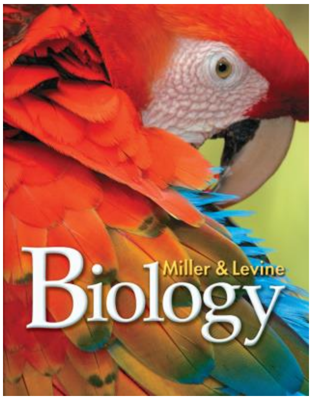


Lesson Overview

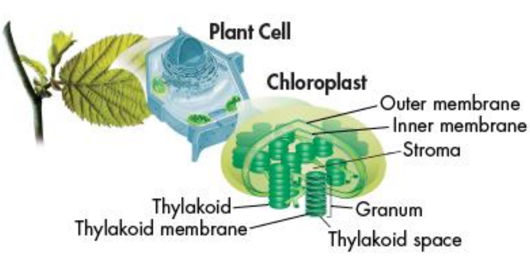
8.3 The Process of Photosynthesis

Lesson Overview The Process of Photosynthesis

THINK ABOUT IT

- Why do chloroplasts contain so many membranes?
- When most pigments absorb light, they eventually lose most of that energy as heat. Chloroplasts avoid such losses. Membranes are the key to capturing light energy in the form of high-energy electrons.

Lesson Overview The Process of Photosynthesis



Lesson Overview The Process of Photosynthesis

The Light-Dependent Reactions: Generating ATP and NADPH

- What happens during the light-dependent reactions?

Lesson Overview The Process of Photosynthesis

The Light-Dependent Reactions: Generating ATP and NADPH

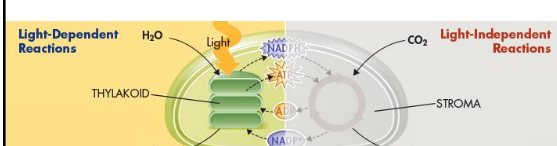
- The light-dependent reactions use energy from sunlight to produce oxygen and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH.

Lesson Overview The Process of Photosynthesis

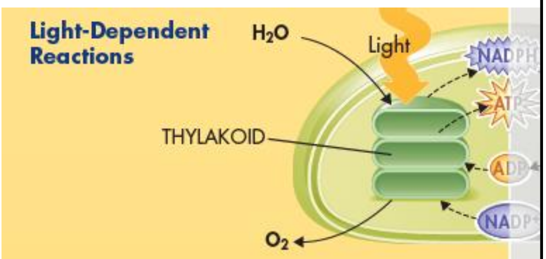
The Light-Dependent Reactions: Generating ATP and NADPH

The light-dependent reactions encompass the steps of photosynthesis that directly involve sunlight.

The light-dependent reactions occur in the thylakoids of chloroplasts.



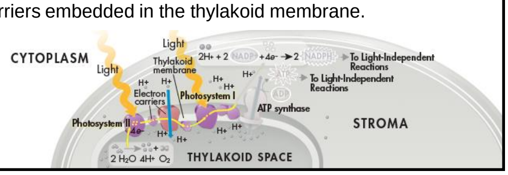
The Light-Dependent Reactions: Generating ATP and NADPH



The Light-Dependent Reactions: Generating ATP and NADPH

Thylakoids contain clusters of chlorophyll and proteins known as **photosystems.**

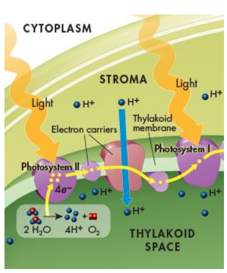
Photosystems absorb sunlight and generate **high-energy electrons** that are then passed to a series of electron carriers embedded in the thylakoid membrane.



Photosystem II

Light energy is absorbed by electrons in the pigments within **photosystem II**, increasing the electrons' energy level.

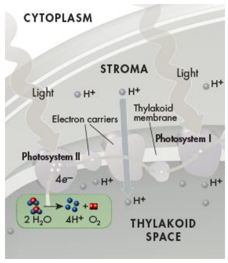
The high-energy electrons are passed to the **electron transport chain**, a series of electron carriers that shuttle high-energy electrons during ATP-generating reactions.



Lesson Overview The Process of Photosynthesis

Photosystem II

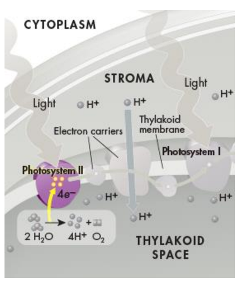
- The thylakoid membrane provides new electrons to chlorophyll from water molecules.
- **Enzymes** of the inner surface of the thylakoid break up water molecules into 2 electrons, 2 H^+ ions, and 1 oxygen atom.



Lesson Overview The Process of Photosynthesis

Photosystem II

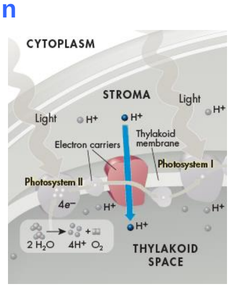
- The 2 electrons replace the high-energy electrons that have been lost to the electron transport chain.
- Oxygen is released into the air. This reaction is the source of nearly all of the oxygen in Earth's atmosphere.
- The H^+ ions are released inside the thylakoid.



Lesson Overview The Process of Photosynthesis

Electron Transport Chain

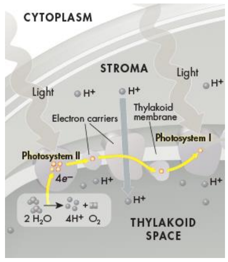
Energy from the electrons is used by proteins in the electron transport chain to pump H^+ ions from the stroma into the thylakoid space.



Lesson Overview The Process of Photosynthesis

Electron Transport Chain

At the end of the electron transport chain, the electrons are passed to photosystem I.

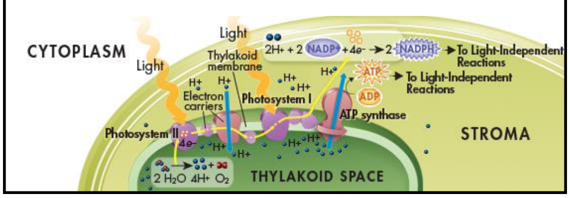


Lesson Overview The Process of Photosynthesis

The End Result of Photosystem II

The splitting of water molecules provide electrons for transport and produce oxygen gas

The buildup of H^+ ions makes the stroma negatively charged relative to the space within the thylakoids.

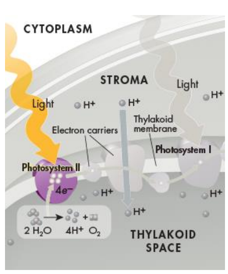


Lesson Overview The Process of Photosynthesis

Photosystem I

Because some energy has been used to pump H^+ ions across the thylakoid membrane, electrons do not contain as much energy as they used to when they reach photosystem I.

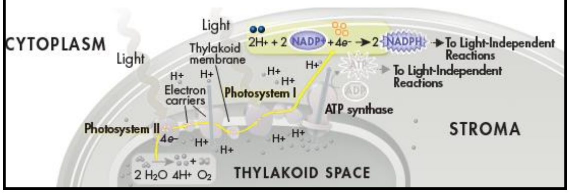
Pigments in photosystem I use energy from light to reenergize the electrons.



Lesson Overview The Process of Photosynthesis

Photosystem I

At the end of a short second electron transport chain, $NADP^+$ molecules in the stroma pick up the high-energy electrons and H^+ ions at the outer surface of the thylakoid membrane to become NADPH.

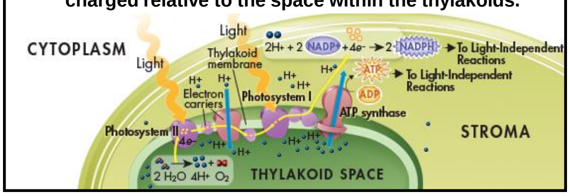


Lesson Overview The Process of Photosynthesis

Hydrogen Ion Movement and ATP Formation

H^+ ions accumulate within the thylakoid space from the splitting of water molecules that are pumped in from the stroma.

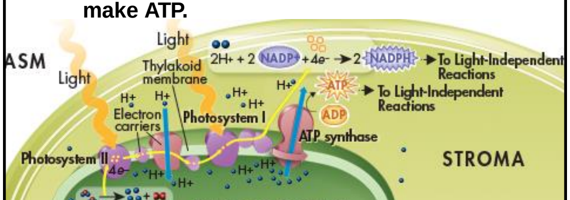
The buildup of H^+ ions makes the stroma negatively charged relative to the space within the thylakoids.



Lesson Overview The Process of Photosynthesis

Hydrogen Ion Movement and ATP Formation

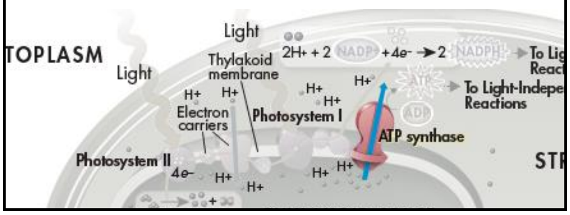
This gradient, the difference in both charge and H^+ ion concentration across the membrane, provides the energy to make ATP.



Lesson Overview The Process of Photosynthesis

Hydrogen Ion Movement and ATP Formation

H^+ ions cannot directly cross the thylakoid membrane. However, the thylakoid membrane contains a protein called **ATP synthase t**hat spans the membrane and allows H^+ ions to pass through it.

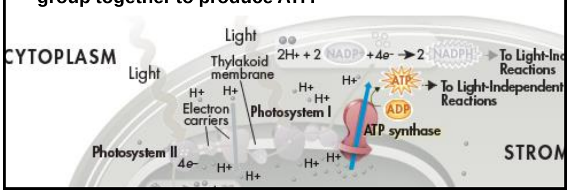


Lesson Overview The Process of Photosynthesis

Hydrogen Ion Movement and ATP Formation

Powered by the gradient, H^+ ions pass through ATP synthase and force it to rotate.

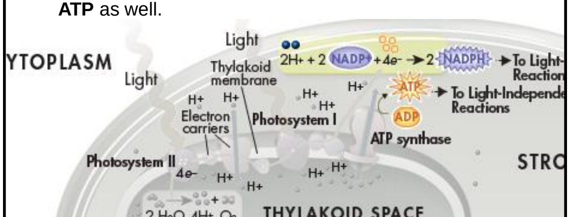
As it rotates, ATP synthase binds ADP and a phosphate group together to produce ATP.



Lesson Overview The Process of Photosynthesis

Hydrogen Ion Movement and ATP Formation

This process, called **chemiosmosis**, enables light-dependent electron transport to produce not only **NADPH** (at the end of the electron transport chain), but **ATP** as well.



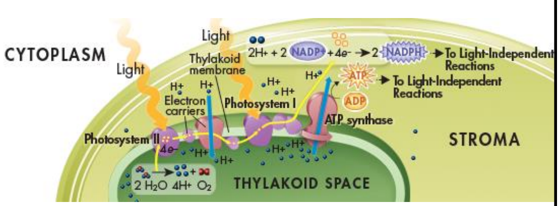
Summary of Light-Dependent Reactions

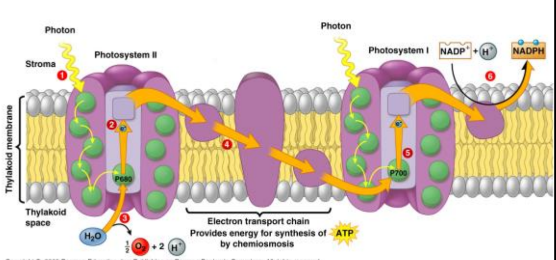
The light-dependent reactions produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH.

Light-dependent reactions take place on and inside the thylakoid space of the chloroplasts

ATP and NADPH provide the energy needed to build high-energy sugars from low-energy carbon dioxide.

Summary of Light-Dependent Reactions

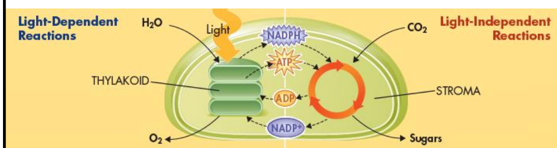




Lesson Overview The Process of Photosynthesis

The Light-Independent Reactions: Producing Sugars

- What happens during the light-independent reactions?



Lesson Overview The Process of Photosynthesis

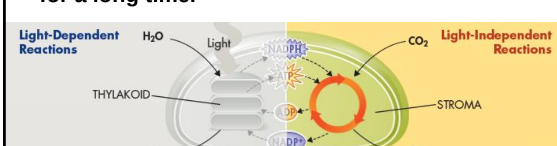
The Light-Independent Reactions: Producing Sugars

- What happens during the light-independent reactions?
- **During the light-independent reactions, ATP and NADPH from the light dependent reactions are used to produce high-energy sugars.**

Lesson Overview The Process of Photosynthesis

The Light-Independent Reactions: Producing Sugars

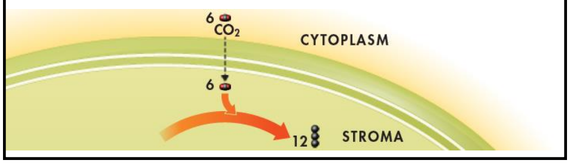
During the light-independent reactions, commonly referred to as the Calvin cycle, plants use the energy that ATP and NADPH contains to build stable high-energy carbohydrate compounds that can be stored for a long time.



Lesson Overview The Process of Photosynthesis

Carbon Dioxide Enters the Cycle

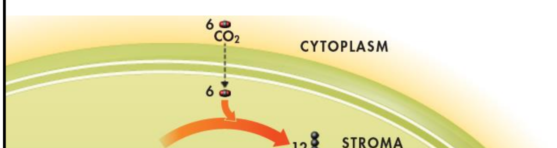
- **Carbon dioxide molecules enter the Calvin cycle from the atmosphere.**
- **An enzyme in the stroma of the chloroplast combines carbon dioxide molecules with 5-carbon compounds that are already present in the organelle, producing 3-carbon compounds that continue into the cycle.**



Lesson Overview The Process of Photosynthesis

Carbon Dioxide Enters the Cycle

For every six carbon dioxide molecules that enter the cycle, a total of twelve 3-carbon compounds are produced.

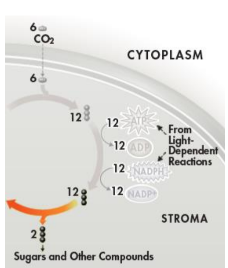


Lesson Overview The Process of Photosynthesis

Sugar Production

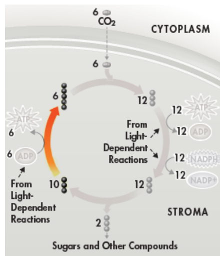
At midcycle, two of the twelve 3-carbon molecules are removed from the cycle.

These molecules become the building blocks that the plant cell uses to produce sugars, lipids, amino acids, and other compounds.



Sugar Production

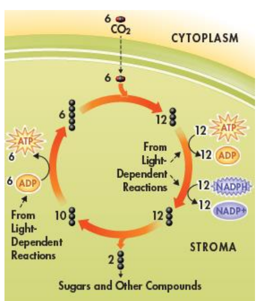
The remaining ten 3-carbon molecules are converted back into six 5-carbon molecules that combine with six new carbon dioxide molecules to begin the next cycle.



Summary of the Calvin Cycle

The **Calvin cycle** uses six molecules of carbon dioxide to produce a single 6-carbon sugar molecule.

$C_6H_{12}O_6$



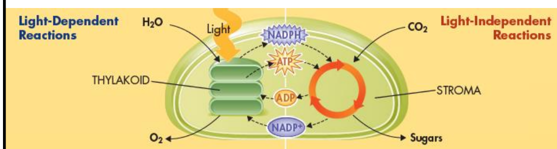
Summary of the Calvin Cycle

The energy for the reactions is supplied by compounds produced in the light-dependent reactions.

This means that photosynthesis can **NOT** occur without sunlight.

Lesson Overview The Process of Photosynthesis

The End Results

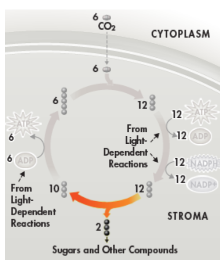


Lesson Overview The Process of Photosynthesis

Summary of the Calvin Cycle

The plant uses the sugars produced by the Calvin cycle to meet its energy needs and to build macromolecules needed for growth and development.

When other organisms eat plants, they can use the energy and raw materials stored in these compounds.



Lesson Overview The Process of Photosynthesis

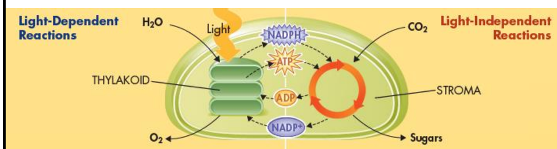
The End Results

The two sets of photosynthetic reactions work together—the light-dependent reactions trap the energy of sunlight in chemical form, and the light-independent reactions use that chemical energy to produce stable, high-energy sugars from carbon dioxide and water.

In the process, animals, including humans, get food and an atmosphere filled with oxygen.

Lesson Overview The Process of Photosynthesis

The End Results



Lesson Overview The Process of Photosynthesis

Factors Affecting Photosynthesis

- What factors affect photosynthesis?
- **Among the most important factors that affect photosynthesis are temperature, light intensity, and the availability of water.**

Lesson Overview The Process of Photosynthesis

Photosynthesis Under Extreme Conditions

In order to conserve water, most plants under bright, hot conditions close the small openings in their leaves that normally admit carbon dioxide.

This causes carbon dioxide within the leaves to fall to very low levels, slowing down or even stopping photosynthesis.

C4 and CAM plants have biochemical adaptations that minimize water loss while still allowing photosynthesis to take place in intense sunlight.

C4 Photosynthesis:
(NOT cyclotrimethylene trinitramine)

C4 plants have a specialized chemical pathway that allows them to capture even very low levels of carbon dioxide and pass it to the Calvin cycle.

C4 plants have a competitive advantage over plants possessing the more common C3 carbon fixation.

C4 Plants are more successful under conditions of drought, high temperatures, and nitrogen or CO_2 limitation.

Lesson Overview The Process of Photosynthesis

C4 Photosynthesis

The name "C4 plant" comes from the fact that the first compound formed in this pathway contains 4 carbon atoms.

The C4 pathway requires extra energy in the form of ATP to function.

C4 organisms include crop plants like corn, sugar cane, and sorghum.

Lesson Overview The Process of Photosynthesis

Sugar Cane

Lesson Overview The Process of Photosynthesis

Sorghum

Lesson Overview The Process of Photosynthesis

Sorghum

Lesson Overview The Process of Photosynthesis

CAM Plants

Members of the Crassulacae family, such as cacti and succulents, incorporate carbon dioxide into organic acids during photosynthesis in a process called Crassulacean Acid Metabolism (CAM).

Lesson Overview The Process of Photosynthesis

CAM Plants

CAM plants are adapted to dry climates and use a different strategy to use carbon dioxide while minimizing water loss.

CAM plants include pineapple plants, many desert cacti, and "ice plants".

Lesson Overview The Process of Photosynthesis

Pineapple Plant

Lesson Overview The Process of Photosynthesis

Cacti

Ice Plant

REVIEW

1. Which of the following is NOT a true statement about ATP?

a. ATP consists of ribose, adenine, and three phosphate groups.

b. ADP is produced when ATP releases energy.

c. ATP provides energy for the mechanical functions of cells.

d. Used ATP is discarded by the cell as waste.

REVIEW

1. Which of the following is NOT a true statement about ATP?

a. ATP consists of ribose, adenine, and three phosphate groups.

b. ADP is produced when ATP releases energy.

c. ATP provides energy for the mechanical functions of cells.

d. Used ATP is discarded by the cell as waste.

Lesson Overview The Process of Photosynthesis

REVIEW

2. Plants gather the sun's energy using molecules called

a. pigments.

b. thylakoids.

c. chloroplasts.

d. glucose.

Lesson Overview The Process of Photosynthesis

REVIEW

2. Plants gather the sun's energy using molecules called

a. pigments.

b. thylakoids.

c. chloroplasts.

d. glucose.

Lesson Overview The Process of Photosynthesis

REVIEW

3.Where in the chloroplast is chlorophyll found?

a. in the ATP

b. in the stroma

c. in the thylakoid membrane

d. in the thylakoid space

Lesson Overview The Process of Photosynthesis

REVIEW

3.Where in the chloroplast is chlorophyll found?

a. in the ATP

b. in the stroma

c. in the thylakoid membrane

d. in the thylakoid space

Lesson Overview The Process of Photosynthesis

REVIEW

4.Which chemical is an electron carrier molecule?

a. H_2O **c.** $NADP^+$

b. carbon dioxide **d.** oxygen

Lesson Overview The Process of Photosynthesis

REVIEW

4.Which chemical is an electron carrier molecule?

a. H_2O **c. $NADP^+$**

b. carbon dioxide **d.** oxygen

REVIEW

5. Photosynthesis uses sunlight to convert water and carbon dioxide into

a. oxygen and carbon.

b. high-energy sugars and proteins.

c. ATP and oxygen.

d. oxygen and high-energy sugars.

REVIEW

5. Photosynthesis uses sunlight to convert water and carbon dioxide into

a. oxygen and carbon.

b. high-energy sugars and proteins.

c. ATP and oxygen.

d. oxygen and high-energy sugars.

REVIEW

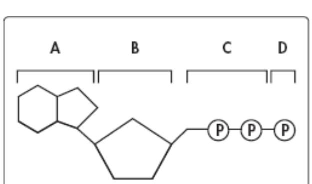
6. Look at the Figure. All of the following are parts of an ADP molecule EXCEPT

a. structure A.

b. structure B.

c. structure C.

d. structure D.



Lesson Overview The Process of Photosynthesis

REVIEW

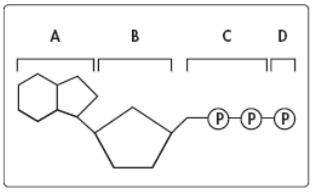
6. Look at the Figure. All of the following are parts of an ADP molecule EXCEPT

a. structure A.

b. structure B.

c. structure C.

d. structure D.



Lesson Overview The Process of Photosynthesis

REVIEW

7.Which of the following organisms is a heterotroph?

a. mushroom

b. Algae

c. wheat

d. sunflower

Lesson Overview The Process of Photosynthesis

REVIEW

7.Which of the following organisms is a heterotroph?

a. mushroom

b. Algae

c. wheat

d. sunflower

REVIEW

8.The Calvin cycle is another name for which of the following processes.

a. light-independent reactions.

b. light-dependent reactions.

c. Photosynthesis

d. Electron transport chain

REVIEW

8.The Calvin cycle is another name for which of the following processes.

a. light-independent reactions.

b. light-dependent reactions.

c. Photosynthesis

d. Electron transport chain

REVIEW

9.Photosystems are clusters of chlorophyll and:

a. Lipids

b. Carbohydrates

c. Proteins

d. Glucose

REVIEW

9. Photosystems are clusters of chlorophyll and:

a. Lipids **c.** **Proteins**

b. Carbohydrates **d.** Glucose

Lesson Overview The Process of Photosynthesis

REVIEW

10. The light-dependent reactions begin when ________absorbs light.

a. Photosystem I **c.** ATP

b. Photosystem II **d.** NADPH

Lesson Overview The Process of Photosynthesis

REVIEW

10. The light-dependent reactions begin when ________absorbs light.

a. Photosystem I **c.** ATP

b. **Photosystem II** **d.** NADPH

Lesson Overview The Process of Photosynthesis

REVIEW

11. ATP and NADPH are two types of __________ carriers

a. Protein **c.** Water

b. Chemical **d.** Electron

Lesson Overview The Process of Photosynthesis

REVIEW

11. ATP and NADPH are two types of __________ carriers

a. Protein **c.** Water

b. Chemical **d.** **Electron**

Lesson Overview The Process of Photosynthesis

REVIEW

12. The Calvin cycle uses this molecule to produce high-energy sugars.

a. O_3 **c.** CO_2

b. Glucose **d.** Protein

REVIEW

12. The Calvin cycle uses this molecule to produce high-energy sugars

a. O_3

b. Glucose

c. CO_2

d. Protein

Lesson Overview The Process of Photosynthesis

REVIEW

13. The ______________ of light determines its color.

a. Speed

b. Wavelength

c. Color

d. Direction

Lesson Overview The Process of Photosynthesis

REVIEW

13. The ______________ of light determines its color.

a. Speed

b. Wavelength

c. Color

d. Direction

REVIEW

14. Where does the Calvin cycle occur?

a. In the stroma
b. On granum
c. In thylakoids
d. Inside the Golgi Apparatus

Lesson Overview The Process of Photosynthesis

REVIEW

14. Where does the Calvin cycle occur?

a. In the stroma

b. On granum
c. In thylakoids
d. Inside the Golgi Apparatus

Lesson Overview The Process of Photosynthesis

REVIEW

15. All heterotrophs must _________to get energy.

a. Eat food
b. Obtain sunlight
c. Use Carbon Dioxide
d. Produce Oxygen

REVIEW

15. All heterotrophs must _________to get energy.

a. Eat food

b. Obtain sunlight

c. Use Carbon Dioxide

d. Produce Oxygen

REVIEW

16.Which of the following organisms is an autotroph?

a. Fungus

b. Sponge

c. Earthworm

d. Sunflower

REVIEW

16.Which of the following organisms is an autotroph?

a. Fungus

b. Sponge

c. Earthworm

d. Sunflower

REVIEW

17. Can photosynthesis occur in the dark?

a. Yes, photosynthesis can occur in the dark

b. No, photosynthesis depends on products produced from the light-dependent reaction

Lesson Overview The Process of Photosynthesis

REVIEW

17. Can photosynthesis occur in the dark?

a. Yes, photosynthesis can occur in the dark

b. No, photosynthesis depends on products produced from the light-dependent reaction

Lesson Overview The Process of Photosynthesis

REVIEW

18. Which of the following contains more energy?

a) ATP

b) ADP

Lesson Overview The Process of Photosynthesis

REVIEW

18. Which of the following contains more energy?

a) ATP

b) ADP

Lesson Overview The Process of Photosynthesis

REVIEW

What two molecules produced in the light-dependent reaction are used in the light independent reaction

Lesson Overview The Process of Photosynthesis

REVIEW

ATP and NADPH