13. Photosynthesis

13.1 Photosynthesis as an Energy Transfer Process

Paper 4

Marking Scheme

Q1.

(b)	*any **three** from:* 1 light absorbed by, photosystem II / P680 **or** photoactivation / photoionisation (of chlorophyll) ; 2 photolysis (of water) ; 3 water-splitting enzyme / oxygen evolving complex ; 4 water splits into protons, electrons and oxygen ; **A** equation	**3**

Q2.

(a)(i)	**A** = stroma ; **B** = thylakoid, lumen / space ;	**2**
(a)(ii)	**1** cyclic photophosphorylation ; **2** ATP synth(et)ase ;	**2**
(a)(iii)	**1** **D** = reduced NADP ; **2** reduces / gives hydrogen to, glycerate (3) phosphate / GP ; **3** forming, triose phosphate / TP ;	**3**

Q3.

(a)	1 calculate R_f value(s) ; 2 (R_f =) distance moved by pigment (from baseline) / distance moved by solvent (from baseline) ; 3 compare with, known / standard / table, values ;	**3**
(b)	*any **three** from:* 1 absorb light wavelengths **not** absorbed by, reaction centre / primary pigment / chlorophyll a ; **A** harvest 2 so extend the range of wavelengths absorbed ; 3 pass **energy** to, reaction centre / primary pigment / chlorophyll a ; 4 *ref. to* accessory pigments ;	**3**

(c)	*any **seven** from:* 1 carbon dioxide, **reacts / combines**, with, ribulose bisphosphate / RuBP ; 2 (catalysed by) rubisco ; 3 *ref. to* carbon (dioxide) fixation ; 4 unstable 6C compound ; 5 forms 2 (molecules of) glycerate 3-phosphate / GP ; 6 glycerate 3-phosphate / GP, **reduced** to, triose phosphate / TP ; 7 **by** reduced NADP and ATP ; 8 triose phosphate / TP, used to regenerate RuBP ; 9 glycerate 3-phosphate / GP, forms amino acids ; 10 (some) TP forms, (named) hexoses / sucrose / maltose / starch / cellulose / glycerol / lipids / amino acids ; 11 *ref. to* Calvin cycle ;	**7**

Q4.

(c)	*any **six** from*: *similarities* **1** photoactivation of chlorophyll ; **2** (energetic) electrons move, along / down, ETC ; **3** chemiosmosis ; **4** ATP produced ; *differences* **5** PSI and PSII in non-cyclic **and** only PSI in cyclic ; **6** photolysis / oxygen produced, in non-cyclic only ; ORA **7** reduced NADP in non-cyclic only ; ORA **8** electrons return to, same photosystem / PSI, in cyclic ;	**6**

Q5.

(b)(i)	carbon (dioxide) fixation ; **A** carboxylation	**1**
(b)(ii)	reduction / hydrogenation ;	**1**
(b)(iii)	6 / 5 ;	**1**
(b)(iv)	*any **two** from: list rule* 1 hexose / named ; e.g. glucose / fructose 2 disaccharide / named ; e.g. sucrose / maltose 3 starch / cellulose ; 4 amino acids ; 5 glycerol / fatty acids ;	**2**

Q6.

(a)	<table><tr><th>description</th><th>letter</th></tr><tr><td>accumulates (builds up) a high concentration of protons</td><td>**B** ;</td></tr><tr><td>makes triose phosphate</td><td>**A** ;</td></tr><tr><td>makes some chloroplast proteins</td><td>**D** ;</td></tr><tr><td>pumps protons</td><td>**C** ;</td></tr></table>	**4**
(b)(i)	*any **four** from:* **1** spot / extract, placed on, pencil line / base line / line of origin ; **2** repeat / concentrate, spot / extract ; **3** end / base, of paper, suspended / placed, in (named) solvent ; **4** mark the solvent front after, some time / paper removed / solvent moves ; **5** R_f value = distance moved by, spot / pigment / component / solute ÷ distance moved by solvent (front) ; **6** compare (R_f) with known R_f values to identify, constituents / pigments ; **7** detail of method ;	**4**
(b)(ii)	*any **three** from:* **1** (pigments / they / to) absorb / capture / harvest, light (energy) ; **2** increase (range of) / more / different, wavelengths / colours of light, can be absorbed ; **3** increase, efficiency / rate, of, photosynthesis / light dependent reaction **OR** increase / broader, action spectrum ; **4** *ref.* two of: chlorophyll a / chlorophyll b / carotene / xanthophyll ;	**3**

Q7.

(a)	*any **four** from:* 1 both photosystem I and photosystem II involved ; **A** both photosystems 2 photoactivation of chlorophyll occurs ; 3 photolysis of water occurs / description ; 4 oxygen production / oxygen-evolving complex involved ; 5 electrons emitted by photosystem I used to reduce NADP **or** NADP is the final electron acceptor ; 6 photosystem I receives electrons from photosystem II **or** photosystem II receives electrons from photolysis (of water) ; 7 ETC / electron transport chain, sets up proton gradient **or** chemiosmosis / ATP produced ;	**4**
(b)	GP used to make, amino acids / fatty acids / lipids ; TP used to make, hexose / starch / cellulose / amino acids / glycerol / lipids ;	**2**

Q8.

(a)(i)	thylakoid(s) ;	**1**
(a)(ii)	*any **four** from:* *up to three descriptions (D) and one / two linked functions (F)* D1 stacked / many (**A** / thylakoids) / large surface area ; F2 to increase light absorption ; D3 (thylakoid) membrane has, (named), pigments / photosystems / electron carriers / enzymes ; F4 (thylakoid membrane role is) light-dependent reaction / photophosphorylation / creates proton gradient / pump protons / chemiosmosis / makes ATP ; D5 (thylakoid) lumen / space ; F6 accumulates H^+ / high H^+ concentration ; D7 appear green (under microscope) ; F8 as / so, chlorophyll absorbs red and blue light ;	**4**
(b)(i)	Calvin (cycle) ;	**1**
(b)(ii)	*any **two** from:* 1 no start and end, point / molecules ; 2 all, molecules / intermediates, present all the time ; 3 ribulose bisphosphate / RuBP / 5C molecule, is regenerated ; 4 numerical detail ;	**2**
(c)(i)	**B**: oxygen ; **D**: sugar / hexose / glucose / triose phosphate / carbohydrate / starch ;	**2**
(c)(ii)	1 (oxygen linked to) aerobic respiration / oxidative phosphorylation ; 2 (glucose stated as) source / store, of (chemical) energy / ATP / food ; 3 *ref. to* energy flow through, food chains / food web / ecosystem ;	**3**

Q9.

(a)	chlorophyll *a* / chlorophyll *b* / (β) carotene ;	**1**
(b)	*any **two** from:* 1 action (spectrum) shows rate of photosynthesis for light, wavelengths / colours ; 2 absorption (spectrum) shows how much each, wavelength / colour, is absorbed ; 3 higher absorption gives higher photosynthesis ;	**2**

(d)	*any **three** from:* 1 RuBP joins with CO_2 to make, 6C intermediate / GP ; 2 GP to TP ; 3 (GP → TP) uses ATP **and** reduced NADP ; 4 TP → glucose / hexose → starch ; 5 condensation / polymerisation / glycosidic bonds ;	**3**

Q10.

(a) *any **four** from:* **4**

	structure	function
1	thylakoid(s) / granum / grana	light dependent reaction / photophosphorylation ;
2	thylakoid membrane(s)	have (named), pigments / photosystems / LHC / electron carriers / ETC / ATP synthase ;
3	thylakoid membranes / grana, have large surface area / are many in number	to absorb (more) light ;
4	stroma	for light independent reaction / Calvin cycle ;
5	stroma	has, (named) enzymes / RuBP / reduced NADP ;
6	stroma colourless **OR** stroma contains water	so light reaches thylakoids **OR** as a medium for reactions / for photolysis
7	DNA / ribosomes	make (named), chloroplast proteins / proteins for photosynthesis ;
8	starch grains / lipid droplets	store, (named) product of photosynthesis / (chemical) energy ;
9	envelope	compartmentalisation ;

(b) *any **three** from:* **3**

1 light excites electrons in, P700 / PS1 (reaction centre chlorophyll) ;

2 electrons passed, along carriers / to ETC ;
3 H^+ / protons, pumped into thylakoid, space / lumen ;

4 H^+ / protons, diffuse (back to stroma) through ATP synth(et)ase ;
5 makes ATP ;
6 AVP ;

(c) *any **seven** from:* **7**

description
D1 identify wavelengths for chlorophyll (a) absorption ;

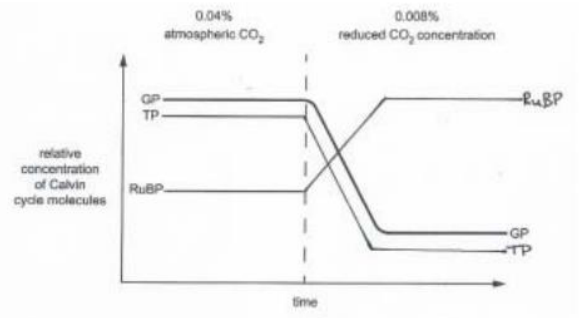
D2 identify wavelengths for phycoerythrin absorption ;

D3 identify wavelengths for phycocyanin absorption ;

D4 chlorophyll (a), has peaks / absorbs mainly, in blue and red ;
D5 phycoerythrin absorbs in blue and green and yellow ;
D6 phycocyanin absorbs in (green) yellow and red ;

explanation
E7 red algae / deep water, get(s) green (and yellow) light ;
E8 chlorophyll (a) absorbs, no / little, green (and yellow) light ;
E9 phycoerythrin / phycocyanin / accessory pigments, absorbs wavelengths not absorbed by chlorophyll (a) ;
E10 combined pigments absorb, greater range of / any / all, wavelengths ;
E11 increases / more / high(er) rate of, light dependent stage / photosynthesis ;
E12 (so) more / lots of, (named) organic compounds / growth ;

Q11.

(a)(ii)	*correctly showing that TP reduces to a plateau below GP* ; *correctly showing that RuBP increases to a plateau* ;  	**2**

(a)(iii)	1. decrease in / no, CO_2, diffusing / moving, to, air spaces / palisade cells / mesophyll cells / chloroplasts / stroma ; *any **two** from:* 2 **stress** response / AW ; 3 *ref. to* abscisic acid / ABA ; 4 *ref. to* action of Ca^{2+} as a second messenger ; 5 stomata close ;	**3**
(b)(i)	$\frac{28-20.5}{20.5} \times 100$ **or** $\frac{7.5}{20.5} \times 100$; **A** 20.4 or 20.6 **A** 37.3 or 35.9 *answer to 1 decimal place* 36.6 (%) ; *apply ecf*	**2**

(b)(ii)	*any **four** from:* *no mention of increased or more – ecf and max 3* 1 Sox4 plants have an **extra copy** of *SBPase* gene ; 2 (overall) increased, expression / transcription, of *SBPase* gene (so more SBPase) ; 3 increased (rate of) / more, regeneration / production, of RuBP ; 4 (so) increased / more, carbon fixation / Calvin cycles / light independent reaction / TP / GP ; 5 more, glucose / sucrose, for respiration / ATP production **or** more, starch / lipid, for storage **or** more cellulose for cell walls ; 6 more, amino acids / proteins, for growth ; 7 more, cell division / cell elongation / mitosis ; 8 AVP ; e.g.(new) SBPase / *SBPase* gene, more efficient	**4**
(b)(iii)	*nitrogen needed to produce:* nucleotides for, transcription (of *SBPase* gene) / expression (of *SBPase* gene) / mRNA production ; amino acids for, protein synthesis / SBPase production / enzyme production ;	**2**

Q12.

(a)(i)	*mark first two answers* ATP ; reduced NADP ; **A** NADPH	**2**
(a)(ii)	*any **two** from:* **1** an accessory pigment ; **2** absorb, light (energy) / photons ; **A** harvest **I** trap / capture **3** pass on energy to, primary pigment / chlorophyll a / reaction centre ; **4** AVP ; e.g. *idea of* extending the range of light wavelengths absorbed / absorbs wavelengths not absorbed by primary pigment	**2**

Q13.

(a)(i)	*any **two** from:* **1** absorb / harvest / capture / trap, light / photons ; **2** (to) excite electrons ; **3** (for, cyclic / non-cyclic) photophosphorylation / electron transport chain ; **4** accessory pigment passes energy to, primary pigment / reaction centre ; **5** (pigments) form a, light harvesting cluster / photosystem / PSI / PSII ;	**2**
(a)(ii)	thylakoid membrane(s) / granum / grana / lamella(e) ;	**1**
(a)(iii)	chromatography ;	**1**

Q14.

(a)	*any **one** from:* 1 industrialisation ; 2 transportation ; 3 power stations ; 4 burning of fuels ;	**1**

(b) — 3

*any **three** from:*

1 genetically modified has a higher (dry) mass throughout the experiment ; **ora**

2 genetically modified has a (slightly) higher rate of / steeper, increase (in dry mass) ; **ora**

3 the largest difference in (dry) mass is after day 8 ;

4 paired data quote with units ;

time / days	dry mass / g dm^{-3}		
	genetically modified ± 0.02	unmodified ± 0.02	difference between the two ± 0.04
2	0.22	0.13	0.09
4	0.48	0.34	0.14
6	0.62	0.48	0.14
8	0.88	0.74	0.14
10	1.24	0.96	0.28
12	1.54	1.31	0.23
14	1.86	1.52	0.34

rate of growth over 14 days
genetically modified = 1.86 / 14 = 0.13 g dm^{-3} day^{-1}
unmodified = 1.52 / 14 = 0.11 g dm^{-3} day^{-1}

(c) — 3

*any **three** from:*

1 (more rubisco so) greater rate of / **more**, carbon (dioxide) fixation ; AW

2 (so) greater rate of / **more**, GP produced ;

3 so greater rate of / **more** TP, produced (from GP) ;

4 (so) greater rate of / **more**, regeneration of RuBP ;

5 (so) greater rate of / **more**, Calvin cycle ;

6 AVP ; e.g. carbon fixation is a rate-limiting step / concentration of rubisco is a limiting factor

(d) — 3

*any **three** from:*

1 glucose for respiration ;

2 starch for storage ;

3 cellulose to make cells walls ;

4 sucrose for, translocation / described ;

5 fatty acids and glycerol / lipid, to make membranes
or
fatty acids and glycerol / lipid / fats, for storage
or
fatty acids to make acetyl CoA (for Krebs cycle) ;

6 amino acids to make, proteins / enzymes ;

7 proteins for, growth / repair ;

(e)	*any* ***one*** *from:* 1 *idea of* fast(er) growth rate / reproduction ; 2 quicker to set up / AW ; 3 cheaper to set up / AW ; 4 (as aquatic) not using (useful) land ; 5 can, culture / grow, algae in the lab ;	**1**

Q15.

(b)	*any **three** from:* 1 less / no, CO_2 fixation / carboxylation of RuBP ; 2 less / no, GP, made into / converted to, TP ; 3 less / no, regeneration of RuBP ; 4 less / no, glucose / hexose, made ;	**3**

Q16.

(a)		**5**

description	letter
enzyme with a high optimum temperature	**D** ;
enzyme in bundle sheath cells	**E** ;
process that slows down the rate of photosynthesis	**J** ;
compound that releases carbon dioxide into bundle sheath cells	**F** ;
cells that stop oxygen reaching bundle sheath cells	**H** ;

Q17.

(a)	**A** – label line pointing to starch grain ; **B** – label line pointing to stroma ;	**2**
(b)(i)	granum / grana ; **A** stack of thylakoids **I** thylakoid	**1**
(b)(ii)	*any **four** from:* **1** (stack of) thylakoids ; **2** (membranes / thylakoids / C) form large / increase, surface area ; **3** for, (named) pigments / photosystems / light-harvesting clusters ; **4** for absorption of light energy ; **5** so, large number of / many, enzymes / ETC / ATP synthase / stalked particles ; **6** for, light dependent stage / photophosphorylation ;	**4**

Q18.

(a)	**A** – line to epidermal cell ; **B** – line to mesophyll cell ;	**2**
(b)(i)	bundle sheath (cell) ;	**1**
(b)(ii)	*any **four** from:* **1** decrease / stop, photorespiration ; **2** mesophyll cells, surround / protect / form ring round, bundle sheath ; **3** air / oxygen, cannot reach, bundle sheath (cells) ; **4** oxygen cannot, reach / bind to, RuBP / rubisco (in BSC) ; **5** high / much, carbon dioxide (in bundle sheath cells) ; **6** AVP ;	**4**

Q19.

(a)(i)	thylakoid (membranes) / grana / lamellae ;	**1**
(a)(ii)	reduced NADP / ATP / oxygen ; **R** reduced NAD	**1**
(a)(iii)	*any **four** from:* 1 *ref. to* rubisco ; 2 forms unstable 6C compound ; 3 (splits into) two molecules of, GP / glycerate–(3)–phosphate ; 4 GP reduced to, TP / triose phosphate ; 5 using reduced NADP **and** ATP ; 6 TP(s) used to form glucose ; **Ignore** hexose 7 *ref. to* polymerisation / condensation / formation of glycosidic bonds ;	**4**

Q20.

(a)	<table><tr><th>compound</th><th>location</th></tr><tr><td>PEP carboxylase</td><td>**C**</td></tr><tr><td>RuBP</td><td>**B**</td></tr><tr><td>rubisco</td><td>**B**</td></tr></table>	**3**
(b)	*any 2 of:* 1 stop, air / oxygen, getting to cells **B** / rubisco / RuBP / bundle sheath cells ; 2 so rubisco does not catalyse reaction of oxygen with RuBP ; 3 reduce / stop, photorespiration ;	**2**

Q21.

(a)(i)	thylakoid (membranes) / lamellae / granum / grana ;	1
(a)(ii)	**A** photolysis (of water) ; **B** chemiosmosis / (cyclic) photophosphorylation ;	2
(a)(iii)	*any one of:* diffuses out / lost / expelled / released, from, leaf / stomata / plant ; used in, (aerobic) respiration / oxidative phosphorylation ;	1
(a)(iv)	chlorophyll a ;	1
(a)(v)	ATP and reduced NADP / NADPH;	1
(b)	*any three from:* regenerate / produce / make/ form, RuBP ; (triose phosphate / glucose / acetyl coA) for respiration ; to make any two of: glucose / sucrose / ribose / deoxyribose / glycerol / acetyl (coA) / fatty acids / amino acids starch / cellulose ; ;	3

Q22.

(a)	compound or structure / location ATP synthase – **C** rubisco – **B** starch grain – **A** phospholipid bilayer – **C** ;;;	3

(b)	*any three from* *description* **1** high(est) / peaks, at, 450 nm and 650 nm / blue and red **or** lowest at, 545 nm / 535–555 nm / green ; *explanations for blue / red* **2** *Elodea* / plant / chloroplasts / (named) pigments, absorb / use, this, (specified) wavelength / (named) colour of light ; **3** light / wavelengths, used for, photosynthesis / photophosphorylation ; **4** so more oxygen, produced / released, from photolysis ; **5** AVP ; e.g. ref. non-cyclic / light-dependent stage / Z-scheme	3
(c)	*any two from* **1** pass, energy / light / photons, to, chlorophyll *a* / primary pigment / reaction centre ; **2** absorb different wavelengths to, chlorophyll *a* / primary pigment / reaction centre ; **3** form / in, light-harvesting cluster / photosystem / antenna complex ;	2