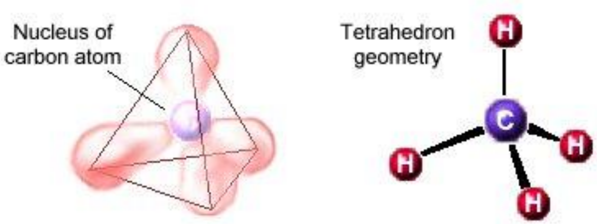
Organic Compounds

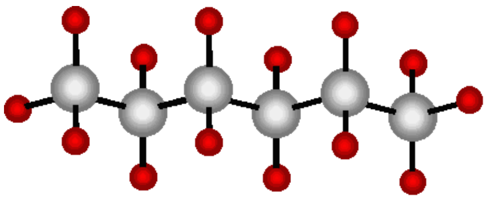
- It used to be thought that only living things could synthesize the complicated carbon compounds found in cells
- German chemists in the 1800’s learned how to do this in the lab, showing that “organic” compounds can be created by non-organic means.
- Today, organic compounds are those that contain carbon. (with a few exceptions such as carbon dioxide and diamonds)

Carbon's Bonding Pattern

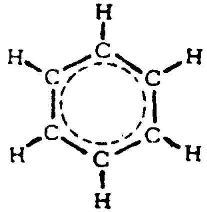
- Carbon has 4 electrons in its outer shell. To satisfy the octet rule, it needs to share 4 other electrons. This means that each carbon atom forms 4 bonds.



- The 4 bonds are in the form of a tetrahedron, a triangular pyramid.



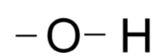
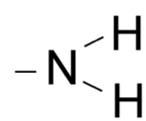
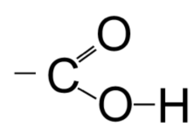
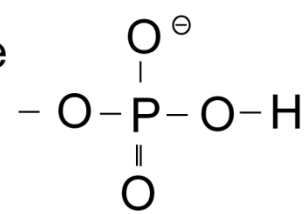
- Carbon can form long chains and rings, especially with hydrogens attached.



- Compounds with just carbon and hydrogen are "hydrocarbons": non-polar compounds like oils and waxes.

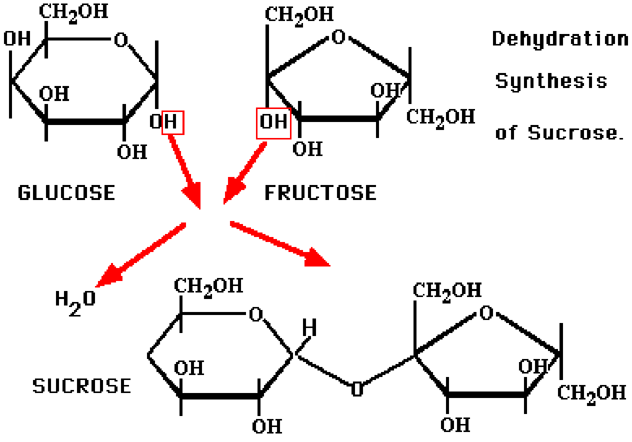
Functional Groups

- Most of the useful behavior of organic compounds comes from functional groups attached to the carbons. A <u>functional group</u> is a special cluster of atoms that performs a useful function.

Alcohol		hydrophilic
Amino		basic
Acid		
Phosphate		energy

Metabolic Reactions

- In cells, compounds are built up and broken down in small steps by enzymes, which are proteins which cause specific chemical reactions to occur. Each enzyme causes one step in a metabolic pathway to occur.
- An example: condensing 2 sugars together by removing a water (H_2O) from two alcohol (-OH) functional groups:
- This reaction can also be reversed by adding water to the bond. This is called hydrolysis, breaking apart a bond by adding water.

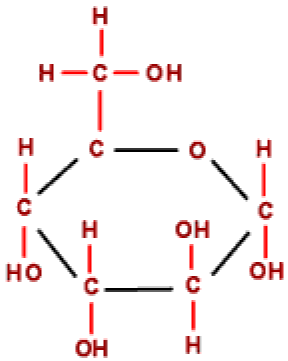


Four Basic Types of Organic Molecule

- Most organic molecules in the cell are: carbohydrates (sugars and starches), lipids (fats), proteins, and nucleic acids (DNA and RNA).
- These molecules are usually in the form of polymers, long chains of similar subunits. Because they are large, these molecules are called macromolecules. The subunits are called monomers.
- The cell also contains water, inorganic salts and ions, and other small organic molecules.

Carbohydrates

- Sugars and starches: “saccharides”.
- The name “carbohydrate” comes from the approximate composition: a ratio of 1 carbon to 2 hydrogens to one oxygen (CH_2O). For instance the sugar glucose is $C_6H_{12}O_6$.
- Carbohydrates are composed of rings of 5 or 6 carbons, with alcohol (-OH) groups attached. This makes most carbohydrates water-soluble.
- Carbohydrates are used for energy production and storage, and for structure.

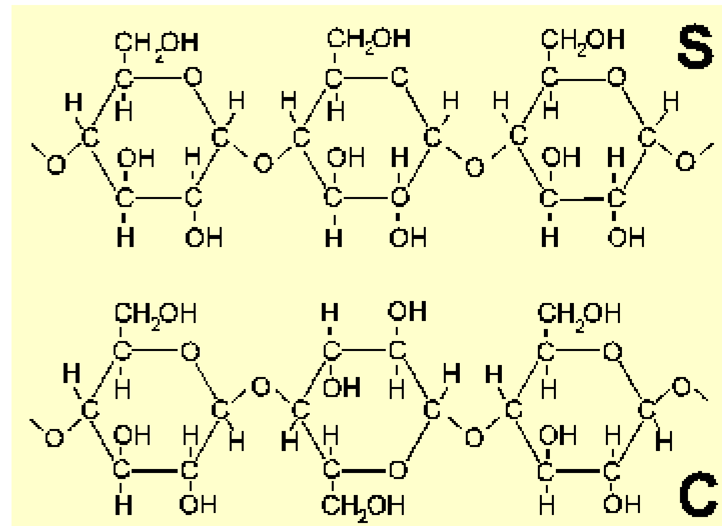


Sugars

- Simple sugars, like glucose and fructose, are composed of a single ring.
- Glucose is the main food molecule used by most living things: other molecules are converted to glucose before being used to generate energy. Glucose can also be assembled into starch and cellulose.
- Fructose is a simple sugar found in corn that is used to sweeten soda pop and other food products.
- Ribose and deoxyribose are part of RNA and DNA: they are 5 carbon sugars.
- Vitamin C is derived from a simple sugar.
- Disaccharides are two simple sugars joined together. Most of the sweet things we eat are disaccharides: table sugar is sucrose, glucose joined to fructose. Plants use photosynthesis to make glucose, but convert it to sucrose for ease of transport and storage. Lactose, milk sugar, is a glucose joined to another simple sugar called galactose. Maltose, malt sugar, is what yeast converts to ethanol when beer is brewed.

Complex Carbohydrates

- = <u>polysaccharides</u> (many sugars linked together).
- Can be linear chains or branched.
- Some is structural: the cellulose of plant cell walls and fibers is a polysaccharide composed of many glucose molecules. The chitin that covers insects and crustaceans is another glucose polymer (with a bit of modification). We don't have enzymes that can digest these polymers. Cows and termites depend on bacteria in their guts to digest cellulose, producing methane as a byproduct.
- Some is food storage: starch and its animal form glycogen. Also glucose polymers, but linked differently: we have enzymes that can digest starch. We animals store glycogen in the liver as a ready source of glucose, the basic food molecule needed by all cells.

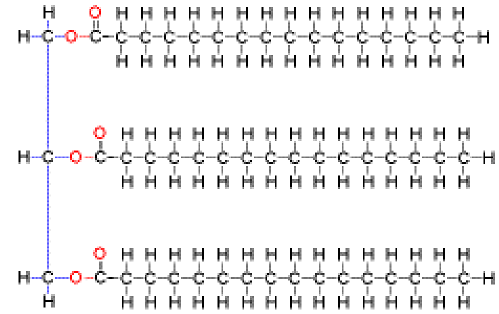


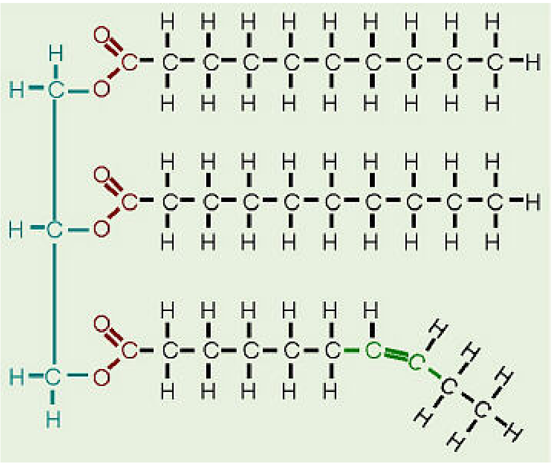
Lipids

- Lipids are the main non-polar component of cells. Mostly hydrocarbons—carbon and hydrogen.
- They are used primarily as energy storage and cell membranes.
- 4 main types: fats (energy storage), phospholipids (cell membranes), waxes (waterproofing), and steroids (hormones).

Fats

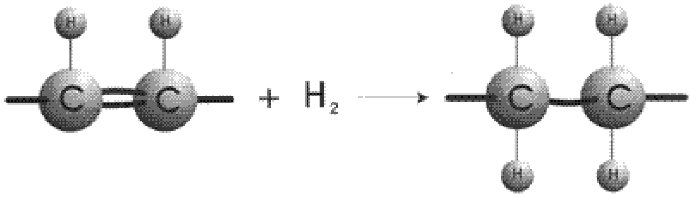
- Triglycerides are the main type of fat. A triglyceride is composed of 3 fatty acids attached to a molecule of glycerol.
- Fatty acids are long hydrocarbon chains with an acid group at one end. The chains pack together to make a solid fat. In liquid fats, like vegetable oils, double bonds kink the hydrocarbon chain, which prevents the chains from packing together nicely. This lowers the melting temperature, making them liquids.
- Glycerol is a 3 carbon carbohydrate. It has 3 alcohol (-OH) groups, which link up with the acid groups in the fatty acids.
- Fats store about twice as much energy per weight as carbohydrates like starch.


Triglyceride

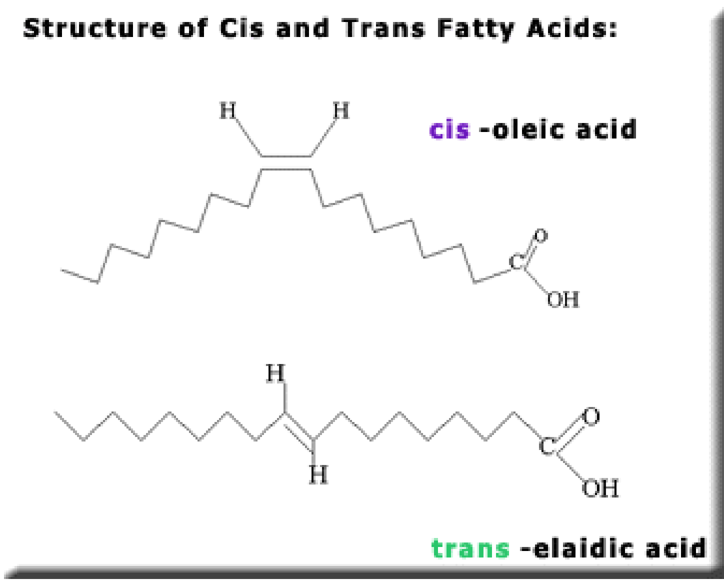


Trans fats

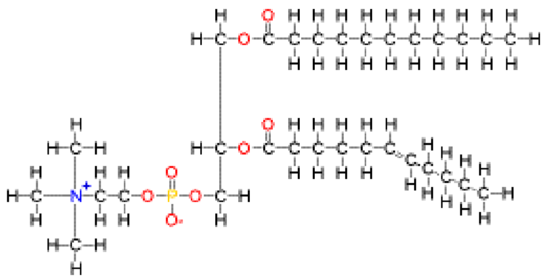
- Hydrocarbon chains with all single bonds (solid fats) are called <u>saturated</u>; fats with double bonds (liquid oils) are called <u>unsaturated</u>.
- Margarine is made by "hydrogenation": reducing the double bonds back to single bonds and adding in hydrogens, which raises the melting temperature, giving solid margarine instead of liquid vegetable oil.



- Most animal fats are saturated. Lard is purified animal fat, and it used to be used for deep frying. However, saturated fat increases blood cholesterol levels and leads to clogged arteries and heart disease.
- Several years ago, most companies replaced lard with partially hydrogenated vegetable oil, which was thought to be much healthier than lard.
- Unfortunately, partial hydrogenation leads to trans-fatty acids instead of the cis-fatty acids that occur naturally. And trans fatty acids proved to be even worse for your health than lard. Oops!

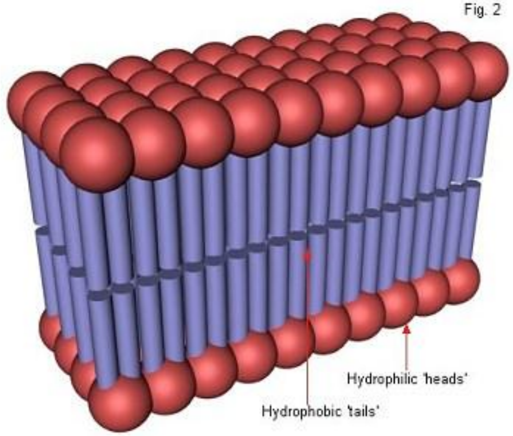


Phospholipids



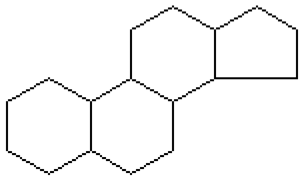
Phospholipid

Fig. 2

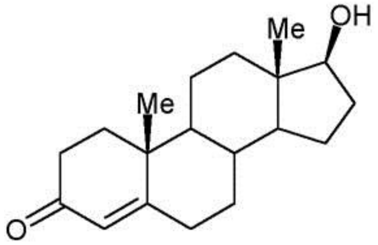


- <u>Phospholipids</u> are the main component of cell membranes.
- Phospholipids are very similar to triglycerides: they have a glycerol with 2 fatty acids attached, plus a phosphate-containing “head” group instead of a third fatty acid.
- The head group is hydrophilic, while the fatty acids are hydrophobic. Cell membranes are 2 layers, with the head groups facing out and the fatty acids forming the interior of the membrane.
- Phospholipid membranes allow only a few molecules to pass through them: water, some gases. They are what keeps the inside of cells separated from the outside.

Steroids and Waxes



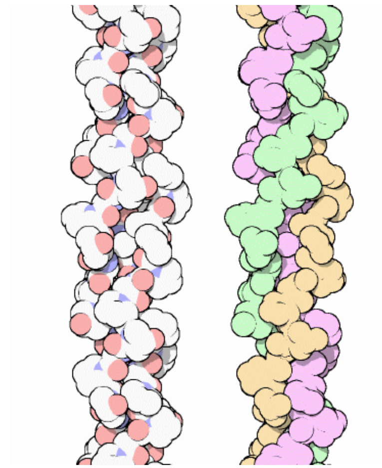
- Steroids are hydrocarbons with the carbon atoms arranged in a set of 4 linked rings.
- Cholesterol is an essential component of cell membranes (along with the phospholipids). However, too much of it in the blood can cause “plaques” to form in the blood vessels, leading to atherosclerosis (hardening of the arteries in the heart).

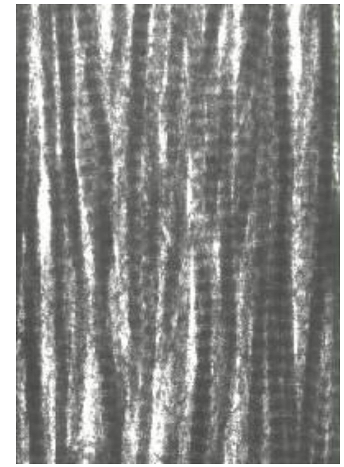


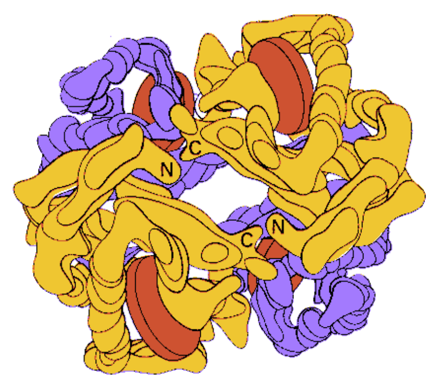
- Steroid hormones are made from cholesterol. These hormones include estrogen, testosterone, vitamin D, cortisone, and many others.
- Waxes: waterproof coating on plants and animals. Composed of fatty acids attached to long chain alcohols.

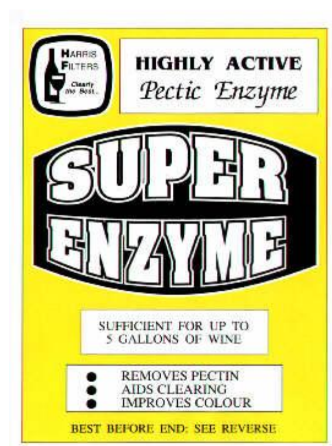
Proteins

- The most important type of macromolecule.
- Roles:
- Structure: collagen in skin, keratin in hair, crystallin in eye.
- <u>Enzymes</u>: all metabolic transformations, building up, rearranging, and breaking down of organic compounds, are done by enzymes, which are proteins.
- Transport: oxygen in the blood is carried by hemoglobin, everything that goes in or out of a cell (except water and a few gasses) is carried by proteins.
- Also: nutrition (egg yolk), hormones, defense, movement



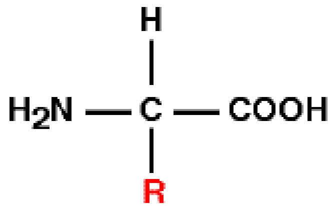




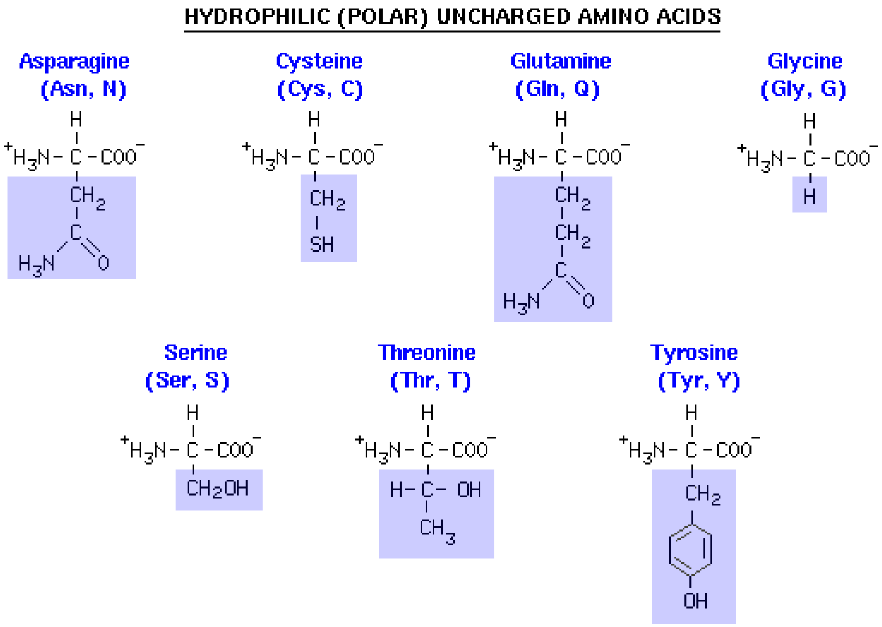


Amino Acids

- Amino Acids are the subunits of proteins.
- Each amino acid contains an amino group (which is basic) and an acid group. Proteins consist of long chains of amino acids, with the acid group of one bonded to the amino group of the next.
- There are 20 different kinds of amino acids in proteins.   Each one has a functional group (the “R group”) attached to it.
- Different R groups give the 20 amino acids different properties, such as charged (+ or -), polar, hydrophobic, etc.
- The different properties of a protein come from the arrangement of the amino acids.

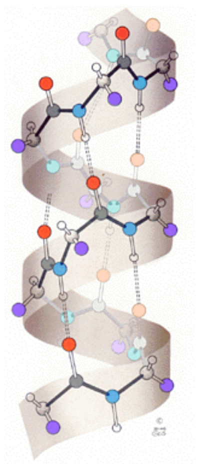


Amino Acid
20 Different R's



Protein Structure

- A polypeptide is one linear chain of amino acids. A protein may contain one or more polypeptides. Proteins also sometimes contain small helper molecules such as heme.
- After the polypeptides are synthesized by the cell, they spontaneously fold up into a characteristic conformation which allows them to be active. The proper shape is essential for active proteins. For most proteins, the amino acids sequence itself is all that is needed to get proper folding.
- Proteins fold up because they form hydrogen bonds between amino acids. The need for hydrophobic amino acids to be away from water also plays a big role. Similarly, the charged and polar amino acids need to be near each other.
- The joining of polypeptide subunits into a single protein also happens spontaneously, for the same reasons.
- Enzymes are usually roughly globular, while structural proteins are usually fiber-shaped. Proteins that transport materials across membranes have a long segment of hydrophobic amino acids that sits in the hydrophobic interior of the membrane.
- Denaturation is the destruction of the 3-dimensional shape of the protein. Denaturation inactivates the protein, and makes it easier to destroy. This is the effect of cooking foods.



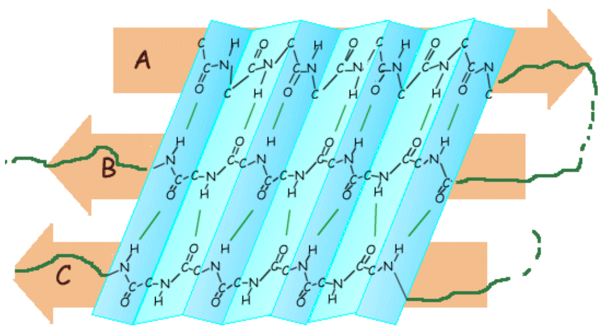
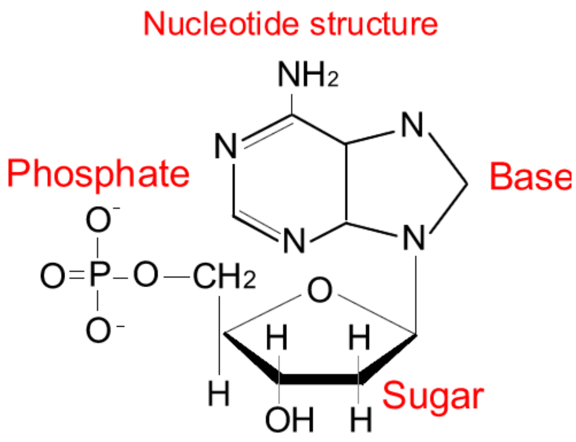
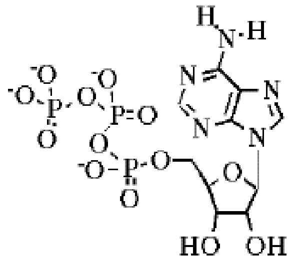


Diagram 1: Beta pleated sheet. The lateral groups (R) are not shown.

Nucleic Acids

- Nucleotides are the subunits of nucleic acids.
- Nucleic acids store genetic information in the cell. They are also involved in energy and electron movements.
- The two types of nucleic acid are RNA (ribonucleic acid) and DNA (deoxyribonucleic acid).
- Each nucleotide has 3 parts: a sugar, a phosphate, and a base.
- The sugar, ribose in RNA and deoxyribose in DNA, contain 5 carbons. They differ only in that an –OH group in ribose is replaced by a –H in DNA.
- The main energy-carrying molecule in the cell is ATP. ATP is an RNA nucleotide with 3 phosphate groups attached to it in a chain. The energy is stored because the phosphates each have a negative charge. These charges repel each other, but they are forced to stay together by the covalent bonds.





DNA and RNA

- DNA uses 4 different bases: adenine, guanine, thymine, and cytosine. The order of these bases in a chain of DNA determines the genetic information.
- DNA consists of 2 complementary chains twisted into a double helix and held together by hydrogen bonds. DNA is a stable molecule which can survive thousands of years under proper conditions
- RNA consists of a single chain that also uses 4 bases: however, the thymine in DNA is replaced by uracil in RNA. RNA is much less stable than DNA, but it can act as an enzyme to promote chemical reactions in some situations.