

Chapter 8 – How Cells Release Chemical Energy

Lecture Outline

Impacts, Issues: When Mitochondria Spin Their Wheels

- A. Mitochondria are the organelles responsible for releasing the energy stored in foods.
 - 1. In Luft's syndrome, the mitochondria are active in oxygen consumption, but with little ATP formation to show for it.
 - 2. In Friedreich's ataxia, too much iron in the mitochondria causes an accumulation of free radicals that attack valuable molecules of life.
- B. Proper or improper functioning of mitochondria is the difference between health and disease.

I. Overview of Energy-Releasing Pathways

- A. ATP is the prime _____ carrier for all cells, both autotrophic and heterotrophic.
- B. Comparison of the Main Types of Energy-Releasing Pathways

- 1. _____ can release small quantities of energy without the use of oxygen, and were the first energy-releasing metabolic pathways on Earth.
- 2. _____ (with oxygen) is the main energy-releasing pathway leading to ATP formation in eukaryotes; it occurs in the mitochondria.
- 3. Every cell begins its energy-releasing pathways with _____, which occurs in the cytoplasm and produces two molecules of pyruvate.

C. Overview of Aerobic Respiration

- 1. Fermentation produces a net yield of _____ ATPs; aerobic respiration yields 36 ATPs.
- 2. The aerobic route is summarized:
$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \longrightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$$
- 3. Three series of reactions are required for aerobic respiration.
 - a. _____ is the breakdown of glucose to pyruvate; small amounts of ATP are generated.
 - b. The _____ degrades pyruvate to carbon dioxide and water, ATP is produced, and NAD accept H^+ ions and electrons to be carried to the electron transfer chain.
 - c. _____ processes the H^+ ions and electrons to generate high yields of ATP; oxygen is the final electron acceptor.

II. Glycolysis—Glucose Breakdown Starts

- A. Enzymes in the _____ catalyze several steps in the breakdown of a six-
carbon sugar glucose into two molecules of _____, a three-carbon sugar.
- B. Glycolysis begins as _____ reactions:
1. Glucose is first phosphorylated, then split to form two using two ATP molecules in the beginning process.
 2. The two intermediates are ready to enter the _____ reaction.
- C. Glycolysis continues as energy-releasing reactions:
1. Enzymes remove H^+ and electrons from the intermediate to change _____ to NADH (which is used later in electron transfer).
 2. _____ ATPs are produced.
- D. The end products of glycolysis are (for each glucose molecule): two _____, two ATPs (net gain), and two NADH.

III. Second Stage of Aerobic Respiration

A. Acetyl-CoA Formation

1. As each pyruvate enters the mitochondria, one _____ is removed and attaches to oxygen, forming carbon dioxide; the two-carbon fragment remaining joins coenzyme A to form Acetyl-CoA.

B. The Krebs Cycle

1. Each three-carbon Acetyl-CoA molecule enters the _____ cycle separately and joins Oxaloacetate, already present from a previous “turn” of the cycle.
2. H^+ and e^- are transferred to NAD^+ to become NADH
3. Two molecules of _____ are formed.
4. Most of the molecules are _____ to conserve oxaloacetate for continuous processing of acetyl-CoA.
5. _____ is released as a by-product.

IV. Third Stage of Aerobic Respiration—The Big Energy Payoff

A. Electron Transfer Phosphorylation

1. NADH gives up its electrons to _____ embedded in the mitochondrial inner membrane.
 - a. The energy is used to pump _____ ions out of the inner compartment.
 - b. When hydrogen ions flow back through the ATP synthases in the channels, the coupling of P_i to ADP yields ATP.

2. Oxygen joins with the “_____” electrons from the glucose molecule and H^+ to yield water.
 - a. Without oxygen, electrons back up the _____, and no H^+ gradients form.
 - b. No gradient means no _____; complex cells cannot survive long without enough ATP for their processes.

B. Summing Up: The Energy Harvest

1. Electron transfer yields 32 ATPs, glycolysis yields two ATPs, and Krebs yields two ATPs for a grand total of 36 ATPs per glucose molecule.

V. Anaerobic Energy-Releasing Pathways

- A. Anaerobic pathways operate when oxygen is _____ (or limited); pyruvate from glycolysis is metabolized to produce molecules other than acetyl-CoA.

B. Fermentation Pathways

1. Organisms that carry on _____ (fermenters) are diverse; many die when exposed to oxygen, while others use oxygen but switch when it becomes scarce.
2. Fermentation yields enough energy for many _____ anaerobic

organisms and is sufficient for some aerobic cells when oxygen _____ drop, but it is insufficient for large, multicelled organisms.

C. Alcoholic Fermentation

1. Fermentation begins with _____ degradation to pyruvate.
2. Cellular enzymes convert pyruvate to _____
- 3 _____ are valuable in the baking industry (carbon dioxide by-product makes dough “rise”) and in alcoholic beverage production.

D. Lactate Fermentation

1. Certain bacteria (as in milk) and _____ cells have the enzymes capable of converting pyruvate to lactate.
2. No additional _____ beyond the net two from glycolysis is produced
3. When muscle cells are very active, they convert to producing lactate temporarily.

VI. Alternative Energy Sources in the Body

A. The Fate of Glucose at Mealtime and between Meals

1. After eating a meal, _____ is absorbed into the blood.
 - a. _____ levels rise, causing greater uptake of glucose by cells for entry into glycolysis.
 - b. Excess _____ is converted into _____ for storage in muscles and the liver.
2. Between meals blood _____ levels fall.
 - a. The hormone _____ prompts liver cells to convert glycogen back to glucose.
 - b. Glycogen levels are adequate but can be depleted in 12 hours.

B. Energy From Fats

1. Excess fats (including those made from _____) are stored away in cells of adipose tissue.
2. Fats are digested into _____, which enters glycolysis, and fatty acids, which enter the Krebs cycle.
3. Because fatty acids have many more _____ and hydrogen atoms, they are degraded more slowly and yield greater amounts of ATP.
4. Excess glucose can be converted to _____

C. Energy From Proteins

1. Amino acids are _____ by digestion and travel in the blood.
2. After the _____ group is removed, the amino acid remnant is fed into the Krebs cycle.

VII. Reflections on Life's Unity

A. Photosynthesis and cellular respiration are intimately connected.

1. _____ in plants produces the organic compounds and oxygen needed to sustain heterotrophic animals.
2. Organisms release the carbon dioxide needed for photosynthesis.

B. Life continues by a capacity for self-reproduction and is sustained by energy from the sun.