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

46 Marks. 1 Minute Reading. 37 Minutes Writing.

Results:

Test Questions	_____ / 42
Extension Question	_____ / 4

Section A: Test Questions (42 Marks)

Question 1 (5 marks)

Tick whether the following statements are **True** or **False**.

	True	False
a. The light-dependent stage of photosynthesis occurs in the thylakoid membranes of the chloroplast.	✓	
b. The light-independent stage (Calvin Cycle) occurs in the stroma of the chloroplast.	✓	
c. Rubisco exclusively binds CO_2 during the Calvin Cycle.		✓
d. CAM plants open their stomata at night to fix CO_2 into malate and store it in vacuoles.	✓	
e. C_4 plants are adapted to cold environments with low temperatures.		✓
f. Photorespiration increases in hot, dry conditions due to stomatal closure, reducing CO_2 levels.	✓	
g. Green light is absorbed efficiently during photosynthesis.		✓
h. ATP and NADPH are both products of the light-dependent stage and are used in the Calvin Cycle.	✓	
i. CRISPR-Cas9 can be used to modify plants to improve photosynthetic efficiency and crop yields.	✓	
j. C_3 plants experience minimal photorespiration under all conditions.		✓

Space for Personal Notes

6	11	12	19	58

This question required an understanding of the processes of photosynthesis. This included the order of the two significant parts, the light dependent reactions and light independent reactions (the Calvin cycle), and the role of each.

Question 2 (1 mark)

The chloroplast is the organelle responsible for photosynthesis in eukaryotic cells.

In chloroplasts:

A. The light independent reactions require water as the initial reactant.

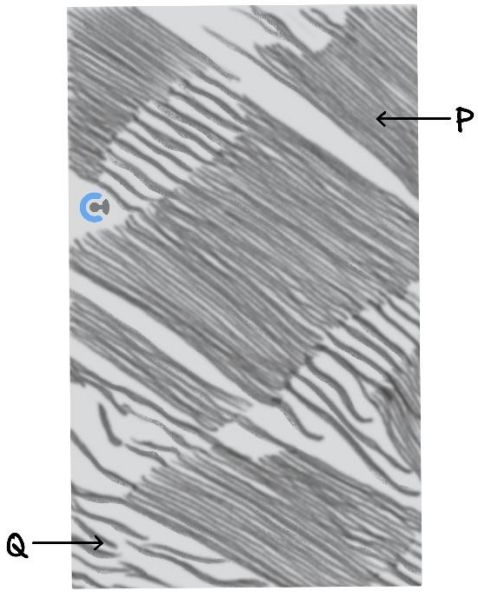
B. The light independent reactions occur in the inner membrane area.

C. The final product of the light reaction is glucose.

D. The light reactions occur in the grana.

Question 3 (1 mark)

The following image shows a portion of an electron photomicrograph of a chloroplast.



Light-dependent reactions occur in region P and the Calvin cycle reactions occur in region Q.

Considering events that occur in a chloroplast during photosynthesis, it is reasonable to claim that:

A. Oxygen is an input to reactions at P.

B. Carbon dioxide is an input to reactions at Q.

18	12	42	16	30

Students needed to know the relationship between the differential structure of an organelle and the role of each part in order to answer this question.

Question 4 (1 mark)

The coenzymes used in the light-independent reaction of photosynthesis include:

A. ATP and NADH.

B. ADP and NADPH.

C. ADP and NADH.

D. ATP and NADPH.

Question 5 (1 mark)

Certain plants combine carbon dioxide with a three-carbon compound (C3) to produce a four-carbon compound (C4) during the night, which can be used in photosynthesis during daylight hours.

This kind of plant is called a:

A. C3 plant.

B. CAM plant.

C. C4 plant.

D. Rubisco plant.

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Question 6 (1 mark)

Consider the process of photosynthesis.

Which of the following shows correct information about each of the two stages of photosynthesis?

	Light-dependent stage	Light-independent stage
A.	Produces oxygen.	Produces carbon dioxide.
B.	Requires water.	Requires NADH.
C.	Occurs in the stroma.	Occurs in the grana.
D.	Energy is provided by light.	Energy is provided by ATP molecules.

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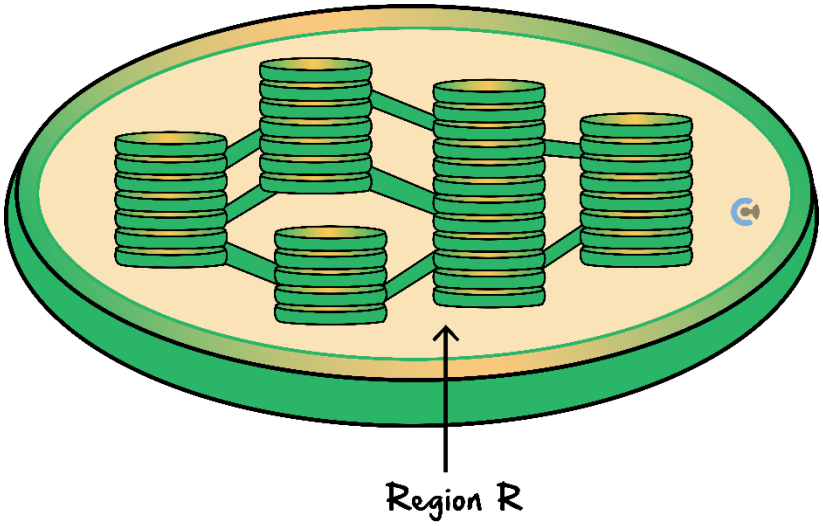
Question 7 (5 marks)

a. A chloroplast is surrounded by a double membrane.

i. Name two molecules, as inputs for photosynthesis, that would need to diffuse from the cytosol of the plant cell across the chloroplast membranes and into the chloroplast. (1 mark)

Water and carbon dioxide (chemical symbols equally acceptable).

ii. Under high magnification, the internal structure of a chloroplast is visible. The diagram below shows part of this structure.



A higher concentration of oxygen is found in Region *R* when a plant is photosynthesising compared to when it is not photosynthesising.

Account for the differences in oxygen concentrations found in this region. (2 marks)

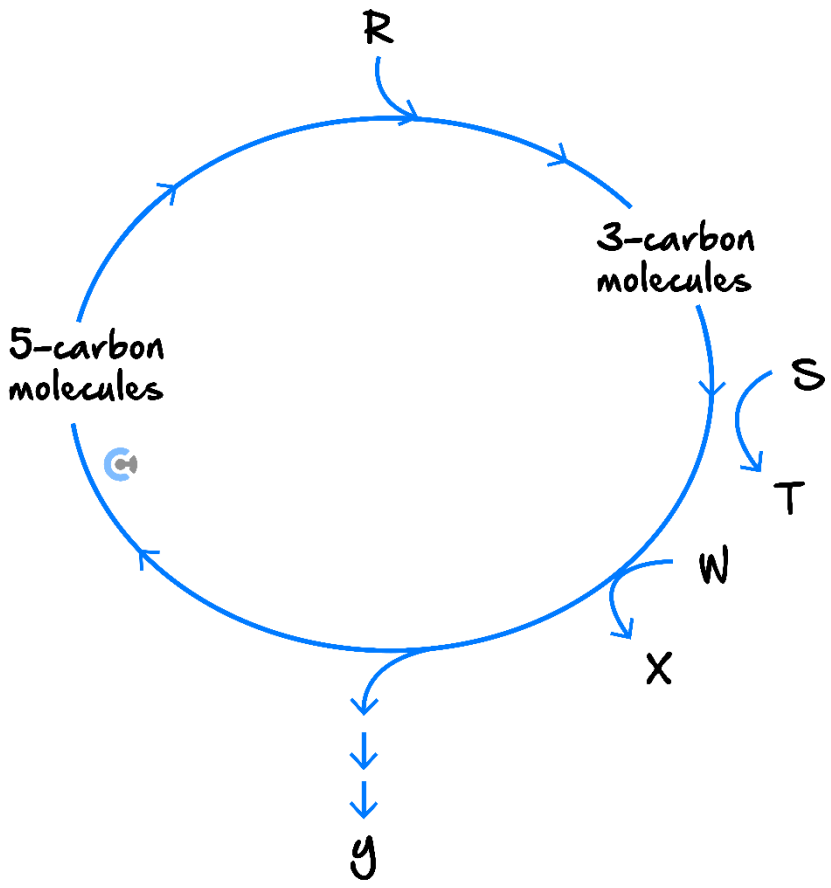
Water is split in the light-dependent reaction to produce oxygen gas.
Oxygen produced diffuses into the stroma (region R) **or** When light is not available, oxygen is not produced.

b. Describe the role played by each of the coenzymes NADPH and ATP in photosynthesis. (2 marks)

NADPH transfers hydrogen ions. Protons and electrons was also an acceptable answer.
ATP transfers energy.

Question 8 (6 marks)

The diagram below is a simplified flow diagram of a series of chemical reactions that occur during photosynthesis.



a. Name the cycle that is represented by the flow diagram above, and state exactly where it takes place. (1 mark)

The Calvin cycle / light independent reaction. It takes place in the stroma of the chloroplast.

b. Complete the following table for the letters on the flow diagram above. (4 marks)

Letter	Name or Chemical symbol
R	
S	
T	
W	
X	
Y	

letter	*name or chemical symbol*
R	CO_2
S	*ATP*
T	*ADP + P*
W	*NADPH*
X	$NADP^+$
Y	*glucose*

c. What is the source of the chemical substances *S* and *W*? (1 mark)

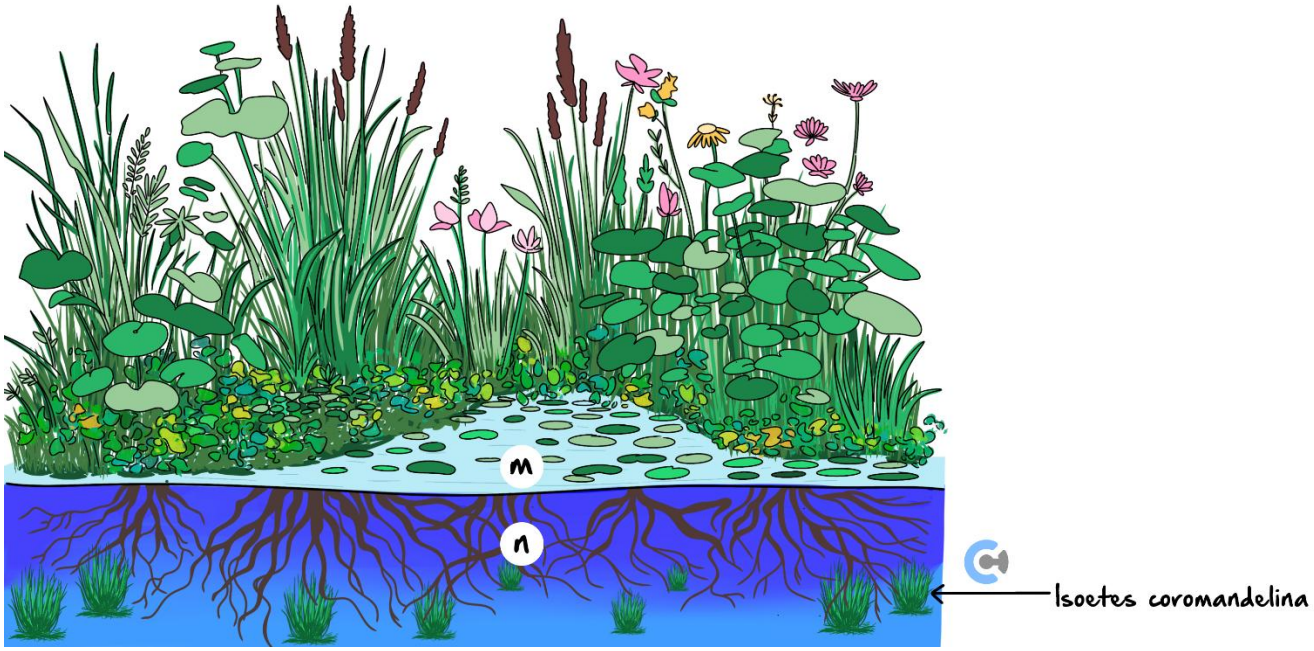
The light dependent reaction.

Space for Personal Notes

Question 9 (6 marks)

Swamps in the Northern Territory of Australia are heavily vegetated. The water typically supports a great variety of plants such as lilies and duckweed as well as abundant green algae which is suspended in the water. Most freshwater plants and green algae use the C3 photosynthetic pathway.

The image below represents a typical vegetation profile of a Northern Territory swamp.



A biologist measured the intensity of various light wavelengths at the water surface (m) and at the benthic floor (n) at noon, He recorded that the intensity of blue light was greater at m than at n.

a. Explain the biologist's results. (1 mark)

a. Water plants and green algae in the water absorb blue light for photosynthesis. Therefore, by the time the light reaches the benthic floor, some of the blue light has been removed and therefore the intensity of blue light is lower at the benthic floor.

He decided to also record the CO_2 concentration in the water at the surface (m) and at the benthic floor (n) at noon.

b. Predict what the results will show, about the relative CO_2 concentration at these two locations at noon. Explain your prediction. (1 mark)

b. The carbon dioxide concentration will be lower at n than at m, because plants and algae in the water absorb CO_2 from the water for photosynthesis. 1 mark

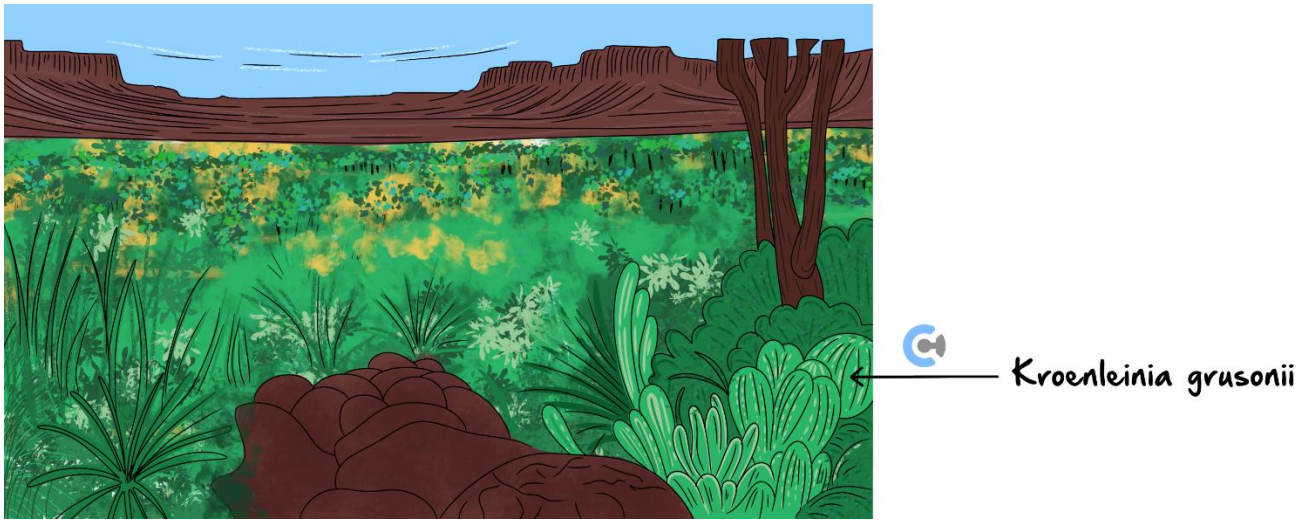
The biologist repeated the measurement, but this time, he recorded the CO_2 concentration at *m* and *n* at midnight.

c. Predict what the results will show, about the relative CO_2 concentration at these two locations at midnight. Explain your prediction. (1 mark)

c. At midnight the concentration of CO_2 at n will be much higher, because the water plants and algae will not be photosynthesising but will be carrying out cellular respiration which produces CO_2, which is dissolved in the swamp water. 1 mark

Other plants live in a desert habitat where it is both hot and arid (dry). Many desert plants such as the golden barrel cactus (*Kroenleinia grusonii*) use CAM photosynthesis instead of C3 photosynthesis.

This is an adaptation to both heat and aridity.



d. Explain how CAM photosynthesis enables *K. grusonii* to thrive in its arid habitat. (1 mark)

d. *K. grusonii* opens its stomata to absorb CO_2, at night when the air is cool and water loss by transpiration will be minimal. The CO_2 is stored as malate in the large vacuoles of mesophyll cells. When the sun rises and photosynthesis becomes possible, the stomata are closed to prevent water loss, and the stored malate is broken down into CO_2 for the Calvin cycle. 1 mark

e. Explain how CAM photosynthesis enables *K. grusonii* to thrive in a hot environment. (1 mark)

e. CO_2 does not dissolve easily in water when the water is warm. When the sun rises on a desert plant such as K grusonii, it gets very hot very quickly. This would normally cause photorespiration to occur because the CO_2 concentration will be low. But in *K grusonii* the stomata are closed at this time, which prevents CO_2 leaving the cell, and large amounts of malate are converted to CO_2, which keeps the CO_2 concentration around RuBisCO high. 1 mark

A small number of aquatic plants such as the Australian quillwort (*Isoetes coromandelina*) are also CAM plants. *Isoetes coromandelina* is labelled in the figure above.

Even though CAM photosynthesis is usually seen as an adaptation to an arid environment, that is not the case for *I. coromandelina* since it grows in water.

f. What advantage would CAM photosynthesis have for an aquatic swamp plant like *Isoetes coromandelina*? (1 mark)

f. Because the concentration of CO_2 in the swamp water is low during the day, this will limit the rate of photosynthesis of plants submersed in the water. But because *I coromandelina* is a CAM plant, it is able to absorb CO_2 at night, when the concentration of CO_2 is very high in the water, and save this CO_2 as malate, for use during the day when there is light, but a lack of CO_2 in the water. 1 mark

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Question 10 (5 marks)

James discovered an unusual plant species in a strange arid environment and wanted to determine its photosynthetic pathway. They conducted experiments to measure glucose production under varying temperatures, humidity levels, and the time of stomatal opening (day or night). The results are summarised in the table below.

Temperature (°C)	**CO_2** (%)	**Humidity** (%)	**Time (Day/Night)**	**Glucose Produced (mg/day)**
20	5	80	Night	40
20	5	10	Night	50
40	5	80	Night	50
40	5	10	Night	70
50	5	80	Night	30
50	5	10	Night	60

a. Based on the information provided, state whether the unknown plant is a C3, C4 or CAM plant. Justify your response. (3 marks)

CAM plant
- Opens stomata at night so increased night time production
- Performs better at higher temperatures and lower humidity
- Use data

b. In reference to the pathway chosen for **part a.**, explain why it is suited to those conditions. (2 marks)

- opens the stomata at night allowing CO2 fixation to occur, storing it as malate in a vacuole

- released during the day to maintain high CO2 concentrations when the stomate is closed avoiding competitive photorespiration.

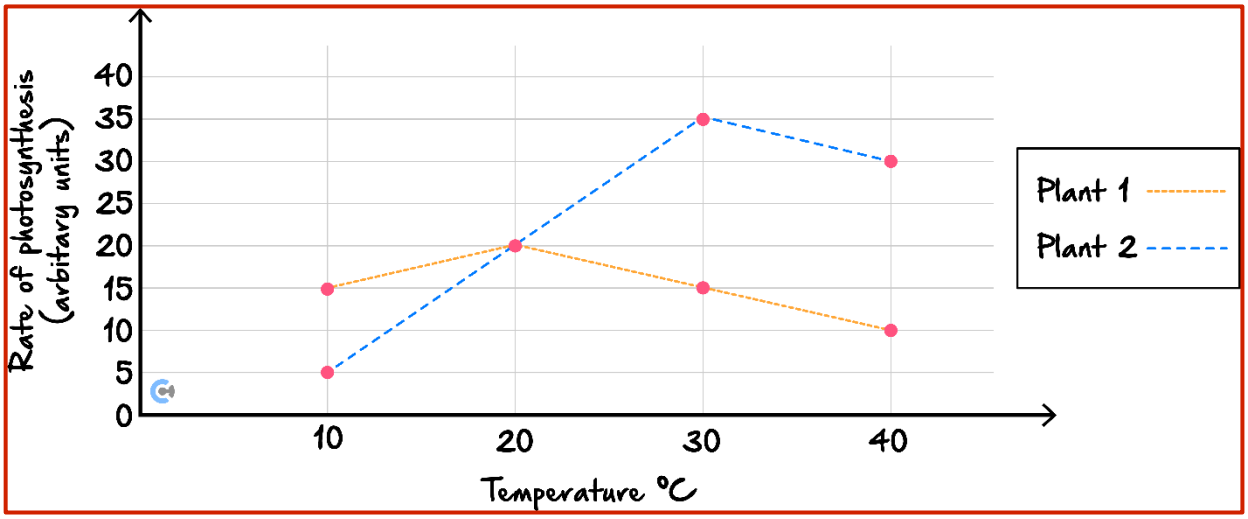
Question 11 (10 marks)

Scientists carried out an experiment to investigate the photosynthetic efficiency of 2 different plant types by measuring the amount of oxygen produced (arbitrary units) at 30 minutes in varying temperatures. The results are shown in Table 2 below.

Temperature °C	Rate of photosynthesis (arbitrary units)
Plant 1	
10 °C	15
20 °C	20
30 °C	15
40 °C	10
Plant 2	
10 °C	5
20 °C	20
30 °C	35
40 °C	30

Table 2: Rate of photosynthesis production (arbitrary units) of two plants subjected to increasing temperatures

a. Using Figure 13, plot a graph of the data collected in Table 2. (4 marks)



b. Analyse the graph of the data collected with reference to the type of photosynthetic pathway undertaken in each plant. Explain. (6 marks)

Plant 1 is a C3 plant **(1 mark)** as it demonstrates its peak photosynthetic rate of 20 arbitrary units at 20 degrees Celsius **(1 mark)**. Beyond this point, photosynthetic rate decreases as the C3 plant undergoes photorespiration, preferentially binding to oxygen instead of carbon dioxide **(1 mark)**. Plant 2 is a C4 plant **(1 mark)** as it demonstrates its peak photosynthetic rate of 35 arbitrary units at 30 degrees Celsius **(1 mark)**. C4 plants can photosynthesise at this higher temperature as it avoids the process of photorespiration **(1 mark)**.

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Section B: Extension Question (4 Marks)

Question 12 (4 marks)

Angad discovered an unusual plant species in a strange arid environment and wanted to determine its photosynthetic pathway. They conducted experiments to measure glucose production under varying temperatures, humidity levels, and light sources, whilst measuring the amount of O_2 that was produced). The results are summarised in the table below.

Temperature (°C)	**Light Source**	**CO_2** (%)	**Humidity** (%)	**Oxygen Output (mg/day)**
20	White	5	75	60
20	Blue	5	75	55
20	Green	5	75	20
40	White	5	30	30
40	Blue	5	30	25
40	Green	5	30	10

Analyse the information provided, stating whether the unknown plant is a C3, C4 or CAM plant. Justify your response.

White and blue light at 20°C promote moderate oxygen output, consistent with efficient photosynthesis in optimal conditions for a C3 plant.
At 40°C, there is a noticeable decrease in oxygen output, even under white or blue light, reflecting the effects of photorespiration, which limits the photosynthetic efficiency of C3 plants at higher temperatures.
Green light shows minimal performance across all temperatures due to its poor absorption by chlorophyll, consistent with general plant physiology.

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