

1. Question part 1/2 | 9700 Feb-March 2016 P4 V2 Q1

- 1 (a) The rate of photosynthesis is affected by a number of environmental factors.

Fig. 1.1 shows the effect of light intensity on the rate of photosynthesis.

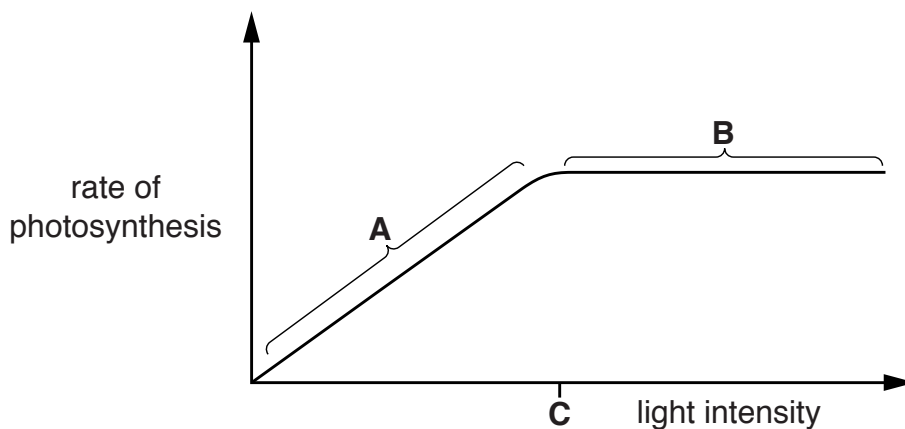


Fig. 1.1

- (i) State the limiting factor in region A of the graph.

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- (ii) Explain what is meant by the term *limiting factor*.

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- (iii) Explain why there is no further increase in the rate of photosynthesis beyond point C.

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(b) For many plants living in temperate regions, the optimum temperature for photosynthesis is approximately 25 °C.

Suggest reasons why the rate of photosynthesis decreases at temperatures above 25 °C.

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[Total: 9]

2. Question part 1/4 | 9700 May-June 2016 P4 V1 Q2

- 2 The concentration of carbon dioxide in the atmosphere and the light intensity often limit the rate of photosynthesis.

(a) Explain what is meant by a *limiting factor* in relation to photosynthesis.

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- (b) Investigations were carried out in Florida, USA, into the effect of different concentrations of atmospheric carbon dioxide and of light intensity on the rate of photosynthesis of soybean plants.

Plants were grown from seed in outdoor, computer-controlled growth chambers at different concentrations of carbon dioxide. The upper parts of the chambers were transparent so that the plants received natural sunlight.

After the seedlings emerged, the air in the soil was separated from the air around the leaves by a gas-tight seal in each chamber.

Suggest why the air in the soil and the air around the leaves of the plants were separated.

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- (c) In one investigation, two sets of plants, **A** and **B**, were grown from seed at different concentrations of carbon dioxide:

- **A** – normal atmospheric concentration of carbon dioxide (0.033%)
- **B** – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

Then, keeping each set of plants in its particular concentration of carbon dioxide, measurements were made of their rates of photosynthesis at different light intensities.

The results are shown in Fig. 2.1 on page 5.

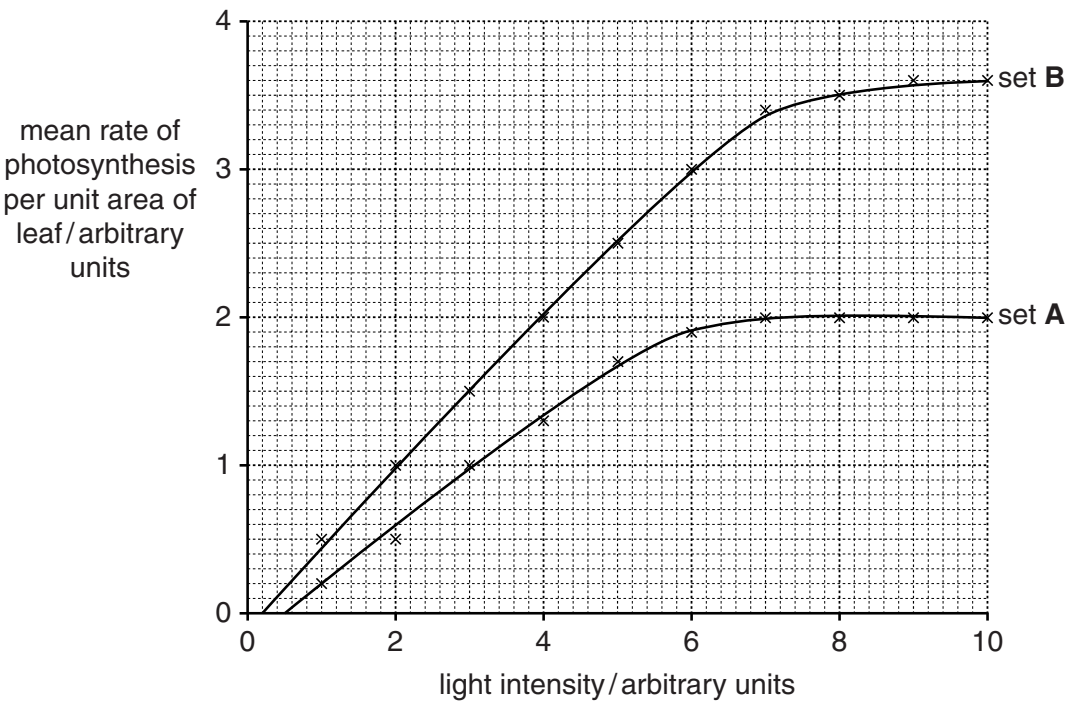


Fig. 2.1

With reference to Fig. 2.1:

(i) describe and explain, in terms of limiting factors, the results from the plants in set A

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(ii) explain the difference between the results of set A and set B at high light intensities.

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(d) In a second investigation, two sets of plants, **C** and **D**, were grown from seed, as before, in different carbon dioxide concentrations:

- **C** – normal atmospheric concentration of carbon dioxide (0.033%)
- **D** – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

When the plants matured, conditions in the growth chambers were changed to investigate the rate of photosynthesis of each set of plants in different concentrations of carbon dioxide.

The results are shown in Fig. 2.2.

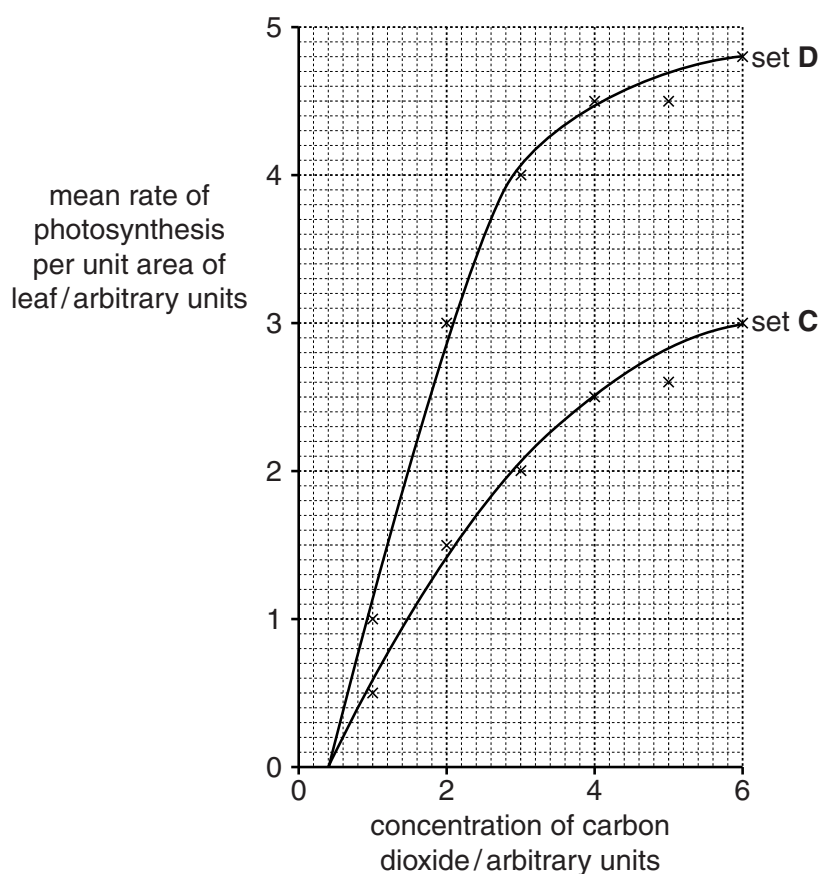


Fig. 2.2

Suggest explanations for the higher rate of photosynthesis **per unit area of leaf** shown by the plants in set **D** compared with those in set **C**.

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[Total: 13]



With reference to Fig. 2.1, describe **and** explain the effect of temperature on the rate of photosynthesis.

[4]

- (b) Fig. 2.2 shows an absorption spectrum for chloroplast pigments and a photosynthetic action spectrum for the same plant.

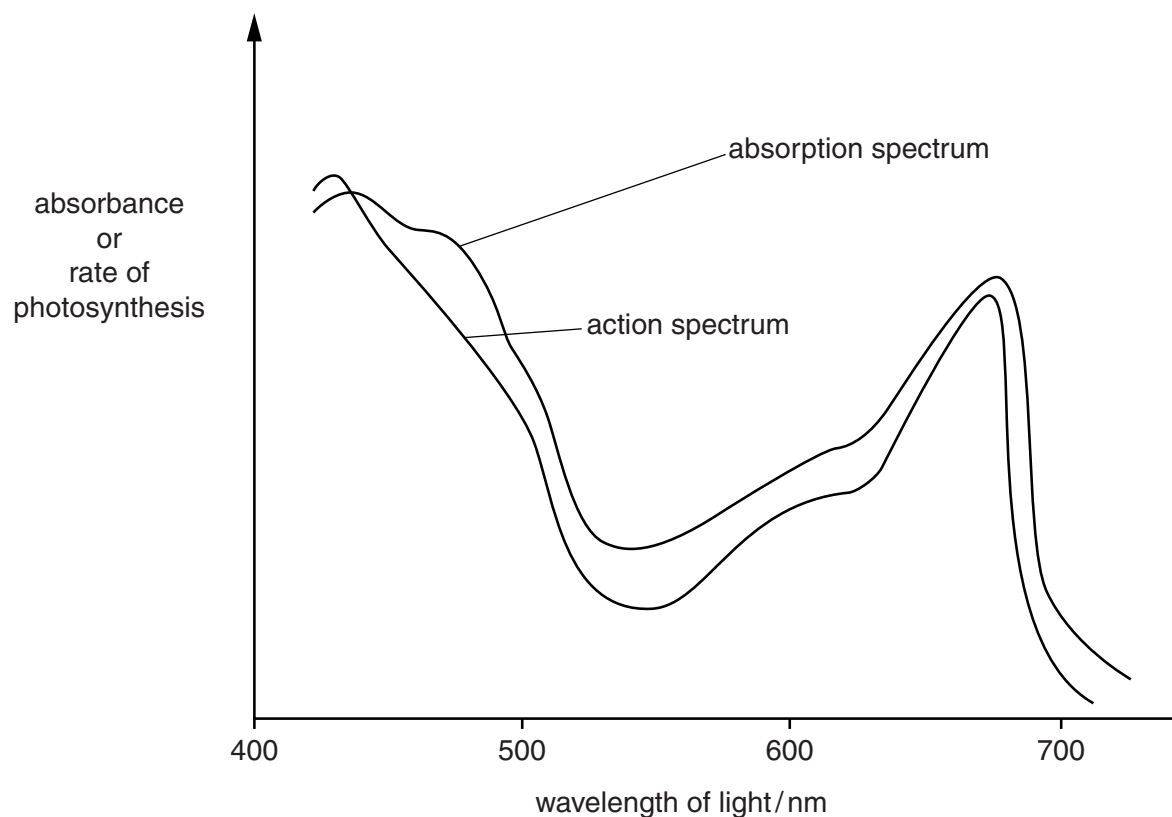


Fig. 2.2

- (i) Distinguish between an absorption spectrum and an action spectrum.

absorption spectrum

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action spectrum

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- (ii) Explain why the two curves shown in Fig. 2.2 have similar shapes.

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3. Question part 3/3 | 9700 May-June 2016 P4 V2 Q2

(c) Describe the role in photosynthesis of an accessory pigment, such as carotene.

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[Total: 10]

- 2** The concentration of carbon dioxide in the atmosphere and the light intensity often limit the rate of photosynthesis.

(a) Explain what is meant by a *limiting factor* in relation to photosynthesis.

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After the seedlings emerged, the air in the soil was separated from the air around the leaves by a gas-tight seal in each chamber.

Suggest why the air in the soil and the air around the leaves of the plants were separated.

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- (c)** In one investigation, two sets of plants, **A** and **B**, were grown from seed at different concentrations of carbon dioxide:

- **A** – normal atmospheric concentration of carbon dioxide (0.033%)
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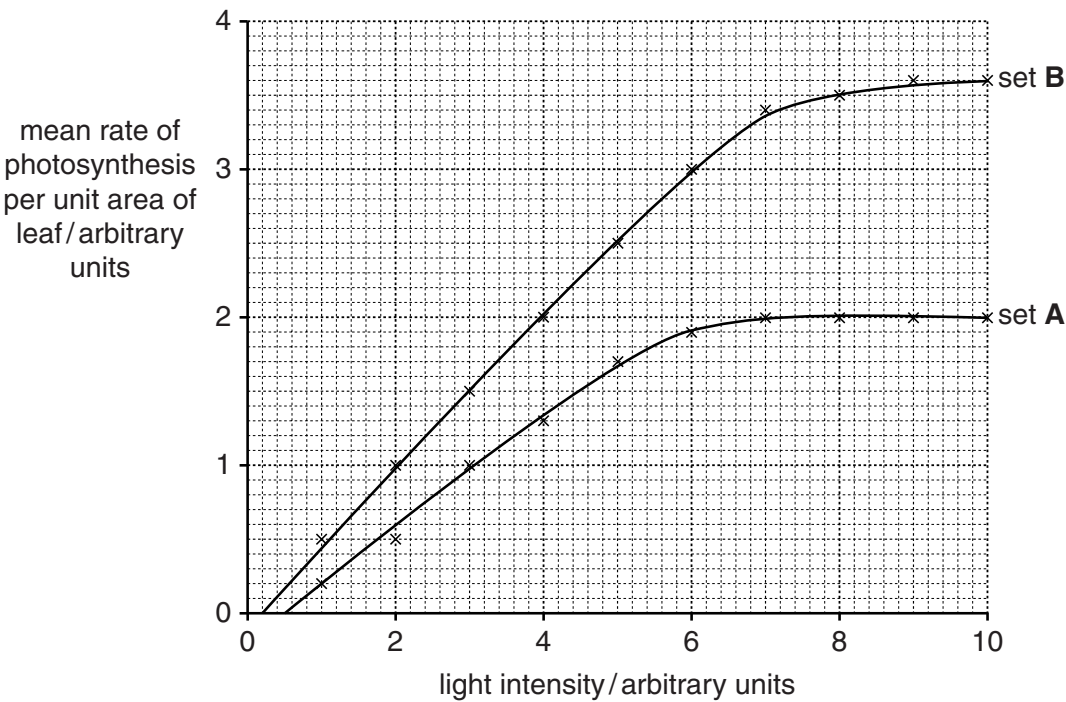


Fig. 2.1

With reference to Fig. 2.1:

(i) describe and explain, in terms of limiting factors, the results from the plants in set A

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..... [3]

(ii) explain the difference between the results of set A and set B at high light intensities.

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- **C** – normal atmospheric concentration of carbon dioxide (0.033%)
- **D** – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

When the plants matured, conditions in the growth chambers were changed to investigate the rate of photosynthesis of each set of plants in different concentrations of carbon dioxide.

The results are shown in Fig. 2.2.

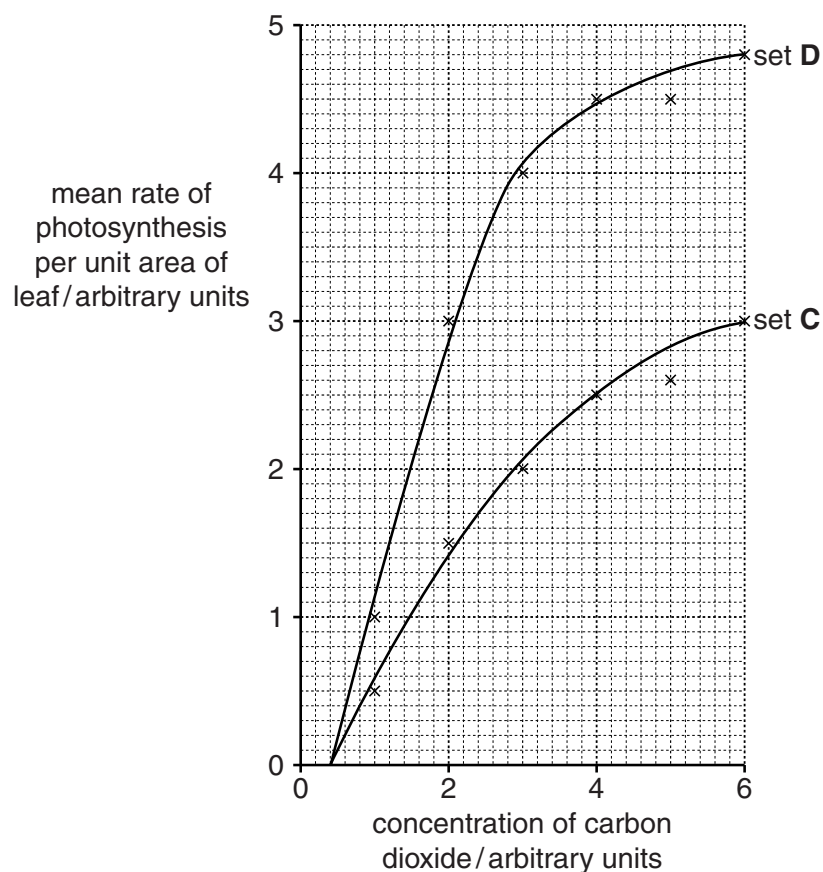


Fig. 2.2

Suggest explanations for the higher rate of photosynthesis **per unit area of leaf** shown by the plants in set **D** compared with those in set **C**.

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[Total: 13]

5. Question part 1/3 | 9700 Oct-Nov 2016 P4 V1 Q2

2 Grass crops such as maize, sorghum and sugarcane are C4 plants. They are common grass crops of tropical regions.

Oats and wheat, commonly grown in temperate regions, are C3 plants. Most plants are C3 plants. They are termed ‘C3’ because the first product of photosynthesis is a three carbon compound.

(a) Outline how the biochemistry of C4 plants differs from that of C3 plants.

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(b) The C4 pathway for fixing carbon dioxide was worked out in 1966 by Hatch and Slack. During their investigation they measured the rates of fixation of carbon dioxide at high light intensities in leaves removed from both temperate and tropical grasses.

They also measured the rates of activity of two carboxylase enzymes in the leaves, ribulose biphosphate carboxylase (rubisco) and PEP carboxylase.

All rates were measured at 30 °C.

Some of their results are shown in Table 2.1.

Table 2.1

grass crop	rate of fixation of carbon dioxide / arbitrary units	rate of activity of rubisco / arbitrary units	rate of activity of PEP carboxylase / arbitrary units
maize	3.5	0.62	17.50
sorghum	3.1	0.35	15.80
sugarcane	2.9	0.30	18.50
oats	1.6	4.50	0.33
wheat	1.7	4.70	0.29

(i) With reference to Table 2.1, compare the rates of fixation of carbon dioxide in C3 and C4 grasses.

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(ii) Describe the role of rubisco in the Calvin cycle.

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(iii) With reference to Table 2.1, suggest reasons for the differences in activity of the two carboxylase enzymes in C3 and C4 grasses.

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- (c) It has been calculated that, to produce one molecule of glucose, the C3 pathway uses 18 molecules of ATP and the C4 pathway uses 30 molecules of ATP.

Suggest why C4 plants can afford this high cost of ATP.

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[Total: 13]

6. Question part 1/3 | 9700 Oct-Nov 2016 P4 V2 Q2

2 Grass crops such as maize, sorghum and sugarcane are C4 plants. They are common grass crops of tropical regions.

Oats and wheat, commonly grown in temperate regions, are C3 plants. Most plants are C3 plants. They are termed ‘C3’ because the first product of photosynthesis is a three carbon compound.

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.....[2]

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Suggest why C4 plants can afford this high cost of ATP.

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.....[2]

[Total: 13]

2 Most plants are C3 plants and are so-called because their first photosynthetic product is a three carbon compound.

The enzyme ribulose biphosphate carboxylase/oxygenase (rubisco) catalyses the fixation of carbon dioxide in the Calvin cycle and is used by both C3 and C4 plants.

Each molecule is made up of eight large polypeptides and eight small polypeptides. Fig. 2.1 shows a side view of the molecule.

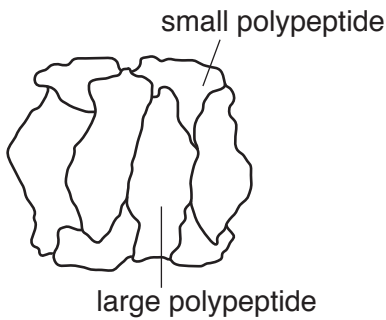


Fig. 2.1

(a) (i) Outline how the biochemistry of C4 plants differs from that of C3 plants.

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(ii) State why rubisco is said to have quaternary structure.

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(iii) Explain what makes a molecule such as rubisco soluble.

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(b) The active sites of rubisco accept ribulose biphosphate (RuBP) and **either** carbon dioxide **or** oxygen and can catalyse the two reactions shown below.

either



or



Explain the consequences to the plant of the reaction involving oxygen.

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(c) In the absence of light, rubisco changes shape from an active form to an inactive form.

Explain why rubisco does **not** need to be in an active form in the absence of light.

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[Total: 10]

8. Question part 1/2 | 9700 Feb-March 2017 P4 V2 Q4

- 4 (a) An investigation was carried out to measure the rate of photosynthesis at different concentrations of carbon dioxide. Two different plants, barley and sugar cane, were tested at two different temperatures, 10 °C and 25 °C.

The results are shown in Fig. 4.1.

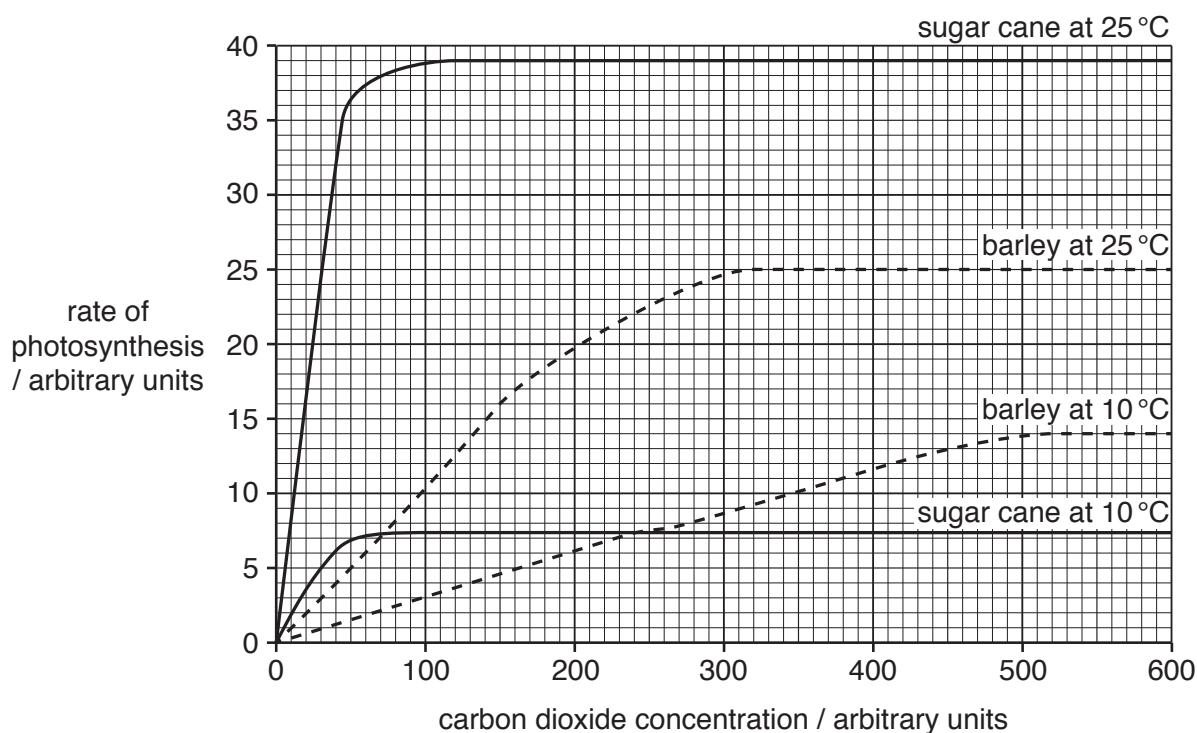


Fig. 4.1

- (i) Suggest why, in all four experiments, the rate of photosynthesis became constant as the carbon dioxide concentration increased.

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- (ii) With reference to Fig. 4.1, describe the difference in the rate of photosynthesis, **at 10 °C**, between barley and sugar cane.

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(iii) Sugar cane is a C4 plant. Barley is **not** a C4 plant.

Explain why, **at 25°C**, sugar cane had a higher rate of photosynthesis than barley.

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(b) Carbon dioxide for photosynthesis enters the leaves through open stomata. Stomata do not stay open all the time.

Changes in environmental conditions can cause stomata to close. Describe these conditions and explain how stomatal closure benefits the plant.

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2 Corals grow in shallow seawater. Corals consist of colonies of small animals called polyps. These polyps have photosynthetic prototists called algae inside their cells, which is advantageous both to the coral polyps and to the algae.

The algae that live within the cells of the polyps can also live independently as free-living algae.

(a) The rate of photosynthesis of algae that live within the cells of coral polyps is higher than that of free-living algae.

Suggest **and** explain how living inside the cells of coral polyps increases the rate of photosynthesis in these algae compared to free-living algae.

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(b) The relative abundance of five different chloroplast pigments in the algae of corals was determined. The results are shown in Table 2.1.

Table 2.1

chloroplast pigment	percentage of total
chlorophyll a	39
peridinin	39
chlorophyll c2	13
dinoxanthin	7
β-carotene	2

Outline the method you would use to separate and identify the pigments present in an extract of these algae.

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(c) Table 2.2 shows the light wavelengths at which each algal chloroplast pigment shows its two largest peaks of light absorption.

Table 2.2

chloroplast pigment	peak 1 wavelength /nm	peak 2 wavelength /nm
chlorophyll a	430	662
peridinin	456	485
chlorophyll c2	450	396
dinoxanthin	442	471
β-carotene	454	480

Corals kept in tanks are often illuminated by lamps radiating mostly violet and blue light with wavelengths in the range of 400–490 nm.

With reference to Table 2.1 and Table 2.2, suggest why lamps radiating mostly violet and blue light are expected to increase coral growth.

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Topical questions | 84 questions

10. Question part 1/2 | 9700 May-June 2017 P4 V2 Q2

2 Chloroplasts belong to a group of organelles called plastids. Although different types of plastid have different structures and functions, one type of plastid can change into another type of plastid in response to environmental or developmental signals.

- Example 1: plants grown in the dark have plastids called etioplasts which lack chlorophyll. If these plants are exposed to light, the etioplasts quickly change into chloroplasts.
- Example 2: chloroplasts in surface tissues of tomato fruits change into plastids called chromoplasts as the fruits ripen. Thylakoid membranes break down and chlorophyll synthesis stops. Chromoplasts synthesise and accumulate red lycopene and orange β -carotene pigments.

(a) For each of these examples, explain the effect on the rate of photosynthesis of one type of plastid changing into another type of plastid.

Example 1

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Example 2

.....[2]

(b) Outline the method you would use to separate and identify the pigments in an extract of tomato chromoplasts.

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- Fig. 2.1 shows the absorption spectra of cyanobacteria grown under two different lighting conditions. One group was grown under fluorescent light and the other group was grown under red light.

The range of light wavelengths absorbed by each group of cyanobacteria was then measured under identical lighting conditions.



With reference to Fig. 2.1 and the information given on pages 4 and 5, explain the effect of different lighting conditions on the absorption spectra of the two groups of cyanobacteria.

[3]

11. Question part 1/2 | 9700 May-June 2017 P4 V3 Q2

2 Corals grow in shallow seawater. Corals consist of colonies of small animals called polyps. These polyps have photosynthetic prototists called algae inside their cells, which is advantageous both to the coral polyps and to the algae.

The algae that live within the cells of the polyps can also live independently as free-living algae.

(a) The rate of photosynthesis of algae that live within the cells of coral polyps is higher than that of free-living algae.

Suggest **and** explain how living inside the cells of coral polyps increases the rate of photosynthesis in these algae compared to free-living algae.

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..... [2]

(b) The relative abundance of five different chloroplast pigments in the algae of corals was determined. The results are shown in Table 2.1.

Table 2.1

chloroplast pigment	percentage of total
chlorophyll a	39
peridinin	39
chlorophyll c2	13
dinoxanthin	7
β-carotene	2

[4]

- ### Table 2.2

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chlorophyll a	430	662
peridinin	456	485
chlorophyll c2	450	396
dinoxanthin	442	471
β-carotene	454	480

With reference to Table 2.1 and Table 2.2, suggest why lamps radiating mostly violet and blue light are expected to increase coral growth.

..... [3]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

12. Question part 1/4 | 9700 Oct-Nov 2017 P4 V1 Q2

- 2** The light dependent stage of photosynthesis in a suspension of isolated chloroplasts can be investigated using the Hill reaction.

Dichlorophenolindophenol (DCPIP) can be used to follow the process. DCPIP is a blue dye which turns colourless when it is reduced by accepting hydrogen and electrons.

oxidised DCPIP → reduced DCPIP
blue → colourless

- (a) (i)** The natural hydrogen acceptor in chloroplasts that is replaced by DCPIP in the Hill reaction is NADP. Reduced NADP is then used in the light independent stage of photosynthesis.

State the role of reduced NADP in the light independent stage.

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.....[2]

- (ii)** Predict **and** explain the effect on the concentration of RuBP in the chloroplasts if DCPIP becomes reduced instead of NADP.

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.....[1]

DCPIP can be used to investigate the effect of light wavelength on the rate of the light dependent stage of photosynthesis. One method is described here:

- Dip a small glass capillary tube into a beaker containing a suspension of isolated chloroplasts. Some of the chloroplast suspension will be drawn into tube **A**, forming a colour standard.
- Mix the rest of the chloroplast suspension with blue DCPIP solution. Dip a second capillary tube into this to draw up a sample, to form tube **B**.
- Store the chloroplast-DCPIP mixture for future use by wrapping the beaker in foil and covering it with a removable foil lid, as shown in Fig. 2.1.

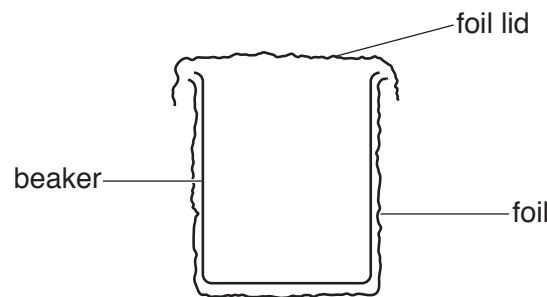


Fig. 2.1

- Place tube **A** and tube **B** on a white tile under a bench lamp placed 15cm away and immediately cover them with a purple filter, as shown in Fig. 2.2.

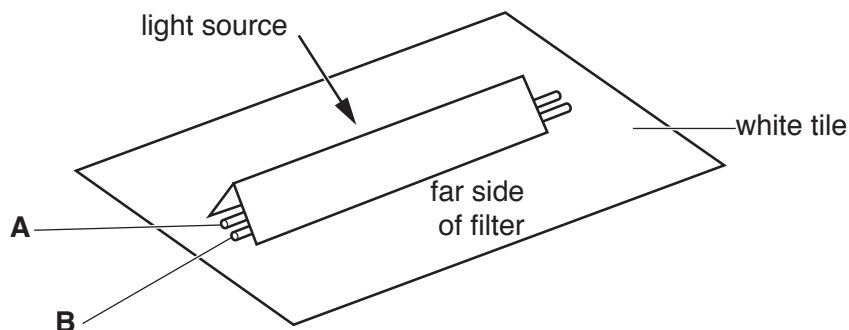


Fig. 2.2

- Measure the time for tube **B** to change colour to match that of tube **A**. This is the time taken for DCPIP to decolourise.
- Repeat four more times using the same tube **A** and a fresh tube **B**, placing the tubes under a different coloured filter each time.

(b) Explain the reasons for:

the colour standard tube **A**

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covering the beaker containing the chloroplast-DCPIP mixture with foil.

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(c) Table 2.1 shows the results of the experiment.

Table 2.1

colour of filter	wavelength of light/nm	time taken to decolourise DCPIP/s	rate of light dependent stage of photosynthesis/s ⁻¹
purple	425	37	27.0
blue	450	84	11.9
green	525	480	2.1
orange	625	45	.....
red	675	50	20.0

(i) Complete Table 2.1 by calculating the rate of the light dependent stage of photosynthesis for the orange wavelength, using the formula:

rate = $\frac{1000}{t}$ where t = time in seconds.

[1]

(ii) With reference to Table 2.1, describe **and** explain the effect of light wavelength on the rate of the light dependent stage of photosynthesis.

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[Total: 13]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

13. Question | 9700 Oct-Nov 2017 P4 V1 Q9

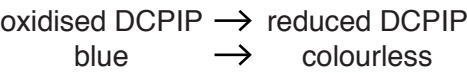
- 9** **(a)** Explain how rice is adapted to grow with its roots submerged in water. [6]
- (b)** Explain how the leaves of maize or sorghum are able to maximise carbon dioxide fixation at high temperatures. [9]

[Total: 15]

14. Question part 1/4 | 9700 Oct-Nov 2017 P4 V2 Q2

2 The light dependent stage of photosynthesis in a suspension of isolated chloroplasts can be investigated using the Hill reaction.

Dichlorophenolindophenol (DCPIP) can be used to follow the process. DCPIP is a blue dye which turns colourless when it is reduced by accepting hydrogen and electrons.



(a) (i) DCPIP is an artificial hydrogen acceptor that can be used in the Hill reaction.

Name the natural hydrogen acceptor found in chloroplasts that is replaced by DCPIP in the Hill reaction.

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(ii) Outline the way in which hydrogen is made available to reduce the hydrogen acceptor in the light dependent stage of photosynthesis.

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(b) A suspension of isolated chloroplasts for measuring the rate of the Hill reaction can be prepared by carrying out the following steps:

- prepare buffer solution with the same water potential as the stroma of chloroplasts
- liquidise (homogenise) spinach leaves in ice cold buffer solution
- filter the liquid and obtain the filtrate
- centrifuge the filtrate to obtain a pellet of chloroplasts
- add the chloroplast pellet to fresh buffer solution in a beaker and mix to obtain a suspension.

Explain the reason for:

(i) keeping the temperature very low

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14. Question part 2/4 | 9700 Oct-Nov 2017 P4 V2 Q2

(ii) using a buffer solution

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(iii) using a solution of the same water potential as the stroma of chloroplasts.

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(c) An experiment was carried out to measure the time taken for decolourisation of DCPIP mixed with a suspension of chloroplasts.

The results are shown in Table 2.1.

Table 2.1

replicate	time taken for DCPIP to decolourise/s	rate/s ⁻¹
1	38	
2	43	
3	48	
mean	.....	.....

Complete Table 2.1 by calculating:

(i) for the three replicates, the mean time taken for the DCPIP to decolourise [1]

(ii) the mean rate using the formula:

rate = $\frac{1000}{t}$ where t = time in seconds.

[1]

(iii) The time taken to decolourise DCPIP was measured at a range of light intensities.

State **and** explain the expected relationship between light intensity and time taken to decolourise DCPIP.

expected relationship
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explanation
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[Total: 15]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

14. Question part 4/4 | 9700 Oct-Nov 2017 P4 V2 Q2

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9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

15. Question part 1/4 | 9700 Oct-Nov 2017 P4 V3 Q2

- 2** The light dependent stage of photosynthesis in a suspension of isolated chloroplasts can be investigated using the Hill reaction.

Dichlorophenolindophenol (DCPIP) can be used to follow the process. DCPIP is a blue dye which turns colourless when it is reduced by accepting hydrogen and electrons.

oxidised DCPIP → reduced DCPIP
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- (a) (i)** The natural hydrogen acceptor in chloroplasts that is replaced by DCPIP in the Hill reaction is NADP. Reduced NADP is then used in the light independent stage of photosynthesis.

State the role of reduced NADP in the light independent stage.

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- Store the chloroplast-DCPIP mixture for future use by wrapping the beaker in foil and covering it with a removable foil lid, as shown in Fig. 2.1.

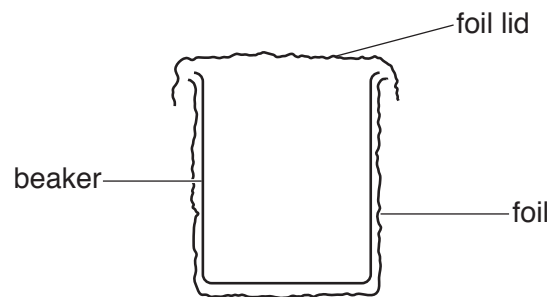


Fig. 2.1

- Place tube **A** and tube **B** on a white tile under a bench lamp placed 15cm away and immediately cover them with a purple filter, as shown in Fig. 2.2.

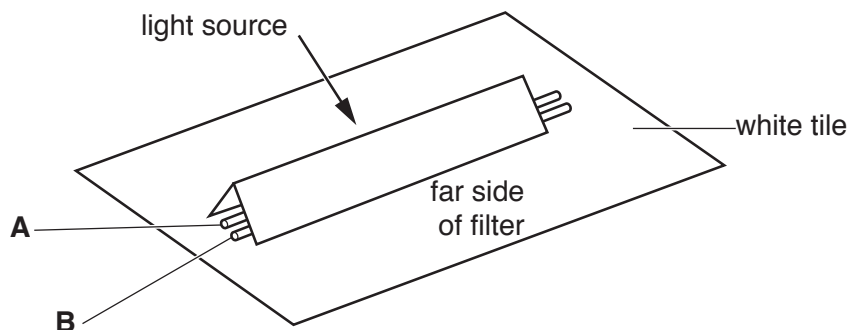


Fig. 2.2

- Measure the time for tube **B** to change colour to match that of tube **A**. This is the time taken for DCPIP to decolourise.
- Repeat four more times using the same tube **A** and a fresh tube **B**, placing the tubes under a different coloured filter each time.

(b) Explain the reasons for:

the colour standard tube **A**

.....

.....

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.....

covering the beaker containing the chloroplast-DCPIP mixture with foil.

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.....[4]

(c) Table 2.1 shows the results of the experiment.

Table 2.1

colour of filter	wavelength of light/nm	time taken to decolourise DCPIP/s	rate of light dependent stage of photosynthesis/s ⁻¹
purple	425	37	27.0
blue	450	84	11.9
green	525	480	2.1
orange	625	45	.....
red	675	50	20.0

(i) Complete Table 2.1 by calculating the rate of the light dependent stage of photosynthesis for the orange wavelength, using the formula:

rate = $\frac{1000}{t}$ where t = time in seconds.

[1]

(ii) With reference to Table 2.1, describe **and** explain the effect of light wavelength on the rate of the light dependent stage of photosynthesis.

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.....[5]

[Total: 13]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

16. Question | 9700 Oct-Nov 2017 P4 V3 Q9

- 9** **(a)** Explain how rice is adapted to grow with its roots submerged in water. [6]
- (b)** Explain how the leaves of maize or sorghum are able to maximise carbon dioxide fixation at high temperatures. [9]

[Total: 15]

17. Question part 1/2 | 9700 Feb-March 2018 P4 V2 Q4

- 4 Ribulose 1,5-bisphosphate carboxylase/oxygenase (rubisco) is an important enzyme involved in the light independent stage (Calvin cycle) of photosynthesis. It fixes carbon by combining carbon dioxide with RuBP.

In certain situations, the active site of rubisco becomes occupied by a sugar phosphate, making the enzyme inactive. Rubisco can become active again in the presence of another enzyme, rubisco activase.

(a) Name all the bonds that are likely to hold a molecule of rubisco in shape.

.....

.....

.....

.....[2]

(b) Suggest how rubisco activase can activate rubisco.

.....

.....[1]

- (c) C4 plants such as maize have adaptations that allow them to have high rates of carbon fixation at high temperatures. Without these adaptations, some plants (C3 plants) are affected at high temperatures by a process known as photorespiration.

In photorespiration, rubisco combines oxygen with RuBP. This leads to a decrease in the rate of photosynthesis.

(i) Describe **and** explain how the anatomy of the leaves of C4 plants such as maize allows them to have high rates of carbon fixation at high temperatures.

.....

.....

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.....

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.....[3]

- (ii) In C3 plants, the rate of photorespiration increases at high light intensities as well as at high temperatures.

Suggest why the rate of photorespiration increases at high light intensities in C3 plants.

.....

.....

.....

.....[2]

- (iii) Explain why the rate of photosynthesis decreases as a result of photorespiration in C3 plants.

.....

.....

.....

.....[2]

[Total: 10]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

18. Question | 9700 Feb-March 2018 P4 V2 Q9

- 9** **(a)** Describe the process of **cyclic** photophosphorylation **and** the structure of the photosystem involved. [9]
- (b)** Explain how **non-cyclic** photophosphorylation produces reduced NADP **and** how reduced NADP is used in the light independent stage. [6]

[Total: 15]

- 7 (a) Fig. 7.1 outlines the process of non-cyclic photophosphorylation in the chloroplast of a leaf mesophyll cell.

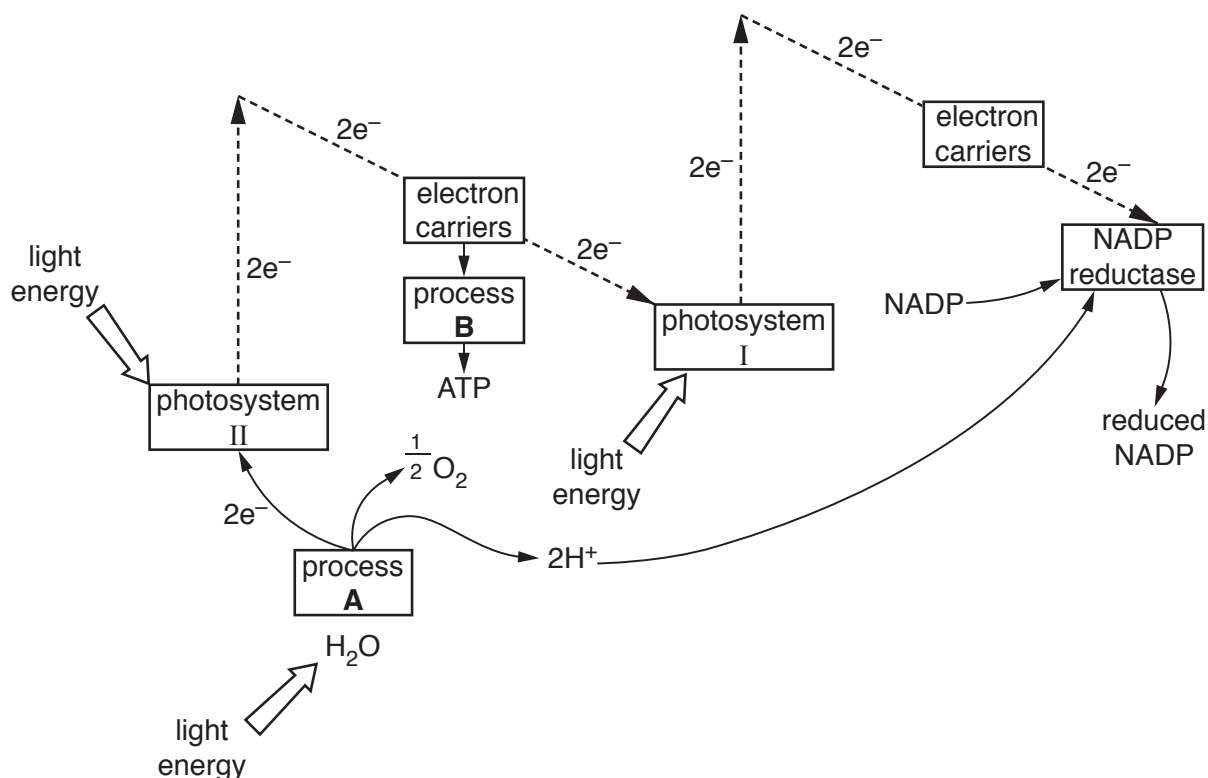


Fig. 7.1

- (i) State precisely where non-cyclic photophosphorylation occurs in the chloroplast.

.....[1]

- (ii) With reference to Fig. 7.1, name processes **A** and **B**.

A

B[2]

- (iii) State what happens to the oxygen produced by process **A**.

.....[1]

- (iv) Name the primary pigment in photosystem I and photosystem II.

.....[1]

- (v) Name **two** compounds shown in Fig. 7.1 that are used in the conversion of glycerate-3-phosphate (GP) to triose phosphate (TP) in the Calvin cycle.

.....[1]

(b) Outline the uses of triose phosphate in the mesophyll cells of the leaf.

.....

.....

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.....

.....

.....[3]

[Total: 9]

- 7 Fig. 7.1 shows part of a section through the leaf of a C₄ plant such as maize. The letters **A**, **B** and **C** show three types of cell found in the leaf.

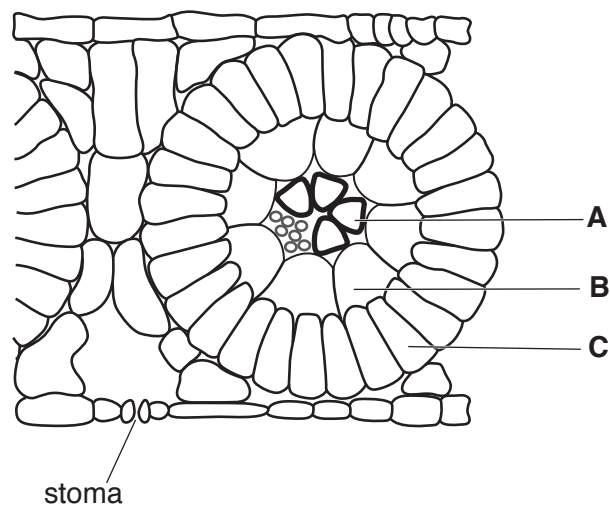


Fig. 7.1

- (a) Complete Table 7.1 by using the letters **A**, **B** or **C** from Fig. 7.1 to show the location of several compounds associated with photosynthesis in C₄ plants.

You may use **A**, **B** and **C** once, more than once, or not at all.

Table 7.1

compound	location
PEP carboxylase	
RuBP	
rubisco	

[3]

- (b) Explain why the cells in **C** form a tight ring around the cells in **B**.

.....
.....
.....
.....
.....[2]

The graph illustrates the temperature dependence of enzyme activity for two plant species. The x-axis represents temperature in degrees Celsius, ranging from 0 to 50. The y-axis represents the percentage of enzyme activity, ranging from 0 to 100. The solid line represents *Amaranthus hypochondriacus* (C4), and the dashed line represents *Pisum sativum* (C3).

Temperature / °C	<i>Amaranthus hypochondriacus</i> (C4) (%)	<i>Pisum sativum</i> (C3) (%)
15	65	25
20	80	40
25	85	45
30	100	55
35	85	70
40	45	75
45	30	100
50	25	70

Describe the differences between the two curves **and** suggest explanations for these differences.

[3]

7 (a) Fig. 7.1 is a transmission electron micrograph of part of a chloroplast of a leaf cell from maize.

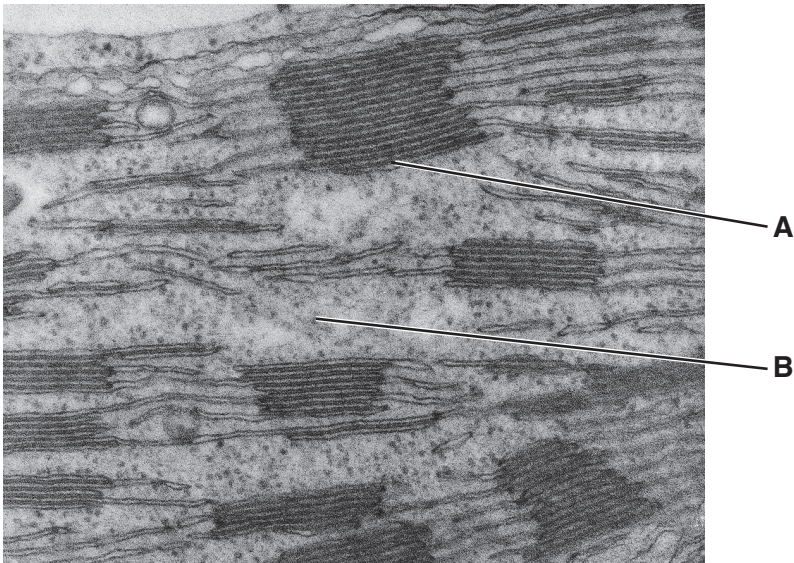


Fig. 7.1

Table 7.1 shows some substrates and products involved in photosynthesis.

Use letter **A** or letter **B** from Fig. 7.1 to complete Table 7.1 to show the location where the substrates or products are used or produced.

Table 7.1

substrate or product	location
oxygen produced	
carbon dioxide used	
reduced NADP used	
ATP produced	
hexose produced	

[3]

(b) Chloroplasts isolated from leaf palisade cells can still function if they are suspended in a buffer solution. The buffer solution has the same water potential as the chloroplasts.

The dye DCPIP is a hydrogen acceptor that changes colour from blue to colourless when it becomes reduced.

Three test tubes were set up as shown in Table 7.2 and left for 20 minutes to allow any colour change to occur. The results are also shown in Table 7.2.

Table 7.2

test-tube	contents	conditions	colour change
1	buffer solution + DCPIP	light	no
2	chloroplast suspension + DCPIP	light	yes
3	chloroplast suspension + DCPIP	dark	no

(i) Explain the results for test-tube 2.

.....

.....

.....

.....[2]

(ii) Test-tube 1 is a control tube. Explain why test-tube 1 was included in the investigation.

.....

.....[1]

(iii) Suggest **and** explain what would happen to the chloroplasts if they were suspended in distilled water.

.....

.....

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.....

.....[2]

(c) The rate of photosynthesis in green plants can be limited by factors such as light intensity, temperature and carbon dioxide concentration.

State which factor would have **no** effect on the reducing ability of a chloroplast suspension. Give a reason for your answer.

factor

reason

.....

.....[2]

[Total: 10]

7 (a) Fig. 7.1 is a transmission electron micrograph of a chloroplast.

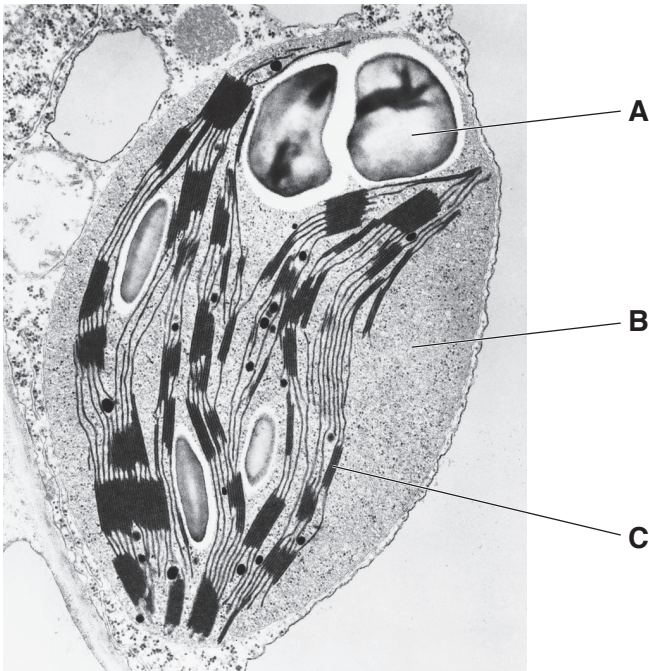


Fig. 7.1

Many compounds and structures involved in photosynthesis are located in a chloroplast.

Using the labels **A**, **B** or **C**, complete Table 7.1 to show the location of four of these compounds or structures.

You may use each of the letters **A**, **B** and **C** once, more than once, or not at all.

Table 7.1

compound or structure	location
ATP synthase	
rubisco	
starch grain	
phospholipid bilayer	

(b) *Elodea canadensis* is an aquatic plant that lives submerged in freshwater.

Equal-sized plants of *E. canadensis* were exposed to different wavelengths of light for the same period of time. As each plant photosynthesised, the number of bubbles of oxygen leaving the plant was counted.

For each wavelength, the rate of oxygen production was calculated.

The results are shown in Fig. 7.2.

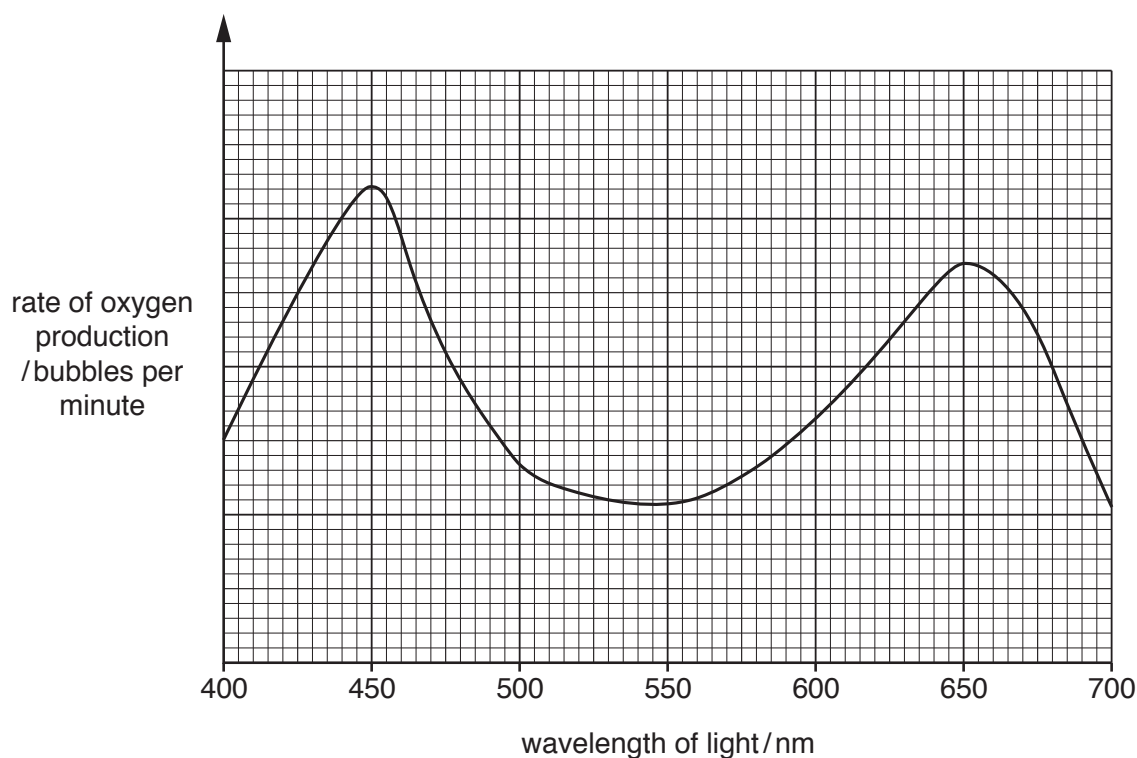


Fig. 7.2

Describe **and** explain the results shown in Fig. 7.2.

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[3]

(c) Chlorophyll b, carotene and xanthophyll are known as accessory pigments. Describe the role of the accessory pigments in photosynthesis.

.....

.....

.....

..... [2]

[Total: 8]

7 (a) Fig. 7.1 is an outline diagram of the Calvin cycle.

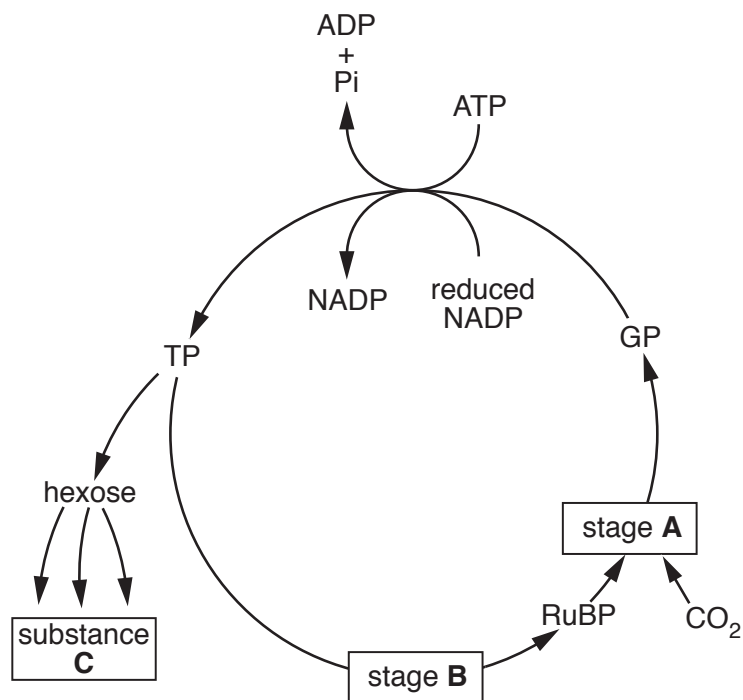


Fig. 7.1

(i) With reference to Fig. 7.1:

name the stage of the Calvin cycle occurring at **A**

.....

name the **enzyme** involved in the stage of the Calvin cycle occurring at **A**

.....

name two examples of substance **C**

1

2

name the biochemical process that produces reduced NADP **and** ATP.

.....

[5]

(ii) With reference to Fig. 7.1, outline what is occurring at stage **B** of the Calvin cycle.

.....

.....[1]

(b) Explain why there is a tight ring of mesophyll cells around the bundle sheath cells in the leaves of a C4 plant.

.....

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.....

.....

.....

.....

..... [3]

[Total: 9]

7 (a) Fig. 7.1 is a transmission electron micrograph of a chloroplast.

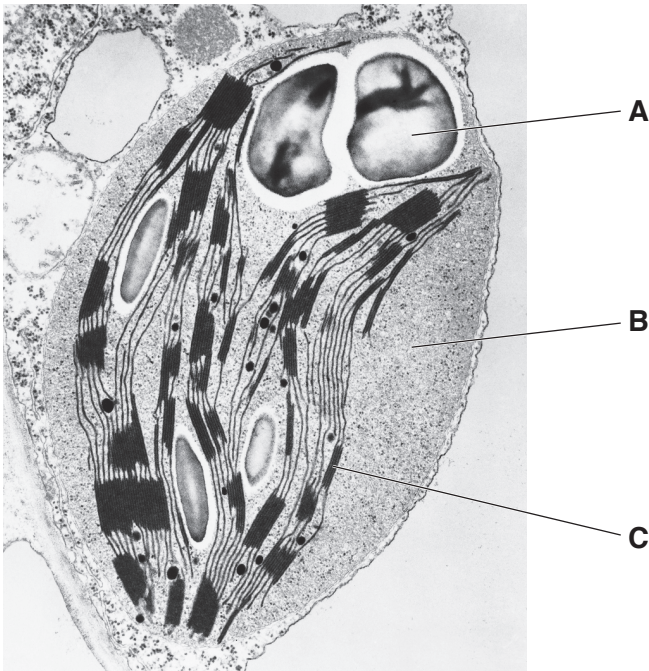


Fig. 7.1

Many compounds and structures involved in photosynthesis are located in a chloroplast.

Using the labels **A**, **B** or **C**, complete Table 7.1 to show the location of four of these compounds or structures.

You may use each of the letters **A**, **B** and **C** once, more than once, or not at all.

Table 7.1

compound or structure	location
ATP synthase	
rubisco	
starch grain	
phospholipid bilayer	

(b) *Elodea canadensis* is an aquatic plant that lives submerged in freshwater.

Equal-sized plants of *E. canadensis* were exposed to different wavelengths of light for the same period of time. As each plant photosynthesised, the number of bubbles of oxygen leaving the plant was counted.

For each wavelength, the rate of oxygen production was calculated.

The results are shown in Fig. 7.2.

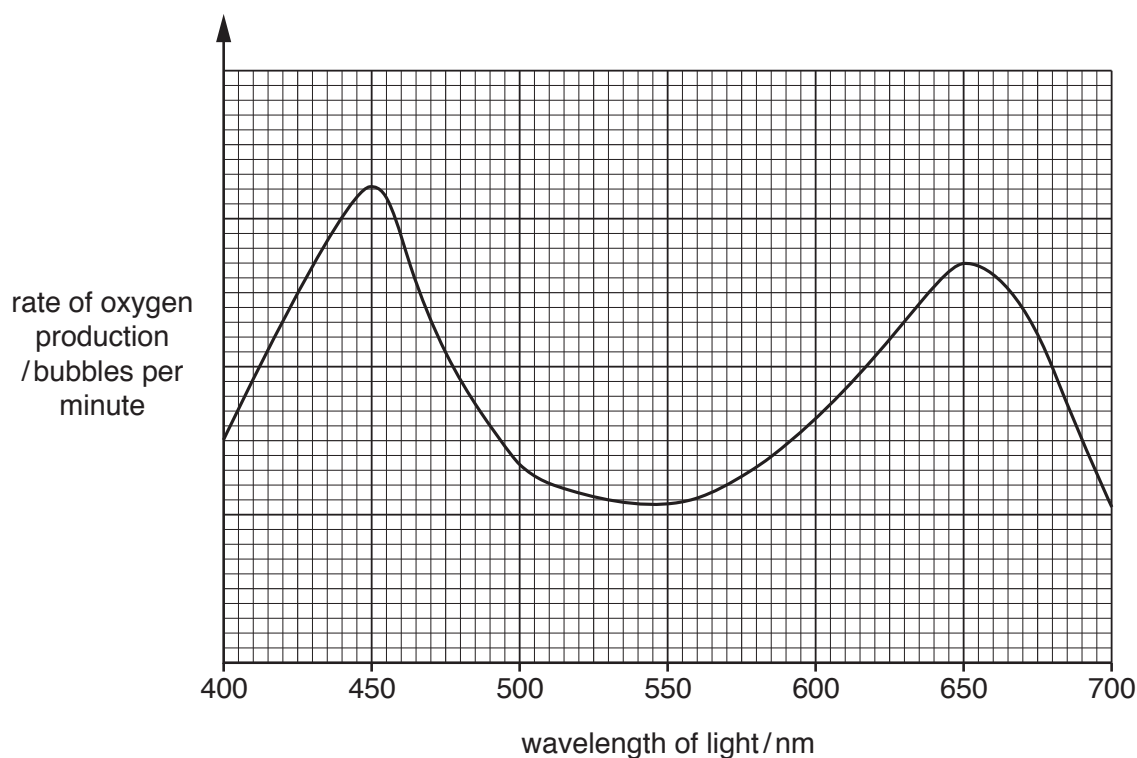


Fig. 7.2

Describe **and** explain the results shown in Fig. 7.2.

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[3]

24. Question part 3/3 | 9700 Oct-Nov 2018 P4 V3 Q7

(c) Chlorophyll b, carotene and xanthophyll are known as accessory pigments. Describe the role of the accessory pigments in photosynthesis.

.....

.....

.....

..... [2]

[Total: 8]

- 1 (a) The effect of light intensity on the rate of photosynthesis can be investigated using a cut shoot of a pond plant.

The apparatus used in the investigation is shown in Fig. 1.1.

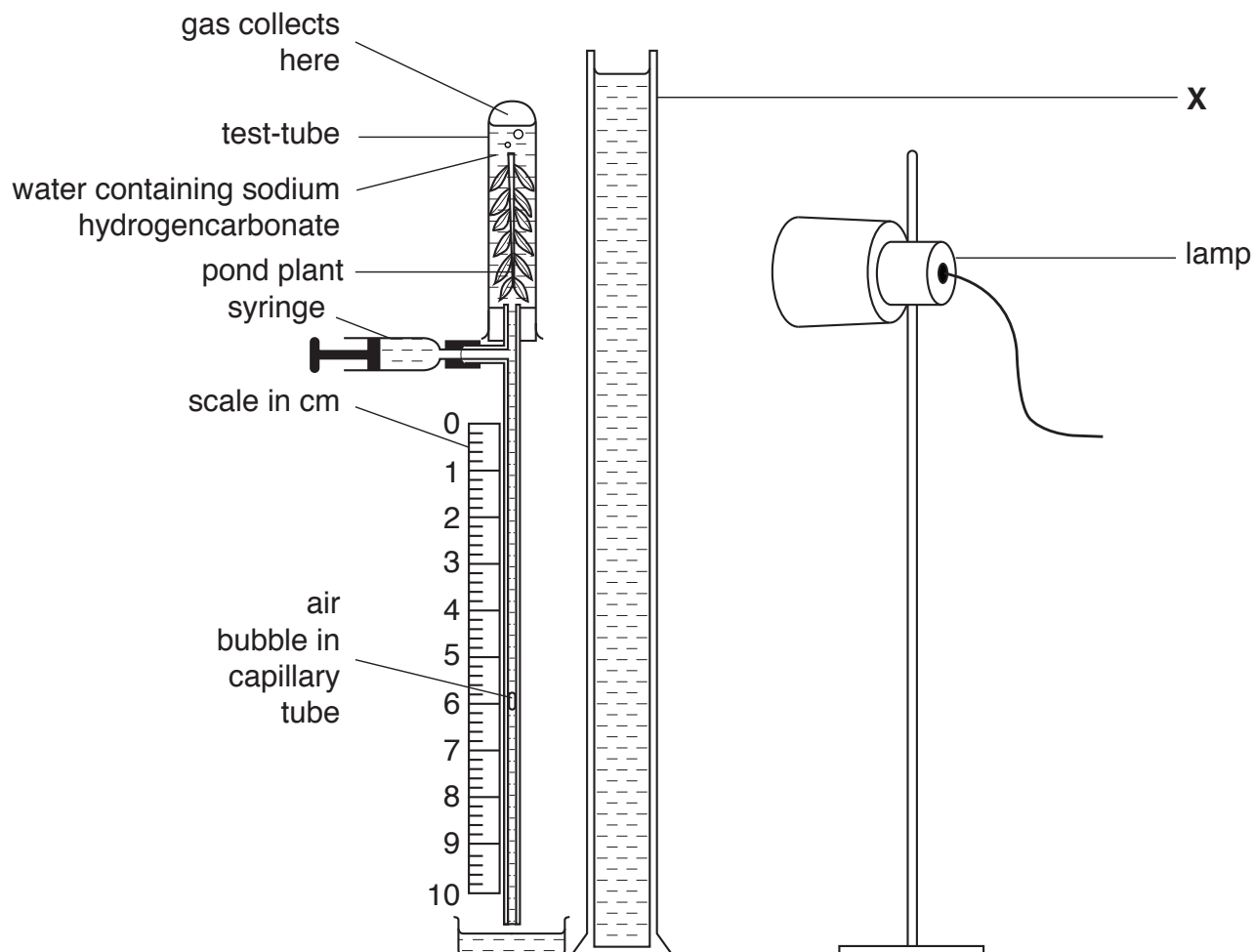


Fig. 1.1

The light intensity can be changed by placing the lamp at different distances from the pond plant.

(i) Apparatus **X**, shown in Fig. 1.1, is a thin glass container filled with water.

Explain the function of apparatus **X**.

.....

.....

.....

.....

..... [2]

(ii) Before completing the assembly of the apparatus shown in Fig. 1.1, sodium hydrogencarbonate is added to the water surrounding the pond plant in the test-tube.

Explain why sodium hydrogencarbonate is added to the water surrounding the pond plant in the test-tube.

.....

..... [1]

(iii) Name the gas collected in the test-tube.

..... [1]

- (b) The investigation was carried out with the lamp at distances of 10, 20, 30, 40 and 50 cm from the pond plant. For each of these distances, the air bubble in the capillary tube was initially positioned at 0 cm on the scale and, after 5 minutes, the distance moved by the air bubble was measured. The rate of movement of the air bubble was then calculated.

The results are shown in Fig. 1.2.

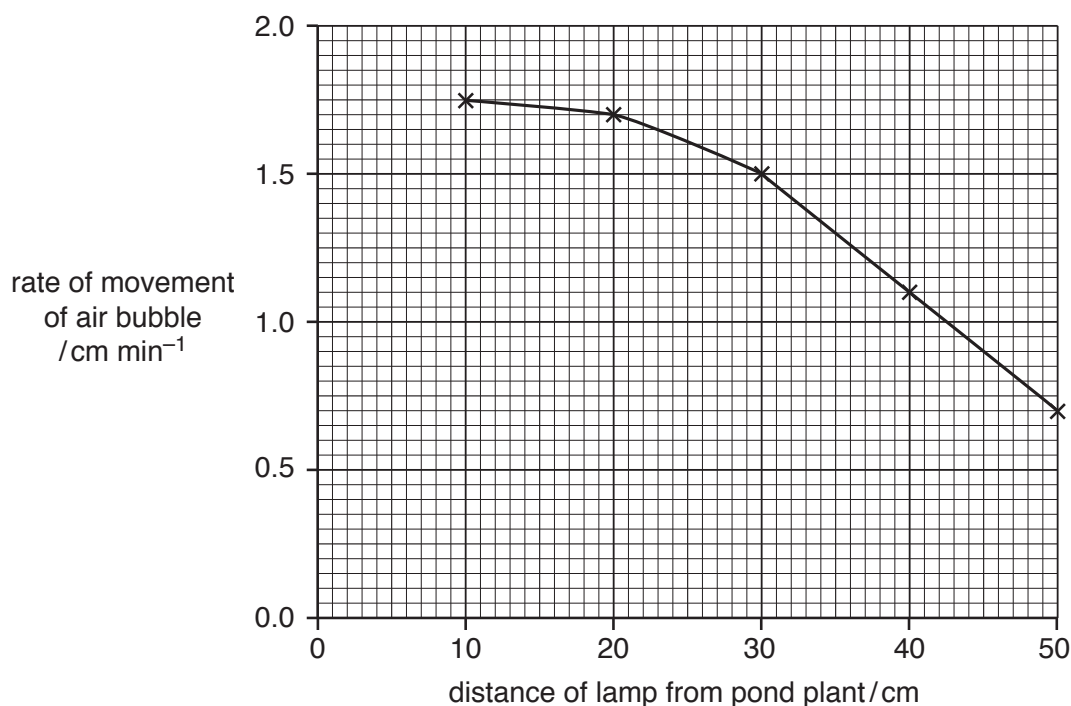


Fig. 1.2

- (i) With reference to Fig. 1.2, describe the relationship between the rate of photosynthesis and **light intensity**.

.....
.....
.....
..... [2]

- (ii) Further investigations showed that at distances of less than 10 cm, the rate of movement of the air bubble was the same as at 10 cm.

Explain why there was no change in the rate of movement of the air bubble at distances less than 10 cm.

.....
.....
.....
..... [2]

(c) Some of the light energy absorbed by the pond plant is used in cyclic photophosphorylation.

Outline the process of cyclic photophosphorylation.

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..... [5]

[Total: 13]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

26. Question | 9700 May-June 2019 P4 V1 Q9

- 9** **(a)** Explain what is meant by the term limiting factor **and** explain how knowledge of limiting factors is used to increase crop yields in glasshouses. [7]
- (b)** Describe the behaviour of chromosomes during meiosis. [8]

[Total: 15]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

27. Question part 1/3 | 9700 May-June 2019 P4 V1 Q10

- 10 (a)** Explain how a cholinergic synapse functions. [7]
- (b)** Describe how you would carry out an investigation into the effect of wavelength of light on the rate of photosynthesis of a plant, using a redox indicator such as DCPIP. [8]

[Total: 15]

[illegible]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

27. Question part 2/3 | 9700 May-June 2019 P4 V1 Q10

[illegible]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

27. Question part 3/3 | 9700 May-June 2019 P4 V1 Q10

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9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

28. Question | 9700 May-June 2019 P4 V2 Q9

- 9 (a)** Describe how you would carry out an investigation into the effect of temperature on the rate of photosynthesis of an aquatic plant. [8]
- (b)** Outline how degraded habitats may be restored, with reference to named examples. [7]

[Total: 15]

29. Question | 9700 May-June 2019 P4 V3 Q9

- 9 (a)** Describe how the structure of a chloroplast is related to its functions. [8]
- (b)** Describe how you would separate chloroplast pigments using chromatography. [7]

[Total: 15]

- 5 (a) Fig. 5.1 shows the seaweed *Laminaria hyperborea*. This is a photosynthetic protocyst found in the coastal waters around Norway.

The seaweed is grown commercially to obtain the glucose polysaccharide called alginate. This is used in certain food products.

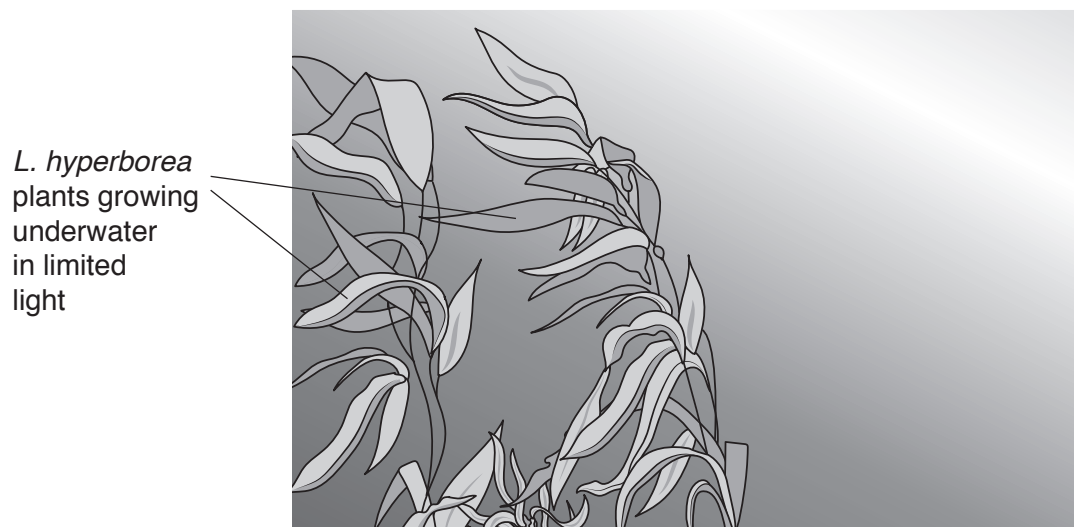


Fig. 5.1

An increase in carbon dioxide concentration in the atmosphere has resulted in higher concentrations of carbon dioxide in the ocean. This has caused a decrease in the pH of the ocean and has resulted in ocean acidification.

Scientists are studying seaweeds such as *L. hyperborea* because they absorb a large quantity of carbon dioxide during photosynthesis. This may help to increase the pH of the ocean and reverse ocean acidification.

- (i) State where light absorption occurs in the chloroplasts of *L. hyperborea*.

..... [1]

- (ii) Name **one** product of the light dependent stage of photosynthesis.

..... [1]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

30. Question part 2/4 | 9700 Oct-Nov 2019 P4 V1 Q5

- (iii) Outline the reactions occurring in the stroma that lead to the production of a polysaccharide, such as alginate.

The first sentence has been completed for you.

Carbon dioxide binds to RuBP.

[4]

[4]

- (b) Laboratory experiments were carried out to investigate the effect of day length on the rate of photosynthesis in another marine autotroph, *Zostera marina*.
- The temperature was controlled at 4 °C.
 - A low concentration of carbon dioxide dissolved in the water was used.
 - The light exposure period (day length) was different for five groups of *Z. marina*.
 - This was maintained for 10 days to allow *Z. marina* to adapt to these conditions.
 - After 10 days, the rate of photosynthesis was measured for each group under the **same** controlled conditions.
 - The experiment was repeated using five groups of *Z. marina* with a high concentration of carbon dioxide dissolved in water.

Table 5.1 shows the rate of photosynthesis for each group.

Table 5.1

day length /hours	rate of photosynthesis /arbitrary units	
	low carbon dioxide concentration	high carbon dioxide concentration
12	2.0	2.5
14	3.0	5.0
16	4.0	7.0
18	5.5	11.0
20	7.5	18.0

- (i) With reference to Table 5.1, explain the difference in the rate of photosynthesis at high carbon dioxide concentration compared to low carbon dioxide concentration.

.....
.....
.....
..... [2]

- (ii) With reference to Table 5.1, describe **and** explain the effect of increasing day length on the rate of photosynthesis for the *Z. marina* in high carbon dioxide concentration.

.....
.....
.....
.....
.....
.....
..... [3]

- (c) In the laboratory, a seaweed was grown in water with different pH values. All other variables, including temperature and light, were standardised.

The mean rate of photosynthesis was calculated over a 24 hour period for each pH value.

The results are shown in Fig 5.2.

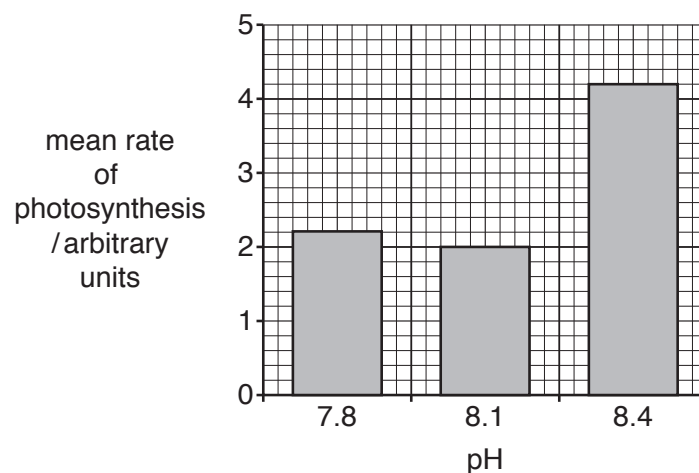


Fig. 5.2

- (i) With reference to Fig. 5.2, explain the effect on the rate of photosynthesis when the pH increases from 8.1 to 8.4.

.....

.....

.....

.....

.....

..... [2]

- (ii) The lower pH values on Fig. 5.2 represent ocean acidification.

Suggest why the results for the lower pH values do **not** fully support the idea that seaweeds can help to reduce ocean acidification.

.....

.....

..... [1]

[Total: 14]

- 5 (a) Fig. 5.1 shows the seaweed *Laminaria hyperborea*. This is a photosynthetic protocyst found in the coastal waters around Norway.

The seaweed is grown commercially to obtain the glucose polysaccharide called alginate. This is used in certain food products.

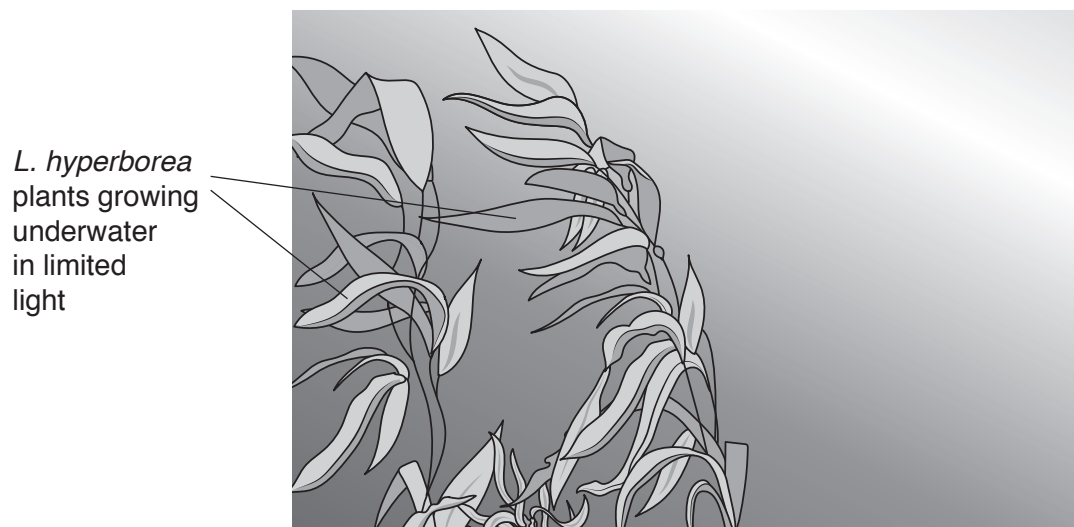


Fig. 5.1

An increase in carbon dioxide concentration in the atmosphere has resulted in higher concentrations of carbon dioxide in the ocean. This has caused a decrease in the pH of the ocean and has resulted in ocean acidification.

Scientists are studying seaweeds such as *L. hyperborea* because they absorb a large quantity of carbon dioxide during photosynthesis. This may help to increase the pH of the ocean and reverse ocean acidification.

- (i) State where light absorption occurs in the chloroplasts of *L. hyperborea*.

..... [1]

- (ii) Name **one** product of the light dependent stage of photosynthesis.

..... [1]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

31. Question part 2/4 | 9700 Oct-Nov 2019 P4 V2 Q5

- (iii)** Outline the reactions occurring in the stroma that lead to the production of a polysaccharide, such as alginate.

The first sentence has been completed for you.

Carbon dioxide binds to RuBP.

..... [4]

[4]

- (b) Laboratory experiments were carried out to investigate the effect of day length on the rate of photosynthesis in another marine autotroph, *Zostera marina*.
- The temperature was controlled at 4 °C.
 - A low concentration of carbon dioxide dissolved in the water was used.
 - The light exposure period (day length) was different for five groups of *Z. marina*.
 - This was maintained for 10 days to allow *Z. marina* to adapt to these conditions.
 - After 10 days, the rate of photosynthesis was measured for each group under the **same** controlled conditions.
 - The experiment was repeated using five groups of *Z. marina* with a high concentration of carbon dioxide dissolved in water.

Table 5.1 shows the rate of photosynthesis for each group.

Table 5.1

day length /hours	rate of photosynthesis /arbitrary units	
	low carbon dioxide concentration	high carbon dioxide concentration
12	2.0	2.5
14	3.0	5.0
16	4.0	7.0
18	5.5	11.0
20	7.5	18.0

- (i) With reference to Table 5.1, explain the difference in the rate of photosynthesis at high carbon dioxide concentration compared to low carbon dioxide concentration.

.....
.....
.....
..... [2]

- (ii) With reference to Table 5.1, describe **and** explain the effect of increasing day length on the rate of photosynthesis for the *Z. marina* in high carbon dioxide concentration.

.....
.....
.....
.....
.....
.....
..... [3]

- (c) In the laboratory, a seaweed was grown in water with different pH values. All other variables, including temperature and light, were standardised.

The mean rate of photosynthesis was calculated over a 24 hour period for each pH value.

The results are shown in Fig 5.2.

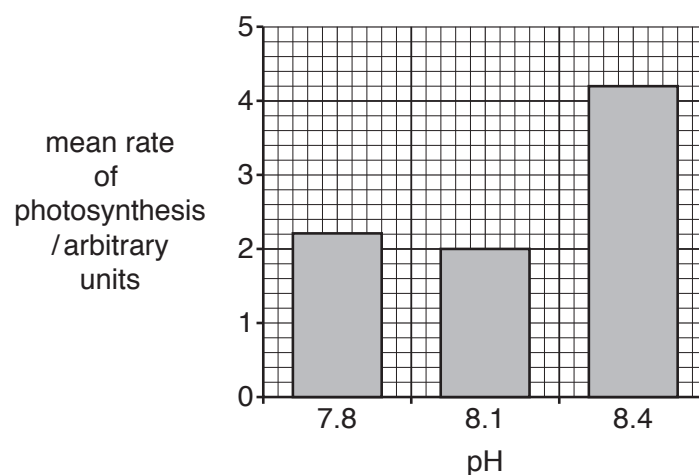


Fig. 5.2

- (i) With reference to Fig. 5.2, explain the effect on the rate of photosynthesis when the pH increases from 8.1 to 8.4.

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.....

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..... [2]

- (ii) The lower pH values on Fig. 5.2 represent ocean acidification.

Suggest why the results for the lower pH values do **not** fully support the idea that seaweeds can help to reduce ocean acidification.

.....

.....

..... [1]

[Total: 14]

- 6** Mining may result in the release of heavy metal ions, causing pollution of lakes and rivers.

High concentrations of these heavy metal ions, such as cadmium (Cd^{2+}) and copper (Cu^{2+}), decrease the rate of photosynthesis in plants.

- (a)** Cadmium ions disrupt the function of photosystem II in chloroplasts.

- (i)** Name the part of the chloroplast where photosystem II is located.

..... [1]

- (ii)** Describe the role of photosystem II in the absorption of light.

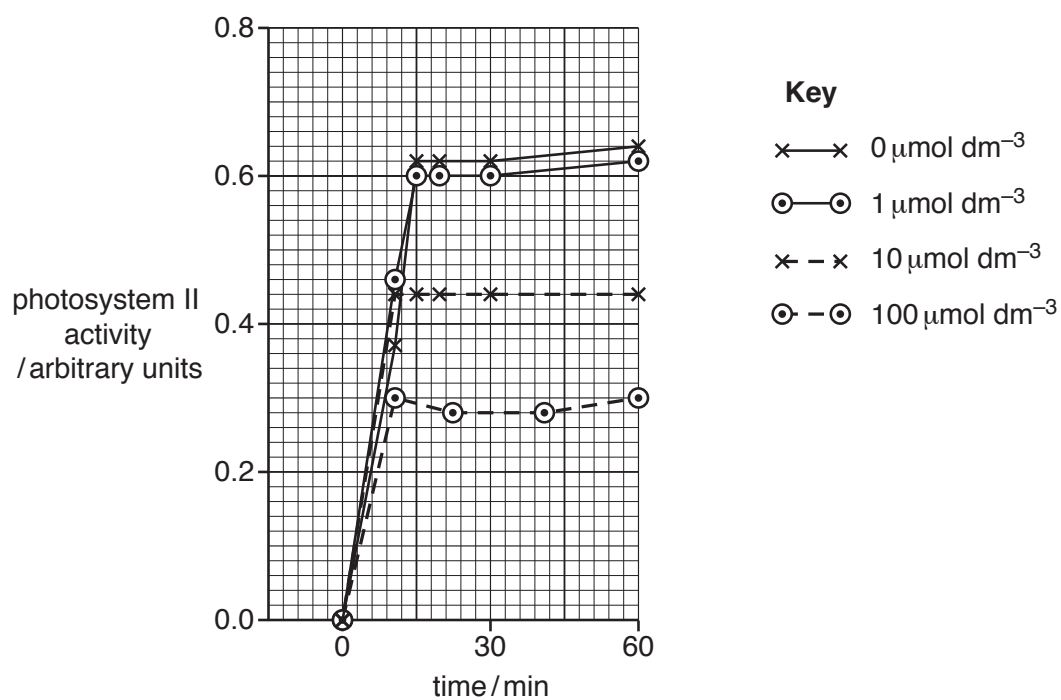
.....
.....
.....
.....
.....
..... [3]

- (b)** An investigation was carried out into the effect of cadmium ion concentration on the aquatic, single-celled, photosynthetic protist, *Chlamydomonas reinhardtii*.

The activity of photosystem II was measured at different concentrations of cadmium ions.

- Four different concentrations of cadmium ions were used, 0, 1, 10 and $100\text{ }\mu\text{mol dm}^{-3}$.
- *C. reinhardtii* was allowed to acclimatise in the dark before the experiment started.
- At time 0 min the light was switched on and the cadmium ions were added.
- At each concentration, the activity of photosystem II was measured over a period of 60 minutes.
- Each experiment was carried out under the same controlled conditions.

The results are shown in Fig. 6.1.

**Fig. 6.1**

Describe the effects of cadmium ion concentration on the activity of photosystem II, as shown in Fig. 6.1.

.....

.....

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.....

.....

..... [2]

- (c) Copper(II) ions (Cu^{2+}) inhibit the function of a proportion of the chlorophyll a present in single-celled, photosynthetic prototists.

The concentration of functional chlorophyll a in these organisms was measured in two different months of the same year in an unpolluted lake and in a lake polluted with copper ions.

The results are shown in Table 6.1.

Table 6.1

lake	concentration of functional chlorophyll a / $\mu\text{g dm}^{-3}$	
	month A	month B
unpolluted	3.45	0.24
polluted with copper ions	1.79	0.24

- (i) Describe **and** suggest explanations for the results shown in Table 6.1.

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..... [4]

- (ii) Copper ions can replace other metal ions present in organic molecules.

Suggest how copper ions change the structure of chlorophyll a.

.....

..... [1]

(d) Chromatography is a method that can be used to separate and identify different photosynthetic pigments in a chloroplast extract.

Describe how chromatography is used to identify chlorophyll a in an extract from chloroplasts.

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..... [4]

[Total: 15]

7 Fig. 7.1 outlines some of the events in the process of photosynthesis in a chloroplast.

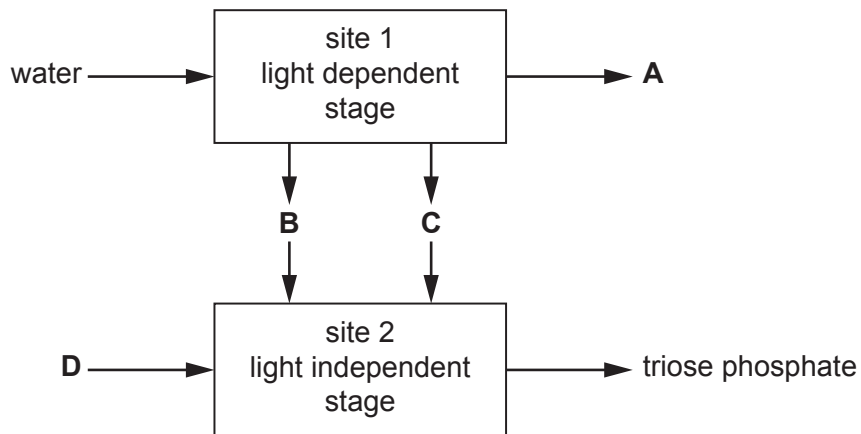


Fig. 7.1

(a) Name the parts of a chloroplast labelled site 1 and site 2 in Fig. 7.1.

site 1

site 2

[2]

(b) Name the substances labelled **A**, **B**, **C** and **D** in Fig. 7.1.

The substances labelled **B** and **C** may be named in either order.

A

B

C

D

[3]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

33. Question part 2/2 | 9700 Feb-March 2020 P4 V2 Q7

- (c) Most of the triose phosphate produced in the light independent stage is used to regenerate RuBP so that the Calvin cycle can continue. Some of the triose phosphate is used to make other organic compounds with a range of functions.

State **three** different functions of these other organic compounds in a plant cell and give **one** example of an organic compound for each function.

function

.....

compound

function

.....

compound

function

.....

compound

[3]

[Total: 8]

7 (a) Structures, processes and compounds involved in photosynthesis in C4 plants include:

- A – carbon dioxide

B – phosphorylation

C – palisade cells

D – PEP carboxylase

E – rubisco

F – malate

G – RuBP
- H – mesophyll cells

I – guard cells

J – photorespiration

K – photolysis

L – oxaloacetate

M – ATP synthase

N – chlorophyll

Complete Table 7.1 by matching each description with **one** letter chosen from **A** to **N** to show the correct structure, process or compound.

You may use each number once, more than once or not at all.

Table 7.1

description	letter
enzyme with a high optimum temperature	
enzyme in bundle sheath cells	
process that slows down the rate of photosynthesis	
compound that releases carbon dioxide into bundle sheath cells	
cells that stop oxygen reaching bundle sheath cells	

[5]

(b) Some plants, such as rice, are adapted to grow when partially submerged in water.

Describe **and** explain the adaptations that allow rice plants to survive in waterlogged fields.

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.....

[3]

Topical questions | 84 questions

[Total: 15]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

35. Question part 2/5 | 9700 May-June 2020 P4 V2 Q10

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting or typing. There are no margins, text, or other markings on the page.

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

35. Question part 3/5 | 9700 May-June 2020 P4 V2 Q10

[illegible]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

35. Question part 4/5 | 9700 May-June 2020 P4 V2 Q10

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

35. Question part 5/5 | 9700 May-June 2020 P4 V2 Q10

This image shows a full page of a worksheet designed for handwriting practice. It features approximately 20 evenly spaced, horizontal dashed lines across the entire width of the page. The background is plain white, providing a clear guide for letter height and placement. There are no margins, text, or other markings present.

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- 6 (a)** Structures and compounds involved in the light dependent stage of photosynthesis are listed, **A** to **J**.

A – thylakoid membrane

F – NADP

B – starch grain

G – electron

C – chlorophyll a

H – proton

D – chlorophyll b

I – ATP

E – water

J – chloroplast envelope

Complete Table 6.1 by matching each description with **one** letter chosen from **A** to **J** to show the correct structure or compound.

You may use each letter once, more than once or not at all.

Table 6.1

description	letter
accessory pigment	
location of ATP synthase	
acts as reaction centre	
transports hydrogen atoms	
diffuses through ATP synthase	
broken down in photolysis	

[6]

- (b)** GP (PGA) and TP (triose phosphate) are intermediates of the Calvin cycle of the light independent stage. Some GP and TP are used for the synthesis of organic compounds.

- (i)** Name a polysaccharide synthesised as a result of TP production.

..... [1]

- (ii)** Name the additional element that is required for the production of amino acids from Calvin cycle intermediates.

..... [1]

[Total: 8]

A black and white micrograph of a plant stem cross-section. The image shows various tissue layers: large, thin-walled parenchyma cells on the left; a vascular bundle in the center-right containing large, circular xylem vessels and smaller phloem elements; and a thin layer of cells on the far right. A label 'C' with a line pointing to it identifies the cambium, the boundary between the xylem and phloem.

(a) On Fig. 1.1, use label lines and letters to show:

B – a cell that contains PEP carboxylase.

[2]

C [1]

[4]

[4]

- (c) Fig. 1.2 shows the results of an experiment comparing the rate of carbon dioxide uptake in a C₃ plant (*Chenopodium album*) and a C₄ plant (*Amaranthus retroflexus*) in high and low carbon dioxide (CO₂) conditions.

The rate of CO₂ uptake is used to measure the rate of photosynthesis.

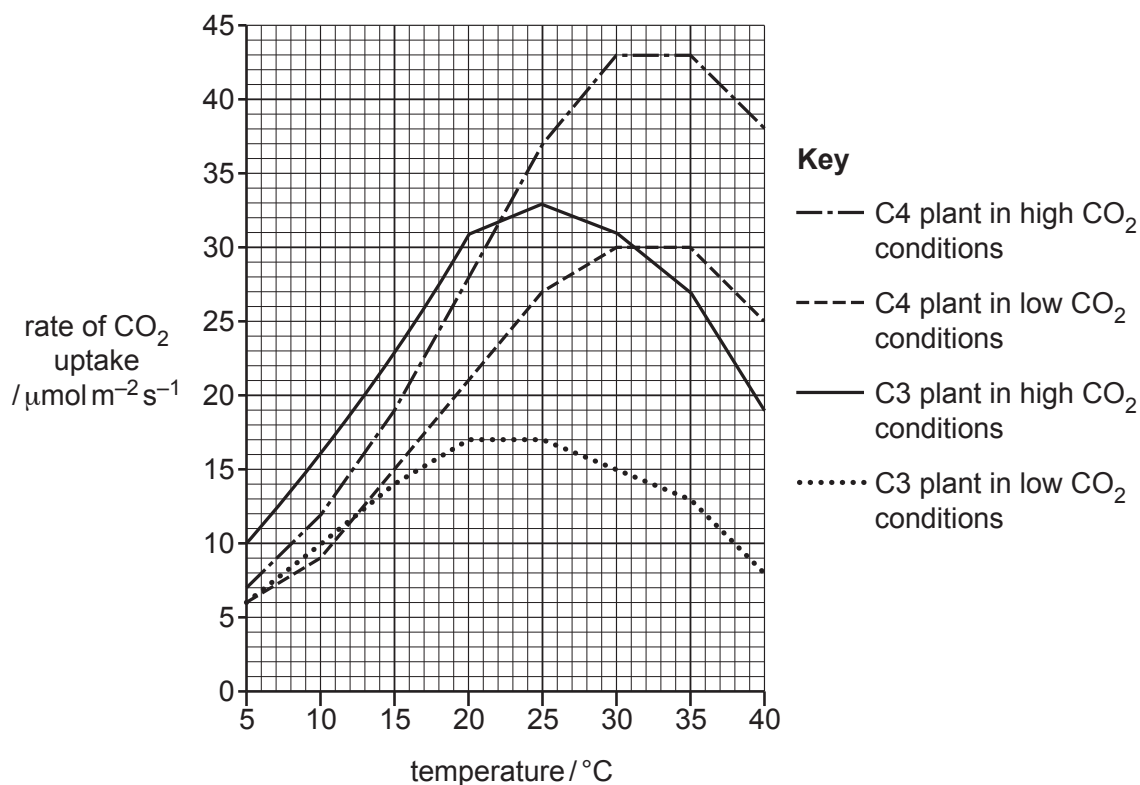


Fig. 1.2

- (i) Using Fig. 1.2, compare the rates of photosynthesis in **high** CO₂ conditions in the C₃ and C₄ plants.

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(ii) Using Fig. 1.2, compare the rates of photosynthesis in low and high CO₂ conditions in the C4 plant between 30 °C and 35 °C **and** suggest an explanation for this difference.

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..... [2]

[Total: 13]

- 1 Fig. 1.1 shows a transmission electron micrograph of a chloroplast.

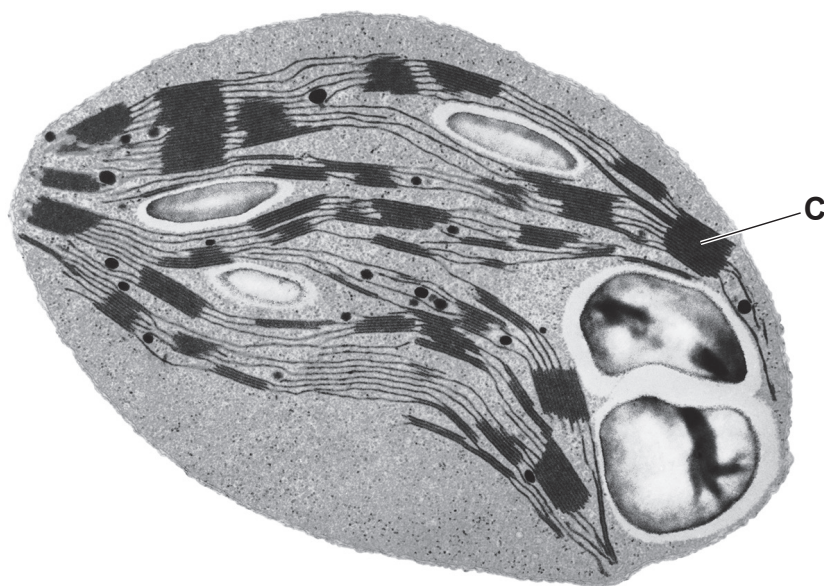


Fig. 1.1

- (a) On Fig. 1.1, use label lines and letters to label:

A – the storage site of the carbohydrate product of photosynthesis

B – the site of the light independent stage.

[2]

(b) (i) Name the structure labelled **C** in Fig. 1.1.

C [1]

(ii) Explain how the structure of **C** is linked to its function.

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..... [4]

(c) (i) The anatomy of C4 plants is adapted to allow the rate of photosynthesis to remain high at high temperatures.

C3 plants do not have these adaptations and an additional reaction occurs at high temperatures that reduces the rate of photosynthesis.

Explain why the reaction that takes place at high temperatures in **C3** plants reduces the rate of photosynthesis.

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..... [2]

- (ii) C4 plants have higher rates of photosynthesis than C3 plants when the ratio of atmospheric oxygen to atmospheric carbon dioxide is high.

Fig. 1.2 shows the atmospheric carbon dioxide concentration in the last 50 million years.

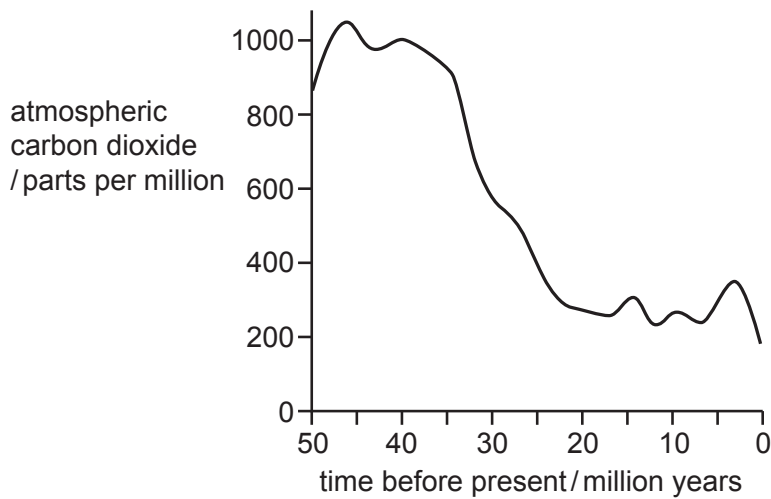


Fig. 1.2

There is evidence that C4 plants first appeared 30 million years ago.

With reference to Fig. 1.2, suggest why C4 plants first appeared 30 million years ago.

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..... [3]

[Total: 12]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

38. Question part 4/4 | 9700 Oct-Nov 2020 P4 V2 Q1

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A black and white micrograph of a plant stem cross-section. The image shows various tissues including large xylem vessels, smaller phloem elements, and a central vascular bundle. A label 'C' with a line pointing to it identifies the cambium, the meristematic tissue located between the xylem and phloem.

(a) On Fig. 1.1, use label lines and letters to show:

B – a cell that contains PEP carboxylase.

[2]

C [1]

[4]

[4]

- (c) Fig. 1.2 shows the results of an experiment comparing the rate of carbon dioxide uptake in a C₃ plant (*Chenopodium album*) and a C₄ plant (*Amaranthus retroflexus*) in high and low carbon dioxide (CO₂) conditions.

The rate of CO₂ uptake is used to measure the rate of photosynthesis.

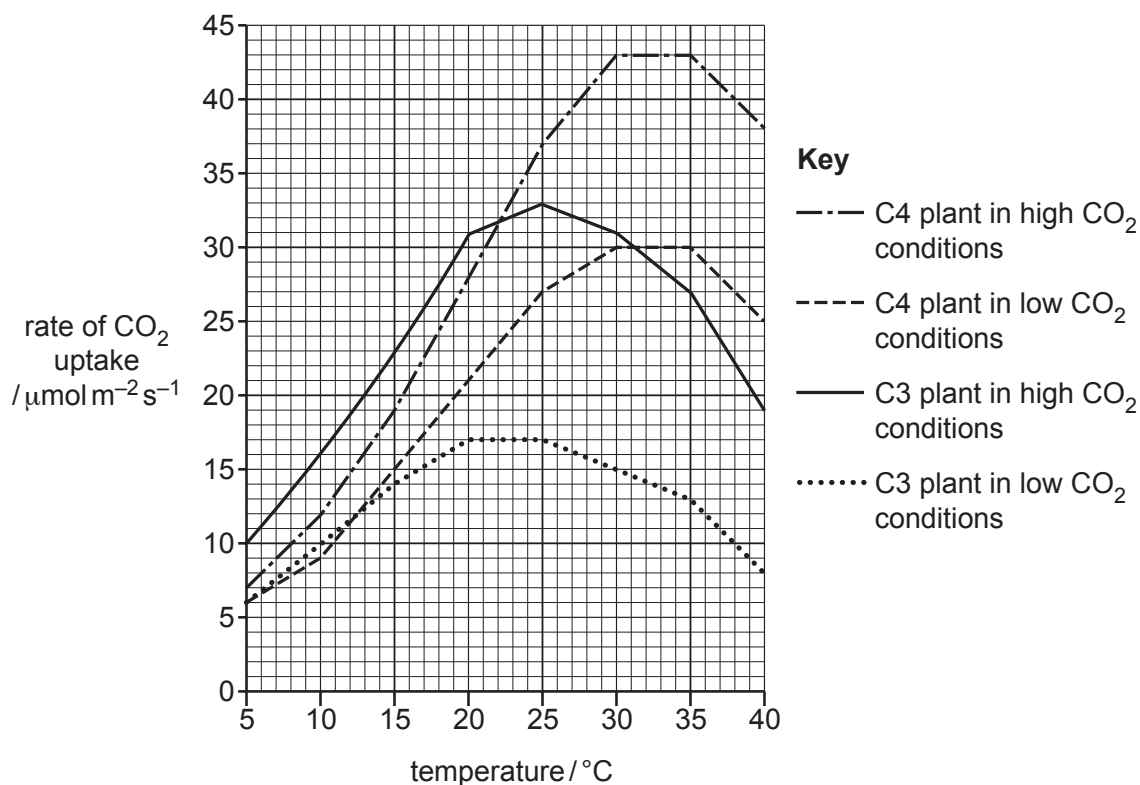


Fig. 1.2

- (i) Using Fig. 1.2, compare the rates of photosynthesis in **high** CO₂ conditions in the C₃ and C₄ plants.

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(ii) Using Fig. 1.2, compare the rates of photosynthesis in low and high CO₂ conditions in the C4 plant between 30 °C and 35 °C **and** suggest an explanation for this difference.

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..... [2]

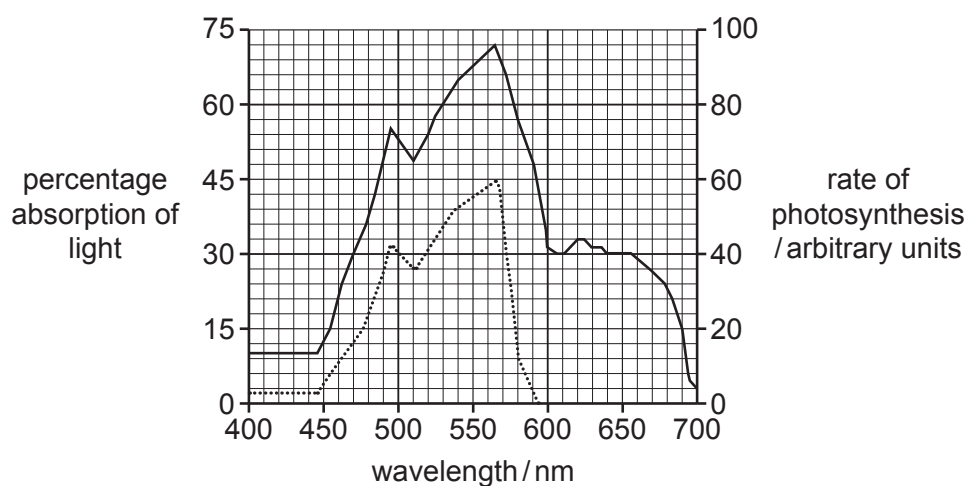
[Total: 13]

40. Question part 1/2 | 9700 Feb-March 2021 P4 V2 Q4

- 4 Red algae are multicellular photosynthetic protists that contain phycoerythrin. Phycoerythrin is a photosynthetic pigment.

(a) Fig. 4.1 shows:

- the absorption spectrum of phycoerythrin
- the action spectrum of red algae.



key

..... absorption spectrum of phycoerythrin

—— action spectrum of red algae

Fig. 4.1

- (i) With reference to Fig. 4.1, state the wavelength of peak absorption by phycoerythrin.

..... [1]

- (ii) Explain how the data in Fig. 4.1 show that phycoerythrin is **not** the only photosynthetic pigment in red algae.

.....
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.....
..... [2]

(iii) Phycoerythrin is **not** the primary pigment (reaction centre pigment) for photosynthesis in red algae.

Suggest the role of phycoerythrin in photosynthesis in red algae.

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..... [2]

(b) Phycoerythrin is rarely found in plants that have green leaves.

(i) State the name of a technique that can be used to separate and identify photosynthetic pigments.

..... [1]

(ii) Explain how the results of this technique would be used to confirm that phycoerythrin is present in red algae and **not** present in a plant with green leaves.

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..... [3]

[Total: 9]

- 1 (a) Photosynthesis is a complex process involving the transfer of light energy into chemical energy.

(i) Describe the role of photosynthetic pigments.

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..... [2]

(ii) Name the precise location in a chloroplast of photosynthetic pigments.

..... [1]

(iii) Name a practical technique to separate photosynthetic pigments.

..... [1]

(b) The rate of photosynthesis is affected by many environmental factors.

A student carried out an experiment to investigate the relationship between the concentration of carbon dioxide available to an aquatic plant, *Cabomba caroliniana*, and its rate of photosynthesis.

Fig. 1.1 shows the experimental set-up for this investigation.

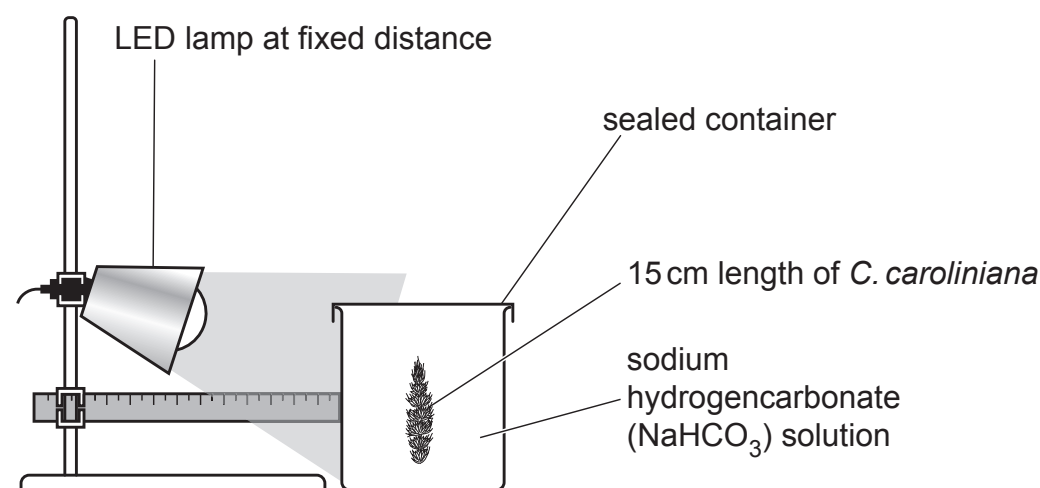


Fig. 1.1

A line graph showing the relationship between the concentration of sodium hydrogencarbonate solution and the percentage change in dissolved oxygen. The x-axis represents the concentration of sodium hydrogencarbonate solution in mol dm^{-3} , ranging from 0.00 to 1.25. The y-axis represents the percentage change in dissolved oxygen, ranging from -15 to 35. The curve starts at the origin (0,0) and increases, showing a decreasing rate of change as concentration increases, eventually leveling off at approximately 31% change for concentrations above 1.0 mol dm^{-3} .

concentration of sodium hydrogencarbonate solution / mol dm^{-3}	percentage change in dissolved oxygen
0.00	0
0.25	21
0.50	27.5
0.75	30
1.00	31
1.25	31

(i) With reference to Fig. 1.2, explain the pattern of results obtained between 0.25 mol dm^{-3} and 1.25 mol dm^{-3} of sodium hydrogencarbonate solution.

..... [3]

41. Question part 3/4 | 9700 May-June 2021 P4 V1 Q1

- (ii) The percentage change in dissolved oxygen for *C. caroliniana* at 0.00 mol dm⁻³ of sodium hydrogencarbonate solution is negative.

Suggest reasons for this negative value.

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..... [2]

- (iii) To minimise temperature changes, the student decided to use an LED lamp as a light source. LED lamps release very little heat energy.

Explain the importance of minimising temperature changes in this experiment.

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..... [3]

[Total: 12]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

41. Question part 4/4 | 9700 May-June 2021 P4 V1 Q1

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5 (a) Photosynthesis is a complex process involving a light dependent stage and a light independent stage.

(i) Name the products of the light dependent stage that are needed in the light independent stage.

.....
 [2]

(ii) Describe the role of chlorophyll b in photosynthesis.

.....

 [2]

A student carried out an experiment to investigate the effect of light intensity and light wavelength on the rate of photosynthesis.

- An aquatic plant, *Elodea canadensis*, was put into a beaker containing sodium hydrogencarbonate solution as a source of carbon dioxide.
- To minimise changes in temperature, an LED lamp was used as a source of light.
- The lamp was switched on and the number of bubbles released by the aquatic plant in 1 minute was counted.
- The lamp was placed at seven different distances from the beaker to change light intensity.
- Five replicates were carried out at each lamp distance.
- All other variables were controlled.

(b) The student calculated the light intensity for each distance (d) using $\frac{1}{d^2}$.

Table 5.1 shows the calculated light intensities for each distance.

Table 5.1

distance between plant and lamp / m	light intensity / $\frac{1}{d^2}$
0.025	1600
0.050	400
0.100	
0.150	44
0.200	25
0.250	16
0.300	11

Complete Table 5.1 by calculating the light intensity for distance 0.100 m.

[1]

- The student calculated the mean rate of bubble production as a measure of the rate of photosynthesis.

rate of photosynthesis / bubbles min⁻¹

light intensity

Key:

- white light
- red light
- blue light
- green light

Light Intensity	White Light (bubbles min ⁻¹)	Red Light (bubbles min ⁻¹)	Blue Light (bubbles min ⁻¹)	Green Light (bubbles min ⁻¹)
0	0	0	0	0
100	105	95	80	58
200	120	105	90	65
400	138	125	110	82
600	138	125	110	82
800	138	125	110	82
1000	138	125	110	82
1200	138	125	110	82
1400	138	125	110	82
1600	138	125	110	82

Fig. 5.1

- (i) With reference to Fig. 5.1:
- state the range over which light intensity is the limiting factor
 - explain why light intensity above this range is not limiting the rate of photosynthesis.

..... [3

(ii) At a light intensity of 1600, explain why different colour filters result in different rates of photosynthesis.

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..... [3]

[Total: 11]

5 Photosynthesis is a process that results in the synthesis of complex organic molecules.

Respiration is a process that involves the breakdown of complex organic molecules.

(a) The light dependent stage of photosynthesis involves cyclic and non-cyclic photophosphorylation.

Describe **two** differences between cyclic and non-cyclic photophosphorylation.

.....

 [2]

(b) Biochemical processes involving carbon dioxide change the external environment of the aquatic plant, *Elodea canadensis*, and the pond snail, *Lymnaea stagnalis*. Carbon dioxide dissolves in water to form carbonic acid.

A student set up 8 test-tubes. Each test-tube contained 30 cm³ of distilled water containing a pH indicator, bromothymol blue.

Fig. 5.1 shows the experimental set up for these 8 test-tubes.

The test-tubes were left for 12 hours.

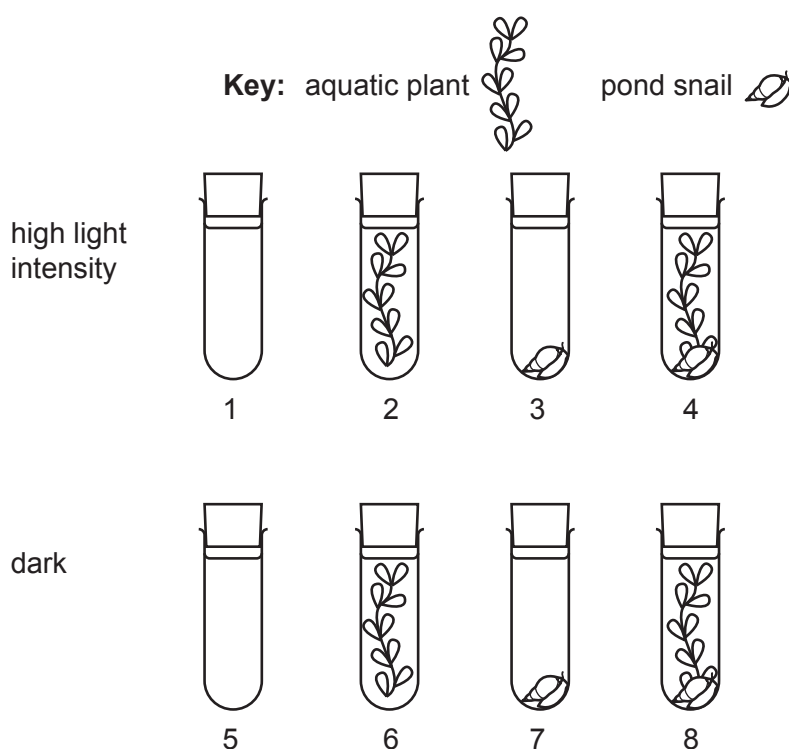


Fig. 5.1

Fig. 5.2 shows how the colour of bromothymol blue changes with pH.

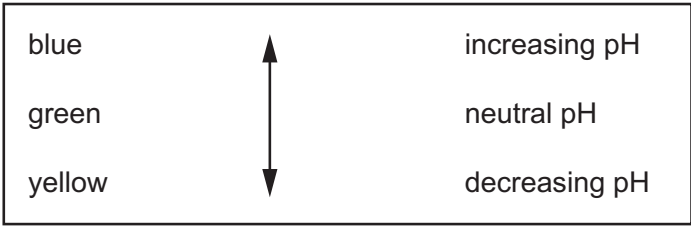


Fig. 5.2

All tubes were green at the start of the experiment.

The results of the experiment are shown in Table 5.1.

Table 5.1

test-tube	colour after 12 hours
1	green
2	blue
3	yellow
4	green
5	green
6	yellow-green
7	yellow
8	yellow

(i) Explain the purpose of test-tube 1 and test-tube 5.

.....
..... [1]

(ii) Explain the results of test-tubes 2, 3 and 4.

test-tube 2

.....

.....

test-tube 3

.....

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test-tube 4

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[5]

(iii) Explain the colour change in test-tube 6.

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.....

[3]

[Total: 11]

Scientists measured the activity of rubisco activase in cotton and in false flax at a range of temperatures.

rubisco activase activity / arbitrary units

temperature / °C

Key

- false flax
- cotton

Temperature (°C)	False flax (arbitrary units)	Cotton (arbitrary units)
20	0.100	0.050
23	0.110	0.070
25	0.113	0.098
27	0.112	0.101
30	0.105	0.103
33	0.098	0.100
35	0.050	0.093
37	0.008	0.065
40	-	0.038
42	-	0.010

Fig. 2.1

- (i) With reference to Fig. 2.1, compare the results obtained for cotton and false flax.

..... [4

(ii) Suggest reasons for the differences shown in Fig. 2.1.

.....

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.....

..... [3]

(b) Rubisco enzymes from cotton and false flax are active at temperatures up to 45 °C and will denature at 45 °C.

Explain how the Calvin cycle is affected when rubisco denatures.

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..... [3]

(c) One goal of genetic engineering is to make crops that are heat tolerant. This means that crops can grow and produce a good yield at high environmental temperatures.

Use the information given in Question 2 to suggest **and** explain a way to improve the tolerance of a crop to high temperatures.

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.....

..... [2]

- 9** **(a)** Describe **and** explain the mechanism by which guard cells open stomata. [7]
- (b)** Explain how the anatomy **and** physiology of the leaves of maize or sorghum are able to maximise carbon dioxide fixation at high temperatures. [8]

[Total: 15]

- 2 Scientists are researching new ways to reduce the global atmospheric carbon dioxide (CO_2) concentration. There are concerns that an increasing atmospheric CO_2 concentration may lead to effects that decrease biodiversity.

(a) Give **one** example of a human activity, other than deforestation, that contributes greatly to the increase in global atmospheric CO_2 concentration.

..... [1]

Algae are aquatic photosynthetic protists. Some researchers genetically modified the unicellular alga, *Chlorella vulgaris*, to try to increase the rate of the light independent stage of photosynthesis.

C. vulgaris was modified to increase the expression of the gene coding for aldolase. Aldolase is an enzyme that causes an increase in the concentration of rubisco.

Two cultures of *C. vulgaris*, one that was not genetically modified (unmodified) and one genetically modified, were grown under controlled conditions for 14 days. Samples were taken from the cultures at regular intervals during the 14 days to obtain measurements of dry mass.

The results are shown in Fig. 2.1.

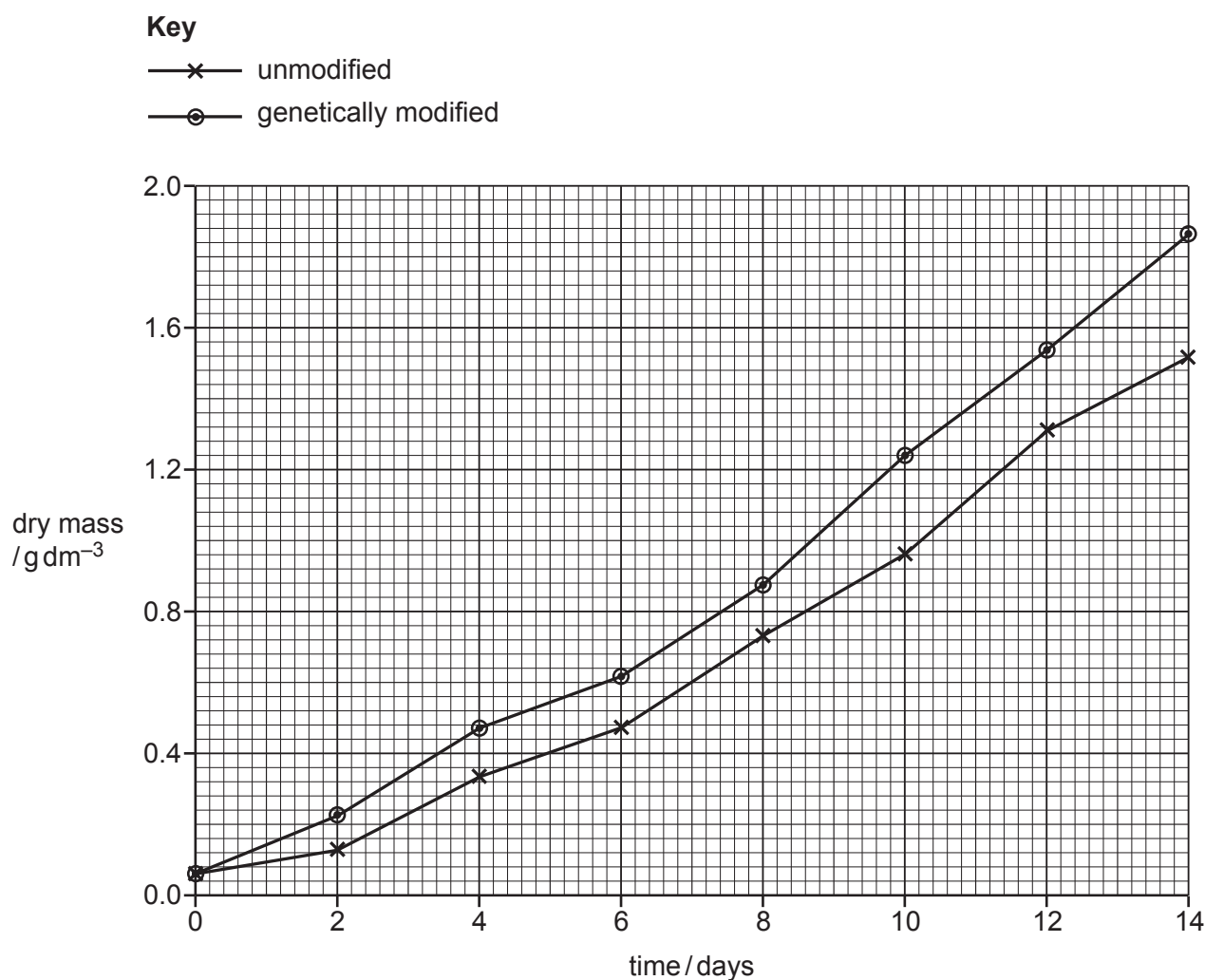


Fig. 2.1

(b) With reference to Fig. 2.1, describe the differences between the results for the two cultures.

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..... [3]

(c) Explain how the Calvin cycle was affected by the genetic modification of *C. vulgaris*.

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..... [3]

(d) Intermediate products of the Calvin cycle are needed to produce organic molecules for use by the cell.

Describe how these organic molecules are used by cells.

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..... [3]

(e) Planting large numbers of trees is one way to reduce global atmospheric CO₂ concentration. Large scale culture of genetically modified *C. vulgaris* could also reduce global atmospheric CO₂ concentration.

Suggest **one** advantage of using genetically modified *C. vulgaris* instead of trees to reduce global atmospheric CO₂ concentration.

.....

..... [1]

Scientists measured the activity of rubisco activase in cotton and in false flax at a range of temperatures.

rubisco activase activity / arbitrary units

temperature / °C

Key

- false flax
- cotton

Temperature (°C)	False flax (arbitrary units)	Cotton (arbitrary units)
20	0.100	0.050
23	0.110	0.070
25	0.113	0.098
27	0.112	0.101
30	0.105	0.103
33	0.098	0.100
35	0.050	0.093
37	0.008	0.065
40	-	0.038
42	-	0.010

Fig. 2.1

- (i) With reference to Fig. 2.1, compare the results obtained for cotton and false flax.

..... [4

(ii) Suggest reasons for the differences shown in Fig. 2.1.

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..... [3]

(b) Rubisco enzymes from cotton and false flax are active at temperatures up to 45 °C and will denature at 45 °C.

Explain how the Calvin cycle is affected when rubisco denatures.

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..... [3]

(c) One goal of genetic engineering is to make crops that are heat tolerant. This means that crops can grow and produce a good yield at high environmental temperatures.

Use the information given in Question 2 to suggest **and** explain a way to improve the tolerance of a crop to high temperatures.

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..... [2]

- 9** **(a)** Describe **and** explain the mechanism by which guard cells open stomata. [7]
- (b)** Explain how the anatomy **and** physiology of the leaves of maize or sorghum are able to maximise carbon dioxide fixation at high temperatures. [8]

[Total: 15]

- 6 (a) The banana plant, *Musa acuminata*, is a tall herbaceous plant with very large leaves.

Fig. 6.1 shows a banana plant.



Fig. 6.1

An investigation was carried out to measure the net carbon dioxide uptake by a banana plant at different light intensities.

Fig. 6.2 shows the results of the investigation.

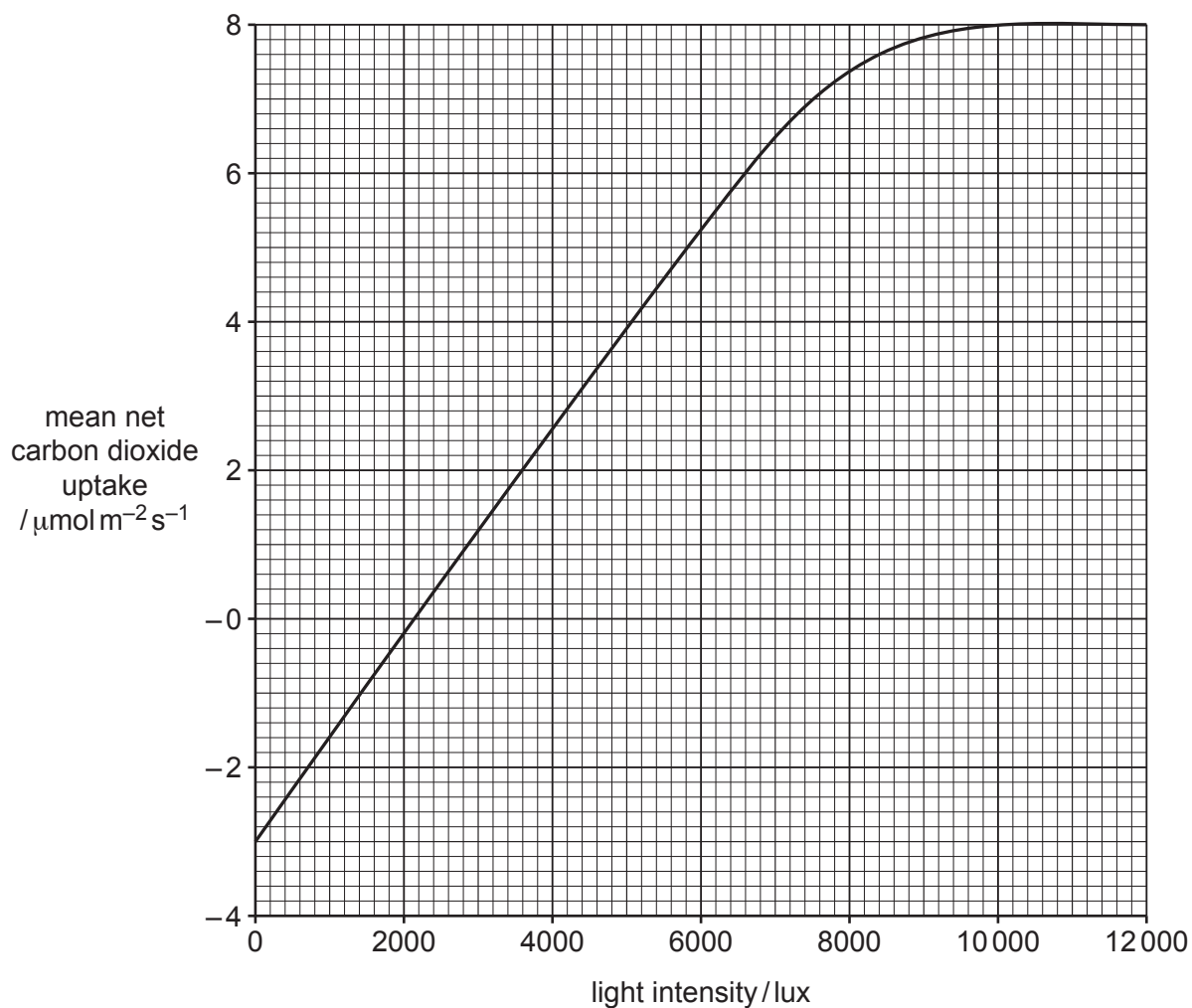


Fig. 6.2

(i) With reference to Fig. 6.2, describe **and** explain the results at a light intensity of 1000 lux.

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..... [3]

(ii) With reference to Fig. 6.2, describe **and** explain what can be concluded from the graph at light intensities of between 2000 lux and 7000 lux.

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..... [3]

(iii) Explain why the rate of carbon dioxide uptake levels off as light intensity increases above 10 000 lux.

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..... [1]

- (b) Pitcher plants are carnivorous plants that trap and digest insects in a large modified leaf called a pitcher.

Fig. 6.3 shows a pale pitcher plant, *Sarracenia alata*.



Fig. 6.3

- (i) Unlike the Venus fly trap, pitcher plants have no moving parts to trap insects. Insects are attracted to scent produced at the top of the pitcher. Once inside the pitcher, the insect slides down to the bottom and into a liquid containing digestive enzymes.

Suggest a type of enzyme found in the pitcher plant that is used to digest insects.

..... [1]

- (ii) Pitcher plants grow in bogs and wet grassland where the soil has a low concentration of minerals such as nitrates. The plants obtain nitrates from the digestion of insects.

Calvin cycle intermediates are used to synthesise more complex compounds, some of which need nitrogen from nitrates.

Name **one** compound that needs nitrogen from nitrates **and** name the Calvin cycle intermediate from which it is synthesised.

compound that needs nitrogen

Calvin cycle intermediate

[2]

[Total: 10]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

49. Question part 4/4 | 9700 Feb-March 2022 P4 V2 Q6

Question 7 starts on page 22.

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

50. Question part 1/4 | 9700 May-June 2022 P4 V1 Q2

2 (a) In eukaryotes, the cells of plants and photosynthetic protists contain chloroplasts.

Describe the relationship between the function of a chloroplast and its structure.

..... [4]

(b) Outline the main features of cyclic photophosphorylation.

..... [3]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

50. Question part 2/4 | 9700 May-June 2022 P4 V1 Q2

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- (c) Red algae are aquatic protocists that are multicellular. The cells of red algae have chloroplasts containing photosynthetic pigments. Many red algae live in deep water.

Two of the accessory pigments of red algae chloroplasts are:

- phycoerythrin (appears red), often present in large concentrations
- phycocyanin (appears blue).

The first few metres of water nearest the surface absorb the red wavelengths of light. If the water also contains particles of organic material it absorbs blue wavelengths.

Fig. 2.1 shows absorption spectra of some pigments in red algae chloroplasts.

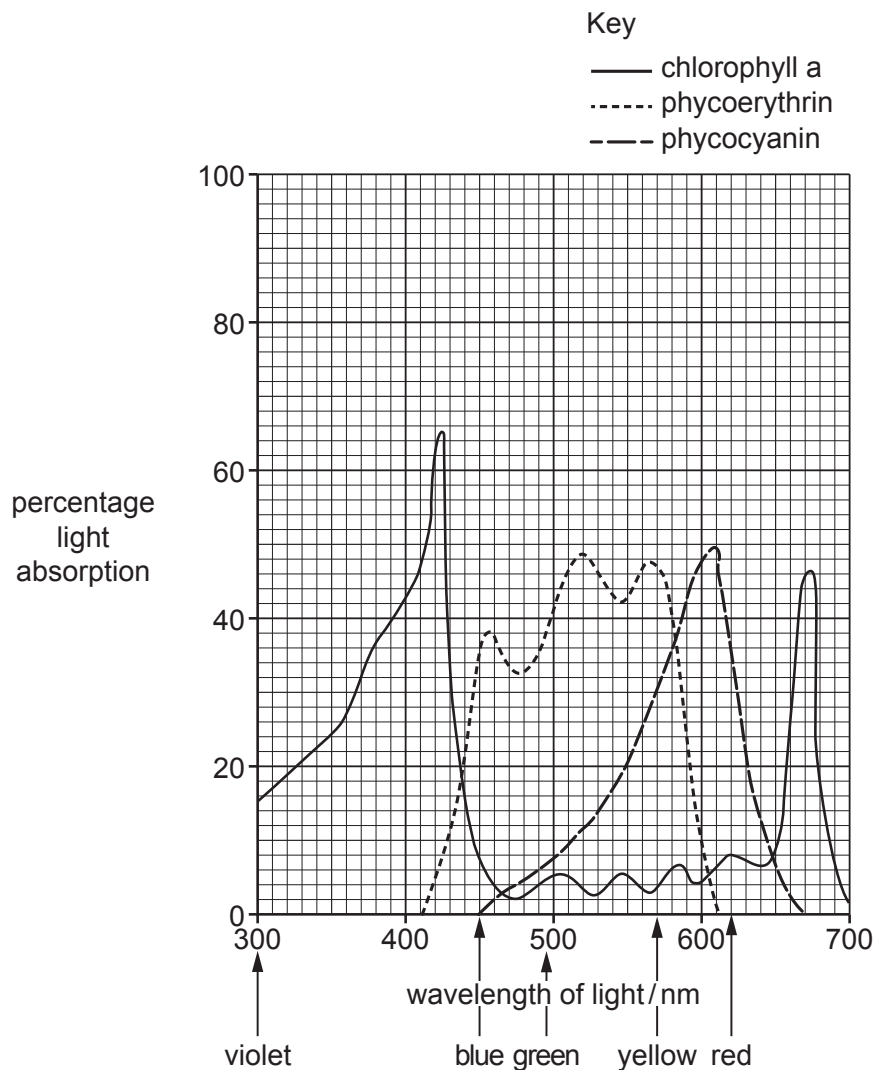


Fig. 2.1

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

50. Question part 4/4 | 9700 May-June 2022 P4 V1 Q2

Describe the differences in the absorption spectra of the three photosynthetic pigments shown in Fig. 2.1 **and** explain how these differences help red algae to survive in deep water.

[7]

[Total: 14]

51. Question part 1/2 | 9700 May-June 2022 P4 V1 Q9

9 (a) Stomata are involved in both transpiration and photosynthesis in plants.

Fig. 9.1 is a diagram of an open stoma, its guard cells and surrounding epidermal cells.

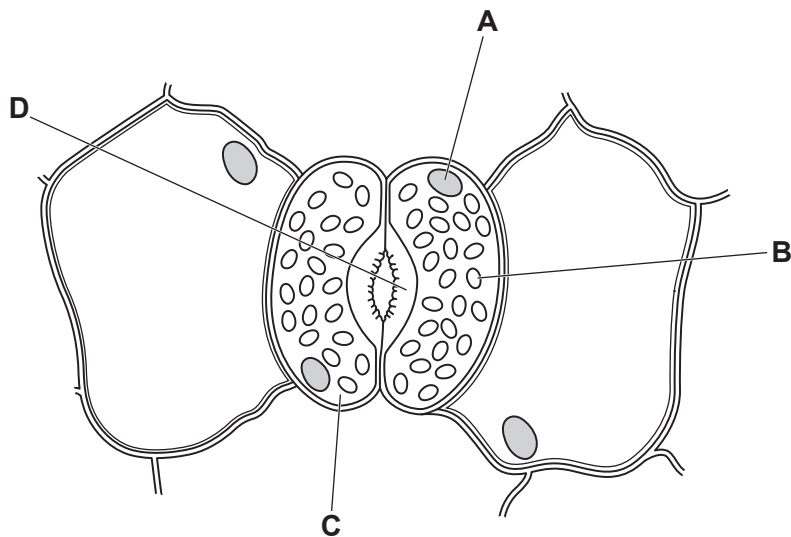


Fig. 9.1

Complete Table 9.1 by choosing the correct letter from Fig. 9.1 to match the feature stated in Table 9.1.

Each letter may be used once, more than once or not at all.

Table 9.1

letter	feature
.....	location of Calvin cycle
.....	made mainly of cellulose

(b) The opening and closing of stomata are due to changes in environmental conditions. Hydrogen ions (H^+) and potassium ions (K^+) are involved in the opening of stomata.

Describe how hydrogen ions and potassium ions are involved in the opening of a stoma.

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..... [4]

[Total: 6]

2 (a) Photosynthesis is affected by many environmental factors.

(i) Explain why light intensity can be a limiting factor in photosynthesis.

.....

 [2]

(ii) The concentration of carbon dioxide (CO_2) can also be a limiting factor. It has an effect on the Calvin cycle in the light-independent stage of photosynthesis.

Ribulose biphosphate (RuBP), triose phosphate (TP) and glycerate 3-phosphate (GP) are three important molecules in the Calvin cycle.

Fig. 2.1 shows how the concentration of GP changes when the concentration of CO_2 is reduced from 0.04% (atmospheric) to 0.008%.

Complete Fig. 2.1 by sketching the lines for RuBP and TP when the concentration of CO_2 is reduced from 0.04% to 0.008%.

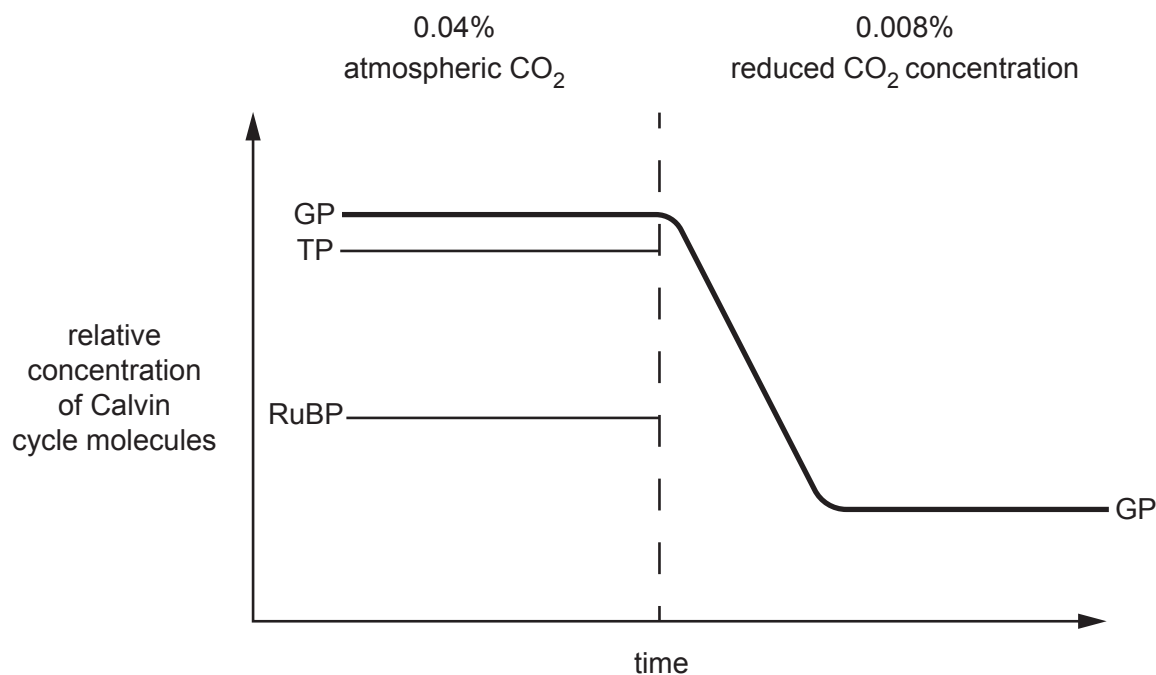


Fig. 2.1

[2]

(iii) In very dry conditions, CO₂ concentration can become the main limiting factor of photosynthesis in plants.

Explain how very dry conditions cause CO₂ concentration to become the main limiting factor of photosynthesis in plants.

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..... [3]

(b) A factor that can limit the rate of photosynthesis is the rate of regeneration of RuBP.

Sedoheptulose-1,7-bisphosphatase (SBPase) is an enzyme in the Calvin cycle that controls the rate of regeneration of RuBP. SBPase is coded for by the gene *SBPase*.

In an experiment, wheat plants were genetically modified to make more SBPase by introducing the *SBPase* gene from another grass species, *Brachypodium distachyon*. The resulting GM wheat plants were named Sox4.

- Wild type plants (not GM) and Sox4 plants were grown in a greenhouse.
- Light intensity, CO₂ concentration and temperature were kept constant.
- Mature plants were removed and dried to measure the biomass.

Fig. 2.2 shows the mean plant biomass for the wild type plants and GM Sox4 plants.

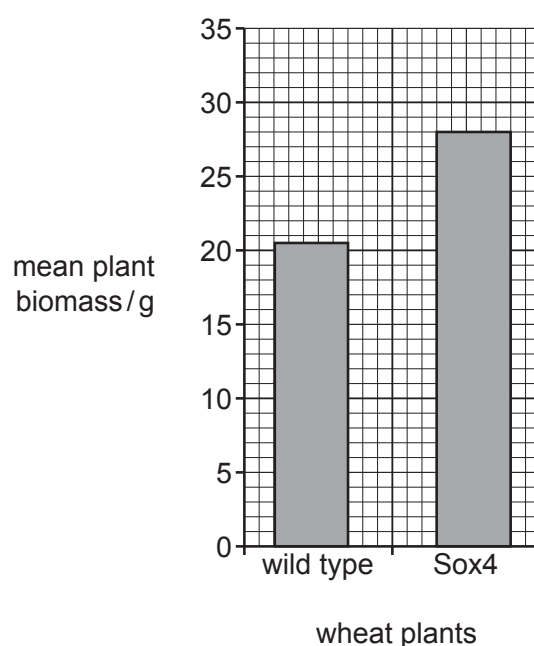


Fig. 2.2

- (i) Calculate the percentage change in mean plant biomass when Sox4 plants are grown compared to wild type plants.

Show your working.

percentage change = ... % [2]

(ii) Suggest **and** explain why Sox4 plants have a different mean plant biomass than wild type plants.

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..... [4]

(iii) Some soils may be deficient in nitrates.

Suggest how nitrate deficiency could limit the quantity of SBPase made by Sox4 plants.

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..... [2]

[Total: 15]

2 Photosynthesis is an energy transfer process that results in the production of carbohydrate. It has two stages: the light-dependent stage and the light-independent stage.

Cyclic photophosphorylation and non-cyclic photophosphorylation are essential pathways in photosynthesis that occur in the light-dependent stage.

(a) (i) Describe the similarities and differences between cyclic photophosphorylation and non-cyclic photophosphorylation.

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..... [4]

(ii) Explain why herbicides that prevent cyclic photophosphorylation and non-cyclic photophosphorylation stop carbohydrate being produced in the chloroplast.

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..... [2]

(b) The rate of regeneration of RuBP in the Calvin cycle is known to limit the rate of photosynthesis.

Sedoheptulose-1,7-bisphosphatase (SBPase) is an enzyme in the Calvin cycle that controls the rate of regeneration of RuBP. SBPase is coded for by the gene *SBPase*.

In an experiment, wheat plants were genetically modified to make more SBPase by introducing the *SBPase* gene from another grass species, *Brachypodium distachyon*. The resulting GM wheat plants were named Sox4.

- Wild type plants (not GM) and Sox4 plants were grown.
- A leaf from the wild type plant was placed in a sealed glass vessel.
- The carbon dioxide (CO_2) concentration in the vessel was increased so that the intercellular air spaces also had an increase in CO_2 concentration.
- The other environmental conditions were kept constant.
- The rate of fixation of CO_2 was measured for the leaf.
- The experiment was repeated with a leaf from a Sox4 plant.

Fig. 2.1 shows the rate of fixation of CO_2 by the leaves of wild type plants and Sox4 plants when the intercellular air space CO_2 concentration was increased.

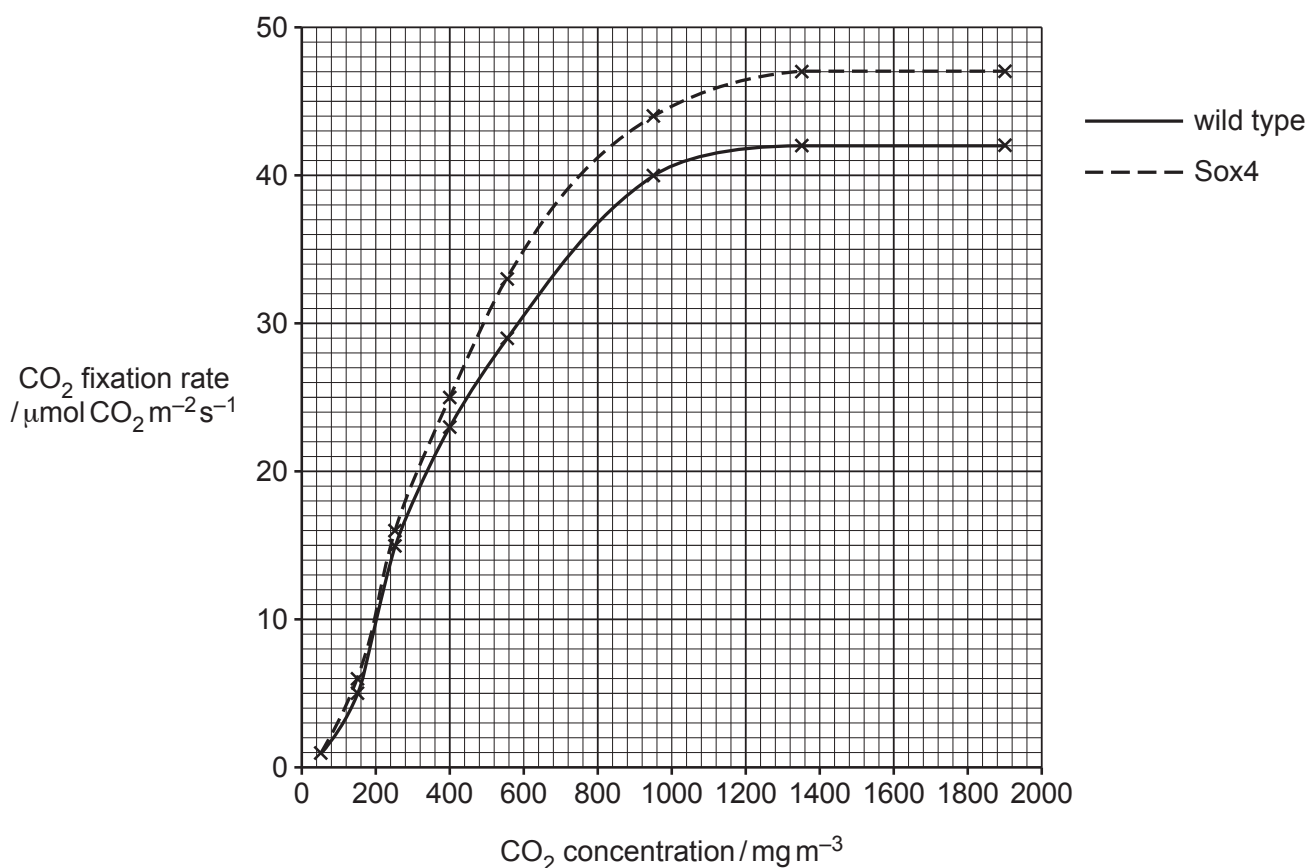


Fig. 2.1

(i) With reference to Fig. 2.1, describe **and** explain the results shown by the **wild type** plants.

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..... [4]

(ii) With reference to Fig. 2.1, describe **and** suggest explanations for the differences in the rate of fixation of CO₂ between wild type plants and Sox4 plants.

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..... [3]

[Total: 13]

2 Photosynthesis is an important energy transfer process.

(a) Name **one** chloroplast pigment.

.....
..... [1]

(b) Explain the relationship between the **absorption** spectrum of the main chloroplast pigments in a species of plant and the **action** spectrum for photosynthesis for that species.

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..... [2]

(c) Explain why temperature can be a limiting factor of photosynthesis.

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..... [3]

(d) Outline how the light-independent stage of photosynthesis leads to the production of carbohydrates such as starch in plant leaves.

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..... [3]

3 (a) Photosynthesis is an energy transfer process that takes place in chloroplasts of plant cells.

(i) Fig. 3.1 shows a diagram of a chloroplast.

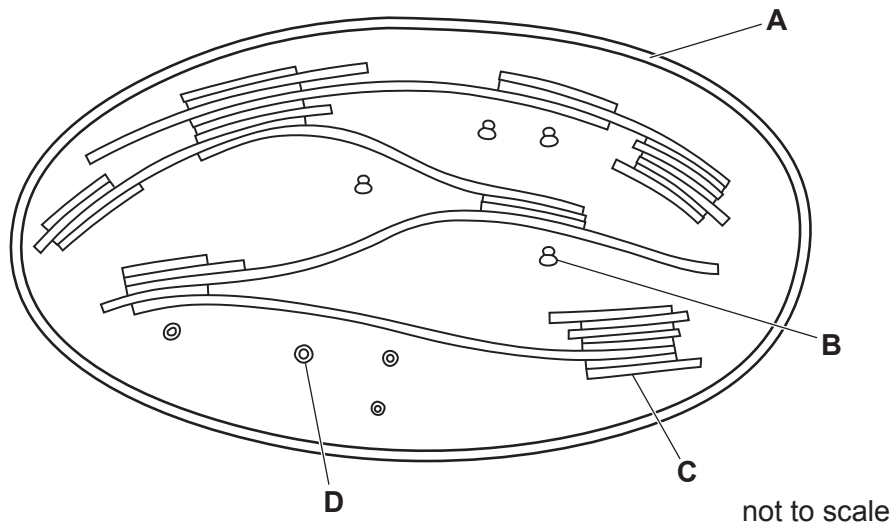


Fig. 3.1

Using the letters **A**, **B**, **C** or **D**, identify the structure that:

- contains genes that code for some of the enzymes used in photosynthesis
.....
- is the site of synthesis of some of the enzymes used in photosynthesis.
.....

[2]

(ii) Explain how grana are adapted for their specific role in photosynthesis.

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[4]

(b) An experiment was carried out to investigate the effect of changing light conditions on the pH of the chloroplast stroma. Scientists followed pH changes in chloroplast stroma using fluorescent chemicals that can be used as pH indicators.

- Chloroplasts were isolated from cells.
- A suspension of chloroplasts was prepared and kept in the dark for 180 seconds.
- The chloroplasts were exposed to a period of light of fixed intensity for 240 seconds, then returned to dark conditions.
- The pH of chloroplast stroma was continuously measured and recorded.

Fig. 3.2 shows the results of this experiment.

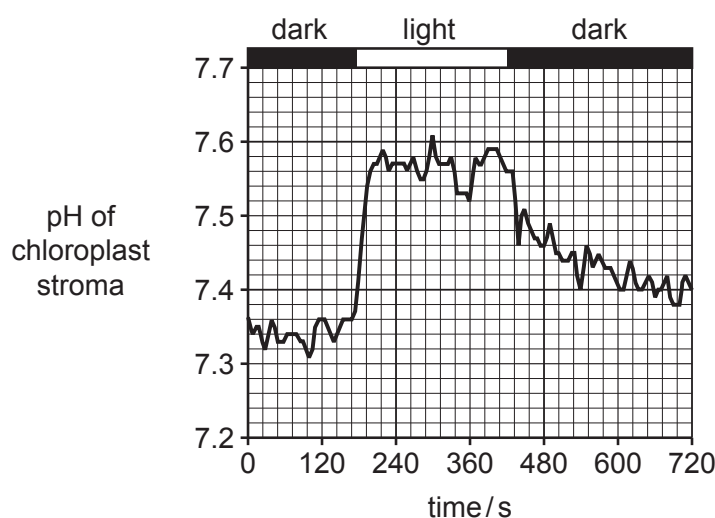


Fig. 3.2

(i) Describe the results shown in Fig. 3.2.

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[3]

(ii) Discuss how the results in Fig. 3.2 support that chemiosmosis occurs during photophosphorylation.

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..... [3]

[Total: 12]

2 Photosynthesis is an important energy transfer process.

(a) Name **one** chloroplast pigment.

.....
..... [1]

(b) Explain the relationship between the **absorption** spectrum of the main chloroplast pigments in a species of plant and the **action** spectrum for photosynthesis for that species.

.....
.....
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..... [2]

(c) Explain why temperature can be a limiting factor of photosynthesis.

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..... [3]

(d) Outline how the light-independent stage of photosynthesis leads to the production of carbohydrates such as starch in plant leaves.

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..... [3]

3 Corals grow in shallow sea water. Corals consist of colonies of small animals called polyps. These polyps have photosynthetic prototists called algae within their cells, which is advantageous both to the coral polyps and to the algae.

The algae that live within the cells of coral polyps can also live independently as free-living algae.

(a) The rate of photosynthesis of algae that live within the cells of coral polyps is higher than that of free-living algae.

Suggest **and** explain why the rate of photosynthesis in algae that live within the cells of coral polyps is higher than that of free-living algae.

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..... [3]

(b) The algae that live within the cells of coral polyps have five different chloroplast pigments.

Table 3.1 shows the light wavelengths at which each algal chloroplast pigment shows its two largest peaks of light absorption.

Table 3.1

chloroplast pigment	peak 1 wavelength / nm	peak 2 wavelength / nm
chlorophyll a	430	662
peridinin	456	485
chlorophyll c ₂	450	396
dinoxanthin	442	471
β-carotene	454	480

Corals can be kept in glass tanks that are usually lit by lamps radiating mainly violet and blue light, with wavelengths in the range of 400 nm to 490 nm.

With reference to Table 3.1, suggest why lamps radiating mainly violet and blue light are expected to increase the growth of **coral polyps** more than lamps radiating light of all wavelengths.

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..... [3]

(c) Photosynthesis in the algae living within the cells of coral polyps is the same as photosynthesis in plant cells.

Outline the process of cyclic photophosphorylation.

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..... [4]

[Total: 10]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

57. Question part 4/4 | 9700 Specimen 2022 P4 Q3

Question 4 starts on page 12

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

58. Question part 1/2 | 9700 Feb-March 2023 P4 V2 Q8

8 (a) Describe the functions of the internal membranes of the chloroplast in photosynthesis.

..... [7]

- Solutions of rubisco and RuBP were added to two tubes, **A** and **B**.
- RA was added to tube **A**.
- Both tubes were incubated at 25 °C for 6 minutes.
- The activity of rubisco was measured every 30 seconds.

The results are shown in Fig. 8.1.

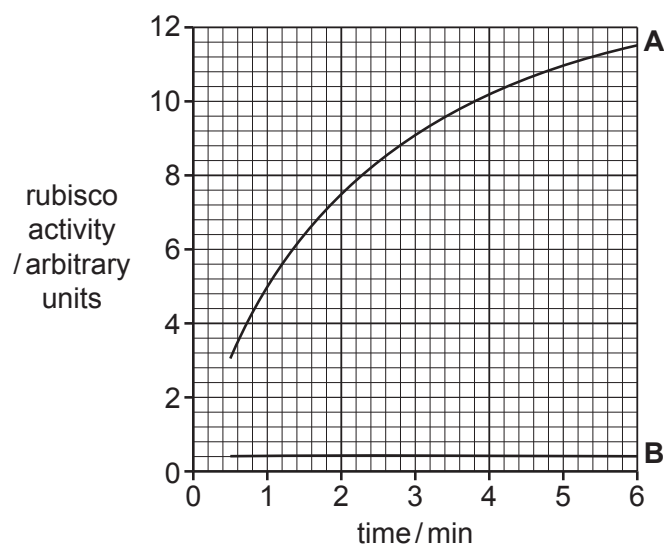


Fig. 8.1

Describe the results shown in Fig. 8.1 **and** suggest an explanation for the effect of RA on the activity of rubisco.

[4]

1 Fig. 1.1 shows a transmission electron micrograph of part of a chloroplast.

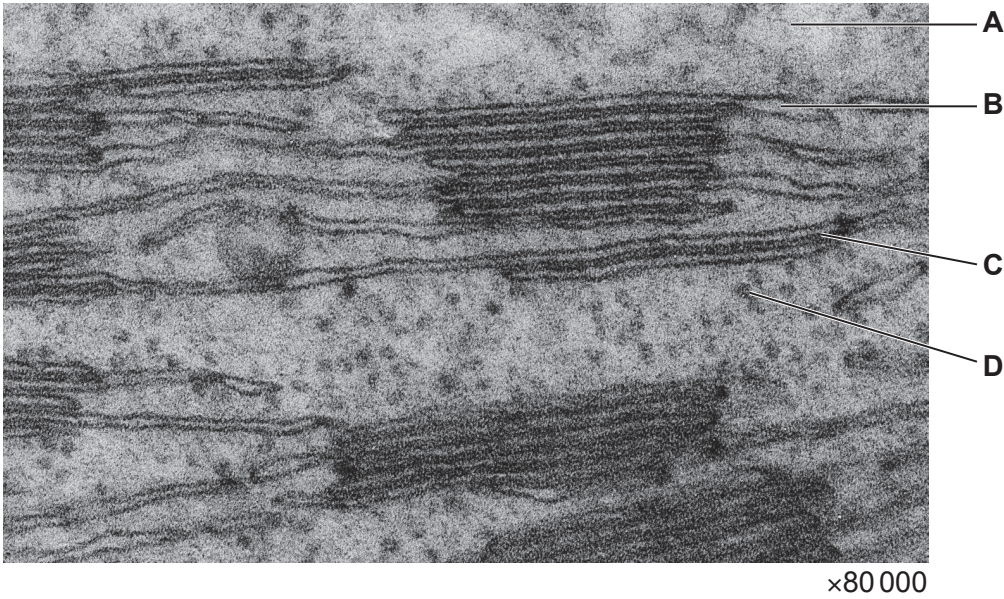


Fig. 1.1

(a) Table 1.1 describes some functions that occur in different parts of a chloroplast.

Complete Table 1.1 by identifying the letter on Fig. 1.1 that is a location matching the description. Each letter may be used once, more than once, or not at all.

Table 1.1

description	letter
accumulates (builds up) a high concentration of protons	
makes triose phosphate	
makes some chloroplast proteins	
pumps protons	

(b) Membranes of the type labelled **C** in Fig. 1.1 were made into a liquid extract. Chromatography was then used to separate and identify the coloured components (pigments) in this extract. The resulting chromatogram showed that these membranes contain a yellow pigment, an orange pigment, a green-brown pigment and two different green pigments.

(i) Describe how you would carry out chromatography to separate and identify the coloured pigments in the liquid extract of **C**.

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..... [4]

(ii) Explain why membrane **C** has many different coloured pigments to function efficiently.

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..... [3]

[Total: 11]

60. Question part 1/2 | 9700 May-June 2023 P4 V2 Q8

- 8 (a) In plants such as rice, *Oryza sativa*, rubisco has a low rate of activity, which in turn affects the rate of photosynthesis. The cereal crop sorghum, *Sorghum bicolor*, has a high rate of activity of rubisco.

A genetically modified (GM) variety of rice was produced. Parts of the quaternary structure of rubisco in rice were altered to be the same as the rubisco in sorghum.

The rate of activity of rubisco in non-GM rice and GM rice was measured at different concentrations of atmospheric carbon dioxide (CO_2).

The results are shown in Fig. 8.1.

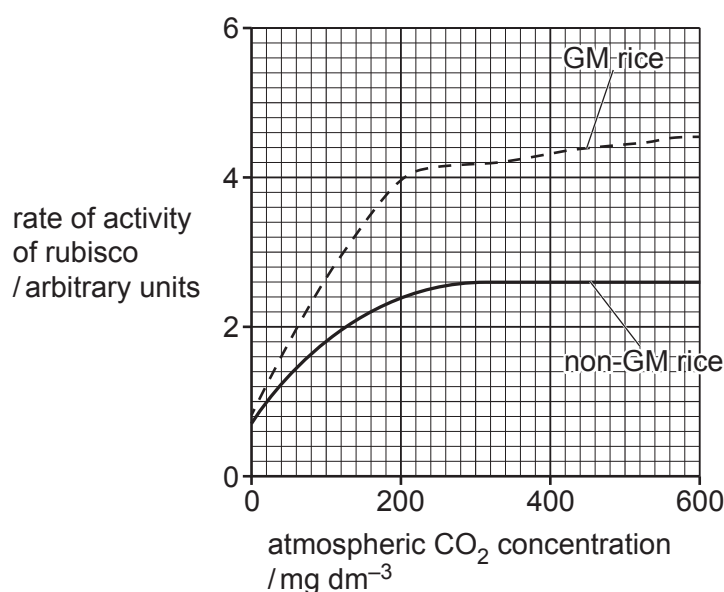


Fig. 8.1

- (i) Compare the two curves shown in Fig. 8.1 **and** explain why the curve for non-GM rice levels off.

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..... [3]

- (ii) Suggest which part of the rubisco molecule was altered to produce the GM variety of rice.

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..... [1]

(b) Fig. 8.2 shows an outline of the Calvin cycle.

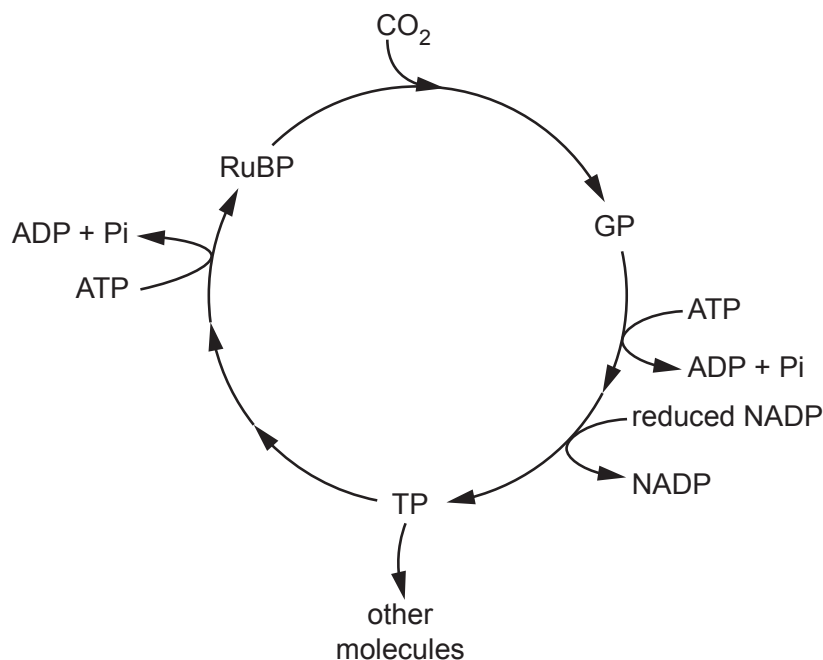


Fig. 8.2

(i) Name the process that involves the enzyme rubisco.

..... [1]

(ii) State the type of reaction that occurs when GP is converted to TP .

..... [1]

(iii) RuBP is regenerated from molecules of TP .

State how many molecules of RuBP are produced from 10 molecules of TP .

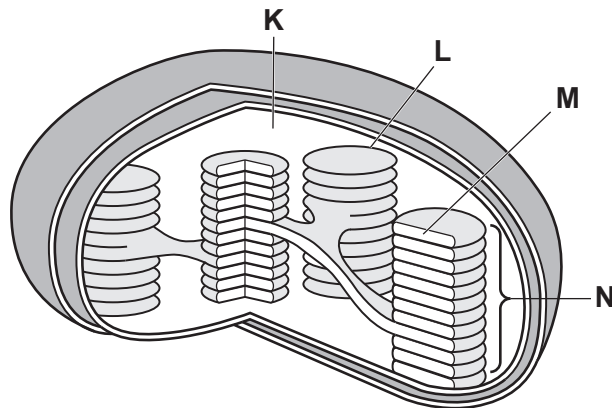
..... [1]

(iv) TP molecules that are **not** involved in the regeneration of RuBP can be used in the synthesis of other molecules.

State **two** molecules that can be produced from these TP molecules.

.....
..... [2]

[Total: 9]



Each letter may be used once, more than once, or not at all.

	letter
high concentration of protons	
location of photosynthetic pigments	
site of light-independent stage	
site of light-dependent stage	

[4]

[4]

[Total: 12]

1 Chloroplasts carry out photosynthesis.

Fig. 1.1 shows some structural features of a chloroplast and some processes that occur within it.

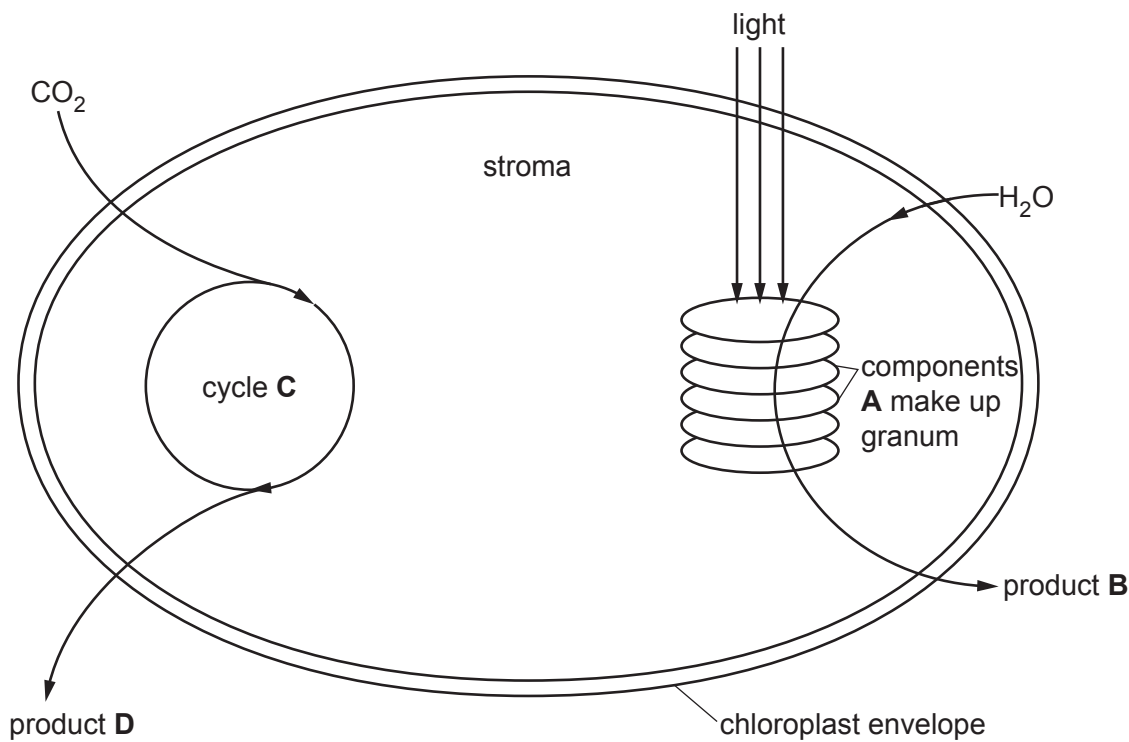


Fig. 1.1

(a) (i) Identify the structures labelled **A** in Fig. 1.1.

A [1]

(ii) Explain how the structure **and** appearance of the granum, and the components labelled **A**, relate to their function.

.....
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.....
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.....
.....
..... [4]

(b) (i) Identify the metabolic pathway labelled cycle **C** in Fig. 1.1.

C [1]

(ii) Explain why pathway **C** is described as a cycle.

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..... [2]

(c) (i) Identify the products of photosynthesis labelled **B** and **D** in Fig. 1.1.

B

D [2]

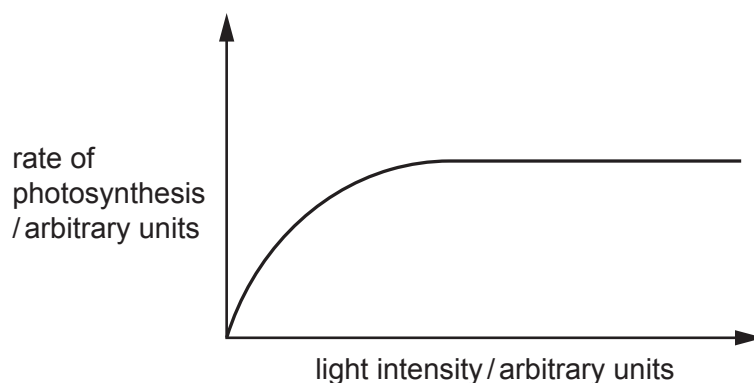
(ii) Suggest **and** explain the importance of glucose and the product labelled **B** in Fig. 1.1 to ecosystems.

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..... [3]

[Total: 13]

8 Environmental conditions such as light intensity affect plant physiology.

- (a) Use the letter **X** to identify a point on the sketch graph in Fig. 8.1 where light intensity is acting as a limiting factor on the rate of photosynthesis. [1]

**Fig. 8.1**

- (b) An experiment investigated how light intensity affected gene expression in kale, *Brassica oleracea sabellica*.

- Two groups of kale plants were grown, with one group in high light intensity and one group in low light intensity. All other conditions were standardised.
- After the same period of time, messenger RNA (mRNA) was extracted from each group of kale plants.
- The mRNA was used to produce cDNA.
- The cDNA was hybridised with probes for 89621 kale genes on a microarray.
- The microarrays showed which genes were switched on (expressed) in each set of conditions.

The results showed that expression of 18% of the genes was affected by light intensity.

- 14% of the genes were switched on only in high light intensity.
- 4% were switched on only in low light intensity.

- (i) State the name of the enzyme that produces cDNA from an mRNA template.

..... [1]

- (ii) State the name of the type of proteins that control gene expression in plants.

..... [1]

(iii) Suggest why **more** genes were switched on only in plants growing in **high** light intensity compared to fewer genes that were switched on only in plants growing in low light intensity.

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..... [3]

[Total: 6]

8 (a) Non-cyclic photophosphorylation occurs in the light-dependent stage of photosynthesis.

Outline the main features of non-cyclic photophosphorylation.

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..... [4]

(b) Some Calvin cycle intermediates are used to produce other molecules that are **not** part of the Calvin cycle.

Name **two** of these intermediates.

For each intermediate, state **one** example of the type of molecule that is produced.

intermediate	.....
molecule produced	.....
intermediate	.....
molecule produced	.....

[2]

(c) Fig. 8.1 shows how the rate of uptake of carbon dioxide by a plant varies with temperature, at an optimum intensity of light on a clear day.

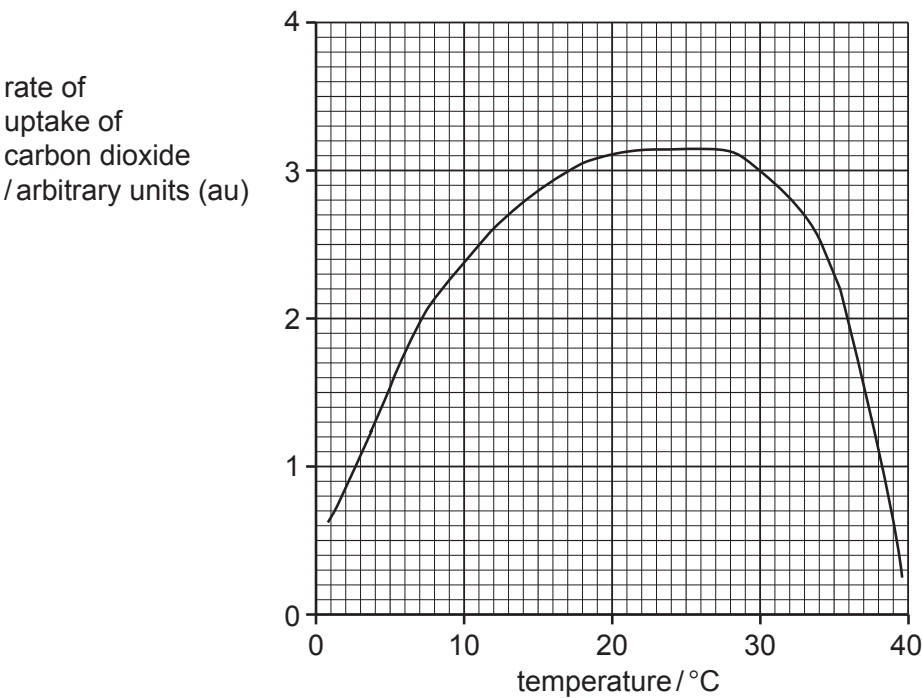


Fig. 8.1

(i) Calculate the mean increase in rate of uptake of carbon dioxide as the temperature increases from 5 °C to 20 °C.

Show your working.

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

..... au °C⁻¹ [2]

(ii) Suggest why the rate of carbon dioxide uptake levels off and then decreases after 20 °C.

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.....
.....
..... [3]

(iii) On Fig. 8.1, draw a curve to show the uptake of carbon dioxide on a cloudy day. [1]

1 Chloroplasts carry out photosynthesis.

Fig. 1.1 shows some structural features of a chloroplast and some processes that occur within it.

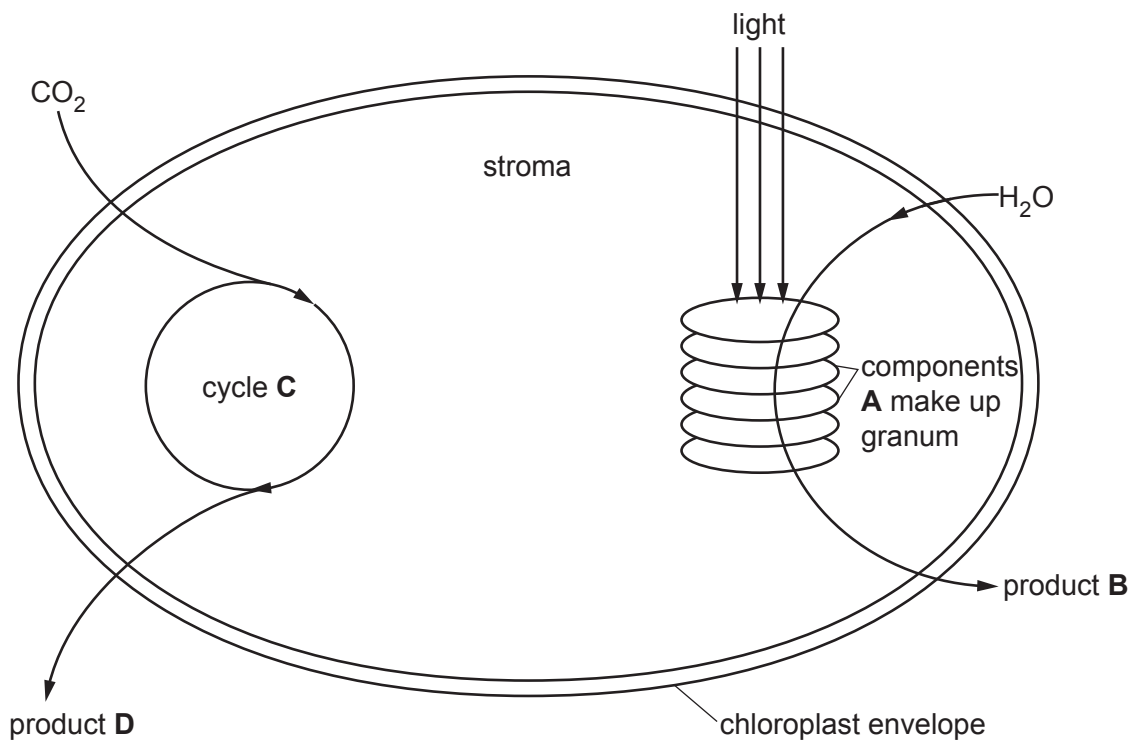


Fig. 1.1

(a) (i) Identify the structures labelled **A** in Fig. 1.1.

A [1]

(ii) Explain how the structure **and** appearance of the granum, and the components labelled **A**, relate to their function.

.....

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..... [4]

(b) (i) Identify the metabolic pathway labelled cycle **C** in Fig. 1.1.

C [1]

(ii) Explain why pathway **C** is described as a cycle.

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.....
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.....
.....
..... [2]

(c) (i) Identify the products of photosynthesis labelled **B** and **D** in Fig. 1.1.

B

D [2]

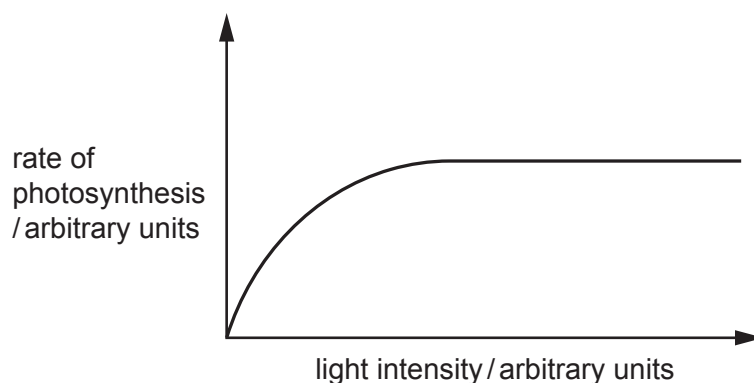
(ii) Suggest **and** explain the importance of glucose and the product labelled **B** in Fig. 1.1 to ecosystems.

.....
.....
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.....
.....
.....
..... [3]

[Total: 13]

8 Environmental conditions such as light intensity affect plant physiology.

- (a) Use the letter **X** to identify a point on the sketch graph in Fig. 8.1 where light intensity is acting as a limiting factor on the rate of photosynthesis. [1]

**Fig. 8.1**

- (b) An experiment investigated how light intensity affected gene expression in kale, *Brassica oleracea sabellica*.

- Two groups of kale plants were grown, with one group in high light intensity and one group in low light intensity. All other conditions were standardised.
- After the same period of time, messenger RNA (mRNA) was extracted from each group of kale plants.
- The mRNA was used to produce cDNA.
- The cDNA was hybridised with probes for 89621 kale genes on a microarray.
- The microarrays showed which genes were switched on (expressed) in each set of conditions.

The results showed that expression of 18% of the genes was affected by light intensity.

- 14% of the genes were switched on only in high light intensity.
- 4% were switched on only in low light intensity.

- (i) State the name of the enzyme that produces cDNA from an mRNA template.

..... [1]

- (ii) State the name of the type of proteins that control gene expression in plants.

..... [1]

(iii) Suggest why **more** genes were switched on only in plants growing in **high** light intensity compared to fewer genes that were switched on only in plants growing in low light intensity.

.....

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..... [3]

[Total: 6]

- 7 (a) The light-dependent stage of photosynthesis occurs within chloroplasts. In this stage, electrons are emitted from the chlorophyll *a* molecules and passed to electron acceptors.

If a redox indicator, such as DCPIP, is added to a suspension of illuminated chloroplasts, electrons will be transferred to DCPIP, causing the colour of the DCPIP to change from blue to colourless.

A student investigated the effect of the wavelength of light (colour of light) on the rate of photosynthesis.

- DCPIP was added to three colorimeter tubes, each containing a suspension of chloroplasts. The chloroplast suspensions were kept in the dark until required.
- The colorimeter tubes were each exposed to light of a different colour: red, blue or green. The intensity of light was the same for all tubes, and each was exposed to light for four minutes. All other conditions were kept the same.
- The absorbance of each chloroplast suspension was measured at one-minute intervals using a colorimeter.

The results are shown in Fig. 7.1.

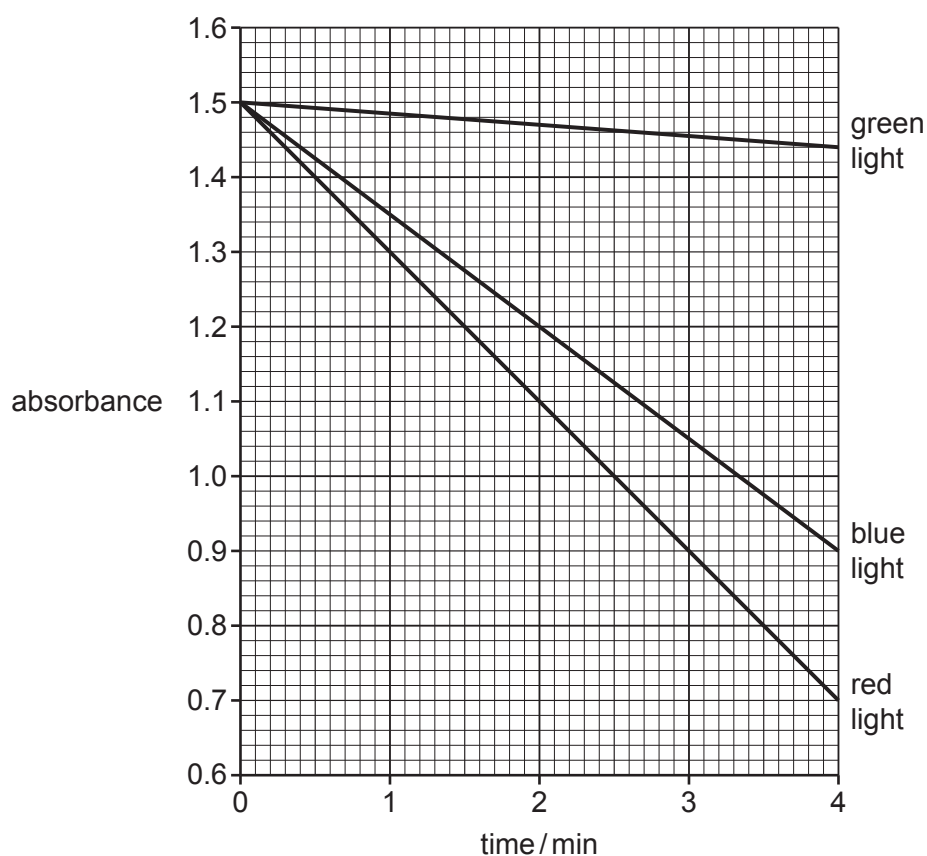


Fig. 7.1

- (i) Explain why the chloroplast suspensions were kept in the dark until required.

.....

.....

..... [1]

(ii) Describe the results shown in Fig. 7.1.

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..... [3]

(iii) With reference to the light-dependent stage of photosynthesis, explain the differences between the results shown in Fig. 7.1 for red light and for green light.

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..... [3]

(b) Changes in the atmospheric carbon dioxide concentration, light intensity and temperature can affect the rate of photosynthesis. These three factors directly affect different processes of photosynthesis.

Complete Table 7.1 using a tick (✓) to identify the processes that can be **directly** affected by each factor or a cross (✗) to identify the processes that are **not directly** affected by each factor.

Indirect effects where a change in the rate of one process affects the rate of a different process should **not** be considered.

A tick or a cross must be placed in the final column of every row.

Table 7.1

factor	process	✓ or ✗
carbon dioxide concentration	Calvin cycle	.....
	photophosphorylation	.....
light intensity	Calvin cycle	.....
	photophosphorylation	.....
temperature	Calvin cycle	.....
	photophosphorylation	.....

[3]

[Total: 10]

- 7 (a) A student investigated the effect of temperature on the rate of photosynthesis at two different light intensities. The rate of photosynthesis was determined by measuring the rate of oxygen production of the plant.

Fig. 7.1 shows the result of the investigation.

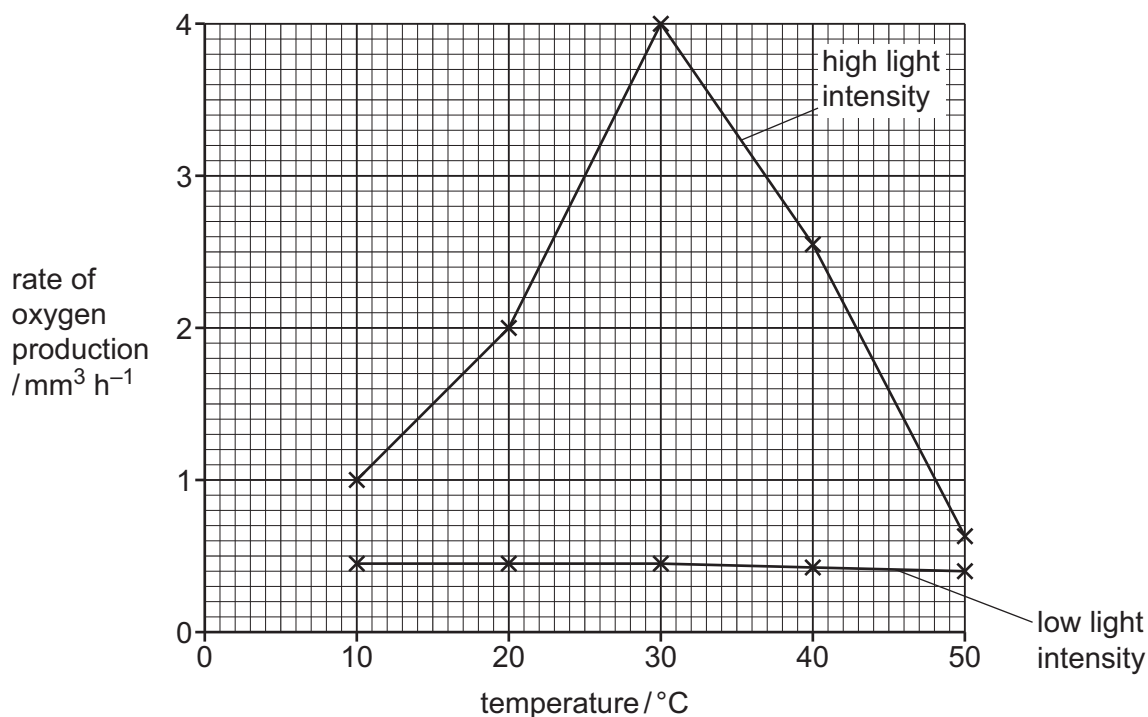


Fig. 7.1

- (i) With reference to Fig. 7.1, describe **and** explain the results of the investigation for the plant in **low** light intensity.

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..... [3]



(ii) With reference to Fig. 7.1, describe **and** explain the results of the investigation for the plant in **high** light intensity **above** 30 °C.

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..... [3]

(b) Describe the process that produces oxygen during non-cyclic photophosphorylation.

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..... [3]

- 7 (a) Experiments were carried out to determine the effect of light intensity on the rate of photosynthesis of a species of the unicellular protocist, *Chlorella*. A cell suspension of *Chlorella* was used.

Carbon dioxide uptake was used as a measure of the rate of photosynthesis.

- The suspension of *Chlorella* was illuminated at a light intensity of 3 lux for 20 seconds.
- The carbon dioxide uptake by *Chlorella* was measured at the end of the 20 second period of illumination.
- The experiment was repeated at 6 lux, 9 lux, 12 lux and in a dark room.
- The suspension was maintained at a temperature of 20 °C.

Table 7.1 shows the results of the experiments.

Table 7.1

light intensity /lux	total CO ₂ uptake after 20 seconds /μmol	rate of photosynthesis /μmol s ⁻¹
0	0	0.0
3	20	1.0
6	44	.....
9	72	3.6
12	80	4.0

- (i) Use Table 7.1 to calculate the rate of photosynthesis at a light intensity of 6 lux.

Complete Table 7.1 by writing your calculated value in the space provided. [1]

(ii) Plot a graph of the data in Table 7.1 on the grid in Fig. 7.1 to show the effect of light intensity on the rate of photosynthesis.

Draw a curve **and** extend your curve to show what would happen to the rate of photosynthesis if the experiment is carried out at 18 lux.

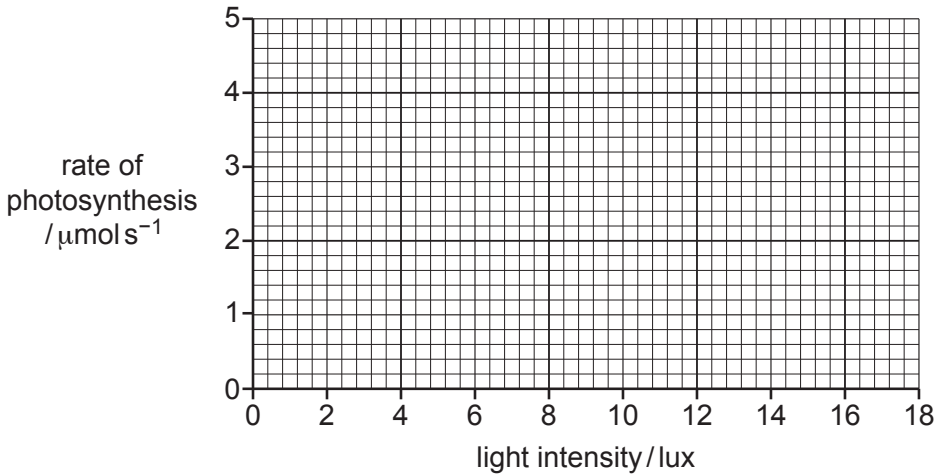


Fig. 7.1

[3]

(iii) Suggest an explanation for the shape of your curve from 12 lux to 18 lux.

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..... [2]

(b) In photophosphorylation, photoactivation of chlorophyll results in the synthesis of ATP.

Describe how photoactivation of chlorophyll results in the synthesis of ATP in photophosphorylation.

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..... [4]

[Total: 10]

- (a)** Explain why it is important for plants to open and close their stomata in a daily rhythm.

[3]

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- open stomata / %
- time/hours
- Key
- day
- night
- | Time (hours) | Open Stomata (%) | Period |
|--------------|------------------|--------|
| 0 | 10 | Day |
| 6 | 90 | Day |
| 12 | 75 | Day |
| 18 | 40 | Night |
| 24 | 25 | Night |
| 30 | 75 | Day |
| 36 | 90 | Day |
| 42 | 40 | Night |
| 48 | 25 | Night |
| 54 | 75 | Day |
| 60 | 85 | Day |
| 66 | 50 | Night |

Fig. 2.1

[illegible]



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..... [6]

(c) The experiment was repeated with *A. thaliana* plants that were left in darkness from 14 to 96 hours. The results are shown in Fig. 2.2.

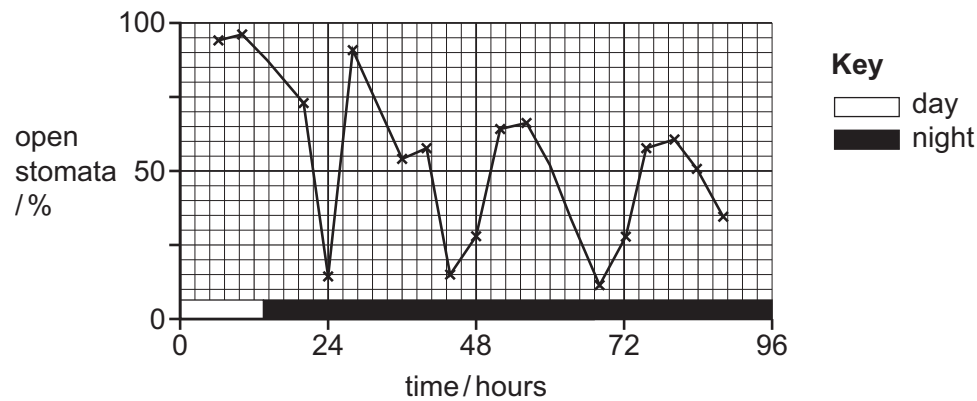


Fig. 2.2

With reference to Fig. 2.1, explain what Fig. 2.2 shows about the role of genes and the role of the environment in controlling the rhythm of stomatal opening and closing in *A. thaliana*.

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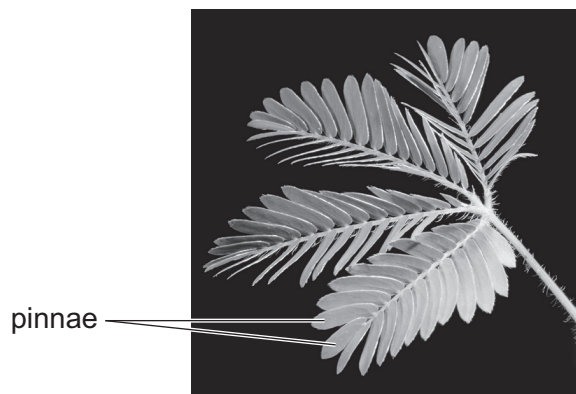
..... [2]

[Total: 11]

71. Question part 1/2 | 9700 Oct-Nov 2024 P4 V1 Q4

- 4 The leaves of *Mimosa pudica* plants are made of a number of structures known as pinnae. The pinnae fold when the leaf is touched. This closes the leaf.

Fig. 4.1 shows an open leaf of *M. pudica* before it is touched. Fig. 4.2 shows the same leaf that has closed after being touched.



A open (not touched)

Fig. 4.1



B closed (touched)

Fig. 4.2

- (a) A touch stimulus to an *M. pudica* leaf causes an action potential to be generated.

The action potential results in changes in cells, which cause the leaf to close.

Fig. 4.3 shows the mechanism in *M. pudica* cells that causes the leaf to close.

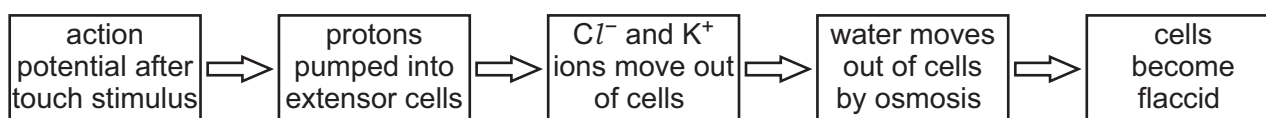


Fig. 4.3

The leaves of *M. pudica* and the leaves of Venus fly traps move in response to touch stimuli, but the mechanisms that cause the responses are different.

Describe the differences between the mechanism shown in Fig. 4.3 and the mechanism that causes the closure of the modified leaves in Venus fly traps.

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Topical questions | 84 questions



- [2]

- [6]

[Total: 11]

7 (a) Paper chromatography is a technique that can be used to separate and identify different chloroplast pigments.

Describe how the **results** of paper chromatography can be used to identify chloroplast pigments.

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..... [3]

(b) Carotene and xanthophyll are chloroplast pigments.

Describe the role played by these pigments in photosynthesis.

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..... [3]

9700 Biology Paper 4 - Photosynthesis

Topical questions | 84 questions

72. Question part 2/2 | 9700 Oct-Nov 2024 P4 V2 Q7



- (c) The light-dependent stage of photosynthesis produces ATP and reduced NADP, which are used in the light-independent stage.

Describe the **light-independent** stage of photosynthesis.

[7]

[Total: 13]

- (a)** Explain why it is important for plants to open and close their stomata in a daily rhythm.

[3]

-
- Key**
- day
■ night
- | Time (hours) | Open Stomata (%) | Light/Dark |
|--------------|------------------|------------|
| 0 | 15 | Day |
| 6 | 90 | Day |
| 12 | 75 | Day |
| 18 | 45 | Day |
| 24 | 25 | Night |
| 30 | 75 | Night |
| 36 | 90 | Night |
| 42 | 55 | Night |
| 48 | 35 | Day |
| 54 | 85 | Day |
| 60 | 75 | Day |
| 66 | 55 | Day |

Fig. 2.1

[illegible]

73. Question part 2/2 | 9700 Oct-Nov 2024 P4 V3 Q2



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..... [6]

(c) The experiment was repeated with *A. thaliana* plants that were left in darkness from 14 to 96 hours. The results are shown in Fig. 2.2.

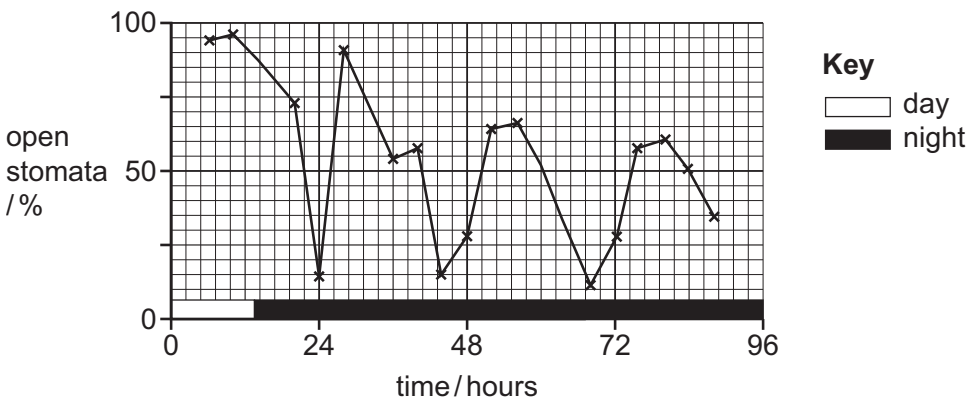


Fig. 2.2

With reference to Fig. 2.1, explain what Fig. 2.2 shows about the role of genes and the role of the environment in controlling the rhythm of stomatal opening and closing in *A. thaliana*.

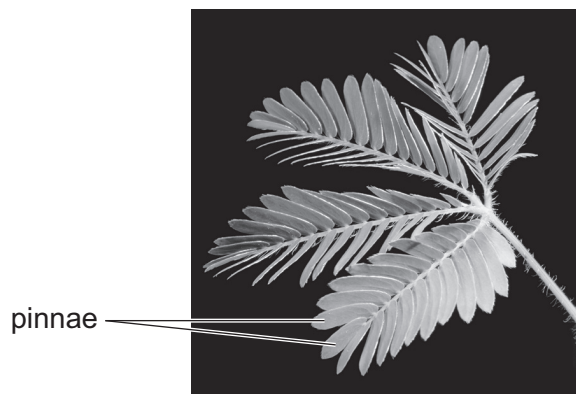
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..... [2]

[Total: 11]

74. Question part 1/2 | 9700 Oct-Nov 2024 P4 V3 Q4

- 4 The leaves of *Mimosa pudica* plants are made of a number of structures known as pinnae. The pinnae fold when the leaf is touched. This closes the leaf.

Fig. 4.1 shows an open leaf of *M. pudica* before it is touched. Fig. 4.2 shows the same leaf that has closed after being touched.



A open (not touched)

Fig. 4.1



B closed (touched)

Fig. 4.2

- (a) A touch stimulus to an *M. pudica* leaf causes an action potential to be generated.

The action potential results in changes in cells, which cause the leaf to close.

Fig. 4.3 shows the mechanism in *M. pudica* cells that causes the leaf to close.

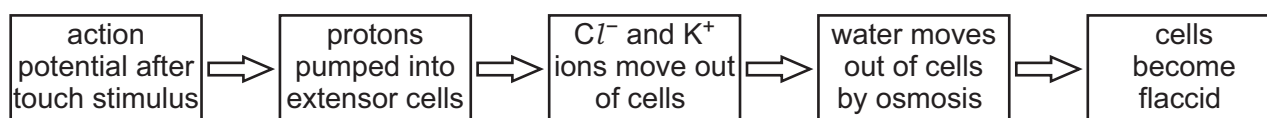


Fig. 4.3

The leaves of *M. pudica* and the leaves of Venus fly traps move in response to touch stimuli, but the mechanisms that cause the responses are different.

Describe the differences between the mechanism shown in Fig. 4.3 and the mechanism that causes the closure of the modified leaves in Venus fly traps.

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Topical questions | 84 questions



- [2]

- [6]

[Total: 11]

75. Question part 1/2 | 9700 Feb-March 2025 P4 V2 Q9

9 The chloroplasts of leaves of tobacco plants, *Nicotiana* sp., contain chlorophyll *a* and chlorophyll *b*.

(a) Describe the role of chlorophyll *b* in photosynthesis.

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..... [2]

(b) A mutant tobacco plant was found to contain more chlorophyll *b* than normal tobacco plants.

An investigation was carried out to measure the rate of photosynthesis of normal and mutant tobacco plants at increasing light intensities. The rate of production of oxygen was used as a measure of the rate of photosynthesis.

Other variables were kept constant.

Fig. 9.1 shows the results of this investigation.

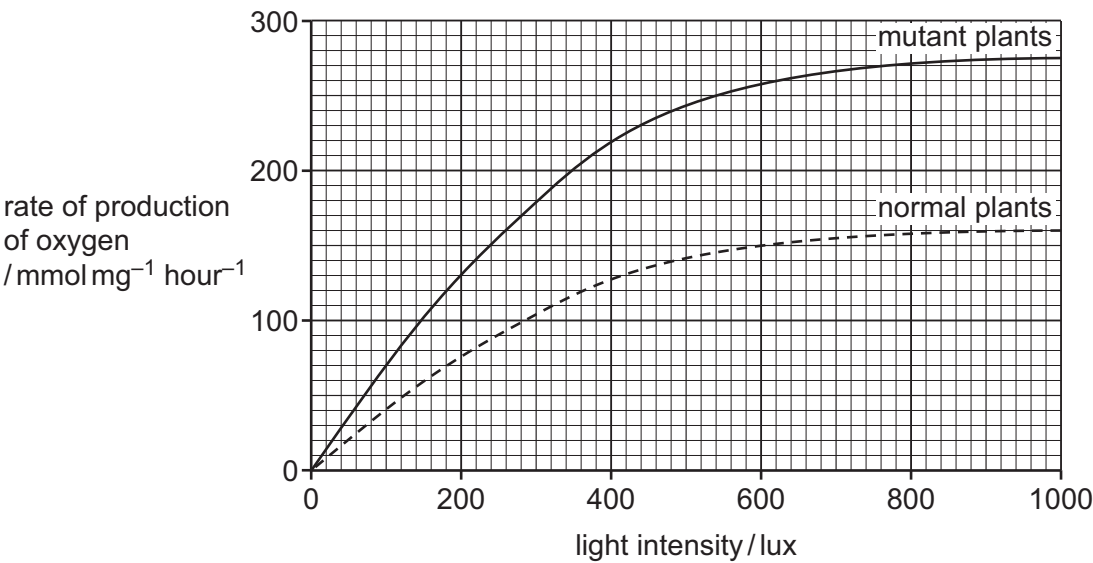


Fig. 9.1

75. Question part 2/2 | 9700 Feb-March 2025 P4 V2 Q9



(i) Describe the results shown in Fig. 9.1.

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..... [3]

(ii) It was observed that the mutant tobacco plants had a faster growth rate than the normal tobacco plants.

Suggest explanations for this observation.

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..... [4]

[Total: 9]

76. Question part 1/3 | 9700 May-June 2025 P4 V1 Q4

4 Scientists have invented a way of producing food by artificial photosynthesis.

- Solar panels convert sunlight energy into electricity.
- The electricity powers an electrolysis reaction between carbon dioxide gas and water to form the organic product acetate.
- The single-celled alga *Chlamydomonas*, a protocist, can use acetate to grow and reproduce in the dark, instead of photosynthesising in the light.
- The algae can be processed to make a food product.

Fig. 4.1 shows an outline of the artificial photosynthesis process.

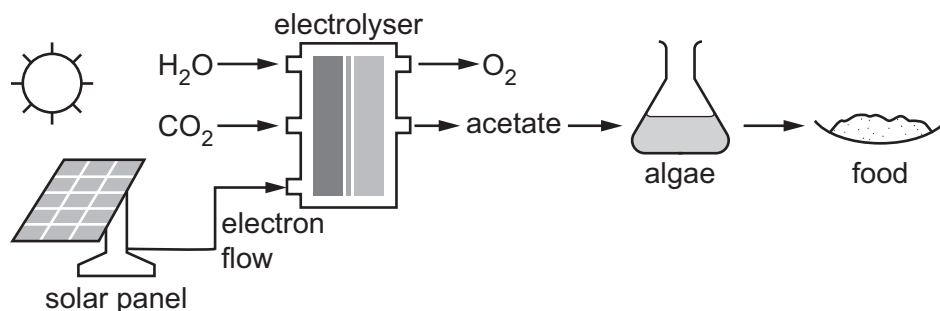


Fig. 4.1

(a) Identify **three** similarities between the artificial photosynthesis process shown in Fig. 4.1 and the normal process of photosynthesis.

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..... [3]

76. Question part 2/3 | 9700 May-June 2025 P4 V1 Q4



- (b) Fig. 4.2 shows the single-celled alga *Chlamydomonas*. It contains a large, cup-shaped chloroplast for photosynthesis.



Fig. 4.2

Structures **A** and **B** in Fig. 4.2 are found within the chloroplast.

Name structures **A** and **B**.

A

B

[2]

- (c) Thylakoid membranes are the site of the light-dependent stage of photosynthesis.

- (i) Name the products of the light-dependent stage of photosynthesis.

..... [1]

76. Question part 3/3 | 9700 May-June 2025 P4 V1 Q4



- (ii) Some of the protein components of the thylakoid membrane have a role in the light-dependent stage of photosynthesis.

Explain the roles of the different proteins that function in the light-dependent stage of photosynthesis.

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..... [4]

- (d) The products of the light-dependent stage of photosynthesis are used in the Calvin cycle. Calvin cycle intermediates are used to produce amino acids, carbohydrates and lipids.

Name the Calvin cycle intermediate that can be used to produce starch.

..... [1]

- (e) Scientists claim that the artificial photosynthesis process shown in Fig. 4.1 is more efficient at converting light energy into food than normal photosynthesis by crop plants.

Give reasons why this claim may or may **not** be true.

true

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not true

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..... [3]

77. Question part 1/2 | 9700 May-June 2025 P4 V2 Q8

- 8 A lichen describes a mutually beneficial association of a fungus with an organism termed a photobiont. An example of a photobiont is the green alga, *Trebouxia* sp., which is a photosynthetic protocist.

Fig. 8.1 shows lichen attached to a tree.



Fig. 8.1

- (a) Outline the characteristic features of the kingdom Fungi.

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..... [4]

- (b) Suggest how a fungus **and** a green alga benefit from the relationship shown by a lichen.

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77. Question part 2/2 | 9700 May-June 2025 P4 V2 Q8



(c) A suspension of *Trebouxia* in water was used to investigate the effect of the intensity of light on the rate of photosynthesis. The volume of oxygen released over a set period of time was used as a measure of the rate of photosynthesis at each different light intensity.

All other conditions were kept constant.

Fig. 8.2 shows how light intensity affected the volume of oxygen released by *Trebouxia*.

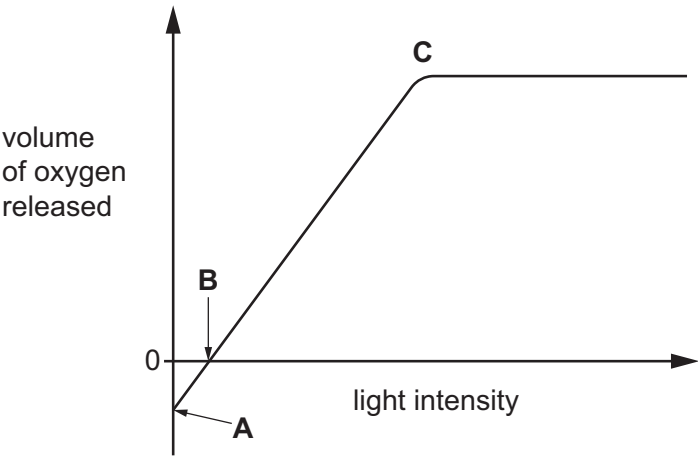


Fig. 8.2

(i) State which photosystem is involved in the release of oxygen.

..... [1]

(ii) With reference to Fig. 8.2:

- explain the curve between **A** and **B**
- explain why the curve levels off after **C**.

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..... [4]

[Total: 11]

78. Question part 1/2 | 9700 May-June 2025 P4 V3 Q7

7 (a) A chloroplast is composed of many structures, each with a different function. Several chloroplast structures are listed.

- stroma
- lamellae
- thylakoid membrane
- ribosome
- thylakoid space
- starch grain
- DNA
- outer membrane

From the list:

(i) identify the structures involved in the production of rubisco

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.....

[2]

(ii) identify the structure that contains a high concentration of protons in daylight.

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[1]

(b) Paper chromatography is a technique that can be used to separate a mixture of four common chloroplast pigments. The pigments can be identified by calculating their R_f values.

A student carried out paper chromatography on a solution containing a mixture of chloroplast pigments.

The results are shown in Table 7.1.

Table 7.1

pigment	distance travelled by pigment from baseline / cm	distance travelled by solvent from baseline / cm	R_f
.....	6.5	8.9	0.73
chlorophyll a	4.6	8.9	0.52
chlorophyll b	.....	8.9	0.38
carotene	8.2	8.9	.....

Complete Table 7.1.

[3]

78. Question part 2/2 | 9700 May-June 2025 P4 V3 Q7



(c) Fig. 7.1 shows the absorption spectrum for carotene and for chlorophyll a.

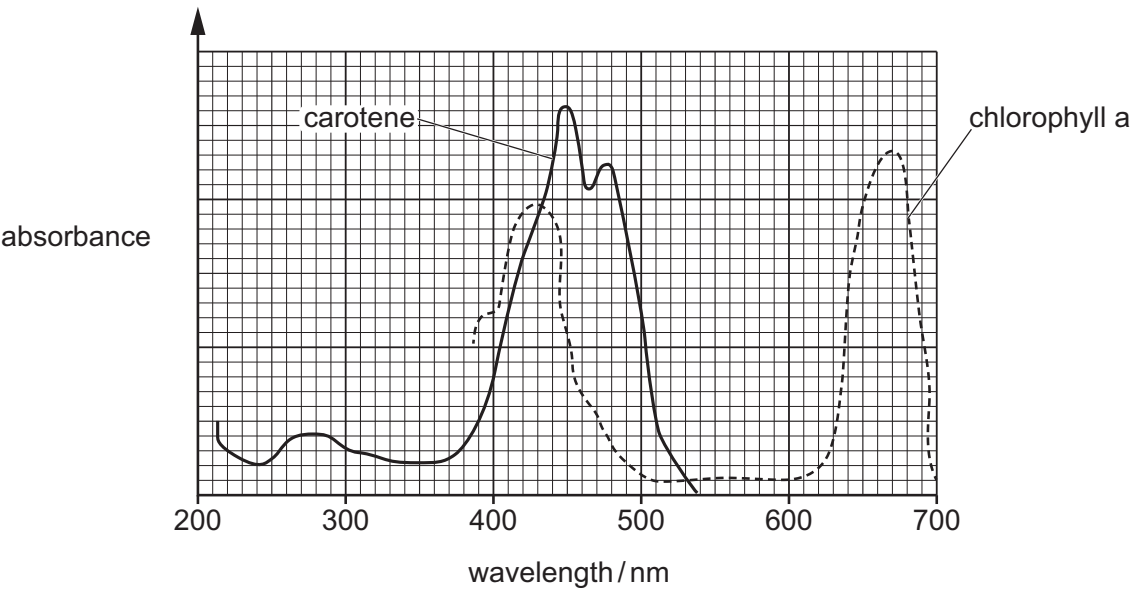


Fig. 7.1

With reference to Fig. 7.1, describe **and** explain the role of carotene in photosynthesis.

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..... [4]

[Total: 10]

- (a) An experiment was carried out to investigate the development of aerenchyma tissue in the roots of rice plants.

- 10-day old seedlings were grown with their roots submerged in water.
- Some were grown in water that was kept oxygenated and others were grown in water that did not contain oxygen (deoxygenated).
- At 12 hour intervals, some seedlings from each group were removed and transverse sections of their roots were prepared and examined.
- The sections were cut at the same distances from the root tip to check for development.
- The percentage of root tissue that had developed into aerenchyma tissue was calculated.

The graph shows the percentage of root tissue as aerenchyma over a 60-hour period. The y-axis represents the percentage (0 to 10) and the x-axis represents time in hours (0 to 60). Two conditions are compared: oxygenated (solid line with 'x' markers) and deoxygenated (dashed line with 'x' markers). The oxygenated condition remains near 0% throughout, while the deoxygenated condition increases sharply after 24 hours, reaching approximately 6.5% by 48 hours and remaining stable thereafter.

Time (hours)	Oxygenated (%)	Deoxygenated (%)
0	0.0	0.0
12	0.1	0.5
24	0.1	0.8
36	0.1	2.5
48	0.1	6.5
60	0.0	6.5

Fig. 7.1

- (i) Describe the results shown in Fig. 7.1.

..... [3]

(ii) Describe the structure of aerenchyma **and** explain how this is an adaptation that allows roots of rice plants to be submerged in water.

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..... [3]

(b) Describe **and** explain **two** other adaptations of rice plants to growing in flooded fields.

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..... [4]

[Total: 10]



With reference to Fig. 9.1, describe the process of non-cyclic photophosphorylation.

..... [7]

(b) Fig. 9.2 shows the relationship between the rate of photosynthesis and light intensity.

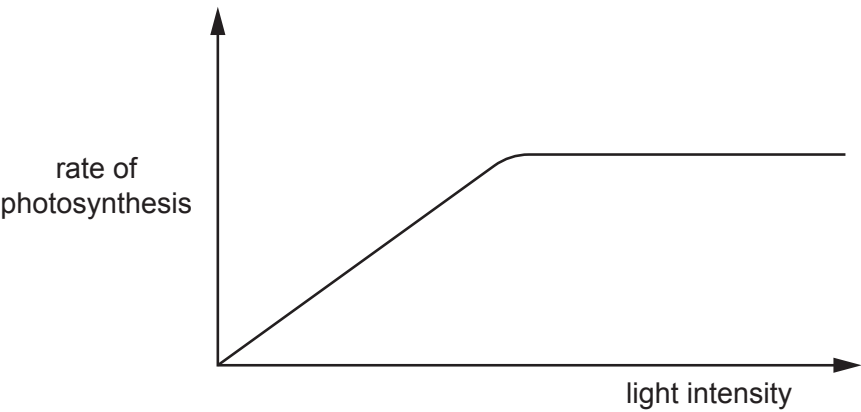


Fig. 9.2

Describe **and** explain the relationship shown in Fig. 9.2.

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..... [3]

[Total: 10]

81. Question part 1/4 | 9700 Oct-Nov 2025 P4 V1 Q3

3 Plants have several different photosynthetic pigments in their chloroplasts.

- (a) A student separated and identified the chloroplast pigments present in a leaf extract from a spinach plant using two slightly different methods.

Method A

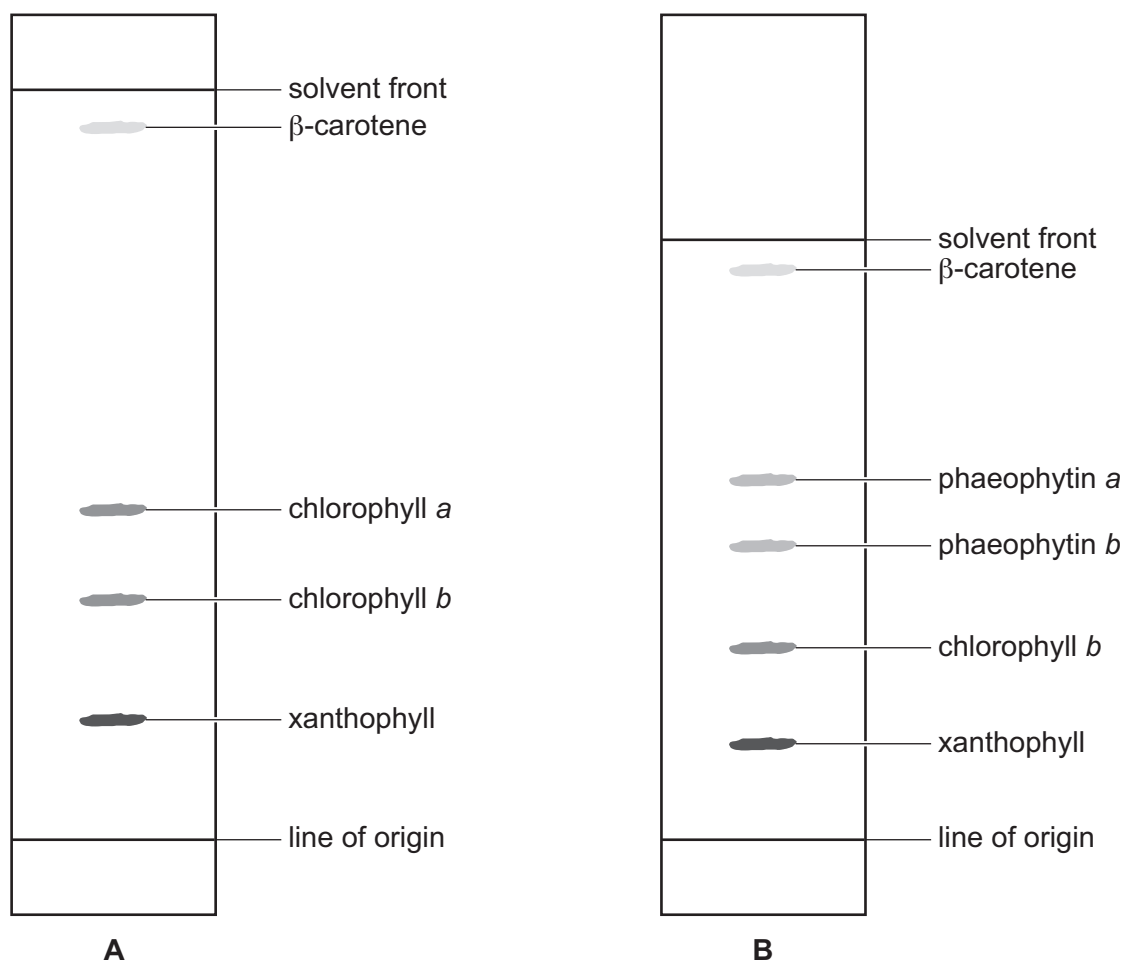
- A type of chromatography known as thin layer chromatography (TLC) was used to separate the pigments.
- A mixture of ether and cyclohexane was used as a solvent in TLC.

Method B

- The student repeated TLC but treated the spinach leaf extract with a chemical. The chemical causes a magnesium ion in a pigment to be replaced by two hydrogen ions.
- The student used a leaf from the same spinach plant, and used the same solvent as in method **A**.

The student calculated R_f values and compared these to reference values to identify the pigments.

Fig. 3.1 shows the results for method **A** and method **B**.

**Fig. 3.1**

81. Question part 2/4 | 9700 Oct-Nov 2025 P4 V1 Q3



(i) Calculate the R_f value of β -carotene in Fig. 3.1.

R_f = ... [2]

(ii) Suggest **two** explanations for the differences in appearance of chromatograms **A** and **B** in Fig. 3.1.

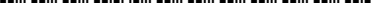
- 1
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-
- 2
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- [2]

(iii) The student found some different R_f values for the chloroplast pigments of spinach in a scientific paper.

The values in the scientific paper were different from the reference values that the student originally used to identify the pigments on chromatograms **A** and **B** in Fig. 3.1.

Suggest **one** reason, other than measurement error, for the different R_f values.

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- [1]



key

———— chlorophyll *a*
- - - - - chlorophyll *b*
..... carotenoids (β -carotene and xanthophyll)



..... [4]

81. Question part 4/4 | 9700 Oct-Nov 2025 P4 V1 Q3



(c) In some species of plant, the absorption of light stimulates seed germination.

The absorption of light increases the production of gibberellin in the embryo of a seed.

Describe the role of gibberellin in the germination of a seed.

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[Total: 13]

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- The graph shows two curves plotted against wavelength (nm) on the x-axis, ranging from 400 to 700 nm. The y-axis represents both light absorption and photosynthetic rate. The 'absorption spectrum' (thick black line) shows high absorption in the blue (400-450 nm) and red (650-700 nm) regions, with a minimum around 550 nm. The 'action spectrum' (thin grey line) shows the rate of photosynthesis, with major peaks in the blue (430 nm) and red (660 nm) regions, closely matching the absorption spectrum. Labels with leader lines identify each curve.

(i) Explain what is meant by an absorption spectrum and an action spectrum.

..... [2]

- [3]



- Fig. 9.2 shows the results of this investigation.



- [4]

82. Question part 3/3 | 9700 Oct-Nov 2025 P4 V2 Q9



- (ii) The rate of photosynthesis in this investigation was obtained by measuring the uptake of carbon dioxide from the atmosphere. It did **not** take into account the use of carbon dioxide produced by respiration.

Using Fig. 9.2, calculate the rate of photosynthesis at 20 °C when the carbon dioxide produced by respiration is taken into account.

rate of photosynthesis [2]

[Total: 11]

83. Question part 1/4 | 9700 Oct-Nov 2025 P4 V3 Q3

3 Plants have several different photosynthetic pigments in their chloroplasts.

- (a) A student separated and identified the chloroplast pigments present in a leaf extract from a spinach plant using two slightly different methods.

Method A

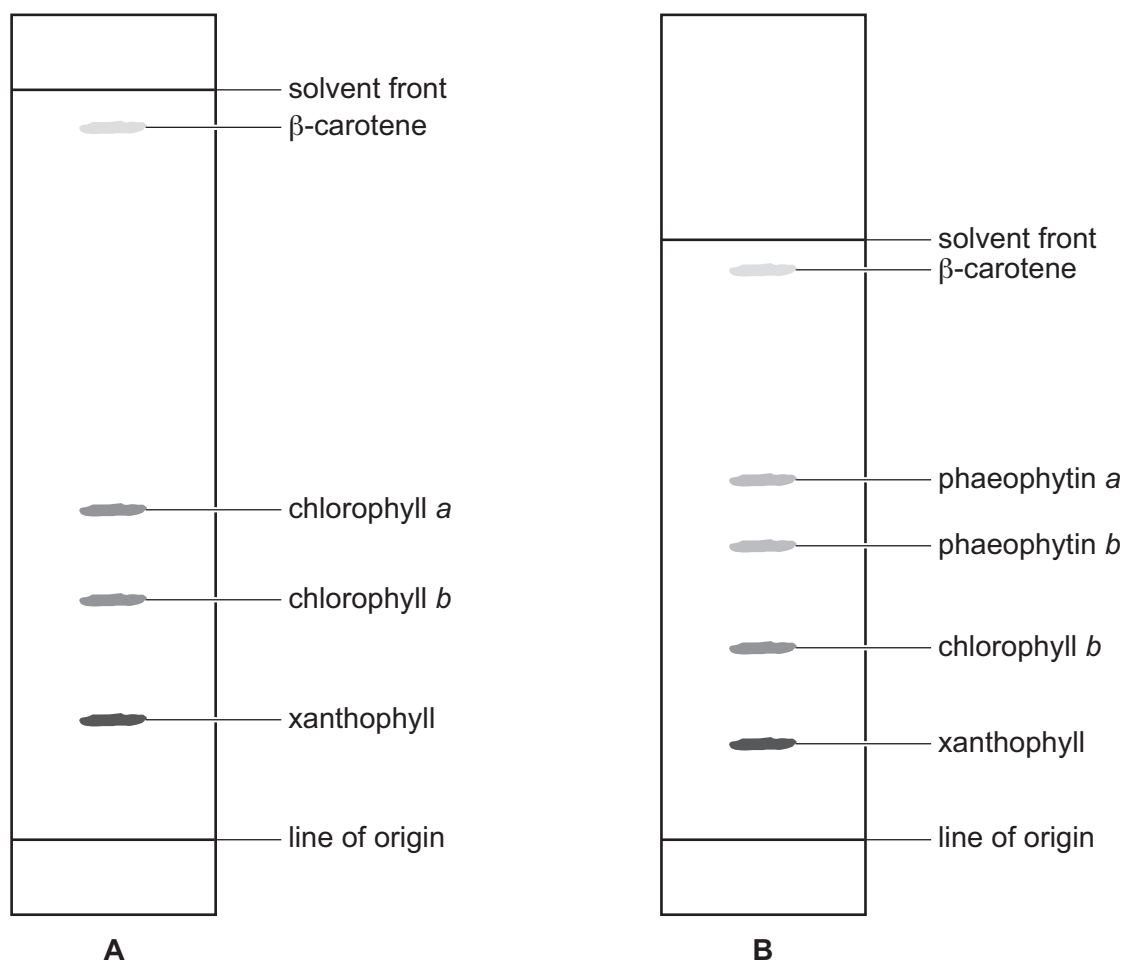
- A type of chromatography known as thin layer chromatography (TLC) was used to separate the pigments.
- A mixture of ether and cyclohexane was used as a solvent in TLC.

Method B

- The student repeated TLC but treated the spinach leaf extract with a chemical. The chemical causes a magnesium ion in a pigment to be replaced by two hydrogen ions.
- The student used a leaf from the same spinach plant, and used the same solvent as in method **A**.

The student calculated R_f values and compared these to reference values to identify the pigments.

Fig. 3.1 shows the results for method **A** and method **B**.

**Fig. 3.1**

83. Question part 2/4 | 9700 Oct-Nov 2025 P4 V3 Q3



(i) Calculate the R_f value of β -carotene in Fig. 3.1.

R_f = ... [2]

(ii) Suggest **two** explanations for the differences in appearance of chromatograms **A** and **B** in Fig. 3.1.

- 1
-
-
- 2
-
-
- [2]

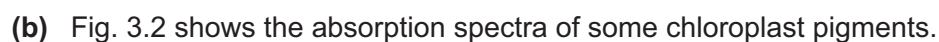
(iii) The student found some different R_f values for the chloroplast pigments of spinach in a scientific paper.

The values in the scientific paper were different from the reference values that the student originally used to identify the pigments on chromatograms **A** and **B** in Fig. 3.1.

Suggest **one** reason, other than measurement error, for the different R_f values.

.....

..... [1]



..... [4

83. Question part 4/4 | 9700 Oct-Nov 2025 P4 V3 Q3



(c) In some species of plant, the absorption of light stimulates seed germination.

The absorption of light increases the production of gibberellin in the embryo of a seed.

Describe the role of gibberellin in the germination of a seed.

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..... [4]

[Total: 13]

84. Question | 9700 Oct-Nov 2025 P4 V4 Q10

10 (a) Cyclic photophosphorylation and non-cyclic photophosphorylation occur during the light-dependent stage of photosynthesis.

Outline the **differences** between cyclic photophosphorylation and non-cyclic photophosphorylation.

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..... [3]

(b) Complete the passage about the Calvin cycle using the most appropriate word or words.

A molecule of combines with a five-carbon molecule, ribulose bisphosphate (RuBP), catalysed by the enzyme

This reaction produces a six-carbon compound that splits into two molecules of a three-carbon compound, glycerate 3-phosphate (GP).

ATP and are used to convert GP molecules into molecules of a three-carbon sugar, triose phosphate (TP).

Some TP molecules are used to make, while others are recycled to regenerate RuBP using ATP.

[4]

[Total: 7]