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VCE Biology ¾
Photosynthesis & Biochemical Pathways [2.1]
Homework Solutions

Homework Outline:

Compulsory Questions	Pg 2 – Pg 33

Section A: Compulsory Questions (70 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.

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Question 2 (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

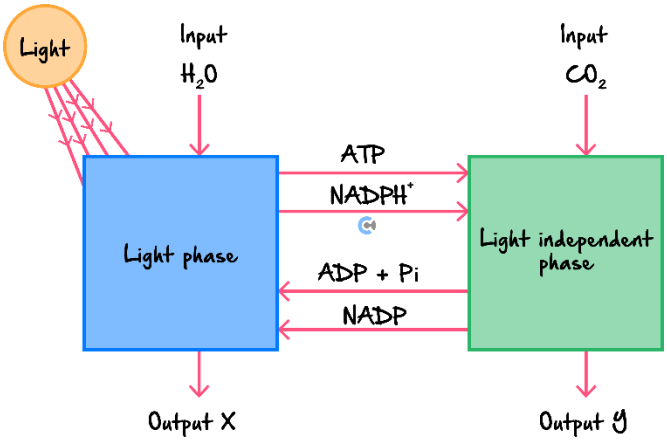
Inputs	Outputs	Location
$6CO_2$	Glucose ($C_6H_{12}O_6$)	Stroma in Chloroplast.
$18ATP$	$18ADP + Pi$	
$12NADPH$	$12NADP +$	

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 3 (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.

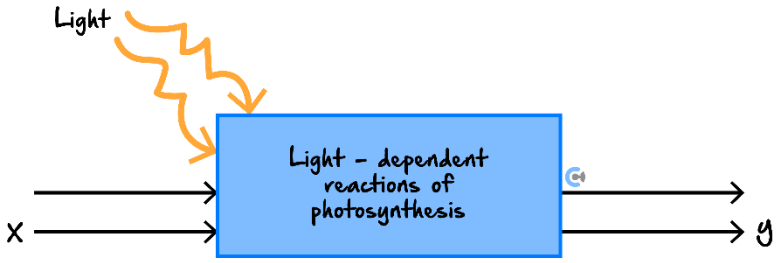
iii. What is output *Y*? (1 mark)

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.

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

Question 4

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 5

A researcher identifies a plant mutation where $NADP^+$ cannot be reduced to NADPH during the light-dependent stage. What is the most immediate consequence for the Calvin Cycle?

A. RuBP will fail to regenerate, halting the cycle.

B. 3-PGA will not be reduced to G3P, preventing glucose synthesis.

C. CO_2 will no longer bind to Rubisco for fixation.

D. ATP synthesis in the thylakoid membrane will completely stop.

NADPH is essential in the Calvin Cycle to reduce 3-PGA (3-phosphoglycerate) into G3P (glyceraldehyde-3-phosphate). Without NADPH, the cycle cannot produce glucose.

Question 6

How do enzymes contribute to the efficiency of photosynthesis?

A. By directly capturing and storing light energy in glucose molecules.

B. By reducing the activation energy needed for key biochemical reactions.

C. By transporting electrons through the thylakoid membrane.

D. By absorbing light energy required for photolysis.

Enzymes like Rubisco and ATP synthase reduce the activation energy for reactions, accelerating processes like CO_2 fixation and ATP production during photosynthesis.

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Question 7 (3 marks)

Describe the role of coenzymes in the process of photosynthesis.

- Coenzymes will help facilitate the biochemical pathway of photosynthesis by assisting enzymes in speeding up the rate of reactions.
- ATP will provide energy for the reactions, formed through the light-dependent stage absorbing light energy through chlorophyll.
- NADPH is an electron and proton carrier which will carry them from the LDS to the LIS to allow for the reduction of CO_2 into glucose through the Calvin Cycle.

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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 8

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 9

Which characteristic makes PEP carboxylase is more effective than Rubisco under low CO_2 conditions?

A. It has no oxygenase activity, so it avoids binding O_2.

B. It fixes CO_2 directly into glucose without needing the Calvin Cycle.

C. It is active only during high light intensity conditions.

D. It requires less energy than ATP for catalysis.

PEP carboxylase, used in C_4 and CAM plants, fixes CO_2 efficiently and does not bind O_2, making it superior to Rubisco in preventing photorespiration.

Question 10

Why is Rubisco considered inefficient under high temperatures?

A. It denatures and stops functioning.

B. It preferentially binds O_2 instead of CO_2, leading to photorespiration.

C. It requires more ATP at higher temperatures.

D. It cannot bind CO_2 under low humidity conditions.

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Question 11 (1 mark)

What is the consequence of photorespiration on photosynthesis?

A. It increases the production of glucose.

B. It enhances CO_2 fixation by Rubisco.

C. It reduces photosynthetic efficiency by wasting energy.

D. It generates additional ATP for the Calvin Cycle.

Question 12 (1 mark)

Which environmental condition is most likely to increase Rubisco's oxygenase activity?

A. High CO_2 concentration.

B. Low temperature.

C. High O_2 concentration and high temperature.

D. High humidity and moderate light.

Question 13 (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

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 14

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 15

How do C_4 plants minimise photorespiration?

A. By opening their stomata only at night to conserve water.

B. By using spatial separation of CO_2 fixation and the Calvin Cycle.

C. By increasing Rubisco's affinity for CO_2.

D. By relying solely on the Calvin Cycle for photosynthesis.

Question 16

What is the key difference between C_4 and CAM plants?

A. CAM plants fix CO_2 in the mesophyll cells, while C_4 plants fix CO_2 in the stroma.

B. CAM plants separate CO_2 fixation and the Calvin Cycle by space, while C_4 plants separate them by time.

C. C_4 plants open their stomata at night, while CAM plants open their stomata during the day.

D. CAM plants separate CO_2 fixation and the Calvin Cycle by time, while C_4 plants separate them by space.

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Question 17

Why are C_3 plants more susceptible to photorespiration compared to C_4 and CAM plants?

A. They lack the enzyme Rubisco.

B. They perform photosynthesis only at night.

C. They rely on Rubisco for direct CO_2 fixation without any adaptations to minimise O_2 binding.

D. They do not use chlorophyll for photosynthesis.

Question 18

Photorespiration is more likely to occur in a leaf when:

A. The level of carbon dioxide is higher than the level of oxygen.

B. The level of oxygen is higher than the level of carbon dioxide.

C. There is a surplus of water and a lack of carbon dioxide.

D. The sun goes down and the stomata close.

B is correct. Photorespiration is the term given to the reaction between oxygen and Rubisco during photosynthesis. Carbon dioxide competes with oxygen for the active site of Rubisco; thus, photorespiration is more likely to occur when the level of oxygen is higher than the level of carbon dioxide.

A is incorrect. A higher level of carbon dioxide promotes carbon fixation, not photorespiration.

C is incorrect. Water availability will not directly affect the action of oxygen or carbon dioxide.

D is incorrect. When the stomata close at night, less oxygen will be present as the light dependent reaction does not occur and more carbon dioxide will be present as cellular respiration increases.

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Question 19 (5 marks)

Compare the photosynthetic pathways of C_3, C_4 and CAM plants.

- **C_3 plants** fix CO_2 directly through the Calvin Cycle using Rubisco, which can bind both CO_2 and O_2, making them more prone to photorespiration, especially in hot or dry conditions.
- **C_4 plants** use a two-step process where CO_2 is initially fixed into a 4-carbon compound by PEP carboxylase in mesophyll cells, then transported to bundle sheath cells for the Calvin Cycle, reducing photorespiration.
- **CAM plants** separate CO_2 fixation and the Calvin Cycle temporally; they open their stomata at night to fix CO_2 into organic acids and use it during the day for photosynthesis, conserving water in arid conditions.
- C_3 plants perform best in cool, moist environments, while C_4 plants are adapted to hot, sunny conditions, and CAM plants thrive in arid, water-scarce environments.
- C_4 and CAM plants have evolved mechanisms to minimise photorespiration, while C_3 plants rely solely on Rubisco, making them less efficient under stress conditions.

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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 20

A plant demonstrates high glucose production at 25°C but shows a sharp decline at 40°C. Which pathway does it most likely use?

A. C_3 photosynthesis.

B. C_4 photosynthesis.

C. CAM photosynthesis.

D. Photorespiration.

C_3 plants are efficient at moderate temperatures but suffer from photorespiration at high temperatures.

Question 21

A plant produces more glucose at 40°C and low humidity compared to 25°C and high humidity. What type of photosynthesis does it use?

A. C_3.

B. C_4.

C. CAM.

D. Both C_4 and CAM.

C_4 plants thrive in hot, low-humidity environments due to their ability to minimise photorespiration through spatial CO_2 fixation.

Question 22

A desert plant performs most of its photosynthesis at night. What photosynthetic pathway is this plant using?

A. C_3.

B. C_4.

C. CAM.

D. None of the above.

CAM plants open stomata at night to fix CO_2 and store it for daytime photosynthesis, conserving water in arid conditions.

Question 23

In a controlled experiment, a researcher measures the photosynthetic rate of a plant at 40°C and 2% humidity. The plant shows no significant decrease in photosynthesis. What adaptation likely allows this?

A. Temporal separation of CO_2 fixation and the Calvin Cycle.

B. High Rubisco activity in mesophyll cells.

C. Spatial separation of CO_2 fixation in bundle sheath cells.

D. High stomatal opening during the day.

The ability to maintain photosynthesis at high temperatures and low humidity indicates the plant is likely a C_4 species. Spatial separation in C_4 plants ensures efficient CO_2 concentration and reduced photorespiration under these conditions.

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Question 24

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 (℃)	**Carbon dioxide in surrounding air (%)**	**Relative humidity of surrounding air (%)**	**Quantity of glucose produced (mg/day)**
20	5	80	85
20	2	80	50
30	5	80	70
30	2	60	45
40	5	30	35
40	2	30	20

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 performs best at moderate temperatures (20°C to 30°C) and high humidity, as shown by the highest glucose production (85 mg/day) at 20°C and 80% humidity.
- At higher temperatures (40°C) and lower humidity (30%), glucose production drops significantly to 35 mg/day or lower, which is characteristic of C_3 plants because photorespiration becomes more prevalent.
- The plant's glucose production also decreases when CO_2 levels are reduced (e.g., from 5% to 2%), which further supports the idea that this plant relies heavily on Rubisco for CO_2 fixation. Rubisco's inefficiency at low CO_2 concentrations and high temperatures is a hallmark of C_3 plants.
- Unlike C_4 plants, which maintain high efficiency under hot and dry conditions, or CAM plants, which thrive in extremely arid environments by fixing CO_2 at night, this plant is highly sensitive to these conditions, indicating a C_3 photosynthetic pathway.

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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 25

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 26

Why is red light more effective than green light for photosynthesis?

A. Red light penetrates deeper into the leaf.

B. Chlorophyll absorbs red light more effectively than green light.

C. Red light stimulates photolysis directly.

D. Green light inhibits chlorophyll production.

Chlorophyll pigments absorb red and blue light efficiently, while green light is mostly reflected.

Question 27

Identify the factor that affects the rate of photosynthesis shown in the figure below:

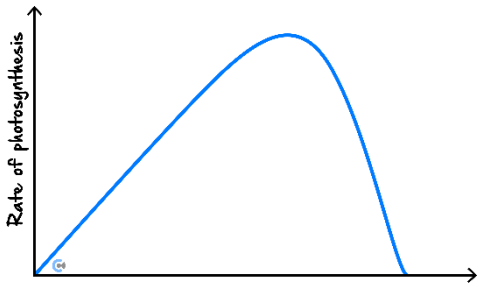


Figure 4: The changing rate of photosynthesis.

A. Temperature.

B. Light intensity.

C. Availability of water.

D. Carbon dioxide concentration.

Question 28

Identify which one of the following will increase the rate of photosynthesis:

A. Increasing water.

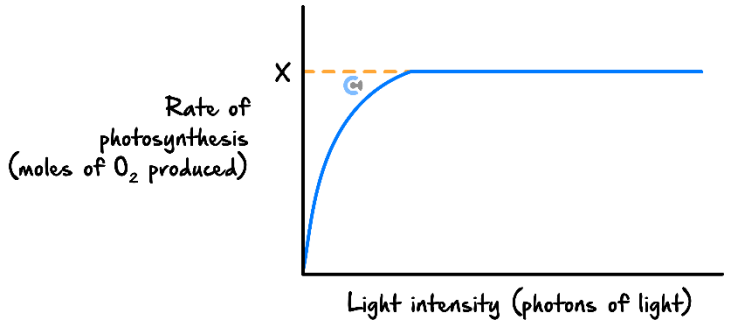
B. Decreasing temperature.

C. Decreasing oxygen.

D. Increasing light.

Question 29

A student shone a light on a green leaf and measured the rate of photosynthesis. The student varied the intensity of the light and graphed the findings as shown below. *X* was the maximum rate of photosynthesis detected by the student.



Which one of the following conditions will increase the value of *X*?

A. Adding a filter to the light used.

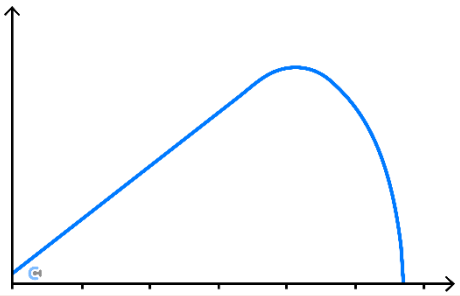
B. Using a leaf that contains more chloroplasts.

C. Moving the light further away from the leaf.

D. Decreasing the temperature of the leaf's environment.

Question 30

A student conducted an experiment investigating factors that affect the rate of photosynthesis. They produced the following graph but forgot to label the axis. The most likely labels would be:



A. *x*-axis: pH; *y*-axis: Rat

The y axis would be the rate of reaction, as this is the dependent variable. The x axis would be temperature as the graph shows an increase in rate of reaction, followed by a steep decline following the peak. If this was a pH graph, the shape would be symmetrical.

B. *x*-axis: Temperature; *y*-axis: Rate of reaction.

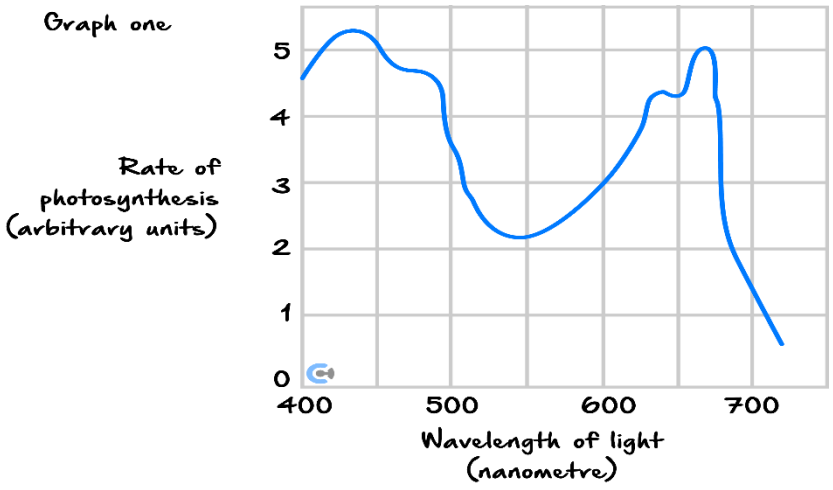
C. *x*-axis: Rate of reaction; *y*-axis: pH.

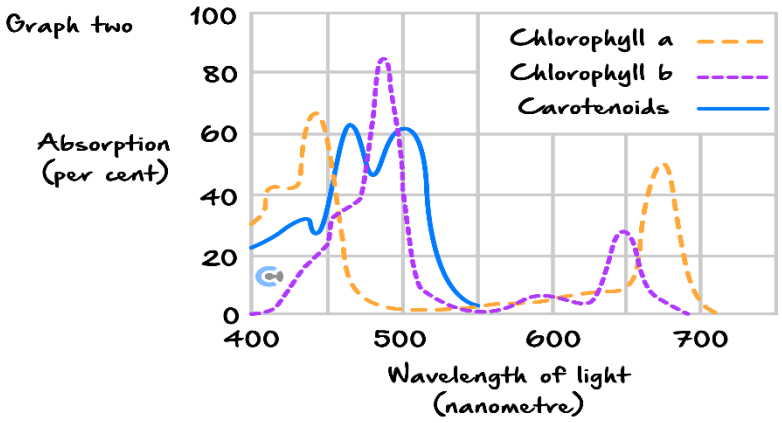
D. *x*-axis: Rate of reaction; *y*-axis: Temperature.

Question 31 (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.

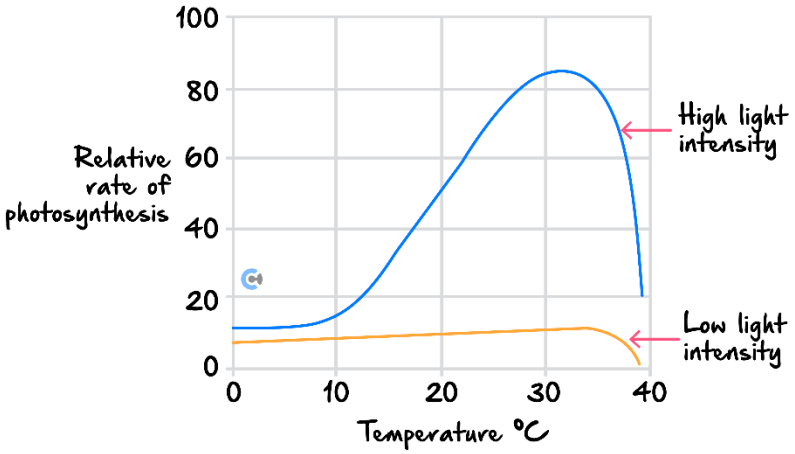
Question 3a.

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.

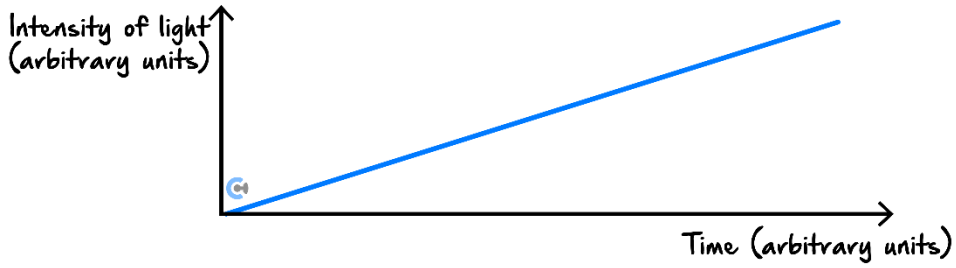


Figure 9

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**).

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

Question 32

A student investigates the effect of light intensity on the rate of photosynthesis using pondweed in water. Which of the following is the most appropriate dependent variable for this experiment?

A. The number of oxygen bubbles released per minute.

B. The distance of the light source from the pondweed.

C. The amount of water added to the container.

D. The wavelength of light used in the experiment.

Oxygen production is a direct indicator of photosynthetic activity, making it the dependent variable in this experiment.

Question 33

A researcher is testing how CO_2 concentration affects photosynthesis. What is the most suitable independent variable?

A. The glucose concentration in plant tissues.

B. The rate of water loss through stomata.

C. The level of CO_2 in the experimental setup.

D. The amount of sunlight received by the plant.

The independent variable is what the researcher changes – in this case, CO_2 concentration.

Question 34

In an experiment testing the effect of temperature on photosynthesis, what control variable should be maintained?

A. The type of plant used in the experiment.

B. The intensity and wavelength of light.

C. The CO_2 concentration in the environment.

D. All of the above.

To ensure reliable results, all other factors (plant type, light, and CO_2) must remain constant, isolating temperature as the variable being tested.

Question 35

A student designs an experiment to measure the effect of different light wavelengths on photosynthesis. What is the most appropriate tool to measure the dependent variable?

A. A spectrophotometer to measure chlorophyll absorbance.

B. A dissolved oxygen sensor to measure oxygen production.

C. A thermometer to measure heat generated by the light source.

D. A hygrometer to measure humidity changes.

Oxygen production is a key indicator of photosynthesis and is directly affected by light wavelength.

Question 36

In an experiment, a student observes that increasing light intensity initially increases the rate of photosynthesis, but eventually the rate plateaus. What is the best explanation for this observation?

A. CO_2 concentration becomes the limiting factor.

B. The chloroplasts become damaged by excess light.

C. ATP production stops in the light-dependent stage.

D. The plant uses green light, which is less effective.

At high light intensity, other factors like CO_2 availability become limiting, preventing further increases in photosynthesis.

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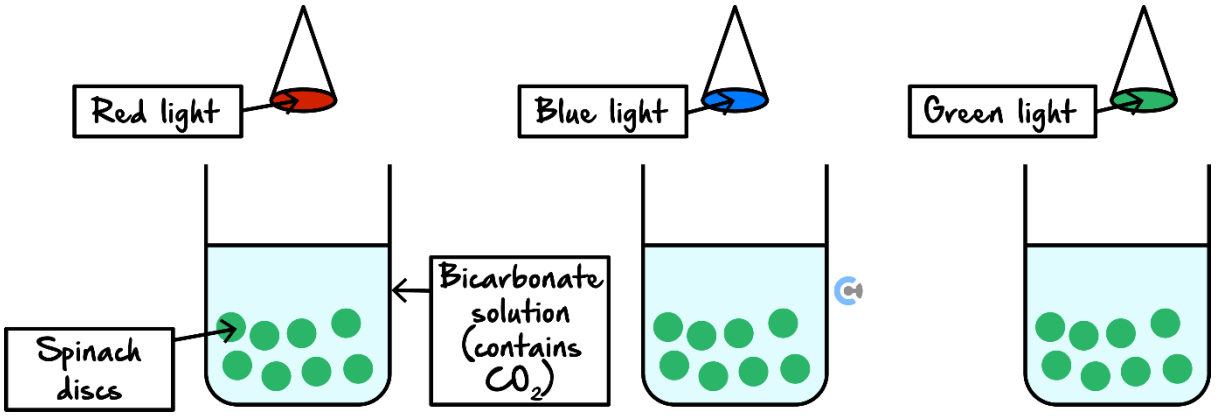
Question 37 (9 marks)

A scientist carries out an investigation into how different wavelengths of light affect the rate of photosynthesis. She takes small discs of spinach and removes the air from them using a syringe. These are then placed into beakers with bicarbonate solution (a source of carbon dioxide) and exposed to either green, red or blue light, as shown below. She leaves them for 10 minutes and counts the number of discs that have risen every minute.



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 (1 mark)
- Oxygen makes the disc rise, therefore faster the discs rise the faster the rate of photosynthesis (1 mark)

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

- The leaf discs under red and blue light will rise faster than those under green light (1 mark)
- Because the leaf discs can absorb red and blue light for use in photosynthesis, but reflect green light (1 mark)

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

Place the same set up in the dark to ensure that no other factors cause the leaf discs to rise (1 mark)

d. This experiment relies on one of the stages of photosynthesis occurring correctly. Identify this stage and state what is produced as a result of this stage. (2 marks)

- Light dependent stage (1 mark)
- produces oxygen, ATP and NADPH (1 mark)

e. The scientist predicted that the levels of glucose produced by the cells in each experiment would be the same. Is she correct? Explain your reasoning. (2 marks)

- Glucose is produced in the light independent stage, using the ATP and NADPH from the light dependent stage to provide the energy for the anabolic reaction (1 mark)
- Under green light the light dependent stage cannot occur, so there will be much less glucose than the red/blue light (1 mark)

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

Question 38

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. Rubisco efficiency:

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 39

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

A. By increasing the expression of Rubisco.

B. By editing Rubisco genes 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 Rubisco gene to reduce its oxygenase activity, thereby minimising photorespiration and improving photosynthetic efficiency.

Question 40

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 pathways.

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 Rubisco or drought-tolerance pathways, improving photosynthetic traits.

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Question 41

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 42

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 43 (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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