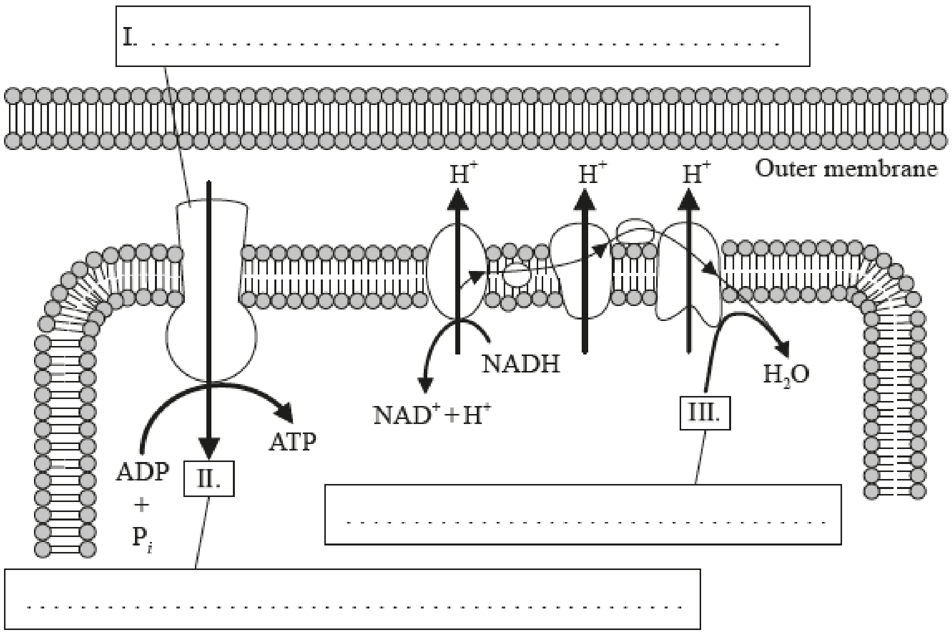
SL Paper 3

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]

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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]

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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]

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

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

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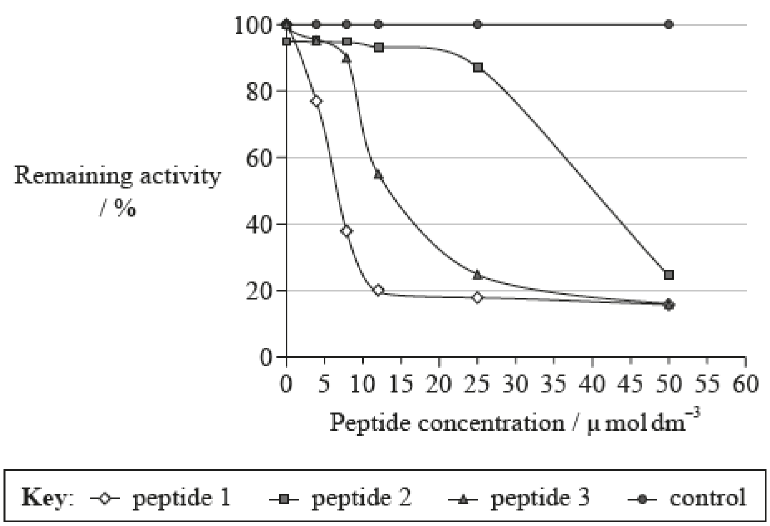
a. Draw a labelled diagram showing the structure of a mitochondrion as seen in electron micrographs. [4]

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

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 $8\ \mu\mathrm{mol\,dm^{-3}}$ 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]

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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]

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

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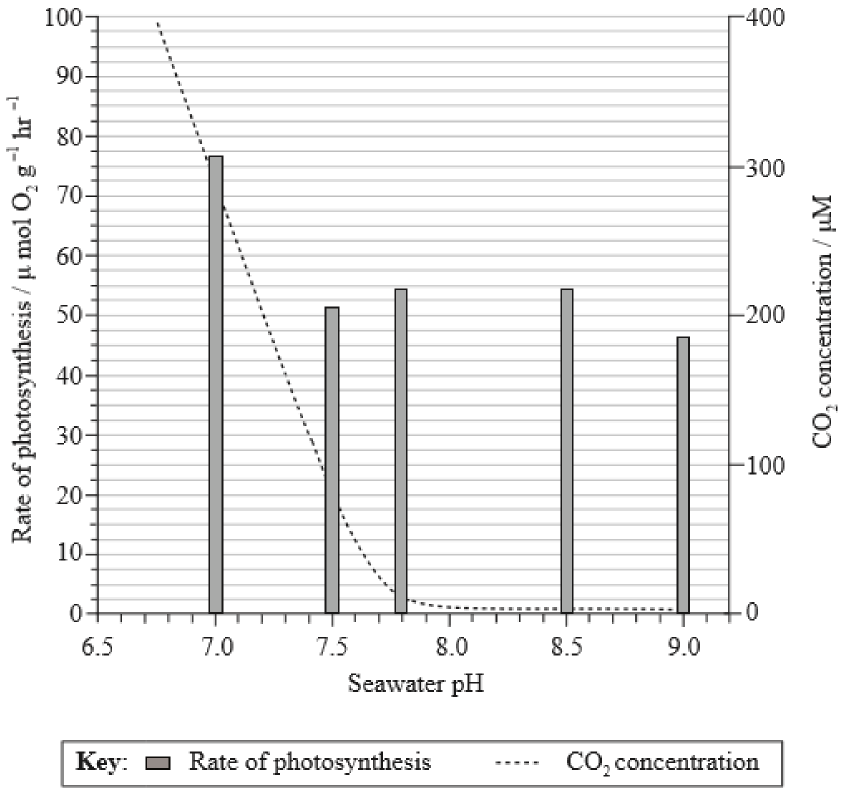
a. Outline the process of glycolysis. [3]

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

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]

Plant physiology by AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS. Copyright 2008 Reproduced with permission of AMERICAN SOCIETY OF PLANT BIOLOGISTS in the format CD ROM via Copyright Clearance Center.

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

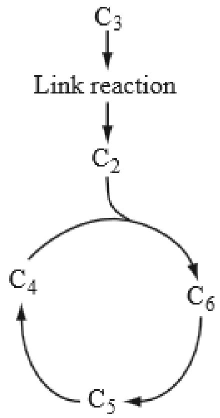
b. Calculate the percentage decrease in the rate of photosynthesis from pH 7 to pH 7.5. [1]

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]

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]

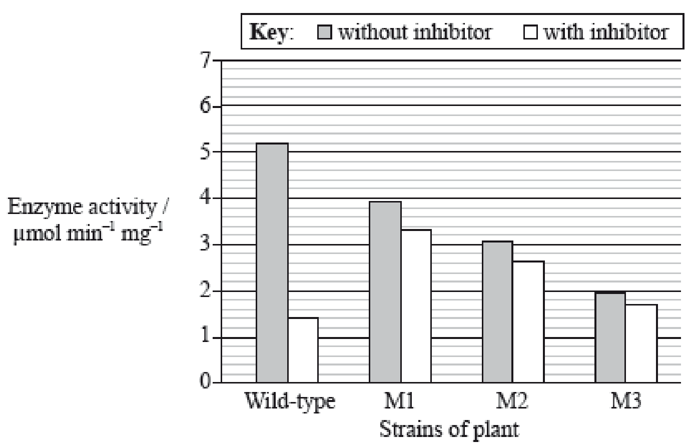
a (iii) List **one** product other than carbon dioxide formed in this stage of respiration. [1]

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

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:

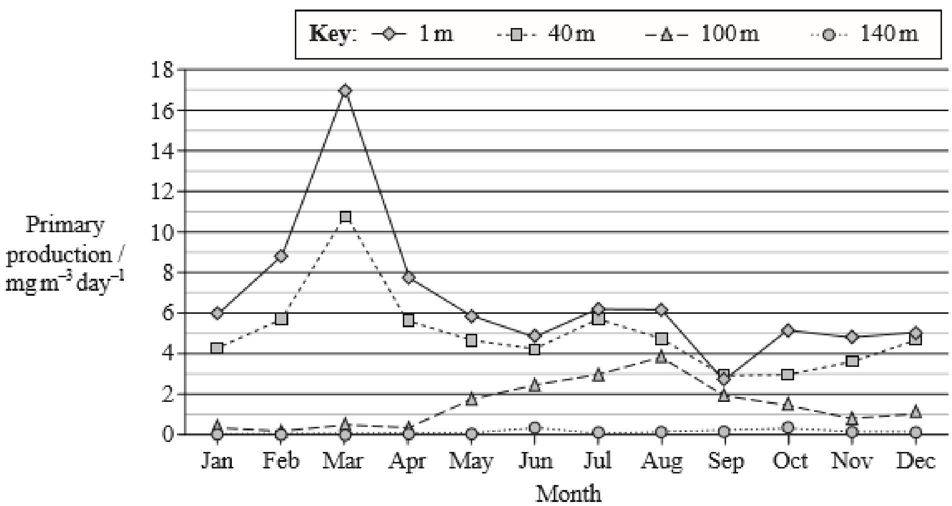
With inhibitor:

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]

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]

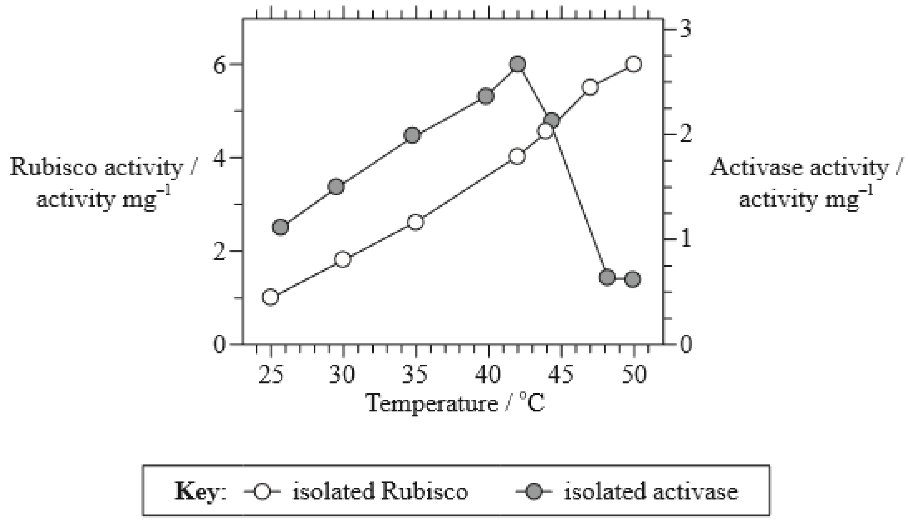
b. Identify, with a reason, the water depth that receives no light. [1]

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]

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]

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

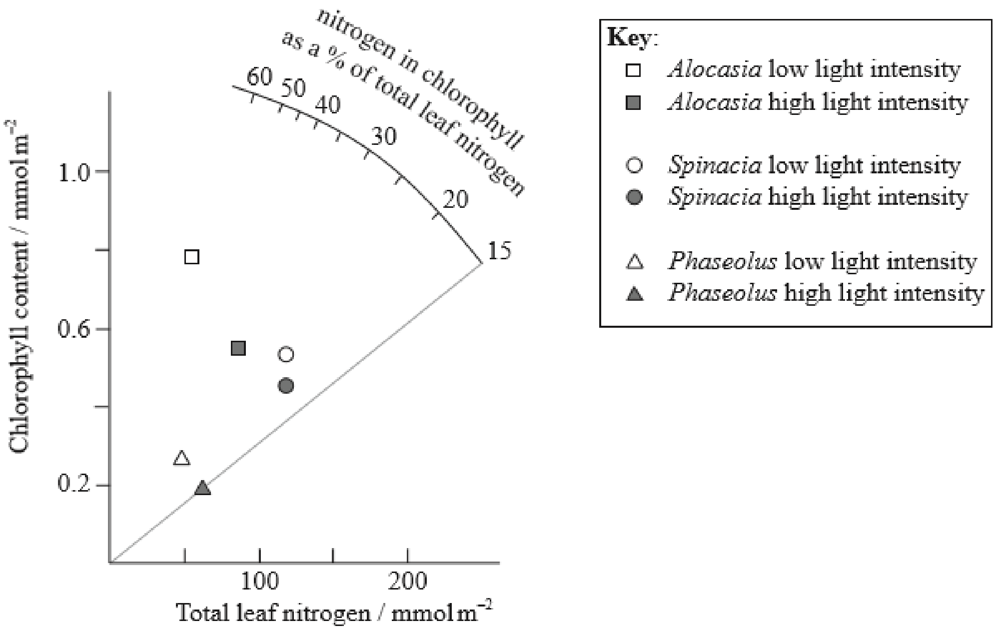
c. Determine which enzyme shows overall greater activity from 25°C to 42°C. [1]

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]

Compare competitive and non-competitive enzyme inhibition

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]

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

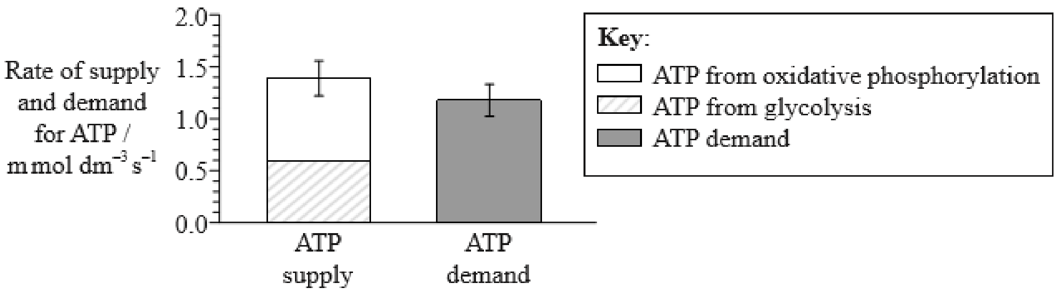
c. Suggest **one** advantage for plants to increase their leaf chlorophyll content per surface area when light intensity is lower. [1]

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

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]

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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]

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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]

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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]

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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]

Outline the differences between competitive and non-competitive inhibitors.

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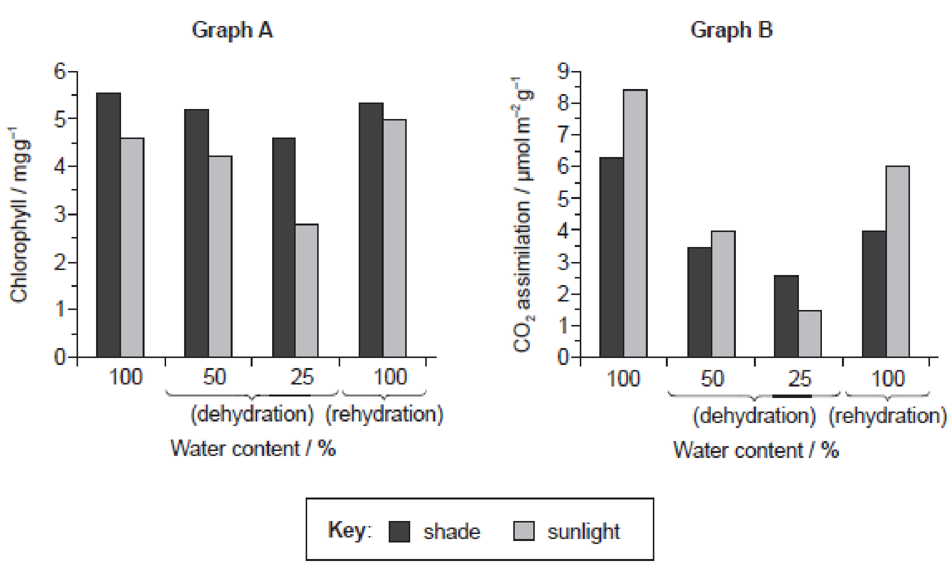
a. Draw a labelled diagram showing the structure of a chloroplast. [3]

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

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

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]

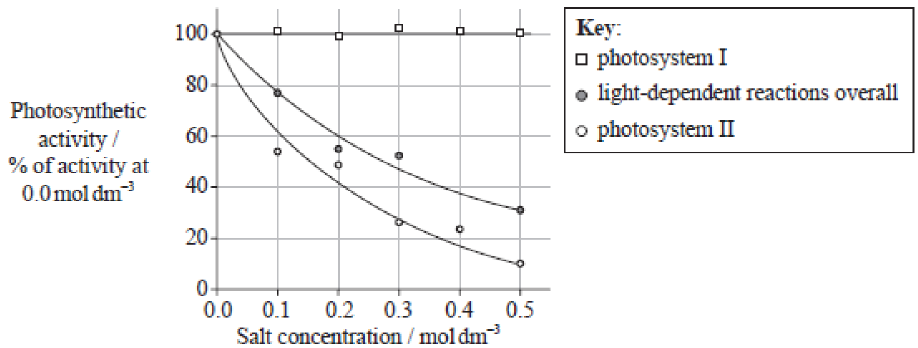
a. State the level of chlorophyll at 50 % water content for plants growing in sunlight, giving the units. [1]

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]

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)]

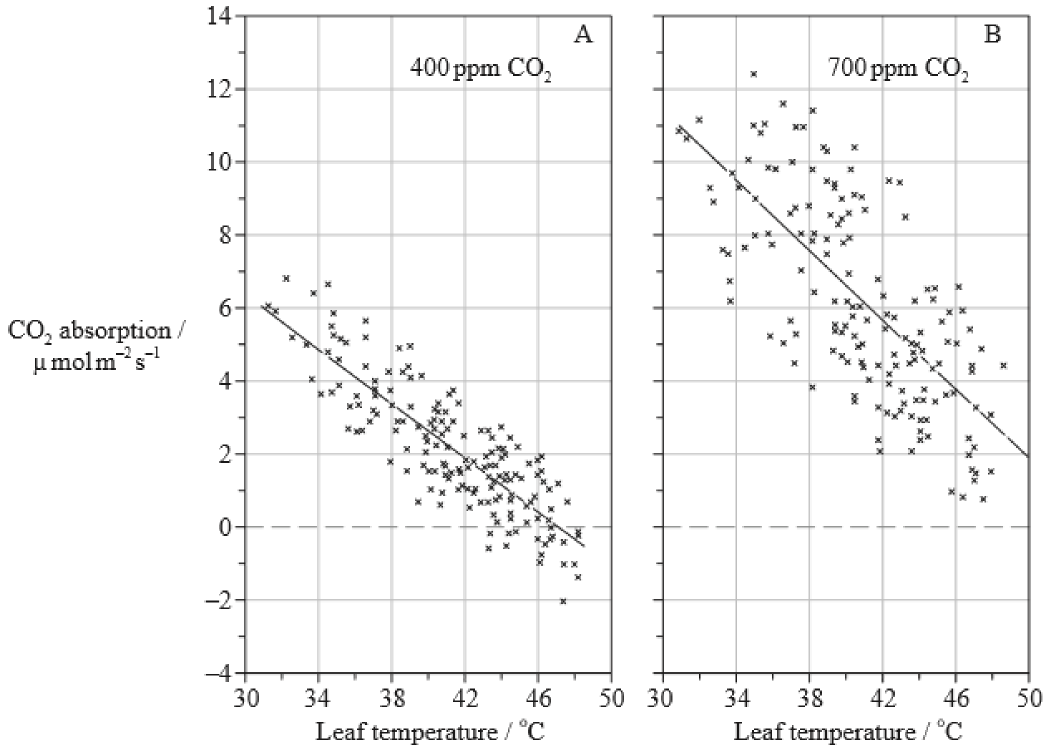
a. Describe the effect of salt concentration on the activity of the light-dependent reactions overall. [1]

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]

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]

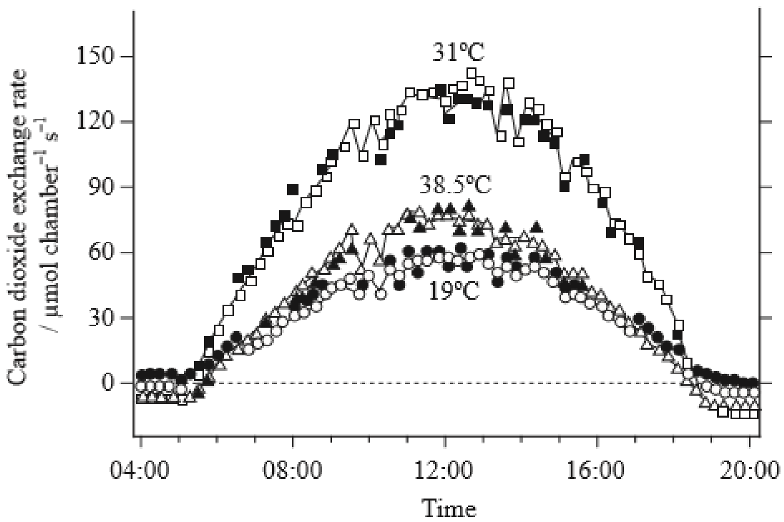
e. State **two** products that pass from the light-dependent to the light-independent stages of photosynthesis. [1]

1. ....

2. ....

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]

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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]

Explain the control of metabolic pathways.

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

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]

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]

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

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

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

[Source: adapted from www.genomicon.com]

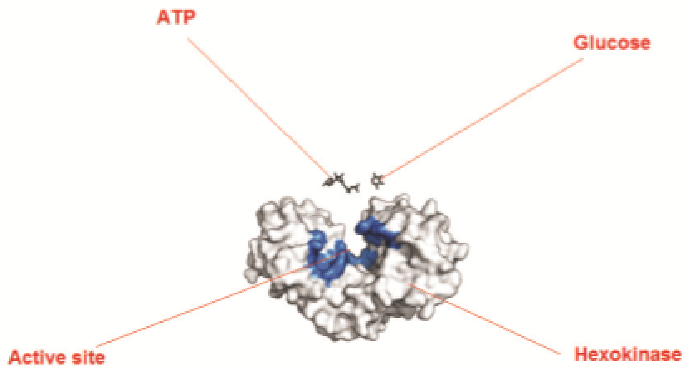
a. Outline how a gene gun inserts genes into plants. [2]

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]

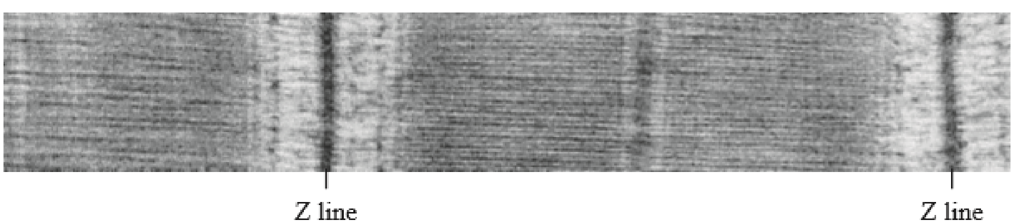
The enzyme hexokinase catalyses the reaction between glucose and ATP to form Glucose –6– phosphate and ADP.



[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.

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

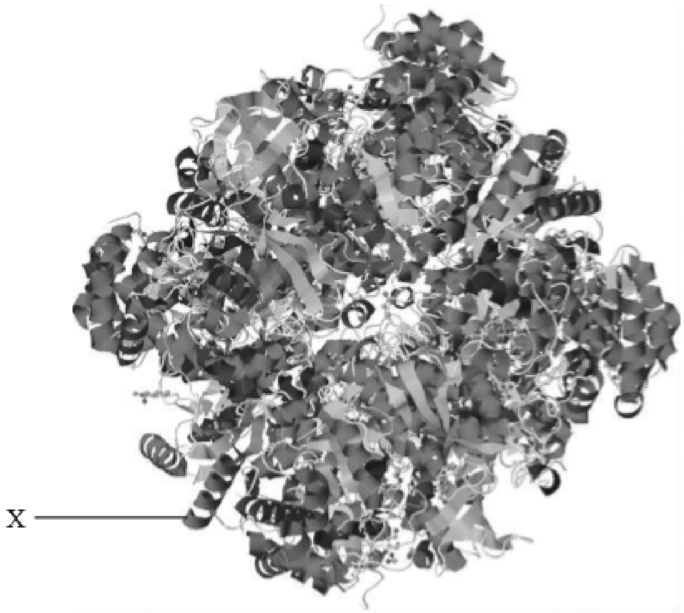


[Source: http://click4biology.info/c4b/11/hum11.2.htm Used with permission.]

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

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

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



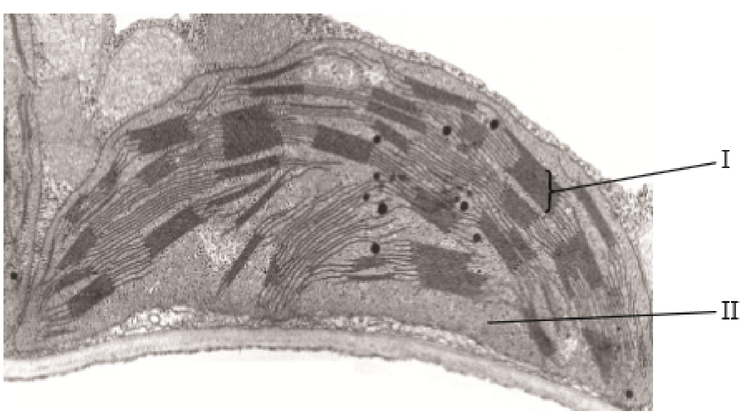
[Source: Image from the RCSB Protein Data Bank: http://www.pdb.org/pdb/explore/jmol.do?structureId=1GK8&bionumber=1]

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]

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]

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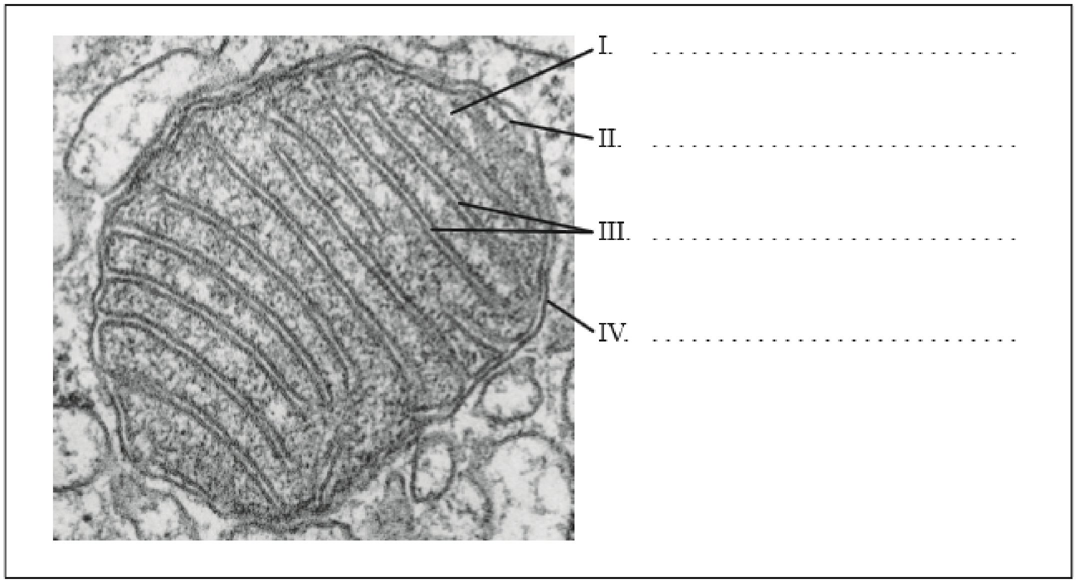
a. Label the following micrograph of a mitochondrion. [2]



[Copyright 2002 from *Molecular Biology of the Cell* by Alberts *et al*., Reproduced by permission of Garland Science/ Taylor & Francis Books LLC]

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