Glycolysis and Respiration

A chemical perspective
**Atom** = Smallest unit of matter that can not be divided by chemical means.

Atoms differ from each other in the number of protons.
How many shells?

How many electrons are in the first shell?

2\textsuperscript{nd} and 3\textsuperscript{rd} shells can each hold 8 electrons and as we move further out shells can hold more and more.

Atoms whose shells are full are chemically stable, and won’t react easily with other atoms.

On the other hand, atoms whose shells are NOT full are chemically unstable, and WILL react easily with other atoms, until they achieve a state where their shells are full.

\textbf{Atoms} will react with each other in such a way as to fill or empty their outermost electron shells.
Octet Rule
First shell holds two electrons

The second and third shells hold eight electrons

Each orbit within a shell holds two electrons
Each orbit is represented with one electron before filling the first orbit with a second electron

Example:
How many bonds are available for an element with 8 electrons?

Answer = 2
**Atoms**: define by the number of protons. Atoms have the same number of protons, neutrons and electrons and are neutrally charged.

**Isotopes**: Atoms with "non-standard" numbers of neutrons. Many, but not all, isotopes are radioactive.

**Ions**: Atoms with "non-standard" numbers of electrons. Very common and important.

2 major types:

Positive ions are missing electrons, and therefore have a positive charge. (H⁺ Li⁺ Na⁺ K⁺)

Negative ions have extra electrons, thus a negative charge. (F⁻ Cl⁻ Br⁻ I⁻)
Ionic Bond

Relatively weak bonds and they become ions.
**Covalent Bond** – Atoms don’t become ions by losing or gaining electrons, instead they share electrons.
Energy in chemical bonds

- Recall that chemical bonds are a source of potential energy.

- If we were to break them apart we could measure the energy holding the chemical bonds together.

- The energy in a chemical bond is derived from nuclear forces that cause the electron shell affinities in the first place.

- Biological systems use this property of chemical bonds to move energy around, store energy, and release it when and where they want it.
Atoms can share more than a single electron pair, forming double or triple bonds.

- **Single bond**
- **Double bond**
- **Triple bond**
Chemical formula

\[
\begin{align*}
\text{H}_2 + \text{O}_2 & \rightarrow \text{H}_2\text{O} \\
\text{C} + \text{O}_2 & \rightarrow \text{CO}_2
\end{align*}
\]

\(\text{H}_2\text{O}\)

\(\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}\)

\(\text{O} + \text{O} \rightarrow \text{O}_2\)

carbon dioxide

\(\text{C} + \text{O}_2 \rightarrow \text{CO}_2\)
\[ C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O \]

<table>
<thead>
<tr>
<th>Left side</th>
<th>Right side</th>
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<tbody>
<tr>
<td>6 C</td>
<td>6 C</td>
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<tr>
<td>12 H</td>
<td>2 H</td>
</tr>
<tr>
<td>8 O</td>
<td>3 O</td>
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Balanced formula

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

\[ \text{energy} \]

\[ \text{ADP + Pi} \rightarrow 36\text{ATP} \]
Cellular Respiration

- Cellular respiration is the process of oxidizing food molecules, like glucose, to carbon dioxide and water.

- The energy released is trapped in the form of ATP for use by all the energy-consuming activities of the cell.

- The process occurs in two phases:
  - glycolysis, the breakdown of glucose to pyruvic acid
  - the complete oxidation of pyruvic acid to carbon dioxide and water
Glycolysis

- Glycolysis is the sequence of reactions that converts glucose into pyruvate with the concomitant production of a relatively small amount of ATP.

- Glycolysis can be carried out anerobically (in the absence of oxygen) and is thus an especially important pathway for organisms that can ferment sugars.

- For example, glycolysis is the pathway utilized by yeast to produce the alcohol found in beer.
Glycolysis (occurs in cytoplasm of cell)

\[ C_6H_{12}O_6 \rightarrow 2C_3H_3O_3 + 6H \]

(glucose) \( \rightarrow \) (pyruvate) + (hydrogen)

Energy \( \rightarrow \) Heat

2 ATP \( \rightarrow \) 2 ADP + 2P; 4 ADP+4P \( \rightarrow \) 4 ATP

Net ATP Yield of Glycolysis = 2 ATP
Mitochondrial reactions (Conversion to acetyl CoA + Kreb's Cycle + Electron Transport Chain)

\[ 2C_3H_3O_3 + O_2 + H \rightarrow CO_2 + H_2O \]

pyruvate + oxygen + hydrogen \( \rightarrow \) carbon dioxide + water

Energy \( \rightarrow \) Heat

\[ ADP + Pi \rightarrow 34ATP \]

Overall Yield

Glycolysis + Mitochondrial reactions = 36 ATP
Balance these for practice:

\[ C_6H_{12}O_6 \rightarrow 2C_3H_3O_3 + 6H \]

\[ 2C_3H_3O_3 + 6O_2 + 6H \rightarrow 6CO_2 + 6H_2O \]

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \]
Fermentation (no O₂)

- Removes byproducts of glycolysis which allows glycolysis to continue.

- No energetic yield (ATP not produced), but by allowing glycolysis to continue, cell can still receive 2 ATP.

- 2 types:
  - Alcoholic fermentation:
    - Pyruvate + H → Alcohol(C₂H₆O) + CO₂
    - Occurs in Fungi (yeast) and some plants
  - Lactate Fermentation:
    - Pyruvate + H → Lactate (C₃H₅O₃)
    - Occurs in animals, many Bacteria
    - Nerve cells cannot ferment since they die without oxygen.
You should be able to:

- Identify the parts of an atom and their charges.
- Use chemical formulas to determine the kind and number of elements in a compound.
- Given the kind and number of elements in a compound, write its chemical formula.
- Determine whether a compound is stable given information about the number of electrons in the outermost shells of its atoms.
- Balance simple chemical equations – even ones you haven't seen before.
- Balance the summary equations for aerobic cellular respiration, glycolysis, and the mitochondrial reactions.
- Identify the energetic components of these reactions in terms of total ATP yield.
- Define the term "Coupled reaction".
- Identify the energy production of fermentation (in terms of ATP), and explain how it helps energy production.
- Identify the products of each type of fermentation.