Photosynthesis Reaction

RACHELL DIXON

OVERVIEW:

Background

Photosynthesis is an important process that occurs in organisms such as plants, algae, and even some bacteria. This process allows light energy from the sun to be converted into chemical energy in the form of glucose. This energy is then stored and used by these organisms for their development and various other metabolic activities. Photosynthesis is vital in maintaining oxygen levels in the atmosphere and regulating the global carbon cycle.

Key Definitions

Chloroplasts - Specialized organelles found in plant cells where photosynthesis takes place. They contain pigments, including chlorophyll, which absorb light energy.

Chlorophyll - The primary pigment involved in photosynthesis, responsible for capturing light energy.

Thylakoid - Membrane-bound structures within chloroplasts where light-dependent reactions occur.

Stroma - The fluid-filled space within chloroplasts where the Calvin cycle (light-independent reactions) takes place.

RuBisCO -The enzyme responsible for fixing carbon dioxide during the Calvin cycle.

PHOTOSYNTHESIS

What Is Photosynthesis in Biology?

Photosynthesis is a process used by phototrophs (organisms that use light as their primary source of energy) to convert light energy into chemical energy, which is then used to power cellular activities. The chemical energy is stored as sugars, which are created from water and carbon dioxide.

Photosynthesis takes place in an organelle known as chloroplasts through photosynthetic pigments such as chlorophyll a, chlorophyll b, carotene and xanthophyll. Green plants and a few other autotrophic organisms (organisms that can produce their own food, using materials from inorganic sources) use photosynthesis to combine nutrients by using carbon dioxide, water and sunlight, resulting in the production of oxygen as a by-product.

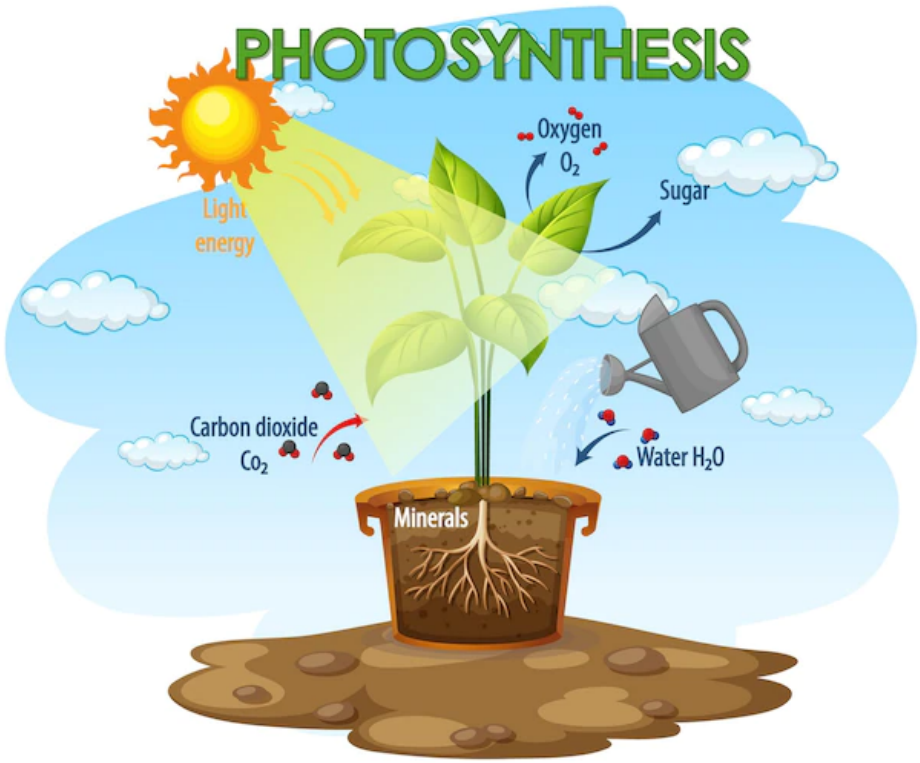
The Photosynthesis Equation

The photosynthesis reaction involves two reactants, carbon dioxide (**$6CO_2$**) and water (**$6H_2O$**). These two reactants yield two products, glucose (**$C_6H_{12}O_6$**)and oxygen (**$6O_2$**).

Photosynthesis Formula

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

The photosynthesis reaction is considered to be an endothermic reaction (absorb or use energy or heat).



A visual representation of the photosynthesis reaction

Factors That Can Affect Photosynthesis

- ✔ **Light Intensity:** As light intensity increases, the photosynthetic rate increases, while low light intensity reduces the photosynthetic rate.

- ✔ **The concentration of CO2:** Higher carbon dioxide concentrations increase the rate of photosynthesis. Carbon dioxide in the range of 300-400 PPM is usually sufficient for photosynthesis.
- ✔ **Temperature:** A temperature range of 25°C to 35°C is critical for efficient photosynthesis.
- ✔ **Water:** Water is an important factor in photosynthesis, lack of water can cause problems with carbon dioxide uptake. A lack of water causes the pores to open, making them unable to hold the amount of water stored in them.
- ✔ **Pollution**: Industrial pollutants and other particles can stick to leaf surfaces. This clogs the stomata and makes it difficult to absorb carbon dioxide.

Where Does This Photosynthesis Occur?

Chloroplasts are the sites of photosynthesis in plants and blue-green algae. These microscopic cellular organelles are present only in plant cells and are located within the mesophyll cells of leaves. Each chloroplast contains a green-coloured pigment called chlorophyll. Four different types of pigments are present in leaves, they are Chlorophyll a, Chlorophyll b, Xanthophylls and Carotenoids. During photosynthesis, light energy is absorbed by chlorophyll molecules whereas carbon dioxide and oxygen enter through the tiny pores of stomata located in the epidermis of leaves.

ACTIVITY 1:

Instructions: Read the information provided above and answer the following questions.

1. Which of the following is the primary pigment involved in photosynthesis?

a) Chlorophyll

b) Carotenoid

c) Anthocyanin

d) Xanthophyll

2. Where does photosynthesis occur?

a) Mitochondria

b) Nucleus

c) Chloroplast

d) Vacuole

3. The primary source of energy for photosynthesis is:

a) Glucose

b) Carbon dioxide

c) Sunlight

d) Oxygen

4. During photosynthesis, oxygen is released as a byproduct from:

a) Carbon dioxide

b) Water

c) Glucose

d) ATP

5. The main purpose of photosynthesis is to:

a) Produce oxygen

b) Generate ATP

c) Convert light energy into chemical energy

d) Break down glucose molecules

6. Which of the following factors affect the rate of photosynthesis by influencing the opening and closing of stomata?

a) Light Intensity

b) Concentration of CO2

c) Temperature

d) Water

7. What is the chemical formula for glucose?

a) $C_6H_{12}O_6$

b) $6O_2$

c) $6H_2O$

d) $6CO_2$

8. Photosynthesis is a process that occurs in:

a) Autotrophs only

b) Heterotrophs only

c) Autotrophs and heterotrophs

d) None of the above

9. What is the primary function of chlorophyll in photosynthesis?

a) Absorb carbon dioxide

b) Release oxygen

c) Capture sunlight

d) Produce glucose

10. Which of the following is a reactant in the process of photosynthesis?

a) Glucose

b) Oxygen

c) Carbon dioxide

d) ATP

11. What effect does an increase in light intensity have on the rate of photosynthesis?

a) It decreases the rate of photosynthesis

b) It has no effect on the rate of photosynthesis

c) It increases the rate of photosynthesis

d) It leads to the cessation of photosynthesis

12. What impact can pollution have on photosynthesis?

a) It enhances the rate of photosynthesis

b) It has no effect on photosynthesis

c) It reduces the rate of photosynthesis

d) It promotes the closure of stomata

13. What is the optimal temperature range for efficient photosynthesis?

a) 0°C to 10°C

b) 15°C to 25°C

c) 25°C to 35°C

d) 40°C to 50°C

14. How does the concentration of carbon dioxide affect the rate of photosynthesis?

a) Higher concentration of CO_2 decreases the rate of photosynthesis

b) Lower concentration of CO_2 increases the rate of photosynthesis

c) Higher concentration of CO_2 increases the rate of photosynthesis

d) Concentration of CO_2 has no effect on the rate of photosynthesis

PHOTOSYNTHESIS REACTIONS

Key Processes

Light-Dependent Reactions - These reactions occur in the thylakoid membranes. They involve the absorption of light energy by chlorophyll and the subsequent conversion of that energy into chemical energy in the form of ATP and NADPH. Water molecules are split, releasing oxygen as a byproduct.

Calvin Cycle (Light-Independent Reactions) - This reaction takes place in the stroma; the Calvin cycle utilizes ATP and NADPH produced in the light-dependent reactions to convert carbon dioxide into glucose. This process involves a series of enzymatic reactions, including carbon fixation, reduction, and regeneration of RuBisCO.

Theoretical Background

Light Absorption and Pigments - Chlorophyll and other pigments in chloroplasts absorb light energy of specific wavelengths. This energy is used to excite electrons, initiating the transfer of energy in photosynthesis.

Electron Transport Chain - During the light-dependent reactions, excited electrons pass through an electron transport chain, releasing energy that is used to generate ATP and reduce NADP+ to NADPH. This electron flow is coupled with the pumping of protons across the thylakoid membrane, creating a proton gradient for ATP synthesis.

Chemiosmosis – This is the process of ATP synthesis through the flow of protons back across the thylakoid membrane via ATP synthase, utilizing the energy stored in the proton gradient.

Carbon Fixation - The conversion of inorganic carbon dioxide into organic molecules through the Calvin cycle, which requires energy from ATP and reducing power from NADPH.

The Process Of Photosynthesis

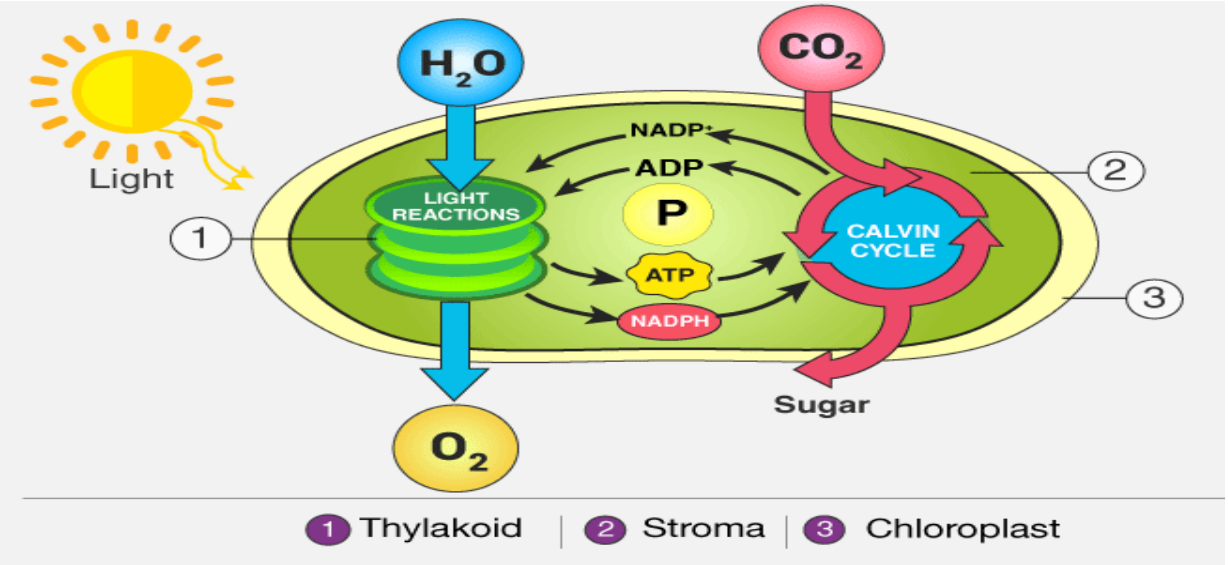
During photosynthesis, carbon dioxide enters through the stomata, and water is absorbed by the root hairs from the soil and is carried to the leaves through structures known as the xylem vessels. Chlorophyll then absorbs the light energy from the sun to split water molecules into hydrogen and oxygen.

The hydrogen from the water molecules and carbon dioxide absorbed from the air is then used to produce glucose. Additionally, oxygen is released into the atmosphere via the leaves as a waste product.

Glucose is the plant's nutrient source, providing energy for growth and development, when not in use it is stored in roots, leaves and fruits for later use.

The process of photosynthesis occurs in two stages:

1. The light-dependent reaction or light reaction
2. The light-independent reaction or dark reaction



Visual representation of Stages of Photosynthesis in Plants depicting the two stages

1. **The Light Reaction of Photosynthesis (or) Light-dependent Reaction**

★ Photosynthesis begins with a light reaction that occurs only during the day in the presence of sunlight. In plants, light-dependent responses occur in the thylakoid membrane of chloroplasts.

★ Grana, membrane-enclosed sac-like structures within thylakoids, function by collecting light and are called photosystems. There are two types of photosystems: photosystem I and photosystem II.

★ These photosystems have large complexes of pigment molecules and protein molecules present in plant cells and play a major role in the light-dependent stage.

★ During light-dependent reactions, light energy is converted into ATP and NADPH for use in the second step of photosynthesis. The ATP and NADPH are generated by two electron-transport chains, where water is used, and oxygen is produced.

<u>The chemical equation in the light reaction of photosynthesis</u>

$$\mathbf{2H_2O + 2NADP+ + 3ADP + 3Pi \rightarrow O_2 + 2NADPH + 3ATP}$$

2. **Dark Reaction of Photosynthesis (or) Light-independent Reaction**

★ The Dark reaction is also called the Carbon-fixing reaction, or the Calvin cycle.

★ In the light-independent process, sugar molecules are formed from the water and carbon dioxide molecules.

★ The light-independent reaction occurs in the stroma of the chloroplast where the products of the light reaction NADPH and ATP are further utilized.

★ Plants capture the carbon dioxide from the atmosphere through stomata and combine it with RuBP (ribulose bisphosphate), a five-carbon molecule, through the enzyme RuBisCO. This specific process is known as carbon fixation, forms an unstable

six-carbon compound that immediately breaks down into two molecules of PGA (3-phosphoglycerate)

★ In the Calvin cycle, the ATP and NADPH formed during light reaction drive the reaction and are used to convert PGA into G3P (glyceraldehyde 3-phosphate), a three-carbon sugar. Some G3P molecules are used to regenerate RuBP, while others are used to synthesize glucose and other organic compounds.

The chemical equation for the dark reaction

$3CO_2$ + 6 NADPH + $5H_2O$ + 9ATP → G3P + 2H+ + 6 NADP+ + 9 ADP + 8 Pi

ACTIVITY 2:

True Or False

1. Photosynthesis is the process by which plants convert light energy into chemical energy.

Answer:

2. The light-dependent reactions of photosynthesis occur in the stroma of chloroplasts.

Answer:

3. Oxygen is released as a byproduct during the light-dependent reactions of photosynthesis.

Answer:

4. The Calvin cycle, or the light-independent reactions, requires ATP and NADPH produced during the light-dependent reactions.

Answer:

5. Chlorophyll is the primary pigment responsible for capturing light energy during photosynthesis.

Answer:

6. Carbon dioxide is converted into glucose during the light-dependent reactions of photosynthesis.

Answer:

7. Photosynthesis is an exothermic reaction, meaning it releases energy.

Answer:

8. The primary function of ATP in photosynthesis is to capture light energy.

Answer:

9. The enzyme responsible for fixing carbon dioxide in the Calvin cycle is called Rubisco.

Answer:

10. Photosynthesis occurs only in autotrophic organisms and not in heterotrophic organisms.

Answer:

ACTIVITY 3:

Complete The Following Tables On Photosynthesis Reactions

Light-dependent reactions

Goal	
Location	
Reactants	
Products	

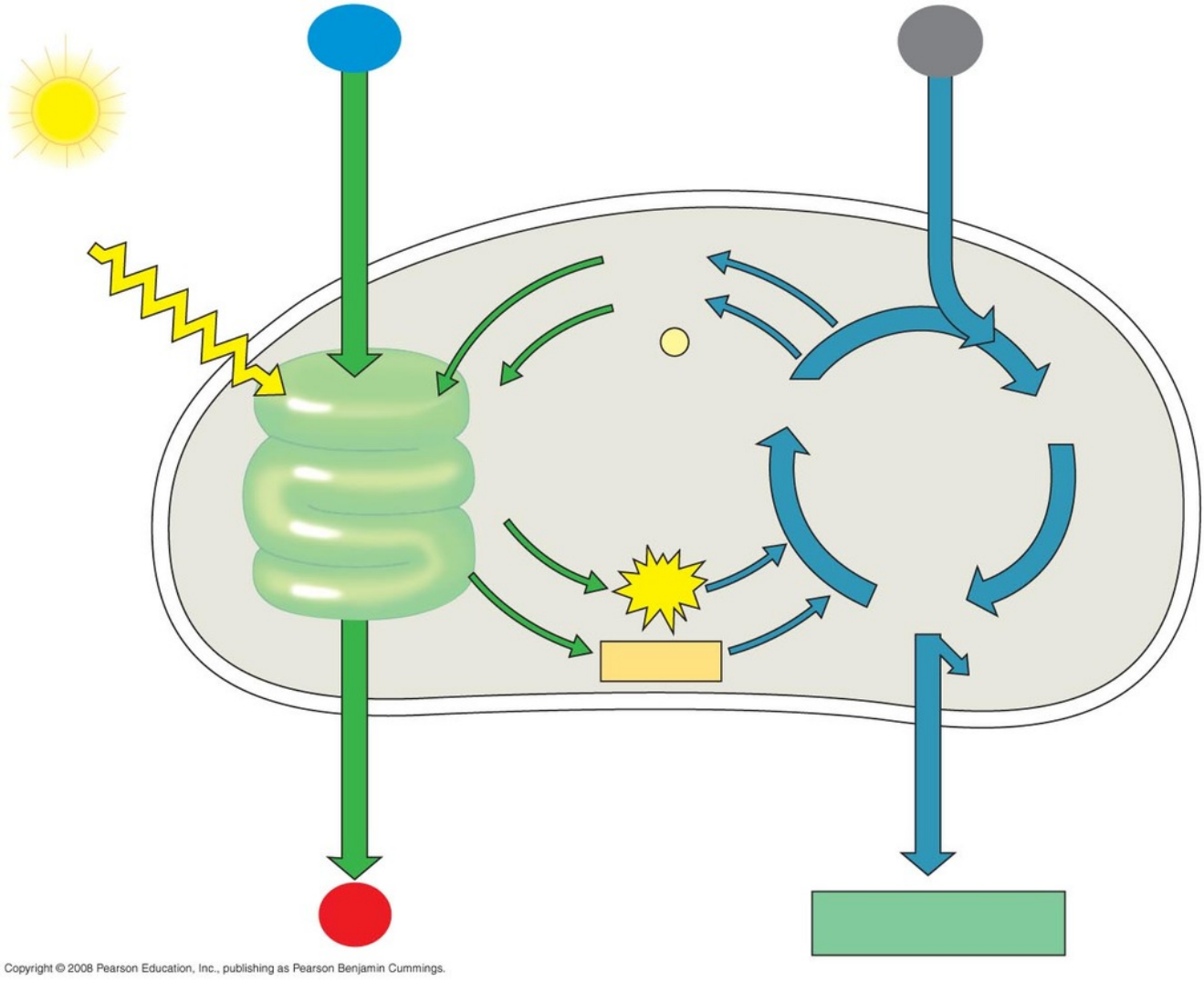
Light-independent reactions

Goal	
Location	
Reactants	

Products	

ACTIVITY 4:

Using The Word List Provided Complete The Diagram Below.



WORD LIST	
Calvin Cycle	**Light**
Stroma	**Light Reactions**
Glucose	**O_2**

Chloroplast	**CO_2**
Thylakoids	**H_2O**
ATP	**P**
ADP	**$NADP^+$**
NADPH	

ACTIVITY 5:

Fill In The Blanks

1. During photosynthesis, light energy is converted into chemical energy in the form of _____.

2. The light-dependent reactions of photosynthesis take place in the _____.

3. Water molecules are split during the light-dependent reactions, releasing _____ as a byproduct.

4. The light-independent reactions, or the Calvin cycle, occur in the _____ of the chloroplasts.

5. The primary pigment involved in photosynthesis is _____.

6. Carbon dioxide is fixed and converted into organic molecules during the _____ cycle.

7. The enzyme responsible for fixing carbon dioxide in the Calvin cycle is called _____.

8. ATP and _____ are produced during the light-dependent reactions and used in the Calvin cycle.

9. The conversion of inorganic carbon dioxide into organic molecules is known as _____.

10. The final product of the Calvin cycle is a three-carbon sugar called _____.

REFERENCES:

BYJU'S. (2018, January 11). *Photosynthesis*. BYJUS; Byju's.

https://byjus.com/biology/photosynthesis/

Photosynthesis - Definition, Process, and Diagrams. (2022, July 8). GeeksforGeeks.

https://www.geeksforgeeks.org/photosynthesis/

Photosynthesis Definition and Examples - Biology Online Dictionary. (2019, October 7).

Biology Articles, Tutorials & Dictionary Online.

https://www.biologyonline.com/dictionary/photosynthesis

Visible Body. (2021). *Light-Dependent and Light-Independent Reactions*.

Www.visiblebody.com.

https://www.visiblebody.com/learn/biology/photosynthesis/reactions

Answer Sheet

ACTIVITY 1:

Instructions: Read the information provided above and answer the following questions.

1. Which of the following is the primary pigment involved in photosynthesis?

a) Chlorophyll

b) Carotenoid

c) Anthocyanin

d) Xanthophyll

Answer: a) Chlorophyll

2. Where does photosynthesis occur?

a) Mitochondria

b) Nucleus

c) Chloroplast

d) Vacuole

Answer: c) Chloroplast

3. The primary source of energy for photosynthesis is:

a) Glucose

b) Carbon dioxide

c) Sunlight

d) Oxygen

Answer: c) Sunlight

4. During photosynthesis, oxygen is released as a byproduct from:

a) Carbon dioxide

b) Water

c) Glucose

d) ATP

Answer: b) Water

5. The main purpose of photosynthesis is to:

a) Produce oxygen

b) Generate ATP

c) Convert light energy into chemical energy

d) Break down glucose molecules

Answer: c) Convert light energy into chemical energy

6. Which of the following factors affects the rate of photosynthesis by influencing the opening and closing of stomata?

a) Light Intensity

b) Concentration of CO2

c) Temperature

d) Water

Answer: d) Water

7. What is the chemical formula for glucose?

a) $C_6H_{12}O_6$

b) $6O_2$

c) $6H_2O$

d) $6CO_2$

Answer: a) $C_6H_{12}O_6$

8. Photosynthesis is a process that occurs in:

a) Autotrophs only

b) Heterotrophs only

c) Autotrophs and heterotrophs

d) None of the above

Answer: a) Autotrophs only

9. What is the primary function of chlorophyll in photosynthesis?

a) Absorb carbon dioxide

b) Release oxygen

c) Capture sunlight

d) Produce glucose

Answer: c) Capture sunlight

10. Which of the following is a reactant in the process of photosynthesis?

a) Glucose

b) Oxygen

c) Carbon dioxide

d) ATP

Answer: c) Carbon dioxide

11. What effect does an increase in light intensity have on the rate of photosynthesis?

a) It decreases the rate of photosynthesis

b) It has no effect on the rate of photosynthesis

c) It increases the rate of photosynthesis

d) It leads to the cessation of photosynthesis

Answer: c) It increases the rate of photosynthesis

12. What impact can pollution have on photosynthesis?

a) It enhances the rate of photosynthesis

b) It has no effect on photosynthesis

c) It reduces the rate of photosynthesis

d) It promotes the closure of stomata

Answer: c) It reduces the rate of photosynthesis

13. What is the optimal temperature range for efficient photosynthesis?

a) 0°C to 10°C

b) 15°C to 25°C

c) 25°C to 35°C

d) 40°C to 50°C

Answer: c) 25°C to 35°C

14. How does the concentration of carbon dioxide affect the rate of photosynthesis?

a) Higher concentration of CO_2 decreases the rate of photosynthesis

b) Lower concentration of CO_2 increases the rate of photosynthesis

c) Higher concentration of CO_2 increases the rate of photosynthesis

d) Concentration of CO_2 has no effect on the rate of photosynthesis

Answer: c) Higher concentration of CO_2 increases the rate of photosynthesis

ACTIVITY 2:

True Or False

1. Photosynthesis is the process by which plants convert light energy into chemical energy.

Answer: True

2. The light-dependent reactions of photosynthesis occur in the stroma of chloroplasts.

Answer: False

3. Oxygen is released as a byproduct during the light-dependent reactions of photosynthesis.

Answer: True

4. The Calvin cycle, or the light-independent reactions, requires ATP and NADPH produced during the light-dependent reactions.

Answer: True

5. Chlorophyll is the primary pigment responsible for capturing light energy during photosynthesis.

Answer: True

6. Carbon dioxide is converted into glucose during the light-dependent reactions of photosynthesis.

Answer: False

7. Photosynthesis is an exothermic reaction, meaning it releases energy.

Answer: False

8. The primary function of ATP in photosynthesis is to capture light energy.

Answer: False

9. The enzyme responsible for fixing carbon dioxide in the Calvin cycle is called Rubisco.

Answer: True

10. Photosynthesis occurs only in autotrophic organisms and not in heterotrophic organisms.

Answer: True

ACTIVITY 3:

Complete The Following Tables On Photosynthesis Reactions

Light-dependent reactions

Goal	Convert light energy into chemical energy
Location	Chloroplasts—thylakoids
Reactants	Sunlight, H_2O, $NADP^+$, ADP
Products	NADPH, ATP, O_2

Light-independent reactions

Goal	Use stored chemical energy to "fix" CO_2 and create a product that can be converted into glucose
Location	Chloroplasts—stroma
Reactants	CO_2, NADPH, ATP
Products	$NADP^+$, ADP, G3P (Two G3P can be made into $C_6H_{12}O_6$)

ACTIVITY 5: Fill In The Blanks

1. During photosynthesis, light energy is converted into chemical energy in the form of _____. Answer: ATP

2. The light-dependent reactions of photosynthesis take place in the _____. Answer: Thylakoid membrane

3. Water molecules are split during the light-dependent reactions, releasing _____ as a byproduct. Answer: Oxygen

4. The light-independent reactions, or the Calvin cycle, occur in the _____ of the chloroplasts. Answer: Stroma

5. The primary pigment involved in photosynthesis is _____. Answer: Chlorophyll

6. Carbon dioxide is fixed and converted into organic molecules during the _____ cycle. Answer: Calvin

7. The enzyme responsible for fixing carbon dioxide in the Calvin cycle is called _____. Answer: RuBisCO

8. ATP and _____ are produced during the light-dependent reactions and used in the Calvin cycle. Answer: NADPH

9. The conversion of inorganic carbon dioxide into organic molecules is known as _____. Answer: Carbon fixation

10. The final product of the Calvin cycle is a three-carbon sugar called _____. Answer: G3P (glyceraldehyde-3-phosphate)