Answer **all** the questions.

1. Phospholipid bilayers play crucial roles within plant cells.
Which of the following statements linked to the importance of membranes in plant cells is / are true?

Statement 1: ATP synthase embedded in thylakoid membranes maintains chemiosmotic gradients.
Statement 2: Phospholipid bilayers within the chloroplast are impermeable to protons.
Statement 3: Thylakoid membranes contain electron transport chain proteins.

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐

[1]

2(a). Plants photosynthesise and respire. **Fig. 18.1** shows the rate of production of carbohydrate in photosynthesis and the rate of use of carbohydrate by respiration.

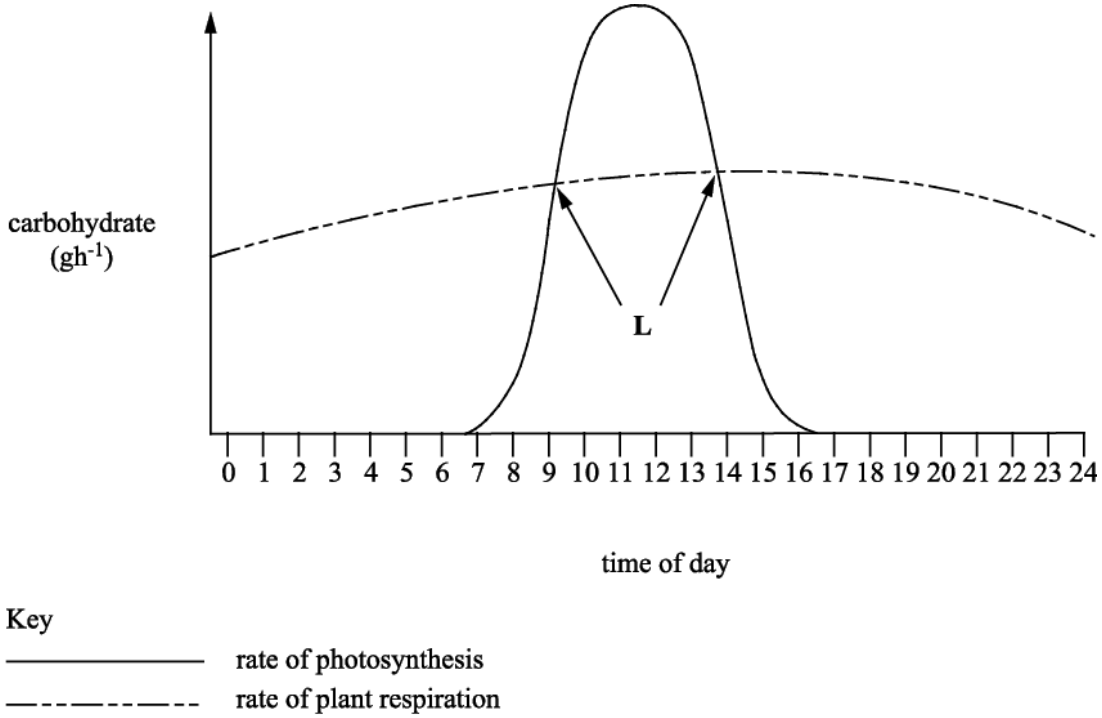


Fig. 18.1

(i) Explain the shape of the curve for the rate of photosynthesis in **Fig. 18.1**.

---**[2]**

(ii) Explain the shape of the curve for the rate of plant respiration in **Fig. 18.1**.

---**[2]**

(iii) What is happening at the points indicated by the letter **L**?

---

[1]

(b). Plants grow successfully in temperatures that are suited to their metabolism. Some plants are adapted for growth in cool climates while others can grow well in warm climates.

Plants also vary in their photosynthetic metabolism. Many plants produce a 3-carbon compound as the first product of carbon fixation and so are referred to as C3 plants. Another group of plants produces a 4-carbon compound as the first product and so are referred to as C4 plants. C3 plants include barley, lentil, rice, soya, sunflower and wheat. C4 plants include maize, millet, sorghum and sugar cane.

Fig. 18.2 shows the assimilation of carbon dioxide by four different crops at different temperatures.

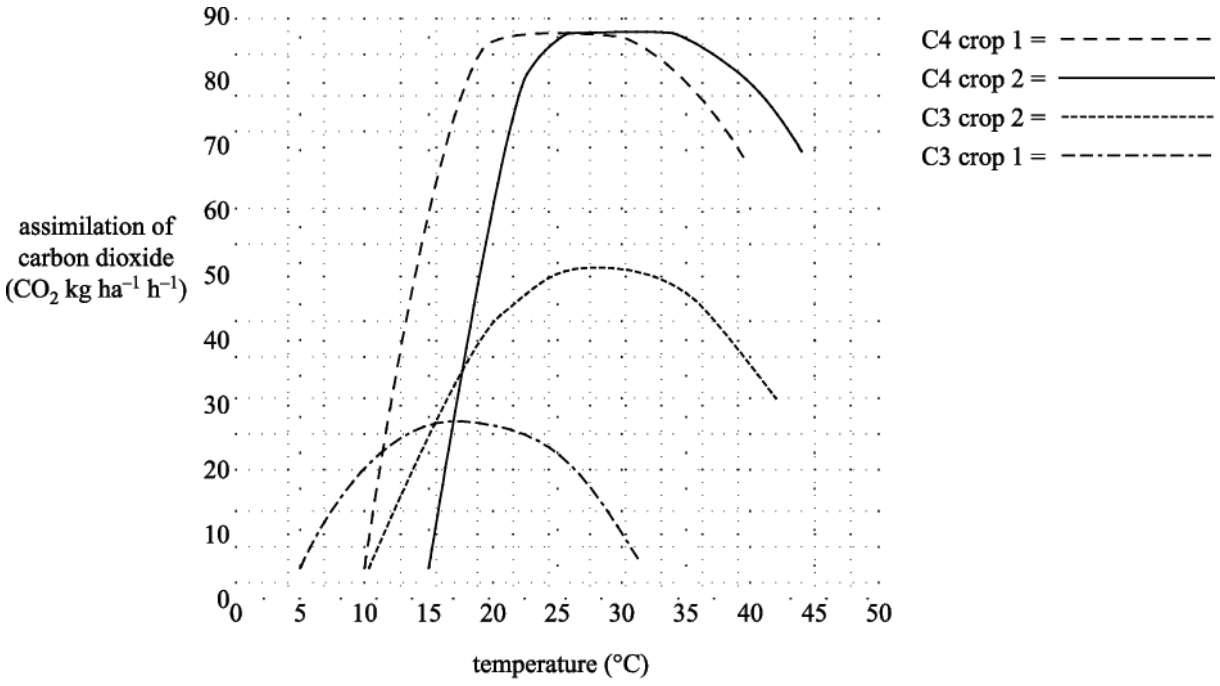


Fig. 18.2

(i) With reference to **Fig. 18.2**, what is the general relationship between increasing temperature and the assimilation of carbon dioxide?

[2]

(ii) Calculate the values for the mean assimilation of carbon dioxide by C3 plants and C4 plants at 20 °C. Include units in your answer.

C3

C4

[2]

(iii) Suggest a conclusion that could be drawn from the mean values you calculated in part **(ii)**.

[1]

(iv) With reference to **Fig. 18.2**, suggest which curve corresponds to each of the following crops:

Sugar cane, which grows in warm climates.

Barley, which grows in cool climates.

[2]

(c). Temperature is very important in determining a plant's ability to photosynthesise effectively.
Temperature stress is becoming of great concern to plant physiologists because of climate change.

- High temperature (HT) stress is defined as the rise in temperature that is sufficient to cause irreversible damage to plant growth and development.

Some of the stress effects of temperature have been recorded in various plants and are outlined in **Table 18.1**.

Temperature	Effect
Moderate HT stress	Heat-induced deactivation of RuBisCO No change in chlorophyll fluorescence in PSII Reduction in stomatal aperture
Severe HT stress	Decrease in chlorophyll content as a result of photodeterioration Changes in the ultrastructure of the chloroplast

Table 18.1

(i) Assess the impact of moderate HT stress on the process of photosynthesis.

[3]

(ii) Suggest **two** ways in which the ultrastructure of the chloroplast can be altered by high temperatures.

For each suggestion, explain the effect that it will have on photosynthesis.

Suggestion

Explanation

Suggestion

Explanation

[4]

3. Melvin Calvin studied the light-independent reaction (Calvin cycle) in plant cells.

He used radiolabelled $^{14}CO_2$ to measure the production of organic molecules in chloroplasts.

- He placed an aquatic plant in water.
- The plant was given light for 20 minutes.
- The light was then turned off (dark conditions) for a further 30 seconds.

He measured the radioactivity of the solutions produced and used these values to calculate the number of molecules of triose phosphate (TP) and ribulose bisphosphate (RuBP) present.

The results are shown in the table below.

Molecule	**Activity of ^{14}C ($x10^{27}$ Bq)**	
	after 20 minutes light	30 seconds dark conditions
TP	5.5	10.1
RuBP	4.9	0.6

Assuming 8.5×10^{18} Bq are generated by each ^{14}C atom in the molecule, how many **new** TP molecules are produced after 30 seconds in the dark?

A 6.47×10^{8}
B 1.80×10^{8}
C 1.83×10^{27}
D 3.37×10^{27}

Your answer ☐

[1]

4. During the light-independent stage of photosynthesis, triose phosphate (TP) is synthesised in the chloroplasts of plant cells.

(i) State **two** possible uses of this molecule within the plant.

1

2

---

[2]

(ii) From which molecule is TP synthesised during the light-independent stage?

---

[1]

5. *Heliamphora*, shown in Fig. 18.1, is a genus of carnivorous plant. Its leaves are adapted to form water-filled traps for insects. The insects are attracted by nectar, then fall into the traps and drown. The plants digest the insects and absorb the mineral ions produced. This allows *Heliamphora* to survive in soils with low mineral content.

Fig. 18.1

Four pigments, A, B, C and D, were extracted from a *Heliamphora* plant. Thin layer chromatography (TLC) was carried out on the pigments. The results of the TLC are shown in Fig. 18.3.

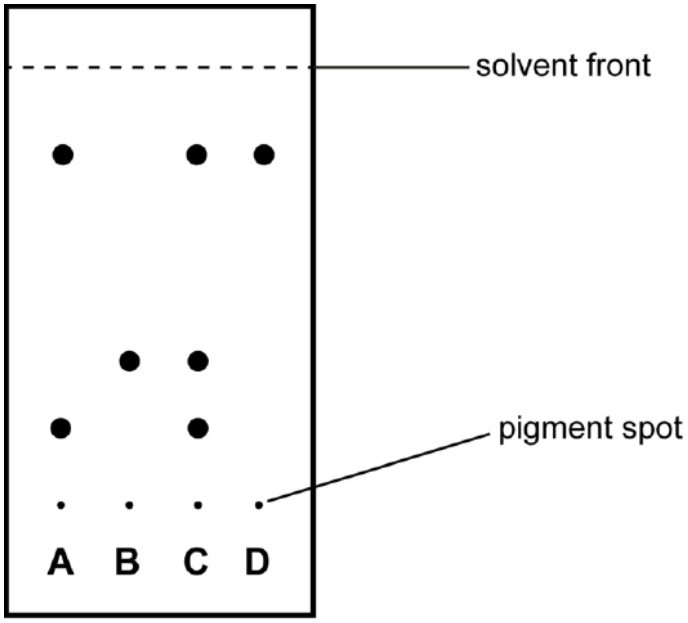


Fig. 18.3

(i) Using Fig. 18.3, what can you conclude about the composition of pigments **A** to **D**?

_____

_____

_____

_____

_____

_____

_____

_____

_____ **[3]**

(ii) Calculate the Rf value of pigment **B**. Give your answer to **two significant figures**.

Show your working.

Answer = _____ **[2]**

6. Much biological knowledge is obtained and verified through observation.

A biologist has a small pond containing goldfish in her garden.

On a sunny day, more pondweed is at the surface of the water but on a cloudy day, less pondweed is at the surface.

Suggest an explanation for this observation.

---

[2]

7(a). The rate of photosynthesis is affected by different factors.

An experiment was carried out to investigate the effect of temperature and carbon dioxide concentration on the rate of photosynthesis.

- Plants were supplied with air (0.04% CO_2) and with air enriched with carbon dioxide (0.19% CO_2).
- The rate of photosynthesis was measured at different leaf temperatures.

The results are shown in the table.

Leaf temperature (°C)	**Rate of photosynthesis (a.u)**	
	in air with 0.04% CO_2	**in air with 0.19% CO_2**
10	8.0	8.0
15	12.3	16.8
20	15.0	24.4
25	16.2	30.0
30	14.3	34.7
35	8.3	38.2
40	–	29.3
45	–	13.2

(i) Describe the effect on the rate of photosynthesis of increasing leaf temperature.

---

[3]

(ii) Calculate the percentage increase in the rate of photosynthesis at **30 °C** as the carbon dioxide concentration

is increased from 0.04% to 0.19%.

Show your working and give your answer to **3 significant figures**.

Answer = _____ %

[2]

(iii) Use the information in the table to state **one other** effect of an increased concentration of carbon dioxide on the rate of photosynthesis.

---

[1]

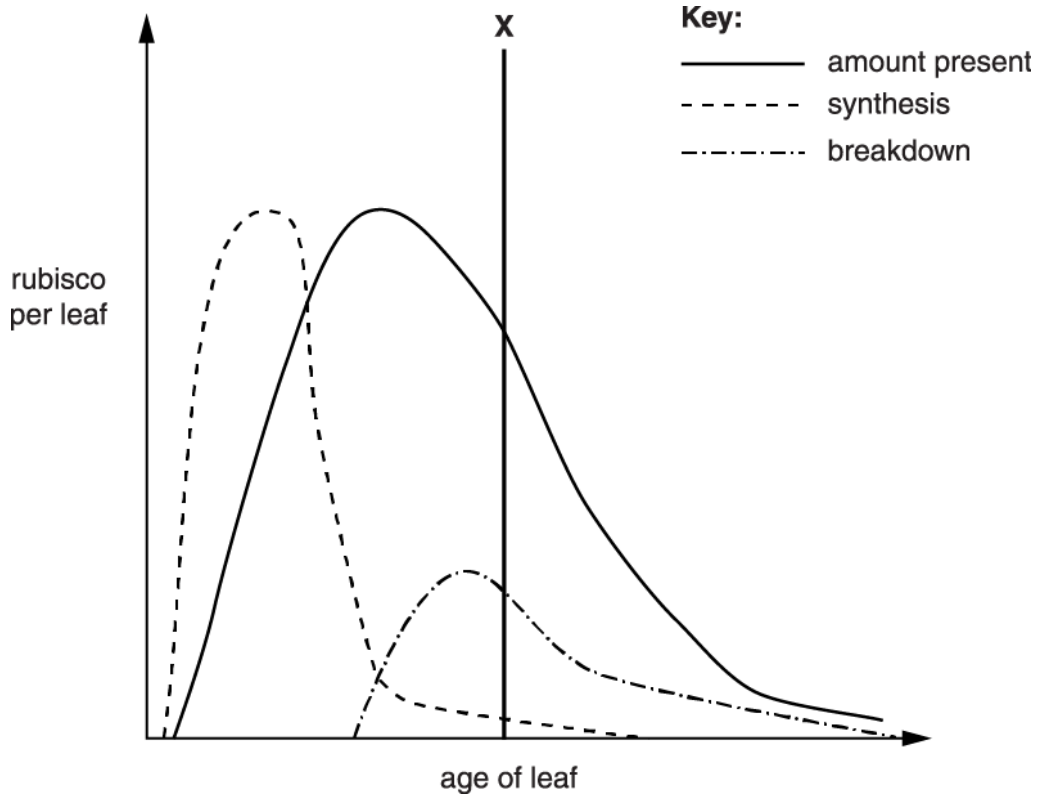
(iv) Suggest why there are no results for 0.04% CO_2 at 40 °C and 45 °C.

---

[2]

(b). As a leaf ages, the ribulose bisphosphate carboxylase (rubisco) content of the leaf changes.

The figure represents the amount of rubisco present, the synthesis of rubisco and the breakdown of rubisco as the leaf ages.



Explain the effect that the levels of rubisco would have **on the rate of photosynthesis** as the age of the leaf increases beyond the line labelled **X**.

[3]

8(a). Photosynthesis involves two main stages:

- the light-dependent stage, which involves photosystems
- the light-independent stage, which involves the Calvin cycle.

Photosynthetic pigments are arranged in groups known as photosystems I and II.

(i) Name the primary photosynthetic pigment in these photosystems.

---

[1]

(ii) Name an accessory pigment.

---

[1]

(iii) State the advantage to the plant of having a range of accessory pigments in photosystems.

---

[1]

(iv) Name the compound that is synthesised in the light-dependent stage as a result of the generation of an electrical and pH gradient across the thylakoid membrane.

---

[1]

(b). The Calvin cycle takes place in the stroma of the chloroplast.

(i) Identify the enzyme that catalyses the fixation of carbon dioxide.

---

[1]

(ii) Identify the first stable product of carbon dioxide fixation.

---

[1]

(iii) Identify the compound that is regenerated in the Calvin cycle so that more carbon dioxide can be fixed.

---

[1]

(iv) Name **two different polysaccharides** that can be synthesised from the end products of the light-independent stage of photosynthesis.

---

[1]

9(a). Fig. 1.1 is a diagram representing a three-dimensional view of a chloroplast.

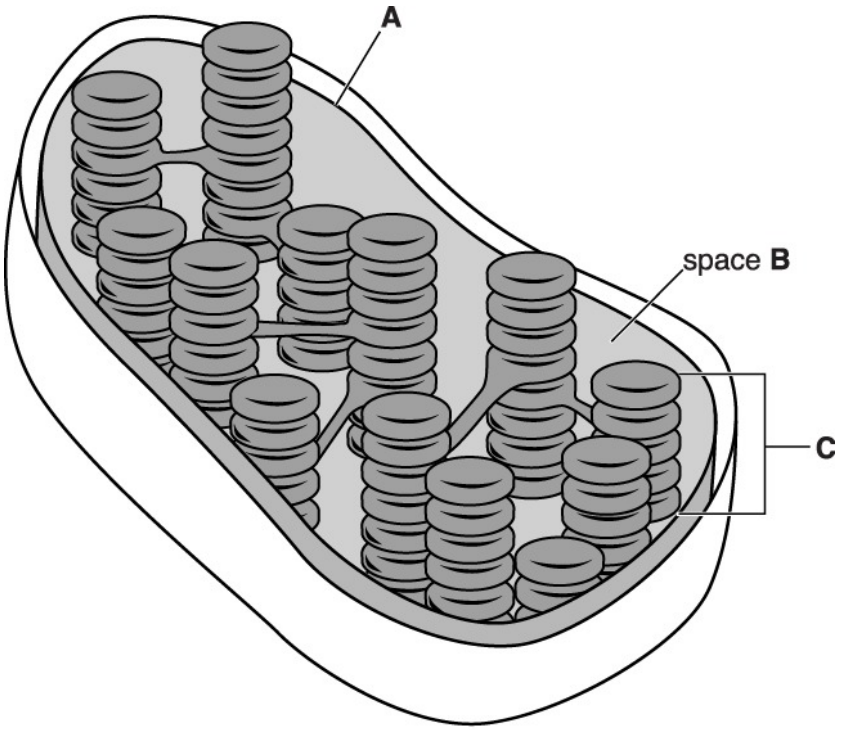


Fig. 1.1

(i) Name parts **A** to **C** in Fig. 1.1.

A

B

C

---

[3]

(ii) Describe **two** ways in which the structure of part **C** is adapted to its function.

---

[2]

(iii) A key aspect of photosynthesis is the metabolic pathway involving carbon dioxide.

Place a tick (✓) in the appropriate box to indicate the part of the chloroplast (**A**, **B** or **C**) in which the metabolic pathway involving carbon dioxide is located.

A	
B	
C	

[1]

(b). Fig. 1.2 shows the theoretical and actual relationship between light intensity and the rate of photosynthesis.

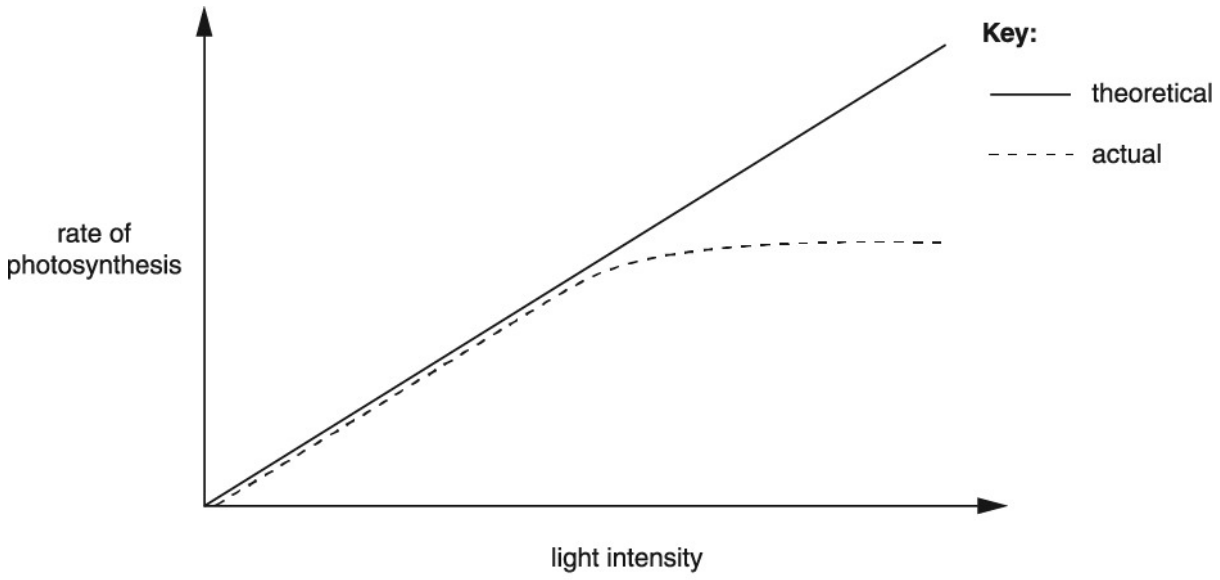


Fig. 1.2

With reference to the biochemistry of photosynthesis, explain why the theoretical rate of photosynthesis is **not** achieved at higher light intensities.

[2]

(c). Plants are usually adapted to living in conditions of different light intensities.

The rate of photosynthesis at different light intensities for two different species of plant was investigated. The results are shown in Fig. 1.3.

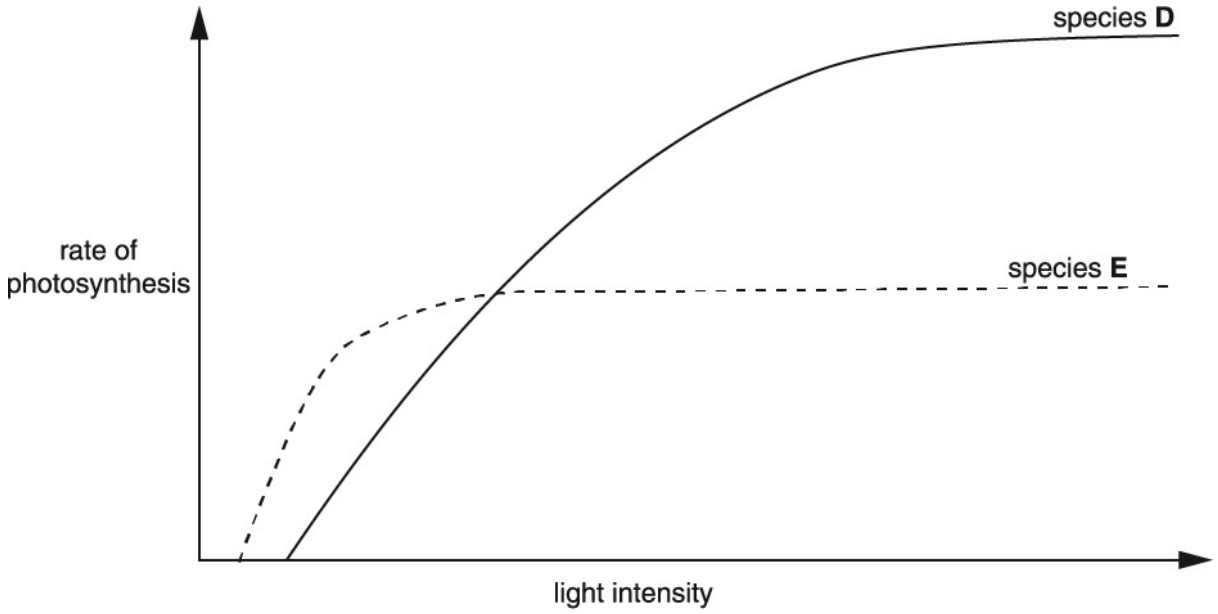


Fig. 1.3

(i) Using the information in Fig. 1.3, explain which of the two species, **D** or **E**, is better adapted to living in **shady** conditions.

[2]

(ii) The leaf of a plant that is adapted to living in shade will differ from the leaf of a plant that is adapted to living in sunlight.

Suggest **one** way in which the **structure** of these leaves will differ.

[1]

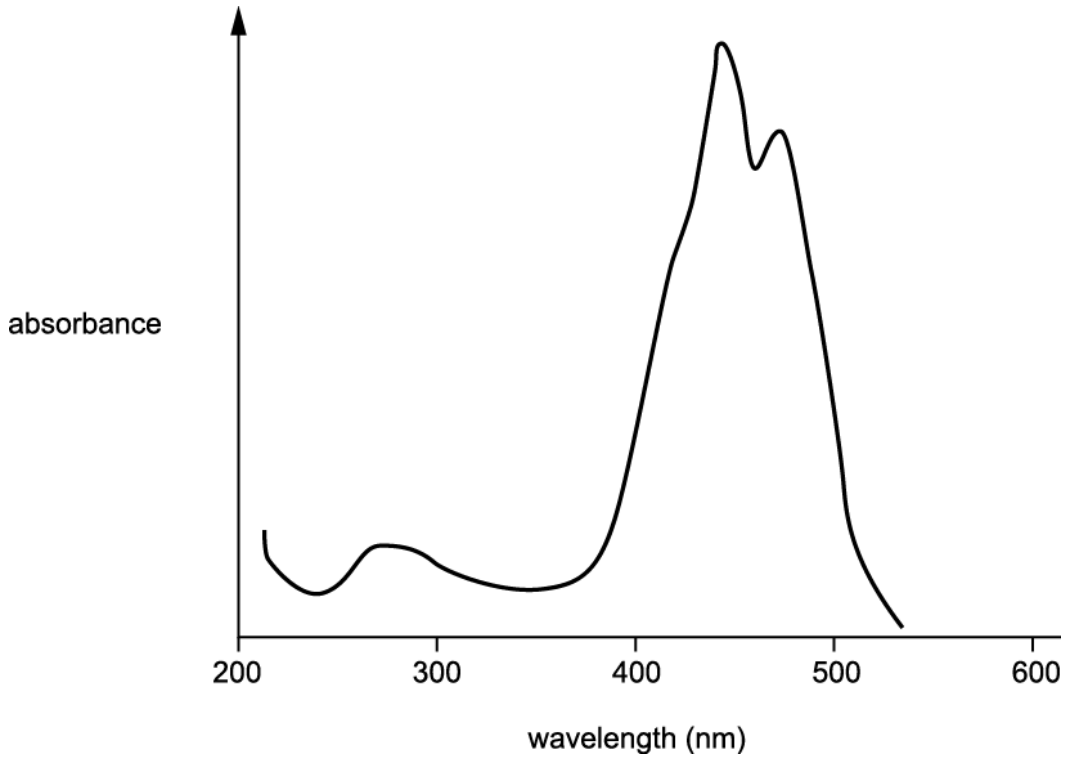
(d). Plants are autotrophs. Most other organisms are heterotrophs.

Outline the ways in which heterotrophic organisms are dependent on plants.

---

[3]

10. The following graph shows the absorbance spectrum of an accessory pigment.



Which of the following statements explains why this pigment is orange-red to the human eye?

1 The pigment absorbs green and blue light.

2 The pigment has an absorption peak at 500 nm.

3 The pigment passes photons to the primary pigment reaction centre.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

[1]

11. Palisade mesophyll cells are an example of a specialised plant cell. These cells are the main site of photosynthesis in plants.

A team of scientists investigated the effect of shining light on the upper and lower surfaces of a leaf on the rate of photosynthesis.

The results are shown in Fig. 3.2.

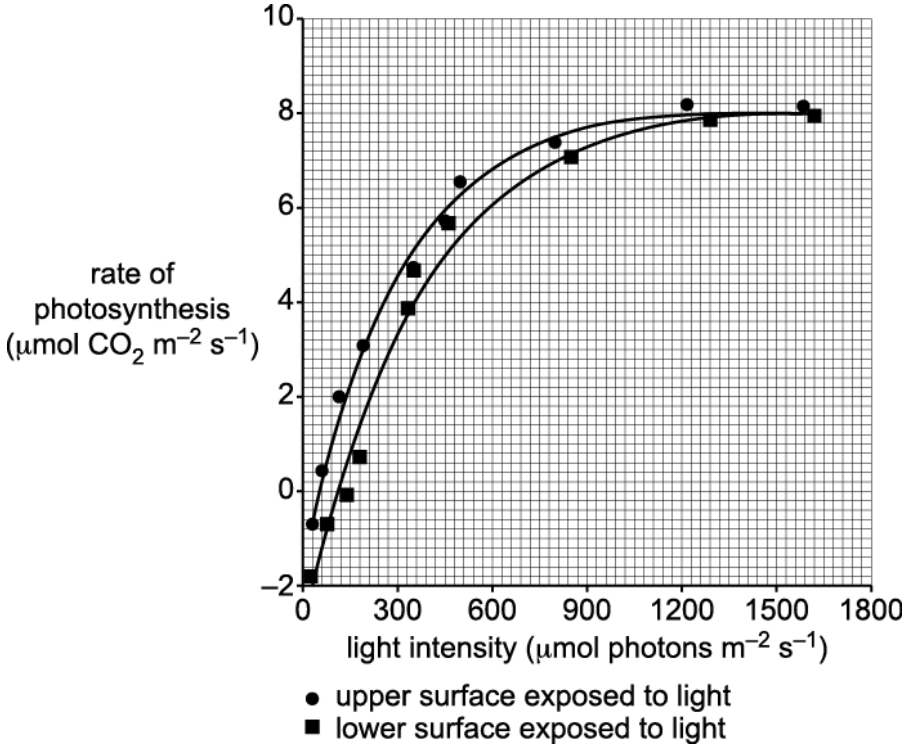


Fig. 3.2

What conclusions can you draw from the data in Fig. 3.2 about the effects of light **and** the internal structure of a leaf? Explain your answer.

---

[4]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2	a	i	increased photosynthetic activity during daylight (1) as light intensity increases there is increased activity of the light dependent reaction (1)	2	No marks available for describing the shape of the curve.
		ii	daytime temperatures generally higher than night time (1) rate of respiration increases with increased temperature as its enzymes are temperature-dependent (1)	2	No marks available for describing the shape of the curve.
		iii	compensation point(s) / carbohydrate produced by photosynthesis equal to carbohydrate used in respiration (1)	1	
	b	i	*for all crops* initial increase in assimilation with increasing temperature (1) at higher temperatures the assimilation decreases (1)	2	**DO NOT ALLOW** accounts that describe the curve for each crop individually.
		ii	*C3* 34.5 **and** *C4* 73.5 (1) CO_2 kg ha^{-1} h^{-1} (1)	2	**1 mark for both means calculated correctly.** **1 mark for correct units given for both.**
		iii	C3 plants assimilate less carbon dioxide than C4 plants **ora**	1	**ALLOW** a conclusion cannot be drawn because there is not enough data on each type of plant.
		iv	*Sugar cane* C4 crop 2 (1) *Barley* C3 crop 1 (1)	2	
	c	i	deactivation of RuBisCO will reduce, carbon dioxide fixation / light independent reaction (1) the light dependent reaction will reduce when the supply of NADP is reduced (1) reduction in stomatal aperture will reduce carbon dioxide available for fixation (1)	3	

Question			Answer/Indicative content	Marks	Guidance
		ii	*four from* damage to chlorophyll / reduction in pigment (1) which will reduce the light dependent stage (1) damage to membranes in chloroplast / reduction in sites for light capture (1) which will reduce the light dependent stage (1) damage to membranes in chloroplast / reduction in reaction sites for electron transfer (1) which will reduce, photophosphorylation / ATP production in the light dependent stage (1) damage to membrane around chloroplast / release of enzymes (1) which will reduce, light independent stage / Calvin cycle (1)	4	**Award 1 mark for the alteration of the ultrastructure (max 2) and 1 further mark for details of its effect on photosynthesis (max 2).**
			Total	**19**	
3			B	1	
			Total	**1**	
4		i	*synthesis of:* (named) carbohydrate (1) hexose sugars (1) amino acids (1) lipids (1)	2	**ALLOW** regeneration of RuBP
		ii	GP / glycerate-3-phosphate	1	
			Total	**3**	

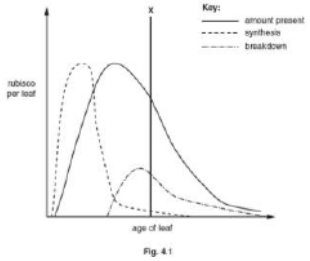
Question			Answer/Indicative content	Marks	Guidance
5		i	pigment A contains 2, components / molecules (1) pigments B and D contain 1, component / molecule (1) pigment C contains 3, components / molecules (1) *idea that* pigments A and C share 2, components / molecules (1) *idea that* pigments A and D **OR** pigments B and C **OR** pigments C and D share 1, component / molecule (1) all pigments are soluble (in liquid phase) (1)	3	
		ii	0.35 ± 0.01 (1)(1)	2	**ALLOW** 1 mark for evidence of 19 ÷ 55 1 mark maximum for incorrect s.f.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
6			1 greater light intensity on a sunny day / less light intensity on a cloudy day; 2 oxygen produced during, photosynthesis / photolysis / light dependent stage; 3 (more) oxygen trapped within weed increases buoyancy;	2 max	**IGNORE** all ref to growth and tropisms 3 **ACCEPT** 'oxygen helps the weed to float' 'oxygen bubbles makes the weed rise' 'trapped oxygen lowers the density' **Examiner's Comments** This was a deceptively difficult question that required candidates to appreciate the higher light intensity in the sunny conditions resulting in a higher rate of photosynthesis which produces oxygen and makes the pondweed more buoyant. While the concept is not inherently difficult, the stretch and challenge aspect of this question was to recognise the principle involved. A common misconception was that the weed moved towards the surface in order that it could access as much light as possible. Some confused the roles of carbon dioxide and oxygen in photosynthesis.
			Total	**2**	

Question			Answer/Indicative content	Marks	Guidance
7	a	i	1 rate of photosynthesis increases (reaches peak) **and** then decreases; 2 peak / optimum, for 0.04% CO_2, between 20°C and 30°C / at 25°C; 3 peak / optimum, for 0.19% CO_2, between 30°C and 40°C / at 35°C; 4 ref to zero rate / no result / no photosynthesis, at 40°C and 45°C / from 40°C / above 35°C, with 0.04% CO_2;	3 max	'it' = rate of photosynthesis Units must be used once (% and °C) for mps 2 to 4 2 either states 25°C **or** states the range 20°C to 30°C 3 either states 35°C **or** states the range 30°C to 40°C 4 **ACCEPT** photosynthesis stops at 40°C **Examiner's Comments** Many candidates scored well on this question. It was generally recognised that the rate of photosynthesis increased and then decreased. Some experienced difficulty in deciding when the peak would occur in each carbon dioxide concentration and so expressed this poorly. In situations such as these, it is important to indicate which set of data is being quoted – in this case by referring to the concentration of carbon dioxide.

Question			Answer/Indicative content	Marks	Guidance
		ii	143 (%);;	2	**Correct answer = 2 marks [please place 2 ticks on script]** **If answer is incorrect, then ALLOW 1 mark for** unrounded or incorrectly rounded answer (e.g. 142.657 or 142) **or** (34.7 – 14.3) ÷ 14.3 **or** 20.4 ÷ 14.3 **or** 100 × (34.7 ÷ 14.3) – 100 **or** 243 **Examiner's Comments** The calculation in (ii) was performed correctly by many candidates. Some of those who took the route of finding the rate at the higher carbon dioxide concentration as a percentage of the lower neglected to subtract 100 and so only scored 1 mark. Few candidates were unable to express their answer to 3 significant figures.
		iii	*idea that* increases the optimum temperature (for photosynthesis) **or** maximum rate of photosynthesis at higher temperature **or** can photosynthesise at higher temperatures **or** maximum rate of photosynthesis is higher **or** rate of photosynthesis starts to decrease at a higher temperature **or** the rate of photosynthesis increased, at a higher rate / faster;	1	**ACCEPT** moves peak upwards **Examiner's Comments** Many candidates supplied a suitable observation here, although weaker responses simply repeated that a higher temperature resulted in a higher rate.

Question			Answer/Indicative content	Marks	Guidance
		iv	1 no, photosynthesis / Calvin cycle / carbon fixation **or** rate too low to be recorded; 2 CO_2 is limiting **or** *idea that* the level of CO_2 is too low to compensate for the high temperature; 3 rubisco is binding to O_2 (instead); 4 decreased enzyme activity; 5 (high temperature has) distorted rubisco active site; 6 AVP;	2 max	2 (as activity had been observed at these temperatures with 0.19% CO_2) 3 look for a clear statement **CREDIT** switches to, photorespiration / oxygenase activity 4 **DO NOT CREDIT** (fully) denatured 5 **DO NOT CREDIT** (fully) denatured (as there is activity at these higher temperatures) 6 e.g. stomatal closure to conserve water reduces CO_2 **Note:** 'the rubisco active site is distorted so it binds to O_2 instead' **= 2 marks (mps 3 and 5)** **Examiner's Comments** Many candidates found this challenging. A frequent comment was that the enzyme rubisco would be denatured, failing to appreciate that as photosynthesis occurred at higher temperatures in higher concentrations of carbon dioxide it cannot have denatured. Those who mentioned a lack of carbon dioxide often did not use the term 'limiting'.

Question			Answer/Indicative content	Marks	Guidance
	b		 Fig. 4.1	3 max	
			1 rate of photosynthesis would decrease;		‘it’ = rate of photosynthesis 1 **IGNORE** no photosynthesis
			2 little rubisco being synthesised **and** the rubisco present being broken down **or** more rubisco is being broken down than being synthesised;		
			3 less / no, enzyme / rubisco, available to fix, carbon dioxide / CO_2;		3 **CREDIT** less rubisco to catalyse the reaction between CO_2 and RuBP
			4 less / no, Calvin cycle / light independent stage, can take place;		4 **CREDIT** build up of red NADP less, triose phosphate / TP / etc, made less glucose made light independent stage takes place at a slower rate
			5 rubisco becomes limiting (factor);		**Note:** ‘less photosynthesis because there is less rubisco which is needed to fix CO_2 in the Calvin cycle’ **= 3 marks (mps 1, 3 and 4)** **Examiner's Comments** Part (b) allowed candidates to demonstrate their knowledge of the light independent reaction once they had established that there is a low level of rubisco. They found it difficult to express the reason for this. Few recognised that rubisco availability would be a limiting factor.
			Total	**11**	

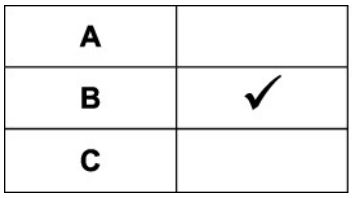
Question			Answer/Indicative content	Marks	Guidance
8	a	i	chlorophyll, a / A;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **ACCEPT** chlorophyll 680 **and** chlorophyll 700 (**Note** that both are required for this option) **IGNORE** P680 / P700 **DO NOT CREDIT** chlorophyll α **Examiner's Comments** Most candidates named chlorophyll a as the primary pigment although some simply stated chlorophyll without any further clarification and very occasionally chlorophyll b was given. A small number of candidates suggested chlorophyll alpha or gave P680 / P700 as a response, neither of which were credited.
		ii	chlorophyll b / xanthophyll(s) / carotenoid(s) / (β / beta-) carotene;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **DO NOT CREDIT** karatine (as could be confused with keratin) **Examiner's Comments** Most candidates were able to name a suitable accessory pigment, most frequently either carotene or carotenoid, although there were some references to xanthophylls (with various spellings). However, those candidates who had given chlorophyll b as their answer to (i) frequently supplied an incorrect response to this section.

Question			Answer/Indicative content	Marks	Guidance
		iii	able to, absorb / use, a range of / different / more / other, (light) <u>wavelengths</u> / λ;	1	e.g. absorb wavelength(s) not absorbed by primary pigment **IGNORE** frequency **IGNORE** absorb all wavelengths **IGNORE** ref to chlorophyll b **DO NOT CREDIT** ref to reflection where ***a*** pigment absorbs and reflects the ***same*** wavelength **Examiner's Comments** The advantage of a plant having a variety of accessory pigments was generally well understood. The most common reason for not achieving the mark was to refer only to light frequencies or to simply state that more light could be absorbed.
		iv	ATP;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **DO NOT CREDIT** O_2 / oxygen / red NADP / NADPH **DO NOT CREDIT** inaccurate name for ATP e.g. 'ATP (adenine triphosphate)' = 0 marks **Examiner's Comments** Most candidates correctly named ATP. The most common incorrect answer was NAD / NADP or water, indicating that the question had not been read carefully. Several candidates lost marks for incorrectly defining ATP - typically as adenine triphosphate or adenosine triose phosphate.

Question			Answer/Indicative content	Marks	Guidance
	b	i	rubisco / RuBP carboxylase / ribulose bisphosphate carboxylase;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **ACCEPT** ribulose biphosphate carboxylase **IGNORE** oxygenase **Examiner's Comments** Well prepared candidates were able to identify all the relevant enzyme and compounds at the different stages of the Calvin cycle although a common mistake was to give the acronym followed by the incorrect name, such as GP - glycerol phosphate, glucose phosphate or glycerate triphosphate. TP was also a common error. A few candidates muddled RuBP and rubisco.
		ii	GP / glycerate(3–)phosphate;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **ALLOW** PGA / phosphoglyceric acid / phosphoglycerate **DO NOT CREDIT** PGAL / GALP / phosphoglyceraldehyde **DO NOT CREDIT** inaccurate name for GP e.g. 'GP (glycerol phosphate)' = 0 marks **Examiner's Comments** Well prepared candidates were able to identify all the relevant enzyme and compounds at the different stages of the Calvin cycle although a common mistake was to give the acronym followed by the incorrect name, such as GP - glycerol phosphate, glucose phosphate or glycerate triphosphate. TP was also a common error. A few candidates muddled RuBP and rubisco.

Question			Answer/Indicative content	Marks	Guidance
		iii	RuBP / ribulose bisphosphate;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **ACCEPT** ribulose biphosphate **Examiner's Comments** Well prepared candidates were able to identify all the relevant enzyme and compounds at the different stages of the Calvin cycle although a common mistake was to give the acronym followed by the incorrect name, such as GP - glycerol phosphate, glucose phosphate or glycerate triphosphate. TP was also a common error. A few candidates muddled RuBP and rubisco.
		iv	starch / amylose / amylopectin **and** cellulose;	1	**Mark the first two answers**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **Examiner's Comments** Few candidates were able to name both starch and cellulose as the two polysaccharides that could be synthesised from the end products of the light dependent stage of photosynthesis. Many suggested either monosaccharides or disaccharides, glycogen, or even lipids and amino acids.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
9	a	i	A inner membrane (of, double membrane / envelope, surrounding organelle) ; B stroma; C granum / grana / granal stack / thylakoid stack;	3	**Mark the first answer on each prompt line.** If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** A **DO NOT CREDIT** inter membrane **DO NOT CREDIT** inner envelope membrane **DO NOT CREDIT** ref to cell / surface / plasma / membrane B correct spelling only C **IGNORE** thylakoid unqualified / lamellae **Examiner's Comments** The parts A, B and C in Figure 1.1 of a chloroplast were correctly named by most candidates. Where errors occurred, they were usually for the misidentification of A (e.g. the inner envelope membrane, thylakoid membrane, or even inner mitochondrial membrane). Very occasionally, stroma was confused with matrix while other candidates referred to C as simply thylakoids.

Question			Answer/Indicative content	Marks	Guidance
		ii	1 contain, (named) pigment (molecules) / photosystems; 2 contain, (named) electron carriers / ETC / ATP synth(et)ase; 3 *idea that* has a large surface area (in a small volume) for, light absorption / light dependent reaction(s) / light dependent stage / electron transport;	2 max	1 **IGNORE** 'accessory' 2 **IGNORE** enzymes unqualified 3 **IGNORE** ref to different wavelengths **Note:** 'the membranes containing the pigments have a large surface area for absorbing light' = **2 marks** (mps 1 & 3) **Note:** 'there is a large surface area for electron transport chain' = **2 marks** (mps 2 & 3) **Examiner's Comments** The majority of candidates were able to describe at least one way in which the structure of the granum (part C) was adapted to its function. References to the presence of pigments, chlorophyll or photosystems on the granal membranes were very frequent and many candidates also went on to add that ATP synthase or the electron carriers would also be contained within the membranes. Many also recognised that there would be a large surface area for light absorption or the light independent stage, although this was also a common omission in weaker answers. Many discussed close proximity to stroma and consequently events occurring in the stroma.
		iii	 ;	1	**DO NOT CREDIT** if more than one tick entered **Examiner's Comments** The vast majority of candidates correctly ticked B for the stroma. The most common error was selection of C, thinking that the light independent reactions take place in the grana.

Question			Answer/Indicative content	Marks	Guidance
	b			2 max	**IGNORE** ref to photorespiration (as Q specifies photosynthesis)
			1 at high light intensity other (named) factor becomes a limiting factor;		1 **ACCEPT** light is no longer the limiting factor e.g. of named factor = temperature / CO_2 concentration **DO NOT CREDIT** if light is given as a limiting factor **DO NOT CREDIT** ref to the rate slowing down **IGNORE** water or other suggestions
			2 idea that temperature becomes limiting as, Calvin cycle / light independent reaction, involves enzymes / relies on kinetic energy of molecules;		2 **ACCEPT** ref to Rubisco being limited by temp (as a named enzyme being in the Calvin cycle)
			3 idea that CO_2 (concentration) becomes limiting as it is required for, Calvin cycle / light independent reaction / formation of (named) Calvin cycle compound / reaction with RuBP / fixation by Rubisco;		3 e.g. of named compound = GP / TP / RuBP **Examiner's Comments** Varied explanations were given as to why the theoretical rate of photosynthesis was not achieved at higher light intensities. Many candidates appreciated that light would no longer be a limiting factor, often suggesting that the other limiting factors could include temperature, carbon dioxide concentration and, occasionally, water. Good answers provided detail of the effect of lower temperatures or the consequences of low carbon dioxide concentration on the light independent reaction. However, some candidates explained why high light intensity would not increase the rate of photosynthesis any further, which was not required by the question.

Question			Answer/Indicative content	Marks	Guidance
	c	i	**No ora** *species **E** because* 1 **E** starts photosynthesising at low(er) light intensity; 2 **E** reaches its maximum rate at low(er) light intensity; 3 **E** steep(er) increase in rate of photosynthesis (with small increase in light intensity); 4 **E** has a, higher / greater / faster, rate of photosynthesis (than **D**) at low light intensities;	2 max	**Only credit answers stating that species E is the shade plant.** **Please indicate this with the green dot annotation.** **IGNORE** ref to time / earlier / later / etc. 2 **IGNORE** plateau (as this is a description of the curve) **IGNORE** ref to optimum rate 3 Needs to relate to the ***increase,*** not just rate i.e. referring to the gradient part of the graph 4 i.e. referring to any point at low light intensity when E is photosynthesising at a higher rate than D **Note** – 'E has a faster increase in the rate of photosynthesis at low light intensities' = **2 marks** (mps 3 & 4) **Examiner's Comments** Almost all candidates identified species E as being better adapted to living in shady conditions although some were unable to explain why. Many candidates stated that species E had a higher rate of photosynthesis at lower light intensities than species D, or that species E started to photosynthesise at a lower light intensity. While some recognised that species E would reach its maximum rate at lower light intensity, it was commonly referred to as the optimum rate or the plateau. Relatively few commented that species E had a steeper increase in rate with a small increase in light intensity.

Question			Answer/Indicative content	Marks	Guidance
		ii	*shade leaf will have* 1 large(r) / more, chloroplast(s) / (palisade) mesophyll; 2 more, grana / thylakoids (in chloroplast); 3 large(r) surface area (of leaves);	1 max	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** *Assume shade leaf unless otherwise stated* **CREDIT** ora for sun leaf **IGNORE** adaptations related to temperature 1 **ACCEPT** more, chlorophyll / photosystems **IGNORE** ref to colour / accessory pigments **Examiner's Comments** The most common correct answer provided gained a mark from shade plants having a large surface area to their leaves whilst others discussed the presence of a higher number of chloroplasts. Weaker answers vaguely referred to size of the leaf, but not to its surface area, or suggested that the number of stomata would be a structural difference, Descriptions of adaptations to prevent water loss via transpiration did not gain credit in this question.
	d		1 animals / heterotrophs (need to), eat / obtain organic material from / AW, plants / autotrophs; 2 (plants / autotrophs) produce (named) organic molecules during, <u>photosynthesis</u> / <u>Calvin cycle</u> / <u>light independent</u> stage; 3 (plants / autotrophs) produce oxygen	3 max	**IGNORE** ref to providing habitat / shelter **DO NOT CREDIT** ref to creating (etc.) energy 1 **CREDIT** (plants / autotrophs) are the start of food chain(s) 3 **IGNORE** photophosphorylation

Question			Answer/Indicative content	Marks	Guidance
			during, photosynthesis / photolysis / light dependent stage; 4 glucose / carbohydrate / oxygen, (produced in photosynthesis) are used in respiration by, animals / heterotrophs;		4 **ALLOW** ref to other respiratory substrate **Examiner's Comments** Candidates generally made the link between the heterotroph's need to gain organic molecules from plants, usually by stating direct ingestion although the mark was occasionally awarded for plants being producers at the start of the food chain. Numerous examples of very wordy answers didn't gain any further marks as there was minimal provision of any description at all about organic molecules being produced in the process of photosynthesis, merely making weak comments about the autotrophs using sunlight to build the organic molecules. Such answers were of GCSE rather than GCE standard. The production of oxygen during photosynthesis and its use during respiration were rarely outlined, but where one of these was mentioned, the other was frequently mentioned as an extension of the same sentence. The importance of products of photosynthesis being used in respiration was a rare extension to good answers.
			Total	**14**	
10			D □	1	
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
11			*idea that* at low light levels, photosynthetic rate is greater when light is shone on the upper surface □ palisade cells are, nearer / AW, upper surface □ *idea that* chloroplasts also present in cells at lower surface □ (little difference because) leaf is thin □ *idea that* light can pass through the leaf from the lower surface to reach palisade cells □ no difference (in rate) at high(er) light intensity □ (at high light intensity) carbon dioxide (concentration) is limiting factor / number of stomata limit carbon dioxide uptake □ figures to support, with units □	4 max	
			Total	**4**	