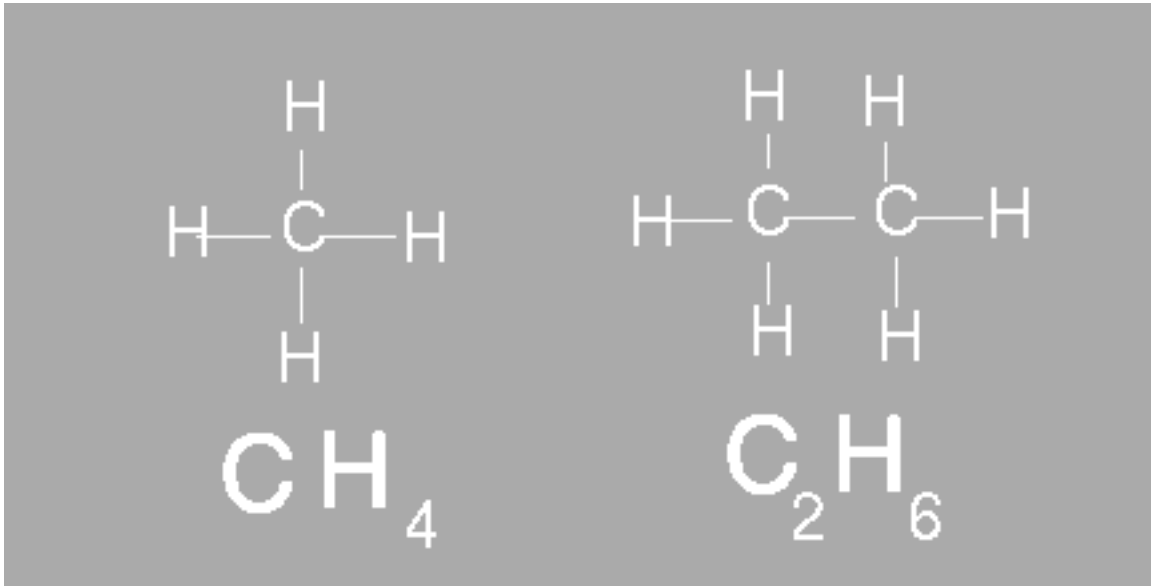


Basic Chemistry of Life

ORGANIC MOLECULES (organic molecules are the molecules of life)

ALL BASED ON CARBON BECAUSE CARBON CAN MAKE 4 BONDS



The C in the figure above represents the atom carbon. A solid line represents a stable chemical bond called a covalent bond...but we will just call it a bond for now. The figures represent the same two chemicals in two different ways. The formula that shows the bonds as lines and what atom is connect to what are called "structural formulas because from the formula you can see how the atom's are attached to each other. The lower formulas are called condensed formulas and do NOT show how the atoms are arranged in a structure. Condensed formulas are easier to write but less informative. In some cases a single condensed formula can represent many different molecules...more on this later.

Some nomenclature first:

NOMENCLATURE is a fancy word for how things can be named.

Nomenclature in science is very exact to keep confusion to a minimum. You are familiar with nomenclature for living organisms. An animal is given a genus and species. This is a nomenclature for living things. Scientists have given a genus and species name to every living thing we have discovered. *Homo sapiens* is the genus and species nomenclature for humans. Can you guess what animal *Felis*

domestiucus is?

Now to the nomenclature for carbon (organic) molecules.

The prefix of a carbon molecule depends on how many carbons are in the molecule.

Prefixes:

- 1 carbon...meth-
- 2 carbon...eth-
- 3 carbon...prop-
- 4 carbon...but-
- 5 carbon...pent-
- 6 carbon...hex-
- 7 carbon...hept-
- 8 carbon...oct-

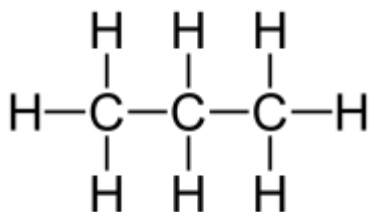
The suffix of a carbon molecule is based on whether the molecule has one or more double or triple bonds between carbon atoms.

Suffixes:

- ane...only single bonds
- ene...contains a double bond
- yne...contains a triple bond

Let's combine the prefix rule and suffix rule:

Propane...has three carbons and all single bonds among the carbon atoms.



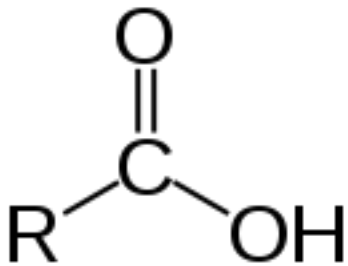
can you draw the condensed formula for propane?

Remember...Polar molecules have positive and negative charges and are therefore attracted to water molecules because water molecules are also polar. They are said to be **hydrophilic** because they interact with (dissolve in) water by forming hydrogen bonds.

Now we have a foundation to move to the four classes of biomolecules. These biomolecules behave in certain ways not only because of their carbon structure but also because of what are called functional groups.

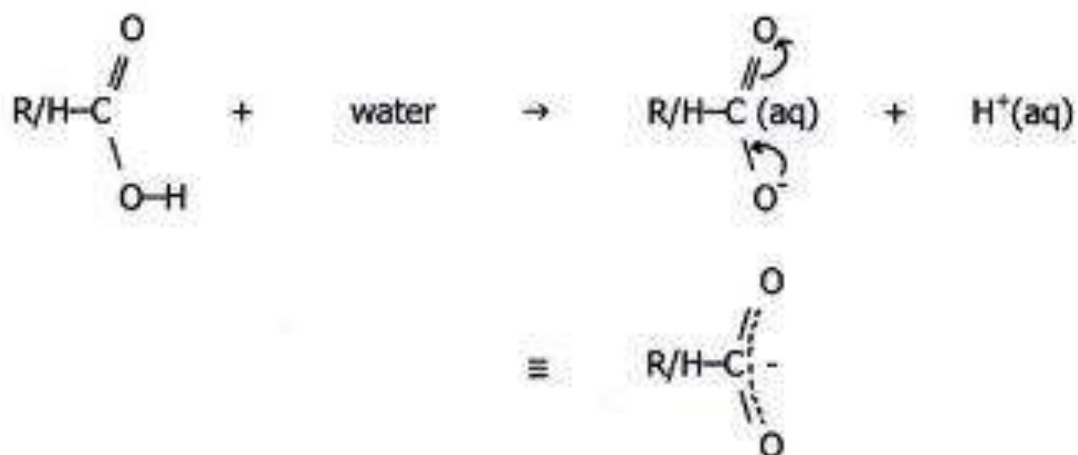
Functional groups are groups of atoms that when found in molecules give those molecules a certain characteristic. For example, any molecule with an acid group will have the potential to act like...you guessed it...an acid. See how logical science is.

This is the functional group called an acid group. Since it is an acid group with carbon it is often called a carboxylic acid group. The capital letter R in the structural formula represents whatever the acid group is attached to.



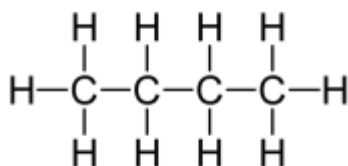
IN WATER...THE REAL WORLD

Acid group will lose their hydrogen (proton) to the water. And the acid group is then charged and polar. The dotted line represents the switching of the double bond back and forth between the oxygens.

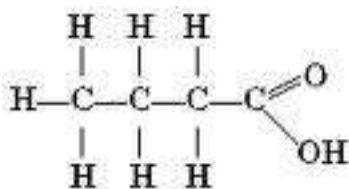


We can now see how an acid group will lend a certain characteristic to a molecule.

The molecule immediately below is a butane molecule.



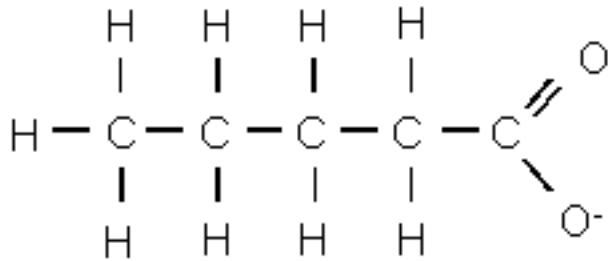
Below, we have attached the acid group to a butane molecule.



When we put it in water it becomes ionized by losing a proton (a

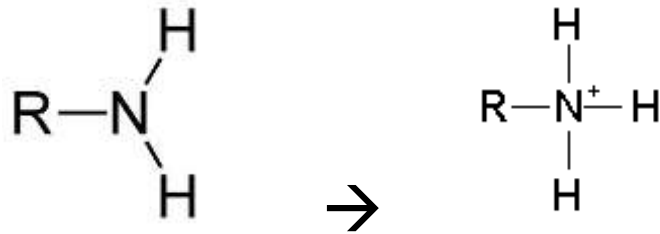
hydrogen).

IS THIS POLAR????????

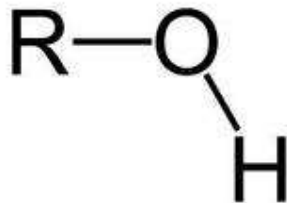


Here are some other important functional groups (remember what the R stands for?):

Amino group when placed in water becomes ionized by taking up a proton (hydrogen nucleus from the water)



Alcohol (or hydroxyl) functional group



METABOLISM (Utilization of energy to make and convert biomolecules)

The buildup and breakdown of biological molecules (anabolism and catabolism)

Before we study the details of metabolism, we must review the structure and functions of biomolecules...most importantly the first three of the following four:

FOUR CLASSES OF BIOMOLECULES (ALL ORGANIC MOLECULES)

1) CARBOHYDRATES 2) LIPIDS 3) PROTEINS 4) NUCLEIC ACIDS

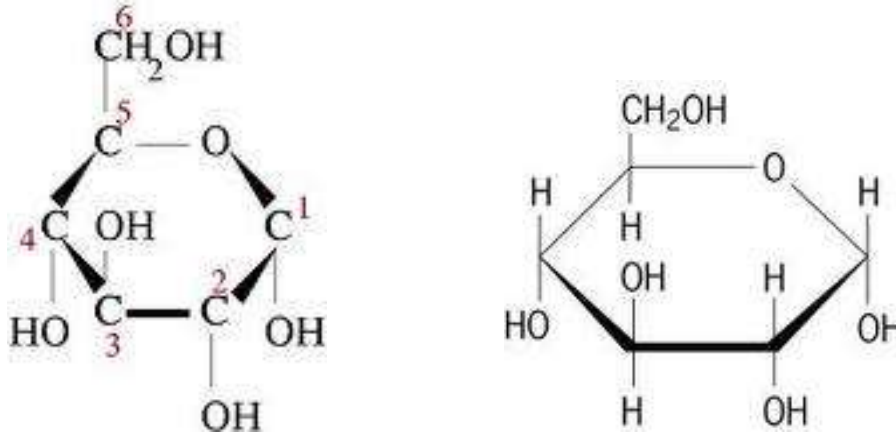
1) Carbohydrates

During photosynthesis, water (H_2O) is combined with Carbon from the CO_2 in the air to form CARBO, HYDRATES (when you drink water you get “hydrated”). Adding water to carbon hydrates the water.

1. **Carbohydrates** (carbon-water) are the most abundant organic compounds (things made of carbon and hydrogen and often some oxygen) on Earth.

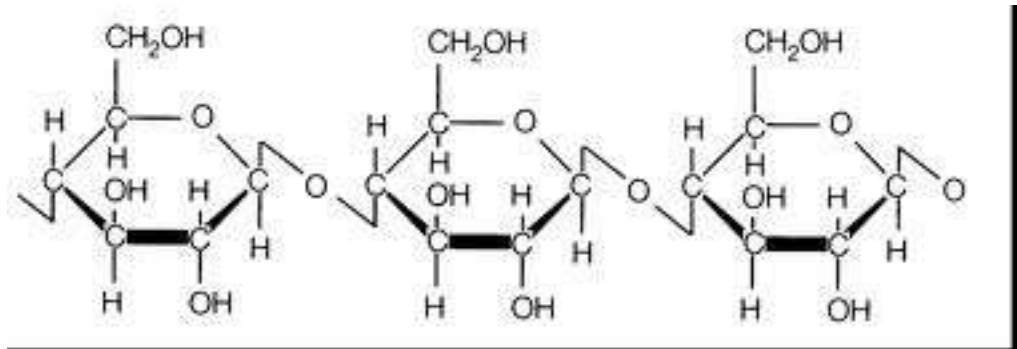
Carbohydrates have carbon and the two elements of water (H and O).

The simplest carbs are single sugar molecules called monosaccharides. A common single sugar is glucose. Glucose is called a ring structure...guess why?

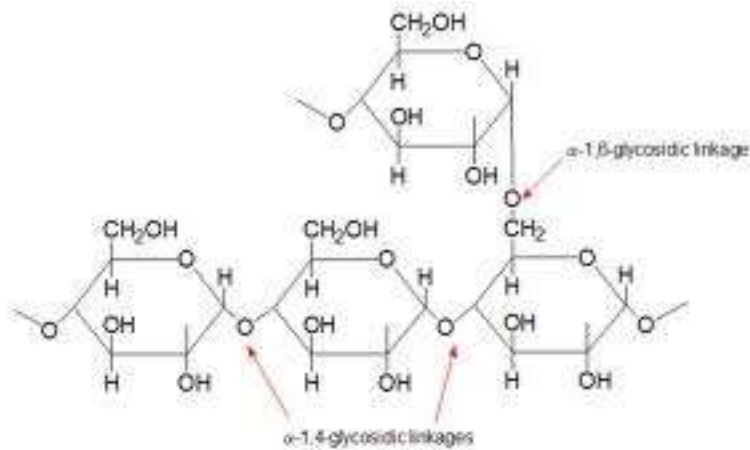


The left formula shows the carbons. The right formula represents most of the carbons as corners in the drawing. Note that the condensed formula for glucose is $C_6H_{12}O_6$

When many sugars are bonded together they are called polysaccharides. Cellulose (plants are mostly cellulose) is the most common polysaccharide (a very big carbohydrate) by weight. Cellulose is a polymer of glucose monomers. Cellulose functions as a structural support molecule in plants but is a food source for many primary consumers and herbivores.



The most common carbohydrate or monosaccharide in mammals is glucose (from the Greek word glukus meaning sweet), which has the chemical formula $C_6H_{12}O_6$.



Fructose (also a $C_6H_{12}O_6$) is a common monosaccharide in fruits (and does not promote tooth decay... so eat lots of fruits).

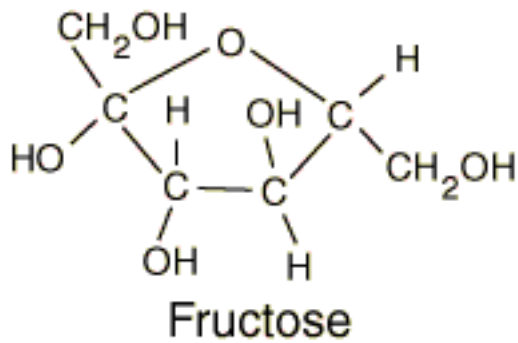
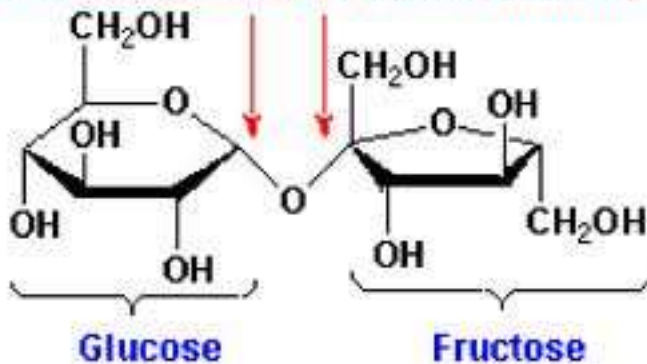


Table sugar or sucrose is a **disaccharide** made of two simple sugars (glucose and fructose bonded together).

Sucrose

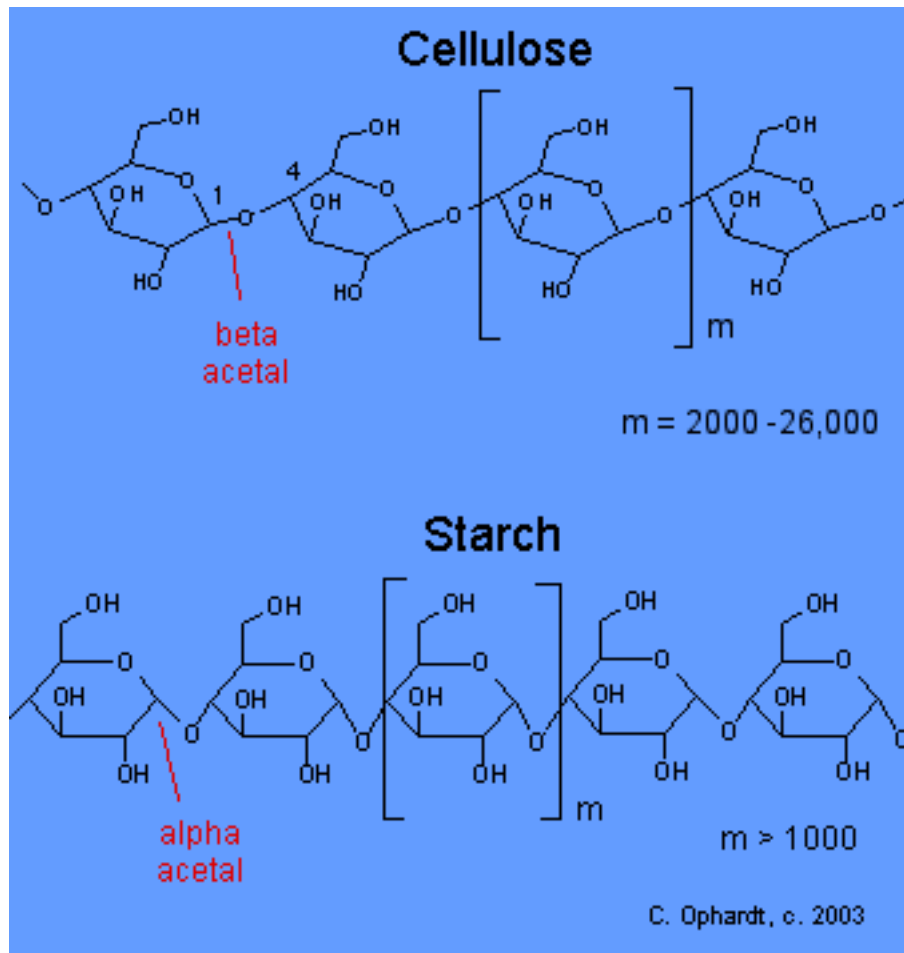
α -Glucosidbinding β -Fructosidbinding



MTJ 5/10,00

Polysaccharides are carbohydrates made of up to thousands of individual sugar molecules (monomers) bonded together in one massive molecule. Starch, glycogen and cellulose are all polysaccharides made of monomers of glucose linked together in slightly different ways.

The figure below shows chemical models of the cellulose and starch molecules. Each hexagonal section represents a glucose monomer. The brackets with the subscript indicate that there are commonly between up to 26,000 glucose monomers in the cellulose molecule and often more than 1,000 glucose monomers in the starch molecule. NOTE that the molecules differ in the different manner in which the glucose molecules are joined.



2. LIPIDS (FATS AND OILS)

- include fats, oils, waxes, steroids, and phospholipids. They function as energy storage, as waterproof coatings, and as chemical messengers.

There are many kinds of lipid molecules

BUT ALL LIPIDS:

-DO NOT dissolve well in water but DO dissolve in oil

-They are mostly non-polar or uncharged molecules

(LIKE DISSOLVES LIKE !!! Birds of a feather flock together)

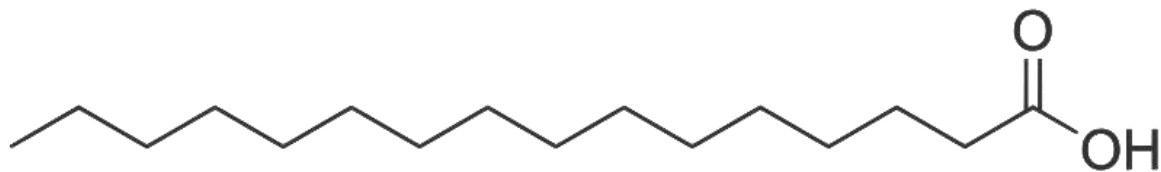
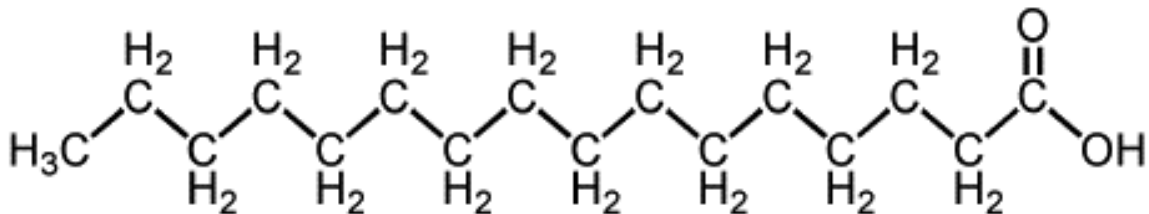
- are made of carbon atoms strung together often in long chains with an acid at the end so these very common lipids are called fatty acids. Palmitic acid is

the most common fatty acid.

There are two general types of fatty acids: Saturated and unsaturated

- a) **Saturated fatty acid (SFA or saturated fat)** are those in which all the carbon atoms of the fatty acids are bonded to at least two hydrogen atoms. They form straight chain polymers in which the fatty acids are packed very closely; these include fats such as bacon fat and lard. Palmitic acid is a common SFA

PALMITIC ACID $C_{16}H_{32}O_2$



hydrocarbon tail HATES WATER
non-polar, hydrophobic, lipophilic
hydrophilic

acid part LIKES WATER
polar and

- b) **Unsaturated fats** are those two adjacent carbon atoms on the fatty acids that share a double bond and therefore have fewer hydrogens. They cannot pack as tightly as saturated fats. At normal temperatures they are liquids (These are the oils). Polyunsaturated fats (PUFA's) have even more of these double bonds.

scientist a fat is solid at room temperature and an oil is a liquid at room temperature. Fats (lipids) were eventually medically classified in to 2 categories, “healthy fats” and “unhealthy fats”. Americans were told “unhealthy fats” were saturated fats and “healthy fats” were unsaturated fats. This has been disproved by more detailed research studies.

An analysis of many research studies on thousands of people disproved the lipid hypothesis. The conclusion was, “In contrast to current recommendations (by the medical profession), this systematic review found no evidence that saturated fat increases the risk of coronary disease, or that polyunsaturated fats have a cardio protective effect.”[1]

TO MAKE MATTER WORSE! **Hydrogenation ... a bad thing**

In the process of recommending people stay away from saturated fats, butter was considered a unhealthy fat BECAUSE IT IS MOSTLY SATURATED FAT. To replace butter people were told to eat margarine. The most common form of margarine was made from corn oil...which is a liquid at room temperature. Chemists figured out how to make corn oil a solid (fat) at room temperature. To do this they bubbled hydrogen (hydrogenation) through the oil and made many of the double bonds break and add a hydrogen to the carbons...this “saturated” the carbons with hydrogens and turned the liquid corn oil into a solid.

Margarine and vegetable oils

Vegetable oils are commonly referred to as "polyunsaturated". This simply means that there are several double bonds present. Vegetable oils may be converted from liquids to solids by the hydrogenation reaction. Margarines and shortenings are "hardened" in this way to make them solid or semi-solids.

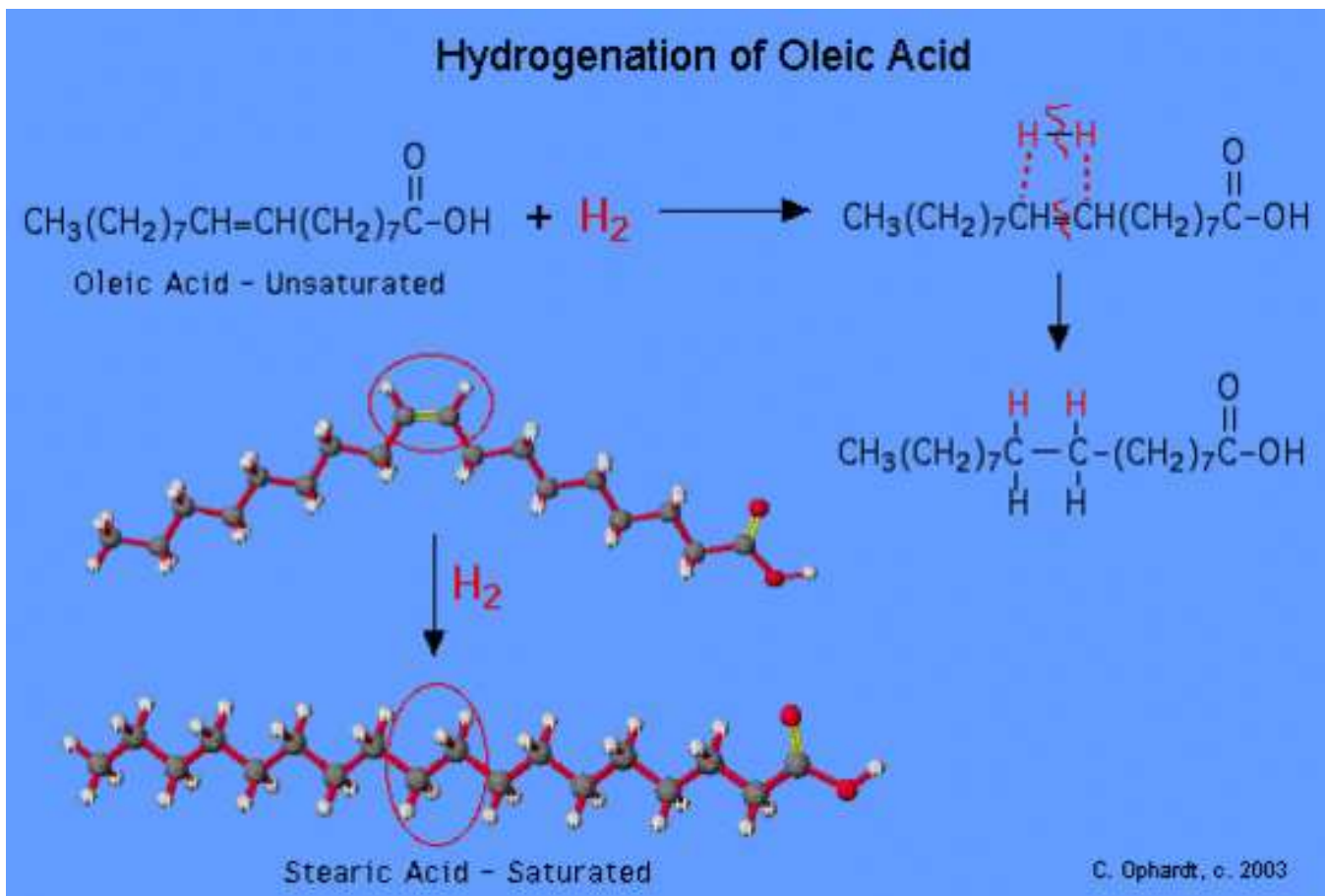
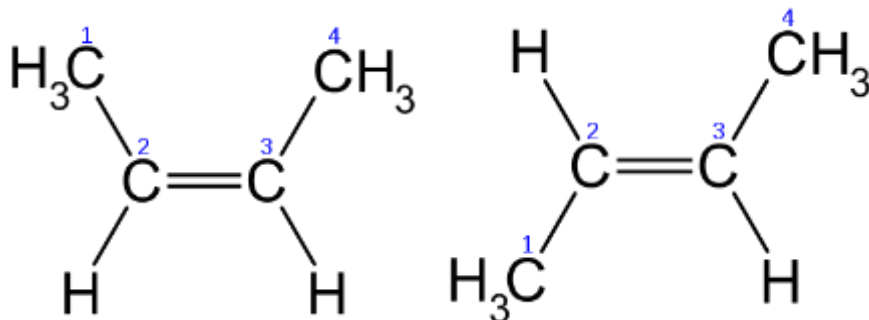


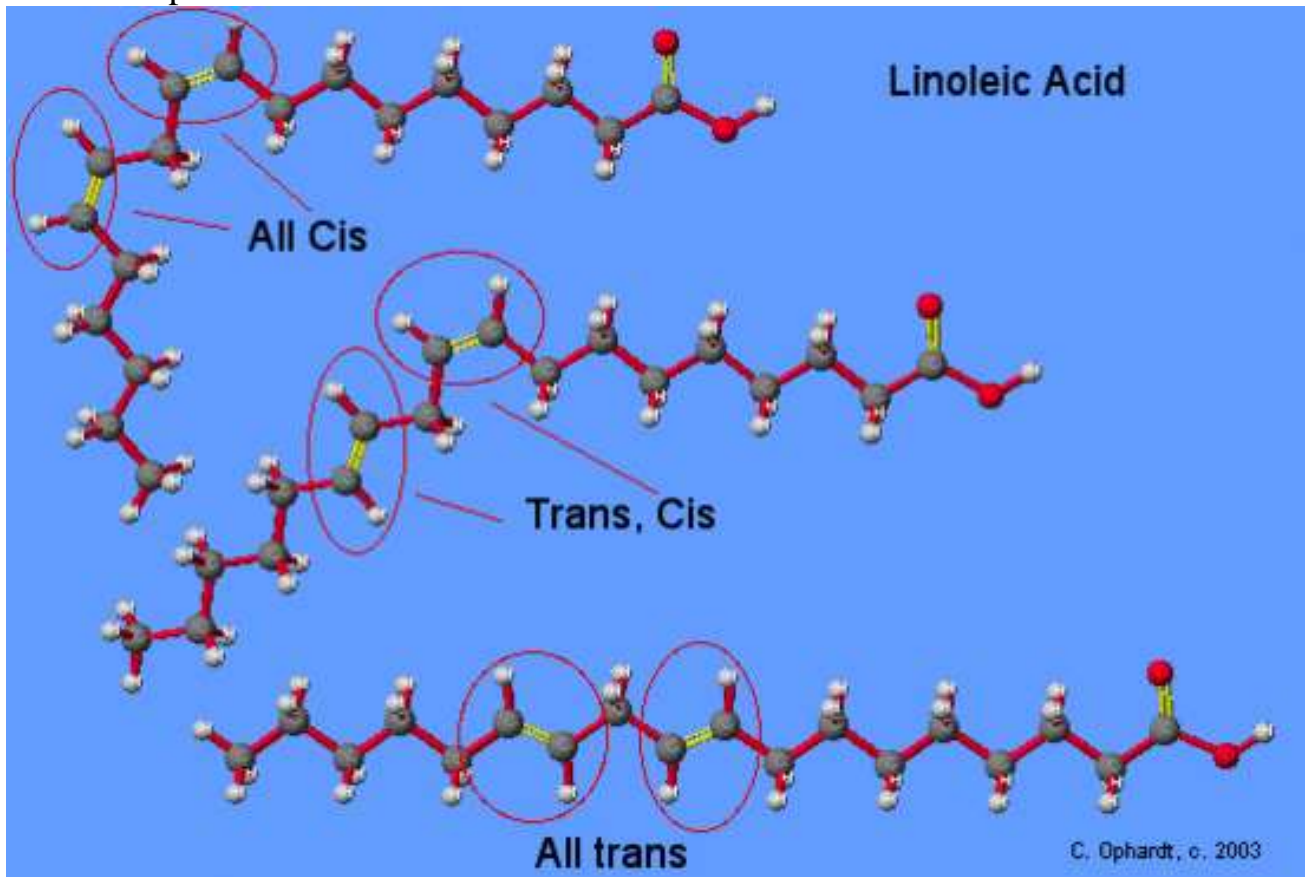
Figure 1: Hydrogenation of oleic acid into stearic acid...adding hydrogen removes the double bond and converts the crooked oleic acid into the straight chain molecule called stearic acid

There was a catch!!! Below on the left is the cis double bond shape and on the right is the trans double bond shape.



As you can see the # 1 and # 4 carbons are in different places.

Trans fats are the result of the hydrogenation process. A cis bond has the carbons on the same side. Due to the added energy from the hydrogenation process, enough energy is added to convert the cis isomers of the unsaturated fat to a trans isomer of the unsaturated fat. The effect is putting one of the hydrogens on the opposite side of one of the carbons. This results in a trans configuration of the double bonded carbons. The human body doesn't digest trans fats. Very few things can digest trans fats. This makes them wonderful preservatives.



“Although the trans fatty acids are chemically "monounsaturated" or "polyunsaturated" they are considered so different from the cis monounsaturated or polyunsaturated fatty acids that they can not be legally designated as unsaturated for purposes of labeling.” (2)

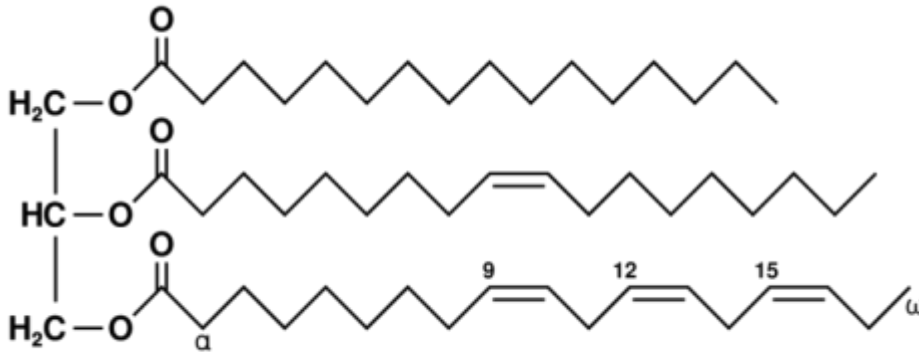
Trans fats have been found to increase the risk for heart disease and stroke.

Triglycerides shown below

Tri means three, triglycerides have three fatty acids attached to a 3 carbon molecule called glycerol.

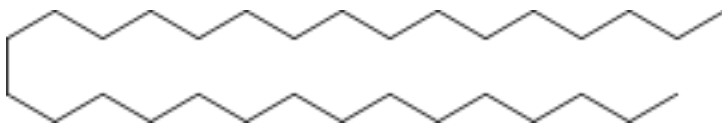
Example of an unsaturated fat triglyceride. Left part in bold: glycerol

Right part from top to bottom: palmitic acid, oleic acid, alpha-linolenic acid.
Chemical formula:



Triglycerides are the main constituents of vegetable oil (typically more unsaturated) and animal fats (typically more saturated). Triglycerides are a major component of human skin oils. They contain more than twice as much energy as carbohydrates per gram.

B. Waxes – long chained hydro-carbon molecules that are insoluble in water, useful as waterproof coatings for organisms, and as a structural component of cell walls.



The hydrocarbon $\text{C}_{31}\text{H}_{64}$ is a typical component of paraffin wax.

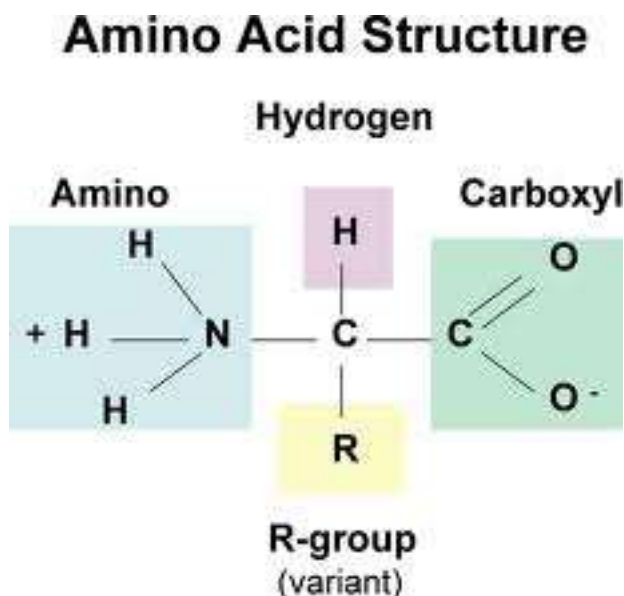
3. Proteins (polypeptides)

The specialized shapes and functions of different cell types (something we will explore later in the course) depend upon the bewildering variety of proteins. Proteins have many roles in cells (and between cells). They include, but are not limited to:

1. Structural proteins - form cell parts
2. Regulatory proteins - control cell processes
3. Enzymes - facilitate (help) many chemical reactions; they do this by lowering the amount of energy needed to start the reaction; the enzyme is not permanently altered in the process
4. Hormones - chemical messengers
5. Transport proteins - carry other substances around cells or from cell to cell.

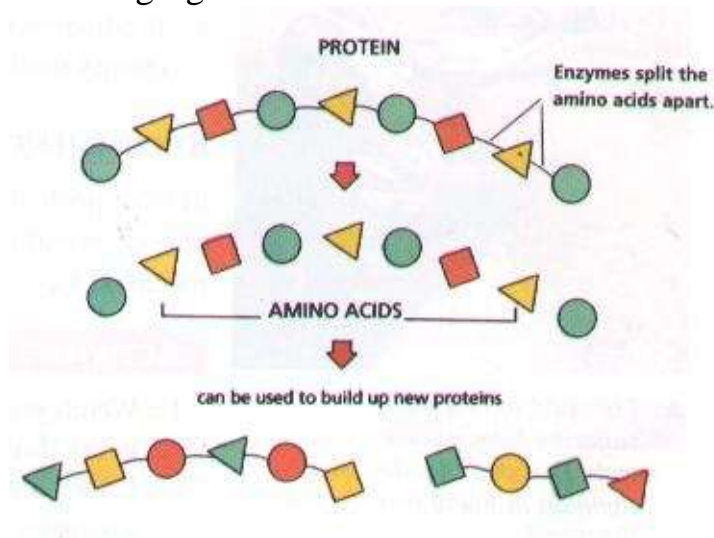
Proteins consist of long chains of **amino acids**, the building blocks of proteins. Proteins are made of one or more polypeptides. There are usually 100 to 10,000 amino acids in a typical protein molecule. Many millions of combinations of amino acids are possible.

The image below is the basic structure of all amino acids. The R will vary among amino acids

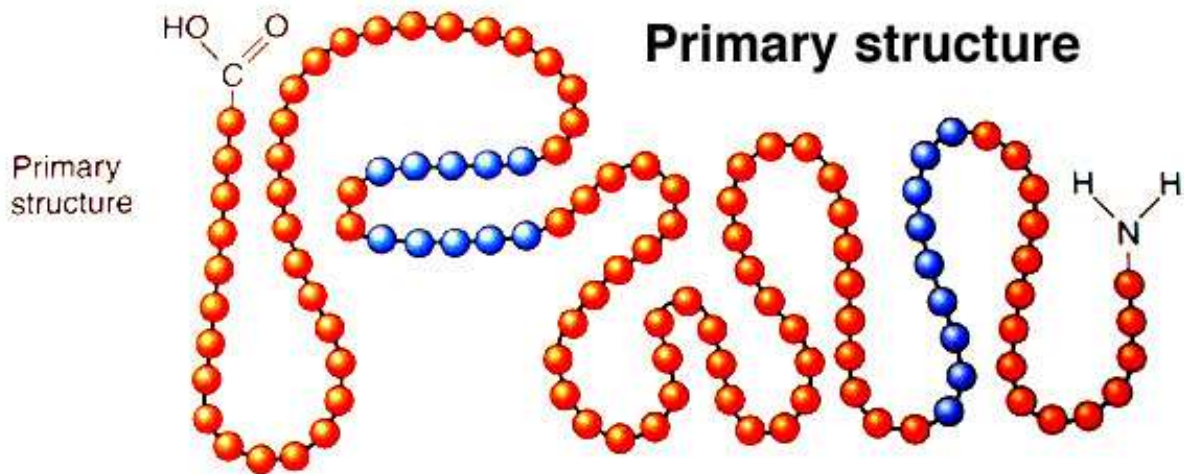


There are 20 different amino acids that we use in our bodies to build the thousands of different proteins we need for life. There are ~10 amino acids (essential amino acids) that we must have in our diet because we cannot make them. Proteins differ in the number and order of these amino acids. Insulin, a hormone that regulates how our bodies use sugar and lipids, is a protein of about 56 amino acids long. Hemoglobin is much larger and is many hundreds of amino acids long.

When we digest protein from what we eat we break the protein down into individual amino acids. Our metabolism then build those amino acids back up into proteins our bodies need. In an odd twist, we need special proteins called enzymes to digest the proteins into amino acids. This is shown in the following figure.



If we represented amino acids as red and blue balls, a protein of about 100 amino acids might have the following starting structure (primary shape).



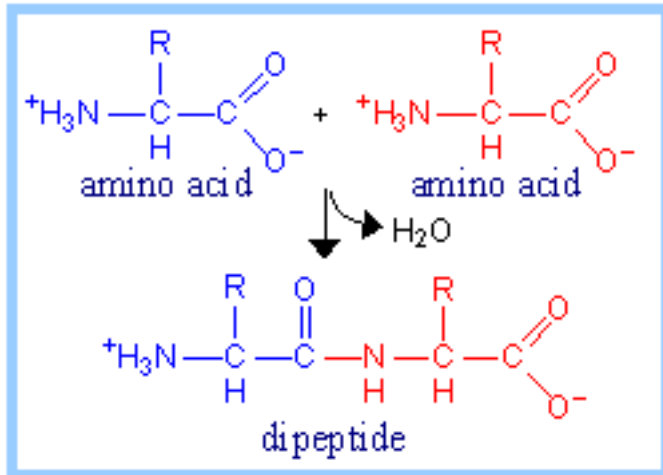
To better understand this, watch the following video

<http://vimeo.com/78082453>

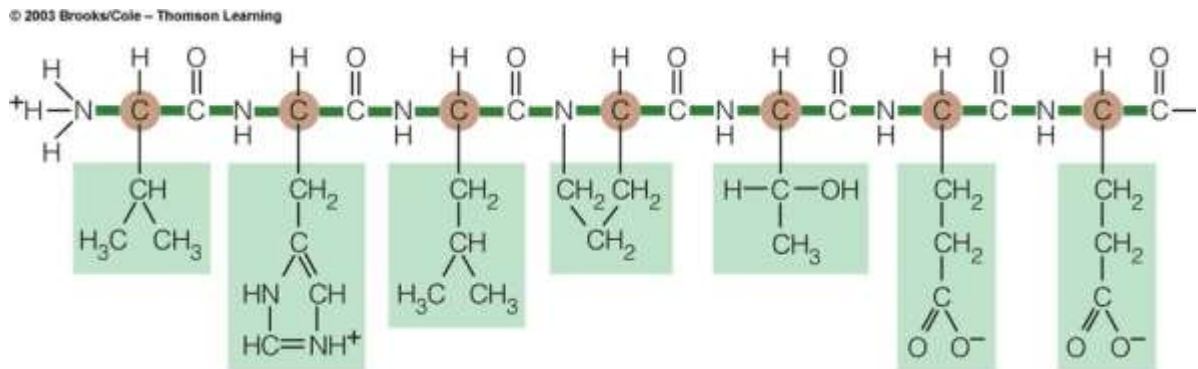
Protein Structure - proteins have four levels of organization (see Figures below)

1. **Primary structure** - simply the order of amino acids in a polypeptide strand as shown above with the red and blue balls.

Amino acids are joined by a peptide bond...a type of chemical bond between the amino group of one amino acid and the acid group of another amino acid.



Many amino acids joined are called a polypeptide or protein.

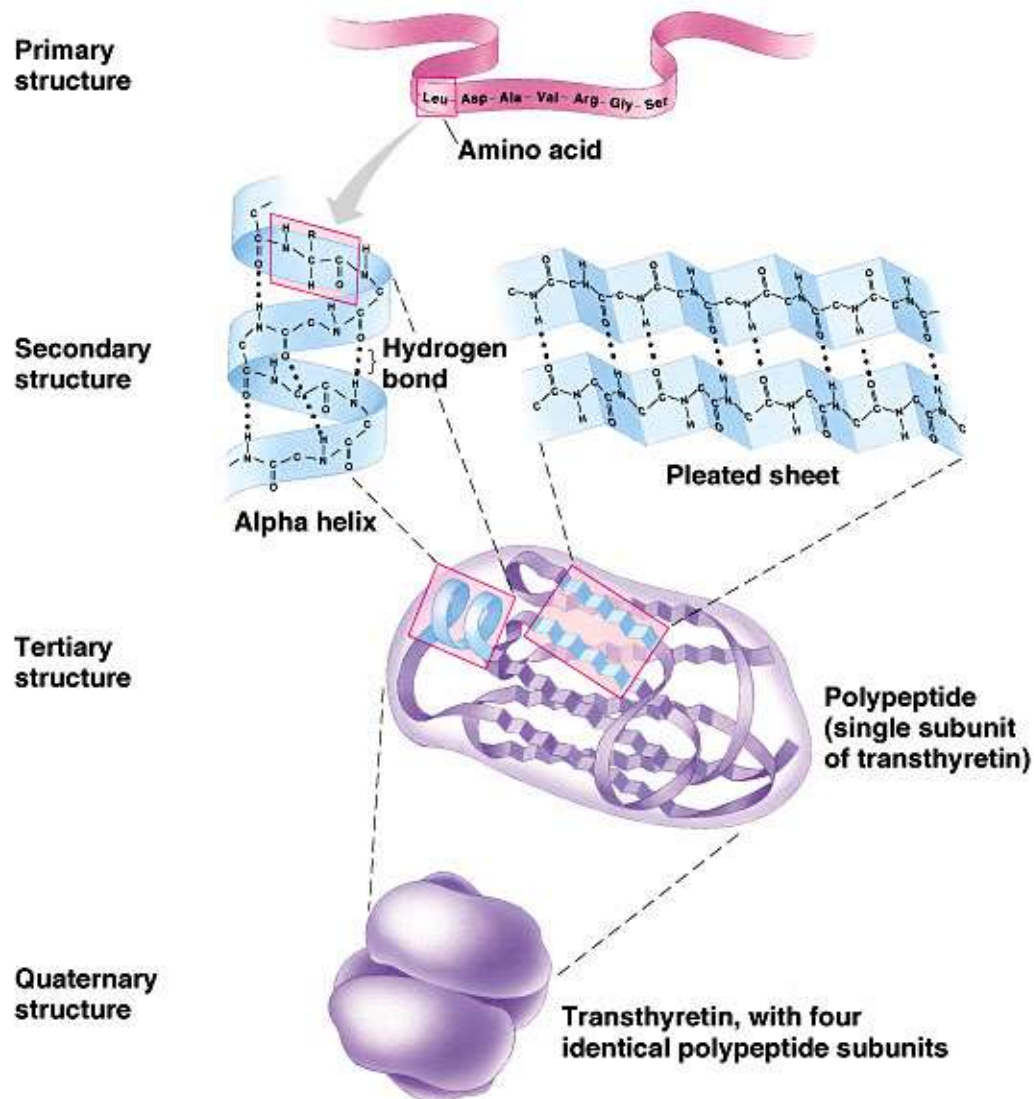


2. Secondary structure - regions of localized bending resulting in a) an alpha helix and/or b) pleating (like an accordion) called beta sheets give proteins their secondary structure. Weak hydrogen bonds cause this structure. (See Figure below and movie) <http://vimeo.com/78082453>

3. **Tertiary structure** - the three-dimensional folding of the entire polypeptide chain. (See Figure below and movie)

<http://vimeo.com/78082453>

4. **Quaternary structure** - the fitting together of two or more polypeptide chains, thus forming a functional protein.



1) <http://www.ncbi.nlm.nih.gov/pubmedhealth/behindtheheadlines/news/2014-03-18-saturated-fats-and-heart-disease-link-unproven/>

2)

http://chemwiki.ucdavis.edu/Biological_Chemistry/Lipids/Fatty_Acids/Hydrogenation_of_Unsaturated_Fats_and_Trans_Fat