Chapter 3: Biological Molecules

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic Acids
Elements in Biological Molecules

Biological macromolecules are made almost entirely of just 6 elements:

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Nitrogen (N)
- Phosphorus (P)
- Sulfur (S)

The most important element is Carbon!
Importance of Carbon

Special features of the element Carbon:
- can form bonds with up to 4 other atoms
- bonds tend to be relatively non-polar, stable
- can form complex linear, branched, ringed structures
- forms the “skeleton” of biological molecules

Organic molecules contain C & H:
- methane (CH₄), glucose (C₆H₁₂O₆) are organic
- water (H₂O), carbon dioxide (CO₂) are inorganic
- organic molecules are typically derived from living things
Carbon “Skeletons”

The carbon skeleton of an organic molecule consists of 1 or more carbon atoms linked together in linear, branched &/or ringed structures.

The remaining bonds are filled in with hydrogen (as with hydrocarbons) or other functional groups…
All biological molecules are essentially carbon skeletons with various functional groups attached:

**Important Functional Groups…**

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>Examples</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxyl group</td>
<td><img src="image" alt="Alcohol" /></td>
<td>polar</td>
</tr>
<tr>
<td>Carbonyl group</td>
<td><img src="image" alt="Aldehyde" /></td>
<td>polar</td>
</tr>
<tr>
<td>Carboxylic group</td>
<td><img src="image" alt="Carboxylic acid" /></td>
<td>acidic</td>
</tr>
</tbody>
</table>

- H (hydrogen) nonpolar
- OH (hydroxyl) polar
- CO (carbonyl): polar
- COOH (carboxyl) acidic
...more Functional Groups

- \( \text{NH}_2 \) (amino) \textit{basic}

- \( \text{H}_2\text{PO}_4 \) (phosphate) \textit{acidic}

- \( \text{CH}_3 \) (methyl) \textit{non-polar}
Many Biomolecules are Polymers

Polymers are chains of smaller monomers:
- like boxcars linked together to make a train

- each addition to a growing polymer involves the loss of H₂O, hence the term dehydration synthesis.
Hydrolysis of Polymers

Polymers are broken down into monomers by the addition of $\text{H}_2\text{O}$ to each bond: **hydrolysis**

- this is what happens to polymers in the foods we eat!
1. Carbohydrates
Carbohydrates

Made of “CH₂O” (1 Carbon : 2 Hydrogen : 1 Oxygen)

Functions:
• source of energy
• structural support

Examples of Carbohydrates:
• sugars
• starch
• cellulose
• glycogen

Glucose (C₆H₁₂O₆)
Carbohydrate Monomers & Polymers

- **monosaccharides**, **disaccharides** & **polysaccharides**
  (*“saccharide”* is Greek for sugar)

Important **monosaccharides**: GLUCOSE & FRUCTOSE

Important **disaccharides**: SUCROSE, LACTOSE & MALTOSE
Polysaccharides

Large polymers of sugars (usually glucose):

PLANTS – starch, cellulose

ANIMALS – glycogen
2. Lipids
Lipids

Hydrophobic, made mostly of C & H.

Functions:
- source of energy
- insulation
- hormones
- membranes

Includes:
- fatty acids (FA)
- triglycerides
- phospholipids
- steroids
Saturation of Fatty Acids

- saturated fatty acids have no C=C double bonds
  - fatty tail saturated with hydrogens
- unsaturated fatty acids have $\geq 1$ C=C double bond
  - monounsaturated
  - polyunsaturated
Phospholipids

The major component of biological membranes:

• have a “polar head” “non-polar tails”

  • polar groups are hydrophilic (“water loving”)

  • non-polar groups are hydrophobic (“water fearing”)
Steroids

All steroids contain the same core 4 ring structure.

Important Steroids:

- cholesterol
- estrogen
- testosterone
3. Proteins
Proteins
Proteins “do” essentially everything in a cell

<table>
<thead>
<tr>
<th>Function</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Collagen in skin; keratin in hair, nails, horns</td>
</tr>
<tr>
<td>Movement</td>
<td>Actin and myosin in muscle</td>
</tr>
<tr>
<td>Defense</td>
<td>Antibodies in bloodstream</td>
</tr>
<tr>
<td>Storage</td>
<td>Albumin in egg white</td>
</tr>
<tr>
<td>Signaling</td>
<td>Growth hormone in bloodstream</td>
</tr>
<tr>
<td>Catalyzing reactions</td>
<td>Enzymes (Examples: amylase digests carbohydrates; ATP synthase makes ATP)</td>
</tr>
</tbody>
</table>
Proteins are polymers of amino acids

Proteins are made of 20 different amino acids:

- the properties of each amino acid depend on its “R” group
  - R groups can be hydrophobic, hydrophilic, or have other important properties

- amino acid properties determine protein structure and function

- made from elements C, H, O, N & S

Leucine (Leu) hydrophobic
Serine (Ser) hydrophilic
Aspartic acid (Asp)
Polypeptides

Amino acid polymer = polypeptide

- each amino acid is joined by a peptide bond
- covalent bond formed between the – COOH & – NH₂ groups of adjacent amino acids

**a functional protein may contain 1 or more polypeptides**
Four Levels of Protein Structure

**Primary structure**
- Amino acids

**Secondary structure**
- Alpha helix
- Pleated sheet

**Tertiary structure**
- Polypeptide (single subunit of transthyretin)

**Quaternary structure**
- Transthyretin, with four identical polypeptide subunits

Protein Structure

Protein function depends on structure:
- Each polypeptide must be folded properly
- Polypeptides in a protein must interact in the right way

If this is not the case, proteins don’t work!
4. Nucleic Acids
Nucleic Acids

The main function of Nucleic Acids is to store and express Genetic Information:

All nucleotides have this basic structure.

• includes DNA, RNA & ATP

• DNA & RNA are linear polymers of nucleotides made from elements C, H, O, N & P
DNA & RNA are Nucleotide Polymers

- Nucleotides are connected by a “sugar-phosphate backbone”
- Genetic information is the nucleotide sequence
- Nucleotide sequence is determined by the “base”
- There are 4 different bases in the nucleotides of DNA
  - Adenine
  - Cytosine
  - Guanine
  - Thymine
DNA is a Double Helix

- DNA molecules consist of 2 linear polymers or *strands* or nucleotides
- the 2 strands of a DNA molecule interact through the bases in each strand
- a double-stranded DNA molecule twists to form a spiral or *helix*

*RNA is a *single*-stranded nucleotide polymer made from slightly different nucleotides*
Key Terms for Chapter 3

• organic, inorganic
• hydroxyl, carboxyl, amino, phosphate, methyl
• polymer, monomer, dehydration synthesis, hydrolysis
• carbohydrate; mono-, di-, polysaccharide
• lipid, fatty acid, triglyceride, phospholipid, sterol
• amino acid, polypeptide
• nucleic acid, nucleotide

Relevant Review Questions:
2-5, 7-12, 14, 16, 17