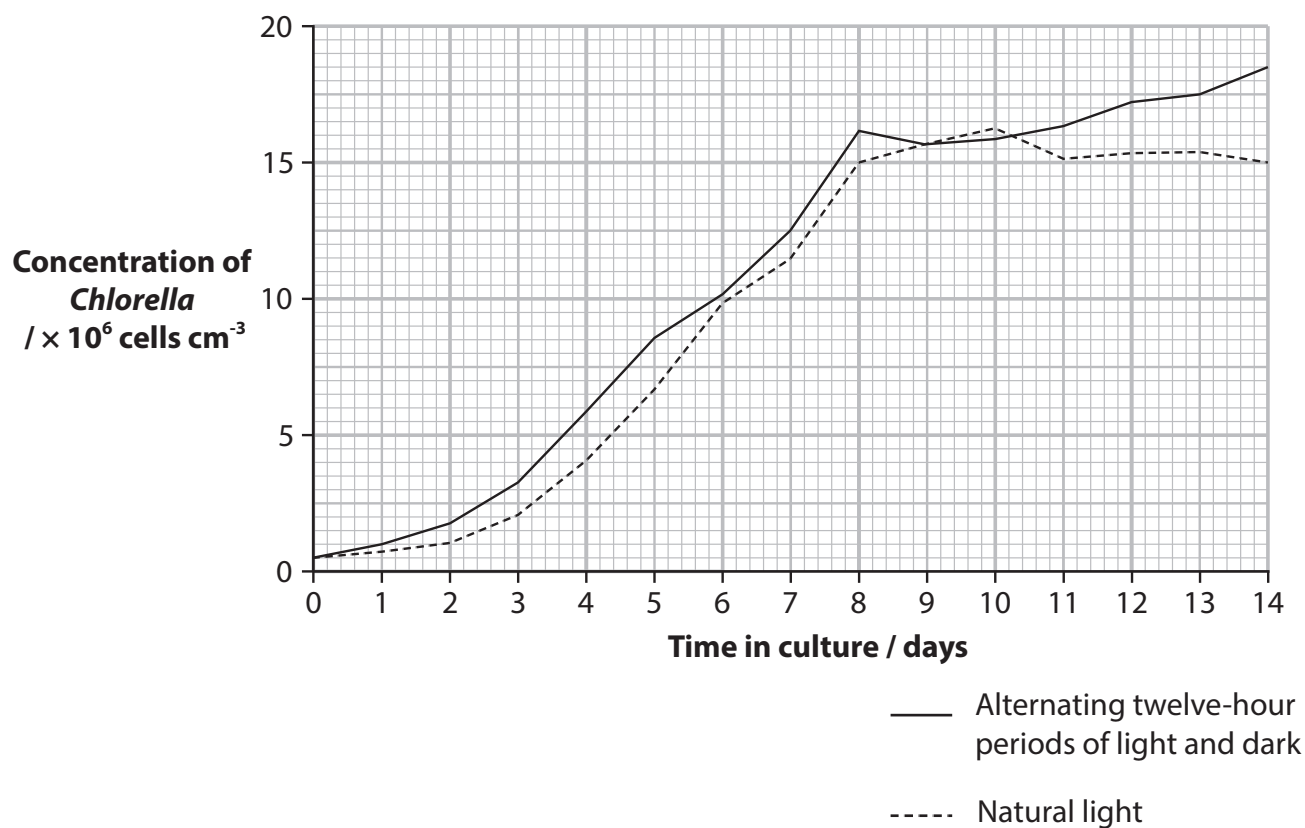
P 7 4 4 5 9 R A 0 1 7 3 6

- (b) Scientists are developing solar cells that contain photosynthetic pigments derived from *Chlorella*.

Solar cells absorb light and generate electricity.

The scientists cultured *Chlorella* under two different lighting conditions.

The graph shows the growth of *Chlorella* exposed to either natural light or to alternating twelve-hour periods of light and dark.



- (i) The mean growth rate for *Chlorella* grown in natural light during the fourteen-day period was 1.04×10^6 cells per day.

Calculate how many times faster *Chlorella* grew in alternating periods of light and dark.

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

(2)

$$\text{increase} = (18.5 - 0.5) \times 10^6 = 18.0 \times 10^6 \text{ cells cm}^{-3}$$

$$\text{rate} = 18.0 \times 10^6 \div 14 = 1.286 \times 10^6 \text{ cells per day}$$

$$1.286 \times 10^6 \div 1.04 \times 10^6 = 1.236$$

Answer 1.2



(ii) The cultures were observed for a further four days.

The table shows the observations.

Time in culture / days	Observation	
	<i>Chlorella</i> grown in alternating periods of light and dark	<i>Chlorella</i> grown in natural light
17	Dark green cells The number of cells had not increased since the previous day	Light green cells The number of cells had increased since the previous day
18	Cells had entered the death phase	Cells had not entered the death phase

Explain these observations.

(5)

Cells in alternating light and dark are dark green because they have synthesised more photosynthetic pigments (more chlorophyll and more chloroplasts) than cells in natural light, so they absorb more light for photosynthesis.

On day 17 their number had not increased because the culture was in the stationary phase: the number of new cells produced equals the number of cells dying. The cells in natural light were still dividing by mitosis, so their number was still increasing.

On day 18 the cells in alternating light and dark entered the death phase, as more cells were dying than being produced.

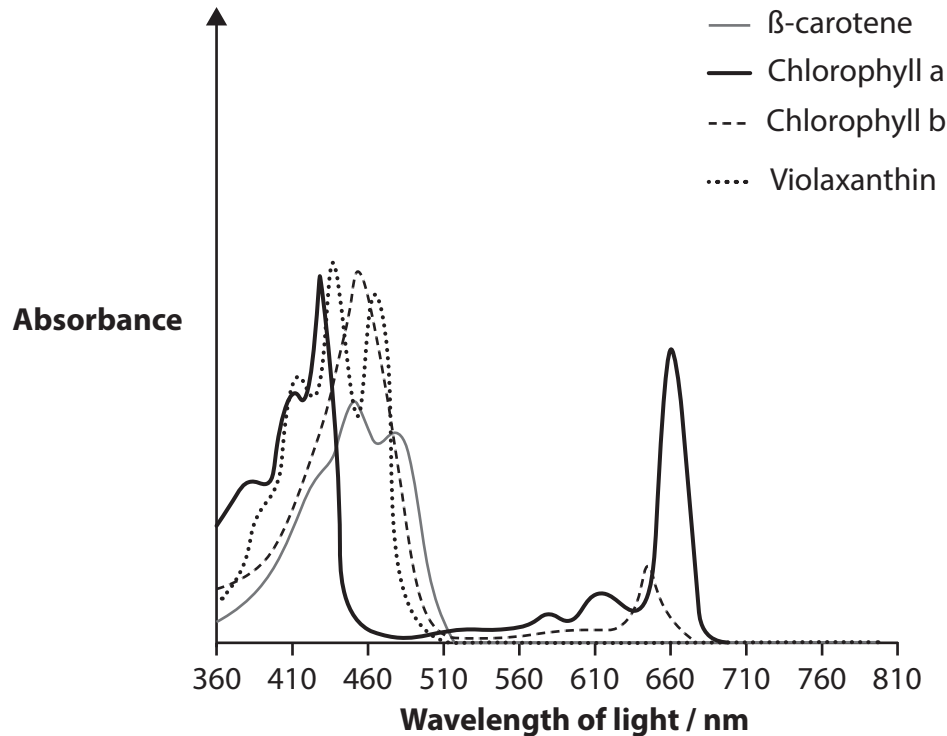
This is due to limiting factors: the large population has used up the minerals and carbon dioxide in the culture, and the dense cells shade each other so less (visible) light reaches them, so photosynthesis is limited.

Toxins and waste products also build up in the culture and there is a lack of space, so cells die. The slower-growing culture in natural light had not yet reached these limits.



- (iii) The scientists chose to use *Chlorella* as a source of photosynthetic pigments for solar cells.

The graph shows the absorption spectra of four photosynthetic pigments found in *Chlorella*.



Explain why *Chlorella* cells are a suitable source of photosynthetic pigments for use in a solar cell.

(3)

Chlorella contains several different photosynthetic pigments (chlorophyll a, chlorophyll b, β -carotene and violaxanthin), which absorb light of different wavelengths, from about 360 to 510 nm and 610 to 680 nm.

So together they maximise light absorption over a wider range of wavelengths.

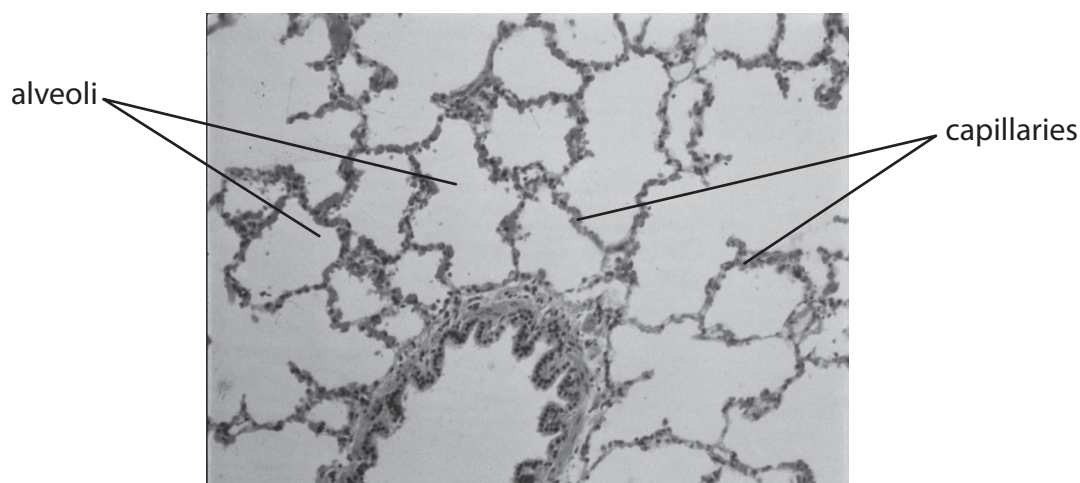
Therefore more light energy is captured, maximising the production of electricity by the solar cells.

(Total for Question 6 = 14 marks)



7 Living organisms have a range of gas exchange systems.

(a) The photograph shows human lung tissue, as seen using a light microscope.



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(i) The typical diameter of an adult alveolus is $200\text{ }\mu\text{m}$.

There are 300 million alveoli in each lung.

Calculate the total surface area of a pair of adult lungs, using the formula:

$$\text{surface area of one alveolus} = 4\pi r^2$$

Give your answer in m^2 .

(3)

$$r = 200 \div 2 = 100\text{ }\mu\text{m} = 0.0001\text{ m}$$

$$\text{one alveolus} = 4 \times \pi \times 0.0001^2 = 1.257 \times 10^{-7}\text{ m}^2$$

$$\text{alveoli in two lungs} = 2 \times 300\,000\,000 = 600\,000\,000$$

$$600\,000\,000 \times 1.257 \times 10^{-7} = 75.4\text{ m}^2$$

Answer 75.4 m^2

(ii) Explain the importance of a large surface area in a gas exchange system.

(2)

A large surface area increases the rate of diffusion of gases, so gas exchange is faster.

This supplies sufficient oxygen to the cells for (aerobic) respiration and removes carbon dioxide quickly.



P 7 4 4 5 9 R A 0 2 1 3 6

(iii) Fluid passes out of the capillaries into the spaces around the alveoli.

Some of this fluid passes into the alveoli.

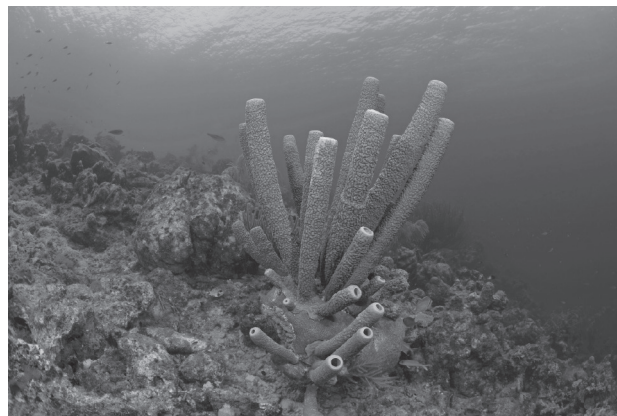
Explain the importance of having fluid inside the alveoli.

(2)

Oxygen dissolves in the fluid (oxygen in solution) before it can diffuse across the alveolar wall into the blood.

The fluid contains surfactant, which prevents the alveoli from collapsing (sticking together); the fluid also maintains the alveolar membrane.

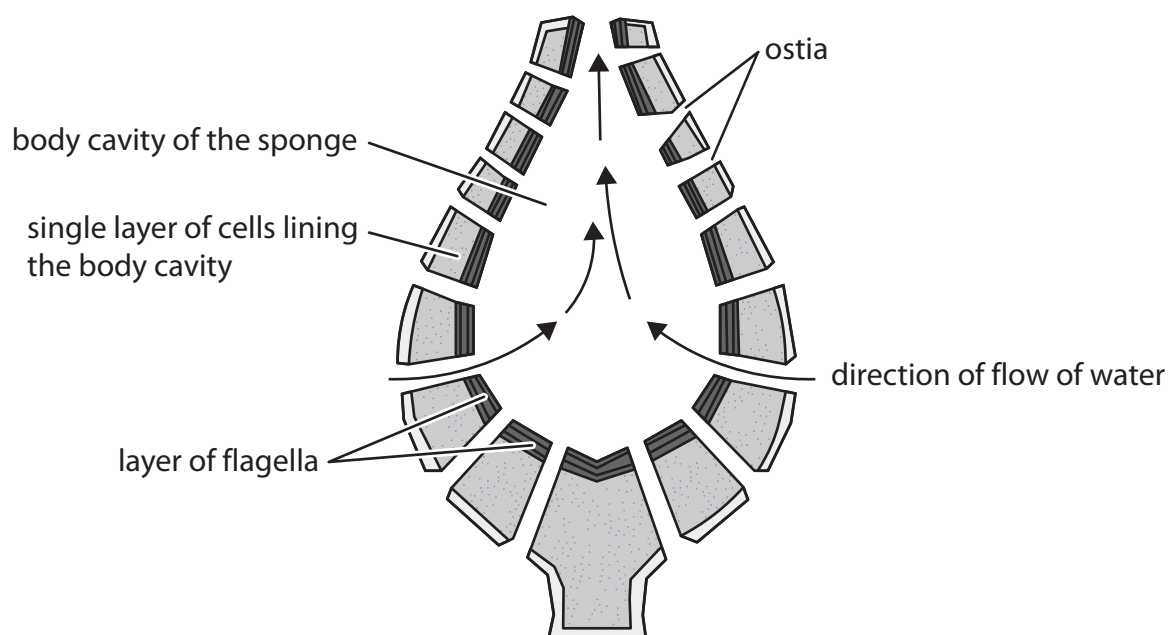
(b) The photograph shows a marine sponge.



© Helmut Corneli/Alamy Stock Photo

Sponges are aquatic animals that are covered in pores called ostia.

The diagram shows a section through a sponge.



Analyse the information in the diagram to explain how this sponge is adapted for gas exchange.

(3)

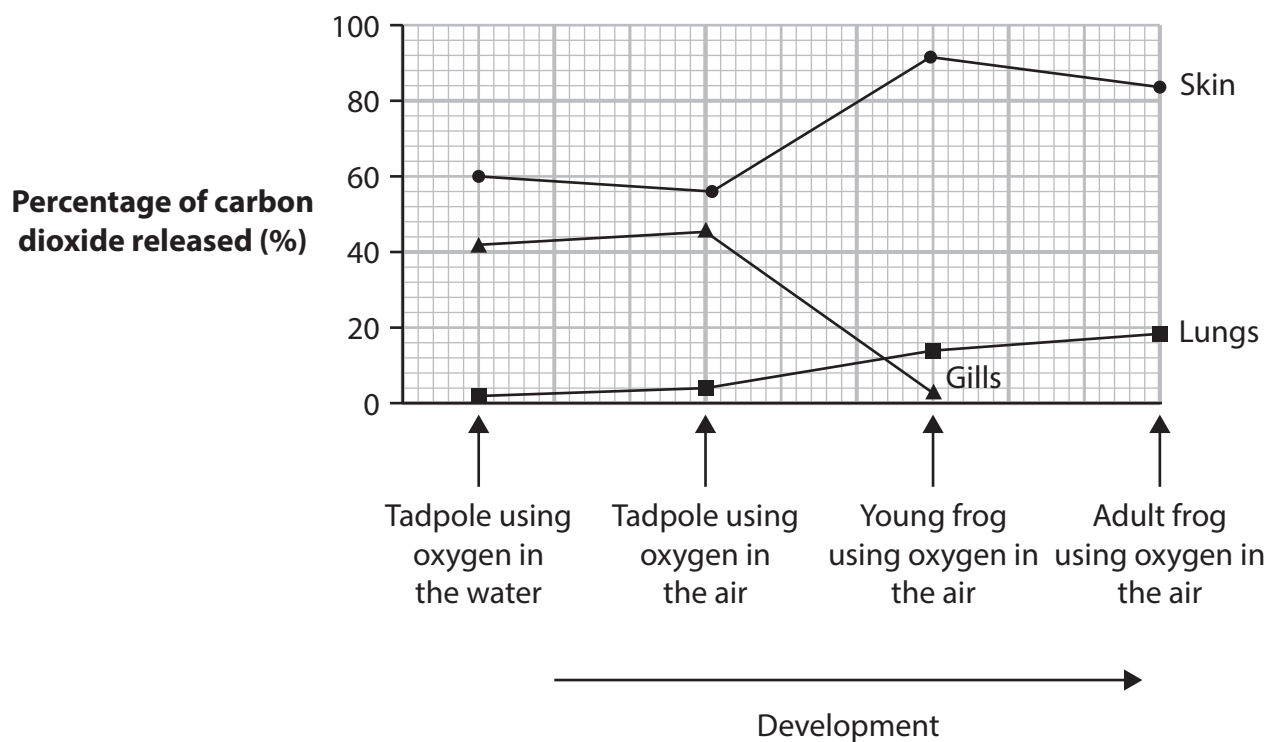
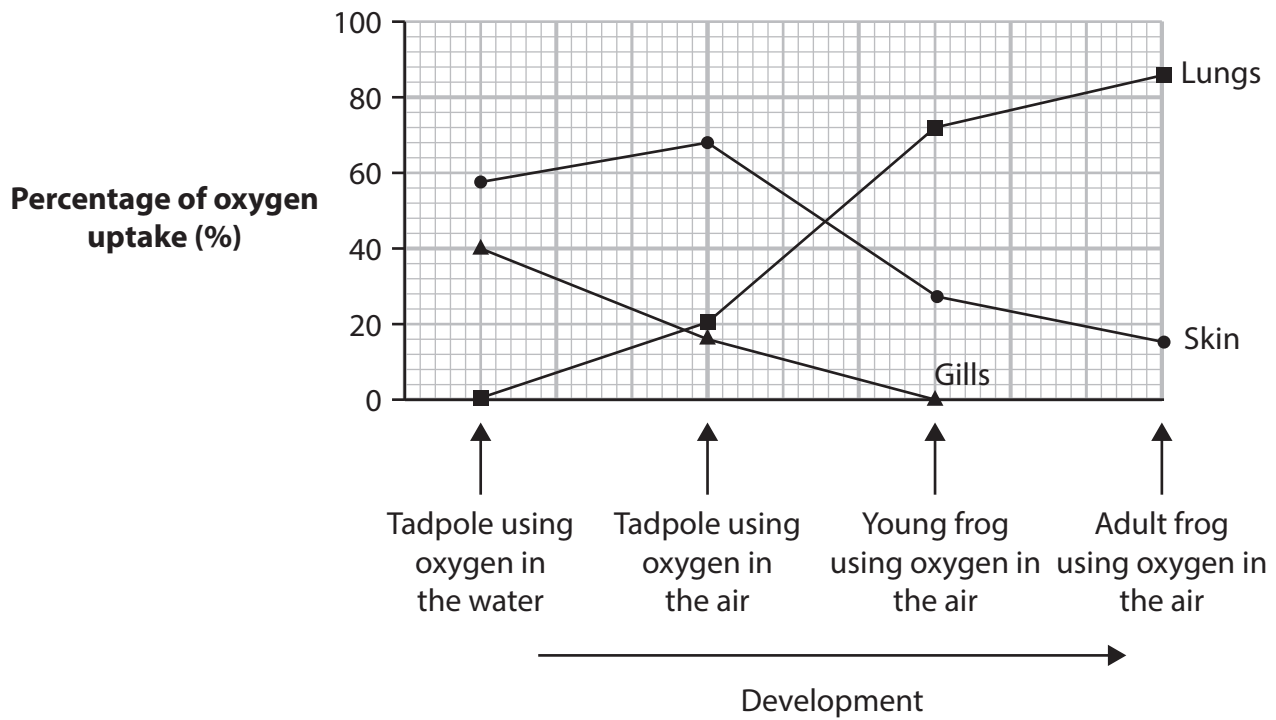
The ostia (gaps) allow water to flow into the body cavity, and the unidirectional flow of water maintains a concentration gradient for oxygen and carbon dioxide.

The body cavity is lined by a single layer of cells, so the gas exchange surface is thin, giving a shorter diffusion distance.

The cells have flagella, which keep the water flowing, and the folded shape of the sponge and its cavity provides a large surface area.



(c) The graphs show changes in gas exchange as a tadpole develops into an adult frog.



Analyse the data to explain the role of the gills, lungs and skin in gas exchange as a tadpole develops into a frog.

(4)

The use of the gills decreases as the tadpole develops into a frog breathing air: the gills take oxygen from the water (about 40% of oxygen uptake) in the tadpole, but are not used (0%) in the young frog.

The use of the lungs increases as the tadpole develops: the lungs are not used (0%) when the tadpole lives in water, but take up about 86% of the oxygen in the adult frog.

The skin is used for gas exchange at all developmental stages. The skin is used in the tadpole because it has a high surface area to volume ratio.

In the adult frog the skin is less important than the lungs in taking up oxygen (about 15% compared with 86%), but more important in releasing carbon dioxide (about 83% through the skin, only 18% through the lungs).

(Total for Question 7 = 14 marks)





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- 8 The rate of photosynthesis in some plants can be affected by the level of nitrogen gas in the air.

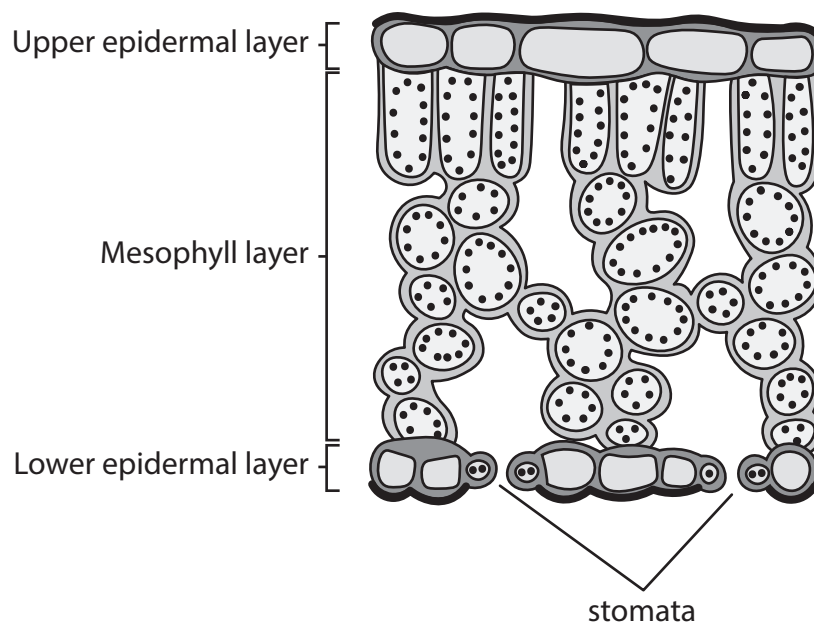
The effects of low, moderate and high nitrogen levels on leaf structure and molecules present in the leaves were investigated.

- (a) Which pair of molecules contains nitrogen atoms?

(1)

- ☐ A carbohydrates and lipids
- ☐ B lipids and nucleic acids
- ☒ C nucleic acids and proteins
- ☐ D proteins and carbohydrates

- (b) The diagram shows a section through a leaf.



- (i) Which is the main gas exchange surface in a leaf?

(1)

- ☐ A lower epidermal layer
- ☒ B mesophyll layers
- ☐ C stomata
- ☐ D upper epidermal layer



*(ii) The table shows some effects on the characteristics of leaves when plants are grown in low, moderate and high levels of nitrogen gas.

Characteristic	Effect compared with plants grown in moderate levels of nitrogen gas	
	Plants grown in low levels of nitrogen gas	Plants grown in high levels of nitrogen gas
Thickness of layers	smaller	larger
Size of chloroplasts	smaller	larger
Surface area of chloroplasts exposed to intercellular air space	lower	higher
RUBISCO activity	lower	lower

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Discuss how growing plants in low levels and high levels of nitrogen gas affects the rate of photosynthesis.

(6)

In low nitrogen the layers are thinner, so the mesophyll layer is narrower, with less chlorophyll for the light-dependent stage and less stroma and RUBISCO for the Calvin cycle, so the rate of photosynthesis falls, although gases diffuse through faster. In high nitrogen thicker layers have more chlorophyll and RUBISCO.

Low nitrogen plants have smaller chloroplasts, so less light is absorbed and less ATP and reduced NADP are made; there is less stroma, so RUBISCO is at a lower concentration and the Calvin cycle is slower. Larger chloroplasts in high nitrogen absorb more light.

A lower surface area of chloroplasts exposed to the air spaces in low nitrogen reduces gas exchange, so there is a lower concentration of carbon dioxide and the Calvin cycle is slower. The higher surface area in high nitrogen increases carbon dioxide uptake.

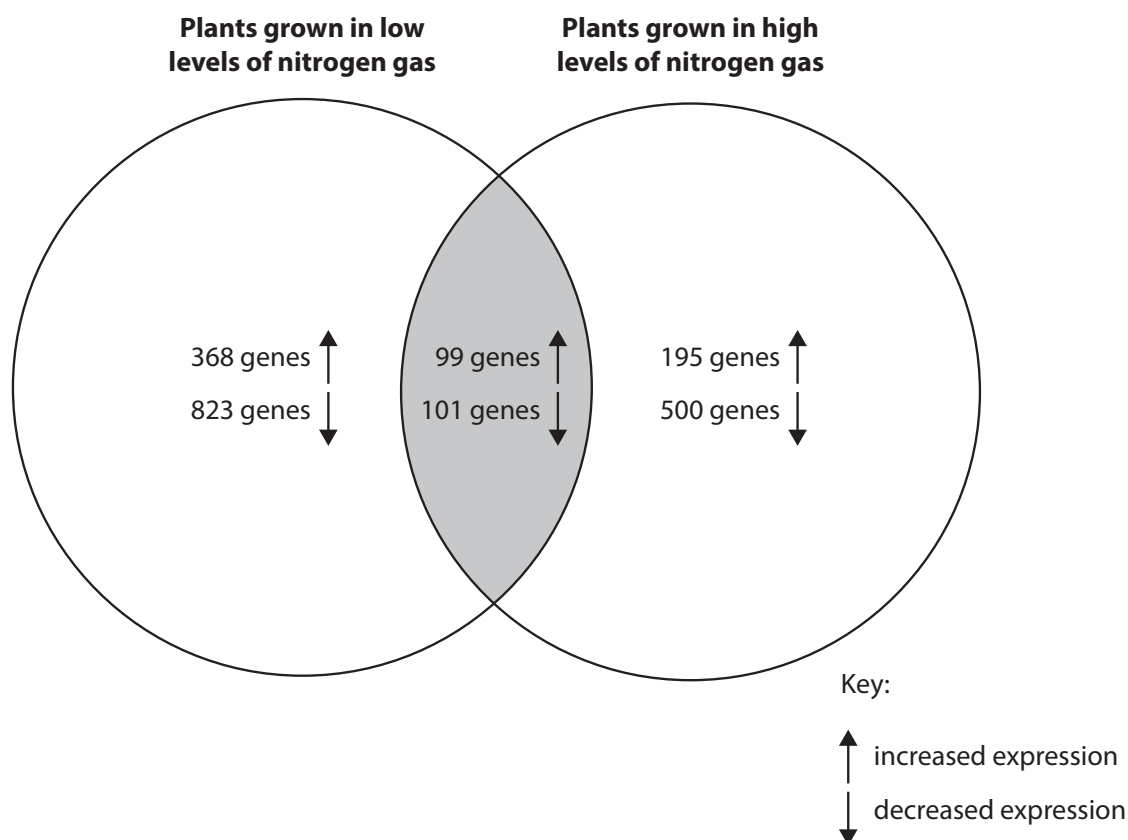
RUBISCO activity is lower in both. RUBISCO catalyses carbon fixation (carbon dioxide + RuBP), so the rate of reaction decreases and the Calvin cycle is slower. So low nitrogen reduces the rate for all four reasons, and in high nitrogen the rate is limited by RUBISCO activity.



- (c) This investigation also studied changes in gene expression in the plants grown in low levels and high levels of nitrogen gas compared with those grown in moderate levels.

The chart shows the results of this part of the investigation.

The shaded area shows the genes that were affected in both groups of plants.



- (i) Determine the effect of growing plants in low levels of nitrogen gas and in high levels of nitrogen gas on the changes in gene expression.

(3)

Low nitrogen causes more changes in gene expression: $467 + 924 = 1391$ genes affected, compared with $294 + 601 = 895$ genes in high nitrogen, so 496 more genes were affected in low levels.

In both groups more genes had decreased expression than increased expression (low: 924 decreased, 467 increased; high: 601 decreased, 294 increased).

Some genes were affected in both groups: 200 genes (99 increased, 101 decreased).



(ii) Describe how gene expression can be changed.

(2)

By epigenetic modification, without changing the DNA base sequence.

For example, DNA methylation or histone modification (acetylation), which changes how tightly DNA is wound, so transcription factors and RNA polymerase can or cannot bind.

(Total for Question 8 = 13 marks)



- 9 Aptamers are single-stranded DNA or RNA sequences that fold into specific three-dimensional structures.

Aptamers bind tightly to targets such as proteins and viruses.

- (a) Compare and contrast the structure of single-stranded DNA with that of single-stranded RNA.

(3)

Similarities: both are made of (mono)nucleotides joined by phosphodiester bonds, and both contain the bases adenine, guanine and cytosine.

Differences: DNA contains the base thymine whereas RNA contains uracil instead.

DNA contains the sugar deoxyribose whereas RNA contains ribose.

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(b) Aptamers can be amplified using PCR.

To amplify an RNA aptamer, reverse transcription-PCR (RT-PCR) must be used.

Describe how RT-PCR can be used to amplify RNA aptamers.

(4)

The enzyme reverse transcriptase is used to synthesise a DNA copy (cDNA) of the RNA aptamer strand.

This DNA is amplified by PCR: it is mixed with primers, DNA (mono)nucleotides, heat-stable DNA polymerase and a buffer.

The mixture is heated to about 95 °C to break the hydrogen bonds and separate the strands, cooled to about 55 °C so the primers anneal, then heated to about 72 °C so DNA polymerase synthesises new complementary strands.

The cycle is repeated many times, doubling the DNA each cycle.

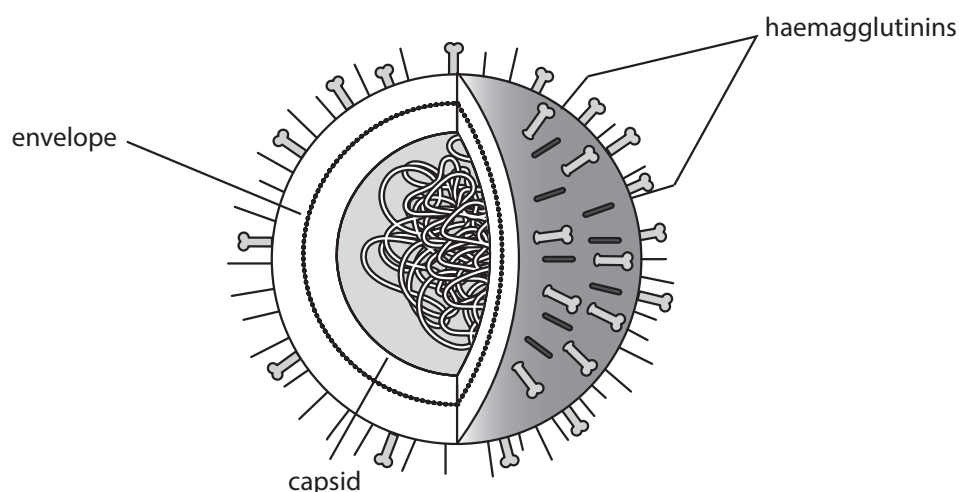
The DNA is then transcribed using RNA polymerase to make many copies of the RNA aptamer.



*(c) The diagram shows the structure of the influenza virus.

Haemagglutinin is a glycoprotein that binds to molecules on the cell membranes of the host cells of this virus.

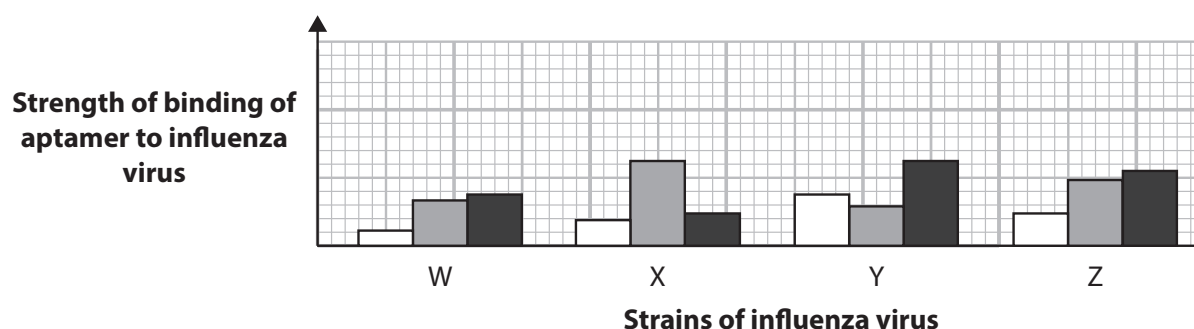
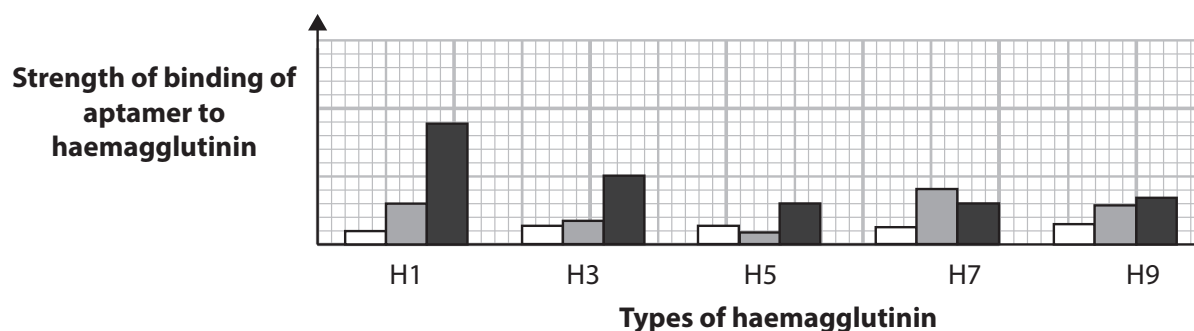
Strains of influenza virus have evolved that have haemagglutinins on their surface, with different antigenic properties.



Aptamers (AT1, AT2 and AT3) have been developed that bind to haemagglutinins (H1, H3, H5, H7 and H9).

The strength of binding of these aptamers to the haemagglutinins and to four strains of influenza virus (W, X, Y and Z) was investigated.

The graphs show the results of this investigation.



Key



Discuss the advantages and disadvantages of using aptamers to prevent infection with the influenza virus.

(6)

Influenza viruses attach to host cells by haemagglutinin binding to receptor molecules on the host cell membrane, so the virus can enter and replicate.

Graph 1: all aptamers bind to each haemagglutinin. AT3 binds most to all types apart from H7, with its strongest binding to H1; AT2 binds most to H7 and least to H5;

AT1 binds least except for H5. Graph 2: all aptamers bind to all strains; AT3 binds strongest to W, Y and Z, AT2 to X, and AT1 binds least apart from Y.

Advantages: aptamer binding to haemagglutinin prevents attachment of the virus to the host cell, so it cannot enter and replicate and the infection does not spread. As aptamers bind to different haemagglutinins and strains, they could prevent infection by a range of strains, and might bind to new haemagglutinins from mutations, giving greater protection.

Disadvantages: the virus may mutate so the aptamer cannot bind. Aptamers are not part of the immune system, so there is no immunological memory and protection could be short-lived. They may bind to other molecules or cells, side effects are not known, and with no error bars we cannot tell if the differences are significant.

(Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 90 MARKS



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