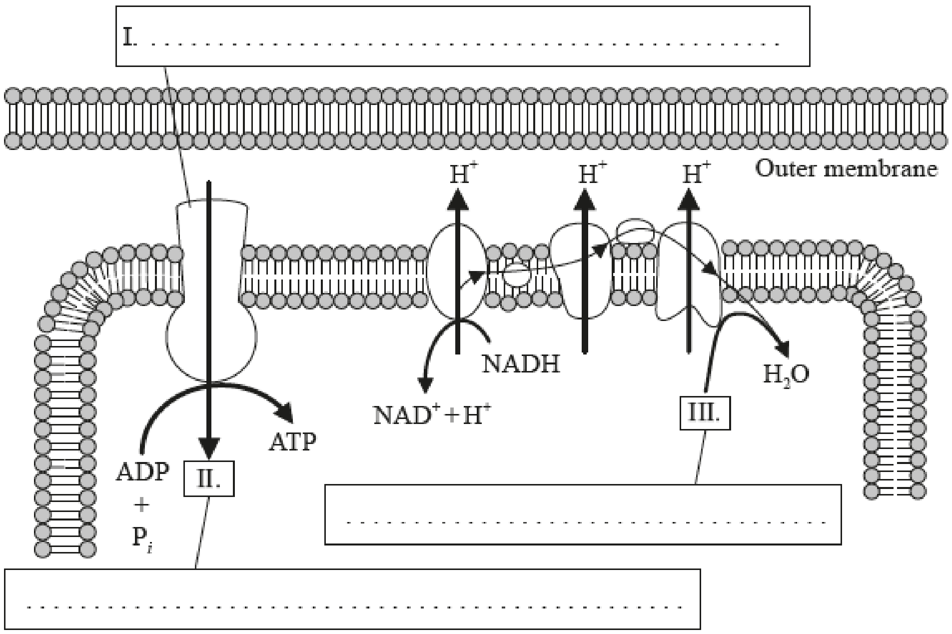
SL Paper 3

a.i. Other than acting as catalysts state **three** functions of proteins, giving an example of each. [3]

b. The diagram shows chemiosmosis in the mitochondrion. Label I, II and III. [3]



[Source: © International Baccalaureate Organization 2014]

Markscheme

a.i. structural – collagen / membrane proteins;

transport – hemoglobin / protein channels;

movement – actin / myosin;

hormones – insulin / vasopressin / growth hormone;

defense – antibodies / immunoglobins;

Award any other valid function and example.

b. I. ATPsynthase; (*accept ATPsynthetase*)

II. H^+ / protons;

III. O_2/oxygen;

Examiners report

a.i. This was an easy question on proteins with most candidates getting full marks for both (i) and (ii)

b. This question was very discriminating as only a few got this correct; it appeared that candidates either scored all 3 marks for correctly labelling what was happening in chemiosmosis, or none. There were some comments on the G2 forms that this diagram was a little unclear. It was felt that this was a very clear diagram, however, it was a bit tricky to decide what substances the arrows were referring to. The use of the word 'molecules' in the stem seemed to have confused some as label II was for protons (H^+).

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a. Draw a labelled diagram showing the structure of a mitochondrion as seen under an electron microscope. [3]

b. Explain the relationship between the structure of the mitochondrion and its function. [3]

Markscheme

a. *Award **[1]** for two correct labels.*

outer membrane;

inner membrane – showing folding to cristae;

cristae – shown as shelf-like infoldings of inner membrane;

matrix;

intermembrane space;

(70S) ribosomes – shown as small dots, not too large;

(naked) loop of DNA;

*Award **[2 max]** for a poorly drawn or inaccurate diagram.*

b. matrix is site of reactions of Krebs cycle;

thin intermembrane space to build up high proton concentration/$[H^+]$;

ATPase enzymes on inner membrane to produce ATP as protons pass back to matrix;

folded inner membrane / cristae to increase surface area (for electron transport chain);

ribosomes to make enzymes (required for Krebs cycle);

Examiners report

a. Drawings of the mitochondrion were often awarded full marks in (a).

b. Many candidates, however, found it more difficult to explain the relationship between structure and function of the mitochondrion in (b) but good candidates knew this.

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a. Distinguish between oxidation and reduction in biological reactions. [2]

Oxidation	Reduction

b. State **two** products of glycolysis. [1]

1. ....
2. ....

c. Explain the role of cristae in mitochondria. [3]

Markscheme

a.

	oxidation	*reduction*
a.	loss of electrons	gain of electrons;
b.	oxygen (often) gained	oxygen (often) lost;
c.	hydrogen (often) lost	hydrogen (often) gained;
d.	energy lost	energy gained;

b. a. ATP;

b. NADH / H^+;

c. three-carbon (atom) compound/pyruvate;

*Award **[1]** for any two of the above.*

c. a. increase the surface area of <u>inner</u> (mitochondrial) <u>membrane</u>; (*note: mitochondria is in the stem*)

b. allow electron transport because of embedded protein electron carriers;

c. facilitate proton pumping because of high surface to volume ratio/increased surface area;

d. increase ATP production because of ATP synthase/synthatase embedded in membrane;

Examiners report

a. Part a and b posed no trouble for the well prepared candidates.

b. Part a and b posed no trouble for the well prepared candidates.

c. In c marks were lost due to imprecise answers which did not mention that the cristae are on the inner membrane.

---

a. Draw a labelled diagram of a mitochondrion. [3]

b. Explain how the structure of a mitochondrion is adapted for its function. [2]

Markscheme

a. *Award **[1]** for each structure clearly drawn and clearly labelled.*

overall circular or cylindrical shape;

smooth outer membrane and inner folded membrane shown close together;

cristae, shown as thin folds of the inner membrane orientated towards the inside of the mitochondrion;

matrix;

ribosomes/circular DNA;

intermembrane space;

b. large <u>inner</u> surface area of cristae for respiratory complexes/electron transport chains;

matrix contains/encloses DNA and ribosomes for protein (enzyme) synthesis / Krebs cycle enzymes;

(double) membrane(s) isolates metabolic processes from the rest of the cytoplasm;

small IM space between inner and outer membranes for accumulation of protons;

Answers must clearly link a <u>structure</u> to a <u>function</u> for a mark.

Examiners report

a. The standard of drawing was fairly good, but common errors included cristae which were too wide, inner and outer membranes too far apart, and often three outer membranes instead of two. Labelling was fairly good on the whole.

b. As the question asked candidates to explain the relationship of structure to function, students were expected to link a specific function to a particular mitochondrial structure, which many failed to do.

---

a. Draw a labelled diagram showing the structure of a mitochondrion as seen in electron micrographs. [4]

b. Explain the relationship between the structure of the mitochondrion and its function. [3]

Markscheme

a. *Award marks for any of the following clearly drawn and correctly labelled.*

cristae;

inner membrane;

outer membrane;

intermembrane space;

matrix;

ribosomes;

DNA;

b. cristae provide surface area for oxidative phosphorylation;

inner membrane contains electron transport chains/ATP synthase (which carry out oxidative phosphorylation);

outer membrane separates the mitochondrion from the rest of the cell;

mitrochondrial DNA/ribosomes make (mitochondrial) proteins;

small volume intermembrane space allows for higher concentration of protons;

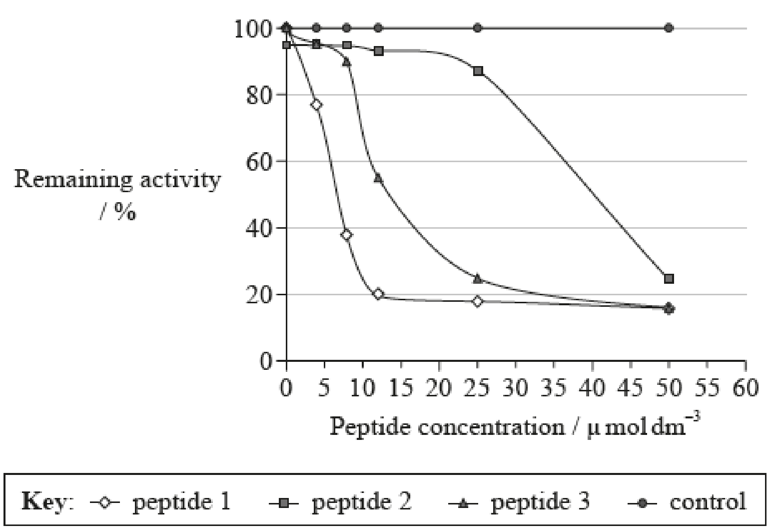
matrix has enzymes for the Krebs cycle;

Examiners report

a. In question C2 (a) the drawing was very poor.

b. (b) proved to be difficult for quite a large number.

Trypanosoma brucei is a parasite which causes sleeping sickness. The parasites rely exclusively on glycolysis for energy production. Peptides acting as inhibitors of an enzyme from the glycolytic pathway are being studied as possible drugs to kill the parasite. The glycolytic enzyme triose phosphate isomerase was incubated in the presence of various concentrations of three different peptides and the remaining activity was measured. As a control, the enzyme was incubated without inhibitor peptides.



[Source: adapted from D A Kuntz, *et al.*, (1992), Eur. J. Biochem, **207**, pages 441–447. Copyright © 2005, John Wiley and Sons]

a. State the remaining activity of triose phosphate isomerase when $8\ \mu\text{mol dm}^{-3}$ of peptide 1 is used. [1]

.... %

b. Compare the effect of increasing the concentration of peptide 2 and peptide 3 on the remaining activity. [2]

c. Identify, with a reason, which of the peptides is the most effective inhibitor of triose phosphate isomerase. [1]

d. Deduce, with reasons, whether the peptides act as competitive **or** non-competitive inhibitors of triose phosphate isomerase. [2]

Markscheme

a. 37(%) *(allow answer in the range of 34(%) to 38(%))*

b. as the concentration increased the remaining activity decreased in both peptides;

peptide 2 does not cause activity to drop significantly until higher concentration/$25\ \mu\mathrm{mol\,dm^{-3}}$ while peptide 3 causes decrease at low concentrations/$10\ \mu\mathrm{mol\,dm^{-3}}$;

(enzyme activity of) peptide 2 decrease steadily after $25\ \mu\mathrm{mol\,dm^{-3}}$ while (activity of) peptide 3 shows little change;

peptide 3 more effective than peptide 2 (after conc. of $10\ \mu\mathrm{mol\,dm^{-3}}$)

c. peptide 1, only low concentrations needed to inhibit enzyme

d. non-competitive does not compete for active site / binds to enzyme away from the active site;

peptides 1/3 non-competitive, only small concentrations cause inhibition;

peptide 2 competitive, only inhibits enzyme at higher concentration;

peptide 2 competes with substrate, at higher concentration it joins the active site more readily than the substrate;

Examiners report

a. Most could read the graph correctly to earn 1 mark. Some were outside the allotted range so candidates do need to be careful and use a ruler for data analysis questions.

b. Many candidates were able to get one mark for stating that as the concentration of both peptides increased the remaining activity decreased. Few were able to get the second mark as they found it difficult to describe what the graph was showing.

c. Most were able to correctly identify peptide 1 as the most effective inhibitor because only low concentrations were needed to inhibit enzyme activity.

d. Very few candidates were able to get any marks for this question.

---

a. State the location of high proton concentration caused by electron transport in the mitochondrion. [1]

b. Outline the role of oxygen in cellular respiration. [2]

c. Explain how any **two** structural features of the mitochondrion are related to its function. [2]

Markscheme

a. inter-membrane space / outside inner membrane / between outer and inner membrane

b. in the electron transport chain;

final electron/hydrogen acceptor;

combines with H^+ (and electrons) to produce water;

c. cristae for increasing surface area;

small inter-membrane space for rapid build-up of concentration gradient;

matrix with chemical concentration to support unique chemical reactions;

Examiners report

a. Most candidates answered this question correctly.

b. Candidates failed to understand the role of oxygen in respiration. They explained how oxygen is necessary for aerobic respiration, but did not understand why.

c. The presence of cristae to increase surface area was among the most common correct answers regarding the features of mitochondria relating to their structure. Other features were hardly mentioned.

Outline which methods of ATP production are used in muscle fibres during different intensities of exercise.

Markscheme

both anaerobic and aerobic are used depending on the intensity of the exercise;

as intensity increases more anaerobic / at low intensity more aerobic;

creatine phosphate used for brief bursts of intense exercise;

Examiners report

Most candidates struggled to outline the methods of ATP production used in muscle fibres during different intensities of exercise.

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a. Outline the process of glycolysis. [3]

b. Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in plants. [3]

Markscheme

a. a. takes place in cytoplasm;

   b. glucose is phosphorylated/two molecules/moles of ATP used;

   c. one hexose sugar/glucose is converted into two three-carbon/3C molecules/hydrolysis;

   d. pyruvate is formed/oxidation of glucose to pyruvate;

   e. small yield/net gain of two ATP;

   f. net gain of two NADH + H^+;

   g. does not require/use oxygen/anaerobic process;

b. a. each photosynthetic pigment has a different absorption spectrum;

   b. as light of different wavelengths is absorbed differently;

   c. absorption spectra combine to create the action spectrum / action spectrum shows how much photosynthesis occurs at each wavelength;

   d. so plant can use a wider range of wavelengths for photosynthesis;

   e. appropriate labelled diagram of absorption and action spectra;

   f. action spectrum takes into account “in vivo”/actual environmental conditions;

Examiners report

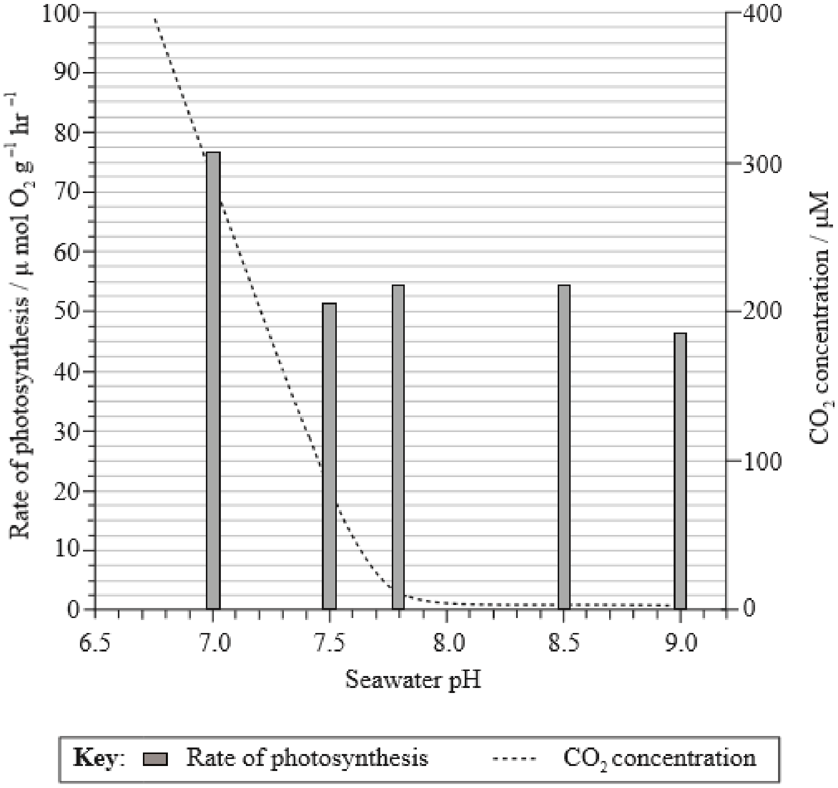
a. A relatively small number of candidates answered this option, but those who did generally achieved well.

   Most candidates were able to outline glycolysis.

b. A relatively small number of candidates answered this option, but those who did generally achieved well.

   The question was generally poorly answered.

The rate of photosynthesis in the marine seagrass, *Zostera marina*, was investigated under a range of pH conditions. After a period of darkness, the plants were illuminated at a constant light intensity at 15°C and the rate of photosynthesis was measured. *Zostera marina* can use both dissolved carbon dioxide (CO_2) and hydrogen carbonate ions for photosynthesis. The rate of photosynthesis is plotted on the *y*-axis on the left. In addition, the concentration of carbon dioxide was measured for each pH investigated and is plotted on the *y*-axis on the right.



[Source: H Carr and L Axelsson, (2008), *Plant Physiology*, **147**, pages 879–885]

a. State the carbon dioxide concentration at pH 7.2. [1]

b. Calculate the percentage decrease in the rate of photosynthesis from pH 7 to pH 7.5. [1]

c. Outline the relationship between pH and the rate of photosynthesis. [2]

d. Suggest how *Zostera marina* can perform photosynthesis even at very low carbon dioxide concentrations. [1]

e. Based on the information and data provided, discuss the role of **one** limiting factor, other than carbon dioxide, and suggest how this would affect the rate of photosynthesis. [2]

Markscheme

a. 200 μM (*units required*)

b. (77–51)/77×100 = 35 % (*Units required. Allow answers in the range of 32–37 %.*)

c. highest rate of photosynthesis at pH 7;

decrease (in rate of photosynthesis) between pH 7 and pH 7.5;

little change (in rate of photosynthesis) at higher pH values;

rate of photosynthesis falls again (slightly) at pH 9;

d. uses hydrogen carbonate ions;

uses stored carbon dioxide / carbon dioxide from respiration;

e. *pH*

optimum pH may be less than 7;

reducing the pH below 7 may lead to a higher rate (of photosynthesis);

(but) enzyme activity can be affected by low pH;

or

Temperature
optimum temperature may not be 15ºC;
enzyme activity is affected by temperature;
temperatures above (or below) 15ºC may lead to a higher rate (of photosynthesis);

or

Light intensity
light intensity may not be optimal/may be limiting;
too low light intensity produces less ATP/NADPH + H^+ ;
higher light intensities may result in a higher rate (of photosynthesis);
as light intensity/temperature increases rate of photosynthesis may not increase as another factor becomes limiting;
***[1]** for named limiting factor and **[1]** for effect on photosynthesis.*

Examiners report

a. This was mainly answered correctly, and again, units were required.

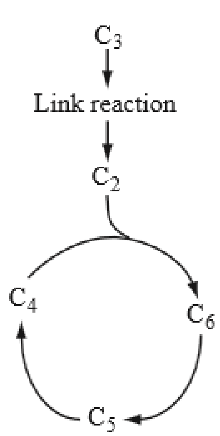
b. The majority gave correct answers within the required range of 32-37%.

c. This question required candidates to refer to the data given in the graph, but many answered in general terms without any referral to the pHs shown in the data. Consequently, answers tended to be too vague to gain marks.

d. Most gained a mark for "use of hydrogen carbonate ions", but few gave the idea of carbon dioxide from respiration being used.

e. Many students could identify a limiting factor correctly, but did not then explain how it could affect photosynthesis.

The diagram below shows part of the respiratory pathway. The number of carbon atoms in each molecule is indicated.



a (i)Label pyruvate and acetyl coenzyme A on the diagram above. [1]

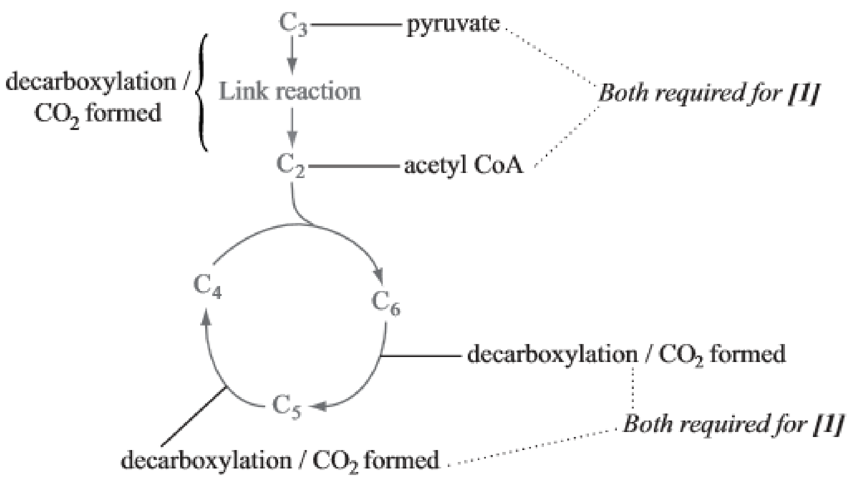
a (ii)Indicate **two** places where decarboxylation occurs on the diagram. [1]

a (iii)List **one** product other than carbon dioxide formed in this stage of respiration. [1]

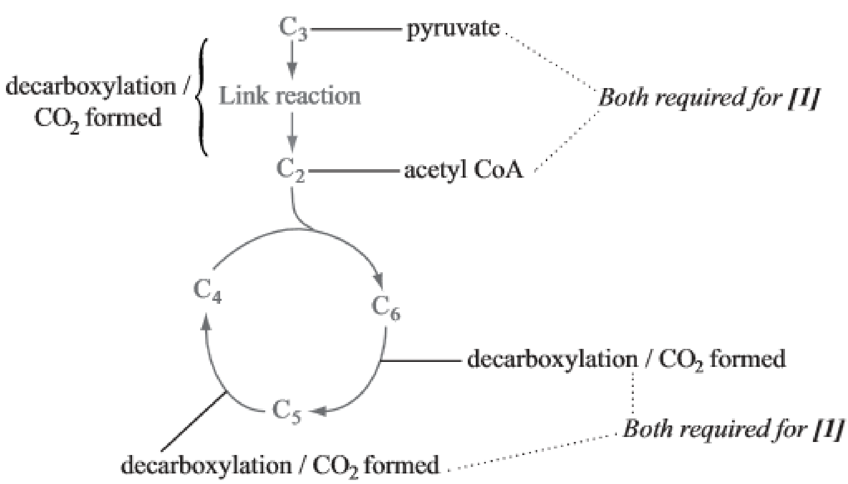
b. State precisely where in a cell this stage of respiration is occurring. [1]

Markscheme

a (i)(i) and (ii)



a (ii)(i) and (ii)



a (iii)NADH + H^+ /$FADH_2$ /ATP (or GTP)

b. matrix of mitochondrion

Examiners report

a (i)The majority were able to gain three marks from the parts of this question.

a (ii)The majority were able to gain three marks from the parts of this question.

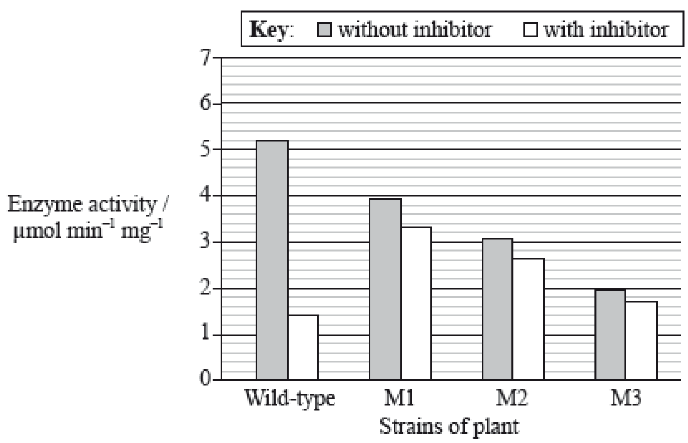
a (iii) The majority were able to gain three marks from the parts of this question.

b. As the question asked, candidates need to be precise in their answers, and many simply gave “mitochondria“ as their answer instead of specifying “matrix”.

Metabolic pathways can be controlled by end-product inhibition of the enzyme-catalysed reactions.

KAS III is the initial enzyme of fatty acid production in plants and bacteria. The substrates for this reaction are acetyl CoA and malonyl-ACP.

Three different strains of plant were generated, each with a different mutated KAS III gene: M1, M2 and M3. The enzyme activity of the normal (wild-type) and the three mutant strains was tested without and with the addition of the inhibitor, dodecanoyl-ACP. Dodecanoyl-ACP has a similar structure to malonyl-ACP. The graph shows the mean activity of the enzymes.



[Abbadi et al., 2010, “Knockout of the regulatory site of 3-ketoacyl-ACP synthase III enhances short- and medium-chain acyl-ACP synthesis”, The Plant Journal, 24 (1) pp. 1-9, Figure 4 (adapted). Reprinted with permission of John Wiley & Sons Inc.]

a. State the activity of the wild-type enzyme without the inhibitor and with the inhibitor. [1]

Without inhibitor:

With inhibitor:

b. Distinguish between the enzyme activity without the inhibitor in the wild-type and the mutant strains. [1]

c. Explain why the activity of the enzyme from wild-type plants changes when the inhibitor is added. [3]

d. The scientists concluded that the enzymes of the mutant plants had a reduced activity, but were insensitive to the inhibition by dodecanoyl-ACP. Evaluate these conclusions. [3]

Markscheme

a. *without inhibitor:* 5.2 µmol min^{-1} mg^{-1} *(units required)*

with inhibitor: 1.4 µmol min^{-1} mg^{-1} *(units required)*

Both needed to award the mark.

b. wild-type enzyme has greater activity than the mutant enzymes

c. a. inhibitor is similar in shape/structure to malonyl-ACP which is a substrate of the reaction;

b. inhibitor is competing for the active site / competitive inhibition;

c. attaches to active site and does not let reaction occur;

d. if more substrate is added then the inhibition will be less;

d. a. activity of mutant enzymes without the inhibitor is always lower than wild-type;

b. activity of mutant enzymes with the inhibitor is always less than without;

c. but the differences are not as great as in the wild-type enzyme / the mutant enzymes were less sensitive to the inhibitor;

d. the activity of the mutant enzymes with the inhibitor are always higher than the activity of the wild-type enzyme with the inhibitor;

e. the data does not indicate whether these differences are significant or not / difference between wild-type enzyme and M1 enzyme not great;

Examiners report

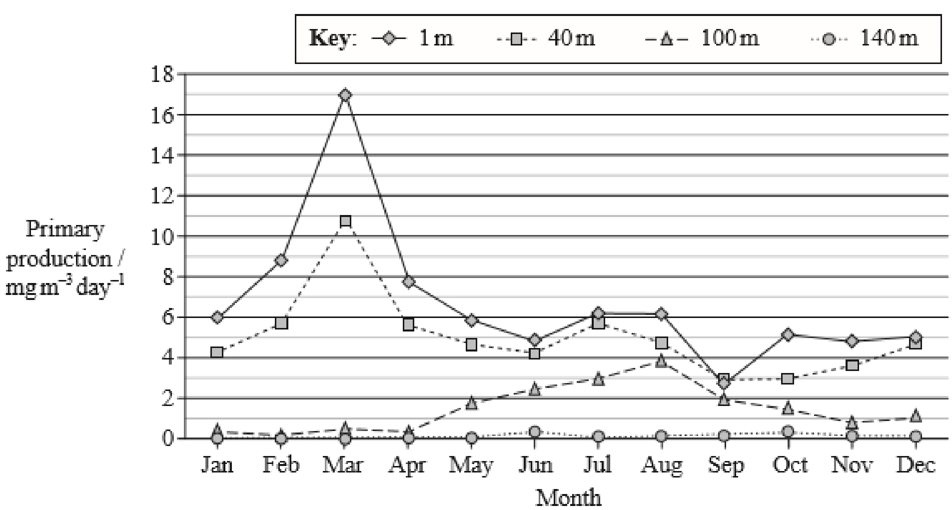
a. Candidates were able to correctly identify the enzyme activity using the graphs.

b. Most saw that the wild-type enzyme had greater activity than the mutant form.

c. There were some good responses earning 2 out of 3 marks but few responses earned full marks.

d. This question was difficult for the candidates and very few answered it correctly. A few candidates earned one mark for stating that the activity of the mutant enzymes without the inhibitor is always lower than the wild-type but they were not able to evaluate the data to identify differences in sensitivity to the inhibitor.

Primary production is directly related to the amount of photosynthesis that occurs in a cubic metre of water. In the waters around Bermuda (32°N) in the Atlantic Ocean, microscopic phytoplankton are the producers. They use trace nutrients from seawater in their metabolism. These nutrients are a limiting factor in total population size. A dense phytoplankton population makes the water cloudy. The data shows primary production per day for each month for the year 2000 at different water depths.



[Source: adapted from DataStreme Ocean, American Meteorological Society, (2004)]

a. State the month when total photosynthesis was greatest. [1]

b. Identify, with a reason, the water depth that receives no light. [1]

c. In the upper 40m there is a drop in photosynthesis from March to June. This is probably due to lack of nutrients, reducing the population density. [1]

Suggest, with a reason other than nutrient levels, what might have increased photosynthesis at 100m from April to August.

d. Compare production in March with production in September. [3]

Markscheme

a. March

b. (at) 140 m (of water depth) because there is no photosynthesis (except slight in June and October)

c. increased light penetration due to decrease in phytoplankton numbers/cloudiness;

(as the summer season approached) the Sun would be directly overhead making deeper light penetration probable;

d. there is greater total production in March than in September;

the water at 100m is relatively more productive in September than in March / the water at 100 m is unproductive in March, but is productive in September;

total production in March is approximately 28 to 29mg m^{-3} day^{-1} whereas in September it is approximately 8mg m^{-3} day^{-1} ;

the upper 40m have their highest productivity in March and their lowest productivity in September;

Examiners report

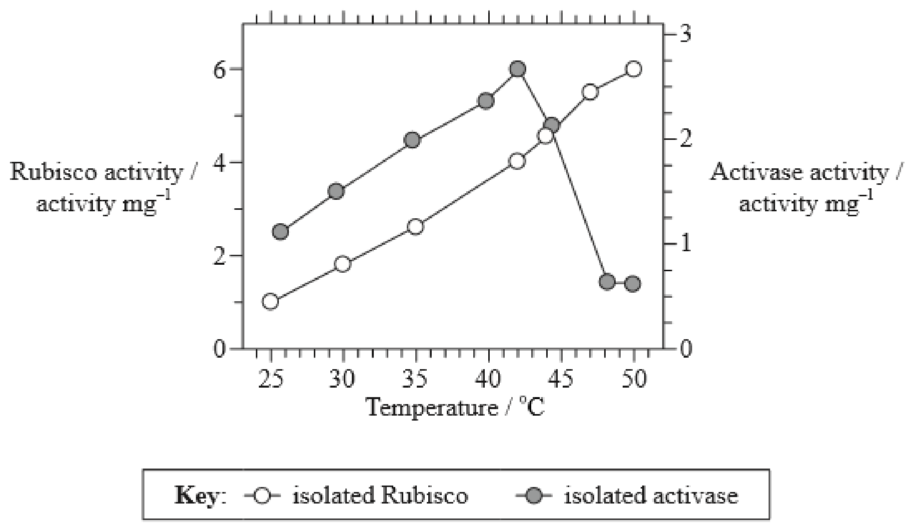
a. In C1 the graph and questions were quite straight forward.

b. In C1 the graph and questions were quite straight forward.

c. In C1 the graph and questions were quite straight forward and only (c) caused problems.

d. In C1 the graph and questions were quite straight forward.

A key reaction in photosynthesis occurs when ribulose bisphosphate carboxylase (Rubisco) catalyses the fixation of carbon dioxide to ribulose bisphosphate (RuBP). To be effective, Rubisco must be activated by another enzyme called activase. The activities of Rubisco and activase (each isolated from tobacco leaves) were independently investigated in a laboratory, under conditions of increasing temperature.



[Source: adapted from S. Crafts-Brandner and M. Salvucci (2000) 'Rubisco activase constrains the photosynthetic potential of leaves at high temperature and CO2.' *PNAS*, **97**, pp. 13 430−13 435. Figure 2.]

a. State the relationship between Rubisco activity and temperature. [1]

b. Calculate the percentage decrease of activase activity from the optimum temperature to 50°C. [1]

.....................%

c. Determine which enzyme shows overall greater activity from 25°C to 42°C. [1]

d. Explain the change in activase activity at temperatures higher than 42 °C. [2]

e. In a leaf, both enzymes are present together. Predict, with a reason, how the rate of photosynthesis would change from 35°C to 50°C. [2]

Markscheme

a. as temperature rises, (Rubisco) activity rises / direct correlation/proportional

b.

(*accept answer in the range of 73 % to 79 %*)

c. Rubisco

d. as an enzyme activase is a protein;

42°C is the optimal temperature (for activase);

activity is decreased because the protein denatures;

denaturation changes enzyme/active site shape reducing catalytic activity;

e. initial increase in photosynthesis rate up to 42°C;

decrease in photosynthesis rate after 42°C;

reduced activity of activase lowers the activation of Rubisco;

less Rubisco activity means less fixation of carbon (dioxide);

Examiners report

a. Most candidates had this answer correct.

b. In C1 (b) there were many good answers.

c. N/A

d. Most candidates explained the change in activase activity at temperatures higher than 42°C by the denaturation of the enzyme.

e. Most candidates failed to analyse the data, they simply described the information on the graph without making any prediction.

Compare competitive and non-competitive enzyme inhibition

Markscheme

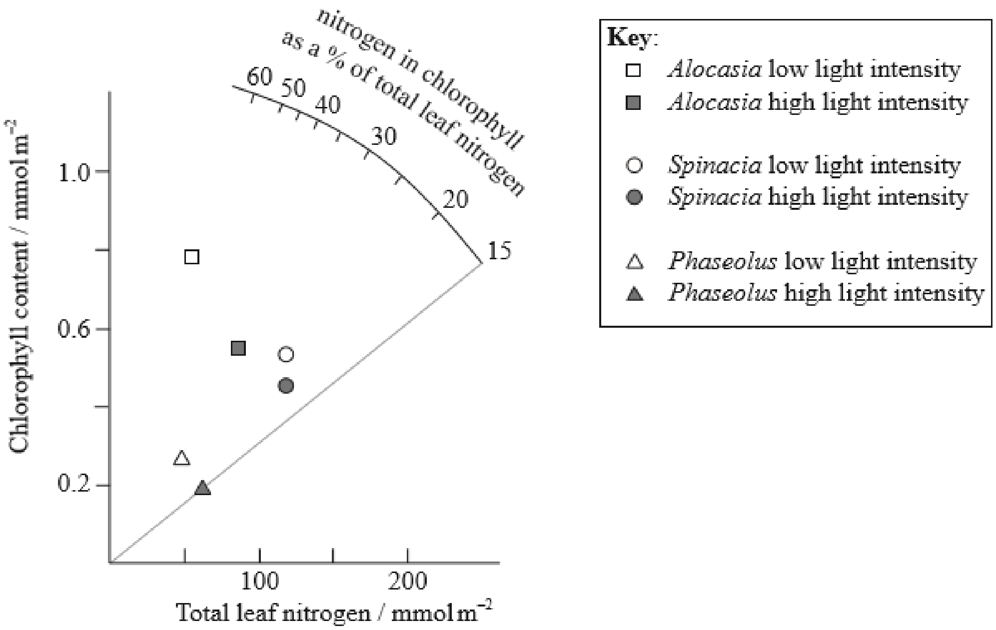
	competitive inhibition	***non-competitive inhibition***
a.	the inhibitor is similar to substrate	inhibitor (usually) different to substrate;
b.	inhibitor binds to active site	inhibitor joins away from active site/allosteric site;
c.	inhibitor prevents binding of substrate	inhibitor changes shape of active site not allowing substrate to join;
d.	increasing the substrate concentration diminishes effect of inhibitor	change in substrate concentration does not diminish inhibition;
e.	both slow down the rate of reaction;	

Answer does not need to be in a table format.

Examiners report

(a) and (b) seemed fairly straightforward questions on enzymes but few candidates failed to score full marks. Comparing competitive and non-competitive enzyme inhibition requires contrasting statements of similarities or differences, not two unrelated descriptions.

The nitrogen content of a leaf is mainly due to the proteins contained in the chloroplasts. These proteins are either in the thylakoids or in the stroma, where most enzymes are found. The quantity of nitrogen from the thylakoids is directly proportional to the amount of chlorophyll; a ratio of approximately 50 mmol nitrogen : 1 mmol chlorophyll would represent 100 % of the leaf nitrogen content. Scientists hypothesized that the higher leaf percentage nitrogen content resulting from a decrease in light intensity is due mainly to an increase in chlorophyll in many plant species, three of which are represented in the following graph.



[Source: With kind permission from Springer Science+Business Media: *Oecologia*, Photosynthesis and nitrogen relationships in leaves of C3 plants, 78, 1989, 9–19, John R. Evans]

a. State the difference in chlorophyll content for *Phaseolus* between high and low light intensity, giving the units. [1]

b. State the percentage value of total leaf nitrogen in chlorophyll for *Spinacia* at low light intensity. [1]

......................%

c. Suggest **one** advantage for plants to increase their leaf chlorophyll content per surface area when light intensity is lower. [1]

d. Evaluate the hypothesis that lower light intensity increases thylakoid nitrogen. [3]

Markscheme

a. 0.08 mmol m^{-2} (*Accept answers between 0.07 and 0.09 mmol m⁻2. Units required.*)

b. 22.5 (%) (*Percentage symbol is not required. Accept answers between 22.0 and 23.0*)

c. to absorb the same quantity of light (as high intensity)

d. a. (hypothesis is supported as) there is an increase in chlorophyll/nitrogen content for the three species at lower light intensity;

b. (hypothesis is not supported as) total leaf nitrogen decreases in low light for *Alocasia* and *Phaseolus* but not for *Spinacia*/remains the same for *Spinacia*;

c. greatest difference in *Alocasia* / smaller differences in the other two species;

d. chosen species may not be representative of all plants;

e. (hypothesis is not supported as) increase in nitrogen may be due to stroma protein;

Reject unqualified answers suggesting only that there are insufficient data.

Examiners report

a. For C1 (a) and (b) most candidates had these answers correct.

b. A relatively small number of candidates answered this option, but those who did generally achieved well.

For C1 (a) and (b) most candidates had these answers correct.

c. A relatively small number of candidates answered this option, but those who did generally achieved well. There were many good answers in 1c.

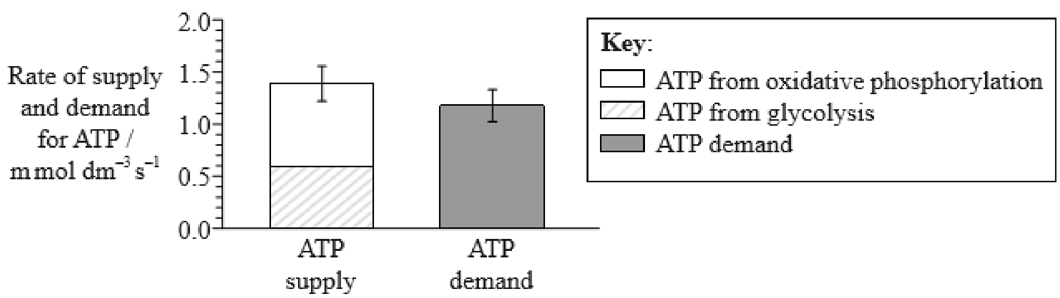
d. A relatively small number of candidates answered this option, but those who did generally achieved well.

Few candidates evaluated the hypothesis. To evaluate, students are required to have arguments for and against. Few did.

The table below shows the results of continuous stimulation of the tailshaker muscle of eight western diamond rattlesnakes (*Crotalus atrox*).

	O_2 content in arteries / mmol dm^{-3}	Lactate content in arteries / mmol dm^{-3}
At rest	2.4±0.5	2.8±1.2
Rattling	2.8±0.1	4.8±0.8

The graph below shows ATP demand and sources of ATP supply in the tailshaker muscle. Contraction of the tailshaker muscle causes a rattling sound.



Adapted from W. F. Kemper *et al.* "Shaking up glycolysis: sustained, high lactate flux during aerobic rattling". *PNAS*, 98 (2), pp. 723–728. Copyright 2001, National Academy of Sciences, USA.

a. Using the graph, measure the amount of ATP produced by oxidative phosphorylation, giving the units. [1]

b. Compare the changes in oxygen and lactate content in the blood when a resting rattlesnake starts rattling. [2]

c. Using the data, deduce, with reasons, whether anaerobic respiration provides some or all of the ATP used in rattling. [3]

Markscheme

a. 0.8 m mol dm $^{-3}$ s $^{-1}$ (*allow responses in the range of 0.7 m mol dm $^{-3}$ s $^{-1}$ to 0.8 m mol dm^{-3} s^{-1}*)

b. small/insignificant increase in oxygen;

much larger increase in lactate;

c. some ATP provided by anaerobic respiration because lactate levels rise;

ATP production by glycolysis is high/about 50 % of ATP demand;

ATP also provided by oxidative phosphorylation in aerobic respiration;

sample number too low to make definite conclusion;

Examiners report

a. Candidates were able to correctly use the graph to find the amount of ATP produced by oxidative phosphorylation.

b. Most saw that there was a much larger increase in lactate than in oxygen content during rattling.

c. Many candidates did poorly on this question which required them to use the data to deduce the role of anaerobic respiration in provision of ATP for rattling. Deduce is a command term that candidates find difficult. It requires them to use the data to reach a conclusion.

---

a. Describe how the tertiary protein structure relates to enzyme function. [2]

b. Explain the control of metabolic pathways by end-product inhibition, including the role of allosteric sites. [3]

Markscheme

a. tertiary is the specific 3D structure (determined by the primary structure);

giving rise to the specific shape of the active site;

(tertiary structure) enables enzymes to bind (effectively) to substrate;

determines whether some enzymes have broad or narrow specificity;

inhibitors/cofactors can affect tertiary structure and therefore function;

b. inhibitor is the product of the last reaction in a metabolic pathway;

inhibits the enzyme that catalyses the first reaction;

prevents build up of unnecessary product/only produced when needed;

the inhibitor binds (reversibly) to the allosteric site (different from active site);

this alters the shape of active site (so substrate will not fit);

To award ***[3]*** *answers must mention allosteric sites*.

Examiners report

a. Candidates had difficulty describing the relationship between protein structure and enzyme function in (a) although many had a general idea of it but not enough to score marks.

b. (b) Some good responses by strong candidates were awarded the full 3 marks, showing a good understanding of end-product inhibition and allosteric sites.

---

a. Define *quaternary structure* in proteins. [1]

b. Outline the importance of polar and non-polar amino acids in proteins. [2]

c. Describe non-competitive inhibition. [2]

Markscheme

a. the linking together of two or more polypeptides to form a protein

b. polar and non-polar amino acids help determine protein structure;

polar amino acids on the outside of proteins make them soluble in water;

polar amino acids in channels in membranes allow passage of polar substances/ reference to surface proteins or membranes;

polarity ***or*** non-polarity of surface amino acids on proteins determines their interaction with other molecules (substrates, hormones, signalling molecules);

c. inhibitor molecule attaches to enzyme at site away from active site/attaches to allosteric site;

binding of inhibitor molecule alters shape of active site/causes conformational change;

shape change in active site disables enzyme from accepting substrate/reduces enzyme activity/destroys enzyme functionality;

increasing substrate concentration has no effect on the inhibitor;

irreversible;

Examiners report

a. Most answers were correct.

b. Very few candidates were able to outline the importance of polar and non-polar amino acids in proteins.

c. In general candidates did know how noncompetitive inhibitors work.

---

a. State the site of the light-independent reactions of photosynthesis. [1]

b. Explain the relationship between the structure of the chloroplast and its function. [3]

Markscheme

a. stroma (of chloroplast)

b. large surface area of thylakoids/grana for light absorption/electron transport chain;

(small) space inside thylakoids for accumulation of protons;

(fluid) stroma for enzymes in Calvin cycle/light independent reactions;

arrangement of photosystems to allow electron transport to take place;

double membrane on the outside allows separation from rest of cell;

presence of DNA/ribosomes for protein synthesis;

starch grains store carbohydrate (from photosynthesis);

Examiners report

a. Most candidates correctly identified the stroma of the chloroplast as the site of the light-independent reactions.

b. Many candidates could get 3 marks for the explaining the relationship between structure and function in the chloroplast.

---

a(i). State **two** products of glycolysis. [2]

a(ii). Explain H^+ movement in mitochondria and its significance for chemiosmosis. [3]

b. State **two** limiting factors of photosynthesis. [2]

Markscheme

a(i). a. pyruvate;

b. ATP;

c. NADH + H^+;

a(ii). a. energy (from electron transport chain) used to pump H^+ across inner mitochondrial membrane;

b. into space between inner and outer membrane;

c. H^+ move from intermembrane space down the concentration gradient;

d. through ATP synthase/synthetase;

e. producing energy used to produce ATP;

b. a. light intensity;

b. temperature;

c. carbon dioxide concentration;

Examiners report

a(i). Many candidates could correctly identify two products of glycolysis.

a(ii)Many scored 2 or 3 marks on the movement of hydrogen ions during chemiosmosis. Candidates seemed to clearly understand the proton gradient and the role of ATP synthase in the production of ATP.

b. Most candidates were able to identify two limiting factors. Some were careless simply stating light rather than light intensity and therefore did not get the mark.

Outline the differences between competitive and non-competitive inhibitors.

Markscheme

Award marks for paired statements only. Answers do not need to be shown in a table format.

competitive inhibition	non-competitive inhibition
the inhibitor and substrate are very similar	the inhibitor and substrate are not similar;
attach to the active site	bind away from the active site;
block the active site	change the shape of the active site;
inhibition (of the active site) is reversible	inhibition (of the active site) is irreversible;
increase in substrate concentration affects/reduces inhibition	increase in substrate concentration does not affect/reduce inhibition;

Examiners report

C2 (b) had some excellent responses, but many were very poor.

---

a. Draw a labelled diagram showing the structure of a chloroplast. [3]

b. Explain how energy is released and used to make ATP by electron carriers in the electron transport chain during aerobic respiration. [4]

Markscheme

a. *Award **[1]** for each of the following clearly drawn and correctly labelled.*

a. outer and inner membranes;

b. stroma;

c. thylakoid;

d. granum;

e. (70S) ribosomes / (naked) DNA;

f. starch granules;

b. a. electron carriers found on inner membrane/cristae of mitochondria;

b. H/H^+/protons transported to electron carriers by NAD and FAD;

c. series of redox reactions in membrane;

d. electrons are passed down energy gradient;

e. establishes proton gradient / protons accumulate (in intermembrane space);

f. oxygen is the final electron acceptor;

g. generation of ATP through chemiosmosis;

Accept correct answers in an annotated diagram.

Examiners report

a. There was a range of diagrams of the chloroplast with the many achieving all 3 marks.

b. The electron transport chain was not well understood. Many candidates assumed it referred to the chloroplast from part (a).

Explain the link reaction that occurs between glycolysis and the Krebs cycle.

Markscheme

pyruvate (from glycolysis) enters a mitochondrion;

enzymes in the matrix remove one carbon dioxide and hydrogen from the pyruvate;

hydrogen is accepted by NAD/forms NADH;

removal of hydrogen is oxidation;

removal of carbon dioxide is decarboxylation;

the whole process/link reaction is oxidative decarboxylation;

the product is an acetyl group which reacts with CoA/coenzyme A;

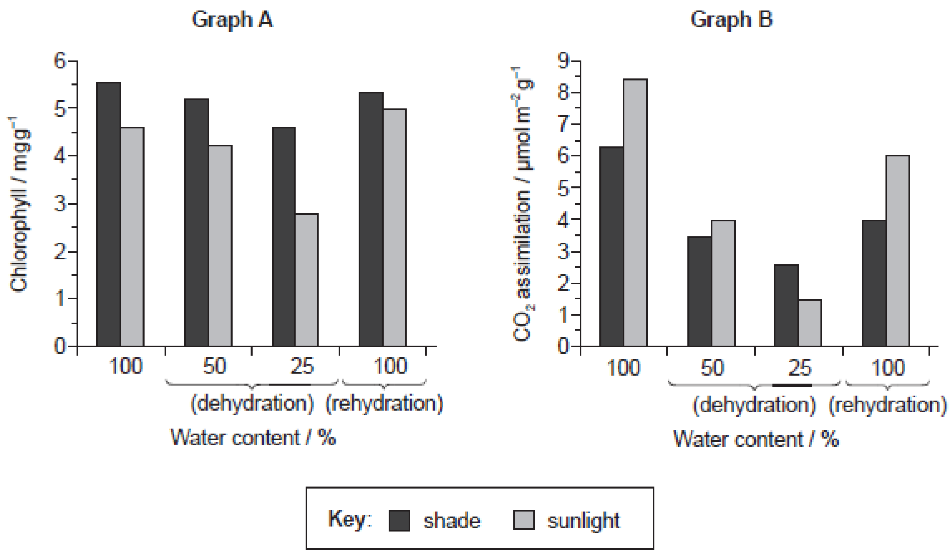
acetyl CoA enters Krebs cycle;

Accept any of the above points in the form of a clearly drawn and correctly labelled diagram.

Examiners report

In C3 many candidates discussed the Krebs cycle, rather than the link reaction as required. Careful reading of the question is vital.

The *Haberlea rhodopensis* plant is capable of tolerating extreme dryness. Chlorophyll levels and CO_2 assimilation were evaluated during dehydration and rehydration using plants grown in shade and sunlight. Graph A shows the changes in chlorophyll content with increasing dehydration and during rehydration. Graph B shows the changes in CO_2 assimilation with increasing dehydration and during rehydration.



[Source: adapted from K Georgieva, *et al.*, (2013), *15th International Conference on Photosynthesis*, pages 536–542]

a. State the level of chlorophyll at 50 % water content for plants growing in sunlight, giving the units. [1]

b. Outline the effect of sunlight and shade on CO_2 assimilation during dehydration. [2]

c. Compare the effect of rehydration on chlorophyll levels in plants grown in shade and sunlight. [2]

d. Using the data, deduce, with a reason, **two** stages of photosynthesis that may be limited during dehydration in a plant. [2]

Markscheme

a. 4.2 mg g^{-1} (units required)

Accept answers in the range of 4.1 mg g^{-1} to 4.3 mg g^{-1}.

b. a. decreases with dehydration in both shade and sunlight;

b. greater decrease in sunlight than shade;

c. at 100/50 CO_2 assimilation greater in sunlight than shade but at 25 shade greater than sunlight;

c. a. both increase (over the 25% water content);

b. (chlorophyll in) shade plants increase to almost the same/slightly less than original levels;

c. plants grown in sunlight have almost the same/slightly more than original levels;

d. the difference between plants grown in the shade and sunlight is less than at any time at dehydration;

d. a. decrease in chlorophyll causes lowered rate of light dependent reaction/less absorption of light energy;

b. decrease in CO_2 assimilation causes lowered rate of light independent reaction/ less CO_2 fixation/Calvin cycle;

c. both stages reduced due to wilting/less surface of leaf/closure of stomata;

Candidates must include a reason to receive the mark.

Examiners report

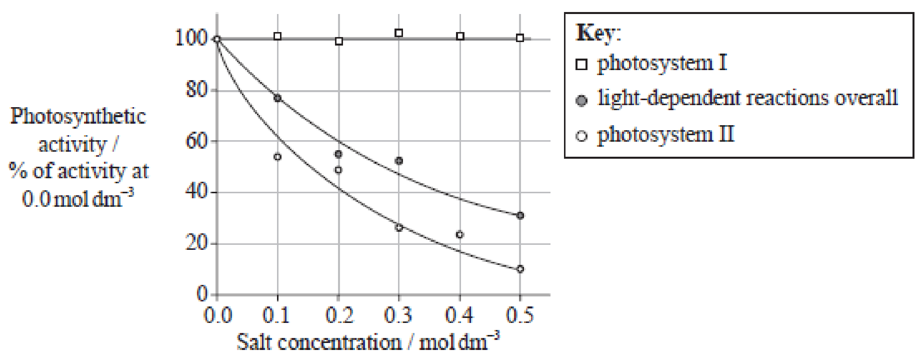
a. The candidates performed well in parts (a) (b) and (c) of the data question but found (d) difficult with many not giving a reason why dehydration affects photosynthesis.

b. The candidates performed well in parts (a) (b) and (c) of the data question but found (d) difficult with many not giving a reason why dehydration affects photosynthesis.

c. The candidates performed well in parts (a) (b) and (c) of the data question but found (d) difficult with many not giving a reason why dehydration affects photosynthesis.

d. The candidates performed well in parts (a) (b) and (c) of the data question but found (d) difficult with many not giving a reason why dehydration affects photosynthesis.

The graph below shows the results of an experiment to determine the effect of salt (NaCl) concentration on photosynthesis of the freshwater green alga *Chlorella vulgaris*. The experiment attempted to determine the effect of salt concentration on the light-dependent reactions overall and separately on photosystem I and photosystem II.



[Source: M M El-Sheekh, "Inhibition of the water splitting system by sodium chloride stress in the green alga *Chlorella vulgaris*", *Brazilian Journal of Plant Physiology*, Volume 16, Issue 1, Figure 1, (2004)]

a. Describe the effect of salt concentration on the activity of the light-dependent reactions overall. [1]

b. Compare the effect of increasing salt concentration on photosystem I with the effect on photosystem II. [1]

c. When salt concentration is increased, some algal cells increase their rates of cyclic photophosphorylation. Deduce the reasons for this. [2]

d. Using the graph, predict the effect of high salt concentration on the growth of *Chlorella vulgaris*. Give a reason for your answer. [2]

Markscheme

a. overall photosynthesis rates go down with increasing salt concentration

b. decline in activity for photosystem II but not for photosystem I

c. cyclic photophosphorylation dependent on photosystem I;

photosystem I is not affected by increasing salt concentration;

d. reduced growth;

due to reduction in rates of photosynthesis/energy fixation;

Examiners report

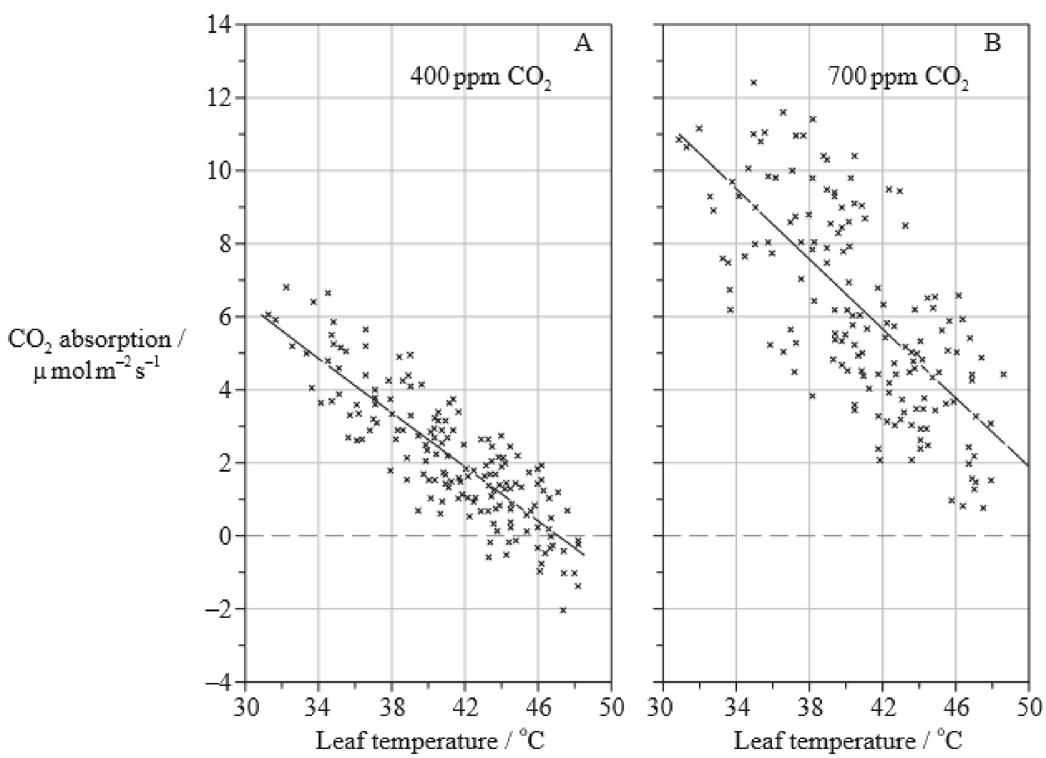
a. Most candidates answered this question correctly.

b. Most candidates answered this question correctly.

c. Many of the candidates obtained one mark, although many did not seem to understand the functional difference between the two photosystems.

d. [N/A]

Sour orange trees (*Citrus aurantium L.*) were grown outdoors in Phoenix, Arizona (USA) in chambers with clear plastic sides and open tops. These chambers were continuously maintained at mean atmospheric CO_2 concentrations of either 400 or 700 ppm (parts per million) for several years. Both the rate of CO_2 absorption of sunlit leaves and the temperature of the leaves were measured on some of the hottest days.



[Source: 'Effects of atmospheric CO2 enrichment and foliar methanol application on net photosynthesis of sour orange tree (Citrus aurantium; Rutaceae) leaves'. S. B. Idso et al. 1995, *American Journal of Botany*, 82 (1), pp. 26–30. Reprinted with permission.]

a. Identify the relationship between temperature and CO_2 absorption shown in both graphs. [1]

b. The line on each graph indicates the mean net photosynthesis rate. Calculate the difference in net photosynthesis at 34°C between plants grown at 400 ppm and 700 ppm CO_2. [1]

c. Compare the data for the sour orange trees growing at 400 ppm with those growing at 700 ppm. [3]

d. Identify, with a reason, whether CO_2 concentration or temperature is the limiting factor on photosynthesis at a temperature of 34°C and 400 ppm CO_2. [1]

e. State **two** products that pass from the light-dependent to the light-independent stages of photosynthesis. [1]

1. ....
2. ....

Markscheme

a. negative correlation / as temperature increases the CO_2 absorption decreases / inverse relationship

b. 4.6(μ mol m^{-2} s^{-1})

Accept answers in the range of 4.3(μ mol m^{-2} s^{-1}) to 4.9(μ mol m^{-2} s^{-1}).

c. both show a decrease in CO_2 absorption/net photosynthesis as temperature rises;

at each temperature the 700 ppm CO_2 sample shows greater rate;

at higher temperatures the 700 ppm CO_2 sample can continue to photosynthesis / at higher temperatures the 400 ppm CO_2 sample loses CO_2/goes to net respiration;

the 700 ppm CO_2 trendline/net photosynthesis is (slightly) steeper;

at high temperatures/above 43°C CO_2 absorption at 400 ppm CO_2 goes below zero while it never goes below zero at 700 ppm CO_2;

more variation/greater scatter of results at 700 ppm CO_2; (*accept converse*)

d. carbon dioxide is a limiting factor at 400 ppm CO_2 as rate increases at same temperature with increased CO_2

e. ATP and $NADPH_2$/NADPH+ H^+ (*both needed*)

Examiners report

a. Most correctly stated that there was a negative correlation in (a).

b. Many candidates carried out the calculation in (b) correctly.

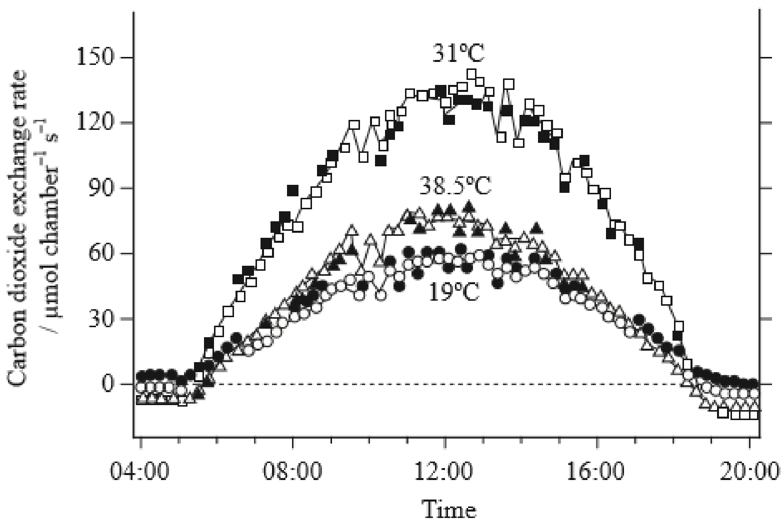
c. Often 2 marks were awarded for (c) but seldom 3. Candidates saw that both show a decrease in net photosynthesis as temperature rises and that at each temperature the 700 ppm CO_2 sample shows a greater rate. Only stronger candidates were able to get a third mark.

d. Most candidates saw that CO_2 was the limiting factor in (d) and why.

e. There were many wrong answers to part (e) which was a recall question from the syllabus.

Global atmospheric carbon dioxide levels are rising. A study was carried out to test if the temperature dependence of photosynthesis was altered by elevated atmospheric CO_2. Maize plants were grown in natural sunlight in controlled environmental chambers at different temperatures using current atmospheric and doubled CO_2 levels.

The graph below shows daily patterns of CO_2 exchange at three different temperatures. Open shapes (○, △, □) represent current atmospheric CO_2 levels and closed shapes (●, ▲, ■) represent elevated CO_2 levels.



[Source: SH Kim, *et al*., (2007), *Environmental and Experimental Botany*, **61**, pages 224–236]

a (i) State the time at which carbon dioxide exchange rate is maximal. [1]

a (ii) Explain the reasons for maximum carbon dioxide exchange rate at this time. [2]

b. State the temperature that resulted in the highest rate of photosynthesis under current atmospheric conditions. [1]

c. Using the data in the table, discuss whether rising carbon dioxide levels in the atmosphere will increase growth rates in maize. [2]

Markscheme

a (i) 12:00 *(Accept 12:00 to 13:00)*

a (ii) photosynthesis in maize requires uptake of CO_2 and light as energy source;

sunlight intensity strongest at midday therefore rate of photosynthesis is highest at this time;

light is limiting factor for photosynthesis so increased intensity increases photosynthesis;

high rate of photosynthesis means high exchange rate of CO_2;

b. 31°C

c. data does not support idea that rising CO_2 levels will increase growth rates in maize;

(at all temperatures) there appears to be no difference between exchange rate at current or elevated CO_2 levels;

temperature has larger effect on growth of maize;

so if rising CO_2 levels causes more of a greenhouse effect/larger temperature increase, this will affect growth of maize;

Examiners report

a (i) A range of answers were given, usually within the range acceptable in the mark scheme.

a (ii) Many gained both marks for this question, but weaker candidates gave incomplete statements, mainly failing to link light intensity and CO_2 exchange to photosynthesis.

b. This was answered correctly by most candidates.

c. Some candidates were able to interpret the data correctly, but there were few references to temperature and its effect on the growth of maize.

---

a. Transport is the function of the protein known as hemoglobin. State the name and function of another protein. Do not use enzymes or membrane proteins for your answer. [1]

Name: ....
Function: ....

b. Explain the role of enzymes in metabolic pathways. [4]

c. Describe how the link reaction and the Krebs cycle are related. [2]

Markscheme

a. name of protein;

function of protein;

(*both needed*)

b. a. enzymes speed up/catalyse metabolic reactions;

b. by reducing the activation energy;

c. each reaction (in the pathway) has a different enzyme;

d. metabolic pathways can be controlled by controlling which enzymes are produced;

e. end-products of a metabolic pathway act as inhibitors;

f. end-product inhibitors bind to/inhibit an enzyme at the start of the pathway;

c. a. the link reaction produces acetyl CoA/acetyl group/CH_3CO;

   b. acetyl group/CH_3CO joins with 4 carbon compound/OAA from cycle;

   c. both occur in the (mitochondrial) matrix;

Examiners report

a. In (a) naming a protein and its use should have been an easy mark. Unfortunately it was very poorly answered.

b. In b most knew the function of enzymes and their reduction of the activation energy. However, only the better candidates gained the other marks by correctly putting them into the context of pathways.

c. In c the production of Acetyl CoA from the link reaction was well understood. Unfortunately its destiny was less well known.

Explain the control of metabolic pathways.

Markscheme

metabolic pathway is a series of reactions carried out in a particular sequence;

products of one reaction become substrates for the next;

each reaction is enzyme-catalyzed (and thus represents point of control);

some enzymes are allosteric;

allosteric control / end-product inhibition/negative feedback;

end-product acts as inhibitor of enzyme at beginning of pathway;

product binding changes the conformation of the active site so substrate of the pathway can no longer bind;

Examiners report

Only the better candidates understood what was required in this question and gained some marks. Many did not attempt an answer.

Explain the control of metabolic pathways by end-product inhibition.

Markscheme

metabolic pathway is a series of enzyme-catalysed reactions;

end-product acts as inhibitor of enzyme at beginning of pathway;

allosteric site for inhibitor to bind / allosteric enzyme with two different binding sites;

more inhibition if end-product concentration rises;

prevents an excess of production/build-up of intermediate products;

Examiners report

Control of metabolic pathways by end-product inhibition was weakly done. Many were able to get one mark for stating that the end-product inhibited an enzyme at the beginning of the pathway and some got a second mark for indicating that there was an allosteric site for the inhibitor to bind with but very few got a third marking point.

---

a. Draw a labelled diagram of the structure of a mitochondrion as seen under the electron microscope. [2]

b. Explain how the structure of a mitochondrion is related to its function. [3]

Markscheme

a. *Award **[1]** for two correct labels. Structures must be drawn correctly for mark to be awarded*.

outer membrane – *drawn as a continuous line*;

inner membrane – *showing folding to create cristae*;

cristae – *shown as distinct infoldings of inner membrane*;

matrix;

intermembrane space – *shown as continuous space between outer and inner membranes*;

(70S) ribosomes – *shown as small dots in proportion with organelle, not too large*;

(naked) loop of DNA;

b. a. matrix is site of reactions of Krebs cycle;

b. thin intermembrane space to build up high proton concentration/$[H^+]$;

c. ATP synthase/respiratory complex on inner membrane to produce ATP as protons pass back to matrix;

d. folded inner membrane / cristae to increase surface area (for electron transport chain);

e. ribosomes to make enzymes/proteins (required for Krebs cycle);

Examiners report

a. There was a very wide range of drawings, many well drawn and labeled, but more that were highly inaccurate. Quite often cristae were drawn as separate entities, rather than as extensions of the inner membrane.

b. If the drawing was poor, then 8(b) on structure vs function was also poorly answered. This was an opportunity to show in-depth knowledge of aerobic respiration.

---

a. Distinguish between oxidation and reduction. [2]

b. Outline the process of glycolysis. [3]

c. Using light as an example, explain the concept of limiting factors in photosynthesis. [3]

Markscheme

a. oxidation is loss of electrons, reduction is gain of electrons;

oxidation frequently involves gaining oxygen, reduction is losing oxygen;

oxidation is losing hydrogen, reduction is gaining hydrogen;

oxidation increases oxidation state / number of elements, reduction lowers it;

b. takes place in cytoplasm;

glucose is phosphorylated/two molecules of ATP are used;

one hexose sugar/glucose is converted into two three-carbon/3C molecules/hydrolysis;

pyruvate is formed/oxidation of glucose to pyruvate;

small yield/net gain of two ATP;

net gain of two NADH + H^+;

does not require/use oxygen/anaerobic process;

c. limiting factors can determine the rate of photosynthesis / if the level of a factor is changed the rate of photosynthesis changes;

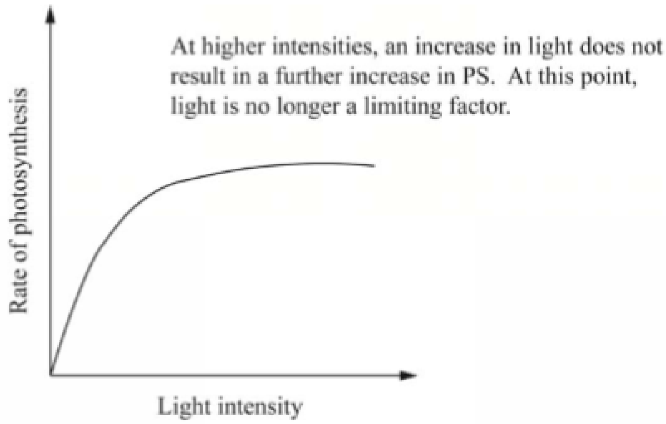
only changes to one factor will affect rate of photosynthesis at a particular time;

light intensity affects the light-dependent reactions/production of ATP/NADPH;

at low light levels the rate of photosynthesis is directly proportional to light intensity/light is limiting;

at high light levels there is no further increase in the rate of photosynthesis/some other factor is limiting (e.g. CO_2/temperature);

Accept the above points illustrated by a suitable correctly sketched graph with both axes labelled and correct shape (see example below).



Examiners report

a. This was answered well by most students, the majority getting two marks for the idea of loss/gain of electrons and loss/gain of oxygen.

b. Many candidates had no difficulty in outlining the process of glycolysis and most gained three marks. Some of the weaker answers were too vague with few precise statements about the different stages and substances produced.

c. The understanding of many candidates was a little limited in this question, and their answers were less well presented. Many had the idea of limiting factors, but few could express clearly the way in which light could affect the rate of photosynthesis.

---

b. Distinguish between the secondary structure and tertiary structure of proteins. [3]

c. Explain what is meant by allosteric inhibition. [3]

Markscheme

b.

secondary structure refers to regular repeating regions within the overall protein structure	while tertiary structure refers to the protein overall / 3-D;
secondary structure α helix/β sheets	while tertiary is globular/fibrous;
forces between amino and carboxyl groups/atoms within backbone in secondary structure	while intramolecular forces between R-groups for tertiary structure;
H-bonds	H-bonds / disulfide bonds / ionic bonds / hydrophobic interactions;

To award a mark responses must refer to both secondary and tertiary structures.

c. form of non-competitive inhibition;

(inhibitor) binds to a site that is not the active site;

causing conformational change;

changes the active site;

so substrate can no longer bind to active site;

Examiners report

b. Many candidates forgot to distinguish between the secondary and tertiary structures of proteins. This command term requires showing the differences between them, not just a description of one of them.

c. Allosteric inhibition was well understood by a number of candidates.

One method of inserting new genes into plants is by gene gun.

[Source: adapted from www.genomicon.com]

a. Outline how a gene gun inserts genes into plants. [2]

b. Marker genes are often inserted together with the new gene. State the function of the marker genes. [1]

c. Outline the characteristics of an open reading frame. [2]

d. Explain, using an example, how gene transfer to a plant could help increase crop yield. [3]

Markscheme

a. a. metal/tungsten/gold/bullet is coated with DNA/gene

Biolistics on its own not accepted.

b. «this DNA is» fired in to a leaf containing the target cells

Accept any plant part, plant suspension, etc.

c. DNA is released and incorporated in to some of the cells

b. marker genes can be detected easily and show the gene has been inserted

Allow a specific example (eg, green fluorescent protein).

c. a. a length of DNA that codes for a polypeptide/protein

OR

length of DNA that can be translated

b. begins with start codon/TAC/ATG/DNA for methionine

c. stop codon occurs after sufficient length *OWTTE.*

d. a. name of GM plant *eg: Soybean.*

b. source of the inserted gene *eg: (Cry1Ac gene) from Bacillus thuringiensis.*
OR
organism used for transfer *eg: plasmid from Agrobacterium tumefaciens.*

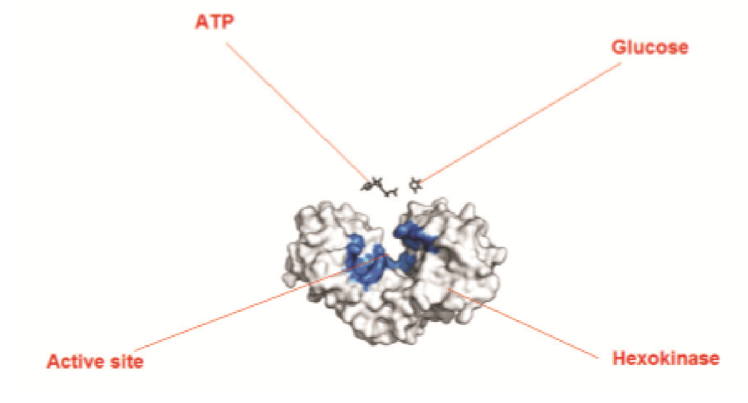
c. purpose of the transfer *eg: increased resistance to glyphosate herbicide.*

d. how it increases yield *eg: reduced competition with weeds killed by glyphosate.*

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

The enzyme hexokinase catalyses the reaction between glucose and ATP to form Glucose –6– phosphate and ADP.



[Source: https://upload.wikimedia.org/wikipedia/commons/thumb/d/d1/Hexokinase_induced_fit.png/400px-Hexokinase_induced_fit.png]

The activity of hexokinase is regulated by end product inhibition. Explain how a reaction can be controlled by end product inhibition.

Markscheme

a. metabolic pathway is a series of enzyme catalysed reactions;

b. allosteric enzyme catalyses one step/first step in the mechanism/chain of reactions;

c. enzyme is inhibited by the end product;

d. end product binds at a site other than the active site/allosteric site;

e. reaction mechanism is interrupted / product formation stops;

f. more inhibition of enzyme as end product concentration rises / less inhibition as end product reduces;

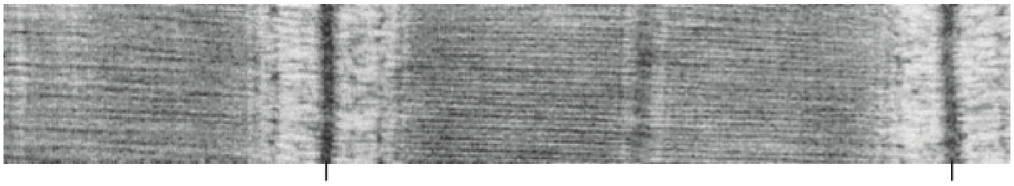
g. example of negative feedback;

Examiners report

There was better knowledge of end product inhibition but again candidates found their explanations hard to express.

---

a. Analyse the electron micrograph for the state of contraction of the muscle fibre. [2]



[Source: http://click4biology.info/c4b/11/hum11.2.htm
Used with permission.]

b. Outline ATP production in muscle fibres during intense exercise. [2]

c. Explain the role of ATP in muscle contraction. [2]

Markscheme

a. a. muscle fibre is (partially) contracted;

b. thick and thin filaments show considerable overlapping;

c. narrow/reduced light bands between Z lines / *OWTTE*;

b. a. for 8–10 seconds creatine phosphate regenerates ATP;

b. anaerobic respiration produces ATP until lactate too high/for about 2 minutes/ 800 m of running;

c. a. ATP breaks cross-bridges (between myosin and actin);

b. ATP resets/activates/changes position of/cocks myosin heads;

c. ATP provides energy to move actin/causes sliding of filaments;

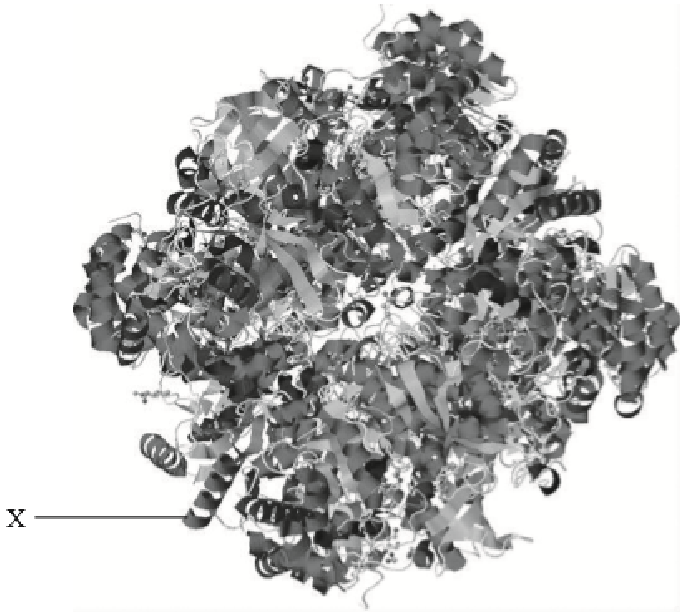
Examiners report

a. In a, the better candidates were able to state that the fibre was (partially) contracted as there was a narrow/reduced light band between the Z lines.

b. b was not well answered, with few considering the duration of ATP regeneration by creatine phosphate or the time taken to build up lactic acid.

c. Better candidates could explain the role of ATP in muscle contraction.

The following image represents a model of ribulose bisphosphate (RuBP) carboxylase (also known as Rubisco) from the green alga *Chlamydomonas*.



[Source: Image from the RCSB Protein Data Bank: http://www.pdb.org/pdb/explore/jmol.do?structureId=1GK8&bionumber=1]

a (i). Identify the level of protein structure of the part labelled X. [1]

a (ii). State the role of ribulose bisphosphate (RuBP) carboxylase in the Calvin cycle. [1]

c. Explain non-competitive inhibition. [2]

Markscheme

a (i). secondary (structure) / α helix

a (ii). fixes/adds carbon/CO_2 to RuBP

c. a. inhibitor binds to enzyme at different location than active site;

b. this causes a change in the shape/conformational change of active site;

c. thus preventing the substrate from binding to the active site / resulting in a decrease of enzyme activity/speed of reaction;

Examiners report

a (i). A relatively small number of candidates answered this option, but those who did generally achieved well.

In C2 (a) (i) most answers were correct.

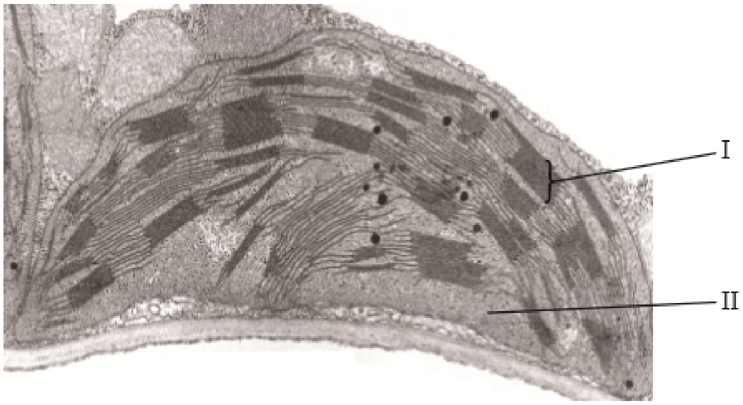
a (ii). A relatively small number of candidates answered this option, but those who did generally achieved well.

A comment on a G2 suggested that the examination should have used the abbreviation Rubisco as this is found in many texts rather than ribulose bisphosphate. Although many texts may use this abbreviation, the examination was based on the terminology used in the subject guide. Teachers who do not use the terminology of the guide may disadvantage students, as appears to have been possible with this question.

c. A relatively small number of candidates answered this option, but those who did generally achieved well.

In C2 (c) in general candidates did know how non-competitive inhibitors work. This is a standard question that revision of past papers would have prepared candidates well for.

The following is an electron micrograph of a chloroplast.



[Source: http://botit.botany.wisc.edu/images/130/Photosynthesis/Chloroplast_EN.html, used with permission.]

a. Label I and II. [1]

I. ....

II. ....

b. Explain the relationship between chloroplast structure and its function. [3]

c. Distinguish between oxidation and reduction. [2]

Markscheme

a. I. granum / grana

II. stroma

(*both needed*)

b. large surface area of grana/thylakoids for light absorption/electron transport chains;

(small) space inside thylakoids for accumulation of protons;

(fluid) stroma contains enzymes/chemicals for light-independent reactions;

presence of DNA/ribosomes means production of specific proteins possible;

different photosynthetic pigments absorb different wavelengths of light;

starch grains store excess carbohydrates from photosynthesis;

c.

oxidation	*reduction*
involves loss of electrons	involves gain of electrons;
(frequently) involves gaining oxygen	(frequently) involves losing oxygen;
(frequently) involves losing hydrogen	(frequently) involves gaining hydrogen;

Responses do not need to be shown in a table format.

Examiners report

a. Many candidates could correctly label the two parts of the chloroplast indicated.

b. Many scored two of the three marks on relating chloroplast structure to function.

c. Candidates seemed to either have a clear understanding of oxidation and reduction with regards to loss and gain of oxygen, hydrogen and electrons, thus gaining the two marks, or to have no idea at all.

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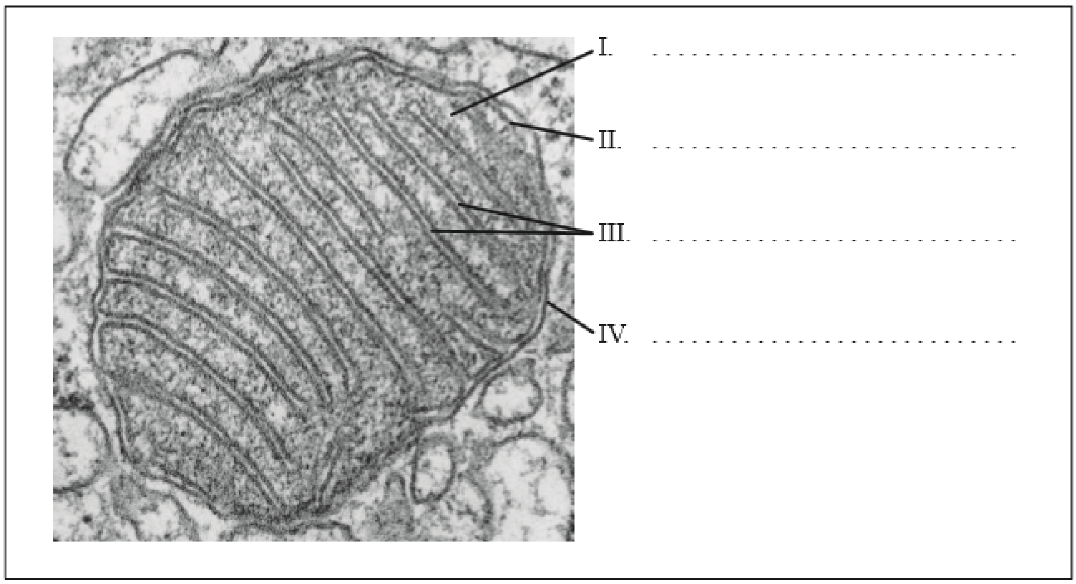
a. Label the following micrograph of a mitochondrion. [2]



b. Explain how oxidative phosphorylation occurs by means of chemiosmosis. [4]

Markscheme

a. *Award **[1]** for any two of the following correctly identified.*

I. matrix;

II. inner membrane;

III. cristae / intermembrane space;

IV. outer membrane;

b. electrons are passed along electron transport system (on inner membrane of mitochondria);

energy is released as electrons move from one carrier to next;

carrier is oxidized as it loses an electron to the next carrier, which becomes reduced;

energy released during electron transport causes proton pumping;

H^+ pumped against concentration gradient from matrix to intermembrane space;

H^+ moves down concentration gradient back through inner membrane/ ATP synthase;

passage of H^+ through ATP synthase causes phosphorylation of ADP/ production of ATP;

Examiners report

a. Most candidates knew the parts of the mitochondrion.

b. The question was either very well answered or the answers were very vague.