First, let’s look at the syllabus in detail to help clarify things.

* I do not be provide printed copies of syllabi, but they are available through the VSU Biology Department Web site:
  
* [http://www.valdosta.edu/biology/](http://www.valdosta.edu/biology/)

* Click on “Department Faculty” then find my name near the bottom of the page and click on it; you’ll get my curriculum vitae (resume). The first heading under “Experience” is my job here at VSU; all my syllabi and lectures are listed. They come in PDF format. Let’s check it out.
And on that note, here's your first in-class assignment.

- On a plain sheet of paper legibly write:
  - Your name, the date, the class number and section, your major, and your class standing;
  - Previous science courses you've taken (high school, if none else); and . . .
  - What you think both "science" and "life" is!

- There's no right or wrong answer; I just want your opinions. Quietly work on this for the remainder of the class, while I deliver the lecture. Yes, you can multitask. Turn these in to me as you leave.
And now, biochemistry: the chemistry of life — but first a little inorganic chemistry

- All matter is made of atoms, either in its elemental form individually (e.g. pure sulfur, $S$), or in multiples (molecules, e.g. oxygen gas, $O_2$); or in combination with other atoms (molecular compounds, e.g. water, $H_2O$).

- 25 elements are essential to life. Of these...

- Bulk elements — make up majority of living things. And...

- Trace elements — required in smaller amounts.

Sunday, January 9, 2011
The Periodic Table...

Organizes elements by physical properties.

Some elements are missing for clarity sake.
Even atoms have parts.

But when you break down an atom, that’s a fission reaction (or radioactive decay), and the results are no longer the same element (or isotope); e.g. Carbon has the atomic number 6, i.e. it has six protons:
Atoms can also gain or lose electrons. These are ions, and many are essential to much of life; e.g. Sodium, \( \text{Na}^+ \); Potassium, \( \text{K}^+ \); Calcium, \( \text{Ca}^{++} \); and Cloride, \( \text{Cl}^- \).

And it usually has six neutrons; therefore, it has an atomic mass of 12. However, some Carbon atoms have eight neutrons, for a mass of 14. These are called isotopes. Carbon-14 dating uses the radioactive \([\text{beta}]\) decay of these into 'normal' Nitrogen, with its mass of 14.
How do atoms combine?

* Molecules are combinations of atoms held together by chemical (covalent) bonds. The chemical formula describes this association, e.g. methane, CH₄, has four Hydrogen atoms bonded to one Carbon atom.

* Electrons occupy “orbital shells” around the nucleus of an atom. These are where covalent bonds happen through the ‘sharing’ of electrons in partially filled outer (valence) shells.
The methane example:

1 carbon atom + 4 hydrogen atoms → 1 methane molecule (CH₄)

a.

CH₄

H
H
H
H

b.
Covalent bonds can be . . .

* Single, double, triple . . . depending on the number of shared electron pairs;

* They can also be nonpolar, where there is no ‘offsidedness’ of electronegativity; or they can be polar, where there are negatively and positively charged ends to the molecule.
An extreme case of polarity is seen in ionic bonds . . .

* They result from an electrical attraction between two ions with opposite charges;
* In general, these form between an atom with a valence shell almost empty and an atom with a valence shell almost full;
* In the NaCl (normal table salt) example these bonds are so strong it forms a crystal:
Hydrogen bonds are different. They happen when . . .

- Opposite partial charges on adjacent molecules, or within the same large molecule, attract each other.
- Hydrogen is usually the partially positive member.
- The water example:
  - Two polar covalent bonds per molecule;
  - Oxygen is more electronegative and pulls electrons away from hydrogens; Therefore . . .
  - The partial positive charge on the hydrogens is attracted to the slight negative charge on the oxygen atom of another molecule.
Here’s the water model.

The hydrogen bond is vitally important to many biological molecules, including DNA.
Here's an overview of chemical bonds:

<table>
<thead>
<tr>
<th>Type</th>
<th>Chemical Basis</th>
<th>Strength</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covalent bond</td>
<td>Atoms share electron pairs</td>
<td>Strong</td>
<td>O–H bond within water molecule</td>
</tr>
<tr>
<td>Ionic bond</td>
<td>One atom donates one or more electrons to another atom, forming oppositely charged ions that attract each other</td>
<td>Strong, but break easily in water</td>
<td>Sodium chloride (NaCl)</td>
</tr>
<tr>
<td>Hydrogen bond</td>
<td>Atom with partial negative charge attracts atom with partial positive charge; form between adjacent molecules or between different parts of a large molecule</td>
<td>Weak</td>
<td>Attracts adjacent water molecules to each other</td>
</tr>
</tbody>
</table>
Water! All life needs it; it’s where it all started.

* **Cohesion** — the tendency of water molecules to stick together (to each other). It is . . .
 * Based on hydrogen bonding. This creates . . .
 * A high surface tension that forms a “skin” strong enough to support small insects.

* **Adhesion** — the tendency to form hydrogen bonds between water and other substances.

* Cohesion and adhesion work together to create capillary action (dye in celery stalks).
More water . . .

- **Water** is a solvent — a chemical in which other substances, solutes, dissolve.

- **Solution** — One or more solutes dissolved in one or more liquid solvents.

- **Aqueous solution** — solvent is water.

- **Hydrophilic** molecules are polar.

- Substance readily dissolves in water; i.e. it is water-loving. An example is salt in water.

- **Hydrophobic** molecules are nonpolar.

- Substance does not dissolve in water; i.e. it is water-fearing. An example is oil on water.
Water is also vital to most chemical reactions in life.

* As the medium in which the reaction occurs and/or as a participant in the reaction.

* pH is critical to all this. It measures how acidic or basic a solution is, i.e. how many H⁺ ions are floating about, the more H⁺, the more acidic and the lower the pH.
Chemical compounds that contain both carbon and hydrogen.

Hydrocarbons consist almost entirely of carbon and hydrogen.

Four types: carbohydrates, lipids, proteins, and nucleic acids.

Monomers (single units) linked together to form polymers.

Linked using dehydration — take water out.

Broken apart by hydrolysis — add water in.
And Biochemistry . . .

* Carbohydrates: simple sugars and complex carb’s — provide energy and structure.

* Lipids: all hydrophobic — provide energy, regulation, and structure.

* Proteins — enzymes, regulation, structure . . . lots and lots of things!

* Nucleic Acids — the ‘informational’ molecules, but also enzymatic structures.
Carbohydrates are . . .

- Organic molecules that consist of carbon, hydrogen and oxygen (often in a 1:2:1 ratio). They include...

- Simple sugars — a ready source of energy. Which include...

- Monosaccharides — 5 or 6 carbon atoms:
  - The same number of carbon atoms can be put together differently to give very different molecules. And...

- Disaccharides:
  - Two monosaccharides joined by dehydration synthesis.
  - For example, sucrose = fructose + glucose.

- And . . . Oligosaccharides — 3-100 monomers:
  - Many of these attach to [glyco]proteins on the cell membrane.
The other carbohydrates are the complex carbohydrates. These are . . .

- Polysaccharides, which consist of . . .
- Hundreds of monosaccharides. And include . . .
- Cellulose — used in plant cell walls. And . . .
- Chitin — used in insect exoskeletons, and fungi cell walls. And . . .
- Starch — used for plant energy storage. And . . .
- Glycogen — used by animals and fungi for energy storage.
For example:

**a. Monosaccharides:** simple sugars composed of carbon, hydrogen, and oxygen in the proportions 1:2:1.

- Glyceraldehyde: $\text{C}_3\text{H}_4\text{O}_3$
- Ribose: $\text{C}_5\text{H}_{10}\text{O}_5$
- Glucose: $\text{C}_6\text{H}_{12}\text{O}_6$
- Fructose: $\text{C}_6\text{H}_{12}\text{O}_6$
- Galactose: $\text{C}_6\text{H}_{12}\text{O}_6$

**b. Disaccharides:** molecules composed of two monosaccharides joined by dehydration synthesis. Hydrolysis converts disaccharides into their component monosaccharides. (The structures of the molecules are simplified to emphasize the joining process.)

- Glucose: $\text{C}_6\text{H}_{12}\text{O}_6$ + Fructose: $\text{C}_6\text{H}_{12}\text{O}_6$ $\rightarrow$ Sucrose: $\text{C}_{12}\text{H}_{22}\text{O}_{11}$

**c. Polysaccharides:** complex carbohydrates composed of long chains of simple sugars, usually glucose. Their chemical characteristics are determined by the orientation and location of the bonds between the monomers.

- Cellulose
- Starch
- Glycogen
Lipids (a.k.a. fats)!

- All cannot dissolve in water. That means they are . . .
- Hydrophobic. They contain . . .
- Large areas with nonpolar bonds.
- They are not polymers; made of monomers.
- This is unlike the other three major macromolecules.
- There are several groups of them:
  - triglycerides, sterols, waxes, and phospholipids.
Triglycerides (normal fats):

* Three fatty acids bonded to a glycerol.
* Use dehydration synthesis and hydrolysis.
* Saturated fatty acids have all single bonds between carbons.
* Animal fats, solid.
* Unsaturated fatty acids have at least one double bond between carbons.
**Sterols:** vital in regulatory and structural roles.

* All have four interconnected carbon rings.
* Examples include Vitamin D, cortisone, testosterone, and . . .
* Cholesterol, used in cell membranes, and to make other lipids.

What makes men men!
Waxes:

* Fatty acids combined with either alcohols or other hydrocarbons.
* Usually forms water-repellent covering, e.g. on leaves, fruits, fur, and feathers.
Proteins: the workers!

- Consist of amino acid monomers.
- Which have a central carbon atom bonded to a hydrogen, a carboxyl group, an amino group, and an R group.
- The R group distinguishes amino acids.
- Dehydration synthesis links amino acids together (peptide bond), hydrolysis break them apart.
- Come as various peptides, dipeptides, tripeptides, polypeptides, and proteins.
**Table 2.5  Protein Diversity in the Human Body**

<table>
<thead>
<tr>
<th>Proteins</th>
<th>Function</th>
<th>Proteins</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actin, myosin, dystrophin</td>
<td>Muscle contraction</td>
<td>Fibrin, thrombin</td>
<td>Blood clotting</td>
</tr>
<tr>
<td>Antibodies, cytokines</td>
<td>Immunity</td>
<td>Growth factors</td>
<td>Promote cell division</td>
</tr>
<tr>
<td>Carbohydrases, lipases, proteases, nucleases</td>
<td>Digestive enzymes*</td>
<td>Hemoglobin, myoglobin</td>
<td>Transport and storage of oxygen</td>
</tr>
<tr>
<td>Casein</td>
<td>Milk protein</td>
<td>Insulin, glucagon</td>
<td>Control of blood glucose level</td>
</tr>
<tr>
<td>Collagen, elastin</td>
<td>Connective tissue</td>
<td>Keratin</td>
<td>Structure of hair, fingernails</td>
</tr>
<tr>
<td>Colony-stimulating factors</td>
<td>Blood cell formation</td>
<td>Transferrin</td>
<td>Iron transport in blood</td>
</tr>
<tr>
<td>DNA and RNA polymerase</td>
<td>Enzymes* required for DNA replication, gene expression</td>
<td>Tubulin, actin</td>
<td>Cell movements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tumor suppressors</td>
<td>Block cell division</td>
</tr>
</tbody>
</table>

*Enzymes, discussed further in chapter 4, are proteins that speed chemical reactions. Without enzymes, most of the cell's reactions would proceed much too slowly to sustain life.
What these molecules really are.
What about these amino acids?
The physiochemical properties of amino acids determine everything about the protein they make.

http://www.bio.davidson.edu/courses/genomics/jmol/aatable.html

The Venn diagram categorizes the twenty naturally occurring amino acids according to their physiochemical properties.

http://prowl.rockefeller.edu/aainfo/pchem.htm
OK, then what sort of structures do they create?

- Protein folding creates unique 3D structures.
- **Primary (1°) structure** — this is the amino acid sequence determined by an organism’s genetic code (DNA).
- **Secondary (2°) structure** — these are the interactions between amino acids to form helices, sheets, and loops.
- **Tertiary (3°) structure** — the overall shape arising from interactions between R groups, 2° structure, and water.
- **Quaternary (4°) structure** — are the interactions between multiple polypeptide subunits (e.g. hemoglobin has 4 subunits, two alpha and two beta in adults).
- **Denaturation** — a loss of structure due to physical means (e.g. heat, salt, pH); causes the loss of function.
Once more. What do these look like?

a. Primary structure—the sequence of amino acids

b. Secondary structure—hydrogen bonds between nonadjacent carboxyl and amino groups

c. Tertiary structure—disulfide and ionic bonds between R groups, interactions between R groups and water

d. Quaternary structure—hydrogen and ionic bonds between separate polypeptides
Nucleic Acids! Information molecules

- Two types: Deoxy-ribonucleic acid (DNA), Ribonucleic acid (RNA).
- Nucleotide monomers: Each has a five carbon sugar, a phosphate group, and a nitrogenous base.

Nucleotides: consist of a sugar (ribose or deoxyribose), a phosphate, and one of five nitrogenous bases.

- Cytosine (C)
- Thymine (T)
- Adenine (A)
- Uracil (U)
Nucleotide polymers = nucleic acids

**DNA**
- Deoxyribose sugar;
- A, C, G and T (not U);
- Double helix.
- Hydrogen bonds hold halves together.
- Always A with T, and C with G.
- Strands are complementary.
- Genetic code — each group of three DNA bases specifies one amino acid.
And . . .

* **RNA**
  * Ribose sugar;
  * A, C, G and U (not T);
  * Often single stranded.
  * Different kinds: messenger, transfer, ribosomal, small nuclear . . . .
  * Most enable DNA to be expressed.
  * Some function as an enzyme.
  * An RNA nucleotide, adenosine triphosphate (ATP), carries energy.
Once more. What do they look like?

**Nucleic acids**: nucleotides joined together in long chains to form DNA or RNA. DNA is composed of the nucleotides A, C, T and G. RNA contains the sugar ribose and the nucleotide U instead of T.
Whew! A lot of information.

* The next several weeks will investigate many of these molecules in much more depth. Perhaps more than you want!
* We’ll see how and where they fit in and out of cells, and in life in general.
* And we’ll see how they relate to energy use and production.
* Plus we’ll see how DNA runs the whole thing along with RNA.