Acids and Bases
Acids and Bases

In any solution, a scientist can talk about the concentration of the atoms that are dissolved in the solvent.

i.e. Salt water is an example of Na\(^+\) and Cl\(^-\) in a solution of water.

Higher concentration = ↑ atoms
Acids and Bases

pH is a measure of the acidity or alkalinity of a solution

\[ pH = - \log([H^+]) \]

The negative logarithm of the concentration of H\(^+\) ions.
Properties

- **ACIDS**
  - Sour to taste
  - NEVER TOUCH
  - Blue litmus to red
  - pH<7
  - React with bases to give a salt and water

- **BASES**
  - Bitter to taste
  - Slippery to touch
  - Red litmus to blue
  - pH>7
  - React with acids to give a salt and water
Indicators

- Phenolphthalein
- Bromothymol blue
- Litmus
- Universal Indicator
Phenolphthalein

- Colorless in acid and light pink in the presence of base.
Bromothymol blue

- Acids appear yellow
  pH < 7

- Bases appear blue
  pH > 7
Red and Blue Litmus

- **Basic solutions** turn red litmus to blue.

- **Acidic solutions** turn blue litmus to red.
Universal Indicator

- Varies in color in response to acids and bases of different concentrations.

Hydrion Paper

- Paper that contains dried Universal Indicator.
Neutralization Reactions
Acids donate protons

Dissociate in water and release hydrogen ions (H⁺)

Hydrochloric acid (stomach acid) is a gas with symbol HCl

- In water, it dissociates into H⁺ and Cl⁻
- Dissociation of HCl is almost total, therefore it is a strong acid
Bases: \textcolor{red}{\text{Accept Protons}}

Either take up hydrogen ions (H\textsuperscript{+}) or release hydroxide ions (OH\textsuperscript{-})

Sodium hydroxide (drain cleaner) is a solid with symbol NaOH

\[ \text{dissociation of } OH^- = \text{strength of base} = \text{pH} \]

- In water, it dissociates into Na\textsuperscript{+} and OH\textsuperscript{-}
- Dissociation of NaOH is almost total, therefore it is a strong base
Buffers and pH

When $H^+$ is added to pure water at pH 7, pH goes down and water becomes acidic.

When $OH^-$ is added to pure water at pH 7, pH goes up and water becomes alkaline (basic).

Buffers are solutes in water that resist change in pH.

When $H^+$ is added, buffer may absorb, or counter by adding $OH^-$. 

When $OH^-$ is added, buffer may absorb, or counter by adding $H^+$. 
Buffers in Biology

Health of organisms requires maintaining pH of body fluids within narrow limits

Human blood normally 7.4 (slightly alkaline)

Many foods and metabolic processes add or subtract H\(^+\) or OH\(^-\) ions

- Reducing blood pH to 7.0 results in acidosis
- Increasing blood pH to 7.8 results in alkalosis
  - Both life threatening situations

Bicarbonate ion (-HCO\(_3\)) in blood buffers pH to 7.4
Organic Chem. Outline

Organic vs Inorganic

Functional Groups and Isomers

Macromolecules

Carbohydrates

Lipids

Proteins

Nucleic Acids
### Organic Molecules

**Inorganic** – Chemistry of elements other than carbon

**Organic** – Carbon-based chemistry

<table>
<thead>
<tr>
<th>Inorganic</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually with + &amp; - ions</td>
<td>Always contain carbon and hydrogen</td>
</tr>
<tr>
<td>Usually ionic bonding</td>
<td>Always covalent bonding</td>
</tr>
<tr>
<td>Always with few atoms</td>
<td>Often quite large, with many atoms</td>
</tr>
<tr>
<td>Often associated with nonliving matter</td>
<td>Usually associated living systems</td>
</tr>
</tbody>
</table>
Carbon Atom

Carbon atoms:

- Contain a total of 6 electrons
- Only four electrons in the outer shell
- Very diverse as one atom can bond with up to four other atoms
Carbon Atom

Carbon atoms:

Often bonds with other carbon atoms to make hydrocarbons

- Can produce long carbon chains like octane
- Can produce ring forms like cyclohexane
Octane & Cyclohexane

Octane

\[\text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H}\]

Cyclohexane

\[\text{H} - \text{C} - \text{C} - \text{H} \quad \text{H} - \text{C} - \text{C} - \text{H} \quad \text{H} - \text{C} - \text{C} - \text{H}\]
Functional Groups

Specific combinations of bonded atoms

Attached as a group to other molecules

- Always react in the same manner, regardless of where attached

- Determine activity and polarity of large organic molecules
## Biologically Important Functional Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Structure</th>
<th>Compound</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Hydroxyl</td>
<td>R–OH</td>
<td>Alcohols</td>
<td>Polar, forms H-bonds; some sugars and amino acids; Example: Ethanol</td>
</tr>
<tr>
<td>Carboxyl</td>
<td>R–CO₂H</td>
<td>Carboxyl</td>
<td>Polar; some sugars and amino acids; Example: Acetone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polar, basic; amino acids; Example: Tryptophan</td>
</tr>
<tr>
<td>Sulfhydryl</td>
<td>R–SH</td>
<td>Thiols</td>
<td>Disulfide Bonds; some amino acids; Example: Ethanethiol</td>
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<tr>
<td></td>
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<td></td>
<td>Polar, acidic; some amino acids; Example: Adenosine triphosphate</td>
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</table>
Dehydration and Hydrolysis

**Dehydration** - Removal of water molecule
- Used to connect monomers together to make polymers
- Polymerization of glucose monomers to make starch

**Hydrolysis** - Addition of water molecule
- Used to disassemble polymers into monomer parts
- Digestion of starch into glucose monomers

Specific enzymes required for each reaction
- Accelerate reaction
- Are not used in the reaction
Synthesis and Degradation of Polymers

(a) Dehydration reaction

(b) Hydrolysis reaction
### Biologically Important Functional Groups

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<tr>
<td>Carboxyl</td>
<td>$\mathbf{R}-\mathbf{COOH}$</td>
<td>Carboxylic Acids</td>
<td>Polar; some sugars and amino acids; Example: Acetic acid</td>
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<tr>
<td>Succinyl</td>
<td>$\mathbf{R}-\mathbf{COOH}$</td>
<td>Succinyls</td>
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Some molecules are called macromolecules because of their large size

Usually consist of many repeating units

- Resulting molecule is a polymer (many parts)
- Each repeating unit is called a monomer
## Macromolecules

<table>
<thead>
<tr>
<th>Category</th>
<th>Example</th>
<th>Subunit(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipids</td>
<td>Fat</td>
<td>Glycerol &amp; fatty acids</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>Polysaccharide</td>
<td>Monosaccharide</td>
</tr>
<tr>
<td>Proteins</td>
<td>Polypeptide</td>
<td>Amino acid</td>
</tr>
<tr>
<td>Nucleic Acids</td>
<td>DNA, RNA</td>
<td>Nucleotide</td>
</tr>
</tbody>
</table>
Four Classes of Organics: 1 - Carbohydrates

Monosaccharides

Disaccharides

Polysaccharides
Monosaccharides

Single sugar molecules
Quite soluble and sweet to taste

Examples

Glucose, fructose (fruit)

Ribose and deoxyribose (in nucleotides)
Carbohydrates

Glucose

a Monosaccharide

$\text{C}_6\text{H}_{12}\text{O}_6$
Disaccharides

Contain two monosaccharides joined
Soluble and sweet to taste

Examples

Sucrose
- Table sugar, maple sugar
- One glucose and one fructose joined
Synthesis of a Disaccharide
Polysaccharides

Polymers of monosaccharides
Low solubility; not sweet to taste

Example

**Starch**
- Used for short-term energy storage

**Cellulose**
- Main component of wood and many natural fibers
- All polymers of glucose, with different structures
Starch
Structure and Function

Amylose: nonbranched

Amylopectin: branched
Cellulose
Structure and Function
### 2 - Lipids

**Insoluble in water**
- Long chains of repeating CH₂ units
- Renders molecule symmetrical and nonpolar

**Types of Lipids**

<table>
<thead>
<tr>
<th>Type</th>
<th>Organismal Uses</th>
<th>Human Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fats</strong></td>
<td>Long-term energy storage &amp; thermal insulation in animals</td>
<td>Butter, lard</td>
</tr>
<tr>
<td><strong>Oils</strong></td>
<td>Long-term energy storage in plants and their seeds</td>
<td>Cooking oils</td>
</tr>
<tr>
<td><strong>Phospholipids</strong></td>
<td>Component of plasma membrane</td>
<td>No-stick pan spray</td>
</tr>
<tr>
<td><strong>Steroids</strong></td>
<td>Component of plasma membrane; hormones</td>
<td>Medicines</td>
</tr>
<tr>
<td><strong>Waxes</strong></td>
<td>Wear resistance/Coating; helps plants retain water</td>
<td>Candles, polishes</td>
</tr>
</tbody>
</table>
Types of Lipids:

**Triglycerides** (Fats)

- Long-term energy storage
- Three fatty acids attached to each glycerol molecule
- Long hydrocarbon chain
Synthesis of Triglyceride from Glycerol and Three Fatty Acids

a. Formation of a fat
Types of Lipids: Triglycerides
Types of Lipids:

**Phospholipids**

Derived from triglycerides

Two fatty acids attached instead of three

Molecules self arrange when placed in water

Polar phosphate “heads” next to water

Nonpolar fatty acid “tails” overlap and exclude water

Spontaneously form double layer & a sphere
Phospholipids Form Membranes

a. Plasma membrane of a cell

b. Phospholipid structure
Lipids and Carbohydrates Review

Monosaccharides
- Deoxyribose
- Glucose
- Fructose

Disaccharides
- Oils
- Steroids
- Polysaccharides
- Triglycerides
- Starch
- Phospholipids
More Types of Lipids:

**Steroids**

testosterone, estrogen and Cholesterol

Skeletons of four fused carbon rings
Steroid Diversity

- a. Cholesterol
- b. Testosterone
- c. Estrogen
Types of Lipids:

Waxes

Long-chain fatty acid bonded to a long-chain alcohol

- High melting point
- Waterproof
- Resistant to degradation
3 - Proteins

Functions

Support – Collagen

Enzymes – Almost all enzymes are proteins

Transport – Hemoglobin; membrane proteins

Defense – Antibodies

Hormones – Many hormones; insulin

Motion – Muscle proteins, microtubules
Protein Subunits: The Amino Acids

- Proteins are polymers of amino acids
- There are 20 different amino acids that make up proteins
- All of them have similar structures
- Amino acids joined together end-to-end
- Special name for this bond - Peptide Bond
- Virtually unlimited number of proteins
Protein Molecules: Levels of Structure

Primary:
String of amino acids

Secondary:
Amino acid chain coils or folds; tied like a knot

Tertiary:
3-D shaped chain of amino acids with peptide bond
Complex knot

Quaternary:
Consists of more than one protein
Like several knots glued together
**Primary Structure**
This level of structure is determined by the sequence of amino acids that join to form a polypeptide.

**Secondary Structure**
Hydrogen bonding between amino acids causes the polypeptide to form an alpha helix or a pleated sheet.

**Tertiary Structure**
Due in part to covalent bonding between $R$ groups the polypeptide folds and twists giving it a characteristic globular shape.

**Quaternary Structure**
This level of structure occurs when two or more polypeptides join to form a single protein.
4 - Nucleic Acids

Polymers of nucleotides

**DNA (deoxyribonucleic acid)**
- Double-stranded helical spiral (twisted ladder)
- Serves as genetic information center
- In chromosomes

**RNA (ribonucleic acid)**
- Part single-stranded, part double-stranded
- Serves primarily in assembly of proteins
- In nucleus and cytoplasm of cell
DNA Structure

RNA Structure
Other Nucleic Acids

ATP (adenosine triphosphate) is composed of adenine, ribose, and three phosphates

In cells, one phosphate bond is hydrolyzed – Yields:

The molecule **ADP** (adenosine diphosphate)

An inorganic phosphate molecule $p_i$

Energy

Breaking phosphate bond in ATP