AQA A-LEVEL · 7402

BIOLOGY



MARK SCHEME

3.5.1 PHOTOSYNTHESIS

SCORE	PERCENTAGE
/419	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a) 1. (Less/no) ATP;

2. (Less/no) reduced NADP;

Accept NADPH, NADPH + H, $NADPH_2$ NADPH + H^+

Reject reduced NAD, NADH etc,

2

(b) 1. (Less/no) carbon dioxide (reacts) with RuBP;

2. (Less/no) GP;

2

(c) 1. Stroma (of/in chloroplast);

Reject: stoma

Reject stroma of cytoplasm/chlorophyll

Reject stroma of mitochondrion

Ignore references to Calvin cycle or the light-independent reaction

1

(d) 1. Rubisco activity increases with temperature
OR
Rubisco optimum temperature is above (**rubisco activase**);

2. (Rubisco) **activase** activity decreases at high temperatures (allow any temperature above 25 ºC.)
OR
(Rubisco) **activase** optimum (allow in range) 25 to 30 ºC.;

Accept denatures at high temperature (allow any temperature above 25 ºC)

3. (Results/graphs suggest) **activase** cannot/does not affect activity of rubisco;

4. (Results are) only for cotton;

Accept may not be the same in other species/types of plant

Ignore: only one study

5. (Results are) for isolated enzymes;

6. No stats test;

4 max

[9]

Q2.

(a) 1. Osmosis does not occur;
2. Chloroplast / organelle does not burst / lyse / shrivel / shrink;

1. Accept: osmosis would occur if water potentials were not the same.

*1 and 2, Accept: correct reference to osmotic lysis for **2***

marks.

2. *Accept: chloroplast would burst / lyse / shrivel / shrink if water potentials were not the same.*
2. *Reject: '<u>cell</u> bursts/shrivels'*
2. *Ignore: damage to chloroplasts on its own is not enough for a mark.*
3. *Reject: becomes turgid / flaccid.*

2

(b) 1. To show light does not affect <u>DCPIP</u>;
2. To show chloroplasts are required;

Ignore: comparison with other tubes.

2

(c) 1. Reduction of DCPIP by electrons;
2. (From) chlorophyll / light dependent reaction;

1. *Accept: hydrogen / H for electrons but not protons / hydrogen ions / H* on their own.*
2. *Accept: from chloroplasts / photosystems / water.*

2

(d) Provides a standard / reference point
OR
Can compare different chemicals/weed-killers
OR
Can compare different concentrations of chemicals / weed-killers;

*Accept: decolourises quicker than 100% **or** saves time waiting for complete decolourisation.*

Note: comparisons must be qualified.

*Accept: find the most effective weed-killer **or** the most effective concentration.*

Accept: answers relating to cost effectiveness.

1

(e) 1. Less / no ATP produced;
2. Less / no reduced NADP produced;
3. Less / no GP reduced / converted to TP;

2, Accept: less / no NADPH / $NADPH_2$ / NADPH + H

2 max

[9]

Q3.

(a) 7.7(%);

1

(b) 1. No error bars / SD;

2. To show if overlap occurs so difference (in means) is not significant / due to chance
OR
To show if no overlap occurs so difference (in means) is significant / is not due to chance.

Do not accept 'no statistical test performed' as Chi squared / Spearman's rank would be inappropriate.

Ignore references to sample size as it can be assumed that scientists completed the study using appropriate methodology.

2

(c) 1. Reduced transfer of protons across thylakoid membrane
OR
Reduced chemiosomotic gradient / proton gradient across thylakoid membrane;

2. (So) less ATP produced;

3. (So) less reduced NADP produced;
Accept NADPH / $NADPH_2$ / $NADPH^+$
Reject reduced NAD

4. (So) light-independent reaction slows / stops;
OR
Less reduction of GP to triose phosphate.

4

(d) Idea that energy is released from high energy / excited electron/s (that were lost from chlorophyll)

1

[8]

Q4.

(a) 1. Oxygen produced in light-dependent reaction;
2. The faster (oxygen) is produced, the faster the light-dependent reaction.

2

(b) 35–36 µmol Oxygen per mg chlorophyll.
Correct difference at 500 µmol photons m^{-2} s^{-1} or incorrect difference but division by 4 shown = 1 mark.

2

(c) At all light intensities, chloroplasts from mutant plants:
1. Have faster production of ATP and reduced NADP;
2. (So) have faster / more light-independent reaction;
3. (So) produce more sugars that can be used in respiration;
4. (So) have more energy for growth;
5. Have faster / more synthesis of new organic materials.
Accept converse points if clear answer relates to non-mutant plants

4 max

[8]

Q5.

(a) Stroma (of chloroplasts);
Reject: stoma.
Reject: stroma of chlorophyll or any reference to chlorophyll.
Accept: stroma of chloroplasts.

1

(b) (i) (Less) RuBP combines with carbon dioxide;

Accept: binds/joins.

1

(ii) 1. Temperature is a limiting factor/below optimum;
2. Light is a limiting factor/below optimum;

Accept: limited by reduced NADP or ATP.

3. Limited by RuBP (available/produced);

Accept: RuBP will always give 2 GP (at high CO_2).

4. Limited by enzyme;

Accept: limited by Rubisco.

2 max

(c) 1. (Provides) hydrogen / protons/H^+ **and** electrons/e^-;

Ignore: if water is used as source of hydrogen.

2. For reduction;

Reject: reduction of NAD.

Reject: reduction by H^+ or protons on their own.

3. Source of electrons for chlorophyll/electron transfer chain;

Accept: electrons for photophosphorylation.

Ignore: photosystems.

1, 2 and 3. Reject: reference to respiration/mitochondria.

2 max

[6]

Q6.

(a) 1. Excites electrons / electrons removed (from chlorophyll);

Accept: higher energy level as 'excites'.

2. Electrons move along carriers/electron transfer chain releasing energy;

Accept: movement of H^+/protons across membrane releases energy.

Reject: 'produces energy' for either mark but not for both.

3. Energy used to join ADP and Pi to form ATP;

Reject: 'produces energy' for either mark but not for both.

Accept: energy used for phosphorylation of ADP to ATP

Do not accept P as Pi but accept phosphate.

4. Photolysis of water produces protons, electrons and oxygen;
5. NADP reduced by electrons / electrons and protons / hydrogen;

Accept: NADP to NADPH (or equivalent) by addition of electrons/hydrogen.

Do not accept NADP reduced by protons on its own.

5

(b) 1. Protein/amino acids/DNA into ammonium compounds / ammonia;

Accept: any named nitrogen containing compound e.g. urea.

2. By saprobionts;

Accept: saprophytes.

3. Ammonium/ammonia into nitrite;

4. Nitrite into nitrate;
5. By nitrifying bacteria/microorganisms;

Reject: nitrifying bacteria in root nodules.

1, 3 and 4. Accept: marks for conversion even if incorrect type of bacteria named as being involved.

2 and 5. Reject: marks for type of bacteria if linked to incorrect process e.g. nitrite converted to nitrate by saprobionts.

3 and 4. Accept: for one mark ammonia/ammonium into nitrate if neither mark point 3 or 4 awarded.

Note: there are no marks for the role of nitrogen-fixing bacteria as the question refers to producing a source of nitrates from the remains of crops.

5

[10]

Q7.

(a) 1. (No grease)
means stomata are open
OR
allows normal CO_2 uptake;

Allow 'gas exchange' for CO_2 uptake.

'As a control' is insufficient on its own.

2. (Grease on lower surface)
seals stomata
OR
stops CO_2 uptake through stomata
OR
to find CO_2 uptake through stomata
OR
shows CO_2 uptake through cuticle / upper surface;

3. (Grease on both surfaces) shows sealing is effective
OR
stops all CO_2 uptake.

3

(b) (i) 1. (Mean rate of) carbon dioxide uptake was constant *and* fell after the light turned off;

Ignore absence of arbitrary units in both marking points.

Both ideas needed for mark.

Accept 'stayed at 4.5' as equivalent to 'was constant'.

2. Uptake fell from 4.5 to 0 / uptake started to fall at 60 minutes and reached lowest at 80 minutes / uptake fell over period of 20 minutes;

One correct use of figures required.

Accept fell to nothing / no uptake for 0.

2

(ii) 1. (Because) water is lost through stomata;

2. (Closure) prevents / reduces water loss;
3. Maintain water content of cells.

This marking point rewards an understanding of reducing water loss e.g. reduce wilting, maintain turgor, and is not related to photosynthesis.

2 max

(c) (i) (Carbon dioxide uptake) through the upper surface of the leaf / through cuticle.

1

(ii) 1. No use of carbon dioxide in photosynthesis (in the dark);
2. No diffusion gradient (maintained) for carbon dioxide into leaf / there is now a diffusion gradient for carbon dioxide out of leaf (due to respiration).

2

[10]

Q8.

(a) Oxygen production / concentration <u>and</u> time.

Accept: oxygen volume / concentration

Reject: oxygen uptake

Neutral: reference to carbon dioxide uptake

1

(b) 1. Intensity of light;

Accept: distance from light

2. Amount / number / mass / species of algae / photosynthesising cells;
3. Carbon dioxide (concentration / partial pressure);
4. Time.

2 max

(c) 1. (pH) increases;

Neutral: becomes more alkaline / less acidic

2. As (more) carbon dioxide removed (for photosynthesis).

2

(d) 1. Less absorption / (more) reflection (of these wavelengths of light);

Reject: no absorption or cannot absorb unless in context of green light.

Note: no green light absorbed <u>or</u> green light reflected = 2 marks.

2. (Light required) for light dependent (reaction) / photolysis

Accept: for excitation / removal of electrons (from chlorophyll)

3. (Represents) green light / colour of chlorophyll.

2 max

[7]

Q9.

(a) 1. Geographic(al) isolation;

2. Separate gene pools / no interbreeding / gene flow (between populations);

Accept: reproductive isolation

This mark should only be awarded in context of during the process of speciation. Do not credit if context is after speciation has occurred.

3. Variation due to mutation;
4. Different selection pressures / different abiotic / biotic conditions / environments / habitats;

Neutral: different conditions / climates if not qualified

Accept: named abiotic / biotic conditions

5. Different(ial) reproductive success / selected organisms (survive and) reproduce;

Accept: pass on alleles / genes to next generation as equivalent to reproduce

6. Leads to change / increase in allele frequency.

Accept: increase in proportion / percentage as equivalent to frequency

6

(b) 1. Capture / collect sample, mark and release;
2. Method of marking does not harm lizard / make it more visible to predators;
3. Leave sufficient time for lizards to (randomly) distribute (on island) before collecting a second sample;
4. (Population =) number in first sample × number in second sample divided by number of marked lizards in second sample / number recaptured.

4

(c) 1. High concentration of / increase in carbon dioxide linked with respiration at night / in darkness;
2. No photosynthesis in dark / night / photosynthesis only in light / day;

Neutral: less photosynthesis

3. In light net uptake of carbon dioxide / use more carbon dioxide than produced / (rate of) photosynthesis greater than rate of respiration;
4. Decrease in carbon dioxide concentration with height;

More carbon dioxide absorbed higher up

Accept: less carbon dioxide higher up / more carbon dioxide lower down

5. (At ground level)
less photosynthesis / less photosynthesising tissue / more respiration / more micro-organisms / micro-organisms produce carbon dioxide.

Neutral: less leaves unqualified or reference to animals

5

[15]

Q10.

(a) Succession;

Ignore any word in front of succession e.g. secondary / ecological succession.

Neutral 'forestation'.

1

(b) 1. Greater variety / diversity of plants / insects / more plant / insect species;

Neutral: more plants.

2. More food sources / more varieties of food;

Neutral: more food / more / greater food source (singular).

3. Greater variety / more habitats / niches;

Accept: more nesting sites.

Q *Neutral: more homes / shelters.*

3

(c) (i) Temperature and carbon dioxide;

Neutral: water, chlorophyll.

1

(ii) Shows (gross) photosynthesis / productivity minus respiration / more carbon dioxide used in photosynthesis than produced in respiration;

Correct answers are often shown as: net productivity = (gross) photosynthesis – (minus) respiration.

1

(iii) 1. (Shade plant) has lower (rate of) respiration / respiratory losses / less CO_2 released at 0 light intensity / in dark;

Accept use of figures.

Accept: lower compensation point.

2. Greater (net) productivity / less sugars / glucose used / more sugars / glucose available;

Neutral: any references to rate of photosynthesis.

2

[8]

Q11.

1. Carbon dioxide combines with ribulose bisphosphate / RuBP;

2. Produces two glycerate (3-)phosphate / GP;

Accept: any answer which indicates that 2 x as much GP produced from one RuBP.

3. GP reduced to triose phosphate / TP;

Must have idea of reduction. This may be conveyed by stating m.p. 4.

4. Using reduced NADP;

Reject*: Any reference to reduced NAD for m.p.4 but allow reference to reduction for m.p. 3.*

5. Using energy from ATP;

Must be in context of GP to TP.

6. Triose phosphate converted to glucose / hexose / RuBP / ribulose bisphosphate / named organic substance;

[6]

Q12.

(a)

Part of ecosystem	**Mean rate of carbon dioxide production / $cm^3\ m^{-2}\ s^{-1}$**	**Percentage of total carbon dioxide production measured by the scientists**
Leaves of plants	0.032	25.0
Stems and roots of plants	0.051	**39.8**
Non-photosynthetic soil organisms	0.045	**35.2**

2 correct = 2 marks;;

Adding rates to get 0.128 = 1;

If rounded to 40 and 35 in table;

- *but working shows decimal points, then award 2 marks*
- *but no working shown, then 1 max*

2 max

(b) 1. Data only include (heterotrophic) soil organisms;

2. Doesn't include animals (above ground) / other (non-soil) organisms;

3. Doesn't take into account anaerobic respiration;

Award points in any combination

Accept for 1 mark idea that CO_2 for leaves doesn't take into account photosynthesis – not told in dark until part (d)

2 max

(c) **All three** of following = 2 marks;;

Two of them = 1 mark;

Volume of carbon dioxide given off

(From known) area / per m^2 / m^{-2}

In a known / set time

Ignore 'amount' / concentration of CO_2

Accept per second / per unit time

2

(d) 1. (In the light) photosynthesis / in the dark no photosynthesis;

2. (In light,) carbon dioxide (from respiration) being used / taken up (by photosynthesis);

2

(e) (i) (Rate of respiration)

Assume "it" means soil under trees

1. In soil under trees (always) higher;

Accept converse for soil not under trees

Accept 'in the shade' means under the trees

2. In soil under trees does not rise between 06.00 and 12.00 / in the middle of the day / peaks at 20:00-21.00 / in the evening;

3. In soil **not** under trees, peaks at about 14:00-15:00 / in middle of day;

2. and 3. No mm grid, so accept 'between 18.00 and 24.00' or 'between 12.00 and 18.00'

2 max

(ii) (Between 06.00 and 12.00, (No Mark))

Respiration higher in soil under tree, (No mark)

Do not mix and match mark points

No list rule

1. Tree roots carry out (a lot of) respiration;

2. More / there are roots under tree;

Accept converse for soil not under trees

OR

3. More food under trees;

4. So more active / greater mass of / more organisms (carrying out respiration);

Accept converse for soil not under trees

OR

Soil not under trees respiration increases (No mark)

5. Soil in sunlight gets warmer;

6. Enzymes (of respiration) work faster;

Accept converse for soil under trees

2 max

(f) (i) 1. Photosynthesis produces sugars;

2. Sugars moved to roots;

Do not penalise named sugars other than sucrose

3. (Sugars) are used / required for respiration;

2 max

(ii) Takes time to move sugars to roots;

Look for movement idea in (i) – can carry forward to (ii)

1

[15]

Q13.

(a) 1. Protein synthesis **and** cell wall synthesis **and** cell expansion stop at −0.7 / at a *higher* water potential than other two;

If all 3 are correctly identified in marking point 1, accept 'the others / the other two' in marking point 2, and vice versa

2. Photosynthesis **and** stomatal opening stop at -1.5 / at a *lower* water potential than other three;

Correct processes must be named in at least one of marking point 1 or marking point 2

Where reference to water potential differences are made, they must be comparative, eg 'higher'

2

(b) 1. Stomata allow uptake of carbon dioxide;

2. Carbon dioxide used in / required for photosynthesis;

2

(c) 1. Growth involves cell division / cell expansion / increase in mass;

Marking point 1 is for the principle

2. Protein synthesis stops **so** no enzymes / no membrane proteins / no named protein (for growth / division);

Marking points 2, 3 and 4 require appreciation of 'why' before credit can be awarded

'named' protein must relate to proteins involved in growth or cell division

3. Cell wall synthesis stops **so** no new cells can be made;

Full credit is possible without a statement of the principle (marking point 1)

4. No cell expansion / increase in mass **because** (cells) stop taking up water;

3 max

[7]

Q14.

(a) (i) So it / CO_2 is not a limiting factor (on growth / photosynthesis);

Accept: CO_2 is a limiting factor

1

(ii) So any difference is due to iron (deficiency);

Accept: iron is the variable

1

(iii) Amount of triose phosphate / TP will be similar / same / low (at start);

Accept: to allow triose phosphate to stabilise / become constant

Reject: so all triose phosphate is used up

Reject: so no triose phosphate

1

(b) 1. (Less) ATP produced;

Accept: alternatives for reduced NADP ie NADP with hydrogen / s attached

2. (Less) reduced NADP produced;

3. ATP / reduced NADP produced during light-dependent reaction;

4. (Less) GP to triose phosphate / TP;

4

(c) 1. Less triose phosphate converted to RuBP;

Accept: less triose phosphate so less RuBP

2. CO_2 combines with RuBP;

2

[9]

Q15.

(a) 1. No effect at 25°C

The question only refers to plants <u>with</u> GB

1. Reject same mass

2. Keeps growing at 30°C and 35°C / up to 35°C (more than without GB);

3. Above 35°C, falls but grows more than plant without GB;

3. Accept at all temperatures above 25°C more growth than without GB

2 max

(b) (i) <u>Significantly</u> different / SEs do not overlap ;

Accept converse without GB

1

(ii) (As temperature increases,)

1. Enzyme activity reduced / (some) enzymes denatured;

2. Less photosynthesis, so fewer sugars formed;

3. Less respiration / less energy / ATP for growth;

4. Less energy for named function associated with growth

4. Eg mitosis, uptake of mineral ions

4

(c) 1. (Rubisco activase attaches to thylakoid and) this changes shape / tertiary structure (of enzyme) / blocks active site / changes active site;

Note - question states enzyme stops working when it attaches to thylakoid, not before

1. Accept rubisco in this context

2. (This) prevents substrate / RuBP entering active site / binding;

2. Accept prevents ES complex forming

2. Accept no longer complementary to substrate / RuBP

2

(d) 1. GB prevents / reduces binding of rubiscoactivase to (thylakoid membrane);

1. Accept enzyme instead of rubiscoactivase. Accept rubisco

2. (Prevents it) up to 35°C;

3. (So) rubiscoactivase / enzyme remains active;

4. (So) photosynthesis / light-independent stage still happens;

4. Accept descriptions of light-independent stage

5. Above 35°C, some binding still occurs but less than without GB, so less reduction in growth;

4 max

(e) 1. Looked for information / journals, on crop plants that grow at high temperatures;

1. "other research" is minimum accepted

1. Accept previous experiments research with temperature resistant crops

Ignore simple references to looking at previous studies / other plants - need to relate to this context

2. (Crop plants cited in this research) contain / make GB;

3. So assumed making plants produce GB makes them resistant to high temperatures;

2 max

[15]

Q16.

(a) 1. Peaks at 420-430 and 660-670;

2. No absorption of light between approximately 500 and 600;

3. Highest peak at 420-430;

2 max

(b) 1. Less (light) energy passes through leaves / reaches ground;

2. Smaller range of wavelengths passes through leaves;

Accept reference to only green (and yellow) light pass through

3. Little light for chlorophyll to absorb;

Accept carotenoids can absorb this light

4. So insufficient photosynthesis (for growth);
Sufficient photosynthesis for plants with carotenoids

5. Photosynthesis unlikely to exceed respiration;

3 max

(c) 1. Light not limiting / lots of light (as no shading);

2. Light-dependent reaction not limiting / fast;

OR

3. Temperature not limiting / Warm (as no shading);

4. Fast reactions of enzymes in light-independent reaction;

OR

5. High use of CO_2;

6. Light-independent reaction is limiting;
Mark as a pair

2

[7]

Q17.

(a) 1. Bar chart;

2. Error bars to represent standard deviation (of mean);

3. Photosynthetic pigment on *x* axis and mass of pigment on *y* axis;
Accept suitable sketch

2 max

(b) 1. Number leaves on the branch;

2. Use random number table / calculator / pick numbers from bag to determine which leaf to pick;
Accept use of random number generator

OR

3. Collect large number of leaves;

4. Pick out of bag with some idea of randomness;

2

(c) No (no mark)

1. No stats test carried out;

2. Standard error / 95% confidence interval calculation identified;
If awarded, student scores 2 marks – for points 1 and 2

Yes (no mark)

3. No overlap shown by the standard deviations;

4. Ranges around mean stated;

88.6-92.8 and 111.0-111.2 (1 × SD) or 86.5-94.9 and 110.9-111.3
(2 × SD)

2 max

(d) In shade leaves:

1. Greater amount of enzyme / enzyme activity (for production of chlorophyll b);

2. Greater gene expression / transcription of the gene / more mRNA produced / gene switched on;

3. Greater translation;

4. Enzyme / substrate is light sensitive – faster rate of reaction with lower light;

2 max

[8]

Q18.

(a) 1. (Some of the) light that passes through is absorbed by chlorophyll b;

2. This is light of around 500 and / or around 640;

Accept any value or range between 460 and 540 and / or 600 and 670

2

(b) (i) Supports hypothesis 2 (no mark)

1. Greater carotenoid found in sun leaves than shade leaves of beech tree;

2. Sun leaves exposed to much brighter light than shade leaves;

OR

It supports hypothesis 2 because it does not support hypothesis 1 (no mark)

3. Although carotenoids absorb wavelengths of light that pass through leaves;

4. There are not more carotenoids in shade leaves;

2

(ii) 1. Mass of pigments / carotenoids in sun and shade leaves of other trees;

2. Position of carotenoids in leaf cells;

3. Effect of bright light on (isolated) chlorophyll;

4. Whether without carotenoids chlorophyll is damaged (supporting

hypothesis 2) / photosynthesis is reduced (supporting hypothesis 1);

1 max

[5]

Q19.

(a) (i) Stroma (of chloroplasts);

Reject: stoma

1

(ii) 2;

1

(b) 1. As oxygen (concentration) increases less Rubisco / RuBP reacts / binds with carbon dioxide;

1. Accept - as oxygen (concentration) increases more Rubisco / RuBP reacts / binds with oxygen

1. Accept – less GP / more phosphoglycolate formed as oxygen (concentration) increases

2. Competitive inhibition / competition between oxygen and carbon dioxide for rubisco / enzyme / active site (therefore) less RuBP formed / regenerated (to join with carbon dioxide);

2. Accept oxygen and carbon dioxide are complementary to active site

2

(c) 1. Less glycerate 3-phosphate / GP produced;

1. Accept one GP formed rather than two GP

2. (Less) triose phosphate to form sugars / protein / organic (product) / any named photosynthetic product;

3. Less RuBP formed / regenerated;

3. Accept RuBP takes longer to form

3

[7]

Q20.

(a) 1. Chlorophyll absorbs light energy;

Accept light energy 'hits' chlorophyll

Accept photon for light energy

2. Excites electrons / electrons removed (from chlorophyll);

Accept higher energy level as 'excites'

3. Electrons move along carriers / electron transport chain releasing energy;

Accept movement of H^+ / protons across membrane releases energy

4. Energy used to join ADP and Pi to form ATP;

Negate 'produces energy' for either mark but not for both

Accept energy used for phosphorylation of ADP to ATP

Do not accept P as Pi

5. Photolysis of water produces protons, electrons and oxygen;

3. and 4.

6. NADP reduced by electrons / electrons and protons / hydrogen;

Accept NADP to NADPH (or equivalent) by addition of electrons / hydrogen

Do not accept NADP reduced by protons on their own

5 max

(b) 1. Variation / variety;

2. Mutation;

Do not accept answers which suggest the mutation is caused by copper

3. Some plants have allele to survive / grow / live in high concentration of copper / polluted soils;

Reference to immunity disqualifies this mark

Do not disqualify mark for references to allele providing resistance to copper

4. (Differential) reproductive success / adapted organisms reproduce;

5. Increase in frequency of allele;

6. No interbreeding (with other populations) / separate gene pool / gene pool differs (from other populations);

Accept reproductive isolation

5 max

[10]

Q21.

(a) Ribulose bisphosphate / RuBP;

Accept Ribulose biphosphate or Ribulose diphosphate

Accept phonetic spellings

Accept any variation in upper or lower case for RuBP

1

(b) ATP and reduced NADP are produced in grana / thylakoids / present in A / both tubes;

Must be reduced NADP but accept any alternative which show hydrogen attached to NADP

Must be reduced NADP not reduced NAD

1

(c) 1. 4 000;

Accept 'same as in (tube) C', but not 'same' on its own

2. Light-dependent reaction does not occur / ATP and reduced NADP are not produced;

Accept converse for mark point 2

2

(d) 1. (Less) GP converted to TP;

GP = glycerate 3-phosphate

TP = triose phosphate but abbreviations are sufficient

2. (Less) TP converted to RuBP;

Accept GALP as TP

2

(e) 1. No / less ATP / ATP produced (during electron transport);

Must be reduced NADP but accept any alternative which shows hydrogen attached to NADP

2. No / less reduced NADP / reduced NADP produced (during electron transport)

2

[8]

Q22.

(a) 530 to 630;

1

(b) 1. Reduced NADP;

Accept NADPH or rNADP

2. ATP;

Reduced NAD is incorrect

2

(c) (i) 1. Unit of volume <u>and</u> unit of time;

Accept any reasonable unit of volume

E.g. cm^3 or ml

Accept any reasonable unit of time

E.g. s, min or h

2. Unit of area / mass;

Accept any reasonable unit of area or mass

E.g. cm^2 or g

Symbols should be correct. Do not accept m for minutes.

2

(ii) 1. (Light intensity) limiting factor;

2. Fewer electrons (released) from chlorophyll;

3. Less photolysis therefore (less) oxygen from water;

3

(d) Will not affect (no mark):

1. Photolysis / splitting of water does not use enzymes;

Will affect (no mark):

2. May increase respiration;

3. Respiration uses oxygen;

3

(e) (i) 1. Overlap in standard deviations;

2. Unlikely that any difference is significant;

2

(ii) 1. **P** / visible light has more wavelengths;

2. **Q** has only light of wavelength 460 nm;

3. Wavelengths over 460 nm can also be used for photosynthesis / wavelengths over 460 nm can also be absorbed;

3

[16]

Q23.

(a) (i) Non-living / physical / chemical factor / non biological;

Do not accept named factor unless general answer given.

1

(ii) Accept an abiotic factor that may limit photosynthesis / growth;

Reject altitude / height

Water

Named soil factor

Not "soil" / "weather"

Light

Carbon dioxide

Accept Oxygen

Incline / aspect

Wind / wind speed

1

(b) 1. Correct explanation for differences between day and night e.g. photosynthesises only during the daytime / no photosynthesis / only respiration at night;

2. Net carbon dioxide uptake during the day / in light

OR

No carbon dioxide taken up at night / in dark / carbon dioxide released at night / in dark;

3. At ground level <u>more</u> respiration / in leaves <u>more</u> photosynthesis;

4. Carbon dioxide produced at ground level / carbon dioxide taken up in leaves;

Principles

Comparing day and night / light and dark

1. Explanation in terms of photosynthesis / respiration

2. Effect on carbon dioxide production / uptake

Comparing leaves with ground level

3. Explanation in terms of photosynthesis / respiration

4. Effect on carbon dioxide production / uptake

2 and 4 must relate to why the change occurs

4

(c) 1. Variation in original colonisers / mutations took place;

2. Some better (adapted for) survival (in mountains);

2. Allow "advantage so able to survive"

3. Greater reproductive success;

4. Allele frequencies change;

4. Reject gene / genotype

3 max

[9]

Q24.

(a) 1. Releases energy in small / manageable amounts;

1. Accept less than glucose

2. (Broken down) in a one step / single bond broken immediate energy compound / makes energy available rapidly;

2. Accept easily broken down

3. Phosphorylates / adds phosphate makes (phosphorylated substances) more reactive / lowers activation energy;

3. Do not accept phosphorus or P on its own

4. Reformed / made again;

4. Must relate to regeneration

4

(b) 1. Substrate level phosphorylation / ATP produced in Krebs cycle;

Accept alternatives for reduced NAD

2. Krebs cycle / link reaction produces reduced coenzyme / reduced NAD / reduced FAD;

2. Accept description of either Krebs cycle or link reaction

3. Electrons released from reduced / coenzymes / NAD / FAD;

4. (Electrons) pass along carriers / through electron transport chain / through series of redox reactions;

5. Energy released;

5. Allow this mark in context of electron transport or chemiosmosis

6. ADP / ADP + Pi;

6. Accept H^+ or hydrogen ions and cristae

7. Protons move into intermembrane space;

7. Allow description of movement through membrane

8. ATP synthase;

8. Accept ATPase. Reject stalked particles

6 max

(c) 1. In the dark no ATP production in photosynthesis;

1. In context of in photosynthetic tissue / leaves

2. Some tissues unable to photosynthesise / produce ATP;

3. ATP cannot be moved from cell to cell / stored;

4. Plant uses more ATP than produced in photosynthesis;

5. ATP for active transport / synthesis (of named substance);

5

[15]

Q25.

(a)

	Photosynthesis	Anaerobic respiration	Aerobic respiration
ATP produced	✓	✓	✓
Occurs in organelles	✓		✓
Electron transport chain involved	✓		✓

1 mark per column

Mark ticks only. Ignore anything else if different symbols such as crosses are used as well.

If crosses are used instead of ticks allow cross as equivalent to a tick.

Reject tick with a line through

3

(b) $ADP + P_i \longrightarrow ATP$;

Both sides correct, but allow other recognised symbols or words for phosphate ion. Reject P unless in a circle.

Accept = as equivalent to arrow

Accept reversible arrow

Ignore any reference to kJ / water

1

(c) 1. Energy released in small / suitable amounts;

2. Soluble;

3. Involves a single / simple reaction;

1. In context of release, not storage. Ignore producing energy / manageable amounts.

2. Reject "broken down easily / readily". Reject "quickly / easily resynthesised".

2 max

(d) 1. ATP cannot be stored / is an immediate source of energy;

2. ATP only releases a small amount of energy at a time;

2

[8]

Q26.

(a) 1. Saprobionts / saprophytes;

2. Digest / break down proteins / DNA / nitrogen-containing substances;

3. Extracellular digestion / release of enzymes;

4. Ammonia / ammonium produced;

5. Ammonia converted to nitrite to nitrate / ammonia to nitrate;

6. Nitrifying (bacteria) / nitrification;

7. Oxidation;

Ignore all references to other parts of the nitrogen cycle

1. Accept saprotrophs. Allow this mark if saprobionts linked to fungi.

2. Ignore"nitrogen in plants"

Ignore enzymes excreted

6. Accept Nitrosomonas / Nitrobacter

5 max

(b) 1. Carbon dioxide combines with ribulose bisphosphate / RuBP;

2. Produces two molecules of glycerate (3-)phosphate / GP;

3. Reduced to triose phosphate / TP;

4. Using reduced NADP;

5. Using energy from ATP;

6. Triose phosphate converted to other organic substances / named organic substances / ribulose bisphosphate;

7. In light independent reaction / Calvin cycle;

3. Accept add hydrogen for reduced

4. Accept alternatives such as NADPH for reduced NADP / GALP for TP / ribulose biphosphate

6 max

[11]

Q27.

(a) (i) Temperature and light;

1

(ii) Increase in temperature causes increase in rate of photosynthesis / uptake of carbon dioxide;

Increase in light / more / medium / high light (intensity) causes increase in rate of photosynthesis / uptake of carbon dioxide;

2

(b) 2.75 – 2.81 (mg g^{-1} hr^{-1})

Accept answers in range 2.75 – 2.81

1

(c) 1. Growth will decrease (at higher temperature);

2. Rate of respiration will increase at higher temperature;

3. Photosynthesis decreases as limited by light / as there is less light;

Ignore references to effect of temperature on rate of photosynthesis

3

[7]

Q28.

(a) 1. High concentration of carbon dioxide linked with night / darkness;

Accept: converse of low in day

2. No photosynthesis in dark / night / light required for photosynthesis / light-dependent reaction;

Ignore references to rate of photosynthesis in day / night
Accept day = light

3. (In dark) <u>plants</u> (and other organisms) respire;

Must be a reference to plants or <u>all</u> organisms

4. In light net uptake of carbon dioxide by plants / plants use more carbon dioxide than they produce / rate of photosynthesis greater than rate of respiration;

Do not allow converse for this point
Accept description of compensation point

5. Decrease in carbon dioxide concentration with height;

Accept: converse of increase closer to ground

6. At ground level fewer leaves / less photosynthesising tissue / more animals / less light;

5 max

(b) 1. Carbon dioxide combines with ribulose bisphosphate / RuBP;

2. To produce two molecules of glycerate 3-phosphate / GP;

3. Reduced to triose phosphate / TP;

4. Requires reduced NADP;

5. Energy from ATP;

This mark scheme is based on specification content. Accept alternate names such as NADPH

Credit relevant diagrams

Accept: description of 'reduced'

5

[10]

Q29.

(a) To see if a difference in hours of sunshine was present / because it is necessary to monitor factors which cannot be controlled;
So that they could eliminate this factor from affecting the yield (with /without extra carbon dioxide);
OR
Duration of light influences length of time for photosynthesis / temperaturein glasshouse;
Higher photosynthesis results in higher yield / more carbohydrates /sugars / proteins produced;

2 max

(b) Named factor;
Explanation of why the factor is important;
E.g.
Density of planting;
Competition for named resource;
or
Same variety of tomato;
Yield will vary with different varieties / with different genotypes;
or
Water (application);
Water needed for expansion of fruit / maintain leaf turgidity / maintain stomatal opening / replace water lost in transpiration / water used in photosynthesis;

For named resourceaccept 'nutrient' but not 'food'

2

[4]

Q30.

(a) (i) Yield increases by 0.6 kg m^{-2} (when extra carbon dioxide present);

1

(ii) Temperature / light intensity so could be lower in these weeks (as temperature / light insensity not fully controlled / monitored) (over period 1998 – 2000);

1

(b) Two marks for correct answer of 50.6%;;
One mark for incorrect answer in which candidate has shown clearly that calculation based on an increase / 0.42 and original mass / 0.83

2

(c) Cost of supplying carbon dioxide;
Price of (very early) tomatoes;

2

(d) Lowest price paid for tomatoes;
Some carbon dioxide lost as windows open in summer;
Little / no mean increase in yield in summer;

2 max

(e) Grow with extra carbon dioxide in one glasshouse and without carbon dioxidein other glasshouse at same time;
So all environmental conditions / light and temperature same for experiment and control;

2

[10]

Q31.

1. Light (energy) excites / raises energy level of electrons in chlorophyll;

2. Electrons pass down electron transfer chain;

   Q *Accept any reasonable alternative for electron transfer chain.*

3. (Electrons) reduce carriers / passage involves redox reactions;

4. Electron transfer chain / role of chain associated with chloroplast membranes / in thylakoids / grana;

   Example such as chemiosmosis;

5. Energy released / carriers at decreasing energy levels;

6. ATP generated from ADP and phosphate / P_i / phosphorylation of ATP;

[5]

Q32.

(a) 1 5C / RuBP combines with CO_2;

2 to form 3C compound / TP / GP;

3 using ATP;

4 and reduced NADP / eq;

5 2 molecules of 3C compound / TP / GP form hexose;

6 all RuBP is regenerated;

7 10 molecules of 3C / TP / GP form 6 molecules of 5C / RuBP;

6 max

(b) 1 electron transport chain accepts excited electrons;

2 from chlorophyll / photosystem;

3 electrons lose energy along chain;

4 ATP produced;

5 from ADP and Pi;

6 reduced NADP formed;

7 when electrons (from transport chain) and H^+ combine with NADP;

8 H^+ from photolysis;

6 max

(c) 1 some hexose / biomass / eq. used in respiration;
growth cancels this point

2 CO_2 produced (is lost to air);

3 some parts of the plant are eaten / some parts lost to decomposers / in leaf fall;

3

[15]

Q33.

(a) dry conditions - stomata partially closed;
due to less turgor in guard cells;
OR
watered conditions - stomata more open;
due to greater turgor in guard cells;

2

(b) (i) *EITHER*
temperature *[Allow heat]* - higher causes more water evaporation / diffusion *[not just transpiration]*
OR
light - causes stomatal opening
OR
soil texture - determines availability of water
OR
humidity - reduces evaporation / reduces gradient / wind
causes more (water) evaporation;

1

(ii) high CO_2 gives less variation AND watering gives less variation;
OR
insignificant difference in variability as small differences in SD;
reject 'no difference'

1

[4]

Q34.

(a) Temperature affects photosynthesis; Affects enzyme activity;
So that any change in photosynthesis rate is result of carbon dioxide / light intensity;

max 2

(b) Carbon dioxide increases rate of photosynthesis;
Up to max;
Something else / correct suggestion is a limiting factor;

3

[5]

Q35.

(a) (i) **P** = 3;
Q = acetylcoenzyme A;

2

(ii) 36 ATP, however derived = 2 marks
30 ATP, however derived = 1 mark

2

(iii) *Correct statement in the context of aerobic respiration or anaerobic respiration concerning*:
Oxygen as terminal hydrogen / electron acceptor allowing operation of electron transport chain / oxidative phosphorylation;
Fate of pyruvate;
Significance of ATP formed in glycolysis;

3

(b) (i) Thick walls exclude oxygen;
Produced by photosynthetic cells (of fern and *Anabaena*);
Contain no chlorophyll so do not photosynthesise;
Do not produce oxygen;
Oxygen would inhibit nitrogen fixation process;

max. 3

(ii) Decomposers / bacteria / fungi / saprobionts (in fields);

Convert protein / organic nitrogen (in cells of fern) into ammonium ions (*allow ammonia*);
Ammonium ions (ammonia) converted to nitrite, then converted to nitrate;

Allow 1 mark for NH_3 / $NH_4^+ \rightarrow NO_3^-$
By nitrifying bacteria / correctly named;
Nitrate used to form protein / amino acids in rice;

5

[15]

Q36.

(a) Excitation of chlorophyll molecule / electrons / energy of (pairs of) electrons raised to higher energy level;

Electron(s) emitted from chlorophyll molecule;

Electron(s) to electron transport chain;

Loss of energy by electron(s) along electron transport chain;

Energy lost by electron(s) is used to synthesise ATP;

From ADP + Pi;

"By electrons" need not be stated in each marking point if it can be reasonably inferred that the candidate is referring to electrons

max 5

(b) Little green light reaches bottom as absorbed by surface dwellers / water;
Red and blue not absorbed and so penetrate;
Variation in pigments of sediment dwellers;

Bacteria with chlorophyll at an advantage as chlorophyll absorbs red and blue;
(Survive to) reproduce in greater numbers and pass on advantageous alleles / genes in greater numbers / increase in frequency of advantageous alleles in subsequent generations;
Increase in frequency / numbers of bacteria with chlorophyll;

6

[11]

Q37.

(a) (i) temperature also affects photosynthesis / rate of reaction; need to ensure the effect of only one variable is being observed;

1

(ii) CO_2 used / O_2 produced / sugar produced / increase in mass; per unit of time;

accept any volume or mass unit; per time unit;)

(allow one mark for indicator of photosynthesis – second mark is for time element)

2

(b) (i) as carbon dioxide increases, rate of photosynthesis increases;

1

(ii) carbon dioxide not limiting photosynthesis / another factor / named factor limiting;
explanation for named factor;

2

[6]

Q38.

(a) Grana / thylakoids / lamellae;

1

(b) **A** = oxygen / O_2
B = ADP <u>and</u> phosphate / P_i / phosphoric acid / correct formula;
C = reduced NADP; ALLOW NADPH / $NADPH_2$ / NADPH + H^+

3

(c) (i) Absorbs light / energy;
Loses electrons / becomes positively charged / is oxidised;
Accepts electrons from water / from OH^- which causes more water to dissociate / pulls equilibrium to the right;

3

(ii) Electrons raised to higher energy level / electrons excited;
Use of electron carriers / cytochromes / acceptors;
For production of ACT

[REJECT 'energy production']

3

(d) (i) GP formed from RuBP + CO_2;
GP → TP / sugar-phosphate / sugar / to RuBP;
GP formed at same rate as it is used;

3

(ii) No CO_2 to combine with / not enough CO_2 to combine with RuBP
RuBP not changed into GP / TP RuBP reformed from GP / TP;

2

[15]

Q39.

(a) On diagram, correctly labelled:

Light-dependent: granum / thylakoid membranes – labelled 'X'
AND
Light-independent: stroma – labelled 'Y';

1

(b) Any two from:

(Water) forms H^+ / hydrogen ions and electrons / e^- ;

O_2 / oxygen formed; [*NOT* 'O', *NOT* 'O^-']

(Light) excites electrons / raises energy level of electrons / electrons to chlorophyll / to photosystem;

max 2

(c) (ATP) Provides energy for GP → TP / provides P for RuP / TP → RuBP;

(Reduced NADP) Provides H / electrons for GP → TP / reduces GP to TP;

2

[5]

Q40.

(a)

✓	✓	x;
x	x	✓;
✓	✓	✓
✓	x	x

4

(b) (i) pyruvate / succinate / any suitable Krebs cycle substrate;

1

(ii) ADP and phosphate forms ATP;
oxygen used to form water / as the terminal acceptor;

2

(iii) Y X W Z;
order of carriers linked to sequence of reduction / reduced carriers cannot pass on electrons when inhibited;

2

[9]

Q41.

(a) electrons;
from chlorophyll / photolysis;

2

(b) (i) RuBP combines with carbon dioxide to produce 2 x GP;

1

(ii) less used to combine with carbon dioxide /
less used to form glycerate 3-phosphate;

1

(c) (i) used in photosynthesis allows detection of products;

1

(ii) ATP and reduced NADP not formed;
GP is not being used to form RuBP / is being formed from RuBP;

2

(iii) used in respiration / formation of starch / cellulose;

1

[8]

Q42.

(a) (i) pigment reflects / does not absorb green or yellow or orange;
pigment absorbs blue or violet;
pigment absorbs red;
(accept correct wavelengths instead of colours)
(any 2 for 1 mark)

1

(ii) light (energy) absorbed by chlorophyll;
raises energy level of electrons / electrons are excited / emitted;
ATP formed;

3

(b) more wavelengths / colours absorbed;
more (efficient) photosynthesis can occur at these depths / low light intensities
or
more (efficient) photosynthesis can occur when some wavelengths are not present;

2

[6]

Q43.

(a) (i) respiration;

1

(ii) decomposers;
(*accept bacteria / fungi*)

1

(b) $\frac{87402}{1.7 \times 10^6}$ × 100 = 5.14 / 5.1%;
(correct answer = 2 marks)

(principle: energy in producers ÷ energy of light absorbed = 1 mark)

2

(c) excites chlorophyll / electrons;
release electron(s);

2 max

(d) reduced NADP;
reduces GP / to change GP to TP;
ATP;
provides the energy to reduce GP / convert GP to TP / TP to RuBP /
provides phosphate to convert TP to RuBP;

4

[10]

Q44.

(a) (i) RuBP – 5; GP – 3; TP – 3; Glucose – 6;
(all correct = 2 marks; 3 or 2 correct = 1 mark)

2

(ii) stroma;

1

(iii) light-dependent reaction / (photo)phosphorylation;
(accept photolysis)

1

(iv) 5 out of 6 / 83% / equivalent;

1

(b) enzymes involved / not a photochemical reaction;
slow rate of enzyme / chemical reaction at low temperature /
less kinetic energy / fewer collisions;

2

[7]

Q45.

(a) adding CO_2 decreases pH / makes more acid
OR removing CO_2 increases pH / makes more alkaline;
(credit anywhere but do not credit this mark if stated that oxygen is an alkaline gas)

rate of photosynthesis > rate of respiration in **A**;
respiration only in **B**;
rate of photosynthesis = rate of respiration in **C**;

4

(b) (i) shows that indicator alone does not change colour in light;

1

(ii) so that all tubes receive same amount of heat

1

[6]

Q46.

(a) the more light absorbed, the greater the rate of photosynthesis;
light provides the <u>energy</u> for light dependent reactions / photolysis /
light independent reactions / production of reduced NADP /
exciting electrons in chlorophyll;

(do not give credit if energy is used in photosynthesis)

2

(b) count the number of bubbles / measure the volume of gas / measure the change in pH / carbon dioxide / hydrogen carbonate ions;

(credit oxygen produced)

1

(c) 530 – 630 nm;

(any values within this range)

limited absorption of light / (green) plants reflect green light /
limited photosynthesis at these wavelengths of light;

(allow references to no light absorbed or no photosynthesis)

2

(d) (i) chlorophyll excited / reduced NADP formed;
<u>electrons</u> from chlorophyll / reduced NADP changes the dye colour;

2

(ii) ADP and phosphate needed to produce ATP / ATP is a product of the light dependent reactions;
ADP levels are a limiting factor;

(must explain the idea of limiting factors – do not credit answers like more ADP causes more photosynthesis)

2

[9]

Q47.

(a) rate of photosynthesis increased;
normal atmospheric concentration a limiting factor / more / faster production of biomass or sugars / more products of photosynthesis transported to fruits;

2

(b) (increased temperature) increases rate of respiration;
rate of photosynthesis too low to replace respiratory loss

2

(c) lower water potential of nutrient solution;
less water absorbed into roots (by osmosis);

(not: water lost from roots)

2

[6]

Q1.

(a) Approximately 41% of students obtained both marks by referring to the reduction in ATP and reduced NADP. Students who gained a single mark usually did so by stating that there was less ATP rather than less reduced NADP. Many of these students incorrectly stated that less NADP or less reduced NAD was produced. Some students suggested that heat stress caused stomata to close and this limited carbon dioxide uptake and photosynthesis. Many students used additional pages for this question due to initially describing denaturation of rubisco or ATP synthase before realising that they needed to name specific products of the light-dependent reaction. It was disappointing to note that nearly a third of students scored zero.

(b) Again, approximately 41% of students obtained both marks by explaining the role of rubisco in photosynthesis. Students gaining a single mark often failed to mention both RuBP and carbon dioxide, or simply referred to a six-carbon product with no mention of GP being formed. A minority of students incorrectly referred to GP as glucose phosphate. One in four students scored zero. Most of these responses were limited to describing how denaturation of rubisco would occur. Some students confused the Calvin cycle with the Krebs cycle.

(c) Almost two-thirds of students correctly named the stroma as the location of rubisco. The thylakoids, crista and matrix were common incorrect responses.

(d) The majority of students (56%) obtained two marks, invariably for describing the effects of an increase in temperature on the activity of rubisco and rubisco activase. However, many students then failed to use all the information successfully to evaluate the scientists' conclusion. Only 25% of students obtained more than two of the four marks available. Relatively few students clearly stated that the results indicate that rubisco activase does not activate rubisco. Similarly, very few students stated that these results were only for cotton plants and were for isolated enzymes. Equally surprising was the scarcity of responses which referred to the lack of a statistical test. Consequently, this question did not discriminate as effectively as had been expected.

Q2.

(a) This was generally well answered, with over 80% of students obtaining at least one mark. Most students understood that using a solution of the same water potential would prevent osmosis, and then described the effects on chloroplasts if the water potentials were not the same. Common errors included discussing the effect of osmosis on 'the cell' rather than on chloroplasts and the use of terms such as 'plasmolysed' and 'turgid'. The need for water in photolysis or the light-dependent reaction was also referred to in weaker responses. Some students suggested that the movement of water had to be prevented to avoid changing the colour of the DCPIP.

(b) This question proved to be more demanding with less than 10% of students obtaining both marks. Many answers simply referred to **Tube 1** as being a control, or that it was set up to allow comparison with other tubes. Some students suggested that it was the DCPIP causing the colour change. However, almost 60% of students gained at least one mark, usually for describing that **Tube 1** showed that chloroplasts were needed to cause the colour change. The idea that **Tube 1** shows that light does not affect DCPIP was less often mentioned.

(c) Over 80% of students obtained at least one mark for this question, usually for outlining the role of chlorophyll or the light-dependent reaction in producing the results in **Tube 3**. Better students did refer to the reduction of DCPIP by electrons. However, common misconceptions suggested that DCPIP was reduced by protons or by reduced NADP (or reduced NAD). Weaker responses referred to the oxidation of DCPIP by oxygen or the release of ions from chlorophyll.

(d) Slightly more than 40% of students obtained this mark, often by stating that different chemicals or concentrations of chemicals could be compared as weed killers. Fewer students referred to using IC_{50} as a standard or benchmark. Responses which did not gain credit often simply stated 'for comparison', without qualification, or simply repeated the information provided in the stem of the question.

(e) Many students provided responses which showed understanding that the light-dependent reaction would not take place, and hence neither would the Calvin cycle. This was then often linked to less glucose being produced for growth. However, many of these answers failed to mention the products of the light-dependent reaction. Consequently, almost 50% of students scored zero. Better answers did refer to ATP and / or reduced NADP not being produced for use in the light-independent reaction. Relatively few students specified that the reduction of GP to form TP would not take place.

Q5.

(a) Almost 80% of students correctly identified the stroma as the site of the Calvin cycle. Common incorrect responses included the matrix and cytoplasm.

(b) (i) Most students correctly stated that less RuBP combined with carbon dioxide. Some students simply stated that carbon dioxide was a limiting factor or described the conversion of glycerate-3-phosphate (GP) to triose phosphate (TP). TP was occasionally thought to combine with carbon dioxide to form GP.

(ii) It was disappointing to find that almost a third of students did not gain any marks for this question. Their answers often suggested that there were limiting factors without naming them or simply stated that the reaction was occurring at its maximum rate. The most frequent correct responses referred to light or temperature as the limiting factors. However, references to the amount of enzyme or to RuBP limiting the reaction were also often included in better answers.

(c) This question caused difficulties for many students with almost 50% failing to obtain a mark. Common misconceptions included hydrogen sulfide providing oxygen, sulfur acting as the final electron acceptor, hydrogen reducing NAD and hydrogen being used in respiration. Better answers referred to hydrogen sulfide providing protons and electrons, the reduction of NADP using hydrogen, and electrons being provided for the electron transfer chain.

Q6.

(a) Over 20% of students gained full marks on this question and almost 80% of students gained at least three marks. Most students displayed a very good understanding of the processes involved in the light-dependent reaction of photosynthesis. Failure to gain four or five marks on this question was often due to the omission of specific details. Although the vast majority of students described the passage of electrons down the electron transfer chain, a significant number failed to mention the release of energy. Similarly, the production of ATP was understood but the use of ADP and Pi in this process was sometimes omitted. Photolysis was

described by the vast majority of students but a significant number omitted oxygen as a product. On a positive note, the reduction of NAD instead of NADP was seen less frequently than in previous years. However, a significant number of students referred to the reduction of NADP by protons on their own.

(b) This question caused very few problems for students. Almost 40% obtained maximum marks and almost 90% obtained at least three marks. Explanations that gained maximum marks were often clear and concise. A significant number of students omitted a named nitrogen-containing compound, e.g. DNA, when describing the formation of ammonia by saprobionts. A limited number of students referred to decomposers rather than saprobionts and occasionally nitrifying bacteria were thought to be in root nodules. However, most students showed an excellent understanding of the specific role of the different types of microorganisms. Some answers did include irrelevant information relating to the roles of nitrogen-fixing and denitrifying bacteria.

Q7.

(a) Most students gave reasonable suggestions for the purpose of treatments 1 and 2 but found the purpose of treatment 3 more difficult to explain. In this question and in question (c)(i), it was important that students had read the information in Resource B stating that these leaves have stomata only on their lower surface.

(b) (i) Students still find it difficult to describe a trend on a graph such as this accurately. Many students failed to state clearly that the rate stayed constant for the first 60 minutes and then fell (as required for mark point 1).

(ii) Some students were not explicit enough in their answer that the water is lost through the stomata in order to achieve mark point 1.

(c) (i) Students who stated that there were stomata on the upper surface of the leaf could not be awarded this mark, as Resource B stated that these leaves have stomata only on their lower surface.

(ii) Most students achieved mark point 1 but only better answers went on to explain why this meant there was no uptake of carbon dioxide.

Q8.

(a) Fewer than fifty percent of students correctly referred to oxygen production and time. Many simply referred to oxygen production or uptake of carbon dioxide. A number of students mentioned the mass / volume of the algal cells and suggested measuring the rate of oxygen production per unit mass of cells per unit time.

(b) Two thirds of students were able to suggest two correct factors and almost every student obtained at least one mark usually for light intensity or carbon dioxide concentration. Despite the rubric stating ‘other than temperature’, a significant minority gave temperature as one of the factors. Common incorrect responses included water concentration, humidity and wavelength of light.

(c) Approximately half the students obtained both marks explaining that the increase in pH was due to carbon dioxide being absorbed and used in photosynthesis. However, other students did not state whether the pH increased or decreased when carbon dioxide was removed from the solution, even though they correctly described the solution becoming more alkaline or less acidic. A decrease in pH sometimes became an increase by the end of an answer. Weaker responses often confused carbon dioxide with oxygen and respiration with photosynthesis. These students

often suggested that carbon dioxide or oxygen was alkaline.

(d) Most students obtained at least one mark usually for outlining the role of light energy in the light-dependent reaction. Fewer students obtained the first mark point as they suggested no light was absorbed rather than less absorption of light. Nevertheless, almost forty percent of students gained both marks by linking less absorption to a decrease in the light-dependent reaction or by suggesting that the wavelengths reflected represented green light. Incorrect responses often referred to limiting factors such as temperature or carbon dioxide.

Q9.

(a) This question proved to be a very effective discriminator despite similar questions on speciation occurring previously in this component. The vast majority of students obtained the mark for geographical isolation / separation. However, many students only referred to the lack of interbreeding after the new species had been formed rather than during the process of speciation. These responses did not obtain the equivalent mark point. Variation and mutation were not always linked or one of these was omitted. Mutations were occasionally caused by the environment or by variation. Different selection pressures were well known although sometimes there were vague references to ‘different conditions’ or ‘different climates’. Most students understood that differential reproductive success resulted in a change in allele frequency although weaker students referred to ‘alleles reproducing’. Less than five percent of students managed to miss every marking point, sometimes after writing a whole page in response. These answers often described succession or directional selection.

(b) As expected this question was very well answered with over seventy percent of students obtaining three out of the four marks available and just over a third obtaining maximum marks. Although there was some variation in which marking points were omitted, a significant number of students did not mention leaving time for lizards to distribute randomly in the population before obtaining a second sample. Other common errors included omitting any reference to releasing the lizards after they were initially captured and / or providing an incorrect equation for calculating the final population. Most students appreciated that the method of marking the lizards should not cause harm or make them conspicuous to predators.

(c) This was another question which proved to be a good discriminator and provided a good spread of marks. There were some excellent answers with these students providing a detailed account of the relative effects of photosynthesis and respiration on the concentration of carbon dioxide in a forest over a period of 24 hours and at different heights above the ground. These answers included reference to the greater rate of photosynthesis than respiration during the day, a concept that was not found in the vast majority of scripts. At the other end of the range ability, students often only gained credit for linking an increase in concentration of carbon dioxide at night to respiration. Better answers did refer to ‘no photosynthesis’ at night for a second mark but a surprising number of students referred to ‘less photosynthesis’ at night, suggesting that it was still occurring. The information about heights above ground tended to be less clear and often failed to include more or less (respiration or photosynthesis). A surprising number of students suggested there was a greater carbon dioxide concentration higher up linked with more photosynthesis, despite previously giving correct descriptions of carbon dioxide uptake for photosynthesis and its release from respiration and gaining some of the earlier marking points. References to microorganisms were rare. A minority of answers described and explained changes in oxygen levels. Some students believed that the light-independent reaction could occur at night. A few responses described carbon dioxide levels in the upper layers of the atmosphere (troposphere, stratosphere).

Q10.

(a) Over 95% of students correctly named the process as succession. Speciation was the most common incorrect response.

(b) Most students obtained at least one mark, usually for stating that more habitats would be available. Many of these students also referred to a greater variety of food sources although a significant minority simply stated there would be more food, which was not credited. Approximately a third of students gained all three marks by also indicating that as the woodland developed there would be an increase in the variety of plants.

(c) (i) 50% of students correctly gave temperature and carbon dioxide as the two limiting factors. Most who did not referred to water rather than temperature. However, humidity, mineral ions / nutrients, oxygen, pH, light intensity and chlorophyll were also given as limiting factors. Only rarely were two incorrect factors selected.

(ii) Most students referred to the uptake of carbon dioxide in photosynthesis and its release during respiration but did not fully explain net productivity. Some students got the use / production of carbon dioxide in photosynthesis / respiration the wrong way round. Almost a third of students did gain this mark, almost invariably by stating that net productivity = gross productivity minus respiration.

(iii) This question was not answered well. Very few students were able to use the information in **Figure 2** to explain how the shade plant is better adapted to gain both marks. The lower rate of respiration was recognised but the lower release of carbon dioxide was usually described at low light intensities rather than at 0 or in the dark. The idea of greater productivity in the shade plant was less frequently described. Most answers related to photosynthesis and many students gained no marks. As in part (ii), the uptake and release of carbon dioxide was sometimes wrongly assigned to respiration and / or photosynthesis. The surface area of the leaves, amount of chlorophyll and number of stomata were also incorrectly used as part of some students' explanations.

Q11.

This question was well answered by most students, with over 75% of students obtaining four or more marks. The most commonly awarded marks were; carbon dioxide combining with RuBP, the formation of 2GP from this reaction, the reduction of GP to TP and the formation of a named compound, usually glucose or RuBP from TP. Approximately one in every four students specifically mentioned that ATP provides the energy for the reduction of GP to TP. A much higher percentage of students stated that reduced NADP is essential for the reduction of GP to TP. However, there was a significant minority of students who referred to reduced NAD rather than reduced NADP.

Q12.

(a) About three quarters of students obtained both marks for the calculation in this part. Some students only scored one mark because of incorrect rounding of numbers in their calculations or answers.

(b) This part proved far more challenging than intended. It was hoped that students would note that only (plants and) non-photosynthetic soil organisms are mentioned in the study and point out that there are lots of other organisms / animals that are

not mentioned. The examiners accepted statements that carbon dioxide from leaves did not take into account effects of photosynthesis, because students were not told until (d) that measurements were taken in the dark. Quite a few students treated the leaves of plants and the stems and roots of plants as separate organisms, rather than different parts of the same organisms. Nearly three quarters of students failed to score any marks.

(c) To obtain two marks in this part, students had to identify three measurements: volume of carbon dioxide, from a given / known area, in a set time. If they identified two of these, they obtained one mark. A quarter of students obtained two marks and about half failed to score. There were many vague references to *amount* of carbon dioxide and *time* unqualified and many students missed out area altogether.

(d) This part was done well by many students and three quarters obtained both marks. They were able to state that there is no photosynthesis in the dark and photosynthesis would take up carbon dioxide. Some students were confused about whether it was photosynthesis or respiration that produces carbon dioxide, or uses it.

(e) (i) Most students noted that respiration in soil under trees is always higher in this part. Over a third went on to describe a difference in the peak times of respiration in soil under trees and soil not under trees. Although a 2 mm grid was not given on the graph, the examiners expected some attempt to describe time frames, rather than just *earlier* or *later*.

(ii) Correct answers to this part usually revolved around respiration in soil not under trees increasing because the soil gets warmer in sunshine and this leads to faster enzyme activity. Very few looked back to the table and noted the high rate of respiration in roots of plants, of which there would be a lot under trees. Many students thought that photosynthesis by the trees would make more oxygen available in the soil under the trees. Others thought that photosynthesis by the soil not under the trees would increase during the day.

(f) As the final interpretive question on the final paper, this part was intended to be challenging and so it proved. Very few students appear to appreciate the relationship between photosynthesis and respiration in plants in terms of respiratory substrate. This was tested last year and proved challenging then. Students should appreciate that plants make their own respiratory substrates via photosynthesis. Those students who did score in this part did understand this. Given that many students treated leaves and roots of plants as separate organisms in (b), it was perhaps not surprising that very few students suggested it takes time for sugars to travel from leaves to roots. Some got ‘close’ by suggesting it took time for oxygen from photosynthesis to travel to the roots.

Q13.

(a) Some of the lower-scoring students failed to access this question. Credit was available for stating that the relative processes stopped at particular values. Reference to processes happening at those values was insufficient, unless qualified by giving the range of values over which the processes happened. Some assessors incorrectly gave credit where positive, rather than negative, values were shown.

(b) This question proved accessible to most but some explanations were unnecessarily complicated by reference to transpiration.

(c) Many students found this question challenging. They were expected to suggest how growth was prevented when the processes stopped. Merely stating that they

stopped was unworthy of a mark. Credit was inappropriately given by some assessors when the potential role of proteins as enzymes or membrane proteins, or the *naming* of a specific protein, had not been given. Some students failed to explain that a lack of cell wall synthesis would affect new cell production and consequently prevent growth. Higher-scoring students frequently achieved full credit.

Q14.

(a) (i) Three out of four students gained this mark by stating that carbon dioxide is a limiting factor on photosynthesis. Inadequate responses often simply stated that carbon dioxide was needed for photosynthesis.

(ii) Twenty percent of students gained this mark by indicating that any difference in growth during the experiment would be due to iron deficiency. There was a large variety of incorrect responses but the majority referred to a 'fair test', 'similar growth' or 'same level of TP'.

(iii) Only the better responses included the realisation that the period in the dark was to ensure that the levels of triose phosphate were similar / low in both groups of plants at the start of the experiment. Many who did mention triose phosphate thought that it would all have been used up or converted to glucose / RuBP, ignoring the evidence from the graph. Weaker responses only referred to preventing the light-dependent reaction, or just preventing photosynthesis.

(b) This question proved to be a very effective discriminator and produced a good range of marks. Most students gained a mark for ATP being produced during electron transport. Although many students then gained a mark for the production of reduced NADP, a significant minority incorrectly referred to NAD. The decrease in production of triose phosphate was not always linked to a decrease in glycerate-3-phosphate. Only better responses referred to ATP and reduced NADP being produced during the light-dependent reaction. Despite the stem of the question stating 'knowledge of photosynthesis' a number of students described electron transport during respiration.

(c) This question caused some difficulty for students, with almost forty percent gaining no marks. It was surprising to find a number of students referring to respiration in their answers and confusing the Calvin cycle with the Krebs cycle. Some students with a better understanding failed to gain credit as they limited their explanation to the Calvin cycle being reduced. Students gaining one mark often referred to the role of RuBP in combining with carbon dioxide. Only the best responses linked iron deficiency to a reduction in the amount of triose phosphate and therefore less RuBP.

Q15.

As a whole, this question tested students' understanding of the relationship between photosynthesis and the growth of plants. The questions were marked on outcome; this is to say that the examiners expected answers of A-level standard.

(a) Many students failed to read the y axis carefully enough. All of the samples of plants increased in dry mass after 3 days, they all grew but some less than others. GB had no effect at 25°C, compared with plants without GB. Few students noted this and quite a number stated that GB produced more growth at all temperatures. Relatively few students made reference to the protection given to growth by GB up to 35°C. However, quite a few noted that growth was reduced less above 35°C with GB.

(b) (i) There was only one mark available for this question and, with this in mind, students were required to refer to the standard error bars not overlapping, or

to state that there was a significant difference between plants producing GB and those that weren't.

(ii) Over a third of students obtained one mark, usually for linking a reduction in photosynthesis to a reduction in glucose (simple sugar) production. Some were also given credit for suggesting that the reduction could be linked to reduced enzyme activity. This was as far as most students went. Indeed, quite a large number wrote about reduced photosynthesis producing 'less food for the plant'. This was disappointing at A-level. For most students, their statement about reduced glucose production was simply followed by 'therefore growth falls'. There were very good answers that linked reduced glucose production to less respiratory substrate and thus less ATP / energy for growth. Others displayed understanding that sugars from photosynthesis form the basis for production of other organic substances and that these add to dry mass.

(c) This was another question where some students failed to read the question carefully. A large majority correctly suggested that *when* the enzyme attaches to the thylakoid, this changes the shape of the enzyme, and / or its active site. They then went on to link this to a failure to bind to its substrate. Those who did not read carefully suggested that the enzyme was changed *before* binding to the thylakoid. This did not preclude them from scoring marks but made it less likely.

(d) It was pleasing to see that the chain of evidence and logic was seen by most students. The number of marks they obtained tended to be a question of how much of the story they gave.

(e) Many students ignored the statement in the stem that the hypothesis was developed on the basis of previous research. Instead, they reiterated the evidence from the study in the question. Good answers included the idea that research might have shown that crops in hot climates naturally produce GB.

Q16.

(a) This was answered well by many students, although some failed to identify the peaks accurately.

(b) This was answered well, with many scoring three marks. Only better answers noted that at all wavelengths less light energy was passing through, for mark point 1. Very few went on to point out that photosynthesis would not exceed respiration (mark point 5). Some students stated that none of the pigments could absorb the wavelengths that pass through, rather than specifying chlorophyll.

(c) Many students gained one mark here but few achieved both. Many identified that light or temperature would not be limiting but did not go on to describe how this would affect the biochemistry of photosynthesis. Some mentioned the use of carbon dioxide in the light-independent reaction but did not link this to the high use of carbon dioxide, to gain both mark points 5 and 6. Several answers were seen with a clear misunderstanding that a higher concentration of oxygen causes a lower concentration of carbon dioxide.

Q17.

(a) This was generally answered well. Some references to error bars without mention of representing standard deviation were seen, and these answers were not given credit for mark point 2.

(b) This was generally answered well. There were some inappropriate uses of grids and coordinates and some trees shaken or beaten to remove leaves; neither method was credited.

(c) The vast majority of students pointed out that there was no overlap of standard deviations (or 2 × the standard deviation) for mark point 3 but did not go any further to gain the second mark. Although the range was calculated correctly by many for mark point 4, very few correctly identified that it was not possible to draw a conclusion without a statistical test result. Many students referred to standard error without appreciating that this had not been given and could not be worked out without knowing the sample size.

(d) This question provided an opportunity for students to shine and express their understanding correctly in the context of the information provided. Many answers were seen, however, relating to sun leaves being warmer and therefore having more enzyme activity to produce chlorophyll. These were in the wrong context and did not gain the marks.

Q18.

Most students identified that chlorophyll b could absorb some of the light that passes through leaves. Many then failed to identify accurately the cross-over ranges of light available and light absorbed to gain the second mark.

Q19.

(a) (i) Slightly more than two-thirds of students correctly identified the stroma as the precise location of the enzyme Rubisco. Common incorrect responses included the ‘matrix’, ‘grana’ and ‘cytoplasm’.

(ii) Most students correctly gave the answer of two as the number of carbon atoms in one molecule of phosphoglycolate. The most common incorrect responses were three and five.

(b) The majority of students clearly understood that, as the oxygen concentration increased, more Rubisco / RuBP reacts with the oxygen rather than with carbon dioxide. However, very few students realised that this was an example of competitive inhibition or mentioned that less RuBP would be regenerated. Consequently, most students obtained only one of the two marks available.

(c) This proved to be a good discriminator. Most students gained one mark for realising that less glycerate 3-phosphate would be produced. A significant percentage of these students then gained a second mark for describing the formation of a named photosynthetic product from triose phosphate. However, less than ten percent of students referred to less RuBP being regenerated. Weaker answers often included references to the Krebs cycle rather than the Calvin cycle and linked the uptake of oxygen to respiration.

Q20.

(a) This question was well answered by students with over eighty percent of students obtaining three or more marks. The most commonly awarded marks were; electrons becoming ‘excited’, energy being released from the ETC, energy being used to form ATP from ADP and Pi and details of the photolysis of water. Marks were often not awarded because of references to chlorophyll absorbing light rather than light energy (or photons), or for referring to NAD being reduced rather than NADP. However, it was clearly evident that this topic is well understood by most students,

with many answers including factual details well beyond the requirements of the specification.

(b) This question proved to be a relatively good discriminator and provided a good spread of marks. There were some excellent answers where students provided a detailed account of speciation, clearly linking this process to the context of the question. At the other end of the range, there were references to plants becoming 'immune to copper' and considerable confusion between genes and alleles. Most students referred to a mutation, to an allele providing 'resistance to copper' and to differential reproductive success. Better answers mentioned the 'allele for copper resistance' and often appreciated that the frequency of the allele would increase in future generations. Far fewer students mentioned 'variation'. A significant minority of students provided a description of succession, often in addition to explaining speciation.

example change

Q21.

(a) Four out of five students were able to name ribulose bisphosphate as the substance which combines with carbon dioxide in a chloroplast.

(b) The formation of ATP and reduced NADP in the grana was well known by many students. A significant number did not state that the NADP was reduced and some referred to reduced NAD. Others knew that the light-dependent reaction occurred in the grana but did not identify the products needed in the light-independent reaction or only identified one of the two. Others only stated that the stroma is where the light-independent reaction takes place which fixes carbon dioxide. Some thought that the grana have no effect on the uptake of carbon dioxide or that the light-dependent reaction occurs in the stroma.

(c) This proved more demanding with only one in four students gaining both marks. Most students did appreciate that the lack of light would prevent the light-dependent reaction from taking place or named the products which could no longer be produced from this process. However, they often did not use this information to predict the uptake of radioactively labelled carbon dioxide if tube **A** were placed in the dark. A few students thought there would be 'no difference' to the uptake of carbon dioxide in the dark as the light-independent reaction does not use light. A small number of students thought that there would be more respiration in the dark leading to an increase in carbon dioxide in tube **A**.

(d) Despite the question asking students to use their knowledge of the light-independent reaction, a significant number of students only referred to the lack of the products of the light-dependent reaction resulting in a lack of RuBP without any details of the pathway of its production. Many students did appreciate that ATP and reduced NADP were involved in reducing glycerate 3-phosphate but not all of them named triose phosphate as the product to gain a mark. Relatively few students obtained the second marking point by outlining that RuBP is formed from triose phosphate.

(e) Less than a third of students obtained both marks in this question. However most gained at least one mark often by linking electron transfer to the production of ATP. The fact that electron transfer is required for the reduction of NADP was less well known. The reference to electron transfer in the question resulted in some weaker students providing details about chemiosmosis in respiration or relating to reduced NAD.

Q22.

(a) Most students correctly identified the relevant wavelength of light.

(b) It was relatively uncommon to encounter errors in the answers to this question, but there were occasional references to inappropriate substances.

(c) (i) Very few students appeared to appreciate that rate required a unit of volume and a unit of time, while the comparison meant that, additionally, there should have been a unit of area or mass. In addition, students are expected either to write units out in full or to use the correct symbols for the units concerned. Given the specification requirement that "students should be encouraged to carry out practical and investigative work throughout the course" the poor standard of the answers to this question was most disappointing.

(ii) Responses to this question frequently lacked appropriate detail, offering little more than a passing reference to the need for light for photosynthesis. A mark allocation of three should have indicated that rather more was required.

(d) This question required students to evaluate the suggestion and, as such, should have evoked responses that both supported and negated the idea. The more able students appreciated that photolysis, or the light-dependent reaction, was not directly controlled by enzymes but frequently failed to consider the role of temperature on respiration and its effect on oxygen release.

(i) Less able students identified this question as inviting a repetition of the conclusions they reached as a result of the statistical test that they had carried out earlier, and failed to make use of data relating to standard deviation in Figure 2.

(ii) Most students commented appropriately about the difference in light emitted by the two lamps but were less successful in explaining how this influenced the rate of photosynthesis in *Ulva pertusa*.

Q23.

(a) Part (i) was correctly answered by many as a non-living factor, and most students gave a suitable example for part (ii).

(b) Answers to this question were frequently very disorganised, with students wasting many lines describing the data before attempting an explanation. The first marking point was often gained, usually for no photosynthesis at night, but students did not then develop the idea and explain that this resulted in no carbon dioxide being taken up at night. The production of carbon dioxide in respiration, and therefore that the uptake in the light was a net movement, was also very rarely mentioned. A few students tried to include the detail of the Calvin cycle to explain the reduction in carbon dioxide levels. Marking point 4 was often awarded for carbon dioxide taken in by leaves. The higher concentration of carbon dioxide at ground level was sometimes explained as being because it is denser than oxygen.

(c) There were many excellent answers where all four marking points were clearly understood and explained using the correct terminology. Many students could clearly explain that advantageous characteristics allowed trees to survive and reproduce successfully. They gained two marks. The change in allele frequency was also often correctly explained with fewer incorrect references to genes. There was some apparent misunderstanding of germination which seemed to be taken by some students to mean reproduction. There was the occasional account of succession or descriptions of features advantageous to survival in the mountains.

Weaker students could say little more than that the trees with an advantage were more likely to survive. There were frequent references to directional and stabilising selection.

Q24.

(a) Some good answers were given to this question, with candiates being confident in their understanding of the way in which ATP rapidly releases small, manageable amounts of energy in a single hydrolytic reaction. Marking points 5 and 6 were the least often seen, and the use of ATP to lower activation energy was very rarely seen, although answers frequently referred to activation of glucose in glycolysis.

(b) Many excellent answers were given in this section that included six or more of the marking points and showed excellent understanding of the processes involved in ATP formation, including chemiosmosis. A significant number gave an account of the whole process of respiration, including glycolysis, using up the space provided and indicating that the answer continued on a separate sheet. One or two included the digestion and absorption of carbohydrates. Weaker students often gained marking points 1, 2 and 6. There was confusion over protons and electrons and hydrogen ions/atoms and molecules. Some students confused the processes of respiration and the light-independent reaction of photosynthesis. Glycerate 3-phosphate (GP) and triose phosphate (TP) were sometimes said to be involved in the Krebs cycle, as was NADP. The movement of protons through the inner mitochondrial membrane into the intermembrane space was often only loosely described, with protons passing into the membrane, along the membrane, or out of the mitochondrion.

(c) Many students did not appear to have any real understanding of the relationship between photosynthesis and respiration. Statements such as ‘plants have to respire so they can make the carbon dioxide so they can photosynthesise’ were not atypical. The weakest students completely reversed the roles of the two processes. Most commonly, students gained two marks, for referring to the uses of ATP in active transport and synthesis. Marking points 1 and 4 were seen rather less often and marking points 2 and 3 were fairly rarely made. Some students demonstrated good knowledge but not the ability to be selective, giving accounts in some detail of both photosynthesis and respiration which failed to address the question fully.

Q25.

(a) The column for aerobic respiration was usually correct, but the other two contained a variety of errors that suggested that these processes were less well understood.

(b) Most candidates gained this mark, but a number did not through the use of P, the symbol for the element phosphorus, rather than one of the many accepted abbreviations for phosphate.

(c) There were some good answers here where candidates showed a sound understanding of ATP releasing energy in small amounts in a single reaction. However, a large number of responses were very vague, simply stating that the production of ATP was quick or easy.

(d) Few candidates understood the significance of ATP being too unstable to be stored within cells. A larger number understood that a high turnover of ATP balances its continuous use within cells. Weaker candidates gained one of the marks by showing that they knew of specific processes that required ATP, such as active transport or muscle contraction. Marks were not given for imprecise terms such as growth.

Q26.

(a) The majority of answers were correct and concise but some candidates included extensive detail about nitrogen fixation, and denitrification that were not required by the question.

(b) A very large number of candidates appeared to have written all they knew about photosynthesis, rather than focus on the light independent reaction as required by the question. Generalising the reactions and writing too superficially, e.g., 'GP is converted to TP using ATP', was common but gained no marks, whereas 'GP is reduced to TP' would have gained one mark and 'GP is reduced to TP using energy from ATP and the reducing power from reduced NADP' would have gained three. Many diagrams and schemes for the light-independent reaction were included and, where these contained additional information, this was credited. However, many were inaccurate or only repeated what had already been written There were also a worrying number of these diagrams labelled as the Krebs cycle.

Q27.

(a) (i) Approximately half the candidates correctly identified light and temperature as the limiting factors between X and Y on the graph. Most incorrect responses referred to only one of these factors or included carbon dioxide.

(ii) Many candidates gained at least one mark by using information from the graph to explain how one of the factors limits the rate of photosynthesis. Better candidates provided evidence to explain how both light and temperature limited the rate of photosynthesis. However, a number of candidates did not refer to evidence from the graph or used evidence which did not relate to rate of photosynthesis between X and Y.

(b) There were very few correct responses. Many candidates failed to notice the different axes for photosynthesis and respiration. It was also evident that many candidates do not fully understand gross/net photosynthesis when presented in an unfamiliar context.

(c) Most candidates gained at least one mark for indicating that a reduction in light intensity would decrease photosynthesis. Although many candidates did appreciate that overall growth would be reduced, they did not all obtain a second mark as their explanations often contained contradictory statements. The effect of temperature on respiration was overlooked by many candidates. A significant number of candidates who did mention respiration stated that increased respiration leads to increased growth. Consequently, very few candidates gained maximum marks.

Q28.

This question allowed candidates to demonstrate their knowledge but this did not mean that all were successful. All parts discriminated across the ability range.

(a) A significant proportion of candidates still gave the impression that they believed that respiration in plants only occurs at night. Others suggested that photosynthesis continues at night, but at a reduced rate. There were contradictions relating to the concentration of carbon dioxide in the canopy and at ground level. Few candidates considered the idea of the relative rates of photosynthesis and respiration in the light and the effect on the net uptake of carbon dioxide. There were, however, many complete and high scoring responses.

(b) Weaker candidates confused substances featuring in the light-independent reaction with those featuring in the Krebs cycle, and confused reduced NADP and reduced

NAD. There were many good answers which identified that two molecules of glycerate-3-phosphate are formed and that this is reduced to triose phosphate using reduced NADP and energy from ATP.

Q29.

(a) Considerable confusion was evident between light duration and light intensity in candidate responses. There seemed to be little appreciation that light intensity would affect the rate of photosynthesis and light duration would only affect the time available for photosynthesis. It was not possible to credit references to light intensity although many centres did so.

Many candidates correctly recognised that it was essential to monitor the number of hours of sunshine to check that both crops were experiencing similar levels.

(b) All factors were seen in responses. The explanations were often weak and were not sufficiently precise to award the mark correctly. Light intensity, light and carbon dioxide were regularly seen but were ~~these~~ often incorrectly awarded marks by the centre.

Q30.

(a) (i) This was correctly answered by the vast majority, although some candidates simply stated that the yield increased. This was incorrectly given credit by some centres.

(ii) This was well understood by the vast majority and marked at the correct level. Some candidates did not answer the question and wrote about differences in mean monthly values rather than in some weeks of the year.

(b) This was well answered and marked at the correct level, two marks being scored frequently. Centres tended to be over-generous in awarding one mark, accepting either of the figures in the marking guidelines instead of requiring both to be present. Incorrect responses usually involved candidates expressing a response based on 0.42 / 1.25, giving an answer of 33.6%.

(c) Most candidates indicated that the addition of extra carbon dioxide would incur costs and realised that the price of tomatoes would also have to be taken into account. A smaller but significant number of candidates realised that customer demand would also be important. This question was generally marked at the correct level.

(d) Many candidates realised that the lowest price was paid for tomatoes during this period. They also observed that there were weeks when there were decreased yields. The more discerning candidates recognised that the yield showed little or no increase in the summer. These candidates also successfully linked the opening of windows to reduce temperature and improved ventilation with the reduced carbon dioxide levels.

(e) Most candidates failed to appreciate that the control would be improved if the experiment took place at the same time. When candidates did appreciate that it would be sensible to ensure that the plants experienced the same growing or environmental conditions, they unfortunately did not express this clearly enough, or failed to mention specific conditions of light and temperature. This question was often too generously marked, with credit being awarded for answers which were below the standard expected by the marking guidelines.

Q31.

This question allowed for continuous prose and accounted for a considerable number of the marks available for knowledge and understanding.

This part of the question was generally answered well with most candidates able to comment sensibly on the raised energy level of electrons and their subsequent passage down an electron transfer chain. There were also frequent references to the release of energy allowing the generation of ATP from ADP and phosphate. Better candidates often made an appropriate reference to oxidation and reduction or to the association of the electron transfer chain with the chloroplast membranes. There was, perhaps, the inevitable confusion between photosynthesis and respiration but most problems arose where candidates had gone far beyond the requirements of the specification. In such cases detail was often confused and led to a range of contradictory and inaccurate statements.

Q32.

(a) Most candidates were able to score quite well here, but too many just produced a standard response to the question “describe the light-independent reactions of photosynthesis”. However, the question required candidates to explain how these reactions allow the continued synthesis of hexose, which demanded that they make use of the information in the diagram.

(b) There were many excellent descriptions of the role of the electron transport chains in the light-dependent reactions in producing both ATP and reduced NADP. However, some candidates did not give any account of the production of reduced NADP, and some confused it with NAD. Others unfortunately described the synthesis of ATP in the electron transport chains involved in oxidative phosphorylation and, consequently, were able to score very few marks.

(c) Although a good number of candidates realised that some of the hexose produced in photosynthesis is used in respiration, only a few could explain that this resulted in mass loss due to the loss of carbon dioxide. Many could not separate mass and energy and suggested that because energy is released in respiration, this accounted for the mass loss. A few candidates realised that, over a twelve-month period, parts of the plant may be lost to decomposers and parts may be eaten by animals, both of which would reduce the increase in dry mass over that period.

Q33.

(a) In an attempt to relate the given transpiration data to carbon dioxide and water supply, many candidates offered explanations which contradicted the experimental evidence. Thus, ‘high carbon dioxide concentration causes stomata to open’ was a contradiction of the reduced rates of transpiration given in the table for these conditions. The essential point of the question related to turgor of the guard cells and thus the opening and closure of the stomata dependent upon the availability of water. A few candidates related the data to the degree of opening of the stomata under the differing watering regimes, but even fewer related this to turgor in the guard cells.

(b) In (i), many candidates selected an appropriate factor to be kept constant in the investigation, such as temperature, light intensity, humidity or wind speed, but explanations were almost universally too weak. Thus light, for example, does not just ‘affect transpiration’; bright light stimulates the opening of stomata and thus facilitates water evaporation. In (ii), better candidates were able to interpret the patterns in the given values of standard deviation in the data, correctly deducing that

both watering and high carbon dioxide concentration reduced the variability in the results. Since the given changes were small, the conclusion that the differences in variability were insignificant was also allowed. Many candidates clearly did not understand the concept of standard deviation and many others wrote about either the carbon dioxide effect or the watering but not about both.

Q34.

(a) Candidates were aware that temperature would affect the rate of photosynthesis. Almost all believed that it would increase the rate of photosynthesis. Only a very small minority expressed this in terms of enzyme activity. Many arguments were simplistically presented as making it a ”fair test’. It was a rare event for candidates to express their answers in terms of allowing the experimenter to identify that change was the result of carbon dioxide concentrations or light intensity. Many arguments related to only having one independent variable.

(b) Candidates regularly scored three or two marks. The only part of the argument sometimes missing was not suggesting that there was a different limiting factor after 300 units.

Q35.

(a) Too many candidates saw two empty boxes in the flowchart in (i) and either wrote the names of both substances in the boxes or the number of carbon atoms in each substance. This clearly is the result of not reading the question carefully. Those who did answer the question set, usually scored both marks. In part (ii) good candidates realised that all ATP is produced in mitochondria, except that produced in glycolysis. They therefore arrived at the correct answer of 36 ATP by deducting 2 from the net total yield of 38 ATP per molecule of glucose, or by deducting 4 from the total production of 40 ATP. Others did arrive at the correct answer by working out where each molecule of ATP was produced, but many attempting this method did so in a disorganised way and so made errors in calculation. In (iii) most candidates knew that, in the absence of oxygen, some of the reactions of respiration could not take place, but many were unable to describe the extent of anaerobic respiration. Well prepared candidates were able to state clearly that only glycolysis would take place and, therefore, the ATP production of the Krebs cycle and electron transport chain would be lost. They also often

(b) Despite being given specific information in part (i) concerning the features of the heterocysts (thick walls and the absence of chlorophyll), and the requirements of nitrogen fixation (anaerobic conditions) candidates too often invented other features and reasons other than maintaining anaerobic conditions for those features. Disappointingly few candidates confined themselves to answers based on excluding oxygen and not producing oxygen, which would inhibit the process of nitrogen fixation. There were some excellent answers to part (ii) from candidates who appreciated that nitrogen-containing compounds in the rice plants would be the starting point for the reactions of the nitrogen cycle, and duly described the roles of decomposition and nitrification accurately and logically. Some realised that the decomposers would produce carbon dioxide as a result of their respiration and that this could be used in photosynthesis by the leaves of the rice plants. However, too many just assumed that the ammonia produced by the heterocysts would be released into the soil, apparently unused by the fern and, in their answers, took this as the starting point for the nitrogen cycle. This clearly shows less appreciation of the situation as described.

Q36.

(a) Nearly all candidates were able to described photophosphorylation accurately and many scored full marks.

(b) A good number of candidates recognised the benefit of sediment-dwelling bacteria being able to absorb wavelengths of light that were not absorbed by the surface-dwelling bacteria. However they often then went on to suggest that the bacteria with this ability would out-compete the surface dwellers, rather than sediment dwellers without the ability to synthesise chlorophyll. As a result, some of the points they made about the process of natural selection were in the wrong context.

Q37.

(a) (i) Many candidates realised that temperature would have an effect on the rate of reaction. The idea that only one variable should be changed was well known. However, weak candidates suggested the need for fair testing without further explanation.

(ii) This was poorly done with many strange responses. Most could give a unit of time but only the best gave a unit of volume or mass as well. Several suggested 'arbitrary units' as the answer.

There was also confusion about which gas was produced.

(b) (i) There were many excellent answers here, with most candidates scoring the mark.

(ii) Most candidates identified that this was due to a limiting factor but only the better candidates gave sufficient detail to achieve two marks.

Q38.

(a) Thylakoids or grana were well known as the site of the light-dependent reaction.

(b) Most recognised that, in the diagram showing the light-dependent reaction, substance **A** was oxygen, **B** was ADP + phosphate and **C** was reduced NADP. One problem arose with abbreviations – while 'Pi' is a suitable abbreviation for inorganic phosphate, 'P' (unqualified) is *not* as it is the chemical symbol for phosphorus.

(c) With respect to the role of chlorophyll in photolysis, better candidates were able to explain how the loss of electrons from chlorophyll, promoted by the absorption of light energy, meant that the chlorophyll molecule was ready to receive electrons from OH^- ions and hence cause more water to dissociate. Many forgot to explain that chlorophyll actually absorbed light and examiners were left to deduce this from its described effect on the chlorophyll's electrons.

It was evident that many candidates were conversant with the principles of electron excitation by light energy and knew that the electrons could then be passed down a series of electron-carriers, releasing energy to drive the synthesis of ATP.

(d) Those with a thorough knowledge of the parts of the Calvin cycle which involved RuBP, carbon dioxide, GP and TP had little problem in applying it in this section. In (i), the main point omitted was that, to keep its concentration constant, GP would have to be produced at the *same rate* as it was converted to something else. In (ii), many realised that, with no carbon dioxide to combine with, RuBP would no longer be converted to GP and so the concentration of RuBP would increase. Some gave the extra detail that RuBP would continue to be formed from GP (perhaps noticing on the graph the fall in concentration of the latter).

Q39.

(a) Most correctly identified the site of the light-dependent reaction as being in the granum and the light-independent reaction in the stroma of the chloroplast. A substantial minority did, however, reverse these, with some labelling the starch grain, an oil droplet or even the chloroplast envelope as one of the sites.

(b) Most knew what was meant by the photolysis of water, but many failed to gain marks through imprecision – 'hydrogen', 'H', 'H_2' could not be regarded as synonymous with *hydrogen ions*; other imprecise symbols included 'e' for electrons and 'O' or 'O^{-}' for molecular oxygen. While candidates are generally at liberty to use chemical symbols in their answers, it is their responsibility to ensure that these are correct. Thus, '$H_2O \rightarrow H^+ + e^- + O_2$' was quite acceptable for 2 marks, even without being correctly balanced. Some candidates also knew that light excited electrons or that they were transferred to a photosystem.

(c) Precise answers were required in this section giving the specific roles of ATP and reduced NADP in particular reactions. Answers such as 'ATP is used to change GP to TP' were regarded as imprecise, whereas ATP providing energy to drive this conversion, and reduced NADP supplying hydrogens for it, were acceptable.

Q40.

Although this question produced a wide range of marks, few candidates gained maximum marks, often due to an inadequate explanation in part (b) (iii).

(a) Few candidates obtained all four marks. Most candidates gained two marks, usually for identifying where NADP is reduced and where ATP is produced. A common error was to indicate NAD is reduced in the light-dependent reaction of photosynthesis.

(b) (i) Most candidates incorrectly suggested glucose as a substrate for this investigation. However, there was a significant number of correct answers usually suggesting pyruvate or acetylcoenzyme A.

(ii) Many candidates referred to the phosphorylation of ADP to produce ATP but the fate of oxygen was less well known. A common misconception was to suggest that oxygen is used in the production of carbon dioxide.

(iii) Although some candidates gave the correct order of the electron carriers, many candidates got the order the wrong way round. Very few candidates could provide an adequate explanation although there were some excellent exceptions to this. It was not uncommon for candidates to simply describe the electron transport chain in mitochondria.

Q41.

There were very few maximum marks in this question with most candidates scoring three or four marks.

(a) This provided the most readily available marks with most candidates appreciating the role of excited electrons from chlorophyll and / or water in reducing NADP.

(b) In part (i), although candidates realised that GP was produced from RuBP and carbon dioxide only the better candidates appreciated that 2GP were formed. Many

candidates gained a mark in part (ii) for explaining that less RuBP would be used as there was less carbon dioxide to react with.

(c) In part (i), many candidates simply stated that carbon dioxide could be 'traced' without indicating that it would be used to form photosynthetic products. In part (ii), many candidates did not link the lack of both ATP and reduced NADP to the rise in GP but gained one mark for realising that it was still being formed from RuBP. Very few candidates referred to the use of glucose e.g. in respiration or in the formation of starch. Most candidates stated glucose was not being formed without explaining the decrease in its level as shown on the graph.

Q42.

Most candidates scored at least half marks, but only a small minority gained full marks.

(a) (i) Most candidates scored a mark, although many just mentioned one colour or wavelength, or referred to wavelengths at either end of the spectrum without specifying what they were.

(ii) Many candidates scored all three marks. There were many vague references to the light dependent reaction without giving any detail and also many who described the whole of the LDR. A significant number of candidates confused chlorophyll and chloroplasts. Many candidates referred to light from the sun hitting chlorophyll with no mention of absorption, or stated that chlorophyll becomes excited.

(b) Many candidates correctly referred to the pigments absorbing more wavelengths of light, but few of these developed their answer to explain the importance of this in terms of more efficient photosynthesis.

Q43.

(a) Most candidates were able to identify process **A** as respiration and the group of organisms represented by box **B** as decomposers. Common incorrect answers included 'consumers' and 'detritivores'.

(b) The calculation was performed well with most candidates realising that to work out the percentage efficiency, the energy in the producers had to be divided by the energy they had absorbed. However, the main error was understanding 'standard form'; the number 1.7×10^6 caused problems, with students finding it difficult to work out how many zeros should be placed after the decimal point.

(c) It was pleasing to see so many candidates realising that the effect of light energy was to excite electrons in chlorophyll but few gave any more information as to what happened to the electron once excited. Vague answers were seen with reference to the production of carbon dioxide and glucose.

(d) Some candidates could name the two end products of the light-dependent reaction as reduced NADP and ATP, but only the very best could explain their function. Usual mistakes were writing reduced NAD or just NADP.

Q44.

(a) Many candidates completed this very well. On the other hand, weaker candidates often appeared simply to guess wildly, and quite often the number of carbon atoms in glucose was completely inaccurate, with 'one' being a surprisingly common answer. In part (i), many could not work out that triose phosphate must have three

carbon atoms. The proportion of the triose phosphate molecules converted to ribulose bisphosphate was the least well done part of the question.

(b) There were many good answers gaining both marks, but some, such as ‘enzymes are less efficient’, were too vague. Misconceptions that were quite common included ‘enzymes are denatured at low temperatures’, and the idea that the light-independent reaction takes place at night after the daytime light-dependent reaction finishes.

Q45.

Whilst a full range of marks was seen on this question, marks of seven or eight were comparatively rare. Most candidates scored between three and five marks.

(a) Whilst most candidates recognised that the experiment was about the effect of light intensity on the rate of photosynthesis, many candidates did not appreciate that the addition or removal of carbon dioxide would affect the colour of the indicator. Only the best candidates compared rates of respiration and photosynthesis in tube A. A large proportion of candidates ignored the uptake of carbon dioxide in tube A and looked for an explanation in terms of alkaline properties of oxygen. With tube B, many saw that photosynthesis had stopped but either ignored respiration, or stated that the plant had switched to respiration. There was quite a large proportion of correct answers with regard to tube C.

(b) In part (i), weaker candidates gave vague answers about a ‘control experiment’. A large number gained the mark by making reference to proving that the plant caused any changes. Only a small minority answered in terms of showing that light did not affect the indicator. In part (ii), very few correct answers were seen. Weak candidates thought that this would make it ‘a fair test’. Most candidates thought that it was to give equal light intensity to each tube but very few mentioned heat or temperature.

Q46.

(a) Most candidates identified the relationship between light absorption and the rate of photosynthesis, but very few went further to give a valid explanation that referred to light energy as being the cause of this relationship. Incorrect responses to this question commonly included references to the wavelength of light instead of a variable given in the question’s stem or they provided literal descriptions about the shape of the curves. An incorrect answer describing the percentage of absorbed light always being higher than the rate of photosynthesis was not uncommon.

(b) This was usually answered correctly, but measuring the production of carbon dioxide rather than measuring how much of it is taken up by a plant was a common error.

(c) Most candidates knew that plants reflect green light, but only a small proportion correctly translated this understanding into a valid range of wavelengths using the graph. In this respect, candidates tended to have a weak appreciation of how to use graphs to communicate their understanding of a biological principle.

(d) This proved to be extremely difficult for nearly all candidates and it did not seem to be a good discriminator between candidates of different levels of ability. Those who could explain processes involved in the light-dependent reaction picked up a mark in part (i) for chlorophyll losing electrons or for the production of reduced NADP. Very few went further and used these electrons to reduce the dye. In part (ii), many candidates explained that ADP and P_i were needed for ATP production, but hardly any linked this back to the question and discussed why the process occurred more

quickly when the concentration of these substrates was increased.

Q47.

(a) Most recognised that the rate of photosynthesis would increase, and quite a few mentioned that carbon dioxide concentration would normally be limiting. Very few gave a clear link to increased yield, often only making a vague statement, such as ‘there would be more food for growth’

(b) Several noted that respiration would increase, but few pointed out that faster use of respiratory substrate would reduce the amount available for growth or that the rate of photosynthesis would be too low to replace the respiratory loss.

(c) Most candidates appreciated that the sodium chloride would lower the water potential in the solution, although some assumed that it would be taken up to the fruits. Only the better candidates who had thought about the information given suggested that the rate of water uptake would be reduced; most assumed a net loss, which would not only reduce yield but also kill the plants.