

Molecules of Living Organisms

We have mentioned that all organisms, from bacteria to Douglas fir trees to humans share a common molecular structure; it's part of the unity of life.

The cells and tissues of virtually all organisms are made up of the same basic molecules. Many of these are substances with which we are familiar: our **carbohydrates, lipids, proteins** and the **nucleic acids**.

These molecules are all compounds with a "backbone" of **carbon**, or more specifically carbon-hydrogen molecules, which are called **hydrocarbons**. The incredible versatility of carbon accounts for the multitude of different organic molecules, built from the common backbones, which are found in different kinds of organisms. In chemistry, molecules with a backbone of carbon that also contain hydrogen are called **organic molecules**. The other atoms and molecules necessary for life are inorganic. Besides carbohydrates, proteins, lipids and nucleic acids, our vitamins are considered to be organic. (Water, oxygen, carbon dioxide and the minerals needed to sustain life are **inorganic**.)

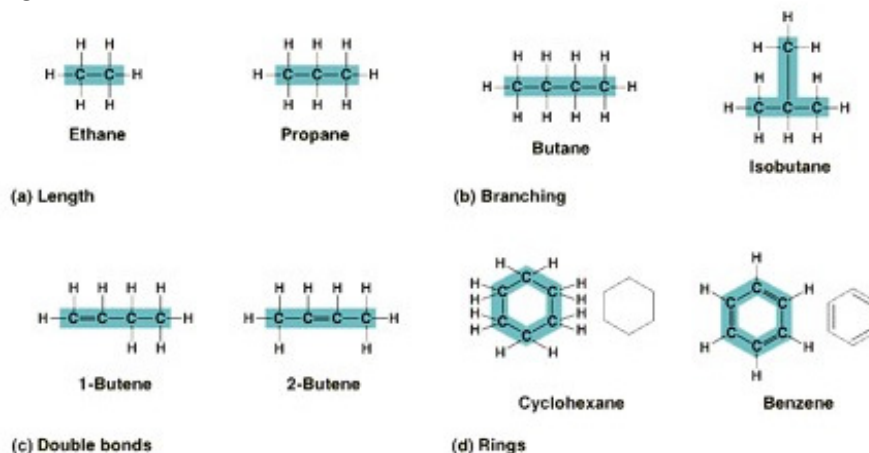
Our organic compounds are responsible for such things as:

- Fuel (energy to do cell work and keep us alive)
- Structure
- Metabolism
- Fuel Storage
- Genetic Information

Before understanding the structure of the major groups of compounds of living organisms, we should first study the element, **carbon**, what a **hydrocarbon** is, and also study the molecules called **functional groups**, which bond to hydrocarbons, altering the chemical nature of the resulting compound.

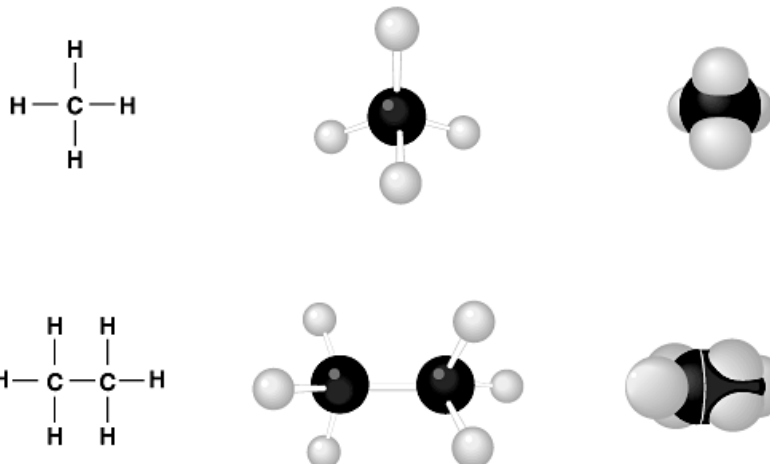
Properties of Carbon

- Carbon is one of the atoms (elements) that forms covalent bonds (joins with other atoms) to become stable. Each carbon atom makes **4 bonds**
- Carbon may make bonds with other carbon atoms forming chains, branching chains or rings of linked carbon atoms.



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- Carbon may also bond to different kinds of atoms, most notably hydrogen. In fact, the basic carbon compound is a **hydrocarbon**, formed from carbon and hydrogen.



Properties of Hydrocarbons

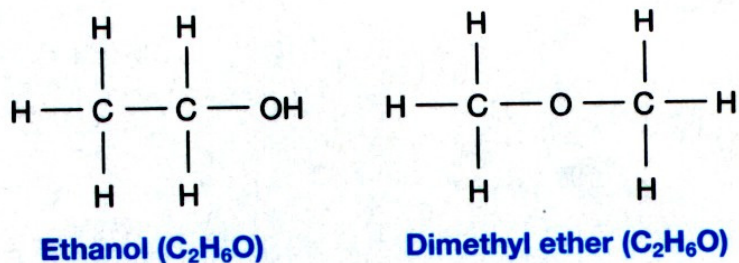
Hydrocarbons, like carbon, typically vary in:

- The number of carbons on the chain
- Straight, branching chains or ring compounds
- What is attached to the carbon chain

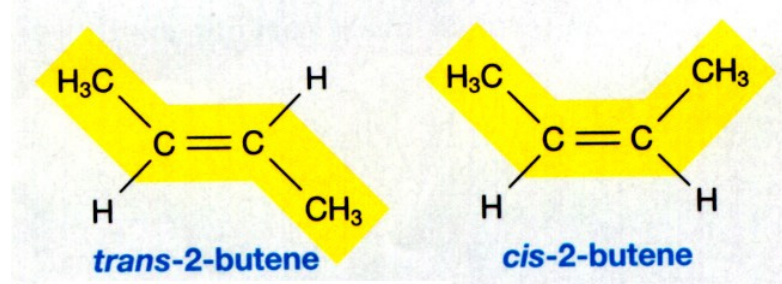
Most hydrocarbons have very similar properties. For example the C—H bond is **energy rich**; so hydrocarbons make good fuels (methane, propane, butane, methanol, alcohol)

Hydrocarbon variations that differ only in the arrangement of atoms are called **isomers**. Isomers are very important in biology, and we shall see many examples of isomers. There are three types of isomers: **structural**, **geometric** and **enantiomers**. (We don't need to worry much about these details in Biology 101, though.)

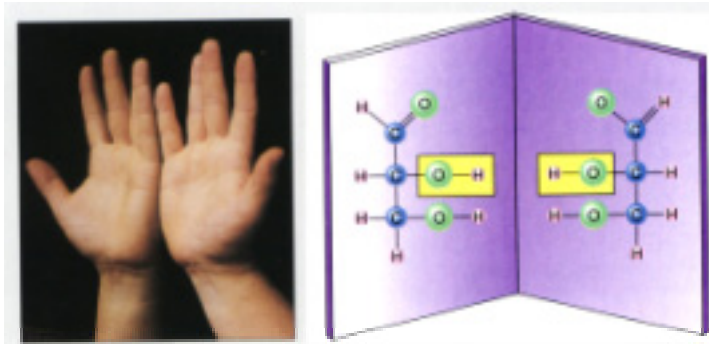
- Structural** isomers vary in their covalent bonding arrangement.



- **Geometric isomers** share common covalent bonding, but have different shapes. The differing shape of geometric isomers can dramatically affect their biological function. (This is sometimes called the cis-trans difference.) Cis-trans changes occur when one partially hydrogenates fats, forming trans-fatty acids.



- **Enantiomers** are isomers that have the same molecular formula but are mirror images of each other.



Hydrocarbons can also have variations in bonding. Carbon may make double or triple bonds as well as single bonds. The resulting compounds will be different in shape and often function.

Carbon ring compounds are common in living organisms. The shape of the ring compound is important to its properties. The covalent bond angles in the ring determine the molecule's shape. Two common ring shapes are the "chair" and the "boat"

The major compounds of living organisms are modifications of hydrocarbons with something (very precise) added. These atoms or molecules are called **functional groups**, because they change how the hydrocarbon functions and gives it properties of a carbohydrate, or lipid or protein, etc.

Functional Groups

The functional groups are molecular fragments which, when substituted for one or more hydrogen atoms in a hydrocarbon, confer particular chemical properties to the new compound. The functional group can be said to determine the "behavior" of the molecule. Once you have learned the properties of some functional groups, the major compounds of living organisms are easy!

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Some Functional Groups Important in Biological Molecules

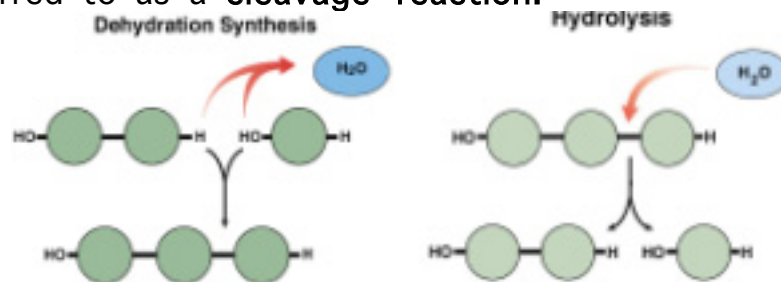
Functional Group Name	Formula	Compound Type	Example
Hydrogen	-H	Alkane	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$
Hydroxyl	-OH	Alcohol	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$
Carbonyl	=O	Aldehyde	$\begin{array}{c} \text{H} \ \text{H} \ \text{H} \\ \ \ \\ \text{H}-\text{C}-\text{C}-\text{C}=\text{O} \\ \ \\ \text{H} \ \text{H} \end{array}$
Carbonyl	=O	Ketone	$\begin{array}{c} \text{H} \ \ \ \ \ \text{H} \\ \ \ \ \ \ \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \ \ " \ \\ \text{H} \ \ \ \ \ \text{O} \ \ \ \ \ \text{H} \end{array}$
Carboxyl	$\begin{array}{c} -\text{C}=\text{O} \\ \\ \text{OH} \end{array}$	Organic Acid	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}=\text{O} \\ \ \\ \text{H} \ \text{OH} \end{array}$
Amino	$\begin{array}{c} \text{H} \\ \\ -\text{N}-\text{H} \end{array}$	Amine	$\begin{array}{c} \text{H} \ \ \ \ \ \text{H} \\ \ \ \ \ \ \\ \text{H}-\text{C}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$
Amino + Carboxyl		Amino Acid	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}=\text{O} \\ \ \\ \text{H}-\text{N} \ \ \text{OH} \\ \\ \text{H} \end{array}$
Methyl	$\begin{array}{c} \text{H} \\ \\ -\text{C}-\text{H} \\ \\ \text{H} \end{array}$	Backbone of Hydrocarbon Chains	$\begin{array}{c} \text{H} \ \ \ \ \ \text{H} \ \ \ \ \ \text{H} \ \ \ \ \ \text{H} \\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \\ \text{H} \ \ \ \ \ \text{H} \ \ \ \ \ \text{H} \ \ \ \ \ \text{H} \end{array}$
Phosphate	$\begin{array}{c} \text{O}-\text{H} \\ \\ -\text{O}-\text{P}=\text{O} \\ \\ \text{O}-\text{H} \end{array}$		Phospholipids Nucleic Acids
Sulfhydryl	-S-H		Found in cysteine

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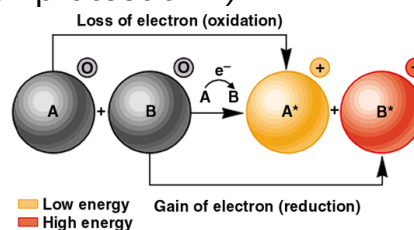
Before discussing the specifics of the molecules of living organisms, we should also be familiar with the chemical processes by which large molecules (**polymers or macromolecules**) are built from smaller molecules (often called **monomers or subunits**) that have a common structure.

Most of our biological molecules are assembled or broken down using the same types of chemical reactions, used to assemble, rearrange and break apart molecules.

Among the most common of reactions are the chemical reactions that involve **adding or removing water molecules**. Polymers are formed from their subunits by removing molecules of water (a hydrogen (H-) from one subunit and the hydroxyl (-OH) from the second subunit) to join the subunits together. This is called a **dehydration synthesis**, or **condensation reaction**. When larger molecules are broken down, such as in digestion, water molecules are added in to break the macromolecules into their subunits, a process called **hydrolysis** or sometimes referred to as a **cleavage reaction**.



A second common set of chemical reactions in living organisms involves the transfer of one or more electrons and is known as **oxidation and reduction**. An oxidation is the loss of one or more electrons. A reduction is the gain of one or more electrons. Oxidations and reductions are always coupled. A substance that can cause a reduction is called a reducing agent, and one that can cause an oxidation is an oxidizing agent. A substance that prevents something from being oxidized is called an anti-oxidant. Vitamin C and vitamin E both function as anti-oxidants in our cells and tissues. (An anti-oxidant works by being so easily oxidized itself that the oxidizing substance oxidizes the anti-oxidant rather than the "target" molecule that needs "protection".)



In addition, there are rearrangement reactions in which the internal bonds of the molecule are literally, rearranged, which may change the compound from one type to another.

Now we can discuss the major compounds of living organisms: **Carbohydrates, Lipids, Proteins and Nucleic Acids**.

Carbohydrates

The word carbohydrate is one of convention, derived from carbon and water, the component elements of the carbohydrate monomers (subunits). Carbohydrates include the simple sugars (properly called monosaccharides and disaccharides) and the large polymers or polysaccharides. There are a few oligosaccharides as well.

Carbohydrate Functions

- Basic energy source (fuel) for virtually all living organisms
- Structural molecules, especially of plants, most fungi and arthropods (e.g., cellulose, chitin)
- Fuel reserve molecules (e.g., starch, glycogen)

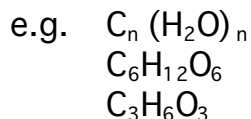
All carbohydrates are composed of one or more **monosaccharides**. The **simple sugars** are formed from one (monosaccharide) or two monosaccharides (called **disaccharides**), and the **complex carbohydrates** (polymers) are formed from long chains of monosaccharides, formed by dehydration synthesis reactions. The complex carbohydrates are also called **polysaccharides** and include starches and fiber. Some plants have **oligosaccharides**, small chain carbohydrates composed of a few monosaccharides. Humans cannot digest oligosaccharides, but the bacteria in our intestines can. Their digestive by-products are often gaseous, something we associate with the consumption of foods that contain oligosaccharides.

Structure of the monosaccharide

Chemically, monosaccharides contain:

- Carbon
- Hydrogen
- Oxygen

The ratio of atoms in a monosaccharide is: (CH_2O)



The functional groups of monosaccharides are:

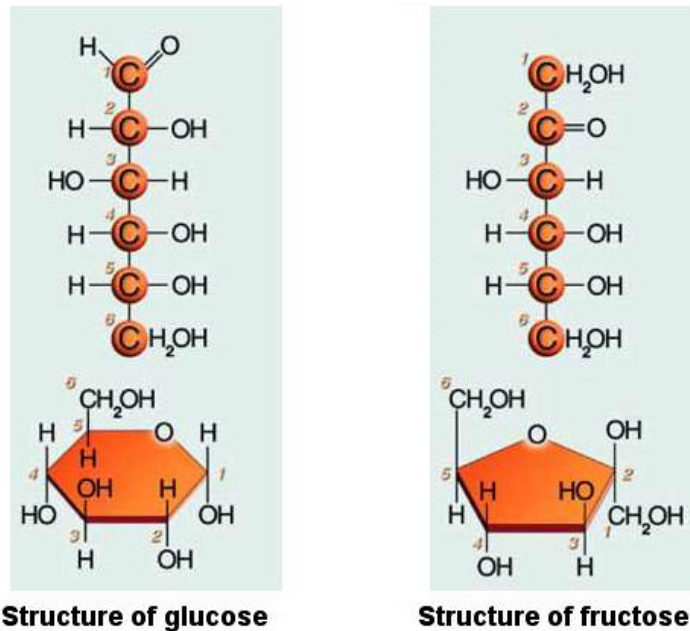
- $-\text{OH}$ Hydroxyl
- $=\text{O}$ Carbonyl

However the arrangement of atoms in the monosaccharide is important. Each monosaccharide is constructed with the following rules:

1. Make a carbon chain
2. Attach the carbonyl group to 1 of the carbon atoms
3. Attach hydroxyl groups to the remaining carbon atoms
4. All remaining open carbon bonds will have hydrogen atoms attached

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Given the rules, there are many variations possible with monosaccharides. Many **isomers** are possible and common.



The common monosaccharides of living organisms are:

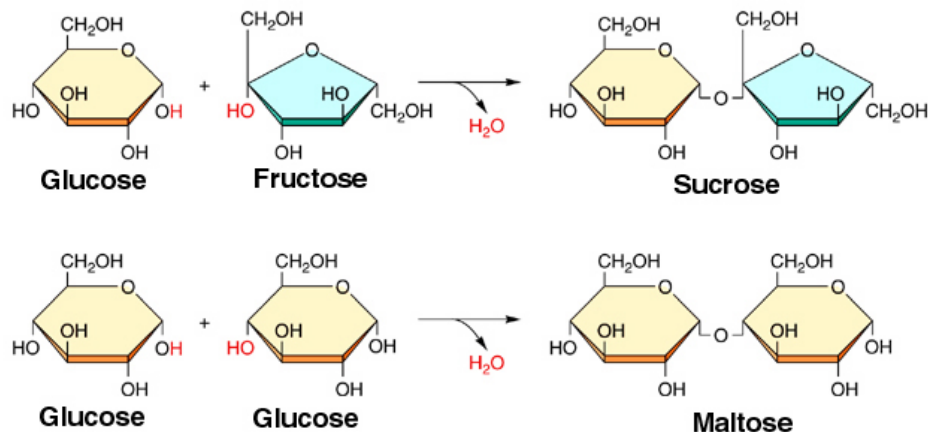
- $C_6H_{12}O_6$ (glucose, galactose, fructose)
- Some 5-carbon (ribose, deoxyribose, ribulose, xylose)

Note: Although we show monosaccharides and other carbohydrates in the chain structure, the carbohydrates in living organisms are found in a ring shape.

Formation of Disaccharides and polysaccharides

Disaccharides

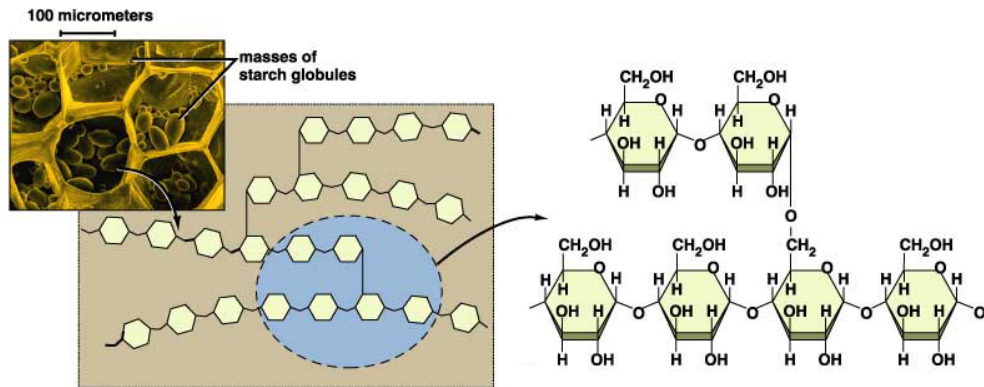
- Disaccharides are 2 monosaccharides joined by a **dehydration synthesis**, or **condensation**, which is the removal of a water molecule. The "H" is taken from a hydroxyl functional group of one monosaccharide and the "OH" from the second. The two molecules are then joined by a C—O—C bond.



Examples of common disaccharides are **sucrose**, **lactose**, and **maltose**

Polysaccharides

- Polysaccharides are formed by joining several monosaccharides, each to the next by a dehydration synthesis.
- The common polysaccharides are:
 - **Starch** (α 1-4 linkage) (boat)

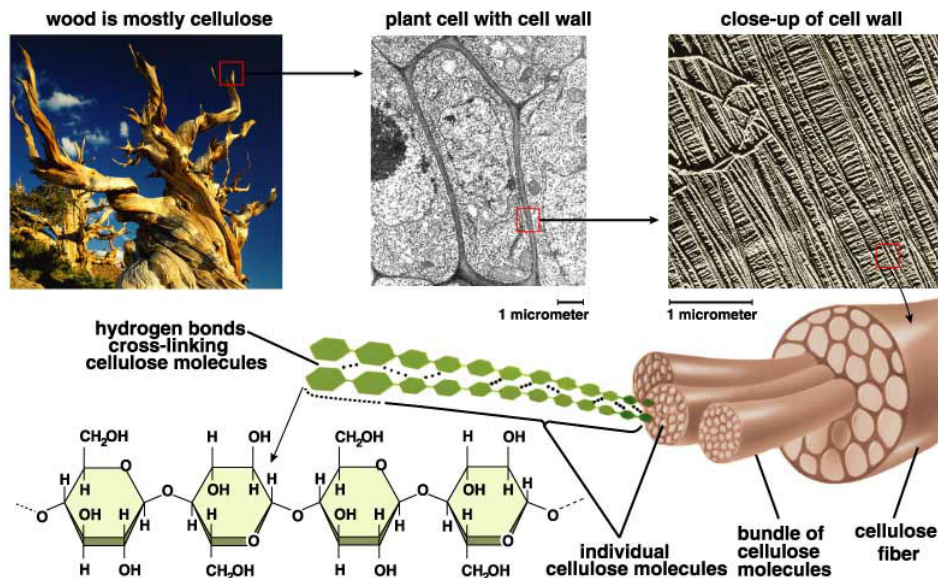


- **Glycogen**

- Both starch and glycogen are polysaccharides of glucose. Starch is a very long coiled, unbranched or branching chain, with about 1000 glucose molecules in any branch. Glycogen branches frequently (about every 10 or so glucose units) and is more easily broken down.
- Starch and glycogen are important fuel storage molecules.

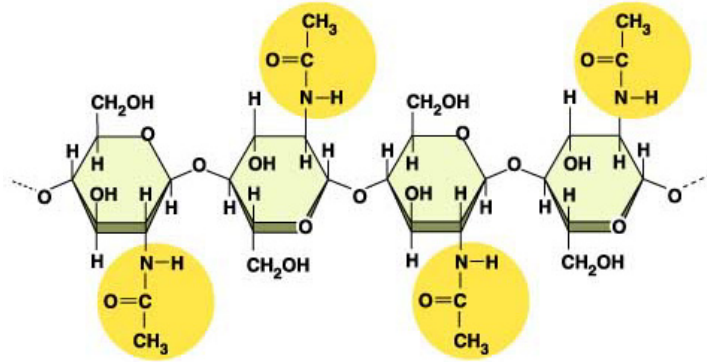
- **Cellulose** (β 1-4 linkage) (chair)

- Long chains of glucose
- Cellulose is for most living organisms, non-digestible. Few organisms have the enzyme needed to break down cellulose. Cellulose and related compounds form most of what we call **fiber**.



- **Chitin**

- Long modified glucose chains, in which a nitrogen-containing functional group replaces one of the hydroxyl groups on each glucose subunit.
- Chitin forms the exoskeleton of many invertebrate animals (mostly arthropods)



Disaccharides and polysaccharides can be digested or broken down by **hydrolysis**. (Appropriate enzymes are required for both dehydration synthesis and for hydrolysis)

In addition to the "pure" carbohydrates, glycoproteins, common in plasma membranes, contain carbohydrate, as do protective mucus layers and all nucleic acids.

Lipids

Many of our common substances are lipids, which include fats, oils, and waxes along with a variety of related substances.

Lipid Functions

- Fuel reserve molecules (Lipids are energy rich)
- Structure of cell (plasma) membranes
- Protective surface coatings and insulation
- Many hormones (regulatory chemicals)

Major types of Lipids

1. Triglycerides commonly known as the fats and oils
2. Waxes (similar to triglycerides)
3. Phospholipids
4. Sterols (or steroids)
5. Terpenes

Lipid Characteristics

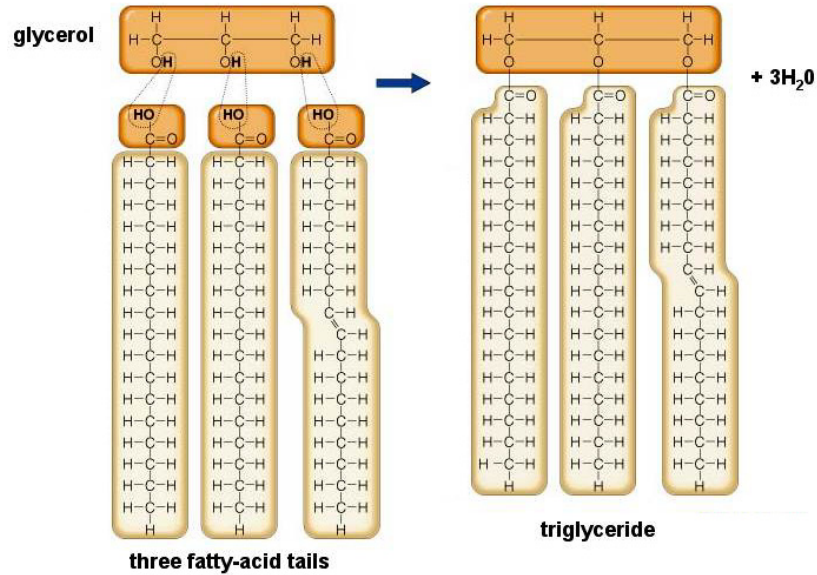
- Most lipids are strictly nonpolar and hydrophobic, so they dissolve in nonpolar substances, but not in water.
- Most lipids feel "greasy"
- Lipids contain large regions of just carbon and hydrogen, as carbon-carbon bonds and carbon-hydrogen bonds

Structure of Lipids

- Lipids contain:
 - carbon
 - hydrogen
 - oxygen
- However – the proportion of oxygen is low, so lipids are mostly **hydrocarbons**
- The chemical structure of our fats and oils, the most common lipids, is based on **fatty acid** building blocks and an alcohol, **glycerol**
- The terms fats and oils are terms of convention
 - Fats are "hard" or solid at room temperature
 - Oils are liquids at room temperature

Structure of Fats and Oils (the Triglycerides)

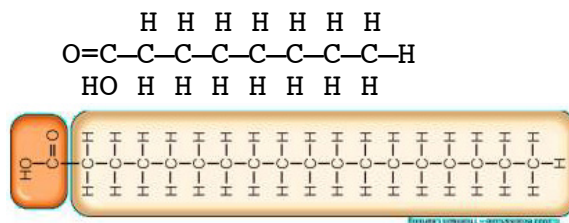
- One molecule of the alcohol, **glycerol**
- Attached to the glycerol (by dehydration synthesis) are **3 fatty acids**. The fatty acids determine the characteristics or properties of the fat. The bond formed between the -OHs of the alcohol and the -OHs of the fatty acid is an ester bond.



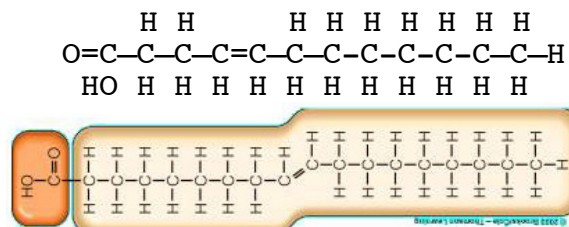
- **Fatty acids** are chains of hydrocarbons 4—22 carbons long with the carboxyl functional (acid) group at end



- Each carbon within the chain has 2 spots for bonds with hydrogen
- If each carbon has 2 hydrogens the fatty acid is **saturated**

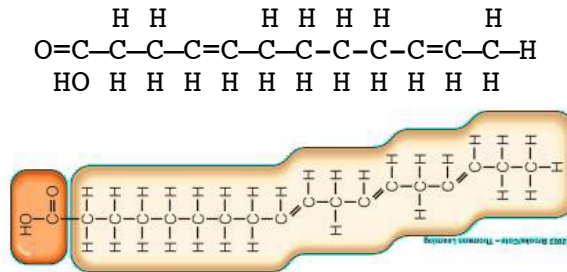


- If two carbon atoms are double bonded, so that there is less hydrogen in the fatty acid, it is **monounsaturated**



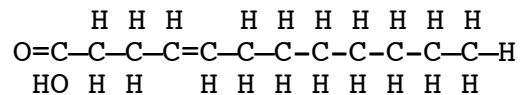
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- If more than 2 carbon atoms are unsaturated, the fatty acid is **polyunsaturated**



In most fatty acids, the hydrogen atoms attached to the double-bonded carbons are both on one side of the carbon chain (either top or bottom). In trans-fatty acids, the hydrogen atoms attached to the carbons forming the double bond are on opposite sides of the carbon chain. When fats are hydrogenated, trans-fatty acids tend to form. We process trans-fatty acids much the same way as saturated fatty acids.

- A **trans-fatty acid** might look like this:



Let's look at ways that fatty acids are different:

- Length of chain in fatty acid
 - 4 - 22 carbons long
 - Usually an even number
 - Short chains are more soluble
 - Short chains are more easily broken down
 - Short chains oxidize more easily (process by which fats become "rancid")
- Degree of saturation
 - Saturated
 - Monounsaturated
 - Polyunsaturated
 - Most plant fats tend to be unsaturated, but fats from tropical plants tend to be very saturated
 - Fish oils tend to be unsaturated (from cold water and salt water fish). Other animal fats tend to be saturated
- Liquid vs solid
 - Short chains and unsaturated chains are liquid at room temperature (molecules are smaller and less dense (the double bonds distort the molecules so they don't fit close together)
 - Saturated chains are solid (denser) because chains fit together better

Synthetic Fat

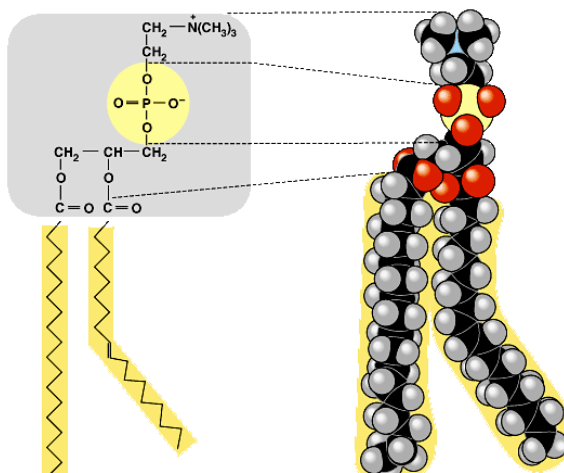
Olestra is a synthetic fat, marketed under the trade name of Olean. It mimics the texture and properties of triglycerides, is fat soluble, but not digestible or absorbed into the body, so all Olestra consumed passes through the digestive tract. Hence, it is considered to be calorie-free. Olestra is a sucrose polyester, composed of fatty acids attached to sucrose rather than glycerol. Six to eight fatty acids are attached to the sucrose molecule so the lipase digestive enzymes can't function to hydrolyze the ester bonds.

Simplese is a fat substitute that mimics the texture of fat in the oral cavity. It is synthesized from egg and milk proteins. The shape of the simplese molecule is spherical, resembling miniature marbles, so the product has the slick texture of fat. Simplese is not heat stable, and cannot substitute for fats in frying or baking.

Phospholipids

Phospholipids are structural molecules forming the major component of all membranes of cells.

Phospholipids are composed of a glycerol molecule with two fatty acids attached by ester bonds and a polar phosphate-containing compound attached to the third carbon.



The benefit of the phospholipid structure is that the phosphate region makes the molecule highly amphipathic, ideal for the cell membrane structure

Hydrophilic portion in the phosphate region

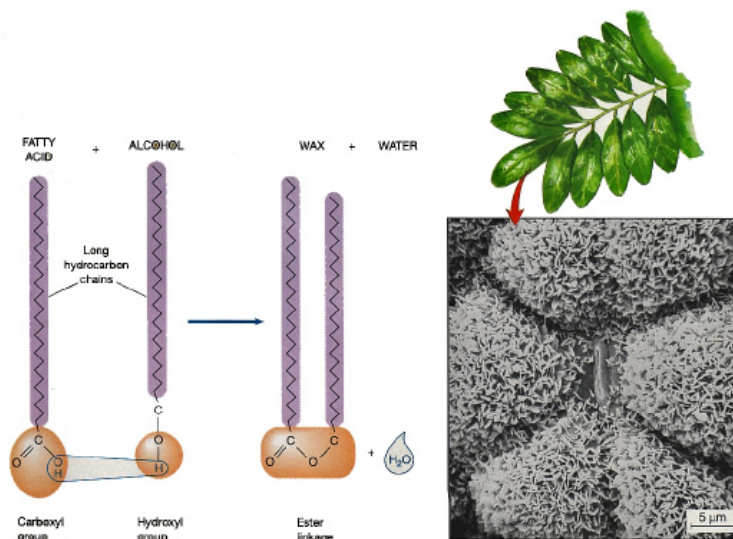
Hydrophobic portion in the fatty acid tails

The most common phospholipid is **lecithin**

Phospholipids also make excellent emulsifiers and are used in a number of food and household products.

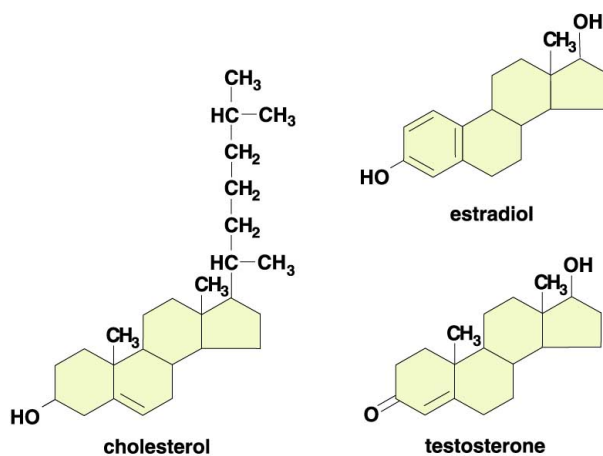
Waxes

Waxes are similar to triglycerides except they are highly saturated with long-chain fatty acids and have a long-chain alcohol or carbon ring to which the fatty acids bond. They have a rigid, solid structure at "normal" temperatures on earth. Waxes form protective layers on surfaces of many organisms, provide water-resistance, and in some cases, structure. Some organisms can digest waxes for fuel.



Sterols (Steroids)

All steroids are composed of hydrocarbon chains with four interconnected rings. Although rarely found in plants, certain plant sterols, such as the soy flavinoids, are similar in structure to the estrogen hormones of animals.



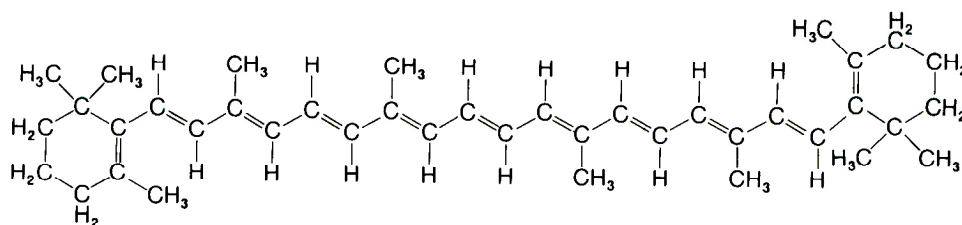
Steroids are used in organisms for a variety of purposes.

- Vitamins A & D
- Hormones (adrenal cortex & sex hormones)
- Cholesterol
 - Precursor to most steroid hormones and vitamin D
 - Necessary for structure of nerve system cells
 - Component of animal cell membranes – not found in plants
 - Cholesterol is made in the liver from digested fatty acids

Terpenes

Over 22,000 different terpenes found in plants, and include some important pigments such as the carotenoid pigments that are responsible for the orange, red and yellow colors of many plants. Chlorophyll, the light absorbing green pigment important in photosynthesis, is a modified terpene.

Many plant aromatic oils are terpenes. Taxol, an extract from yew, is used to treat ovarian cancer, and digitalin is a cardiac medicine. Two plant hormones are also terpenes, as are two important electron transfer molecules. Economically, rubber is an important terpene. Terpenes are lipid soluble and hydrophobic.



β -carotene

Amino Acids and Proteins

Proteins are very large molecules composed of combinations of 20 different amino acids. The precise physical shape of a protein is very important for its function. A single cell may have 10,000 or more different proteins. This diversity of proteins is essential for the functioning of each cell in a living organism.

Functions of Protein

1. Structural
 - Component of all cell membranes
 - Component of cytoplasm "cytoskeleton"
 - Component of movement or contractile structures, such as muscle, cilia and flagella microtubules --- contractile properties
 - Component of hair, nails horns, etc. (Keratin is the main protein of these substances)
2. Metabolic molecules
 - Hormones – regulatory chemicals
 - Energy transfer molecules for cell respiration (cytochromes)
 - Oxygen carrier in circulation (hemoglobin)
 - Antibodies
 - Enzymes
 - Probably most "famous"
 - Facilitate rate of chemical reaction

Protein Structure

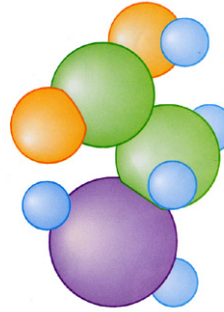
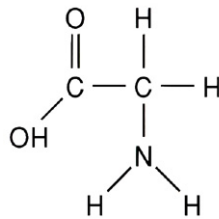
The protein structure is critical for its function. Each protein has a unique shape or **conformation**. However, all proteins are composed exclusively of subunits of amino acids, which join together in long chains called **polypeptides** that fold or coil into the unique shape of the functional protein.

- To discuss protein one must
1. Discuss amino acids
 2. Discuss formation of protein from amino acid

Amino acids

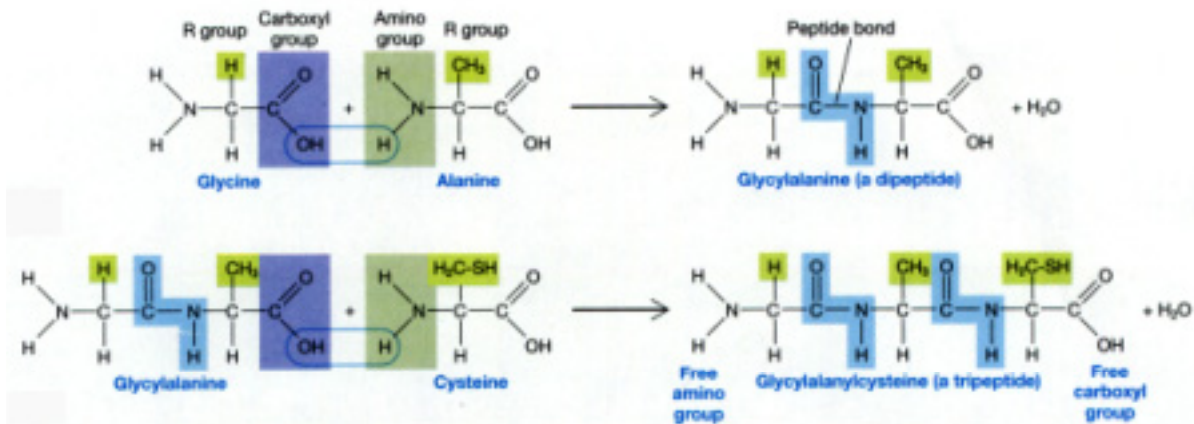
- Amino acids contain Carbon, Hydrogen, Oxygen, Nitrogen, and sometimes Sulfur
- Amino acids have two function groups (both of which are typically in the ionized form)
 - NH₂ Amino functional group
 - COOH Carboxyl functional group
- Both functional groups attach to a specific carbon, the alpha (α) carbon, of the carbon chain. The third bonding site of the alpha carbon is typically Hydrogen.
- The alpha carbon will have at its fourth bonding site a side chain, or R group which gives the amino acid its unique structure and properties.
- There are 20 + different amino acids in protein. All have a common structure except for the R group.

- Some amino acids have R groups that are polar (so they are hydrophilic), some R groups are nonpolar (and hydrophobic), some have acidic side chains (generally with a negative charge) and some are basic. One, **cysteine**, contains sulfur in the R group, so cysteines can form disulfide bonds (**disulfide bridges**)
- Amino acids are joined together by a dehydration synthesis of amino/carboxyl groups forming a **peptide bond**.



How do amino acids join to make a protein?

1. A protein starts as a chain of amino acids, called a **polypeptide**
2. Amino acids are joined by the **peptide bond**, via dehydration synthesis to form the polypeptide
3. The polypeptide chain is referred to as the **primary structure** of the protein.
4. The specific amino acids in the polypeptide chain will determine its ultimate conformation, or shape, and hence, its function. Even one amino acid substitution in the bonding sequence of a polypeptide can dramatically alter the final protein's shape and ability to function.



Peptide Bond

How do polypeptides vary?

1. Number of amino acids in the chain: 50—1000 or so
2. Which kind of amino acids are in the chain (of the 20 types)
3. How many of each kind of amino acid
4. The bonding order or **sequence** of amino acids

Protein shape and structure

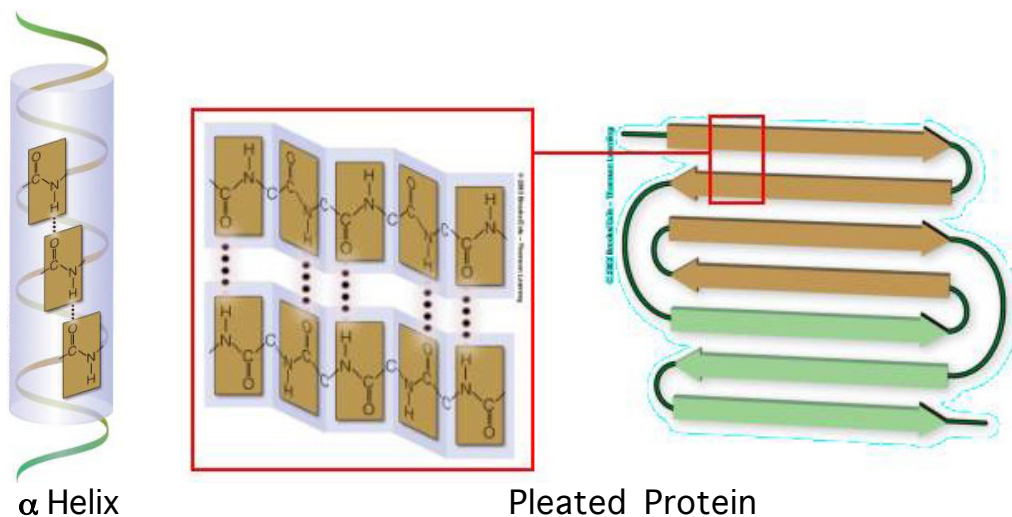
The polypeptide chain is just the beginning of a protein. Functional proteins undergo further processing to obtain a final functional shape. Some proteins are composed of more than one polypeptide. The surface structure of the protein is critical for its function.

The function of many proteins depends on a specific region of the protein that binds to another molecule. Antibodies, critical to the immune system, function by binding to specific regions of the antigen molecules, to deactivate them. An enzyme binds to the substrate (the reactants) at a specific active site on the enzyme.

Secondary Structures

The ultimate shape of each protein is determined by bonds that form the secondary and tertiary protein structure. As peptide bonds are formed, aligning the amino acids, hydrogen bonds form between different amino acids in the chain.

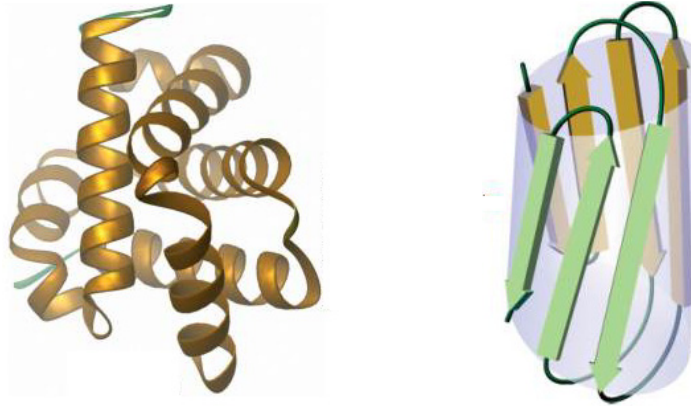
This bonding coils the polypeptide into the **secondary structure** of the protein, most commonly the **alpha helix**, discovered by Linus Pauling. The α -helix coils at every 4th amino acid.



Some regions of the polypeptide have portions that lie parallel to each other (still held by hydrogen bonds) instead of in the alpha helix, in which the amino acids' hydrogen bonds form a pleated structure. Fibrous proteins have significant pleated structures.

Domain and Tertiary Structure

Following the secondary shape, openings for bonding along the side chains (the R groups) of amino acids may fold independently into a functional unit called the **domain**. Domains are connected by the rest of the polypeptide. Domain formation is part of the **tertiary** structure of proteins. **Disulfide bonds** (which are strong covalent bonds) between nearby cysteine molecules are important to the tertiary structure as well, as are **hydrogen bonds**, some **ionic bonds** between charged R-groups and **van der Waals interactions**. The final shape for most proteins is a globular shape.



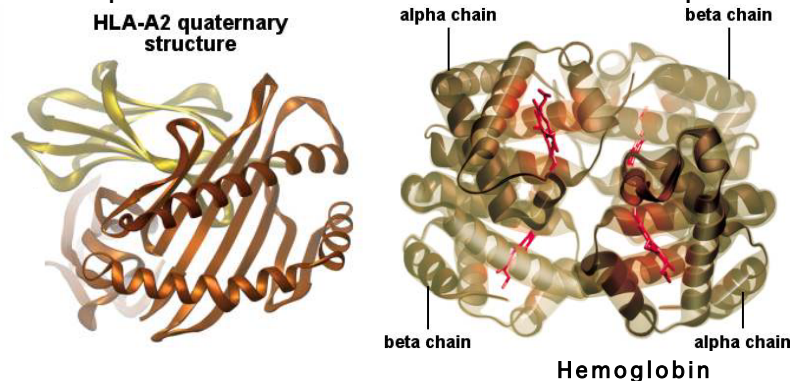
Tertiary Protein Structures

Functionally, domains may perform different functions for a given protein. For example, one domain of an enzyme might be the attachment site for a co-factor and a second domain may function as the active site of the enzyme.

Quaternary Protein Structure

If two or more polypeptide chains join in aggregates, they form a **quaternary** structure, such as in the protein molecule, hemoglobin. Often quaternary proteins are complexed with a different molecule, often a mineral. Hemoglobin contains iron, for example.

If two or more polypeptide chains join in aggregates, they form a **quaternary** structure, such as in the protein molecule, hemoglobin. Often quaternary proteins are complexed with a different molecule, often a mineral. Hemoglobin contains iron, for example. Other quaternary proteins function in cell defense, with one section anchored in the plasma membrane and a second shaped to catch invaders.



Protein Stability

As we have seen, the physical shape of a protein is determined by the amino acid sequence and maintained by weak bonds.

A mistake in the genetic coding of the amino acid sequence may result in a protein whose shape is different, and the protein will not function. One serious example of this is in the hemoglobin protein. An error in the sixth amino acid of the polypeptide chain produces a hemoglobin that causes red blood cells to become sickle-shaped rather than the normal "doughnut" shape.

Many of the bonds that form the tertiary shape of proteins are hydrogen bonds formed from the **polarity** of the amino acids and their "R" groups. If these weak bonds are broken, the protein structure is destroyed and the molecule can no longer function. This process is called **denaturation**.

Things that can denature protein:

1. Heat (as low as 110 F, many @ 130 F)
2. Heavy metals (e.g., silver, mercury)
3. pH changes
4. Salts
5. Alcohols
 Ethyl alcohol least toxic
6. Many proteins will denature if placed in a non-polar substance.
7. Other chemicals

Enzymes are seriously affected by denaturation – but other proteins of the body can also be denatured. Although in most cases, a denatured protein loses its function permanently, in some cases, re-naturation can occur if the substance that promotes the denaturation is removed from the protein. This is more true of chemical denaturants and particularly in experimental environments.

Nucleotides and Nucleic Acids

Nucleic acids are our information carrying compounds -- our genetic molecules. As with many of our other compounds, the nucleic acids are composed of subunits of nucleotides. Nucleotides, in addition have independent functions.

Functions of Nucleotides

- Components of nucleic acids (which are long chains of nucleotides)
- Energy carrier molecules (ATP)
- Energy transport coenzymes (NAD⁺, NADP⁺, FAD⁺)
- Chemical intracellular messengers
(e.g., Cyclic AMP, a cyclic nucleotide that carries messages from the cell membrane to molecules within the cell, to stimulate essential reactions)

Functions of Nucleic Acids

Storage of genetic information (DNA)

Transmit genetic information from generation to generation (DNA)

Transmit genetic information for cell use (RNA)

DNA self-replication

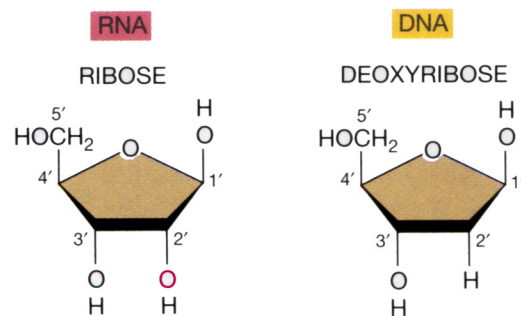
Most of the information on nucleotides and nucleic acids will be discussed when we discuss genetics and energy relationships of cells. For now we shall just present the basic structure of the nucleotides and nucleic acids.

Nucleotide Structure

1. 5-carbon sugar component

Ribose

Deoxyribose

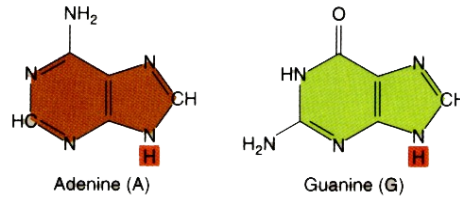
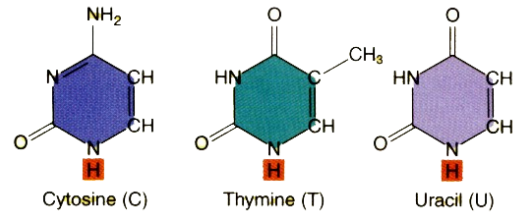


2. Phosphate group

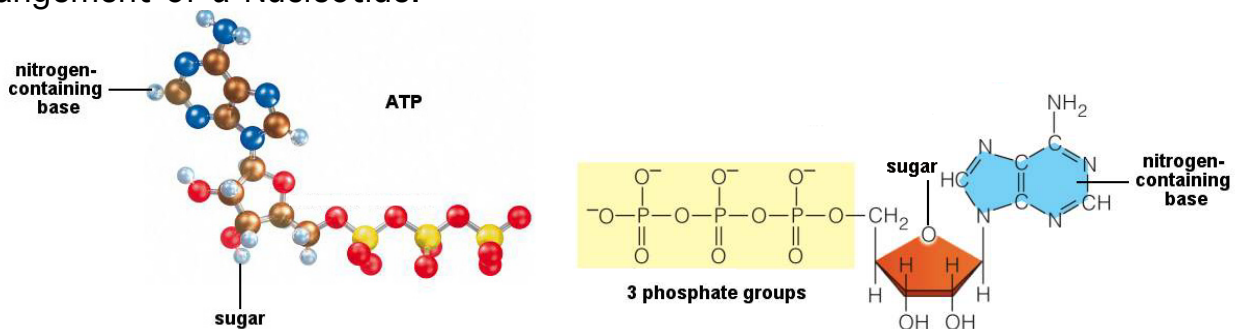
Attached to the sugar's 5' carbon with a phosphodiester bond

3. Nitrogen Base component attached to the sugar's 1' carbon.
There are two types of nitrogen bases:

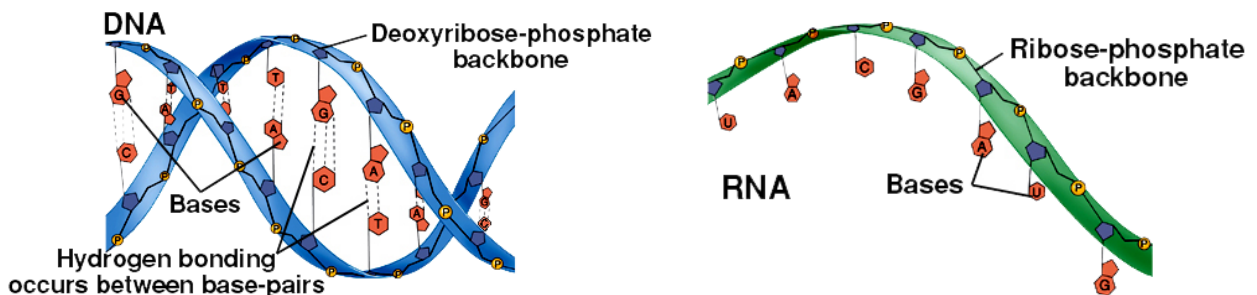
- Single six-sided ring **pyrimidines**
Cytosine
Thymine
Uracil
- Double ring **purines**
(six- and five-sided)
Adenine
Guanine



Arrangement of a Nucleotide:



Nucleic acids (polynucleotides) are formed when S-P covalent phosphodiester linkages form long chains. In DNA, a double chain is formed when 2 nitrogen bases hydrogen bond. RNA molecules are single chains.



Genes (specific regions of DNA molecules) contain the hereditary information of an organism. The linear sequence of nitrogen bases of the nucleotides determines the amino acid sequence for proteins in the cells and tissues. As with all of biology, the processes of evolution are validated in DNA information. Organisms more closely related evolutionarily, have more similar DNA.