Cellular Respiration

- **Electrons carried via NADH**
- **Electrons carried via NADH and FADH$_2$**

**Glycolysis**
- Glucose $\rightarrow$ Pyruvate

**Cytosol**
- ATP (substrate-level phosphorylation)

**Krebs Cycle**
- ATP (substrate-level phosphorylation)

**Mitochondrion**
- ATP (oxidative phosphorylation)

**Electron Transport Chain and Oxidative Phosphorylation**
Cellular Respiration

Have you ever wondered why exactly you need to breathe? What happens when you stop breathing?
Cellular respiration is the set of the metabolic reactions and processes that take place in the cells of all organisms to convert biochemical energy from nutrients into adenosine triphosphate (ATP – cell energy), and then release waste products.
Respiration Formula

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6 CO_2 + 6H_2O + 36 \text{ ATP} \]

Look familiar?
The **best respiration occurs in the presence of oxygen** - called AEROBIC.

Without oxygen, fermentation, or anaerobic respiration, is used, but it’s not as good *(We’ll come back to this...)*
There are three stages in Aerobic Respiration

1. Glycolysis

2. Kreb's Cycle (aka Citric Acid Cycle)

3. Electron Transport Chain and Oxidative Phosphorylation
GLYCOLYSIS = "glyco - lysis " is the splitting of a 6 carbon glucose into two 3-Carbon pyruvates

- net yield of 2 ATP and 2 NADH per glucose molecule (4 total produced ATP – 2 used ATP = 2 net produced ATP)
2. **Citric Acid or Krebs Cycle**

- **a)** occurs in the mitochondria
- **b)** an aerobic process; will proceed only in the presence of O2

It is not necessary to know the individual steps.
- net yield of 2 ATP, 6 NADH and 2 FADH2, which are all sent to ETC.

c) in this stage of cellular respiration, the oxidation of glucose to CO₂ is completed.

(this is why and when we exhale carbon dioxide)
3. **ETC and Ox Phos:**

a) consists of a series of enzymes on the inner mitochondrial membrane

b) electrons are released from NADH and FADH2 and passed along a series of enzymes, giving up energy which is used to fuel chemiosmosis

c) **Makes ATP with ATP Synthetase** (just like the ETC in Photosynthesis, just different names)
c) **Total net yield of 32-34 ATP per glucose**

d) **6 H₂O** are formed when the electrons unite with **O₂** at the end of electron transport chain.

*Note: This is the function of oxygen in living organisms!

Without oxygen to serve as the final electron acceptor, the process shuts down.
Does this picture look familiar?

You've seen this before in photosynthesis.

Animation of the ETC
McGraw Hill Animation
What about no oxygen situations? Anaerobic Respiration, AKA - Fermentation

This happens when the Krebs cycle cannot occur due to lack of oxygen; purpose is to regenerate NAD+ so glycolysis can continue.

Two types of fermentation – lactic acid (animals) and alcoholic (yeast/bacteria). Byproducts include lactic acid and alcohol.

- Note: Lactic Acid in muscle cells causes muscle cramps.
Fermentation is used in making food products and alcohol products.
What are the 3 stages of cellular respiration?

1. 

2. 

3.
Food for thought

1. What is the purpose of cellular respiration?

2. Where does cellular respiration occur within the cell?

3. What is the waste product of cellular respiration?

Would you go to an oxygen bar?
4. Compare Photosynthesis to Respiration

a. Where does each occur?

b. What are the products of each?

c. What compounds are needed to start the processes?

d. What is the function of the electron transport chain in each process?

e. Describe the role of ATPase in both processes.
Self Test

1. In order to produce energy, cells start with glycolysis. If oxygen is NOT present after glycolysis, what process occurs next?
   a) Electron Transport Chain  b) Krebs Cycle  c) Fermentation

2. If oxygen IS present after glycolysis, what process occurs next?
   a) Electron Transport Chain b) Krebs Cycle  c) Fermentation

3. A process that does NOT require oxygen is known as what?
   a) Aerobic  b) Anaerobic

4. In glycolysis, glucose is broken into 2 molecules of __________________ acid

5. Where does the Kreb's cycle occur? __________________

6. What gas is a waste product produced in the Krebs cycle? _____
7. What enzyme is used in the electron transport chain to create ATP?
   a. citric acid       b. pyruvate       c. ATPase

8. Where does glycolysis occur?
   a. cytoplasm        b. mitochondria     c. chloroplast

9. Which process produces the largest amount of ATP?
   a. fermentation    b. Krebs Cycle    c. ETC

10. The oxygen required by cellular respiration is reduced and becomes part of which molecule?
   a. ATP            b. CO₂           c. H₂O
The Mystery of the Seven Deaths

Case Study: [http://sciencecases.lib.buffalo.edu/cs/files/cellular_respiration.pdf](http://sciencecases.lib.buffalo.edu/cs/files/cellular_respiration.pdf)

In this case study, students learn about the function of cellular respiration and the electron transport chain and what happens when that function is impaired. Students play the role of medical examiner as they analyze the autopsy results to determine the cause of the mysterious deaths of these seven victims.

- Explain the overall purpose of cellular respiration.
- Describe the intermediate metabolites of cellular respiration.
- Explain the function and importance of the electron transport chain.
- Describe the role of oxygen in cellular respiration.