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# VCE Biology ¾

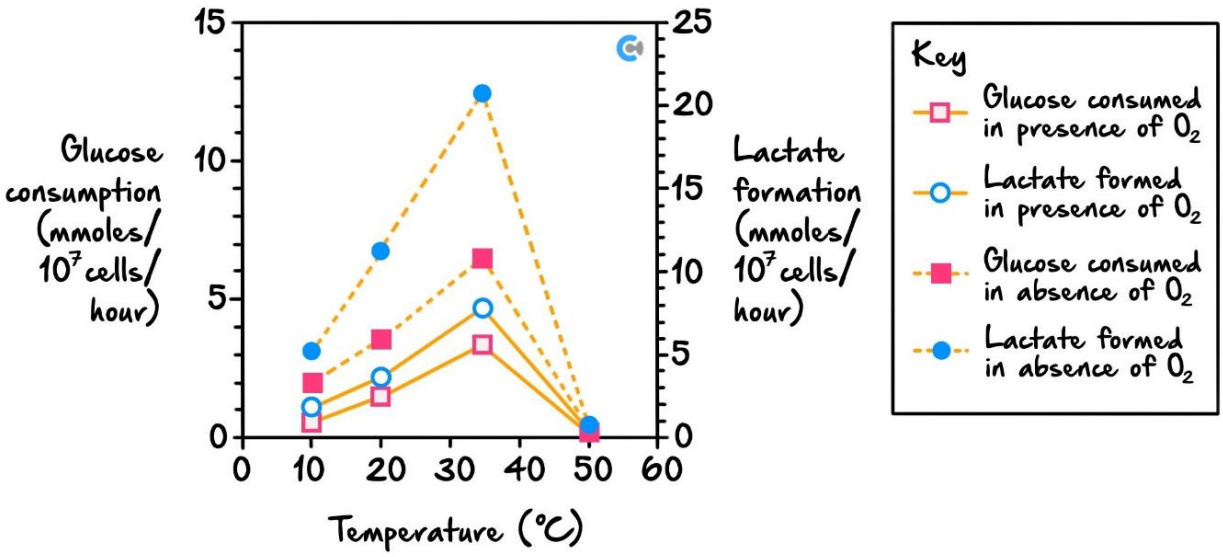
## Cellular Respiration & Anaerobic Fermentation [0.10]

## Workshop

## Section A: Multiple Choice Questions (21 Marks)

**Question 1** (1 mark)

The graph below shows the effect of temperature and oxygen on the rate of consumption of glucose and the corresponding rate of production of lactate in white blood cells at four different temperatures (10°C, 20°C, 35°C, and 50°C).




Under which of the following conditions is the rate of lactate formation highest?

**A.** 10°C in the absence of oxygen.

**B.** 20°C in the absence of oxygen.

**C.** 35°C in the presence of oxygen.

**D.** 50°C in the presence of oxygen.

**Question 2** (1 mark)

Why is the rate of consumption of glucose higher in the absence of oxygen than in its presence at 35°C?

**A.** Oxygen stimulates lactate formation.

**B.** Oxygen inhibits the uptake of glucose by the cell.

**C.** Glycolysis reactions require the presence of oxygen.

**D.** Less ATP is formed from glucose in the absence of oxygen.

**Question 3** (1 mark)

Why are the rates of consumption of glucose and formation of lactate at 50°C the same irrespective of oxygen levels?

**A.** Most of the enzymes involved in glycolysis have become denatured.

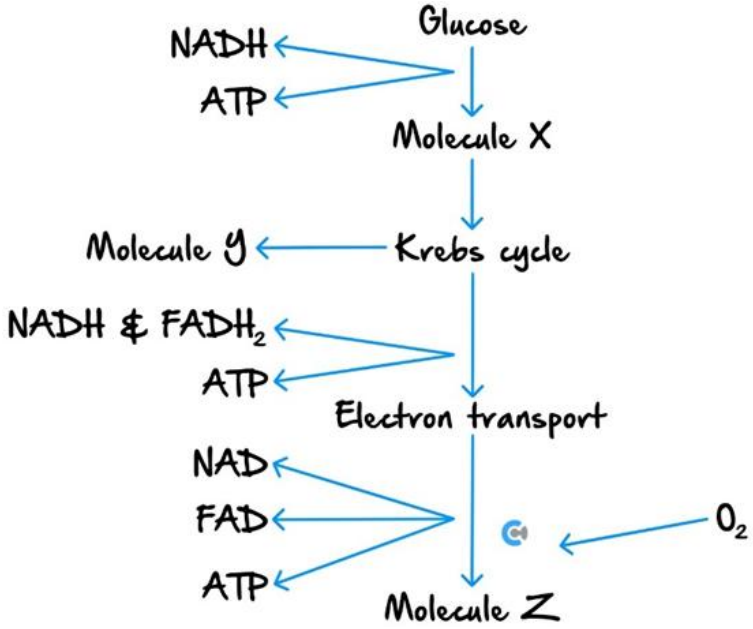
**B.** Glucose is converted to ATP by a single chemical reaction.

**C.** At 50°C the cell uses heat as a source of energy.

**D.** At 50°C metabolic pathways are very efficient.

*The following information applies to the three questions that follow.*

The flowchart shows the process of cellular respiration in an eukaryotic cell.




**Question 4** (1 mark)

Molecules $X, Y$ and $Z$ respectfully are:

**A.** Carbon dioxide, pyruvate and water.

**B.** Pyruvate, water and carbon dioxide.

**C.** Pyruvate, carbon dioxide and water.

**D.** Water, carbon dioxide and pyruvate.

**Question 5** (1 mark)

Molecule *X* is produced in the:

**A.** Cristae of the mitochondria.

**B.** Grana.

**C.** Cytosol.

**D.** Mitochondrial matrix.

**Question 6** (1 mark)

Inputs of the electron transport stage include:

**A.** NADH, $FADH_2$, ADP + Pi, oxygen.

**B.** NADH, $FADH_2$, ATP, water.

**C.** NAD+, FAD+, ADP + Pi, ATP.

**D.** NADP, $FADH_2$, ADP + Pi, oxygen.

**Question 7** (1 mark)

The build-up of lactic acid in the muscle cells of weight-lifters is the result of anaerobic conditions and:

**A.** Rapid ATP production during the Krebs cycle.

**B.** Rapid ATP production during glycolysis.

**C.** Slow ATP production during electron transport.

**D.** Slow ATP production during cellular respiration.

Space for Personal Notes

**Question 8** (1 mark)

A change in which of the following would **not** affect the rate of anaerobic cellular respiration?

**A.** Oxygen concentration.

**B.** Glucose concentration.

**C.** ATP production.

**D.** Temperature.

**Question 9** (1 mark)

Some species of bacteria can be added to biomass to produce bioethanol, a renewable source. The production of bioethanol involves the breakdown of starch:

**A.** By glycolysis followed by alcoholic fermentation.

**B.** Via aerobic respiration followed by carbon dioxide production.

**C.** Through the Krebs cycle followed by lactic acid fermentation.

**D.** In the presence of oxygen followed by fermentation energy.

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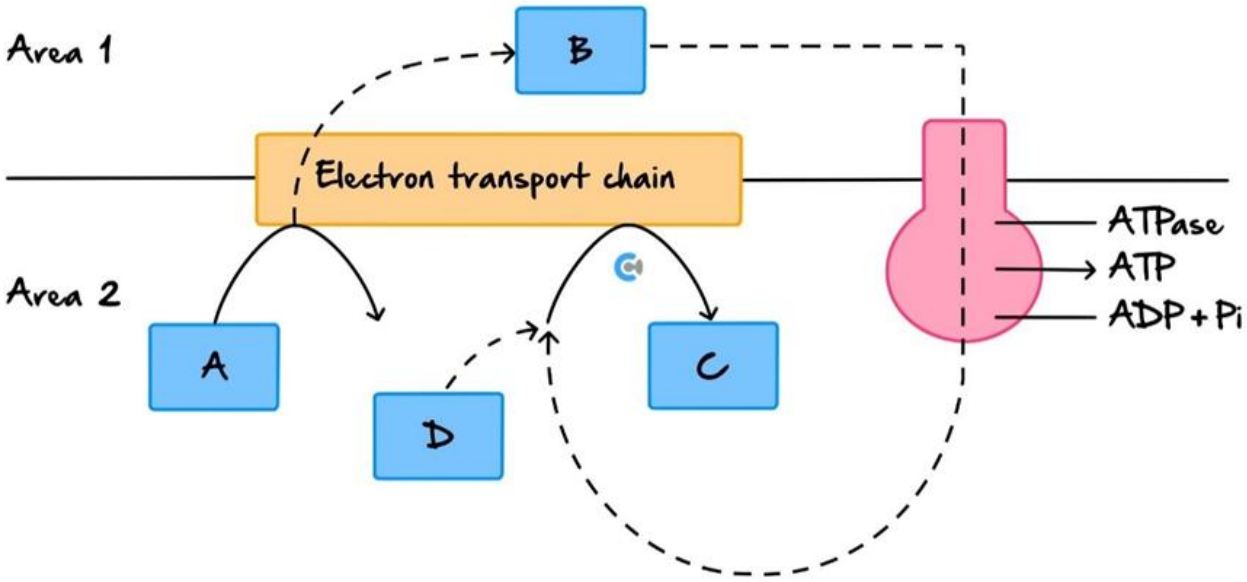
**Question 10** (1 mark)

The diagram below shows a reaction that occurs in most eukaryotic cells. Chemicals *A*-*D* are involved in the process.




Which one of the following identifies chemicals *A*-*D*?

| | Chemical *A* | Chemical *B* | Chemical *C* | Chemical *D* |
|---|---|---|---|---|
| **A.** | NADPH | Hydrogen | Oxygen | Water |
| **B.** | Oxygen | NADH | Water | Hydrogen |
| **C.** | Water | Carbon dioxide | Oxygen | Hydrogen |
| **D.** | NADH | Hydrogen | Water | Oxygen |

**Question 11** (1 mark)

The role of oxygen in aerobic cellular respiration is:

**A.** As a reactant in glycolysis.

**B.** As a waste product in the Krebs cycle.

**C.** As a reactant to produce acetyl-CoA.

**D.** As an electron acceptor in the electron transport chain.

**Question 12** (1 mark)

Identify the correct statement below.

**A.** The Krebs cycle produces NADPH.

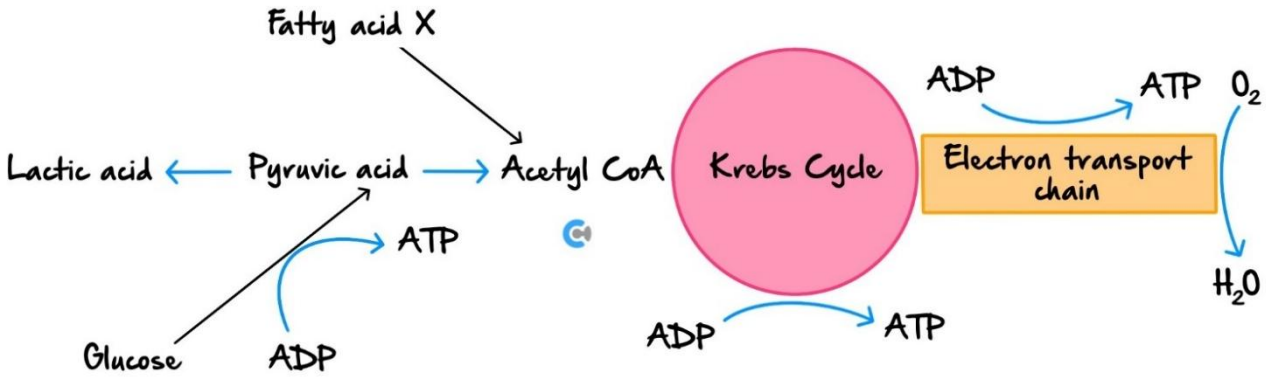
**B.** Glycolysis produces 1 ATP molecule.

**C.** The electron transport chain produces water.

**D.** More ADPs are used in glycolysis than in other stages.

**Question 13** (1 mark)

If there is insufficient glucose for cellular respiration, fatty acids can be changed to acetyl CoA. Each fatty acid *X* molecule produces eight molecules of acetyl CoA.
The diagram below summarises the pathways for the breakdown of fatty acid *X* and glucose. The number of molecules produced in each step is not shown.




Referring to the information above and your knowledge of cellular respiration, which one of the following conclusions can be made?

**A.** Most of the ATP is made in the Krebs Cycle.

**B.** Pyruvic acid is converted to acetyl CoA under anaerobic conditions.

**C.** No ATP can be formed from the breakdown of glucose under anaerobic conditions.

**D.** One fatty acid *X* molecule produces more ATP in aerobic conditions than one glucose molecule does.

Space for Personal Notes

**Question 14** (1 mark)

The following reaction represents the ATP cycle:

$$\mathrm{ATP} + \mathrm{H_2O} \leftrightarrows \mathrm{ADP} + P_i$$

A reasonable conclusion to make about the ATP cycle would be:

**A.** The formation of ATP is a catabolic reaction requiring an input of energy.

**B.** The formation of ADP from ATP would occur while digesting fats.

**C.** The formation of ATP from ADP and the formation of ADP from ATP would occur in the same cellular location.

**D.** The formation of ATP is an example of a condensation reaction that is anabolic and endergonic.

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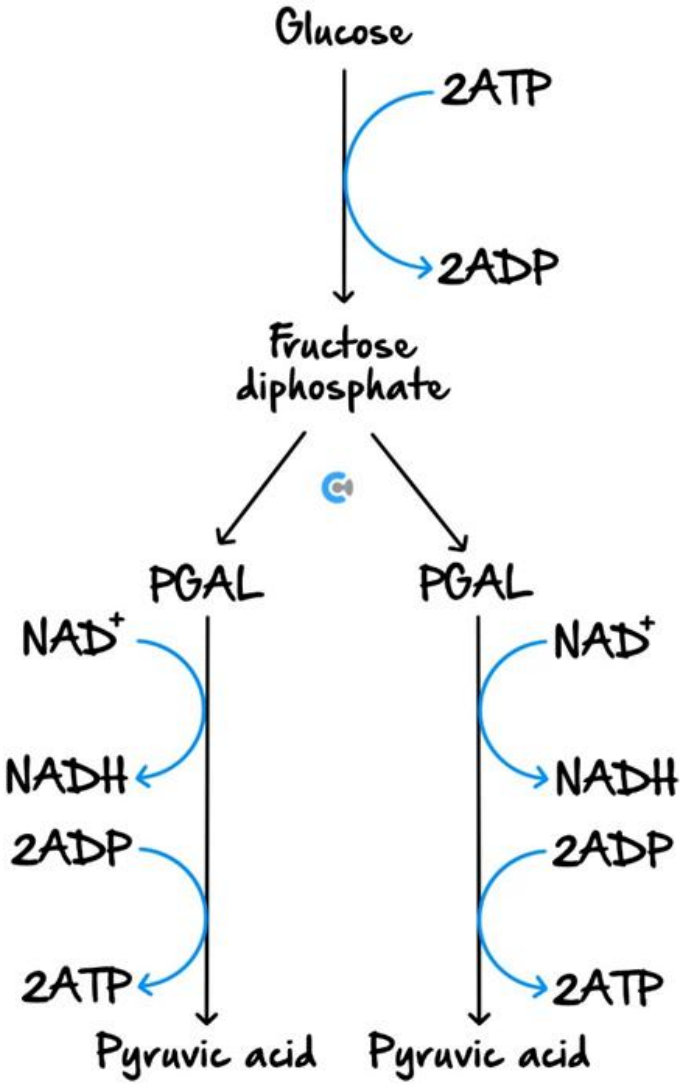
*The following information applies to the two questions that follow.*

The following chemical pathway proceeds in virtually all cells.




**Question 15** (1 mark)

The name of the above chemical pathway is:

**A.** The Krebs cycle.

**B.** The electron transport chain.

**C.** The link reaction.

**D.** Glycolysis.

**Question 16** (1 mark)

The products and by-products of this reaction are:

**A.** Pyruvic acid, ATP, ADP and NADH.

**B.** 2 pyruvic acid, 2 ATP and 2 NADH.

**C.** 2 pyruvic acid.

**D.** 2 ATP and 2 NADH.

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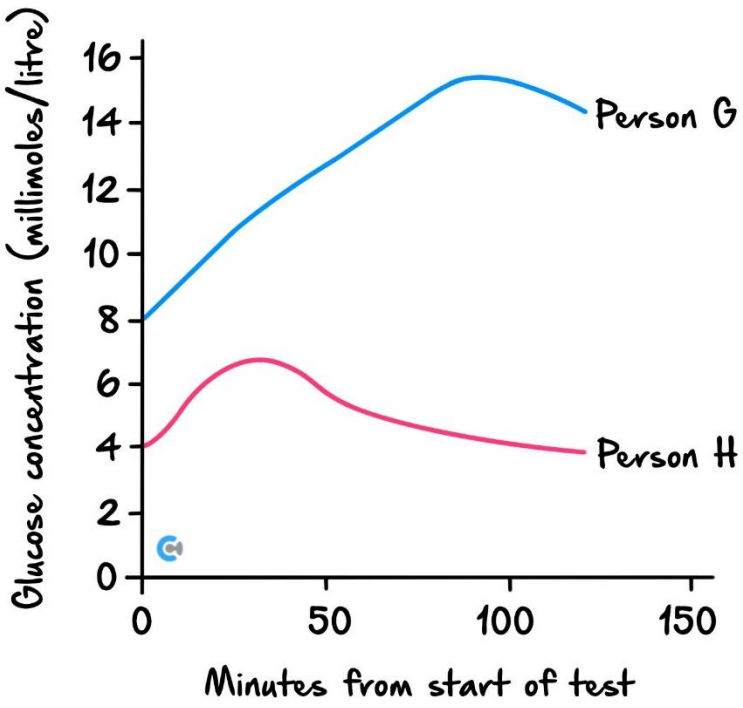
**Question 17** (1 mark)

Gestational diabetes mellitus (GDM) is a condition that is diagnosed when higher-than-normal blood glucose levels first appear during pregnancy. In Australia, 8-10% of pregnant women will develop GDM around the $24^{th}$ to $28^{th}$ week of pregnancy, which is why routine screening occurs at this time. Women take a glucose challenge test that involves drinking a glucose solution and testing the amount of glucose that remains in the blood after one hour.
The graph shows the results of GDM glucose challenge tests that were taken by two women.




From the graph, it is possible to conclude that:

**A.** Person $G$ does not have diabetes as the amount of glucose in her blood begins to decline after around 100 minutes after drinking the glucose solution.

**B.** Person $H$ does not have diabetes as the level of glucose in her bloodstream peaks for a short time and then returns to its original level.

**C.** Both patients have diabetes.

**D.** Neither patient has diabetes.

Space for Personal Notes

**Question 18** (1 mark)

Which one of the following gives a biochemical reaction correctly linked with its corresponding cellular location?

**A.** The light-independent reaction occurs within the lumen of the grana inside the chloroplast.

**B.** ATP hydrolysis occurs at the ribosomes in the cytosol.

**C.** Glycolysis occurs within the matrix of the mitochondria.

**D.** The Krebs cycle occurs within the stroma of the chloroplast.

**Question 19** (1 mark)

A patient is diagnosed with a rare disease that impairs the function of Complex I of the electron transport chain in mitochondria.

What is the most likely consequence of this dysfunction on cellular respiration?

**A.** Increased efficiency of glycolysis.

**B.** Decreased production of ATP during oxidative phosphorylation.

**C.** Enhanced activity of the Krebs cycle.

**D.** Increased lactic acid production in the absence of oxygen.

**Question 20** (1 mark)

Which of the following correctly identifies which loaded carriers are produced during the Krebs cycle?

**A.** NADH only.

**B.** $FADH_2$ only.

**C.** NADH and $FADH_2$.

**D.** NADPH and $FADH_2$.

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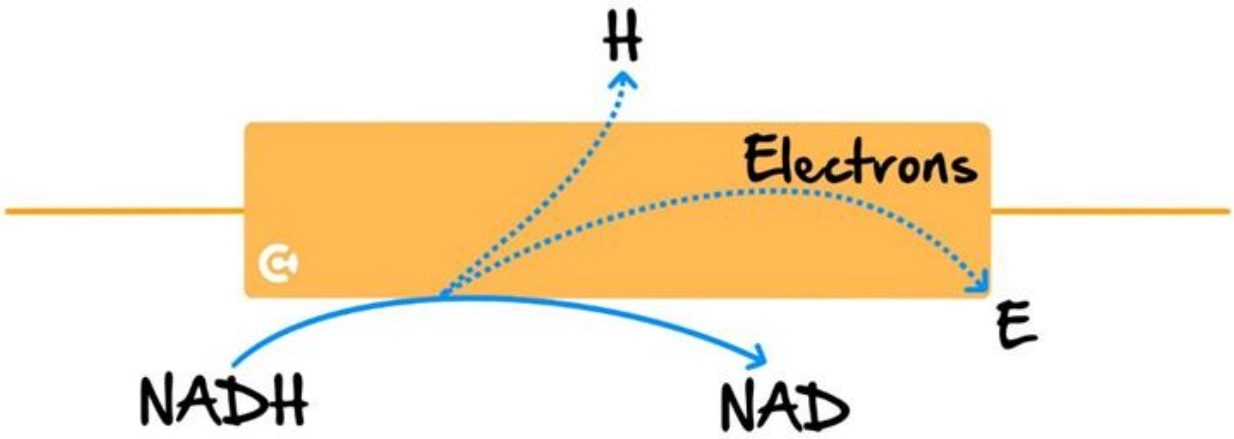
**Question 21** (1 mark)

The diagram below simplifies what occurs to NADH at the cristae of the mitochondria. The electrons ($E$) are available for oxygen to eventually form water. The hydrogen ($H$) forms a concentration gradient across the mitochondrial membrane.




Once the NADH offloads its hydrogen and electrons, it would:

**A.** Collect more hydrogen from the breakdown of molecules in the Krebs cycle.

**B.** Collect more hydrogen from the breakdown of water within the grana.

**C.** Digest the NAD into raw materials so it can be recycled.

**D.** Move to the cytosol to collect more hydrogen from the condensation of amino acids at the ribosome.

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## Section B: Short Answer Questions (105 Marks)

**Question 22** (9 marks)

The process of cellular respiration is a biochemical pathway with a few key steps.

Fill in the tables with inputs, outputs, and locations of each step.

**a.** Glycolysis. (3 marks)

| Inputs | Outputs | Location |
|---|---|---|
| | | |
| | | |
| | | |

**b.** Krebs Cycle. (3 marks)

| Inputs | Outputs | Location |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

**c.** Electron Transport Chain. (3 marks)

| Inputs | Outputs | Location |
|---|---|---|
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**Question 23** (6 marks)

Scientists measured the metabolic activity of mammalian cells by measuring the uptake of glucose into the cells. The cells were maintained at 37°C with a pH of 7.4 and suspended in a nutrient solution containing glucose. The uptake of glucose into the cells was recorded for the next 30 minutes.

**a.** Explain why the uptake of glucose into the cells could be used to measure the metabolic activity of the cells. (2 marks)

**b.** The scientists repeated the experiment. They kept all conditions the same as for the first experiment, except that the cells were kept in low-oxygen conditions.

Would the uptake of glucose into the cells be expected to be higher, lower, or the same as for the first experiment? Justify your response. (4 marks)

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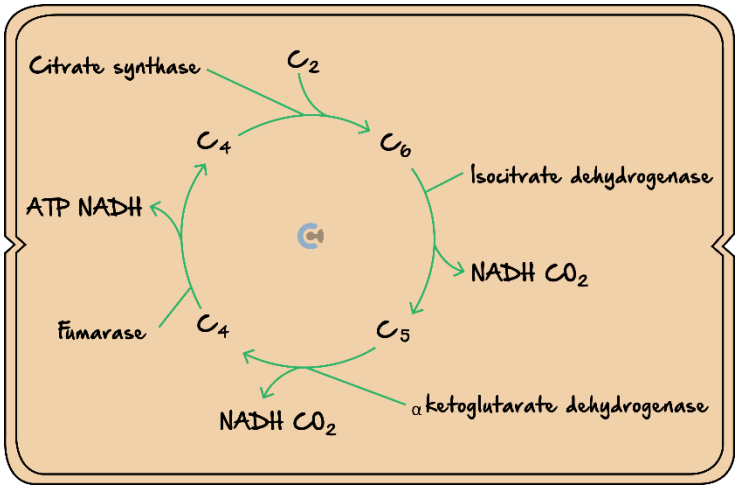
**Question 24** (6 marks)

A simplified version of a stage of cellular respiration that occurs in the matrix of the mitochondria is shown in the diagram below.

**Note:** $C_2$, $C_4$, $C_5$, and $C_6$ are different-sized carbon molecules ($C_2$ represents two carbon atoms in the molecule, $C_4$ represents four carbon atoms, and so on).




**a.**

**i.** Name the stage of cellular respiration illustrated in the diagram. (1 mark)

_____

_____

**ii.** State the outputs from the simplified diagram of this stage of cellular respiration. (1 mark)

_____

_____

**b.** Describe the function of citrate synthase. (2 marks)

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**c.** Fumarase deficiency is a very rare genetic disorder that causes individuals with the condition to have extremely low levels of fumarase.

Use the information provided with the simplified version of cellular respiration to describe **two** effects of fumarase deficiency. (2 marks)

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**Question 25** (11 mark)

Anaerobic Respiration is one mechanism by which glucose can be metabolised in animals, plants, and bacteria.

**a.** What is meant by the phrase 'anaerobic'? (1 mark)

_____

_____

**b.** Other than ethanol, what is the product of this process (anaerobic respiration)? (1 mark)

_____

_____

A limitation of using this process to manufacture bioethanol is the toxicity of ethanol to the cell, which causes death in most cases. A proposed method to solve this limitation is to increase the activity of alcohol dehydrogenase (which metabolises ethanol) by genetic editing via CRISPR-Cas9.

**c.** Describe the process by which the scientist can edit the gene coding for alcohol dehydrogenase using CRISPR-Cas9. (3 marks)

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**d.** Evaluate the suitability of using this method for optimising bioethanol production. (2 marks)

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Another method proposed by which ethanol production can be optimised is by introducing a gene coding for a synthetic cellulase into either sugarcane or yeast cells and causing the gene to be expressed in large quantities. Cellulase breaks down cellulose, a major component of plant cell walls, into glucose.

**e.** Explain, with reference to cellulase's function, how the overexpression of the cellulase gene would lead to increased rates of bioethanol production. (2 marks)

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**f.** Explain whether it is more suitable to introduce the cellulase transgene into sugarcane cells or yeast cells in aiming to optimise bioethanol production. (2 marks)

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**Question 26** (10 marks)

A scientist isolated mitochondria from a muscle cell and placed them inside an appropriate solution with a suitable substrate, ADP and inorganic phosphate, as well as other relevant coenzymes. Oxygen was bubbled through the solution. The scientist decided against using glucose as a substrate for this experiment. Each solution would be placed at a different temperature.

**a.** Why is glucose not suitable as a substrate? (1 mark)

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**b.** How would you expect the oxygen levels to change around the mitochondria? Explain. (2 marks)

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_____

**c.** Why is it important for an electron acceptor to be present in aerobic cellular respiration, and why does the Krebs cycle also not occur in the absence of one? (3 marks)

**d.** What would you expect the differences in the oxygen level changes to be between the different solutions? Explain. (2 marks)

**e.** What other factors would need to be maintained if this experiment is to be valid? Name 2. (2 marks)

Space for Personal Notes

**Question 27** (8 marks)

In most mammalian cells, the ATP produced from the complete breakdown of glucose occurs by a series of chemical reactions. Coenzymes also play an important role in glucose metabolism.

**a.** Describe the roles of coenzymes in the formation of ATP. (3 marks)

A student measured the effect of oxygen on the metabolism of glucose in red blood cells at 37°C and observed the results shown in the table below.

Effect of oxygen availability on the metabolism of glucose by red blood cells

| **Oxygen** | **Glucose consumed ($n$ moles/$10^7$ cells/hour)** | **Lactate produced ($n$ moles/$10^7$ cells/hour)** |
|---|---|---|
| Absent | 1.6 | 3.2 |
| Present | 1.6 | 3.2 |

**b.** Why are the results the same irrespective of the presence of oxygen? Explain your answer. (3 marks)

During outbreaks of citrus canker, the infected trees and fruit are removed and burned. Recently it has been proposed that instead of being burnt, the trees could be used to produce biofuel.
The first stage in the production of biofuel from infected trees could involve a technique known as steam explosion. This involves using very hot steam at high pressures inside a pressure chamber to break open the cells from the trees. An investigation was conducted to determine the relationship between temperature and the percentage of cells broken open during the steam explosion technique. The results are shown below.

| Temperature inside pressure chamber (°C) | Percentage of cells broken open |
|---|---|
| 20 | 36 |
| 80 | 47 |
| 150 | 57 |
| 200 | 85 |
| 250 | 94 |

**c.** Scientists decided to use the steam explosion technique at 250°C. The temperature was then lowered to 35°C and yeast was added to the ruptured cell mixture.

Why did the scientists decide to do each of the following?

**i.** Use 250°C. (1 mark)

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_____

**ii.** Lower to 35°C and add yeast. (1 mark)

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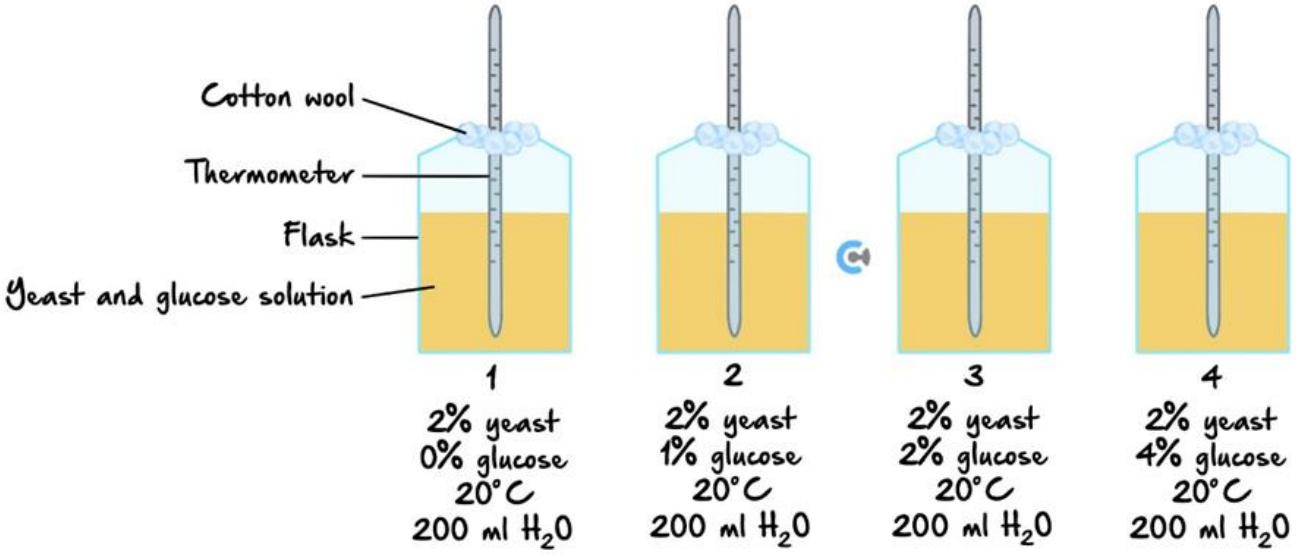
**Question 28** (9 marks)

Four insulated flasks containing yeast (Saccharomyces cerevisiae), glucose, and a variety of other conditions were set up during a Biology class. The setup is illustrated in the diagram below.




**a.** What was the purpose of the cotton wool in this experiment? (1 mark)

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**b.** The temperature of each flask was recorded every 30 minutes for 24 hours. The maximum temperature increase of each flask was recorded in the table below.

| **Flask number** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Maximum temperature increase (°C)** | 1 | 10 | 13 | 15 |

**i.** Explain why there was an increase in temperature in flask 1. (2 marks)

_____

_____

_____

_____

**ii.** Predict the maximum temperature increase that would be observed if there was a fifth flask that contained 8% glucose (all other variables are the same as above). (1 mark)

_____

_____

**c.** The water that was used throughout the series of experiments had been aerated. However, if the water had been boiled prior to the experiment, the yeast would have been exposed to anaerobic conditions.

**i.** Discuss the difference/s that would be apparent in flask 4 during the 24-hour experiment if the conditions were anaerobic compared to aerobic. (1 mark)

_____

_____

**ii.** Discuss the benefit to the yeast of aerobic conditions rather than anaerobic conditions. (1 mark)

_____

_____

Respiration is a complex process that occurs in different cellular locations and involves three main stages.

**d.** Discuss the main events of glycolysis. Include in your answer the cellular location, the inputs and the outputs of the process. (3 marks)

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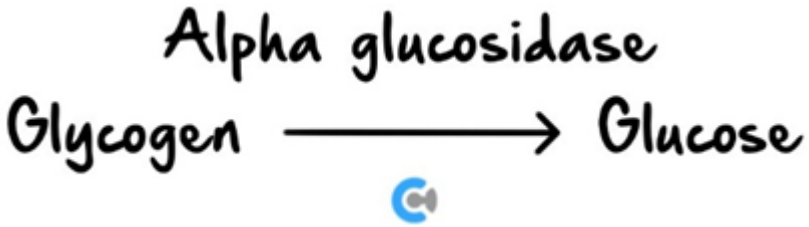
Space for Personal Notes

**Question 29** (10 marks)

Infantile-onset Pompe disease (IOPD) is an inherited metabolic disorder that results from a mutation in the GAA gene. Symptoms include an accumulation of glycogen in the heart, liver, and skeletal muscles of the body. This can cause damage to the cells in the heart and liver, muscle weakness, and death. A functioning form of this gene produces the enzyme acid alpha-glucosidase (GAA), an enzyme responsible for the breakdown of glycogen in the body.



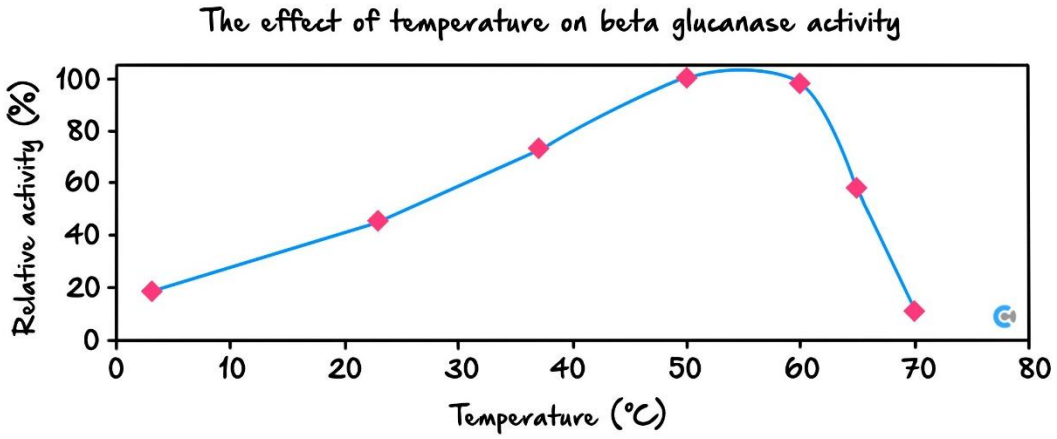

There are a number of mutations in the GAA gene that can result in a non-functioning enzyme.

| | | | | | | |
|---|---|---|---|---|---|---|
| Normal | Gly | Pro | Arg | Asn | Ala | Gln |
| | GGG | CCC | CGG | GAT | GCC | CAG |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mutation | Gly | Pro | Arg | Asn | Ala | Gln |
| | GGG | CCC | CGG | GAT | GCC | CAG |

**a.** Explain why the inability to break down glycogen can cause damage to heart and liver cells. (4 marks)

To ensure that the enzyme is able to work effectively, it is important that the temperature of *Saccharomyces cerevisiae* is kept at a constant level.




**b.** Use the graph above to identify the optimum temperature for *Saccharomyces cerevisiae* in the brewing process. (1 mark)

_____

_____

**c.** Explain why a temperature of 10°C is not used in the brewing process. (2 marks)

_____

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At the end of fermentation, portions of the yeast can be removed from the solution for the next brew. The top part of the solution will contain younger yeast, while the lower part of the solution will contain ‘aged' yeast. Brewers claim that aged yeast cultures produce a 'better' beer with an increased ability to use the sugars to produce a high yield of ethanol and other flavours, as well as an increased flocculation potential (frothing when poured).

**d.** Identify the inputs and outputs of the fermentation process. (2 marks)

| Inputs | Outputs |
|---|---|
| | |

**e.** Identify a coenzyme that is part of the process of fermentation. (1 mark)

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**Question 30** (4 marks)

The emerging Australian biofuels industry hopes to use farming waste such as plant stubble for profit within the next decade. Bioethanol is a liquid fuel that is chemically derived from cellulose-rich plant stubble, making it economically attractive. Bioethanol burns much more cleanly than fossil fuels, which reduces pollution and originates from renewable resources, which is a crucial factor for a sustainable future.

**a.** Bioethanol is one example of a biofuel. Identify **one** other example of a biofuel. (1 mark)

_____

_____

**b.** How is bioethanol produced from cellulose-rich plant stubble? (2 marks)

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**c.** Explain why biofuels are regarded as renewable energy resources. (1 mark)

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Space for Personal Notes

**Question 31** (2 marks)

Plant materials containing cellulose and other polysaccharides are reacted with acids to break them down to produce glucose. This glucose is then used by yeast cells for fermentation.

**a.** Why is fermentation important for yeast cells? (1 mark)

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**b.** What are the products of fermentation in yeast cells? (1 mark)

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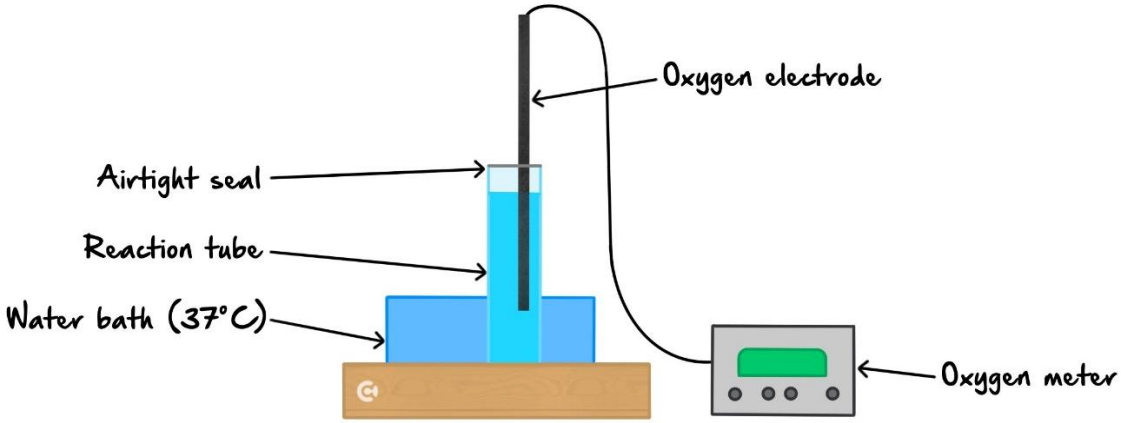
**Question 32** (6 marks)

The apparatus shown below was used in a series of experiments to study aerobic respiration.




In three different experiments, the reaction tube initially contained the following:

**a.** Suspension of mitochondria.

**b.** Cytosol of cells from which the mitochondria had been removed.

**c.** Suspension of mitochondria and cytosol of cells.

The temperatures and pH of the mixtures within the reaction tubes were carefully controlled so as not to damage the mitochondrial structure or any of the enzymes.
In each experiment, a solution containing glucose was first added to the mixture in the reaction tube, and the oxygen concentration was measured for three minutes. Then, a pyruvate solution was added, and the oxygen concentration was measured again for three minutes.

Using your knowledge and understanding of aerobic respiration and mitochondria, complete the tables below with your prediction of the change in oxygen concentration of the mixture in the reaction tube after the addition of each substance and give a reason for your prediction.

Experiment 1 - Suspension of mitochondria

| Substance added | Change in oxygen concentration (increase/decrease/no change) | Reason |
|---|---|---|
| glucose | | |
| pyruvate | | |

Experiment 2 - Cytosol of cells from which the mitochondria had been removed

| Substance added | Change in oxygen concentration (increase/decrease/no change) | Reason |
|---|---|---|
| glucose | | |
| pyruvate | | |

Experiment 3 - Suspension of mitochondria and cytosol of cells

| Substance added | Change in oxygen concentration (increase/decrease/no change) | Reason |
|---|---|---|
| glucose | | |
| pyruvate | | |

**Question 33** (3 marks)

Briefly summarise the process of making bioethanol from sugarcane.

Space for Personal Notes

**Question 34** (9 marks)

A study investigated the effect of a drug called **Metabozone**, which inhibits the function of the enzyme citrate synthase, critical for the Krebs cycle. Researchers analysed glucose metabolism in actively growing muscle cells in two groups. One group was treated with 3 micromoles of **Metabozone**, while the other was not. The results are shown below:

| **Metabozone (micromoles)** | **Glucose Consumed (micromoles/$10^6$ cells)** | **Lactate Produced (micromoles/$10^6$ cells)** |
|---|---|---|
| 0 | 15.20 | 6.12 |
| 3 | 30.45 | 55.80 |

**a.** Explain why both glucose consumption and lactate production change when cells are treated with 3 micromoles of **Metabozone**. (2 marks)

_____

_____

_____

_____

**b.** For cells that were not treated with **Metabozone**, from which metabolic pathways would they be obtaining most of their energy, and where do these pathways occur in the cell? (2 marks)

_____

_____

_____

_____

c. **2-Deoxy-ATP (2-DATP)** inhibits the activity of the enzyme **phosphofructokinase (PFK)**, a key enzyme in glycolysis that converts fructose-6-phosphate to fructose-1,6-bisphosphate. You can measure the formation of fructose-1,6-bisphosphate in muscle cells.

Design a controlled experiment to determine whether **2-DATP** is a competitive or non-competitive inhibitor. In your response, include the setup, controls, and expected results for each type of inhibitor. (5 marks)

Space for Personal Notes

**Question 35** (12 marks)

**a.** Metabolic pathways possess a number of key regulatory enzymes. If one of these enzymes were inhibited using a non-competitive inhibitor, explain how this inhibitor would affect the activity of this enzyme. (2 marks)

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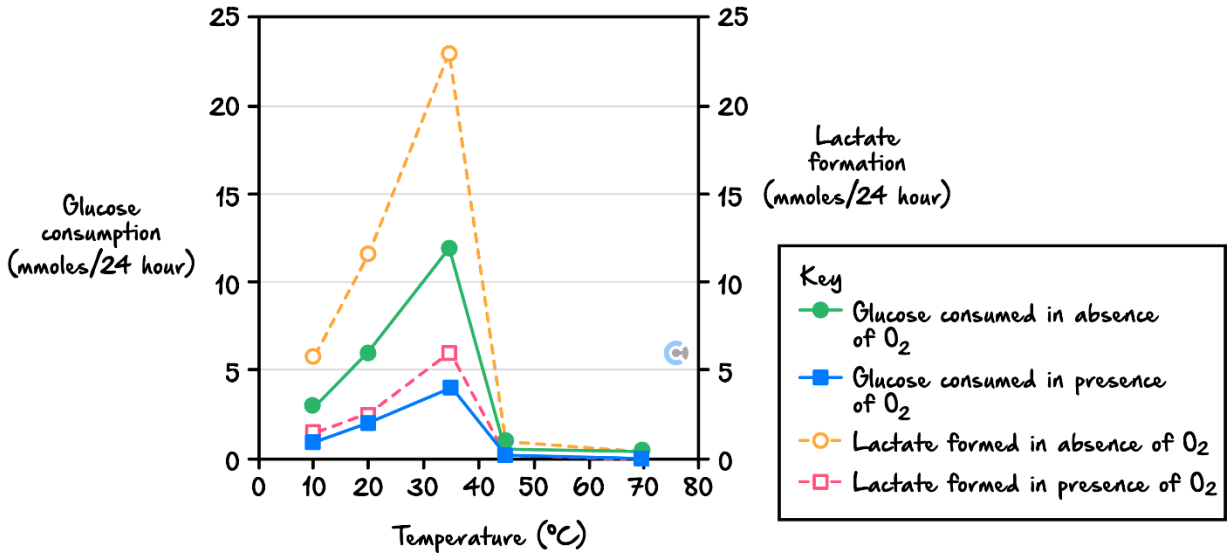
_____

A student was conducting an experiment using cultured human kidney cells. The student added the same number of cells suspended in the same volume of nutrient solution to 10 identical containers. Each container was then placed into its own incubator.

Ten incubators were set at one of five temperatures, 10°C, 20°C, 35°C, 45°C, or 70°C. At each temperature setting there were two incubators. One incubator at each temperature, setting was supplied with oxygen while the other was not. After 24 hours, the student measured the amount of glucose consumed and the amount of lactate produced in each cell population. The results they obtained were plotted below.




**b.**

**i.** What were the values for glucose consumption and lactate production at 35°C for the cells grown in the presence of oxygen? (2 marks)

Glucose consumption: _____

Lactate production: _____

**ii.** Explain why the consumption of glucose and the production of lactate by these cells at 35°C was different if they were grown in the presence or absence of oxygen. (5 marks)

**c.** Explain why both glucose consumption and lactate production in the cells grown at 45°C were lower than those grown at 35°C. (3 marks)

Space for Personal Notes

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