

Cellular Respiration involves glycolysis, The Krebs cycle, and electron transport: *AN OVERVIEW*

- Respiration occurs in three metabolic stages:
 1. **Glycolysis** – occurs in the cytoplasm (can occur with or without oxygen)
 2. **The Krebs cycle** – occurs in the mitochondrial matrix (compartment enclosed by the inner membrane)
 3. **The electron transport chain and oxidative phosphorylation** – occurs on the cristae (infoldings of the inner membrane) of mitochondria
- **Glycolysis** occurs in the cytoplasm.
- It begins catabolism by breaking glucose into two molecules of pyruvate, each containing 3 C atoms.
- The **Krebs cycle** occurs in the mitochondrial matrix.
- It further breaks down these 2 molecules of pyruvate
- Several steps in glycolysis and the Krebs cycle transfer electrons from substrates to NAD^+ , forming NADH.
- NADH passes these electrons to the **electron transport chain**. This chain is built into the inner mitochondrial membrane, and is made up of mostly protein. There are literally thousands of copies of this chain in each mitochondrion.
- In the electron transport chain, the electrons move from molecule to molecule, with each move to a more electronegative molecule, until they combine with oxygen and hydrogen ions to form water.
- As they are passed along the chain, the energy carried by these electrons is stored in the mitochondrion in a form that can be used to synthesize ATP via **oxidative phosphorylation**.
*(The production of ATP using energy derived from the redox reactions of the **electron transport chain**)*
- Oxidative phosphorylation produces almost **90%** of the ATP generated by respiration.

- Some ATP is also generated in **glycolysis and the Krebs cycle** by **substrate-level phosphorylation**.
 - Here an enzyme transfers a phosphate group, Pi, from an organic molecule (an intermediate substrate) to ADP, forming ATP.
- Respiration uses the **small steps** in the respiratory pathway to **break** the large amount of energy contained in glucose into the smaller units of ATP.
 - *Think of it as how we eat – many smaller meals throughout the week is more efficient than one gigantic meal once a week*
 - The quantity of energy in ATP is **more appropriate** for the level of work required in the cell.
- Ultimately up to **38** ATP are produced per mole of glucose that is degraded to carbon dioxide and water by respiration.
 - 2 ATP from glycolysis
 - Up to 2 ATP from the Krebs' cycle (two "turns of the cycle", one for each molecule of pyruvate)
 - Up to 34 ATP from the electron transport chain

**Glycolysis harvests chemical energy by oxidizing glucose to pyruvate:
A CLOSER LOOK**

- During glycolysis, glucose, a six carbon-sugar, is split into two, three-carbon sugars.
- These smaller sugars are oxidized (they lose electrons) and rearranged to form two molecules of pyruvate.
- There are 10 steps (chemical reactions) that need to occur to change glucose into pyruvate
- Each of the **ten steps** in glycolysis is catalyzed by a specific enzyme (*see pages 162-163 in text*).

Glycolysis harvests chemical energy by oxidizing glucose to pyruvate: A CLOSER LOOK

- These steps can be divided into two phases: an energy investment phase and an energy payoff phase.
- In the energy investment phase, ATP provides activation energy by **phosphorylating** glucose. (*Remember...the transfer of the terminal phosphate group (Pi) from ATP to another molecule is called phosphorylation*) - - so ATP is **NEEDED**
 - This requires 2 ATP per glucose.
- In the energy payoff phase, ATP is produced by substrate-level phosphorylation and NAD⁺ is reduced to NADH.
- 4 ATP and 2 NADH are produced per glucose during this part (in addition to the 2 pyruvate molecules)
- The **net yield** from glycolysis is 2 ATP, 2 pyruvate and 2 NADH per glucose.
 - **NO** CO₂ is produced during glycolysis.
- Glycolysis means “sugar splitting”
- Glycolysis occurs in the cytoplasm of cells (*have I told you this enough???*)
- Glycolysis is **universal** in **all** organisms, and probably evolved first (when oxygen was NOT available)
- Glycolysis occurs whether O₂ is present or not.
 - If O₂ **is** present, the 2 pyruvate move to the **Krebs cycle** and the energy stored in NADH can be converted to ATP by the electron transport system and oxidative phosphorylation.