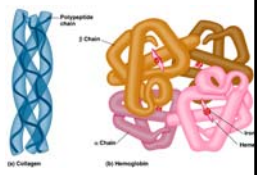
Organic & Biochemical Compounds

Pre-AICE Biology
& Biology Honors

Mrs. King



Fields of Science

Organic chemistry is of vital importance to

- petrochemical
- pharmaceutical
- textile industries
- prime concern is the synthesis of new organic molecules and polymers

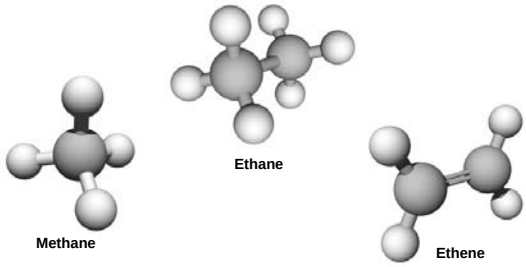
The Importance of Carbon

1. Organic chemistry
2. Most versatile building blocks of molecules
3. Variation in carbon skeletons contributes the diversity of organic molecules

Organic Compounds

- Carbon forms by far the greatest number of different compounds.
- Compounds containing only hydrogen and carbon are called hydrocarbons, the simplest is methane (CH_4).

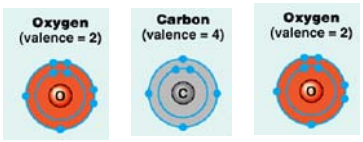
Arrangement of Carbon Atoms



Carbon most versatile building block of molecules

- 4 valence electrons – little tendency to gain or loose electrons
- Can form 4 single covalent bonds
- Capable of forming double and triple covalent bonds
- Can combine with atoms of many different elements

Valences for the major elements of organic molecules



carbon dioxide

The structural formula, O = C = O, shows that each atom has completed its valence shells

CO_2 can be classified as either organic or inorganic

CO_2 is the source for all organic molecules in organisms via the process of photosynthesis.

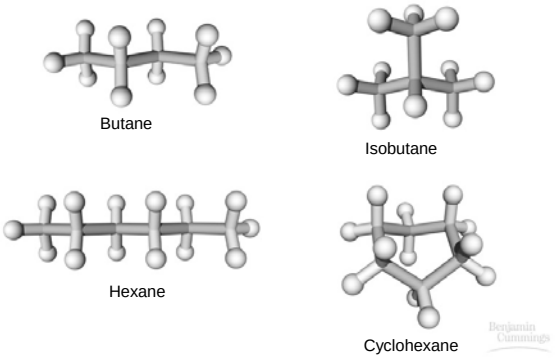
Variation = Diversity

- Carbon chains form the skeletons of most organic molecules.
  - Skeletons vary in length and may be **straight, branched,** or **closed rings.**
  - May also include double bonds

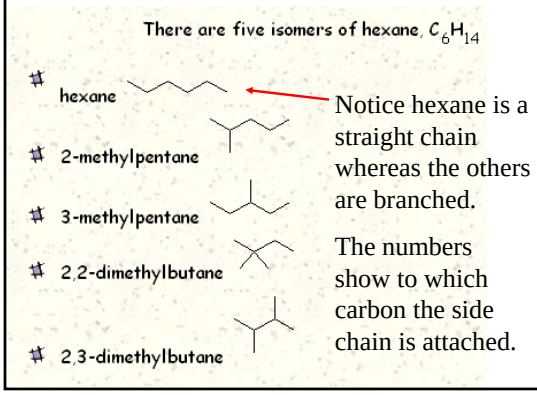
Alkanes

- C-H single bonds
- Hydrocarbons
- Straight chains, branched or cyclic
- Name ends in –ane
  - Meth**ane**
  - Eth**ane**
  - Prop**ane**
  - But**ane**

Hydrocarbons



Alkane Chemical Formulas



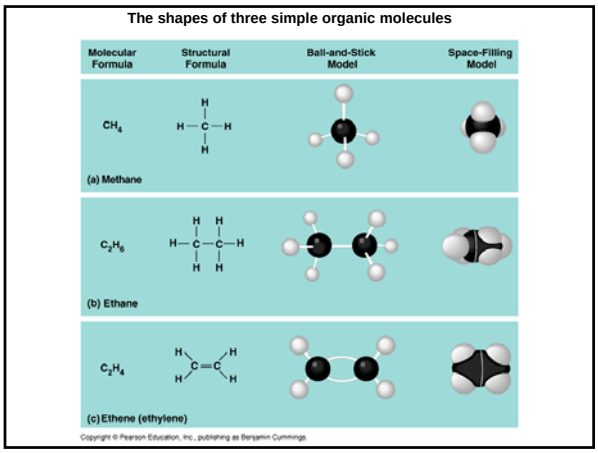
Notice hexane is a straight chain whereas the others are branched.

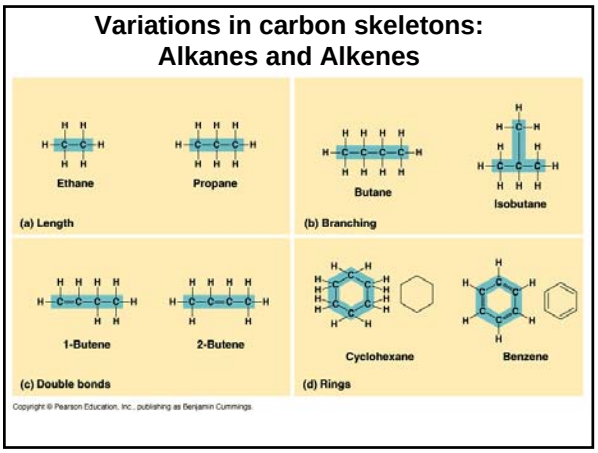
The numbers show to which carbon the side chain is attached.

Alkenes

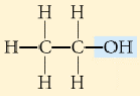
- Double carbon bonds and single carbon-hydrogen bonds:

  C=C and C-H
- Name ends in -ene
- Simplest is eth**ene** (ethylene)
  - C_2H_4
  - Formed when fruit ripens
- Prop**ene** used to make rubbing alcohol and some plastics





Alcohols



- One or more -OH groups *(hydroxyl)*
- Name ends in *–ol*
  - Methan**ol**
  - Ethan**ol**
- Behave similarly to water molecules
- Liquid at room temp
- Much higher boiling point than other organic molecules of the same size

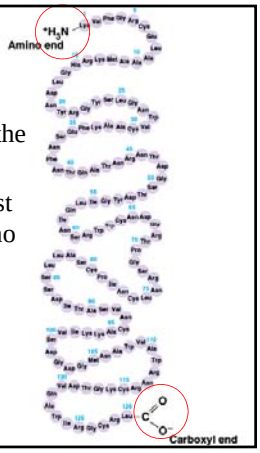
Polymers

- Form when small organic molecules bond to form long chains (string of pearls)

Natural	Man Made
•Cotton	•Plastic (flexible, easily molded)
•Wool	•Fibers (long thin chains)
•Wood	
•Rubber	
•DNA	

Conformation

- Determines the activity of the protein
- <u>*Primary* structure</u>: (The first level) the sequence of amino acids
- *Secondary* structure
- *Tertiary* structure
- *Quaternary* structure



Polymers

- Some are long strings, like cooked spaghetti, that slide past each other
  - Bending or flexing
  - Ex. plastic soda bottle
- Some are meshed like a net
  - Elastic property or memory
  - Ex. rubber band

Biochemical Compounds

- Naturally occurring organic compounds
- Important to living things
  - Carbohydrates
  - Proteins
  - DNA
- All are polymers

Carbohydrates

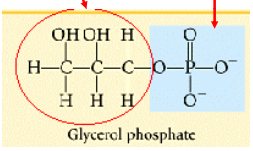
- Sugar
  - Glucose
  - Stored as glycogen
- Starch
  - Many glucose molecules bonded together
- Provide energy

Amino Acids

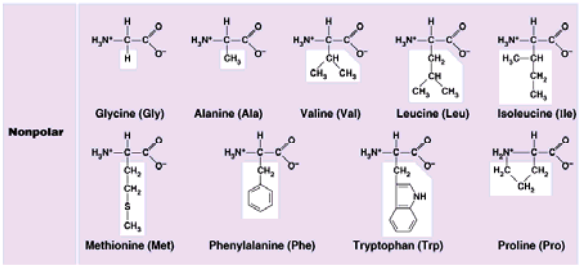
- Made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.
- Bond together to make proteins- building blocks
- 20 amino acids in naturally occurring proteins
- Have amino and carboxyl groups

So what's a "R" group???

R groups are attached to the functional group

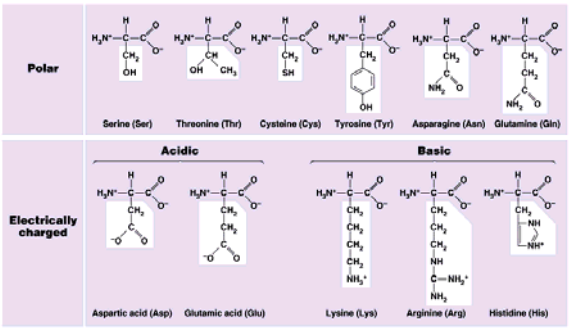


Nonpolar Amino Acids



hydrophobic

Polar & Electrically charged Amino Acids



hydrophillic

Condensation Reaction (or **Dehydration Synthesis)**

- The process of connecting monomers to make a polymer.
  - This process requires energy and is aided by enzymes.
  - Removes water molecule
    One monomer provides a hydroxyl group and the other provides a hydrogen

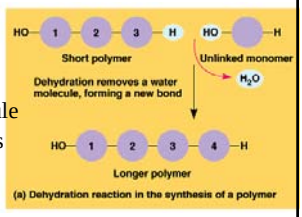
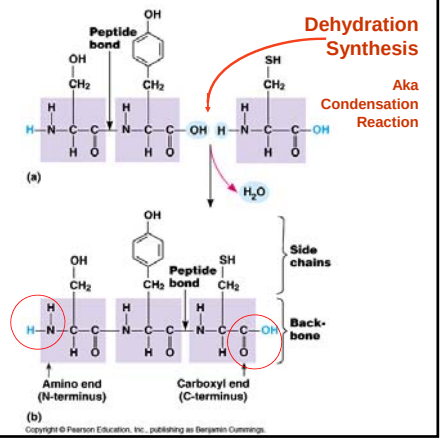


Fig. 5.2a

Making a polypeptide chain



Hydrolysis

The process of breaking a polymer with the help of water.

- Basically the reverse of dehydration synthesis.
- In hydrolysis as the covalent bond is broken a hydrogen atom and hydroxyl group from a split water molecule attaches where the covalent bond used to be.
- Hydrolysis reactions dominate the digestive process, **guided by specific enzymes.**

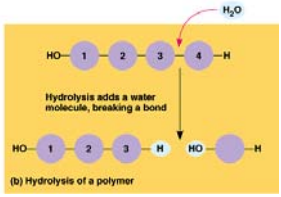


Fig. 5.2b

- In a **hydroxyl group** (-OH), a hydrogen atom forms a polar covalent bond with an oxygen atom, which forms a polar covalent bond to the carbon skeleton.
  - polar covalent bonds improve the solubility of organic molecules.
  - Called **alcohols** and their names typically end in ***-ol.***

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Hydroxyl	—OH	Alcohols	Ethanol (the drug of alcoholic beverages)

- A **carbonyl group** (>CO) consists of an oxygen atom joined to the carbon skeleton by a double bond.
  - If the carbonyl group is on the end of the skeleton, the compound is an **aldelhyde**.
  - If not, then the compound is a **ketone**.
  - Isomers with aldehydes versus ketones have different properties.

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Carbonyl		Aldehydes	Propanal
		Ketones	Acetone

- A **carboxyl group** (-COOH) consists of a carbon atom with a double bond to an oxygen atom and a single bond to a hydroxyl group.
  - Compounds with carboxyl groups are **carboxylic acids**.
  - A carboxyl group acts as an acid because the combined electronegativities of the two adjacent oxygen atoms increase the dissociation of hydrogen as an ion (H^+).

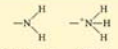
Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Carboxyl	(non-ionized) (ionized)	Carboxylic acids	Acetic acid* (the acid of vinegar)

*The ionized forms of the carboxyl and amino groups prevail in cells. However, acetic acid and glycine are represented here in their non-ionized forms.

- An **amino group** (-NH_2) consists of a nitrogen atom attached to two hydrogen atoms and the carbon skeleton.
  - Organic compounds with amino groups are **amines**.
  - The amino group acts as a base because ammonia can pick up a hydrogen ion (H^+) from the solution.
  - Amino acids, the building blocks of proteins, have amino and carboxyl groups.

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Amino	 (non-ionized) (ionized)	Amines	 Glycine* (an amino acid)

*The ionized forms of the carboxyl and amino groups prevail in cells. However, acetic acid and glycine are represented here in their non-ionized forms.

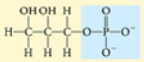
- A **sulfhydryl group** (-SH) consists of a sulfur atom bonded to a hydrogen atom and to the backbone.
  - This group resembles a hydroxyl group in shape.
  - Organic molecules with sulfhydryl groups are **thiols**.
  - Sulfhydryl groups help stabilize the structure of proteins.

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Sulfhydryl	—SH	Thiols	 Ethanethiol

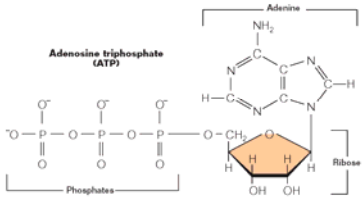
- A **phosphate group** (-OPO_3^{2-}) consists of phosphorus bound to four oxygen atoms (three with single bonds and one with a double bond).
  - A phosphate group connects to the carbon backbone via one of its oxygen atoms.
  - Phosphate groups are anions with two negative charges.
  - One function of phosphate groups is to transfer energy between organic molecules (ATP).

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Phosphate		Organic phosphates	 Glycerol phosphate

ATP

- **Adenosine triphosphate (ATP)** releases energy during cell processes, enabling organisms to function.



Proteins

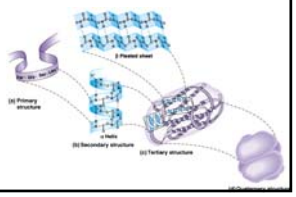
Important in about everything an organism does- many functions & many structures

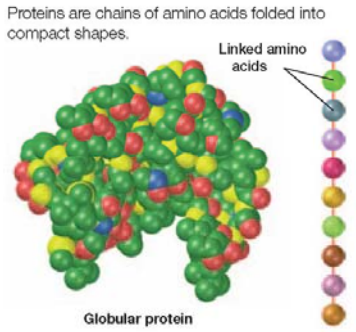
- Made of amino acids (20 different)

  Each amino acid has:
  - Hydrogen group
  - A carboxyl group
  - A variable R group (side chain) attached to a central carbon
  - The R group determines the characteristics of the amino acid

Proteins

- Polymers of amino acids
- Carbon, hydrogen, oxygen, nitrogen
- Each with their own structure and function
- Regulate metabolism





Protein Functions

Table 5.1 An Overview of Protein Functions

Type of Protein	Function	Examples
Structural proteins	Support	Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin provide a fibrous framework in animal connective tissues. Keratin is the protein of hair, horns, feathers, and other skin appendages.
Storage proteins	Storage of amino acids	Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo. Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds.
Transport proteins	Transport of other substances	Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.
Hormonal proteins	Coordination of an organism's activities	Insulin, a hormone secreted by the pancreas, helps regulate the concentration of sugar in the blood of vertebrates.
Receptor proteins	Response of cell to chemical stimuli	Receptors built into the membrane of a nerve cell detect chemical signals released by other nerve cells.
Contractile proteins	Movement	Actin and myosin are responsible for the movement of muscles. Other proteins are responsible for the undulations of the organelles called cilia and flagella.
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes catalyze the hydrolysis of the polymers in food.

Proteins continued

Physical & Chemical Changes

- Alterations in pH, salt concentration, temperature, or other factors can *denature* and/or change the shape of the protein.
- These factors can disrupt H bonds, ionic bonds, and disulfide bridges that hold them together.
  - Ex. Mutations in DNA

Proteins continued

- **Function in:**
  - support
  - storage
  - transport of other substances
  - intercellular signaling
  - movement
  - and defense against foreign substances
- Enzymes!
  - An **enzyme** is a catalytic protein.
- Enzymes regulate the movement of molecules through metabolic pathways

Enzymes

- **Enzymes** speed up chemical reactions and bind to specific substrates.
  - The binding of a substrate with an enzyme causes a change in the enzyme's shape and reduces the activation energy of the reaction.

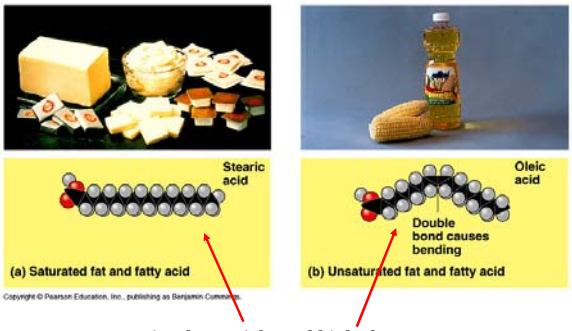
Lipids
Diverse Hydrophobic Molecules

- Most are hydrophobic due to covalent bonds
- Highly diverse in form and function
- 3 forms:
  - fats
  - phospholipids
  - steriods

Fats

- Constructed of glycerol and fatty acids
- Used for energy
- Insulation and cushions vital organs
- Fatty acid chains are very hydrophobic
  - may vary in length and in types of bonds

Saturated and Unsaturated fats and fatty acids



Notice the straight and kinked nature

Fats continued

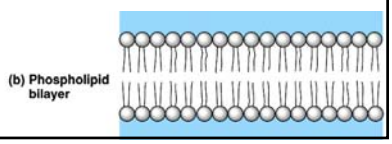
- Saturated Fats:
  - Have no double bonds between carbons, therefore they are "saturated" with hydrogen.
  - Straight chains
  - Solid at room temperature
  - Most come from animal sources
  - May lead to heart disease

Fats continued

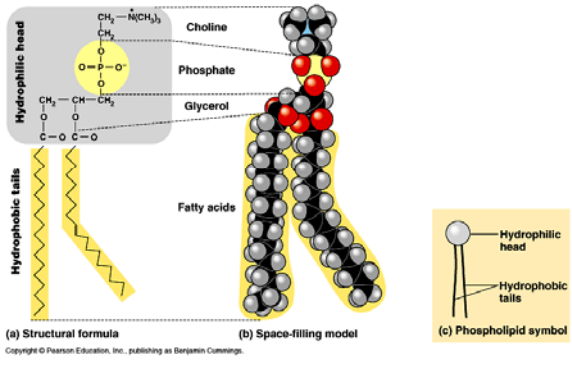
- Unsaturated Fats
  - Have one or more double bonds between carbons
  - Causes the fatty acid chain to kink or bend
  - Liquid at room temperature
  - Plant and fish fats (also called oils)

Phospholipids

- Two fatty acids, a glycerol and a phosphate group
- Phosphate group makes the head hydrophilic
- Tails are still hydrophobic
- Major component of cell membranes

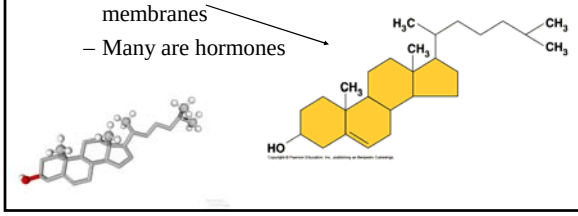


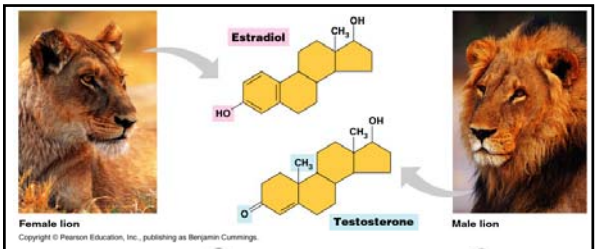
The structure of a phospholipid



Steroids

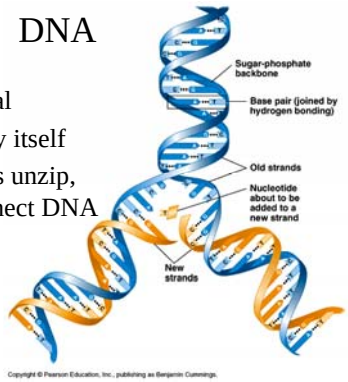
- Lipids with 4 fused carbon rings
- Steroids are different due to the functional groups attached
  - Cholesterol is an important component of cell membranes
  - Many are hormones





DNA

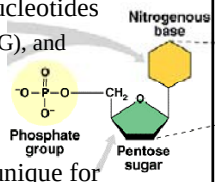
- Genetic Material
- DNA must copy itself
- Certain Proteins unzip, pair, and reconnect DNA strands



DNA is made up of Nucleotides

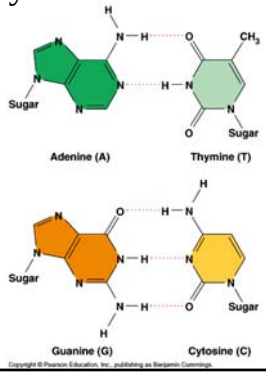
Structure:

- Each nucleic acid is made of nucleotides
  - A nitrogen base: purines (A and G), and pyrmidines (C, T and U)
  - Pentose: Ribose or Deoxyribose
  - Phosphate group
- The sequence of the bases are unique for each gene.

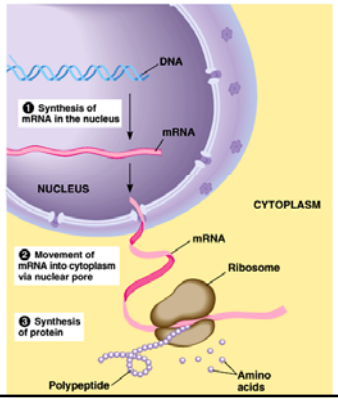


Purines and Pyrmidines

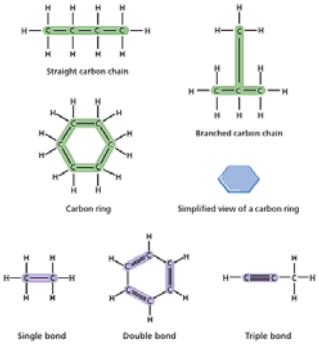
- **Purines:**
  1) adenine and guanine
  2) double ring structure
- **Pyrimidines:**
  1) thymine, uracil, and cytosine
  2) single ring



DNA and RNA protein



Review



- **Condensation reactions** join **monomers** (small simple molecules) to form **polymers**. A condensation reaction releases water as a by-product.
- In a **hydrolysis reaction**, water is used to split polymers into monomers.