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...

Important Functional Groups

All biological molecules are basically carbon skeletons w/ various functional groups attached

–H (hydrogen: nonpolar “default” group)
–OH (hydroxyl: polar)
–COOH or –COO⁻ (carboxyl: acidic)
–NH₂ or –NH₃⁺ (amino: basic)
–H₂PO₄⁻ or –PO₄²⁻ (phosphate: acidic)
–CH₃ (methyl: non-polar)

<table>
<thead>
<tr>
<th>Group</th>
<th>Structure</th>
<th>Properties</th>
<th>Type of Molecule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen (–H)</td>
<td></td>
<td>Polar or nonpolar, depending on which other hydrogen is substituted, related to hydrocarbons</td>
<td>Almost all organic molecules.</td>
</tr>
<tr>
<td>Hydroxyl (–OH)</td>
<td></td>
<td>Polar, bonded in condensation and functions</td>
<td>Carbohydrates, nucleic acids, alcohol, some acids, and esters.</td>
</tr>
<tr>
<td>Carboxyl (–COOH)</td>
<td></td>
<td>Acidic, negatively charged when H⁺ dissociates, involved in peptide bonds</td>
<td>Amino acids, fatty acids</td>
</tr>
</tbody>
</table>

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</thead>
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<tr>
<td>Amino (–NH₂)</td>
<td></td>
<td>Basic, may bond on sidechain of H⁺, bearing a positive charge, involved in peptide bonds</td>
<td>Amino acids, nucleic acids</td>
</tr>
<tr>
<td>Phosphatase (–PO₄⁻)</td>
<td></td>
<td>Acidic, up to two negative charges, involved in many molecules, especially those in ATP</td>
<td>Nucleic acids, phospholipids</td>
</tr>
<tr>
<td>Methyl (–CH₃)</td>
<td></td>
<td>Nonpolar, teach molecules to interact</td>
<td>Many organic molecules</td>
</tr>
</tbody>
</table>
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 $H_2O$, hence the term dehydration synthesis. Breaking down a polymer involves the addition of $H_2O$, and thus is called hydrolysis.

1. Carbohydrates

Carbohydrates
Made of “CH$_2$O”
$1C : 2H : 1O$

Functions:
• energy source
• structural support

Includes:
• sugars
• starches
• cellulose
• glycogen
Carbohydrate Monomers & Polymers

- monosaccharides
- disaccharides
- polysaccharides

"saccharide" = sugar

2 monosaccharides
1 disaccharide

Important monosaccharides – glucose, fructose
Important disaccharides – sucrose, lactose

Polysaccharides

- large polymers of sugars (usu. glucose)

starch

Important polysaccharides:

PLANTS – starch (amylose), cellulose (plant fiber)
ANIMALS – glycogen (stored in liver, muscles)

2. Lipids
Lipids (fats & oils)

Made mostly of carbon, hydrogen.

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

Includes:
- fatty acids (FA)
- triglycerides
- phospholipids
- steroids

“unsaturated” FA
“saturated” FA (no C=C bonds)

Phospholipids

A major component of biological membranes

They have a “polar head”, “non-polar tails”
- polar groups are hydrophilic (“water loving”)
- non-polar groups are hydrophobic (“water fearing”)

Steroids

Important Steroids:
- cholesterol
- estrogen
- testosterone

All steroids contain the same core 4 ring structure
3. Proteins

Proteins “do” essentially everything in a cell

Table 3-3 Functions of Proteins

<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 linear polymers of amino acids (AAs)

- 20 different AAs
- properties depend on “R” group
**Polypeptides**

Amino acid polymer = polypeptide

- amino acids joined by peptide bonds
- covalent bond formed between the -COOH & -NH₂ groups of adjacent amino acids

A functional protein may contain 1 or more polypeptides

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**Importance of Protein Structure**

Protein function depends entirely on protein structure:

- each polypeptide in a protein must be properly folded
- all polypeptides in a protein must fit together properly

If this is not the case, proteins don't work!

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4. **Nucleic Acids**
Nucleic Acids

- All nucleotides have this basic structure.

Nucleic Acids are the Genetic Material

- DNA & RNA
- linear polymers of nucleotides
  - nitrogenous “base”
  - sugar
  - phosphate

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”
- 4 different bases in the nucleotides that make up DNA
  - Adenine
  - Cytosine
  - Guanine
  - Thymine

DNA Double Helix

- the 2 strands of a DNA molecule interact through the bases in each strand and form a double helix
Key Terms for Chapter 3

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

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