13. Photosynthesis

13.2 Investigation of Limiting Factors

Paper 4

Question Paper

1 **(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.

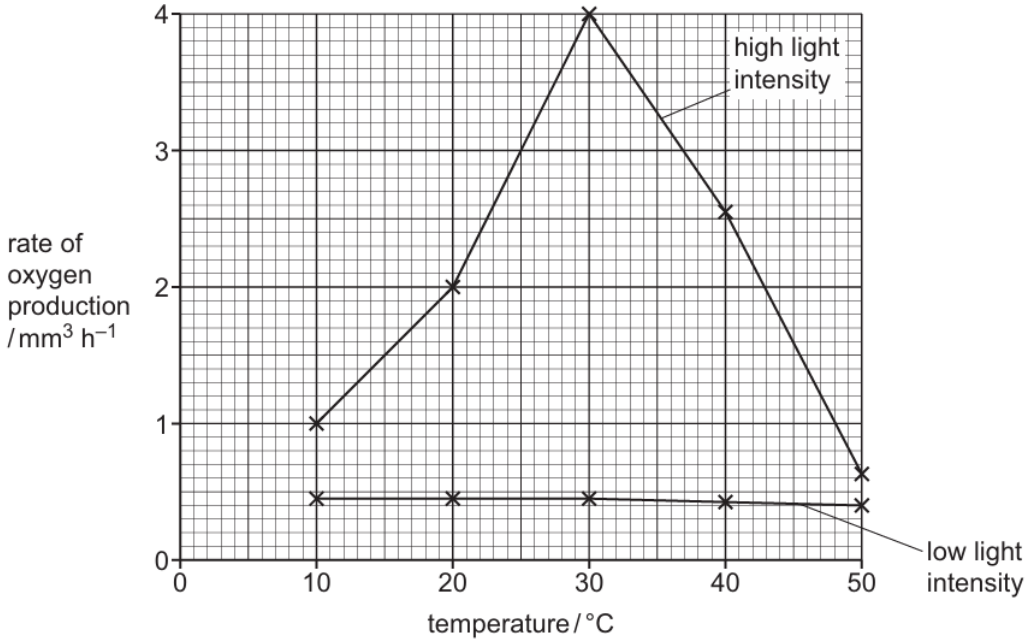


Fig. 7.1

(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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(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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2 Photosynthesis is the energy transfer process that occurs in chloroplasts.

Fig. 5.1 shows some biochemical events that occur in a chloroplast during the light-dependent stage of photosynthesis. Photosystems I and II (PSI and PSII) and some associated proteins of the thylakoid membrane are shown.

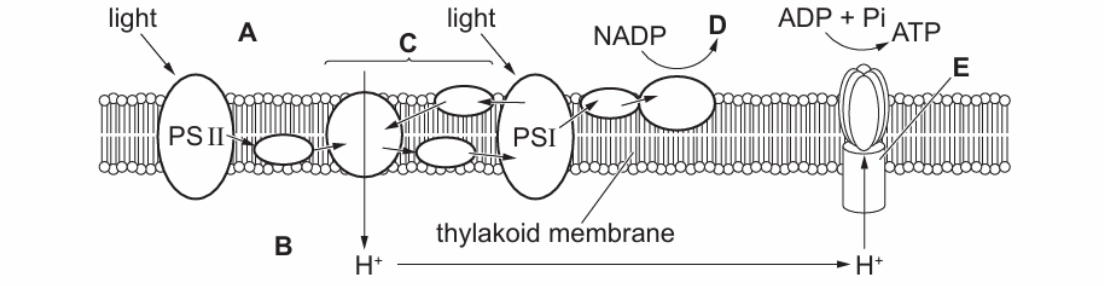


Fig. 5.1

(b) The rate at which plants use photosynthesis to transfer light energy into chemical energy that is stored in plant biomass can be measured in megajoules per square metre per year ($MJ\,m^{-2}\,yr^{-1}$).

Fig. 5.2 compares the rates of energy transfer for different ecosystems.

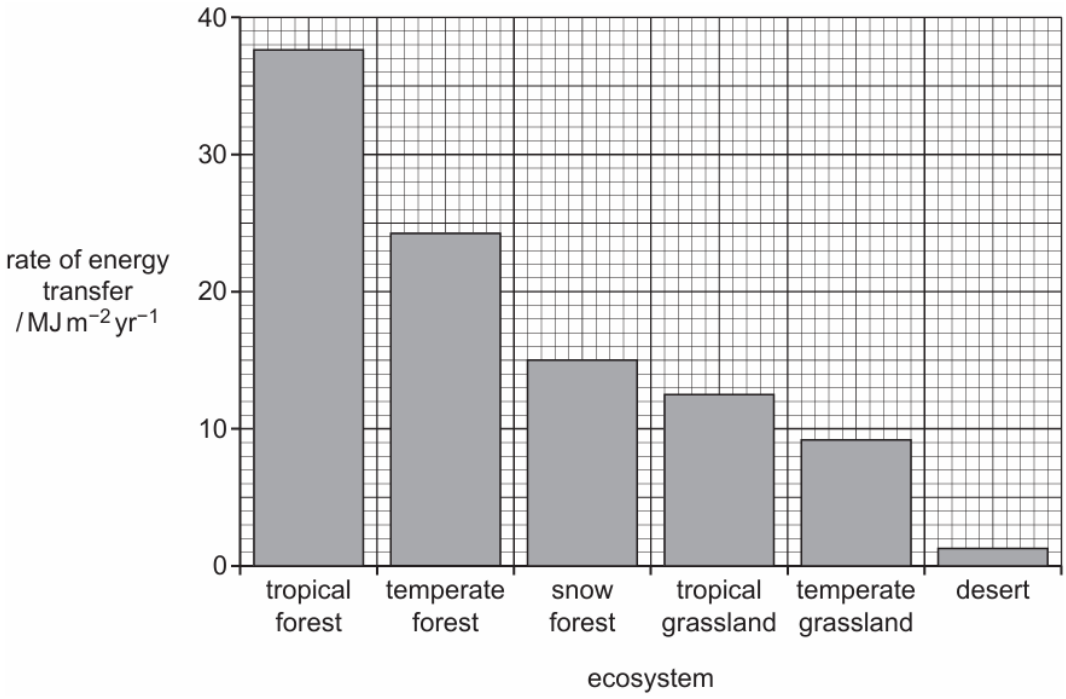


Fig. 5.2

(i) Limiting factors affect the rate of photosynthesis.

Describe **and** suggest how the results for tropical forest, temperate forest and snow forest in Fig. 5.2 show the effect of limiting factors on photosynthesis.

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(ii) Suggest reasons why grasslands and desert have a lower rate of energy transfer by photosynthesis than forests.

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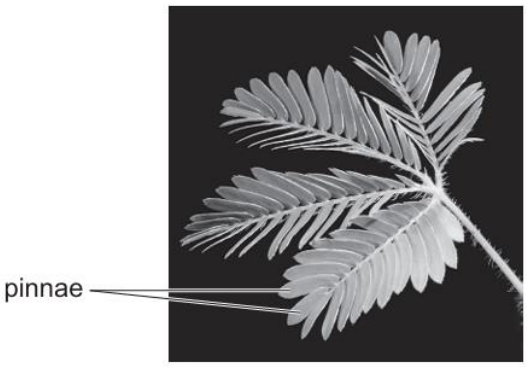
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3 The leaves of *Mimosa pudica* plants are made of a number of structures known as pinnae. The pinnae fold when the leaf is touched. This closes the leaf.

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

(b) The rate of photosynthesis decreases by 40% when the leaves of *M. pudica* close.

Explain why the rate of photosynthesis decreases when the leaves of *M. pudica* close.

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4 **(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.

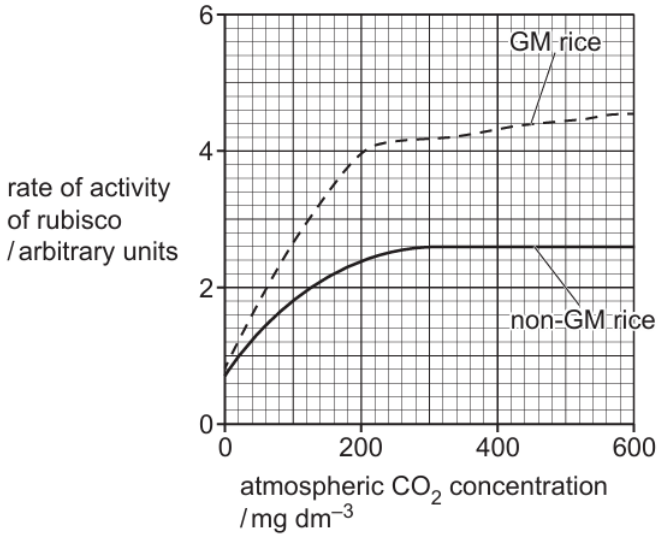


Fig. 8.1

(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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5 **(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.

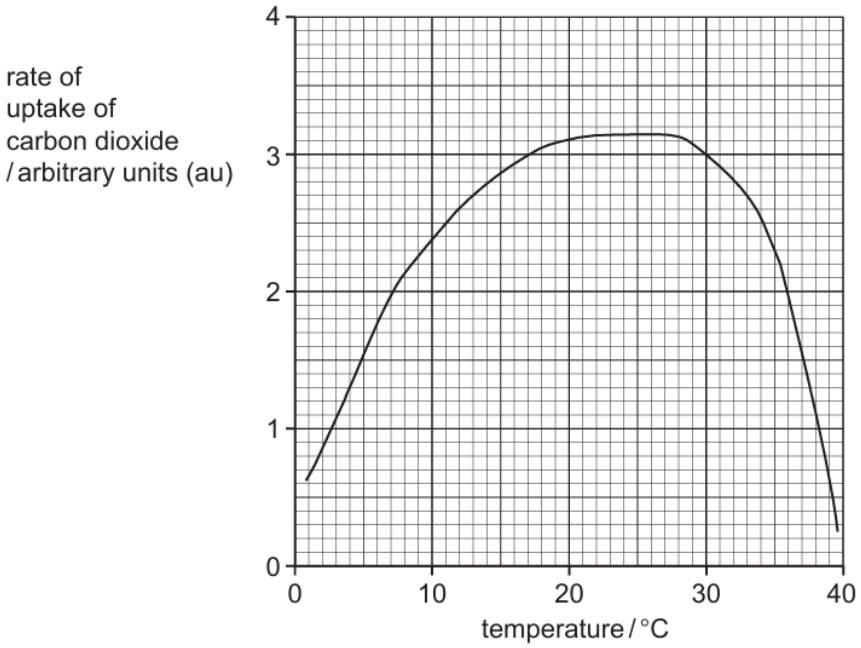


Fig. 8.1

(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.

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

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

6 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]

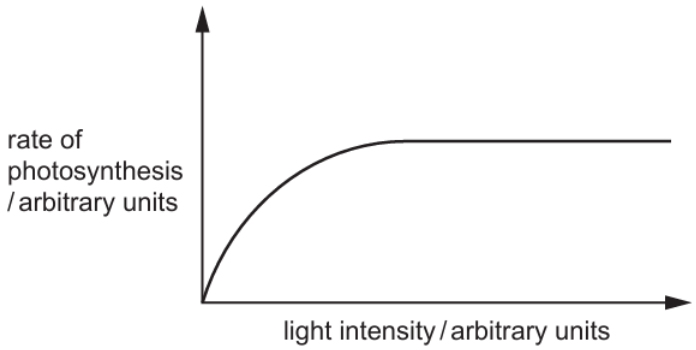


Fig. 8.1

(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 89 621 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.

(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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7 Photosynthesis is an important energy transfer process.

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

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8 **(a)** Photosynthesis is affected by many environmental factors.

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

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9 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]

(c) At each distance from the lamp, the experiment was repeated using a red filter in front of the lamp to give a different wavelength of light. The experiment was repeated using a blue filter and then using a green filter. Each filter transmitted the same light intensity.

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

Fig. 5.1 shows a graph of the results.

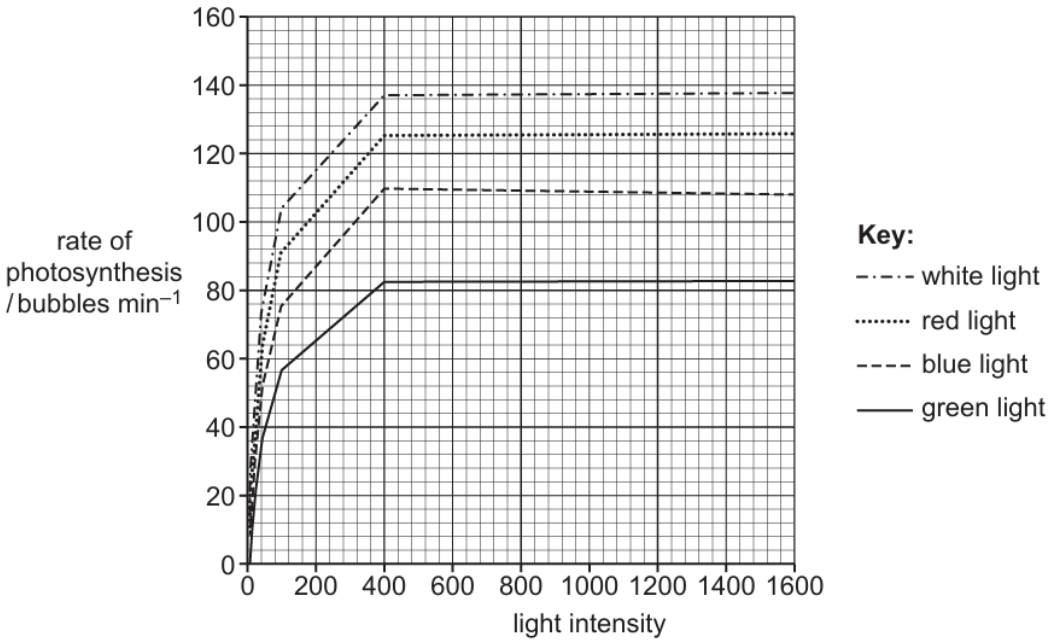


Fig. 5.1

(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.

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

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10 **(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.

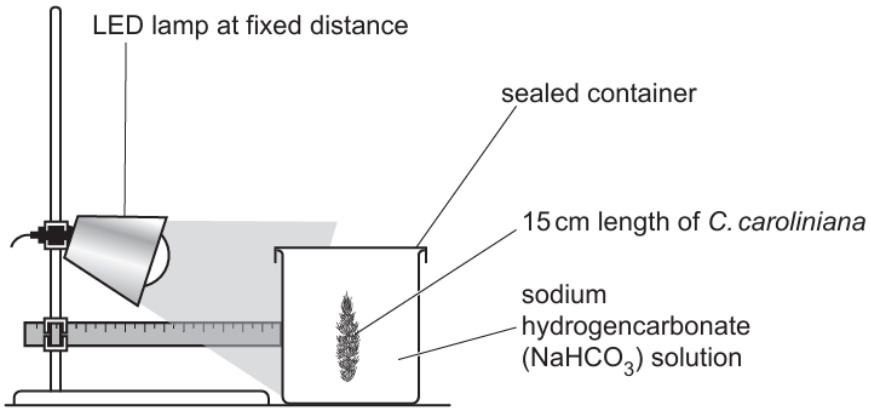


Fig. 1.1

- Sodium hydrogencarbonate solution was used as a source of carbon dioxide.
- The concentration of carbon dioxide was varied using six different concentrations of sodium hydrogencarbonate solution.
- All *C. caroliniana* plants were kept in the dark before the light was switched on at the start of the experiment.
- Five replicates were carried out at each concentration.
- The rate of photosynthesis was obtained by calculating the percentage change in dissolved oxygen concentration in the solution over five minutes.

Fig. 1.2 shows the results of the investigation.

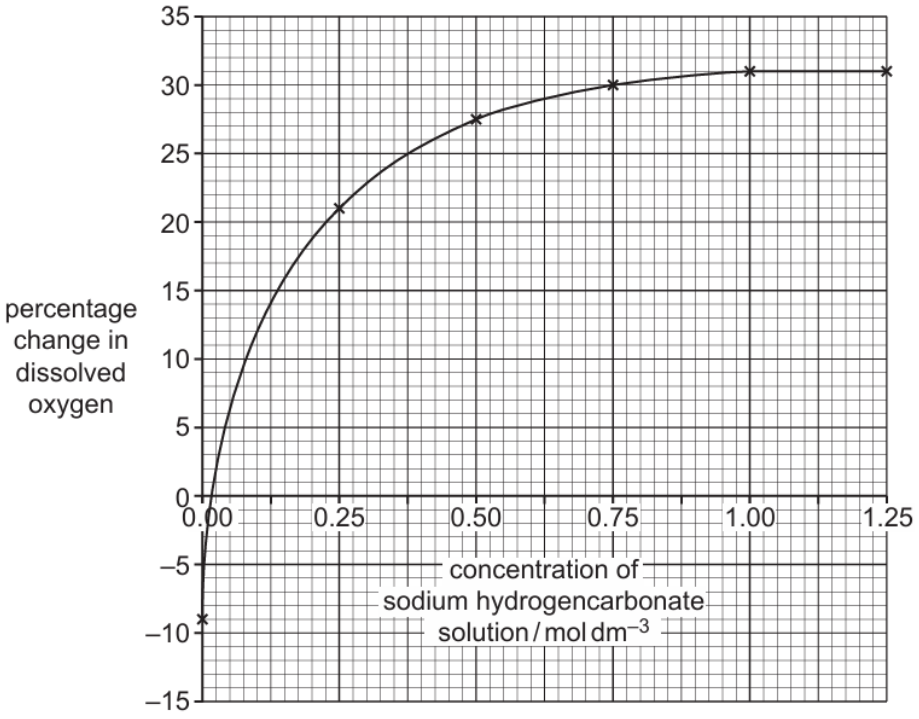


Fig. 1.2

(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.

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(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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(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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11 **(a)** Cotton, *Gossypium hirsutum*, and false flax, *Camelina sativa*, are crop plants that are grown in different parts of the world.

Rubisco activase is an enzyme in the stroma of chloroplasts that is needed to maintain the activity of a second enzyme, rubisco.

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

Fig. 2.1 shows the results.

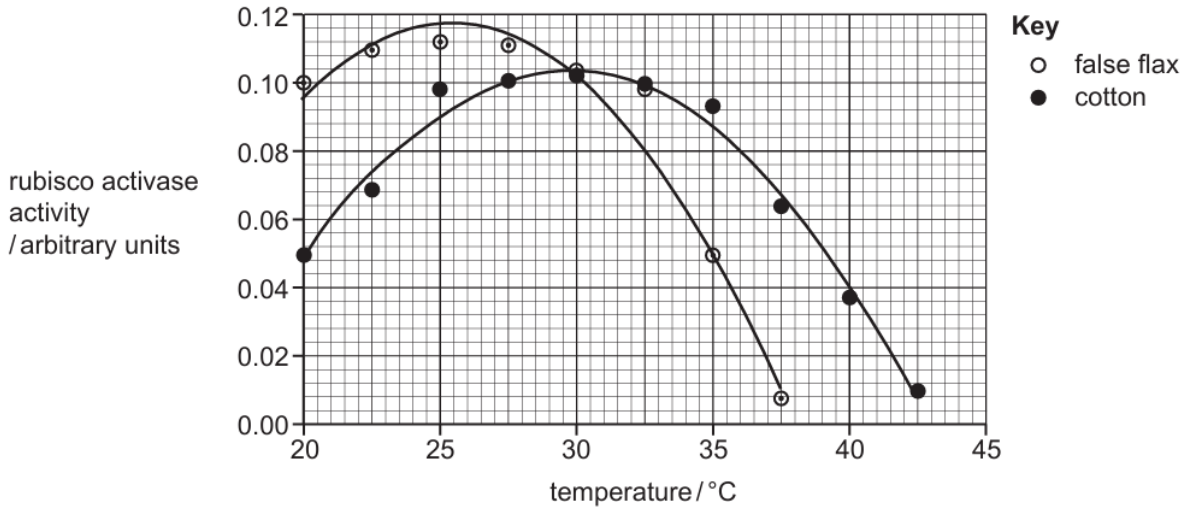


Fig. 2.1

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

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

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12 Fig. 1.1 shows a transmission electron micrograph of a chloroplast.

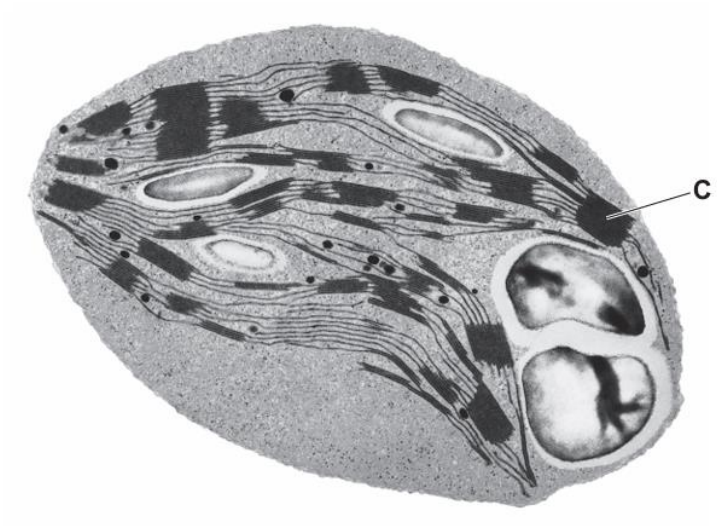


Fig. 1.1

(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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(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.

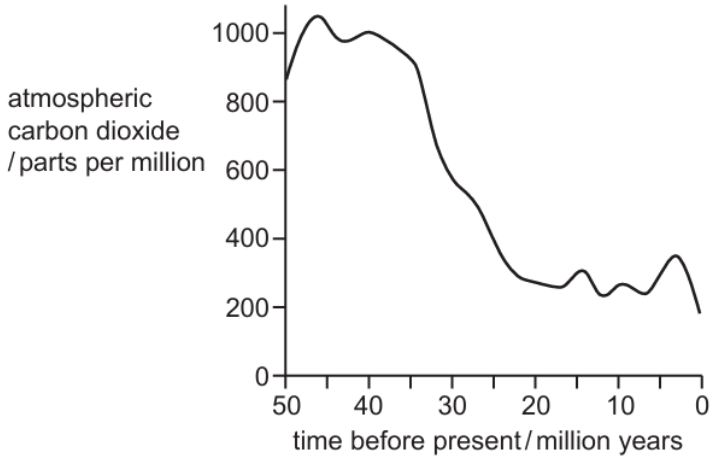


Fig. 1.2

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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13 Fig. 1.1 is a transverse section through a leaf from the maize plant, *Zea mays*.

Maize is a **C4** plant.

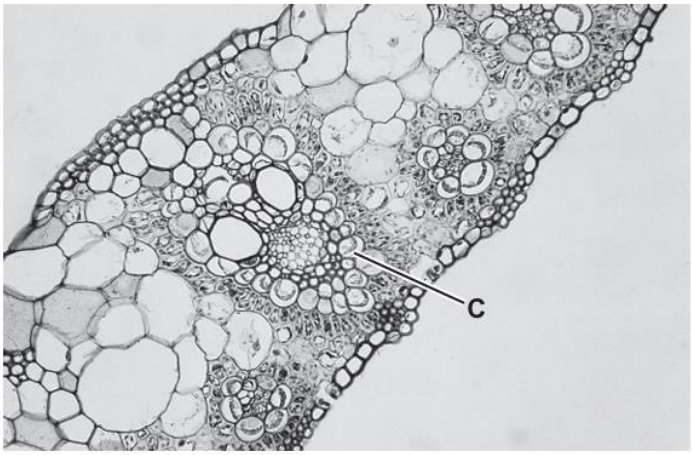


Fig. 1.1

(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 (CO_2) conditions.

The rate of CO_2 uptake is used to measure the rate of photosynthesis.

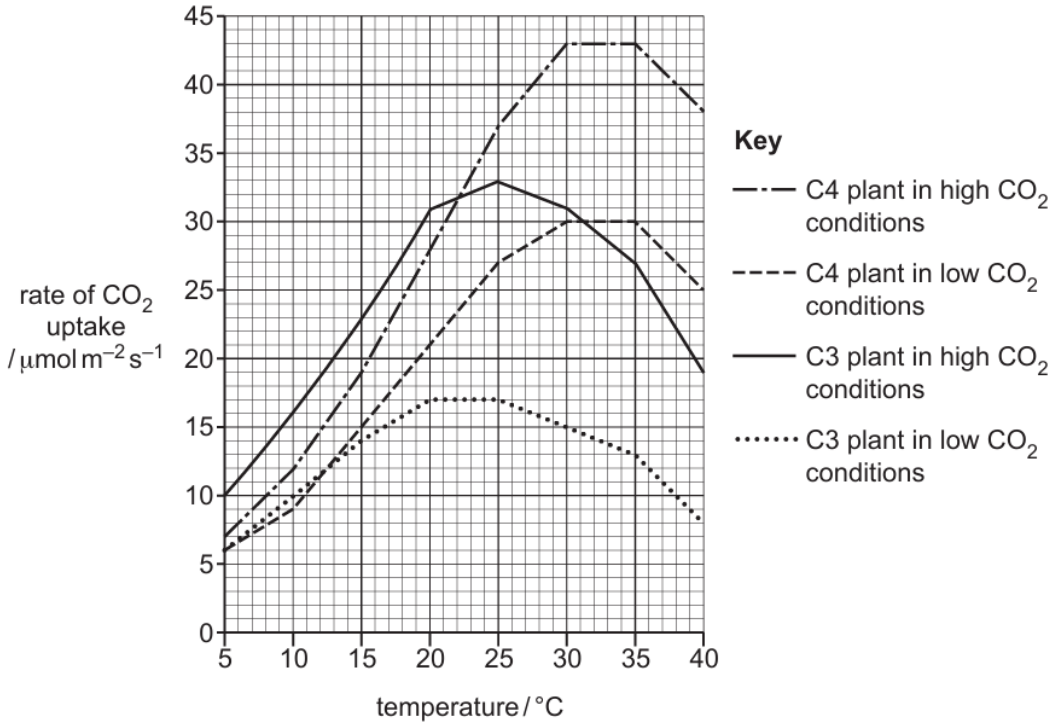


Fig. 1.2

(i) Using Fig. 1.2, compare the rates of photosynthesis in **high** CO_2 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 CO_2 conditions in the C4 plant between 30 °C and 35 °C **and** suggest an explanation for this difference.

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14 **(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.

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(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.

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(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.

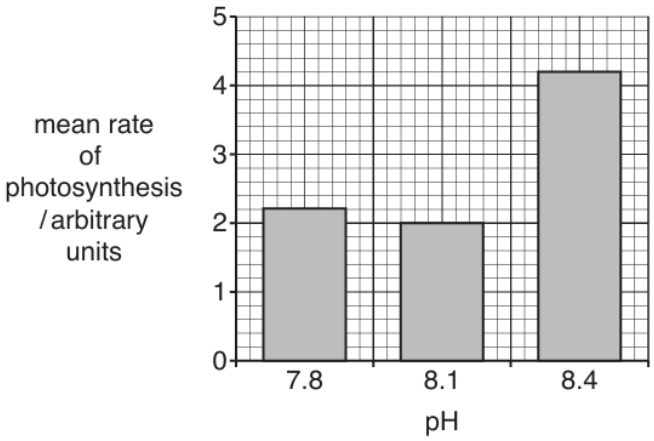


Fig. 5.2

(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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(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.

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15 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.

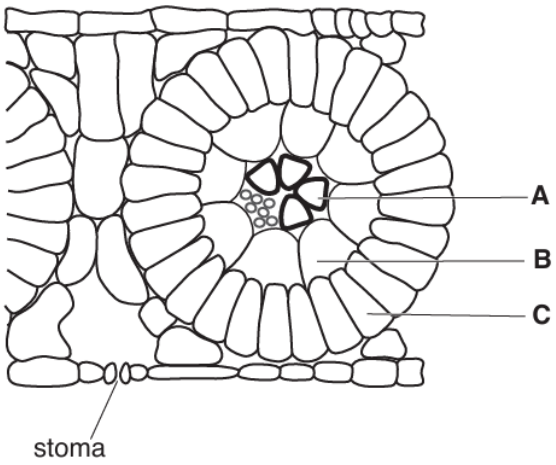


Fig. 7.1

(c) Several enzymes have a role in the light independent stage of photosynthesis.

Fig. 7.2 shows the activity of one of these enzymes at different temperatures for a C3 plant, *Pisum sativum*, and a C4 plant, *Amaranthus hypochondriacus*.

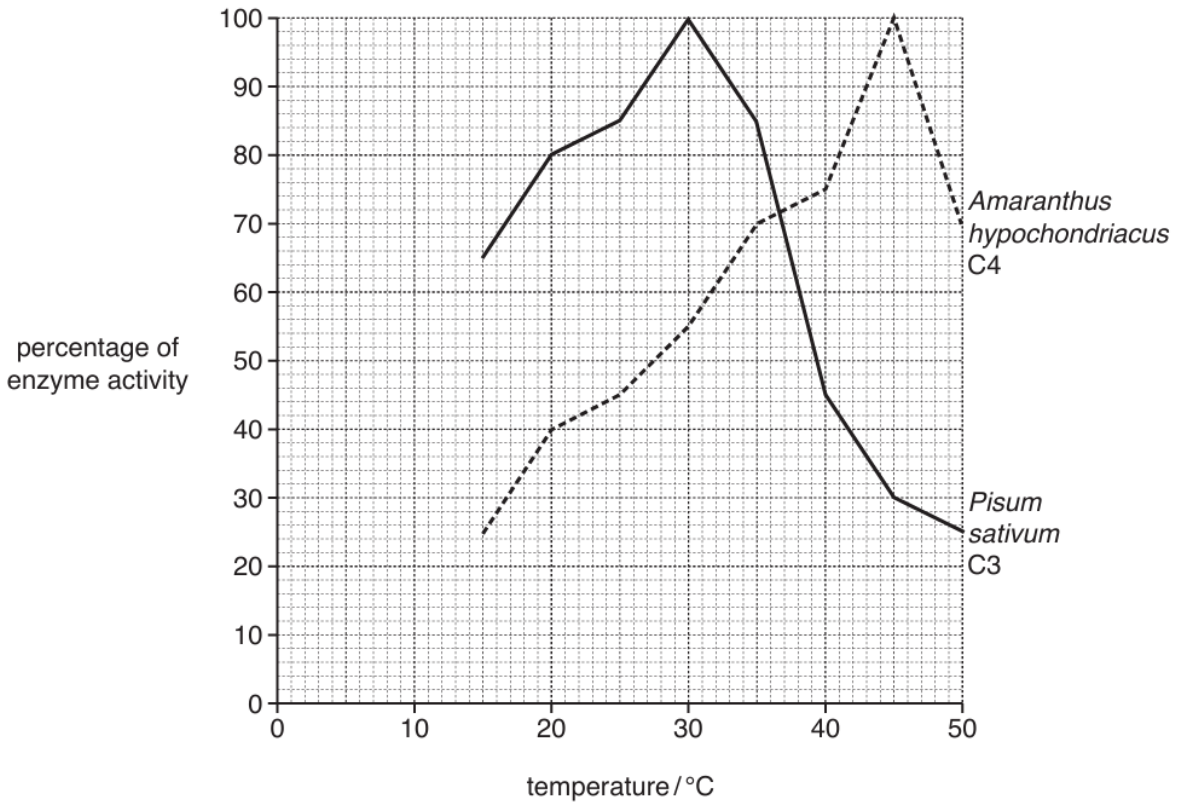


Fig. 7.2

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

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