

Chapter 8
Harvesting Energy: Glycolysis and Cellular Respiration

I. How is Glucose Metabolized?

- A. Glucose is not the only chemical that can be metabolized by cells to produce ATP, but it is one of the simpler processes and amenable for teaching purposes.
- B. The Generalized Equation of Complete Glucose Metabolism



- C. One important point to remember is that due to the Second Law of Thermodynamics you can't even break even. This means an amount of energy is always lost to waste, even though the reaction is theoretically the reverse of photosynthesis.
- D. Our cellular machinery is even pretty good, in that we can capture approximately 40% of available energy in glucose, while electric motors and gasoline engines rarely cross the 25% mark.

II. How is the Energy in Glucose Captured during Glycolysis?

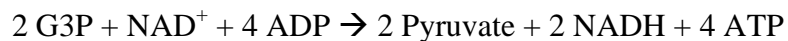
- A. **Glycolysis** – the process of breaking down glucose into pyruvate, yielding a small amount of ATP.
- B. Glycolysis appears to be one of the most ancient metabolic pathways, given that it is done in similar ways in all known organisms.
- C. Glycolysis occurs in the cytoplasm
- D. Glycolysis breaks down Glucose to Pyruvate, Releasing Chemical Energy
 - 1. Activation - Glucose enters into the process of Glycolysis by first becoming activated, requiring an input of energy.



- 2. Fragmentation – Fructose bisphosphate is fragmented and transformed into three-carbon molecules of glyceraldehyde 3-phosphate (G3P).



- 3. Energy Harvesting – The molecules of G3P are rearranged into molecules of pyruvate, during which time each conversion (through multiple steps) leads to the production of 1 NADH and 2 ATP.



- 4. Final Products of Glycolysis
 - i. 2 molecules of Pyruvate

- ii. 2 molecules of NADH
- iii. 2 molecules of ATP (Net gain after accounting for the 2 used in step 1)



- E. The following section in your book dealing with fermentation is an oversimplification of the process and in some ways wrong, you will be responsible for the following.
1. **Fermentation** - a process of harvesting energy from organic compounds without oxygen or an electron transport system, and uses an organic compound as the terminal electron receptor.
 2. Fermentation has a number of possible outcomes (i.e. lactate, ethanol, or butyrate are some examples), but all have the same purpose of recycling NADH into NAD⁺
 3. Fermentation occurs in an environment deprived of oxygen, termed **anaerobic**, but is not the only way for organisms to operate anaerobically.

III. How does Cellular Respiration Capture Additional Energy from Glucose?

- A. Cellular Respiration – A series of reactions in which large amounts of ATP are produced and electrons are passed to an inorganic terminal electron receptor (remove the phrase ‘under aerobic conditions’ that is in your book)
- B. Aerobic Cellular Respiration
1. Transport of Pyruvate from the cytoplasm into the matrix of the mitochondria.
 2. Pyruvate is split into carbon dioxide and a molecule called acetyl CoA
 3. Acetyl CoA enters what is called the Krebs’s Cycle, producing a small amount of ATP and a large number of electron carriers (NADH and FADH₂)
 4. The Electron Carrier’s from step 3 enter an Electron Transport Chain (ETC) that harvests the electron energy to pump hydrogen ions from the matrix of the mitochondria into its intermembrane compartment. The electrons are accepted by oxygen to produce water as a byproduct.
 5. The Hydrogen Gradient is harvested through the mechanism of Chemiosmosis to produce ATP.
 6. ATP is transported out of the mitochondria and used by the cell.
- C. Aerobic Cellular Respiration leads to a production of 36 – 38 ATP molecules per glucose molecule (36 for eukaryotes, 38 for prokaryotes)
- D. Anaerobic Cellular Respiration is possible; though it never produces as many ATP and utilizes some other inorganic molecule as a terminal electron receptor... this is how many anaerobic organisms live.

- E. Chemiosmosis is accomplished through specialized enzyme complexes in the inner membrane of the mitochondria (plasma membrane of prokaryotes) that have a hydrogen ion channel that is coupled to an ATP synthase.