Cellular Respiration: An Overview

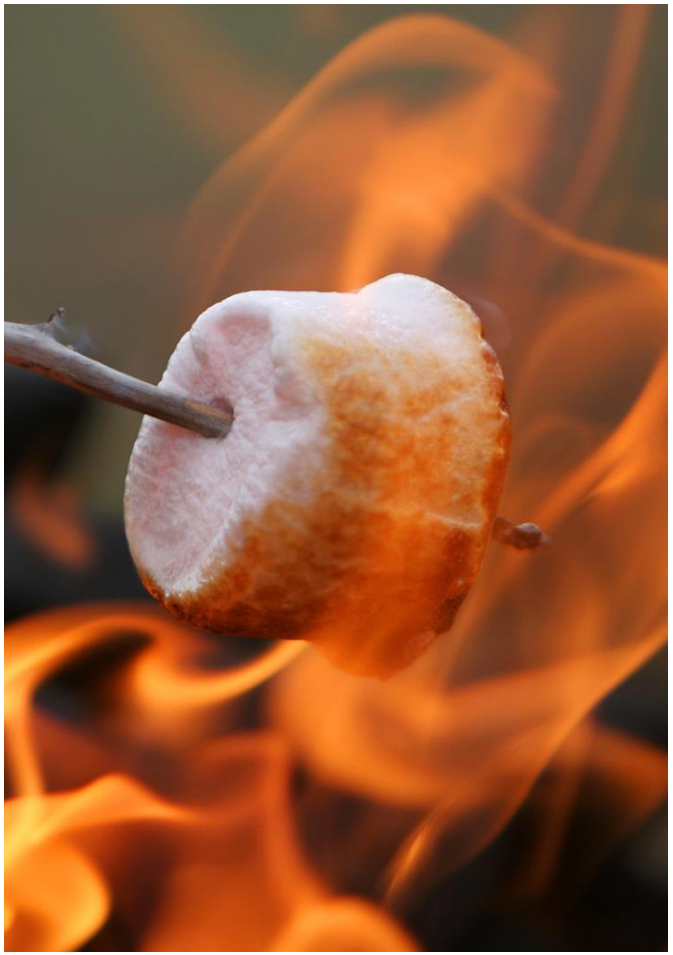
Learning Objectives

- Identify how organisms get energy.
- Explain how cellular respiration works.
- Explain the relationship between photosynthesis and cellular respiration.

Cellular Respiration

Cellular respiration is a process of energy conversion that releases energy from food in the presence of oxygen.

What forms of energy are produced from the toasting of the marshmallow?



The chemical energy in food is released slowly throughout cellular respiration

Cellular Respiration

The chemical summary of cellular respiration is:

Oxygen + Glucose $\rightarrow$ Carbon Dioxide + Water + Energy

What does the equation look like expressed in symbols?

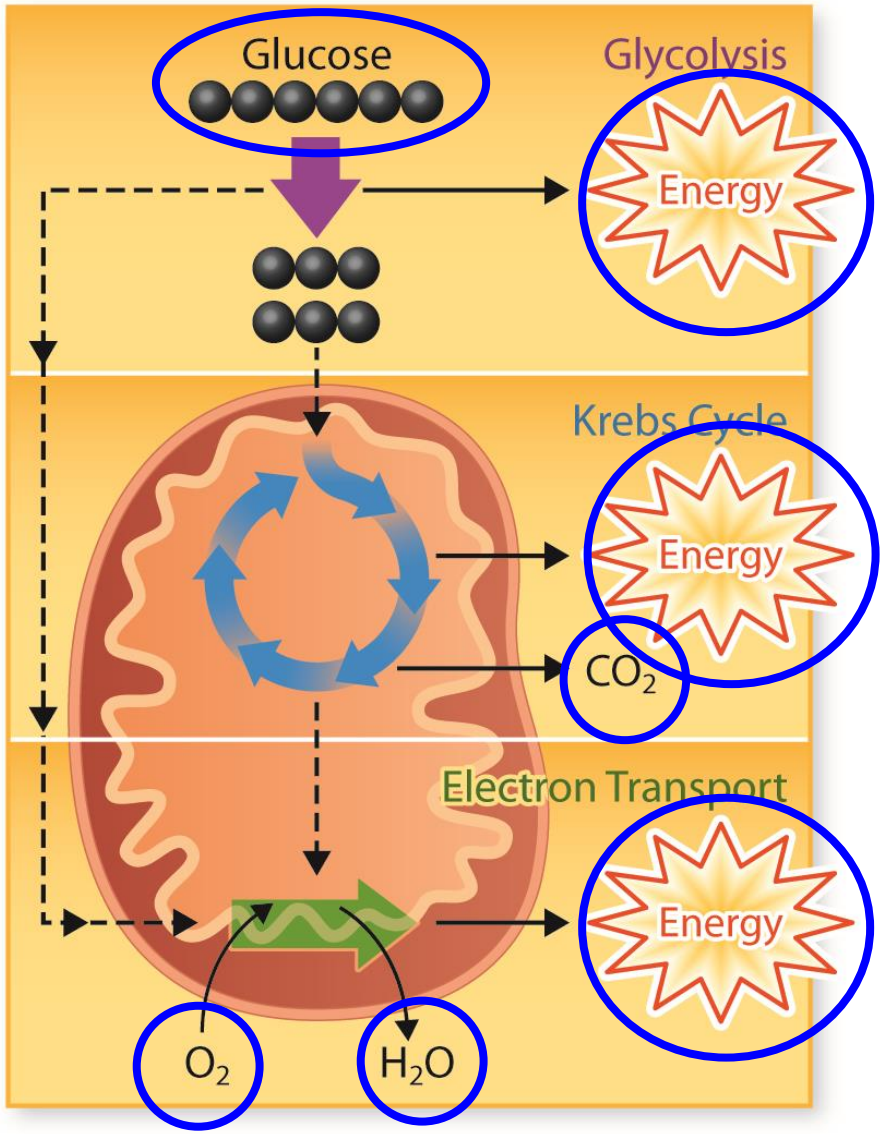
$$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Note: this equation is a summary of many sub-reactions

Stages of Cellular Respiration

- Glycolysis
- Krebs cycle
- Electron transport

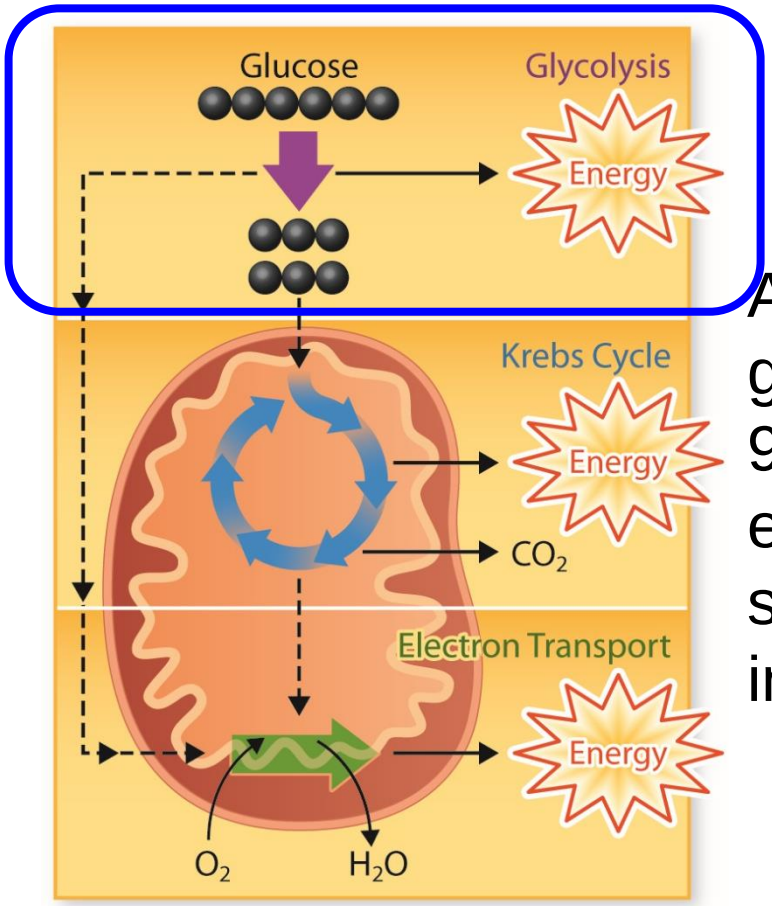
Discuss: Compare the equation to the diagram-where are oxygen and glucose used?



Stage 1: Glycolysis

Glucose first enters a chemical pathway known as glycolysis. A small amount of energy is captured to produce ATP.

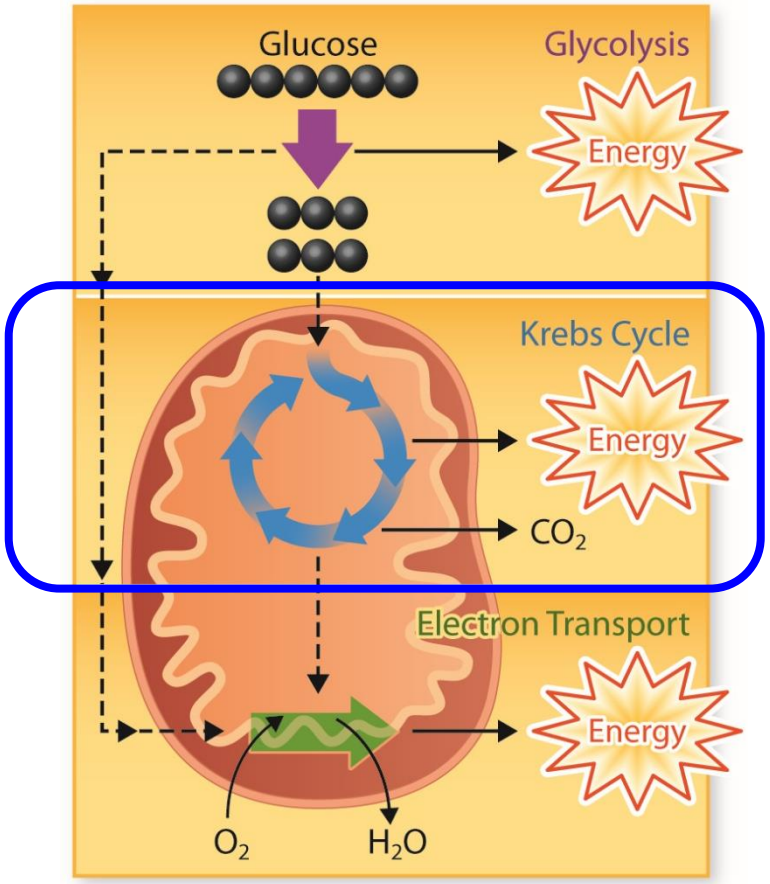
What happens to glucose in this stage?



At the end of glycolysis, about 90% of the chemical energy in glucose is still unused-locked in pyruvic acid

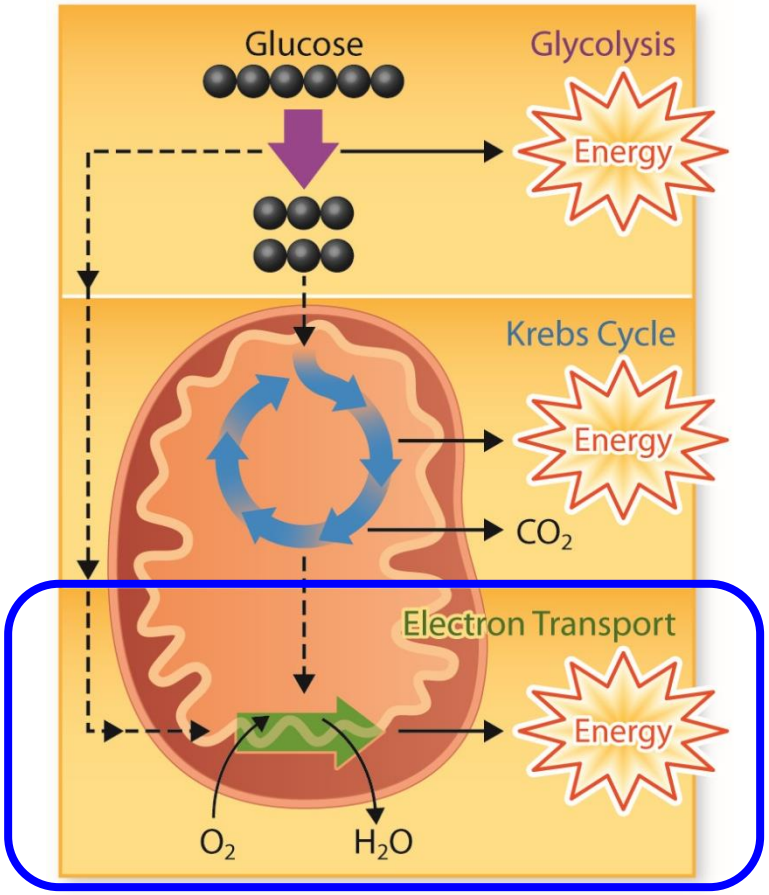
Stage 2: Krebs Cycle

In the second stage of cellular respiration a little more energy is converted.



Stage 3: Electron Transport

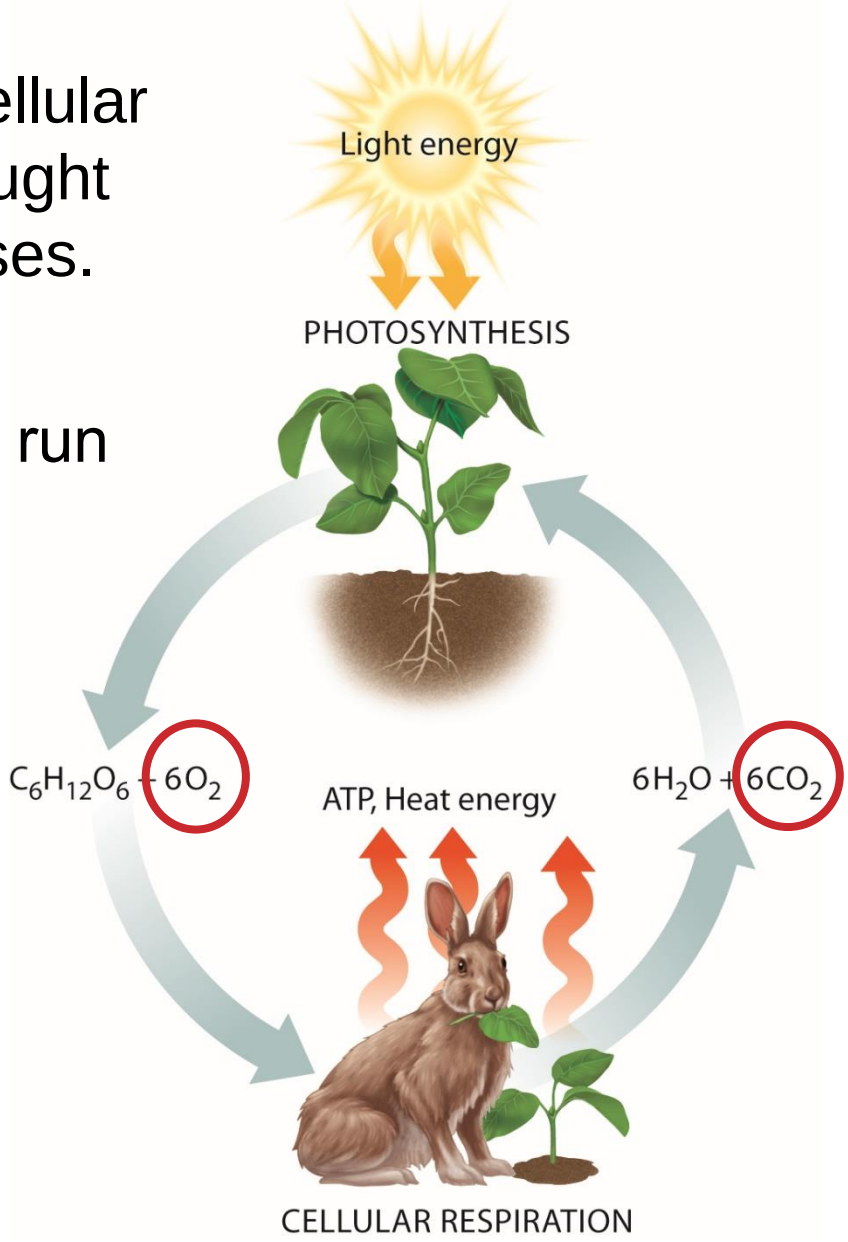
The final stage requires reactants from the other two stages of the process. The most energy comes from this stage.



Photosynthesis and Cellular Respiration

Photosynthesis and cellular respiration can be thought of as opposite processes.

Why doesn't the Earth run out of oxygen?



The Process of Cellular Respiration

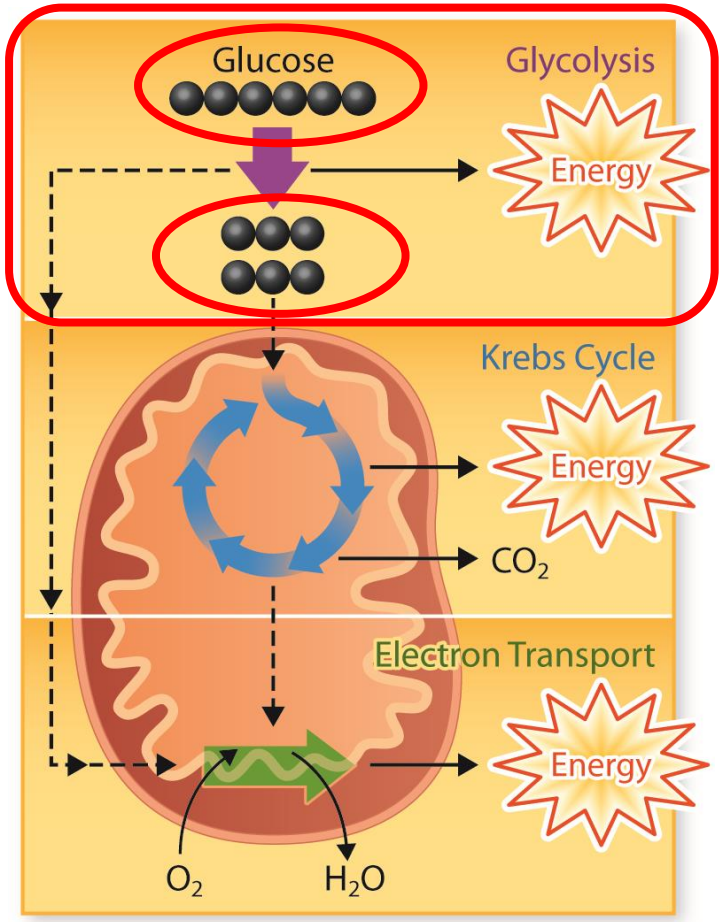
Learning Objectives

- Identify what happens during glycolysis.
- Identify what happens during the Krebs cycle.
- Explain how the electron transport chain uses high-energy electrons from glycolysis and the Krebs cycle.
- Calculate how much ATP cellular respiration generates.

Glycolysis

One molecule of glucose is converted to two molecules of pyruvic acid.

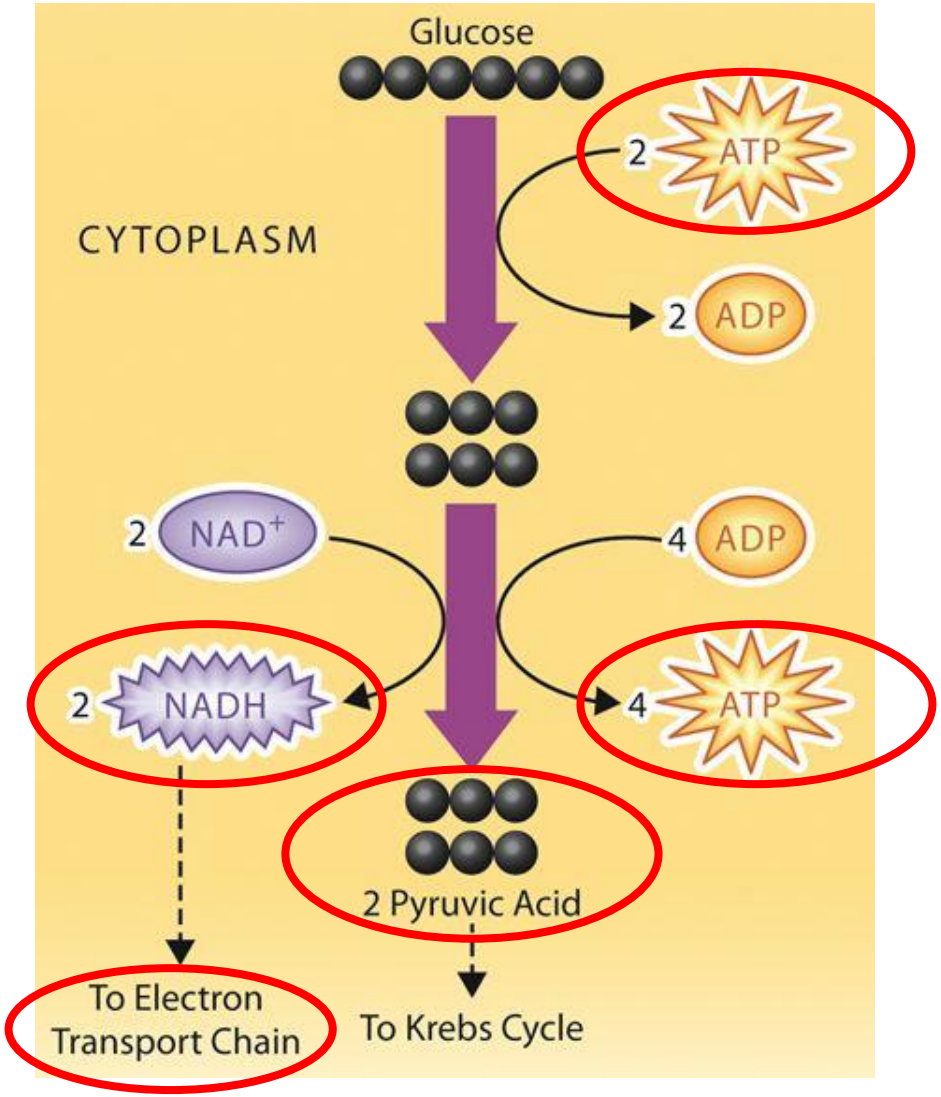
What do the dark balls represent?



Glycolysis: ATP and NADH Production

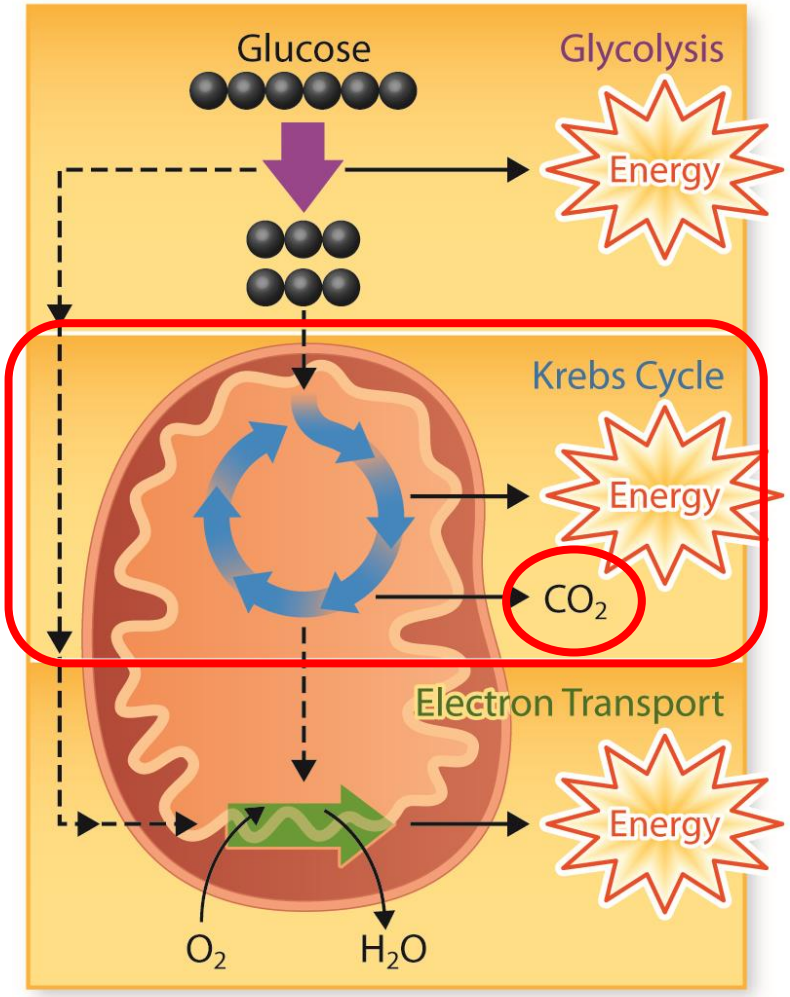
ATP and NADH are produced during glycolysis.

What is required to start glycolysis, besides glucose?



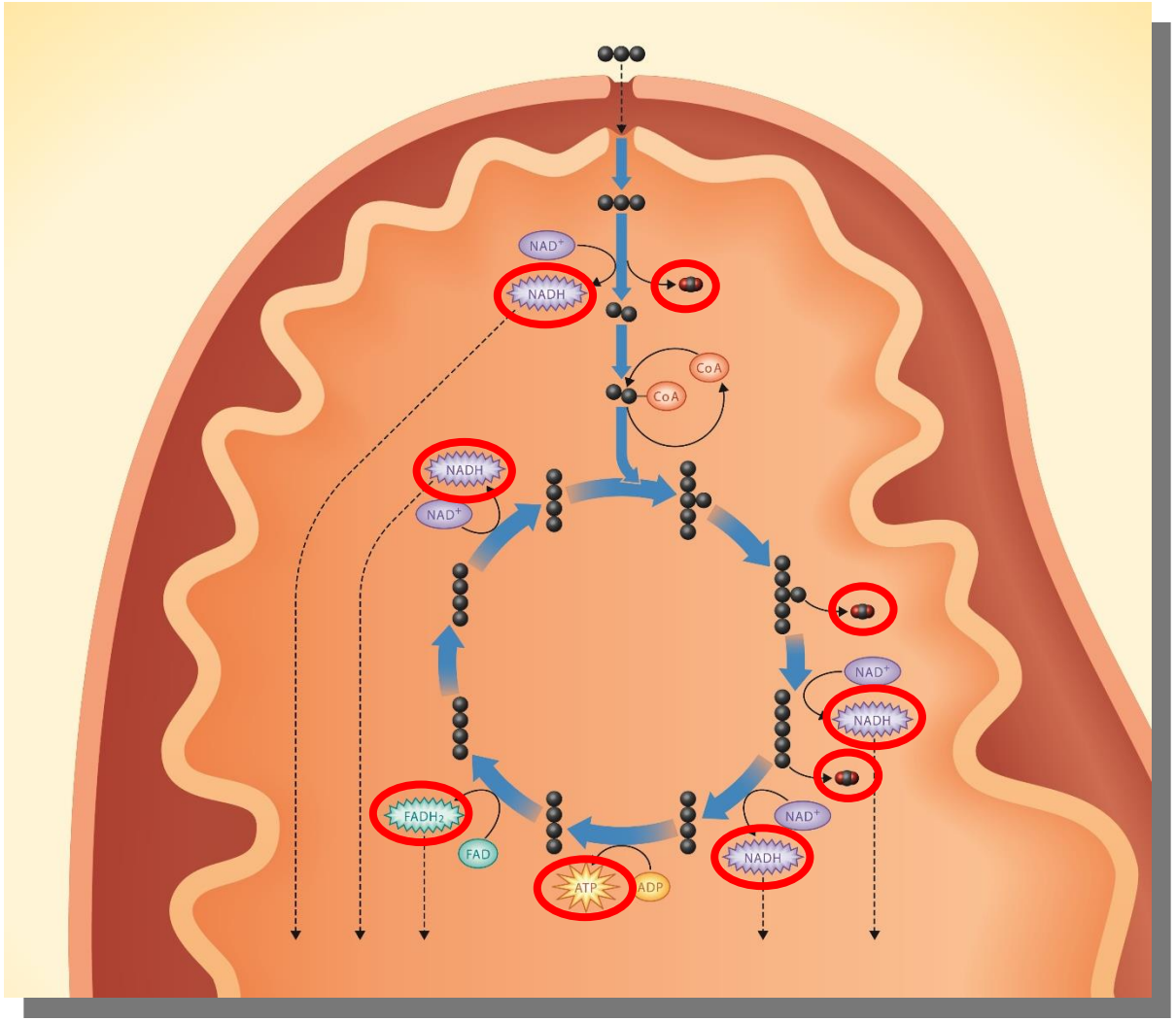
The Krebs Cycle

Pyruvic acid is broken down into carbon dioxide in a series of energy-extracting reactions.



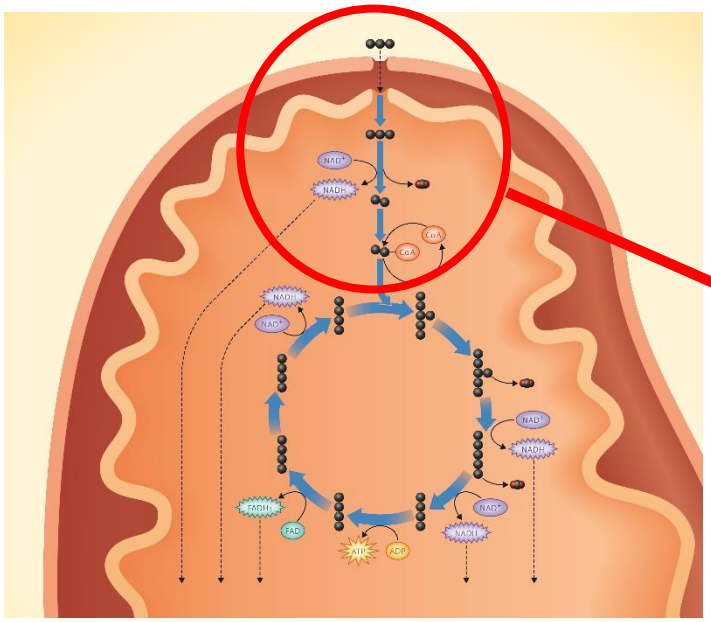
The Krebs Cycle

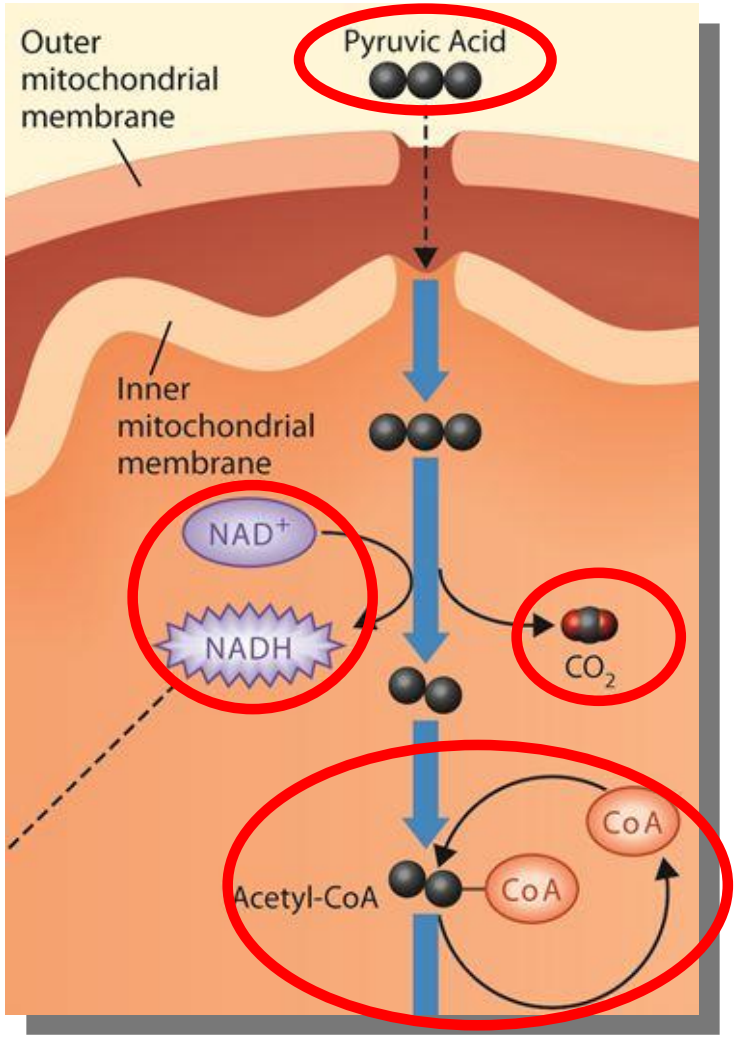
Pyruvic acid from glycolysis is used to make NADH, ATP, and $FADH_2$, with carbon dioxide as a by-product.



The Krebs Cycle

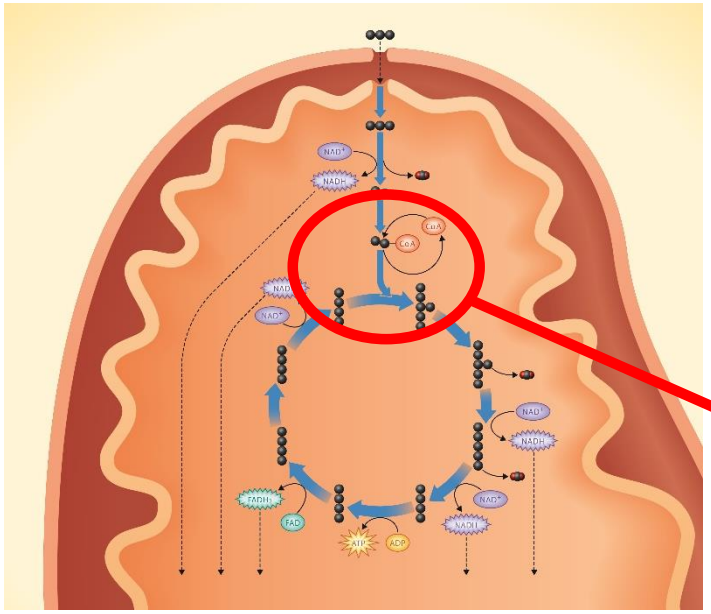
Pyruvic acid passes through the two membranes of the mitochondrion and into the matrix.

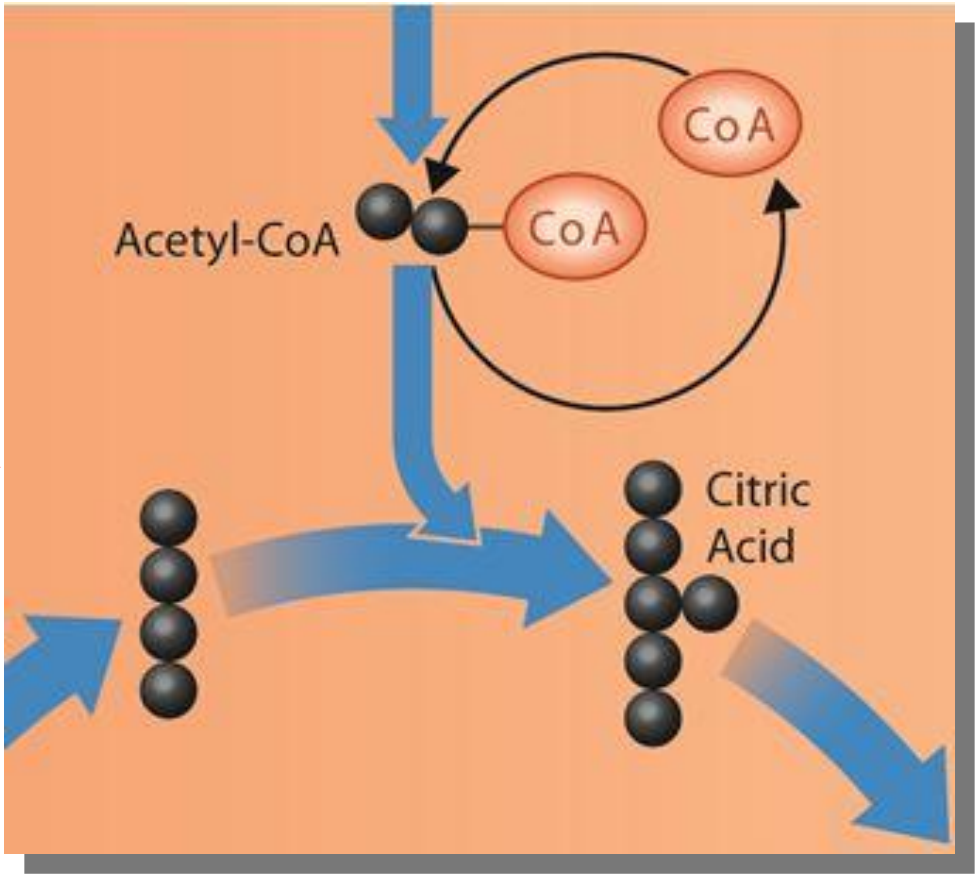




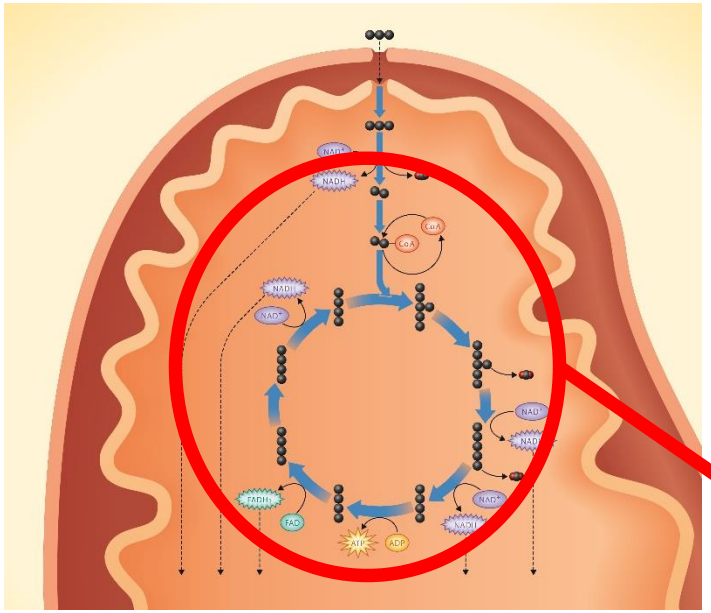
The Krebs Cycle: Citric Acid Production

Acetyl-CoA adds the 2-carbon acetyl group to a 4-carbon molecule already present, producing a 6-carbon molecule called citric acid.

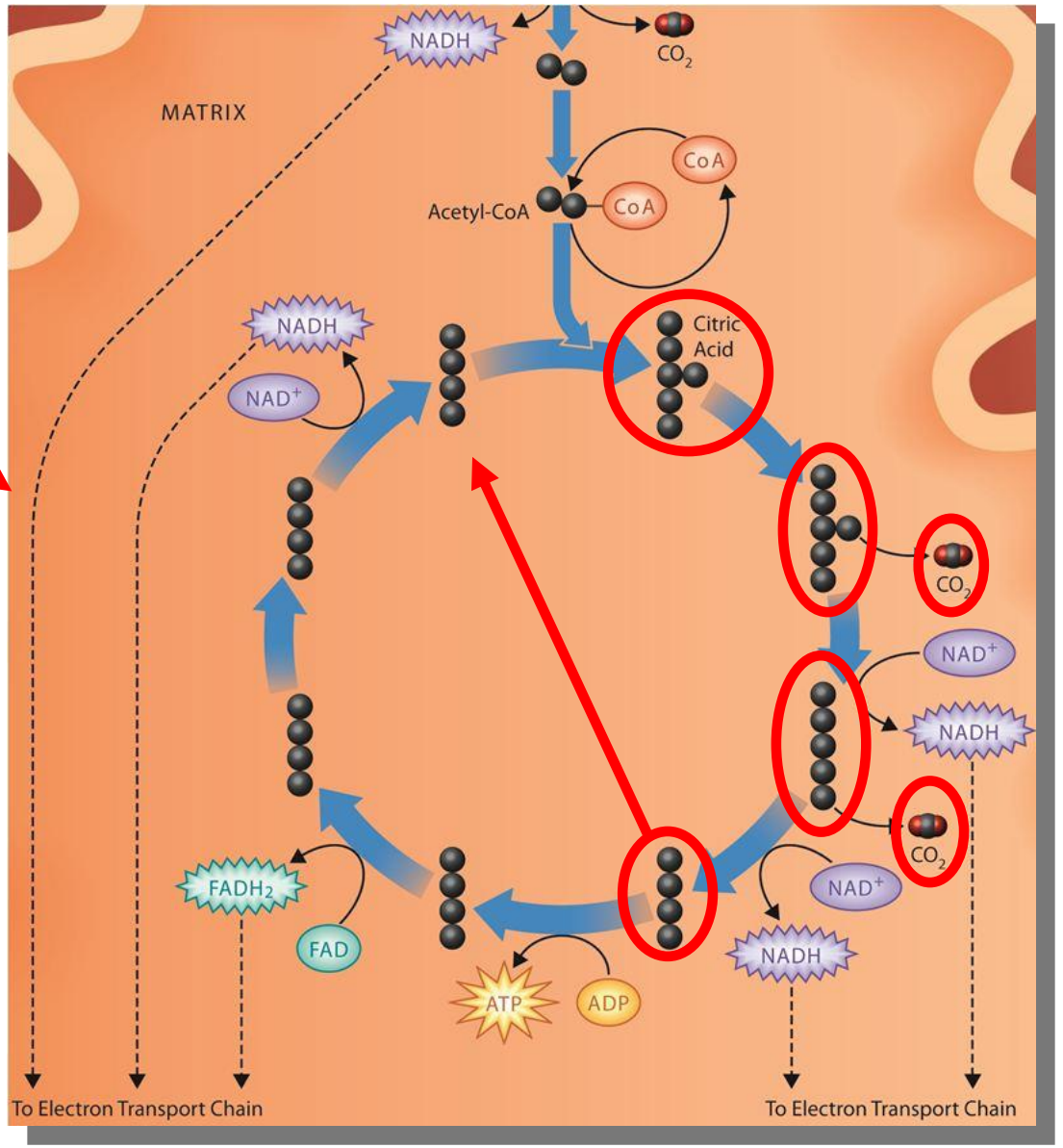




The Krebs Cycle: Energy Extraction

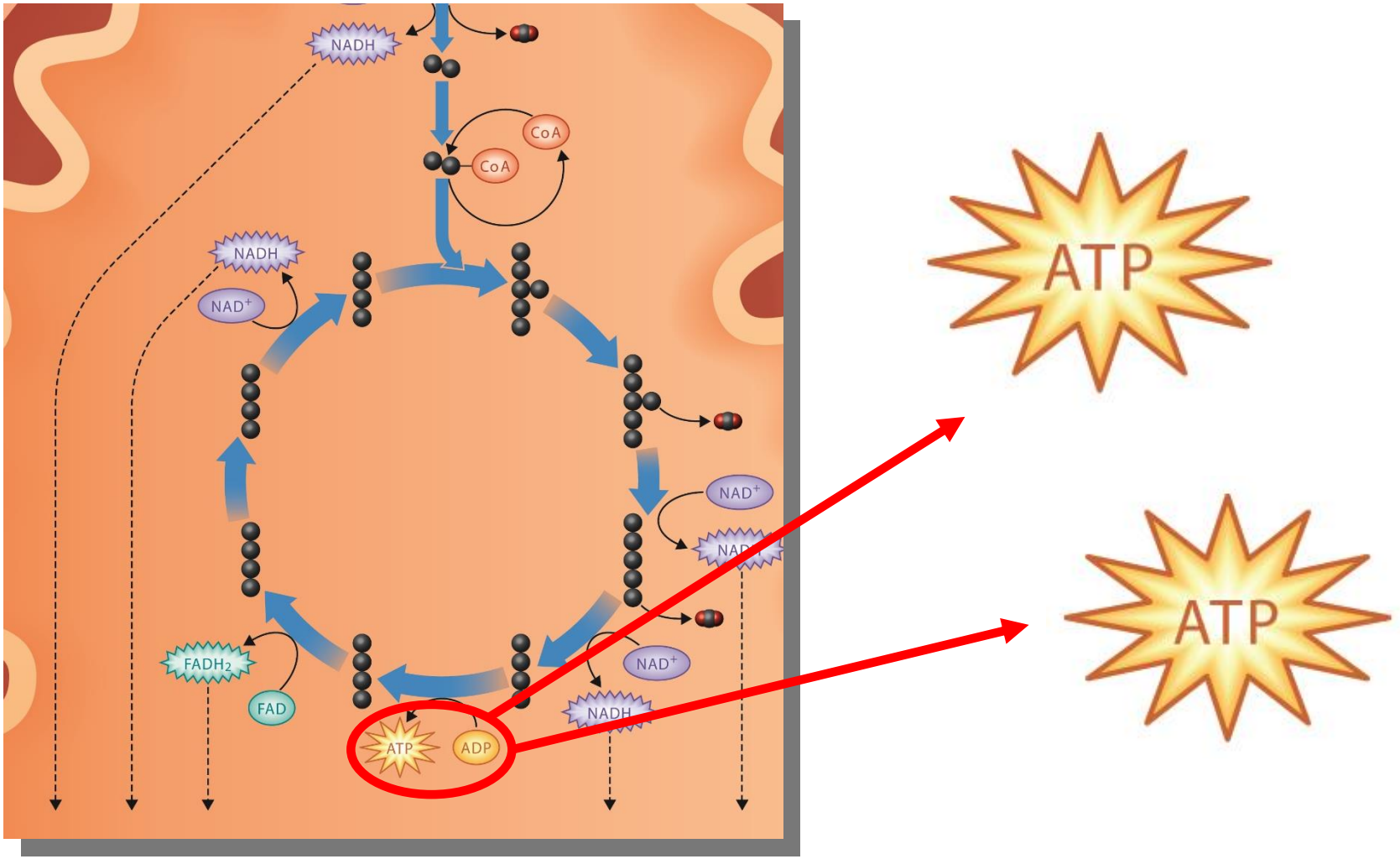


Citric acid is broken down into a 4-carbon molecule, more carbon dioxide is released, and electrons are transferred to energy carriers.



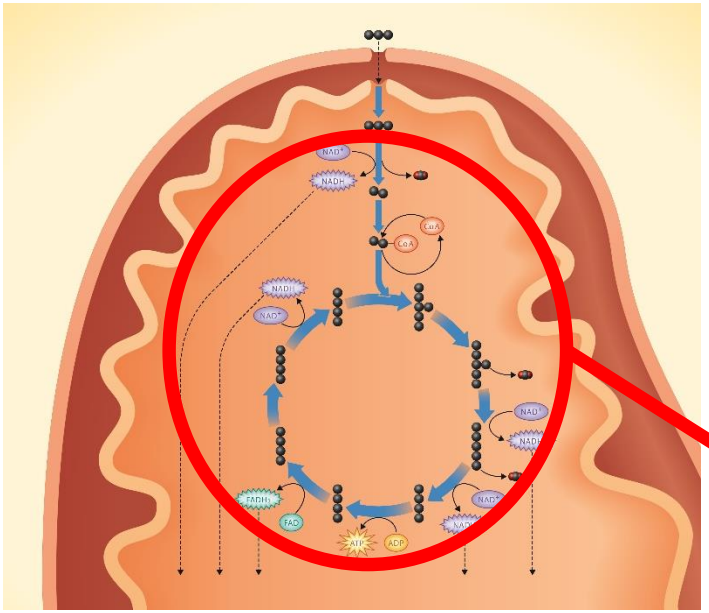
The Krebs Cycle: Energy Extraction

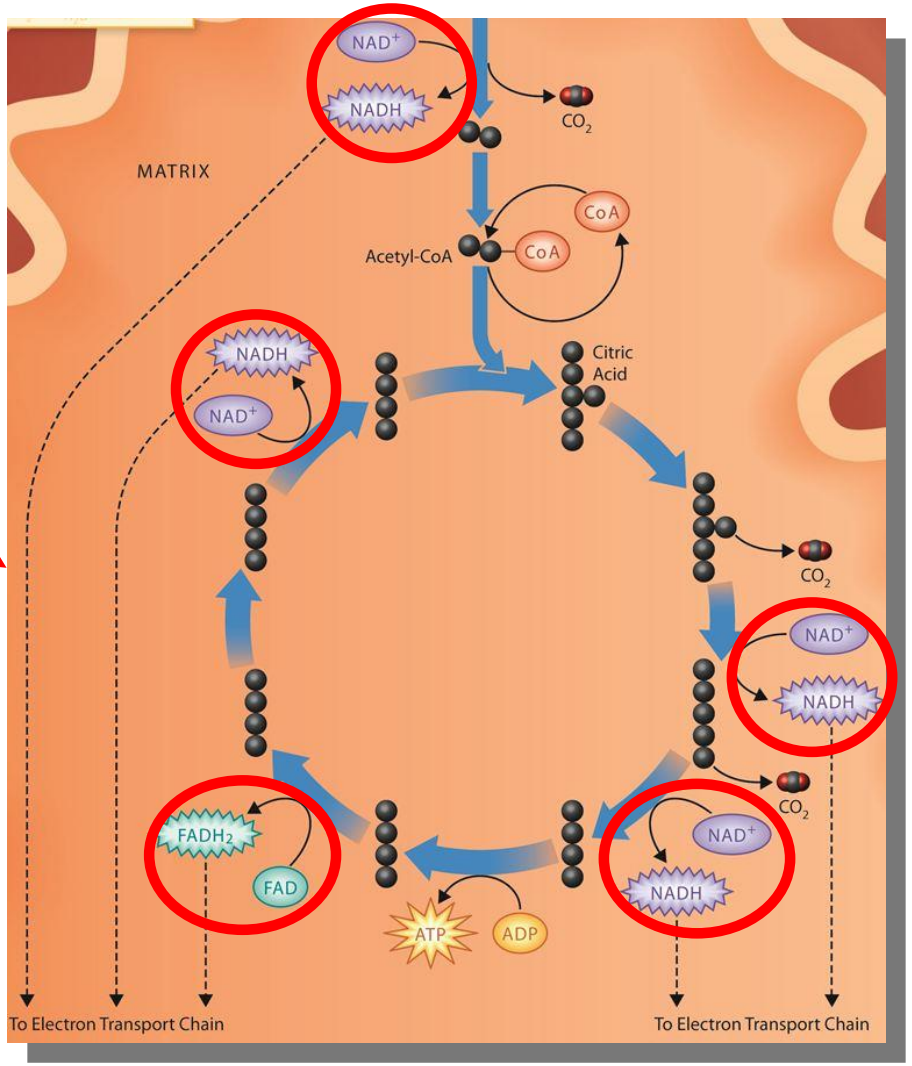
For each turn of the cycle, a molecule of ADP is converted to a molecule of ATP.



The Krebs Cycle: Energy Extraction

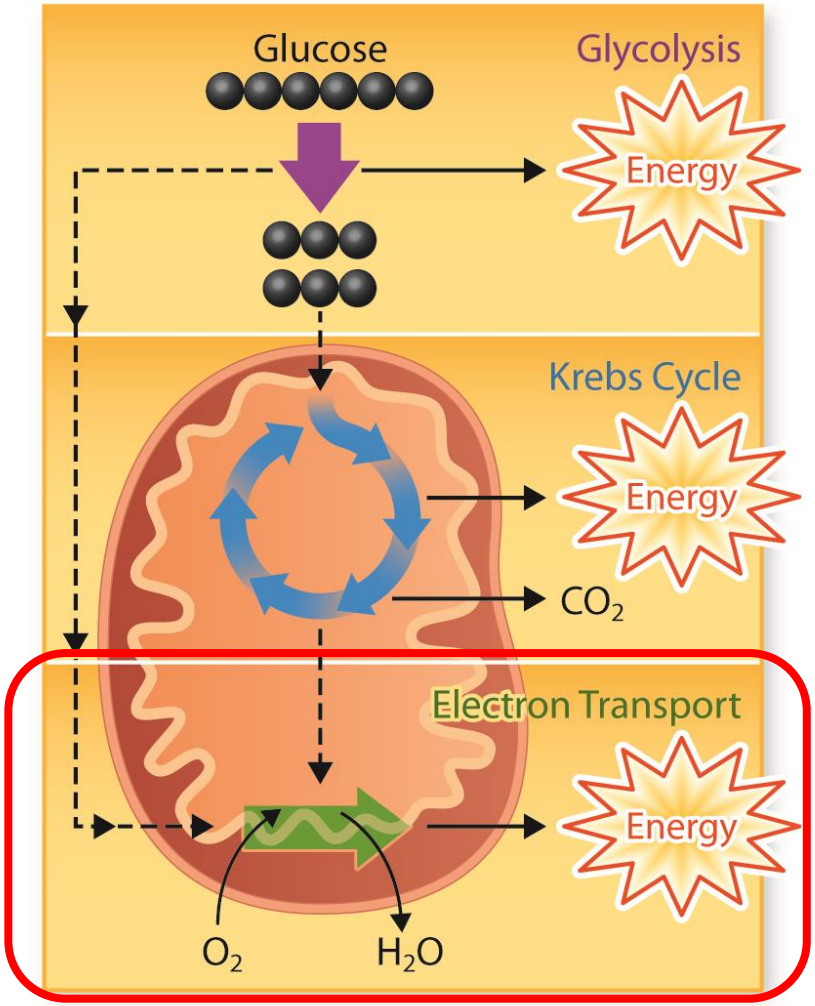
At five places in the cycle, electron carriers accept a pair of high-energy electrons, and NAD^+ and FAD are converted to NADH and $FADH_2$.





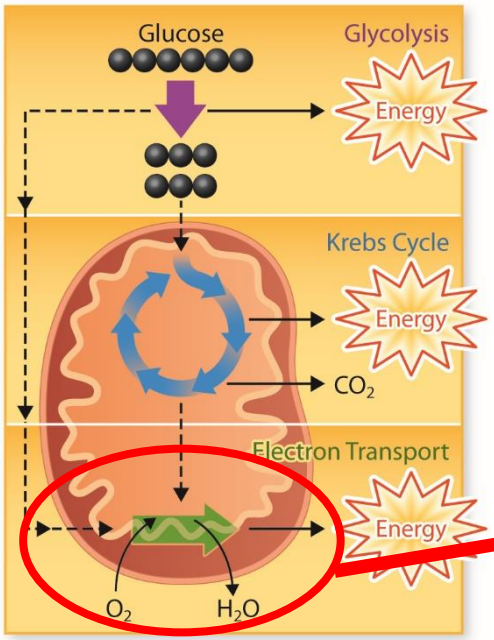
Electron Transport

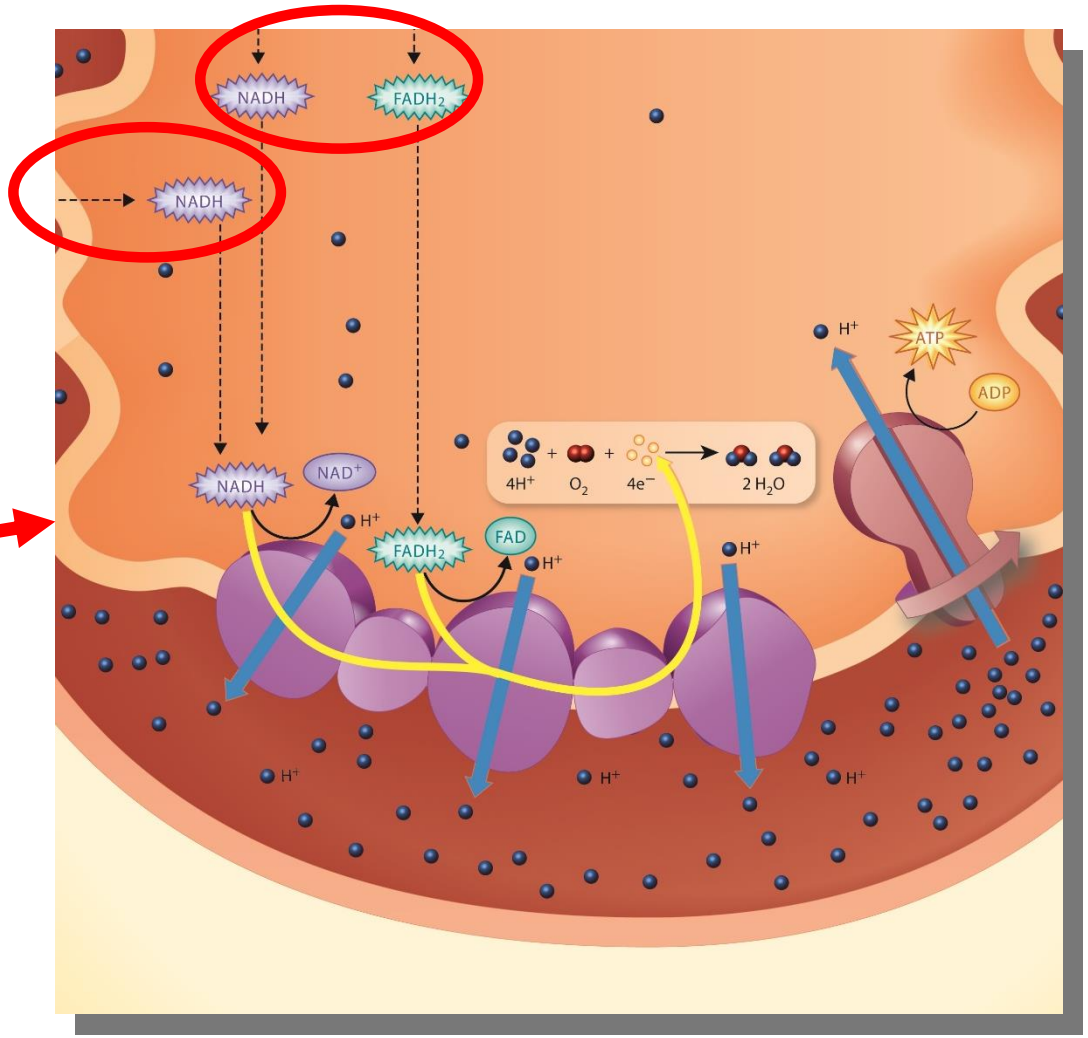
Products from the Krebs cycle and glycolysis feed into the last step of cellular respiration.



Electron Transport

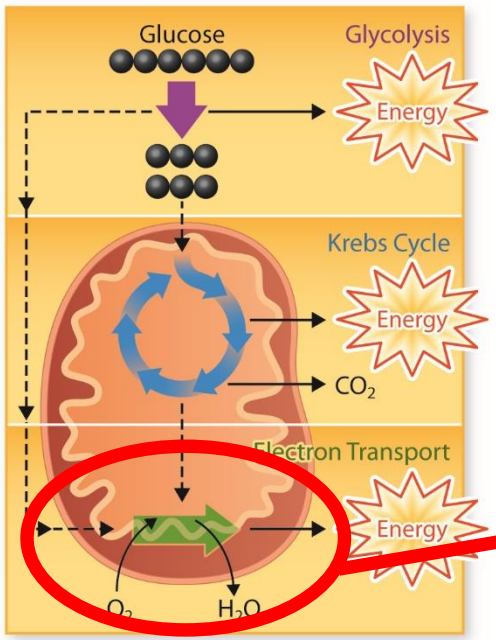
Electron transport uses the high-energy electrons from glycolysis and the Krebs cycle to synthesize ATP from ADP.

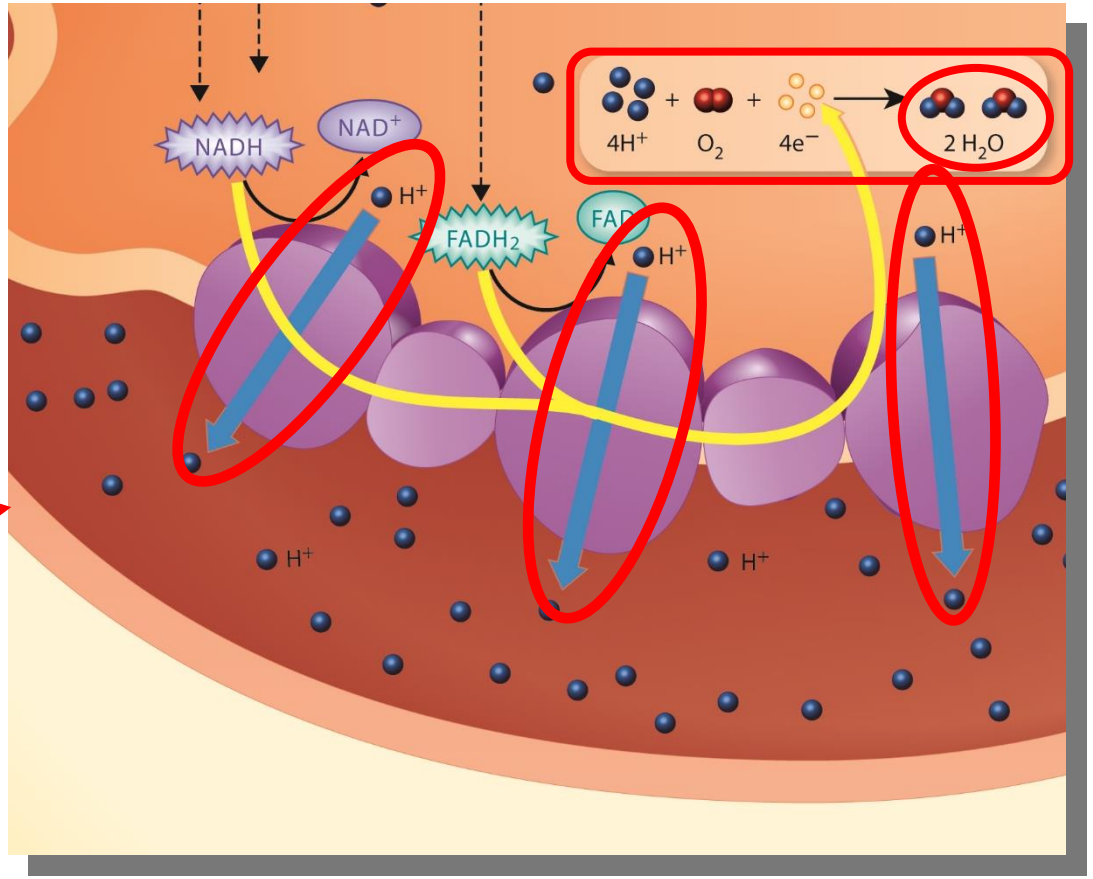




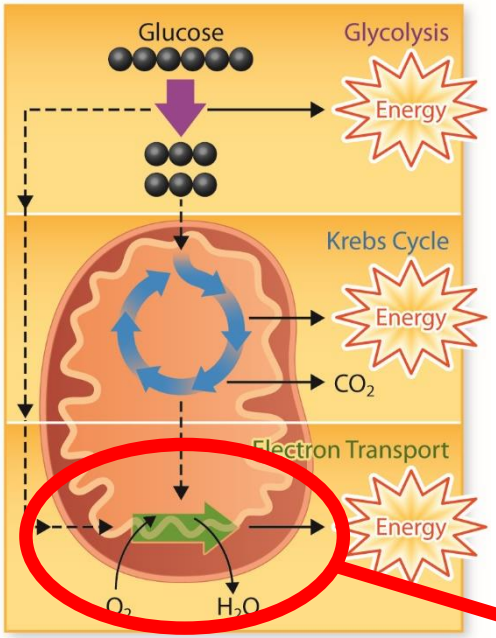
Electron Transport

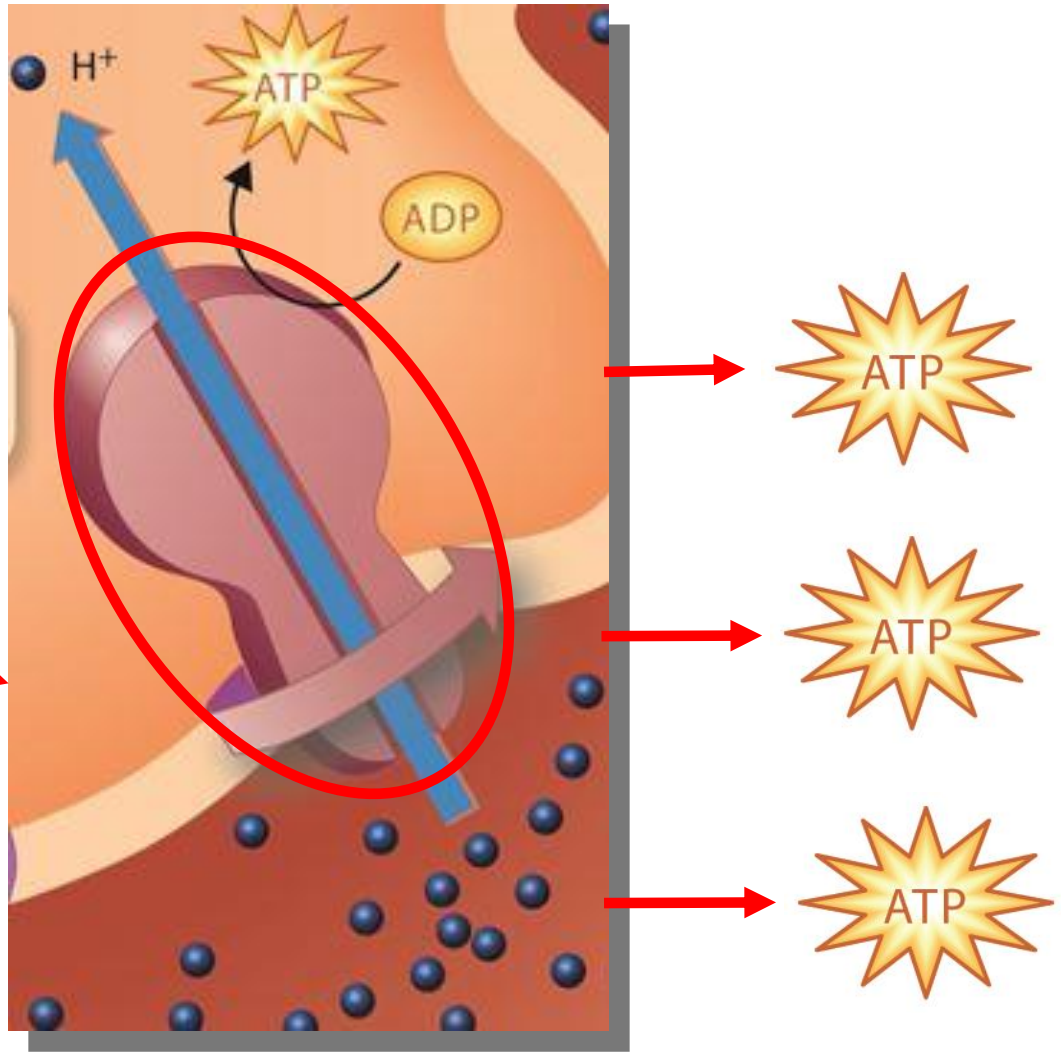
Electron transport chain is composed of a series of electron carriers located in the inner membrane of the mitochondrion.





Electron Transport: ATP Production

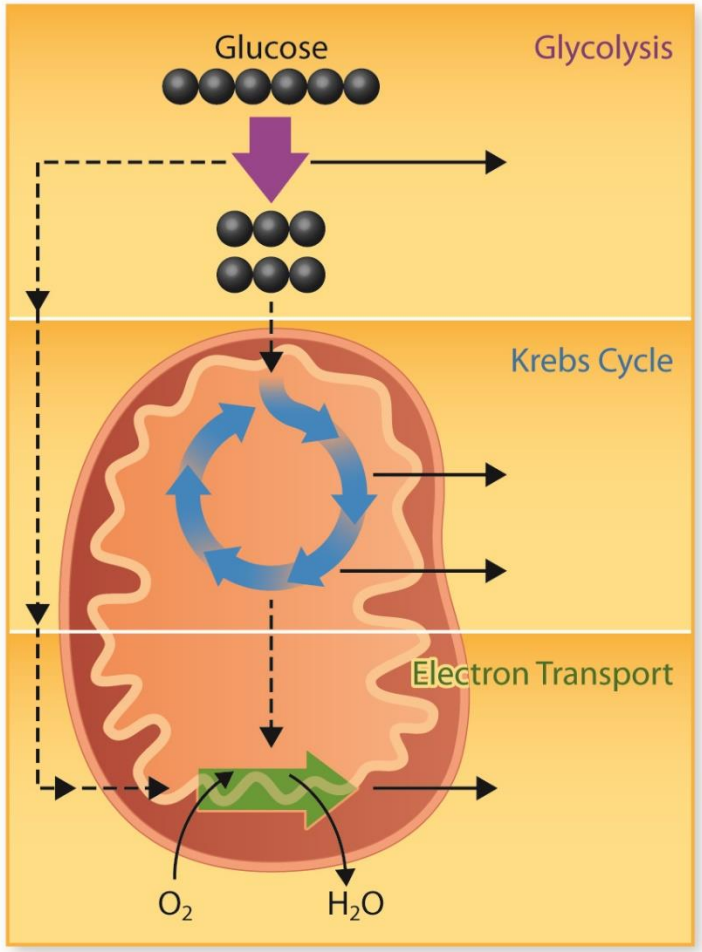




The cell uses a process known as chemiosmosis to produce ATP.

Total ATP from Cellular Respiration

Glycolysis, the Krebs cycle, and the electron transport chain release about 36 molecules of ATP per molecule of glucose.



2 ATP

2 CO_2 ATP

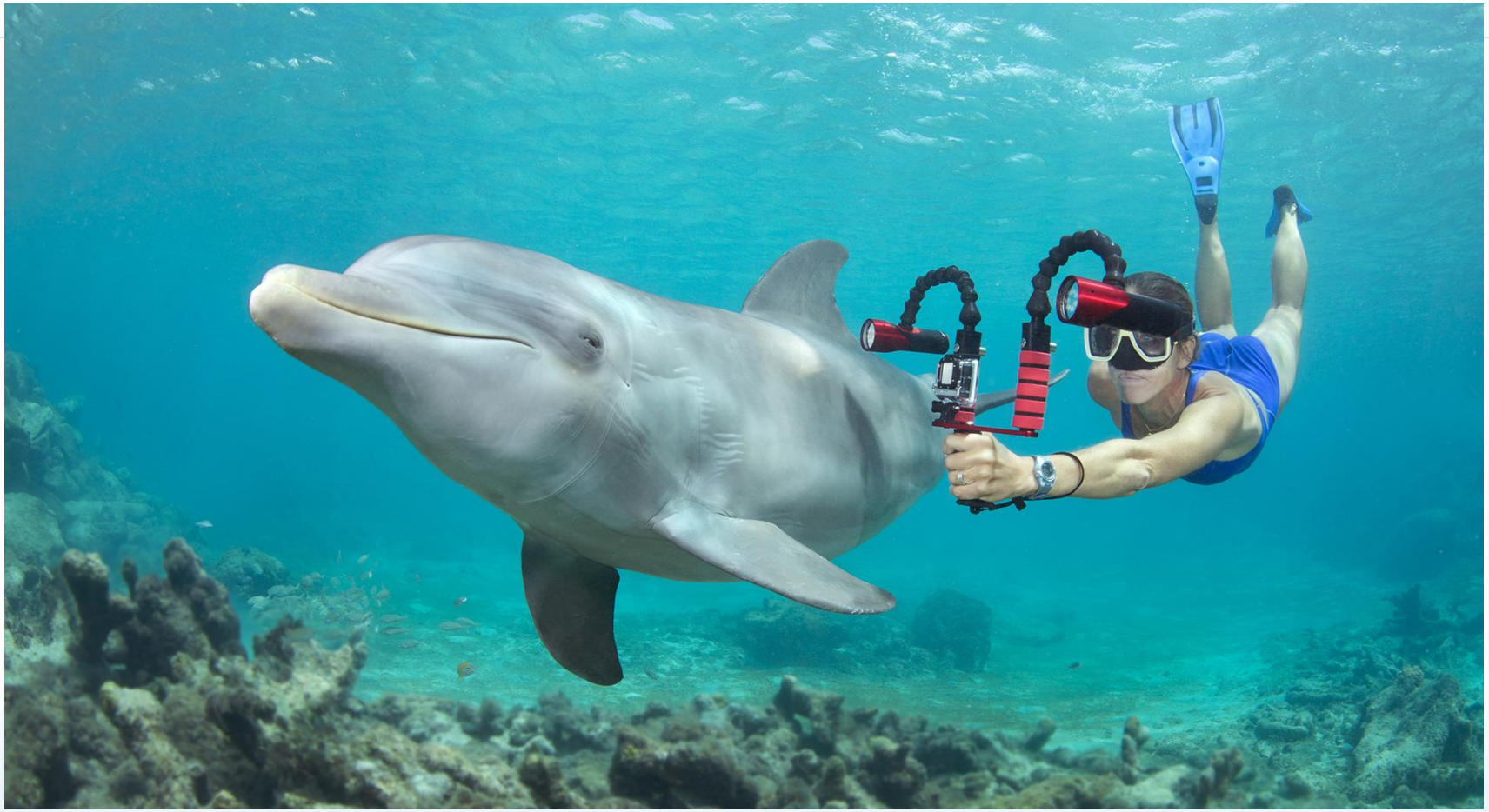
32 ATP

ATP

Total ATP?

30 to 42

Fermentation

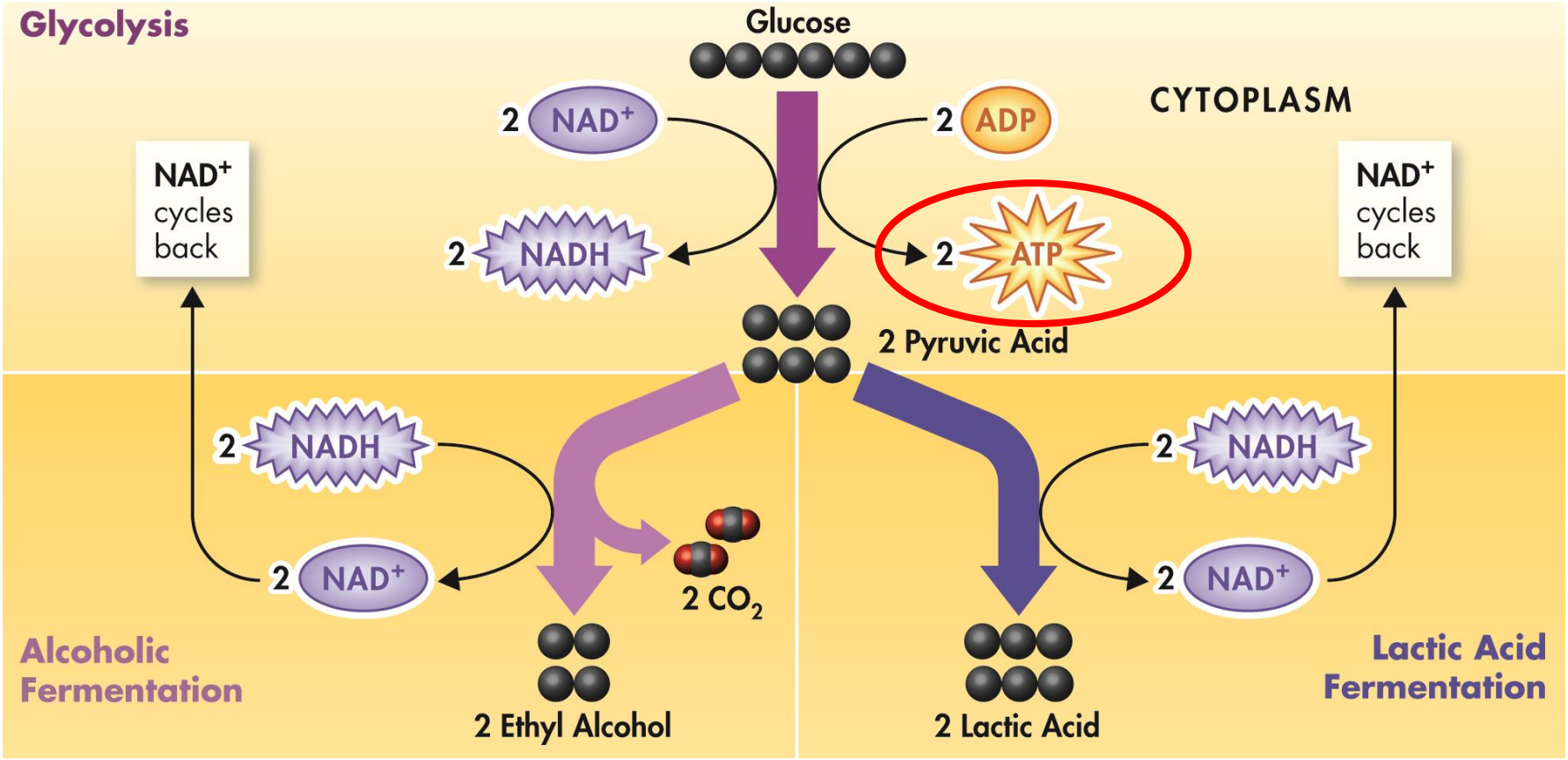


Learning Objectives

- Explain how organisms get energy in the absence of oxygen.
- Identify the pathways the body uses to release energy during exercise.

Fermentation

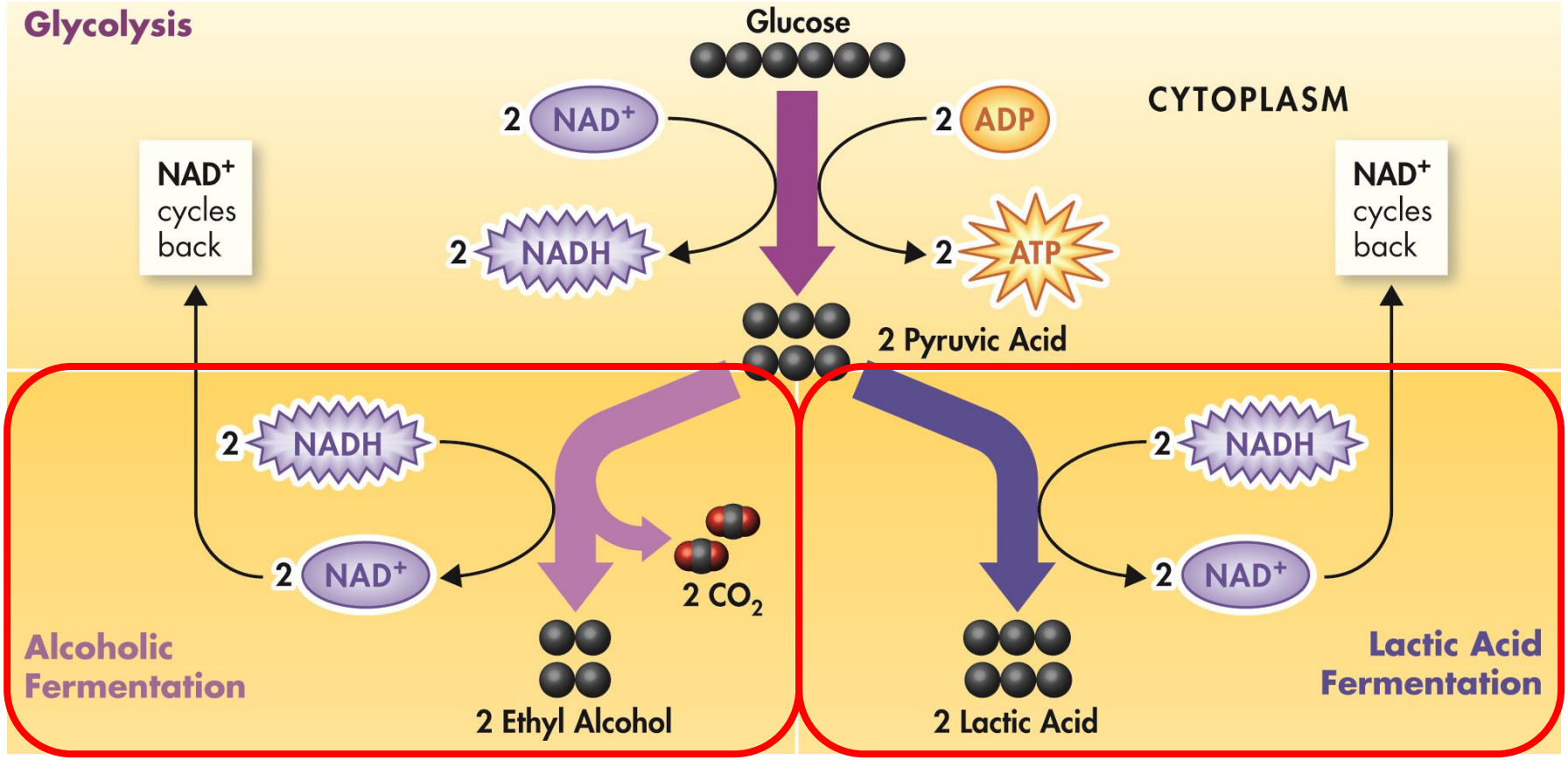
In the absence of oxygen, fermentation releases energy from food molecules by producing ATP.



Fermentation

There are two slightly different forms of the process:

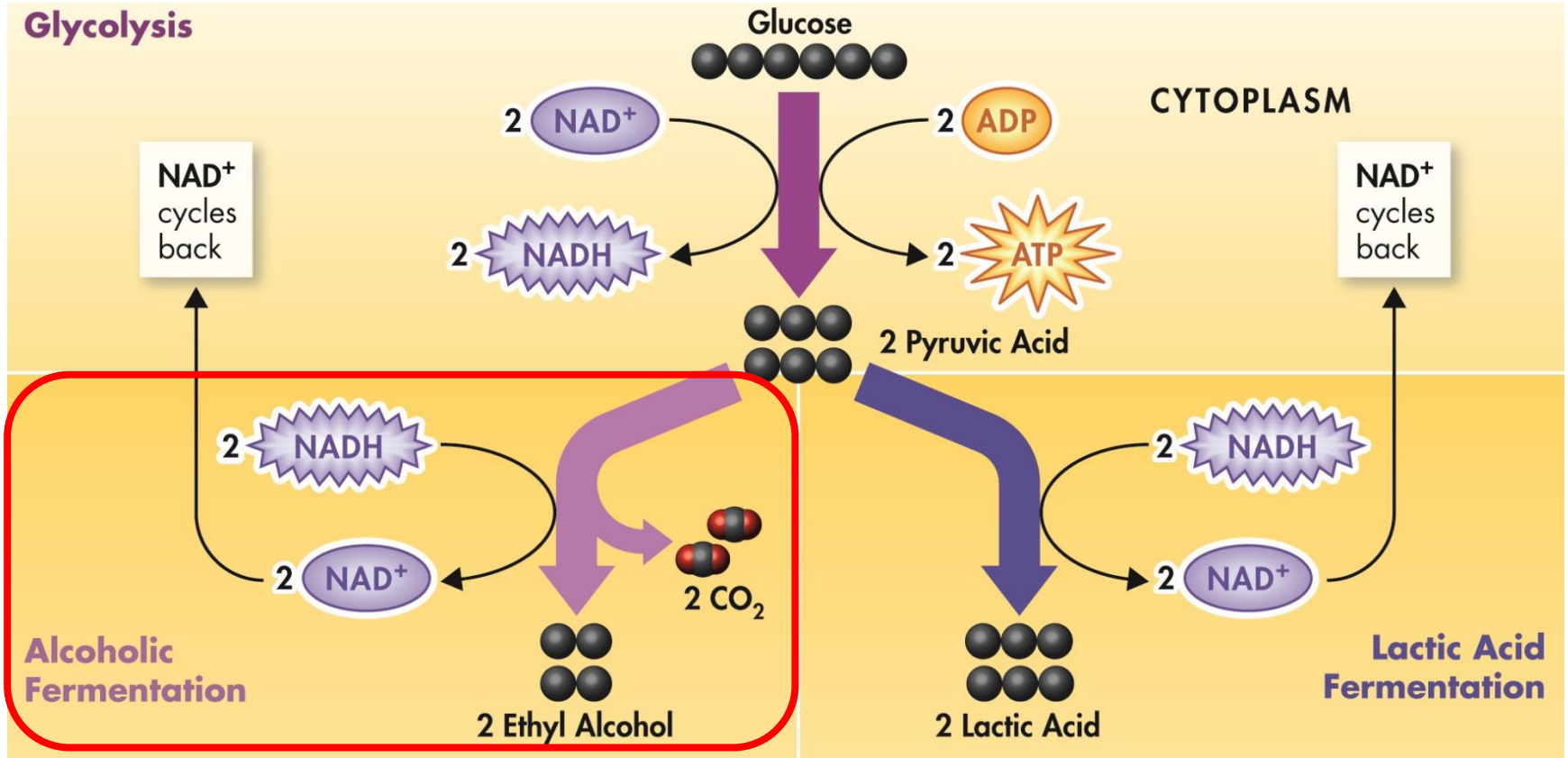
- Alcoholic fermentation
- Lactic acid fermentation



Alcoholic Fermentation

Yeasts and a few other microorganisms use alcoholic fermentation, which produces ethyl alcohol and carbon dioxide.

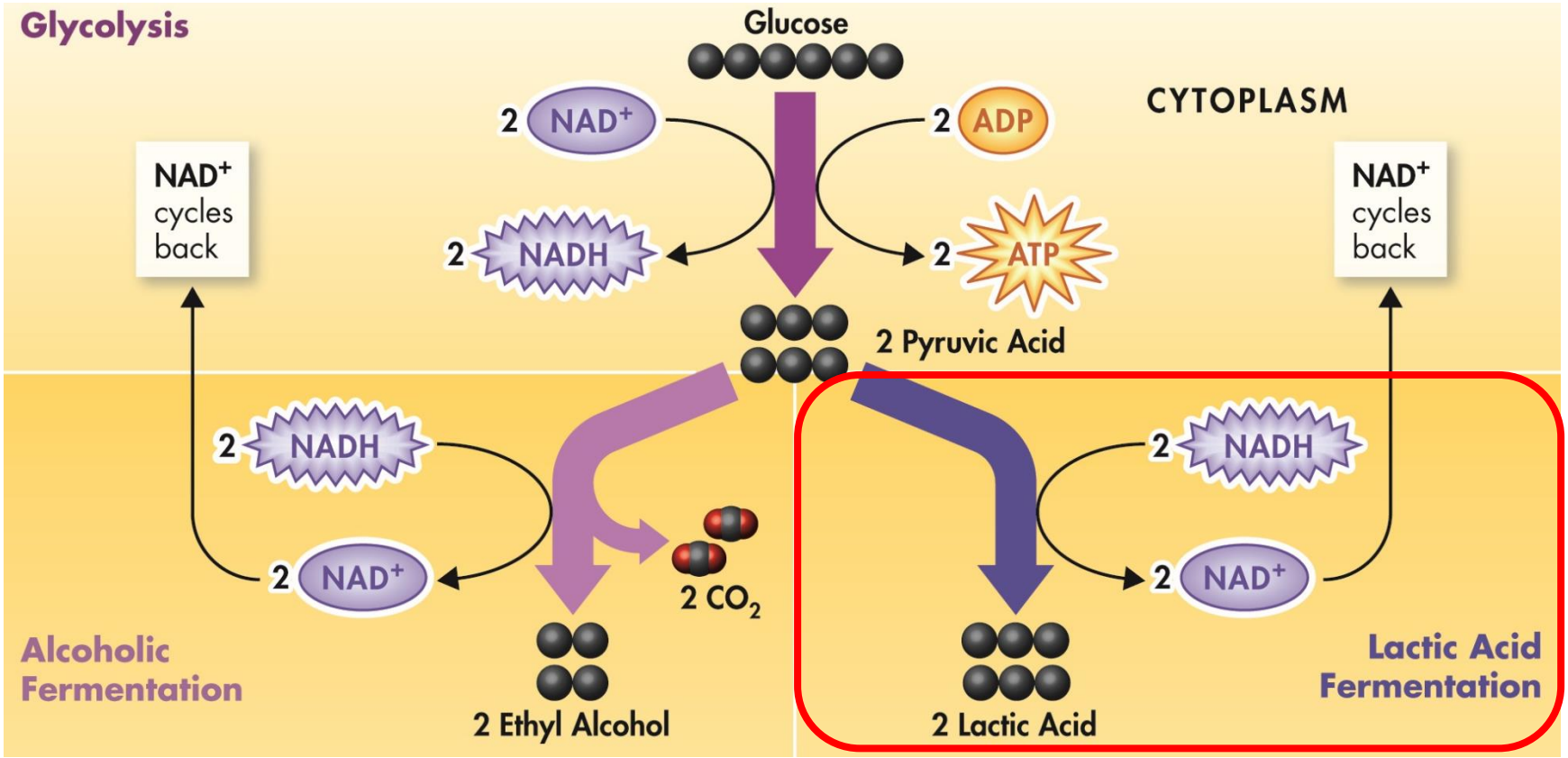
Pyruvic acid + NADH → Alcohol + CO_2 + NAD^+



Lactic Acid Fermentation

Most organisms carry out fermentation using a chemical reaction that converts pyruvic acid to lactic acid.

Pyruvic acid + NADH → Lactic acid + NAD^+



Quick Energy

For short, quick bursts of energy, the body uses ATP already in muscles as well as ATP made by lactic acid fermentation.

Long-Term Energy

For exercise longer than about 90 seconds, cellular respiration is the only way to continue generating a supply of ATP.