2017 Photosynthesis and Respiration STQ

2017 / H2 / AJC PRELIM / P2 Q6

1 In anaerobic respiration in yeast, the pyruvate molecules are broken down to produce ethanol and carbon dioxide. The release of carbon dioxide can be used to investigate the rate of anaerobic respiration.

Fig. 6.1 shows an experiment which was set up to find the rate of anaerobic respiration.

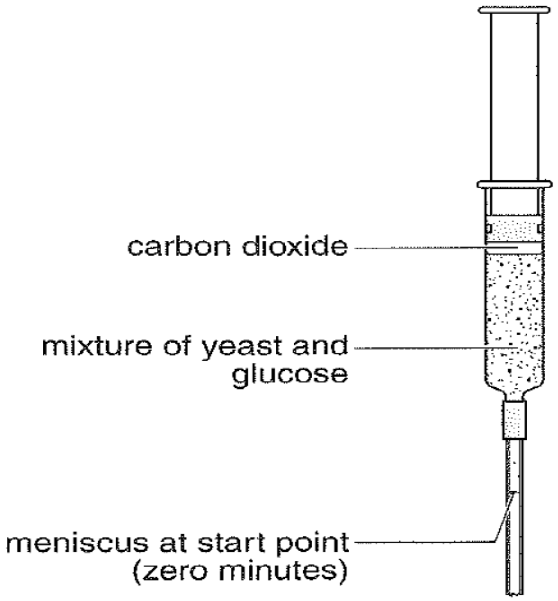

Fig. 6.1

The meniscus moves down the tube as carbon dioxide is released.

Table 6.1 shows the distance moved by the meniscus from the start point. This was recorded every 10 minutes.

Table 6.1

Time/ min	0	10	20	30	40	50	60	70	80	90
Distance travelled by meniscus from start point/ mm	0	1	2	5	9	14	21	45	73	98

(a) The rate of anaerobic respiration can be calculated by using the rate of movement of the meniscus.

Calculate the rate of anaerobic respiration between 70 and 80 minutes.

You will lose marks if you do not show your working.

[2

(b) This experiment was repeated three more times. Each time, the glucose (a monosaccharide) was replaced with a different disaccharide sugar:

- Maltose – a disaccharide of glucose and glucose
- Sucrose – a disaccharide of glucose and fructose
- Lactose – a disaccharide of glucose and galactose.

Tables 6.2 (a), (b) and (c) show the results of these experiments.

Table 6.2 (a): Using maltose

Time/ min	0	10	20	30	40	50	60	70	80	90
Distance travelled by meniscus from start point/ mm	0	0	0	0	0	2	3	6	9	12

Table 6.2 (b): Using sucrose

Time/ min	0	10	20	30	40	50	60	70	80	90
Distance travelled by meniscus from start point/ mm	0	0	0	1	3	11	22	37	48	61

Table 6.2 (c): Using lactose

Time/ min	0	10	20	30	40	50	60	70	80	90
Distance travelled by meniscus from start point/ mm	0	0	0	0	0	0	0	0	0	0

With reference to the information provided in Tables 6.2 (a), (b) and (c) and your biological knowledge:

(i) Describe the difference in the results for maltose and sucrose, and suggest one explanation for this difference,

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(ii Suggest two explanations for the results for lactose.
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[2

(c) An electron micrograph of yeast, *Candida albicans*, is shown in Fig. 6.2.

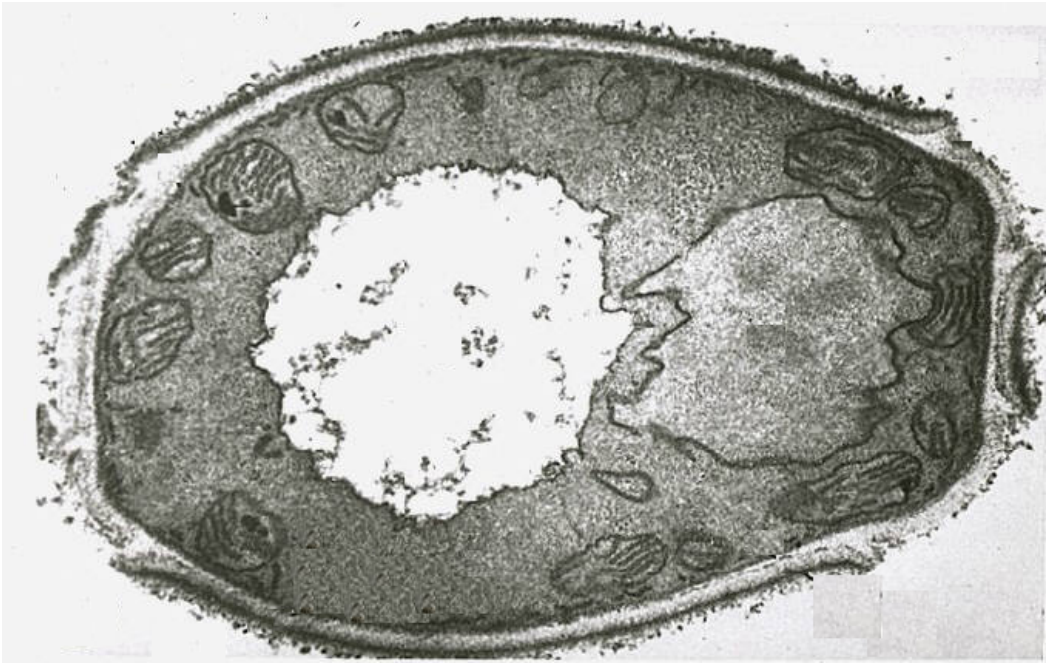


Fig. 6.2

(i) On Fig. 6.2, label site of
i. Glycolysis
ii. Oxidative phosphorylation [2

(ii State one visible structure of mitochondria from Fig. 6.2 and describe how it supports mitochondria's fun**)**ction.

[1

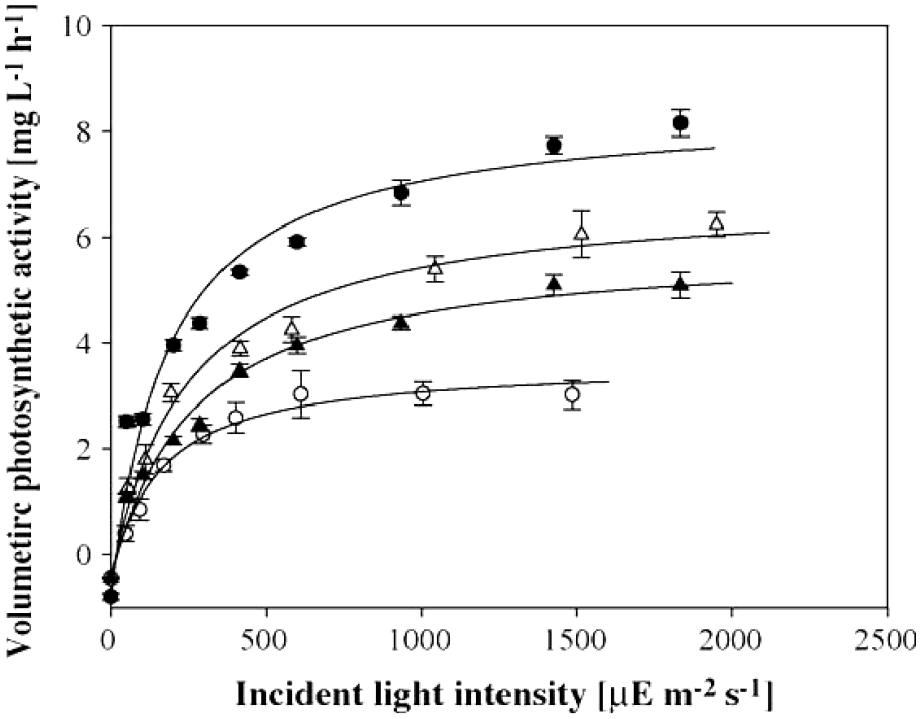
(ii) Besides location, compare between oxidative phosphorylation and photophosphorylation.

[4]

[Total: 13 marks]

2 Microalgae have been extensively studied for various purposes, such as the production of biomass as a source of valuable chemicals of health foods and for wastewater treatment. Recently, microalgal photosynthesis was considered to be an effective means to reduce the emission of carbon dioxide, a major greenhouse gas, in the atmosphere. Light is the most important factor affecting microalgal photosynthesis kinetics. In general, most microalgal mass culture systems are limited by light, because light is easily absorbed and scattered by the microalgal cells. Therefore, understanding and quantification of light dependence of microalgal activity is of great importance in designing an efficient photobioreactor, in predicting process performance, and in optimizing operating conditions.

Fig. 6.1



The volumetric photosynthetic activity as a function of incident light intensity at different light types and cell concentrations. Data points and error bars were average values and standard deviations of three replicated experimental results. Solid lines represent the calculated results from the photosynthesis–irradiance model. The light types and cell concentrations were:

( ) simulated daylight and 0.215 g L−1;

(▲) simulated daylight and 0.123 g l△1;

( ) red light and 0.123 g L−1; and

( ) green light and 0.123 g L−1.

Jeon *et al* 2005 Measurement of microalgal photosynthetic activity depending on light intensity and quality. Biochemical Engineering Journal 27 (2005) 127–131

(a) Explain the trends seen when red, green and daylight (at 0.123gL-1) are compared.

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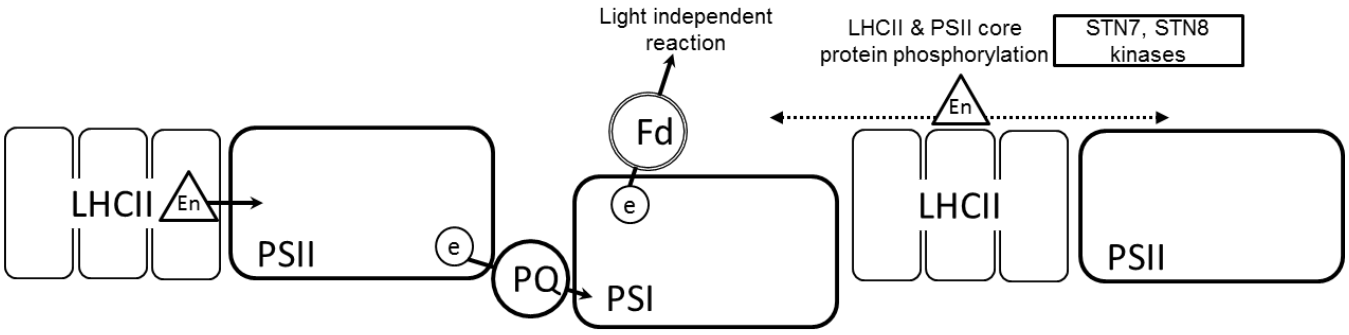
.....[5]

Fig. 6.2 shows a schematic showing the functional relationship between light harvesting complexes (LHC) and photosystems II & I. Regulatory complexes are also shown comprising of kinases and the regulation of excess energy between PS II and I.



Gollan et al 2015 Photosynthetic light reactions: integral to chloroplast retrograde signalling. Current Opinion in Plant Biology 27:180-191modified.

Fig. 6.2

(b) Explain what is the LHC and its role in photosynthesis.

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……[2]

(c) With reference to Fig. 6.2 explain the role of electrons in the photosynthesis as they move from Photosystem II to Photosystem I.

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……[3]

(d) With reference to Fig. 6.2 suggest the implications of the role of LHC and PSII core protein phosphorylation from Photosystem II to Photosystem I.

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[3]

[Total: 13]

Question 3

Studies were carried out on soil-dwelling aerobic bacteria. Soil samples were taken at two depths, **A** and **B**. The samples were taken at intervals over six years to determine the activity of dehydrogenases, involved in the Krebs cycle.

Fig. 8 shows the mean dehydrogenase activity of the bacteria in these samples.

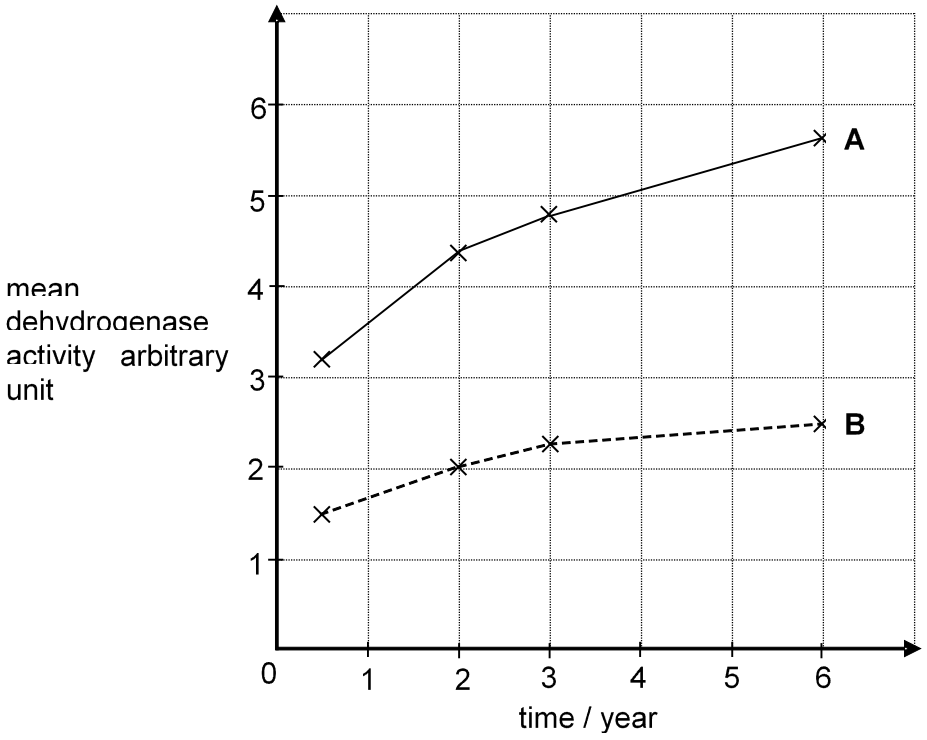

Fig. 8

(a) (i) Explain the importance of Krebs cycle dehydrogenase in ATP synthesis. [3]

(ii) With reference to **Fig. 8** and your knowledge on enzymes, explain which samples, **A** or **B**, were taken from a greater depth. [4]

(b) Dehydrogenase is also required for anaerobic respiration. Describe the process catalysed by the lactate dehydrogenase. [2]

(c) Photosynthetic bacteria can be found in the ocean. Samples of bacteria were collected at the same depth from different locations and the activity of the enzyme RUBISCO was studied. Results obtained show that the samples collected near factories had higher RUBISCO activities than samples collected near forests.

(i) Identify the factor which explains the differing result. [1]

(ii) Explain how the factor mentioned in **(c)(i)** affects the activity of RUBISCO in samples near factories. [2]

Total: [12]

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4 Fig. 6.1 shows some stages in mammalian respiration.

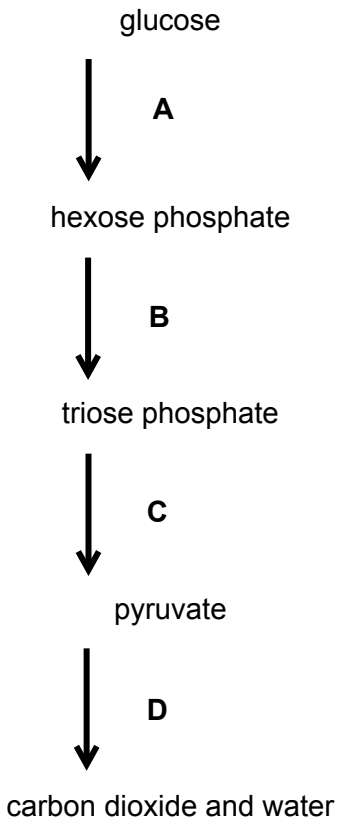

Fig. 6.1

(a) Name the processes taking place during Stage D and state precisely where they occur. [3]

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(b) Intermediates produced at the end of Stages B and C are important in the conversion of carbohydrates to lipids such as triglycerides. Some of the triose phosphate can be converted into glycerol-3-phosphate, while pyruvate can undergo further reactions to form intermediates required for the synthesis of fatty acids.

(i) Describe the formation of triglycerides. [3]

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(ii) State two roles of triglycerides in living organisms. [2]

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(c) The first reaction in Stage A is catalysed by the enzyme hexokinase. It has been observed that hexokinase is bound to the outer mitochondrial membrane in muscle cells which undergo high rates of glycolysis.

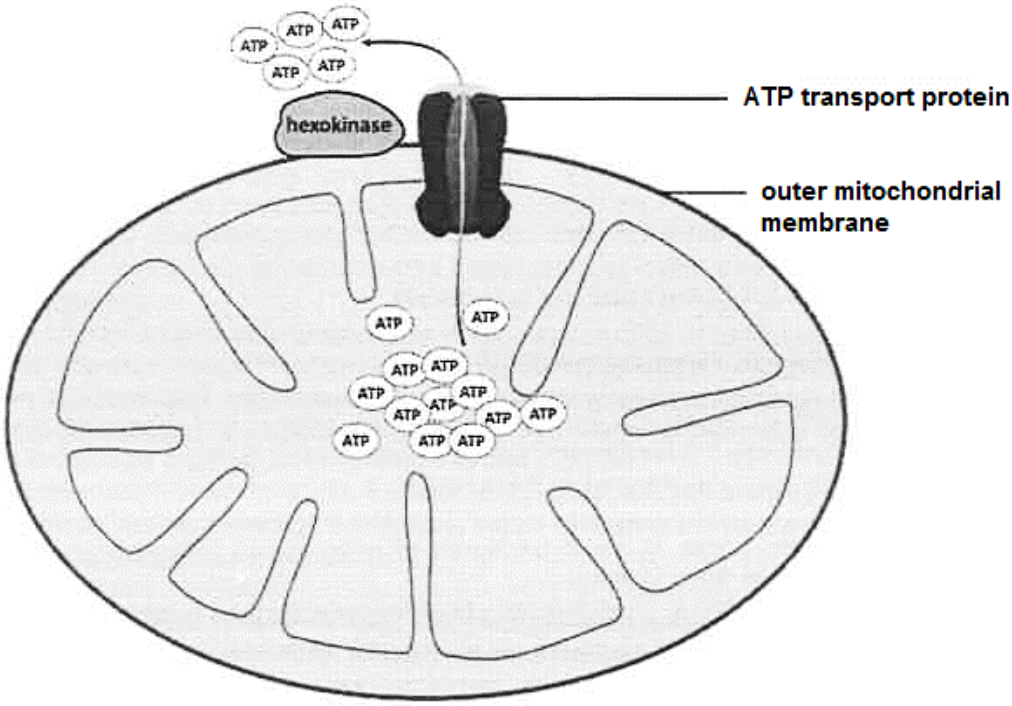

Fig. 6.2

With reference to the role of mitochondria and Fig. 6.2, suggest how the association of hexokinase with mitochondria can lead to high rates of glycolysis. [2]

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Fig. 6.3 shows an electron micrograph of a mitochondrion.

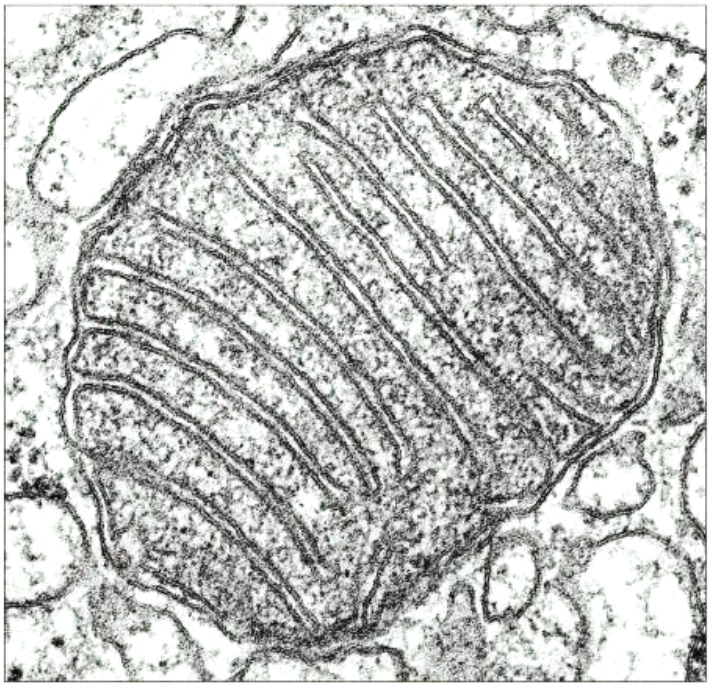

Fig. 6.3

(d) With reference to features visible in Fig. 6.3, outline how the structure of the mitochondrion is adapted for its function. [2]

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[Total: 12]

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5 During photosynthesis, carbon dioxide reacts with ribulose bisphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme Rubisco.

Rubisco can also catalyse a reaction between RuBP and oxygen to form one molecule of GP and one molecule of phosphoglycolate. However, phosphoglycolate cannot be used in the light-independent reaction of photosynthesis.

Fig. 6.1 shows both the reactions catalysed by Rubisco.

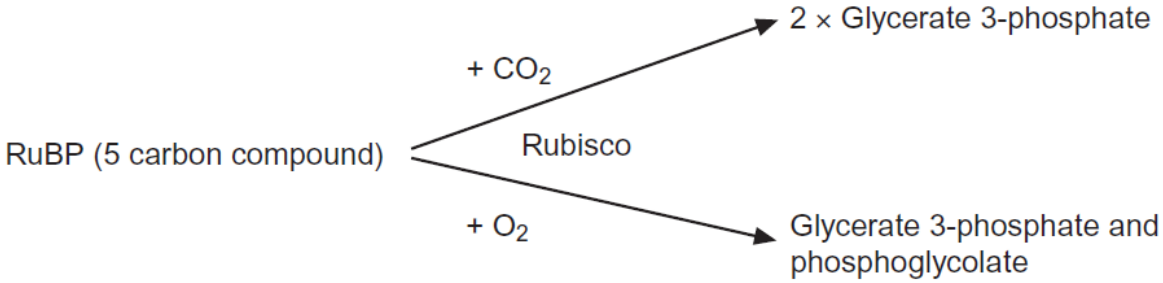

Fig. 6.1

(a) (i) State exactly in a cell where the enzyme Rubisco is found

[1]

(ii) Use the information provided to give the number of carbon atoms in one molecule of phosphoglycolate.

[1]

(b) A scientist investigated the effect of different concentrations of oxygen on the rate of absorption of carbon dioxide by leaves of soya bean plants. His results are shown in Fig. 6.2.

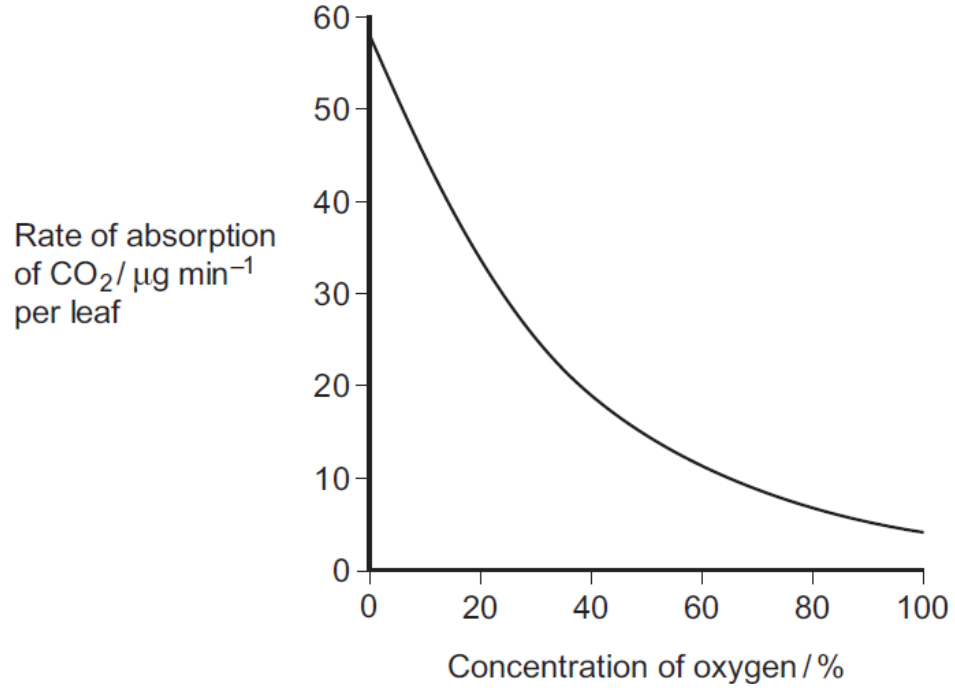

Fig. 6.2

(i) Use Fig. 6.1 to explain the results shown in Fig. 6.2.

[2]

(ii) Using the information provided and your knowledge of the light-independent reaction, explain why the glucose yield from soya bean plants is decreased at higher concentrations of oxygen.

[3]

(c) Another scientist investigated the uptake of radioactively labelled carbon dioxide in chloroplasts. She used three tubes, each containing different components of chloroplasts.

Table 6.1 shows the uptake of radioactively labelled carbon dioxide in each tube.

Table 6.1

Tube	Contents of tube	Uptake of radioactively labelled CO_2 / counts per minute
A	Stroma and grana	96 000
B	Stroma, ATP and reduced NADP	97 000
C	Stroma	4 000

(i) Explain why the result in tube **B** is similar to that in tube **A**.

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[1]

(ii) Use the information in Table 6.1 to predict the uptake of radioactively labelled carbon dioxide if tube **A** was placed in the dark. Explain your answer.

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[2]

[Total: 10]

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1
2
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4
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6 Heart muscle cells and epidermal cells were extracted from Chinese hamsters. The cells were lysed and the mitochondria and cytosol were isolated. The mitochondria and cytosol were then mixed and re-suspended in a culture of essential nutrients. This suspension system was used to study the process of cellular respiration.

At time **0**, glucose was added to the system. At Time **X**, digitonin, a detergent which disrupts membranes was introduced to the suspension system. A probe was used to measure the concentrations of ATP as well as the pH level in the mitochondria.

The experimental results are recorded in the graphs shown.
Fig. 8.1 shows the rate of ATP production for heart muscle cells and epidermal cells.
Fig. 8.2 shows the pH level of the mitochondria in both heart muscle and epidermal cells.

Fig. 8.1

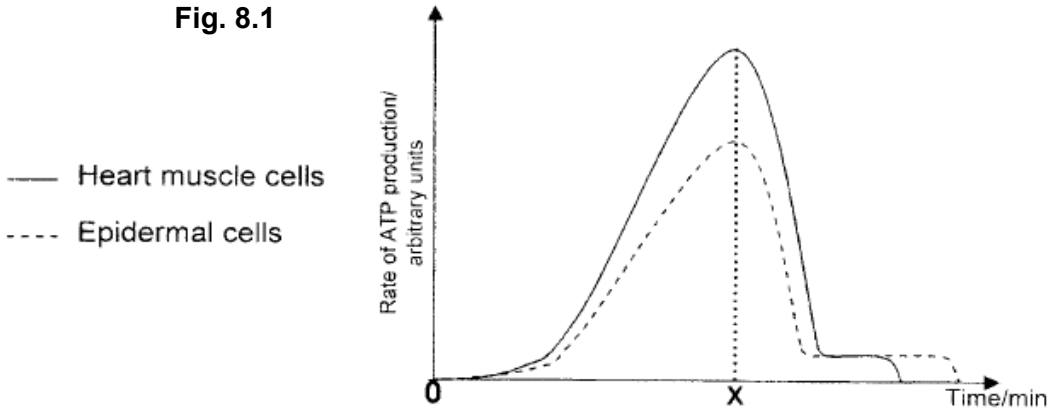
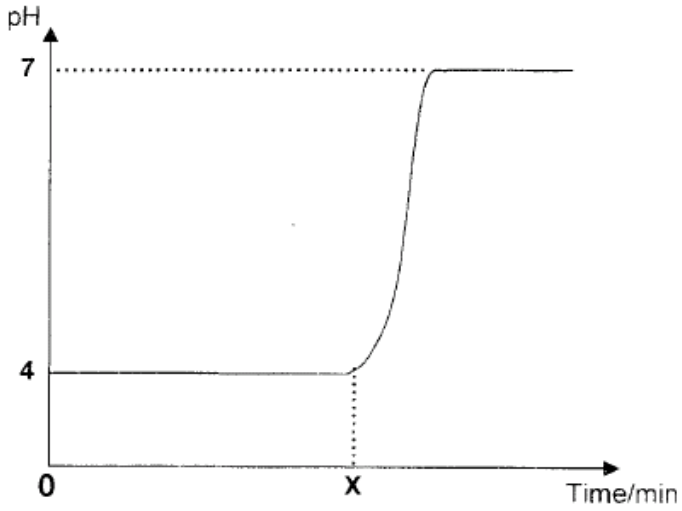


Fig. 8.2



(a) Account for the difference in the level of ATP production in both tissues after glucose was added.

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[1]

(b) With reference to **Fig. 8.1**, explain the changes in ATP production over time for the heart muscle cell suspension.

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[3]

(c) With reference to **Fig. 8.2**, state which region of the mitochondrion the pH probe was measuring. Explain your conclusion.

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[2]

(d) Suggest why cytosol was used to re-suspend the mitochondria.

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[1]

(e) From your biological knowledge, explain the adaptation of the double membrane for its role in the production of energy.

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[2]

[Total: 9]

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Question 7 [12 marks]

An experiment was conducted to investigate how various factors affect the rate of photosynthesis in cabbage. **Fig. 7.1** below shows the results of the experiments conducted.

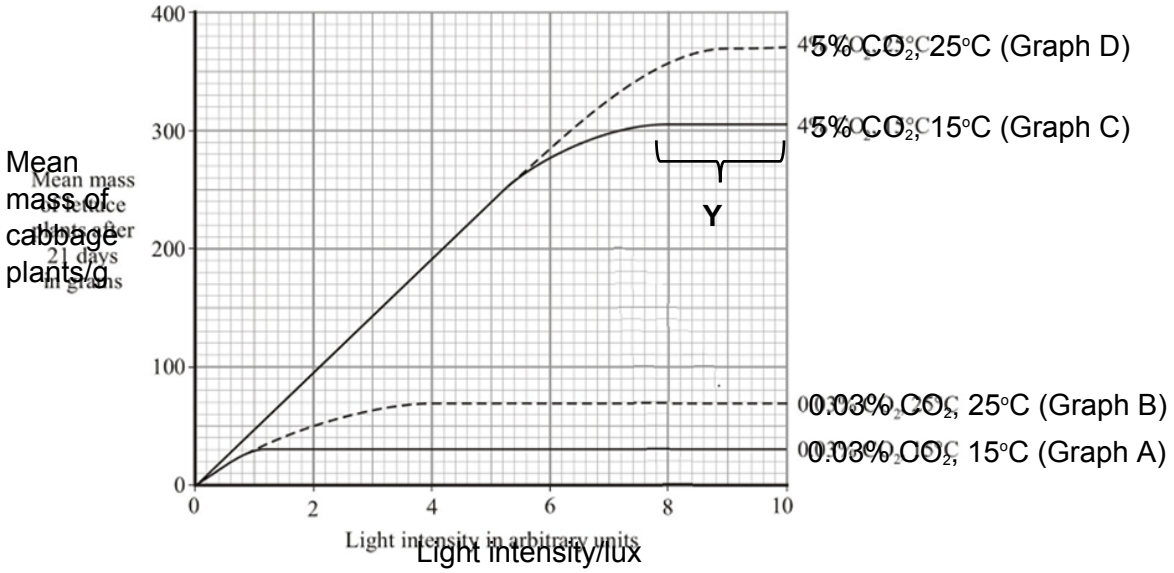

Fig. 7.1

(a) With reference to **Fig. 7.1**,

(i) state the best conditions for the growth of cabbage. [1]

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(ii) explain the region marked **Y**. [2]

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(iii) describe and explain the effect of increasing carbon dioxide concentration on the mean mass of cabbage at 25 ºC. [3]

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6 Pyruvate, a product of glycolysis, needs to move from the cytosol into the mitochondrion. After some processing, pyruvate will be converted to acetyl Co A which then enters the Kreb cycle.

Fig. 6.1 is an electron micrograph of a mitochondrion.

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(iv) The average carbon dioxide content of the natural environment is 0.035%. Using this fact, and the information given in **Fig. 7.1**, what conclusion can be made about how carbon dioxide affects rate of photosynthesis in the natural environment? [2]

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(b) While photosynthesis is the process by which carbon dioxide and water are used as starting materials for the synthesis of glucose using light energy, respiration involves releasing chemical energy in organic molecules such as glucose by oxidation and made available to living cells in the form of ATP. In particular, the yield of ATP under aerobic and anaerobic respiration are very different.

Explain the small yield of ATP from anaerobic respiration in both yeast and animals. [4]

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(a) Name the region within the mitochondrion where the Krebs cycle occurs and using the symbol **X**, indicate this region on Fig. 6.1.

region
X:…..……..……[1]

(b) Pyruvate requires the help of pyruvate translocase to enter the mitochondrion. The structure of pyruvate is shown in Fig. 6.2.

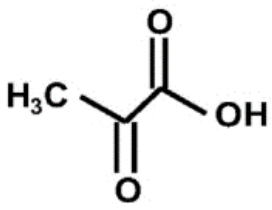

Fig. 6.2

Pyruvate translocase is located on the membrane labelled ‘A’ in Fig. 6.1.

Fig. 6.3 shows how pyruvate is transported across the membrane A.

(i) Explain why pyruvate requires the help of pyruvate translocase to cross membrane A.

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…… [2]

(ii) With reference to Fig. 6.3, describe the transport of pyruvate across membrane A.

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…… [1]

(c) Other than pyruvate translocase, the electron transport chain and ATP synthase can also be found on membrane A.

(i) Explain how pyruvate translocase, the electron transport chain and ATP synthase are held in membrane A.

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…… [2]

(ii) Explain how mitochondria are adapted to contain many structures such as pyruvate translocase, the electron transport chain and ATP synthase.

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…… [1]

(d) Fig. 6.4 shows a section of membrane A.

Dinitrophenol (DNP), cyanide and oligomycin are chemicals that interfere with the normal functioning of the components shown in membrane A.

(i) DNP can shuttle H^+ across biological membranes.

With reference to Fig. 6.4, explain why fewer ATP molecules were produced when DNP was added to mitochondria.

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…… [1]

(ii) Cyanide inhibits complex IV shown in Fig. 6.4.

Explain why in the presence of cyanide, oxygen consumption decreases and lactate production increases.

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…… [4]

(iii) Oligomycin inhibits ATP synthase by blocking the proton channel, as seen in Fig. 6.4.

Indicate in the graph below, the effect of administering a fixed amount of oligomycin on the rate of ATP synthesis. [1]

[Total: 13]

7 Fig. 8.1 is an electron micrograph of a mitochondrion.

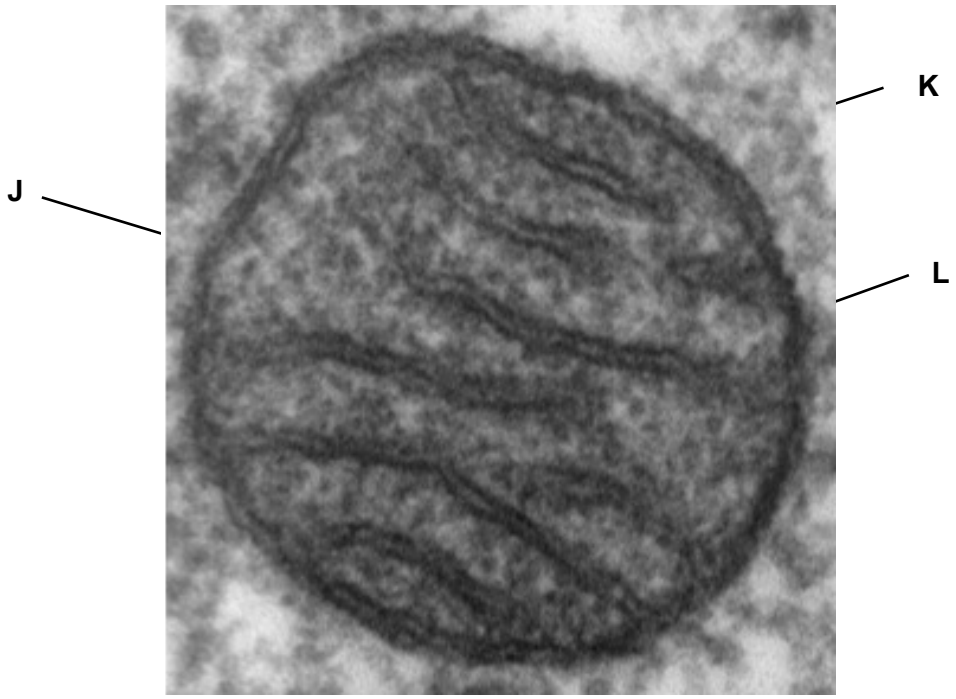

Fig. 8.1

(a) **(i)** Identify structures **J** and **K**. [1]

J _____

K _____

(ii) Describe how structure **J** is adapted to its function. [1]

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(b) **(i)** State the role of high concentration of protons at **L**. [1]

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(ii) Explain how the high concentration of protons is generated at **L**. [3]

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In an investigation to determine the effect of chemical **M** on respiration, mitochondria were incubated in four ways:

1. with glucose
2. with pyruvate
3. with glucose and chemical **M**
4. with pyruvate and chemical **M**

The results are summarised in Table 8.1.

Table 8.1

	CO_2 evolution	O_2 consumption	ATP production by oxidative phosphorylation
Glucose	x	x	x
Pyruvate	✓	✓	✓
Glucose + chemical **M**	x	x	x
Pyruvate + chemical **M**	✓	✓	x

(c) **(i)** Explain why carbon dioxide is produced when mitochondria are incubated with pyruvate but not when incubated with glucose. [3]

(ii) Suggest why when mitochondria were incubated with pyruvate and chemical **M**, oxygen consumption occurs but not ATP production. [2]

[Total: 11]

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QUESTION 8

A student set up an experiment to investigate the effect of carbon dioxide on photosynthesis. First, he de-starched a small potted plant by putting it in the dark for two days. Then, he chose two leaves and inserted them into conical flasks, **A** and **B**, fitted with rubber stoppers. Lithium hydroxide was placed in Flask **B** to absorb all carbon dioxide present. The plant was then left under a table lamp for 15 minutes. Fig 5.1 shows the experimental setup.

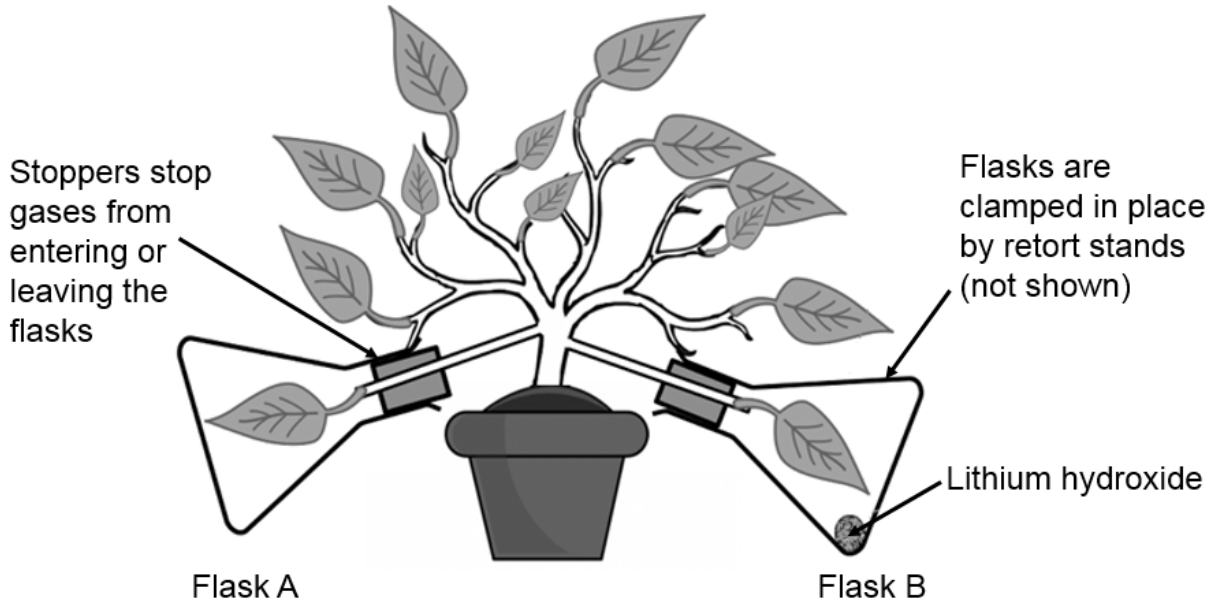

Fig 5.1

He removed a sample of each leaf every 5 minutes (by punching out a leaf disc of approximately 0.2 cm in diameter, using a single-hole puncher) and return the leaves to their respective flasks immediately. Each leaf disc was then tested for the presence of ribulose bisphosphate (RuBP) and starch. Table 5.2 shows the results he obtained.

Table 5.2

Flask	Concentration of RuBP / $\mu molm^{-2}$				Concentration of starch / $\mu molm^{-2}$			
	0 min	5 min	10 min	15 min	0 min	5 min	10 min	15 min
A	0.0	2.2	3.0	3.1	0.0	2.1	3.4	6.5
B	0.0	2.7	4.2	6.8	0.0	0.3	0.5	0.5

(a) State two other variables which must be kept constant to maximize the validity of the results obtained for this experiment.

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……...[1]

(b) With reference to Table 5.2, describe the relationship between the presence of carbon dioxide and concentration of starch.

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……[2]

(c) Explain the absence of RuBP in both leaves at the start of the experiment.

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……[2]

(d) The increase in RuBP concentration for the leaf in Flask A reached a plateau from 10 min to 15 min of exposure to light but continued to increase in the leaf in Flask B up to 15 min. Explain why.

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……[3]

The student watered the potted plant too excessively, causing the soil to become waterlogged. Fortunately, the roots of this plant could carry out anaerobic respiration under low oxygen conditions in the soil.

(e) Outline the process of anaerobic respiration in the roots under waterlogged conditions.

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……[4]

[12 marks]

2017 / H2 / TJC PRELIM / P2 Q7

9 Glucose and fructose are two common fruit sugars used in winemaking. Another sugar used in the fermentation industry is sucrose. The effects of the three sugars on fermentation by yeast were investigated and the results are shown in Fig. 7.1 and Fig. 7.2.

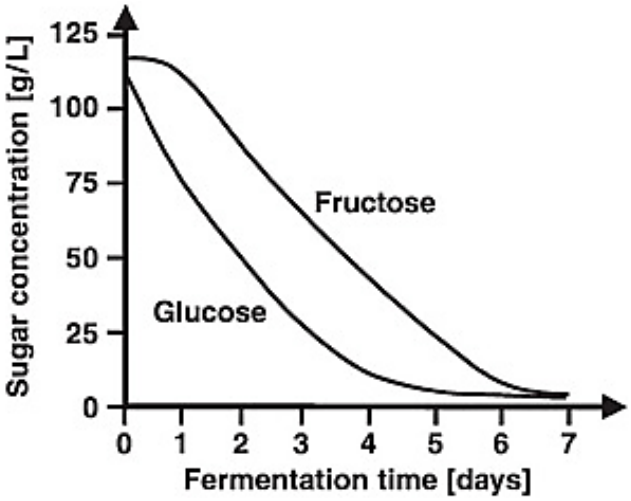

Fig. 7.1

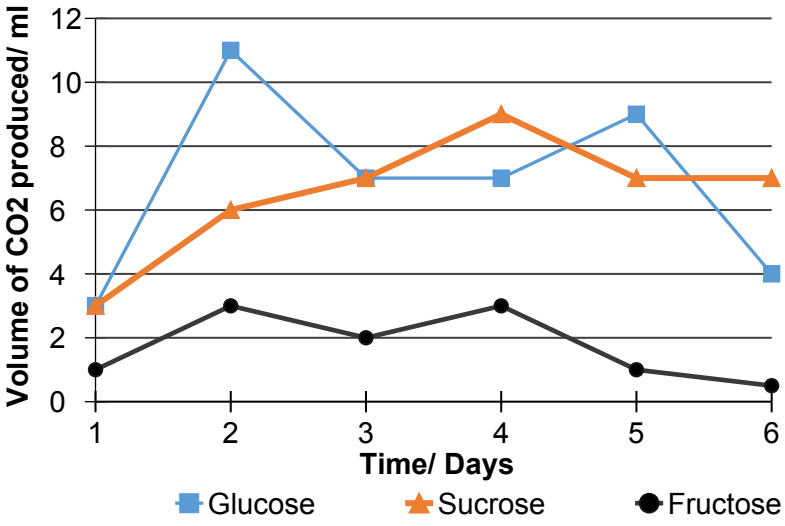

Fig. 7.2

(a) Describe how ethanol is formed by yeast.

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_____ [2]

(b) With reference to Fig. 7.1 and Fig. 7.2, explain the order in which the sugars were utilized by yeast for fermentation.

[4]

Fig. 7.3 shows a respirometer.

Fig. 7.3

Briefly explain how you can determine the rate of respiration using the set-up shown in Fig. 7.3.

[2]

Suggest how the compensation point of a plant will be affected when it undergoes anaerobic respiration.

[3]

[Total: 11]

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