Website: contoureducation.com.au | **Phone:** 1800 888 300
Email: hello@contoureducation.com.au

VCE Biology ¾

AOS 2 Revision [2.0]

Contour Check Solutions

Contour Checklist

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Section A: [2.1] - Photosynthesis & Biochemical Pathways (Checkpoints) (73 Marks)

Sub-Section [2.1.1]: Recall the Inputs, Outputs & Locations & the Relationship between Both Stages of Photosynthesis

Question 1

Definitions:

a. Photosynthesis:

The process by which plants convert light energy into chemical energy stored in glucose using CO_2 and water.

b. Light-dependent stage:

The first stage of photosynthesis where light energy is captured to produce ATP and NADPH, occurring in the thylakoid membranes.

c. Light-independent stage (Calvin Cycle):

The second stage where ATP and NADPH are used to fix CO_2 into glucose, occurring in the stroma.

d. Thylakoid membrane:

The site of the light-dependent reactions where pigments like chlorophyll absorb light.

e. Stroma:

The fluid-filled space in chloroplasts where the Calvin Cycle occurs.

f. ATP (Adenosine triphosphate):

An energy carrier molecule produced in the light-dependent stage and used in the Calvin Cycle.

g. NADPH:

An electron carrier molecule produced in the light-dependent stage and used in the Calvin Cycle.

h. Photolysis:

The splitting of water molecules during the light-dependent stage to produce oxygen, electrons, and protons.

i. Glucose:

The end product of photosynthesis, used as a source of energy and building material for plants.

Question 2 (1 mark)

Which of the following best describes the role of the thylakoid membrane in photosynthesis?

A. A site where glucose is synthesised.

B. The location where CO_2 is reduced into organic compounds.

C. A structure that facilitates ATP and NADPH production during the light-dependent stage.

D. A storage site for water used in photolysis.

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Question 3 (1 mark)

During the light-independent stage, why is ATP critical for glucose synthesis?

A. It directly combines with RuBP to produce glucose.

B. It provides the energy required for the reduction of 3-PGA to G3P.

C. It acts as an electron carrier for CO_2 reduction.

D. It oxidises NADPH to facilitate carbon fixation.

Question 4 (1 mark)

If the stroma of a chloroplast becomes more acidic, what is the most likely impact on photosynthesis?

A. ATP production in the light-dependent stage would increase.

B. Carbon fixation in the Calvin Cycle would slow down.

C. NADPH would accumulate in the thylakoid membrane.

D. Glucose synthesis would occur at a higher rate.

Question 5 (1 mark)

Why is it crucial for the products of the light-dependent stage to immediately feed into the Calvin Cycle?

A. To ensure that photolysis continues uninterrupted.

B. To regenerate RuBP for ongoing carbon fixation.

C. To maintain a high concentration of oxygen in the stroma.

D. To allow the thylakoid membranes to absorb more CO_2.

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Question 6 (1 mark)

A scientist introduces a mutation that prevents water from splitting during the light-dependent stage. What is the most immediate effect?

A. ATP synthesis would increase.

B. Oxygen production would cease.

C. $NADP^+$ reduction to NADPH would accelerate.

D. The Calvin Cycle would proceed without interruption.

Question 7 (3 marks)

a. Light-Dependent Stage:

Inputs	Outputs	Location
$12H_2O$	$6O_2$	Thylakoid Membranes in Chloroplast.
$18ADP + Pi$	$18ADP$	
$12NADP^+$	$12NADPH$	

b. Light-Independent Stage:

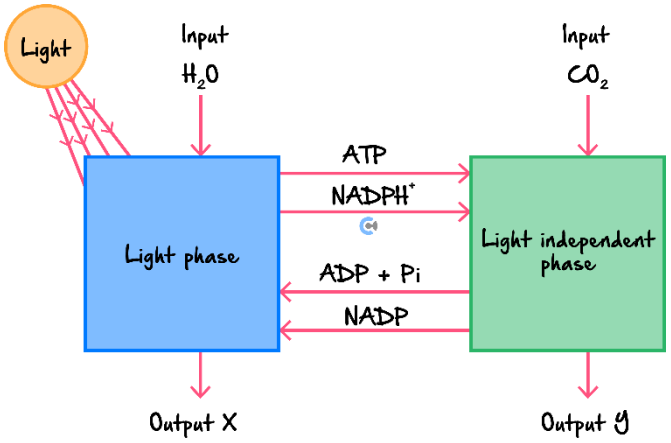
Inputs	Outputs	Location
$6CO_2$	Glucose ($C_6H_{12}O_6$)	Stroma in Chloroplast.
$18ATP$	$18ADP + Pi$	
$12NADPH$	$12NADP^+$	

c. Describe the relationship between the light-dependent and independent stages of photosynthesis. (3 marks)

1. ATP and NADPH Production: In the light-dependent stage, light energy is absorbed by chlorophyll, producing ATP and NADPH. These energy-rich molecules are essential for the next stage of photosynthesis.
2. Carbon Fixation: The light-independent stage (Calvin cycle) occurs in the stroma, where ATP and NADPH from the light-dependent stage are used to convert carbon dioxide into glucose.
3. Interdependence: The light-independent reactions cannot occur without the ATP and NADPH produced in the light-dependent stage, highlighting their dependency on each other for the overall process of photosynthesis.

Question 8 (5 marks)

a. Although photosynthesis is often summarised by a single equation, in fact, the process occurs in two distinct phases; the light phase and another phase called the carbon fixation phase or the light-independent phase. These two phases can be summarised in diagrammatic form as follows.



The diagram shows outputs *X* and *Y*.

i. What is output *X*? (1 mark)

Marks	0	1	2	Average
%	47	23	29	0.8

3ai.
Oxygen

ii. How is output *X* produced? (1 mark)

Either of following responses was accepted:

- the two hydrogens are removed from water and used to form $NADPH^+$, leaving the oxygen as an output product
- the breakdown of water into hydrogen and oxygen.

Many students had an understanding of the process of photosynthesis but fewer had a clear understanding of the two distinct phases that occur in photosynthesis.

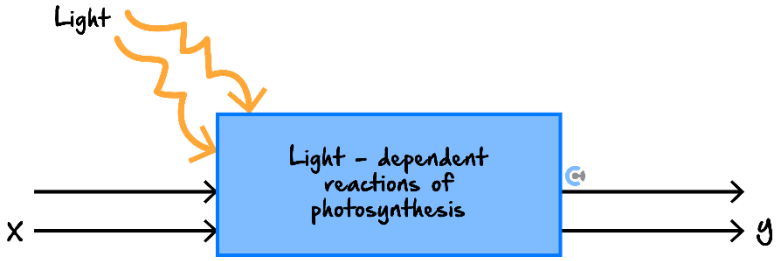
iii. What is output *Y*? (1 mark)

Marks	0	1	Average
%	56	44	**0.4**

A carbohydrate, **or** glucose **or** sugars.

Incorrect responses that were not awarded a mark included 'sucrose' and 'starch'.

b. The following diagram shows a simplified representation of the first stage of photosynthesis.



i. Name one input item that ***X*** could represent. (1 mark)

Marks	0	1	2	Average
%	24	35	40	**1.2**

Any one of:
- water
- NADP
- ADP and Pi.

ii. Name one input item that ***Y*** could represent. (1 mark)

Any one of:
- oxygen
- NADPH
- ATP.

Space for Personal Notes

Sub-Section [2.1.2]: Explain the Role of Enzymes & Coenzymes on t Process of Photosynthesis

Question 9

Definitions:

a. Enzyme:

A biological catalyst that speeds up chemical reactions without being consumed.

b. Rubisco (Ribulose-1, 5-bisphosphate carboxylase/oxygenase):

The enzyme that fixes CO_2 during the Calvin Cycle.

c. PEP carboxylase:

An enzyme in C_4 and CAM plants that fixes CO_2 into a 4-carbon molecule, preventing photorespiration.

d. Coenzyme:

A non-protein molecule that assists enzymes in catalysing reactions, such as $NADP^+$.

e. $NADP^+$ (Nicotinamide adenine dinucleotide phosphate):

A coenzyme that accepts electrons during the light-dependent stage to form NADPH.

f. Active site:

The part of an enzyme where the substrate binds and the reaction occurs.

g. Substrate:

The molecule upon which an enzyme acts, e.g., CO_2 or RuBP in photosynthesis.

Question 10 (1 mark)

Why is RuBisCo considered both essential and inefficient for photosynthesis?

A. It facilitates CO_2 fixation but is easily denatured by light.

B. It fixes CO_2 into RuBP but competes with O_2 due to oxygenase activity.

C. It catalyses ATP production but is prone to breaking down in high temperatures.

D. It absorbs light energy but requires high concentrations of CO_2 to function.

Question 11 (1 mark)

A researcher genetically modifies a plant to produce a coenzyme that can store twice as many electrons as NADPH. What is the most likely consequence of photosynthesis?

A. Photolysis would proceed at a faster rate.

B. The Calvin Cycle would slow down due to $NADP^+$ accumulation.

C. Glucose synthesis would be more efficient, especially under low light.

D. ATP production would stop as electrons bypass the ETC.

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Question 12 (1 mark)

If PEP carboxylase were absent in C_4 plants, which step in their photosynthetic pathway would be most affected?

A. Regeneration of RuBP.

B. CO_2 fixation into a 4-carbon compound.

C. Transfer of electrons from NADPH to CO_2.

D. Reduction of 3-PGA to G3P.

Question 13 (1 mark)

What role does the active site of RuBisCo play in photorespiration?

A. It reduces RuBP into 3-PGA when O_2 is available.

B. It binds O_2 instead of CO_2 under high-temperature conditions.

C. It generates ATP by facilitating proton movement.

D. It allows NADPH to deliver electrons to CO_2.

Question 14 (1 mark)

In an experiment, RuBisCo activity is measured at high temperatures. Which result would support the hypothesis that photorespiration is occurring?

A. A decrease in G3P production.

B. An increase in NADPH concentration in the stroma.

C. Enhanced ATP production in the thylakoid membrane.

D. Accumulation of 4-carbon intermediates in bundle sheath cells.

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Question 15

A researcher observes that a plant's Calvin Cycle is unable to proceed efficiently due to a lack of energy and reducing power. Upon further investigation, it is found that the light-dependent stage is functioning but ATP and NADPH are not being transported to the stroma.

Explain the role of coenzymes in the process of photosynthesis and why their absence affects the Calvin Cycle in this scenario.

- Coenzymes such as ATP and NADPH are essential for facilitating biochemical pathways by providing energy and reducing power.
- ATP supplies the energy needed for the conversion of 3-PGA into G3P during the Calvin Cycle, enabling the synthesis of glucose.
- NADPH acts as an electron and proton carrier, transferring electrons from the light-dependent stage to the Calvin Cycle for reducing CO_2 into glucose.
- In this scenario, the lack of ATP and NADPH in the stroma prevents the reduction of CO_2 into G3P, halting glucose production and demonstrating their critical role in linking the light-dependent and light-independent stages of photosynthesis.

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Sub-Section [2.1.3]: Explain the Function of RuBisCo in Photosynthesis & Describe the Factors that Increase its Affinity for O_2

Question 16

Definitions:

a. RuBisCo:

The key enzyme in the Calvin Cycle that catalyses the fixation of CO_2 to RuBP, but can also bind O_2, leading to photorespiration.

b. Photorespiration:

A wasteful process where RuBisCo binds O_2 instead of CO_2, reducing photosynthetic efficiency.

c. Affinity:

The strength of an enzyme's ability to bind to a specific molecule, such as CO_2 or O_2.

d. RuBP (Ribulose-1,5-bisphosphate):

A 5-carbon molecule that reacts with CO_2 in the Calvin Cycle.

e. Carboxylase:

The activity of RuBisCo when it fixes CO_2 into RuBP.

f. Oxygenase:

The activity of Rubisco when it binds O_2 instead of CO_2.

g. Stomata:

Pores on the leaf surface that regulate gas exchange (CO_2 in, O_2 out) and water loss.

Question 17 (1 mark)

Under which conditions is RuBisCo most likely to bind O_2 instead of CO_2?

A. Low light intensity and high humidity.

B. High temperature and low CO_2 concentration.

C. Low temperature and low O_2 concentration.

D. High light intensity and high CO_2 concentration.

Question 18 (1 mark)

How does the activity of RuBisCo affect overall plant productivity in C_3 plants?

A. It increases photosynthetic rates at high oxygen levels.

B. It decreases photosynthetic efficiency when O_2 is present.

C. It ensures consistent glucose production regardless of environmental conditions.

D. It accelerates ATP synthesis during photorespiration.

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Question 19 (1 mark)

A mutation enhances RuBisCo′s carboxylase activity but reduces its oxygenase activity. How would this affect photosynthesis in a C_3 plant?

A. Photorespiration would increase.

B. CO_2 fixation would become more efficient.

C. Glucose synthesis would decrease at low temperatures.

D. The Calvin Cycle would become unnecessary.

Question 20 (1 mark)

Why do stomata remain closed during hot, dry conditions, and how does this affect RuBisCo's function?

A. To prevent CO_2 loss, causing RuBisCo to bind O_2 instead of CO_2.

B. To conserve oxygen, enhancing RuBisCo's carboxylase activity.

C. To prevent water loss, ensuring RuBP is regenerated.

D. To limit glucose production, reducing ATP usage.

Question 21 (1 mark)

A scientist measures the CO_2 affinity of RuBisCo in a plant grown at 10°C versus one grown at 35°C. What difference would they likely observe?

A. Higher CO_2 affinity at 10°C due to reduced photorespiration.

B. Lower CO_2 affinity at 10°C because RuBisCo denatures.

C. Higher CO_2 affinity at 35°C due to increased enzymatic activity.

D. No difference, as RuBisCo activity is independent of temperature.

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Question 22 (3 marks)

a. What is the function of RuBisCo? (1 mark)

Rubisco is an enzyme that catalyses the inclusion of carbon dioxide into the Calvin cycle, as it combines carbon dioxide and RUBP to form a C3 compound.

b. RuBisCo can undergo another process called photorespiration. When is photorespiration most likely to occur? (2 marks)

Photorespiration occurs when Rubisco binds with oxygen instead of carbon dioxide. 1 mark

Thus, it is most likely that photorespiration will occur when there is a higher concentration of oxygen than carbon dioxide. 1 mark

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Sub-Section [2.1.4]: Describe the Adaptations of C_4 & CAM Plants for Reducing Photorespiration, as Compared to C_3 Plants, Including Structural & Physiological Differences

Question 23

Definitions:

a. C_3 plants:

Plants that use only the Calvin Cycle for CO_2 fixation and are more prone to photorespiration.

b. C_4 plants:

Plants that use a two-step CO_2 fixation process to reduce photorespiration, involving PEP carboxylase and spatial separation of steps.

c. CAM plants:

Plants that use temporal separation of CO_2 fixation to conserve water and minimise photorespiration in arid environments.

d. PEP carboxylase:

An enzyme in C_4 and CAM plants that fixes CO_2 into a 4-carbon compound, preventing O_2 binding.

e. Spatial separation:

The division of photosynthetic steps between different cells (mesophyll and bundle sheath) in C_4 plants.

f. Temporal separation:

The division of photosynthetic steps by time (day vs. night) in CAM plants.

g. Photorespiration:

The process that occurs when RuBisCo binds O_2, leading to energy loss.

Question 24 (1 mark)

What adaptation allows CAM plants to conserve water in arid environments?

A. Storing CO_2 as a 4-carbon compound during the day.

B. Conducting the Calvin Cycle only at night.

C. Temporally separating CO_2 fixation and the Calvin Cycle.

D. Using PEP carboxylase in mesophyll cells.

Question 25 (1 mark)

Which feature of C_4 plants helps reduce photorespiration?

A. High chlorophyll concentration in mesophyll cells.

B. Spatial separation of CO_2 fixation and the Calvin Cycle.

C. Exclusive reliance on RuBisCo for CO_2 fixation.

D. Ability to fix CO_2 directly into glucose.

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Question 26 (1 mark)

In an experiment comparing photosynthesis in C_3, C_4, and CAM plants, which condition would favour CAM plants?

A. Cool temperatures with high humidity.

B. Intense sunlight with limited water availability.

C. High CO_2 concentration and moderate light intensity.

D. Continuous light exposure with abundant water.

Question 27 (1 mark)

Why are C_3 plants less efficient than C_4 plants in hot, dry environments?

A. C_3 plants rely solely on ATP from the light-dependent stage.

B. C_3 plants cannot prevent O_2 from binding to RuBisCo.

C. C_3 plants use PEP carboxylase for CO_2 fixation.

D. C_3 plants do not require stomata for gas exchange.

Question 28 (1 mark)

How would increasing CO_2 concentration in the atmosphere affect the relative efficiency of C_3 and C_4 plants?

A. C_3 plants would become more efficient than C_4 plants.

B. C_4 plants would be unaffected due to spatial CO_2 fixation.

C. Both plant types would exhibit reduced photorespiration.

D. C_4 plants would increase oxygenase activity in RuBisCo.

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Question 29 (5 marks)

A researcher is studying three different plant species (Plant *A*, Plant *B*, and Plant *C*) under various environmental conditions. The plants are observed for their photosynthetic pathways:

- **Plant *A*** performs best at 25°C and 80% humidity but struggles at 40°C and low humidity.
- **Plant *B*** maintains photosynthetic efficiency at 40°C and low humidity but shows poor growth in low light conditions.
- **Plant *C*** performs photosynthesis primarily at night in arid conditions.

a. Which photosynthetic pathway is most likely utilised by each plant? Explain the reasoning for your answer. (2 marks)

- Plant *A*: **C_3 pathway**, as it performs best in cool, moist environments but struggles with photorespiration under high temperature and low humidity.
- Plant *B*: **C_4 pathway**, as it thrives in hot, dry conditions due to its spatial separation of CO_2 fixation, reducing photorespiration.
- Plant *C*: **CAM pathway**, as it fixes CO_2 at night to conserve water in arid environments.

b. Why does Plant *A* exhibit reduced efficiency under hot and dry conditions compared to Plant *B*? (1 mark)

Plant *A* relies solely on RuBisCo, which binds O_2 instead of CO_2 at high temperatures, leading to increased photorespiration. Plant *B*, using the C_4 pathway, minimises photorespiration by spatially separating CO_2 fixation and the Calvin Cycle.

c. Under which conditions would Plant *C* have an advantage over Plant *B*, and why?

Plant *C* has an advantage over Plant *B* in arid, water-scarce environments because it fixes CO_2 at night, allowing its stomata to remain closed during the day to minimise water loss. Plant *B*, while adapted to heat, still requires open stomata during the day for photosynthesis.

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Sub-Section [2.1.5]: Use Data to Identify an Unknown Plant as C_3, C_4 or CAM with Reference to Conditions Where they Perform Photosynthesis Best

Question 30 (1 mark)

A plant demonstrates high glucose production at 25°C and 80% humidity but shows a sharp decline at 40°C and 30% humidity. Which photosynthetic pathway is this plant most likely to use?

A. C_3 photosynthesis.

B. C_4 photosynthesis.

C. CAM photosynthesis.

D. Photorespiration.

C_3 plants perform best under cool, moist conditions but are prone to photorespiration under hot and dry conditions.

Question 31 (1 mark)

Which of the following is a key characteristic of C_4 plants that allows them to perform photosynthesis efficiently under hot and dry conditions?

A. Stomata remain open during the night to conserve water.

B. CO_2 fixation occurs in the mesophyll cells and the Calvin Cycle in the bundle sheath cells.

C. RuBisCohas a higher affinity for oxygen than CO_2.

D. Photosynthesis is limited to low-light conditions.

C_4 plants utilise spatial separation of CO_2 fixation and the Calvin Cycle to minimise photorespiration and maintain efficiency under hot conditions.

Question 32 (1 mark)

A plant produces glucose efficiently at 40°C but only under low humidity. At moderate temperatures, it performs poorly compared to other species. Which type of photosynthetic pathway does this plant most likely use?

A. C_3 photosynthesis.

B. C_4 photosynthesis.

C. CAM photosynthesis.

D. None of the above.

CAM plants are adapted to arid conditions, performing CO_2 fixation at night and photosynthesis during the day to conserve water.

Question 33 (1 mark)

Which observation would most strongly suggest that a plant utilises CAM photosynthesis?

A. High photosynthetic rate at 25°C and 90% humidity.

B. Glucose production is highest when CO_2 is supplied during the night.

C. Photosynthesis is equally efficient under both day and night conditions.

D. Photosynthesis ceases completely when exposed to high temperatures.

CAM plants fix CO_2 at night into organic acids and use it for photosynthesis during the day, a key adaptation for conserving water in arid environments.

Question 34 (1 mark)

If a plant relies on RuBisCofor direct CO_2 fixation and shows reduced glucose production when the oxygen concentration is increased, which photosynthetic pathway does it most likely use?

A. C_3 photosynthesis.

B. C_4 photosynthesis.

C. CAM photosynthesis.

D. Both C_4 and CAM.

C_3 plants rely solely on RuBisCo, which binds O_2 instead of CO_2 at high oxygen concentrations, leading to photorespiration and reduced efficiency.

Space for Personal Notes

Question 35

A group of scientists conducted experiments investigating the photosynthetic output of a newly discovered plant species. The plants were exposed to differing environmental conditions in an enclosed greenhouse. Light and water availability were kept the same. The amount of glucose produced was measured and recorded in the table below. Plants of the same size were used in each of these experiments.

Air temperature (°C)	**Carbon dioxide in surrounding air** (%)	**Relative humidity of surrounding air** (%)	**Quantity of glucose produced** (mg/day)
15	5	90	90
15	2	90	55
25	5	70	75
25	2	50	40
35	5	30	30
35	2	30	15

Plants can be placed into three main groups, **C_3, C_4** or **CAM** plants, based on their photosynthetic adaptations.

To which of these groups would this newly discovered plant species most likely belong? Justify your answer.

- The plant most likely belongs to the C_3 group based on the following observations:
- **Performance at moderate temperatures (15°C to 25°C):**
- The plant achieves its highest glucose production (90 mg/day) at 15°C and 90% humidity, which is characteristic of C_3 plants that thrive in cool, moist environments. At 25°C and 5% CO_2, the glucose production drops to 75 mg/day, which still aligns with typical C_3 plant behavior under slightly warmer conditions.
- **Sensitivity to high temperatures (35°C):**
- At 35°C, glucose production drops significantly to 30 mg/day or lower, regardless of CO_2 or humidity levels. This indicates the plant struggles with photorespiration under hot, dry conditions, a hallmark of C_3 plants.
- **Effect of CO_2 concentration:**
- Glucose production is reduced when the CO_2 concentration drops from 5% to 2%. For instance, at 15°C, glucose production decreases from 90 mg/day to 55 mg/day, suggesting that the plant heavily relies on RuBisCo for CO_2 fixation. This reliance makes it vulnerable to low CO_2 conditions.
- **Comparison with C_4 and CAM plants:**
  - Unlike C_4 plants, which maintain high photosynthetic efficiency at 35°C due to spatial separation of CO_2 fixation, this plant's performance declines sharply at higher temperatures.
  - CAM plants, adapted to arid conditions, perform photosynthesis at night to conserve water. However, this plant does not show any evidence of nighttime CO_2 fixation or adaptation to water-scarce conditions.

Conclusion:

The plant's glucose production pattern under varying temperature, humidity, and CO_2 levels indicates it follows the **C_3 photosynthetic pathway**, as it relies on RuBisCo and performs best under cool, humid

Sub-Section [2.1.6]: Identify & Explain the Factors - Light Colour, Intensity, CO_2 Concentration, Temperature, Water Availability - that Affect the Efficiency of Photosynthesis

Question 36

Definitions:

a. Light intensity:

The amount of light energy available for photosynthesis; higher intensity increases the rate until saturation.

b. Light wavelength:

Specific wavelengths (red and blue) are most effective for photosynthesis.

c. CO_2 concentration:

The availability of CO_2 directly affects the rate of the Calvin Cycle.

d. Temperature:

Affects enzyme activity; optimal temperatures increase the rate, but extreme heat leads to denaturation and photorespiration.

e. Water availability:

Essential for photolysis in the light-dependent stage; water scarcity causes stomatal closure, limiting CO_2 uptake.

Question 37 (1 mark)

Why does high temperature reduce photosynthesis efficiency in C_3 plants?

A. It denatures chlorophyll pigments, reducing light absorption.

B. It increases photorespiration due to the higher oxygenase activity of Rubisco.

C. It reduces ATP production in the light-dependent stage.

D. It causes stomata to remain open, losing CO_2.

Question 38 (1 mark)

How does light wavelength influence the efficiency of photosynthesis?

A. Green light is absorbed most efficiently, boosting glucose production.

B. Red and blue light maximise chlorophyll absorption, enhancing photosynthesis.

C. Infrared light increases the rate of ATP production.

D. Yellow light is required for photolysis.

Question 39 (1 mark)

In an experiment, plants are exposed to varying CO_2 concentrations. Which observation would indicate a saturation point has been reached?

A. Increased ATP production with increasing CO_2 levels.

B. Glucose production remains constant despite rising CO_2.

C. Photorespiration increases with higher CO_2 levels.

D. NADPH synthesis decreases as CO_2 rises.

Space for Personal Notes

Question 40 (1 mark)

Why might water availability indirectly limit photosynthesis?

A. It inhibits ATP production in the light-dependent stage.

B. It prevents $NADP^+$ reduction in the Calvin Cycle.

C. It forces stomata closure, reducing CO_2 uptake.

D. It increases photorespiration by raising O_2 levels in the stroma.

Question 41 (1 mark)

Which combination of conditions would maximise photosynthesis efficiency in a typical C_3 plant?

A. High temperature, low humidity, low light intensity.

B. Moderate temperature, high CO_2 concentration, ample water.

C. High CO_2, high temperature, and intense light.

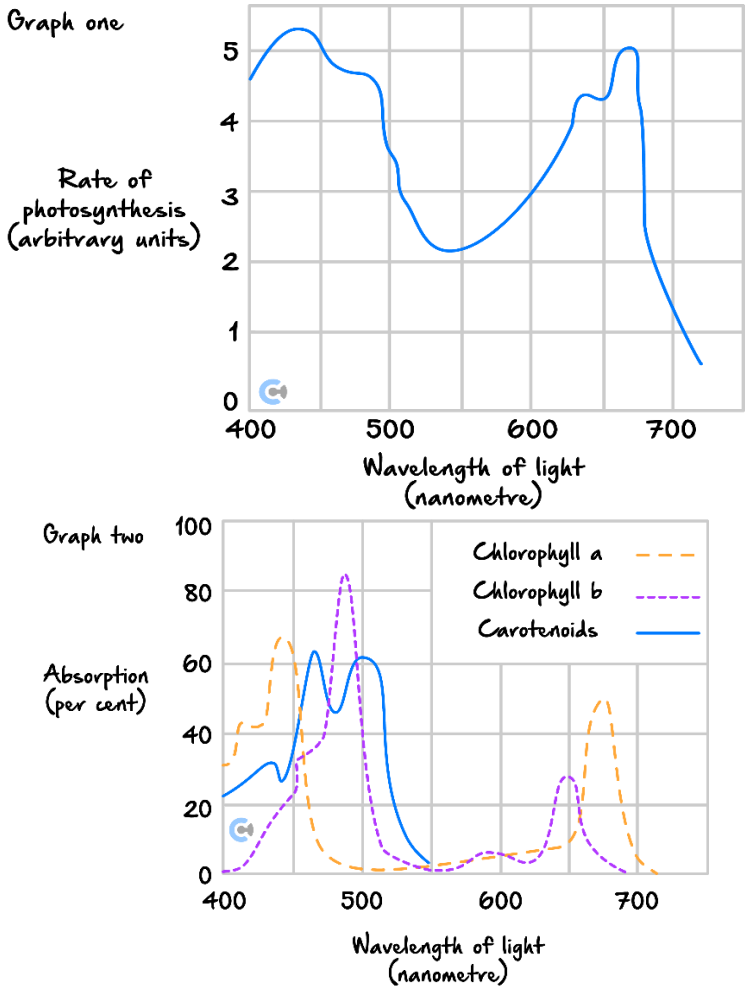
D. Low CO_2, high humidity, and low light.

Space for Personal Notes

Question 42 (5 marks)

a. The following diagrams show:

- **Graph one:** The rate of photosynthesis in a green plant at different wavelengths of light.
- **Graph two:** The estimated absorption of the different wavelengths of light by the different plant pigments.



Explain why the graph showing the rate of photosynthesis has approximately the same shape as the absorption graphs of the plant pigments. (1 mark)

Many answers to this question demonstrated students' knowledge and understanding of photosynthesis and cellular respiration.

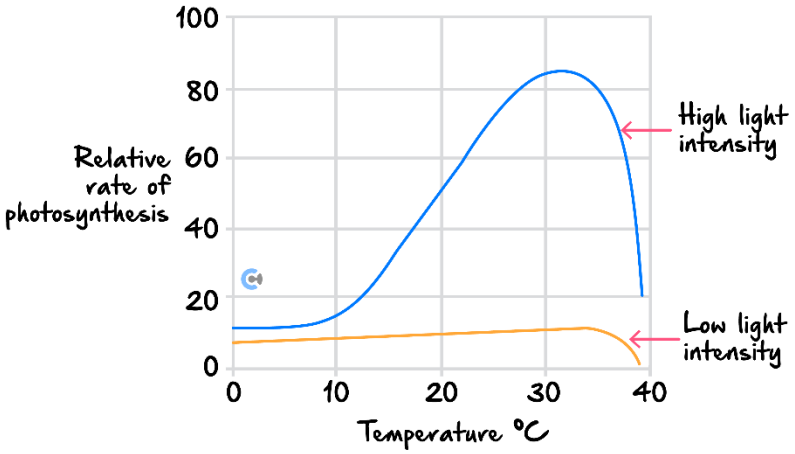
Question 3a.

Marks	0	1	Average
%	51	49	0.5

Light is necessary for photosynthesis, and where light absorption was high so was the rate of photosynthesis.

It was important for students to make a comparative statement between the two graphs. Some students incorrectly stated that the chlorophyll was absorbed, not the light. Other students **described** the graphs rather than giving an explanation as requested by the question.

b. Scientists exposed two groups of identical plants to a range of temperatures. One group was kept in a low-light intensity and the other in a high-light intensity environment. The following graph summarises the results obtained by the scientists.



Account for the difference in the rate of photosynthesis for the two groups of plants over the range of temperatures shown. (2 marks)

Marks	0	1	2	Average
%	33	50	17	**0.9**

Both of:

- the higher the light intensity, the more light can be absorbed and the rate of photosynthesis is greater
- at higher temperatures, enzymes are denatured.

It is important for students to understand that enzymes, **not** plants, are denatured by extremes of temperature.

This question asked students to **account** for the differences. Often students **described** the graphs and did not provide an explanation. Marks were given for interpreting the graph and providing further information that was not given in the question.

This question highlighted the problems some students have with reading and interpreting data. Students would benefit from more practice answering this style of question.

c. A light is placed near a plant and the rate of photosynthesis is measured. The intensity of the light is increased over time as shown in the figure below.

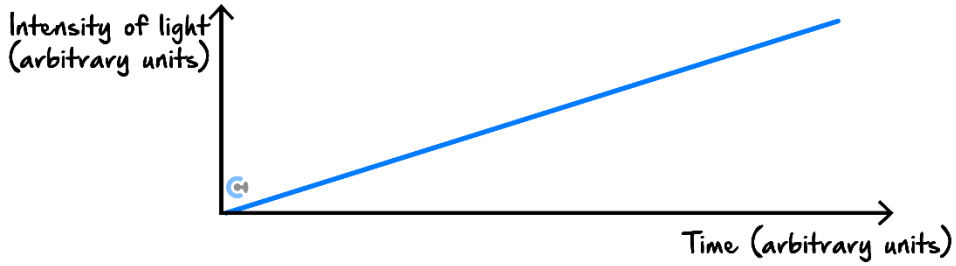


Figure 9

List the three possible limiting factors that may stop the rate of photosynthesis from increasing, even though the light intensity continues to increase. (2 marks)

As the experiment provides unlimited light, the rate of photosynthesis is limited by the supply of carbon dioxide, the supply of water and the amount of chlorophyll (**2 marks** for all three, **1 mark** for two, otherwise **0 marks**).

Space for Personal Notes

Sub-Section [2.1.7]: Apply Experimental Principles to Investigate Factors Affecting the Rate of Photosynthesis

Question 43 (1 mark)

A student investigates the effect of light intensity on photosynthesis using pondweed. If the number of oxygen bubbles released begins to plateau despite increasing light intensity, what is the most likely limiting factor?

A. Water availability.

B. CO_2 concentration.

C. Temperature.

D. ATP availability.

Question 44 (1 mark)

A researcher designs an experiment to measure the effect of temperature on photosynthesis. What control variable is critical for ensuring reliable results?

A. The amount of light provided to the plants.

B. The concentration of oxygen in the environment.

C. The type of plant species used in the study.

D. Both A and C.

Question 45 (1 mark)

In an experiment, plants are exposed to different wavelengths of light. Which dependent variable would provide the best indicator of photosynthetic activity?

A. The chlorophyll content in the leaves.

B. The rate of oxygen production in the plants.

C. The concentration of NADPH in the chloroplasts.

D. The amount of CO_2 absorbed by the plants.

Question 46 (1 mark)

During an experiment, a student increases the CO_2 concentration around a plant and observes a temporary increase in photosynthetic rate before it plateaus. What most likely caused this plateau?

A. Insufficient ATP and NADPH production.

B. Limited availability of water for photolysis.

C. Decreased activity of chlorophyll pigments.

D. The saturation of enzymes in the Calvin Cycle.

Question 47 (1 mark)

A scientist is testing the effect of light wavelength on photosynthesis using spinach leaf discs. Which setup would serve as the most appropriate control for the experiment?

A. Exposing the leaf discs to white light.

B. Keeping the leaf discs in complete darkness.

C. Exposing the leaf discs to red light only.

D. Using a leaf disc from a non-photosynthetic plant.

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Question 48 (9 marks)

A scientist conducts an experiment to investigate how different concentrations of carbon dioxide affect the rate of photosynthesis. She uses small discs of spinach leaves and removes the air from them using a syringe. These discs are then placed in beakers with bicarbonate solutions of varying CO_2 concentrations (0.2%, 0.5%, and 1.0%) and exposed to bright white light for 10 minutes. She counts the number of leaf discs that rise every minute as an indicator of photosynthetic activity.

a. Why does the rate of rising of the leaf discs allow the scientist to determine the extent of photosynthesis? (2 marks)

- Oxygen is produced during photosynthesis.
- The oxygen produced makes the discs buoyant, causing them to rise. A faster rate of disc rising indicates a higher rate of photosynthesis.

b. Write a suitable hypothesis for this experiment. Explain your hypothesis. (2 marks)

- Hypothesis: The rate of photosynthesis, as measured by the number of rising leaf discs, will increase as the CO_2 concentration increases.
- Explanation: Higher CO_2 concentrations provide more substrate for the Calvin Cycle, leading to increased glucose production and oxygen release.

c. What would be the suitable control for this experiment? (1 mark)

Place the same setup in a beaker with no bicarbonate solution (water only) to ensure that CO_2 is the variable affecting the rate of photosynthesis.

d. Identify the stage of photosynthesis being tested in this experiment. State what is produced as a result of this stage. (2 marks)

- **Stage:** The light-independent stage (Calvin Cycle).
- **Products:** Glucose is produced by reducing CO_2 using ATP and NADPH generated in the light-dependent stage.

e. The scientist predicted that the rate of photosynthesis would plateau at a certain CO_2 concentration. Is she correct? Explain your reasoning. (2 marks)

- **Yes, she is correct.**
- Once the enzymes involved in the Calvin Cycle (e.g., RuBisCo) are saturated, increasing CO_2 concentration will no longer increase the rate of photosynthesis. Other factors, such as light intensity or enzyme activity, may become limiting.

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Sub-Section [2.1.8]: Explain How CRISPR-Cas9 Can Be Used to Increase Photosynthetic Efficiency

Question 49

Definitions:

a. CRISPR-Cas9:

A gene-editing tool used to modify DNA sequences with high precision.

b. Genome editing:

The process of altering specific genes to improve traits like photosynthetic efficiency.

c. RuBisCoefficiency:

A target for improvement using CRISPR to reduce oxygenase activity and enhance CO_2 fixation.

d. Drought tolerance :

The ability of plants to survive water scarcity, potentially enhanced by genetic modifications.

e. Crop yield:

The total amount of crop produced, which can be increased by improving photosynthesis.

f. Photorespiration reduction:

_____ _____

_____ _____

A key goal of CRISPR to enhance photosynthetic efficiency by suppressing wasteful processes.

Question 50 (1 mark)

How can CRISPR-Cas9 be used to reduce photorespiration in plants?

A. By increasing the expression of RuBisCo.

B. By editing RuBisCogenes to improve CO_2 specificity and reduce O_2 binding.

C. By modifying chlorophyll molecules to absorb more light.

D. By introducing genes for PEP carboxylase into C_3 plants.

CRISPR can edit the RuBisCogene to reduce its oxygenase activity, thereby minimising photorespiration and improving photosynthetic efficiency.

Question 51 (1 mark)

Which of the following is a key advantage of using CRISPR-Cas9 in improving photosynthesis?

A. It can directly increase glucose production in all plants.

B. It allows for precise editing of genes involved in photosynthetic pathw

C. It enables plants to perform photosynthesis without sunlight.

D. It eliminates the need for the Calvin Cycle.

CRISPR-Cas9 enables precise edits to genes such as those coding for RuBisCoor drought-tolerance pathways, improving photosynthetic traits.

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Question 52 (1 mark)

A researcher uses CRISPR-Cas9 to introduce genes for C_4 photosynthesis into a C_3 plant. What is the expected outcome?

A. The C_3 plant will increase photorespiration.

B. The C_3 plant will perform photosynthesis more efficiently at high temperatures.

C. The C_3 plant will only perform photosynthesis at night.

D. The C_3 plant will switch to CAM photosynthesis.

Introducing C_4 photosynthetic traits into a C_3 plant can reduce photorespiration and enhance efficiency under hot, dry conditions.

Question 53 (1 mark)

Which of the following traits can be targeted using CRISPR-Cas9 to improve photosynthesis in crops?

A. Increasing RuBisCo's affinity for O_2.

B. Enhancing the water-use efficiency of plants.

C. Eliminating the need for light in photosynthesis.

D. Shortening the Calvin Cycle to produce glucose faster.

CRISPR can be used to modify genes involved in stomatal regulation or drought resistance, improving water-use efficiency in crops.

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Question 54 (4 marks)

Describe the steps used in using CRISPR to edit plants.

1. Identify the target DNA sequence and design a specific guide RNA (gRNA).
2. Introduce the CRISPR-Cas9 system into plant cells using delivery methods like Agrobacterium or gene gun.
3. Cas9 protein cuts the target DNA, and the cell repairs it, introducing the desired genetic change.
4. Regenerate edited plant cells into full plants and confirm successful edits.

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Section B: [2.2] - Cellular Respiration & Anaerobic Fermentation (Checkpoints) (66 Marks)

Sub-Section [2.2.1]: Recall the Inputs, Outputs & Locations of All Stages of Aerobic Cellular Respiration

Question 55

Definitions:

a. Glycolysis.

The first stage of cellular respiration that occurs in the cytoplasm, breaking down one molecule of glucose (a 6-carbon sugar) into two molecules of pyruvate (each containing 3 carbons).

b. Link Reaction.

Converts pyruvate into acetyl-CoA in the mitochondrial matrix, releasing CO_2 and generating NADH.

c. Krebs Cycle (Citric Acid Cycle).

A series of reactions in the mitochondrial matrix that oxidises acetyl-CoA, producing ATP, NADH, $FADH_2$, and CO_2.

d. Electron Transport Chain (ETC).

A series of protein complexes in the cristae of the mitochondria where NADH and $FADH_2$ donate electrons, driving ATP production via oxidative phosphorylation.

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Question 56 (1 mark)

Which of the following best explains the importance of the Link Reaction in aerobic respiration?

A. It produces pyruvate for glycolysis.

B. It connects glycolysis to the Krebs Cycle by producing acetyl-CoA and NADH.

C. It generates ATP directly via substrate-level phosphorylation.

D. It allows electrons to flow through the Electron Transport Chain.

Question 57 (1 mark)

During the Electron Transport Chain, what creates the proton gradient necessary for ATP synthesis?

A. The reduction of oxygen in the water.

B. The release of CO_2 from the Krebs Cycle.

C. The transfer of electrons between protein complexes.

D. The movement of pyruvate into the mitochondria.

Question 58 (1 mark)

Where in the cell does glycolysis occur, and why is this location significant?

A. Mitochondrial matrix; it contains the enzymes for glycolysis.

B. Cristae; it provides the surface area needed for glycolysis.

C. Cytoplasm; it allows glycolysis to proceed without oxygen.

D. Cytoplasm; it maximises ATP production under aerobic conditions.

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Question 59 (1 mark)

What would most likely occur if oxygen is unavailable during aerobic respiration?

A. The Krebs Cycle would continue, but the Electron Transport Chain would stop.

B. The Link Reaction would cease due to a lack of pyruvate.

C. Glycolysis would proceed anaerobically, leading to lactic acid or ethanol production.

D. Oxidative phosphorylation would continue at a slower rate.

Question 60 (1 mark)

How is ATP synthesis in glycolysis different from ATP synthesis in the Electron Transport Chain?

A. ATP in glycolysis is produced by substrate-level phosphorylation, while ATP in the ETC is generated by oxidative phosphorylation.

B. ATP in glycolysis requires oxygen, whereas ATP in the ETC does not.

C. Glycolysis generates ATP using NADH, while the ETC does not.

D. ATP in glycolysis is produced in the mitochondria, whereas ATP in the ETC is produced in the cytoplasm.

Question 61

Stage	Inputs	Outputs	Location
Glycolysis	Glucose, 2ADP + Pi, $2NAD^+$	2 Pyruvate, 2NADH, 2ATP	Cytosol
Link Reaction	2 Pyruvate, $2NAD^+$	2 Acetyl-CoA, 2 CO_2, 2NADH	Mitochondrial Matrix
Krebs Cycle	2 Acetyl-CoA, 2ADP + Pi, NAD^+, FAD	$4CO_2$, 2ATP, 4NADH, $FADH_2$	Mitochondrial Matrix
Electron Transport Chain	$\frac{26}{28}$ ADP + Pi, NADH, $FADH_2$, O_2	$\frac{26}{28}$ ATP, NAD^+, FAD, H_2O	Cristae of Mitochondrial

Sub-Section [2.2.2]: Recall the Inputs, Outputs & Locations of All Stages of Anaerobic Cellular Respiration

Question 62

Definitions:

a. Lactic Acid Fermentation.

Occurs in animals when oxygen is absent; pyruvate is reduced to lactic acid, regenerating NAD^+ to sustain glycolysis.

b. Alcoholic Fermentation.

Occurs in yeast, converting pyruvate into ethanol and CO_2, also regenerating NAD^+ for glycolysis.

c. Anaerobic Respiration Location.

Cytoplasm for both fermentation types.

Question 63 (1 mark)

Why is NAD^+ regeneration critical during anaerobic respiration?

A. It ensures the complete breakdown of glucose in glycolysis.

B. It provides energy directly for ATP production.

C. It allows glycolysis to continue producing ATP in the absence of oxygen.

D. It prevents the buildup of CO_2 in the cytoplasm.

Question 64 (1 mark)

What is the key difference between lactic acid fermentation and alcoholic fermentation?

A. Lactic acid fermentation produces CO_2, while alcoholic fermentation does not.

B. Lactic acid fermentation occurs in yeast, while alcoholic fermentation occurs in humans.

C. Lactic acid fermentation produces lactic acid, while alcoholic fermentation produces ethanol and CO_2.

D. Lactic acid fermentation generates more ATP than alcoholic fermentation.

Question 65 (1 mark)

Why does glycolysis occur in both aerobic and anaerobic respiration?

A. It directly provides ATP for all cells regardless of oxygen availability.

B. It supplies pyruvate for fermentation or further aerobic processing.

C. It occurs in the mitochondria, allowing for oxygen-independent respiration.

D. It is the only stage of respiration that generates water.

Question 66 (1 mark)

During alcoholic fermentation in yeast, why is CO_2 released?

A. It results from the breakdown of glucose during glycolysis.

B. It is a byproduct of pyruvate decarboxylation.

C. It is produced when ethanol is oxidised.

D. It is generated by the regeneration of NAD^+.

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Question 67 (1 mark)

Which of the following best explains why anaerobic respiration produces less ATP than aerobic respiration?

A. It occurs in the cytoplasm rather than the mitochondria.

B. It relies solely on glycolysis, which produces a small amount of ATP.

C. It uses NADH to regenerate pyruvate instead of sending it to the ETC.

D. It does not utilise oxygen to complete the Electron Transport Chain.

Question 68

Stage	Inputs	Outputs	Location
Glycolysis	Glucose, 2ADP + Pi, $2NAD^+$	2 Pyruvate, 2NADH, 2ATP	cytoplasm
Lactic Acid Fermentation	2 Pyruvate, 2NADH	2 Lactic Acid, $2NAD^+$	cytoplasm

Stage	Inputs	Outputs	Location
Glycolysis	Glucose, 2ADP + Pi, $2NAD^+$	2 Pyruvate, 2NADH, 2ATP	cytoplasm
Alcoholic Fermentation	2 Pyruvate, 2NADH	2 Ethanol + $2CO_2$, $2NAD^+$	cytoplasm

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Sub-Section [2.2.3]: Describe the Significance of the Mitochondria as the Necessary Location for Aerobic Respiration

Question 69

Definitions:

a. Cristae.

Folded inner membranes of mitochondria where the ETC occurs, maximising ATP production through a large surface area.

b. Matrix.

Inner compartment of mitochondria where the Link Reaction and Krebs cycle take place.

c. Endosymbiotic Theory.

Explains mitochondria's origin as once-independent prokaryotes, evidenced by their double membrane and DNA.

Question 70 (1 mark)

Which feature of the cristae directly supports efficient ATP production?

A. Its ability to trap oxygen for the Krebs Cycle.

B. Its increased surface area for Electron Transport Chain reactions.

C. Its capacity to store ATP until it is needed.

D. Its location next to the mitochondrial matrix.

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Question 71 (1 mark)

If the mitochondrial matrix was depleted of enzymes, which stage of aerobic respiration would fail?

A. Glycolysis

B. Krebs Cycle

C. Electron Transport Chain

D. Pyruvate Oxidation

Question 72 (1 mark)

What evidence supports the Endosymbiotic Theory regarding the mitochondria's origin?

A. Mitochondria have a single membrane similar to bacterial cell walls.

B. Mitochondria replicate independently and contain their own DNA.

C. Mitochondria are capable of glycolysis, an ancestral metabolic pathway.

D. Mitochondria produce their own glucose for energy.

Question 73 (1 mark)

If protons leaked through the inner mitochondrial membrane, how would this affect aerobic respiration?

A. ATP production would decrease as the proton gradient dissipates.

B. Glycolysis would halt because of reduced oxygen availability.

C. The Krebs Cycle would produce more NADH to compensate.

D. Oxidative phosphorylation would speed up to restore equilibrium.

Space for Personal Notes

Question 74 (1 mark)

Why is the mitochondrial matrix essential for aerobic respiration?

A. It provides the environment for oxidative phosphorylation.

B. It contains the enzymes required for the Krebs Cycle and pyruvate oxidation.

C. It stores glucose for glycolysis.

D. It allows oxygen to diffuse directly into the Electron Transport Chain.

Question 75 (1 mark)

A scientist designs an experiment to test the effect of temperature on cellular respiration using yeast cells. Which factor should be the dependent variable?

A. The concentration of glucose in the medium.

B. The temperature of the environment.

C. The rate of carbon dioxide production by yeast.

D. The type of respiration (aerobic or anaerobic).

Question 76 (1 mark)

In an experiment testing how glucose concentration affects the rate of cellular respiration in mitochondria, what would serve as a suitable control?

A. Using a non-respiring substance instead of glucose.

B. Measuring oxygen levels at varying light intensities.

C. Maintaining the same glucose concentration for all groups.

D. Testing mitochondrial respiration in the absence of glucose.

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Question 77 (1 mark)

A student investigates the effect of oxygen concentration on the rate of ATP production in cells. Which of the following would best measure the dependent variable?

A. The amount of glucose consumed.

B. The amount of CO_2 produced per unit time.

C. The pH of the solution.

D. The temperature of the cellular environment.

Question 78 (1 mark)

In an experiment measuring the effect of pH on cellular respiration, which setup would serve as the independent variable?

A. Varying the pH levels of the environment.

B. Measuring the amount of ATP produced.

C. Keeping the oxygen concentration constant.

D. Using a control without any cellular respiration occurring.

Question 79 (1 mark)

Why is it important to control other factors, such as temperature and oxygen levels, when testing the effect of glucose availability on cellular respiration?

A. To ensure oxygen is the primary limiting factor.

B. To isolate the effect of glucose concentration as the independent variable.

C. To maximise ATP production in the mitochondria.

D. To ensure glycolysis continues uninterrupted.

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Sub-Section [2.2.4]: Identify & Describe Factors - Such As Temperature, Glucose Availability, & Oxygen Concentration - On the Rate of Cellular Respiration

Question 80

Definitions:

a. Temperature.

Enzymes operate at an optimal temperature; extreme heat denatures enzymes, and low temperatures slow reaction rates.

b. Glucose Availability.

Determines the substrate supply for glycolysis; excess glucose does not increase the rate beyond enzyme saturation.

c. Oxygen Concentration.

Essential for the ETC; low oxygen halts aerobic respiration, leading to reliance on anaerobic pathways.

d. pH.

Enzymes in glycolysis and the Krebs cycle function optimally within a specific pH range, usually near neutral. Extreme pH levels can denature enzymes, reducing their efficiency.

Space for Personal Notes

Question 81 (1 mark)

Why does a decrease in oxygen concentration slow cellular respiration?

A. Oxygen is needed for glycolysis to proceed.

B. It prevents the regeneration of NAD^+ in the Electron Transport Chain.

C. It denatures enzymes in the Krebs Cycle.

D. It inhibits glucose transport into the cell.

Question 82 (1 mark)

A student measures the rate of respiration at 20°C, 30°C, and 60°C. At 60°C the rate drops dramatically. What is the most likely explanation?

A. The Krebs Cycle produces less ATP at high temperatures.

B. Enzymes involved in respiration are denatured at 60°C.

C. Glycolysis cannot occur at high temperatures.

D. Oxygen concentration decreases as temperature increases.

Question 83 (1 mark)

Why does the availability of glucose not always increase the rate of respiration?

A. . Excess glucose inhibits the Krebs Cycle.

B. Glycolysis has a maximum rate due to enzyme saturation.

C. Oxygen becomes the primary limiting factor when glucose is abundant.

D. Glucose availability only affects anaerobic respiration.

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Question 84 (1 mark)

What happens if pH deviates significantly from the optimal range during cellular respiration?

A. Glucose cannot be transported into the cell.

B. Enzymes involved in glycolysis and the Krebs Cycle become less effective.

C. The ETC speeds up to compensate.

D. Pyruvate is no longer converted to acetyl-CoA.

Question 85 (1 mark)

How does a drop in temperature below optimal levels affect cellular respiration?

A. ATP production increases due to enhanced enzyme activity.

B. Enzyme activity slows, reducing the rate of respiration.

C. Glycolysis stops entirely, halting glucose breakdown.

D. Oxygen availability decreases, leading to anaerobic respiration.

Space for Personal Notes

Question 86 (2 marks)

A student investigated the rate of carbon dioxide production by yeast undergoing fermentation at different temperatures. The following results were obtained:

Temperature (℃)	**Mean Rate of CO_2 Production (cm^3/min)**
0	0.001
10	0.045
20	0.110
30	0.210
40	0.225
50	0.180

Explain the results observed.

- As the temperature increases to 40℃, the rate of respiration rises because the substrates and enzymes gain kinetic energy, leading to more frequent and effective collisions (1 mark).
- Beyond 40℃ , the enzymes involved in fermentation begin to denature due to high temperatures, resulting in a decline in the rate of respiration (1 mark).

Space for Personal Notes

Question 87 (2 marks)

A student investigated the effect of pH on the rate of carbon dioxide production by yeast undergoing fermentation. The following results were recorded:

pH Level	Mean Rate of CO_2 Production (cm^3/min)
4	0.030
5	0.095
6	0.200
7	0.220
8	0.190
9	0.100

Explain the results observed.

- The rate of respiration increases as pH approaches the optimal level (around pH 7) because enzymes involved in fermentation work most efficiently at this pH (1 mark).
- Beyond pH 7, the rate decreases as the enzymes begin to lose their activity due to suboptimal pH conditions, which disrupt enzyme structure and function (1 mark).

Space for Personal Notes

Question 88 (2 marks)

A student measured the effect of oxygen concentration on the rate of carbon dioxide production during aerobic respiration in yeast. The results are as follows:

Oxygen Concentration (%)	**Mean Rate of CO_2 Production (cm^3/min)**
0	0.050
10	0.150
20	0.275
30	0.280
40	0.270

Explain the results observed.

- The rate of respiration increases as oxygen concentration rises up to 30%, as oxygen is required for the Electron Transport Chain in aerobic respiration (1 mark).
- Beyond 30%, the rate of respiration plateaus because the enzymes and other factors involved in respiration are already saturated with oxygen, making it no longer the limiting factor (1 mark).

Space for Personal Notes

Question 89 (2 marks)

A student investigated the effect of glucose concentration on the rate of carbon dioxide production by yeast undergoing fermentation. The following results were obtained:

Glucose Concentration (%)	Mean Rate of CO_2 Production (cm^3/min)
1	0.050
2	0.120
4	0.250
6	0.260
8	0.260

Explain the results observed.

- The rate of respiration increases as glucose concentration rises up to 4%, as more substrate is available for glycolysis, leading to increased ATP and CO_2 production (1 mark).
- Beyond 4%, the rate of respiration plateaus because the enzymes involved in fermentation become saturated, making glucose concentration no longer the limiting factor (1 mark).

Space for Personal Notes

Sub-Section [2.2.5]: Identify & Explain the Role of Enzymes & Coenzymes in Cellular Respiration

Question 90

Definitions:

a. Enzymes.

Biological catalysts that speed up reactions, e.g., ATP synthase in the ETC produces ATP.

b. Co-enzymes.

NAD^+ and FAD transport electrons and protons to the ETC; their reduced forms (NADH, $FADH_2$) are critical for ATP production.

Question 91 (1 mark)

What role do coenzymes such as NAD^+ play in cellular respiration?

A. They directly phosphorylate ADP to form ATP.

B. They act as carriers for electrons and protons to the ETC.

C. They break down glucose into pyruvate during glycolysis.

D. They denature enzymes in the Krebs Cycle.

Space for Personal Notes

Question 92 (1 mark)

What would happen if NADH could not be oxidised during the ETC?

A. ATP production via oxidative phosphorylation would decrease.

B. Glycolysis would continue without interruption.

C. The Krebs Cycle would produce more NADH to compensate.

D. Cellular respiration would switch entirely to anaerobic pathways.

Question 93 (1 mark)

How does ATP synthase produce ATP in the Electron Transport Chain?

A. It transfers electrons to oxygen, forming ATP as a byproduct.

B. It uses the proton gradient across the inner mitochondrial membrane to drive ATP synthesis.

C. It catalyses the breakdown of NADH into ATP.

D. It directly absorbs energy from glucose breakdown.

Question 94 (1 mark)

What distinguishes enzymes from coenzymes in cellular respiration?

A. Enzymes are catalysts, while coenzymes transport molecules like electrons or protons.

B. Coenzymes catalyse reactions, while enzymes are passive carriers.

C. Both enzymes and coenzymes are regenerated during cellular respiration.

D. Coenzymes are used only in glycolysis, while enzymes are used in the Krebs Cycle.

Space for Personal Notes

Question 95 (1 mark)

What would happen if $FADH_2$ levels were significantly reduced?

A. ATP production in the ETC would decrease.

B. Glycolysis would stop due to a lack of substrate.

C. Oxygen consumption in the ETC would increase.

D. The Krebs Cycle would continue unaffected.

Question 96 (5 marks)

In mammalian cells, the breakdown of glucose involves a series of metabolic pathways facilitated by enzymes and coenzymes. Coenzymes play a crucial role in transferring energy during cellular respiration.

a. Describe the roles of coenzymes in glycolysis and the Electron Transport Chain (ETC). (3 marks)

- Coenzymes such as NAD^+ and FAD assist in glycolysis and the Electron Transport Chain by acting as electron and proton carriers (1 mark).
- NAD^+ is reduced to NADH in glycolysis and the Krebs Cycle, transferring high-energy electrons to the ETC to drive ATP production (1 mark).
- FAD is reduced to $FADH_2$ in the Krebs Cycle and similarly contributes electrons to the ETC for ATP synthesis (1 mark).

When glucose enters a cell, it is converted into glucose-6-phosphate by hexokinase. This intermediate can be further processed through glycolysis, or diverted to other pathways. Enzymes with specific active sites ensure efficient processing of these intermediates.

b. Identify one structural feature of enzymes mentioned in the information above and explain how this structural feature affects their specificity. (2 marks)

- **Structural Feature:** Enzymes have uniquely shaped active sites that are specific to their substrates (1 mark).
- **Importance:** The specific shape of the active site allows only complementary substrates, such as glucose or glucose-6-phosphate, to bind, ensuring efficient catalysis and regulation of metabolic pathways (1 mark).

Space for Personal Notes

Sub-Section [2.2.6]: Apply Experimental Design Principles to Create Methodologies to Test Factors That Affect Cellular Respiration

Question 97 (1 mark)

In an experiment testing the effect of temperature on respiration, which variable is independent?

A. Rate of CO_2 production.

B. Amount of glucose used.

C. The temperature at which the experiment is conducted.

D. The concentration of oxygen in the environment.

Question 98 (1 mark)

Why is it important to use a control group when testing the effect of glucose concentration on cellular respiration?

A. To ensure that glycolysis occurs properly.

B. To compare the effect of glucose against a baseline where no glucose is present.

C. To isolate the role of oxygen in the experiment.

D. To measure the rate of fermentation instead of respiration.

Question 99 (1 mark)

What would be a valid dependent variable for an experiment testing the effect of oxygen availability on respiration?

A. The concentration of glucose in the medium.

B. The rate of CO_2 production.

C. The temperature of the environment.

D. The pH of the solution.

Question 100 (1 mark)

A student investigates the effect of pH on the Krebs Cycle. Which step would best serve as the independent variable?

A. Adjusting the pH of the mitochondrial solution.

B. Measuring the amount of ATP produced.

C. Keeping the oxygen concentration constant.

D. Measuring the amount of CO_2 produced.

Question 101 (1 mark)

Why does controlling temperature matter when designing an experiment to test respiration?

A. Temperature variations can denature enzymes, affecting the results.

B. Low temperatures increase ATP production artificially.

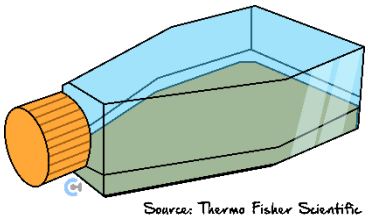
C. High temperatures prevent glucose from entering the Krebs Cycle.

D. Temperature changes directly affect oxygen concentration.

Space for Personal Notes

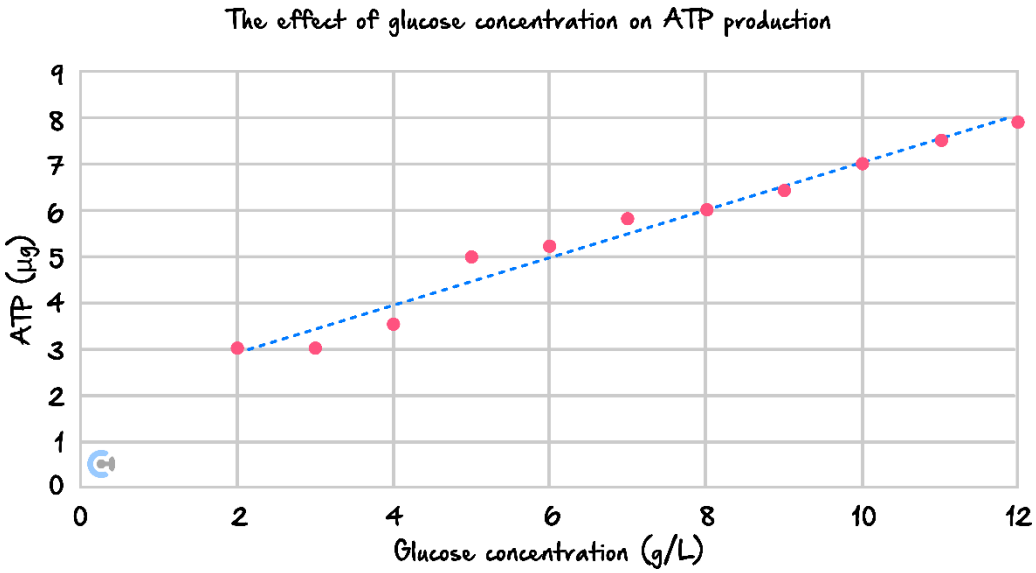
Question 102 (9 marks)

A researcher carries out an experiment to test the effect that altering glucose concentration has on ATP production in muscle cells. This was accomplished by placing samples of muscle cells into sealed tissue culture flasks (as shown in the image below). Each sample of muscle cells was provided with a nutrient solution that contained a different concentration of glucose.



Source: Thermo Fisher Scientific

The amount of ATP produced in each condition was recorded and used to construct the graph shown below.



a. Explain why the experimenter chose to use muscle cells in this experiment. (1 mark)

Worked solution

Because the experiment tested the effect of glucose concentration on ATP production, cells with mitochondria were required. Muscle cells have large numbers of mitochondria, making them an appropriate choice.

Mark allocation: 1 mark

- 1 mark for providing an answer that links the purpose of the experiment to the requirement for cells with mitochondria

b. Name the independent variable in this experiment. (1 mark)

Worked solution

The concentration of glucose in g/L

Mark allocation: 1 mark

- 1 mark for stating glucose concentration

Tip

- *It is important that all answers are precise because incomplete answers may not be awarded a mark. In this example, writing 'glucose' as the answer would be insufficient.*

c. Name the dependent variable in this experiment. (1 mark)

Worked solution

The mass of ATP produced

Mark allocation: 1 mark

- 1 mark for stating the amount of ATP as the dependent variable

d. Name a specific variable that would need to be controlled in this experiment. Explain why this variable would need to be controlled. (2 marks)

Worked solution

The mass of muscle cells used in each tissue culture flask

The muscle cells are responsible for carrying out aerobic cellular respiration. If the mass of cells were to be varied in each flask then this would introduce an additional independent variable to the experiment and we would not be sure whether the change in the amount of ATP was due to glucose concentration or muscle mass.

Mark allocation: 2 marks

- 1 mark for stating a factor that would need to be controlled (e.g. length of time or volume of nutrients supplied)
- 1 mark for explaining how that factor will affect the result of the experiment

e. Describe the trend that is shown in the graph. Explain why this trend occurs. (2 marks)

Worked solution

The amount of ATP produced increases linearly as glucose concentration increases.

Glucose is an input of aerobic cellular respiration (specifically glycolysis), and ATP is an output of aerobic cellular respiration. If the glucose input is increased then the ATP output should also increase.

Mark allocation: 2 marks

- 1 mark for correctly stating the trend
- 1 mark for explaining why the trend occurred

f. The researcher found that when the glucose concentration was $0\ g/L$, ATP production was $1.5\ \mu g$. The researcher did not include this data on their graph because they believed it was an error.

Instead of leaving the information off the graph, what should the researcher have done to increase the validity of their results? Explain why this action should have been taken. (2 marks)

Worked solution

The researcher should have performed the experiment several more times.

This action should have been taken to see whether or not the results were concordant. If the experiment were to be repeated several times and the results were concordant then it is unlikely that the ATP production at 0 g/L glucose concentration is an error and so it should be included on the graph.

Mark allocation: 2 marks

- 1 mark for stating the action that should be taken
- 1 mark for explaining why this action should be taken

Space for Personal Notes

Sub-Section [2.2.7] & [2.2.8]: Describe the Importance of Breaking Do Biomass Into Simple Sugars for Biofuel Production; Explain How Yeast Can be Used to Produce Bioethanol From Biomass

Question 103 (1 mark)

Biofuels are an alternative to traditional energy sources that are finite, such as fossil fuels. Which of the following is an implication that should be considered with the use of biofuels?

A. Excess carbon dioxide will be produced through the fermentation pathway.

B. Not everyone will have access to biofuels.

C. Contamination from other products mixed with the initial fuel source.

D. All the above.

Carbon dioxide is a by-product of fermentation, and if there is not sufficient plant material to absorb the carbon dioxide, this would be released to the atmosphere. Access to any new technology creates implications for equity and contamination of fuel sources may also occur.

Question 104 (1 mark)

What would happen if oxygen were present during bioethanol production?

A. Yeast would switch to aerobic respiration, reducing ethanol production.

B. Ethanol production would increase due to faster fermentation.

C. The enzymatic hydrolysis process would stop.

D. The biomass would not break down into simple sugars.

Question 105 (1 mark)

Why are simple sugars essential for yeast fermentation?

A. They provide the enzymes required for ethanol production.

B. They serve as the primary substrate for glycolysis and fermentation.

C. They prevent oxygen from interfering with fermentation.

D. They act as a solvent for ethanol production.

Question 106 (6 marks)

a. Bioethanol and biodiesel are 2 biofuels produced from biomass. For biomass to be converted into a usable energy source for commercial use a series of steps must occur.

Complete the following table outlining what occurs at each step of the bioethanol production. (4 marks)

Steps	Key Events
Pre-treatment	Surface area of biomass increased by grinding substrate (1).
Enzymatic Hydrolysis	Enzymes added to break the bonds between monomers (1)
Fermentation	Oxygen removed to allow fermentation to occur (1).
Distillation and Purification	Water is removed to create a usable biofuel (1).

b. Is bioethanol renewable? Explain with reference to its definition. (2 marks)

Bioethanol is produced from renewable biological sources such as crops (e.g., corn, sugarcane, or wheat). These crops are grown annually, and their sugars are fermented to produce bioethanol. Since the source (biomass) can be replenished each year through planting, bioethanol is considered a renewable energy source. Additionally, the carbon dioxide released when bioethanol is burned is absorbed by plants during photosynthesis, completing a continuous carbon cycle.

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Section C: [2.1 – 2.2] – Overall (VCAA Qs) (53 Marks)

Question 107 (11 marks)

Elsa read that blue algae survive better under low light intensity than green algae because blue algae possess specialised pigments that absorb a wider range of light wavelengths. Elsa decided to investigate this by carrying out an experiment.

Using a standard technique, single-celled algae were trapped in jelly balls. One set of balls contained green algae, and another set contained blue algae.

To measure the rate of photosynthesis, Elsa used a stopwatch and an oxygen sensor to detect the concentration of oxygen dissolved in the solution. Oxygen production is an indicator of photosynthetic activity. Elsa placed the jelly balls into test tubes and illuminated them using a lamp with blue light filters. She then measured the change in dissolved oxygen concentration over time.

a. State the hypothesis that Elsa was testing. (1 mark)

- Blue algae photosynthesise faster than green algae when exposed to blue light.
- OR Blue algae produce more oxygen than green algae under blue light.

b. List three variables that would need to be controlled to ensure the experiment produced valid results. (3 marks)

Examples of controlled variables (any three):
- The number of jelly balls in each test tube.
- The duration of exposure to blue light.
- The intensity of the blue light provided by the lamp.
- The volume of solution in each test tube.
- The temperature of the environment.

c. State the independent variable and the dependent variable in this experiment. (2 marks)

- **Independent variable:** The type of algae (green algae or blue algae).
- **Dependent variable:** The rate of oxygen production (dissolved oxygen concentration).

d. Explain how Elsa could confirm that the oxygen concentration is a reliable indicator of photosynthetic activity. (2 marks)

- Elsa could confirm this by ensuring that other variables affecting oxygen concentration, such as respiration, are minimised or accounted for.
- She could also measure oxygen concentration in the absence of light to rule out non-photosynthetic processes.

e. Predict what Elsa might observe if her hypothesis is correct. (3 marks)

- Test tubes containing blue algae would show a higher rate of oxygen production compared to those with green algae.
- Oxygen levels in the blue algae test tubes would increase more quickly over the same period of exposure to blue light.
- Green algae would exhibit slower oxygen production under the same conditions.

Question 108 (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)

Glucose is the substrate for aerobic cellular respiration (a metabolic process), and hence the levels of glucose uptake into the cell can show its rate. For example, the more glucose being taken into the cell can indicate a higher rate of respiration.

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)

Higher uptake
- With less oxygen, the cell would not respire aerobically, producing less ATP for each glucose molecule.
- The cell would take up more glucose to get the same amount of energy.

OR

Lower uptake
- With less oxygen, the cell would respire anaerobically and produce toxic products that could cause damage to cells.

OR

Same uptake
- Oxygen is not required for the breakdown of glucose, so glycolysis still occurs and produces less ATP and less energy for the cell.

The marking scheme is weird for this one - as long as you elaborate and expand on one of the options, it should be fine.

Question 109 (6 marks)

In most mammalian cells, ATP is produced from the complete breakdown of glucose through various chemical reactions. Coenzymes play an essential role in facilitating these reactions, particularly in energy transfer.

a. Describe the roles of coenzymes in cellular respiration. (3 marks)

- Coenzymes such as NAD^+ and FAD play a critical role in cellular respiration by acting as electron and proton carriers (1 mark).
- NAD^+ is reduced to NADH in glycolysis and the Krebs Cycle, transferring high-energy electrons to the Electron Transport Chain for ATP production (1 mark).
- FAD is reduced to $FADH_2$ in the Krebs Cycle, which also delivers electrons to the ETC, albeit at a lower energy level (1 mark).

A researcher measured the effect of oxygen availability on the metabolism of glucose in skeletal muscle cells at 37°C. The results are shown in the table below:

Oxygen Availability	Glucose Consumed (*n* moles/ 10^7 cells/hour)	Lactate Produced (*n* moles/ 10^7 cells/hour)
Absent	2.0	4.0
Present	1.2	0.5

b. Why do the results differ in the presence and absence of oxygen? Explain your answer. (3 marks)

- In the absence of oxygen, skeletal muscle cells rely on anaerobic respiration, leading to higher glucose consumption and lactate production (1 mark).
- When oxygen is present, aerobic respiration occurs, allowing the cells to generate more ATP per glucose molecule, reducing glucose consumption and lactate production (1 mark).
- The presence of oxygen enables oxidative phosphorylation in the mitochondria, which is far more efficient than anaerobic pathways (1 mark).

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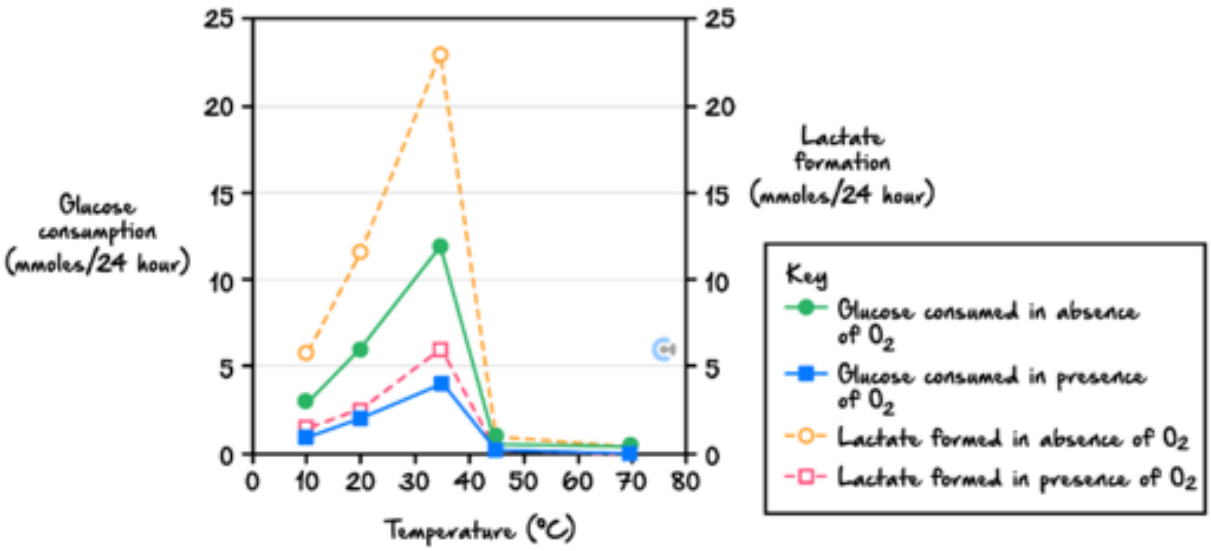
Question 110 (12 marks)

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)

A non-competitive inhibitor binds to a site on the enzyme away from the active site, causing a change to the active site. This results in the substrate no longer binding to the enzyme, or the rate of product formation is lower, or the enzyme cannot catalyse the reaction as efficiently.

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: Glucose consumption at 35°C is 4 moles/24 hours.

Lactate production: Lactate production at 35°C is 6 moles/24 hours.

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)

Students were required to recognise that glucose is consumed in both the presence and absence of oxygen and were then required to account for the results both in terms of the presence and absence of oxygen.
When there is no oxygen, glucose/pyruvate is converted into only lactate. Double the amount of lactate is produced for every one glucose consumed through glycolysis and fermentation, or more glucose will need to be consumed as less ATP/energy is produced. When oxygen is present, glucose/pyruvate can also be converted into water and carbon dioxide. This leads to a smaller ratio of lactate formed compared to glucose consumed, or a greater amount of ATP/energy is produced through aerobic cellular respiration to meet its energy requirements.

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)

At 45°C, enzymes involved in biochemical processes begin to denature, resulting in a decreased rate of reaction compared to when there is optimal glucose consumption and lactate production at 35°C.

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Question 111 (11 marks)

A study investigated the effect of a drug called Pyruvablock, which inhibits the enzyme pyruvate dehydrogenase, a key enzyme required to convert pyruvate into acetyl-CoA. Researchers analysed glucose metabolism in actively growing muscle cells in two groups: one treated with 5 micromoles of Pyruvablock and the other untreated. The results are shown below:

Pyruvablock (micromoles)	Glucose Consumed (micromoles/10^6 cells)	Lactate Produced (micromoles/10^6 cells)
0	12.10	4.50
5	24.25	48.60

a. Explain why both glucose consumption and lactate production change when cells are treated with 5 micromoles of Pyruvablock. (2 marks)

- In the presence of Pyruvablock, the conversion of pyruvate into acetyl-CoA is inhibited, preventing pyruvate from entering the Krebs Cycle (1 mark).
- As a result, the cell consumes more glucose to meet its energy demands through glycolysis, which is less efficient, and lactate production increases due to reliance on anaerobic fermentation to regenerate NAD^+ for glycolysis (1 mark).

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

- **Metabolic Pathways:** Glycolysis, Link Reaction, Krebs Cycle, and Electron Transport Chain (1 mark).
- **Locations:**
  - Glycolysis: Cytoplasm
  - Link Reaction, Krebs Cycle, and Electron Transport Chain: Mitochondria (Link Reaction and Krebs Cycle in the matrix; ETC on the cristae). (1 mark).

c. Predict what would happen to ATP production if the concentration of Pyruvablock were increased to 10 micromoles. Explain your reasoning. (3 marks)

- ATP production would decrease further (1 mark).
- The higher concentration of Pyruvablock would inhibit more pyruvate dehydrogenase, preventing a greater proportion of pyruvate from entering the Krebs Cycle and reducing the availability of NADH and $FADH_2$ for the Electron Transport Chain (1 mark).
- The cell would rely almost entirely on glycolysis for ATP production, which is far less efficient, and lactate accumulation would increase further (1 mark).

d. **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)

Experiment Design for 2-DATP:

- To determine if 2-DATP is a competitive or non-competitive inhibitor for phosphofructokinase (PFK), set up the following experiment:

Steps:

1. Prepare multiple test tubes with varying concentrations of fructose-6-phosphate (substrate).
2. Add the same concentration/volume of 2-DATP to each test tube.
3. Include a control test tube with no 2-DATP.
4. Maintain constant conditions (e.g., temperature, pH).
5. Measure the amount of fructose-1,6-bisphosphate formed under each condition.

Results Interpretation:

- **Competitive Inhibition**:
  - Increasing the substrate (fructose-6-phosphate) concentration will overcome inhibition.
  - At high substrate concentrations, the rate of fructose-1,6-bisphosphate formation will approach the same level as the uninhibited control.
- **Non-competitive Inhibition**:
  - Increasing the substrate concentration will not restore the enzyme activity.
  - The formation of fructose-1,6-bisphosphate will remain lower than the control across all substrate concentrations, as the inhibitor affects the enzyme's active site or functionality irreversibly.

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Question 112 (7 marks)

Yeast is a single-celled, microscopic fungus that uses sucrose as a food source. An experiment was carried out to investigate cellular respiration by a particular species of yeast.

Yeast cells were placed in a container and a sucrose solution was added. An airtight lid was placed on the container. The percentages of oxygen and ethanol in the container were recorded over a one-hour period. The experiment was carried out at room temperature. The results are shown in the following table.

	Percentage of oxygen	**Percentage of ethanol**
At the start of the experiment	21	0
At the end of the experiment	18	4

a. Explain any changes that have been observed in oxygen and ethanol levels within the airtight container. (2 marks)

Ethanol levels rose as ethanol is a product of anaerobic respiration. Oxygen levels decreased as oxygen is required for aerobic respiration.

Cellular respiration was not a suitable term to use in the answer.

Levels of carbon dioxide were also monitored during the experiment.

b. Predict whether the carbon dioxide concentration inside the airtight container would increase, stay the same or decrease within the time the experiment was carried out. Explain the reasoning behind your prediction. (2 marks)

Prediction: Increase

Explanation: CO_2 is a product of (one of)

- cellular respiration
- aerobic respiration
- anaerobic respiration.

Respiration alone was not awarded any marks.

Scientists are looking at ways to increase the efficiency of photosynthesis in plants, including the way in which carbon dioxide is captured.

c.

i. Name the stage of photosynthesis in which carbon dioxide is captured. (1 mark)

Light-independent stage or Calvin (Benson) cycle

Many students initially gave the light-independent stage, but changed their answer to the light-dependent stage.

ii. The stage of photosynthesis in which carbon dioxide is captured requires other inputs. Name two other inputs and describe the role played by each in this stage of photosynthesis. (2 marks)

Name of input	Role
ATP	provides energy to form glucose
NADPH	carries hydrogen ions

NAD was incorrect as it is a carrier molecule in cellular respiration and not in photosynthesis.

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