11ADVANCE BIOLOGY TERM 1 EXAM CONTENT 2025-2026

- **MODULE 8**
  CELLULAR ENERGY

  Lesson 1: How Organisms Obtain Energy?

  Lesson 2: Photosynthesis

  Lesson 3: Cellular respiration

- **MODULE 27**
  IMMUNE SYSTEM

  Lesson 1: Infectious Diseases

  Lesson 2: The Immune System

  Lesson 3: Non Infectious Disorders

- **MODULE 4**
  POPULATION ECOLOGY

  Lesson 1: Population Dynamics

Cellular processes require **energy** – the ability to do work.

Thermodynamics is the study of the flow and transformation of energy in the universe.

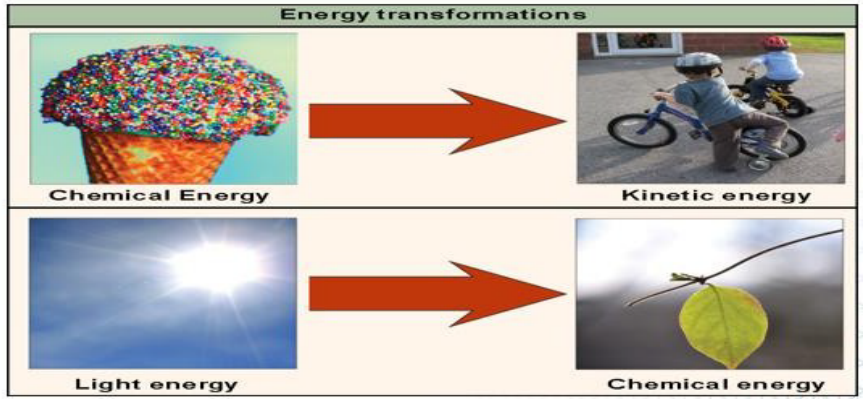
Compare ***the laws about how energy flows. Give an example of each.***

	First Law of Thermodynamics	Second Law of Thermodynamics
Defined	**Energy is neither created nor destroyed, only transformed.**	**The amount of entropy in a system is always increasing..**
Example	**The body converts stored energy in food into chemical energy..**	**Some energy is changed to thermal energy as energy moves through food chain.**

Or to mechanical energy when you kick a ball

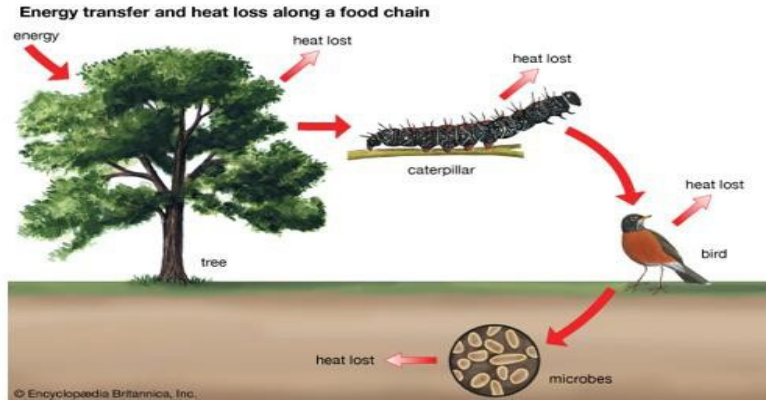
Laws of Thermodynamics

- ***First Law—The Law of Conservation of Energy*: Energy can be converted from one form to another, but it cannot be created or destroyed.**



***Second Law:* Energy cannot be converted without the loss of usable energy; the energy that is lost generally converted to thermal energy.**

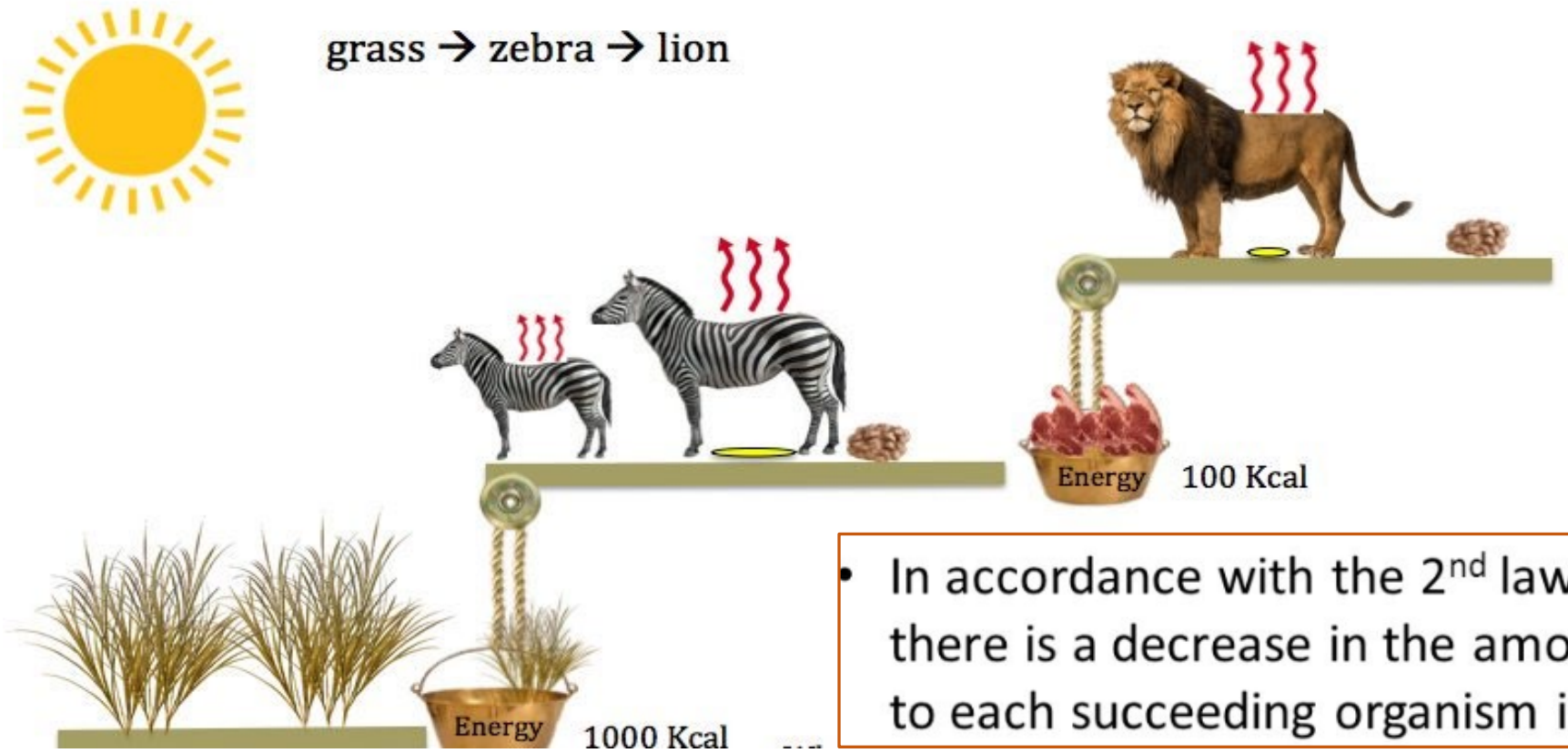
It also stated as "entropy increases". Entropy is the measure of disorder or unusable energy in a system.



- **Entropy:** is the measure of disorder, or unusable energy, in a system.

Explain second law of thermodynamics stated as **entropy increases?**

In a food chain, the amount of usable energy that is available to the next trophic level decreases.



- In accordance with the 2nd law of thermodynamics, there is a decrease in the amount of energy available to each succeeding organism in a food chain or web.

BIO.3.4.01.028 Describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems, and explain how human activities can disrupt the balance achieved by these processes

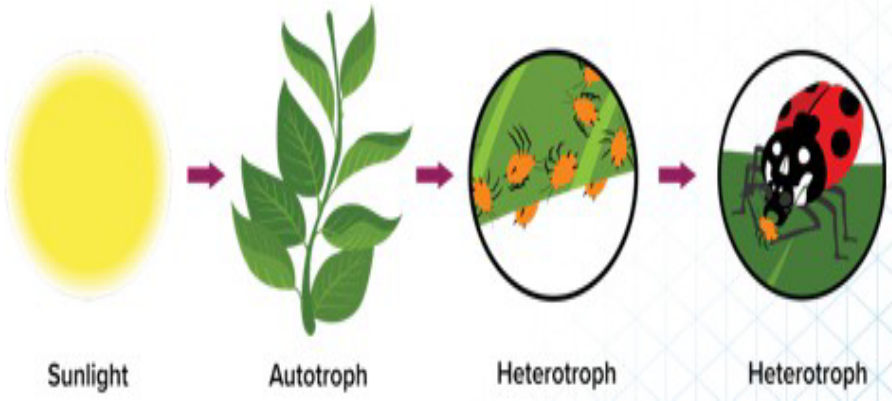
Figure 2,3

Autotrophs and Heterotrophs

- Directly or indirectly, nearly all the energy for life comes from the Sun.

Autotrophs are organisms that make their own food. Some autotrophs, called chemoautotrophs, use inorganic substances such as hydrogen sulfide as a source of energy. Other autotrophs, such as plants, convert light energy from the Sun into chemical energy. Autotrophs that convert energy from the Sun are called photoautotrophs.

- Heterotrophs ingest food to obtain energy.



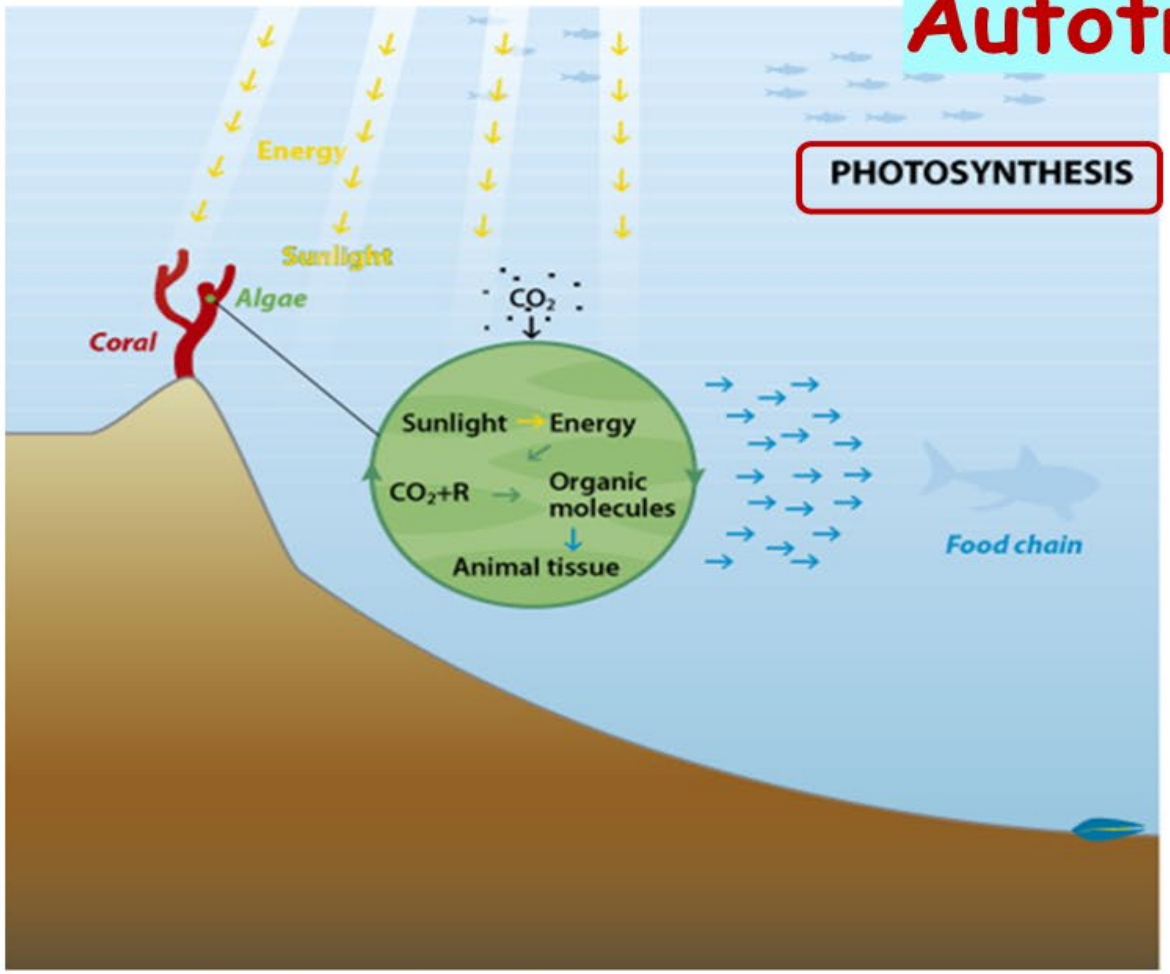
Types of Autotrophic Nutrition

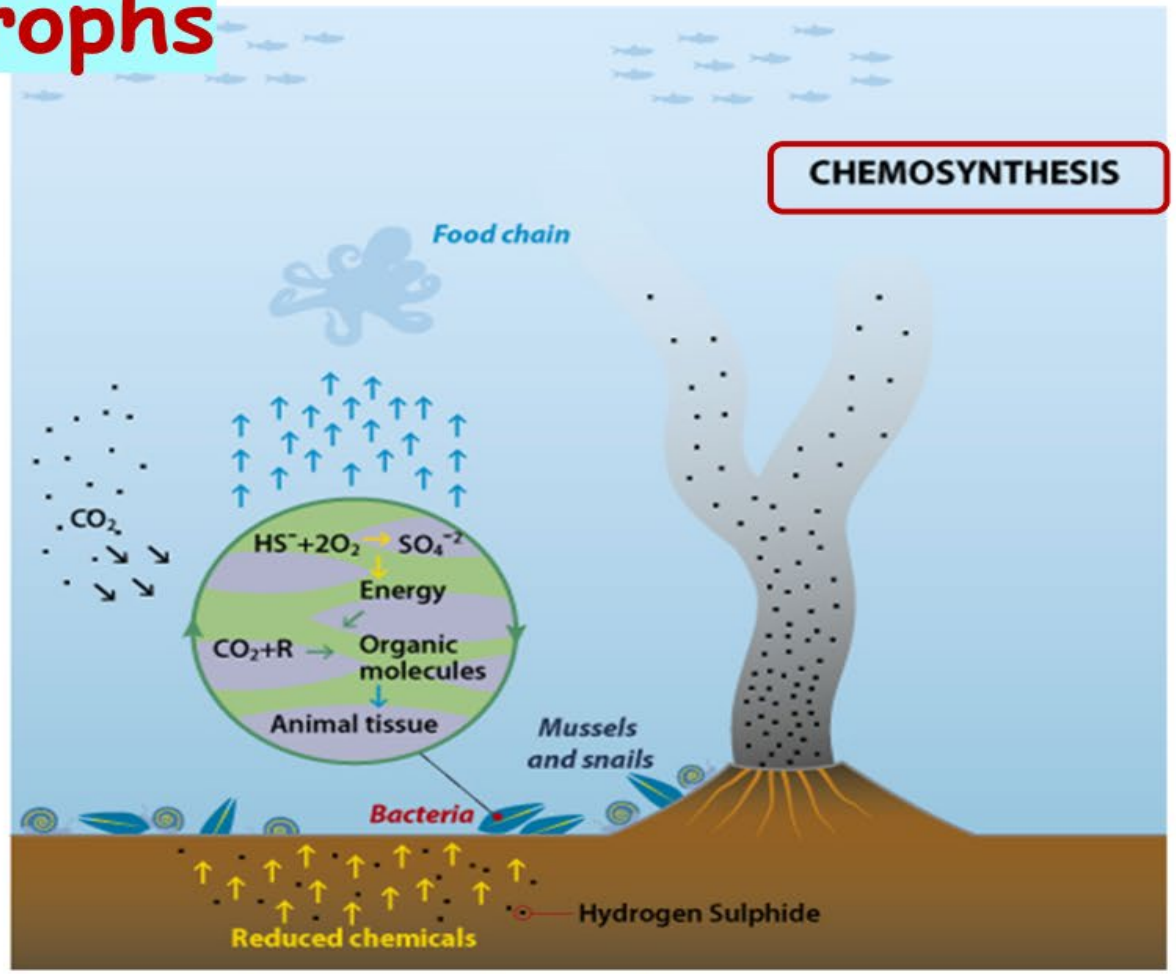
1. **Chemosynthesis-** makes food from chemicals — chemoautotrophs
2. **Photosynthesis-** makes food from sunlight — photoautotrophs

67) Match each of the following definitions with its term.

organisms that make their own food	autotrophs
all the chemical reactions in a cell	metabolism
anabolic pathway that converts energy from the Sun to chemical energy for use by cells	photosynthesis
ability to do work	Energy
organisms that need to ingest food to obtain energy	heterotrophs
biological molecule that provides chemical energy	ATP
study of the flow and transformation of energy	Thermodynamics
catabolic pathway that breaks down organic molecules	Cellular respiration

Autotrophs





- Use light (sun) energy as a source .

- Use inorganic substances such as hydrogen sulfide as a source of energy.

BIO.3.1.02.025 Identify examples of the functions performed by the living organisms in which ATP is converted into ADP and inorganic phosphate.

Information from text	32
"Demonstrate Undertanding: Question 3"	33

BIO.3.4.01.028 Describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems, and explain how human activities can disrupt the balance achieved by these processes

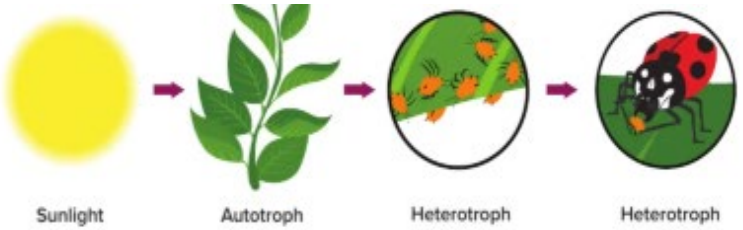


Figure 2 Almost all the energy in living organisms originates from the Sun, and energy flows from autotrophs to heterotrophs.

Autotrophs make their own food. Chemoautotrophs use inorganic substances such as hydrogen sulfide as a source of energy. Photoautotrophs, such as the plant in **Figure 2**, convert light energy from the Sun into chemical energy. Heterotrophs, such as the aphids and the ladybug in **Figure 2**, ingest food to obtain energy.

Metabolism

All of the chemical reactions in a cell are referred to as the cell's **metabolism.** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. A series of chemical reactions in which the product of one reaction is the substrate for the next reaction is called a metabolic pathway. There are two main types of metabolic pathways: catabolic (ka tuh BAH lik) pathways and anabolic (a nuh BAH lik) pathways. Catabolic pathways release energy by breaking down larger molecules into smaller molecules. Anabolic pathways use the energy released by catabolic pathways to build larger molecules from smaller molecules. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.

Energy continually flows between organisms. **Photosynthesis** is the anabolic pathway in which light energy is converted to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The energy stored in glucose is transferred to other organisms when the molecules are consumed as food.

Cellular respiration is a catabolic pathway in which organic molecules are broken down to release energy. In cellular respiration, oxygen is used to break down organic molecules, producing carbon dioxide and water. Notice the cyclical nature of these processes in **Figure 3**.

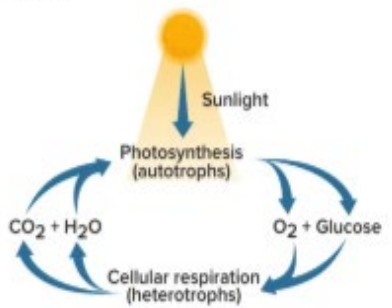


Figure 3 Photosynthesis and cellular respiration provide most of the energy for life processes.

ATP: The Unit of Cellular Energy

CHEMISTRY Connection Energy exists in many forms, such as mechanical energy and chemical energy. In organisms, chemical energy stored in biological molecules can be converted to other forms. For example, chemical energy is converted to mechanical energy when muscles contract. **Adenosine triphosphate** (uh DEN uh seen • tri FAHS fayt)—ATP—is the most important biological molecule that provides chemical energy.

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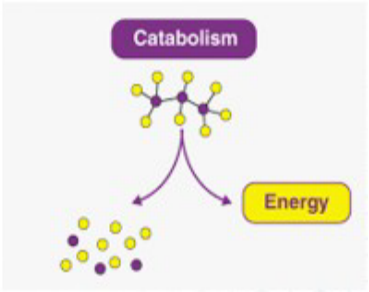
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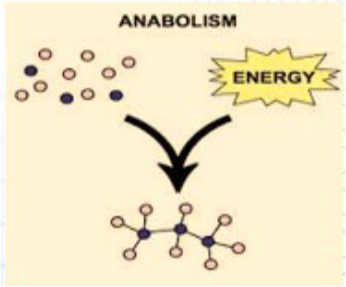
- All of the chemical reactions in a cell are referred to as the cell's metabolism.

A series of chemical reactions in which the product of one is the substrate for the next is called a **metabolic pathway.**

- **Catabolic pathways** release energy by breaking down larger molecules.

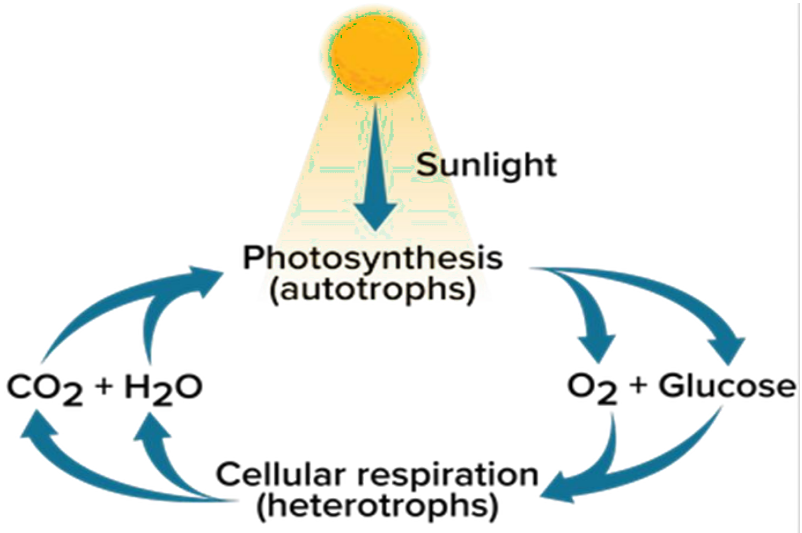


- **Anabolic pathways** use energy to build larger molecules.



Photosynthesis: anabolic pathway in which **light energy** from the Sun is converted to stored chemical energy for use by the cell

Cellular respiration: catabolic pathway in which organic molecules are broken down to **release energy** for use by the cell

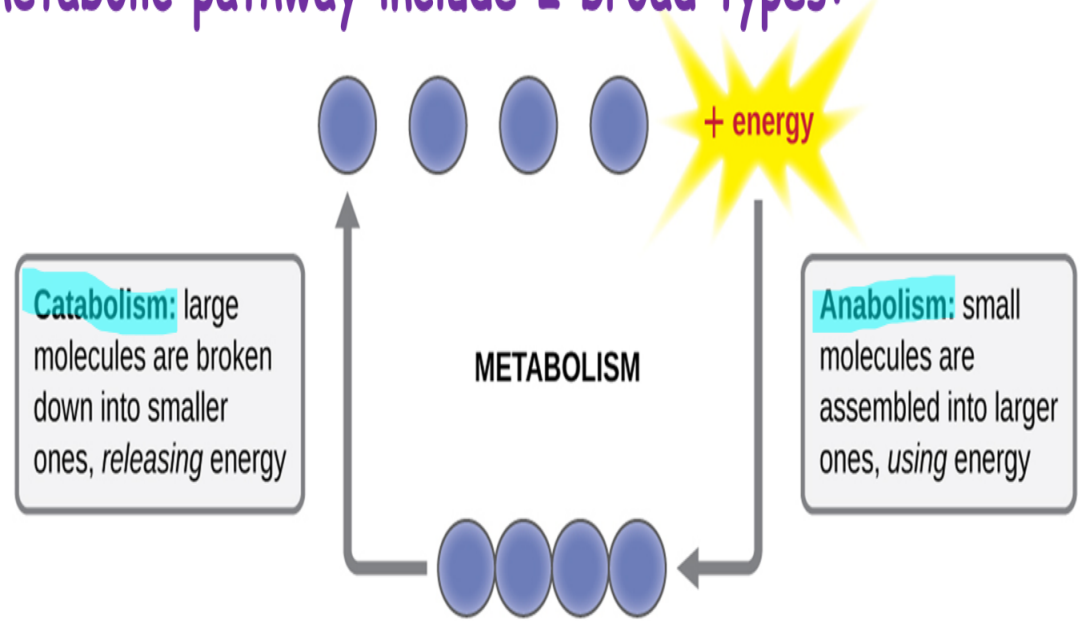


Metabolism

- All of the chemical reactions in a cell

Metabolic Pathway

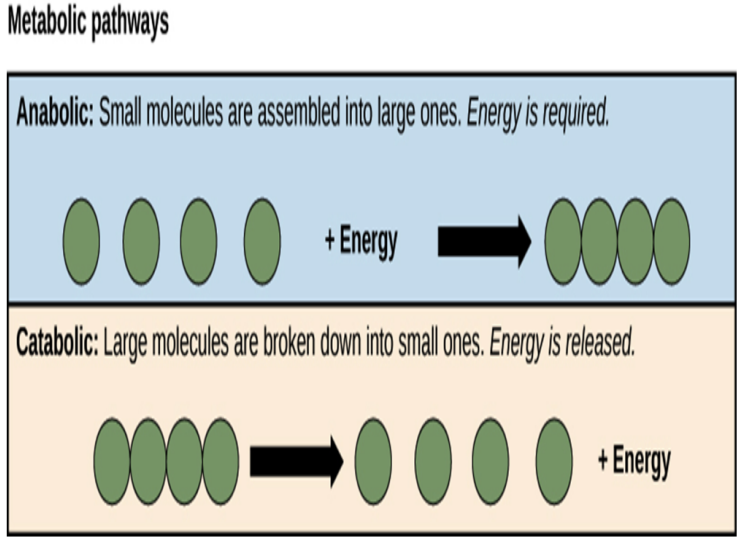
- A series of chemical reactions in which the product of one reaction is the substrate for the next reaction.
- Metabolic pathway include 2 broad types:



- What is the relationship between catabolism and anabolism?

- What is the relationship between catabolism and anabolism?

-Catabolic reactions release energy, While anabolic reactions require energy.
-The relationship of anabolic and catabolic pathways results in the continual flow of energy within an organism.
-Energy continually flows between the metabolic reactions of organisms in an ecosystem.





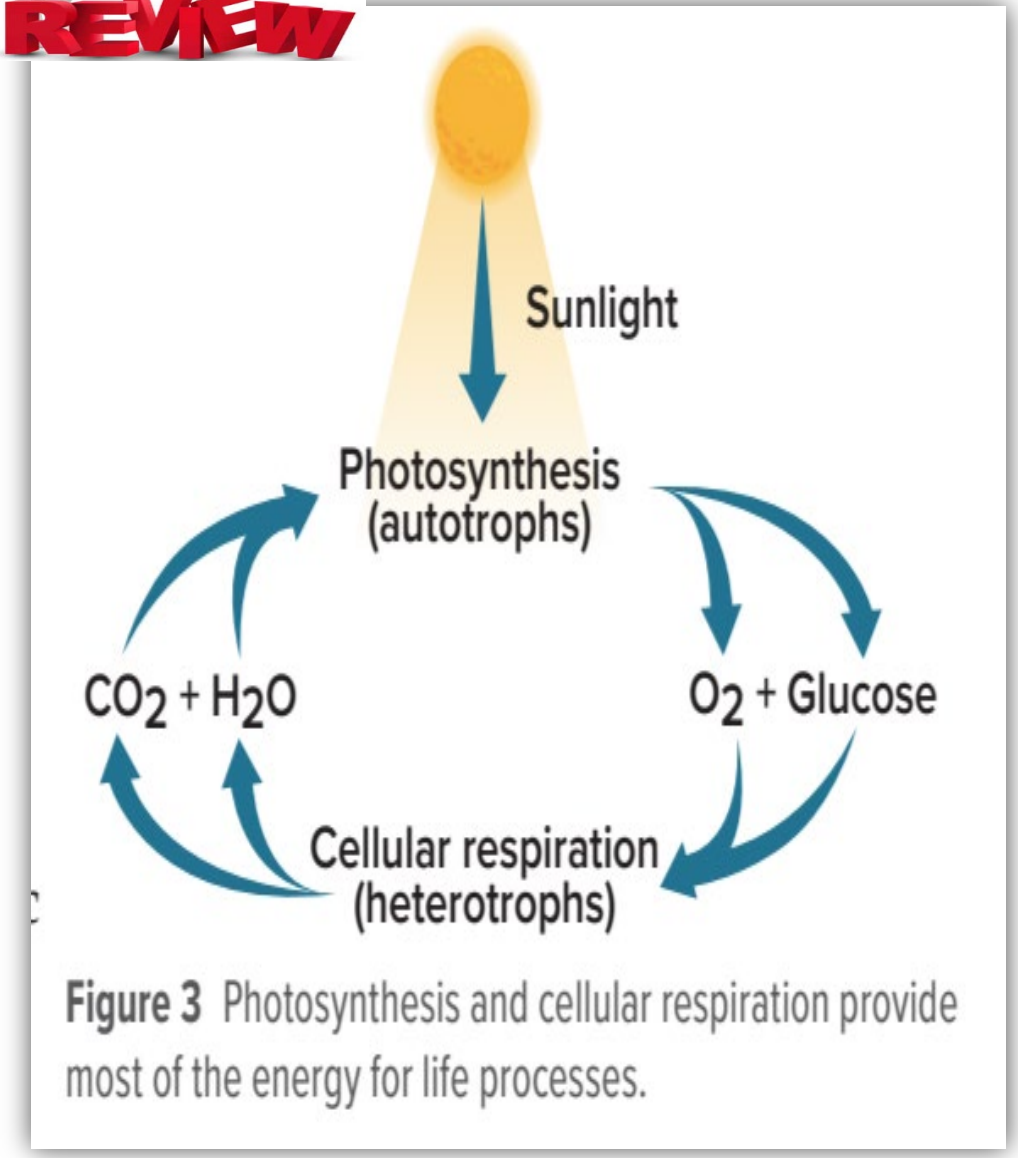


Figure 3 Photosynthesis and cellular respiration provide most of the energy for life processes.

- What is the differences between catabolism and anabolism?

Anabolism:

-The <u>buildup</u> of complex organic molecules from simpler ones,

-<u>require</u> energy .

-reactions are called <u>anabolic</u> .

Catabolism:

- The <u>breakdown</u> of complex organic molecules into simpler ones,

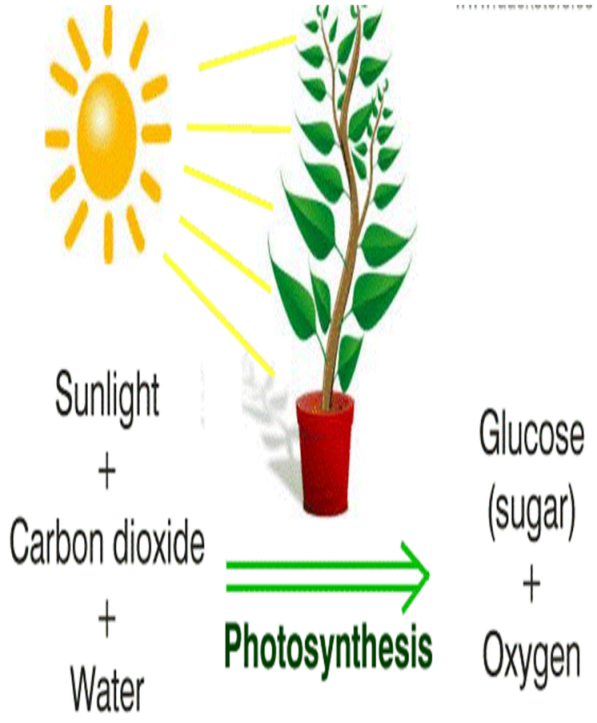
-<u>release</u> energy.

-Reactions are called <u>catabolic</u>

Metabolism

- **Photosynthesis**: light energy from the Sun is converted to chemical energy for use by the cell

Answer the questions



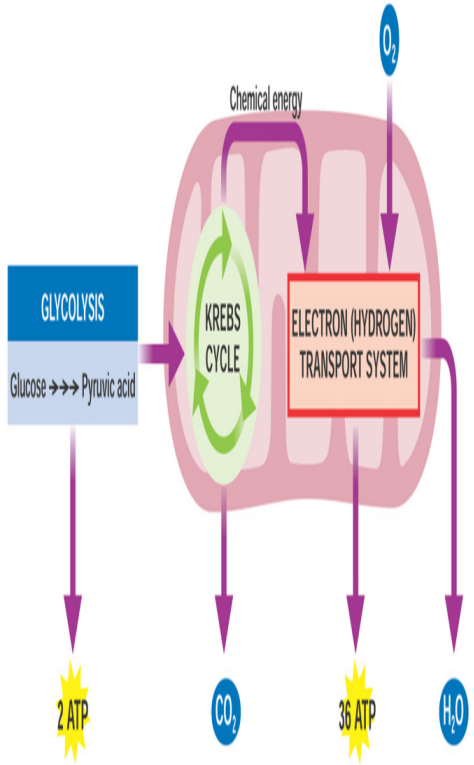
1-Photosynthesis is anabolic pathway.
2-The reaction happen in autotrophs
(autotrophs/heterotrophs/all organisms)
3-Indicate the materials involved in the reaction.
Light energy, Co_2 and water
4-What results from the reaction?
Glucose and O_2
5-What is the importance of glucose?
The energy stored in the glucose produced by photosynthesis can be transferred to other organisms when the molecules are consumed as food.

Metabolism

- **Cellular respiration**: organic molecules are broken down to release energy for use by the cell

Answer the questions

1-Cellular respiration is catabolic pathway.
2-The reaction happen in All organisms
(autotrophs/heterotrophs/all organisms)
3-Indicate the materials involved in the reaction.
Glucose and O_2
4-What results from the reaction?
ATP energy, Co_2 and water
5-What is the importance of oxygen?
Oxygen is used to break down organic molecules (glucose) so the stored energy release .



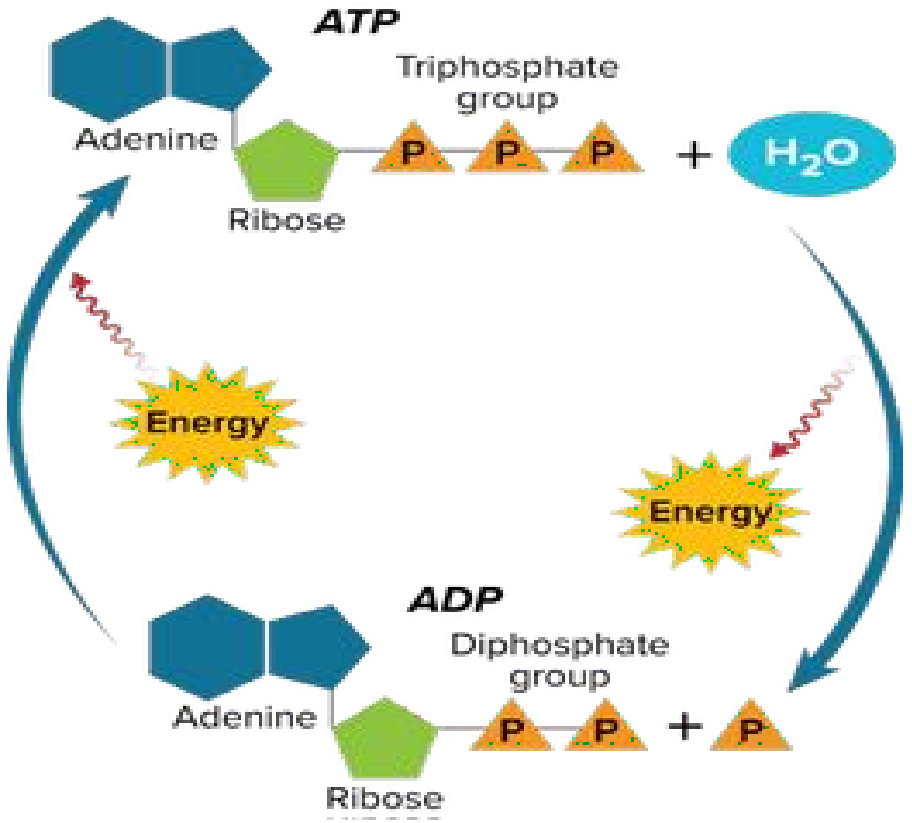
ATP: The Unit of Cellular Energy

Adenosine triphosphate (ATP) is the most important biological molecule that provides chemical energy.

Chemical energy is stored in ATP , chemical energy is converted to mechanical energy when the muscle contract

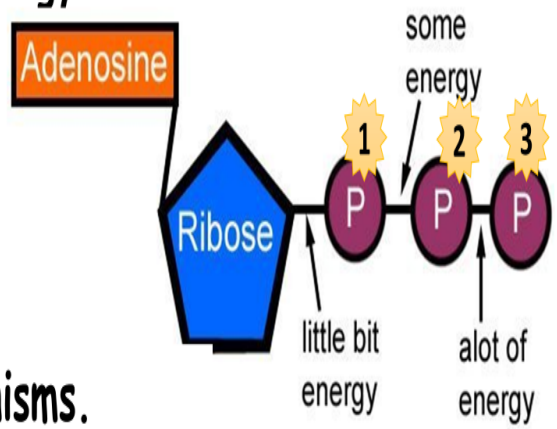
- ATP is a **nucleotide** made of **an adenine base, a ribose sugar, and three phosphate groups.**

ATP **releases energy** when **the bond between** the **second and third phosphate groups is broken forming a molecule called adenosine diphosphate (ADP) and a free phosphate group.**



ATP Structure

- Adenosine triphosphate (ATP):is the most important biological molecule that provides chemical energy.
- ATP is the storehouse of chemical energy that can be used by cells in reactions.
- ATP is found in all types of organisms.



- ATP is a nucleotide made of .....base/.....sugar/3..... .



- Is there other carrie molecules transport energy within cells?



Vocabs:
ATP, ADP, Phosphate bond, Metabolism, Anabolic, Catabolic

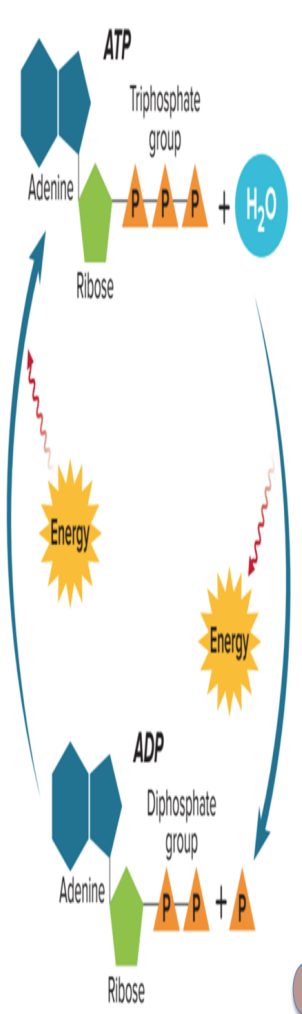
Learning outcomes :
Describe how energy is stored and released by ATP
Success criteria
can label ATP cycle and explain energy release.
- can compare photosynthesis and respiration.

ATP function

- ATP releases energy when the bond between the second and third phosphate groups is broken, forming a molecule called adenosine diphosphate (ADP) and a free phosphate group.

- When is energy stored again?

Energy is stored in the phosphate bond formed when ADP receives a phosphate group and becomes ATP.

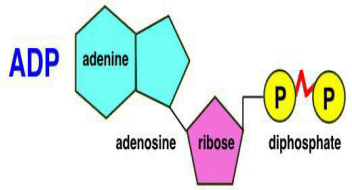


Learning outcomes :
Describe how energy is stored and released by ATP
Success criteria
can label ATP cycle and explain energy release.
- can compare photosynthesis and respiration.

Vocabs:
ATP, ADP, Phosphate bond, Metabolism, Anabolic, Catabolic

Figure 4 The breakdown of ATP releases energy for powering cellular activities in organisms.





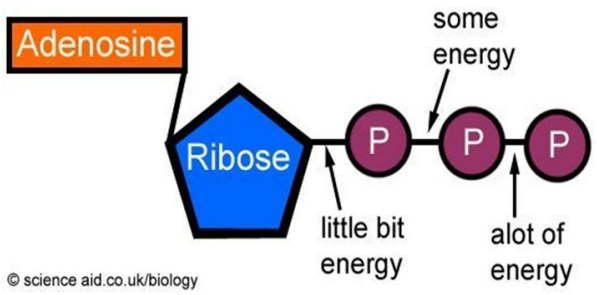
Vocabs:
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Learning outcomes :

Describe how energy is stored and released by ATP

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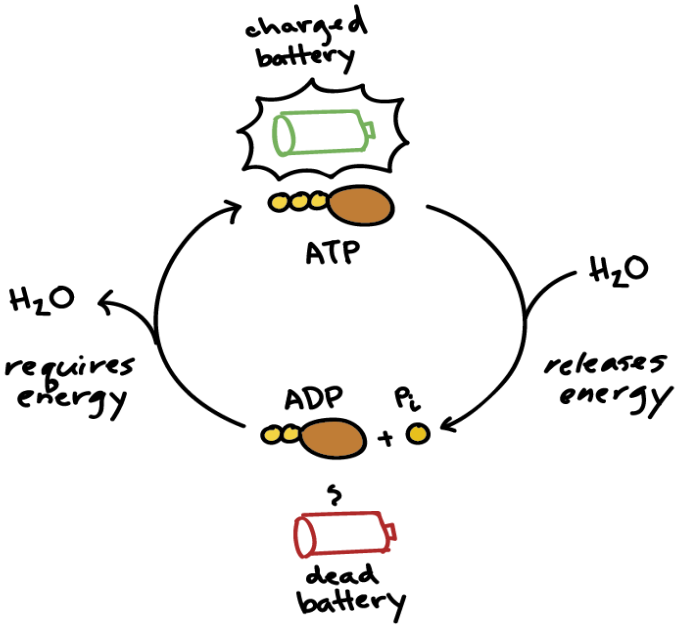


Q. Which of the following can be compared to a battery in need of recharging?

- ADP
- ATP
- Ribose
- Adenosine

Q. Which of the following results in the storage of energy in terms of the ATP/ADP cycle?

- The breaking of the bond between the 5-carbon sugar and the 1st phosphate group
- The addition of a phosphate group
- The removal of a phosphate group
- The addition of glucose



Understand Main Ideas

Understand Main Ideas

6. D
7. B
8. D
9. A

6. Which is not a characteristic of energy?

A. cannot be created nor destroyed
B. is the capacity to do work
C. exists in forms such as chemical, light, and mechanical
D. changes spontaneously from disorder to order

7. Which organism depends on an external source of organic compounds?

A. autotroph
B. heterotroph
C. chemoautotroph
D. Photoautotroph



8. Which part of this food chain provides energy to just one other part?

A. the chemoautotroph
B. the heterotroph
C. the Sun
D. the photo-autotroph

9. What do cells store and release as the main source of chemical energy?

A. ATP
B. ADP
C. $NADP^+$
D. NADPH

Which of the following paths of energy transformation can occur only in autotrophs?

Learning Outcomes Covered

- BIO.3.1.02.028

a. Chemical energy into mechanical energy

b. Electrical energy into thermal energy

c. Light energy into chemical energy

d.

Mechanical energy into thermal energy

Which of the following molecules is the most abundant energy carrier in cells and the main source of chemical energy?

Learning Outcomes Covered

- BIO.3.1.02.028

a. ATP

b. ADP

c. $NADP^+$

d. NADPH

34) In cellular respiration, which of the following are products?

- ☐ O_2
- ☐ energy
- ☐ H_2O
- ☐ CO_2
- ☐ $C_6H_{12}O_6$

1) Sam is building a campfire while camping with his family. Sam's younger brother asks how energy is generated from the burning log to make fire and heat. Sam studied thermodynamics in science class the month before and is able to answer his brother's question. Which answer does he give?

- ○ The matter in the log is destroyed to generate excess energy.
- ○ The increasing entropy in the system creates usable energy.
- ○ Energy is continually generated by the fire's high temperature.
- ○ Chemical energy in the log is converted to heat and light energy.

Correct Answer

Chemical energy in the log is converted to heat and light energy.

2) Elena is taking a guided hike through a New Hampshire forest in October to enjoy the changing colors of autumn leaves. Her guide explains that the leaves change color as the green pigment chlorophyll used in photosynthesis decomposes. Another hiker asks the guide to explain photosynthesis. Which is the guide's answer?

- ○ Photosynthesis is the process autotrophs use to make energy.
- ○ Photosynthesis is the process autotrophs use to make sugar.
- ○ Photosynthesis is the process heterotrophs use to make sugar.
- ○ Photosynthesis is the process heterotrophs use to make energy.

Correct Answer

Photosynthesis is the process autotrophs use to make sugar.

8) Which of the following defines metabolic pathways?

- ○ a series of chemical reactions in which organic molecules are broken down to release energy
- ○ a series of chemical reactions in which the product of one reaction is the substrate for the next reaction
- ○ a series of chemical reactions in which light energy converts into chemical energy
- ○ a series of chemical reactions in which mechanical energy converts into chemical energy

Correct Answer

a series of chemical reactions in which the product of one reaction is the substrate for the next reaction

11) Which of the following are parts of the structure of ATP? Select all that apply.

- ☐ thymine
- ☐ two phosphate groups
- ☐ adenine
- ☐ three phosphate groups
- ☐ ribose
- ☐ deoxyribose

17) In photosynthesis, which of the following are reactants? Select all chemical formulas that apply.

- ☐ O_2
- ☐ H_2O
- ☐ energy
- ☐ CO_2
- ☐ $C_6H_{12}O_6$

1. Which is not a characteristic of energy?

- changes spontaneously from order to disorder
- is the capacity to do work
- exists in different forms
- D can be created and destroyed CORRECT

2. Which organism depends on an external source of organic compounds?

- autotroph
- chemoautotroph
- B heterotroph CORRECT
- photoautotroph

3. Which part of this food chain provides energy to just one other part?



- the chemoautotroph
- the Sun
- the heterotroph
- D the photoautotroph CORRECT

5. Which does NOT describe photosynthesis?

- a series of chemical reactions
- an anabolic pathway
- B a catabolic pathway CORRECT
- a process that stores energy

4. What do cells store and release as the main source of chemical energy?

- A ATP CORRECT
- AMP
- ADP
- ribose

Photosynthesis

BIO.3.1.02.030 Describe that photosynthesis converts carbon dioxide plus water into sugars plus oxygen, which is released.

BIO.3.1.02.024 Explain that the hydrocarbon backbones of the sugars formed during photosynthesis are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules used, for example, to form new cells	Information from text	34

P34

LESSON 2

PHOTOSYNTHESIS

FOCUS QUESTION

What do lettuce plants need to survive?

Overview of Photosynthesis

Recall the first law of thermodynamics, which states that energy can be converted from one form to another, but it cannot be created nor destroyed. Photosynthesis is a complex chemical process that converts energy from one form to another. It is the main way that solar energy is captured and stored on Earth. Along with cellular respiration, it provides most of the energy for life processes.

Most autotrophs, including plants, make organic compounds, such as sugars, by a process called photosynthesis. Recall that a basic function of photosynthesis is the conversion of light energy into chemical energy. The products and reactants of photosynthesis are identified in the overall chemical reaction for photosynthesis, which is shown below.

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

Photosynthesis occurs in two phases. Phase one of photosynthesis consists of reactions called the light-dependent reactions. First, light energy is captured, or absorbed, by organelles called chloroplasts. It is then converted into chemical energy, which is stored in ATP and NADPH molecules.

Phase two of photosynthesis consists of a series of reactions called the light-independent reactions. In phase two, molecules of ATP and NADPH that were formed in the phase one light-dependent reactions are used to make glucose, a form of sugar.

Once glucose is produced, it can be joined to other simple sugars to form complex carbohydrates, such as starch. The glucose molecules that are formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules such as proteins, lipids, or DNA used, for example, to form new cells.

Overview of Photosynthesis

- All life on Earth depends on solar energy.
- Photosynthetic organisms (algae, plants, and cyanobacteria) transform solar energy into the chemical energy of carbohydrates.
- Called autotrophs because they produce their own food.

What is the benefit of photosynthesis for humans and animals?.

Photosynthetic reaction produce oxygen which humans & animals breathe, and food (chemical energy) in plants which humans & animals eat.

How does photosynthesis benefit plants?.

Photosynthetic process enables plants to produce carbon molecules (glucose) , which are storehouse for energy, and used for pant metabolisms.

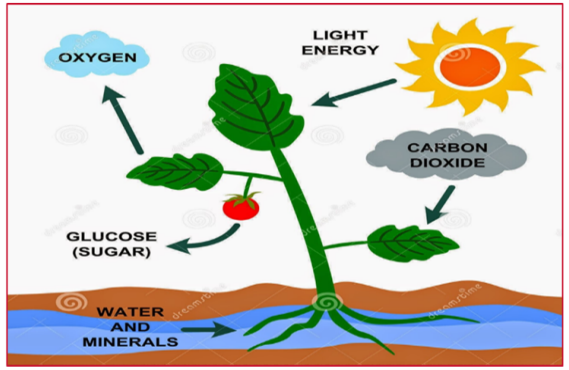
Do air(Co_2),water provide energy for photosynthesis?.

No.
The only source of energy for photosynthesis is light energy.

Indicate light energy and chemical energy?

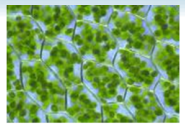
Photosynthesis:

-A **process** that captures light energy.
-Transforms light energy into chemical energy.
-Energy ends up stored in a sugar.

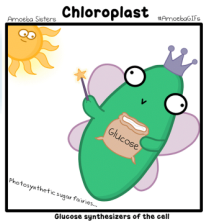


The overall chemical equation for photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$







-But this equation does not explain how process of photosynthesis occur.

-Is blending carbon dioxide with the water in exposed light condition results in glucose and oxygen?



Once glucose is produced, it can be joined to other simple sugars to form complex carbohydrates, such as starch. The glucose molecules that are formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules such as proteins, lipids, or DNA used, for example, to form new cells.

BIO.3.1.02.027 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy	Information from text	35
	Figure 5 + Question below it	35

-Photosynthesis occurs inside plant cell chloroplasts.
-Photosynthesis occurs in 2 phases.
1-Light-dependent reaction (Light Reaction)
2-Light-independent reaction (The Calvin Cycle)

Phase One: Light Reactions

The absorption of light is the first step in photosynthesis. Plants have organelles that capture, or absorb, light energy. Once the energy is captured, two energy storage molecules, NADPH and ATP, are produced. These molecules are used in the light-independent reactions.

Chloroplasts

Large organelles called chloroplasts capture light energy in photosynthetic organisms. In plants, chloroplasts are found mainly in the cells of leaves. As shown in **Figure 5**, chloroplasts are disk-shaped organelles that contain two main compartments essential to photosynthesis. The first compartment is called the thylakoid (THI la koyd). **Thylakoids** are flattened, saclike membranes that are arranged in stacks. The stacks of thylakoids are called **grana** (singular, granum). The light-dependent reactions take place within the thylakoids. The second important compartment within the chloroplast is called the **stroma,** the fluid-filled space that is outside the grana. The stroma, shown in **Figure 5,** is the location of the light-independent reactions that take place in phase two of photosynthesis.

Get It?
Apply Look back at the photo at the beginning of the module. What cellular structures in the plants absorb the light that passes into the greenhouse?

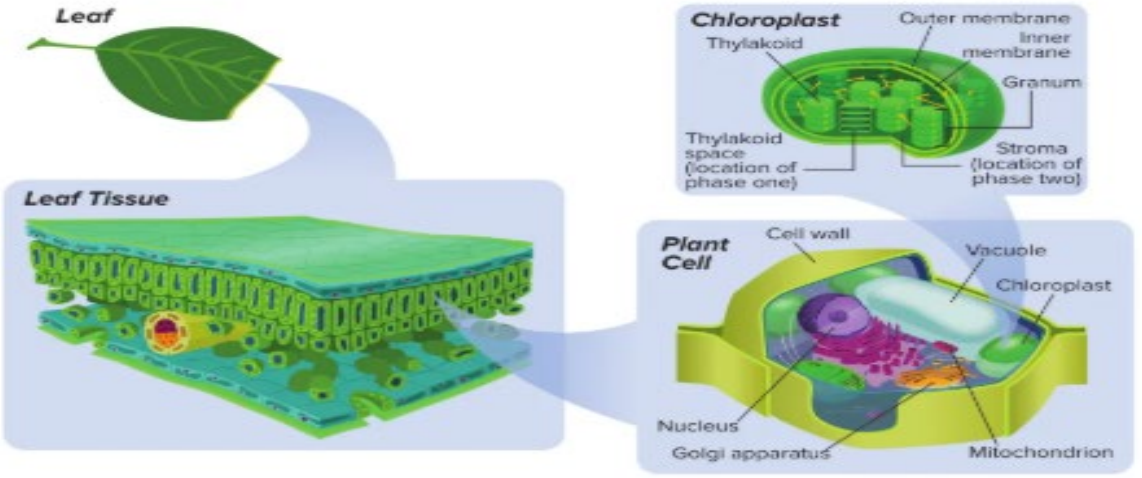
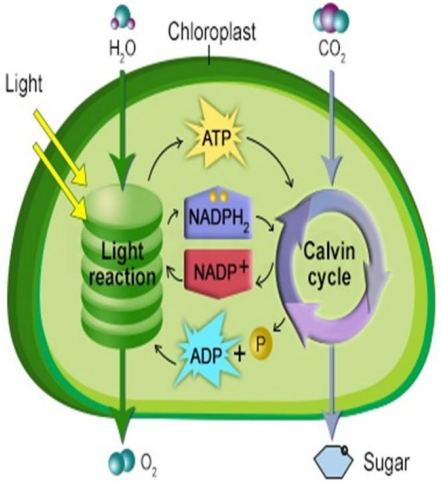
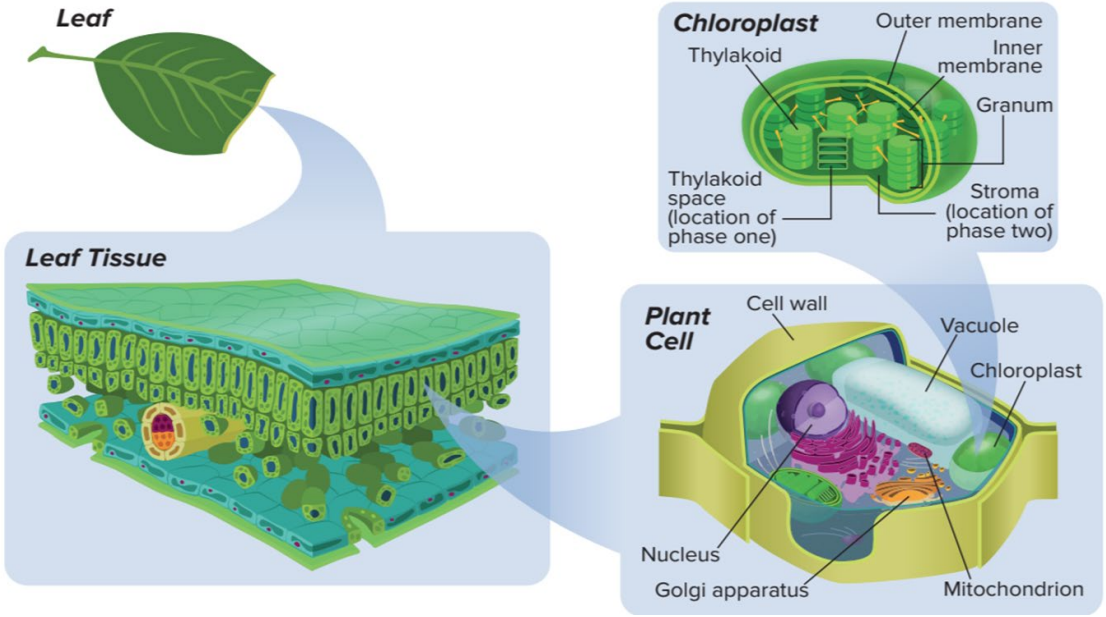


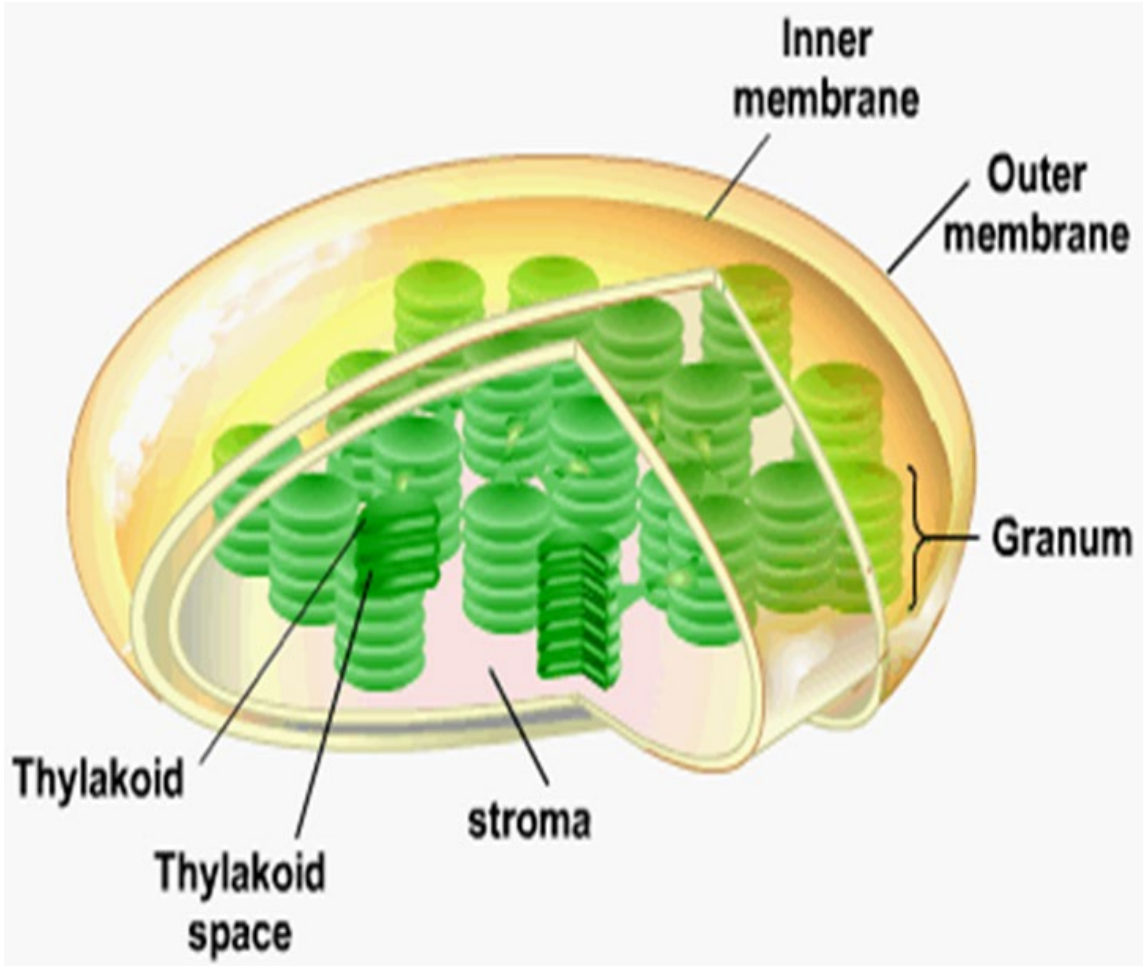
Figure 5 Photosynthesis occurs inside pigmented organelles called chloroplasts.
Identify *the location of the stroma and thylakoids within a plant cell.*

Phase One: Light Reactions

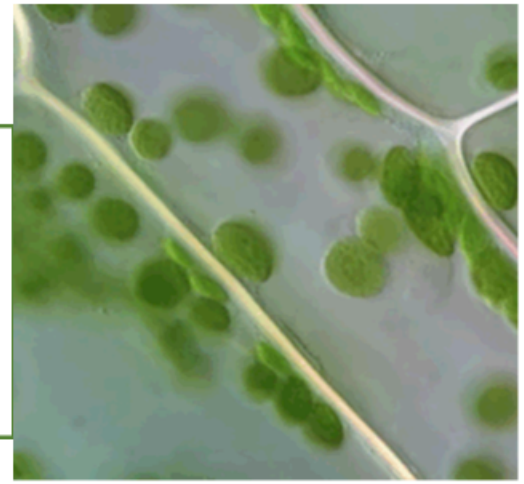
- The absorption of light is the first step in photosynthesis.
- Chloroplasts capture light energy.
- NADPH and ATP (energy storage molecules) are produced.
- These molecules are used in the light-independent reaction.





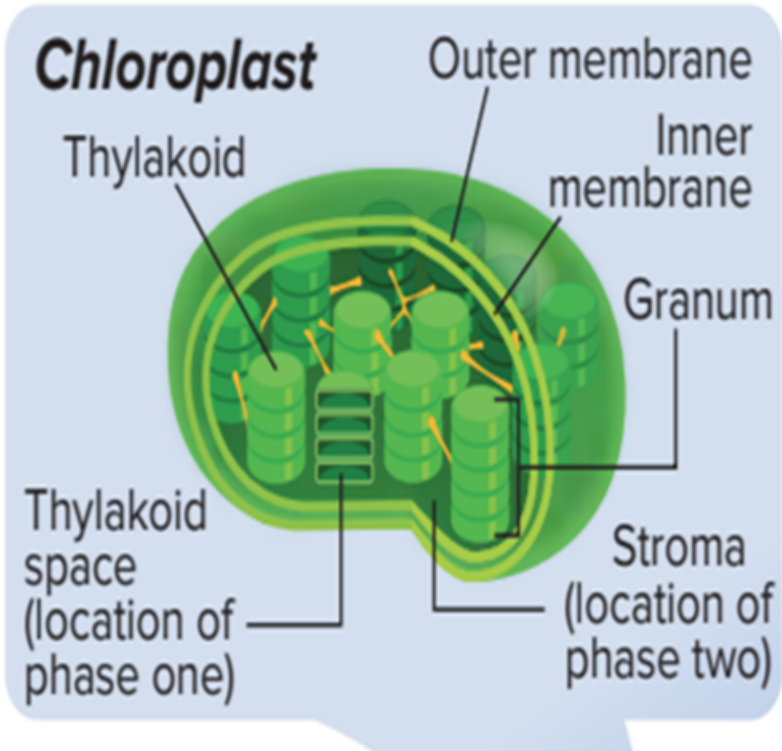


Chloroplast



-Large organelles in plant cell (mainly in the cells of leaves).
-Capture light energy.
-Are disk-shaped organelles.
-Has 2 membranes:* outer membrane & inner membrane.
-Contain 2 compartments essential to photosynthesis:*Thylakoids & Stroma

Compare between	Thylakoids	Stroma
The shape	Flattened, saclike membranes ,arranged in stacks (grana, singular granum)	Fluid-filled space outside the grana.
Type of Reaction	light-dependent reaction	light-independent reaction
Continents	Light-absorbing pigments	Molecules and enzyme need for phase2 reaction



BIO.3.1.02.027 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy	Information from text	36
	"Get it?" question	36

Pigments

Light-absorbing colored molecules called **pigments** are found in the thylakoid membranes. Pigments absorb specific wavelengths of light energy, as illustrated in **Figure 6**. Different pigments absorb different wavelengths of light.

The major light-absorbing pigments in plants are chlorophylls. There are several types of chlorophylls, but the two most common types are chlorophyll *a* and chlorophyll *b*. The structure of chlorophyll can differ from one molecule to another, enabling distinct chlorophyll molecules to absorb light at unique areas of the visible spectrum. In general, chlorophylls absorb light energy most strongly in the violet-blue region of the visible light spectrum and reflect light in the green region of the spectrum. This is why plant parts that contain chlorophyll appear green to the human eye.

Get It?

Explain why many plant parts appear green in color.

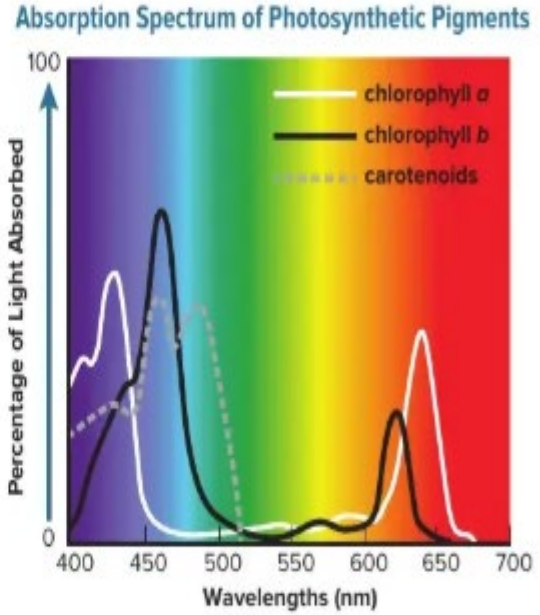


Figure 6 Colorful pigments found in the leaves of trees differ in their ability to absorb specific wavelengths of light.

Hypothesize *the effect on light absorption if a plant did not have chlorophyll* b.

In addition to chlorophylls, most photosynthetic organisms contain accessory pigments that allow plants to trap additional light energy from other areas of the visible spectrum. One such group of accessory pigments is the carotenoids (kuh ROH tuh noydz). Carotenoids, such as ß-carotene (beta-carotene), absorb light mainly in the blue and green regions of the spectrum, while reflecting most light in the yellow, orange, and red regions, as shown in **Figure 6**. Carotenoids are the pigments that produce the colors of carrots and sweet potatoes.

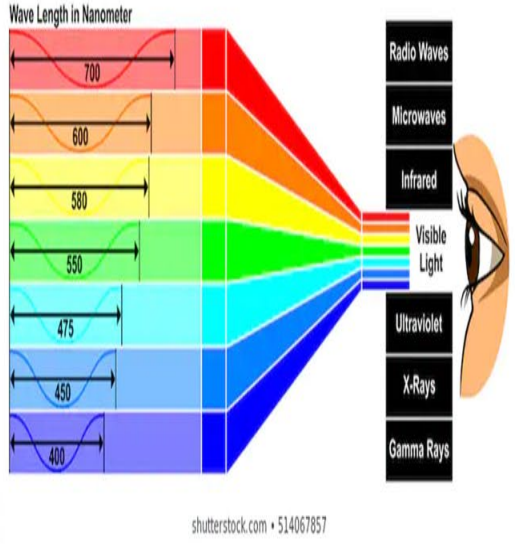
Chlorophylls are more abundant than other pigments in leaves, and thus hide the colors of the other pigments. However, autumn in certain parts of the United States can bring out shades of yellow, red, and orange as the leaves turn colors, as shown in **Figure 7**. As trees prepare to lose their leaves before winter, the chlorophyll molecules break down, revealing the colors of the other pigments.



Figure 7 When chlorophyll breaks down in the leaves of some trees, the other pigments become visible.

Pigments.

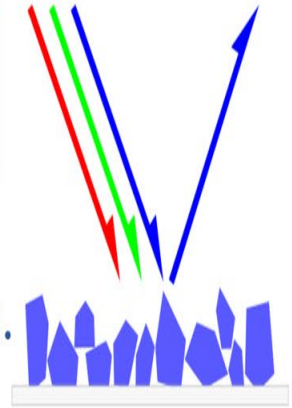




Describe pigments?.

-Light-absorbing-colored molecules.

In the figure **what** is the pigment color ? **Explain** your answer.



-Blue, The surface absorb all visible light spectrum and reflect light in the blue region.

Where pigment molecules found in plant cell.

-Are found in the thylakoid membranes of chloroplasts.

Absorption Spectrum of Photosynthetic Pigment

-The major light-absorbing pigments in plants are chlorophylls,
The most common 2 are chlorophyll a & chlorophyll b.

-In which region the chlorophylls absorb light energy more?



Get It?

Explain why many plant parts appear green in color.



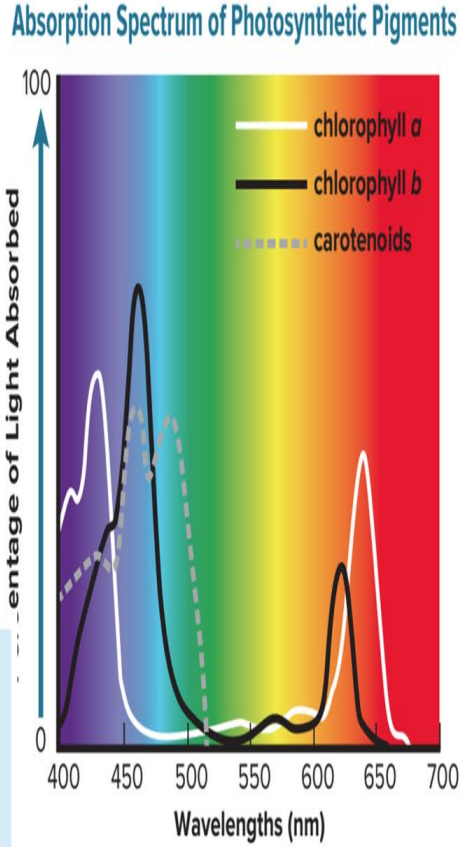


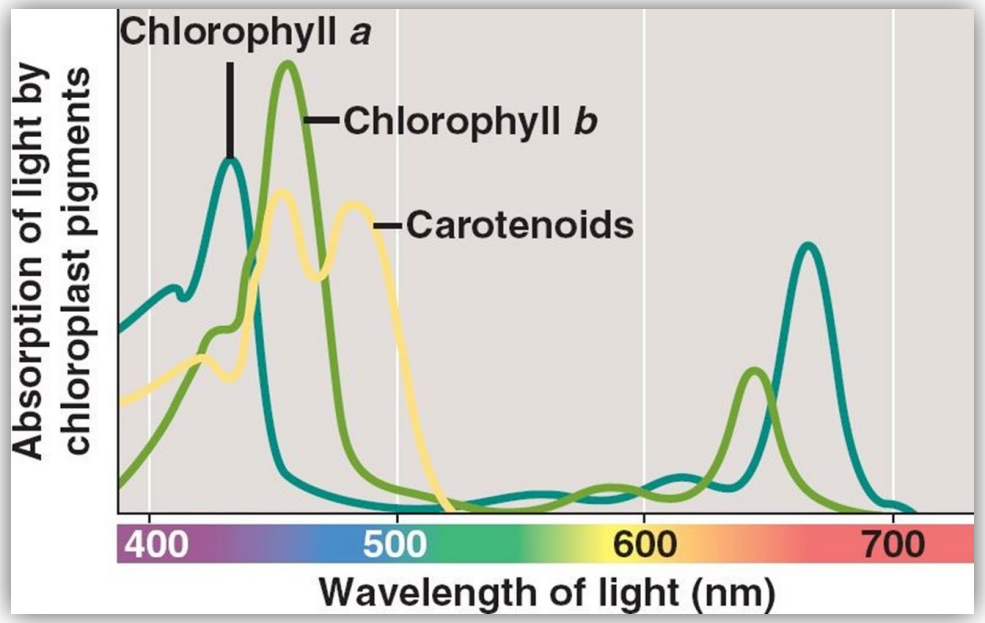
Figure 6 Colorful pigments found in the leaves of trees differ in their ability to absorb specific wavelengths of light.

Absorption Spectra of Photosynthetic Pigment

Compare between colorful pigment in ability to absorb wavelengths of light.

Pigment	Role in photosynthetic	Absorbed wavelengths	Color
Chlorophyll a	major		green
Chlorophyll b	major		green
carotenoids	accessory		yellow-orange

chlorophylls absorb light energy most strongly in the violet-blue region of the visible light spectrum and reflect light in the green region of the spectrum. This is why plant parts that contain chlorophyll appear green to the human eye.



■ **Caption Question** **Fig. 6** Without chlorophyll b, the plant would absorb less light. This might cause a reduction in the rate of photosynthesis.

Hypothesize *the effect on light absorption if a plant did not have chlorophyll* b.

Absorption Spectrum of Photosynthetic Pigment

-There are accessory pigments that allow plants to trap additional light energy such as carotenoids.
Example: ß-carotene

-In which region the carotenoids absorb light energy more?

-In which region the carotenoids reflect light energy more?

Analyze and conclude



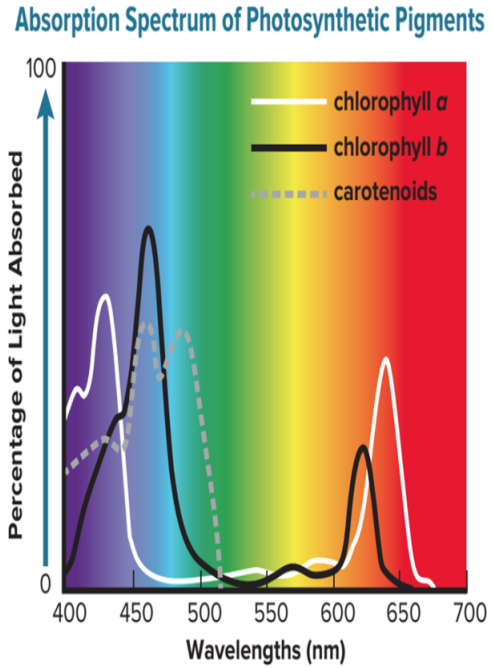


Figure 6 Colorful pigments found in the leaves of trees differ in their ability to absorb specific wavelengths of light.

(kuh ROH tuh noydz). Carotenoids, such as ß-carotene (beta-carotene), absorb light mainly in the blue and green regions of the spectrum, while reflecting most light in the yellow, orange, and red regions, as shown in **Figure 6**. Carotenoids are the pigments that produce the colors of carrots and sweet potatoes.

- Tree prepare to lose their leaves before autumn, the chlorophyll molecules break down revealing the colors of other pigments.

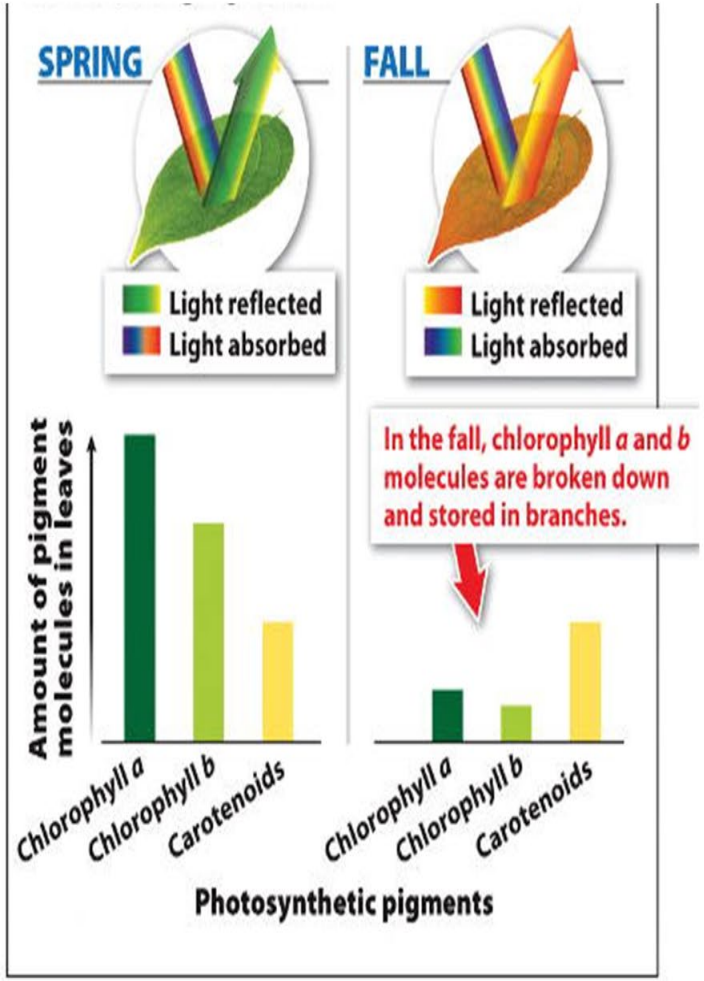




Figure 7 When chlorophyll breaks down in the leaves of some trees, the other pigments become visible.



1) What three things do plants need for the process of photosynthesis?

- Sunlight, oxygen, and sugar
- Water, soil, and oxygen
- **Sunlight, carbon dioxide, and water**
- Carbon dioxide, oxygen, and soil
- Sunlight, soil, and water

2) If plants breathe in carbon dioxide, what do they breathe out?

- Nitrogen
- **Oxygen**
- Carbon monoxide
- Hydrogen
- Helium

3) What is the compound that plants use to absorb the energy from light?

- Carbon Dioxide
- H2O
- Nitrogen
- DNA
- **Chlorophyll**



4) What color is chlorophyll?

- Red
- Blue
- Yellow
- **Green**
- Brown

Why do we perceive chlorophyll as being green?

- Because it is green.
- Because it absorbs green light.
- **Because it reflects green light.**
- Because it absorbs yellow light.





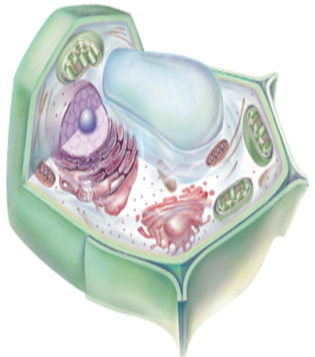
At the end of the Calvin cycle, where is energy stored?

A. NADPH
B. ATP
C. chloroplast
D. glucose



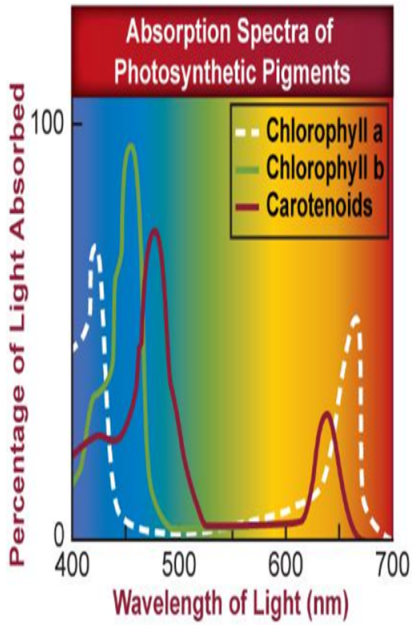
Where in the plant cell does photosynthesis take place?

A. chloroplasts
B. Golgi apparatus
C. mitochondria
D. vacuoles



Which range of wavelengths is reflected by chlorophylls *a* and *b*?

A. 400-500 nm
B. 500-600 nm
C. 600-700 nm



Look at the following figure. Which part of the chloroplast is a sac-like membrane arranged in stacks?

A. grana
B. stroma
C. thylakoids
D. Golgi apparatus



stroma	⟷	light-independent reactions of photosynthesis occur here
thylakoid space	⟷	light-dependent reactions of photosynthesis occur here
inner membrane	⟷	houses the thylakoids, grana, and stroma
outer membrane	⟷	protects the chloroplast from harmful substances
grana	⟷	houses numerous thylakoids
thylakoid	⟷	traps energy from the sunlight using chlorophyll

72) Fill in the blanks using the available answer choices.

Rubisco is a(n) enzyme **that converts inorganic carbon dioxide into organic molecules during the final step of the Calvin cycle.**

73) The major electron carrier involved in electron transport during photosynthesis is ___.

- ○ FAD
- ○ $NADP^+$
- ○ NAD^+
- ○ ADP

68) Where is the location of the light-dependent reactions?

- ○ matrix
- ○ thylakoid
- ○ stroma
- ○ granum

69) What is the term called when referring to a stack of thylakoids?

- ○ stroma
- ○ granum
- ○ thylakoid
- ○ matrix

28) Place the steps of photosynthesis into the correct order from top to bottom

1) 1. Light energy breaks down water into oxygen and hydrogen ions.
2) 2. Electrons move through the electron transport and convert NADP+ into NADPH.
3) 3. Hydrogen ions move through the ATP synthase converting ADP into ATP.
4) 4. NADPH and ATP are used in the Calvin cycle.
5) 5. Carbon dioxide is used to create glucose molecules.

Carbon dioxide is used to create glucose molecules.

Hydrogen ions move through the ATP synthase converting ADP into ATP.

Light energy breaks down water into oxygen and hydrogen ions.

Electrons move through the electron transport and convert NADP+ into NADPH.

NADPH and ATP are used in the Calvin cycle.

BIO.3.1.02.027 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy	Information from text	37
	"Get it?" question	37

BIO.3.1.02.027 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy	Information from text	37
	Figure 8	38

Electron transport

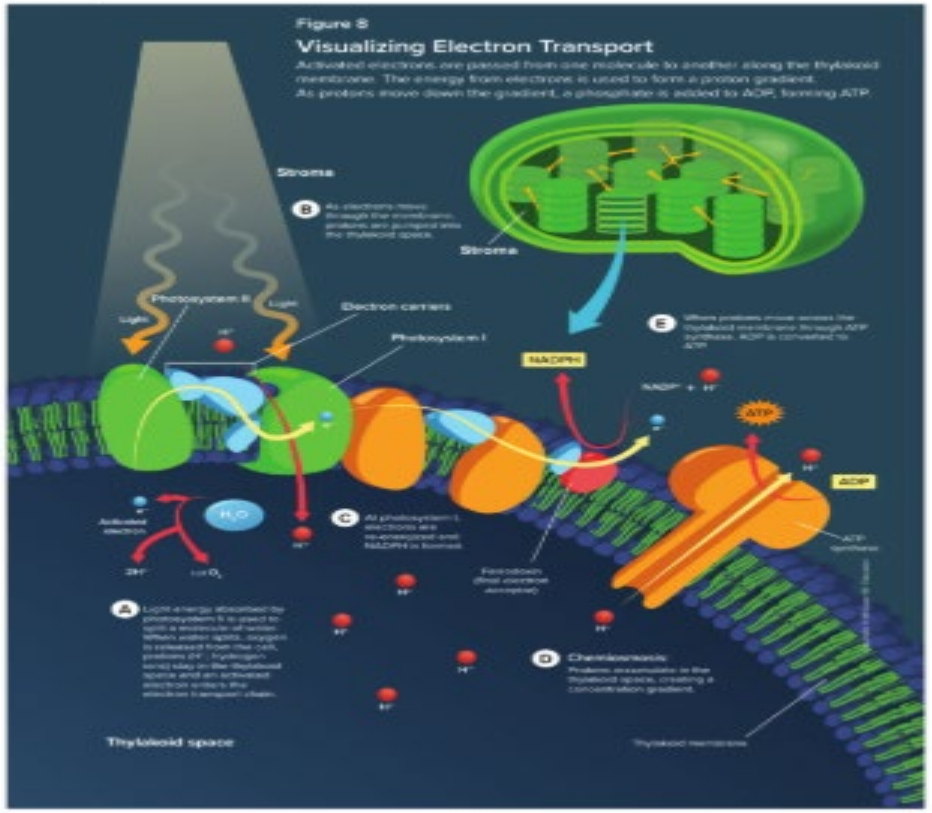
The structure of the thylakoid membrane is the key to efficient energy transfer during electron transport. Thylakoid membranes have a large surface area, which provides the space needed to hold large numbers of electron-transporting molecules and two types of protein complexes called photosystems. Photosystem I and photosystem II contain light-absorbing pigments and proteins that play important roles in the light reactions.

Follow along in **Figure 8** on the next page as you continue to read about electron transport.

- First, the light energy excites electrons in photosystem II. The light energy also causes a water molecule to split, releasing an electron into the electron transport system, a hydrogen ion (H^+)—also called a proton—into the thylakoid space, and the release of oxygen (O_2) as a waste product. This breakdown of water is essential for photosynthesis to occur.
- The excited electrons move from photosystem II to an electron-acceptor molecule in the thylakoid membrane.
- Next, the electron-acceptor molecule transfers the electrons along a series of electron-carriers to photosystem I.
- In the presence of light, photosystem I transfers the electrons to a protein called ferrodoxin. The electrons lost by photosystem I are replaced by electrons shuttled from photosystem II.
- Finally, ferrodoxin transfers the electrons to the electron carrier **$NADP^+$**, forming the energy-storage molecule NADPH.

Chemiosmosis ATP is produced in conjunction with electron transport by the process of chemiosmosis, the mechanism by which ATP is produced as a result of the flow of electrons down a concentration gradient. The breakdown of water is essential to this process, not only for providing the electrons that initiate the electron transport chain, but also for providing the protons (H^+) necessary to drive ATP synthesis during chemiosmosis.

The protons (H^+) released during electron transport accumulate in the interior of the thylakoid, creating a concentration gradient. As a result of a high concentration of H^+ in the thylakoid interior and a low concentration of H^+ in the stroma, H^+ protons diffuse down their concentration gradient out of the thylakoid interior into the stroma through ion channels spanning the membrane, as shown in **Figure 8.** These channels are enzymes called ATP synthases. As H^+ moves through ATP synthases, ATP is formed in the stroma.

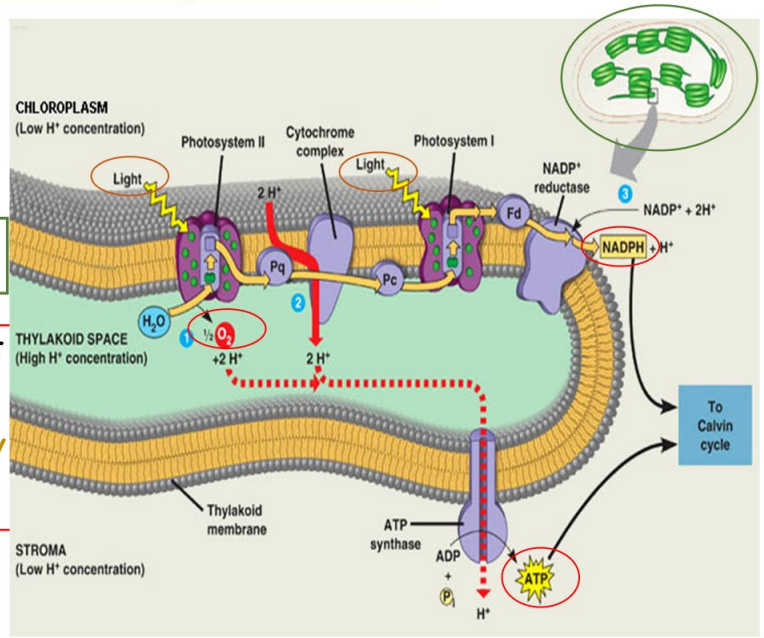


Photosynthesis Phase One: Light Reactions

*The absorption of light is the first step in photosynthesis.

*Chloroplasts capture light energy.

*Use energy from light to produce oxygen gas and convert ADP and NADP+ into the energy carriers ATP and NADPH

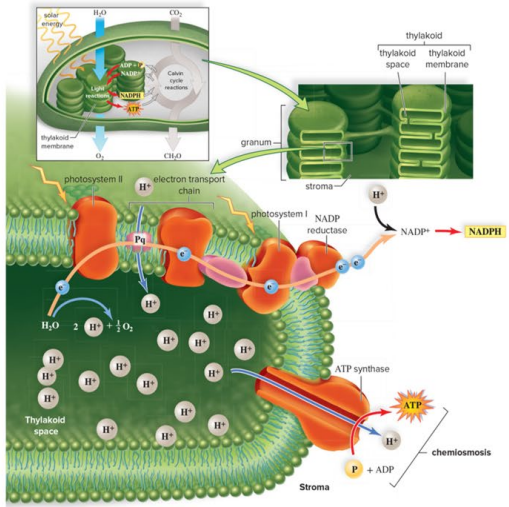


Phase One: Light Reactions

* Light reaction start when pigments absorb the light along the thylakoid membrane in a chloroplast.

The structure of the thylakoid

- Thylakoid membrane
- Thylakoid space
  - the H+ release during electron transport accumulate in.

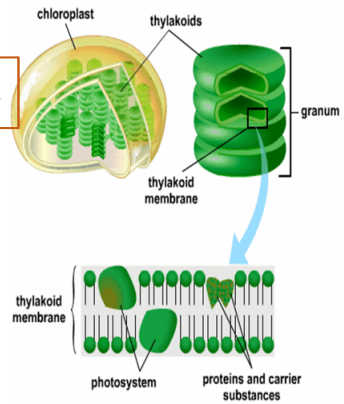


Phase One: Light Reactions

* Light reaction start when pigments absorb the light along the thylakoid membrane in a chloroplast.

The structure of the thylakoid

- Thylakoid membrane
  - a large surface area hold
    - electron-transporting molecules
    - Protein complexes photosystems
      - Photosystems I
      - Photosystems II
    - ATP synthase (Ion channels)
- Thylakoid space



Lets identify the components of Electron Transport

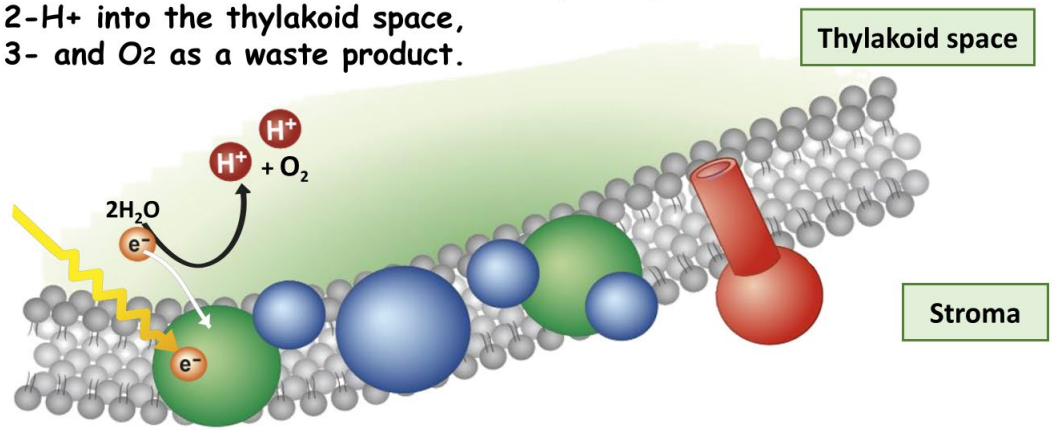
Complete (label) the figure of Thylakoid membrane.



Electron Transport

First

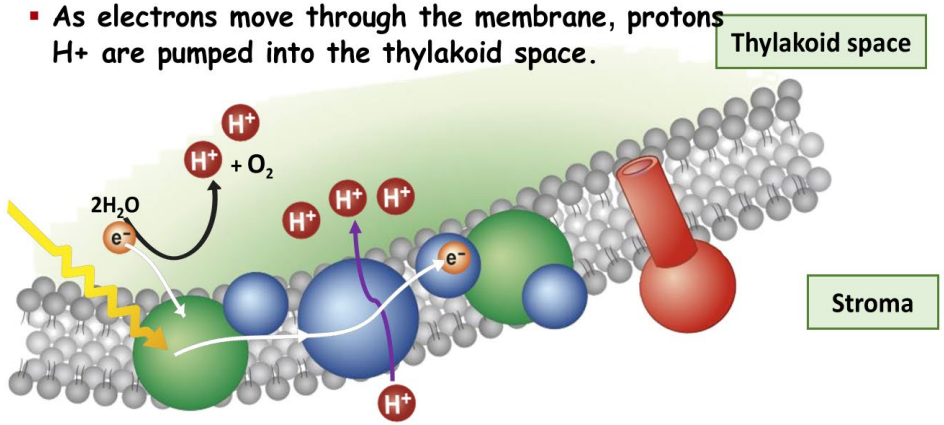
- Light energy excites electrons in photosystem II
- and also causes a water molecule to split, releasing:
  1-an electron into the electron transport system,
  2-H+ into the thylakoid space,
  3- and O_2 as a waste product.



Electron Transport

Second

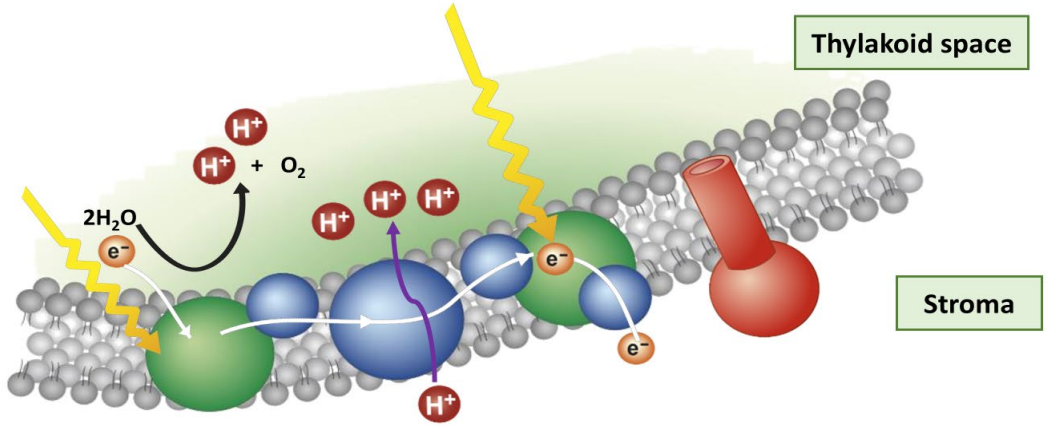
- The excited electrons move from photosystem II to an electron-acceptor molecule in the thylakoid membrane.
- As electrons move through the membrane, protons H+ are pumped into the thylakoid space.



Electron Transport

Third

- The electron-acceptor molecule transfers the electrons along a series of electron-carriers to photosystem I.



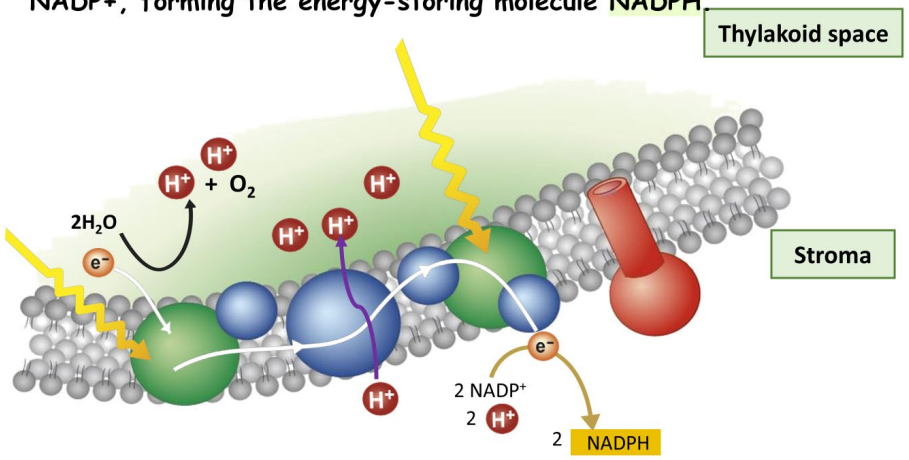
Fourth

- In the presence of light, Photosystem I transfers the electrons to a protein called ferredoxin.

Electron Transport

Finally

- Ferrodoxin transfers the electrons to the electron carrier NADP+, forming the energy-storing molecule NADPH.



Electron Transport

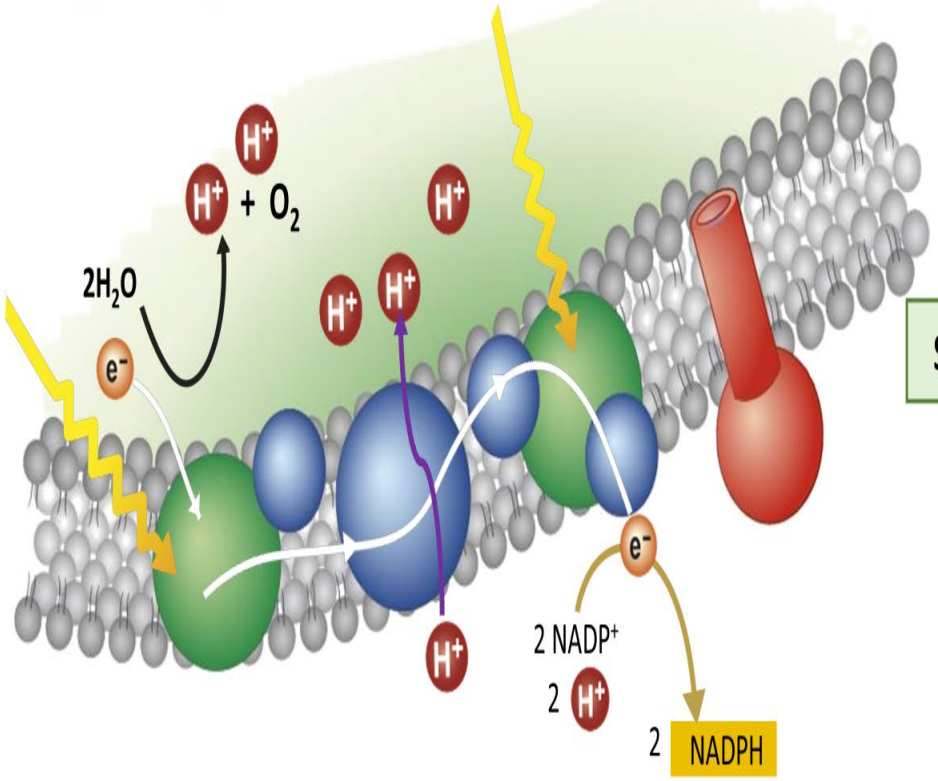
- How to make up for the lost electrons by photosystem I ?.

They are replaced by electrons shuttled from photosystem II

- How to make up for the lost electrons by photosystem II ?.

They are replaced by electrons shuttled from water splits.

Thylakoid space

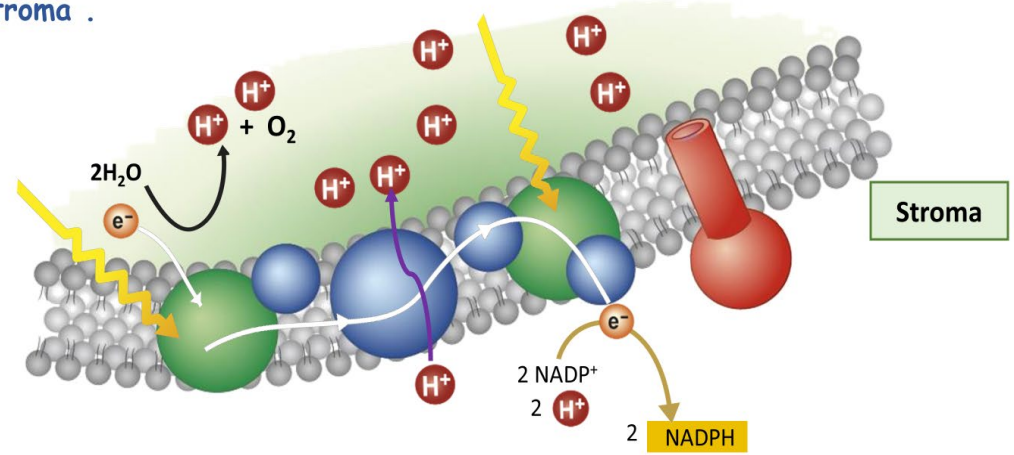


Chemiosmosis

- Describe the concentration of protons (H+) on both sides of thylakoid membrane.

A high concentration of protons (H+) in the thylakoid interior (thylakoid space) and a low concentration of protons (H+) in the stroma .

Thylakoid space



Chemiosmosis

- Explain the high concentration of protons (H+) in the thylakoid interior

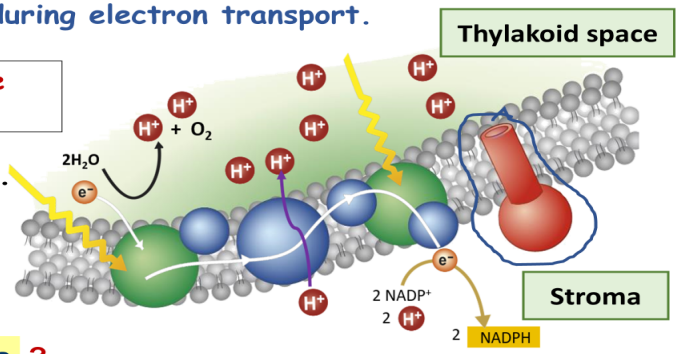
1- The breakdown (split) of water.
2-The proton released during electron transport.

- On the figure, indicate ATP synthase.

- Describe ATP synthase.

Ion channels spanning thylakoid membrane, these channels are enzymes .

Thylakoid space



- What is Chemiosmosis ?

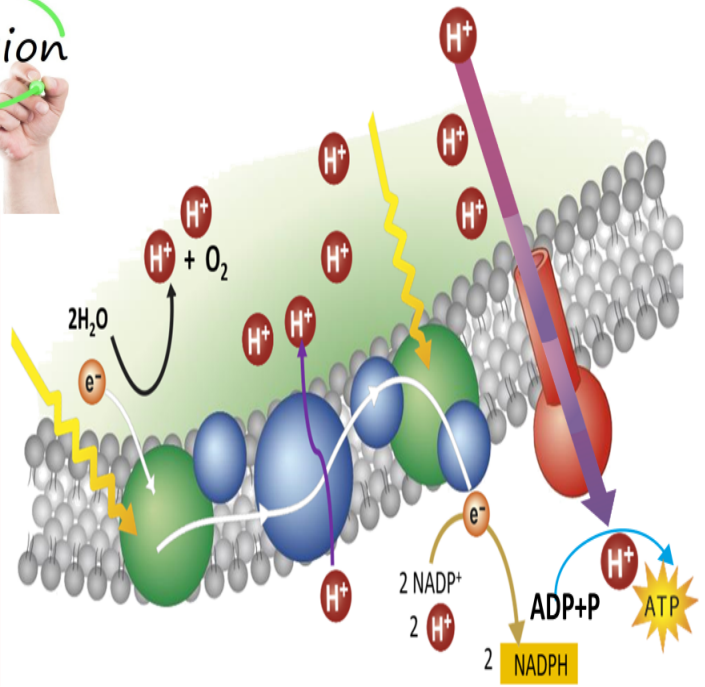
the mechanism by which ATP is produced as a result of the flow of electrons down a concentration gradient.

Chemiosmosis

- H+ protons diffuse down their concentration gradient out of the thylakoid interior into the stroma through ATP synthases
- As H+ moves through ATP synthases, ATP is formed in the stroma.

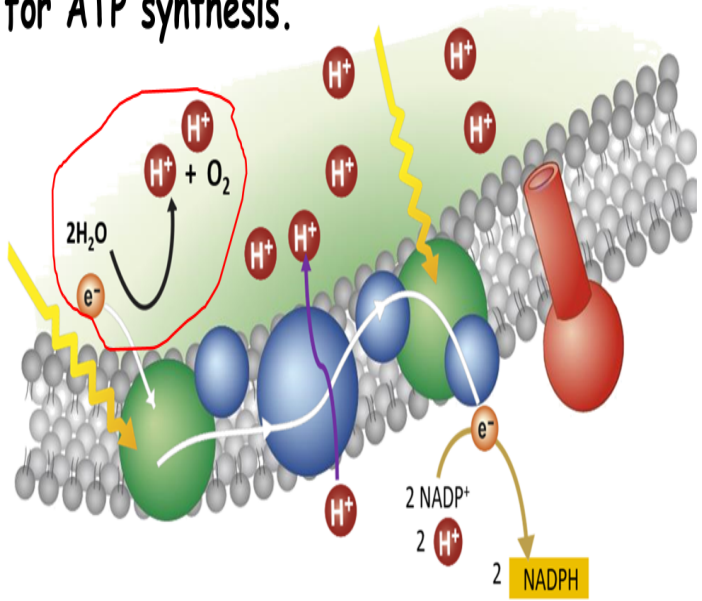


-Activated electrons are passed from one molecule to another along the thylakoid membrane in a chloroplast.
-The energy from electrons is used to form a proton gradient.
-As protons move down the gradient, a phosphate is added to ADP, forming ATP.



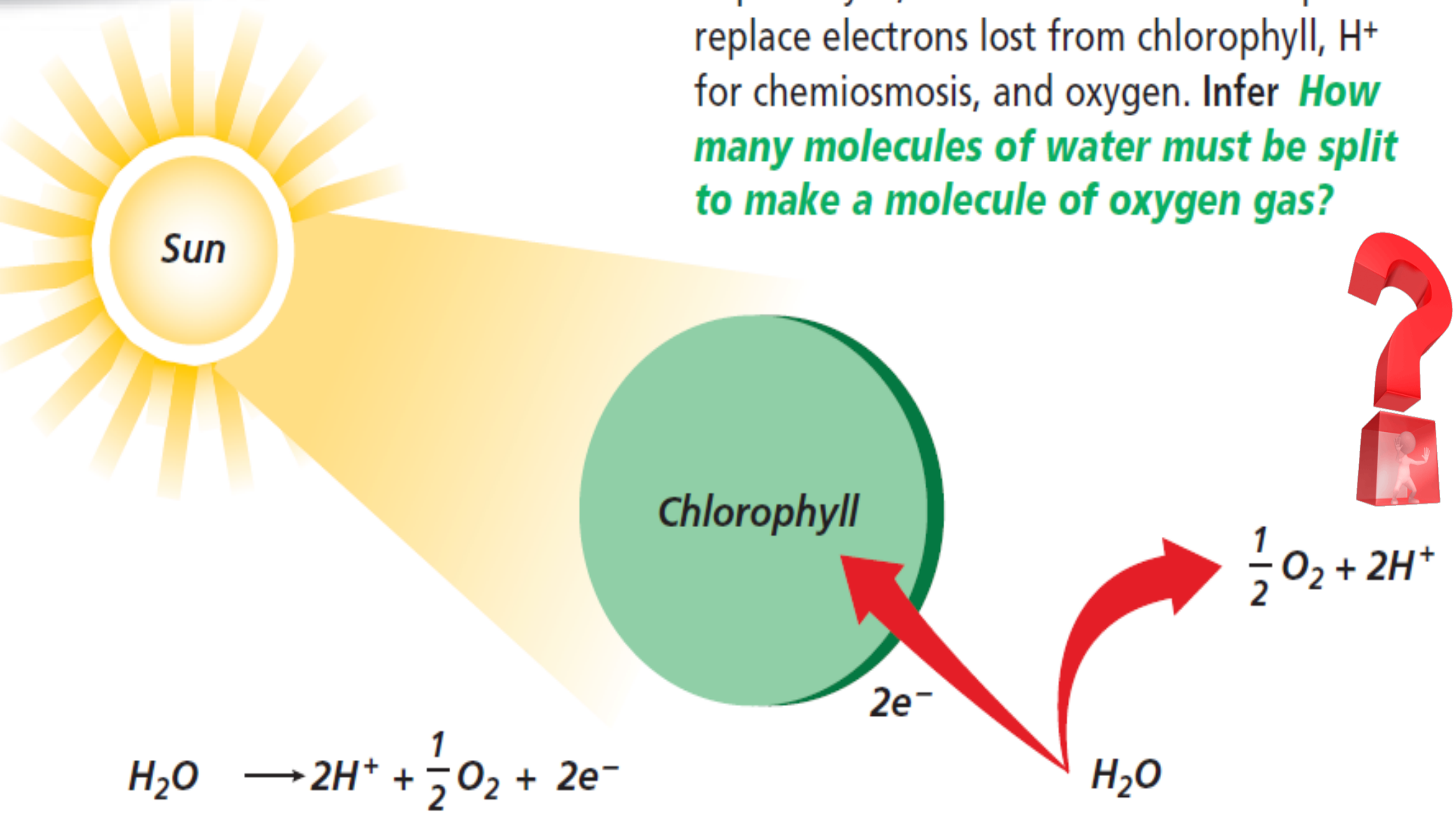
Chemiosmosis

- ATP is produced in conjunction with electron trans-port by the process of chemiosmosis.
- ATP is produced due to the flow of electrons down concentration gradient.
- The breakdown of water provides the necessary protons for ATP synthesis.



In photolysis, a molecule of water is split to replace electrons lost from chlorophyll, H^+ for chemiosmosis, and oxygen. **Infer** ***How many molecules of water must be split to make a molecule of oxygen gas?***





$$H_2O \longrightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$$

22) Place the steps of electron transport into the correct order.

1)
2)
3)
4)
5)
6)
7)

Correct Answer

1. Light energy excites electrons in photosystem II.
2. Light energy causes a water molecule to split, creating hydrogen ions and oxygen.
3. Excited electrons move from photosystem II through electron-acceptor molecules.
4. Light energy excites electrons in photosystem I and transfers electrons to ferredoxin.
5. Ferredoxin transfers electrons to NADP+, forming NADPH.
6. Hydrogen ions in the stroma diffuse through ATP synthase.
7. ADP is converted to ATP in the stroma.

Hydrogen ions in the stroma diffuse through ATP synthase.

Light energy causes a water molecule to split, creating hydrogen ions and oxygen.

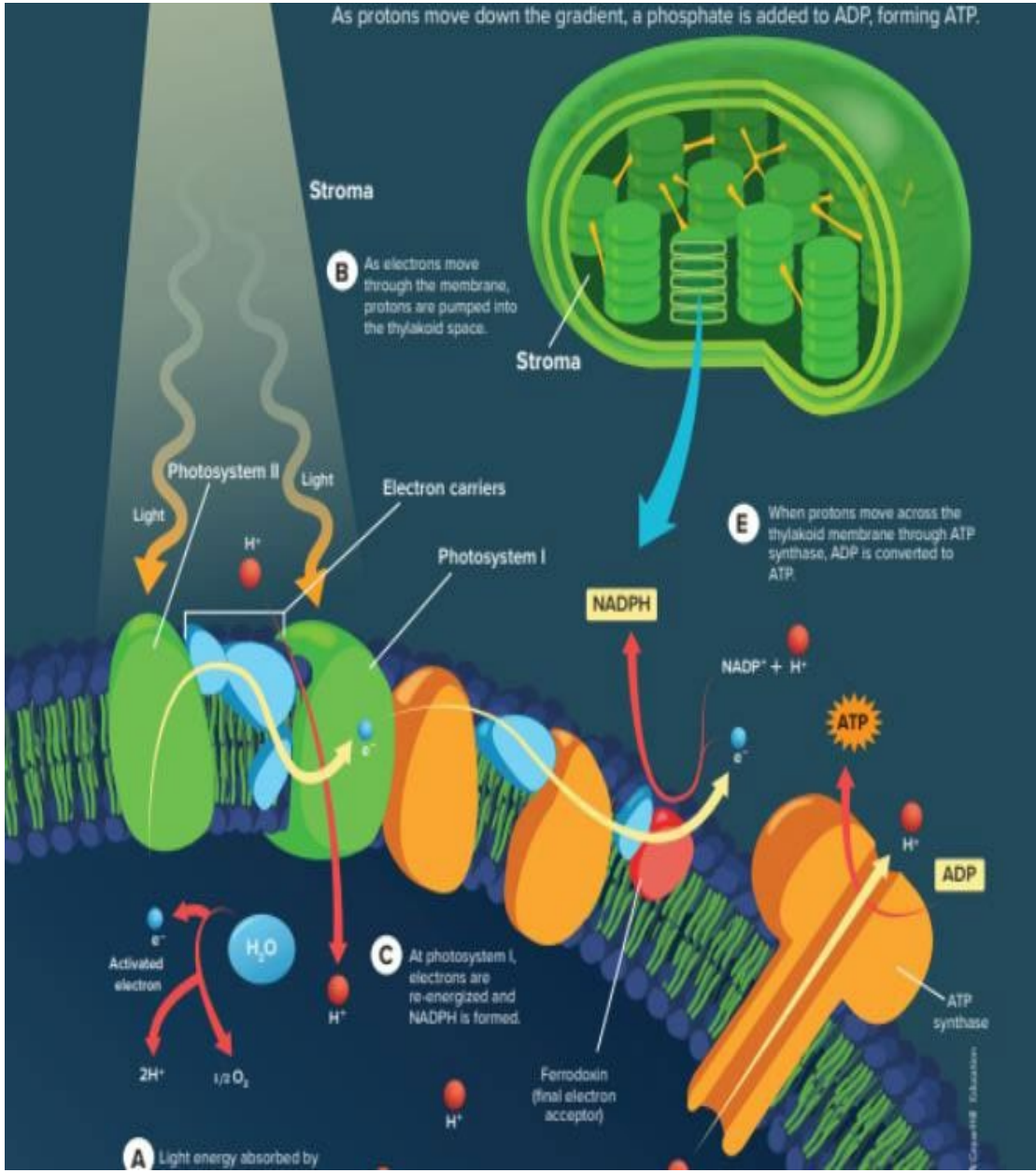
Light energy excites electrons in photosystem I and transfers electrons to ferredoxin.

Light energy excites electrons in photosystem II.

ADP is converted to ATP in the stroma.

Excited electrons move from photosystem II through electron-acceptor molecules.

Ferredoxin transfers electrons to NADP+, forming NADPH.



At the beginning of photosynthesis, which molecule is split to produce oxygen (O_2) as a waste product?

A. CO_2
B. H_2O
C. $C_6H_{12}O_6$
D. 3-PGA

Which mechanism of photosynthesis uses the movement of hydrogen ions (H^+) across a concentration gradient to synthesize ATP?

A. absorption
B. chemiosmosis
C. electron transport
D. C_2 pathway

Q. Where do the light-dependent reactions occur?

answer choices

- thylakoid membrane
- stroma
- mesophyll
- mitochondria



Q. What supplies the electron that is lost in PS II?

answer choices

- oxygen
- water
- glucose
- rubisco

Q. After the electron leave PS II, where does it go next?

- Electron Transport Chain
- NADPH Reductase
- PS I
- Stroma

5) What is the name of the chemical where the energy is stored during the first phase of photosynthesis?

- ATP
- Carbon dioxide
- Chlorophyll
- Oxygen
- DNA

10) True or False: Photosynthesis is responsible for the world's oxygen supply which is needed for animals to survive.

- TRUE
- FALSE

8) What are the structures inside plant cells that contain chlorophyll called?

- Nucleus
- Ribosomes
- Chloroplasts
- Lysosomes
- Mitochondria

Which photosystem does the light-dependent reaction begin with?

A. Photosystem I

B. Photosystem II

Light absorbed by photosystem II serves to excite electrons in what molecules?

A. Chlorophyll b molecules

B. Chlorophyll a molecules

C. Accessory pigment molecules

After NADP reductase transfers the electron from ferredoxin to NADP+, the NADP+ required how many electrons so that it can be reduced into NADPH?

A. 1

B. 2

C. 3

What are the products of the light-dependent reaction?

A. Glucose

B. Ferredoxin

C. NADPH and ATP

HO.3.1.02.030 Describe that photosynthesis converts carbon dioxide plus water into sugars plus oxygen, which is released.	Information from text	39
	Figure 9	39

HO.3.1.02.030 Describe that photosynthesis converts carbon dioxide plus water into sugars plus oxygen, which is released.	Information from text	39
	Figure 9	39

Phase Two: The Calvin Cycle

Although NADPH and ATP provide cells with large amounts of energy, these molecules are not stable enough to store chemical energy for long periods of time. Thus, there is a second phase of photosynthesis called the **Calvin cycle**, in which energy is stored in organic molecules such as glucose. The reactions of the Calvin cycle are also referred to as the light-independent reactions. Follow along in **Figure 9** as you learn the steps of the Calvin cycle.

- In the first step of the Calvin cycle, six carbon dioxide (CO_2) molecules combine with six 5-carbon compounds to form twelve 3-carbon molecules called 3-phosphoglycerate (fahs foh GLI suh rayt) (3-PGA). The joining of carbon dioxide with other organic molecules is called carbon fixation.
- In the second step, the chemical energy stored in ATP and NADPH is transferred to the 3-PGA molecules to form high energy molecules called glyceraldehyde 3-phosphates (G3P). ATP supplies the phosphate groups for forming G3P molecules, while NADPH supplies hydrogen ions and electrons.
- In the third step, two G3P molecules leave the cycle to be used for the production of glucose and other organic compounds.
- In the final step of the Calvin cycle, an enzyme called **rubisco** converts the remaining ten G3P molecules into 5-carbon molecules called ribulose 1, 5-bisphosphates (RuBP). These molecules combine with new carbon dioxide molecules to continue the cycle.

Because rubisco converts inorganic carbon dioxide molecules into organic molecules that can be used by the cell, it is considered one of the most important biological enzymes. Plants use the sugars formed during the Calvin cycle both as a source of energy and as building blocks for complex carbohydrates, including cellulose, which provides structural support for plants.

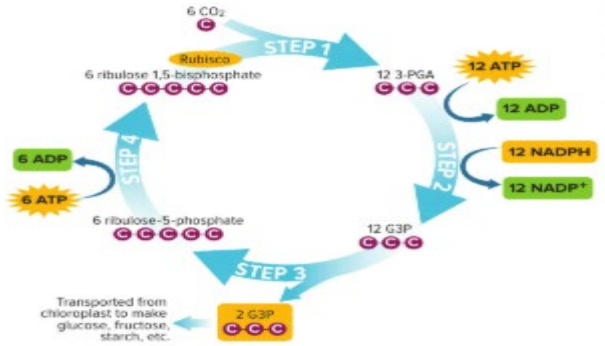


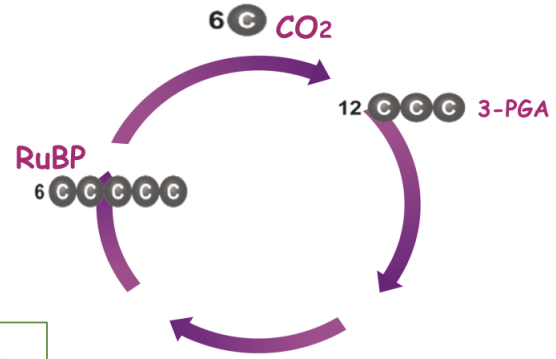
Figure 9 The Calvin cycle joins carbon dioxide with organic molecules inside the stroma of the chloroplast.
Determine *the compound in which energy is stored at the end of the Calvin cycle.*

1 The Calvin Cycle

In the first step of the Calvin cycle, called carbon fixation,

What dose Co2 fixation mean?.

-Carbon fixation or carbon assimilation is the conversion process of inorganic carbon (carbon dioxide) to organic compounds by living organisms.

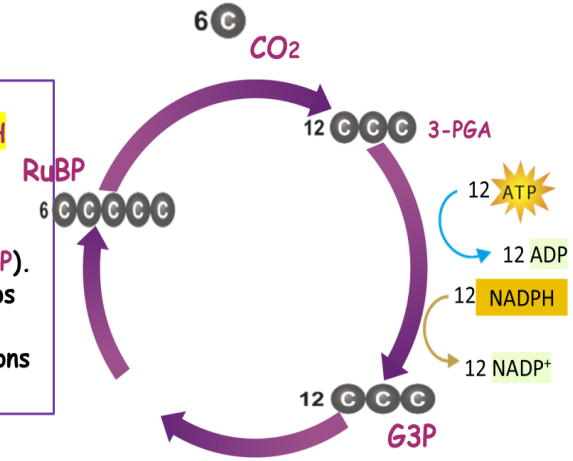


The joining of carbon dioxide with other organic molecules is called carbon fixation.

Carbon fixation,
* six carbon dioxide (CO_2) molecules combine with six 5 carbon compounds (RuBP) to form →→→→ twelve 3-carbon molecules called 3phosphoglycerate (3-PGA).

2 The Calvin Cycle

In the second step, the chemical energy stored in ATP and NADPH is transferred to the 3-PGA molecules to form →→→ high-energy molecules called glyceraldehyde 3-phosphates (G3P). ATP supplies the phosphate groups for forming G3P molecules, while NADPH supplies hydrogen ions and electrons.

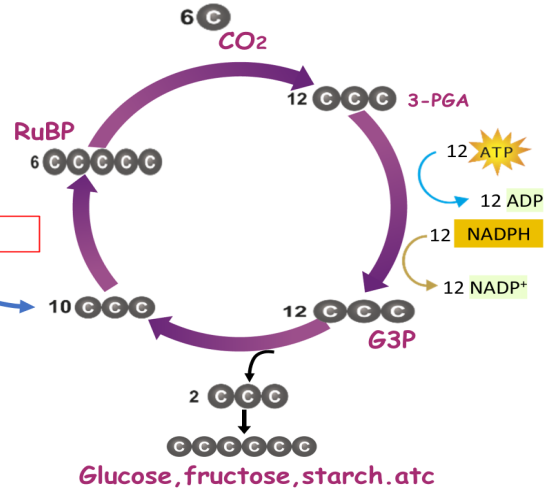


The chemical energy stored in ATP and NADPH is transferred to make a G3P molecule.

3 The Calvin Cycle

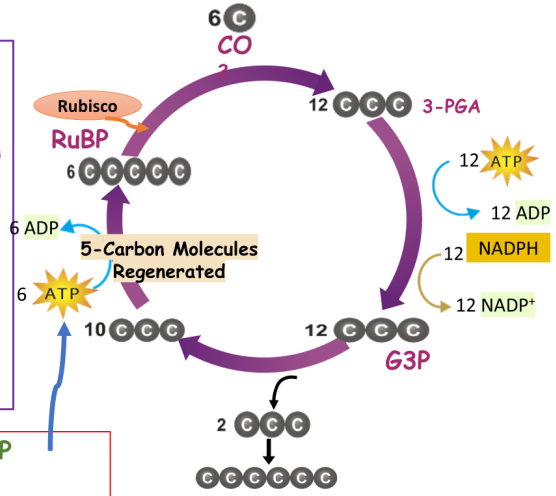
In the third step, two G3P molecules leave the cycle to be used for the production of →→→ glucose and other organic compounds.

How many G3P left?.

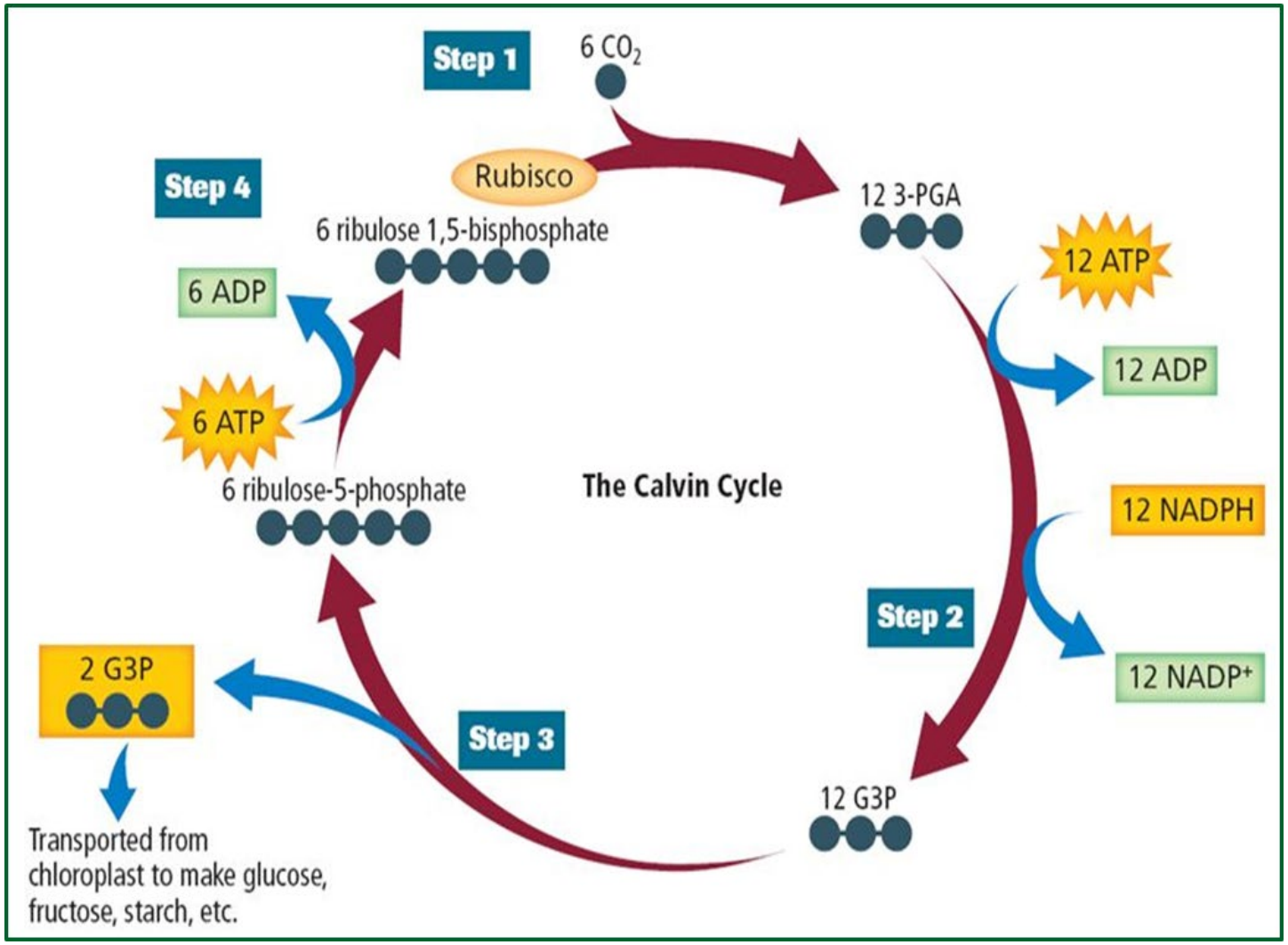


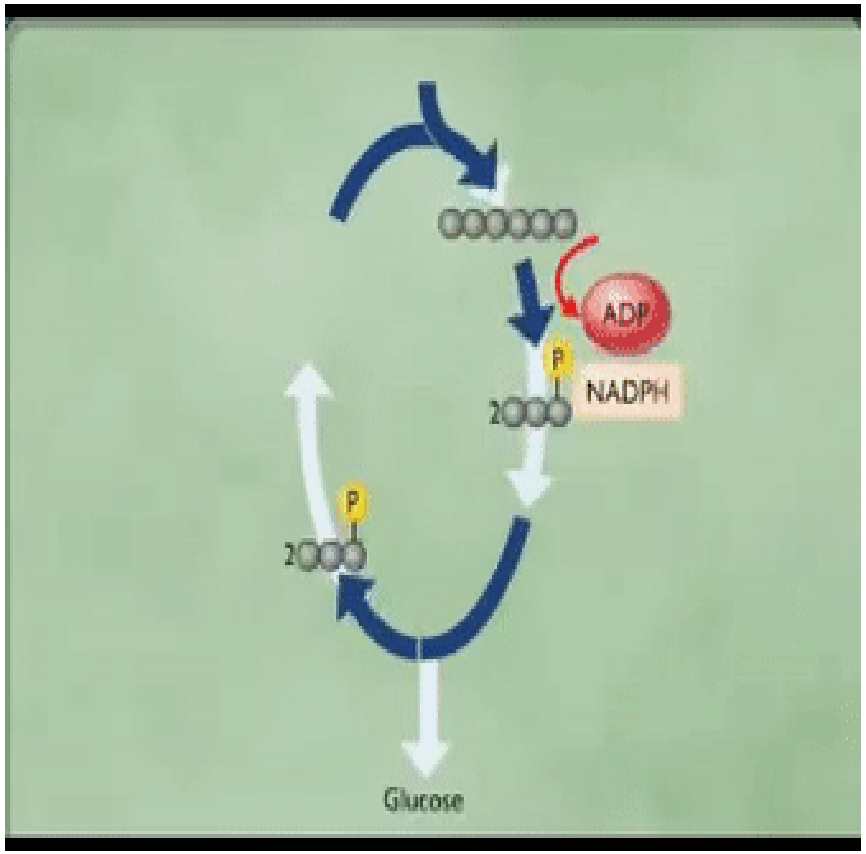
4 The Calvin Cycle

In the final step of the Calvin cycle, an enzyme called rubisco converts the remaining ten G3P molecules into 5-carbon molecules called ribulose 1, 5-bisphosphates (RuBP). These molecules combine with new carbon dioxide molecules to continue the cycle



At converting G3P to RuBP, G3P molecules regenerated,
How many ATP would be consumed?.

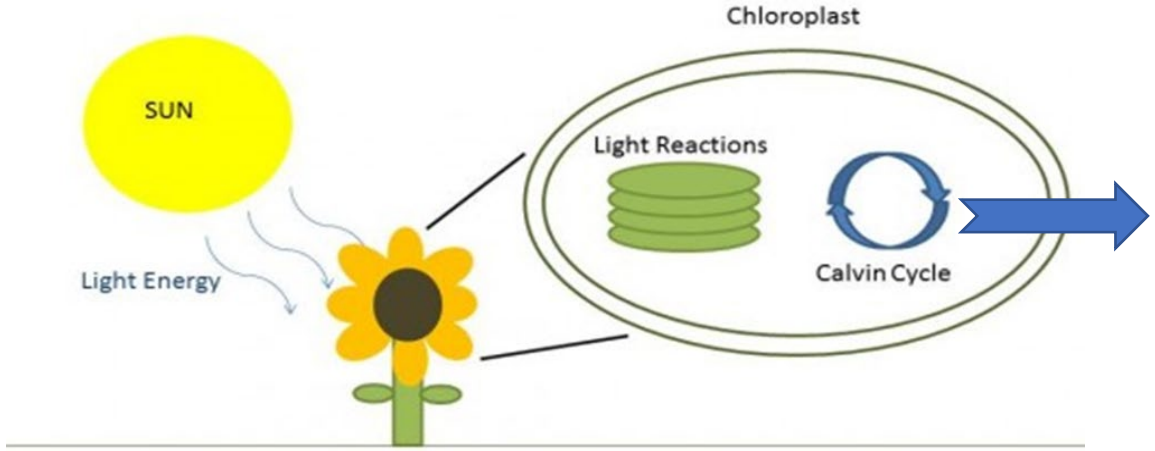




Determine the compound in which energy is stored at the end of the Calvin cycle

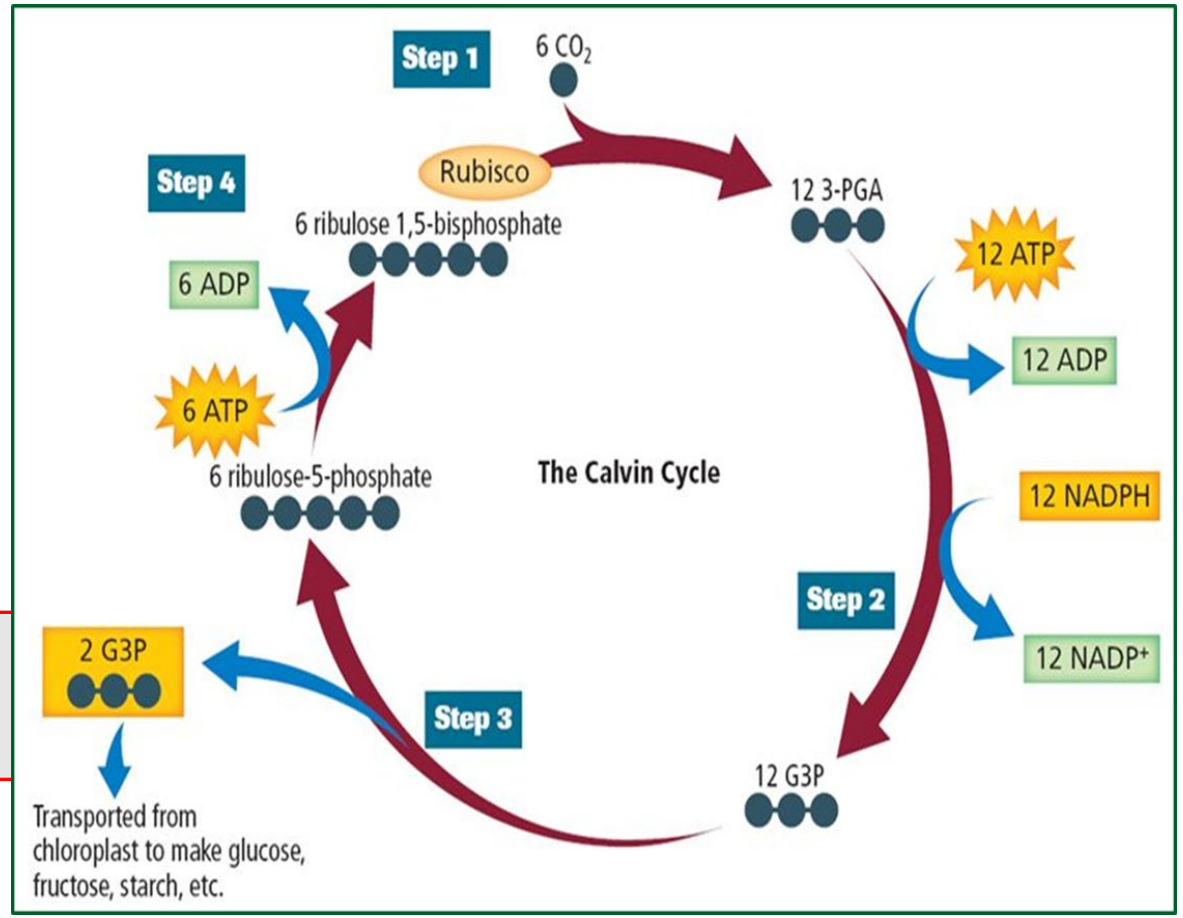
In glucose and other organic molecules (fructose, starch); also accept G3P





Overall Reaction

$6\,CO_2 + 12\,H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$



Explain rubisco is considered one of the most important biological enzymes

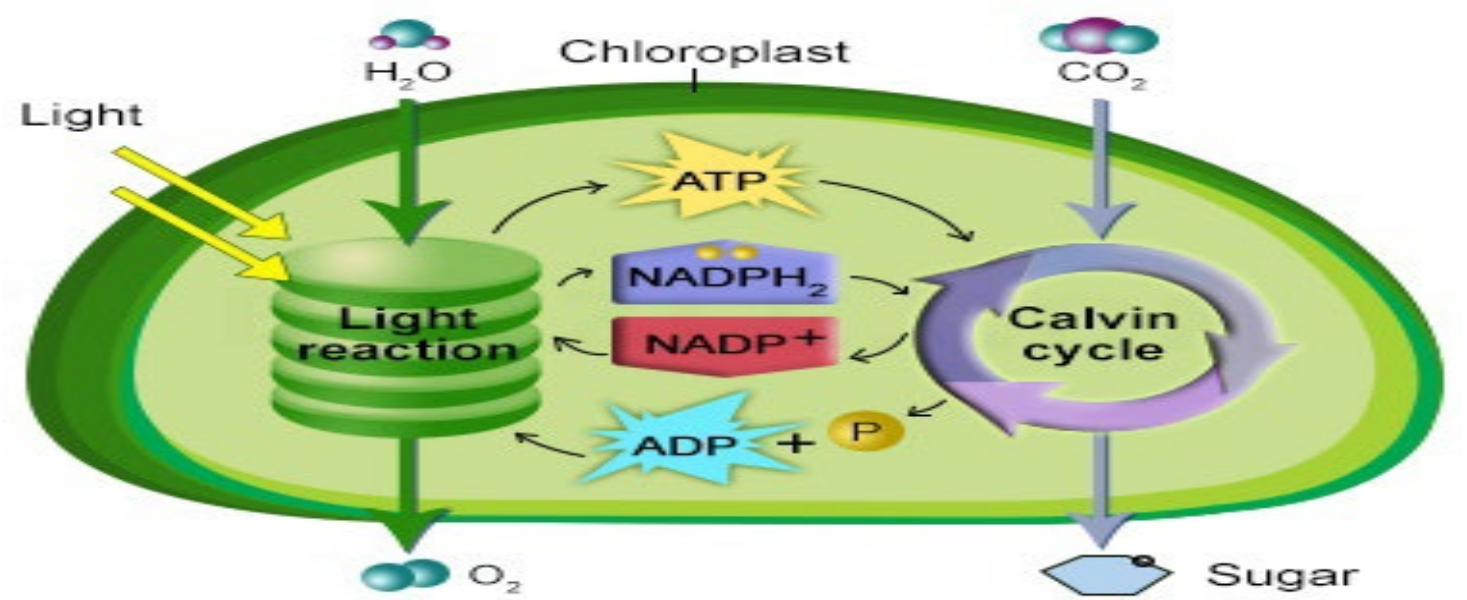
Because rubisco converts inorganic carbon dioxide molecules into organic molecules that can be used by the cell

Plants use the sugars formed during the Calvin cycle both as:

1- a source of energy

2- Building blocks for complex carbohydrates, including cellulose, which provides structural support for plants.

Compare between light reaction & Calvin cycle

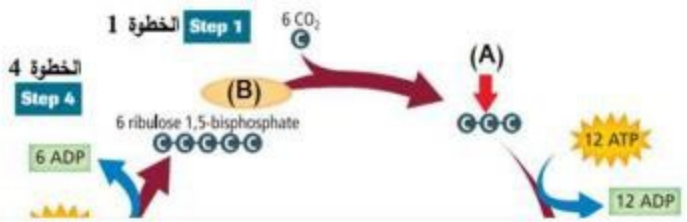




Stages / Differences	Light dependent reactions	Light independent reactions (calvin cycle)
Location	Thylakoid membranes	Stroma
Input Requirements	light / H_2O Chlorophyll (photosystem I, photosystem II) ADP / NADP	CO_2 /ATP / NADPH Rubisco (enzyme)
Out put Products	NADPH / ATP(chemical energy stored) Oxygen (waste product)	Suger (Glucose) ADP+P / NADP+

The figure below shows Calvin's cycle, study it and answer the question: which letter of the following refers to rubisco enzyme?

حلقة كالفن، أدرسة ثم أجب عن ما يلي يشير إلى إنزيم روبيسكو؟



A

B

C

D

Use the equation below to answer the question: Which of the following molecules is the waste product of photosynthesis that is released to the environment?

السؤال: ية البناء

$$6CO_2+6H_2O \rightarrow C_6H_{12}O_6+?$$

Learning Outcomes Covered

- BIO.3.1.02.030

a. Carbon dioxide

b. Oxygen

c. Water

d. Ammonia

Based on the diagram below, that shows the structure of the chloroplast, which of the following refers to a stack of thylakoids?

تركيب البلاستيده الخضراء. الثايلاكويد؟



Learning Outcomes Covered

- BIO.3.1.01.087
- BIO.3.1.02.027

a. 1

b. 2

c. 3

d. 4

1. What is a waste product of photosynthesis that is released into the environment?

$$6CO_2 + 6H_2O \xrightarrow{\text{energy}} C_6H_{12}O_6 + ?$$

- carbon dioxide
- water
- C oxygen CORRECT
- ammonia

5. Which best describes the role of rubisco?

- It collects, stores, and converts light energy from the Sun.
- It produces the electrons that are carried along the electron transport chain.
- C It converts inorganic carbon dioxide into organic molecules that can be used by the cell. CORRECT
- It splits molecules of water, releasing protons.

4. Which supplies energy used to synthesize carbohydrates during the Calvin cycle?

- CO_2 and ATP
- NADPH and H_2O
- B ATP and NADPH CORRECT
- H_2O and O_2

51) Fill in the blanks using the available answer choices.

_____ Glucose _____ **is formed during the light-independent phase of photosynthesis.**

58) Fill in the blanks using the available answer choices.

Inorganic carbon dioxide cannot be converted into organic molecules during photosynthesis without the enzyme _ Rubisco

At the end of the Calvin cycle, where is energy stored?

A. NADPH
B. ATP
C. chloroplast
D. glucose

Which mechanism of photosynthesis uses the movement of hydrogen ions (H^+) across a concentration gradient to synthesize ATP?

A. absorption
B. chemiosmosis
C. electron transport
D. C_2 pathway

How are the C_4 pathway and the CAM pathway an adaptive strategy for some plants?

A. They accelerate photosynthesis.
B. They release more oxygen.
C. They help the plant conserve water.
D. They reduce the requirement for ATP.

At the beginning of photosynthesis, which molecule is split to produce oxygen (O_2) as a waste product?

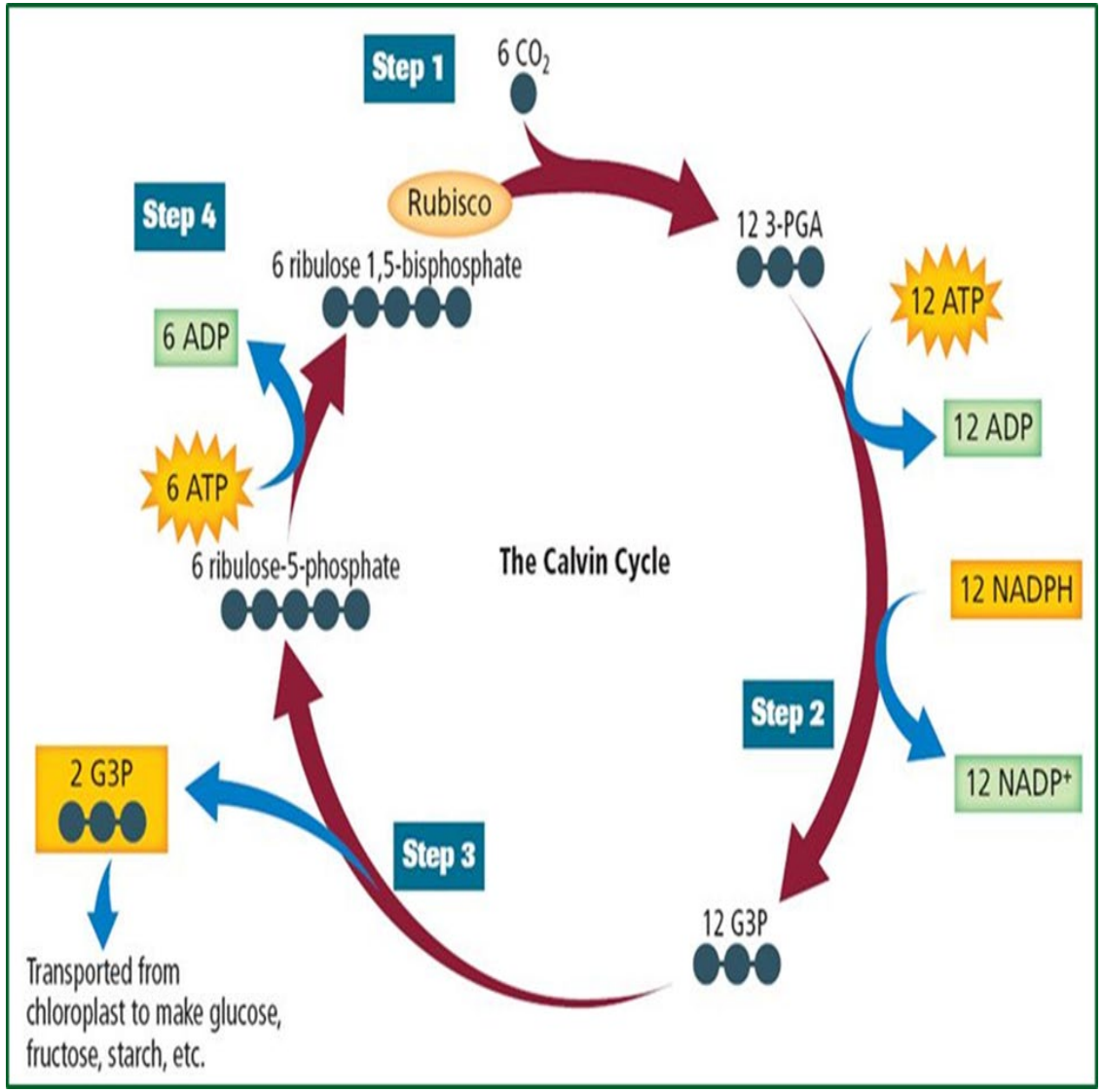
A. CO_2
B. H_2O
C. $C_6H_{12}O_6$
D. 3-PGA

Which molecule helps provide the energy that drives this cycle?

A. 3-PGA
B. CO_2
C. NADPH
D. rubisco

Which product of the Calvin cycle is used for the production of glucose and other organic compounds?

A. ADP
B. CO_2
C. G3P
D. $NADP^+$



Alternative Pathways

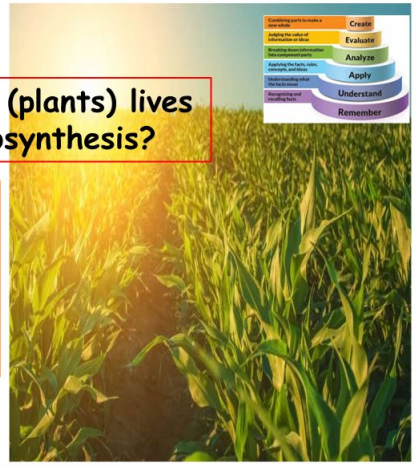
The environment in which an organism lives can impact its ability to carry out photosynthesis. Environments with insufficient water or carbon dioxide can decrease the ability of a photosynthetic organism to convert light energy into chemical energy. For example, plants in hot, dry environments are subject to excessive water loss that can lead to decreased photosynthesis. Many plants in extreme climates have alternative photosynthesis pathways to maximize energy conversion.

C_4 plants One adaptive pathway that helps plants maintain photosynthesis while minimizing water loss is the C_4 pathway. The C_4 pathway occurs in plants such as sugarcane and corn. These plants are called C_4 plants because they fix carbon dioxide into four-carbon compounds instead of three-carbon molecules during the Calvin cycle. C_4 plants also have significant structural modifications in the arrangement of cells in the leaves. In general, C_4 plants keep their stomata (plant cell pores) closed during hot days, while the four-carbon compounds are transferred to special cells where CO_2 enters the Calvin cycle. This allows for sufficient carbon dioxide uptake, while simultaneously minimizing water loss.

CAM plants Another adaptive pathway used by some plants to maximize photosynthetic activity is called crassulacean (KRAH soo lay shun) acid metabolism (CAM photosynthesis). The CAM pathway occurs in water-conserving plants that live in deserts, salt marshes, and other environments where access to water is limited. CAM plants, such as cacti, orchids, and pineapples allow carbon dioxide to enter the leaves only at night, when the atmosphere is cooler and more humid. At night, these plants fix carbon dioxide into organic compounds. During the day, carbon dioxide is released from these compounds and enters the Calvin cycle. This pathway allows for sufficient carbon dioxide uptake while minimizing water loss.

Alternative Pathways

Is the environment in which an organism (plants) lives can impact it's ability to carry out photosynthesis?



Yes, A mount of **water** or CO_2 available is insufficient can **decrease** the ability of a photosynthetic organism to convert light energy into chemical energy.

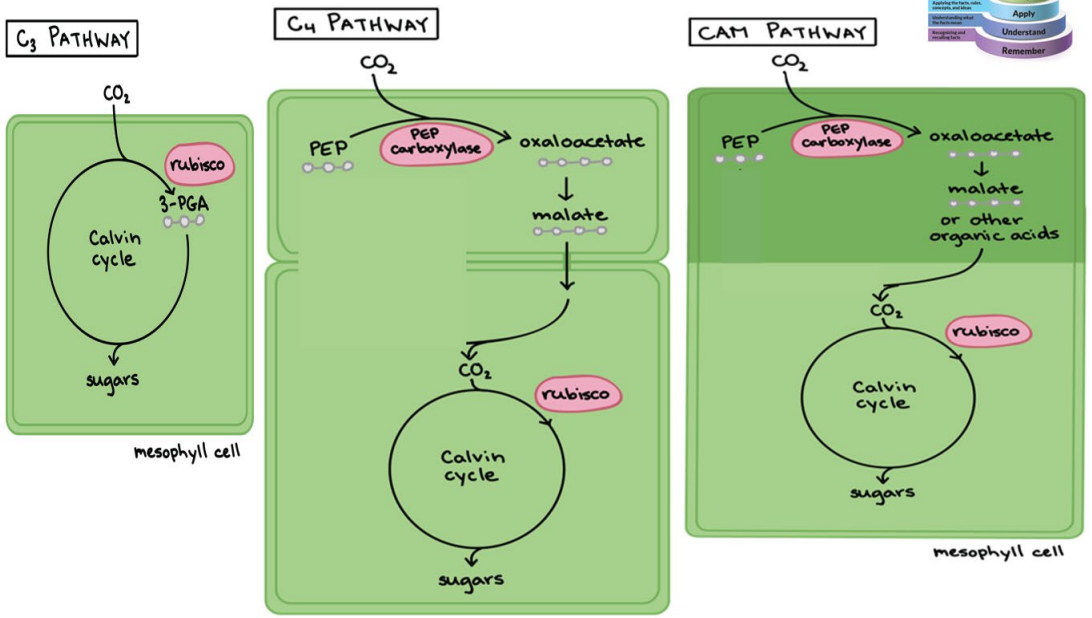
In **hot**, **dry** environments plants have **adapted** to a different way to perform photosynthesis→→→→ **Alternative Pathways**



- C_4 plants
- CAM plants



What is the difference in the photosynthesis pathways?



Adaptive pathway helps plants **maintain photosynthesis** while **minimizing water**

Alternative Pathways

C_4 plants

-Fix carbon dioxide into four carbon C4.
-Have structural modifications in the arrangement of cells in the leaves.
-Are able to make glucose in different cells.
-Keep their **stomata closed** during hot days.
-Ex: Corn and sugarcane.

CAM plants

-Called crassulacean acid metabolism (CAM) pathway .
-Occurs in plants that live in environments where access to water is limited (deserts, salt marshes).
-At night, CO_2 fix into organic compounds, During the day, CO_2 is released from these compounds and enters the Calvin cycle.
-Are able to make glucose at different time of the day.
-Ex: Pineapples,orchids and cacti

Explain why C4 photosynthesis is advantageous in hot, dry conditions?

The four carbon compounds are transferred to special cells where CO2 enters the Calvin cycle.
This allows for sufficient carbon dioxide uptake, while simultaneously minimizing water loss.



Explain why CAM photosynthesis is advantageous in environments where access to water is limited?



At night, CAM plants fix CO_2 into organic compounds.
During the day, CO_2 is released from these compounds and enters the Calvin cycle.
This pathway allows for sufficient carbon dioxide uptake while minimizing water loss.

How do CAM plants differ from both C3 and C4 plants?



CAM plants open their stomata at night, whereas C3 and C4 plants open their stomata during the day.

BIO.3.1.02.028 Use a model to illustrate that aerobic cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	Information from text	42

BIO.3.1.02.028 Use a model to illustrate that aerobic cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	Information from text	43
	Figure 12	43

Glycolysis

Glucose is broken down in the cytoplasm through the process of **glycolysis.** Two molecules of ATP and two molecules of NADH are formed for each molecule of glucose that is broken down. Follow along with **Figure 11** as you read about the steps of glycolysis. First, two phosphate groups, derived from two molecules of ATP, are joined to glucose. Notice that some energy, two ATP, is required to start the reactions that will produce energy for the cell. The 6-carbon molecule is then broken down into two 3-carbon compounds. Next, two phosphates are added and electrons and hydrogen ions (H^+) combine with two NAD^+ molecules to form two NADH molecules. NAD^+ is similar to NADP, an electron carrier used during photosynthesis. Last, the two 3-carbon compounds are converted into two molecules of pyruvate. At the same time, four molecules of ATP are produced.

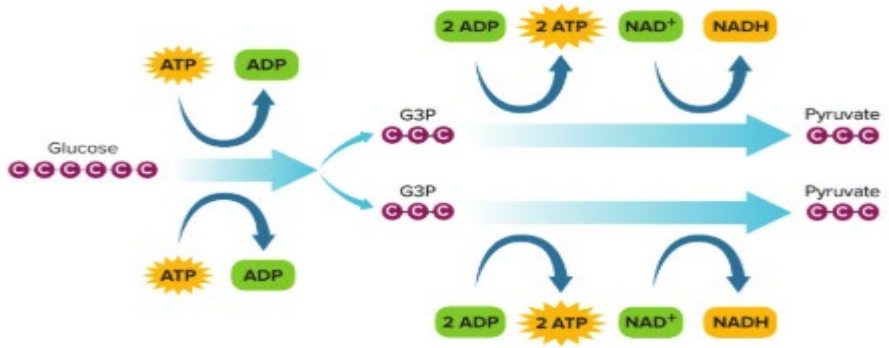


Figure 11 Glucose is broken down during glycolysis inside the cytoplasm of cells.

Krebs Cycle

Glycolysis has a net result of two ATP and two pyruvate molecules. Most of the energy from the glucose is still contained in the pyruvate. In the presence of oxygen, pyruvate is transported into the mitochondrial matrix, where it is eventually converted to carbon dioxide. The series of reactions in which pyruvate is broken down into carbon dioxide is called the **Krebs cycle,** or the tricarboxylic acid (TCA) cycle. This cycle also is referred to as the citric acid cycle.

Preparatory reaction

Prior to the Krebs cycle, the three-carbon pyruvate first reacts with coenzyme A (CoA) to form a two-carbon intermediate called acetyl CoA and carbon dioxide (CO_2). NAD^+ is converted to NADH. Carbon dioxide is given off by the cell. Since there are two molecules of pyruvate for every preparatory reaction, it results in the production of two carbon dioxide molecules and two NADH molecules. Acetyl CoA then moves to the mitochondrial matrix.

Steps of the Krebs cycle

Follow along in **Figure 12** as you continue reading about the steps of the Krebs cycle.

- The Krebs cycle begins with acetyl CoA combining with a 4-carbon compound to form a 6-carbon compound known as citric acid.
- Citric acid is then broken down in the next series of steps, releasing two molecules of carbon dioxide and generating one ATP, three NADH, and one $FADH_2$. FAD is another electron carrier similar to NAD^+ and $NADP^+$.
- Finally, acetyl CoA and citric acid are generated and the cycle continues.

Recall that two molecules of pyruvate are formed during glycolysis, resulting in two "turns" of the Krebs cycle for each glucose molecule. The net yield from the Krebs cycle is six carbon dioxide molecules, two ATP, eight NADH, and two $FADH_2$. Ten NADH and two $FADH_2$ move on to play a significant role in the next stage of aerobic respiration.

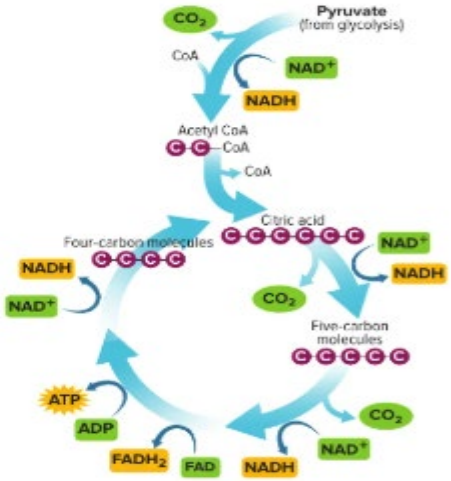


Figure 12 Pyruvate is broken down into carbon dioxide during the Krebs cycle inside the mitochondria of cells.

Trace *Follow the path of carbon molecules that enter and leave the Krebs cycle.*

- Cellular respiration occurs in two main parts.

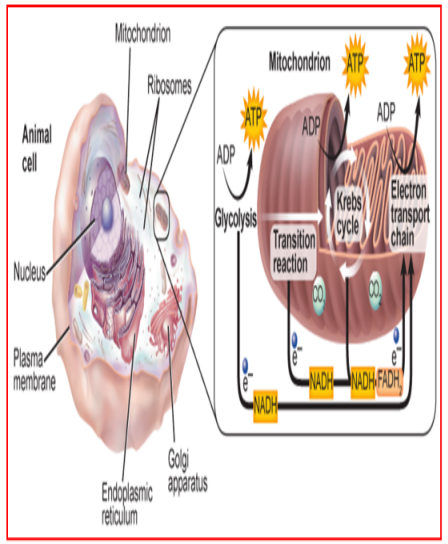
1-Glycolysis
- In the cytoplasm
- Do not require O_2

2-Aerobic respiration
- In mitochondrion
- Require O_2
- Includes 2 steps

Krebs cycle

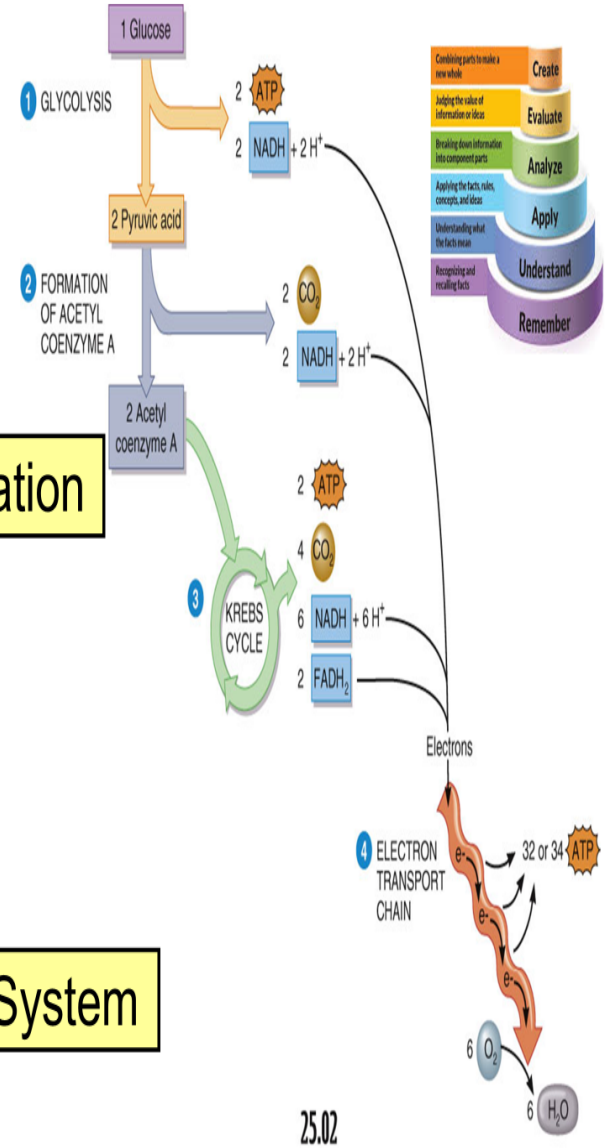
Electron transport chain

One glucose yields
- Eukaryotic 36 ATP
- Prokaryotes 38 ATP



List Steps Involved

1. Glycolysis
2. Acetyl CoA Formation
3. Krebs Cycle
4. Electron Transport System



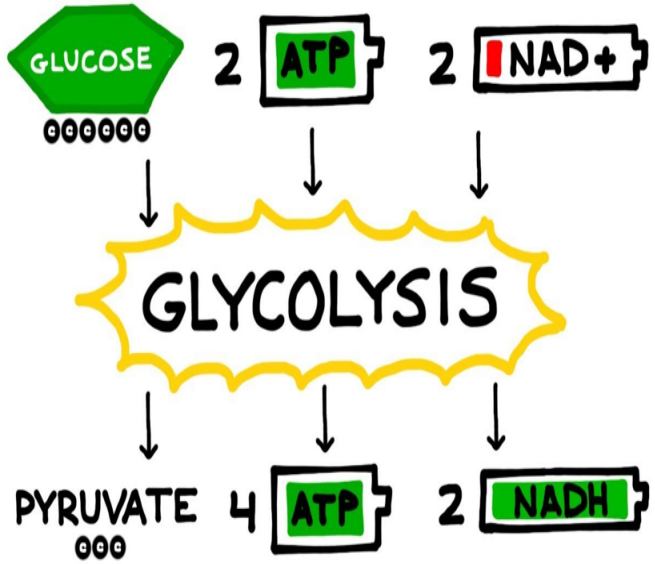
25.02

1 Glycolysis

Process in which one molecule of glucose is broken in half, producing :

- two pyruvic acid
- a small amount of energy in the cytoplasm (2 ATP +2 NADH)

4(produced)−2(used)=2ATP net gain



VOCABULARY

WORD ORIGIN

Glycolysis comes from the Greek words *glykys*, meaning *sweet* and *lysis*, meaning *to rupture or break*

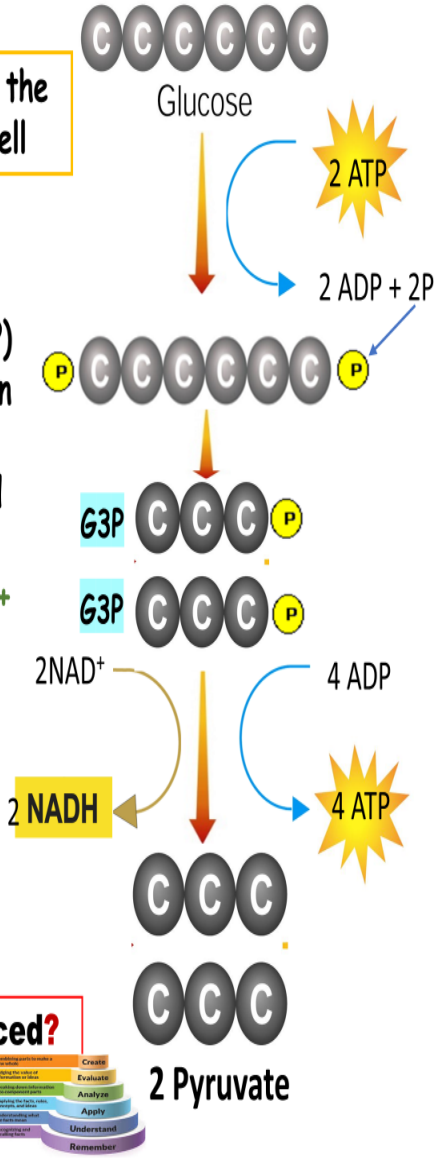
NET GAIN OF HOW MANY ATP MOLECULES?

Glycolysis has a net result of two ATP and two pyruvate.

Glycolysis

Two molecules of ATP are required to start the reactions that will produce energy for the cell

1-Two phosphate groups are joined to glucose.
(the 2 Phosphate are derived from 2ATP)
2-The Glucose is broken into two 3-Carbon compounds G3P.
3-For each G3P: two Phosphate are added to form 2ATP, also electrons (e) and hydrogen ions (H+) combine with two NAD+ molecules to form NADH molecules
*NAD+ is an electron carrier that is similar to NADP (an electron carrier used during photosynthesis)
4-The two 3-Carbon compounds are converted into two molecules of pyruvate.



At this time HOW MANY ATP MOLECULES are produced?

4 molecules of ATP are produced

Glycolysis



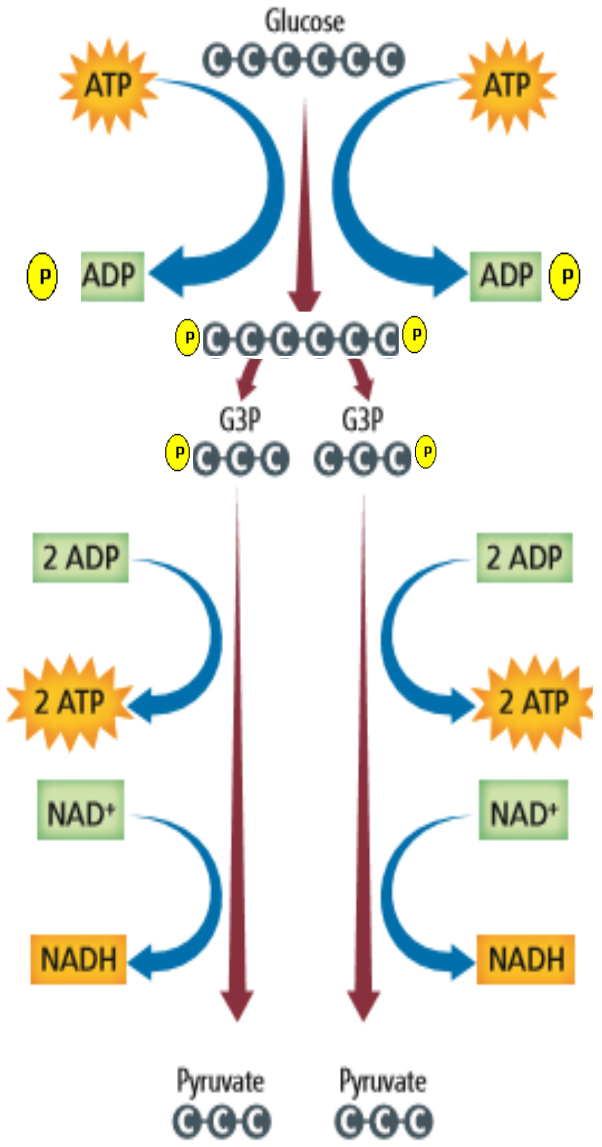
Summarize *the reactants and products of glycolysis.*

-The reactants are:
one molecule of glucose, two ATP, two NAD+, and four ADP.
-The products are:
two ADP, two NADH, four ATP, and two pyruvates.

Reading Check **Explain** why there is a net yield of two, not four, ATP molecules in glycolysis.

Glycolysis begins with the input of two molecules of ATP.

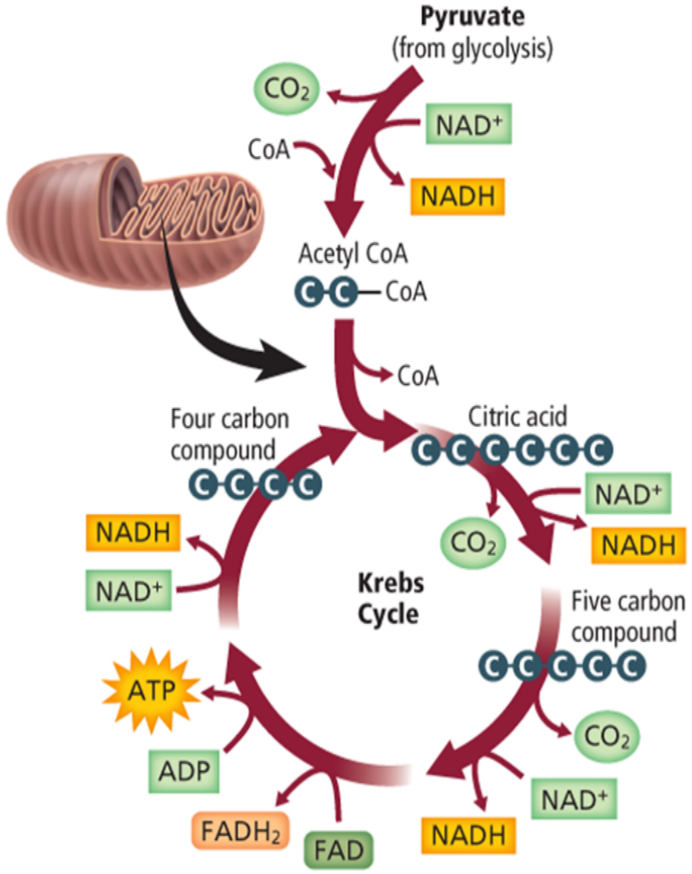
Figure 12 Glucose is broken down during glycolysis inside the cytoplasm of cells.



Steps of Krebs Cycle

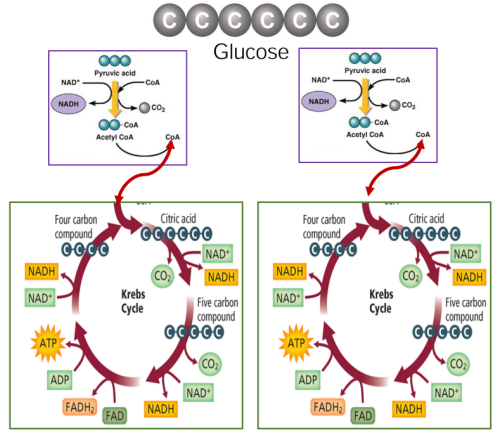
1-Acetyl CoA combining with a 4-Carbon compound to form a 6 -Carbon compound known as citric acid

- Citric acid is then broken down in the next series of steps, releasing 2 molecules of CO2 and generating 1ATP, 3NADH, and 1FADH2.
- FAD is another electron carrier similar to NAD+ and NADP+
- Acetyl CoA and citric acid are generated and the cycle continues.



Krebs Cycle

- Two molecules of pyruvate are formed during glycolysis.
- This means that there are two "turns" of the Krebs Cycle for each glucose molecule.



- The net yield from the Krebs cycle is=
  - -6 CO2 molecules
  - -2 ATP
  - -8 NADH
  - -2 FADH2.

BIO.3.4.01.028 Describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems, and explain how human activities can disrupt the balance achieved by these processes	Information from text	46
	"Demonstrate Undertanding: Question 4"	46
BIO.3.1.02.029 Investigate factors that affect the processes of fermentation or cellular respiration in living organisms.	Information from text	45
BIO.3.1.02.028 Use a model to illustrate that aerobic cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	Information from text	44
	Figure 13	44
BIO.3.4.01.028 Describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems, and explain how human activities can disrupt the balance achieved by these processes	Figure 15	46

BIO.3.1.02.029 Investigate factors that affect the processes of fermentation or cellular respiration in living organisms.	Information from text	44, 45
	Explain Your Thinking Question 5	46
BIO.3.1.02.029 Investigate factors that affect the processes of fermentation or cellular respiration in living organisms.	Figure 14 + Question below it	45
BIO.3.1.02.029 Investigate factors that affect the processes of fermentation or cellular respiration in living organisms.	Information from text	45

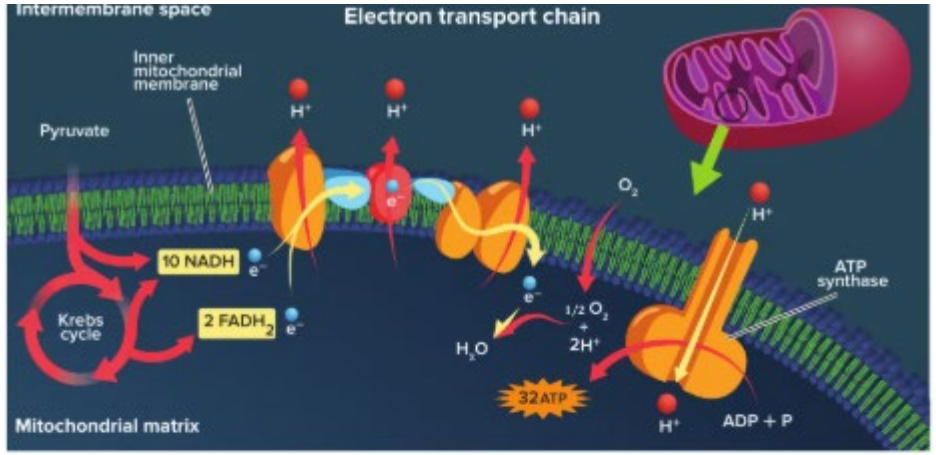


Figure 13 Electron transport occurs along the mitochondrial membrane.

Compare and contrast *electron transport in cellular respiration and photosynthesis.*

As shown in **Figure 13**, electrons move along the mitochondrial membrane from one protein to another.

- The start of the electron transport chain begins with the ten NADH molecules and the two $FADH_2$ molecules releasing electrons. The released electrons move along the mitochondrial membrane from one protein to another. The energy carriers are converted to NAD^+ and FAD, and H^+ ions are released into the mitochondrial matrix.
- The H^+ ions are pumped into the intermembrane space through the proteins in the inner mitochondrial membrane. This creates an increase in the concentration of H^+ ions in the intermembrane space.
- As a result of high concentration in the intermembrane space and a low concentration in the mitochondrial matrix, the H^+ ions diffuse down their concentration gradient back across the inner mitochondrial membrane and into the mitochondrial matrix through ATP synthase proteins in chemiosmosis. As the H^+ ions move through the ATP synthase, ADP is converted into ATP in the mitochondrial matrix.
- Oxygen is the final electron acceptor in the electron transport system in cellular respiration. The H^+ ions and electrons are transferred to oxygen to form water.

Overall, electron transport produces 32 ATP. Each NADH molecule produces three ATP and each group of three $FADH_2$ produces two ATP. In eukaryotes, one molecule of glucose yields 36 ATP under ideal conditions.

Prokaryotic cellular respiration Some prokaryotes also undergo aerobic respiration. Because prokaryotes do not have mitochondria, there are differences in the process. The main difference involves the use of the prokaryotic cellular membrane as the location of electron transport. In eukaryotic cells, pyruvate is transported to the mitochondria. In prokaryotes, this movement is unnecessary, saving the prokaryotic

Anaerobic Respiration

Some cells can function for a short time when oxygen is low. Some prokaryotes are anaerobic organisms—they live without oxygen. In some cases these cells continue to produce ATP through glycolysis. However, there are problems with solely relying on glycolysis for energy. Glycolysis provides only two net ATP for each molecule of glucose, and a cell has a limited amount of NAD^+. Glycolysis stops when NAD^+ is used up. The anaerobic pathway that follows glycolysis is anaerobic respiration, or fermentation.

Fermentation occurs in the cytoplasm and regenerates the cell's supply of NAD^+ while producing a small amount of ATP. There are two types of fermentation.

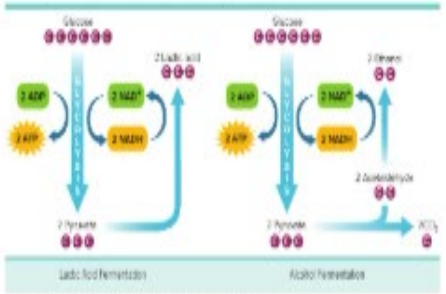


Figure 14 When oxygen is absent or in short supply, fermentation occurs.

Identify the reactants and products of lactic acid fermentation and alcohol fermentation.

HEALTH Connection Lactic acid fermentation In lactic acid fermentation, enzymes convert the pyruvate made during glycolysis to lactic acid, as shown in **Figure 14**. This involves the transfer of high-energy electrons and protons from NADH. Skeletal muscles produce lactic acid when the body cannot supply enough oxygen, such as during periods of strenuous exercise. When lactic acid concentration in muscle cells increases, muscles become fatigued and sore.

Alcohol fermentation Alcohol fermentation occurs in yeast and some bacteria. **Figure 14** shows the chemical reaction that occurs during alcohol fermentation when pyruvate is converted to ethyl alcohol and carbon dioxide. Similar to lactic acid fermentation, NADH donates electrons during this reaction and NAD^+ is regenerated.

SCIENCE USAGE v. COMMON USAGE

concentration

Science usage: the relative amount of a substance dissolved in another substance

The concentration of hydrogen ions is greater on one side of the membrane than on the other.

Common usage: the directing of one's understanding or attention

The student's concentration was focused on the exam.

Photosynthesis and Cellular Respiration

Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. **Figure 15** shows the interrelated, cyclical nature of photosynthesis and cellular respiration. The products of photosynthesis are oxygen and glucose, the reactants needed for cellular respiration. The products of cellular respiration, which are carbon dioxide and water, are the reactants for photosynthesis.

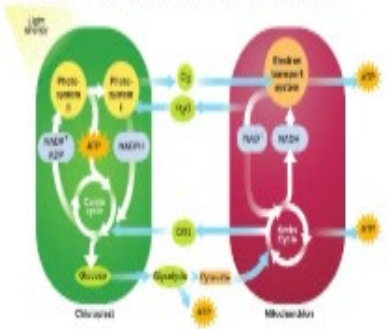


Figure 15 Photosynthesis and cellular respiration form a cycle.

Check Your Progress

Summary

- Many living organisms use cellular respiration to break down glucose.
- The stages of cellular respiration are glycolysis, the Krebs cycle, and electron transport.
- NADH and $FADH_2$ are important electron carriers for cellular respiration.
- In the absence of oxygen, cells can sustain glycolysis by fermentation.

Demonstrate Understanding

1. **Summarize** the stages of cellular respiration and explain its relationship to body temperature.
2. **Identify** how many carbons from one glucose molecule enter one round of the Krebs cycle.
3. **Explain** how high-energy electrons are used in electron transport.
4. **Explain** how energy drives the cycling of matter in photosynthesis and cellular respiration.

Explain Your Thinking

5. **MATH Connection** How many ATP, NADH, and $FADH_2$ are produced in each step of cellular respiration? How is the number of ATP produced different from the net ATP available?
6. **Compare and contrast** the two types of fermentation.

LEARNSMART Go online to follow your personalized learning path to review, practice, and reinforce your understanding.

4 Electron Transport Chain

1

- The final step in the breakdown of glucose.
- Point where most ATP is produced.
- Electrons and hydrogen ions from NADH and FADH2 produced in Acetyl CoA Formation and Krebs Cycle are used to convert ADP to ATP.

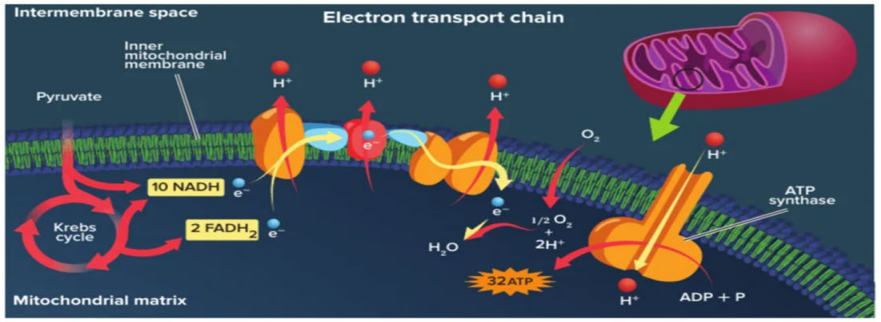


Figure 13 Electron transport occurs along the mitochondrial membrane.
Compare and contrast *electron transport in cellular respiration and photosynthesis.*

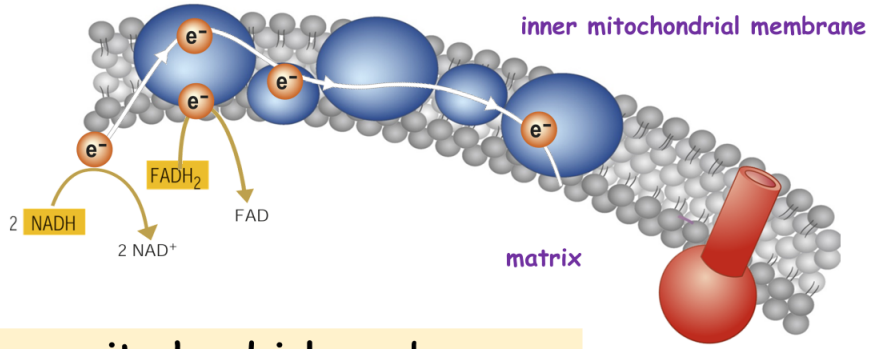
- **Occurs along the mitochondrial membrane.**

Electron Transport Chain

2

Uses high-energy electrons from the Krebs Cycle to convert ADP into ATP

*NADH and FADH2 transfer their electrons to protein (the beginning of the transport chain).
*In this process, they turn back into NAD+ and FAD.

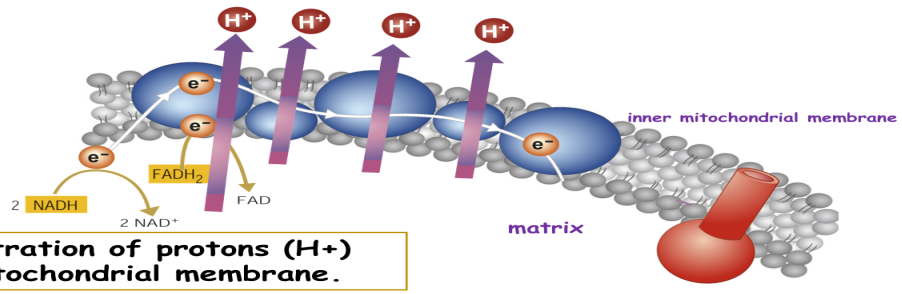


- **Electrons move along mitochondrial membrane from one protein to another.**

Electron Transport Chain

3

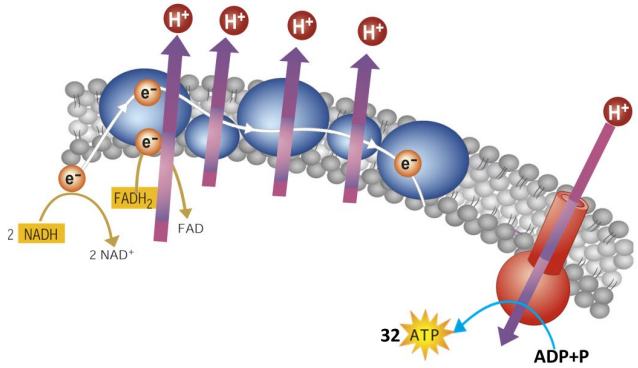
*As electrons are move they release energy. Some of the energy is used to pump H+ out of the matrix and into the inner membrane space. This pumping establishes an electrochemical gradient.



- Describe the concentration of protons (H+) on both sides of mitochondrial membrane.

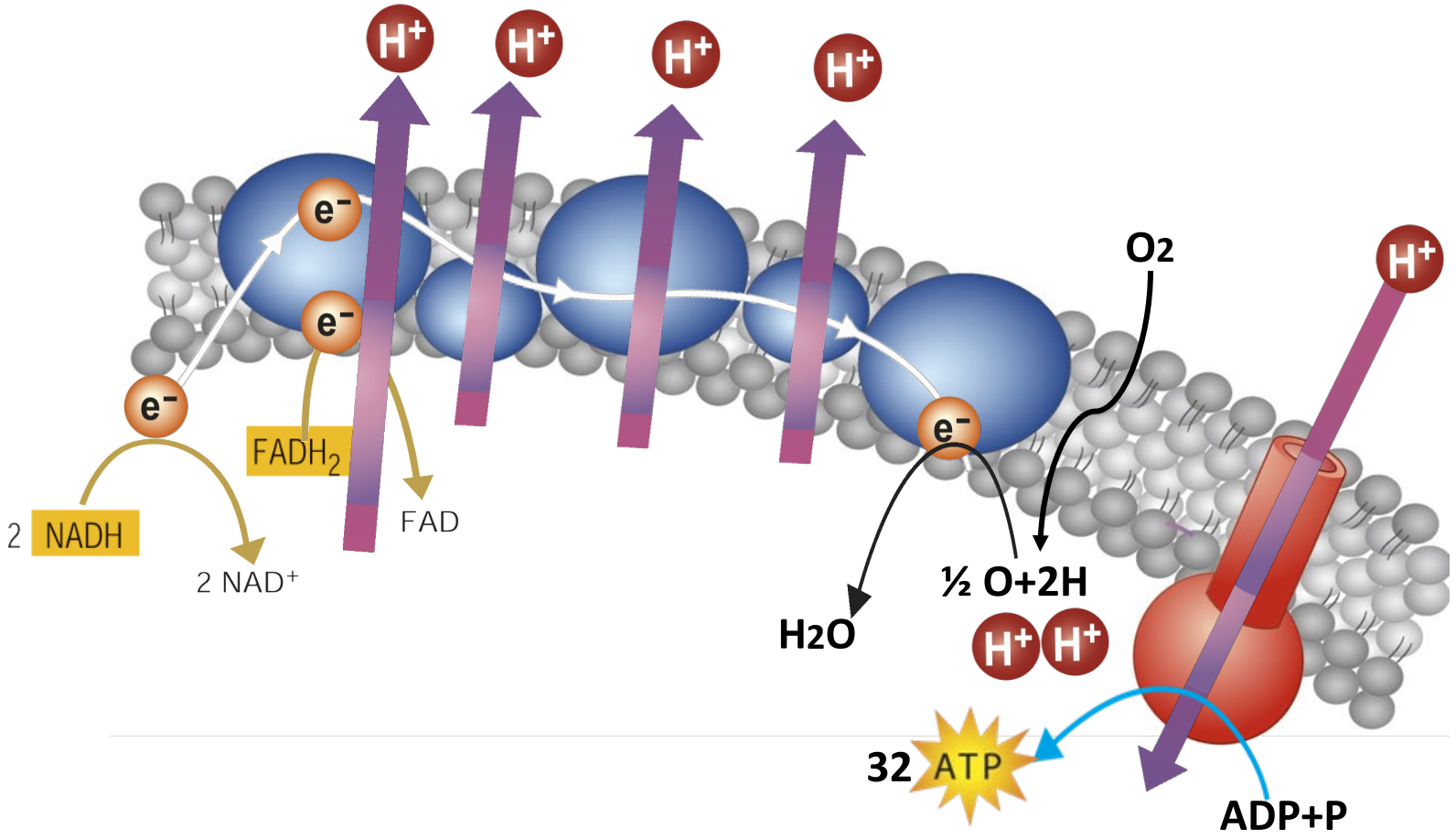
4

- Those H+ ions then diffuse through ATP synthase into the mitochondrial matrix.
- This process converts ADP to ATP in a process called chemiosmosis



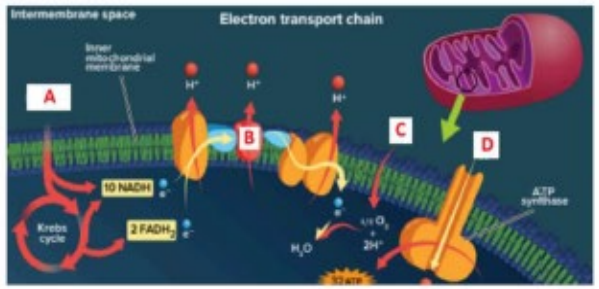
Splitting of oxygen to form water.

- Protons and electrons are transferred to O_2 to form H_2O.
- Oxygen is the final electron acceptor.



The figure below shows the electron transport chain in eukaryotic cell.

Which letter of the following refers to the final electron acceptor?



Learning Outcomes Covered

- BIO.3.1.02.028

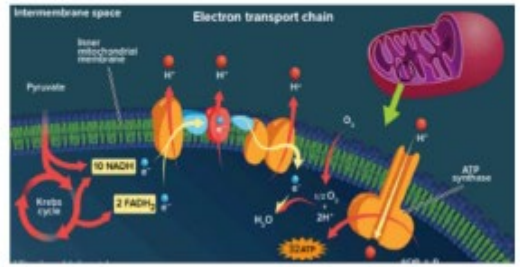
a. A

b. B

c. C

d. D

The figure below shows the electron transport chain in eukaryotic cell. Which of the following steps does not occur in prokaryotic cells?



Learning Outcomes Covered

- BIO.3.1.02.028

a. Krebs cycle

b. H^+ ions pumping

c. Water formation

d. Pyruvate transportation

- **How many** ATP, NADPH, and $FADH_2$ are produced in each glucose molecules?.

Cellular respiration

Learning outcomes :

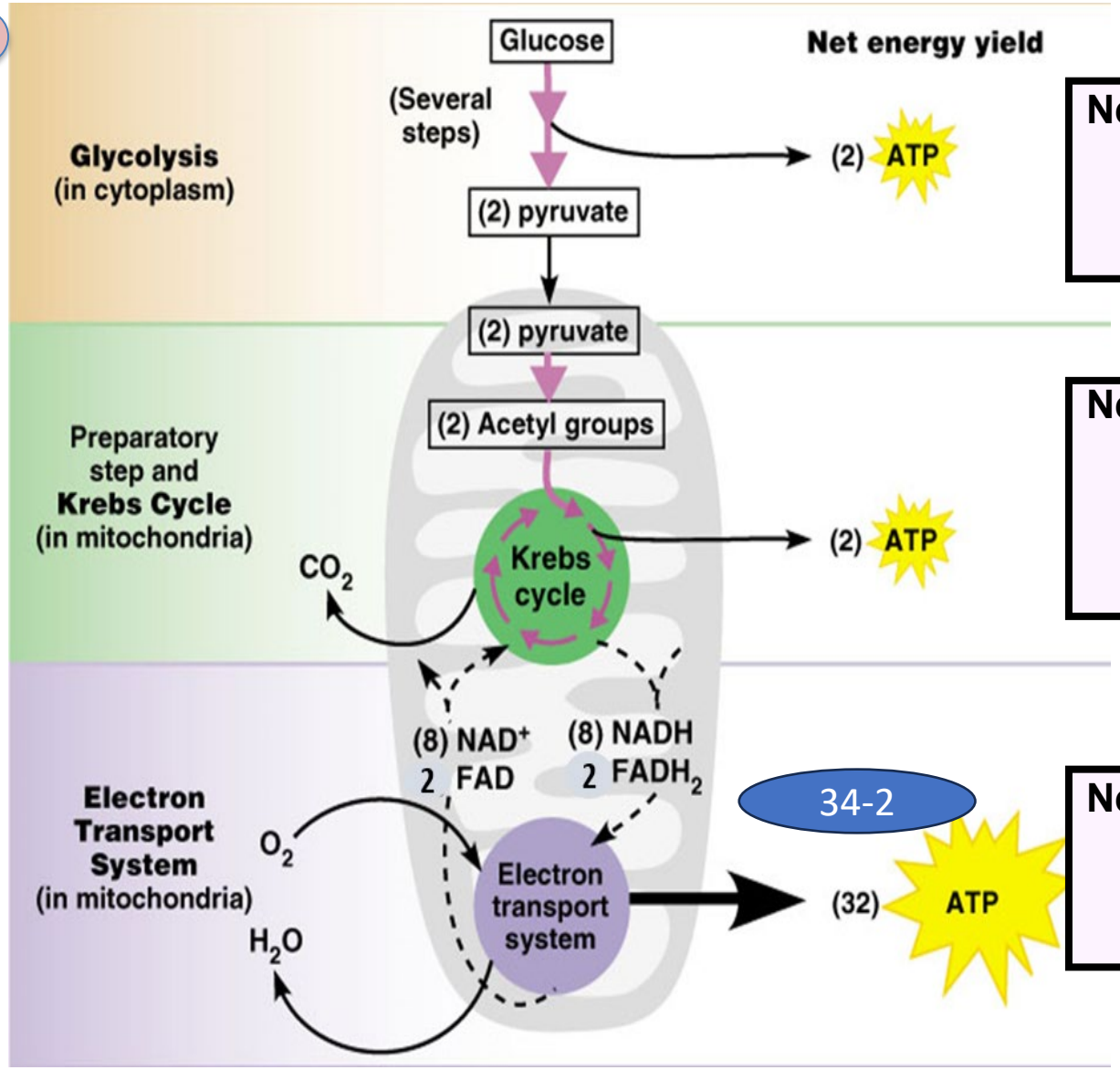
Explain the stages of cellular respiration and ATP production.

Success criteria

. State the cellular respiration equation (reactants/products) .Identify stages, locations, and ATP yield.

Key Vocabs

Glycolysis-Pyruvate-Krebs Cycle-Acetyl CoA-NADH-$FADH_2$-Electron Transport Chain-Chemiosmosis

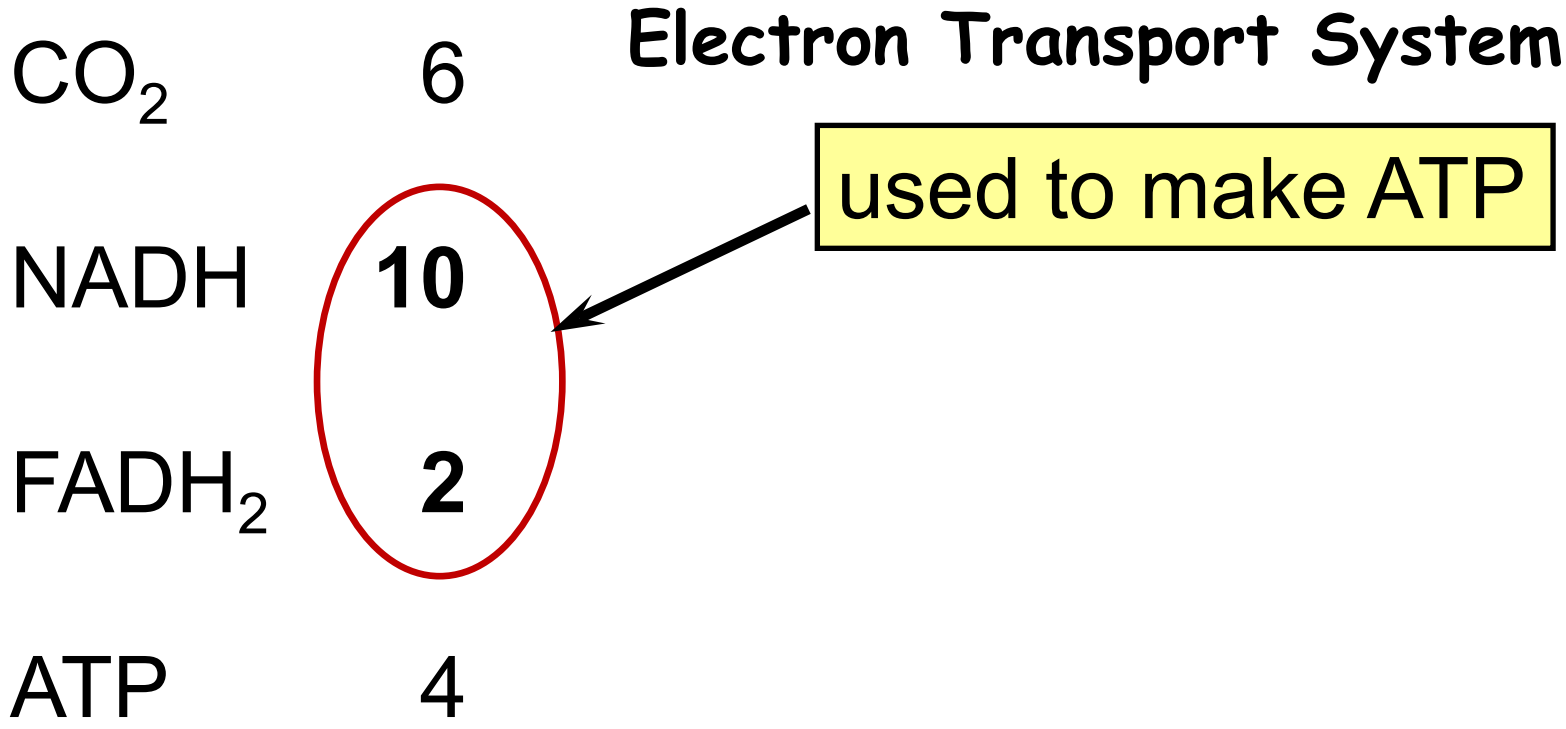


Net:
- •2 ATP
- •2 NADH
- •2 Pyruvate molecules

Net:
- •6 CO2
- •2 ATP
- •8 NADH
- •2 FADH2

Net:
- •Each NADH =3ATP
- •Each FADH= 2ATP
- •O2 +H2O

Each Glucose Molecule



Each Glucose Molecule

CO_2	6
NADH	10
$FADH_2$	2
ATP	4

Electron Transport System

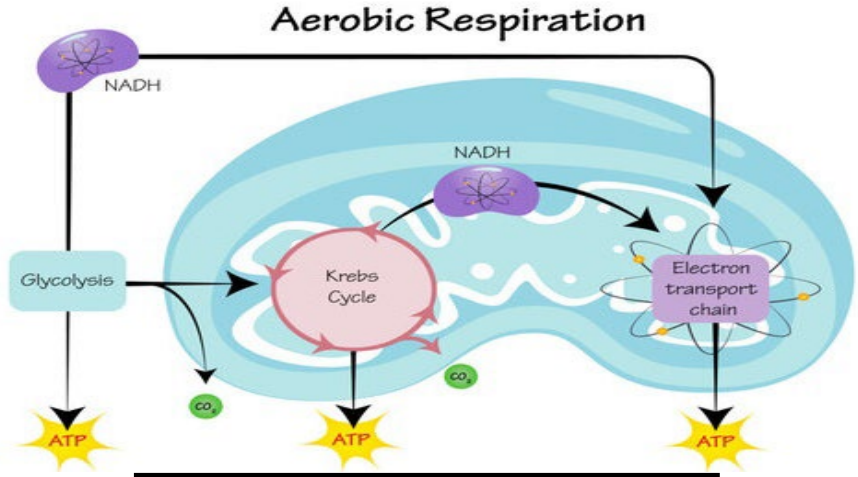
used to make ATP

Overall ATP Production

Electron Transport System	34
Citric Acid Cycle	2
Glycolysis	2
SUBTOTAL	38

When Pyruvate transport into Mitochondrion use NADH -2ATP

TOTAL	36



Glycolysis
Net:
- 2 ATP
- 2 NADH
- 2 Pyruvate molecules

Krebs Cycle
Net:
- 6 CO2
- 2 ATP
- 8 NADH
- 2 FADH2

Electron Transport
Net:
- Each NADH =3ATP
- Each FADH= 2ATP
- O2 +H2O

Overall ATP Production

Electron Transport System	34
Citric Acid Cycle	2
Glycolysis	2
SUBTOTAL	38
When Pyruvate transport into Mitochondrion use NADH	-2ATP
TOTAL	36

At the end of the glycolysis process, which molecule stores most of the energy of glucose?

Learning Outcomes Covered

- BIO.3.1.02.028

a. Pyruvate

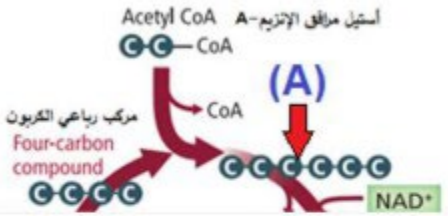
b. Acetyl CoA

c. Carbon compound G3P

d. NAD+ an electron carrier

The figure below shows the Krebs cycle. Study it and answer the question: which of the following does the letter (A) indicate?

عن السؤال:



Learning Outcomes Covered

- BIO.3.1.01.089
- BIO.3.1.02.028

a. Citric acid

b. Pyruvate

c. Lactic acid

d. Acetaldehyde

45) Under ideal conditions, how many ATP molecules are created from cellular respiration in eukaryotic cells?

- 32
- 34
- 36
- 38

Which of the following occurs during the Krebs cycle?

Learning Outcomes Covered

- BIO.3.1.02.028

a. Breaking down pyruvate

b. Capturing light energy

c. Creating glucose molecules

d. Producing ethyl alcohol

35) Why is glycolysis an anaerobic process?

- Glycolysis produces carbon dioxide in its steps.
- Glycolysis does not produce carbon dioxide in its steps.
- Glycolysis utilizes oxygen in its steps.
- Glycolysis does not utilize oxygen in its steps.

37) Why is there a net yield of two, not four, ATP molecules in glycolysis?

- 2 molecules of ATP are used to begin glycolysis.
- 2 molecules of ATP are produced from ATP synthase.
- 2 molecules of ATP are produced during glycolysis.
- 2 molecules of ATP are used to complete glycolysis.

38) Select the products of the preparatory reaction and the Krebs cycle after two turns. Select all that apply.

- ☐ 8 NADH
- ☐ 6 CO_2
- ☐ 4 NADH
- ☐ 1 ATP
- ☐ 2 $FADH_2$
- ☐ 1 $FADH_2$
- ☐ 3 CO_2
- ☐ 2 ATP

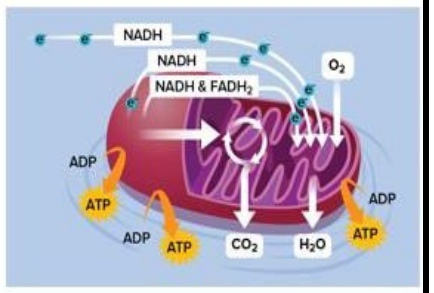
39) What is the importance of NADH and $FADH_2$?

- These molecules are useless by-products.
- These molecules are recycled for use in glycolysis.
- These molecules are used in the electron transport chain.
- These molecules are used as products in photosynthesis.

75) What is the series of reactions in which pyruvate is broken down into carbon dioxide called?

- Krebs cycle
- Calvin cycle
- fermentation
- glycolysis

1. Which organelle is illustrated in the figure?



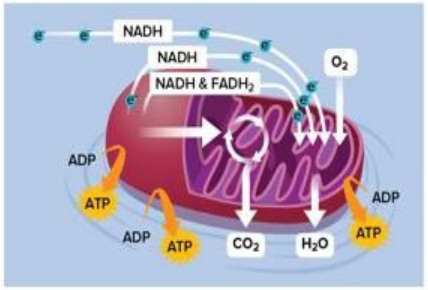
~~Golgi apparatus~~

B mitochondrion CORRECT

~~nucleus~~

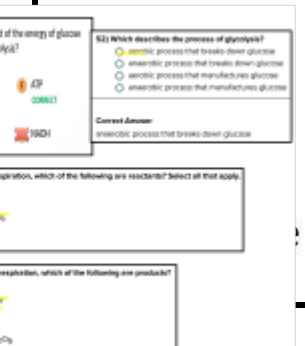
~~endoplasmic reticulum~~

2. Which process does not occur in the organelle illustrated above?



~~conversion of pyruvate to acetyl CoA~~

~~electron transport~~



5. In which molecule is most of the energy of glucose stored at the end of glycolysis?

~~pyruvate~~

C ATP CORRECT

~~acetyl CoA~~

~~NADH~~

52) Which describes the process of glycolysis?

- aerobic process that breaks down glucose
- anaerobic process that breaks down glucose
- aerobic process that manufactures glucose
- anaerobic process that manufactures glucose

Correct Answer

anaerobic process that breaks down glucose

33) In cellular respiration, which of the following are reactants? Select all that apply.

- ☐ O_2
- ☐ CO_2
- ☐ $C_6H_{12}O_6$
- ☐ H_2O
- ☐ energy

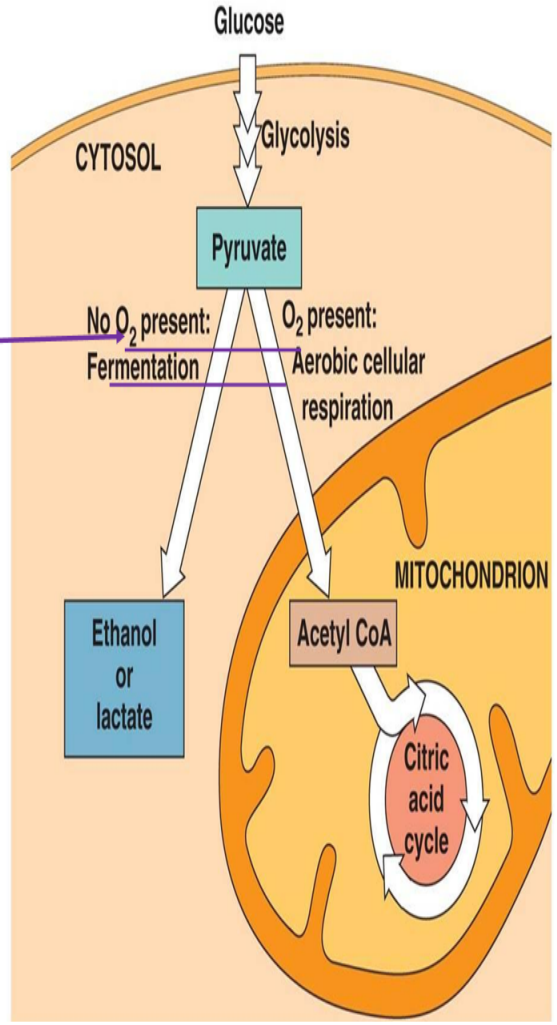
34) In cellular respiration, which of the following are products?

- ☐ O_2
- ☐ energy
- ☐ H_2O
- ☐ CO_2
- ☐ $C_6H_{12}O_6$

Anaerobic Respiration =Fermentation

- The anaerobic pathway that follows glycolysis

Releases energy from food (glucose) by producing ATP in the absence of oxygen



2-Occurs when O_2 **is absent**

3-Regenerates the cell's supply of NAD+

1-Occurs in cytoplasm

4-Produce a small amount of ATP

Fermentation

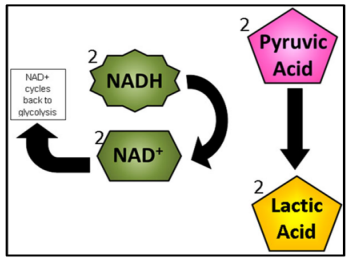
Anaerobic Respiration =Fermentation

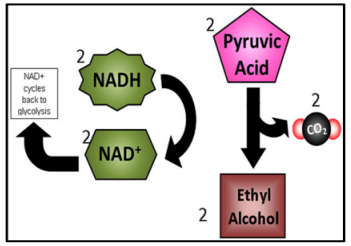
WHY IS THIS IMPORTANT TO CELLS?



-Cell can function for a short time when O_2 levels are low.
-Some prokaryotes are anaerobic organisms (grow and reproduce without O_2)

cell can't rely on glycolysis for a long time, because it stop when all NAD+ is used up if there is not a process to replenish.

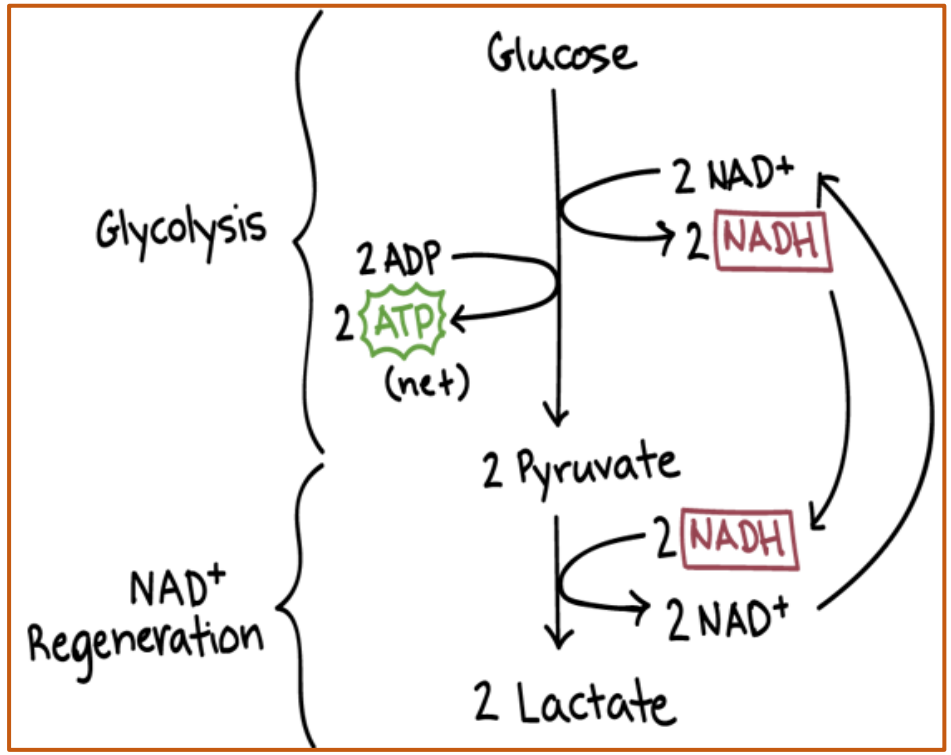




Two main types of Fermentation

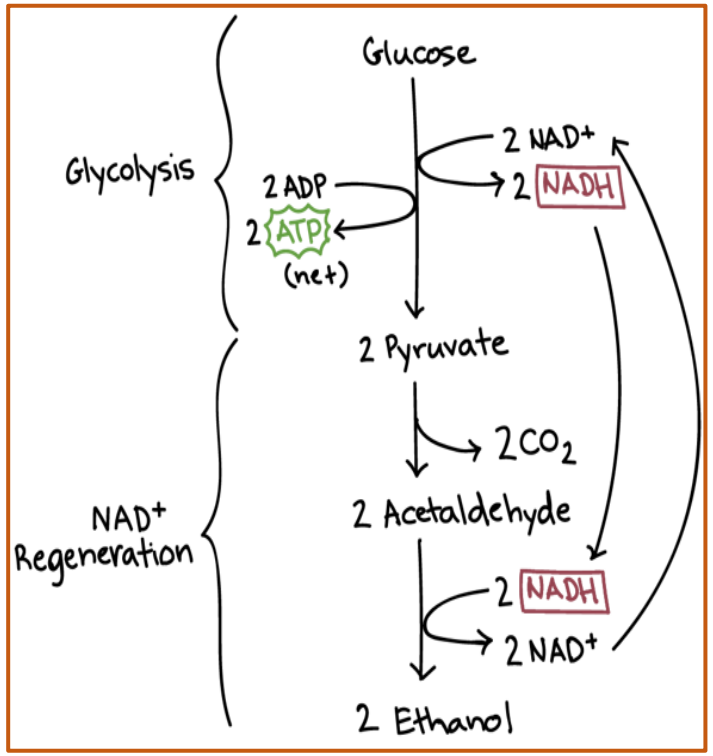
Lactic acid fermentation

enzymes convert the pyruvate in glycolysis to lactic acid



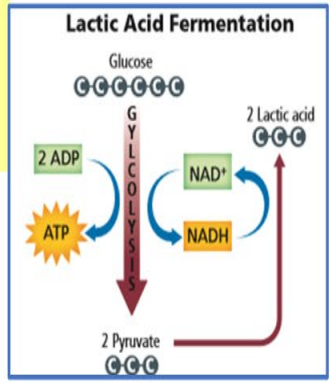
Alcohol fermentation

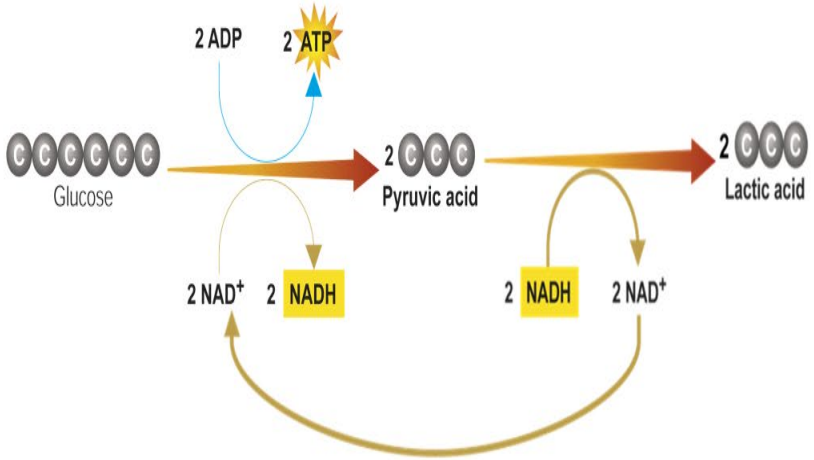
pyruvate is converted to ethyl alcohol and carbon dioxide



Lactic acid fermentation

Conversion of pyruvic acid into lactic acid . Transfer high energy electrons and H+ from NADH (as well as NAD+)





Ex: Several microorganisms produce lactic acid used to produce cheese, yogurt and sour cream





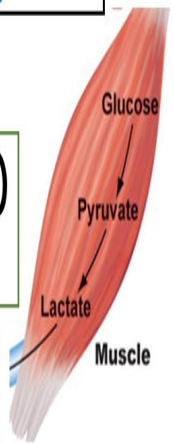


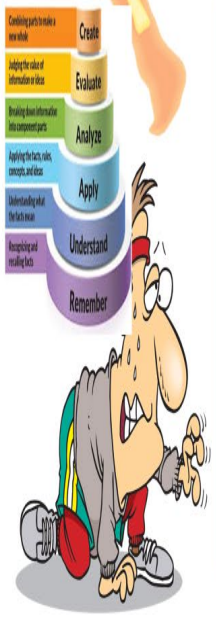
Infer when your body might perform fermentation reactions.

Skeletal muscles produce lactic acid when the body cannot supply enough O_2.



Explain the sense of sore (pain) in the muscles after exercise?





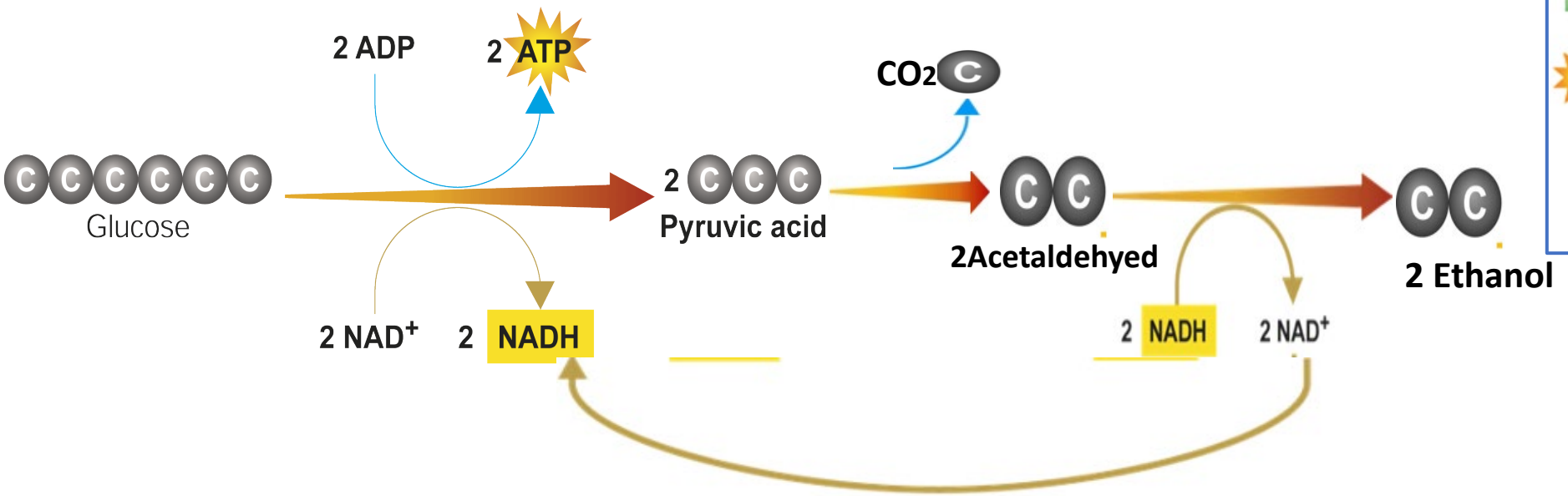
This happens when your cells don't have enough O2 present for cellular respiration then fermentation take place producing lactic acid which give sore muscle.

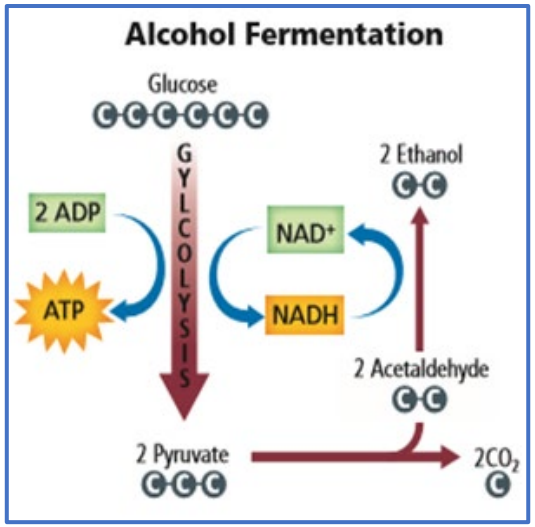




Alcohol fermentation

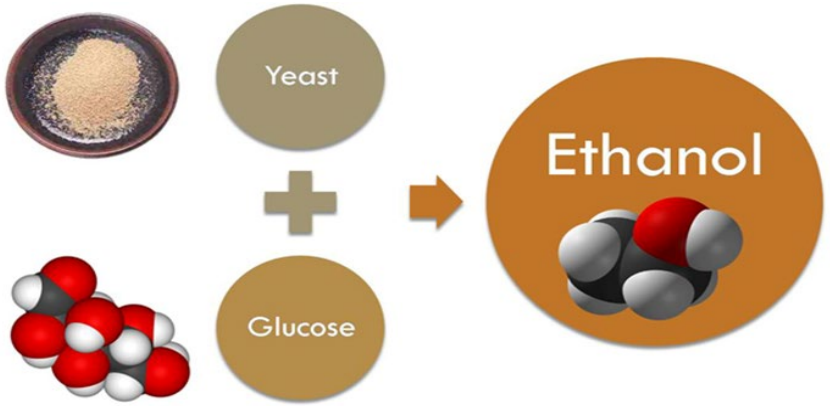
***Conversion** of pyruvic acid **into alcohol** (**ethanol**) and **carbon dioxide** .Transfer high energy electrons and H+ from NADH (as well as NAD⁺)*





Ex: Occurs in yeasts and microorganisms





$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Compare and contrast lactic acid fermentation and alcohol fermentation

-Lactic acid fermentation replenishes (restore)the supply of NAD+ by converting pyruvate to lactic acid.
-Alcohol fermentation converts pyruvate to ethanol and carbon dioxide to replenish NAD+.
-Both occur without oxygen.

Comparison of Fermentation to Cellular Respiration

Lactic Acid	Alcoholic	Cellular respiration
glucose	glucose	glucose
↓	↓	↓
glycolysis (pyruvic acid)	glycolysis (pyruvic acid)	glycolysis (pyruvic acid)
↓	↓	↓
lactic acid	carbon dioxide	carbon dioxide
+	+	+
2 ATP	alcohol	water
	+	+
	2 ATP	36 ATP

Photosynthesis and Cellular Respiration

-Photosynthesis and cellular respiration are two important processes that cells use to obtain energy.

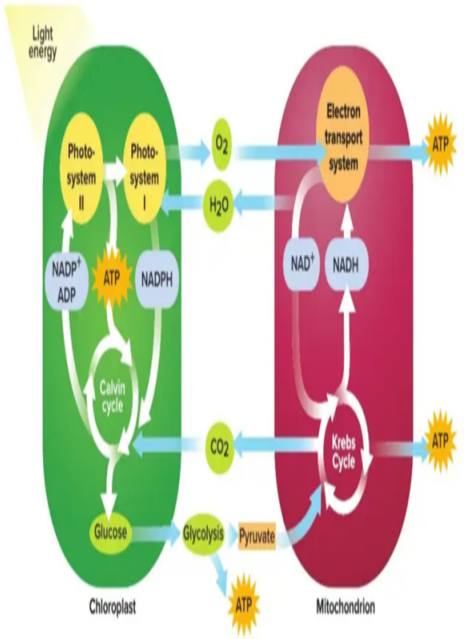
-They are metabolic pathways that produce and break down simple carbohydrates (glucose).

	PHOTOSYNTHESIS	RESPIRATION
Where?	Chloroplasts	Mitochondria
When?	In the presence of light	All the time
Input	Carbon dioxide and water	Glucose and oxygen
Output	Glucose and oxygen	Carbon dioxide and water
Energy sources	Light	Chemical bonds
Energy result	Energy stored	Energy released

-How these two processes are related?

-The products of photosynthesis are oxygen and glucose, the reactants needed for cellular respiration.

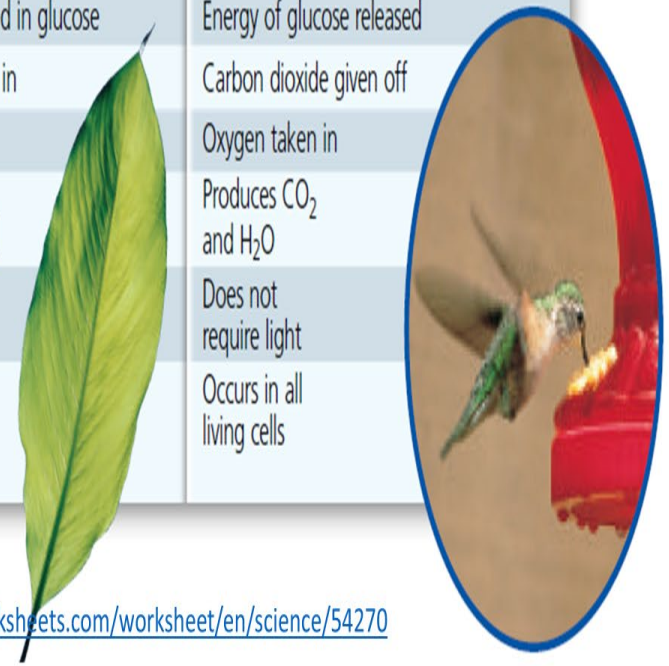
-The products of cellular respiration, which are carbon dioxide and water, are the reactants for photosynthesis.



summary

Comparison of Photosynthesis and Cellular Respiration

Photosynthesis	Cellular Respiration
Food synthesized	Food broken down
Energy from sun stored in glucose	Energy of glucose released
Carbon dioxide taken in	Carbon dioxide given off
Oxygen given off	Oxygen taken in
Produces sugars from PGAL G3P	Produces CO_2 and H_2O
Requires light	Does not require light
Occurs only in presence of chlorophyll	Occurs in all living cells



https://www.liveworksheets.com/worksheet/en/science/54270

https://www.liveworksheets.com/worksheet/en/science/769535



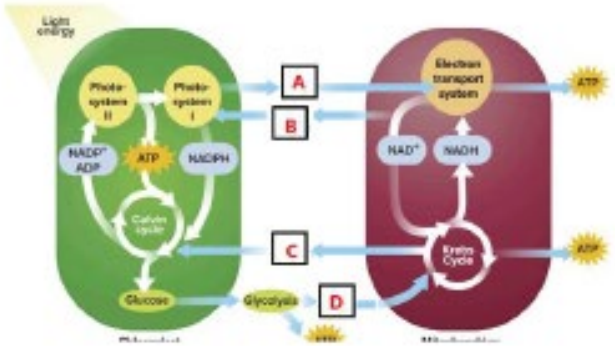
Photosynthesis vs. Cellular Respiration

	Photosynthesis	Cellular Respiration
Stores Energy as glucose	✓	
Releases Energy in glucose		✓
Occurs in Living Cells	✓	✓
Uses an Electron Transport Chain	✓	✓
Occurs in Plant Cells	✓	✓
Occurs in Animal Cells		✓
Releases Oxygen	✓	
Releases Carbon Dioxide		✓
Creates Energy	Neither!	

Feature	Photosynthesis ETC	Cellular Respiration ETC
Location	Thylakoid membrane (chloroplast)	Inner mitochondrial membrane
Electron source	H_2O	NADH, $FADH_2$
Final electron acceptor	$NADP^+$	O_2
Energy input	Light (photons)	Chemical energy (reduced coenzymes)
Proton gradient site	Thylakoid lumen	Intermembrane space
ATP synthesis site	Stroma	Matrix
Main products	ATP, NADPH, O_2	ATP, H_2O

The figure below shows that photosynthesis and cellular respiration form a cycle,

Which letter of the following refers to pyruvate?



earning Outcomes Covered

- BIO.3.1.02.028

A

B

C

D

In which metabolic process are molecules broken down to produce carbon dioxide and water?

A. photosynthesis
B. cellular respiration
C. homeostasis
D. fermentation

At the end of the Calvin cycle, where is energy stored?

A. NADPH
B. ATP
C. chloroplast
D. glucose

Why is cellular respiration a catabolic pathway?

A. Energy is used to form glucose and oxygen.
B. Energy is converted from water to carbon dioxide.
C. Energy that is lost is converted to thermal energy.
D. Energy is released by the breakdown of molecules.

What is the overall purpose of cellular respiration?

A. to make ATP
B. to process H_2O
C. to store glucose
D. to deliver oxygen

Why is adenosine triphosphate (ATP) such an important biological molecule?

A. It captures light energy from the sun.

B. It is produced in anabolic pathways.

C. It stores and releases chemical energy.

D. It converts mechanical energy to thermal energy.

Which represents the general sequence of cellular respiration?

A. TCA cycle → chemiosmosis → glycolysis

B. glycolysis → Krebs cycle → electron transport

C. electron absorption → catalysis → phosphorylation

D. aerobic pathway → anaerobic pathway → fermentation

Which is *not* a process that occurs in both cellular respiration and glycolysis?

A. chemiosmosis
B. electron transport
C. glycolysis
D. production of G3P

Which stage of cellular respiration is the anaerobic process?

A. glycolysis
B. Krebs cycle
C. electron transport

What is the final step of cellular respiration?

A. O_2 and H^+ form H_2O.

B. Electrons and H_2O generate ATP.

C. $C_6H_{12}O6$ is broken down into CO_2.

D. NADH and $FADH_2$ gain electrons.

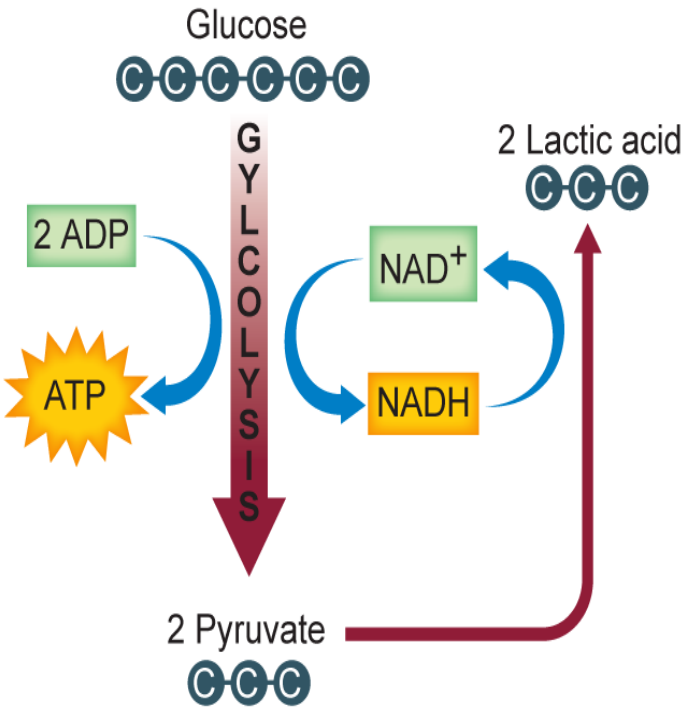
What prevents pyruvate from entering the Krebs cycle and instead results in this pathway?

A. a buildup of CO_2

B. a lack of oxygen

C. an excess of glucose

D. an increased demand for ATP



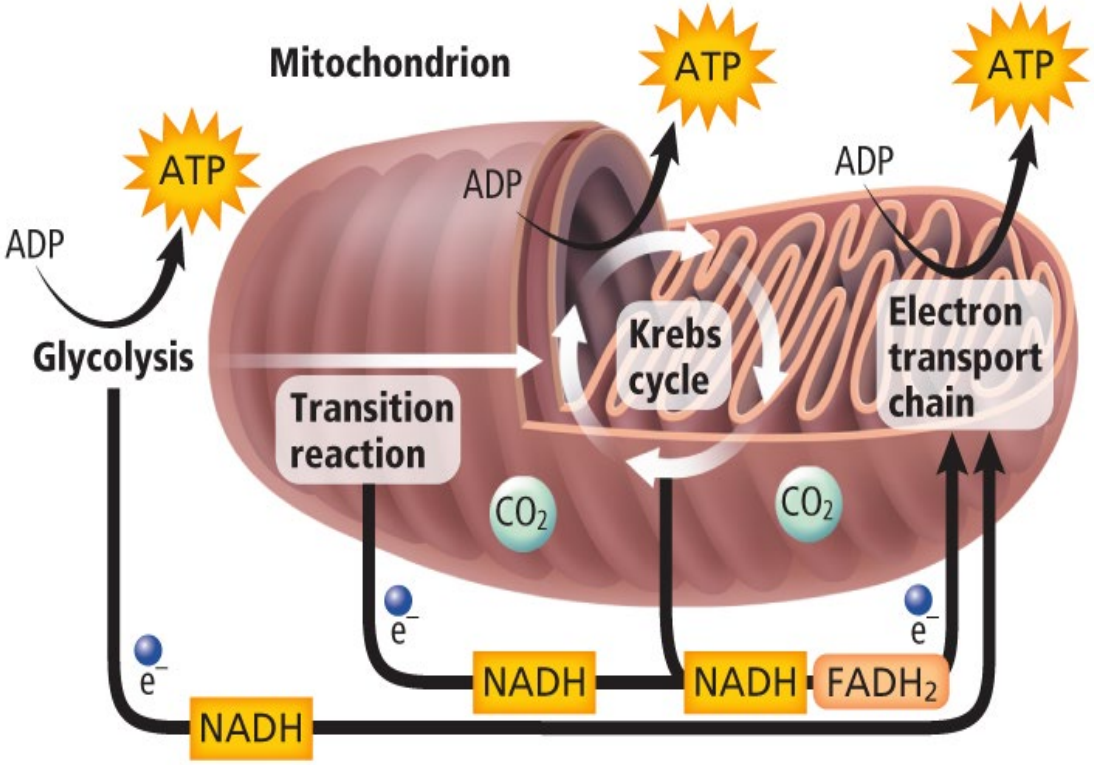
Which molecule generated by the Krebs cycle is a waste product?

A. CoA

B. CO_2

C. $FADH_2$

D. NADH



During the Krebs cycle, pyruvate is broken down into what compound?

A. H_2O

B. O_2

C. CO

D. CO_2

