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VCE Biology ¾
Photosynthesis & Biochemical Pathways [0.9]
Workshop

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Section A: Multiple Choice Questions (21 Marks)

Question 1 (1 mark)

Consider the role played by light in the light-dependent stage of photosynthesis.

Which one of the following statements is correct?

A. Light is the source of electrons that provide the energy needed to produce ATP.

B. Light provides the energy that is absorbed by chlorophyll, which facilitates the light-dependent stage.

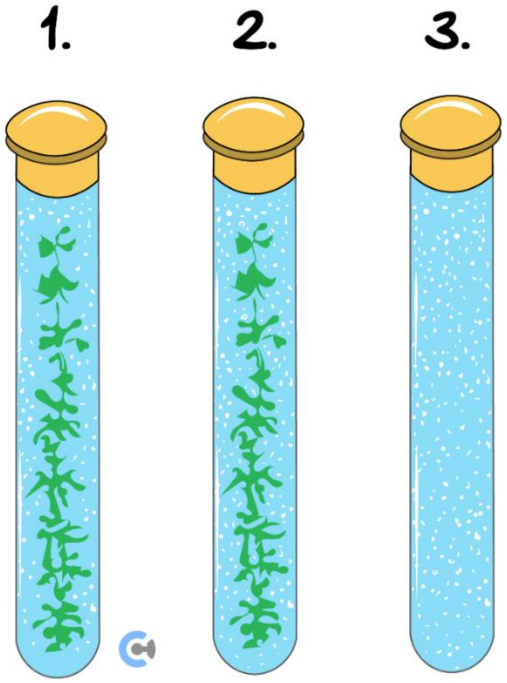
C. Light provides the heat required to split water molecules into hydrogen ions and oxygen gas.

D. Light breaks down ATP molecules, releasing the energy required for NADPH to be moved from the grana to the stroma.

Space for Personal Notes

The following information applies to the two questions that follow:

The following experiment was set up to test the rate of photosynthesis. Elodea (a type of aquatic plant) was used and each of the test tubes was left under a light for 10 minutes. The amount of oxygen produced in each test tube was recorded.



Test tube #	Condition	Result
1	Deoxygenated water and a piece of elodea.	12 units of oxygen were produced.
2	Deoxygenated water, a piece of elodea and 2 g of sodium bicarbonate (an inorganic substance that has the chemical formula $NaHCO_3$ and breaks down to produce CO_2 in solution).	27 units of oxygen were produced.
3	Deoxygenated water only.	No oxygen was produced.

Question 2 (1 mark)

The purpose of including test tube 3 in the experiment was to:

A. Increase the sample size being tested.

B. Enable the effect of the dependent variable to be established.

C. Prove that supplying sodium bicarbonate to elodea plants causes them to produce carbon dioxide.

D. Prove that any oxygen present at the end of the experiment must have been produced by the elodea plants.

Question 3 (1 mark)

Which one of the following reasons accurately explains the difference in the results in test tubes 1 and 2?

A. Sodium bicarbonate is a toxin that decreases the rate of photosynthesis.

B. Sodium bicarbonate acted as a nutrient that improved the ability of the elodea in test tube 2 to carry out photosynthesis.

C. Sodium bicarbonate provided the elodea in test tube 2 with an additional source of carbon dioxide and increased the rate of photosynthesis.

D. Sodium bicarbonate acted as a coenzyme that activated the chlorophyll in the elodea in test tube 2 and caused the rate of photosynthesis to increase.

Question 4 (1 mark)

Chlorophyll is essential for photosynthesis. Concerning chlorophyll, it can be stated that it:

A. Provides electrons that are used to produce ATP.

B. Provides enzymes needed for photosynthesis.

C. Is found in the stroma of the chloroplast.

D. Absorbs light in the green part of the visible spectrum.

Question 5 (1 mark)

C4 plants are adapted to survive in tropical climates. They use a two-staged process to produce glucose whereby PEP carboxylase is used instead of RubisCO for the initial process of carbon fixation. The purpose of using PEP carboxylase to fix carbon dioxide is to:

A. Prevent the process of photorespiration, as oxygen can bind to PEP carboxylase.

B. Prevent the process of photorespiration, as oxygen cannot bind to PEP carboxylase.

C. Allow the process of photorespiration, as carbon dioxide cannot bind to PEP carboxylase.

D. Allow the process of photorespiration, as carbon dioxide can bind to PEP carboxylase.

Space for Personal Notes

Question 6 (1 mark)

Two Biology students, Arun and Chanul, are discussing the effect of coloured lights on photosynthesis. Arun believes that green light increases the rate of photosynthesis because plant leaves are green and absorb the wavelengths of green light. Chanul believes that violet and red light increases the rate of photosynthesis because plant leaves absorb the wavelengths of both violet and red light.

Which student is correct?

A. Arun only.

B. Chanul only.

C. Both Chanul and Arun.

D. Neither Chanul nor Arun.

Question 7 (1 mark)

Which one of the following is the location of the light-dependent reaction of photosynthesis?

A. The matrix.

B. The grana.

C. The cytoplasm.

D. The stroma.

Question 8 (1 mark)

Identify the plant that has stomata only open during the night.

A. C3 plants.

B. C4 plants.

C. CAM plants.

D. All plants.

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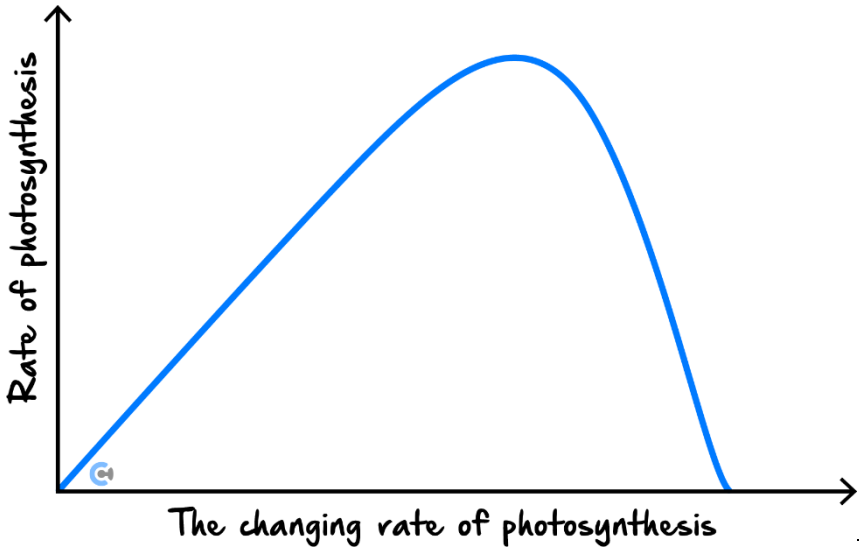
Question 9 (1 mark)

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



A. Temperature

B. Light intensity

C. Availability of water.

D. Carbon dioxide concentration.

Question 10 (1 mark)

CRISPR-Cas9 can be used to modify the genome of RubisCO, increasing its affinity to carbon dioxide over oxygen. This improves photosynthetic affinity as:

A. Oxygen cannot act as a non-competitive inhibitor to carbon dioxide.

B. Carbon dioxide is required for the light-dependent reaction to occur.

C. Carbon dioxide is required for the light-independent reaction.

D. More atmospheric oxygen is available for cellular respiration.

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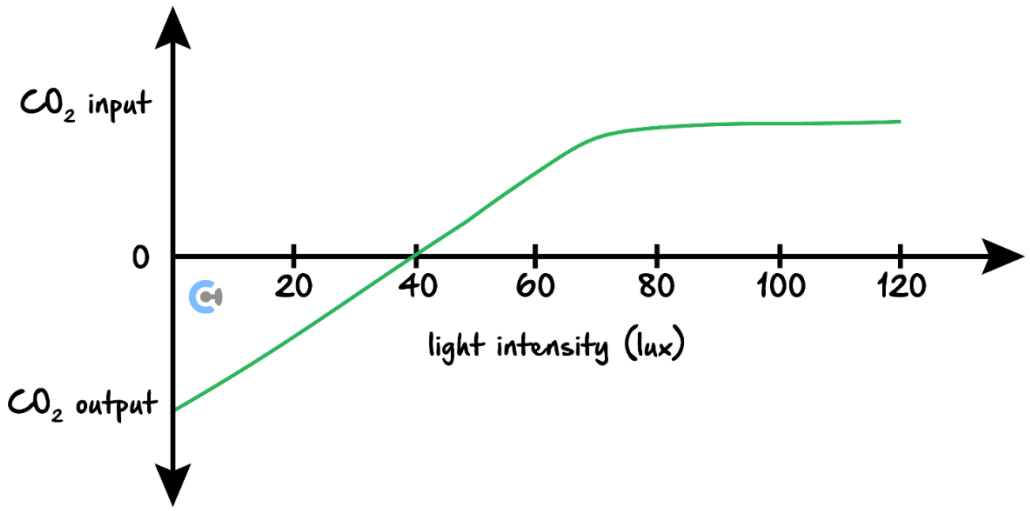
Question 11 (1 mark)

The graph below shows the changes in carbon dioxide (CO_2) levels in a tomato plant as the light intensity is progressively increased.



Reading from the graph, it could be concluded that:

A. The rate of respiration in the tomato plant is at its lowest level at 0 lux.

B. The tomato plant is not photosynthesising at 20 lux.

C. The tomato plant is not metabolising at 40 lux.

D. The concentration of RubisCO is limiting the tomato plant's CO_2 input at 100 lux.

Question 12 (1 mark)

What is the difference between C3, C4 and CAM plants?

A. Unlike C3 and C4 plants, CAM plants, such as cactus, absorb carbon dioxide (CO_2) during the day.

B. C4 plants immediately integrate CO_2 into a 3-carbon compound, whereas C3 and CAM plants initially integrate CO_2 into a 4-carbon compound.

C. C3 plants absorb more CO_2 during the day, whereas C4 and CAM plants absorb more CO_2 at night.

D. CAM plants are suited to temperate climates, C3 plants are suited to dry environments and C4 plants are suited to marine environments.

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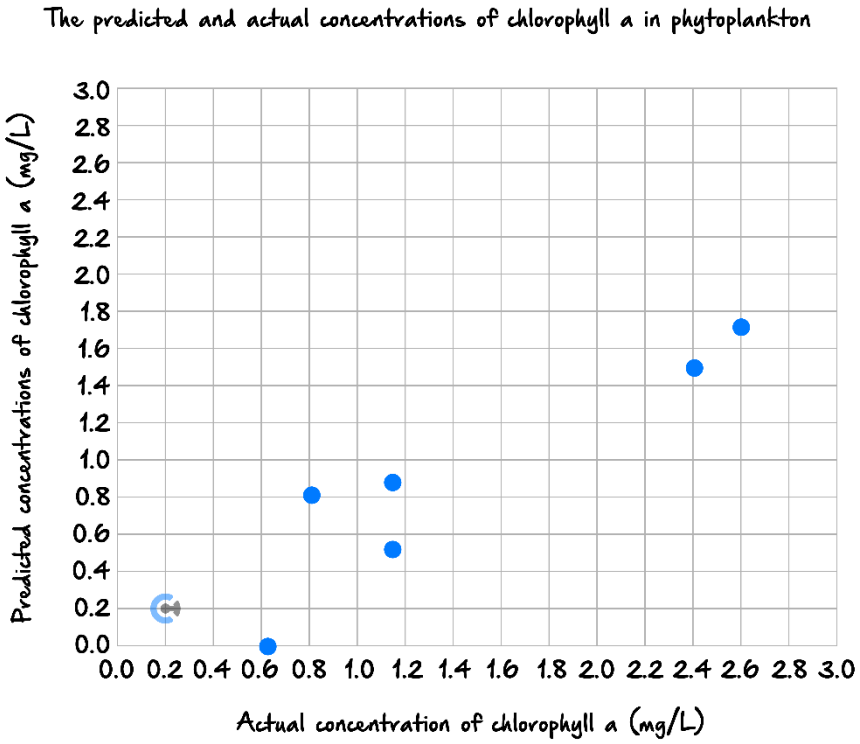
Question 13 (1 mark)

The graph below shows the relationship between the predicted and actual concentrations of chlorophyll a in phytoplankton.



Source: Fairooz Binti Johan et al, 'Chlorophyll a conentration of fresh water phytoplankton analysed by algorithmic based spectroscopy, Journal of Physics: Conference Series, 1083 (2018) 012015, <https://iopscience.iop.org/article/10.1088/1742-6596/1093/1/012015/pdf>; licensed CC-BY3.0 <https://creativecommons.org/licenses/by/3.0/>

From the graph, it can be inferred that:

A. The actual concentration of chlorophyll a was lower than the predicted concentration in all recorded measurements.

B. At 2.4 mg/L, the actual concentration of chlorophyll a, the predicted concentration of chlorophyll a was 2 mg/L.

C. At 0.8 mg/L, the predicted concentration and the actual concentration of chlorophyll a were the same.

D. At zero predicted concentration of chlorophyll a, photosynthesis did not occur.

Space for Personal Notes

Question 14 (1 mark)

During photosynthesis:

A. ATP and NADH created in the light-independent stage are transported to the chloroplasts' thylakoid membranes.

B. ADP and NADH are used in the electron transport chain after being created in the light-dependent stage.

C. ATP and NADPH are created in the grana of the chloroplasts and are used in the light-independent stage.

D. ADP and NADPH are created during the Krebs cycle and carried to the stroma of the chloroplasts.

Question 15 (1 mark)

CAM plants are well adapted to arid environments because they:

A. Open their stomata at night to reduce water loss.

B. Perform the light-dependent and light-independent reactions in different cells.

C. Utilise a unique pigment that absorbs water more efficiently.

D. Can perform photosynthesis without opening their stomata.

Question 16 (1 mark)

Considering environmental factors, which of the following conditions would most likely enhance the efficiency of photosynthesis in C3 plants but not in C4 plants?

A. High light intensity and low temperatures.

B. High temperatures and high CO_2 concentrations.

C. Low oxygen concentrations and high CO_2 concentrations.

D. High oxygen concentrations and low CO_2 concentrations.

Space for Personal Notes

Question 17 (1 mark)

C4 and CAM plants have evolved mechanisms to minimise photorespiration. Which of the following statements correctly distinguishes between C4 and CAM plants?

A. C4 plants fix CO_2 into a four-carbon compound and perform the Calvin cycle in the same cell, whereas CAM plants separate these processes temporally.

B. C4 plants separate the initial CO_2 fixation and the Calvin cycle spatially within different cell types, whereas CAM plants separate these processes temporally within the same cells.

C. CAM plants exclusively use PEP carboxylase for carbon fixation, while C4 plants use both PEP carboxylase and RubisCO.

D. C4 plants are adapted to cold environments, while CAM plants are adapted to high-light environments.

Question 18 (1 mark)

How does an increase in carbon dioxide concentration affect the rate of photosynthesis up to a certain point?

A. It increases the rate of photosynthesis by increasing RubisCO activity until a saturation point is reached.

B. It decreases the rate of photosynthesis due to a reduction in oxygen availability for photorespiration.

C. It has no effect on the rate of photosynthesis as light intensity is the limiting factor.

D. It increases the rate of photosynthesis indefinitely as long as other factors are not limiting.

Question 19 (1 mark)

A biologist is examining a chloroplast exposed to light of varying wavelengths. She notes that oxygen production increases significantly under blue light. This observation is directly related to which aspect of the light-dependent reactions?

A. Absorption of light by chlorophyll leads to the splitting of water molecules, releasing oxygen as a byproduct.

B. Carbon dioxide is being fixed more efficiently into sugars, thereby requiring more oxygen output.

C. ATP and NADPH production rates are highest, leading to excess oxygen production.

D. Blue light increases the permeability of the chloroplast membrane to oxygen, enhancing its release.

Question 20 (1 mark)

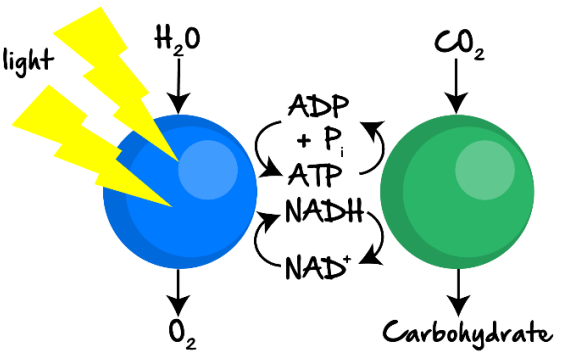
In the context of photosynthesis, evaluate the statements below about the light-dependent and light-independent stages. Which option accurately describes a feature of each stage?

	Light-dependent stage	Light-independent stage
A.	Liberates ATP.	Fixes oxygen.
B.	Splits water molecules.	Utilises ATP.
C.	Takes place in the thylakoid membranes.	Takes place in the cytoplasm.
D.	Generates NADPH.	Recycles ADP and P_i.

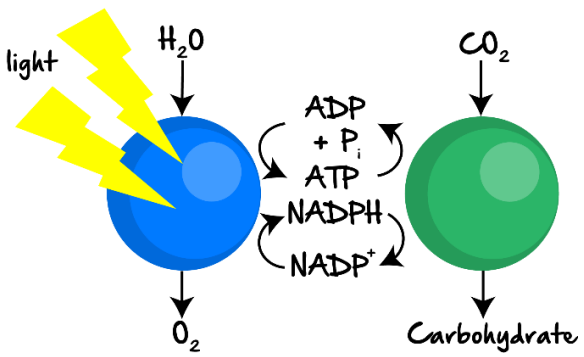
Question 21 (1 mark)

Which one of the following diagrams correctly represents the inputs and outputs of photosynthesis?

A.



B.



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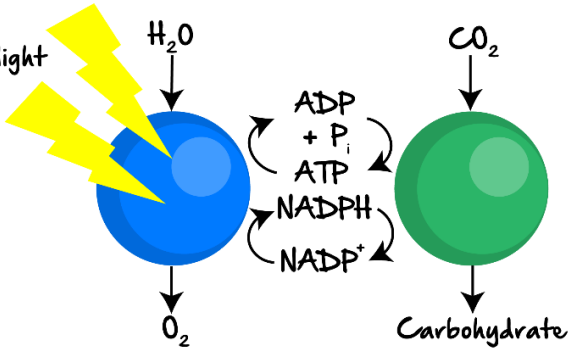
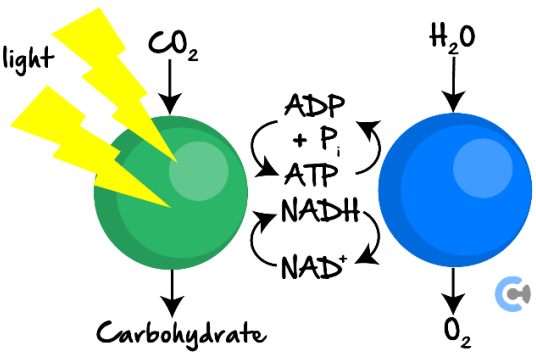


D.



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Section B: Short Answer Questions (108 Marks)

Question 22 (12 marks)

A high school runs an experiment that seeks to investigate a factor that may impact the rate of photosynthesis by using spinach leaves.

This involves submerging them in a solution of Sodium bicarbonate (to provide gas) and water. The spinach was cut into discs, which were then 'vacuum sealed' using a syringe to get rid of all the gases within it.

There were 15 discs in each solution and each solution was placed at a different distance from a lamp.

The time taken for the discs to start floating was measured and recorded.

a. What is the independent variable in this experiment? Describe theoretically how this factor impacts the rate of photosynthesis. (2 marks)

b. What is the dependent variable in this experiment? Describe how this is a valid method of recording the results. (2 marks)

c. What gas is most likely to be present within the spinach leaf in the highest concentrations as they float? Where is this gas produced? (2 marks)

d. Name 2 controlled variables in this experiment. (2 marks)

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The results of this experiment indicated that there was an increase in the rate of photosynthesis, until a certain point at which the rate stopped increasing.

e. Considering the experimental set-up, what is most likely to have been the other limiting factor and why? (2 marks)

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An experiment was conducted testing the effect that temperature had on the time taken for the least discs to float. The results are shown below:

Temperature (°C)	**Time taken for the leaf discs to float (seconds)**
15	480
30	90
45	150
60	480

f. The results gained at 15°C and 60°C are the same, yet the explanation for them is very different. Explain these differences. (2 marks)

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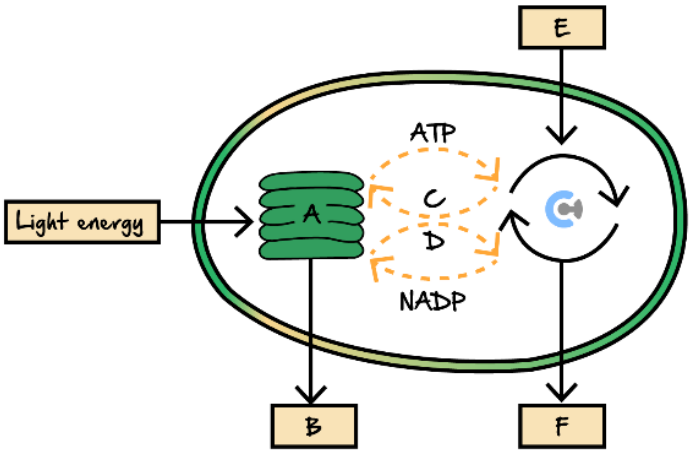
Question 23 (12 marks)

The diagram below summarises the main steps of photosynthesis in C3 plants. Labels *A* - *F* represent structures or chemicals involved in the process.



a. Complete the table by naming components *A* - *F*. (4 marks)

Component	Name
A	
B	
C	
D	
E	
F	

b. What is the function of RubisCO? (1 mark)

_____

_____

c. RubisCO can undergo another process called photorespiration.

When is photorespiration most likely to occur? (2 marks)

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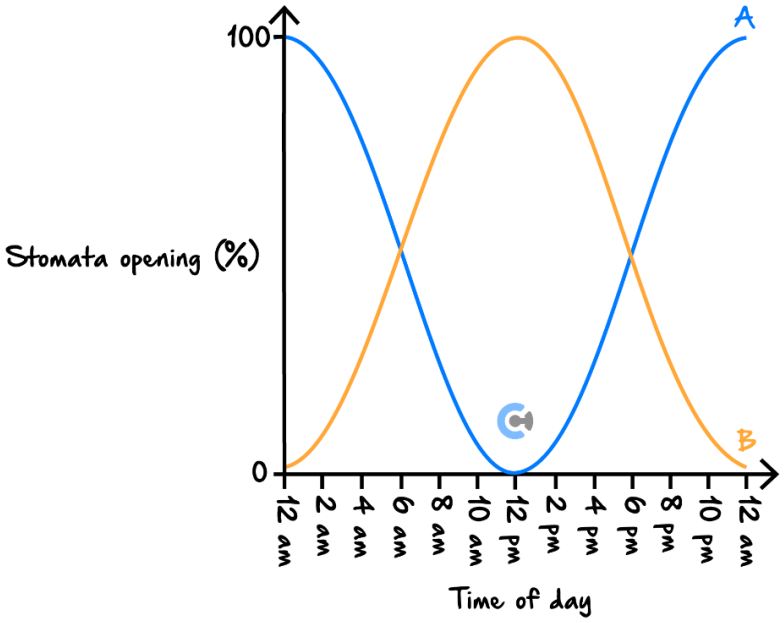
d. Plants have evolved in various ways to reduce the rate of photorespiration. The diagram below shows the pattern of stomatal opening for two types of plants, *A* and *B* over 24 hours.



i. The stomatal opening pattern of plant *B* suggests it is part of a group of plants that have evolved to reduce their rate of photorespiration.
Name the group of plants and state the type of environment in which they are usually found. (2 marks)

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_____

ii. Explain why a plant closing its stomata during the day would increase the rate of photorespiration. (2 marks)

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iii. Describe how the group of plants named in **part d.i.**, reduce the rate of photorespiration. (1 mark)

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Question 24 (8 marks)

There are many different pathways in which plants are able to photosynthesise, including C3, C4 and CAM pathways.

a. In which conditions would C4 and CAM plants be most suited to operate? Explain and compare the two processes of photosynthesis. (4 marks)

b. Explain why it may be beneficial to convert a plant like rice to C4 given the direction that global temperatures are heading in. (2 marks)

c.

i. What DNA manipulation technology might be involved in this process? (1 mark)

_____

_____

ii. If C4 and CAM are more efficient, propose a reason why all plants haven't evolved to suit this process. (1 mark)

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Question 25 (12 marks)

It is known that photosynthesis is temperature-sensitive in C3 plants and for a particular plant, there is an optimal temperature of photosynthesis and if it were to increase from there, the rate of photosynthesis would decrease. This is generally related to a particular enzyme's function and stomatal closure in plants.

a. How might temperature impact this specific enzyme and how does stomatal closure impact the rate of photosynthesis? (3 marks)

b. Name TWO other factors that impact the rate of photosynthesis. (2 marks)

c. State the reaction equation of photosynthesis. (1 mark)

d. Describe the function of photosynthesis. (1 mark)

e. Name the two stages of C3 photosynthesis in plants. (2 marks)

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f. What is the source of ATP in the second stage of photosynthesis? (1 mark)

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_____

g. What other coenzyme is involved in the second stage of photosynthesis? Describe its purpose. (2 marks)

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Question 26 (9 marks)

In an urban greenhouse, a botanist came across a distinctive variety of plant. Lacking information on the plant's classification, the botanist conducted a series of experiments to gauge its photosynthetic performance. The experiments involved recording the rate of starch production each day while subjecting plants of uniform size to varying environmental factors. The findings are tabulated below.

Effect of different environmental conditions on starch production per day:

Temperature (°C)	**Light source**	**Carbon dioxide** (%)	**Relative humidity** (%)	**Rate of starch formed** (mg/day)
20	White	5	60	1.5
20	White	1	60	1.2
20	White	5	35	1.8
20	Green	5	60	0.3
20	Blue	5	60	1.4
40	White	5	60	2.8
40	White	1	60	2.4
40	White	5	35	3.0
40	Green	5	60	0.4
40	Blue	5	60	2.7

a. Considering the experimental outcomes, which photosynthetic classification (C3, C4, or CAM) does this unique plant species likely fall into? Provide a justification for your response. (3 marks)

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_____

b. Describe ONE other way that the scientist could determine which plant type it is. (2 marks)

c. Why does exposing the plants to green or blue light as opposed to white light affect the formation of starch? Justify your answer. (4 marks)

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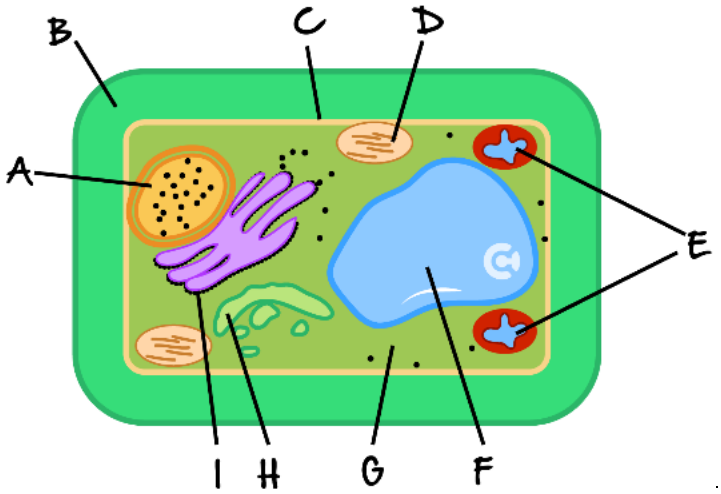
Question 27 (3 marks)

The following diagram is of a photosynthetic plant cell. Labels *A* to *I* represent structures or areas that are important to the functioning of the cell.



In completing the parts below, state which of the labels (*A* to *I*) are consistent with the following structures/processes. Note that there may be more than one answer.

a. Which structures contain DNA? (1 mark)

_____

_____

b. Which structure contains thylakoid membranes? (1 mark)

_____

_____

c. In which area is the electron transport chain located? (1 mark)

_____

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Space for Personal Notes

Question 28 (11 marks)

CRISPR-Cas9 is an emerging technology that can be used to edit genomes in a faster, more cost-effective manner. The proposed usage of this technology is to edit tomato plants so that they become resistant to herbicides.

a. Why this might be a beneficial edit? (1 mark)

_____

_____

b. Discuss the ethical implications of this edit, using a consequences-based approach to ethics. (3 marks)

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c. Describe the process by which CRISPR-Cas9 could actually be applied to this scenario to edit the tomato plant. (3 marks)

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These plants can also be edited to confer resistance to powdery mildew, a fungus that impacts the plant.

d. How might this edit improve crop yields? (2 marks)

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C3 Photosynthesis is inefficient due to an enzyme that is less efficient in certain conditions.

e. How could CRISPR-Cas9 technology be used to alter this enzyme in order to improve its function? (2 marks)

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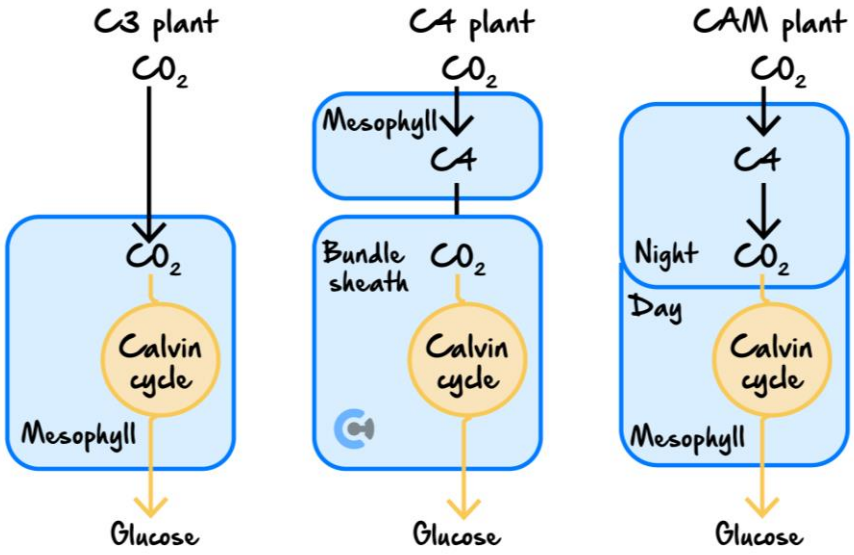
Space for Personal Notes

Question 29 (8 marks)

Plants have the unique ability to photosynthesise and utilise sunlight. They are able to produce high-energy-containing molecules that fix carbon dioxide (CO_2) into forms of carbohydrates that can be stored or used by plant cells. Most plants use the C3 pathway to fix CO_2 and some use the C4 pathway. A small group of plants use a combination of both pathways. This smaller number of plants are called the CAM plants.



Source: Adapted from H Kheyrodin and S Kheyrodin, 'CO_2 gas exchange in Crassulacean acid metabolism and C3 and C4 plants', International Journal of Advanced Research in Biological Sciences, vol. 4, issue 10, 2017, <http://dx.doi.org/10.22192/ijarbs.2017.04.10.007>

As part of their VCE Biology practical investigation, a group of students collected plant samples from their school grounds. While the students were able to identify most of the plants they collected, there was one they had not seen before. They performed a series of experiments with this plant in the laboratory. The observations they made, as well as documented information for C3, C4 and CAM plants are shown in the table below.

Plant Characteristic	Unknown Plant	C3 Plant	C4 Plant	CAM Plant
The ideal temperature for photosynthesis.	25 - 35°C	15 - 25°C	30 - 40°C	> 40°C
Pathway to fix CO_2.	C4 pathway and Calvin cycle.	Only Calvin cycle.	C4 pathway and Calvin cycle.	C4 pathway and Calvin cycle.
Stomata open during the day.	Yes	Yes	Yes	No
Photorespiration occurring.	Moderate to low	High	Low	Only observed in the middle of the day.
Water loss during the day.	Moderate	High	Moderate	Low
Plant growth rate.	Moderate	Moderate	Fast	Very slow

a. Based on the information provided, state whether the unknown plant is a C3, C4 or CAM plant. Justify your response. (5 marks)

b. Outline three additional steps that could be carried out to extend the investigation and assist with identifying the unknown plant. (3 marks)

Space for Personal Notes

Question 30 (8 marks)

A researcher had just landed on Contour Land shores and realised that there were a bunch of sick-looking plants that he had never seen before. He tests them under a bunch of conditions to find out what they are.

Plant *A*

Temperature (°C)	**Light Intensity**	**CO_2 Concentration** (%)	**Stomata Status**	**Relative Humidity** (%)	**Starch Production (mg/day)**
18	Low	0.03	Always Open	70	0.9
18	High	0.03	Always Open	70	1.0
18	High	0.06	Always Open	70	1.1
25	Low	0.03	Always Open	70	1.0
25	High	0.03	Always Open	70	1.2
25	High	0.06	Always Open	70	1.1
40	High	0.06	Always Open	70	0.6

a. Based on the information provided, state whether the unknown plant is a C3, C4 or CAM plant. Justify your response. (4 marks)

He finds another plant!

Plant *B*

Temperature (°C)	**Light Intensity**	**CO_2 Concentration** (%)	**Relative Humidity** (%)	**Starch Production (mg/day)**
20	Low	0.02	70	20
20	High	0.02	30	20
20	High	0.04	30	20
40	Low	0.02	70	30
40	High	0.02	20	21
40	High	0.04	10	18

b. Based on the information provided, state whether the unknown plant is a C3, C4 or CAM plant. Justify your response. (4 marks)

Space for Personal Notes

Question 31 (8 marks)

A local middle school undertakes a study to explore the effects of varying carbon dioxide levels on the rate of photosynthesis in aquatic plants.

The experiment involves placing samples of Elodea (an aquatic plant) in different concentrations of carbonated water, which is achieved by dissolving varying amounts of baking soda in the water. Each sample is then exposed to the same intensity of light from a grow lamp.

The number of oxygen bubbles produced by each plant sample over a set period is counted as they rise to the surface of the water, providing a measure of the photosynthetic activity of the plants.

a. What is the independent variable in this experiment? Theoretically, explain how this factor could influence the rate of photosynthesis. You may draw a graph. (2 marks)

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b. What is the dependent variable in this experiment? Justify why this method of measuring the rate of photosynthesis is scientifically sound. (2 marks)

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Angad wanted to expand the results of the experiment to a greenhouse where the Elodea could be produced in large quantities. Vishal told him that he must keep the temperature tightly controlled.

c. Explain why Angad must keep the temperature tightly controlled for photosynthesis. (2 marks)

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d. Scientists are developing a new material to cover greenhouses which can split incoming light and convert rays from green wavelengths to red wavelengths.

Explain how this new material increases crop yields. (2 marks)

_____

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Question 32 (8 marks)

Seedlings of three different plant species were exposed to three different environments to compare their growth in each environment. One of the three plant species was classified as a C3 plant, another as a C4 plant and the third as a CAM plant. The three environmental conditions were as follows:

Environment 1: 22°C with daily watering, exposed to natural light conditions.
Environment 2: 30°C with minimal water, exposed to natural light conditions.
Environment 3: 30°C with minimal water, exposed to 24-hour light.

The following results were observed after two weeks under these conditions.

Environment	**Observations After Two Weeks**		
	Plant *A*	**Plant *B***	**Plant *C***
1	The plant has grown and appears to be healthy.	The plant has grown and appears to be healthy.	The plant has grown and appears to be healthy.
2	The plant has grown and appears to be healthy.	The plant has only grown a little and appears wilted and unhealthy.	The plant has grown and appears to be healthy.
3	The plant has only grown a little.	The plant has only grown a little and appears wilted and unhealthy.	The plant has grown and appears to be healthy.

a. From the table of observations, identify each of the plants *A*, *B* and *C* as either the C3 plant, C4 plant or CAM plant. Give reasons for your answers, referring to their adaptations to different environments. (4 marks)

b. Describe the role of RubisCO in photosynthesis and describe the effects of high temperatures on this process. (2 marks)

c. Describe a limitation of the type of data collected in this experiment and suggest a modification of the investigation that may address this. (2 marks)

Question 33 (9 marks)

Calandrinia balonensis is an Australian flowering plant found in arid regions west of the Great Diving Range and throughout central Australia. It is well-adapted to its warm climate and is usually found growing in red sandy soils and spinifex zones. Like many plants that adapted to a hot, dry climate, *C. balonensis* utilises the CAM pathways of photosynthesis.

a. Describe how the adaptations of *C. balonensis* maximise the efficiency of photosynthesis in a warm, arid environment. (2 marks)

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b. Briefly describe the role of RubisCO in synthesising glucose in photosynthesis and outline how coenzymes are involved in this process. (2 marks)

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c. Referring to the role of RubisCO, explain why photorespiration is more likely to occur at higher temperatures. (2 marks)

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d. Like CAM plants, C4 plants are adapted to hot climates. Compare the process of photosynthesis in C4 and CAM plants. (3 marks)

Space for Personal Notes

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