Bil 255 - CMB
Molecules of Living Systems
Chemical Makeup of Cells

Lecture Topic #5 - Chemistry of Life –
is a review of your freshman biology course material that describes the structure of the fundamental biomolecules (sugars, lipids, nucleotides, & amino acids) that make up the major macromolecules of cells: starches/glycogen, triglycerides, phospholipids, nucleic acids and proteins.

YOU ARE RESPONSIBLE for reviewing topic #5 (below) on your own and I will quiz you on this material during our tests.

The chemicals of life...

ELEMENTS - substances composed of atoms all having an identical number of protons...
- can't be reduced to simpler substances by normal chemical means
- only 30 of 92 elements occur in living systems...
- 99% of living matter is made of C H O N P S

Water (H2O).................................................. 70 %
Inorganic ions (Na, K, Cl, PO4)......................... 1 %
Small molecules (aa's, sugar, nucleotides),..... 5 %
Macromolecules (protein, n.a., etc)............... 24 %

Molecules of Living Systems
chapter 2 pg 31-54

The structure of biological molecules how their shape determines the roles they play in the complex chemical processes of life.

Even the most complicated biological molecules can be divided into smaller and smaller functional groups

REDUCTIONISM

A Web Resource that gives 3-D shapes of Biomolecules

A Site of the Molecules of Life mwk

Biomolecules, Weak Forces, & Design of Metabolism

1. BIOMOLECULES... (carbon skeletons)
- mostly carbon compounds are found in living systems...
WHY Carbon? - easily forms 4 covalent bonds...
thus makes many small biomolecules
- allows 3-D shapes that can evoke biological activity
- possesses great chemical reactivity...
- interacts with common chemical functional groups

Functional Groups - groups of atoms, acts as a unit, give organic molecules their physical properties, chemical reactivity, & solubility in aqueous solutions.

most groups possess electronegative atoms [O, N, P, S]
key bonds are: ester \( \text{C}-\text{O}-\text{C}^\text{+} \) & amide \( \text{C}-\text{N}^- \)
most are ionizable at physiological (pH 6.8 to 7.4) read pages 40-50
2. small Biomolecules [monomers]

Four major groups of small biomolecules:

a. **SUGARS** - compounds with formula \( [CH_2O]_n \)
   - **Aldoses vs. Ketoses**
   - **α & β links**
   - **Rings**
   - **Glucose vs. Galactose**
   - **Monosaccharides vs. Disaccharides**
   - **Long chain polymers of mono- saccharides**

b. **FATTY ACIDS** - long chain hydrocarbons
   - **Saturated vs. Unsaturated**
   - **Lipids** (triaclylglycerols = animal fats)
   - **Phospholipids** of membranes
   - Easily self-assembly into **Aggregates** (soap micelles)

   - Steroid & Cholesterol (4-ring skeleton) are lipids because:
   - They're insoluble

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**Amino Acids & their role in Proteins...**

Proteins - the penultimate molecules?
- Structurally complex
- Functionally sophisticated
- Long repeats of individual monomers (amino acid's)
- Most abundant molecule in cells
- 15% of cell's dry mass

Amino Acids

\[
\begin{align*}
R & \quad H_2N - C - COOH \\
H &
\end{align*}
\]

20 common amino acids – mcb 2.14 p42 & panel 2.5

- Lys-Arg-His-Glu-Ala-Val-Ile-Leu-Pro-Phe-Met-Trp-Gly-Cys-Ser-Thr-Tyr


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**why only these 20?**

- All are structurally similar
  - alpha-amino acids and the L-stereoisomers...
  - It may be an evolutionary anomaly...
- There are some unusual aa's...
  - And all play structurally important roles.
  - 4-hydroxy proline occurs in plant cell wall proteins
  - 5-hydroxy lysine occurs in fibrous proteins as collagen
  - N-methyl lysine occurs in myosin contractile proteins
  - γ-carboxy glutamate occurs in prothrombin

Amino Acids... **structures & chemical properties of AA's [m.w.king]**
1st amino acid discovered was **asparagine** (1806 in asparagus)  
last amino acid found was **threonine** (1938)

**STRUCTURE** - amino acids have a carboxyl group (-COOH) & amino group (-NH2) bound to an asymmetric carbon

20 ubiquitous aa’s have 4 groups in a tetrahedron shape

2 stereo-isomers (enantiomers = mirror images)  
- [**levo-rotatory** (left)] & [**dextro-rotatory** (right)]
- only L-amino acids occur in living cell proteins

**Zwitterion** - (an ampholyte) holds 2 groups of opposite sign

**Isoelectric Point** - pH where no net charge in molecule

**pK** - pH where groups are 50% ionized & 50% non-ionized

**classes of amino acids [classified... by R-Groups]**

<table>
<thead>
<tr>
<th>Acidic</th>
<th>R group with 2nd COOH that ionizes above pH 7.0 mcb 2.14*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>positively charged LYS, ARG, HIS R group with 2nd amide that protonates below pH 7.0</td>
</tr>
<tr>
<td>Polar Uncharged</td>
<td>SER, THR, TYR, ASN, GLN are soluble in water, i.e., hydrophilic</td>
</tr>
<tr>
<td>Non-Polar</td>
<td>(aliphatic) ALA, VAL, ILE, ILE contain only hydrocarbons R groups = hydrophobicity</td>
</tr>
<tr>
<td>Aromatic</td>
<td>(hydrophobic non-polars) PHE, MET, TRP, GLY, PRO, CYS contain R groups with ring structures &amp; others</td>
</tr>
</tbody>
</table>

**Peptide Bond...**

formed by condensation reaction between amino of one aa... & carboxyl of another aa... mcb 6e fig 3.3

substituted amide covalent bond –
- dipeptide has partial double bond character –
- shorter & stronger than C-C longer, yet weaker than C≡C
- no free rotation (group in same plane, but TRANS)
- results is zig-zag planar molecule figure*

**Some common terminology:**

- dipeptide, tripeptide, oligopeptide, polypeptide protein - polymer of α-L-amino acids joined by peptide bonds

**whale myoglobin** - ecb panel 4.2 pg 132-133
some naturally occurring small oligopeptides

[many are vertebrate hormones]

<table>
<thead>
<tr>
<th>Oligopeptide</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insulin</strong></td>
<td>Two polypeptides... controls carbohydrate metabolism&lt;br&gt;1. alpha chain of 30 aa's &amp; 2. beta chain of 21 aa</td>
</tr>
<tr>
<td><strong>Glucagon</strong></td>
<td>Pancreatic hormone 29 aa... opposes insulin action</td>
</tr>
<tr>
<td><strong>NutraSweet</strong></td>
<td>A dipeptide (2aa) of L-aspartyl-phenylalanyl-methyl</td>
</tr>
<tr>
<td><strong>Corticotropin</strong></td>
<td>39aa... anterior pituitary hormone... stimulates adrenal cortex</td>
</tr>
<tr>
<td><strong>Oxytocin</strong></td>
<td>9aa... hormone of posterior pituitary... stimulates uterine contractions</td>
</tr>
<tr>
<td><strong>Bradykinin</strong></td>
<td>9aa... hormone acts on smooth muscle... vasodilatation/inflammation</td>
</tr>
<tr>
<td><strong>Angiotensin</strong></td>
<td>Octapeptide (derived from angiotensinogen by kidney enzyme renin)&lt;br&gt;Increases blood pressure&lt;br&gt;ACE Inhibitors block AT &amp; lower bp. [sport]</td>
</tr>
<tr>
<td><strong>Thyrotropin releasing factor (TSH)</strong></td>
<td>3 aa's of hypothalms... stimulates thyroid to release thyroid hormone</td>
</tr>
<tr>
<td><strong>Enkephalins</strong></td>
<td>Either of two pentapeptides with opiate &amp; analgesic activity, occurs naturally in brain &amp; have marked affinity for opiate receptors... compare endorphins</td>
</tr>
</tbody>
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