

Q1.

- 1 (a) top half of leaf/just below (upper) epidermis;
packed (densely);
long axis in line with incident light/AW;
2 max
- (b) contain large numbers of chloroplasts/large amount of chlorophyll;
large vacuole; (*only give if linked to next point*)
chloroplasts (in cytoplasm) close to cell wall/cell membrane;
short diffusion pathway;
(cell) elongated/arranged to intercept (maximum) light;
thin (cell) wall;
ref. movement of chloroplasts;
3 max
- (c) contains photosystems/PS1 and PS2/chlorophyll and accessory pigments/
reaction centres;
maintain carriers/receptors in position;
site of photophosphorylation/light reaction;
site of ETC;
ref. proton pumping/proton gradient;
large surface area;
produce ATP/ref. ATP synthase;
produce reduced NADP;
4 max
- (d) ref. to Rubisco;
carbon dioxide combines with RuBP;
driven/powered by ATP;
and reduced NADP;
forms PGA;
2 max

Total: 11

Q2.

Question	Marks
4 (a) A epidermal cell ; B guard cell ;	2
(b) allows carbon dioxide into leaf ; as rest of leaf covered with waxy / waterproof cuticle ; down concentration gradient / diffuses ; <i>for either O₂ or CO₂</i> controls water (vapour) loss ; ref. to faster diffusion through small pores / edge effect ; oxygen out ;	4 max
(c) ref. to chloroplasts ; sausage shaped / AW ; joined only at ends ; unevenly thickened walls / thick above and below / thin furthest from the pore ; ref. vacuole ;	2 max
	Total: 8

Q3.

Question	Marks
5 (a) stroma of chloroplast ;	1
(b) combines with (5C compound) RuBP ; to form unstable 6C compound / forms 2 molecules of (3C) GP ; ref. enzyme / rubisco ;	2 max
(c) reduced NADP and ATP ; (ATP is) source of energy ; (reduced NADP is for) reduction of GP(PGA) to triose phosphate (TP) ; ref. use of ATP in regeneration of RuBP ; ref. to source of phosphate / phosphorylation ;	3 max
(d) RuBP, accumulates / goes up ; due to reduced combination with CO ₂ / AW ; <i>in either RuBP or GP, not both</i> GP, goes down / not as much being formed ; due to conversion to TP ;	3 max
	Total: 9

Q4.

2	(a) (i)	at low light intensities ; rate of photosynthesis is proportional to light intensity / light intensity is limiting ; after 1 units of light ; rate levels off / reaches plateau ; relevant fig plus units ;	[3 max]
	(ii)	(B) after 3 units light intensity not limiting ; CO ₂ now limiting ; (C) curve continues to increase until 5 units of light ; light intensity limiting ; correct description of law of limiting factors ; detail. collisions of CO ₂ and enzymes ; AVP ; e.g., further detail of enzymes	[4 max]
	(b)	optimum temperature ; method e.g. heaters / ventilation ; optimum CO ₂ concentration ; burners / combustion / add dry ice / pump in CO ₂ up to 1% ; high light intensity / longer duration of light / artificial lighting ; ref. irrigation ; ref. fertilisers ; ref. pest / disease control ; ref. artificial pollination ;	[2 max]
			[Total: 9]

Q5.

- 7 (a) (i) *ref. wavelength*
- 1 chlorophyll **a** peaks at 430nm and chlorophyll **b** peaks at 450nm ;
 - 2 chlorophyll **a** peaks at 660nm and chlorophyll **b** peaks at 635–640nm ;
 - 3 ref. linking 400–500nm with blue light / ref. linking 600–700nm with red light ;
 - 4 (both have) little absorption, between 500–600nm / in green light ;
A little absorption, chlorophyll **a** 450–600 and chlorophyll **b** 500–600 ;
- ref. light absorption*
- 5 (both) peaks in blue light are higher than peaks in red light ;
 - 6 chlorophyll **b** higher than chlorophyll **a** in the blue end / chlorophyll **a** higher than chlorophyll **b** in the red end / AW ; A converse
 - 7 comparative figures for light absorption to illustrate points 5 or 6 ; [3 max]
- ignore units*
- (ii) 1 absorbed light used for photosynthesis ;
- 2 higher rate of photosynthesis in red and blue light ;
 - 3 action peak(s) / high rate of photosynthesis, correspond to absorption peak(s) ;
 - 4 blue / shorter wavelength, light has more energy / ora ;
 - 5 not an exact match between absorption and action spectra (in middle region) ;
 - 6 role of carotenoids / accessory pigments, (in middle region) ; [3 max]
- (iii) they contain chlorophyll ;
- green / blue green / yellow green, light reflected ; [2]
- (b) W – label line to stroma ;
- Y – label line to, granum / intergranal membranes ; [2]
- (c) 1 light not limiting ;
- 2 much, ATP / reduced NADP, available ;
 - 3 CO₂ is the limiting factor ;
 - 4 because low concentration CO₂ (in atmosphere) ;
 - 5 more CO₂ combines with RuBP ;
 - 6 ref. rubisco ;
 - 7 Calvin cycle / light independent stage ;
 - 8 GP to TP ;
 - 9 more hexose produced ;
 - 10 ref. fate of hexose ; [5 max]

[Total:15]

Q6.

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- 8 (a) M – palisade ;
 N – vascular bundle / phloem and xylem / vein ; [2]
- (b) 1 ref. ABA absence ;
 2 H^+ transported out of guard cells, actively / using ATP ;
 3 low H^+ conc / negative charge, inside cell ;
 4 K^+ channels open / K^+ diffuses into cell ;
 5 water potential of cell falls ; **A** decrease in solute potential
 6 water moves into cell by osmosis ;
 7 volume of guard cells increase / turgor increases ;
guard cells:
 8 have hoops of cellulose microfibrils which ensure increase in length rather than diameter ;
 9 have ends that are joined together ;
 10 have, thicker inner walls / thinner outer walls ;
 11 curve apart / bend, (to open stoma) ; [6 max]
- (c) (i) cyclic photophosphorylation ; [1]
 (ii) photolysis ;
 (water splits into) $2e^-$, $2H^+$ and $(\frac{1}{2})O_2$;
 enzyme is involved ; [2 max]
- (iii) ATP ; [1]
- (iv) hydrogen carrier ;
 GP, reduced / hydrogen added ; **R** H_2
 to, TP / 3 carbon sugar ;
 uses ATP ; [2 max]
- [Total: 14]**

Q7.

- 4 (a) (i) J – epidermis/epidermal cell ;
 K – mesophyll (cell) ;
 L – bundle sheath (cell) ; [3]
- (ii) 1 mesophyll cells tightly packed/AW ;
 2 so O₂ cannot reach bundle sheath cells ;
 3 light independent stage/Calvin cycle **or** RuBP, in bundle sheath cells ;
 4 ref. malate shunt ;
 5 maintains high CO₂ concentration (in bundle sheath cells) ;
 6 PEP carboxylase, has high optimum temperature/has higher affinity for CO₂/doesn't accept O₂ ;
 7 (PEP carboxylase) not denatured ;
 8 photorespiration is avoided ; [4 max]
- (b) 1 reduces water loss/AW ;
 2 wax does not melt ;
 3 shiny surface reflects radiation ; [2 max]
- (c) (i) greater reduction in sorghum than in soybean ;
 use of comparative figures ; e.g. sorghum 5.5 to 1.2 **or** by 4.3
 soybean 5.2 to 1.6 **or** by 3.6 [2]
- (ii) *reject 'no' for all points*
- 1 less surface area ;
 2 less absorption of light ;
 3 less, photophosphorylation / light dependent reaction ;
 4 less chemiosmosis ;
 5 (due to) smaller thylakoid space **or** reduced proton gradient ;
 6 less ATP (produced) ;
 7 less reduced NADP (produced) ;
 8 light-independent reaction / Calvin cycle, slows down ;
 9 less carbon dioxide, fixed / combined with PEP ; **R** uptake [4 max]
- [Total: 15]

Q8.

- 8 (a) (i) 1. 26 °C optimum temperature for, rubisco / enzyme of Calvin cycle ;
 2. (at just over 40 °C) enzymes / rubisco, denatured ;
 3. so less carbon dioxide fixed ;
 4. reduction in Calvin cycle / AW ;
 5. increased rate of transpiration / AW ;
 6. so stomata close ;
 7. less carbon dioxide uptake ;
 8. oxygen more likely to combine with rubisco ;
 9. so increased photorespiration ; [5 max]
- (ii) curve of C4 drawn with optimum to the right of existing curve ; 1 mark
1. C4 / sorghum, enzymes, have higher optimum temperature (than C3) ;
 2. has leaf structural features to avoid photorespiration ;
 3. adapted to hot climate ; 2 max [3 max]

(b) (i)

light intensity / lux	total CO ₂ uptake / μmol	rate of photosynthesis / μmol s ⁻¹
5	36	1.8
10	84	4.2
13	104	5.2
15	120	6.0

all 3 correct = 1 mark

[1]

- (ii) axes correct ;
 units ;
 correct plotting ;
 suitable curve ; between 5 and 15 lux

accept ecf from table

[3 max]

- (iii) when a process is affected by more than one factor / AW ;
 the rate of photosynthesis is, restricted by / AW, the factor that is nearest its lowest value ; [2]
- (iv) light intensity ; [1]
- [Total: 15]**

Q9.

- 8 (a) (guard cell) thicker inner / unevenly thickened, cell wall ; **ora**
 ref. to differences in, size / shape ; [1 max]
- (b) (i) (receptors) on plasma / cell surface, membrane (of guard cells) ; [1]
 (ii) K^+ / potassium ; [1]
 (iii) (guard cell has) higher water potential than epidermal cell ; **ora** [1]
 (iv) decrease ; [1]
- (c) (i) provides carbon dioxide ; [1]
 (ii) 0.1 ;
 % per minute ; *reject plural* [2]
 (iii) 0 – 10 mins / initially, rate for **B** is faster than rate for **A** ;
 10 – 20 mins / AW, rate decreases for **B** and not for **A** / rate decreases more for **B** ;
 paired figs ; *A & B % at same time (minutes)* [2 max]
- (iv) no, photosynthesis / light dependent reaction ;
 oxygen used up in respiration ; [2]
- (v) temperature ; [1]
- (d) reduced NADP ;
 ATP ; [2]
- [Total: 15]**

Q10.

- 1 (a) A – palisade, mesophyll/cell/tissue/layer;
 B – guard cell;
 C – (sub-stomatal) air space; [3]
- (b) (i) 1. through the stoma(ta);
 2. by diffusion/description;
 3. from the, atmosphere/air; [max 2]
- (ii) ribulose biphosphate;
 I RuBP [1]
- (iii) reduces/donates hydrogen ; [2]
 A H/hydrogen atoms/H⁺ AND e⁻
 R H⁺ / H₂
 GP to TP ;
 A PGA to PGAL
- [Total: 8]

Q11.

- 1 (a) (i) *in high light intensity*
 1. (as temperature increased) the volume of oxygen released / rate of photosynthesis, increased to a peak **and** then fell;
- in low light intensity*
 2. (as temperature increased) the volume of oxygen released / rate of photosynthesis, remained constant **and** then fell;
 3. supporting figures (two oxygen values at two different temperatures plus units); [3]
- (ii) 1. light no longer limiting / temperature now limiting;
 2. enzymes denatured / described;
 3. so fewer enzyme-substrate complexes / AW;
 4. so less photolysis (leads to less oxygen produced); [2 max]
- (b) (i) photolysis; [1]
 (ii) P680; A (photosystem) II [1]
 (iii) respiration uses oxygen; [1]
- [Total: 8]

Q12.

Question 1

(a)

(i)

increase ;
rapid/sharp/steep ;
then decrease ;
does not drop to original value ;

2 max

(ii)

decreases to 0 / all used up ;

1

(b)

(i)

GP continues to be formed from RuBP;
(until) all RuBP used up ;
the GP falls as converted to hexose/glucose/TP ;

2 max

(ii)

in dark RuBP not regenerated/converted to GP ; **R** used up
requires the products /ATP/reduced NADP from the light reaction / photophosphorylation ;

2

(c)

ATP ;
reduced NADP ;

2

Total : 9

Q13.

Question 1

- (a)
- 1 sun leaves reach compensation point / zero gas exchange at higher light intensity;
 - 2 rate of photosynthesis increases more rapidly in sun leaves ;
 - 3 CO₂ uptake is greater in shade leaves (ora) at low light intensity ;
 - 4 higher rate of photosynthesis / CO₂ uptake in sun leaves (ora) at higher light intensity ;
 - 5 more respiration in sun leaves (ora) at zero or low light intensity;
 - 6 CO₂ uptake levels off in shade leaves (ora) ;
- 3 max**

*accept CO₂ uptake for photosynthesis and vice versa
accept CO₂ production for respiration and vice versa*

- (b) light no longer limiting ;
some other factor limiting ;
example carbon dioxide concentration / temperature / ref:chlorophyll ;
- 3**

- (c) at low light intensity little or no effect / light (dependent reaction) limiting rate ;
at high light intensity increasing temperature will increase the rate of photosynthesis ;
ref. (effect of temperature on the rate of) enzyme controlled reactions / light independent stage ;
detail – e.g. named enzyme (RuBISCO) / ref. Calvin Cycle ;

ignore reference to sun / shade leaves

3 max

Total : 9

Q14.

-
- 1 (a) 1 chlorophyll absorbs mainly red and blue light;
2 light absorbed by antenna complex;
3 energy transferred;
4 reaction centres/P700/P680;
5 light energy excites electron(s)/reference passing to higher energy level;
6 electron lost from chlorophyll **3 max**
- (b) 1 water is split into H^+ and OH^- ;
2 electron removed from OH^- ;
3 to replace electron from photosystem/chlorophyll;
4 OH^- breaks down into O_2 and water;
5 H^+ used to form reduced NADP;
6 reference correct, balanced equation; **3 max**
- (c) 1 reference flow of electrons along ETC;
2 reference to pumping H^+ across membrane;
3 reference to H^+ /proton gradient across the thylakoid membrane;
4 flow of protons down gradient;
5 via ATPase/stalked particles;
6 formation of ATP from ADP and P_i ;
7 cyclic, electron returns to original photosystem;
8 non-cyclic, electron from PSII to PSI; **3 max**
- (d) reference increased efficiency/short diffusion distance/close together; **1**

Total 10

Q15.

- 9 (a) (i) ribulose ; [1]
(ii) ribulose biphosphate carboxylase / rubisco ; [1]
(iii) stroma ; R stoma [1]
(iv) ATP / reduced NADP ; R reduced NAD [1]
- (b) 1 light independent reaction / Calvin cycle, continues ;
2 RuBP (still) converted to GP ;
3 until used up ; *link to 2*
4 light dependent reaction stops ;
5 no, ATP / reduced NADP, produced ;
6 RuBP not regenerated ;
7 GP, converted to TP / used to make hexose ; [4 max]
- [Total: 8]

Q16.

8	(a)	<p>(i) <i>at low light intensity</i></p> <ol style="list-style-type: none"> 1. rate of photosynthesis increases as light intensity increases ; 2. light <u>intensity</u> is limiting factor ; <p><i>at higher light intensity</i></p> <ol style="list-style-type: none"> 3. graph, levels off / forms a plateau / rate becomes constant ; 4. CO₂ / some other factor, becomes limiting ; 	[3 max]
		<p>(ii)</p> <ol style="list-style-type: none"> 1. above light intensity of 1 rate is always higher for expt. 2 ; 2. plateau reached at lower light intensity for expt. 1 ; 3. maximum / plateau, rate is double for expt. 2 ; 4. expt 2 has much more CO₂ (conc) (compared to expt 1) ; 5. CO₂, no longer limiting after 4.2 in expt.2 / is limiting in expt. 1 up to 2.8 ; 	[3 max]
	(b)	<ol style="list-style-type: none"> 1 enzymes, denatured / active site changes shape ; 2 rubisco / enzyme in cyclic photophosphorylation ; 3 Calvin cycle affected / description ; 4 less photolysis ; 5 less ATP produced ; 6 increased rate of respiration ; 7 respiration rate faster than photosynthesis rate / ref. compensation point ; 8 increased rate of transpiration ; 9 stomatal closure ; 10 less CO₂ uptake ; 	[5 max]
			Total:111

Q17.

8	(a)	1	stomata ;	[4 max]
		2	air spaces (between cells) ;	
		3	thin cell walls ;	
		4	moist internal walls ;	
		5	<u>thin</u> leaf ;	
		6	cylindrical palisade cells ;	
		7	large surface area of, palisade / mesophyll, cells ;	
	(b)		0.0025 / 2.5×10^{-3} ; A 0.003 only if 0.0025 in answer	[1]
	©	1	photosynthesis takes place ;	[3 max]
		2	oxygen is produced ;	
		3	collects, inside disc / on surface of disc ;	
		4	disc, less dense / more buoyant ;	
	(d)		<u>rate</u> of photosynthesis increases as light intensity increases ; paired data quotes from columns 2 and 4 ;	[2]
	(e)	1	light intensity no longer limiting ;	[2 max]
		2	<u>carbon dioxide</u> , concentration / rate of diffusion, now limiting ;	
		3	temperature, too high / denatures enzymes ;	
				[Total: 12]

Q18.

- 8 (a) 1 absorb light; **A** harvest light / trap light **R** collect light
 2 pass energy to, primary pigment / chlorophyll / reaction centre ; [2 max]

- (b) *cyclic photophosphorylation*
 1 electron emitted returns to, PSI / same photosystem or same chlorophyll molecule ;
non-cyclic photophosphorylation
 2 electron emitted from PSII absorbed by PSI ;
 3 reduced NADP produced ;
 4 photolysis occurs ; **A** splitting of water
 5 (photolysis) only involves PSII ;
 6 oxygen produced 3 max
accept ora for cyclic for marking points 3, 4 and 6
mark to max 3 if cyclic and non-cyclic are described the wrong way round [4 max]

- (c) (i) some other factor becomes limiting / temperature no longer limiting ;
 CO₂ / light intensity ; [2]
 (ii) line falls towards 70°C ; [1]
 (iii) *rate of photosynthesis falls*
 enzyme / rubisco, denatured / AW ;
 substrates not able to fit active site / AW ; [2]

(d)

adaptation	how the adaptation helps photosynthesis
thin cell wall	greater light penetration / short diffusion distance (for gases) ;
cylindrical shape	air spaces ;
large vacuole	chloroplasts near outside of cell for better light absorption / maintains turgor ;
chloroplasts can be moved within the cell	absorb maximum light / avoid excessive light intensities ;

[4]

[Total: 15]

Q19.

- 8 (a) 1 high rate of photosynthesis at 430–435nm and 655nm wavelengths ;
 2 idea of (high) absorption of light at these wavelengths ;
 3 highest rate, at 430–435 nm ;
 4 shorter wavelengths have more energy ;
 5 low(er rate) in, middle range / 500–600, of wavelengths ;
 6 low light absorption here ;
 7 absorbed light used for photosynthesis ;
 8 in light-dependent stage ; [4 max]
- (b) (i) ATP ;
 reduced NADP ; [2]
- (ii) 1 ATP provides energy ;
 2 reduced NADP, is reducing agent / provides hydrogen ;
 3 for converting GP to TP ;
 4 (ATP used to) regenerate RuBP ; [3 max]
- (c) process / photosynthesis, affected by more than one factor ;
 rate is limited by the factor nearest its minimum value / AW ; [2]
- (d) 1 enters leaf through (open) stomata ;
 2 by diffusion ;
 3 substomatal air space ;
 4 many air spaces in spongy mesophyll ;
 5 spaces between palisade cells ;
 6 dissolves in moisture on cell (walls) ;
 7 enters through cell walls ; [4 max]
- [Total: 15]**

Q20.

- 7 (a) (i) 1. (blue) light is absorbed and used for photosynthesis ;
 2. CO₂ , used / concentration decreased ;
 3. leads to, rise in pH / decrease in acidity ; [max 2]
- (ii) 1. respiration **but no** photosynthesis ;
 2. CO₂, produced / released ;
 3. leads to, decrease in pH / increase in acidity ; [max 2]
- (b) (i) absorb light (energy) ;
 pass (light) energy onto, primary pigment / chlorophyll a / reaction centre ; [2]
- (ii) $\text{H}_2\text{O} \longrightarrow 2\text{H}^+ + 2\text{e}^- + \frac{1}{2} \text{O}_2$;
A $2\text{H}_2\text{O} \longrightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$ [1]
- (iii) grana / thylakoid, membrane ; [1]
- [Total: 8]

Q21.

- 7 (a) **A** – photosystem II / P680 / PS II ;
B – photosystem I / P700 / PS I ; [2]
if photosystem given for both but wrong way round give one mark
- (b) (i) 1. carbon dioxide fixation ;
 2. production of GP ;
 3. ref. to rubisco ; [max 2]
- (ii) 1. reduction (of GP) / donates hydrogen ;
 2. GP to TP ; [2]
- (iii) 1. supplies, energy / phosphate ;
 2. (to convert) GP to TP ;
 3. (to) regenerate of RuBP ; [max 2]
- [Total: 8]

Q22.

1 (a) (i) stroma ; [1]

(ii) lower CO₂ concentration ;

less, carbon fixation / CO₂ combining with RuBP / RuBP converted to GP ;

RuBP reformed from TP ;

[max 2]

(iii) 0.01 ;;

A 0.012 or $1.8 \div 150$ or $\frac{2.0 - 0.2}{150}$ or $\frac{2.0 - 0.2}{350 - 200}$ for 1 mark

[2]

(b) less TP ;

(so less) conversion to, (other) carbohydrates / lipids / amino acids / proteins ;
A named examples, e.g. glucose / hexose / cellulose / starch

AVP ; e.g. 1 – (amino acids) used to make proteins for, growth / cell
division

e.g. 2 – (carbohydrate / lipid) for respiration for, growth / cell division

[max 2]

[Total: 7]

Q23.

1 (a) transport proteins – Y ;

pigments – X ;

[2]

(b) DNA

codes for, proteins/polypeptides/enzymes ;

one example of protein or enzyme ;

e.g. rubisco/electron acceptor/ATP synthase/transport

ref. transcription/ mRNA ;

[max 2]

(c)

factor	stage	✓ or ✗
carbon dioxide concentration	Calvin cycle	✓
	photolysis	✗
light intensity	Calvin cycle	✗
	photolysis	✓
temperature	Calvin cycle	✓
	photolysis	✗

⋮

all 6 correct = 3 marks

4 or 5 correct = 2 marks

2 or 3 correct = 1 mark

[3]

[Total:7]

Q24.

- 8 (a) (i) A – RuBP/ribulose biphosphate ;
 B – fatty acid ;
 C – nitrates ; A suitable nitrogenous substance e.g. ammonium ions
 I nitrogen/ammonia [3]
- (ii) non-cyclic photophosphorylation ; [1]
- (iii) condensation/polymerisation ; A anabolic
 glycosidic ; [2]
- (iv) 1 enters via stoma(ta) ;
 2 by diffusion/down a concentration gradient ;
 3 passes through air spaces ;
 4 dissolves in film of water (on cell surface) ;
 5 (diffuses) through cell, wall /surface membrane (of palisade cells) ; [max 3]
- (b) 1 excited electrons leave, chlorophyll a/photosystem ;
 2 pass along ETC ;
 3 protons present from photolysis ;
 4 protons (pumped) into intermembrane space ;
 5 rubisco is in stroma ;
 6 *idea that* protons leaving stroma raises pH ; [max 3]
- [Total: 12]**

Q25.

- 8 (a) X pointing to chloroplast ;
 Y pointing to cell wall ;
 Z pointing to any membrane ; [3]
- (b) (i) rate on y-axis **and** light intensity on x-axis ;
 all points plotted accurately ;
 line of best fit ; [3]
- (ii) 1 at low light intensity light is the limiting factor ;
 2 at high light intensity other factors become limiting ;
 3 such as, temperature / carbon dioxide concentration ; [3]
- (c) (i) chlorophyll b **and** carotenoids ; [1]
- (ii) 1 absorb light (energy) ;
 2 at wavelengths not readily absorbed by, chlorophyll a / primary pigment ;
 3 pass energy to, chlorophyll a / primary pigment ;
 4 in reaction centre ; [max 3]
- (iii) reflected ; [1]
- (iv) action spectrum ; [1]
- [Total: 15]

