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 ; *for **either** O_2 **or** CO_2*	
		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 ; *in either RuBP or GP, not both*	
		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 CO_2 is the limiting factor ;

4 because low concentration CO_2 (in atmosphere) ;

5 more CO_2 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.

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 $(½)O_2$;

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 O_2 cannot reach bundle sheath cells ;

3 light independent stage/Calvin cycle **or** RuBP, in bundle sheath cells ;

4 ref. malate shunt ;

5 maintains high CO_2 concentration (in bundle sheath cells) ;

6 PEP carboxylase, has high optimum temperature/has higher affinity for CO_2/doesn't accept O_2 ;

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 <u>reduction</u> 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 bisphosphate;
I RuBP [1]

(iii) reduces/donates hydrogen ; [2]
A H/hydrogen atoms/H^+ **AND** e^-
R H^+ / H_2

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 CO_2 uptake is greater in shade leaves (ora) at low light intensity ;
4 higher rate of photosynthesis / CO_2 uptake in sun leaves (ora) at higher light intensity ;
5 more respiration in sun leaves (ora) at zero or low light intensity;
6 CO_2 uptake levels off in shade leaves (ora) ; **3 max**

accept CO_2 uptake for photosynthesis and vice versa
accept CO_2 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 bisphosphate 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, coverted to TP / used to make hexose ;	[4 max]
				[Total: 8]

Q16.

8	(a)	(i)	*at low light intensity* 1. rate of photosynthesis increases as light intensity increases ; 2. light intensity is limiting factor ; *at higher light intensity* 3. graph, levels off / forms a plateau / rate becomes constant ; 4. CO_2 / some other factor, becomes limiting ;	[3 max]
		(ii)	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 CO_2 (conc) (compared to expt 1) ; 5. CO_2, no longer limiting after 4.2 in expt.2 / is limiting in expt. 1 up to 2.8 ;	[3 max]
	(b)	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 CO_2 uptake ;	[5 max]
				[Total:11]

Q17.

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

CO_2 / 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 430–435 nm **and** 655 nm 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. CO_2 , used / concentration decreased ;

3. leads to, rise in pH / decrease in acidity ; [max 2]

(ii) 1. respiration **but no** photosynthesis ;

2. CO_2, 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) $H_2O \longrightarrow 2H^+ + 2e^- + \frac{1}{2} O_2$;

A $2H_2O \longrightarrow 4H^+ + 4e^- + O_2$ [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 CO_2 concentration ;

less, carbon fixation / CO_2 combining with RuBP / RuBP converted to GP ;

RuBP reformed from TP ; [max 2]

(iii) 0.01 ;;

A 0.012 **or** 1.8 ÷ 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 bisphosphate ;

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]