Question			Answer	Mark	Guidance
1	(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
1	(a)	(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)

Question			Answer	Mark	Guidance
1	(a)	(iii)	<table><tr><td>A</td><td></td></tr><tr><td>B</td><td>✓</td></tr><tr><td>C</td><td></td></tr></table> ;	1	**DO NOT CREDIT** if more than one tick entered
1	(b)		**1** *at high light intensity* other (named) factor becomes a limiting factor ; **2** *idea that* temperature becomes limiting as , Calvin cycle / light independent reaction , involves enzymes / relies on kinetic energy of molecules ; **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 ;	2 max	**IGNORE** ref to photorespiration (as Q specifies photosynthesis) **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** **ACCEPT** ref to Rubisco being limited by temp (as a named enzyme being in the Calvin cycle) **3** e.g. of named compound = GP / TP / RuBP

Question			Answer	Mark	Guidance
1	(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)
1	(c)	(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

Question			Answer	Mark	Guidance
1	(d)				**IGNORE** ref to providing habitat / shelter **DO NOT CREDIT** ref to creating (etc.) energy
			1 animals / heterotrophs (need to) **,** eat / obtain organic material from / AW **,** plants / autotrophs **;**		**1** **CREDIT** (plants / autotrophs) are the start of food chain(s)
			2 (plants / autotrophs) produce (named) organic molecules during **,** photosynthesis / Calvin cycle / light independent stage **;**		
			3 (plants / autotrophs) produce oxygen during **,** photosynthesis / photolysis / light dependent stage**;**		**3** **IGNORE** photophosphorylation
			4 glucose / carbohydrate / oxygen **,** (produced in photosynthesis) are used in respiration by **,** animals / heterotrophs **;**	**3 max**	**4** **ALLOW** ref to other respiratory substrate
			Total	**14**	

Question			Answer	Mark	Guidance
2	(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
2	(a)	(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)
2	(a)	(iii)	able to **,** absorb / use **,** a range of / different / more / other **,** (light) wavelengths / 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
2	(a)	(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

Question			Answer	Mark	Guidance
2	(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
2	(b)	(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
2	(b)	(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
2	(b)	(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**
			Total	**8**	

Question			Answer	Marks	Guidance
3	(a)		rubisco ;	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**
	(b)		ATP / reduced NADP ;	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** oxygen (as it is not used in the light independent reaction)
	(c)		glycerate-3-phosphate / GP / triose phosphate / TP ;	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**
	(d)		amino acid ;	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**
	(e)		ribulose bisphosphate / RuBP ;	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
	(f)		oxygen ;	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** ATP / reduced NADP (as they are used in the light independent reaction)
			Total	6	

Question			Answer	Marks	Guidance
4	(a)		*autotroph* can make **,** organic molecule(s) / named organic molecule(s) **,** from **,** inorganic molecule(s) / carbon dioxide **;** *heterotroph* relies on / needs to use / has to obtain / feeds on and digests **,** (named) organic molecules (that have been made by another organism) **;**	**2**	**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** **IGNORE** ref to biological molecules **ACCEPT** fixes carbon dioxide to produce (named) carbohydrates / protein / lipid idea of ***need*** or ***taking in and breaking down*** is important 'gets its organic molecules from another organism' = **0 marks** 'has to get its organic molecules from another organism' = **1 mark**
	(b)	(i)	**E** granum / grana **;** **F** stroma **;**	**2**	**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** **E** **IGNORE** ref to stacks of **,** lamellae / thylakoids **F** **DO NOT CREDIT** stoma / storma
	(b)	(ii)	for membrane formation **or** phospholipid / cholesterol / glycolipid **,** for membrane **;** fatty acid / (named) pigment **,** synthesis **;**	**1 max**	**IGNORE** ref to ATP production (as primarily generated by photophosphorylation in a chloroplast) **ACCEPT** ref to repair of membrane **ACCEPT** ref to (chloroplast) envelope instead of membrane **DO NOT CREDIT** ref to cell surface membrane (as this is not in the chloroplast)

Question			Answer	Marks	Guidance
4	(c)			4 max	**IGNORE** ref to photophosphorylation, as irrelevant to Q
			1 (primary & accessory) **pigment**s **,** are in / form a(n) **,** photosystem / complex / **antenna complex ;**		**1** if pigments are named, state that chlorophyll a **and** at least 1 named accessory pigment are **in a photosystem**
			2 **photon** / light energy **,** absorbed by pigment (molecule(s)) **;**		**2** *idea of* absorption required in the context of this Q **IGNORE** falls on / hits / strikes
			3 electron **,** excited / moves to higher energy level / delocalised **,** and returned to pigment **;**		**3** **DO NOT CREDIT** if ***this*** electron is passed to **,** electron acceptor / ETC **DO NOT CREDIT** in context of chlorophyll a
			4 (energy / photon) passed from one pigment to another **;**		**4** **DO NOT CREDIT** ref to electron being passed
			5 (energy / photon) passed to **, reaction centre / chlorophyll a** / P680 / P700 / PSI / PSII / **primary** pigment **;**		**5** **DO NOT CREDIT** ref to electron being passed **But** apply ecf from mp 4
			6 range of / **accessory ,** pigments allow range of **wavelengths** to be absorbed **;**		**6** **CREDIT** 'photon energy' for 'wavelengths' **IGNORE** in context of P680 and P700
			QWC – technical terms used appropriately and spelt correctly **;**	**1**	Use of **three** terms from: **pigment** **antenna complex** **photon** **reaction centre** **chlorophyll** , **a / A** **primary** **accessory** **wavelength**(s) **Please insert a QWC symbol next to the pencil icon, followed by a tick (✓) if QWC has been awarded or a cross (×) if QWC has not been awarded You should use the green dot to identify the QWC terms that you are crediting.**

Question			Answer	Marks	Guidance
4	(d)	(i)	- 864.3 (kg ha^{-1}) ; - 7.4 (%) ;	2	**DO NOT CREDIT** answer that is not given to 1 dp **DO NOT CREDIT** correct numerical answer without minus sign If no answers on the answer lines, then look in the appropriate boxes in the table for the answers. **ALLOW** ecf from candidate's value for kg ha^{-1}
	(d)	(ii)	*idea that* the number of , plots / samples , was , too / very , small ;	1	Just ref to a smaller number of plots is not quite enough **CREDIT** *idea that* the number of plots was not large enough **IGNORE** ref to the idea that the difference is very large
	(d)	(iii)	**1** prevents non-cyclic photophosphorylation ; **2** no electron(s) available to form reduced NADP ; **3** *idea that* ATP production by cyclic photophosphorylation is not prevented ; **4** no / less , ATP and no reduced NADP available for , Calvin cycle / light independent reaction / conversion of GP to TP ;	2 max	**1** **IGNORE** ref to cyclic photophosphorylation **2** **CREDIT** red NADP / NADPH / NADPH + H^+ / $NADPH_2$ for 'reduced NADP'
	(d)	(iv)	*idea that* energy given off from , high energy / excited , electron (emitted by , chlorophyll / reaction centre) ;	1	
			Total	16	

Question			Answer	Marks	Guidance
5	(a)		*oxygen* **1** oxygen ***only*** produced in one (named) stage of photosynthesis **;** **2** oxygen ***produced*** might be used for respiration **;** *carbon dioxide* **3** CO_2 ***only*** used in one (named) stage of photosynthesis **;** **4** CO_2 ***produced*** during respiration might be used for **,** photosynthesis / light independent reaction / Calvin cycle **;** **5** O_2 / CO_2 / both **,** could be an underestimate **or** represents net production (O_2) **or** represents net use (CO_2) **;**	2 max	***1*** **CREDIT** for O_2 'only measures the rate of the light dependent stage / photolysis' ***3*** **CREDIT** for CO_2 'only measures the rate of the Calvin cycle' ***5*** **ACCEPT** a description e.g. 'measurement is less than expected because not all the oxygen produced can be measured' (but not if expressed in terms of terms of experimental error – e.g. dissolves in the water) **IGNORE** refs to reliability / accuracy
5	(b)	(i)	light <u>intensity</u> **;**	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**

Question			Answer	Marks	Guidance
5	(b)	(ii)	carbon dioxide <u>concentration</u> / partial pressure of CO_2 / temperature **;** AVP **;**	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** **'**high' or 'low', as these indicate situations rather than factors eg • stomatal density • stomatal size • chlorophyll concentration • number of chloroplasts • enzyme turnover rate **IGNORE** (temporary) changes in stomatal **,** opening / closing **IGNORE** ref to water availability
	(b)	(iii)	(aerobic / anaerobic) respiration **;**	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** Krebs cycle / link reaction / decarboxylation **DO NOT CREDIT** photorespiration (as light intensity stated as being low)

Question			Answer	Marks	Guidance
5	(b)	(iv)	**1** at 0 **,** respiration only / no photosynthesis **;** *between 0 and X* **2** *idea that* (rate of) respiration is greater than (rate of) photosynthesis **;** *at X* **3** *idea that* (rate of) respiration equals (rate of) photosynthesis / at compensation point **;** *after X* **4** *idea that* (rate of) photosynthesis is greater than (rate of) respiration **;**	3 max	Assume that candidate is answering in the same order as the bullet points, unless otherwise indicated. **IGNORE** photorespiration throughout **CREDIT** **'**Calvin cycle' for 'photosynthesis' throughout For **mps 2, 3 & 4** must include clear ref. to both respiration and photosynthesis ***2*** **DO NOT CREDIT** no photosynthesis
5	(c)	(i)	reduced NADP / NADPH / $NADPH_2$ / $NADPH^+$ **;** ATP **;** oxygen **;**	3	**Mark the first 3 answers.** **IGNORE** numbers of molecules **ACCEPT** O_2 (to be consistent with the other answers to this question)

Question			Answer	Marks	Guidance
5	(c)	(ii)	**1** prevents photophosphorylation **;** **2** cyclic **and** non-cyclic **;** **3** no / less **,** ATP / reduced NADP **,** for **,** light-independent stage / Calvin cycle / GP to TP **;** **4** no (named) substrate made for respiration **;**	2 max	***3*** 'no ATP for photosynthesis' is not quite enough **DO NOT CREDIT** (oxidised) NADP ***4*** substrate eg glucose / starch / carbohydrate / sucrose / sugars **IGNORE** triose phosphate / food / nutrients
			Total	**13**	