12. Energy and Respiration

12.2 Respiration

Paper 4

Question Paper

1 **(a)** Fig. 6.1 is a diagram of part of a mitochondrion.

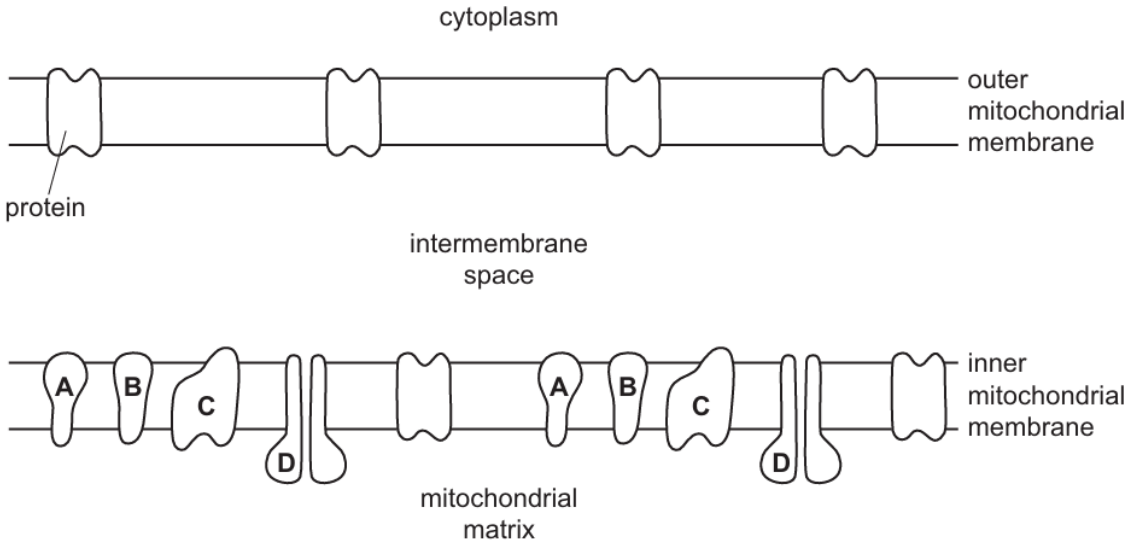


Fig. 6.1

On Fig. 6.1, use arrows to show the route taken by oxygen from the cytoplasm into the mitochondrial matrix. [1]

(b) Identify protein **D** and the group of proteins represented by **A**, **B** and **C and** describe their roles in oxidative phosphorylation.

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(c) The matrix of a mitochondrion contains small circular DNA. In the cells of humans, the mitochondria have circular DNA that contains 37 genes.

Suggest functions for these mitochondrial genes.

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..... [3]

2 Oxygen is needed for aerobic respiration in cells.

In eukaryotic cells, the mitochondrion is the organelle used for aerobic respiration.

(a) Fig. 1.1 shows a transmission electron micrograph of a mitochondrion.

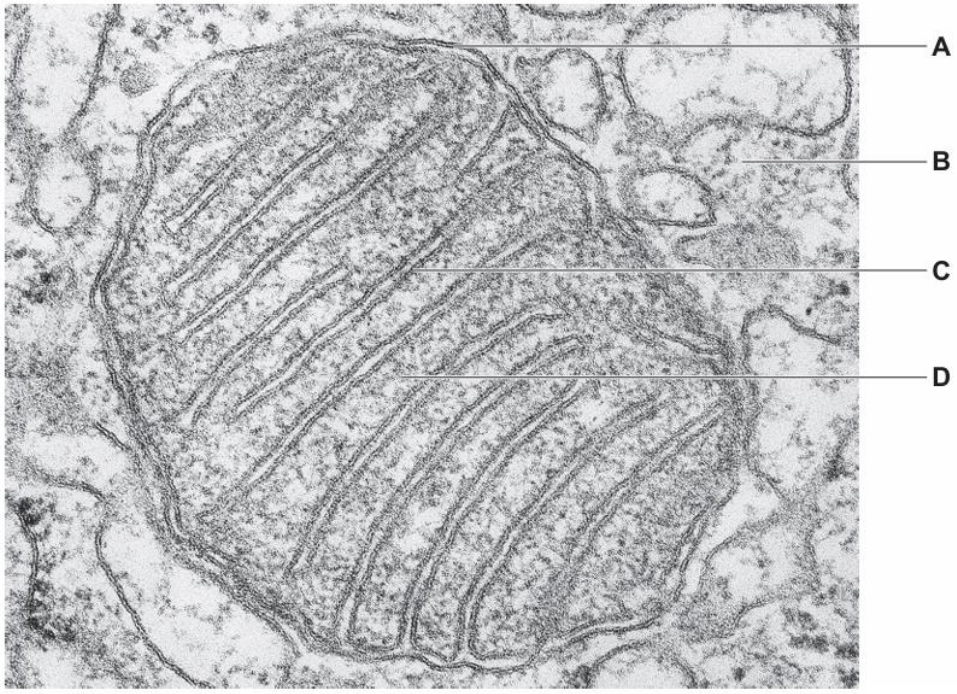


Fig. 1.1

Table 1.1 lists the four stages of aerobic respiration.

With reference to Fig. 1.1, complete Table 1.1 using the letters **A–D** to show where each stage occurs.

Each letter may be used once, more than once or not at all.

Table 1.1

stage of respiration	letter
glycolysis	.....
link reaction	.....
Krebs cycle	.....
oxidative phosphorylation	.....

[3]

(b) In anaerobic conditions, no ATP can be synthesised by oxidative phosphorylation because the process stops.

Explain why ATP synthesis by oxidative phosphorylation stops in anaerobic conditions.

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(c) Up to 60% of the ATP that is produced in cancer cells comes from lactate fermentation of glucose, even though oxygen is present.

Scientists are developing cancer treatments to inhibit the enzyme that catalyses the last step of lactate fermentation.

Explain how the inhibition of this enzyme reduces the production of ATP in cancer cells.

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3 **(a)** DCPIP is an indicator and can be used to determine the rate of respiration of organisms such as yeast.

(i) State the category of indicators to which DCPIP belongs.

..... [1]

(ii) Describe the colour change that occurs in DCPIP during experiments to determine the rate of respiration.

..... [1]

(b) An investigation was carried out to determine the effect of temperature on the rate of respiration of yeast.

- A suspension of yeast cells was added to a test-tube containing glucose solution.
- A further four test-tubes were set up in the same way.
- One test-tube was placed in a water-bath at 10 °C for 5 minutes.
- DCPIP was added to the test-tube and the time taken for the DCPIP to change colour was measured.
- The experiment was repeated using the other test-tubes at 20 °C, 30 °C, 40 °C and 50 °C.

The results are shown in Fig. 6.1.

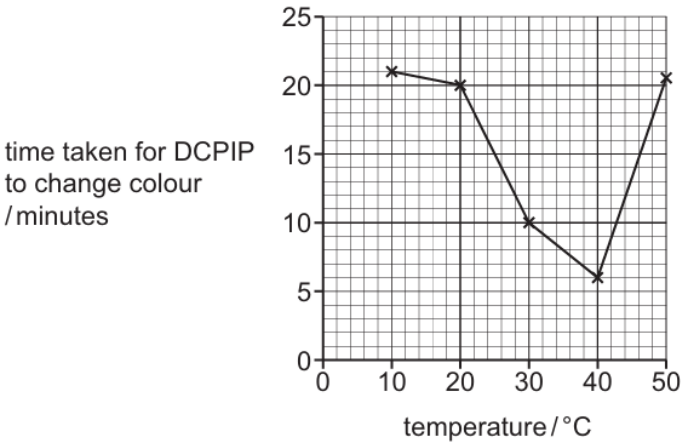


Fig. 6.1

(i) State **two** variables that need to be kept constant in this experiment.

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(ii) Explain the results shown in Fig. 6.1.

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4 During aerobic respiration, cells respire substrates such as glucose to produce ATP.

Some events that occur during aerobic respiration are:

- The respiratory substrate breaks down into smaller and smaller molecules. These series of reactions are described as catabolism.
- Coenzymes take part in various reactions. In some reactions, coenzymes are reduced or oxidised.
- Carbon dioxide is released.

(a) Aerobic respiration occurs in four successive stages: glycolysis (**G**), link reaction (**LR**), Krebs cycle (**KC**) and oxidative phosphorylation (**OP**).

Complete Table 3.1 to show which events occur in each stage of aerobic respiration. Use a tick (✓) to show that the event does occur or a cross (✗) to show that the event does **not** occur.

Table 3.1

event	stage			
	G	**LR**	**KC**	**OP**
catabolism				
coenzyme is reduced or oxidised				
a coenzyme forms a covalent bond with a respiratory intermediate				
carbon dioxide is released				

[4]

5 **(a)** Glycolysis is a biochemical pathway that occurs in the cytoplasm of cells.

In glycolysis, a molecule of glucose is metabolised to two molecules of pyruvate. The process is outlined in Fig. 1.1.

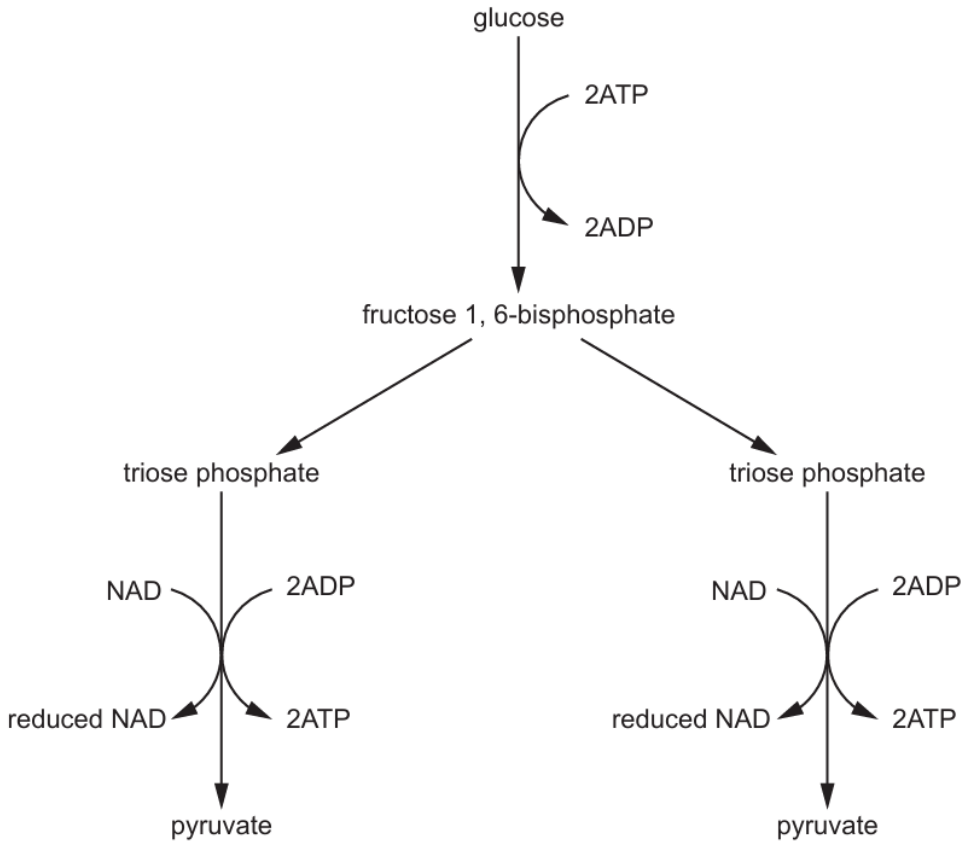


Fig. 1.1

(i) Explain why glucose is phosphorylated at the beginning of glycolysis.

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(ii) Suggest **one** use of the reduced NAD that is produced in glycolysis.

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..... [1]

(iii) Name the type of phosphorylation reaction by which ATP is made during glycolysis.

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(b) Pyruvate can enter the mitochondrion by active transport.

Describe the main conditions that are required for pyruvate to enter the mitochondrion by active transport.

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(c) Pyruvate is involved in the link reaction in the matrix of the mitochondrion.

Describe the link reaction.

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6 *Oryza* is a genus of grass plants that includes the rice, *Oryza sativa*, a food crop.

(a) Farmers flood fields of rice because this encourages faster growth and higher yields.

(i) An adaptation of rice plants that allows them to grow in water is the development of aerenchyma.

State the function of aerenchyma.

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..... [2]

(ii) State **one other** way in which the roots of rice are adapted to being submerged in water.

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..... [1]

7 Amino acids are the monomers that are used to produce proteins in organisms. Amino acids also have other, non-protein, roles in the body.

(a) Fig. 7.1 shows the structures of five amino acids with varying numbers and arrangements of carbon atoms.

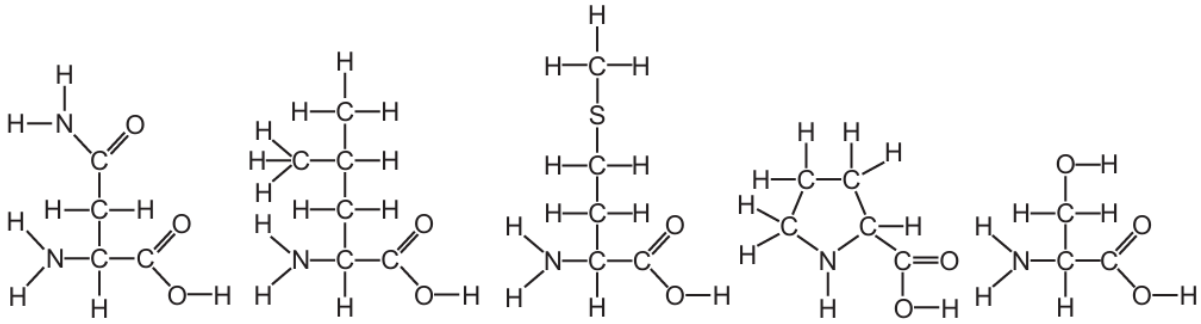


Fig. 7.1

In the liver, one of these amino acids can be converted to pyruvate and one of these amino acids can be converted to oxaloacetate.

Suggest which of the amino acids shown in Fig. 7.1 would be most directly converted to:

- pyruvate
- oxaloacetate.

amino acid converted to pyruvate .....

amino acid converted to oxaloacetate .....

[2]

8 Many factors affect the rate of cellular respiration.

(b) Coenzymes are important in aerobic respiration.

Outline the roles of named coenzymes in aerobic respiration.

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9 **(a)** Some organisms carry out respiration in anaerobic conditions when oxygen is not available or when there is a low concentration of oxygen. In yeast and some plants, this is called ethanol fermentation. In mammals, it is called lactate fermentation.

Fig. 1.1 outlines ethanol fermentation and lactate fermentation.

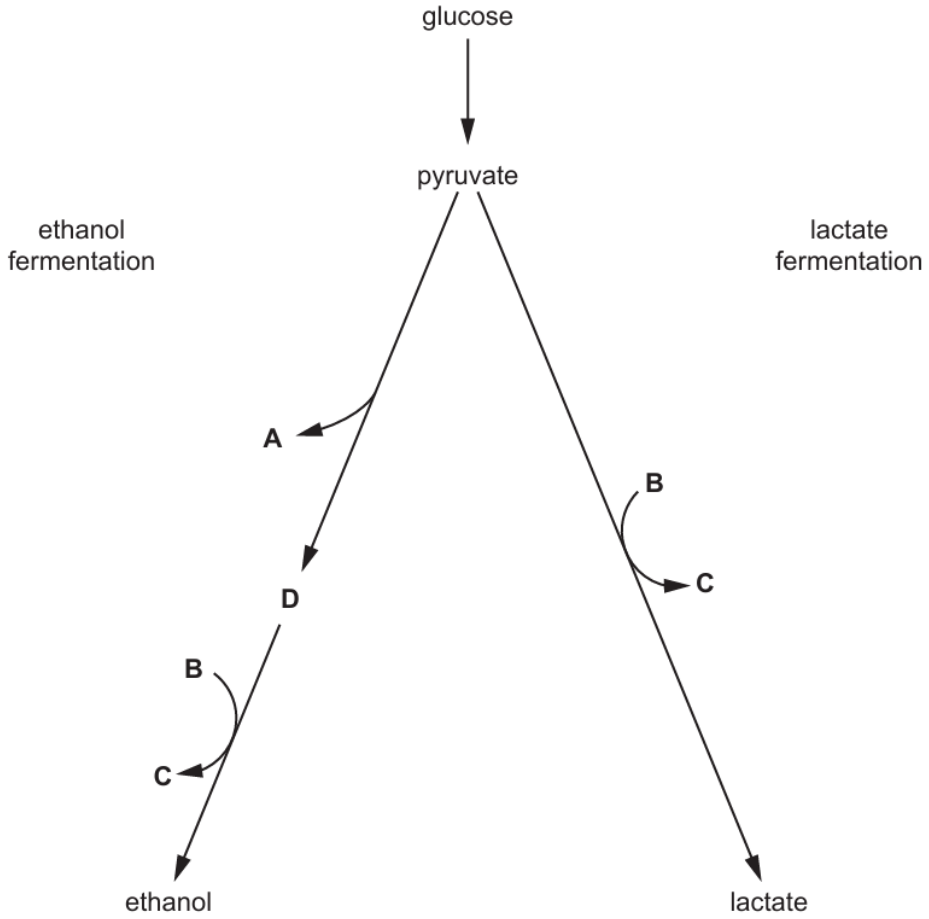


Fig. 1.1

Identify substances **A**–**D**.

A .....

B .....

C .....

D .....

[3]

(b) Explain how processes such as ethanol fermentation and lactate fermentation allow cells to continue to function in the absence of oxygen.

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..... [3]

(c) The cereal crop rice, *Oryza sativa*, grows in fields that are flooded with water. The roots of the rice plants are submerged in water that contains very little oxygen.

Describe **and** explain how rice plants are adapted to grow in flooded fields.

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10 **(b)** In anaerobic conditions, the production of ATP in mammals and yeast involves glycolysis and fermentation.

Describe the similarities **and** differences between fermentation in mammals and in yeast.

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..... [5]

11 **(a)** The results of investigations carried out on mitochondria show how the structure of a mitochondrion is related to its role in aerobic respiration.

- Intact mitochondria (not damaged) were removed from cells.
- A technique was used to remove the outer mitochondrial membrane, leaving the inner membrane intact.
- The inner mitochondrial membrane was separated from the contents of the matrix so that both could be analysed.

(i) The removal of the outer membranes of mitochondria involves placing the organelles in pure water. This results in the rupture (bursting) of the outer membrane. The inner mitochondrial membrane does not rupture and remains intact.

Suggest **and** explain why the inner membrane of a mitochondrion remains intact when the organelle is placed in pure water.

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(ii) Name **three** molecules, other than coenzymes, that are found in the mitochondrial matrix **and** explain their role in aerobic respiration.

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(iii) The inner membrane contains a very high proportion of the molecule cardiolipin. Cardiolipin makes the membrane impermeable to some ions.

Suggest why the inner membrane contains a very high proportion of cardiolipin.

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..... [1]

(b) In further experiments it was found that, in an intact mitochondrion:

- there is a membrane potential across the inner mitochondrial membrane, with the matrix having a negative charge
- the transport of ATP, ADP and inorganic phosphate (P_i) is driven by the membrane potential across the inner membrane.

Fig. 3.1 shows the location of some inner membrane carrier proteins.

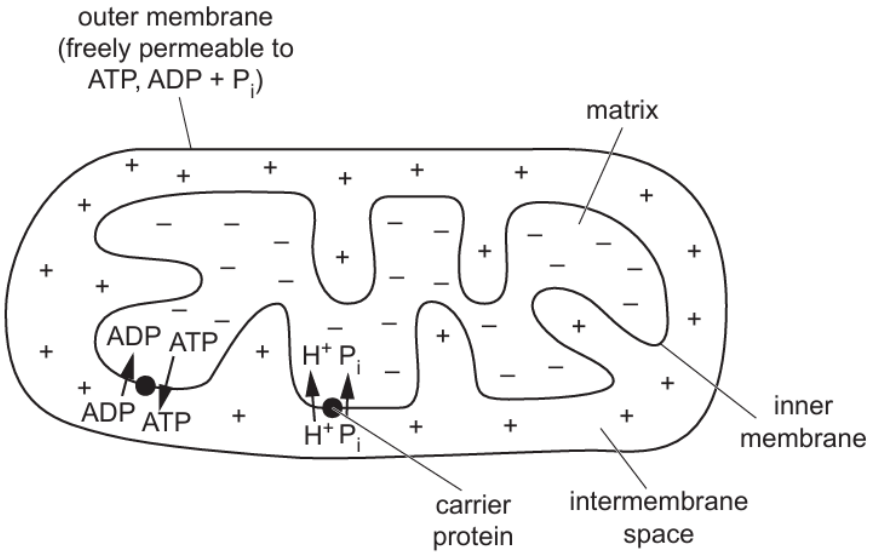


Fig. 3.1

(i) Reduced NAD and reduced FAD transfer hydrogen atoms to carriers located in the inner mitochondrial membrane.

Explain how hydrogen atoms from reduced NAD and reduced FAD lead to a membrane potential forming across the inner mitochondrial membrane during oxidative phosphorylation.

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(ii) Suggest **and** explain how P_i is transported across the inner membrane of the mitochondrion into the matrix.

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(iii) Suggest the advantages of linking ATP transport to ADP transport across the inner membrane of the mitochondrion.

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12 Respiration is a process that results in the synthesis of ATP. The ATP can be used within the cell for energy-requiring reactions and processes.

There are four stages in aerobic respiration: glycolysis, the link reaction, the Krebs cycle and oxidative phosphorylation.

(b) The first part of glycolysis uses ATP.

Explain why ATP is needed in the first part of glycolysis.

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(d) Explain what happens to pyruvate in the link reaction in aerobic respiration.

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(e) Chemiosmosis is a process that occurs in mitochondria during aerobic respiration and in chloroplasts during photosynthesis.

Describe the differences between the process of chemiosmosis in mitochondria and the process of chemiosmosis in chloroplasts.

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13 Aerobic respiration occurs when oxygen is available. A much greater energy yield is obtained from aerobic respiration than from respiration in anaerobic conditions.

(a) Explain why the link reaction only occurs when oxygen is available.

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(b) Outline the stage of aerobic respiration that occurs in the cytoplasm of eukaryotic cells.

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14 **(b)** Fur seals are mammals that are adapted to live in cold temperatures. Fur seals have large quantities of a type of fat tissue known as brown adipose tissue. Brown adipose cells contain many mitochondria. These mitochondria contain a transport protein called thermogenin.

Fig. 2.1 shows the role of thermogenin in a mitochondrion of a brown adipose cell when external temperatures are cold.

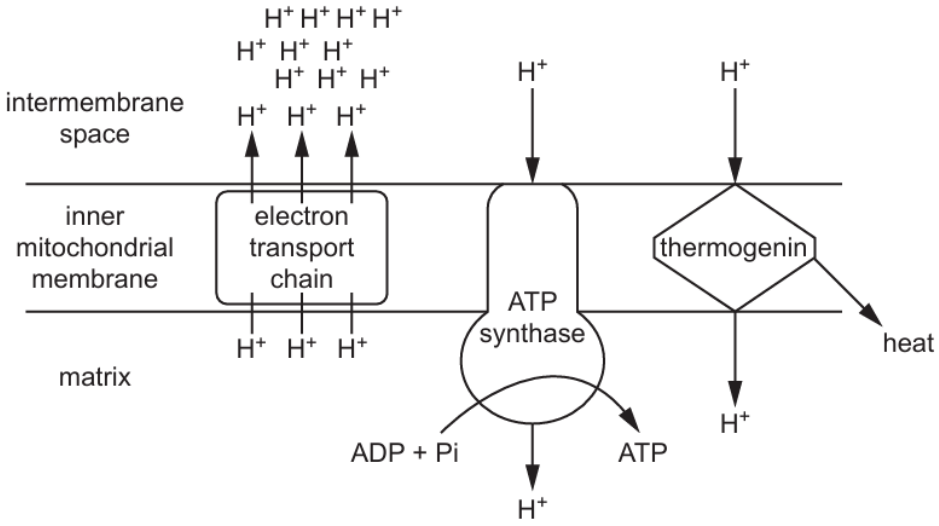


Fig. 2.1

(i) With reference to Fig. 2.1, describe **and** explain the effect of thermogenin on ATP synthesis.

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..... [3]

(ii) When the external temperature is warm, thermogenin cannot function.

When the external temperature becomes cold, thermogenin is able to function as a result of cell signalling:

- adrenaline is released
- adrenaline acts on brown adipose cells
- a sequence of events is triggered that results in the activation of the enzyme lipase
- lipase hydrolyses triglycerides in the cells into fatty acids
- fatty acids enter the mitochondrion
- thermogenin starts to function.

Outline the stages of cell signalling that trigger the functioning of thermogenin.

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..... [3]

15 **(a)** All organisms respire to release energy from energy-rich molecules such as glucose.

(i) Anabolic reactions **use** energy.

State **two** examples of anabolic reactions occurring in living organisms.

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..... [2]

(ii) Describe **and** explain the use of ATP in glycolysis.

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..... [3]

(b) Some factory workers in the early 20th century were exposed to chemical X and experienced serious side-effects.

Some of the effects of exposure to chemical X are:

- decreased production of ATP
- increased lipid metabolism, with weight loss
- increased production of pyruvate and lactate
- excess heat energy release, causing an increase in body temperature, which can be fatal.

Chemical X increases the permeability of the inner mitochondrial membrane to protons (hydrogen ions), causing some protons to leak out into the matrix.

(i) Explain why people exposed to chemical X show:

- decreased production of ATP
- increased lipid metabolism.

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..... [3]

(ii) Suggest **and** explain why chemical X causes increased production of pyruvate and lactate.

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..... [2]

(iii) Suggest why excess heat energy is released.

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..... [1]

16 **(b)** Fig. 6.1 is a diagram of mitochondrion.

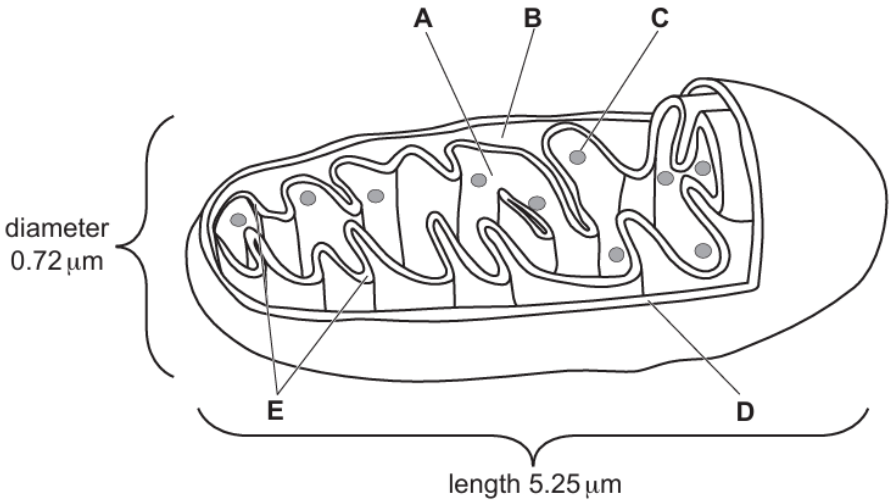


Fig. 6.1

(i) Complete Table 6.1 using the letters **A** to **E** from Fig. 6.1.

Each letter may be used once, more than once, or not at all.

Table 6.1

statement	letter
the site of the Krebs Cycle	.....
a phospholipid bilayer impermeable to H^+ ions	.....
the site of translation	.....

[2]

(ii) Assume that the mitochondrion in Fig. 6.1 is a cylinder.

Calculate the surface area of this mitochondrion.

Use the formula: Surface area of cylinder = $2\pi r^2 + 2\pi rh$

Show your working.

surface area = ... μm^2 [2]

(iii) The inner membrane of the mitochondrion has a much larger surface area than the outer membrane because of the presence of cristae.

Different cell types vary in the number of cristae present per mitochondrion. Cardiac muscle cells have mitochondria with a very large number of cristae.

Suggest **and** explain why cardiac muscle cells have mitochondria with very large numbers of cristae.

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..... [2]

17 **(c)** Dinitrophenol (DNP) is a compound used in the production of a number of products, including chemical dyes, insecticides and wood preservers. People who work in factories with DNP are at risk of exposure if they do not follow health and safety guidelines.

DNP is a molecule that can transport protons across the inner mitochondrial membrane, allowing protons to leak out of the intermembrane space.

(i) Suggest **and** explain the effects of DNP on aerobic respiration in human cells.

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..... [4]

(ii) Suggest **two** symptoms that may be experienced by people after exposure to DNP for several months.

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..... [2]

18 Fig. 6.1 outlines the first three stages of respiration in aerobic conditions.

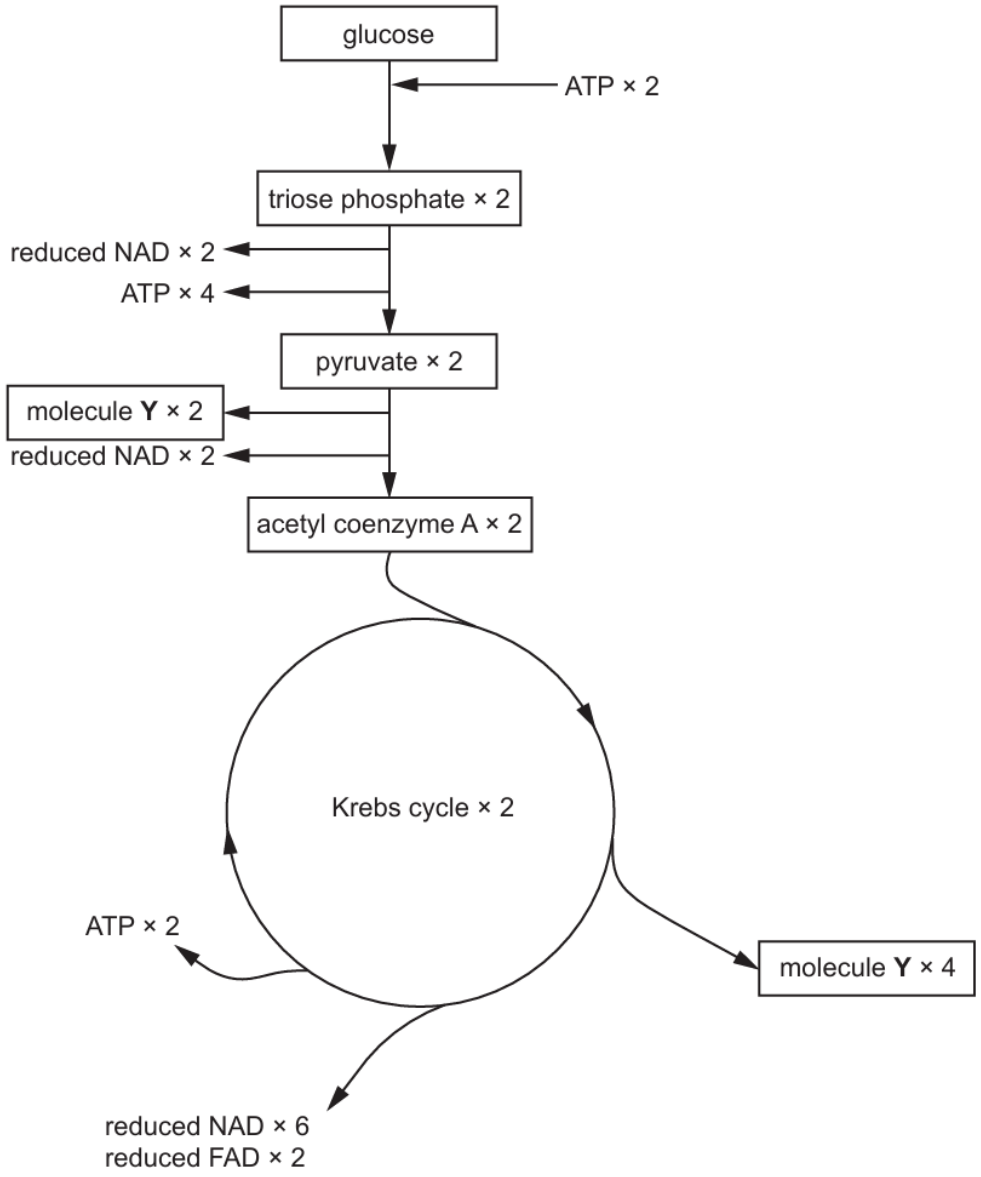


Fig. 6.1

(a) Name molecule **Y** in Fig. 6.1.

..... [1]

(b) Explain how Fig. 6.1 shows that glycolysis involves oxidation.

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..... [1]

(c) At one time it was thought that the oxidative phosphorylation of:

- one molecule of reduced NAD results in the synthesis of 3 ATP molecules
- one molecule of reduced FAD results in the synthesis of 2 ATP molecules.

Using Fig. 6.1, a theoretical value for the net number of ATP molecules that are synthesised for each molecule of glucose can be calculated.

Modern research has shown that the actual net number of ATP molecules synthesised for each glucose molecule respired is much lower than this theoretical value.

(i) Using Fig. 6.1, calculate the theoretical value for the net number of ATP molecules that are synthesised for each molecule of glucose respired in **all** phosphorylation reactions.

Show your working.

answer = ... [2]

(ii) Suggest **two** reasons why the actual net number of ATP molecules synthesised is less than the theoretical number.

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..... [2]

(d) Outline the roles of NAD and FAD in aerobic respiration.

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..... [3]

(e) Rotenone is used as an insecticide. Rotenone kills insects by inhibiting the transfer of electrons in the electron transport chain of the mitochondrion.

Explain how rotenone affects ATP synthesis in the mitochondrion.

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..... [3]

19 Mitochondrial complex I is a large enzyme complex that forms part of the electron transport chain. The enzyme is composed of many different polypeptides.

The genes coding for these polypeptides are located either in mitochondrial DNA (mtDNA) or in nuclear DNA. Mutations in these genes can lead to the production of an enzyme that does not function efficiently. This results in a disease known as mitochondrial complex I deficiency. If severe, this can lead to death in early childhood.

(a) Explain why people with mitochondrial complex I deficiency may have muscle weakness and difficulty with nervous coordination of movement.

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..... [2]

20 **(a)** At the end of glycolysis in mammalian muscle tissue, pyruvate is formed. Pyruvate can be further metabolised along two different pathways, pathway 1 and pathway 2.

Fig. 6.1 outlines the two pathways.

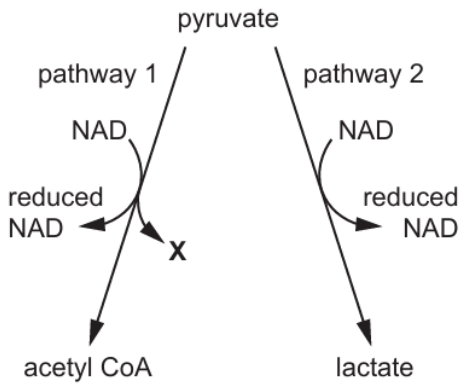


Fig. 6.1

(i) State the condition under which pyruvate would be metabolised along pathway 2.

..... [1]

(ii) Name compound **X**.

..... [1]

(iii) Name the two **types** of reaction that are involved in pathway 1.

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..... [2]

(iv) Suggest a cell in a mammal that **cannot** carry out pathway 1.

Give a reason for your answer.

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..... [2]

(v) ATP is synthesised during glycolysis.

Name the process by which ATP is synthesised.

..... [1]

21 **(b)** Some plants, such as rice, are adapted to grow when partially submerged in water.

Describe **and** explain the adaptations that allow rice plants to survive in waterlogged fields.

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..... [3]

22 **(a)** Structures and compounds involved in respiration in anaerobic conditions include:

A – pyruvate

B – reduced NAD

C – ethanol

D – carbon dioxide

E – cytoplasm

F – NAD

G – ethanal

H – lactate

I – oxygen

J – mitochondrion

Complete Table 7.1 by matching each description with **one** letter chosen from **A** to **J** to show the correct structure or compound.

You may use each letter once, more than once or not at all.

Table 7.1

description	letter
end product of glycolysis	
cellular location of respiration in anaerobic conditions	
end product of respiration in anaerobic conditions in yeast cells	
compound used to reduce pyruvate	
end product of respiration in anaerobic conditions in muscle cells	
gas released during alcoholic fermentation	

[6]

(b) Respiration in anaerobic conditions in muscle cells during vigorous exercise can create an oxygen debt. Extra oxygen is breathed in after exercise to pay back the oxygen debt.

Explain **two** ways in which the mammalian body uses this **extra** oxygen.

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..... [2]

23 The passage below outlines the process of oxidative phosphorylation in mitochondria.

Complete the passage by using the most appropriate scientific terms.

Reduced ..... releases hydrogen atoms to cytochrome carriers.

Hydrogen atoms split into protons and electrons and the electrons are passed from carrier to carrier. Energy from electron transfer is used to pump protons into the

..... , so that a proton gradient is set up across the

..... .

Protons ..... through the channel protein known as

..... , into the matrix, producing ATP. The protons combine with electrons and ..... atoms to form water.

24 **(a)** Oxidative phosphorylation takes place in the mitochondrion.

Table 8.1 shows the different stages of oxidative phosphorylation.

The stages are **not** listed in the correct order.

Table 8.1

stage	description of stage
Q	protons diffuse through the membrane proteins into the matrix
R	a proton gradient is set up across the crista membrane
S	hydrogen atoms split into protons and electrons
T	protons combine with electrons and oxygen atoms to form water
U	electrons are passed from carrier to carrier
V	reduced NAD releases hydrogen atoms to cytochrome carriers
W	energy from electron transfer is used to pump protons into the intermembrane space
X	ATP synthase produces ATP

Complete Table 8.2 to show the correct order of the stages.

Two of the stages have been completed for you.

Table 8.2

correct order	letter of stage
1	**V**
2	.....
3	.....
4	.....
5	**R**
6	.....
7	.....
8	.....

[4]

(b) State the precise location in a mitochondrion of each of the following.

ATP synthase .....

Krebs cycle .....

electron transport chain .....

coenzyme A .....

pyruvate .....

[5]

25 **(a)** The link reaction and Krebs cycle take place in the mitochondrion.

The main stages of the link reaction and Krebs cycle are listed in Table 4.1.

They are **not** listed in the correct order.

Table 4.1

stage	description of stage
A	acetyl group combines with coenzyme A to form acetyl CoA
B	citrate is formed
C	hydrogen atoms are accepted by NAD and FAD
D	oxaloacetate is regenerated
E	pyruvate enters the mitochondrial matrix
F	acetyl group is formed
G	acetyl CoA enters Krebs cycle
H	ATP is made by substrate-linked phosphorylation
I	pyruvate is decarboxylated and dehydrogenated
J	acetyl CoA combines with oxaloacetate
K	citrate is decarboxylated and dehydrogenated

Complete Table 4.2 to show the correct order of the stages.

Three of the stages have been done for you.

Table 4.2

correct order	letter of stage
1	**E**
2	.....
3	.....
4	.....
5	.....
6	**J**
7	.....
8	.....
9	.....
10	.....
11	**D**

[4]

(b) Outline the role of NAD in respiration in aerobic conditions.

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..... [4]

(c) Carbon dioxide is removed from compounds in the link reaction and Krebs cycle by decarboxylation.

(i) State the total number of molecules of carbon dioxide removed in the link reaction and Krebs cycle for each molecule of glucose respired.

..... [1]

26 Fig. 6.1 is an outline diagram showing two stages of aerobic respiration.

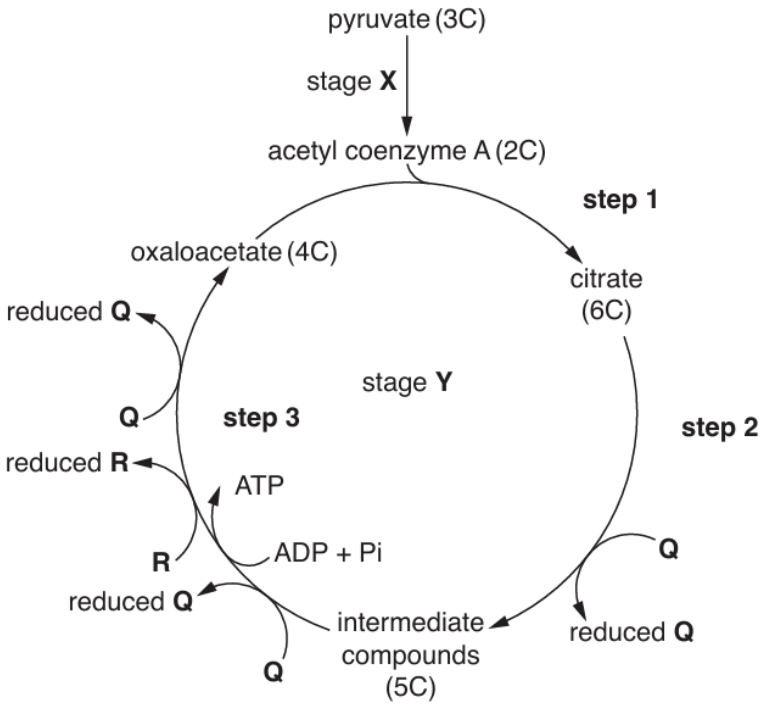


Fig. 6.1

(a) With reference to Fig. 6.1:

name stage **X**

.....

state the precise location of stage **Y**

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state the numbered steps in stage **Y** in which decarboxylation occurs

.....

name the type of reaction by which ATP is made during **step 3**

.....

name substances **Q** and **R**.

.....[5]

(b) Uncontrolled cell division can lead to a cancerous tumour. Many cancer cells break down the amino acid glutamine and convert it to a 5-carbon intermediate compound, which is shown in Fig. 6.1.

Suggest how the breakdown of glutamine can lead to the production of ATP in a cancer cell, other than that directly produced during **step 3**.

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.....[2]

27 **(a)** Fig. 6.1 shows a transmission electron micrograph of a section through a mitochondrion.



Fig. 6.1

Table 6.1 shows some structures and compounds involved in aerobic respiration.

Use letter **P** or letter **Q** from Fig. 6.1 to complete Table 6.1 to show the location of the structures and where the compounds are used.

Table 6.1

compound or structure	location
ATP synthase	.....
acetyl CoA	.....
phospholipid bilayer	.....
oxaloacetate	.....

[3]

(b) The number of mitochondria differs from cell to cell. Cells also vary in size and volume.

Table 6.2 shows the mean number of mitochondria per cell, the mean cell volume and the mean number of mitochondria per μm^3 of three types of mammalian cells.

Table 6.2

cell type	mean number of mitochondria per cell	mean cell volume / μm^3	mean number of mitochondria per μm^3
fat cell	100	600 000	0.17×10^{-3}
heart cell	2000	45 000	44.44×10^{-3}
liver cell	2000	125 000	.....

(i) Calculate the mean number of mitochondria per μm^3 for the liver cell.

Write your answer in Table 6.2. [1]

(ii) Suggest reasons for the difference in mean number of mitochondria per μm^3 between the fat cell and the heart cell.

.....

.....

.....

.....[2]

(iii) Suggest why it is difficult to compare the ability of the three types of cell to respire aerobically, based **only** on the mean number of mitochondria per cell.

.....

.....

.....[1]

28 **(a)** Fig. 6.1 outlines some of the steps of glycolysis.

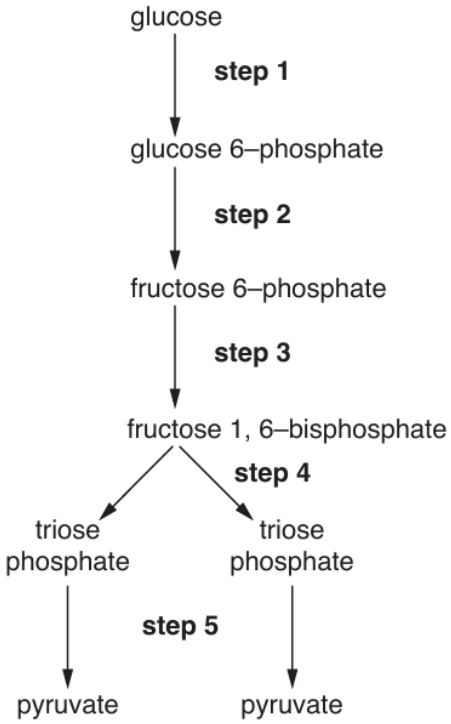


Fig. 6.1

(i) State the precise location of glycolysis in the cell.

..... [1]

(ii) With reference to Fig. 6.1:

state the steps where phosphorylation occurs

.....

state the step where oxidation occurs

.....

name the type of reaction by which ATP is made during **step 5**.

.....
[3]

(b) Some cancer cells have different metabolic requirements from normal cells. These cancer cells obtain most of their ATP from glycolysis, even if oxygen is available.

State how the glucose and oxygen requirements of these cancer cells differ from normal cells.

.....

.....

.....

.....

.....

..... [2]