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EDEXCEL A LEVEL BIOLOGY B: QUESTIONS BY TOPIC

Energy for Biological Processes (5)

A Level Biology B Topic 5

32 questions · 355 marks · Mark schemes included

Pearson Edexcel AS (8BI0) and A Level (9BI0) Biology B, June 2016 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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2. Q2	A Level Paper 1 June 2025	5	6
3. Q3 <i>also Topic 9</i>	A Level Paper 2 June 2018	6	8
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QUESTIONS

32 questions · 355 marks · grouped by sub-topic, lowest tariff first



SUB-TOPIC 5(a)

RESPIRATION

17 questions in this sub-topic · 186 marks · lowest tariff first



- 2 An investigation was carried out to compare the aerobic respiration of different sugars by yeast.

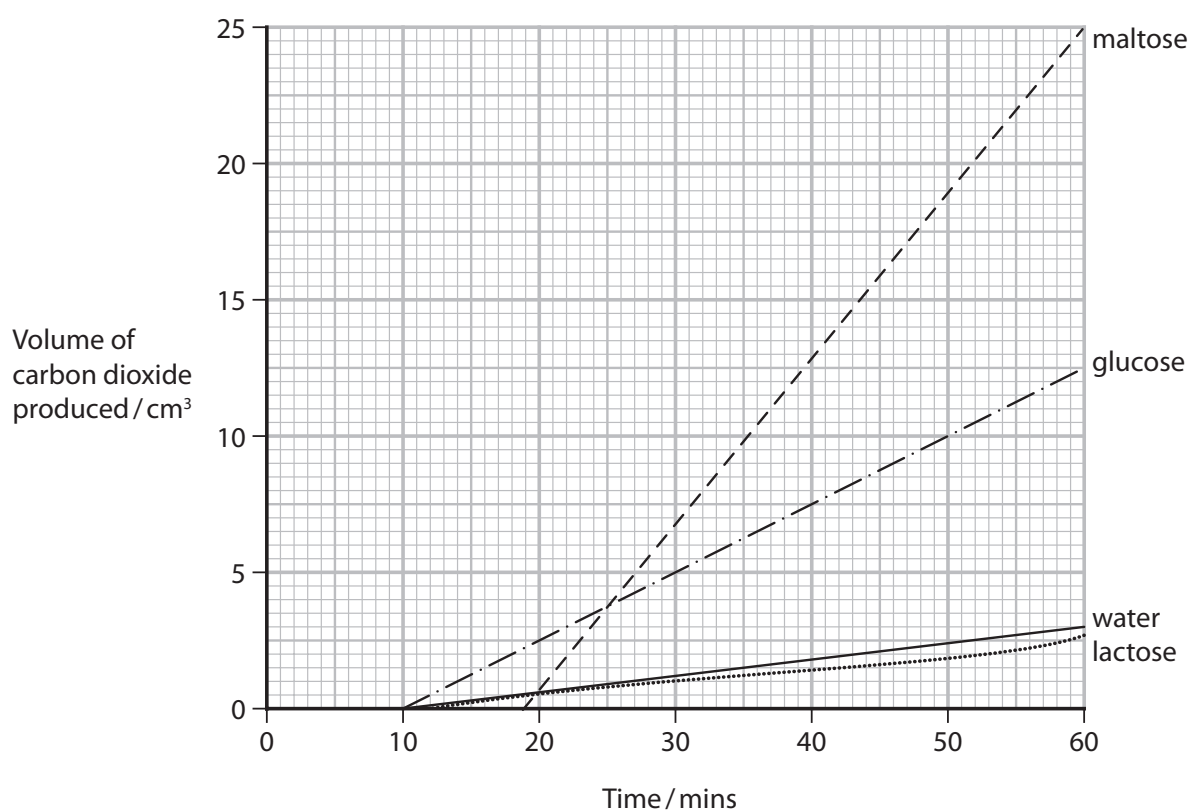
A suspension of yeast was used to produce three cultures, each one with a different sugar.

A control was set up that had a suspension of yeast cultured with water only.

The volume of carbon dioxide produced was measured.

The mass of yeast and the concentration of each sugar were controlled.

The graph shows the results of this investigation.



- (a) (i) Give one difference between the structure of glucose and the structure of maltose.

(1)

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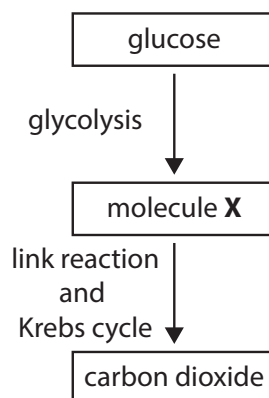
(ii) Explain the results for the yeast cultured with glucose and the yeast cultured with maltose.

(2)

(b) Explain the results for the yeast cultured with lactose.

(2)

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)

Answer %

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

(1)

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(Total for Question 2 = 5 marks)



3 The retina contains rod cells and bipolar neurones.

Rod cells contain large numbers of mitochondria.

(a) Explain the role of mitochondria in the functioning of rod cells.

(2)

(b) Rod cells release glutamate, an inhibitory neurotransmitter.

Describe how light causes a change in the release of glutamate from rod cells.

(4)

5 Some antibiotics work by inhibiting the production of ribosomes in bacteria.

The structure of ribosomes in bacteria is similar to the structure of ribosomes in mitochondria.

(a) (i) Describe the structure of a ribosome.

(2)

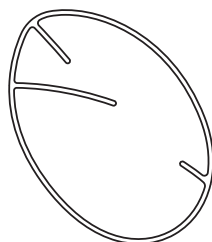
(ii) Describe the role of ribosomes in protein synthesis.

(2)



- (b) These antibiotics can destroy cancer cells in humans.

The diagram shows the membranes of a mitochondrion from a cancer cell treated with these antibiotics.



- (i) Give one difference in the membranes of this mitochondrion compared with the membranes of a mitochondrion from an untreated cancer cell.

(1)

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- (ii) Some cancer cells depend on oxidative phosphorylation for ATP production.

Explain why the antibiotics that inhibit the production of ribosomes prevent oxidative phosphorylation when used to treat cancer cells.

(2)

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- (iii) Some scientists suggested that inhibiting both glycolysis and mitochondrial respiration may be an effective way of treating cancer cells.

Explain why this suggestion may be an effective way of treating cancer cells.

(2)

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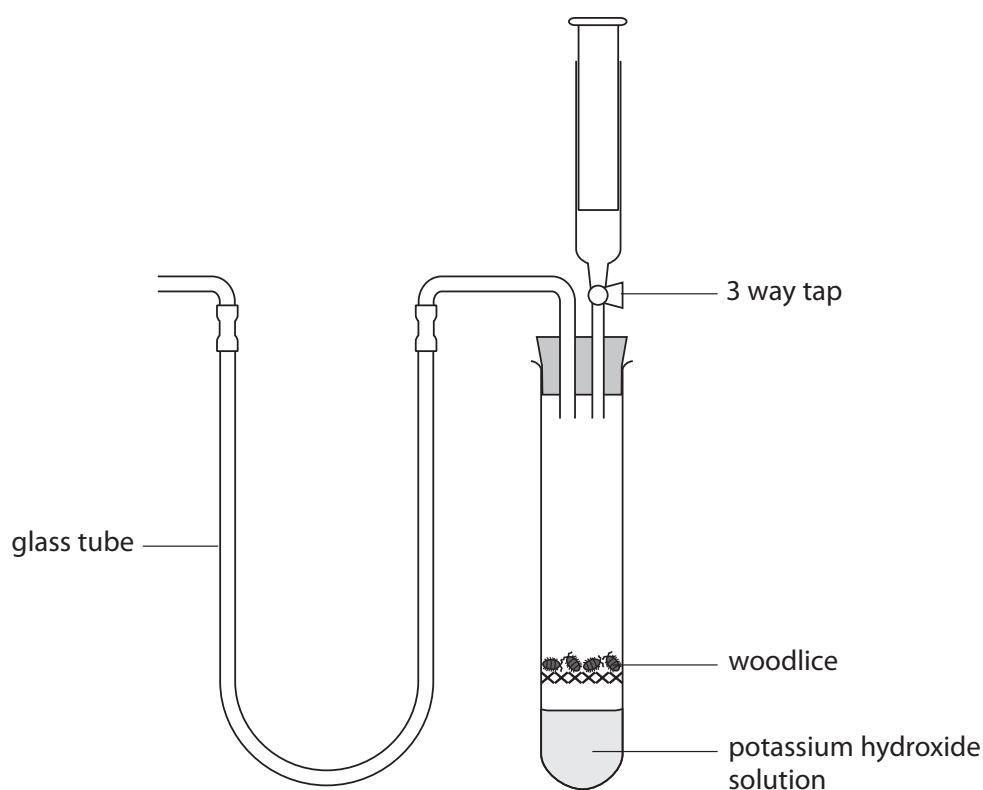
- 5** Fluoride ions reduce anaerobic respiration in yeast by inhibiting the action of the enzyme enolase.

Fluoride ions combine with magnesium ions and phosphate ions to resemble the substrate of enolase.

- (a) Name the type of inhibition produced by fluoride ions.

(1)

- *(b) The diagram shows some apparatus that can be used to measure the rate of respiration in small animals such as woodlice.



Discuss how you would modify this apparatus and use it to find out if fluoride ions have a significant effect on the rate of anaerobic respiration in yeast.

(9)

4 Mitochondria can be extracted from liver cells.

In order to monitor the purification of a sample of mitochondria, a protein concentration : enzyme activity ratio can be determined.

(a) Describe the structure of a globular protein.

(2)

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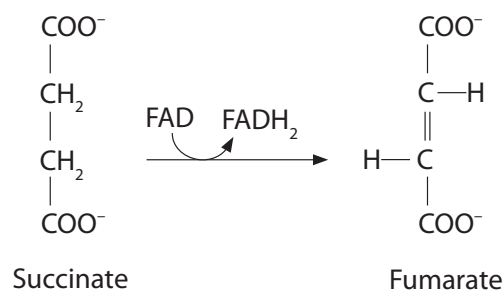
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(b) The enzyme used to monitor the purification of mitochondria is succinate dehydrogenase.

This enzyme is involved in the Krebs cycle and converts succinate into fumarate in this reaction.



(i) When succinate is converted into fumarate, succinate is

(1)

- ☐ **A** hydrolysed
- ☐ **B** oxidised
- ☐ **C** phosphorylated
- ☐ **D** reduced

(ii) Explain the role of the Krebs cycle.

(4)

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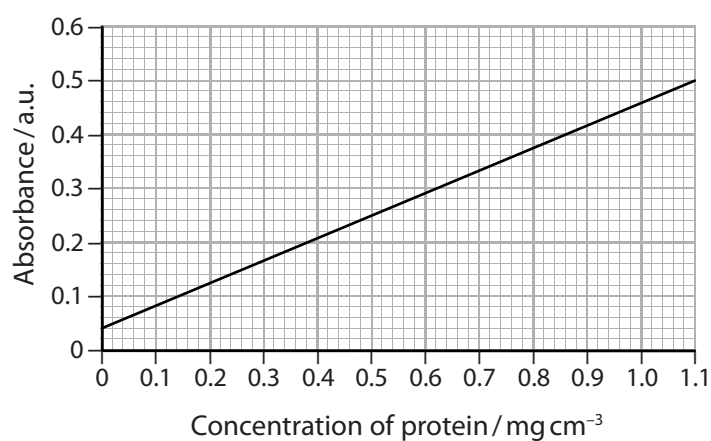
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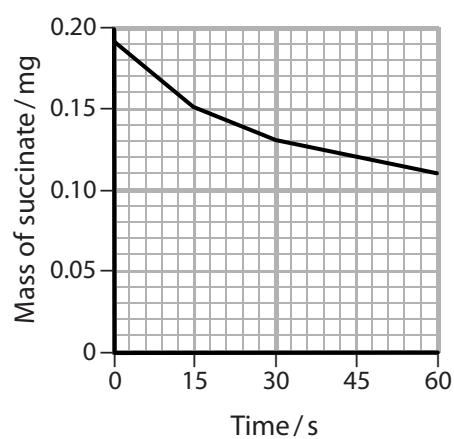
(c) Protein concentrations can be determined by using a calibration curve, shown in graph 1.

The initial rate of activity of succinate dehydrogenase, from a sample of mitochondria, can be determined using graph 2.

Graph 1



Graph 2



- (i) This sample of mitochondria had an absorbance of 0.28 when the protein concentration was measured.

Determine the protein concentration of this sample of mitochondria.

(1)

Answer

- (ii) Determine the initial rate of enzyme activity to obtain the protein : enzyme activity ratio for this sample of mitochondria.

(2)

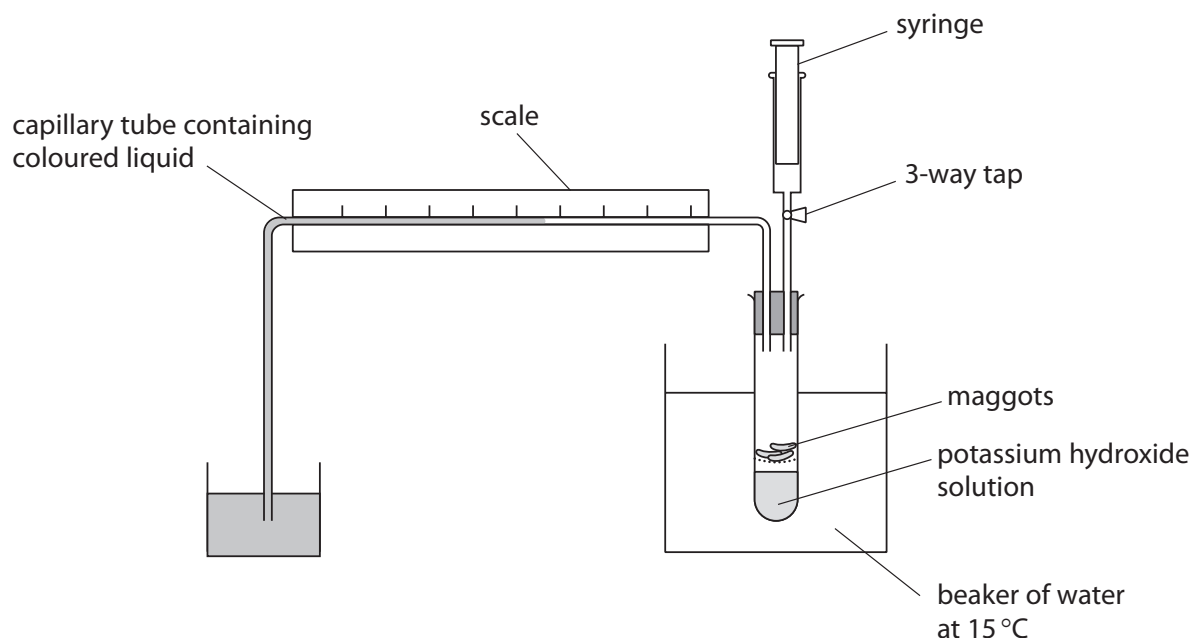
Ratio

(Total for Question 4 = 10 marks)



- 10** Five groups of students used respirometers to investigate the rate of aerobic respiration by maggots.

The diagram shows the type of respirometer used.



Maggots were placed in the boiling tube and the 3-way tap was closed.

The distance the coloured liquid had moved was measured after 15 minutes.

The rate of oxygen uptake was calculated.

The table shows the results obtained.

Group number	1	2	3	4	5
Rate of oxygen uptake / $\text{mm}^3 \text{min}^{-1} \text{g}^{-1}$	0.14	0.16	0.13	0.12	0.14

- (a) The rate of aerobic respiration was determined as the oxygen uptake calculated in mm^3 per minute per gram.

State the **two** additional measurements that you would make to calculate the rate using these units.

(2)

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- (b) Justify **two** improvements that would ensure the validity of this investigation.

(2)

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- (c) (i) For enzyme-controlled reactions, a 10°C rise in temperature will double the rate of reaction.

Predict the mean rate of oxygen uptake if the water bath had been set at 5°C .

(1)

Answer $\text{mm}^3 \text{min}^{-1} \text{g}^{-1}$



(ii) Explain why decreasing the temperature affects the rate of respiration of maggots.

(2)

(d) Describe the role of oxygen in the formation of ATP during aerobic respiration.

(3)

- 7** Mitochondrial disorders may be caused by mutations in the genes coding for mitochondrial components. Some of these genes are found in mitochondrial DNA (mtDNA) and some are found in nuclear DNA.

Leigh syndrome is an example of a mitochondrial disorder. In this syndrome, a number of different proteins involved in respiration are affected.

These mutations may be inherited or may occur when DNA replicates.

- (a) Explain why mutations in nuclear DNA can be inherited from either the mother or the father whereas mutations in mtDNA are only inherited from the mother.

(2)

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- (b) Some people with Leigh syndrome have a mutation in the MT-ATP6 gene. This gene codes for ATP synthase.

This is a point mutation at nucleotide 8993 that changes thymine to guanine.

- (i) What type of mutation is this?

(1)

- ☐ **A** insertion
- ☐ **B** monosomy
- ☐ **C** substitution
- ☐ **D** translocation

- (ii) Explain how this mutation could affect oxidative phosphorylation.

(3)

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(c) Leigh syndrome can also be due to a mutation in the SURF1 gene.

This mutation results in a shortened protein.

Explain how a mutation can result in a shortened protein being produced.

(2)

(d) Some people with Leigh syndrome have mutations that affect proteins involved in the electron transport chain.

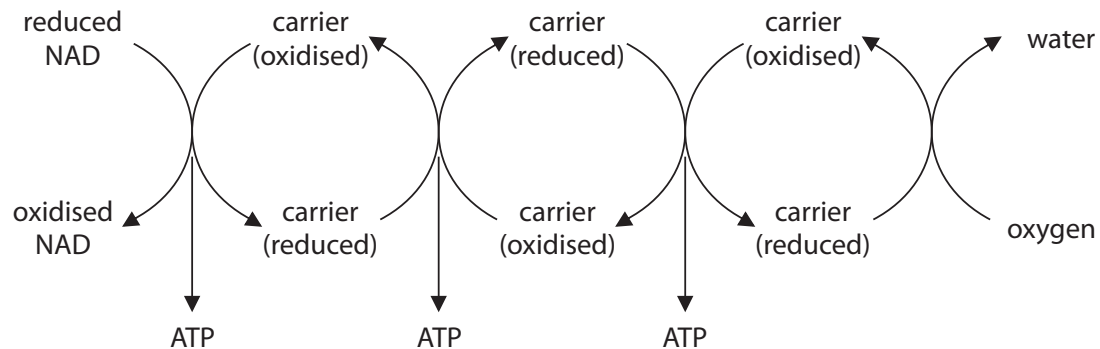
Explain why these mutations lead to a build-up of lactate.

(3)



8 The electron transport chain generates ATP.

The diagram shows the electron transport chain.



(a) State the location of the electron transport chain in a mitochondrion.

(1)

(b) Hydrogen cyanide gas is a poison that can kill an animal if it is inhaled.

Cyanide is a non-competitive inhibitor of the enzyme cytochrome oxidase.

Cytochrome oxidase is the last carrier in the electron transport chain.

(i) Explain why hydrogen cyanide gas can kill an animal.

(5)

(ii) A dose of 1.0 mg of hydrogen cyanide per kilogram of body mass is fatal.

An animal with a body mass of 10 kg inhaled air containing 0.24 mg dm^{-3} of hydrogen cyanide.

The animal breathed at a rate of 15 dm^3 of air per minute.

Calculate how many minutes it would take for this animal to obtain a fatal dose.

Give your answer to three significant figures.

(3)

Answer minutes

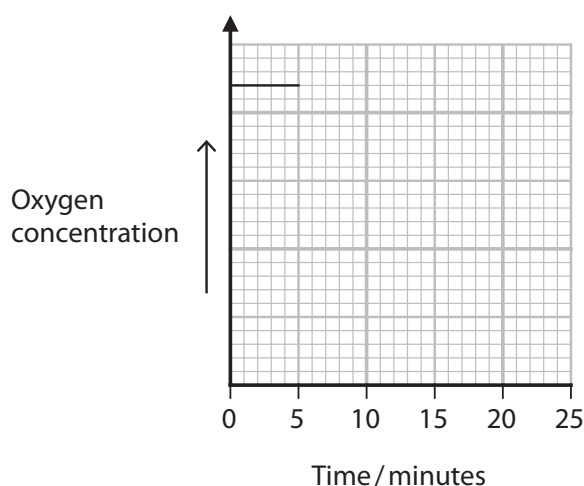
(c) The effect of cyanide on oxygen uptake by mitochondria was investigated using the following method:

- suspend mitochondria in a flask containing a buffer solution
- measure the concentration of oxygen in the flask for the first five minutes
- then add a respiratory substrate and ADP to the flask
- measure the concentration of oxygen in the flask for the next 10 minutes
- then add cyanide solution to the flask
- measure the concentration of oxygen in the flask for the next 10 minutes.

The graph shows the results for the first five minutes.

Complete the graph to show the results for the next 20 minutes.

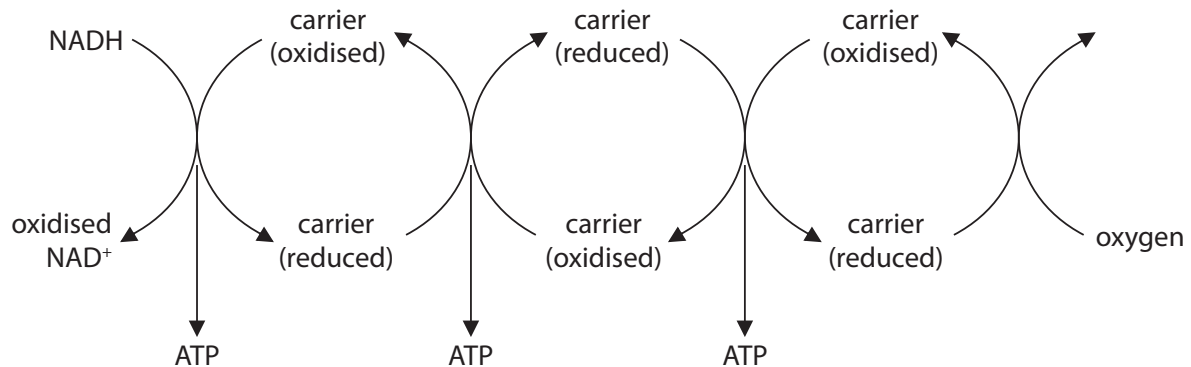
(2)



(Total for Question 8 = 11 marks)

- 8 The electron transport chain requires oxygen and synthesises ATP.

The diagram below shows part of the electron transport chain.



- (a) Describe what happens to oxygen at the end of the electron transport chain.

(2)

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- (b) A scientist investigated the oxygen consumption of four different mammals.

The table shows the results of this investigation.

Mammal	Body mass / kg	Oxygen consumption / $\text{dm}^3 \text{ h}^{-1}$	Oxygen consumption / $\text{dm}^3 \text{ kg}^{-1} \text{ h}^{-1}$
Shrew	0.002	0.0216	1.08×10^1
Cat	3	1.5	5.00×10^{-1}
Human	80	24	3.00×10^{-1}
Elephant	4000	50	

- (i) Calculate the oxygen consumption of the elephant.

Convert your answer into standard form.

(2)

Answer $\text{dm}^3 \text{kg}^{-1} \text{h}^{-1}$

- (ii) Explain the relationship between body mass and oxygen consumption in these mammals.

(4)

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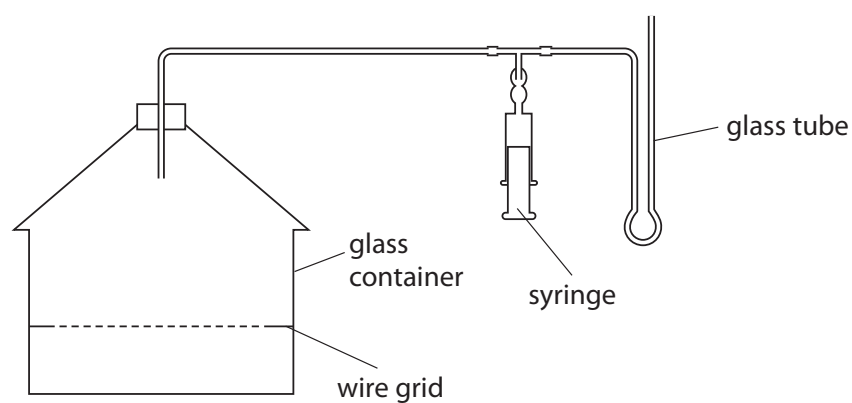
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(c) The diagram shows a respirometer.



Explain how a student could modify this respirometer and use it to measure the mean oxygen consumption of a rat.

(4)

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- 9 The photograph shows a shortfin molly.



(Source: © WILDLIFE GmbH/Alamy Stock Photo)

This fish has adapted to survive in environments where levels of hydrogen sulfide (H_2S) are toxic to other organisms.

- (a) Hydrogen sulfide can interrupt mitochondrial respiration by inactivating cytochrome c oxidase, one of the proteins in the electron transport chain.

- (i) Where is the electron transport chain located in mitochondria?

(1)

- ☐ A inner membrane
- ☐ B intermembrane space
- ☐ C matrix
- ☐ D outer membrane

- (ii) Explain why inactivating cytochrome c oxidase could be fatal.

(3)

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(b) The adaptation of these fish to H_2S in their environment is thought to be due to epigenetic modification by DNA methylation.

(i) State the meaning of the term epigenetic modification.

(1)

(ii) Which of the following is another type of **epigenetic** modification?

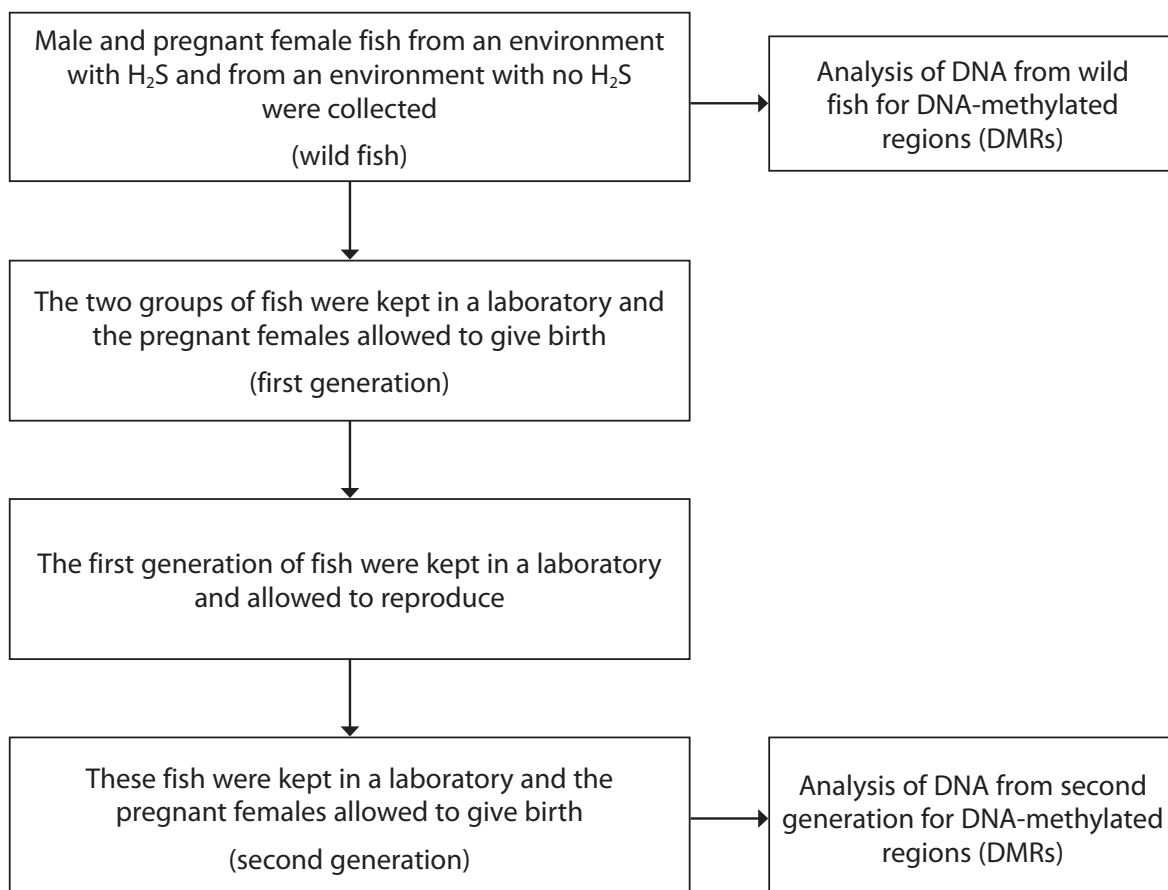
(1)

- ☐ **A** deletion mutation
- ☐ **B** histone modification
- ☐ **C** translation
- ☐ **D** translocation

*(c) The effect of hydrogen sulfide (H_2S) on DNA methylation in these fish was investigated.

The flow diagram shows part of the method used in this investigation.

All the fish kept in the laboratory were in water with no H_2S .



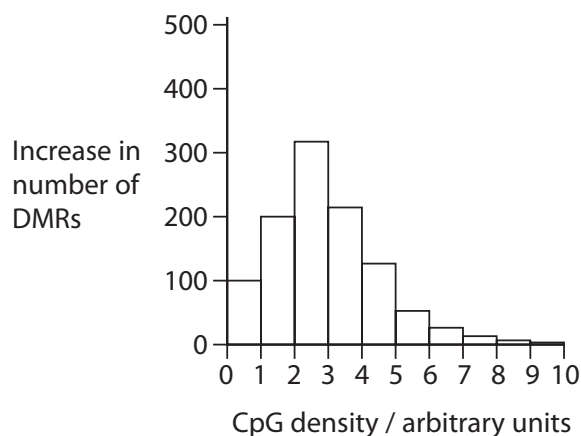
A CpG site is a region of DNA where a cytosine nucleotide is followed by a guanine nucleotide on the sense strand.

The DNA was analysed for the number of DNA-methylated regions (DMRs) at areas of DNA with different CpG densities. The numbers of DMRs for each group of fish were then compared.

The graphs show the increase in the number of DNA-methylated regions (DMRs) in each group of fish.

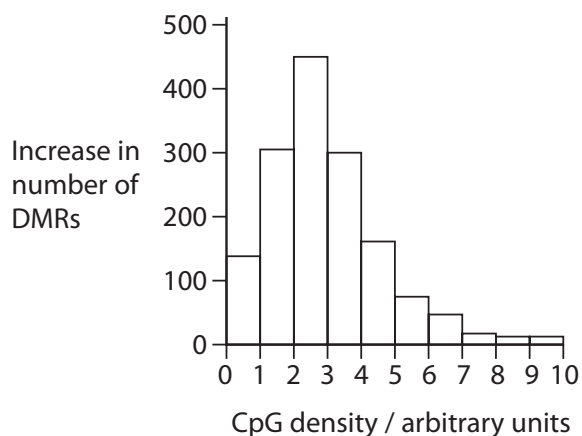
Graph 1: Wild male fish

fish from environment with H_2S compared with fish from environment with no H_2S



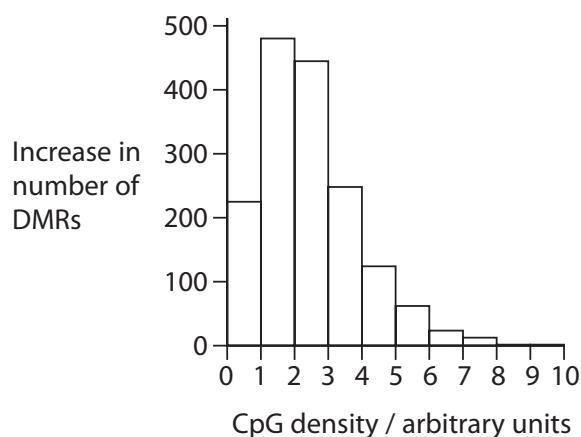
Graph 2: Wild female fish

fish from environment with H_2S compared with fish from environment with no H_2S



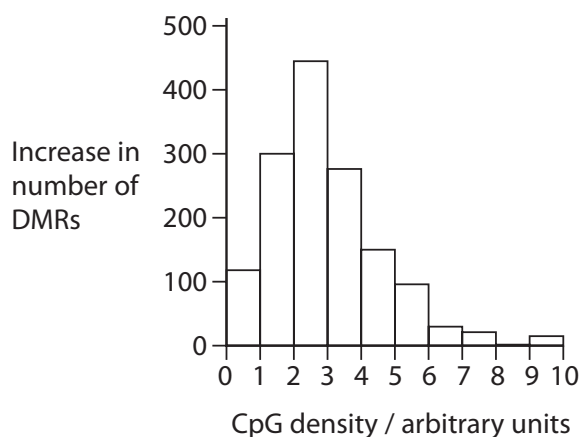
Graph 3: Second generation male fish

fish from environment with H_2S compared with fish from environment with no H_2S



Graph 4: Second generation female fish

fish from environment with H_2S compared with fish from environment with no H_2S



Discuss the results of this investigation.

(6)

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- 8** Hypoxia is an inadequate supply of oxygen to tissues and cells that restricts their function.

- (a) The normal partial pressures of oxygen vary from tissue to tissue.

The table shows the normal partial pressure of oxygen in two tissues.

Tissue	Partial pressure of oxygen / kPa
Pulmonary arterial blood	5.3
Other arterial blood	13.3

- (i) Calculate the ratio of the partial pressures of oxygen in these two tissues.
Give your answer to one decimal place.

(1)

Answer

- (ii) Explain why the partial pressures of oxygen in these two tissues are different.

(2)

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- (b) The body responds to hypoxia by releasing hypoxia-inducible transcription factors (HIF).

Investigations have shown that one effect of HIF is an increase in the rate of glycolysis in the affected cells.

- (i) Explain how HIF could result in an increase in the rate of glycolysis.

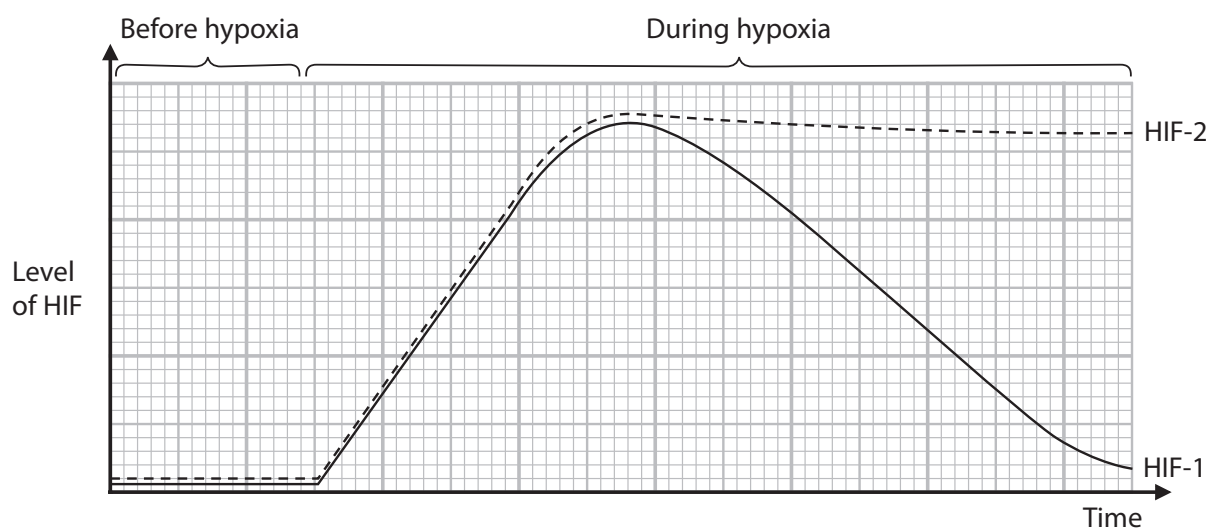
(2)

- (ii) Explain why cells need to respond to hypoxia with an increase in the rate of glycolysis.

(4)



(iii) The graph shows the changes in levels of two HIFs, HIF-1 and HIF-2, before and during hypoxia.



Compare and contrast the changes in the levels of HIF-1 and HIF-2 during hypoxia.

(2)

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(iv) Explain the changes in levels of HIF-1 and HIF-2 during hypoxia.

(2)

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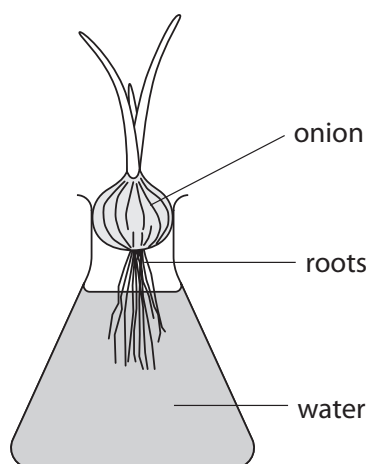
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- 5 A student read that some plants do not grow well in waterlogged soil.

The student formed the following hypothesis:

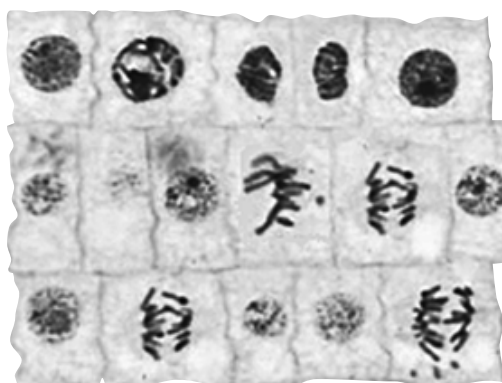
Adding water to soil inhibits mitosis in root cells.

To test this hypothesis, the student grew onion roots in the apparatus shown.



The tips of the onion roots were removed and observed for stages of mitosis.

The photomicrograph shows a preparation from one onion root tip.



- (a) Calculate the percentage of cells in this photomicrograph in anaphase.

(2)

Answer

(b) Describe how to prepare a microscope slide of root tissue to show stages of mitosis.

(4)

(c) Devise a method the student should use to investigate the effect of waterlogged soil on mitosis in root cells.

(4)

(d) Waterlogged soil lacks oxygen.

Explain why a lack of oxygen in waterlogged soil could reduce the growth of a plant.

(4)

[illegible]

4 Woodlice are crustaceans found in many gardens and woodland habitats.

There are several species that are native to the UK and Ireland.

They obtain oxygen through gills, which are on their legs.

The photograph shows one species of woodlouse, *Armadillidium vulgare*.



Magnification $\times 2$

(Source: © TED KINSMAN / SCIENCE PHOTO LIBRARY)

- (a) (i) Describe how you could measure the respiration rate of woodlice collected from a garden.

(5)

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- (ii) Identify **one** safety issue and **one** ethical issue involved in your method in part (a)(i) and state how you would minimise the effect of these.

(2)

Safety issue

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Ethical issue

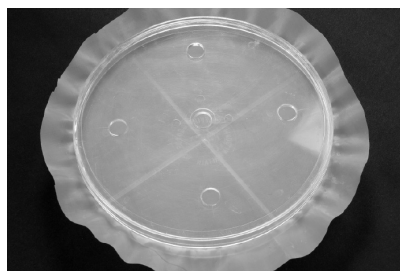
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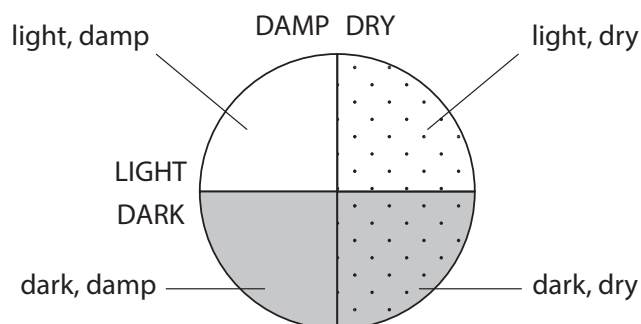
- (b) A student used a choice chamber to investigate the habitat preferences of woodlice.

The photograph shows a choice chamber.



(Source: © TREVOR CLIFFORD PHOTOGRAPHY / SCIENCE PHOTO LIBRARY)

The diagram shows the conditions in each of the four sections.



Woodlice were able to move freely to all areas of the chamber.

The student suggested the hypothesis that woodlice show no habitat preference.

- Five woodlice were placed in each of the four sections and left to move.
- The position of the woodlice was recorded after five minutes.
- This was repeated three more times.

The table shows the results obtained.

Section	Number of woodlice in each section of the chamber after 5 minutes			
	Trial 1	Trial 2	Trial 3	Trial 4
Light and dry	2	1	0	2
Light and damp	4	4	1	5
Dark and dry	4	3	3	3
Dark and damp	10	12	16	10

(i) Explain which statistical test could be used to analyse these results.

(2)

(ii) The results suggest woodlice prefer some conditions to others.

Explain why it is an advantage for them to live in these conditions.

(2)

(iii) Describe **three** improvements that could be made to this investigation to ensure the conclusion is valid.

(3)



- 10** During respiration, yeast cells break down sugars to produce carbon dioxide and ethanol.

The respiration rate of yeast is affected by several factors. It can be estimated by measuring the rate of production of carbon dioxide gas.

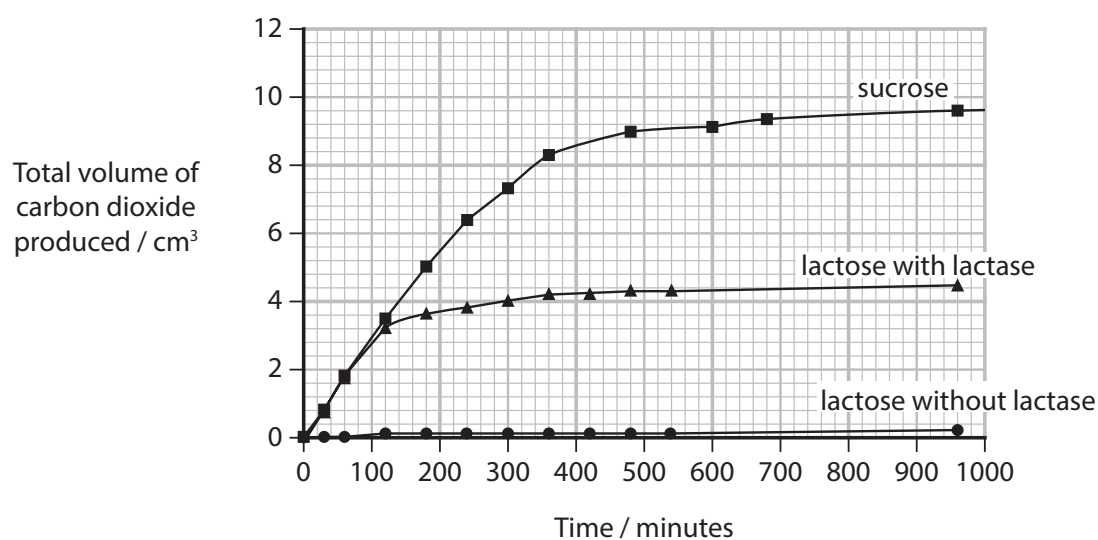
- (a) Scientists measured the rate of respiration of yeast using the sugar sucrose as a substrate.

This was repeated using the sugar lactose with and without lactase.

Lactase is an enzyme that hydrolyses lactose.

The same concentrations of both sugars were used and the suspensions were incubated at 30°C.

The graph shows the results.



- (i) Calculate the initial rate of respiration of yeast with sucrose.

(1)

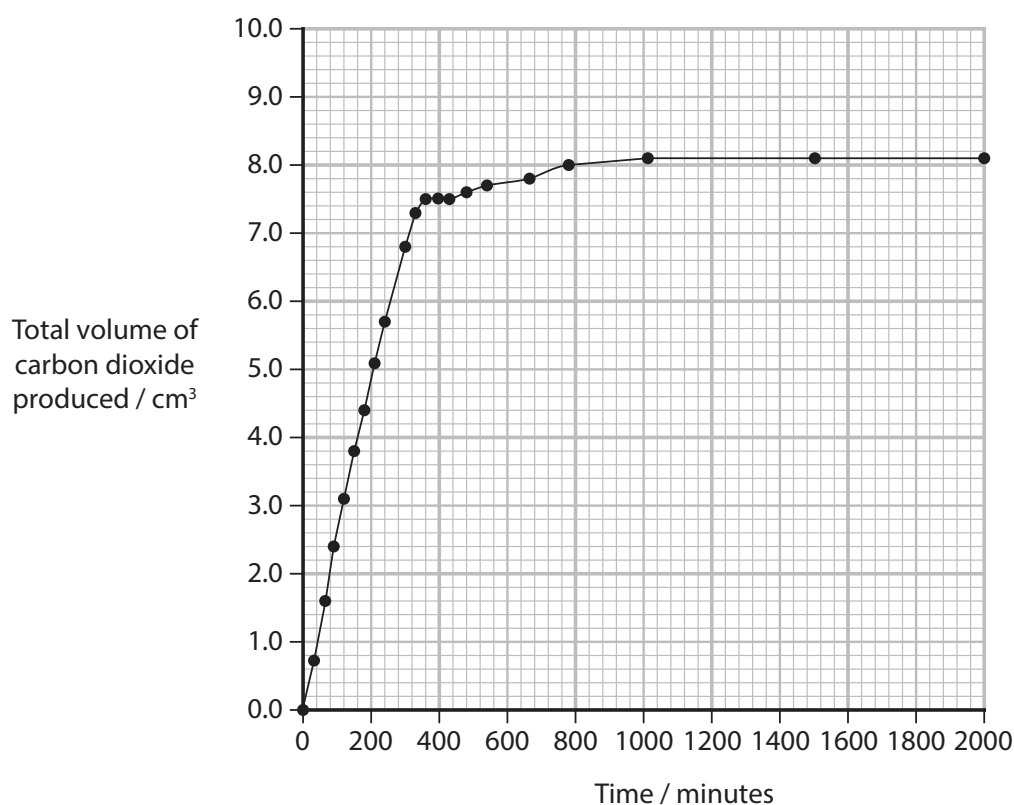
Answer cm³ min⁻¹



- (c) The effect of changing the concentration of yeast on the rate of respiration was also investigated.

Two yeast suspensions were made by adding different masses of yeast to 100 cm^3 of water containing 20 g of sucrose.

The graph shows the results for a suspension containing 7.0 g of yeast.



- (i) Sketch a line on this graph to show the expected results for a suspension containing 3.5 g of yeast.

(1)

- (ii) Explain the effect of the concentration of yeast on the volume of carbon dioxide produced in this investigation.

(3)

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7 Lipids and carbohydrates are used as respiratory substrates.

The respiration of lipids generates more ATP than the respiration of carbohydrates.

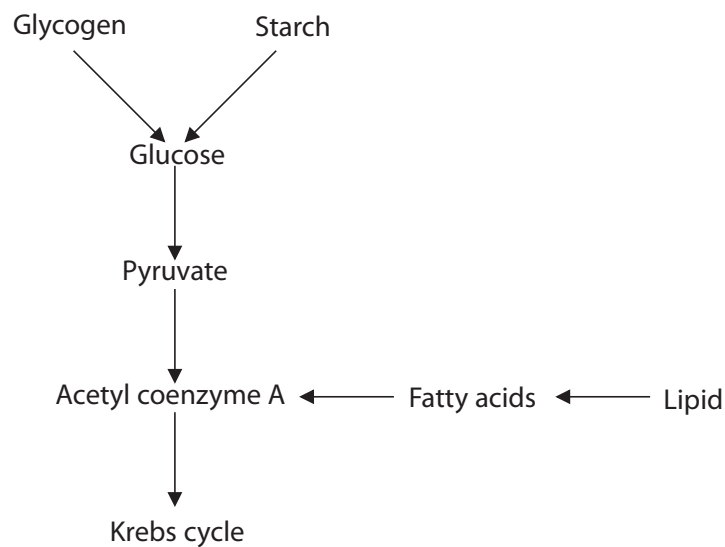
(a) The table shows bonds that may be found in carbohydrates and lipids.

Which box in each row shows whether the bond may be found in these molecules?

(3)

Bond	Molecule that bond may be found in			
	carbohydrate only	lipid only	both carbohydrate and lipid	neither carbohydrate nor lipid
covalent	☒	☒	☒	☒
ester	☒	☒	☒	☒
hydrogen	☒	☒	☒	☒

(b) The diagram shows some steps in the respiration of carbohydrates and lipids.



(i) Where in a cell does the conversion of pyruvate to acetyl coenzyme A take place?

(1)

- ☒ **A** cytoplasm
- ☒ **B** matrix
- ☒ **C** stroma
- ☒ **D** tonoplast

(ii) Explain why lipids can be respired only in aerobic conditions.

(3)

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(c) The electron transport chain uses hydrogen ions to generate ATP.

Explain why the respiration of lipids generates more ATP than the respiration of carbohydrates.

(2)

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(d) The respiratory quotient (RQ) can indicate which substrate is being used in respiration.

The formula used to calculate RQ is

$$\text{RQ} = \frac{\text{volume of carbon dioxide produced}}{\text{volume of oxygen used}}$$

(i) State why the RQ for carbohydrate is 1.0.

(1)

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- (ii) The table shows the formula for calculating the volume of oxygen used and the volume of carbon dioxide produced in the respiration of lipids.

The number of carbon atoms in the lipid is represented by n .

Volume of oxygen used / a.u.	Volume of carbon dioxide produced / a.u.
$4.5n + 3.75$	$3n + 6$

Calculate the RQ for a lipid containing 21 carbon atoms.

(2)

Answer

- (e) Explain why an insect has an RQ of 1.0 at rest and an RQ of 0.7 during flight.

(3)

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- 7 Coal tits, blue tits and great tits are three species of bird found in the UK all year round.

The photograph shows a blue tit.



(Source: © Andrew_Howe/Getty Images)

These birds all have mitochondria in their red blood cells.

- (a) More than 90% of ATP is produced by mitochondrial respiration.

- (i) Describe how the remaining ATP is produced.

(2)

- (ii) In the mitochondria, ATP is synthesised on the inner mitochondrial membrane.

Leakage of protons (H^+) across the inner mitochondrial membrane reduces ATP synthesis and generates more heat. This is called leaked respiration.

Explain why leakage of protons reduces ATP synthesis.

(3)

(b) The table shows some information about adult coal tits, blue tits and great tits.

Species of bird	Length from head to tail / cm	Wing span / cm	Mass / g
Coal tit	11	19	11
Blue tit	12	18	11
Great tit	14	24	18

(i) Calculate the magnification of the photograph of the blue tit.

Measure from the top of the head to the tip of the tail.

(1)

Answer

(ii) Calculate the length from head to tail:mass ratio for the **great tit**.

Give your answer to **one decimal place**.

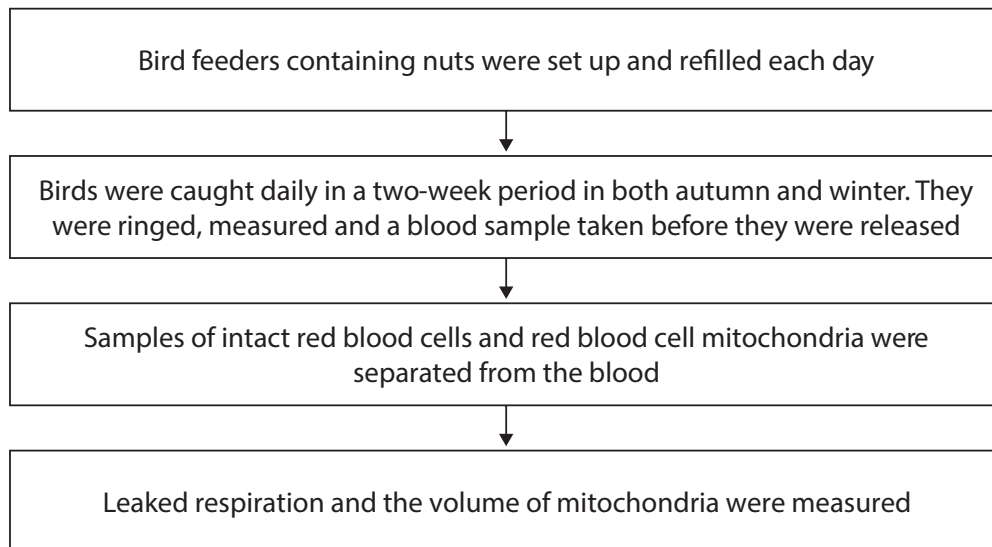
(1)

Answer

- (c) The generation of heat by red blood cell mitochondria in these birds in autumn and winter was investigated.

The mean air temperature in autumn was 10.7°C and in winter 7.2°C.

The flowchart shows some of the stages in this investigation.



- (i) Explain why well-stocked bird feeders containing nuts were available throughout this investigation.

(2)

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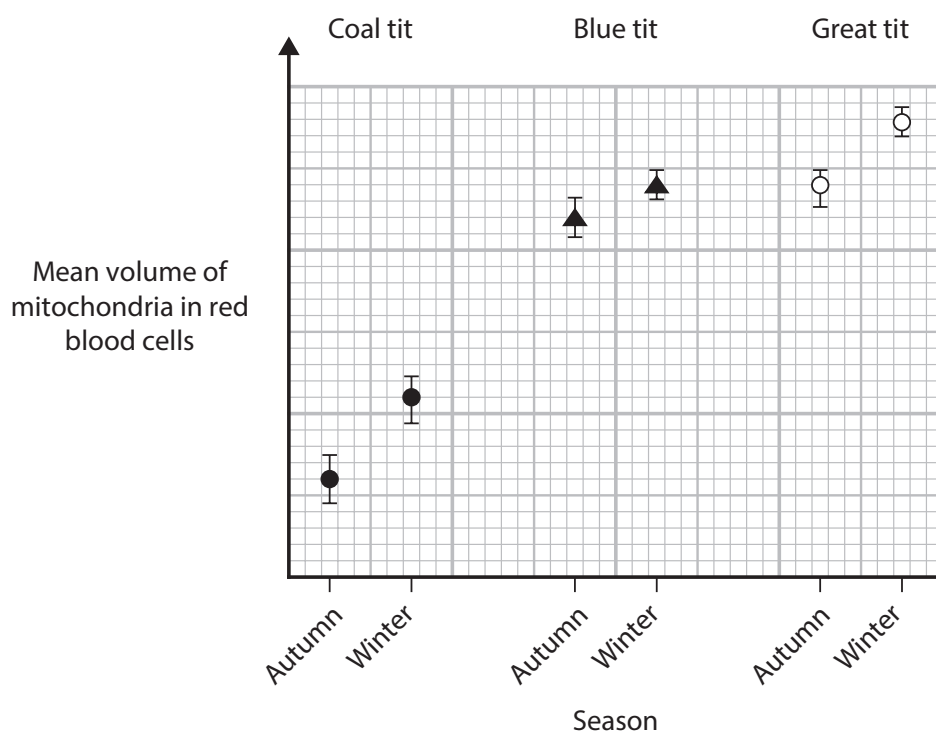
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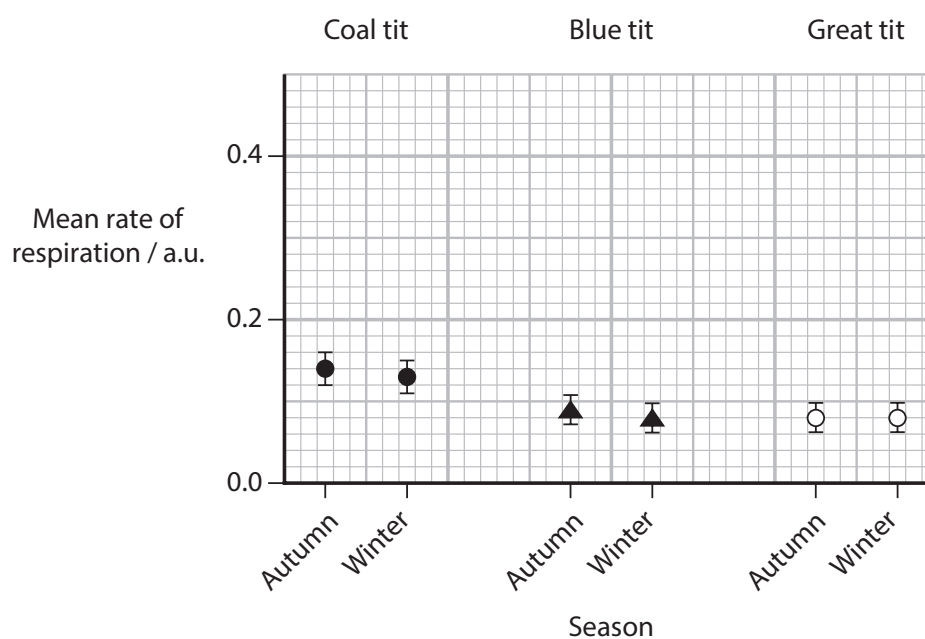
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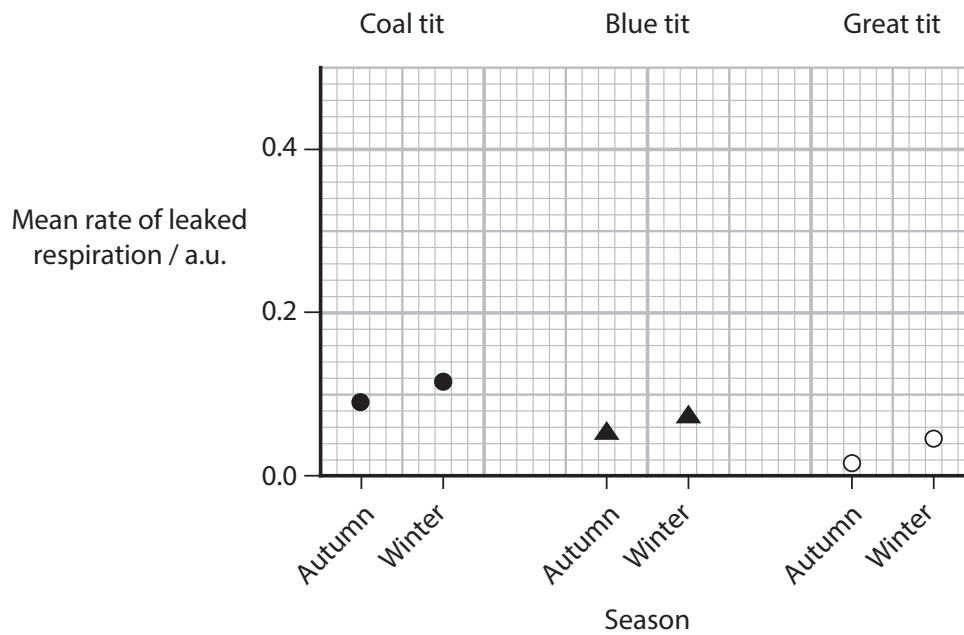
*(ii) The graphs show the results of this investigation.

Graph 1: volume of mitochondria



Graph 2: respiration producing ATP



Graph 3: leaked respiration

Explain the results of this investigation.

Use all the information in the question to support your answer.

(6)

SUB-TOPIC 5(b)

PHOTOSYNTHESIS

15 questions in this sub-topic · 169 marks · lowest tariff first



- 4 Photosynthesis results in the production of GALP. This molecule is used by plants to produce glucose and other organic molecules.

(a) Glucose consists of the elements of carbon, hydrogen and oxygen.

Name the inorganic molecules that supply these elements for photosynthesis.

(2)

Carbon

Hydrogen

Oxygen

- (b) Light is essential for photosynthesis. It is needed for photolysis and for the excitation of electrons in the photosystems.

Which row in the table shows where photolysis and the excitation of electrons occurs?

(1)

	Photolysis	Excitation of electrons
☐ A	stroma	stroma
☐ B	stroma	thylakoid membrane
☐ C	thylakoid membrane	stroma
☐ D	thylakoid membrane	thylakoid membrane

- (c) Scientists have developed an experimental technique that uses artificial photosynthesis.

Electricity generated from solar panels was used to convert carbon dioxide and water into the organic compound acetate.

Plants were then able to grow in the dark using the acetate.

- (i) Explain why these plants were able to grow in the dark.

(3)

- (ii) The scientists hope that this technique will be able to produce plant-based food.

State **one** advantage of using this method.

Give a reason for your answer.

(1)

(Total for Question 4 = 7 marks)

- 3 Single-celled algae can be trapped in gel beads and used to study photosynthesis.

The beads are placed in a test tube of hydrogencarbonate indicator.

The table shows the colour of the indicator when it contains different concentrations of carbon dioxide.

Colour of indicator	Relative carbon dioxide concentration
yellow	highest
orange	higher than atmospheric air
red	same as atmospheric air
magenta	lower than atmospheric air
purple	lowest

A student used the following method to investigate the effect of light intensity on the rate of photosynthesis.

1. Set up five test tubes, each half-filled with red hydrogencarbonate indicator.
2. Add a teaspoon of gel beads containing single-celled algae to each test tube and close with a bung.
3. Place each test tube at a different distance from a lamp in a dark room.
4. Leave the tubes for 30 minutes.
5. Record the colour of the hydrogencarbonate indicator in each tube and the position of the gel beads.

The table shows the results.

Distance from lamp / cm	5	15	25	35	45
Colour of indicator after 30 minutes	purple	purple	red	orange	orange
Position of gel beads in tube after 30 minutes	half-way up	less than half-way up	bottom	bottom	bottom

(a) (i) Describe two control tubes that should be used in this investigation.

(2)

(ii) Explain the changes in colour of the hydrogencarbonate indicator in this investigation.

(3)

(b) The colour of the indicator and the position of the beads can be used to give a quantitative measure of the effect of light intensity.

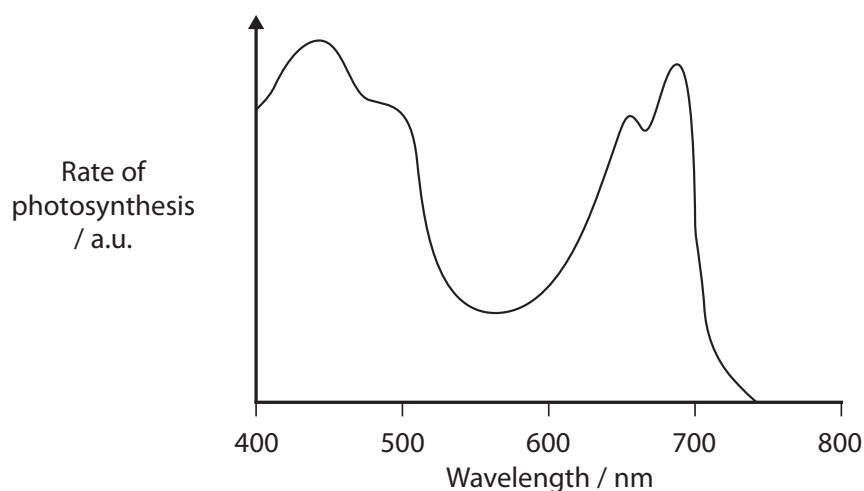
Describe how the method could be modified to give valid, quantitative results.

(3)



3 The wavelength of light affects the rate of photosynthesis.

(a) The graph shows an action spectrum for a filamentous green alga.



A scientist investigated the effect of wavelength of light on the rate of photosynthesis using this alga.

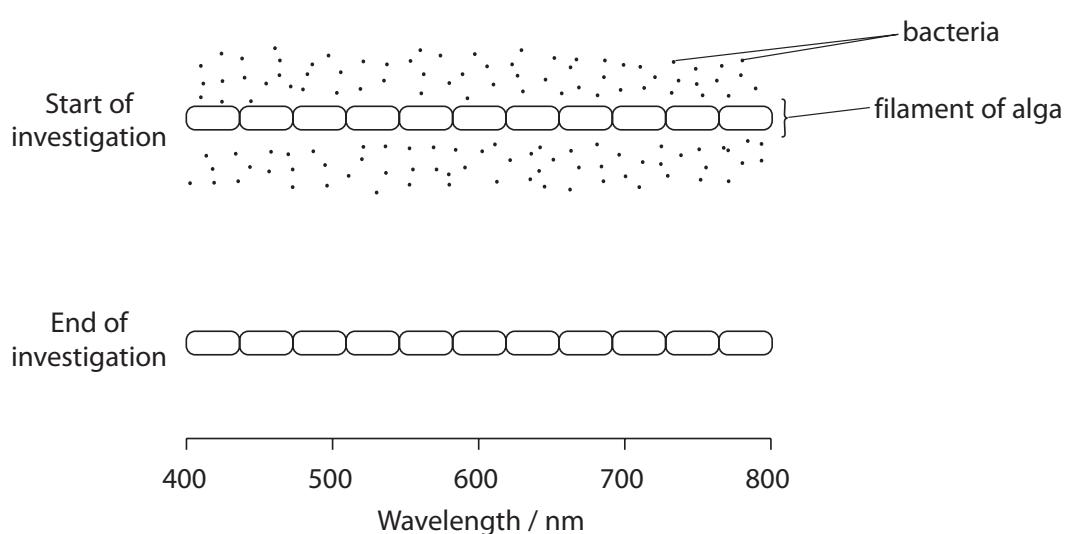
Filaments of the alga were placed on a microscope slide in water containing bacteria that move to areas of high oxygen concentrations.

Light of different wavelengths was shone onto different parts of the filament and the positions where the bacteria accumulated were recorded.

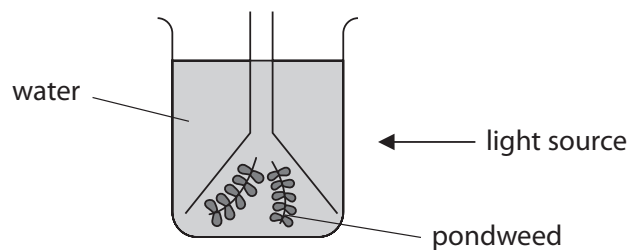
The diagram shows the position of the bacteria at the start of the investigation, and the wavelengths of light shone onto the parts of the filament.

Complete the diagram to show the position of the bacteria you would expect at the end of the investigation.

(2)



- (b) The diagram shows apparatus that can be used to study the effect of light on photosynthesis in pondweed.



Describe how you could modify and use this apparatus to find the optimum wavelength of light for photosynthesis of the pondweed.

(5)

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- (c) Explain why plants have a variety of photosynthetic pigments.

(2)

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4 Photosynthetic pigments are found in plant leaves.

(a) Describe how you could use chromatography to separate these pigments.

(3)

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(b) A scientist investigated the effect of lead pollution by cars on the chlorophyll content of plant leaves.

Quadrat sampling was used to collect leaves from a plant species.

Leaf samples were collected from an area with little car traffic and from an area with heavy car traffic.

The leaf samples were tested for lead content and chlorophyll content.

The table shows the results of this investigation.

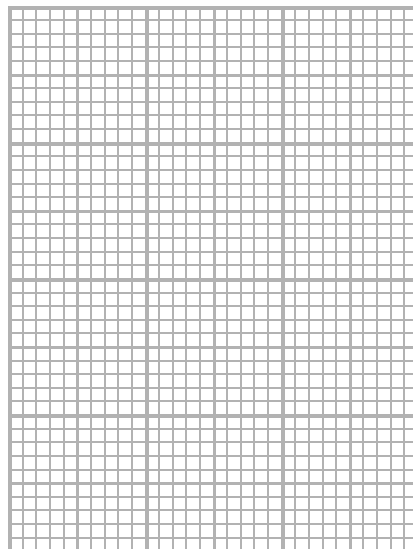
Area	Mean lead content of leaves / $\mu\text{g g}^{-1}$	Mean chlorophyll content of leaves / $\mu\text{g g}^{-1} \times 10^2$
Little traffic	1.28 ± 0.64	64.00 ± 4.00
Heavy traffic	3.11 ± 0.31	22.50 ± 3.00



- (i) Plot a graph to show the data for mean chlorophyll content.

(2)

Mean chlorophyll content of leaves / $\mu\text{g g}^{-1} \times 10^2$



- (ii) Explain how the quadrat sampling should have been carried out.

(3)

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- (iii) The scientist concluded that lead pollution from cars reduces the photosynthesis of plants. Criticise the validity of this conclusion.

(2)

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4 Plant pigments are involved in photosynthesis.

The action spectrum of chloroplasts and the absorption spectrum of the pigments can be determined.

- (a) (i) State the difference between an action spectrum and an absorption spectrum.

(1)

- (ii) State how an action spectrum and an absorption spectrum show that chlorophyll is used in photosynthesis.

(1)

- (b) Cadmium is an environmental pollutant that affects the synthesis of plant pigments.

A scientist investigated the effect of cadmium on the synthesis of chlorophyll and carotenoid pigments in plants.

The scientist used the following steps in the method.

Step 1: plants were grown in darkness for one week to produce yellow leaves

Step 2: leaf discs of the same diameter were taken from the first pair of these leaves

Step 3: a total of 25 discs was put into tubes containing different cadmium chloride concentrations

Step 4: these tubes were kept at 27°C and exposed to the same source of light



The table shows information about the pigments chlorophyll a and chlorophyll b and the carotenoids present in the leaf discs after 48 hours.

Cadmium chloride concentration / a.u.	Mean concentration of chlorophyll / mg kg^{-1}	Mean concentration of carotenoid / mg kg^{-1}	Ratio of chlorophyll a : b	Ratio of carotenoid : chlorophyll
0.0	384 ± 4.2	444 ± 6.2	1.23	1.15
0.1	204 ± 4.9	270 ± 4.5	1.00	1.32
1.0	180 ± 3.6	207 ± 5.2	0.83	1.15
3.0	146 ± 4.1	140 ± 3.1	0.81	0.95
5.0	126 ± 2.7	91 ± 1.0	0.56	0.71
10.0	102 ± 1.9	64 ± 1.1	0.80	0.63

- (i) Analyse the data to deduce the effect of cadmium on the synthesis of plant pigments. (3)

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- (ii) Justify the method used by the scientist. (5)

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6 Macroalgae and microalgae are photosynthetic organisms.

Seaweeds are macroalgae that live attached to rock in coastal areas.

Some seaweeds are green, some are brown and some are red.

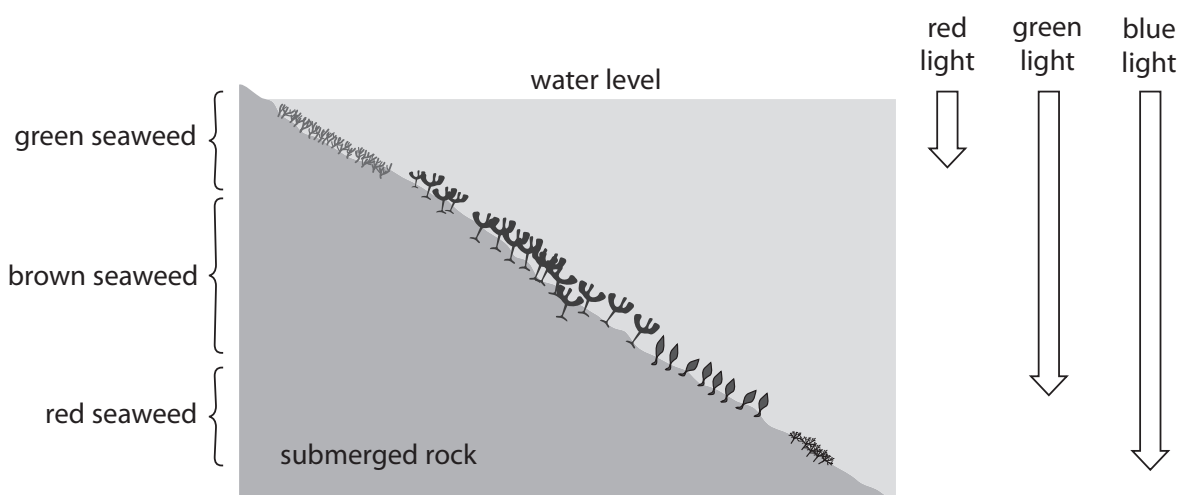
The colour of seaweeds depends on the photosynthetic pigments contained in their cells.

Green seaweeds contain chlorophyll, brown seaweeds contain chlorophyll and fucoxanthin and red seaweeds contain chlorophyll and phycoerythrin.

(a) (i) Explain why these seaweeds have different absorption spectra and action spectra.

(3)

(ii) The diagram shows the position that these seaweeds occupy on submerged rock and the depth to which different wavelengths of light penetrate into the water.



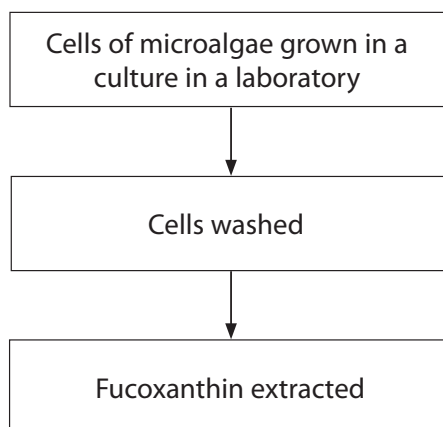
Explain why the seaweeds occupy different positions on the submerged rock.

(3)

(b) Fucoxanthin is found in both macroalgae and microalgae.

Fucoxanthin has anti-inflammatory, anti-tumour, anti-diabetes, anti-malarial and anti-obesity activity in humans.

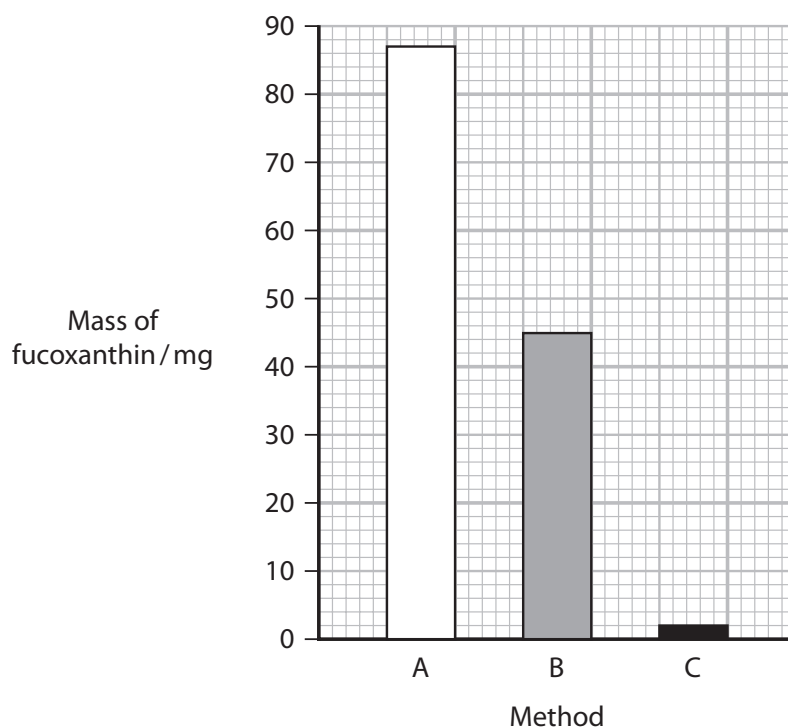
The diagram outlines the steps taken to extract fucoxanthin from microalgae.



The table shows three methods used for washing the cells and extracting the fucoxanthin.

Method	Liquid used for washing cells	Chemical used to extract fucoxanthin
A	water	ethanol
B	culture media	ethanol
C	culture media	water

The graph shows the mass of fucoxanthin extracted from 1 dm³ of cell culture.



- (i) Calculate how many times more fucoxanthin was extracted using method A compared with method B.

(1)

Answer

- (ii) Explain why different masses of fucoxanthin were extracted using these three methods.

(3)

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- 8 When a photosynthetic plant cell grows, the number of chloroplasts in the cell increases. This increase in the number of chloroplasts can result from the division of chloroplasts already present in the cell.

The electron micrograph shows a chloroplast dividing.



- (a) What is the name of the part of the chloroplast labelled Y?

(1)

- ☐ A cytoplasm
- ☐ B matrix
- ☐ C nucleoplasm
- ☐ D stroma

- (b) The envelope consists of two membranes. These membranes are separated by a gap of 10×10^{-3} to $20 \times 10^{-3} \mu\text{m}$.

The magnification of this electron micrograph is $\times 12\,000$.

- (i) Calculate the maximum width of this gap in this electron micrograph.

(2)

Answer

(ii) Explain why the envelope in this electron micrograph cannot be seen as two separate membranes.

(2)

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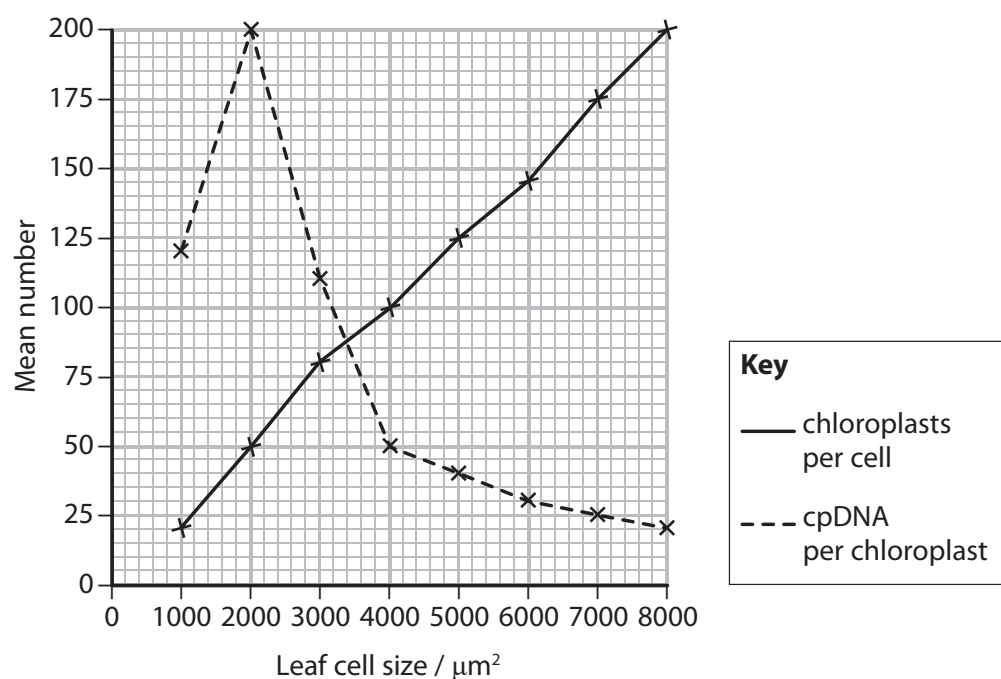
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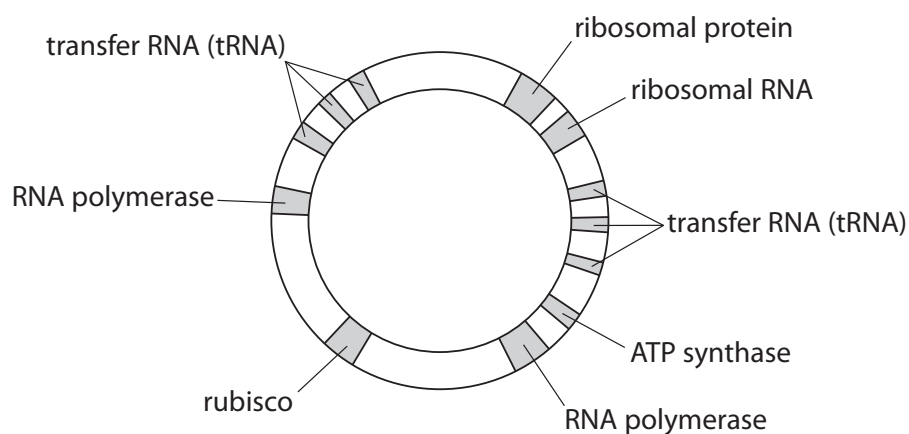
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*(c) In an investigation, the mean size of leaf cells was determined. The mean number of chloroplasts per cell and the mean number of DNA molecules (cpDNA) per chloroplast were also determined.

The graph shows the results of this investigation.



The diagram shows the location of some genes found in cpDNA.



Analyse the information to explain the changes that occur in a leaf cell as it grows.

(6)

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- 11** White clover plants provide a rich source of nitrogen for cattle when grown with grass plants in fields.

The photograph shows a clover plant growing in a field of grass.



A student noticed that the grass plants growing near patches of clover were a darker green than other grass plants.

- (a) Devise an investigation to show whether the presence of clover plants affects the concentration of the green pigment chlorophyll in grass plants.

(6)

(b) Clover plants have bacteria living in root nodules.

These bacteria convert atmospheric nitrogen (N_2) to ammonia (NH_3) using the enzyme nitrogenase.

(i) State one organic molecule containing nitrogen atoms which is found in plant cells.
(1)

(ii) Nitrogen is a relatively unreactive gas that forms 80% of the atmosphere.

The enzyme nitrogenase catalyses the reaction shown:



The activation energy for this reaction is very high.

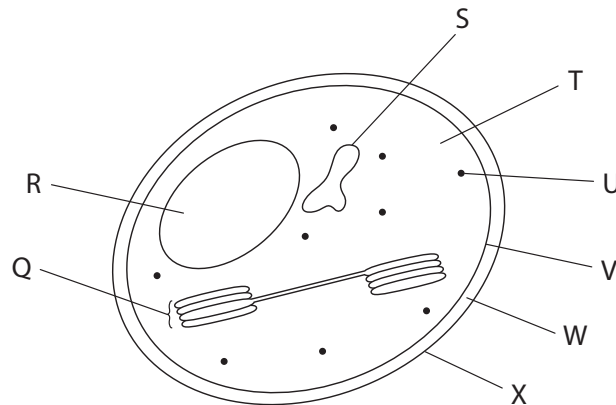
Analyse the information to explain how the enzyme nitrogenase is involved in the energy changes required for this reaction.
(4)



- 5 The light-dependent stage and the light-independent stage of photosynthesis both take place in the chloroplast.

The rate of photosynthesis is affected by a number of different factors, including carbon dioxide concentration and temperature.

(a) The diagram shows a chloroplast.



- (i) Where does the light-dependent stage take place?

(1)

- ☐ A Q
☐ B T
☐ C V
☐ D X

- (ii) The light-dependent stage produces hydrogen ions.

Where do these hydrogen ions accumulate?

(1)

- ☐ A Q
☐ B R
☐ C S
☐ D W

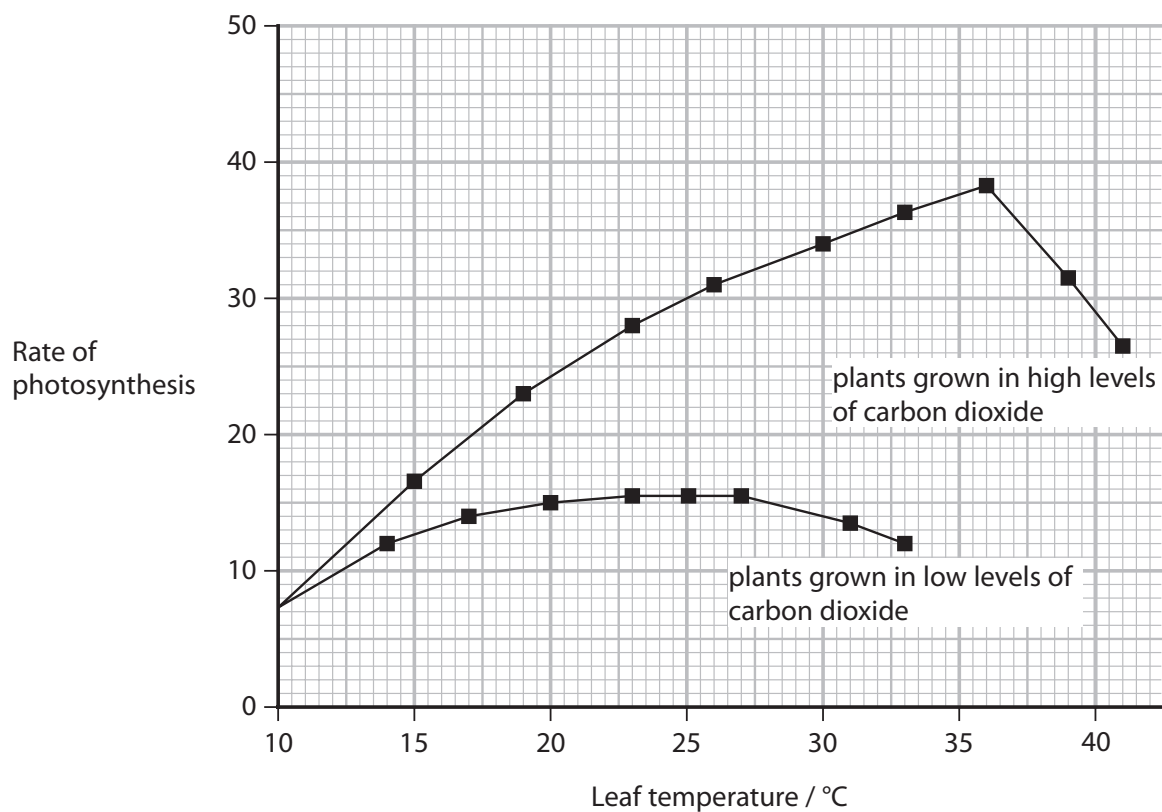
- (iii) Where does translation take place?

(1)

- ☐ A Q
☐ B R
☐ C S
☐ D U

- (b) Scientists measured the effect of two different concentrations of carbon dioxide on the rate of photosynthesis at different leaf temperatures, in one species of plant.

The results are shown in the graph.



- (i) Which units are suitable for measuring the rate of photosynthesis in leaves?

(1)

- ☐ A $\mu\text{mol m}^{-1} \text{sec}^{-1}$
- ☐ B $\mu\text{mol m}^{-1} \text{sec}^{-2}$
- ☐ C $\mu\text{mol m}^{-2} \text{sec}^{-1}$
- ☐ D $\mu\text{mol m}^{-2} \text{sec}^{-2}$

(ii) Analyse the data to identify **three** conclusions that can be made from this graph.

(3)

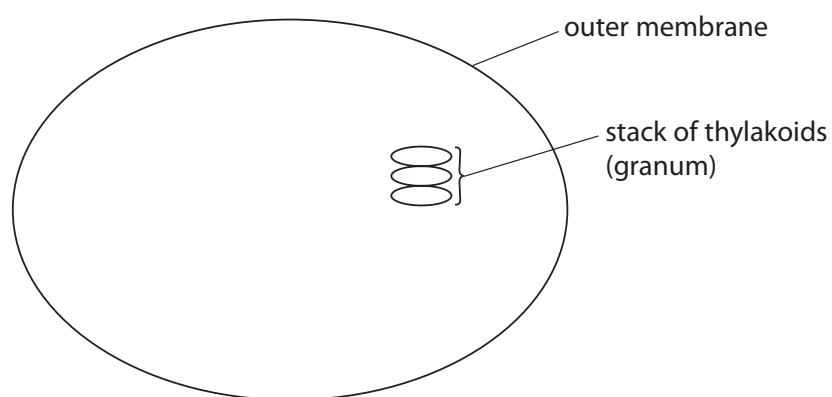
(iii) Explain the effects of carbon dioxide concentration and temperature on the rate of formation of GALP.

(4)



6 Scientists have removed thylakoids from chloroplasts to make artificial chloroplasts.

(a) The diagram shows part of a chloroplast.



(i) Draw and label **three** other structures found in a chloroplast.

(3)

(ii) Chloroplasts can be $3\text{ }\mu\text{m}$ in length.

Calculate the magnification of this diagram for a chloroplast that is $3\text{ }\mu\text{m}$ in length.

Give your answer to two significant figures.

(2)

Answer

- (b) Explain the importance of the thylakoid membranes in the light-dependent stage of photosynthesis.

(4)

- (c) The artificial chloroplasts made by the scientists consisted of thylakoids removed from spinach leaves, and enzymes involved in carbon fixation.

These components were put into water, forming a suspension.

This suspension was dropped into a medium containing oil.

The suspension formed cell-sized droplets of water containing the thylakoids and the enzymes.

- (i) Name the enzyme that fixes carbon dioxide in the light-independent stage of photosynthesis.

(1)

- (ii) Explain why it is necessary to keep the thylakoids and enzymes together within droplets.

(2)

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

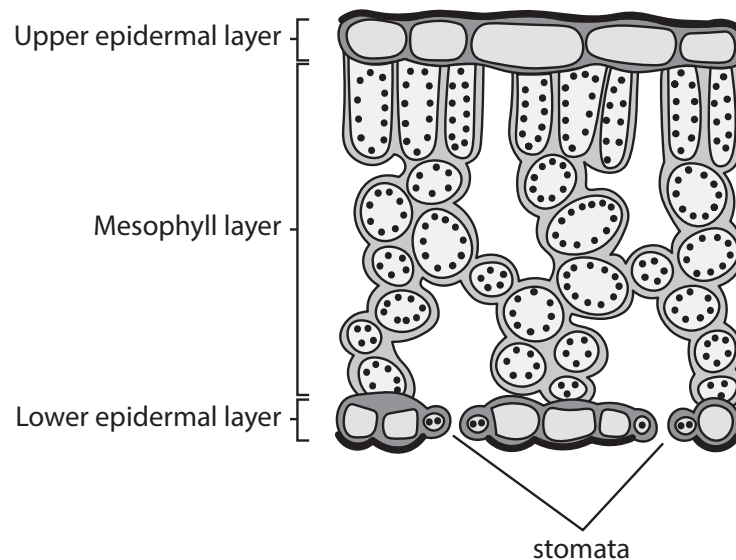
The effects of low, moderate and high nitrogen levels on leaf structure and molecules present in the leaves were investigated.

- (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

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

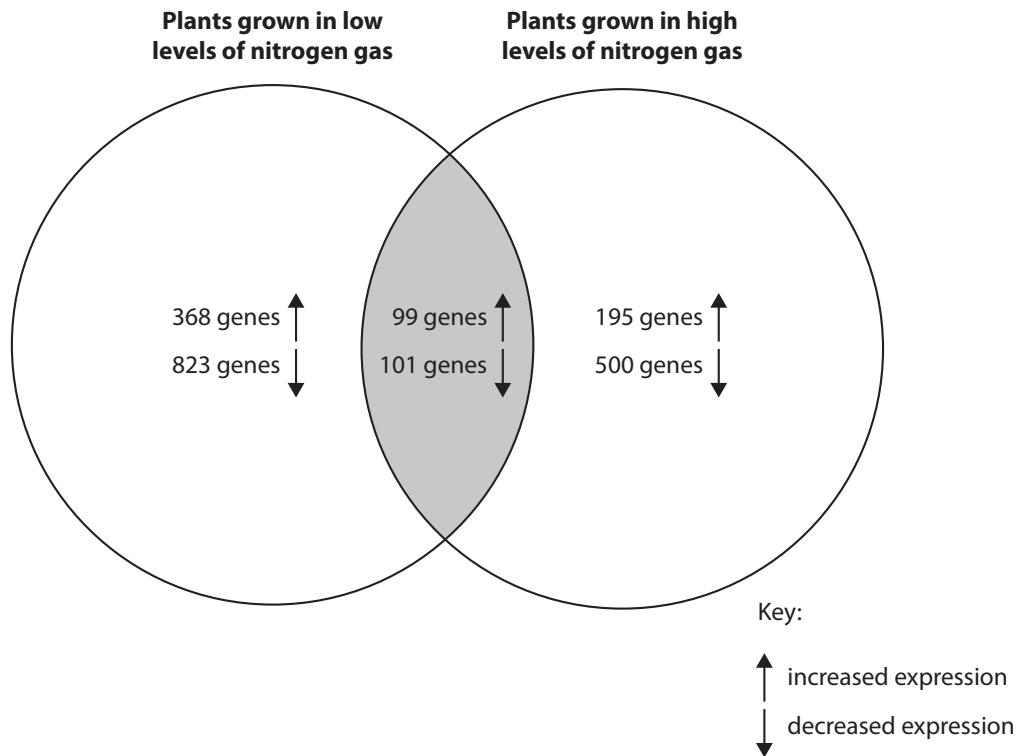
(6)



- (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)

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(ii) Describe how gene expression can be changed.

(2)



9 Last year, eight million Christmas trees were bought in the UK.

There are many Christmas tree farms that supply these trees.

The photograph shows young Christmas trees growing on a farm.



Christmas tree farmers remove the other plants (weeds) in order to increase tree growth.

A farmer investigated two methods of removing weeds:

- removing weeds by hand
- spraying herbicides that inhibit weed growth.

The table shows the mean height of Christmas trees using each method, over a five-year period.

Year	Mean height of trees / cm	
	Removing by hand	Using herbicide
0	20	20
1	50	60
2	70	100
3	90	130
4	110	160
5	130	200

(a) (i) Calculate the difference between the mean rate of growth of these trees over the five years.

(2)

Answer



(ii) Analyse the data to explain the difference in the mean height of the trees at the end of the five-year period.

(2)

(iii) Explain two biotic variables that need to be controlled to allow a valid comparison of the effect of each method on tree growth.

(2)

(b) A student read that some herbicides work by inhibiting electron transport in photosynthesis.

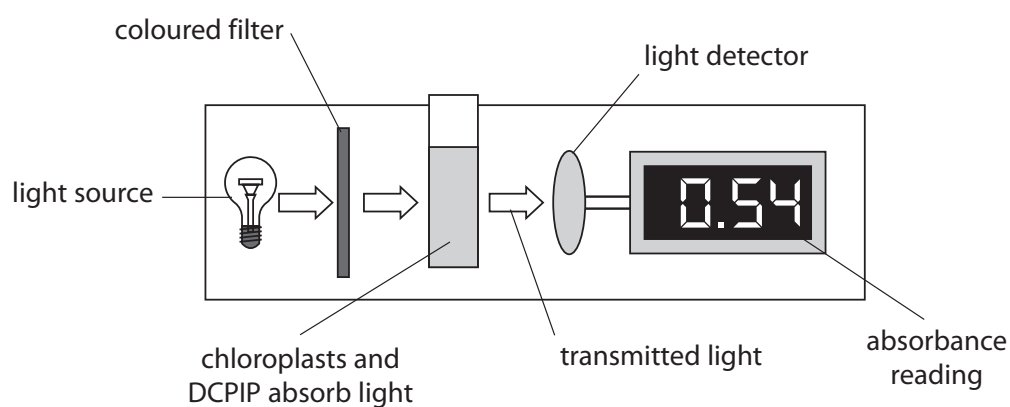
The student investigated this using the indicator DCPIP.

This indicator changes from blue to colourless when it is reduced.

The student used the following method:

- chloroplasts were suspended in two tubes, each containing a solution of DCPIP
- herbicide was added to one of the tubes and no herbicide was added to the other tube
- both tubes were exposed to light
- a colorimeter was used to measure the absorbance in each tube at five minute intervals for 20 minutes.

The diagram shows details of the workings of the colorimeter used by the student.



As DCPIP changes from blue to colourless, the absorbance of light decreases.

(i) Explain how the student used this method to collect valid data.

(4)

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The table shows the results.

Time / min	Absorbance / a.u.	
	With herbicide	Without herbicide
0	0.53	0.54
5	0.54	0.31
10	0.54	0.24
15	0.54	0.20
20	0.53	0.16

(ii) Analyse the data to explain the effect of this herbicide on the growth of weeds. (4)

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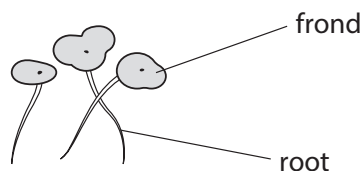
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- 6 Duckweed, *Lemna minor*, is a small plant that floats on the surface of freshwater ponds.

Each plant consists of a frond, which contains photosynthetic pigments, and a root which absorbs inorganic ions from the water.

The diagram shows duckweed plants.

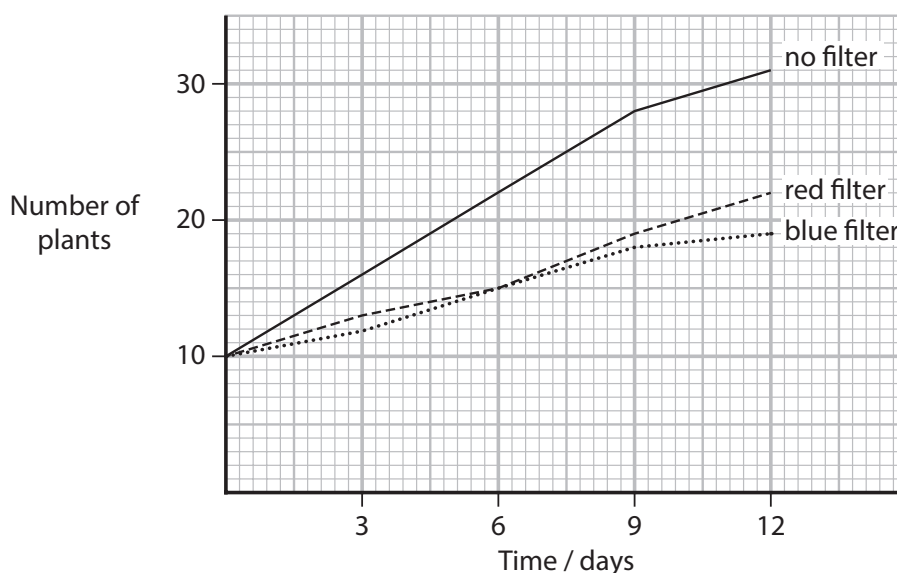


Duckweed typically reproduces asexually by budding, to produce daughter plants. In ideal conditions, the doubling time is around 3 days.

A student investigated the effect of changing the wavelength of light on the time taken for the number of duckweed plants to double.

- Ten duckweed plants were added to a tank containing 3 dm³ of water with dissolved inorganic ions. The temperature was maintained at 10°C.
- A lamp with no filter was placed at a known distance from the tank.
- The total number of plants were counted at intervals of 3 days.
- The investigation was repeated with a red filter over the lamp and then again with a blue filter over the lamp.

The graph shows the results of this investigation.



(a) (i) Explain the results of this investigation.

(2)

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(ii) The shortest time for the number of plants to double was more than 3 days.

Give **two** ways of reducing the time taken for the number of plants to double.

(2)

1

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2

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(iii) Give **one** reason why the results may not be accurate.

(1)

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(iv) Describe a method that could be used to measure the growth of the plants more accurately.

(2)

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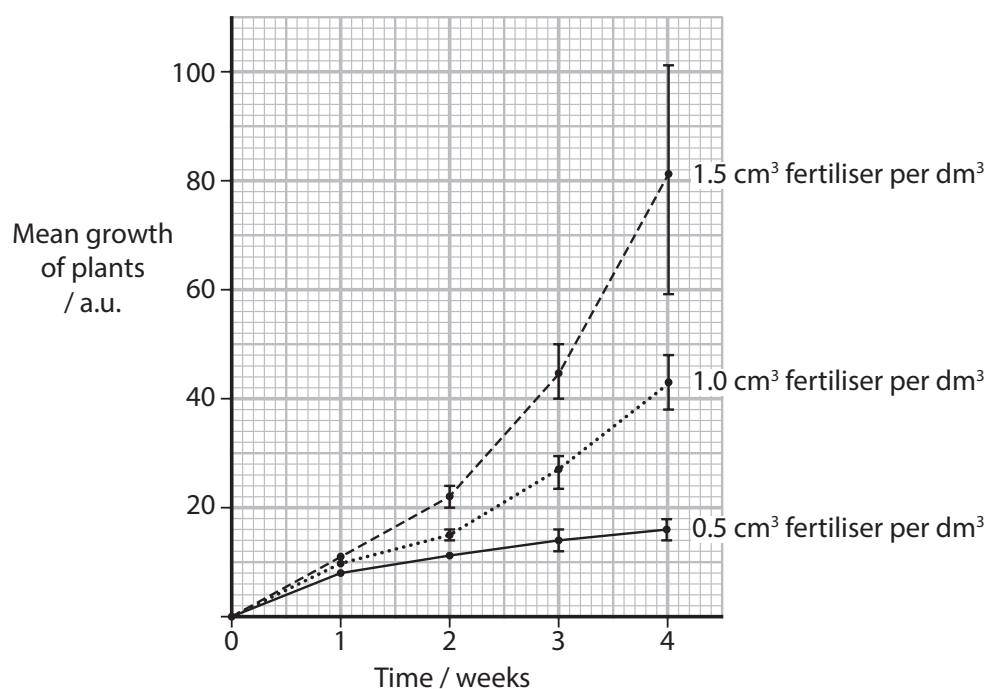


- (b) In another investigation, the student grew duckweed plants in water containing a fertiliser.

The fertiliser contained nitrate, phosphate and magnesium ions.

Three concentrations of the fertiliser were used, with all other conditions kept constant.

The graph shows the results of this investigation.



Explain the effect of increasing fertiliser concentration on the growth of these plants.

(3)

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- (c) It has been suggested that duckweed could be grown in water polluted with organic waste from cows.

These plants could be processed to make feed for poultry and cattle.

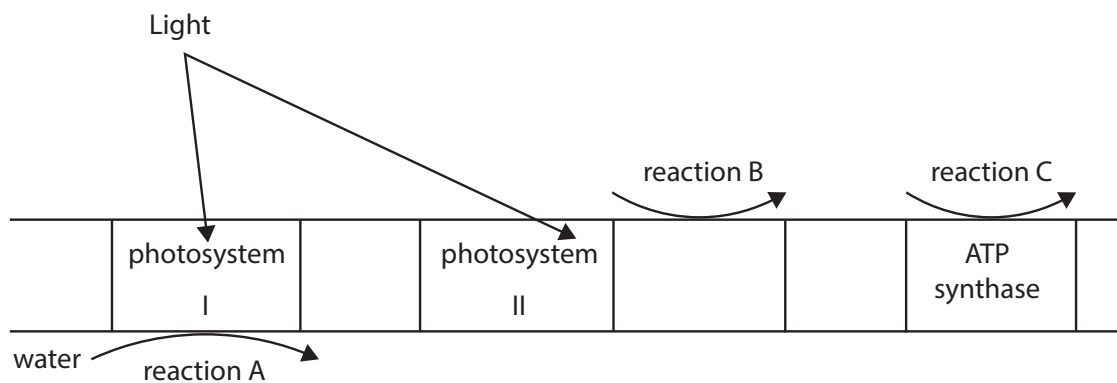
Analyse the information to comment on this suggestion.

(4)



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)

(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.

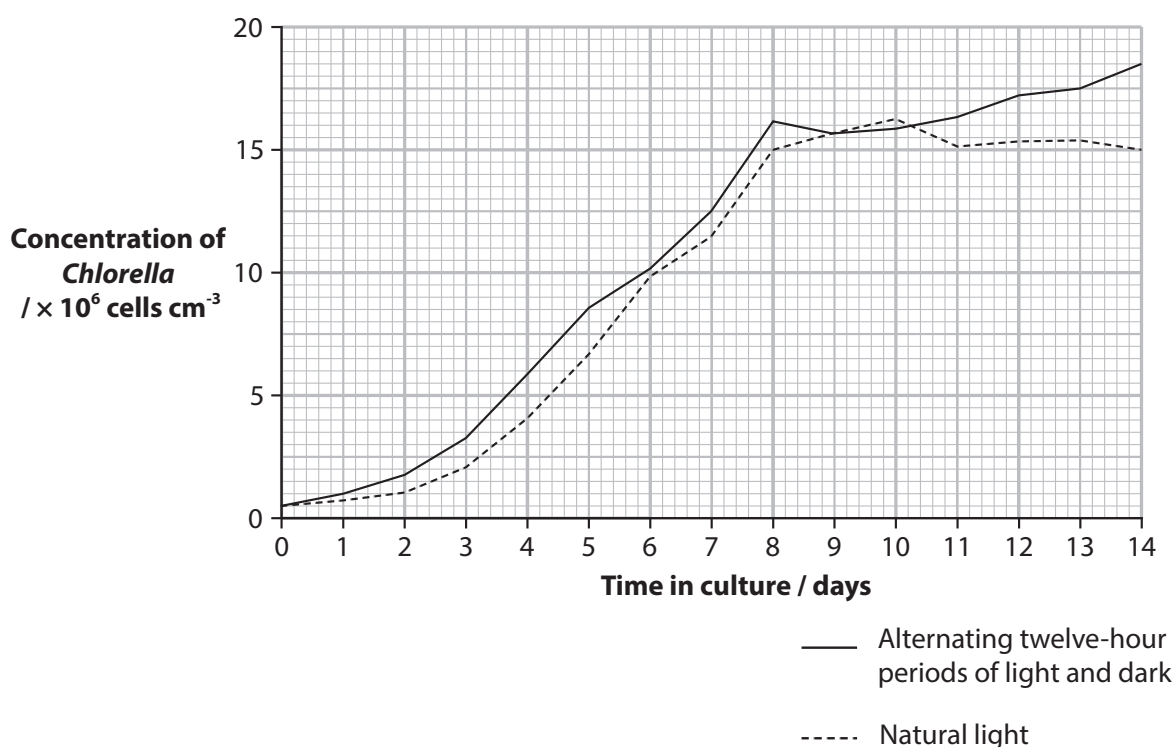
(1)

- (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)

Answer

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

The table shows the observations.

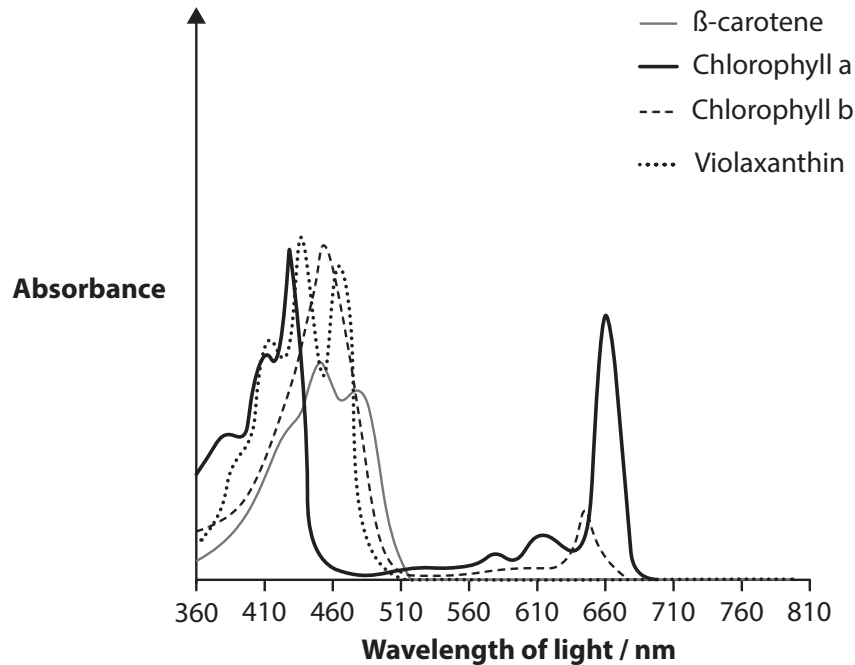
Time in culture / days	Observation	
	<i>Chlorella</i> grown in alternating periods of light and dark	<i>Chlorella</i> grown in natural light
17	Dark green cells	Light green cells
	The number of cells had not increased since the previous day	The number of cells had increased since the previous day
18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

Explain these observations.

(5)

- (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)

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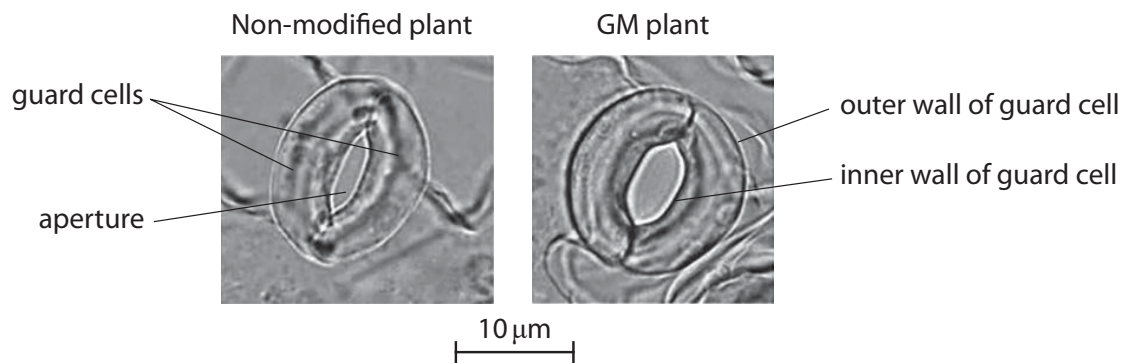
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- 8 Genetically modified (GM) crop plants have been produced that have stomata with a wider aperture than non-modified crop plants.

This difference in the width of the aperture is only evident in daylight.

The photographs show the appearance of each type of stoma in daylight.



Sourced from: http://www.aip.nagoya-u.ac.jp/en/public/nu_research/images/Wang_f1.jpg

- (a) (i) Calculate the magnification of the GM plant photograph using the scale bar.

Give the answer in standard form.

(2)

Answer

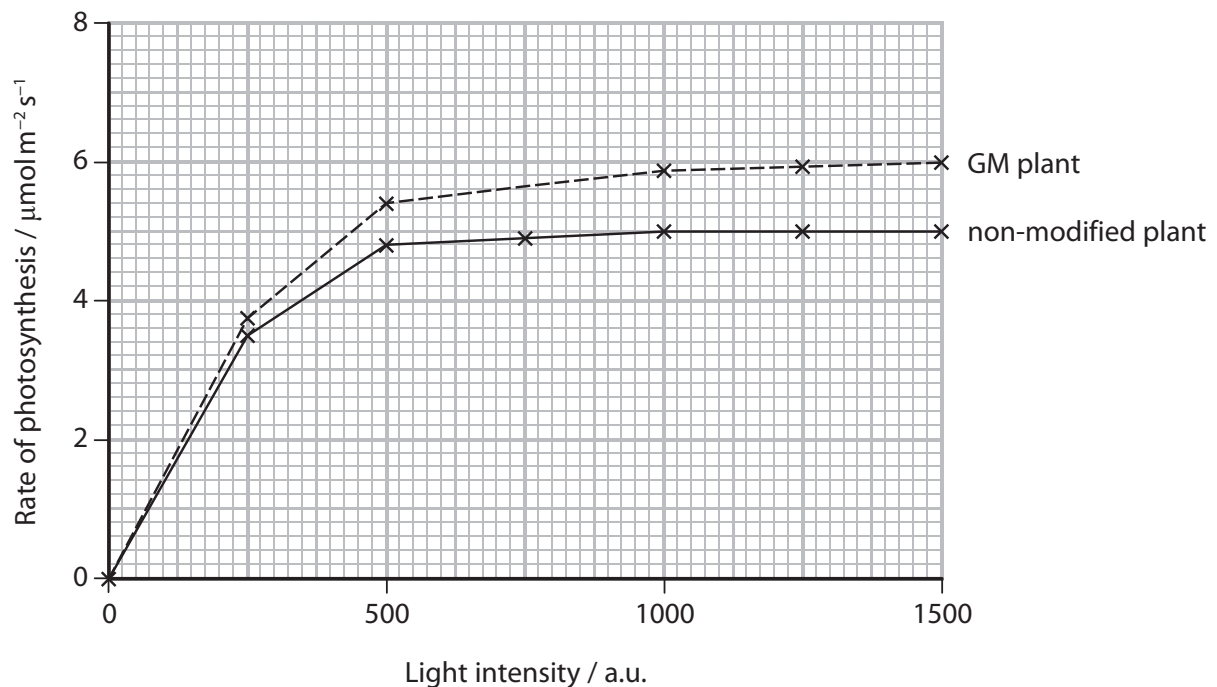
- (ii) Calculate how many times wider the aperture of the stoma of the GM plant is compared with the stoma of the non-modified plant.

(1)

Answer

- (b) An investigation was carried out to compare the effect of light intensity on the rate of photosynthesis in GM plants with the effect in non-modified plants.

The graph shows the results of this investigation.



- (i) The rate of photosynthesis is expressed as $\mu\text{mol m}^{-2} \text{s}^{-1}$.

Describe what was measured to find the rate of photosynthesis.

(3)

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(ii) Explain the results of this investigation.

(3)

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(c) Explain why the wider stomata in GM crop plants could increase their yield.

(3)

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(d) The flow chart shows some of the steps involved in opening the aperture of a stoma.

Hydrogen ions actively transported out of the guard cells



Potassium ions diffuse into the guard cells



Starch broken down into malate



Water moves into the guard cells



Aperture of the stoma widens

(i) What happens when hydrogen ions are actively transported out of the guard cells?

(1)

- ☐ **A** ADP and phosphate ions are converted into ATP by a hydrolysis reaction
- ☐ **B** ADP and phosphate ions are converted into ATP by a condensation reaction
- ☐ **C** ATP is broken down into ADP and phosphate ions by a condensation reaction
- ☐ **D** ATP is broken down into ADP and phosphate ions by a hydrolysis reaction

(ii) Which of the following explains why water moves into the guard cells?

(1)

- ☐ **A** malate lowers the water potential of the cytoplasm
- ☐ **B** malate raises the water potential of the cytoplasm
- ☐ **C** starch lowers the water potential of the cytoplasm
- ☐ **D** starch raises the water potential of the cytoplasm

(iii) Which of the following explains why the aperture of the stoma widens?

(1)

- ☐ **A** The guard cells become smaller and the inner wall of the guard cell is more flexible than the outer wall
- ☐ **B** The guard cells become smaller and the inner wall of the guard cell is less flexible than the outer wall
- ☐ **C** The guard cells become larger and the inner wall of the guard cell is more flexible than the outer wall
- ☐ **D** The guard cells become larger and the inner wall of the guard cell is less flexible than the outer wall

(Total for Question 8 = 15 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Additional Guidance	Mark
2(a)(i)	glucose is a monosaccharide and maltose is {a disaccharide / made of two glucoses / made of two monosaccharides} (1)	ACCEPT maltose has a glycosidic bond and glucose does not glucose has 6 carbons and maltose has 12 glucose has the formula $C_6H_{12}O_6$ and maltose $C_{12}H_{22}O_{11}$ ACCEPT a labelled diagram	(1)

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An explanation that makes reference to two of the following: - neither sugars respired immediately because the yeast need to {acclimatise / adjust to the conditions} (1) - delay is longer for maltose as {enzymes need to be synthesised / maltose needs to be broken down into glucose} (1) - respiration of maltose is faster (than glucose) as maltose has {twice the number of sugar units / more glucoses / more hydrogens} (1)	ACCEPT glycosidic bonds have to be broken ACCEPT because maltose contains more energy / maltose is a disaccharide and glucose is a monosaccharide	(2)

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following: - lactose is not {respired / used} as the yeast do not produce {the appropriate enzymes / lactase} (1) - sugars in the cytoplasm are {used / respired} (1)	ACCEPT yeast cannot break lactose down NB at least one reference to respiration for both marks to be awarded	(2)

Question Number	Answer	Additional Guidance	Mark
2(a)	The only correct answer is D A is incorrect because glycerate 3-phosphate is an intermediary of glycolysis B is incorrect because glycogen is a storage molecule C is incorrect because lactate is the product of anaerobic respiration		(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	The only correct answer is B A is incorrect because only glycolysis occurs in the cytoplasm C is incorrect because glycolysis takes place in the cytoplasm D is incorrect because glycolysis takes place in the cytoplasm		(1)

Question Number	Answer	Additional Guidance	Mark
2 (c)(i)	- free energy in 36 ATP molecules calculated (1) - correct answer calculated (1)	$(30\,566 \times 36 =) 1\,100\,376$ $38.34 = 2$ marks Correct answer gains full marks	(2)

Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	heat (energy) is lost (1)	Accept thermal energy	(1)

Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following: - release energy / make ATP (1) - for {ion pump / Na⁺ - K⁺ pump / active transport of ions / regeneration of rhodopsin / combine opsin and retinal / convert trans retinal into cis retinal} (1)	DO NOT ACCEPT active transport alone	(2)

Question Number	Answer	Additional Guidance	Mark
3(b)	A description that makes reference to four of the following: - rhodopsin involved (1) - retinal changes from cis to trans form / opsin and retinal formed (1) {Na⁺ / cation} channels close / Na⁺ stop diffusing into rod cell (1) - Na⁺ still moves out / inside cell becomes more negative / hyperpolarisation (1) - stops {glutamate / neurotransmitter} release (1)	ACCEPT blocks sodium channels	(4)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	An answer that makes reference to the following: - composed of protein and RNA (1) (arranged in) two {(sub) units / parts} (1)	ACCEPT large and small subunit / 60S and 40S subunit / 50S and 30S subunit	(2)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An answer that makes reference to two of the following: - translation (1) - to hold the tRNA on the mRNA (1) - whilst peptide bonds form to join (adjacent) amino acids together (1)		(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	{fewer / smaller} cristae / less folding of the inner membrane / reduced surface area of inner membrane		(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	An explanation that makes reference to two of the following: (fewer cristae / lower surface area) therefore reduced electron transport chain (1) - because ribosomes prevented from synthesising {enzymes / ATPase / electron transport molecules} (1) - credit reason linked to protein not made (1)	e.g. no enzymes to catalyse steps in Krebs cycle, no ATPase channels for {protons to pass through / phosphorylation of ADP}, no ETC so no redox reactions ACCEPT less intermembrane space for accumulation of protons = 1 mark	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(iii)	An explanation that makes reference to the following: - no ATP will be produced (if both inhibited / glycolysis inhibited) (1) - therefore no {energy / ATP} for metabolic process / named metabolic processes / cell division} (1)		(2)

Indicative content	Answer
according to candidates' deployment of knowledge and understanding of the material in and skills outlined in the generic mark scheme.	reference to five of the
allow is not prescriptive and candidates are not required to include all the material which is additional content included in the response must be scientific and relevant.	ons are moved out of the
	ermeable to water (1)
fast / droxide / remove gauze to tubing	in / low(er) water poten
st / glucose mixture / use boiled glucose solution	s a counter-current mul
asure the carbon dioxide released ions of fluoride / plus and minus fluoride it	re permeable to water (:
ast / mass of yeast / volume of mixture / temperature atise with the three-way tap open finish before measuring rate of reaction	s out (of the collecting c
is	
ne / distance divided by time n tube diameter ion against fluoride concentration late standard deviation	

9BIO3

le content es isolated elements of biological knowledge and understanding to the given context with comments made. omments related to consequences are made with limited linkage to a range of scientific ideas, techniques and procedures. ion will contain basic information with some attempt made to link knowledge and ing to the given context. to 3 ideas with no analysis lice means Level 1 max es adequate knowledge and understanding by selecting and applying some relevant cts/concepts. es are discussed which are occasionally supported through linkage to a range of scientific sses, techniques and procedures. ion shows some linkages and lines of scientific reasoning with some structure. m 4 to 6 ideas including at least 1 analysis ate method eg. yeast and photosynthesis / aerobic respiration / Benedict's / OH means Level 2 and maximum of 5 marks es comprehensive knowledge and understanding by selecting and applying relevant of biological facts/concepts. es are discussed which are supported throughout by sustained linkage to a range of eas, processes, techniques or procedures. ion shows a well-developed and sustained line of scientific reasoning which is clear and uctured. r more ideas including at least 2 analysis o statistical analysis

9B103

Question Number	Answer	Additional Guidance	Mark
4(a)	A description that makes reference to two of the following: - has a {tertiary structure / three dimensional structure (and quaternary structure)} (1) - held by named bond (1) - hydrophilic on the outside of the molecule (1)	ACCEPT hydrophobic R groups in the centre of the structure	(2)

Question Number	Answer	Mark
4(b)(i)	The only correct answer is B <i>A is not correct because no bonds are being broken</i> <i>C is not correct because no phosphate group is being added</i> <i>D is not correct because if FAD is reduced to FADH₂ the succinate is being oxidised</i>	(1)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An explanation that makes reference to four of the following: - completely oxidises {pyruvate / acetyl Co A} (1) - to release as much energy as possible (1) - to generate ATP (directly) (1) - to produce {reduced coenzyme / NADH} (1) - so that ATP can be produced {in the ETC / by oxidative phosphorylation} (1)	ACCEPT glucose DO NOT ACCEPT makes ACCEPT FADH₂ / FADH / reduced {NAD / NADH} / reduced {FAD / FADH / FADH₂}	(4)

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	concentration of protein read from graph	0.58 / 0.57 (mg cm ⁻³)	(1)

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	- initial rate of reaction calculated (1) - ratio calculated (1)	0.00267 / 0.0027 (mg sec⁻¹) / 0.16 (mg min⁻¹) 0.58 : 0.0027 = 214.81 : 1 or 3.63 : 1 21481 : 100 or 363 : 100 0.57 : 0.0027 = 211.11 : 1 or 3.56 : 1 21111 : 100 or 356 : 100 CE applies from both 4(c)(i) and the value for initial rate of reaction	(2)



Number	Answer	Additional Guidance	Mark
10(a)	An answer that includes the following • mass of maggots (1) • {radius / diameter / area} of capillary tubing Ignore volume of capillary tubing	Accept weight Accept volume of air (read from syringe) needed to reset liquid to original position (1)	(2)

Question Number	Answer	Additional Guidance	Mark
10(b)	An answer that includes two of the following: • use thermostatically controlled waterbath so temperature does not {change / affect the rate of respiration} (1) • control age of maggots as respiratory rate may change with age (1) • control species of maggot as some may have a {higher / lower} respiratory rate (1) • use of a control tube without maggots to account for changes in {temperature / pressure} (1) • maggots left to equilibrate in apparatus before results are recorded (1)	Accept putting apparatus in an incubator to control temperature Accept affects rate Accept affects rate Accept to determine changes in liquid movement without maggots	(2)

Question Number	Answer	Additional Guidance	Mark
10(c)(i)	0.07 (1)	Accept 0.069	(1)

Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	An explanation that includes the following: • {enzymes / substrates} will have less kinetic energy (1) • (so) collisions (between enzymes and substrates) are less {likely / frequent} (1)	Accept so fewer {collisions / enzyme-substrate complexes form} per unit time Accept E-S complexes {are less likely to form / form less frequently}	(2)

Question Number	Answer	Additional Guidance	Mark
10(d)	A description that includes the following: - oxygen is the {final / terminal} {hydrogen acceptor / electron acceptor} (1) - allows electrons to pass down electron transport chain (1) - allows {FAD / NAD} to be replaced (1) - movement of {hydrogen ions / protons} through {pores / stalked particles} in membrane drives synthesis of ATP (1)	Accept allows electrons to be passed through electron carriers Accept {hydrogen ions / protons} move through {ATP synthase / ATPase} forming ATP	(3)

(Total for Question 10 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	An explanation that makes reference to the following: - because nuclear DNA is present in both the male and female {gametes / sex cells} (1) - because mitochondria are present in the { female gamete / ovum / secondary oocyte / egg cell} and not the sperm head (1)	Accept in male and female nuclei in the context of fertilisation Accept mitochondria are present in sperm {neck / mid piece} / mitochondria (DNA) not released by the sperm	(2)

Question Number	Answer	Mark
7(b)(i)	7(b)(i). The only correct answer is C <i>A is not correct because an insertion adds an additional base</i> <i>B is not correct because monosomy is a chromosome mutation</i> <i>D is not correct because translocation is a chromosome mutation</i>	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to three of the following: - it will change the {amino acid sequence / primary structure} of ATP synthase (1) - therefore the ATP synthase active site could be a different {structure / shape} so ADP cannot {bind / bind as well} (1) - therefore the {channel / ATP synthase} the wrong {structure / shape} so {hydrogen ions / protons} cannot {pass through / pass through as well} (1) - therefore { no / less} {ATP made / oxidative phosphorylation} (1)	Accept a stop codon could result changing the {length / shape / structure} of the protein	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)	An explanation that makes reference to the following: - the mutation may produce a stop codon (1) - therefore translation will stop {sooner / when the stop codon is reached} (1) Or {one / several} bases deleted (1) - therefore the mRNA is shorter (1)	Accept no more amino acids added to the peptide / peptide synthesis stops sooner	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)	An explanation that makes reference to three of the following: - mutation may prevent {electrons being passed down the electron transport chain / ATPase from working properly} (1) - therefore {NADH / reduced NAD} cannot be oxidised (1) - therefore pyruvate and {NADH / reduced NAD} will produce lactate (1) - lactate produced at a faster rate than it can be removed (1)	Accept reformed / converted back	(3)

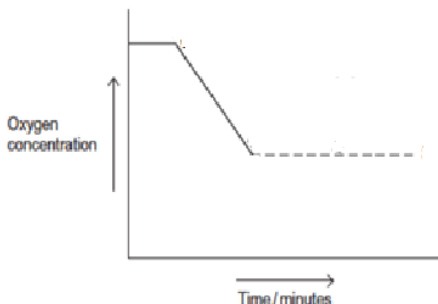
Total for Question 7 = 11 MARKS



8 (a)	inner membrane / cristae		(1)
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Question Number	Answer	Additional guidance	Mark
8(b)(i)	An explanation that makes reference to five of the following: • (cyanide) changes tertiary structure / changes active site / substrate no longer fits {active site / enzyme} (1) • therefore transport of {electrons / hydrogen ions} stops (1) • carrier(s) cannot be reduced (1) • (so that) ATP manufacture stops / less ATP made (1) • muscles {cannot contract / go into spasm} / breathing stops / heart stops (1) • any other named biological process that requires ATP stops eg active transport (1)		(5)

Question Number	Answer	Additional guidance	Mark
8(b)(ii)	• mass of cyanide that kills = 10 mg (1) • mass of cyanide inhaled per minute • time taken to inhale lethal dose (1) OR • mass of cyanide that kills = 10 mg (1) • volume that provides lethal dose (1) • time taken to inhale lethal dose (1)	$1 \times 10 = 10 \text{ mg}$ $0.24 \text{ mg dm}^{-3} \times 15 = 3.6 \text{ (mg per minute)}$ $10 \div 3.6 = \mathbf{2.78} \text{ minutes (3sf)}$ $1 \times 10 = 10 \text{ mg}$ $10 \div 0.24 = 41.67 \text{ (dm}^3\text{)}$ $41.67 \div 15 = \mathbf{2.78} \text{ minutes (3sf)}$	(3)

Question Number	Answer	Additional Guidance	Mark
8 (c)	An answer that makes reference to the following: • line decreasing from 5 to 15 minutes (1) • line level from 15 to 25 minutes (1)		(2)

	Additional Guidance	Mark		Additional Guidance	Mark
	ACCEPT large(r) mammals consume more oxygen in $\text{dm}^3 \text{ h}^{-1}$		eg: tor /	DO NOT ACCEPT hydrogen ACCEPT for 2 marks $2\text{H}^+ + \text{O}^{2-} \longrightarrow \text{H}_2\text{O}$	(
r^2d	ACCEPT converse for Mps 1, 3 and 4 and 5	(4)		<u>Example of calculation</u> $50 \div 4\,000 = 0.0125$ 1.25×10^{-2} Correct answer gains full marks, with no working shown ACCEPT one mark in working for 0.0125	(

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	The only correct answer is A <i>B is incorrect because electron transport chain is located on the inner membrane</i> <i>C is incorrect because electron transport chain is located on the inner membrane</i> <i>D is incorrect because electron transport chain is located on the inner membrane</i>		(1)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following: - because the electron transport chain can no longer function (1) - resulting in protein carriers / named carrier} becoming reduced (1) - therefore cells can only respire anaerobically (1) - therefore insufficient {ATP / energy} generated to sustain the fish (1)	ACCEPT {electrons transfer can no longer occur / electrons cannot flow through the cytochromes} slower / less DO NOT ACCEPT in context of no oxygen present ACCEPT cannot become oxidised / {NAD / FAD} cannot be regenerated / redox reactions cannot occur ACCEPT oxidative phosphorylation will be prevented / no protons pumped into intermembrane space / ATPase cannot synthesise ATP ACCEPT a reason for fish not being able to survive e.g. {heart / muscles} to contract, active transport, metabolism, chemical reactions lactic acid build up denaturing enzymes / stopping muscle contraction IGNORE no energy for respiration energy to swim too vague	(3)

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	changes in {gene expression / phenotype} without a change in {base sequence / DNA / gene / genotype / genetic code} (1)	ACCEPT switching genes on or off DO NOT ACCEPT mutation	(1)

Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	The only correct answer is B <i>A is incorrect because deletion mutation changes the base sequence</i> <i>C is incorrect because translation is the synthesis of a peptide chain</i> <i>D is incorrect because translocation affects the DNA base sequence</i>		(1)



Question number *9(c)	Data : <u>First generation fish</u> - male fish from environment with H₂S have more DMRs than male fish from environment without H₂S - female fish from environment with H₂S have more DMRs than female fish from environment without H₂S - number of DMRs increase up to a CpG density of 3 a.u. and then decrease - the number of female DMRs and male DMRs show a similar pattern - female fish have more DMRs than male fish <u>Second generation fish</u> - second generation fish show similar patterns of DMRs as the original fish - but there are differences e.g. male fish showing more DMRs at a CpG density of 2 than {original fish / female fish} - there are significant differences for the males at lower CpG densities, original females higher but 2nd gen females lower Lower level discussion points : recall of knowledge of epigenetics / experimental design : - DNA methylation of cytosine at CpG sites - Methylations adds a CH₃ - DNA methylation causes silencing of genes - by preventing transcription - epigenetic modifications are {inherited / passed down} - no details of experiment - no statistical analysis Higher level discussion points : - the presence of H₂S could be causing {DNA-methylation / epigenetic modification} - but no indication of other differences in the water that could be causing this (wild) males could be less susceptible to DNA-methylation than female fish (so increase not so great) / genetic effects - females have more methylation sites on second X chromosome - female fish already more adapted to toxic environment - DMRs have been retained by the second generation of fish - and stable / retained even after H₂S no longer present - but it appears that the laboratory conditions are also causing more DMRs to be formed in male fish - DNA methylation is a survival advantage - fish with more DNA methylation are better adapted to H₂S - as interruption to mitochondrial respiration is reduced / ETC can continue - DNA methylation can stimulate gene expression - so proteins synthesised that {inhibit H₂S / provide an alternative to cytochrome c oxidase}
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NB IGNORE all values given unless clearly wrong

Level 1 : Data commented on without any discussion

1 mark = any relevant comment

2 marks = some comparison of data

Level 2 : Some data discussed

3 marks = 1 discussion point

4 marks = 2 discussion points

Level 3 : Data discussed with some application of ideas

5 marks = comparisons described + 3 discussion points, including at least one higher level point

6 marks = comparisons described + 4 discussion points, including at least one higher level point



Question Number	Answer	Additional Guidance	Mark
8(a)(i)	(other : pulmonary) 2.5 : 1 / 2.5 / 1 : 0.4 / 0.4 (pulmonary : other) 1 : 2.5 / 2.5 / 0.4 : 1 / 0.4	DO NOT ACCEPT with units	(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	An explanation that makes reference to the following: (partial pressure of oxygen is low in) pulmonary artery is carrying deoxygenated blood to lungs (1) (partial pressure of oxygen is high in) arterial blood is carrying oxygenated blood to the {body / cells / tissues} (1)	NB piece together ACCEPT deoxygenated as it has come back from the body ACCEPT oxygenated as it has been through lungs	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	An explanation that makes reference to two of the following: - because HIF can switch on gene (expression) (1) - bind to a promotor region / stimulate transcription / stimulate protein synthesis} (1) - for {enzymes / proteins} involved in glycolysis (1)	ACCEPT increased gene expression ACCEPT increase rate of transcription IGNORE enzymes ACCEPT named {enzyme / protein} involved in glycolysis e.g. enzyme that makes NAD	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to the following: (because if conditions are hypoxic) there is not much oxygen available to act as a terminal electron acceptor (1) - therefore the electron transport chain will not operate (1) - therefore ATP production by oxidative phosphorylation will be reduced (1) - ATP is produced (directly / SLP) during glycolysis (during these anaerobic conditions) (1)	ACCEPT no oxygen	(4)

Question Number	Answer	Additional Guidance	Mark
8(b)(iii)	An answer that makes reference to the following: - both HIF-1 and HIF-2 increase (during hypoxia) (1) - levels of HIF-2 remain high (after a small decrease) but levels of HIF-1 fall (1)	DO NOT PIECE TOGETHER	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(iv)	An explanation that makes reference to two of the following: - HIF-1 and HIF-2 switch on different genes (1) {products / transcription of genes} resulting from the presence of both HIF-1 and HIF-2 are needed in the early stages of hypoxia (1) {products / transcription of gene} resulting from the presence of HIF-2 are needed {for longer periods of hypoxia / to sustain glycolysis} (1)	ACCEPT bind to different promotor regions ACCEPT converse for HIF-1	(2)

Number	Answer	Additional Guidance	Mark
5(a)	• division (1)	$3 \div 16 = 0.1875$	(2)
	• multiplication (1)	$0.1875 \times 100 = 18.75 / 18.8 / 19$	

Question Number	Answer	Additional Guidance	Mark
5(b)	A description that makes reference to four of the following: • use warm acid (1) • remove acid using water (1) • add named stain (1) • macerate or tease with needle (1) • use coverslip and squash (1)	e.g. acetic orcein / toluidine blue / Schiff's / Giemsa / Feulgen / (aceto) carmine	(4)

Question Number	Answer	Additional Guidance	Mark
5(c)	An answer that makes reference to four of the following: • use waterlogged soil and non-waterlogged soil / range of water content (1) • use same plant variety / type / species / age / size (1) • control {temperature / light / soil type / mineral ions / pH} (1) • leave for same stated time (1) • take cells from same part of root tips (1)	DO NOT ACCEPT nutrients DO NOT ACCEPT less than 24 hours e.g both cut at 2mm	(4)

Question Number	Answer	Additional Guidance	Mark
5(d)	An explanation that makes reference to four of the following: • aerobic respiration inhibited / anaerobic respiration occurs (1) • therefore {electron transport chain / oxidative phosphorylation} inhibited / therefore {glycolysis occurs / ethanol produced} (1) • less {ATP synthesis / reduced NAD} (1) • (less) active transport (of mineral ions) (1) • less {GP / GALP / IAA pumping / spindle fibre contraction / protein synthesis} (1)	ACCEPT valid substances / energy requiring processes DO NOT ACCEPT starch	(4)

Number	Answer	Additional Guidance	Mark
4(a)(i)	A description that includes five of the following: - find mass of woodlice (1) {description / diagram} of respirometer (1) - with {sodium hydroxide / potassium hydroxide / soda lime} (to absorb carbon dioxide) (1) - measure distance moved by liquid in stated time (1) - method of control of temperature (1) - method of finding volume of oxygen used (1) - method of calculation of rate (1)	Allow same / stated mass Accept description of basic respirometer or detail of method eg way of keeping woodlice away from soda lime Allow time to move fixed distance Accept thermostatically controlled waterbath Accept control tube described (to compensate for changes in temperature / air pressure) Accept volume of air needed to reset liquid to original position if syringe used / use of $\pi r^2 d$ Accept volume of oxygen used divided by time divided by mass Accept units ie $\text{mm}^3 \text{min}^{-1} \text{g}^{-1}$ Accept finding the gradient on a graph	(5)

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that includes the following: One from Safety - soda lime is corrosive, so wear gloves / goggles (1) {allergy to woodlice / they may have bacteria on them} so wear gloves (1) - glassware may break, so wear gloves (1) And one from Ethics - avoid harm to woodlice by {handling carefully / handling with a paintbrush / handling with a teaspoon / returning to garden} (1) - woodlice may be harmed by soda lime, so make sure they are separated from it eg {gauze / small bag} (1) - woodlice might use all the oxygen in the respirometer so refresh the air (1)	Accept harmful / toxic / irritant Accept avoid reducing population by returning woodlice to garden (once investigation is over) (1)	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	A explanation that includes the following: Test - chi squared (1) Reason {used to compare observed and expected frequencies / we are investigating the distribution of a single categoric variable} (1)	Accept to compare observed and expected data / values	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An explanation that includes the following: (woodlice prefer dark conditions as) more likely to be {humid / damp} so woodlice less likely to lose water (1) (woodlice prefer) damp so can absorb oxygen (more) effectively (when gills are damp) (1)	Accept less likely to be eaten by predators Accept gas exchange for absorbing oxygen	(2)



Question Number	Answer	Additional Guidance	Mark
4(b)(iii)	A description that includes three of the following: • set up choice chamber in advance (1) • leave woodlice for longer than 5 minutes (1) • ensure all woodlice are the same species (1) • use more woodlice (than 5 / 20) (1) • {take a photograph and analyse that to count numbers / statement of how to deal with woodlice on boundary} (1)	Accept clean chamber between trials to remove scent trails	(3)

(Total for Question 4 = 14 marks)

Number	Answer	Additional Guidance	Mark
10(a)(i)	An answer that includes the following correct rate of respiration (1)	0.03 (cm ³ min ⁻¹) accept 0.028 – 0.032	(1)

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	An explanation that includes the following: (yeast) can use sucrose to produce carbon dioxide (1) (yeast) cannot use lactose, so no respiration (1) - because lactose cannot be broken down (1) {respiration stops / volume of carbon dioxide remains constant} because all {sucrose / substrate} has been used up (1)	Accept (yeast) can use sucrose to respire Accept line levels off because all {sucrose / substrate} {has been used up / is a limiting factor}	(3)

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)	An explanation that includes the following: - lactase breaks down lactose to give glucose and galactose (1) - yeast can use one of these (sugars) as a respiratory substrate (1) - because volume of CO₂ is approx. half of that {expected / produced by sucrose} (1) - rate of respiration at 400 minutes is close to zero as all {glucose / substrate} has been used up (1)	Accept yeast can respire using glucose /one of these sugars Accept yeast cannot use one of them / galactose to respire Accept because the volume of CO ₂ has levelled out as all the {glucose / substrate} has been used up	(3)

Question Number	Answer	Additional Guidance	Mark
10(b)	An explanation that includes three of the following: - at lower temperature, there will be less kinetic energy, so respiration rate is lower (1) - because fewer enzyme-substrate collisions <u>per unit time</u> (1) - respiration will continue until all of the {sucrose / substrate} is used up (1) - so that {the same volume (of CO₂) is produced / (eventually) rate of respiration will reach zero} (1)	Accept at lower temperature, there will be less kinetic energy, so less CO ₂ produced per unit time Accept less ES complexes per unit time Accept less frequent / likely collisions Do not accept no ES collisions Do not accept in context of enzyme denatured (at a lower temperature) it will take longer for the {rate of respiration to reach zero / same volume of CO ₂ to be produced}	(3)

Question Number	Answer	Additional Guidance	Mark
10(c)(i)	An answer that includes the following: line drawn to the right of existing line ie slower initial rate and reaching same final value (1)	Total volume of carbon dioxide produced / cm³ Time / minutes	(1)

Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	An explanation that includes three of the following: (7g yeast / high concentration) more yeast cells present, so {carbon dioxide is produced faster / more carbon dioxide produced (at start)} (1) (more yeast cells present), so more enzymes to {hydrolyse sucrose / carry out respiration} (1) - final volume of CO₂ produced is the same for 7g and 3.5g yeast (1) - because {mass / concentration} of {sucrose / substrate} is the same for both (1) - line levels off sooner for 7.0g because sucrose is used up more quickly} (1) 3.5g yeast will produce half the rate of reaction compared to 7.0g yeast (1)	All marking points must be comparative Accept converse for 3.5g yeast for all points Accept more enzymes (for more yeast) Accept more yeast cells so higher respiration rate Accept line levels off sooner for 7.0g because rate of respiration is faster Accept it takes twice as long for the line to plateau (with 3.5g yeast)	(3)

(Total for Question 10 = 14 marks)

Question Number	Answer				Mark		
7(a)					(3)		
	Bond	Molecule that bond may be found in					
		carbohydrate only	lipid only	both carbohydrate and lipid		neither carbohydrate nor lipid	
		covalent	☐	☐		X	☐
		ester	☐	X		☐	☐
		hydrogen	X	☐		☐	☐

Question Number	Answer	Mark
7(b)(i)	The only correct answer is B matrix A is incorrect because only glycolysis takes place in the cytoplasm C is incorrect because stroma is in chloroplasts not mitochondria D is incorrect because tonoplasts are in plant cells only	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to three of the following: - in anaerobic conditions, the pyruvate is used to reoxidise NADH so no Krebs cycle (1) - no oxygen available to act as a (terminal) electron acceptor (1) - so reduced { NAD / FAD / coenzyme } cannot be reoxidised (1) - so no (oxidised) coenzyme to bind {hydrogen ions / protons / H⁺/electrons} (1)	ACCEPT oxygen binds to electrons ACCEPT NADH / FADH₂	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)	An explanation that makes reference to two of the following: - because a lipid molecule contains a higher proportion of hydrogen (than a carbohydrate molecule) (1) - therefore more reduced {NAD / FAD / coenzyme} (1) - therefore more hydrogen (ions) {to accumulate in the inter-membrane space / to produce a proton gradient / to pass through ATP synthase channels / for chemiosmosis / for oxidative phosphorylation} (1)	ACCEPT converse throughout ACCEPT NADH / FADH₂	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	when one molecule of carbohydrate is respired the number of carbon dioxide molecules produced is the same as the number of molecules of oxygen used	ACCEPT carbon dioxide produced = oxygen used	(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	- volume of both gases calculated (1) - RQ value calculated to {1 / 2} decimal places (1)	<u>Example of calculation:</u> oxygen volume = $4.5 \times 21 + 3.75 = 98.25$ carbon dioxide volume = $3 \times 21 + 6 = 69$ $69 \div 98.25 = 0.70$ / 0.7 / 0.702 ACCEPT ecf	(2)

Question Number	Answer	Additional Guidance	Mark
7(e)	An explanation that makes reference to three of the following: - insect is respiring carbohydrates at rest and lipid during flight (1) - respiration of carbohydrate provides enough energy for the insect at rest (1) - it requires more {energy / ATP} (for contraction) (1) - therefore the insect has to respire lipid to provide this energy (1)	NB uses for respire throughout but reference to respiration must be made at least once for full marks to be awarded PIECE TOGETHER	(3)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	A description that makes reference to two of the following: - during glycolysis (1) - glucose is converted to pyruvate (1) - by substrate level phosphorylation (1)	ACCEPT anaerobic respiration	(2)

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	An explanation that makes reference to the following: - because the proton gradient would be shallower (1) - so protons would flow through the ATP synthase more slowly (1) - therefore less energy for the phosphorylation of ADP (1)	ACCEPT electrochemical/chemiosmotic gradient IGNORE fewer protons ACCEPT less ADP + Pi converted to ATP	(3)

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	length from head to tail in photo in cm $\div$ 12 (1)	40-42 mm $40 = 0.33 \times 41 = 0.34 \times 42 = 0.35 \times$	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	0.8 : 1 (1)		(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	An explanation that makes reference to two of the following: - To attract the birds to be caught (1) - so that respiration would not be limited by energy source (1) - to make the investigation valid (1)	so that all birds had plenty to eat	(2)

Question Number	Indicative content	Mark
*7(c)(ii)	Graph 1 (volume of mitochondria) - great tits have larger volume of mitochondria than blue tits - blue tits have more mitochondria than coal tits - error bars do not overlap between autumn and winter so differences are significant - because bigger birds need to produce more ATP for flying - coal tits are smaller so need less ATP - all three birds increase their number of mitochondria in the winter - by division - because more heat needs to be generated to keep warm in the colder season - greater volume needed in winter because more leaked respiration Graph 2 (respiration producing ATP) - coal tits respire faster than blue tits and great tits - because they have fewer mitochondria - no significant difference between blue tits and great tits - there is no difference in rate of respiration in great tits between autumn and winter - the rate of respiration decreases in winter in blue tits and coal tits - because they need to {produce more heat / switch to leaked respiration} - as they have a larger surface area : volume ratio - and therefore lose more body heat - if switch to leaked respiration is made there is a smaller proton gradient - therefore less respiration to make ATP Graph 3 (leaked respiration) - Rate of leaked respiration is faster in all three species in winter - rate of leaked respiration is faster in coal tits than blue tits - rate of leaked respiration is similar in great tits than blue tits - there are no error bars so cannot say if any differences are significant - because leaked respiration produces more heat	(6)



	- needed for coal tits because they have a larger surface area : volume ratio - and therefore lose more body heat	
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			Additional guidance
Level 0	0	No awardable content	
Level 1	1-2	An explanation may be attempted but with limited interpretation or analysis of the scientific information and with a focus on mainly just one piece of scientific information. The explanation will contain basic information, with some attempt made to link knowledge and understanding to the given context.	Simple descriptions of the data 1 mark = a description relating to one graph 2 marks = a description for three graphs
Level 2	3-4	An explanation will be given, with occasional evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows some linkages and lines of scientific reasoning, with some structure.	Some explanation of the data 3 marks = explanation for one of the graphs 4 marks = explanation for two of the graphs
Level 3	5-6	An explanation is made that is supported throughout by sustained application of relevant evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows a well-developed and sustained line of scientific reasoning, which is clear and logically structured.	Detailed explanation of the data 5 marks = explanation of two graphs and discussion of error bars 6 marks = explanation of all three graphs and both size and seasonal variation discussed



Question Number	Answer	Additional Guidance	Mark
4(a)	An answer that makes reference to the following: • (carbon) carbon dioxide • (hydrogen) water • (oxygen) carbon dioxide	1 or 2 correct = 1 mark All 3 correct = 2 marks IGNORE CO ₂ , H ₂ O	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)	The only correct answer is D A is incorrect because both photolysis occurs on thylakoid membrane and the pigments are embedded in the thylakoid membrane B is incorrect because photolysis occurs on thylakoid membrane C is incorrect because the pigments are embedded in the thylakoid membrane		(1)

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	An explanation that makes reference to three of the following: • because carbon dioxide has already been fixed (1) • acetate used to form {GALP / glucose / organic molecules} (1) • and store {organic molecules / named organic molecule} as biomass (1) • acetate can be used in respiration	(Acetate) generates amino acids/proteins for growth	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	An answer that makes reference to one of the following: • can be grown anywhere (indoors) because no need for {sunlight / nutrients / water} (1)	can be grown where daylight is limited/ at any time of year so higher yield/can be grown day or night so increased yield	(1)

Number	Answer	Additional Guidance	Mark
3(a)(i)	A description that includes the following: - tube (containing hydrogencarbonate indicator in light) with no gel beads (1) - tube (containing hydrogencarbonate indicator and gel beads) in light-proof cover (1)	Accept tube (containing only hydrogencarbonate indicator in light) with no algae Accept tube (containing hydrogencarbonate indicator and gel beads) in the dark	(2)

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	An explanation that includes three of the following: {at 5cm and 15cm / at high light intensity / close to lamp} (indicator is purple) there is more photosynthesis, so carbon dioxide being taken in (1) (at 5 and 15cm) there is more photosynthesis than respiration so net uptake of carbon dioxide (1) - at 25cm (indicator is red) the carbon dioxide used in photosynthesis equals the carbon dioxide produced in respiration (1) {at 35 or 45cm / at low light intensity / far from lamp} (indicator is orange) there is more respiration than photosynthesis, so {carbon dioxide released / more carbon dioxide is present} (1)	Allow ref to LDR or carbon fixation for photosynthesis Accept at 5 and 15 cm light is not a limiting factor for photosynthesis, so carbon dioxide is taken in. Accept converse Accept reference to compensation point Accept rate of photosynthesis equals rate of respiration Accept there is less light for photosynthesis so less carbon dioxide is used than is produced in respiration Accept net increase in carbon dioxide linked to photosynthesis and respiration	(3)

Question Number	Answer	Additional Guidance	Mark
3(b)	A description that includes three of the following: Up to two examples of standardisation (2) and a maximum of two from: - set up a reference set of solutions at different carbon dioxide concentrations (1) - compare by {colour matching / using a colorimeter} (1) - time taken for gel beads to rise {a known distance / to the surface of the tube} (as oxygen is being produced in photosynthesis) (1)	eg equal volume of (sodium hydrogencarbonate) indicator / equal {number of gel beads / mass of algae / mass or volume of beads} / same temperature Accept control as eq to same Accept measurement of {position of / distance moved by} gel beads in tube	(3)

Total for Question 3 = 8 marks

Number	Answer	Additional Guidance	Mark
3(a)	An answer that includes the following: - one peak of bacteria drawn around 440 nm (1) - one peak of bacteria drawn around 690 nm (1)	Allow peak on one side only (ie above or below filament) and drawn with dots or a line Allow between 400 and 500 Allow between 650 and 720	(2)

Question Number	Answer	Additional Guidance	Mark
3(b)	A description that includes five of the following: - use of different (coloured) filters (placed between lamp and beaker of water) (1) - heat shield in front of beaker (1) - add sodium hydrogencarbonate to beaker (1) - method to exclude ambient (white) light (1) - pondweed allowed to acclimatise at each wavelength (before results collected) (1) - description of method of measuring rate of production of gas produced by pondweed (1) - control of {pondweed / light intensity} (1)	Accept coloured bulbs used (to change wavelength of light) Accept beaker placed in thermostatically controlled water bath Accept use of {measuring cylinder / gas syringe / capillary tubing (with scale)} and reference to time Ignore photosynthometer unqualified Ignore potometer / respirometer Ignore counting bubbles Accept same length or mass / use same pondweed / keeping lamp at a constant distance	(5)

Question Number	Answer	Additional Guidance	Mark
3(c)	An explanation that includes two of the following: - to absorb (light of) different wavelengths (1) (so that) more wavelengths can be used (in photosynthesis) (1) - to protect chlorophyll from damage caused by absorbing too much light (1)	Ignore refs to phytochromes Accept a range of wavelengths can be absorbed Allow captured for absorbed Accept more light used (in photosynthesis) Allow faster rate of photosynthesis Allow because photosystems I and II use different wavelengths of light	(2)

(Total for Question 3 = 9 marks)

Number	Answer	Additional Guidance	Mark
4(a)	A description that makes reference to three of the following: • add {extract / pigment} to (start) line (1) • (concentrate spot by) dry and repeat (1) • place paper in named solvent (1) • obtain solvent front / place paper so line or spot above solvent / until reaches near top (1)	e.g. propanone / ethanol / petroleum ether DO NOT ACCEPT water	(3)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that makes reference to the following: • axis for chlorophyll content is linear and uses at least half grid (1) • accurate plot and standard deviation for little traffic (1)		(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An explanation that makes reference to three of the following: • quadrats placed at random / sampling at random (1) • method of random number sampling (1) • sampling done at same distance from {traffic / road} / transect placed parallel to {traffic / road} (1) • therefore removes bias / obtain running mean / ensures valid data (1)	e.g. use of random number generator	(3)

Question Number	Answer	Additional Guidance	Mark
4(b)(iii)	An answer that makes reference to two of the following: • {heavy traffic / more lead} reduces chlorophyll content (1) One from: • photosynthesis not measured (1) • lead may be from other sources / other named factor may be responsible (1) • only one species of plant investigated (1)	ACCEPT converse e.g. light / Mg / other pollutant	(2)

Mark	
	obtain discs / ts pigment ulate SD (1) acts synthesis of pigments (1)
(5)	

Additional Guidance	Mark
ACCEPT absorption spectrum involves wavelengths only and action spectrum involves photosynthesis / oxygen production only	

Additional Guidance	Mark
ACCEPT similar peak at blue / similar peak at red / similar trough at green	

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	An explanation that makes reference to three of the following: - each pigment will absorb different wavelengths (of light) (1) - each pigment will absorb different amounts of light at each wavelength (1) - action spectrum is different because the seaweeds are absorbing different wavelengths of light (1) - the rate of photosynthesis will therefore be different at each wavelength(1)	ACCEPT each pigment will reflect different wavelength (of light) description of which colour light is {reflected / absorbed}	(3)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	An explanation that makes reference to three of the following: - green seaweeds found in shallow water as they {cannot absorb the green light / can absorb the red light} (1) {brown / red} seaweeds can absorb {green / blue / other} wavelengths of light so are positioned further down as these wavelengths can penetrate further (1) - seaweeds positioned so that they can absorb light for {photosynthesis / light-dependent reactions / photolysis} (1) - seaweeds positioned to avoid competition with the other types of seaweed (1)	ALLOW plants for seaweeds	(3)

Question Number	Answer	Additional Guidance	Mark
6(b)(i)	2.0 / 1.9 / 1.93 (times / ×)	DO NOT ACCEPT 1.93 recurring	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	An explanation that makes reference to three of the following: - water is more effective than culture media for washing (1) {water is not the solvent / ethanol is the solvent} for fucoxanthin (1) - ethanol {increases permeability of / disrupts} (cell / vacuole) membrane (1) - more fucoxanthin extracted in method A (compared with method B) because water enters the seaweed {by osmosis / causing the cells to burst} (1)	ACCEPT more fucoxanthin extracted in A because washed with water	(3)

Question Number	Answer	Mark
8(a)	8(a). The only correct answer is D <i>A is not correct because there is no cytoplasm inside the chloroplast</i> <i>B is not correct because the matrix is found inside mitochondria</i> <i>C is not correct because nucleoplasm is found inside the nucleus</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	- maximum width × magnification (1) - correct gap width with appropriate units (1)	$20 \times 10^{-3} \times 12\,000 = 240$ $= 0.24\text{ mm} / 240\text{ }\mu\text{m} / 240\,000\text{ nm} / 24 \times 10^4\text{ nm}$ Accept correct minimum gap width with appropriate units for 1 mark	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to the following: - because the resolution of the microscope is {not high enough / is too low} (1) - as the membranes are too close together to be distinguished as separate structures (1)	Do not accept magnification Accept as separate lines Do not accept magnification	(2)

Question Number	Indicative content
*8(c)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Descriptions of graph or diagram: - as the leaf size increases so does the number of chloroplasts per cell - as the leaf size increases cpDNA per chloroplast increases then decreases - as the leaf continues to grow the number of chloroplasts per cell continues to increase but the number of cpDNA per cell drops Explanations of graph or diagram: - as the leaf increases in size more chloroplasts needed for photosynthesis - cpDNA replicates to provide the cpDNA for newly made chloroplasts - this ensures that the new chloroplasts have identical genetic information - the cpDNA per chloroplast begins to drop as the leaf cells get older, since there are more chloroplasts per cell Interpretation of the genes found in the cpDNA : - cpDNA codes for RNAs and ribosomal proteins that will be needed for transcription and translation of proteins needed in the new chloroplasts - cpDNA codes for proteins needed in photosynthesis e.g. RUBISCO

Level 0	Marks	No awardable content
Level 1	1-2	An explanation may be attempted but with limited interpretation or analysis of the scientific information with a focus on mainly just one piece of scientific information. The explanation will contain basic information with some attempt made to link knowledge and understanding to the given context. Description given of the changes shown in the graph in the number of chloroplasts, cpDNA and increase in leaf size
Level 2	3-4	An explanation will be given with occasional evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows some linkages and lines of scientific reasoning with some structure. An explanation given for these changes
Level 3	5-6	An explanation is made which is supported throughout by sustained application of relevant evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows a well-developed and sustained line of scientific reasoning which is clear and logically structured. Links made between the genes in the cpDNA and the processes of photosynthesis and protein synthesis

Total for Question 8 = 11 MARKS

Number	Answer	Additional Guidance	Mark
11(a)	An explanation that makes reference to six of the following: - grass taken from in or near clover and from an area without clover (1) - standardised mass of grass plants collected (1) - use of known volume of (named) solvent to extract pigment from (known mass of) grass (1) - absorbance measured in colorimeter (1) - red filter used to measure absorbance of green chlorophyll (1) - colorimeter zeroed with solvent (1) - replicates taken and means calculated (1) - t test used to look for significant difference (1) - other relevant factor monitored (1)	Allow lab-based experiment where grass is grown with and without clover Allow use of {sand / pestle and mortar/ food mixer} to grind up grass Allow extract filtered Allow details of chromatography if carried out as an alternative with area or intensity of green spots measured Allow compare standard deviation	(6)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	The only correct answer is A B is incorrect because light-dependent stage takes place on thylakoid membrane and not in the stroma C is incorrect because light-dependent stage takes place on thylakoid membrane and not on the inner membrane D is incorrect because light-dependent stage takes place on thylakoid membrane and not on the outer membrane		(1)

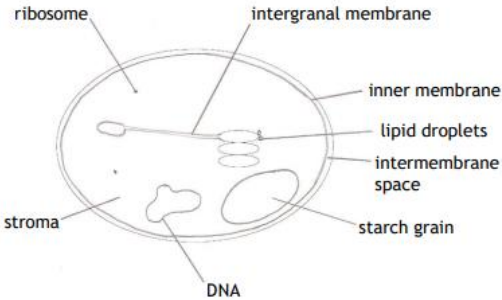
Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	The only correct answer is A B is incorrect because hydrogen ions accumulate inside the thylakoids and not in the starch grain C is incorrect because hydrogen ions accumulate inside the thylakoids and not in the DNA loop D is incorrect because hydrogen ions accumulate inside the thylakoids and not in the inner membrane space		(1)

Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	The only correct answer is D A is incorrect because translation occurs on the ribosomes and not inside the thylakoids B is incorrect because translation occurs on the ribosomes and not in the starch grain C is incorrect because translation occurs on the ribosomes and not in the DNA loop		(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	The only correct answer is C A is incorrect because per area is m^{-2} B is incorrect because per area is m^{-2} and per second is sec^{-1} C is incorrect because per second is sec^{-1}		(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	An answer that makes reference to three of the following: - as temperature increases so does rate of photosynthesis (1) - rate of photosynthesis is faster in high levels of carbon dioxide (1) - the optimum temperature for photosynthesis is higher in higher levels of carbon dioxide (1) - optimum for photosynthesis are high levels of carbon dioxide and a temperature of 37°C (1)	ACCEPT converse throughout ACCEPT temp value between 35.5 and 36.5	(3)

Question Number	Answer	Additional Guidance	Mark
5(b)(iii)	An explanation that makes reference to four of the following: - more carbon dioxide and higher temperatures (below optimum) mean more GALP formed (1) - higher carbon dioxide concentration means {more carbon dioxide for / faster} {light-independent stage / Calvin cycle / carbon fixation} (1) - higher temperatures means that RUBISCO can catalyse carbon fixation faster (1) - because more (kinetic / heat) energy so more {enzyme-substrate complexes / energetic collisions between enzymes and substrates} (1) - therefore GP formed to be converted into GALP (1)	ACCEPT converse throughout ACCEPT pieced together ACCEPT description e.g. carbon dioxide reacting with RuBP ACCEPT temperatures too high, RUBISCO will denature	(4)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	A drawing that labels three of the following: - DNA (loop) (1) - stroma (1) - starch {grain / granule} (1) - inner membrane / envelope (1) - inter membrane space (1) - intergranal membrane / (stromal) lamellae / intergranal thylakoid (1) (small / 70S) ribosome (1) - lipid droplets IGNORE thylakoid membrane / lumen of thylakoid / grana drawing quality, unless completely wrong e.g. strand of DNA	DO NOT ACCEPT if drawn as linear DNA DO NOT ACCEPT stoma  NB 1 correct + 1 or 2 wrong = 1 mark 1 correct + 3 wrong = 0 marks 2 correct + 1 wrong = 2 marks 2 correct + 2 or 3 wrong = 1 mark 3 correct + 1 wrong = 2 marks 3 correct + 2 wrong = 1 mark 3 correct + 3 wrong = 0 marks	(3)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	- length measured and converted to μm / length measured and actual chloroplast length converted into same units (1) (magnification given to 2 significant figures, with no units) 27 000 (1)	80 000 / 81 000 / 82 000 + 3 80 / 81 / 82 + 0.003 8.0 / 8.1 / 8.2 + 0.0003 80 000 $\div$ 3 = 26,666.66 81 000 $\div$ 3 = 27,000 82 000 $\div$ 3 = 27,333.3333 ECF figures of 27 given but wrong order of magnitude NB Correct answer with no working = 2 marks Correct answer with too many sig figs = 1 mark Figures of 27 given but wrong order of magnitude = 1 mark	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to four of the following: (contain) {photosystems / PSI / PSII / chlorophyll / named pigment} so that {light / photons} can be <u>absorbed</u> (1) (contain) electron {carrier proteins / carriers / transport chain} so that {reduced NADPH is formed / hydrogen is pumped into thylakoid (space) / so that a series of redox reactions can take place} (1) (contain) ATP synthase so that hydrogen ions can pass through (1) - membranes {enclose a space / form a barrier} so that hydrogen ions can accumulate (1) - membranes are the site of {photolysis / chemiosmosis / photophosphorylation} (1)	ACCEPT ETC ACCEPT ATPase ACCEPT membranes trap hydrogen ions protons ACCEPT compartmentalisation / description of	(4)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	RUBISCO / ribulose biphosphate carboxylase / ribulose biphosphate oxygenase	ACCEPT ribulose biphosphate carboxylase / ribulose biphosphate oxygenase RUBISCO in capitals / lowercase / mixture	(1)

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	An explanation that makes reference to two of the following: - keep the thylakoids and enzymes <u>close</u> together (1) - so that products of the light-dependent stage {are not lost / can collide with enzymes more frequently} (1) - because enzymes need to be in solution to function (1)	ACCEPT other terms meaning close e.g. nearby, constant contact, touching, small distance {products / named products} of light-dependent stage needed in {light-independent stage / Calvin cycle / carbon fixation / by enzymes} ACCEPT easier for collisions to occur	(2)

Question Number	Answer	Additional Guidance	Mark
8(a)	The only correct answer is C A is incorrect because neither carbohydrates nor lipids contain N B is incorrect because lipids do not contain N D is incorrect because carbohydrates do not contain N		(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	The only correct answer is B A is incorrect because the mesophyll layer is the gas exchange surface C is incorrect because the mesophyll layer is the gas exchange surface D is incorrect because the mesophyll layer is the gas exchange surface		(1)

Question Number	Indicative content	
*8(b)(ii)	Indicative content: Depth of layers • smaller in low N (D)/(larger in high N (D)) • therefore mesophyll layer may be narrower (E) • therefore less chlorophyll for light-dependent stages (E) • therefore less stroma / RUBISCO for Calvin cycle (E) • therefore diffusion of gases will be higher (E) • therefore higher concentration of carbon dioxide for Calvin cycle (E) • Allow converse for all statements above (E) Size of chloroplasts • smaller in low N (D)/(larger in high N (D)) • therefore less chlorophyll for light-dependent stages/less light absorbed (E) • therefore less ATP/NADPH (E) • less stroma / RUBISCO for Calvin cycle (E) • therefore RUBISCO maybe at a lower concentration • therefore Calvin cycle will be slower • Allow converse for all statements above (E) Surface area of chloroplasts exposed to intercellular air space • lower in low N plants (D)/(higher in high N (D)) • therefore reduced gas exchange (E) • therefore lower concentration of carbon dioxide (E) • so Calvin cycle will be slower (E) • converse of statements above (E) RUBISCO activity • lower in low N (D) • lower in high N (D) • therefore Calvin cycle will be slower (E) • as RUBISCO catalyses carbon fixation (E) • and rate of reaction decreases with decrease in enzyme concentration (E)	Allow converse for all statements Level 1 1 mark = description of 2 characteristics 2 marks = explanation for 1 of the characteristics Level 2 : 3 marks = explanation for 2 of the characteristics 4 marks = explanation for 3 of the characteristics Level 3: 5 marks = extended explanation for 3 of the characteristics 6 marks = extended explanation for all 4 characteristics

	Marks	AO2 discuss
0	0	No awardable content
1	1-2	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context.
2	3-4	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure.

3	5-6	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.
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Question Number	Answer	Additional Guidance	Mark
8(c)(i)	An answer that makes reference to three of the following: Any two from - more {changes/increase/decrease} in gene expression in low levels of nitrogen (1) - more genes were not expressed in plants than expressed in both groups of plants (1) - some of the genes that were either expressed or not expressed were the same in both groups of plants (1) And - calculation used to illustrate at least one of the changes (1)	e.g Low levels 467 genes increased, 924 increased. High levels 294 genes increased, 601 decreased. Expression of 200 genes was similar in high and low levels of N. 496 more genes were affected in low levels than high levels.	(3)

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Question Number	Answer	Additional Guidance	Mark
8(c)(ii)	A description that makes reference to the following: - epigenetic modification (1) - credit example of epigenetic modification (1)	e.g. methylation, transcription factors, histone modification, acetylation	(2)

Number	Answer	Additional Guidance	Mark
9(a)(i)	- calculate rate of growth for both treatments (1) - subtraction (1)	rate for weeds $11 \div 5 = 22$ rate for herbicide $180 \div 5 = 36$ $36 - 22 = 14$ (cm year ⁻¹) Correct answer gains full marks, with no working shown	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following: - herbicide is more effective at removing weeds (1) - therefore there is less competition for {light / carbon dioxide / mineral ions / water} (1)	ACCEPT converse e.g. herbicide kills all the weeds but removing by hand lets them grow again DO NOT ACCEPT nutrients	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	An explanation that makes reference to two the following: - same species of tree because trees grow at different rates (1) {animals / pests / disease / herbivores / insects} as they {affect growth / feed on trees} (1) - same {number / spacing} of trees to control (intraspecific) competition (1)	ACCEPT trees get same light / mineral ions / water	(2)

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to four of the following: - use same light intensity (1) - use red filter (1) - use tube {with clean sides / no scratches / holding opaque side} (1) - use a control tube with water to {calibrate / obtain zero absorbance} (1) - same {concentration / volume} of {chloroplasts / DCPIP} (1)	DO NOT ACCEPT same lamp / same bulb / same power / same distance	(4)

Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	An explanation that makes reference to four of the following: - with herbicide DCPIP not {decolourised / reduced / stays blue} (1) - no electrons available / reduced electron transport (1) - less {reduced NADP / NADPH} (1) - therefore less ATP (1) - because the {Calvin cycle / light independent stage} are affected (1)	ACCEPT converse DO NOT ACCEPT absorbance does not change DO NOT ACCEPT if from ETC implies respiration	(4)

Number	Answer	Additional Guidance	Mark
6(a)(i)	A explanation that includes two of the following: • <u>rate</u> of photosynthesis is {high / higher / highest} in {white light / with no filter} / (1) • because the {chlorophyll / plant} is able to absorb more (wavelengths of) light when no filter is present (1) • so more {GP / GALP / glucose / amino acids / cellulose / ATP} is made OR more glucose allows faster respiration OR so mitosis occurs more rapidly producing daughter plants (1)	Accept converse for red and blue filters Accept <u>rate</u> of photosynthesis is slower in red or blue light / with red or blue filters Accept pigments / other named pigments Accept {red filter does not transmit {blue / green} light / blue filter does not transmit {red / green} light so less light for chlorophyll / plant to absorb Accept "products of light independent stage"	(2)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	An answer that includes two of the following • higher light intensity (1) • higher temperature (1) • higher concentration of carbon dioxide (1) • add {fertiliser / more mineral ions} (1)	Accept move lamp closer Accept place heater in tank Accept add sodium hydrogen carbonate / bubble carbon dioxide through water	(2)

Question Number	Answer	Additional Guidance	Mark
6(a)(iii)	An answer including one of the following • plants may overlap (so difficult to count) (1) • {frond / plant} size may vary (so not comparable) (1) • (when budding is occurring it is) hard to tell when one plant becomes two (1)	Ignore difficult to count unqualified	(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(iv)	A description including two of the following • measure mass of plants (1) • detail of technique eg blotting dry / use of replicates and dry mass (1) OR • measure surface area covered (1) • detail of technique eg use of squared paper, or photograph (1) OR • measure root length (1) • detail of technique eg use of calipers / straighten root (1)	Accept estimate % cover Accept use of quadrat / grid Accept plant length	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that includes three of the following - as fertiliser concentration increases, {mitosis / cell division / growth} increases (1) - because nitrate is needed to make {amino acids / proteins / enzymes / DNA / RNA / chlorophyll} (1) - because phosphate is needed to make {nucleic acids / DNA / RNA / ATP / ADP / NADP / phospholipid} (1) - because magnesium is needed to make chlorophyll (1)	Accept positive correlation Accept more fertiliser / higher mass of fertiliser	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)	An answer that includes a maximum of three of the following: Positives - removes excess minerals from the water (1) <u>rapid growth rate</u> so large amounts of animal feed produced (1) - cheap (as it uses waste products) (1) - floats so not shaded by manure in water (1) - error bars do not overlap, so concentration affects growth (1) and a maximum of three of the following: Negatives - need a large surface area to grow it (as it floats in a single layer) (1) - needs a warm temperature for rapid growth (1) - very high levels of minerals may inhibit growth of duckweed (1) - duckweed may be killed by pollutant chemicals in water (1) - duckweed may have negative effects on other aquatic life (1) - error bars are large so good growth not certain (1) - animal feed may be contaminated with bacteria (1)	Accept duckweed removes pollutants Accept large amounts of animal feed produced in <u>a short time</u> Accept idea of renewable / recycling / sustainable Accept would have to be grown indoors in the winter Accept not all required minerals may be present / not right ratio Ignore pH Accept relevant example of effect Accept causing disease	(4)

(Total for Question 6 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	The only correct answer is D A is incorrect because crista are in mitochondria B is incorrect because the photosystems are not in the inner membrane D is incorrect because the photosystems are not in the outer membrane		(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	• photolysis (1)		(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(iii)	The only correct answer is C A is incorrect because reduced NADP is formed B is incorrect because reduced NADP is formed D is incorrect because an electron is gained when a substance is reduced		(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(iv)	• $\text{ADP} + \text{P}_i \rightarrow \text{ATP}$ (1)	ACCEPT ADP / adenosine diphosphate P_i / phosphate / phosphate ions ATP / adenosine triphosphate Do not accept any other arrow	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)(i)	An answer that makes reference to the following: • Correct value calculated from graph (1) • Answer calculated (1)	$(18.5 - 0.5) \div 14 = 1.28571428571 \times 10^6$ $\div 1.04 \times 10^6 = 1.236$ 1.2 1.3 gains 1 mark Correct answer gains 2 marks	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	An explanation that makes reference to the following: • darker green (because synthesis of) {more photosynthetic pigments /more chlorophyll/more chloroplasts} (1) • (more pigments) absorb more light for photosynthesis (1) • cells not increased in number as number of new cells equals number of dying cells /stationary phase (1) • explanation of death phase (1) • credit one reason explained for cells entering death phase (1) • credit second reason explained for cells entering death phase (1)	Accept converse cells in natural light still dividing (by mitosis) e.g more cells are dying than are being produced e.g. limiting factors are: (visible) light minerals/ carbon dioxide build up of toxins/waste in the culture space	(5)

Question Number	Answer	Additional Guidance	Mark
6(b)(iii)	An explanation that makes reference to the following: • <i>Chlorella</i> produce several (different photosynthetic) pigments (1) • therefore {maximises/more} light absorption(1) • therefore {maximises/more} production of electricity (by the solar cells) (1)		(3)

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	- length of scale line given in μm - magnification calculated	1.7×10000 / 17000 1.7×10^3 / 0.0017×10^6	

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	width of GM aperture divided by width of non-modified aperture	In the range of 1.3 to {4 / 4.0} to no more than 1 decimal place DO NOT ACCEPT with units or %	

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	A description that makes reference to the following: (μmol) carbon dioxide used / {oxygen / GP / GALP / glucose} made (1) (m^{-2}) is the area of the {leaf / open stomata} (1) (s^{-1}) in one second (1)	ACCEPT example e.g. measure for 120 seconds and divide by 120	

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to three of the following: - increase in light intensity increases photosynthesis (1) - increase is greater in GM plants because the wider aperture will result in a more {gas exchange / uptake of carbon dioxide} (1) - therefore {light-independent reactions / Calvin cycle / carbon fixation} is faster (1) - rate levels off when {another factor / carbon dioxide concentration / temperature} becomes rate limiting (1)	ACCEPT GM plants photosynthesise faster than non-GM ACCEPT carbon dioxide not limiting the rate of {light-independent reactions / Calvin cycle / carbon fixation}	

Question Number	Answer	Additional Guidance	Mark
8(c)	An explanation that makes reference to three of the following: - because (faster photosynthesis will result in) more {GALP / glucose} produced (1) - to form a named plant molecule (1) - because transpiration stream will be faster (1) - therefore more mineral ions for named product (1)	ACCEPT biomass / other organic molecules more {oxygen / glucose} for ATP production e.g. Mg^{++} for chlorophyll, nitrates for protein	

Question Number	Answer	Additional Guidance	Mark
8(d)(i)	D ATP is broken down into ADP and phosphate ions by a hydrolysis reaction	A is incorrect because ATP is broken down B is incorrect because ATP is broken down C is incorrect because condensation reactions form bonds	

Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	A malate lowers the water potential of the cytoplasm	B is incorrect because increase in solute concentration raises water potential so water would leave the cells C is incorrect because starch has no osmotic effect D is incorrect because starch has no osmotic effect	

Question Number	Answer	Additional Guidance	Mark
8(d)(iii)	D The guard cells become larger and the inner wall of the guard cell is less flexible than the outer wall	A is incorrect because entry of water would make the cell more larger B is incorrect because entry of water would make the cell more larger C is incorrect because the stoma would not form if the inner wall was flexible	

