

Question #4:

The process of photosynthesis and respiration can be thought of as a cycle because:

- A. One is used only by plants and the other is used only by animals
- B. Both give off oxygen to be used by animals
- C. The products of one are used as the raw materials of the other
- D. They both have the same purpose

Comparison of Photosynthesis and Respiration

	Photosynthesis	Respiration
Raw Materials	water and CO ₂	glucose and oxygen
Products	glucose and oxygen	water and CO ₂
Purpose	store energy	release energy

Transformation of Energy

- All living organisms use energy to carry out all biological processes.
- **Energy** – the ability to do work
- **Thermodynamics** – the study of the flow and transformation of energy in the universe

Laws of Thermodynamics

- LOT #1: “Energy cannot be created or destroyed; it can only be converted from one form to another.”
- LOT #2: “Energy cannot be converted without the loss of usable energy (which is usually converted to thermal energy.)”
 - Law of Entropy: the measure of disorder (unusable energy) in a system
 - Ex: Evident in food chains

Autotrophs and Heterotrophs

- All energy for life comes from the sun, either directly or indirectly
- Autotrophs: produce their own energy
 - Chemoautotrophs – use inorganic substances, like hydrogen sulfide, as a source of energy (Chemosynthesis)
 - Photoautotrophs – convert energy from the sun into chemical energy (Photosynthesis)
- Heterotrophs: need to ingest other organisms in order to obtain energy

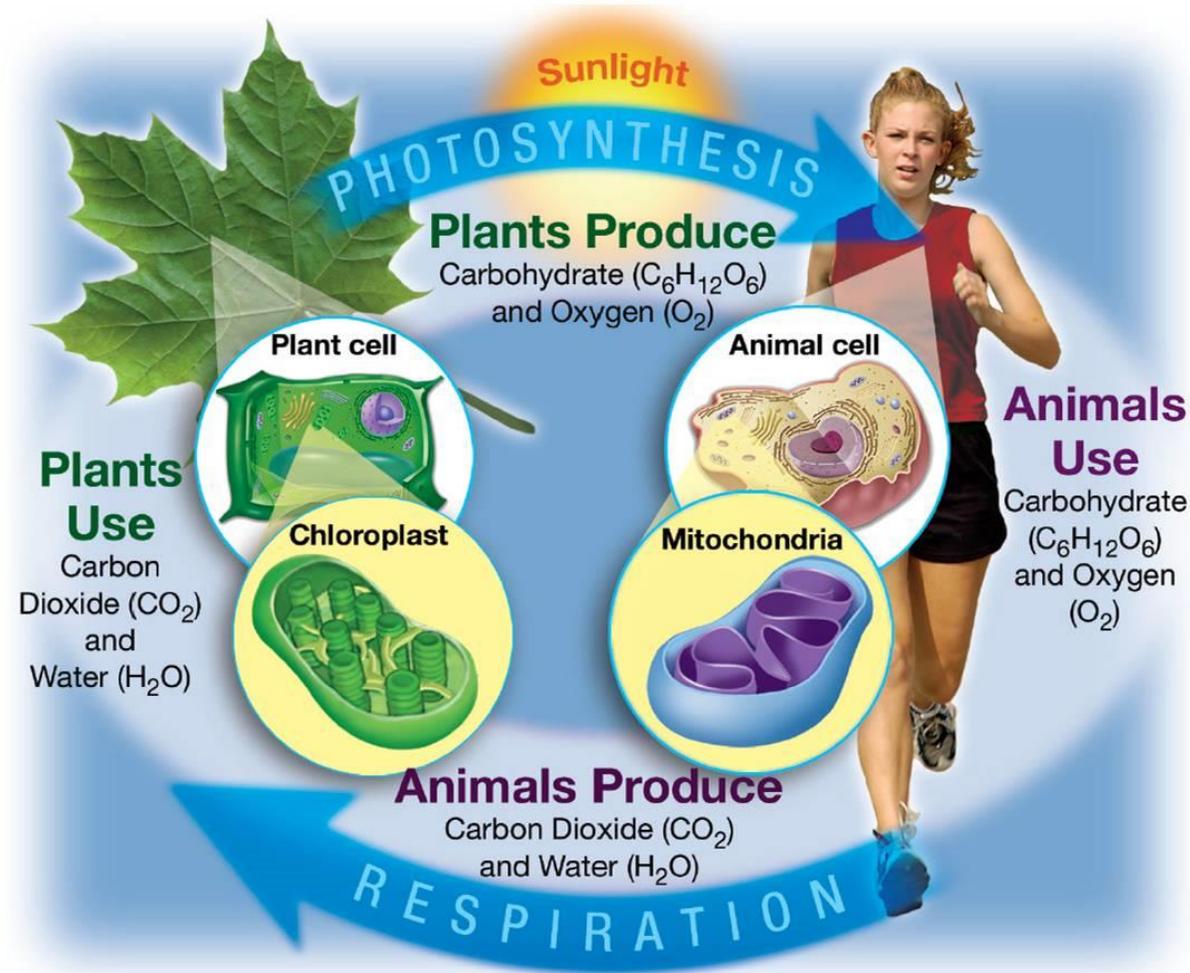
Metabolism

- **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

Two types of Metabolic pathways

- **Catabolic pathways:** release energy by breaking down large molecules into smaller molecules
- **Anabolic pathways:** use energy release by catabolic pathways to build larger molecules from smaller molecules
- This results in in continual flow of energy within an organism.

Photosynthesis & Cellular Respiration





Copyright ©

Cellular Respiration

Let's get energized!

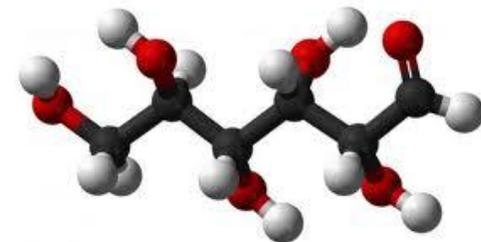
THE IMPORTANCE OF FOOD

Food provides living things with the: chemical building blocks they need to grow and reproduce.

Food serves as a source of energy.



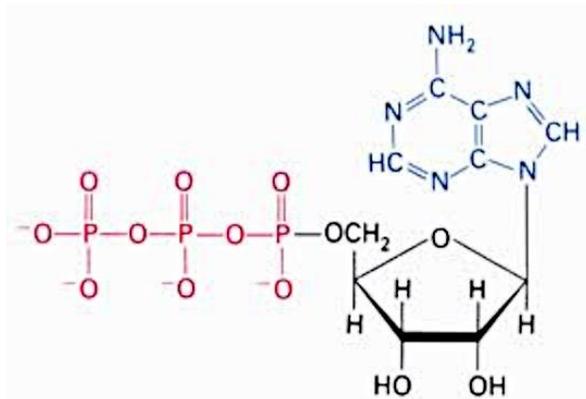
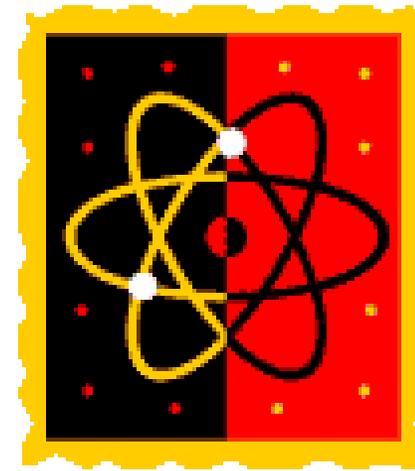
Food serves as a source of...
...raw materials for the cells of the body.



Chemical Energy and ATP

Inside living cells, energy can be stored in chemical compounds.

One of the principal chemical compounds that cells use to store and release energy is:



ADP and ATP

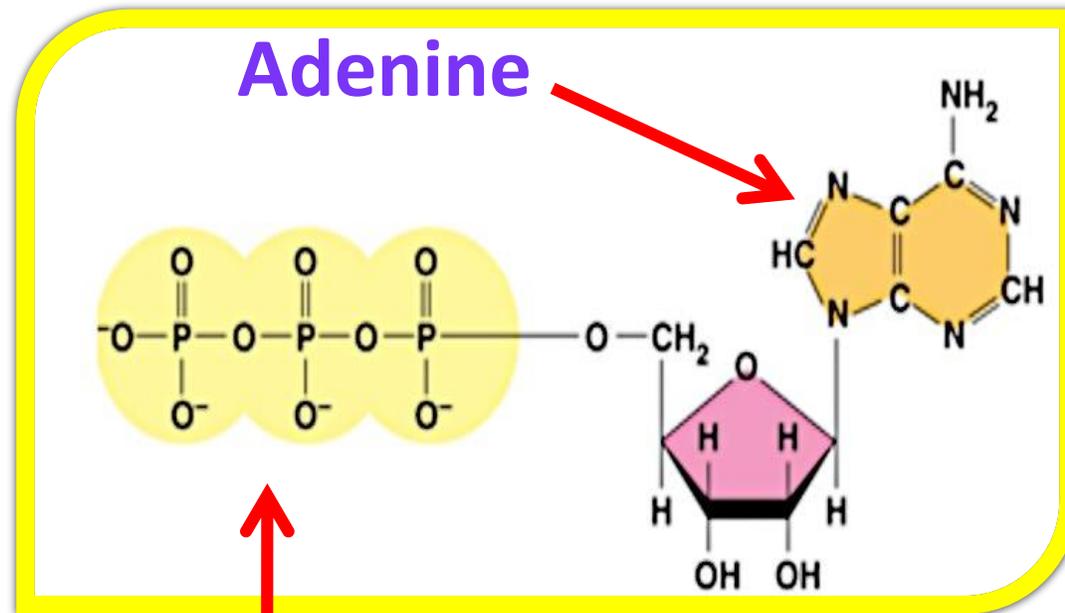
ATP -- Adenosine Triphosphate

ADP – Adenosine Diphosphate

ADP is energy poor (like a dead battery.)

ATP is energy rich (like a charged battery.)

Structure of ATP



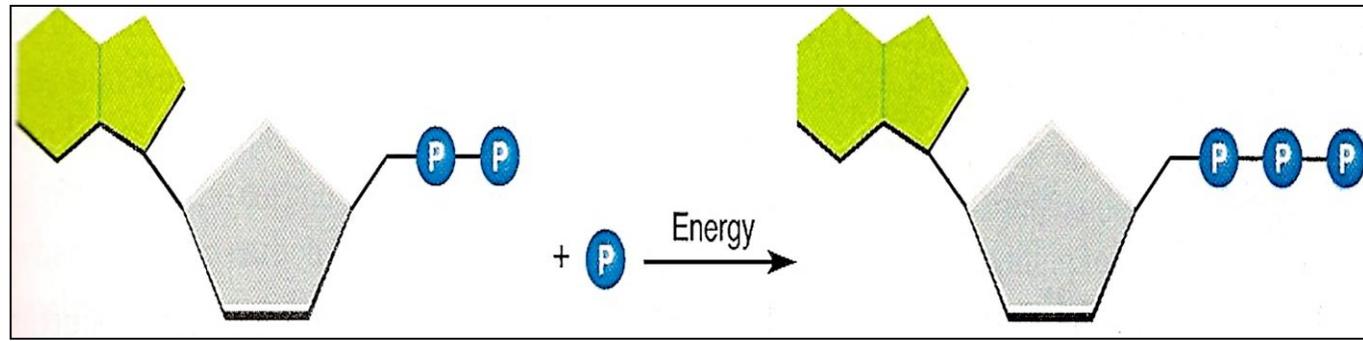
3 Phosphates

Ribose

Consists of:

- 1) Adenine, a nitrogen base
- 2) Ribose, a five-carbon sugar
- 3) A chain of three phosphate groups

How ADP Becomes ATP



ADP is a compound that looks almost like ATP. The difference is that....

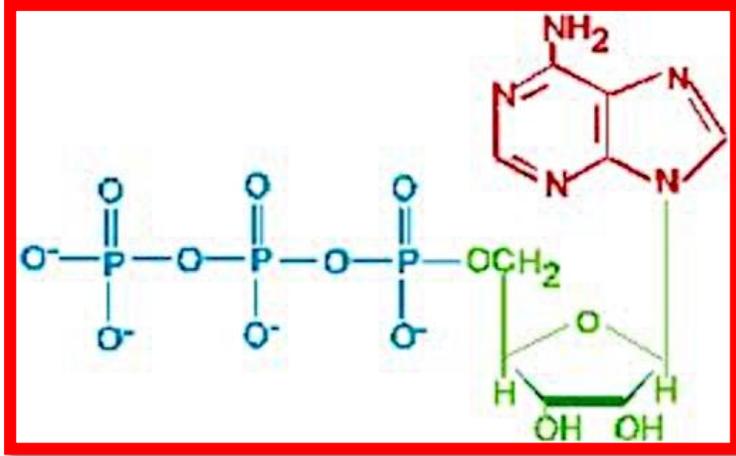
...ADP has 2 phosphate groups and ATP has three phosphate groups.

When a cell has energy available, it can store small amounts of it by adding a phosphate group to ADP.

Adding a phosphate to ADP forms a molecule of ATP. The addition of the third phosphate stores energy.

When a cell needs energy, the third phosphate will be removed. This releases energy.

ATP has enough stored energy to power a variety of cellular activities such as.....



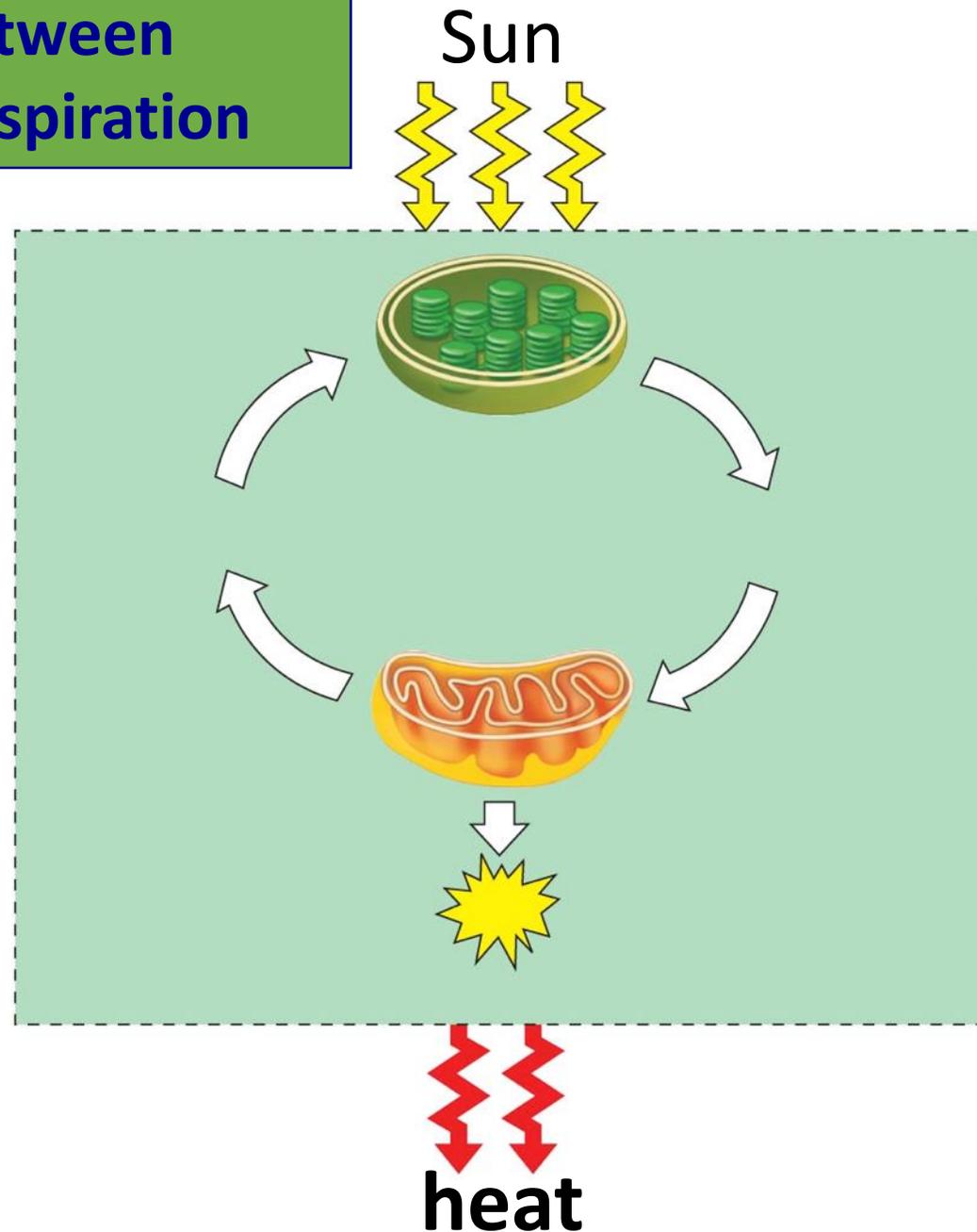
1. Photosynthesis
2. Protein synthesis
3. Muscle contraction
4. Active transport across the cell membrane

The ATP molecule is the basic energy source of all living cells.

In a cell, ATP is used continuously and must be regenerated continuously. In a working muscle cell, 10 million ATP are consumed and regenerated per sec.

The Relationship Between Photosynthesis and Respiration

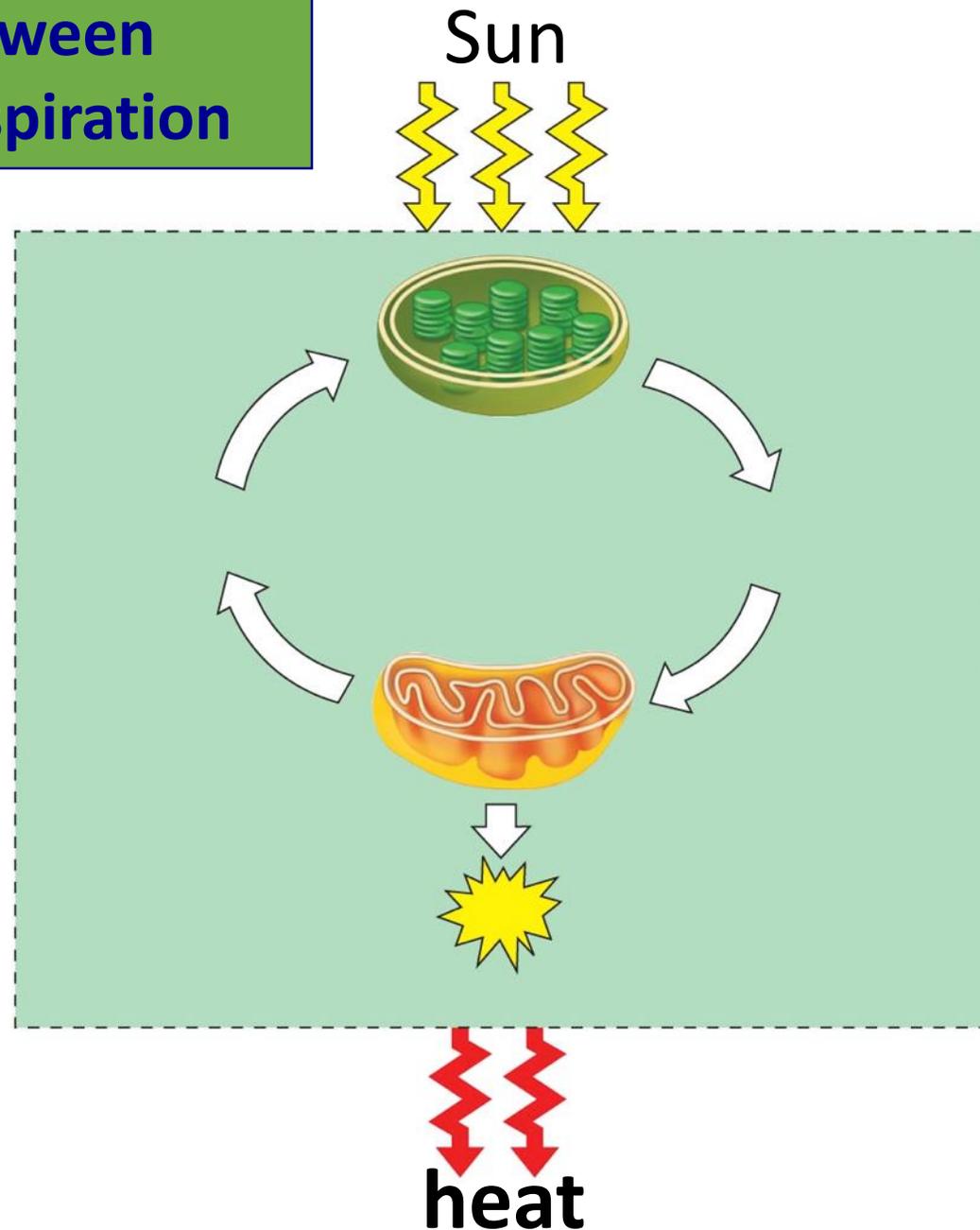
Energy flows into an ecosystem as sunlight and leaves as heat. Energy is not recycled. Energy follows a one-way path through our ecosystem.



The Relationship Between Photosynthesis and Respiration

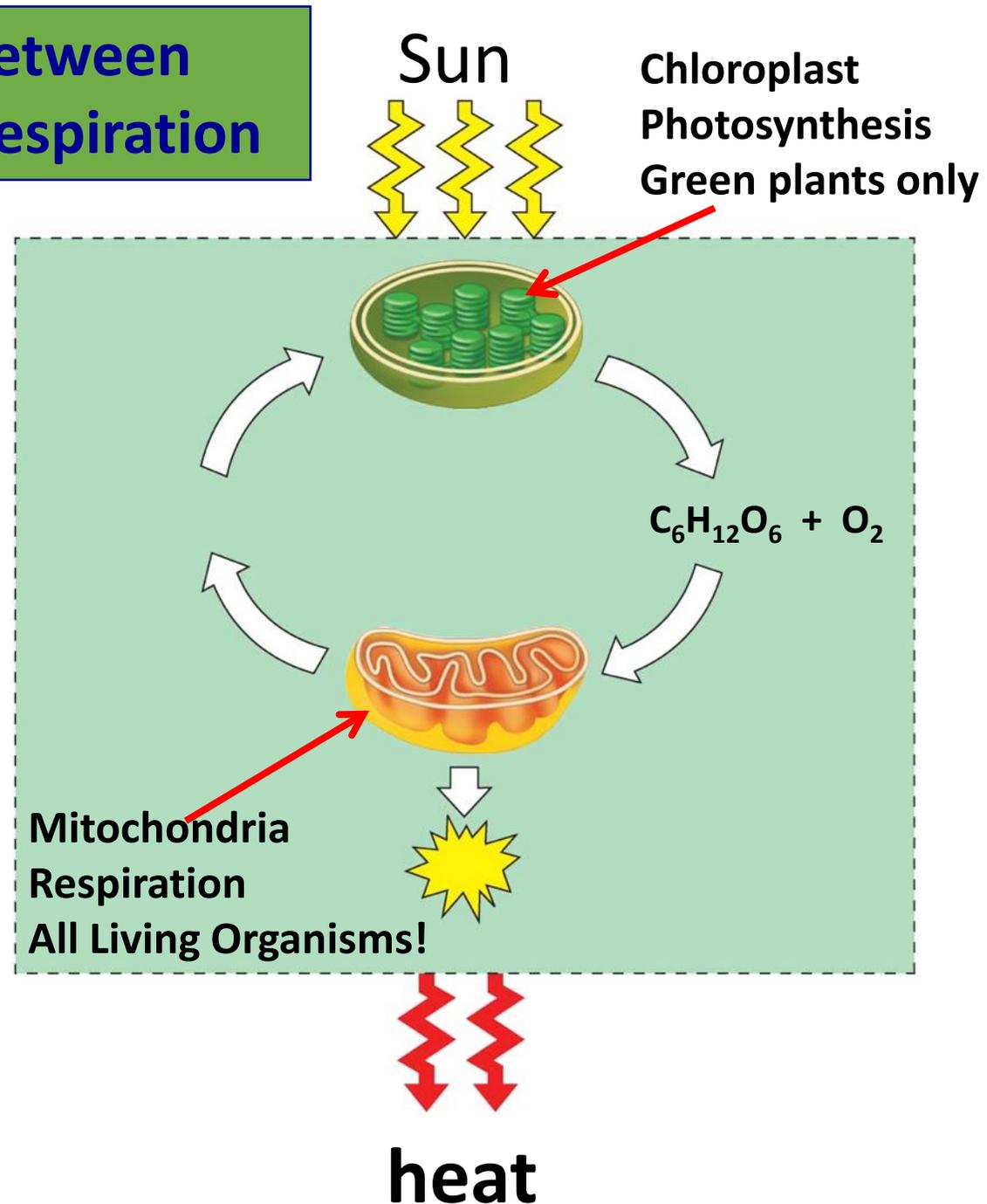
However, the chemical elements essential to life are recycled.

Photosynthesis converts light energy from the sun into chemical energy, which is stored in carbohydrates and other organic compounds.



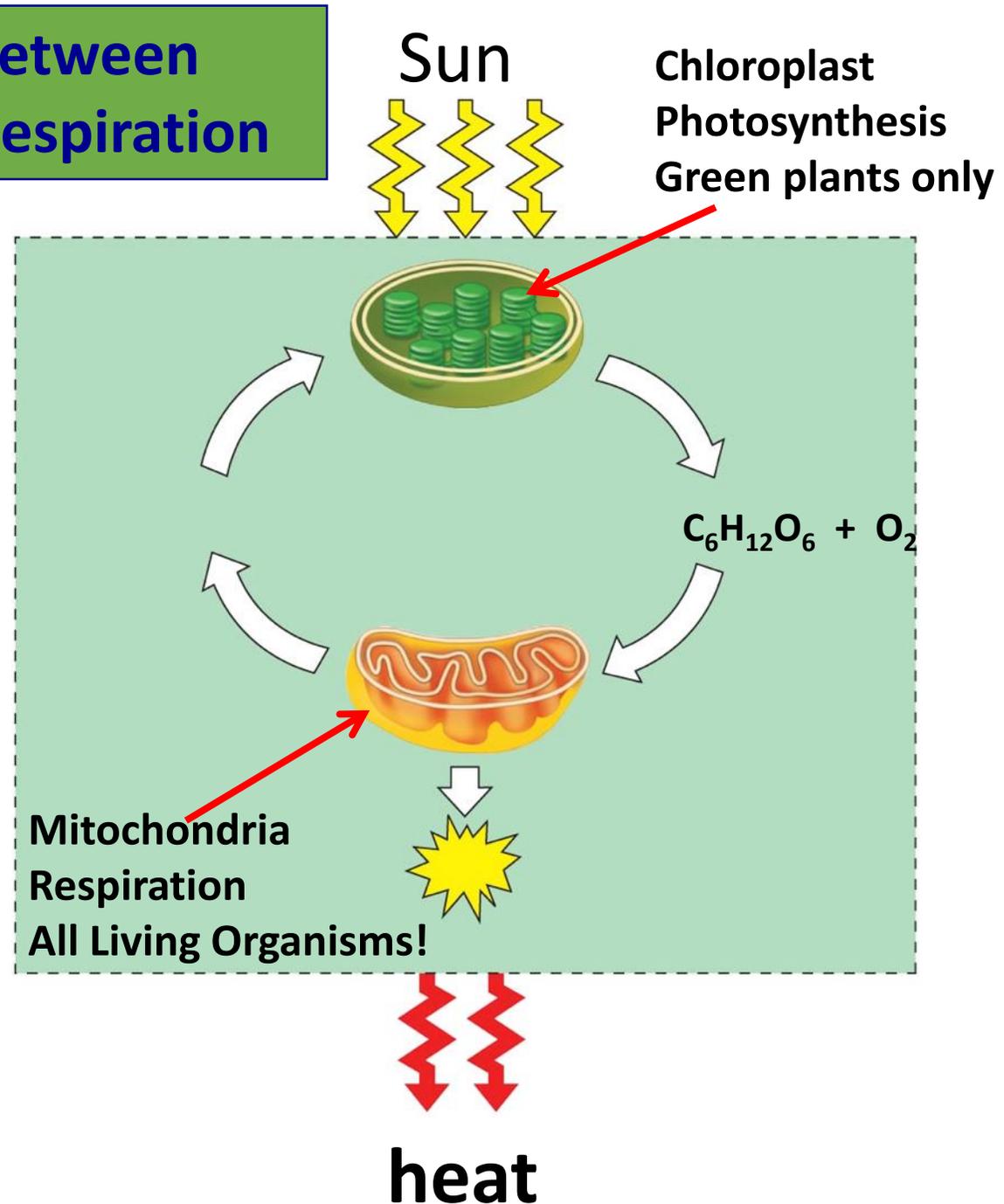
The Relationship Between Photosynthesis and Respiration

Photosynthesis generates the oxygen and glucose used by the mitochondria of eukaryotes as fuel for: cellular respiration.



The Relationship Between Photosynthesis and Respiration

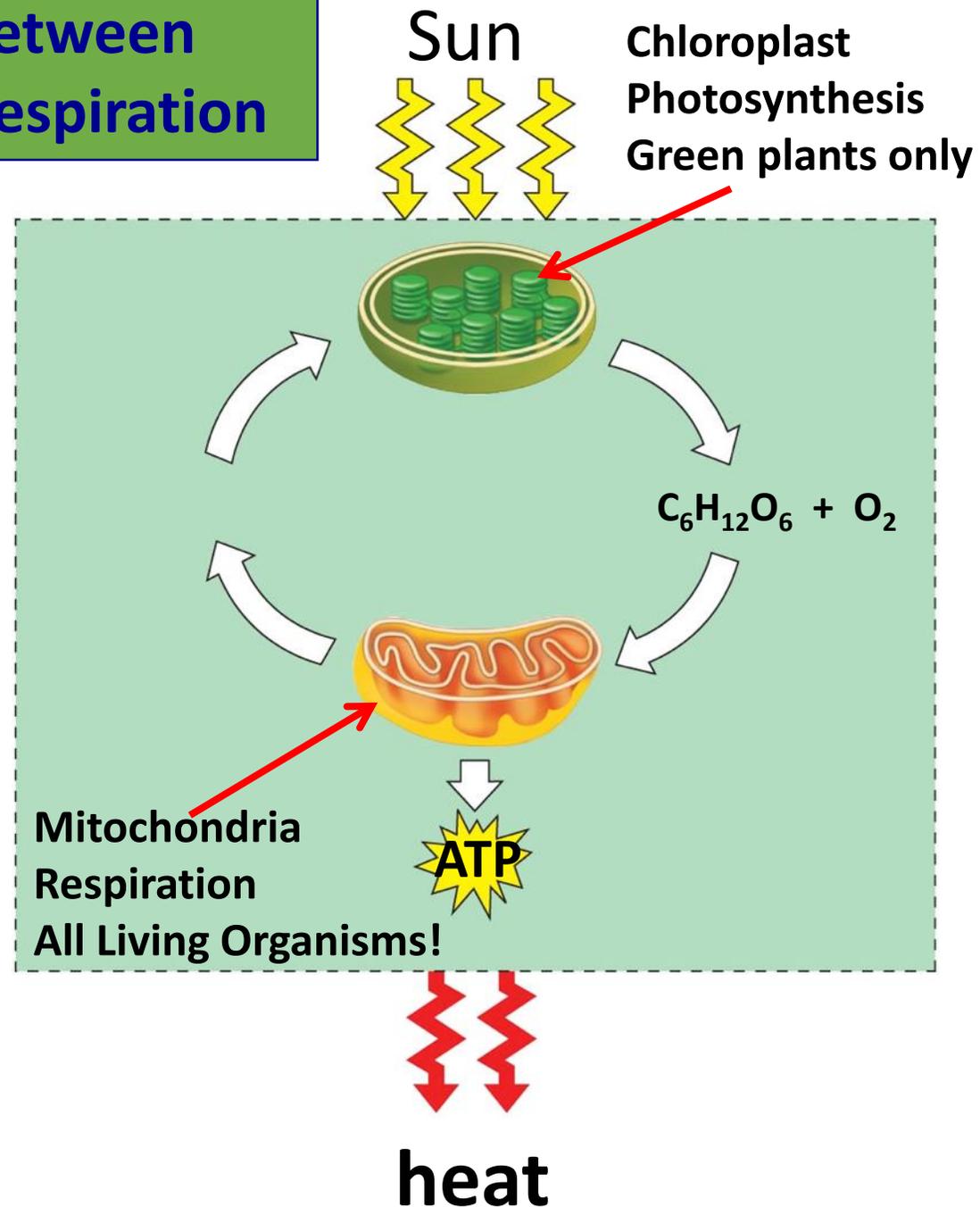
Cellular respiration breaks down glucose into simpler substances and releases the stored energy.



The Relationship Between Photosynthesis and Respiration

Some of this energy is used to make ATP from ADP.

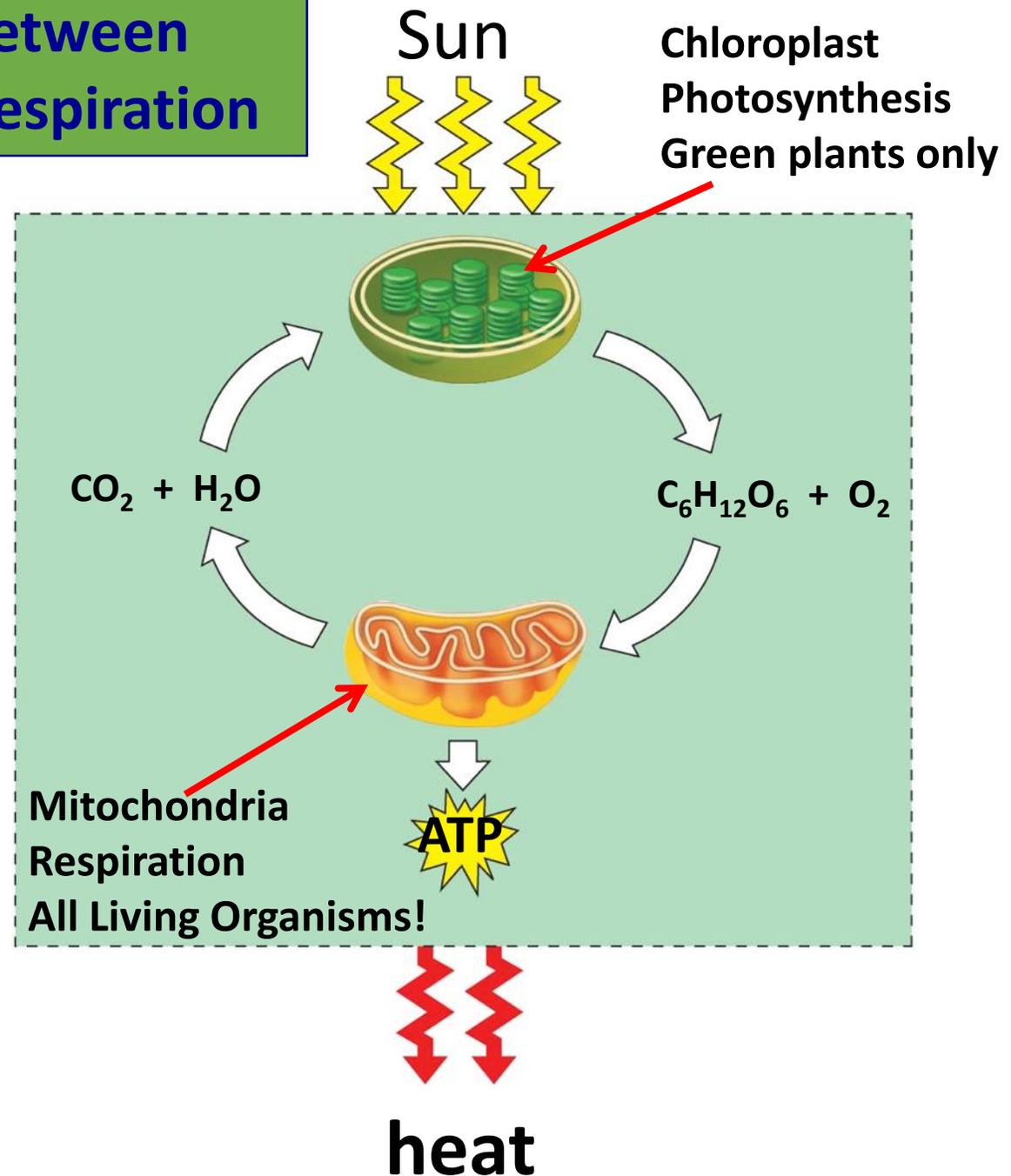
Some of this energy is lost as heat.



The Relationship Between Photosynthesis and Respiration

The waste products of respiration, CO₂ and H₂O, are the raw materials for photosynthesis.

IMPORTANT NOTE: While only green plants carry out photosynthesis, ALL living things carry out respiration.



Overview of Respiration

Cellular respiration is the process that **releases energy by breaking down glucose and other food molecules in the presence of oxygen.**

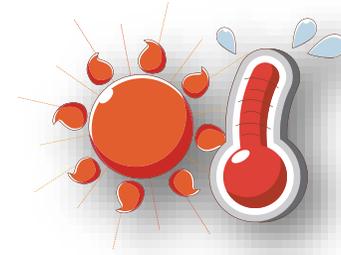
It is the process of converting **glucose to ATP.**

Equation for respiration:





There is much energy stored in this molecule of glucose. This energy must be released in small, controlled steps. If all the energy from glucose were released at once, most of it would be lost as heat and light.



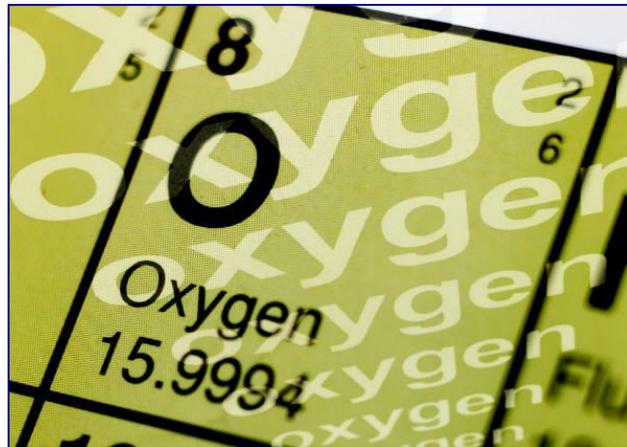
The energy stored in glucose will be released bit by bit and this energy will be used to produce ATP.

The energy cannot be released from the glucose all at once. It would be the equivalent of the gas tank in your car exploding in one single reaction, rather than in the small controlled combustions that drive your car.



There are 2 types of
respiration:

**Aerobic
Respiration:
Requires oxygen**



**Anaerobic
Respiration:
Does NOT require
oxygen**

Respiration

Respiration takes place in three main stages:

Glycolysis
(anaerobic)

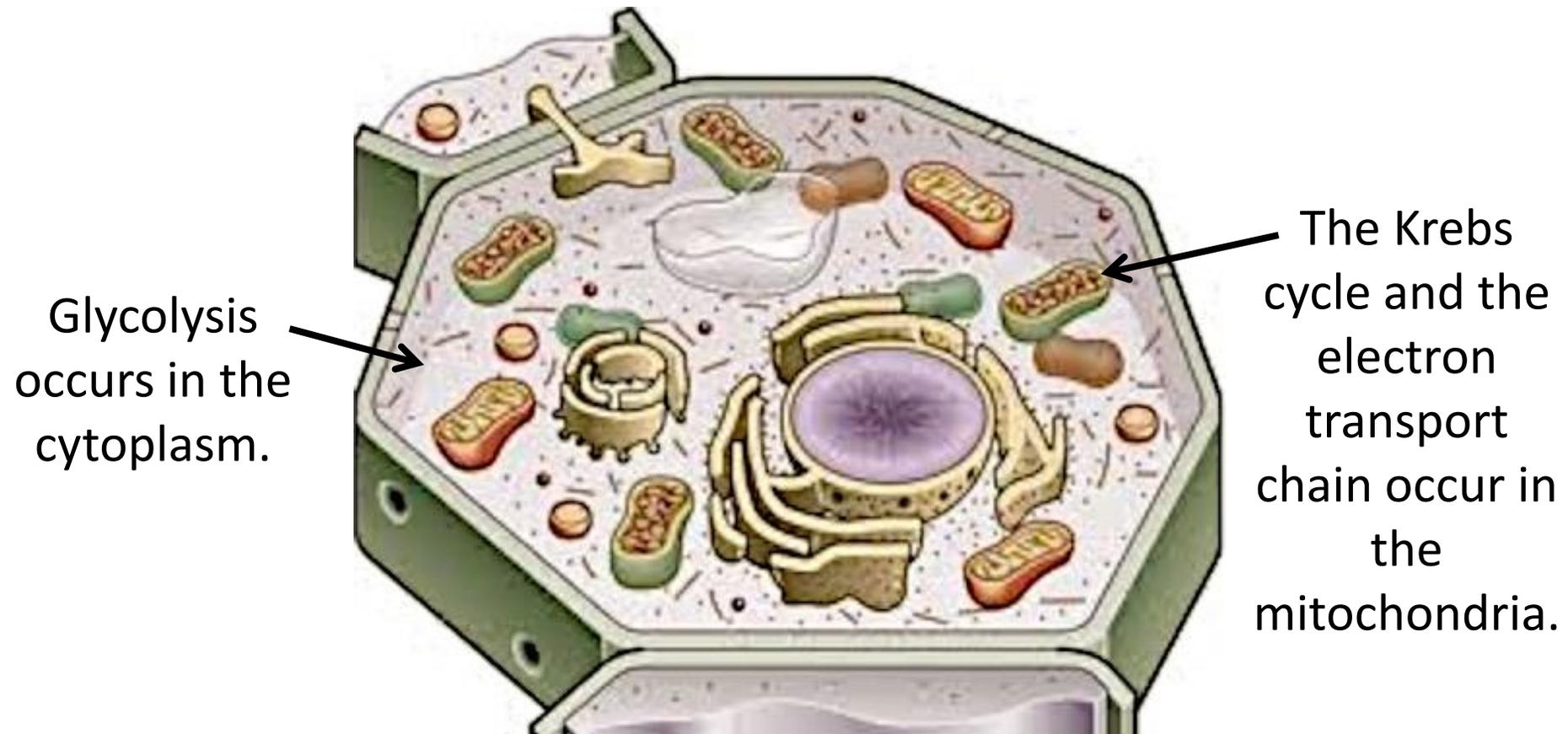
Krebs cycle
(aerobic)

Electron Transport
Chain (aerobic)



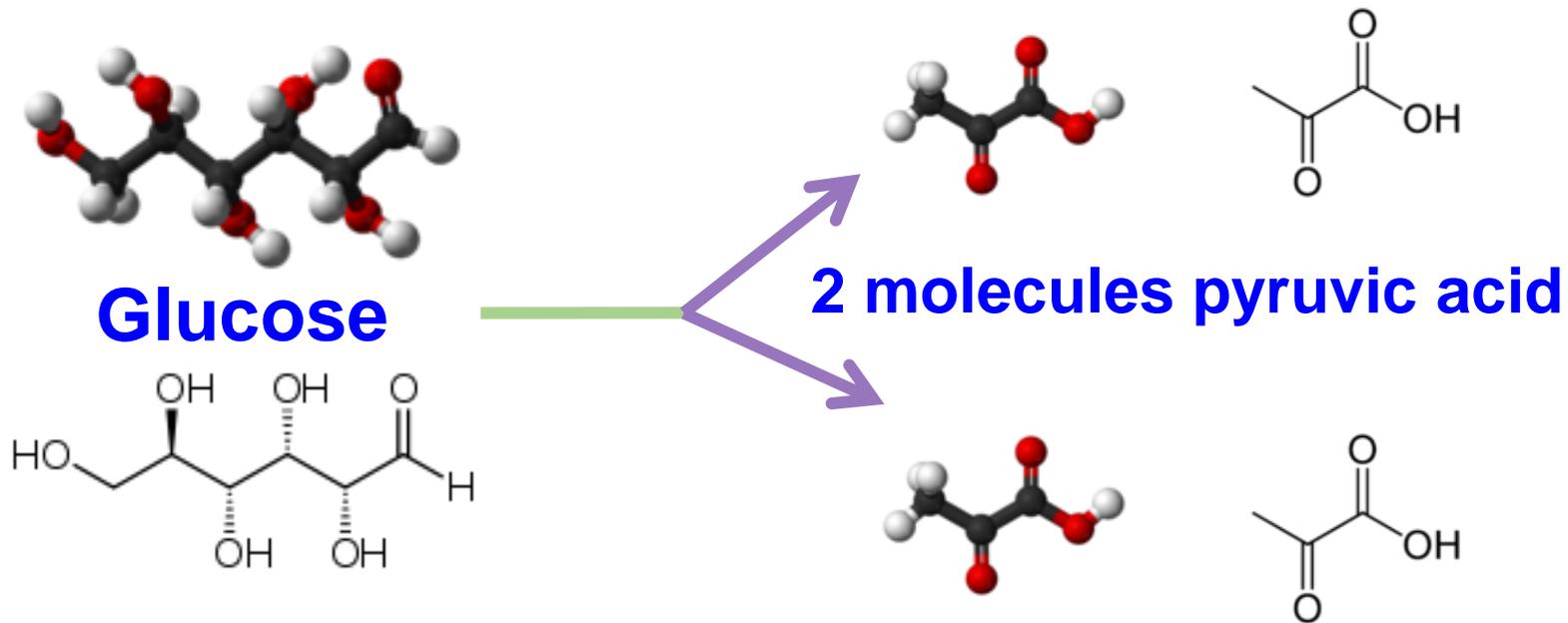
ATP

Glycolysis occurs in the cytoplasm, but the Krebs cycle, and electron transport chain occurs in the mitochondria.



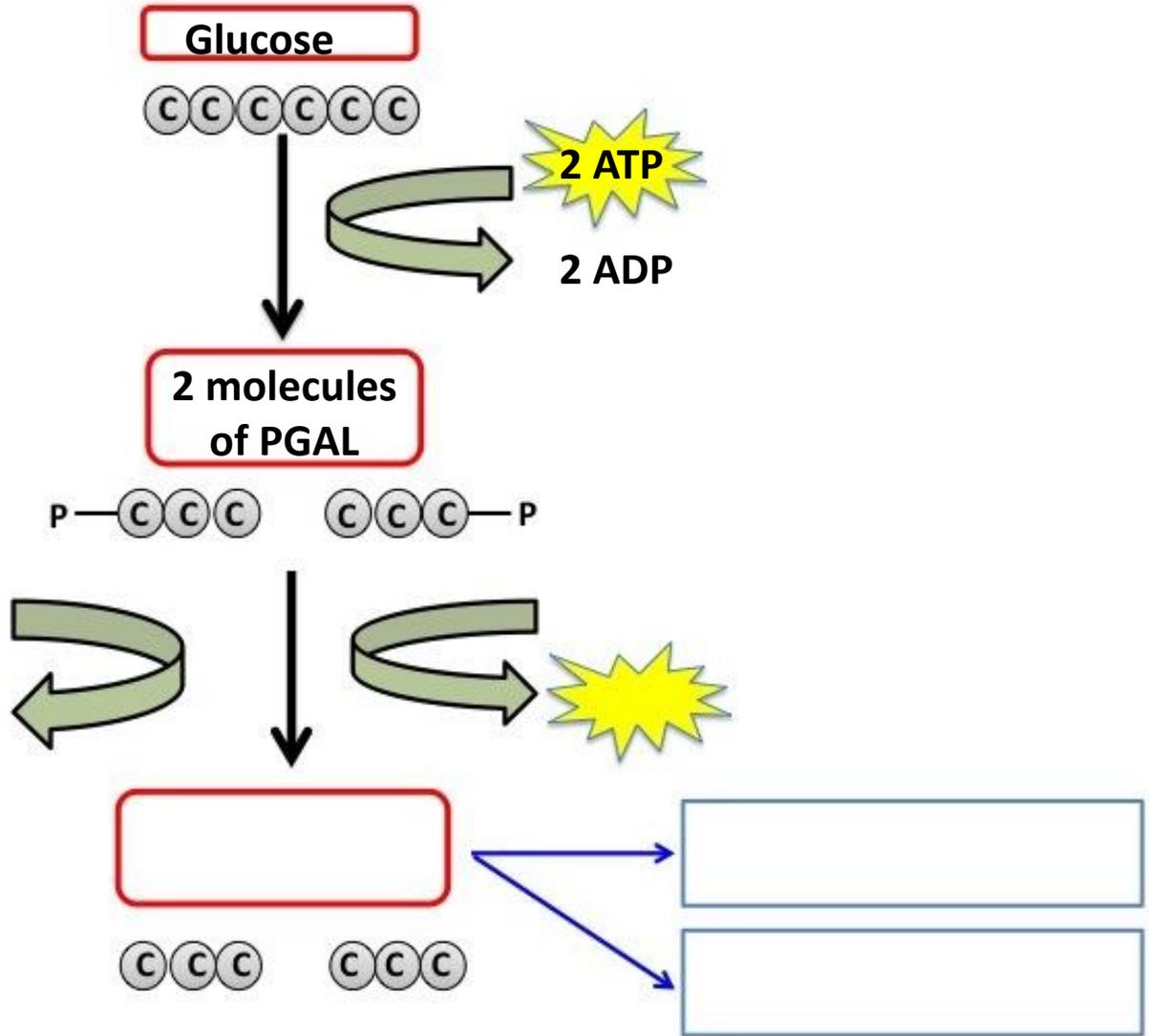
Definition:

Glycolysis is the process in which one molecule of glucose is oxidized to produce two molecules of pyruvic acid.



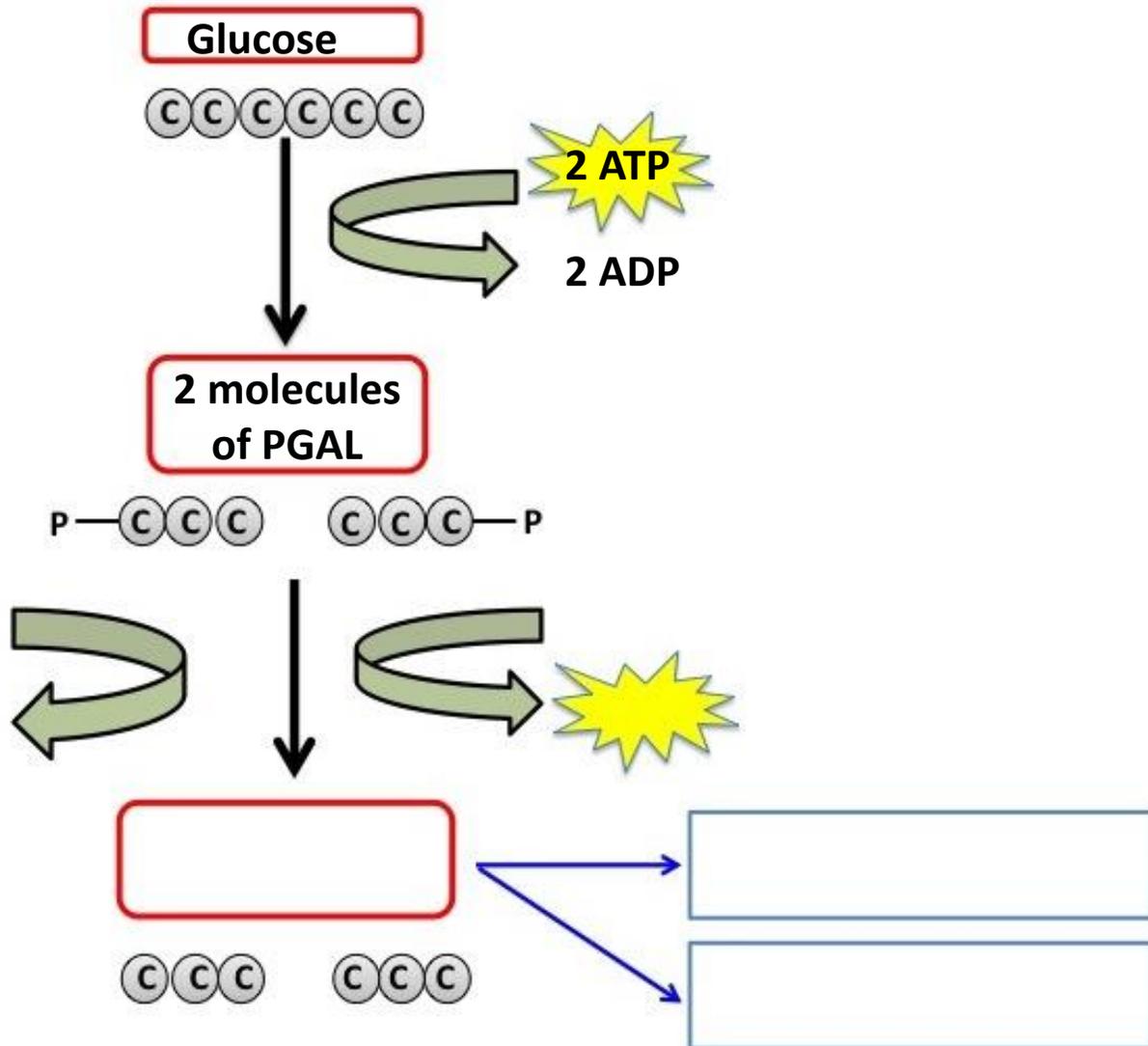
G
L
Y
C
O
L
Y
S
I
S

Steps in Glycolysis



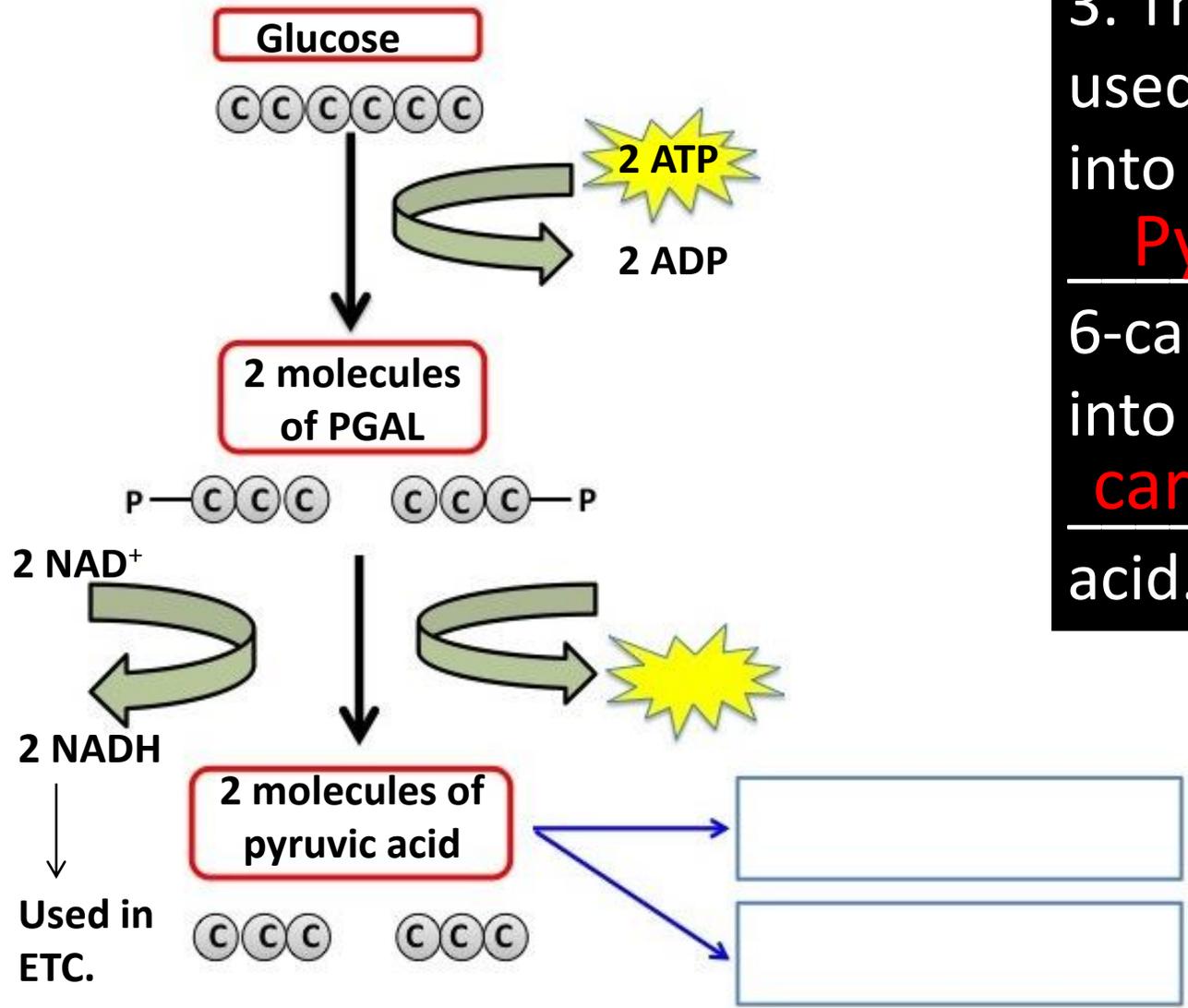
1. Glucose is the primary energy molecule for CELLULAR RESPIRATION

Steps in Glycolysis



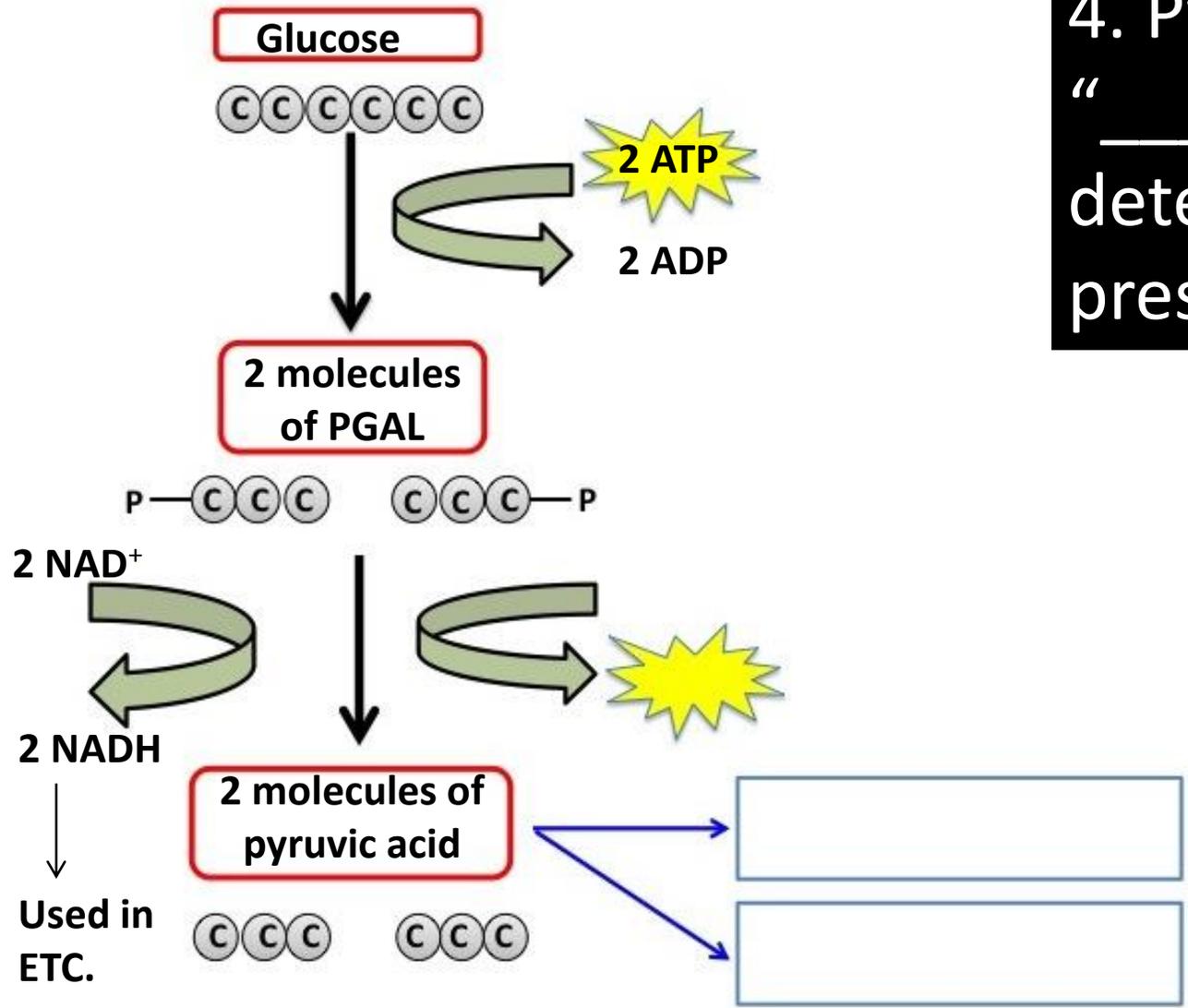
2. The first step of respiration is Glycolysis, which operates in the Mitochondria

Steps in Glycolysis



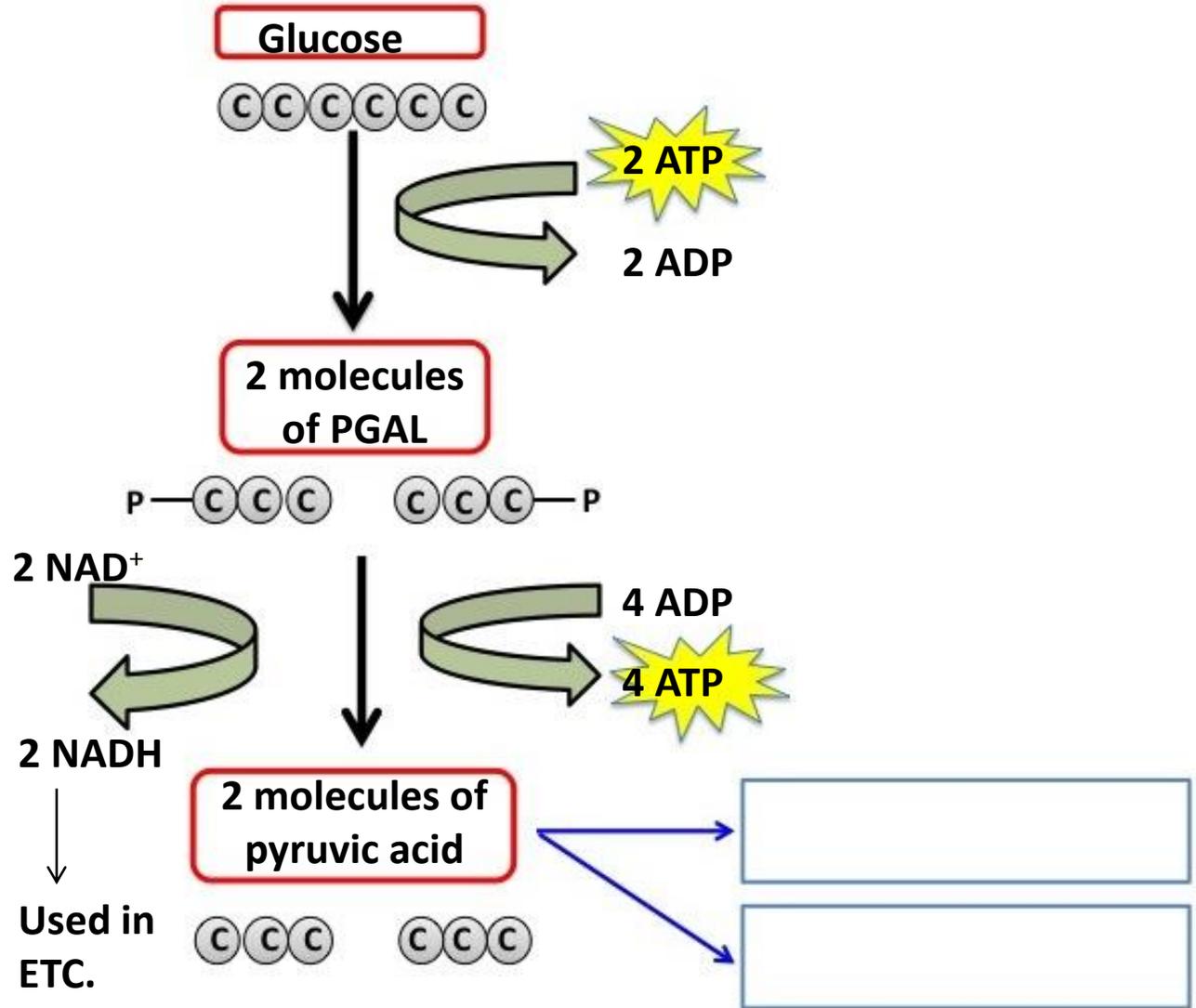
3. The energy from ATP is used to convert Glucose into two molecules of Pyruvic acid by splitting the 6-carbon Glucose molecule into two separate 3 carbon molecules of pyruvic acid.

Steps in Glycolysis

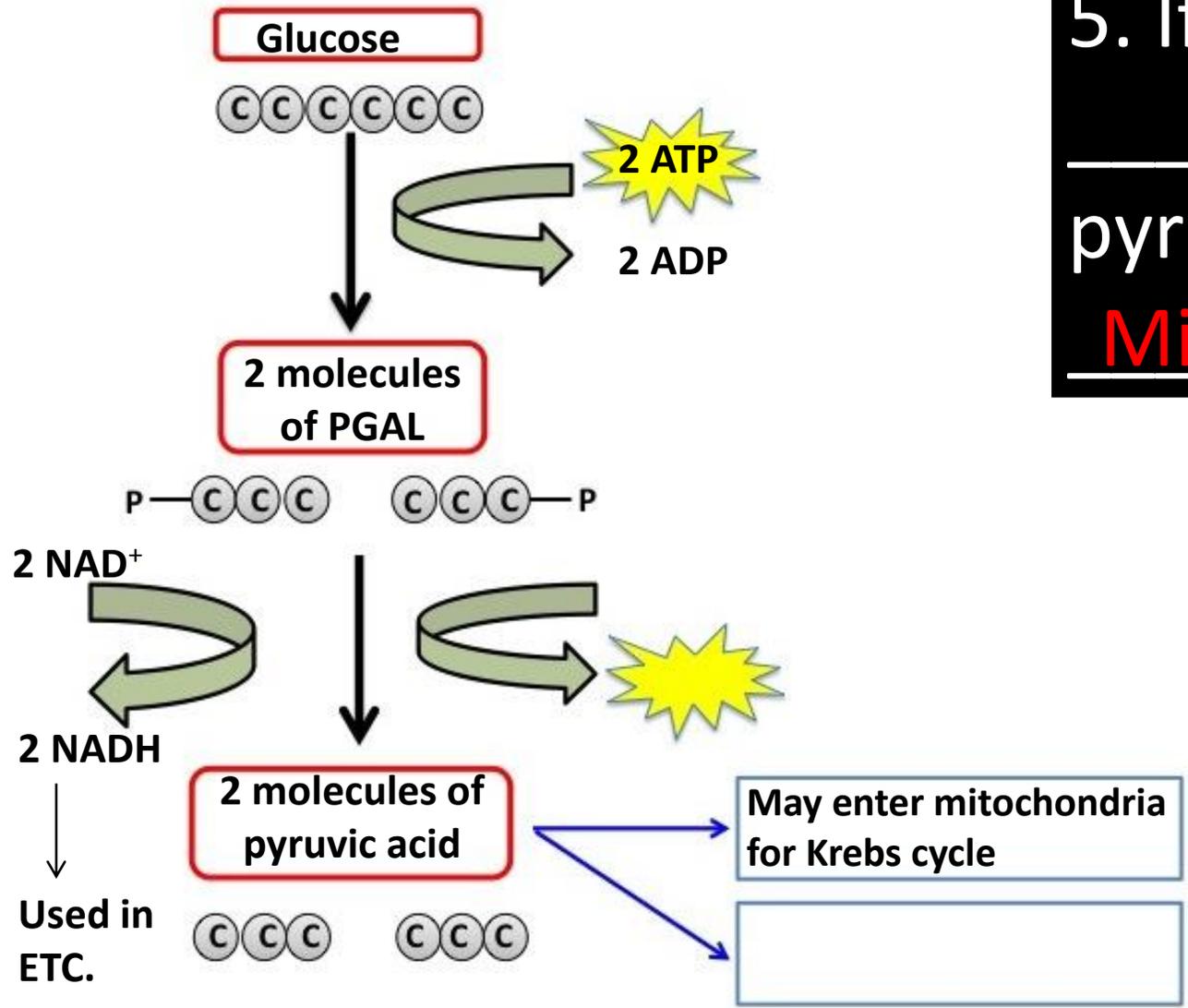


4. Pyruvic acid acts as a “**Seeker**”, detecting/looking for the presence of **Oxygen**.

Steps in Glycolysis

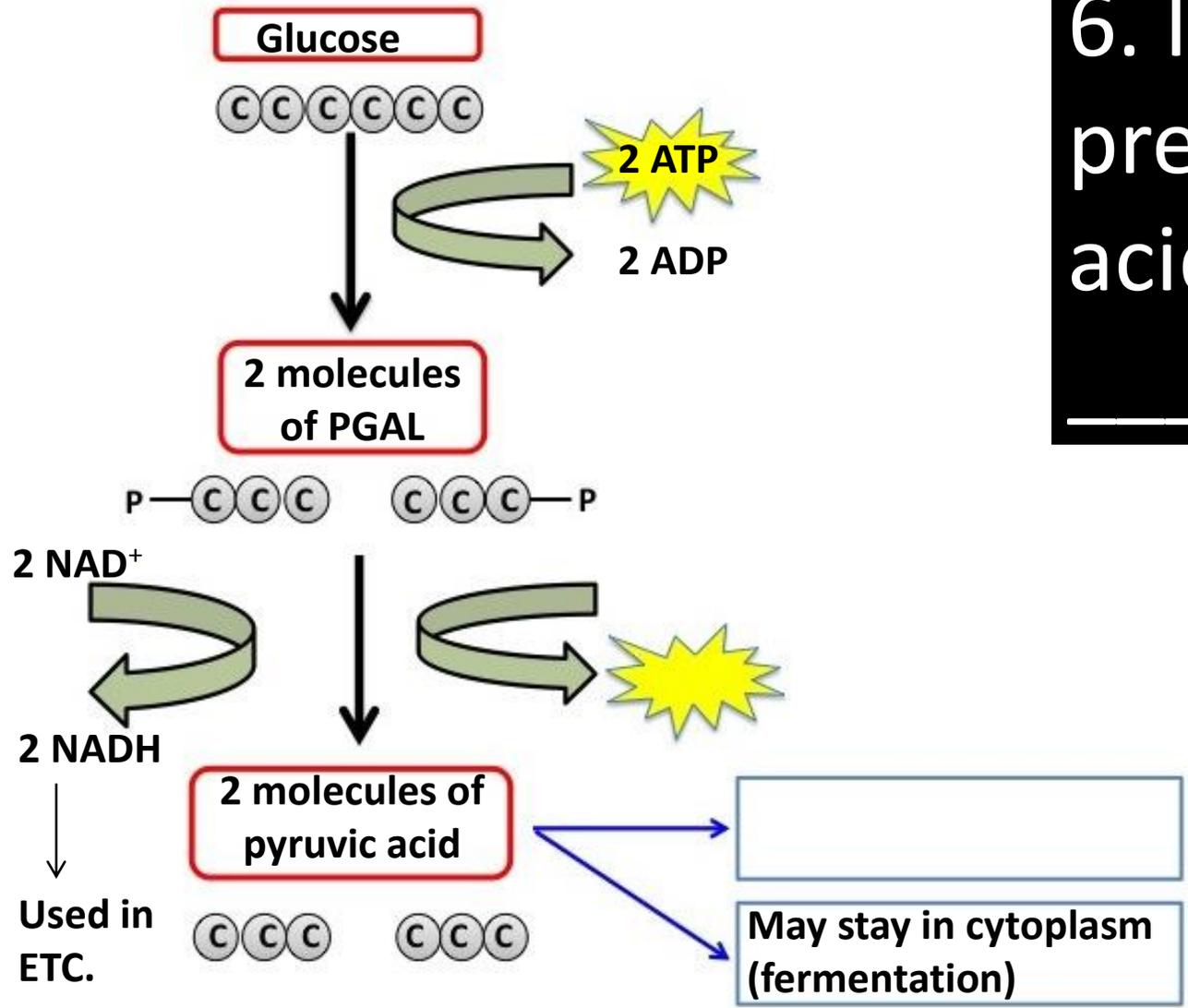


Steps in Glycolysis



5. If oxygen is Present, then pyruvic acid moves to the Mitochondria.

Steps in Glycolysis



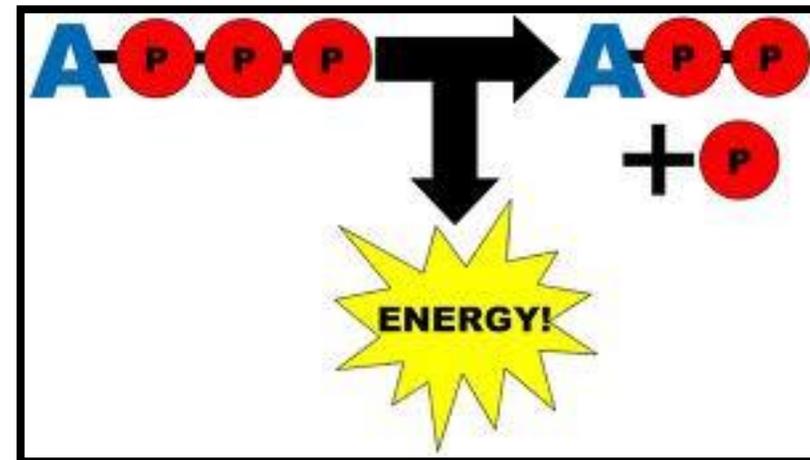
6. If oxygen is NOT present, then pyruvic acid moves stays in the cytoplasm.

ATP Production:

Two molecules of ATP are consumed at the beginning, but four molecules of ATP are produced by the end of glycolysis.

Glycolysis has a gain of 2 ATP.

Even though cellular respiration is an energy releasing process, the cell must invest a small amount of energy to get the reaction going.

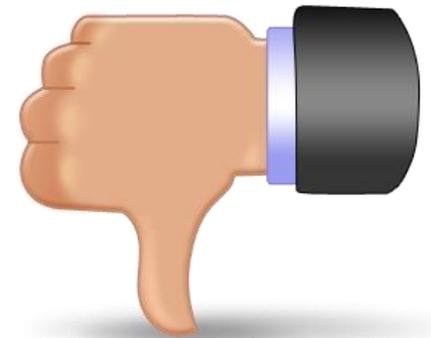


Advantages and Disadvantages of Glycolysis



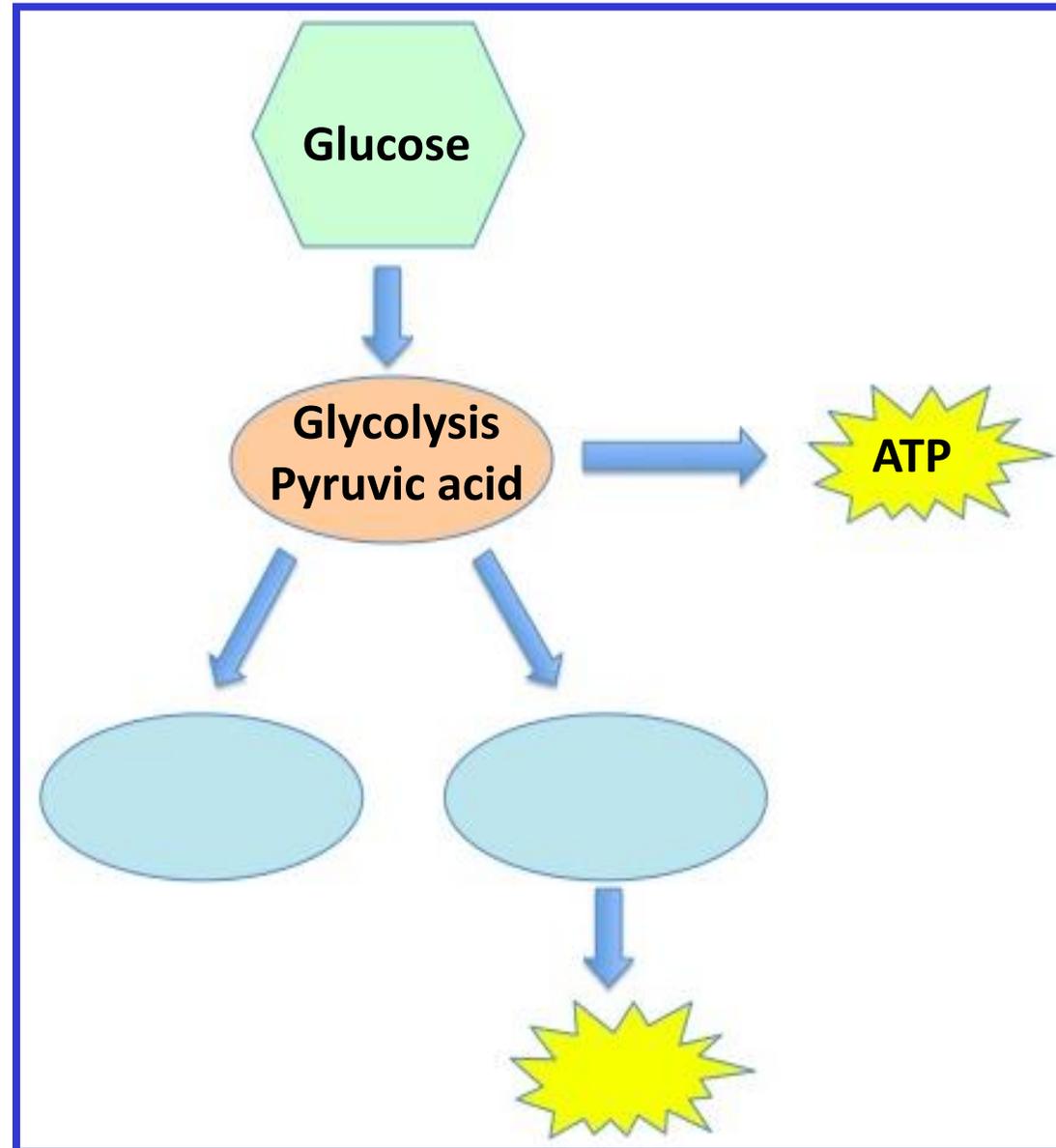
1. Glycolysis only produces a gain of 2 ATP per molecule of glucose, but the process is so fast that 1000's of ATP are produced in just a few milliseconds.
2. Another advantage is that glycolysis does not require oxygen. Energy can be produced for the cell even if no oxygen is present.

3. Disadvantage: If the cell relied only on glycolysis for ATP production, the cell would quickly run out of Energy because only 2 ATP are netted.



The Fate of Pyruvic Acid – What happens to it?

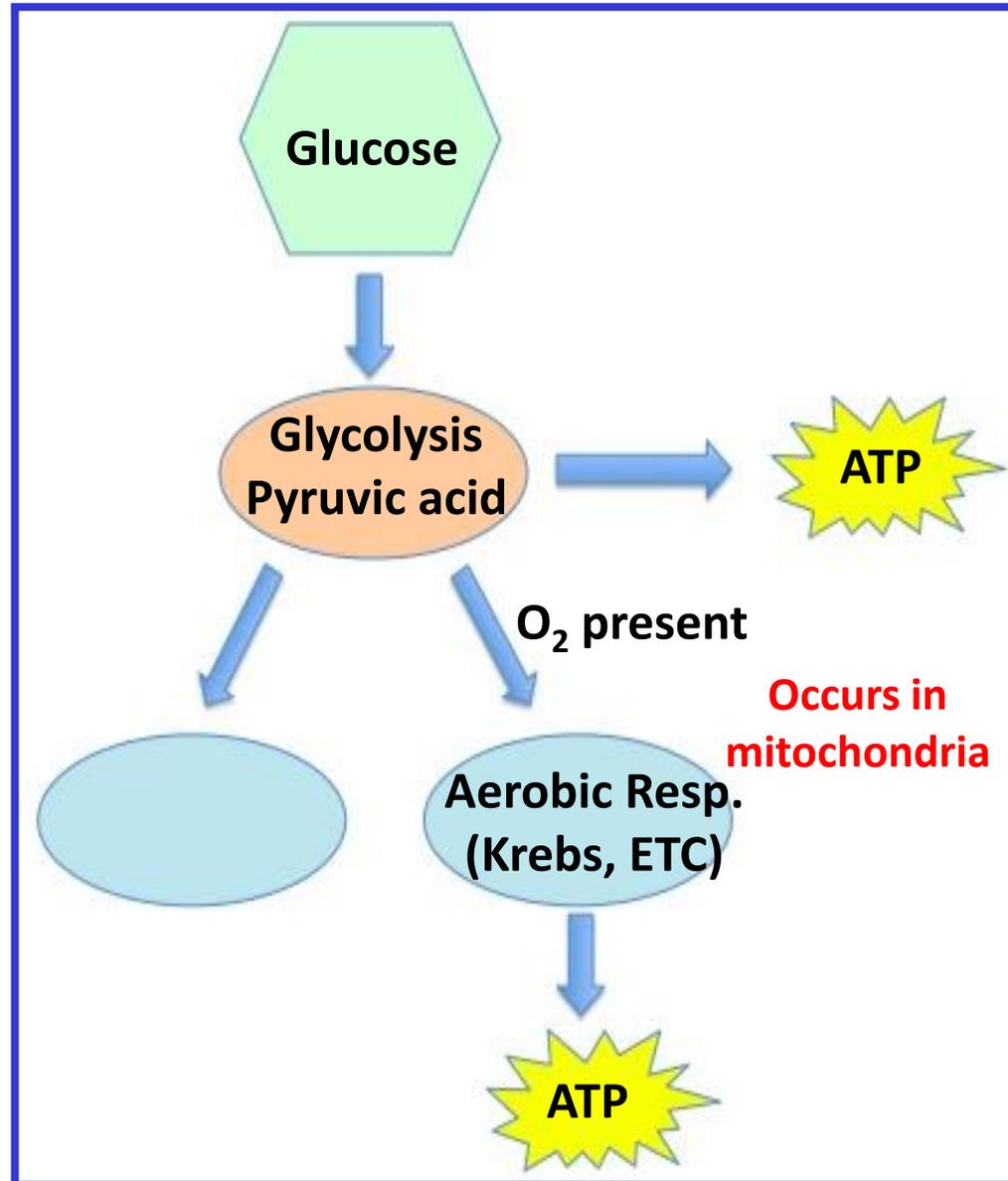
There are two possibilities for the path that pyruvic acid will now take. It depends on whether or not oxygen is present.



The Fate of Pyruvic Acid – What happens to it?

If oxygen is present:

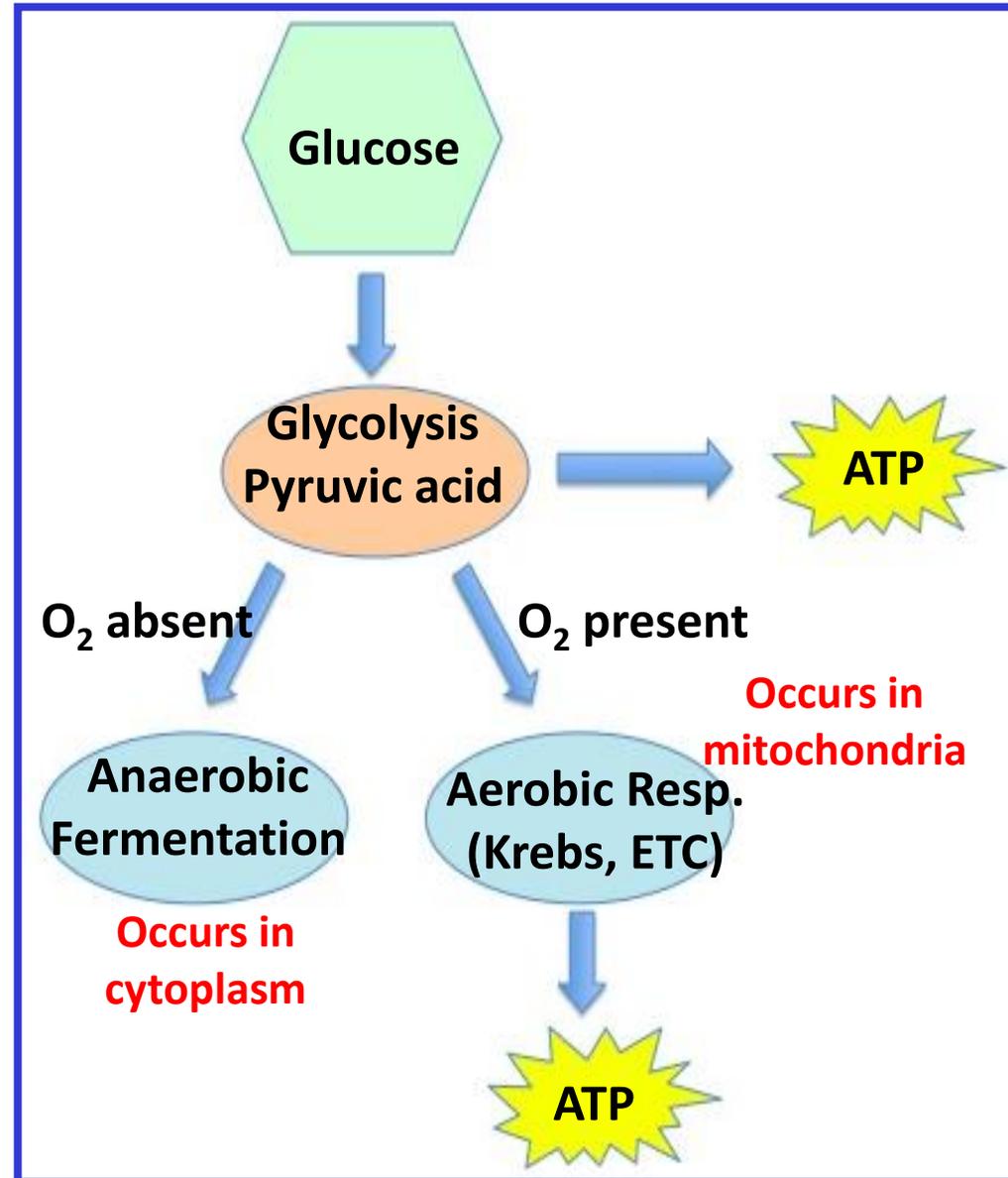
1. In the presence of oxygen, the pyruvic acid will enter the mitochondria and undergo aerobic respiration.
2. Aerobic respiration includes the stages known as the Krebs cycle and the electron transport chain.
3. Aerobic respiration will yield many more ATP than glycolysis.



The Fate of Pyruvic Acid – What happens to it?

If no oxygen is present:

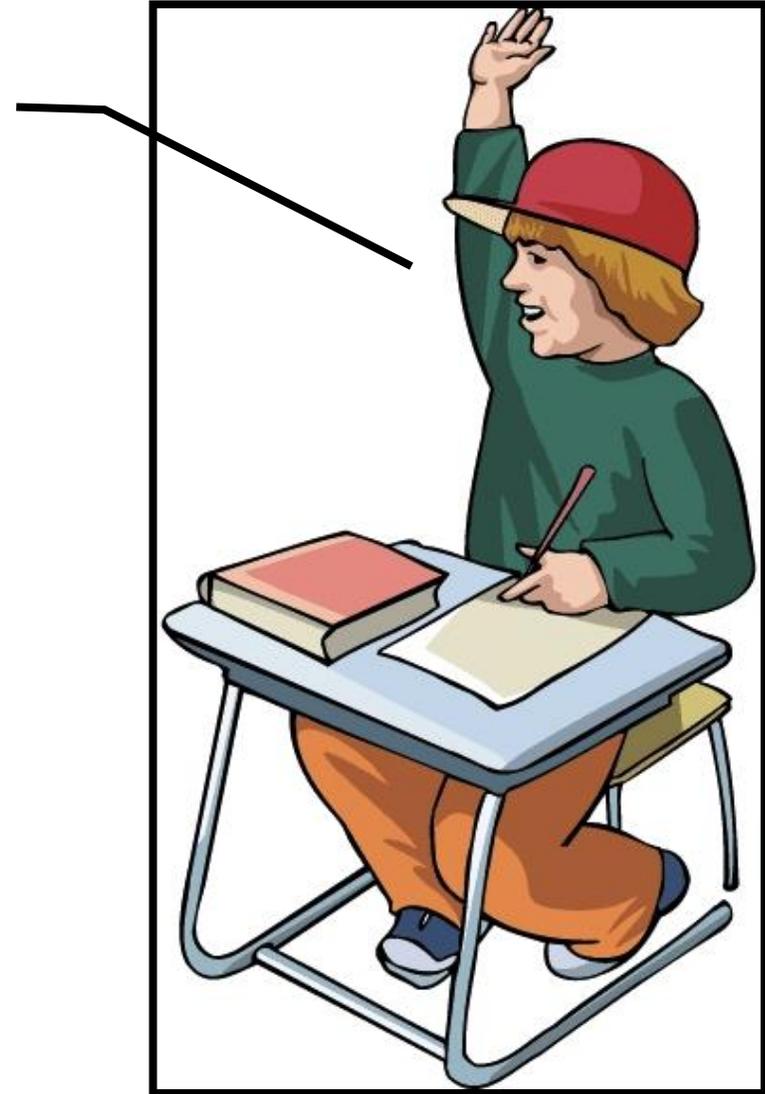
1. In the absence of oxygen, the pyruvic acid will enter the anaerobic pathways of fermentation.
2. Fermentation yields no additional ATP.
3. Occurs in the cytoplasm.



What are the two major stages of aerobic respiration?

Aerobic respiration has two major stages:

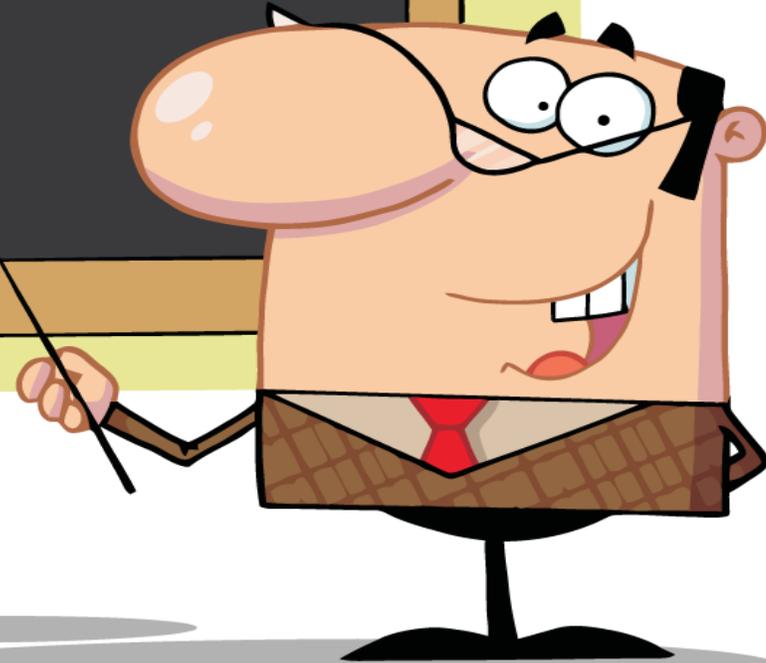
1. The Krebs cycle
2. The electron transport chain



What are the main points of the Krebs cycle?

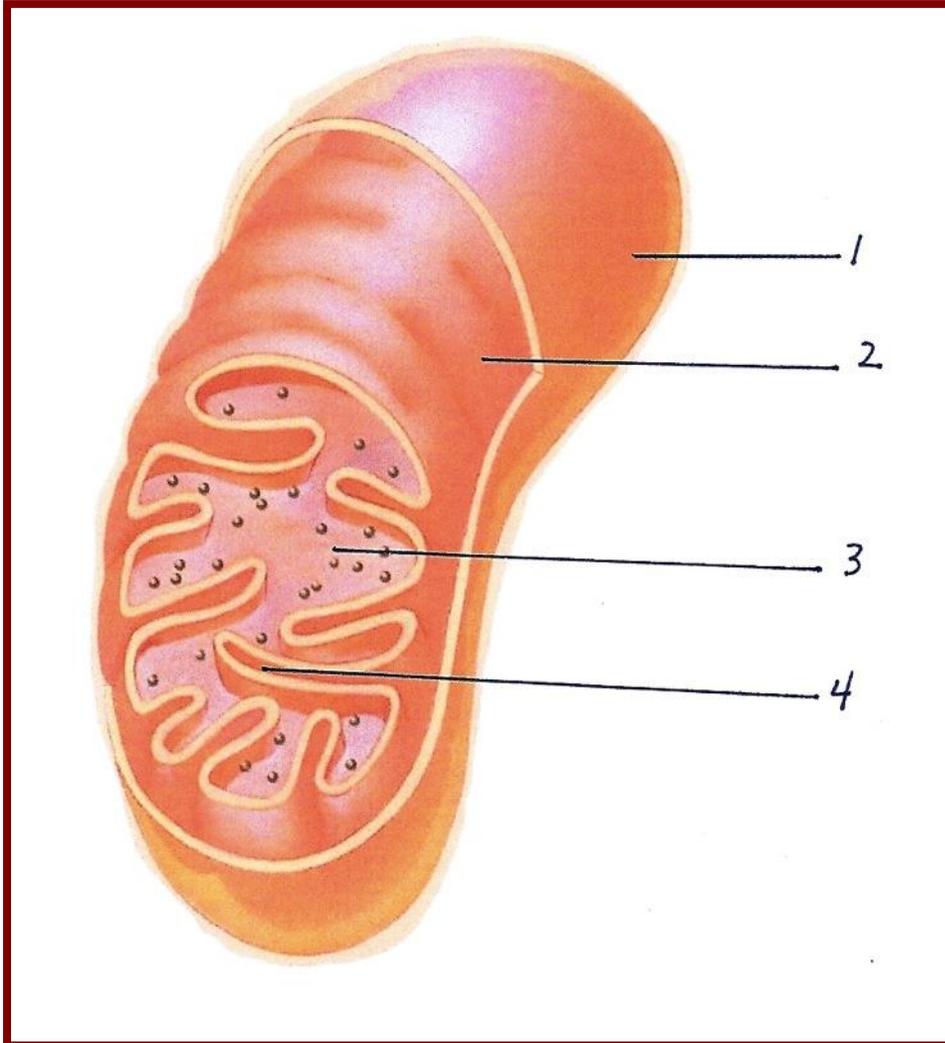
Krebs cycle:

1. The oxidation of glucose is completed.
2. The hydrogen that is removed from pyruvic acid will be accepted by NAD⁺ to form NADH.
3. There will be:
a small yield of ATP.



Structure of the Mitochondria

Label the following structures found in the mitochondria.



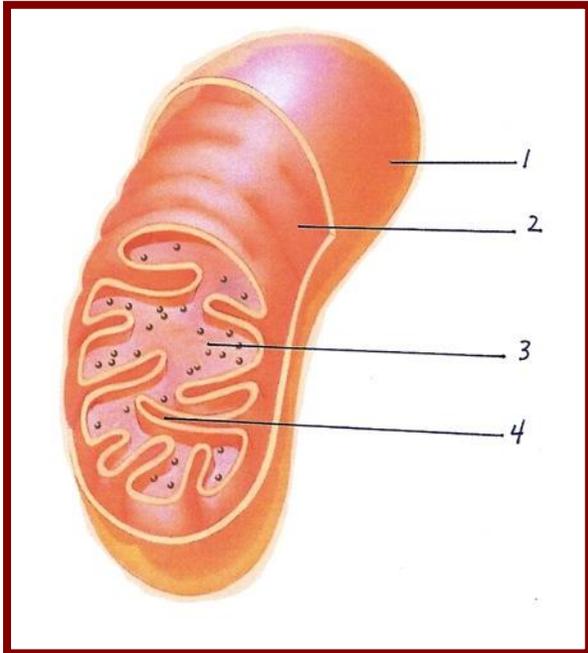
1 – Outer membrane

2 – Inner Membrane

3 – Matrix

4 – Cristae

Structure of the Mitochondria



The Krebs cycle occurs in the matrix of the mitochondria and the electron transport chain occurs along the cristae membranes.

The matrix is the space inside the inner membrane.

It contains...

...the enzymes that are needed for the reactions of the Krebs cycle as well as mitochondrial DNA and ribosomes.

The inner membrane has folds and loops called **cristae**

The cristae:

increase the surface area for the reactions of the respiration process.

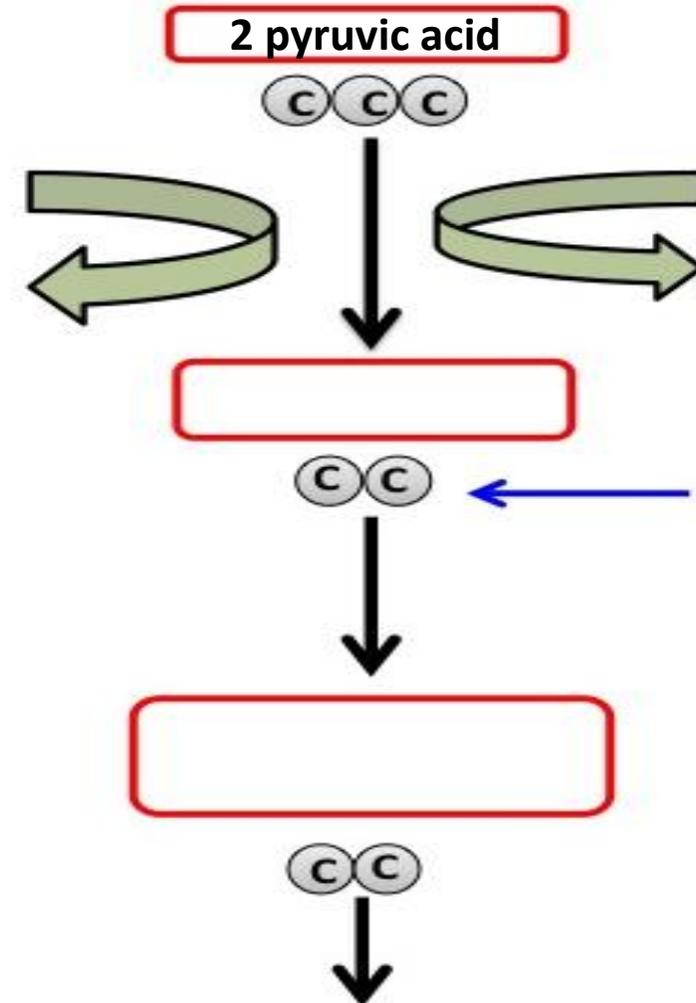
At the end of glycolysis, about 90% of the chemical energy that was available in the glucose molecule is still unused. This energy is locked in: **the high-energy electrons of pyruvic acid.**

The Bridge Reactions:

As the pyruvic acid enters the mitochondria, the following reaction occurs.

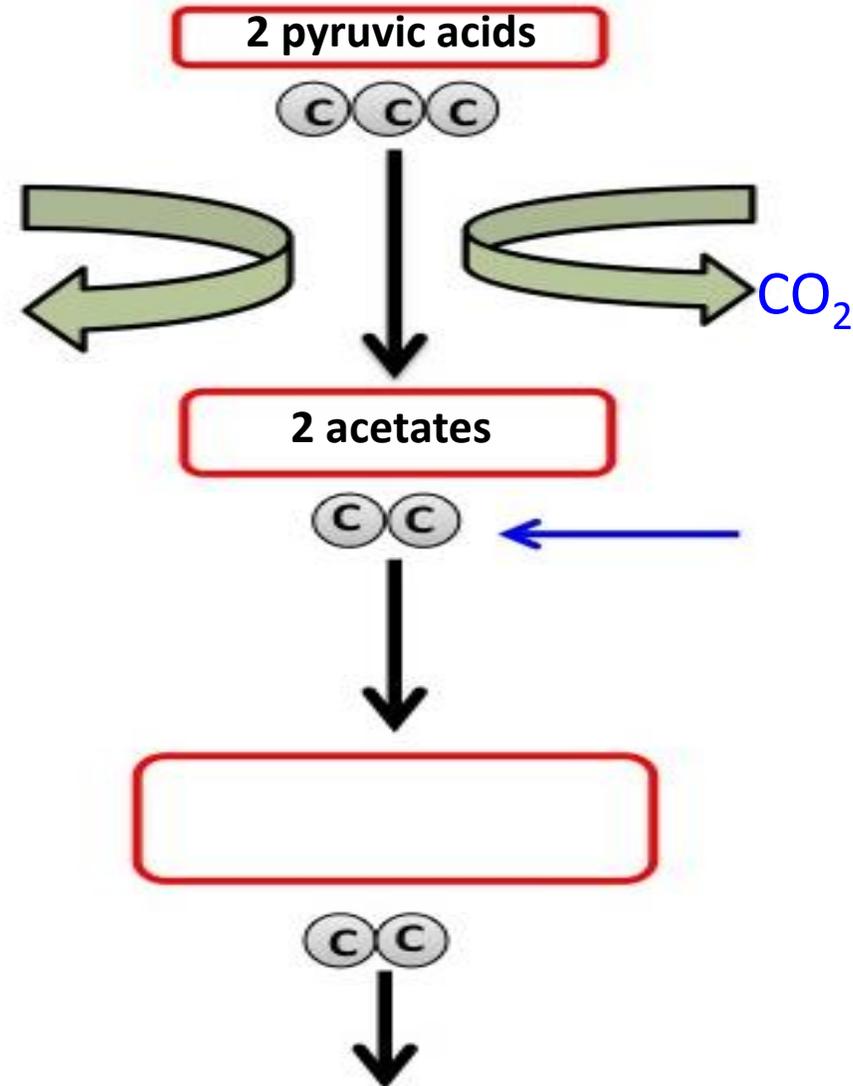
Steps in the Bridge Reaction:

1. Pyruvic acid enters the mitochondria.



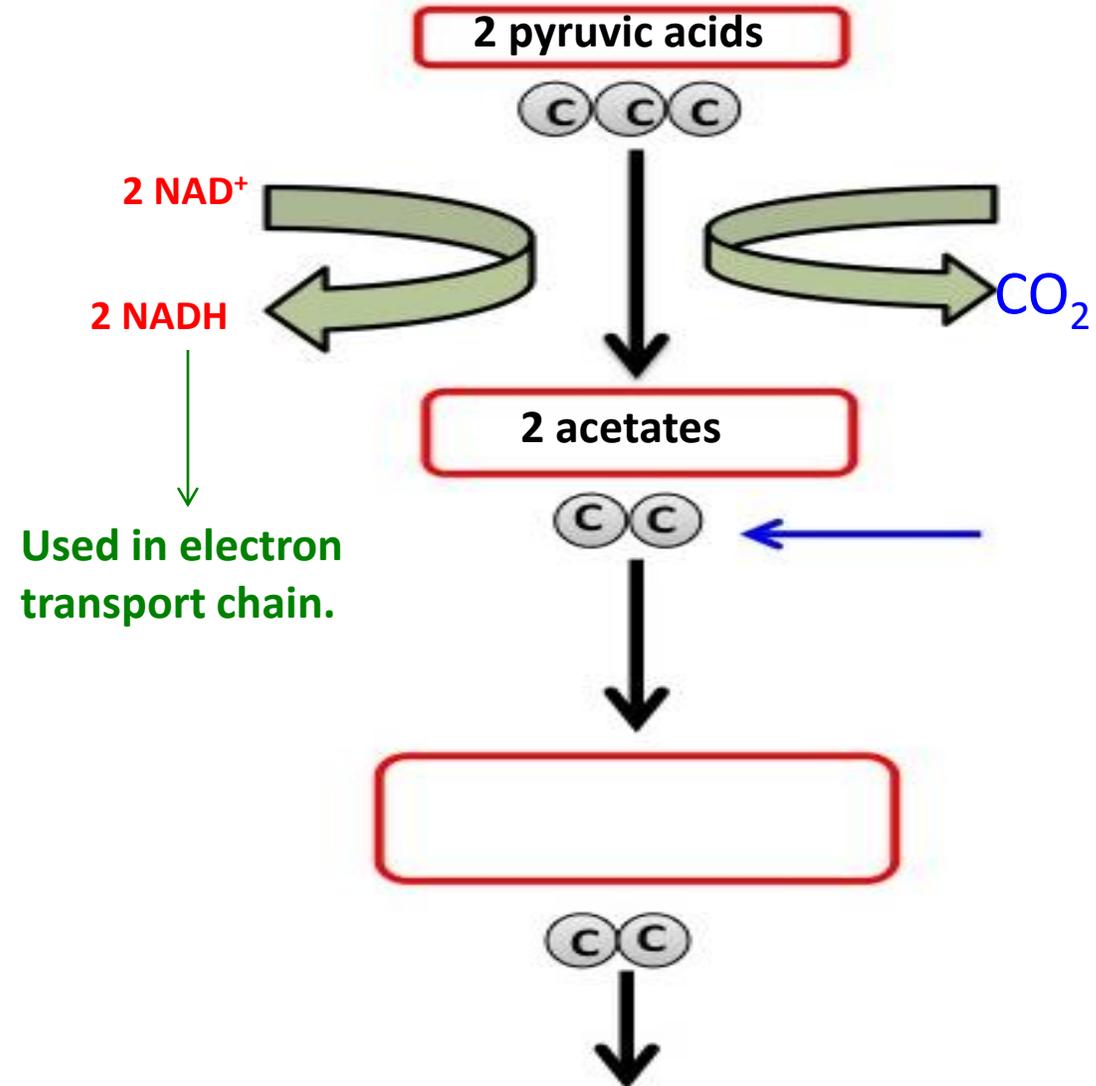
Steps in the Bridge Reaction:

2. The 3-C pyruvic acid is converted to 2-C acetate. This is accomplished by removing a molecule of CO₂ from each molecule of pyruvic acid. The carbon dioxide is: released into the air.



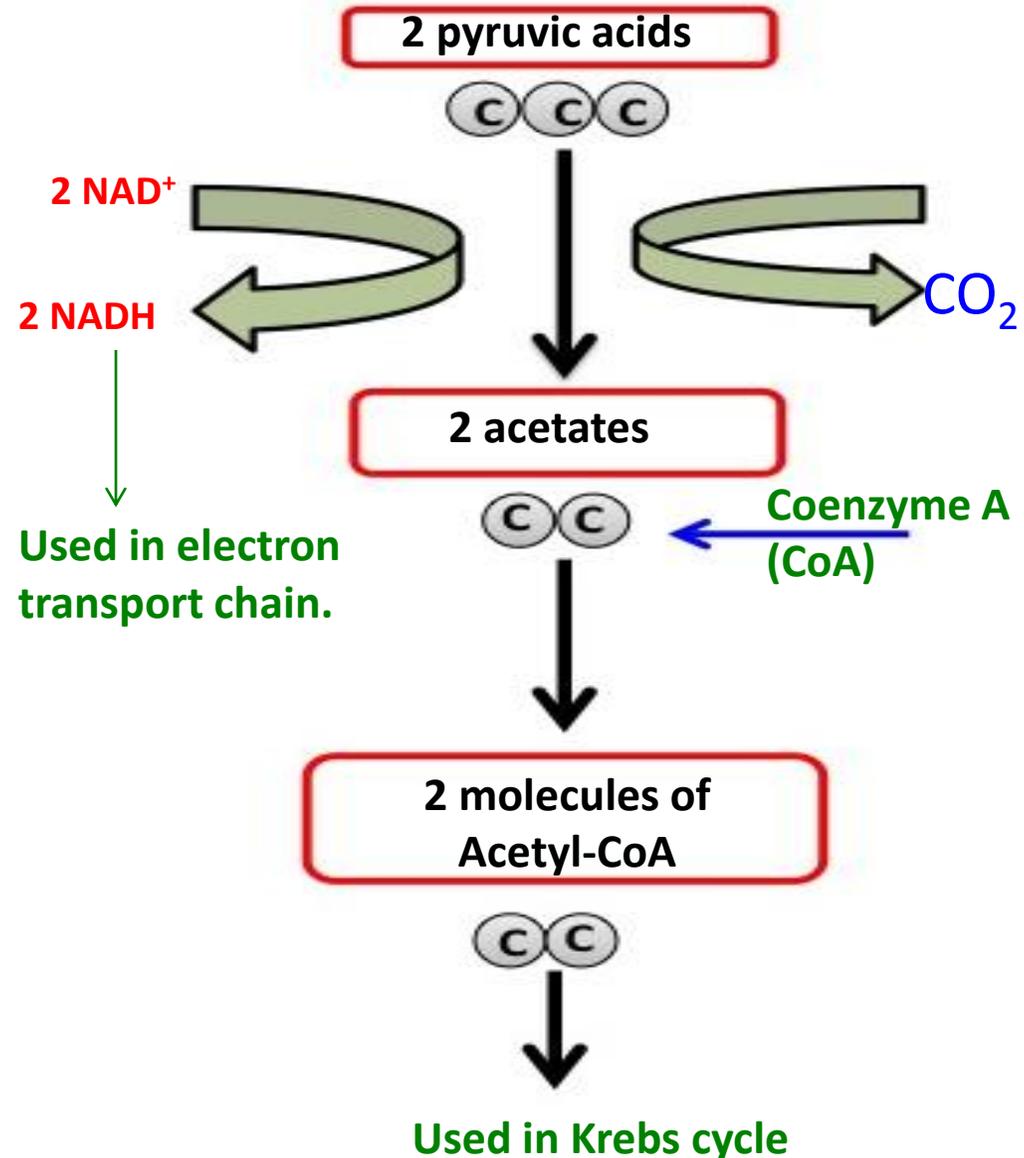
Steps in the Bridge Reaction:

3. For each pyruvic acid that is converted to acetate, one molecule of NAD⁺ is converted to NADH.



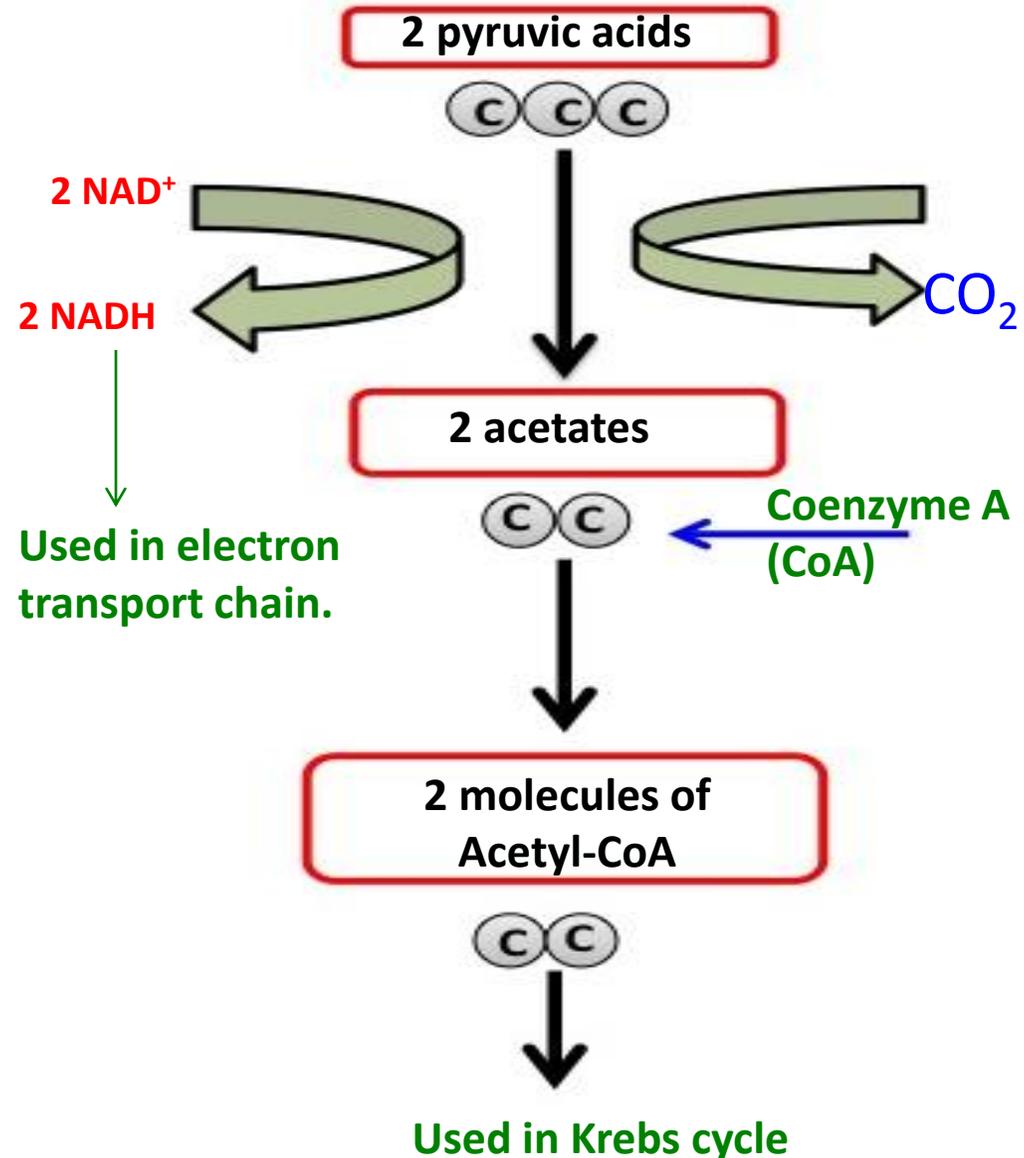
Steps in the Bridge Reaction:

4. Coenzyme A attaches to the acetate to form acetyl CoA. The acetyl-CoA will be used in the Kreb's cycle.



Steps in the Bridge Reaction:

5. This reaction is often referred to as "The Bridge Reaction". It is the bridge between:
- the cytoplasm and the mitochondria
 - anaerobic and aerobic respiration
 - glycolysis and the Krebs cycle.



The Krebs Cycle

The Krebs cycle is a biochemical pathway that uses the acetyl-CoA molecules from the bridge reactions to produce:

- hydrogen atoms
- 2 ATP
- carbon dioxide.

In the **mitochondria**



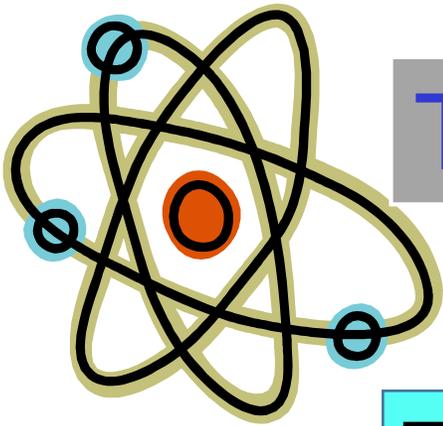
The Krebs cycle is so named to honor Hans Krebs. He was a German – British scientist who was largely responsible for working out the pathway in the 1930's.

What happens to each of these products?



- a) The carbon dioxide is released when you exhale.
- b) The ATP is used for cellular activities.
- c) The NADH and the FADH_2 will be used in the next stage to generate huge amounts of ATP.

Most of the energy contained in the original glucose molecule still has not been transferred to ATP. This transfer of energy will occur in the next step, the electron transport chain.



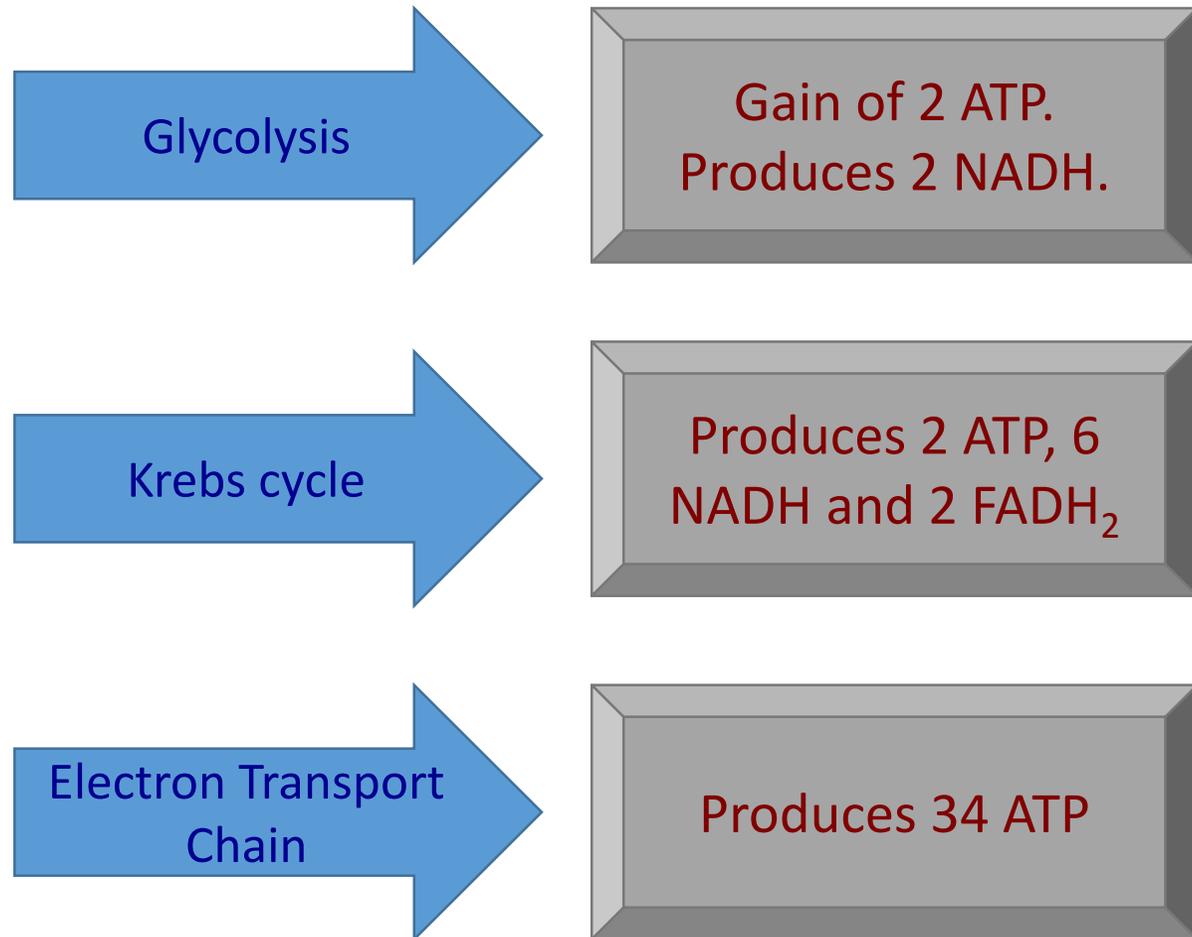
The Electron Transport Chain

The electron transport chain consists of a series of proteins that are embedded in the cristae of the mitochondria in eukaryotic cells.

The purpose of NADH and FADH₂ is to... **release hydrogen atoms, generating energy to produce 34 ATP.**

ATP Accounting

Let's summarize what has happened prior to the electron transport chain:



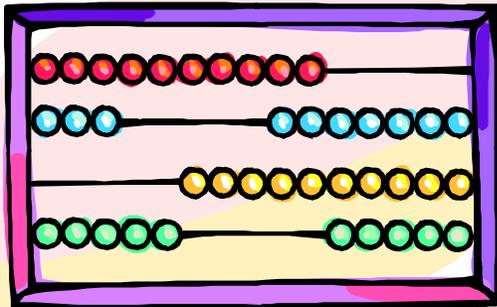
ATP Accounting

Glycolysis → 2 ATP

Krebs cycle → 2 ATP

Electron Transport Chain
→ 34 ATP

One molecule of glucose has produced 38 ATP.



Only about 40% of the energy contained in the glucose molecule has been converted to ATP. The remaining 60% is given off as heat.

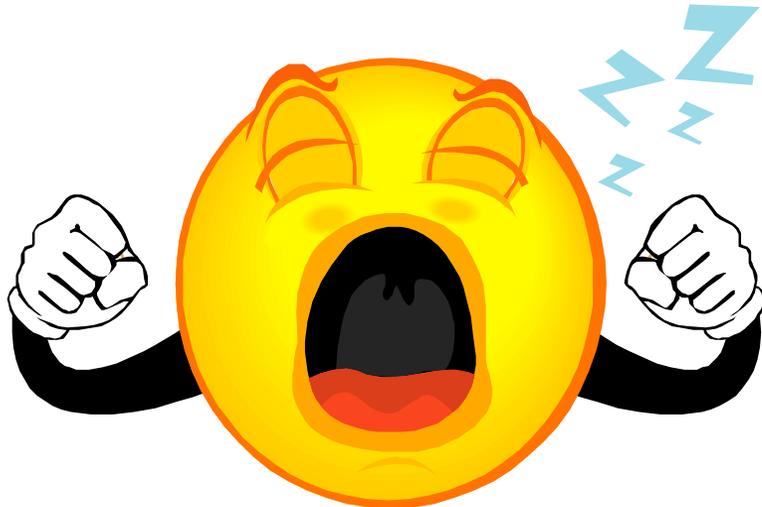
F E R M E N T A T I O N

Fermentation occurs when:
oxygen is not present.



Since no oxygen is required,
fermentation is an anaerobic
process.

The anaerobic pathways are not very efficient in
transferring energy from glucose to ATP.



Fermentation will
yield only a gain of
2 ATP per
molecule of glucose.

There are two main types of fermentation:

Alcoholic fermentation →

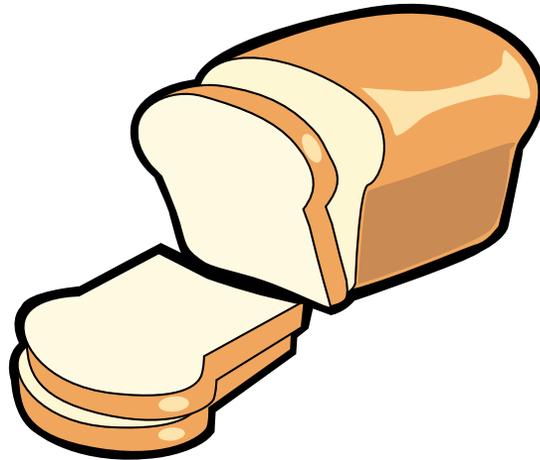


← Lactic acid fermentation

Alcoholic Fermentation

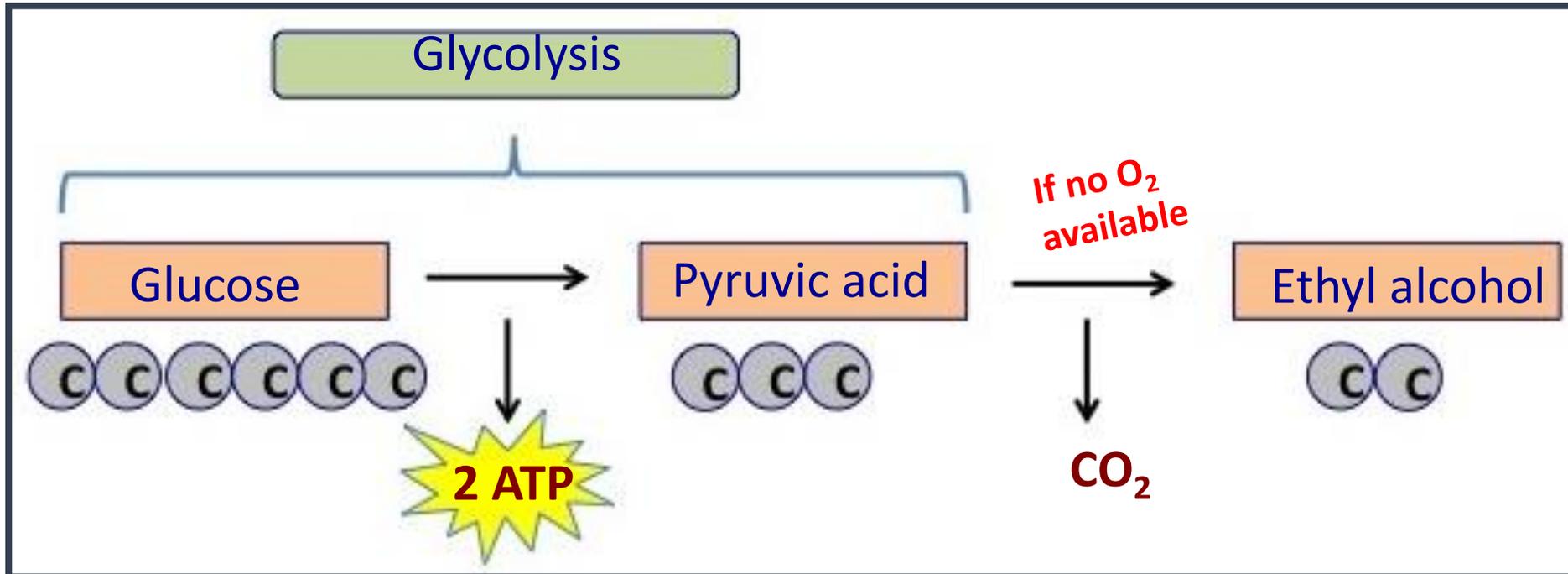
Yeasts perform alcoholic fermentation.

Yeasts convert pyruvic acid into ethyl alcohol when they run out of oxygen.



Yeasts are used to make breads and alcohol.

The Steps of Alcoholic Fermentation

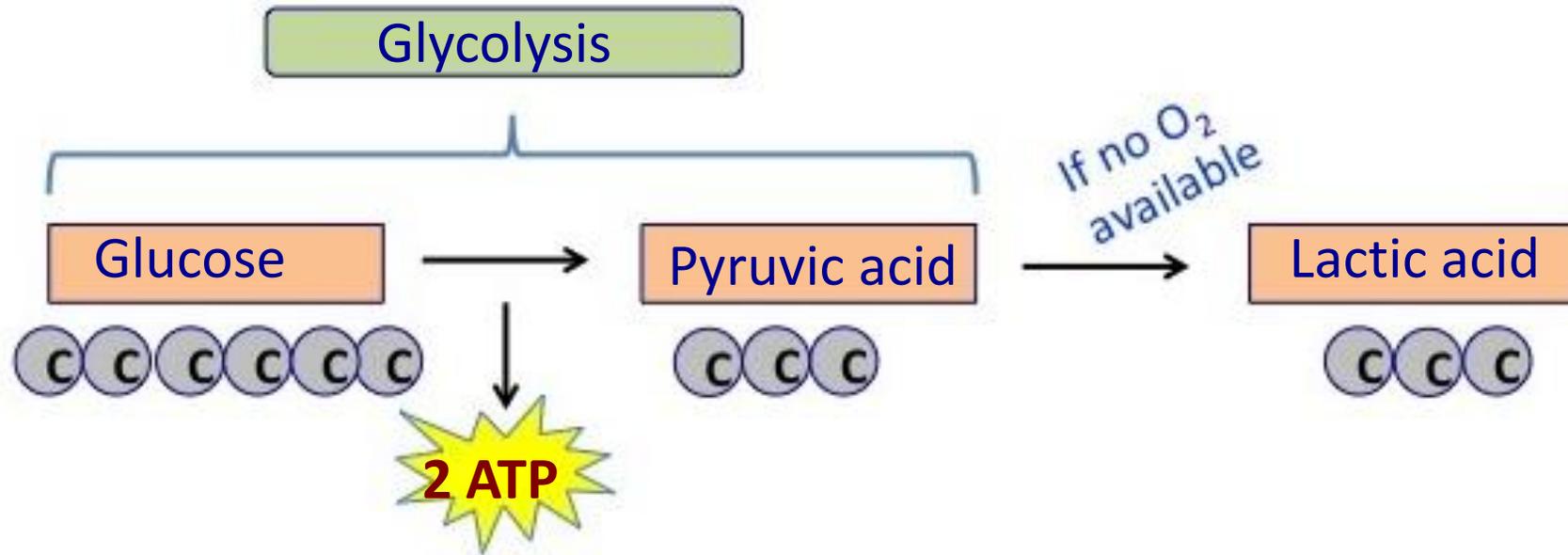


Yeasts are used in this way in both the alcohol and the baking industries.

The alcohol makes alcoholic beverages.

The carbon dioxide that is given off causes bread dough to rise. Small bubbles are formed in the dough, making the bread rise. (The alcohol evaporates during the baking process.)

The Steps of Lactic Acid Fermentation



Pyruvic acid is converted to lactic acid by muscle cells when there is a shortage of oxygen. It is produced in muscle cells during strenuous exercise because the muscles are using up the oxygen that is present and the body is not supplying the muscle tissue with enough additional oxygen.



This causes severe cramps because it lowers the pH of the muscle and reduces the muscle's ability to contract.
When oxygen returns to the muscles, the lactic acid will be converted back to pyruvic acid. The pyruvic acid will then go into aerobic respiration.

A wide variety of foods are produced by bacteria using lactic acid fermentation: cheese, yogurt, buttermilk, sour cream, pickles, sauerkraut.



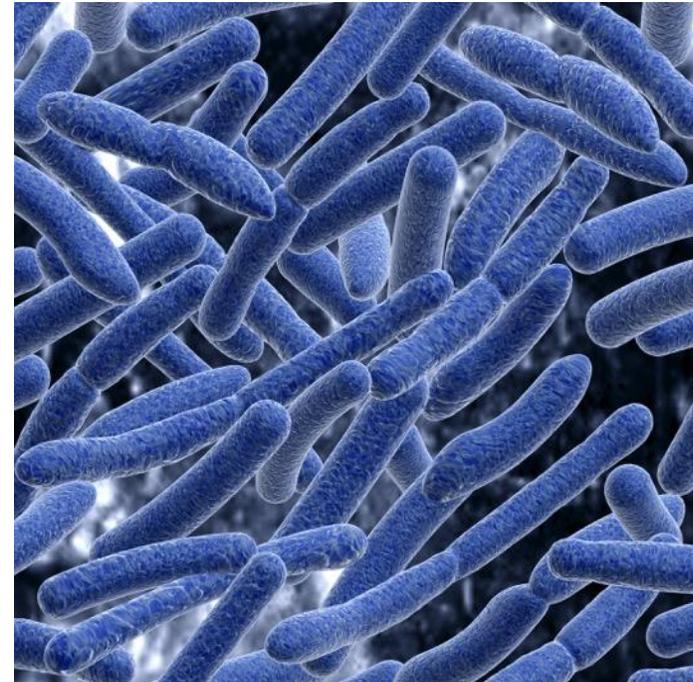
Evolution of Anaerobic Pathways



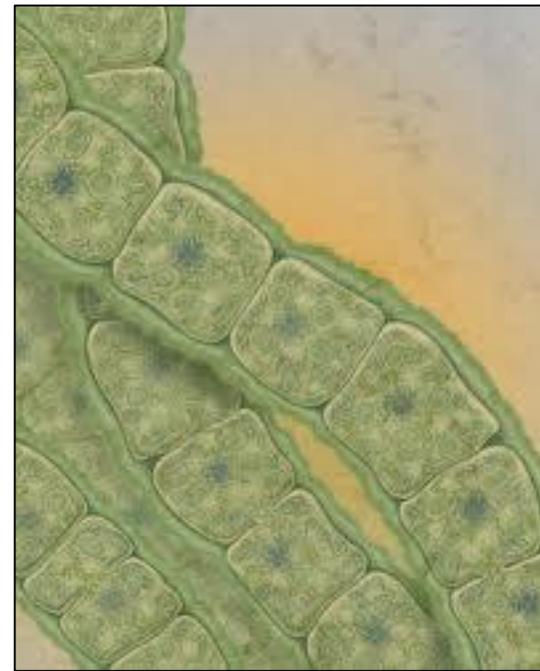
The anaerobic pathways probably evolved very early in the history of life on Earth.

The first organisms were bacteria and they produced all of their ATP through glycolysis.

It took over a billion years for the first photosynthetic organisms to appear on Earth.

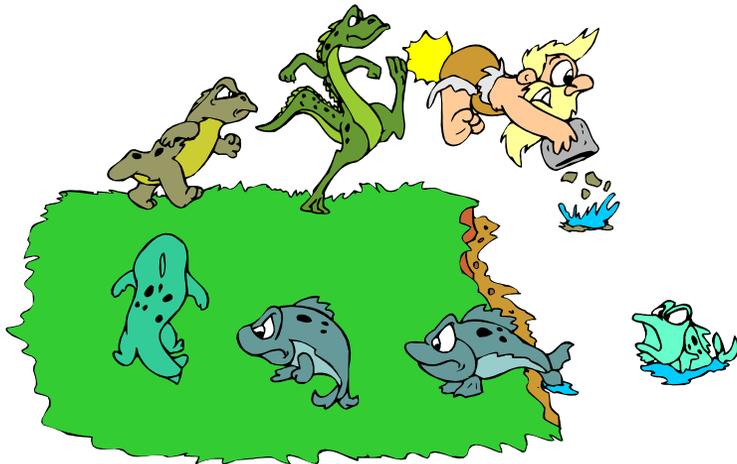


These photosynthetic organisms began to fill the atmosphere with oxygen, which stimulated the evolution of organisms that use aerobic respiration.



The anaerobic pathways provide enough energy for only:

small, unicellular organisms.



Larger organisms have much greater energy requirements that cannot be satisfied by anaerobic respiration alone. Larger organisms rely on the more energy efficient pathways of aerobic respiration.

Comparing Photosynthesis to Respiration

	Photosynthesis	Respiration
Function	Energy capture.	Energy release.
Location	Chloroplasts	Mitochondria
Reactants	CO ₂ and H ₂ O	C ₆ H ₁₂ O ₆ and O ₂
Products	C ₆ H ₁₂ O ₆ and O ₂	CO ₂ and H ₂ O
Equation	$\text{CO}_2 + \text{H}_2\text{O} + \text{sun} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 \text{ and } \text{O}_2$	$\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 38 \text{ ATP}$