





AP Biology: Cellular Respiration

Lesson Objectives

-  Describe what happens during glycolysis.
-  Describe what happens during the Citric acid cycle.
-  Explain how high-energy electrons are used by the electron transport chain.
-  Identify how much ATP cellular respiration generates.

Lesson Summary

Glycolysis The word **glycolysis** literally means “sugar-breaking.” The end result is 2 molecules of a 3-carbon molecule called pyruvic acid.

- ▶ 2 ATP molecules are used at the start of glycolysis to get the process started.
- ▶ High-energy electrons are passed to the electron carrier **NAD⁺**, forming two molecules of NADH.
- ▶ 4 ATP are synthesized during glycolysis for a net gain of 2 ATP.

The Citric acid Cycle The second stage of cellular respiration is the **Citric acid cycle**, which operates only when oxygen is available. The Citric acid cycle is a series of energy-extracting reactions.

- ▶ Pyruvic acid produced by glycolysis enters mitochondria. In the innermost compartment of a mitochondrion, or the **matrix**, pyruvic acid molecules are broken down into carbon dioxide and acetyl-CoA molecules.
- ▶ Acetyl-CoA combines with a 4-carbon compound, producing a 6-carbon molecule—citric acid. Energy released by the breaking and rearranging of carbon bonds is captured in ATP, NADH, and FADH₂.
- ▶ The Citric acid cycle produces four types of products:
 - high-energy electron carriers (NADH and FADH₂)
 - carbon dioxide
 - 2 ATP molecules (per glucose molecule)
 - the 4-carbon molecule needed to start the cycle again

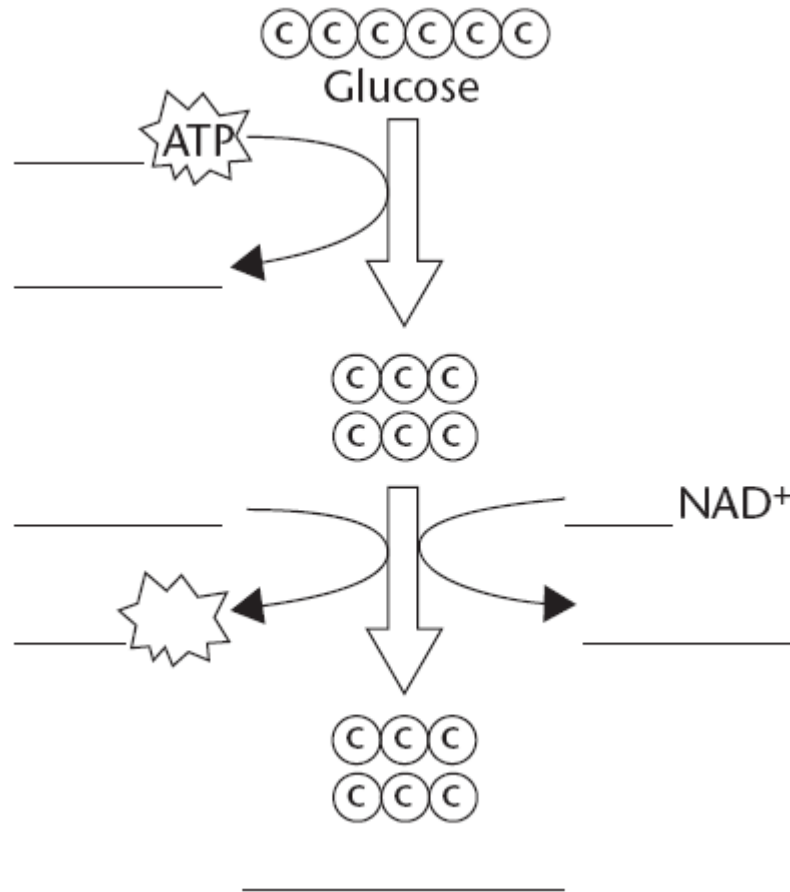
Electron Transport and ATP Synthesis The electron transport chain uses the high-energy electrons from glycolysis and the Citric acid cycle to convert ADP into ATP.

- ▶ The electron carriers produced during glycolysis and the Citric acid cycle bring high-energy electrons to the electron transport chain. Oxygen is the final electron acceptor.
- ▶ The passing of electrons through the electron transport chain causes H⁺ ions to build up in the intermembrane space, making it positively charged relative to the matrix.
- ▶ The charge difference across the membrane forces H⁺ ions through channels in enzymes known as ATP synthases. As the ATP synthases spin, a phosphate group is added to ADP, generating ATP.

The Totals Together, glycolysis, the Citric acid cycle, and the electron transport chain generate about 36 molecules of ATP per molecule of glucose.

Glycolysis

1. **THINK VISUALLY** Complete the diagram by writing on the lines provided the names and numbers of molecules used and produced during glycolysis.



2. Why is it an investment for the cell to use two ATP at the beginning of glycolysis?

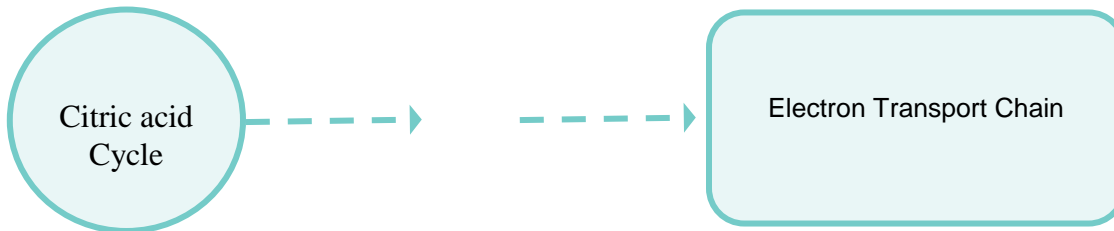
3. What are two advantages of glycolysis?

The Citric Acid Cycle

For Questions 4–7, write *True* if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

- _____ 4. The pyruvate produced in glycolysis enters the chloroplasts if oxygen is present in a cell.
- _____ 5. In the matrix, pyruvate is converted to lactic acid before the Citric acid cycle begins.
- _____ 6. The compound that joins with a 4-carbon molecule in the Citric acid cycle is called acetyl-CoA.
- _____ 7. Carbon dioxide is the only product of the Citric acid cycle that is not re-used or used in other stages of cellular respiration.

8. Complete the flowchart to show which of the Citric acid cycle's many products go on to the third stage of cellular respiration.



Electron Transport and ATP Synthesis

For Questions 9–14, complete each statement by writing the correct word or words.

9. In eukaryotes, the electron transport chain is composed of a series of electron carriers located in the _____ of the mitochondrion.
10. In prokaryotes, the electron transport chain is in the _____.
11. _____ serves as the final electron acceptor of the electron transport chain.
12. _____ and _____ pass high-energy electrons to the electron transport chain.
13. The transfer of high-energy electrons down the electron transport chain causes ___ to be transported across the mitochondrial membrane.
14. ATP synthases produce the force needed to add one _____ to each ADP molecule by spinning when hydrogen ions flow through them.

The Totals

15. How many ATP molecules per glucose molecule does a cell gain from each of the three stages of cellular respiration?

16. Besides glucose, what other kinds of molecules can be used to produce ATP in cellular respiration?

17. Why is cellular respiration considered an efficient process?

Apply the Big idea

18. Where does the heat that warms your body come from? Explain your answer.
