Introduction to Biochemistry
(Chapter 16 Chemistry for Changing Times)

*Biochemistry* is the chemistry of living things and life processes.
Human and animals cannot produce their own energy. They must obtain such energy by eating plants or other animals that eat plants.
Photosynthesis

C₆H₁₂O₆ + 6 O₂ →
6 CO₂ + 6 H₂O

• carbohydrates
• fats
• proteins
Photosynthesis

Respiration

Modified from *Biochemistry* (Mathews, van Holde, and Ahern)
Introduction to Biomolecules

• Carbohydrates (sugars, starches, cellulose)
• Lipids
• Proteins
• Nucleic acids (DNA & RNA)
Carbohydrates

\[ C_6H_{12}O_6 = C_6(H_2O)_6 \]

- Glucose
- Galactose
- Fructose
Monosaccharides

Carbohydrates that cannot be hydrolyzed into simpler compounds
Most monosaccharides actually exist in cyclic form

Glucose

Galactose

Fructose

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Disaccharides

Carbohydrates that can be hydrolyzed into two monosaccharide units

Sucrose

Lactose
Both starch and cellulose are polymers of glucose. The linkages between glucose molecules in starch are alpha (α) linkages, whereas in cellulose they are beta (β) linkages.
Lipids: biomolecules that are insoluble in water, but soluble in organic solvents

A primary example: Fats and Fatty acids

Table 15.1 Some Fatty Acids in Natural Fats

<table>
<thead>
<tr>
<th>Number of Carbon Atoms</th>
<th>Condensed Structure</th>
<th>Common Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>CH₃CH₂CH₂COOH</td>
<td>Butyric acid</td>
<td>Butter</td>
</tr>
<tr>
<td>6</td>
<td>CH₃(CH₂)₄COOH</td>
<td>Caproic acid</td>
<td>Butter</td>
</tr>
<tr>
<td>8</td>
<td>CH₃(CH₂)₆COOH</td>
<td>Caprylic acid</td>
<td>Coconut oil</td>
</tr>
<tr>
<td>10</td>
<td>CH₃(CH₂)₈COOH</td>
<td>Capric acid</td>
<td>Coconut oil</td>
</tr>
<tr>
<td>12</td>
<td>CH₃(CH₂)₁₀COOH</td>
<td>Lauric acid</td>
<td>Palm kernel oil</td>
</tr>
<tr>
<td>14</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>Myristic acid</td>
<td>Oil of nutmeg</td>
</tr>
<tr>
<td>16</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>Palmitic acid</td>
<td>Palm oil</td>
</tr>
<tr>
<td>18</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>Stearic acid</td>
<td>Beef tallow</td>
</tr>
<tr>
<td>18</td>
<td>CH₃(CH₂)₁₇CH=CH(CH₂)₇COOH</td>
<td>Oleic acid</td>
<td>Olive oil</td>
</tr>
<tr>
<td>18</td>
<td>CH₃(CH₂)₁₈CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>Linoleic acid</td>
<td>Soybean oil</td>
</tr>
<tr>
<td>18</td>
<td>CH₃CH₂(CH=CHCH₂)₃(CH₂)₆COOH</td>
<td>Linolenic acid</td>
<td>Fish oils</td>
</tr>
<tr>
<td>20</td>
<td>CH₃(CH₂)₄(CH=CHCH₂)₄CH₂CH₂COOH</td>
<td>Arachidonic acid</td>
<td>Liver</td>
</tr>
</tbody>
</table>

Palmitic Acid:
Triglyceride and its formation

**Triglycerides** are triesters of glycerol and fatty acids.
Proteins are polymers of amino acids.
Amino acids:
Building Blocks for Proteins

A zwitterion

Amino acids contain both an amine and carboxylate group attached to the same carbon called the alpha carbon.
### The 20 Amino Acids

#### Table 16.3: The 20 Amino Acids Specified by the Human Genetic Code

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Structure</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine (Ala (A))</td>
<td>CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Nonpolar amino acids</td>
</tr>
<tr>
<td>Valine (Val (V))</td>
<td>CH₃−CH−COO⁻</td>
<td>Nonpolar amino acids</td>
</tr>
<tr>
<td>Phenylalanine (Phe (F))</td>
<td>Nonpolar amino acids</td>
<td></td>
</tr>
<tr>
<td>Proline (Pro (P))</td>
<td>Nonpolar amino acids</td>
<td></td>
</tr>
<tr>
<td>Leucine (Leu (L))</td>
<td>CH₂CHCH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Essential to growing children but not to adults</td>
</tr>
<tr>
<td>Isoleucine (Ile (I))</td>
<td>CH₃CHCH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Essential to growing children but not to adults</td>
</tr>
<tr>
<td>Methionine (Met (M))</td>
<td>CH₃−S−CH₂CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Essential to growing children but not to adults</td>
</tr>
<tr>
<td>Tryptophan (Trp (W))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lysine (Lys (K))</td>
<td>H₃NCH₂CH₂CH₂CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Basic amino acids</td>
</tr>
<tr>
<td>Arginine (Arg (R))</td>
<td>H₂N−C−NHCH₂CH₂CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Basic amino acids</td>
</tr>
<tr>
<td>Histidine (His (H))</td>
<td>H₂N−C−CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Basic amino acids</td>
</tr>
<tr>
<td>Aspartic acid (Asp (D))</td>
<td>HOOC−CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Acidic amino acids</td>
</tr>
<tr>
<td>Glutamic acid (Glu (E))</td>
<td>HOOC−CH₂CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Acidic amino acids</td>
</tr>
<tr>
<td>Serine (Ser (S))</td>
<td>HO−CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Polar amino acids</td>
</tr>
<tr>
<td>Threonine (Thr (T))</td>
<td>CH₃CH−CH−COO⁻  <code>NH₂</code></td>
<td>Polar amino acids</td>
</tr>
<tr>
<td>Asparagine (Asn (N))</td>
<td>H₂N−C−CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Polar amino acids</td>
</tr>
<tr>
<td>Glutamine (Gln (Q))</td>
<td>H₂N−C−CH₂CH₂−CH−COO⁻  <code>NH₂</code></td>
<td>Polar amino acids</td>
</tr>
<tr>
<td>Tyrosine (Tyr (Y))</td>
<td>HO−CH₂−CH−COO⁻  <code>NH₂</code></td>
<td></td>
</tr>
</tbody>
</table>
The Peptide Linkage

H$_3$N$^+$—CH—C—NH—CH—C—O$^-$

Peptide bond

H$_3$N$^+$CHC—NHCHC—(NHCHC)—NHCHC—NHCHC—C—O$^-$

N-terminal

C-terminal
Protein structure
The primary structure of a protein is simply the sequence of amino acids from N-terminal to C-terminal.
Secondary structure
How the polypeptide chain folds and coils due to hydrogen bonding of the backbone amide groups. Examples include the alpha helix and beta-pleated sheet.
β-Sheet

Interchain hydrogen bonds

Top view

(a)
**Tertiary structure**: The three-dimensional shape of a protein due to the spatial relationships of groups that are far apart on the protein chain. One example is the protein chain in globular proteins.
Tertiary structure

Four-helix bundle: Myohemerythrin

Antiparallel β-barrel: Immunoglobulin, V2 domain

Parallel β-barrel, α/β: Pyruvate kinase, domain 1
Cofactors (coenzymes)

Iron-sulfur cluster

Heme

Metals: Cu, Zn, Fe, Mg, Ca, Ni, Co

Flavin
Quaternary structure: Involves the interaction of more than one peptide chain.
Structural Interactions in Proteins
Nucleotides - A Sum of 3 Parts

(a) Sugars

2-Deoxyribose (in DNA)

Ribose (in RNA)

(b) Heterocyclic bases

Thymine (T)

Adenine (A)

Guanine (G)

Cytosine (C)

Uracil (U)

(c) Phosphate ($P_i$)
An Example: AMP

Phosphate ester linkage

Adenosine monophosphate
DNA and RNA are long chains of nucleotides, bonded through phosphate groups.

Each is a series of heterocyclic bases attached by a phosphate and sugar backbone.
DNA structure
Transcription: DNA to RNA

RNA here is called messenger RNA (mRNA)
A series of codons in part of a messenger RNA (mRNA) molecule. Each codon consists of three nucleotides, usually coding a single amino acid.
Translation: RNA to protein

For a more detailed instruction, watch this video: http://www.youtube.com/watch?v=Ynmxwqiv7j8