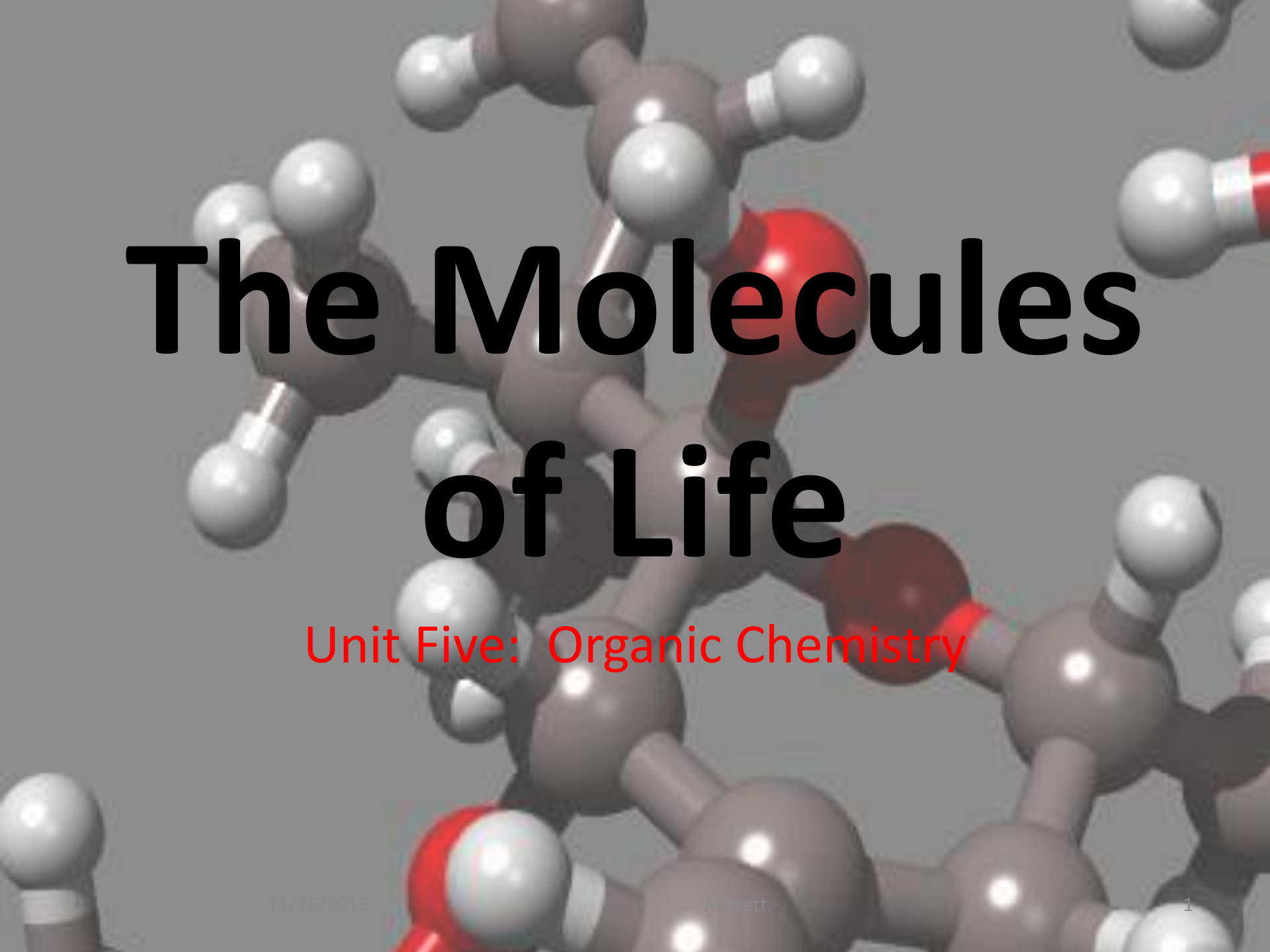
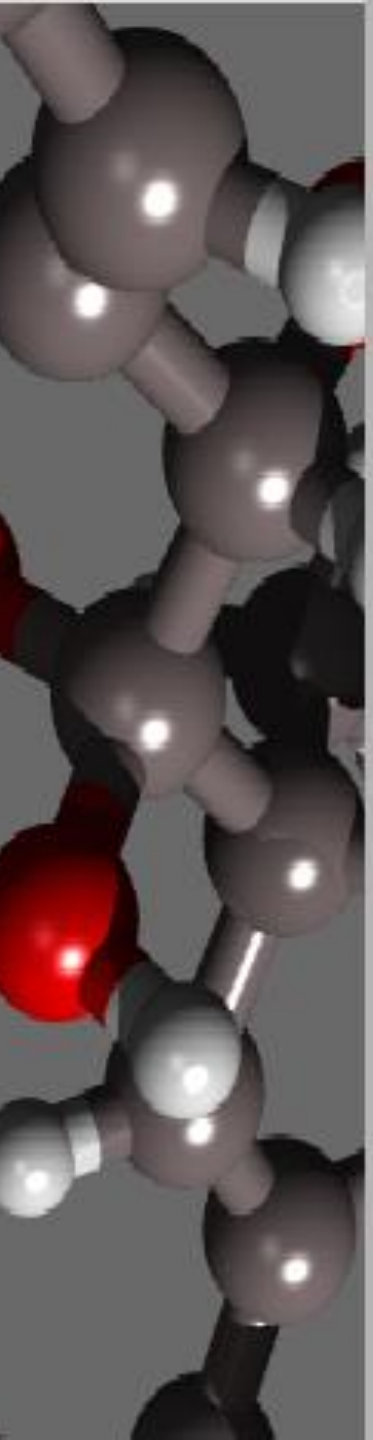


The Molecules of Life

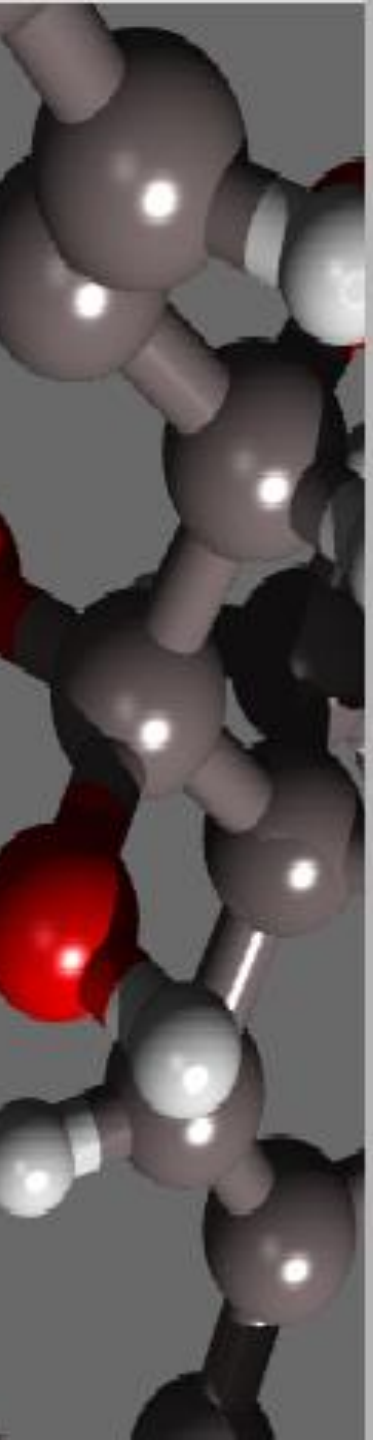
Unit Five: Organic Chemistry



Organic vs. Inorganic Molecules

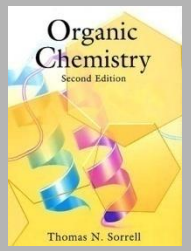
- **Organic compounds are molecules containing carbon.**
- **Inorganic compounds are molecules NOT containing carbon.**

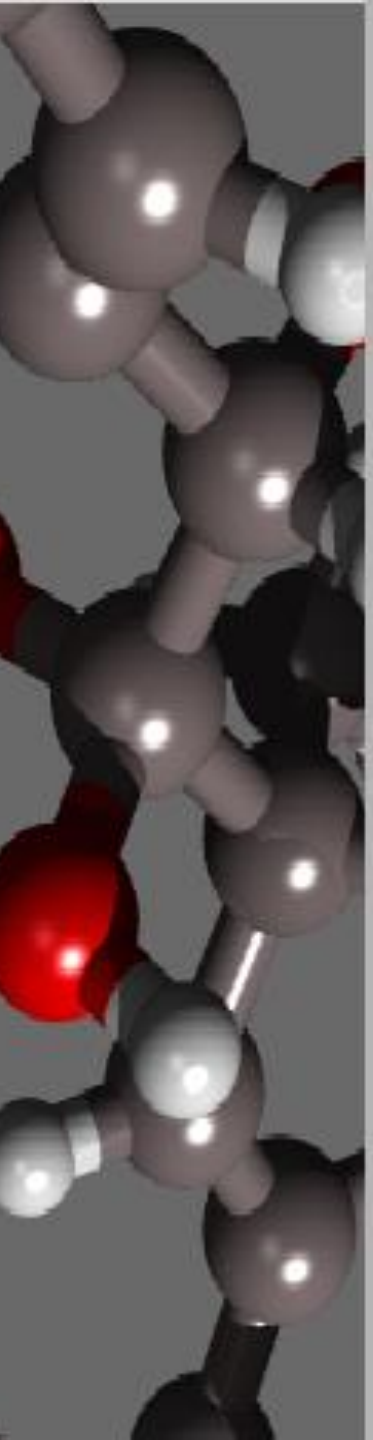
Organic Compounds	Inorganic Compounds
1. Organic compounds usually do not dissolve in water.	1. Inorganic compounds usually dissolve in water.
2. Organic compounds generally dissolve in organic solvents like ether, alcohol, benzene and chloroform.	2. Inorganic compounds generally do not dissolve in organic solvents.
3. Organic compounds have usually low melting points and boiling points; and they usually decompose on heating.	3. Inorganic compounds usually have high melting points and boiling points. They usually do not decompose on heating.
4. Organic compounds are inflammable; they catch fire easily.	4. Inorganic compounds are usually non inflammable; they do not burn easily.
5. Organic compounds exist as covalent molecules, so they are non-electrolytes.	5. Most of the inorganic compounds are ionic, so they are electrolytes.



Organic Molecules

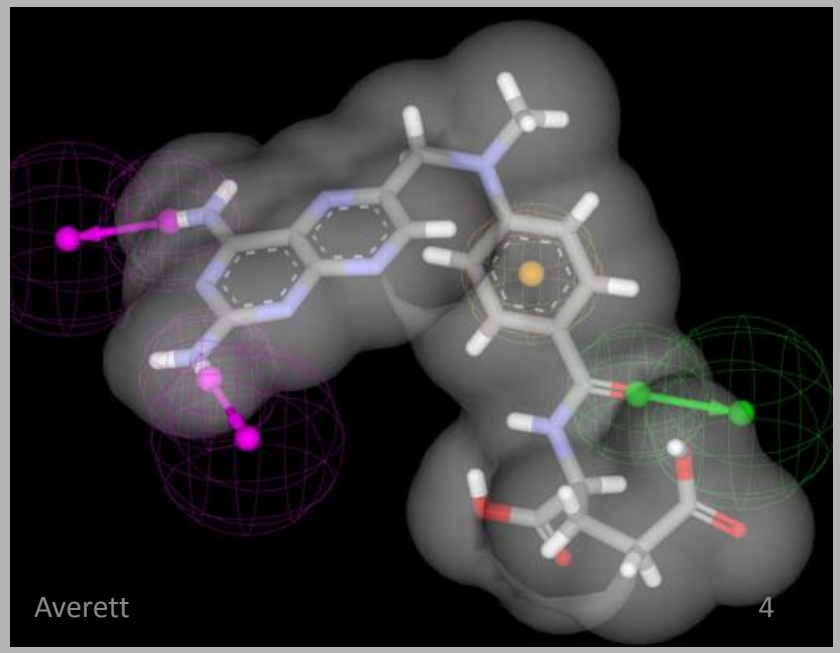
- Organic molecules are derived from living things and contain carbon
  - Example: glucose ($C_6H_{12}O_6$) methane (CH_4)
- Inorganic molecules are derived from nonliving things
  - Examples: water (H_2O) Sodium Chloride (NaCl)
- Organic chemistry – the study of all compounds that contain bonds between carbon atoms
  - The study of carbon and its role in life

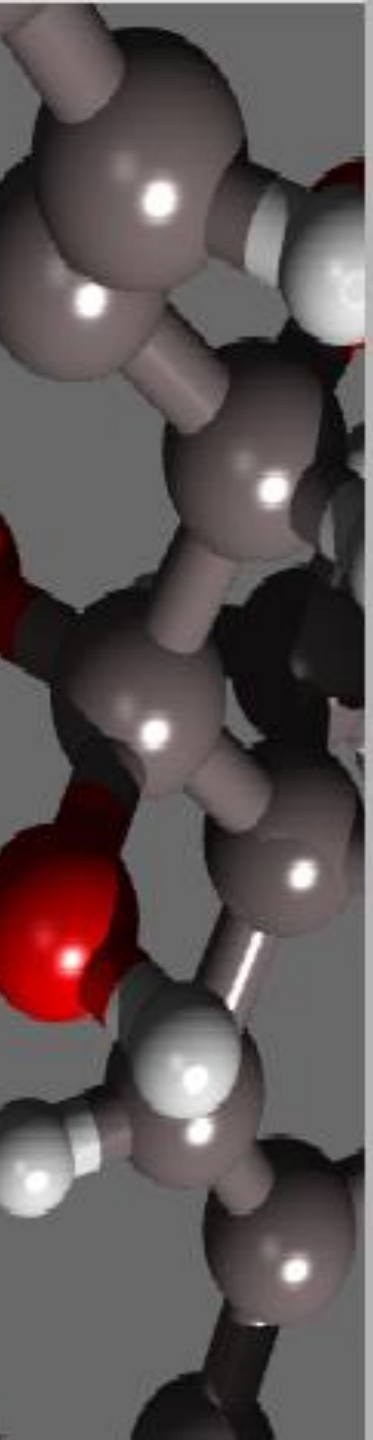




Carbon

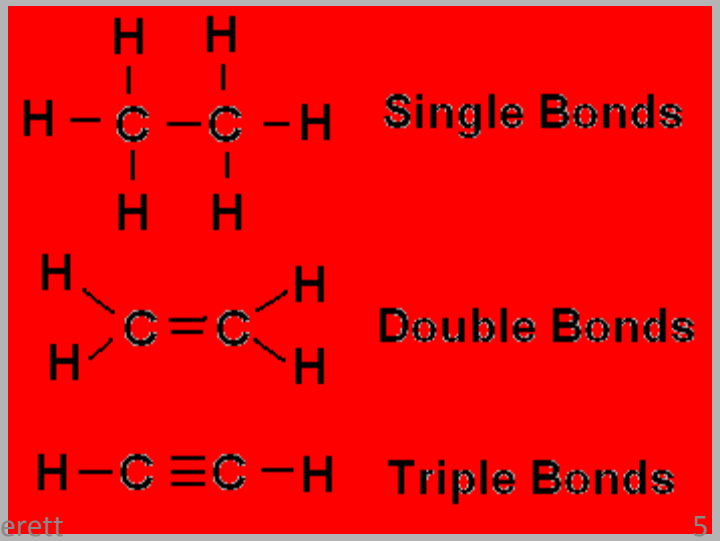
- **All life on earth is carbon based**
  - **Carbon atoms are the basis of most molecules that make up living things**
    - **Forms the structure of all living things**
    - **Carbon based molecules carry out most processes required for life**

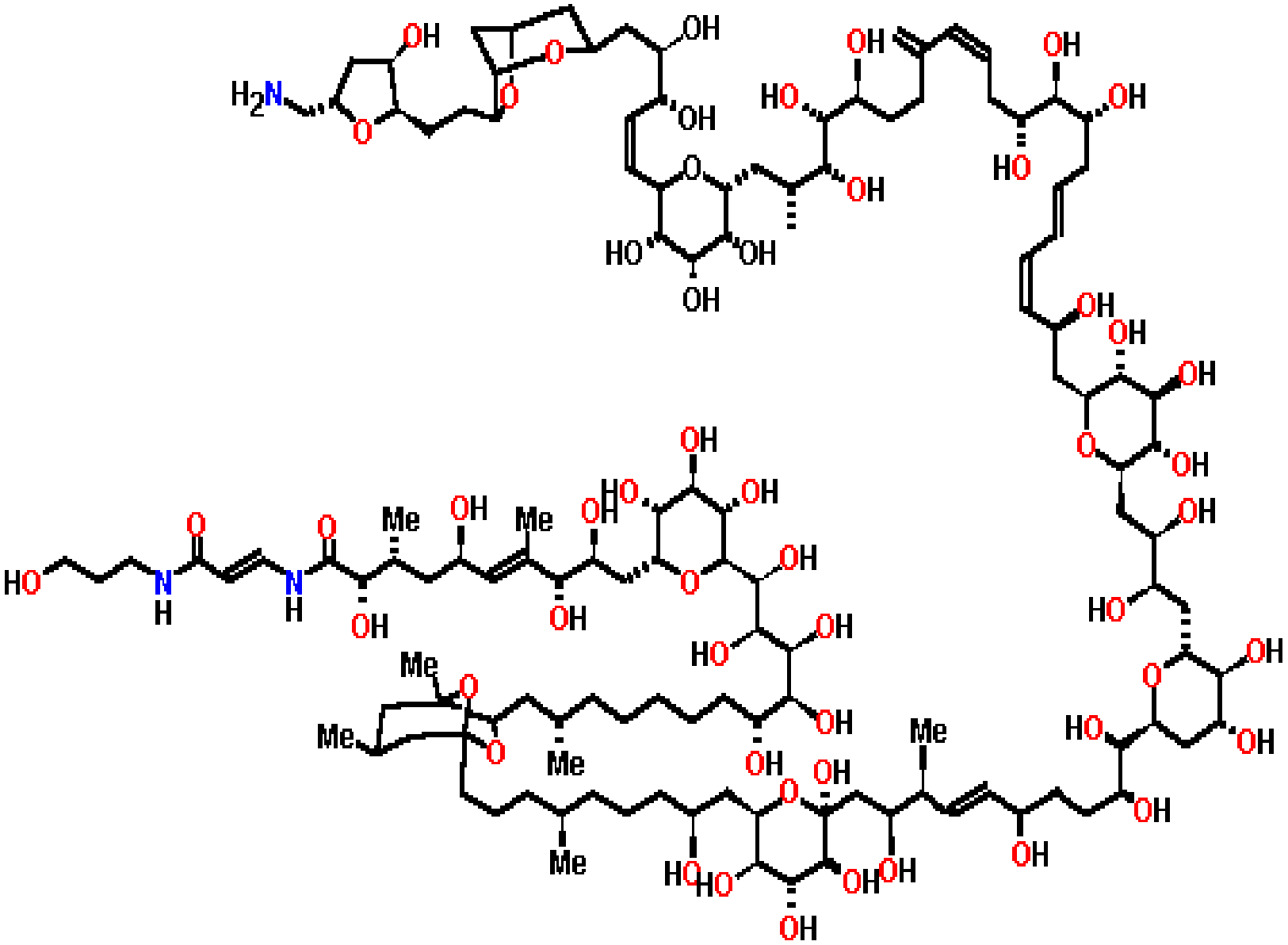




Carbon

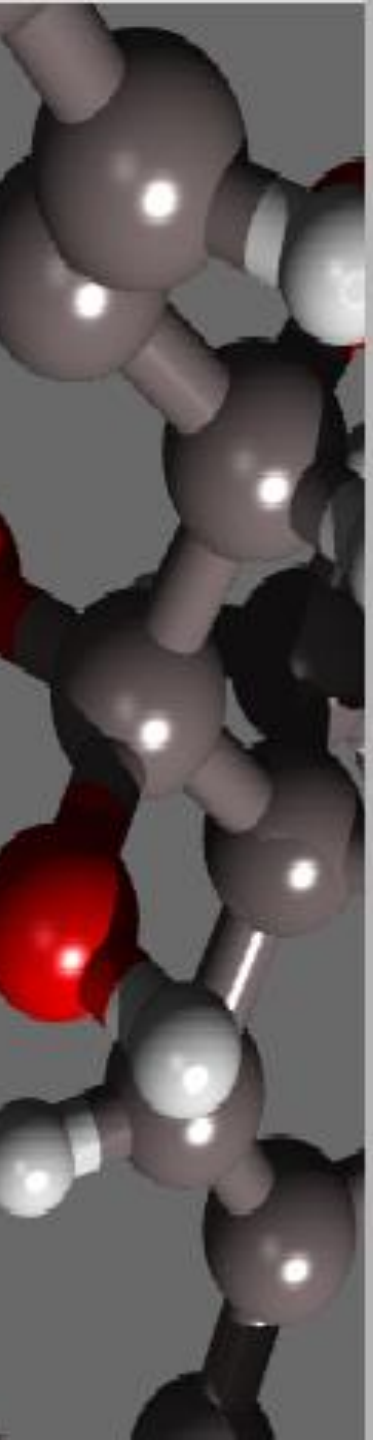
- **Carbon has 4 e- in its outer shell**
  - **Therefore carbon will form 4 covalent bonds**
    - **This gives carbon containing compounds structural support**





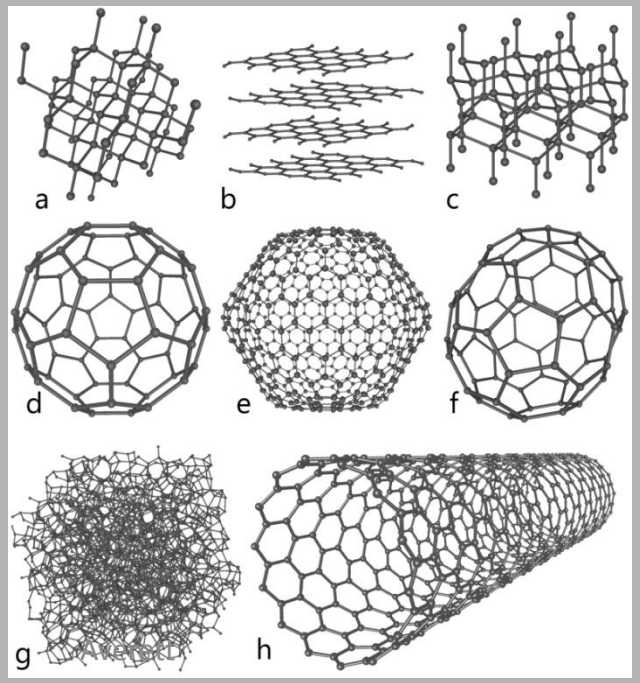
Palytoxin

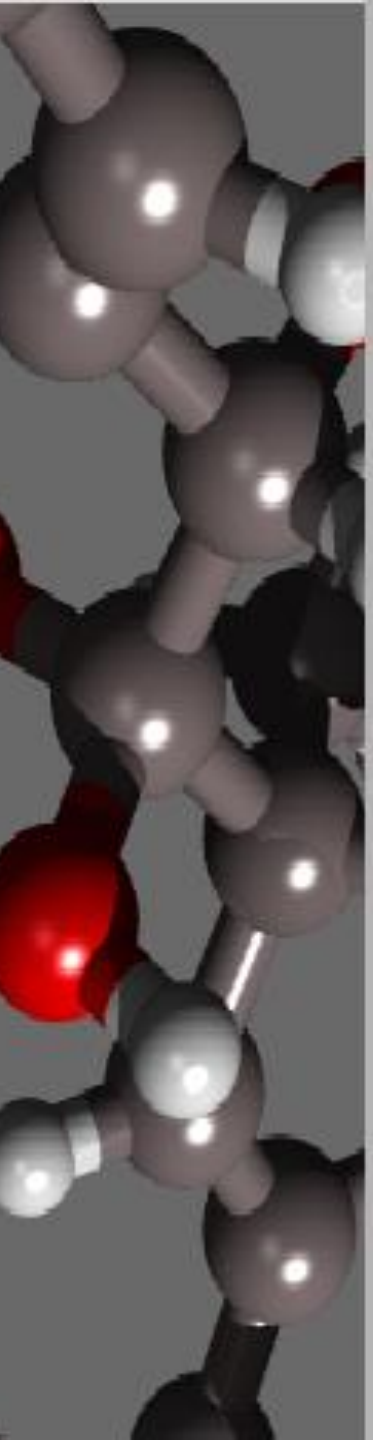
Synthesis: Kishi *et al* J. Amer. Chem. Soc., *111*, 7525, **1989**



Carbon

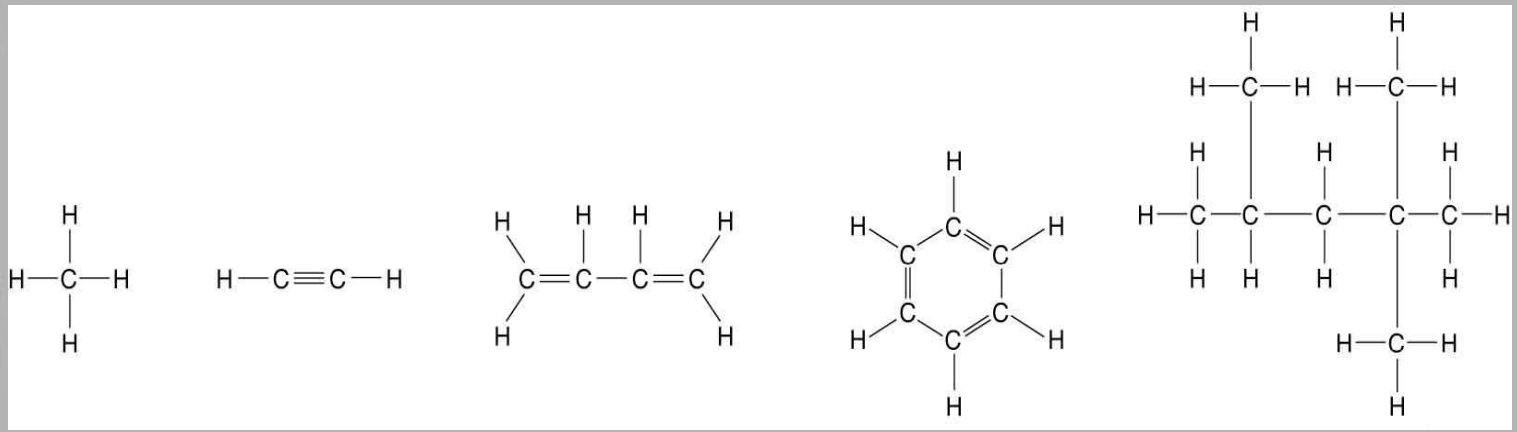
- **Carbon atoms will form covalent bonds with other elements or other carbon atoms**
  - **This variety of possible bonding is what is responsible for the diversity among living things**



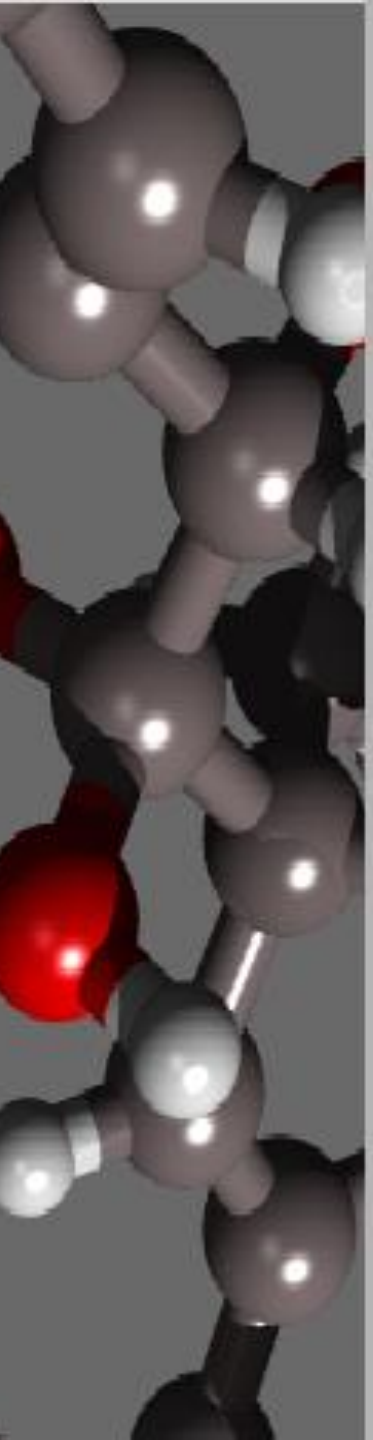


Carbon

- **Single, double or triple covalent bonds can form between carbon atoms**
- **Carbon atoms can bond to form short or long chains**
  - **Carbon chains can be straight or branched.**
  - **Carbon chains can wrap to form rings**

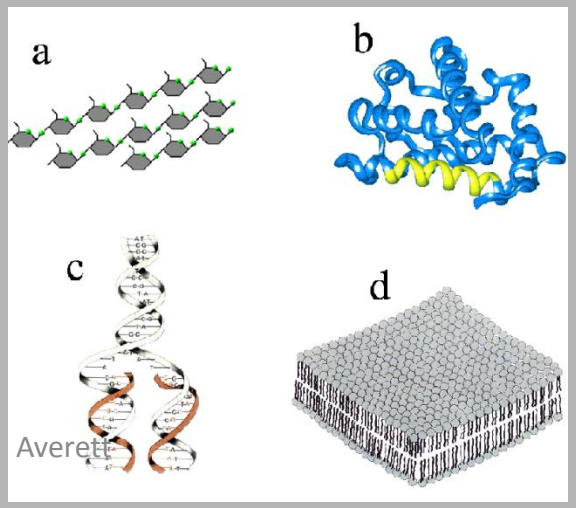


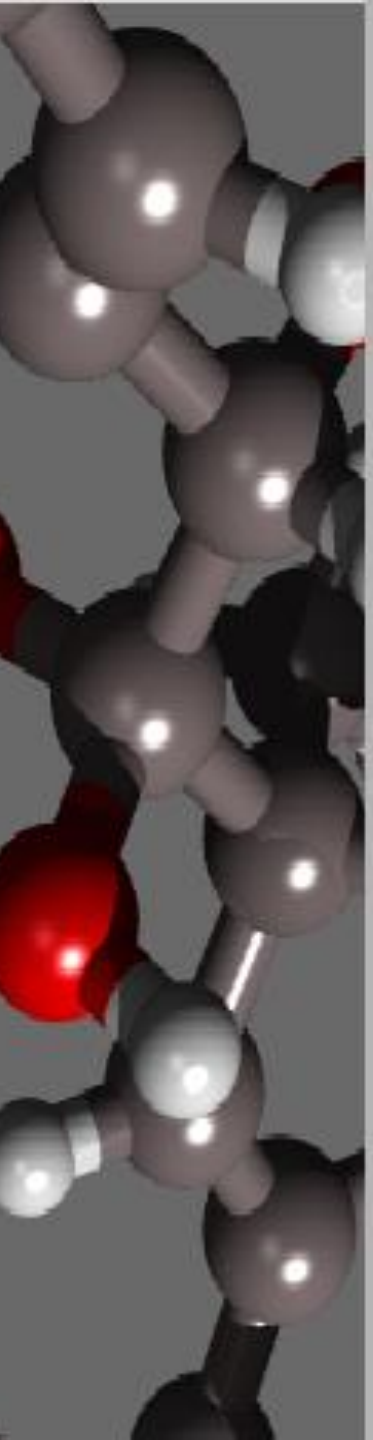
Methane Acetylene Butadiene Benzene Isooctane



The Molecules of Life

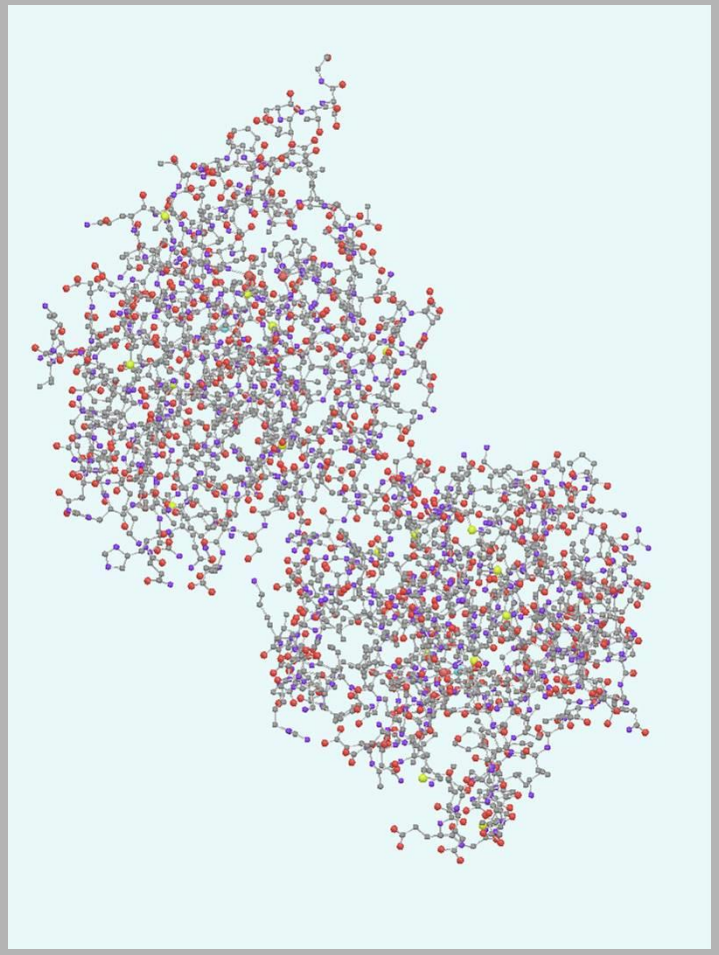
- **Given the rich complexity of life on Earth, we might expect organisms to have an enormous diversity of molecules.**
  - **Remarkably, the critically important large molecules of all living things fall into just four main classes:**
    - **Carbohydrates**
    - **Proteins**
    - **Nucleic Acids**
    - **Lipids**

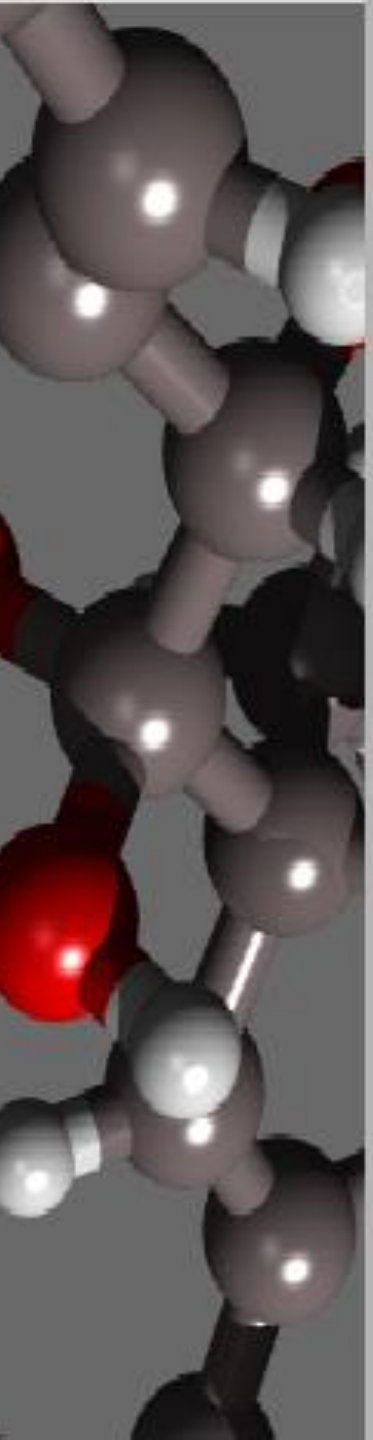




Macromolecules

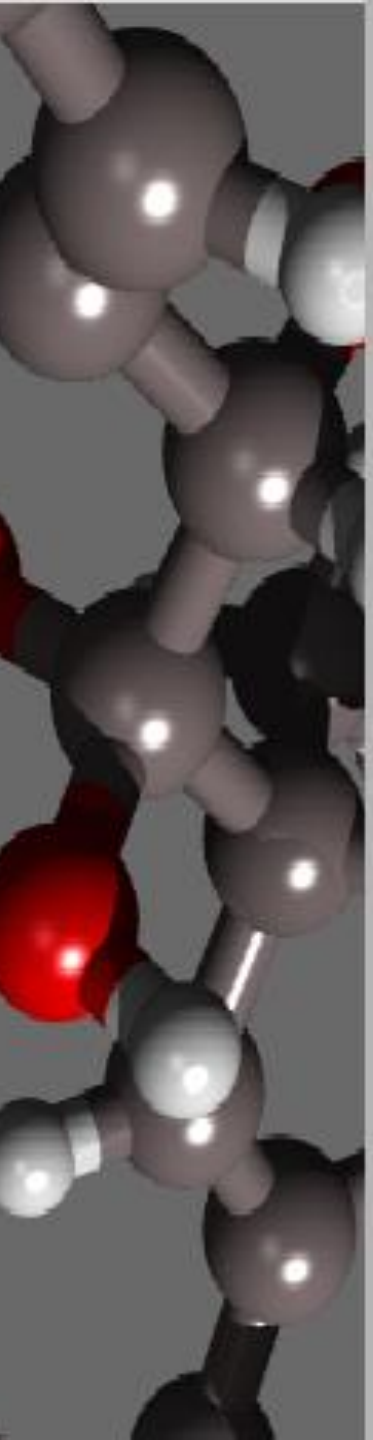
- **Macromolecules**
  - **large organic molecules**
  - **Made from thousands or even hundreds of thousands of smaller molecules called polymers**





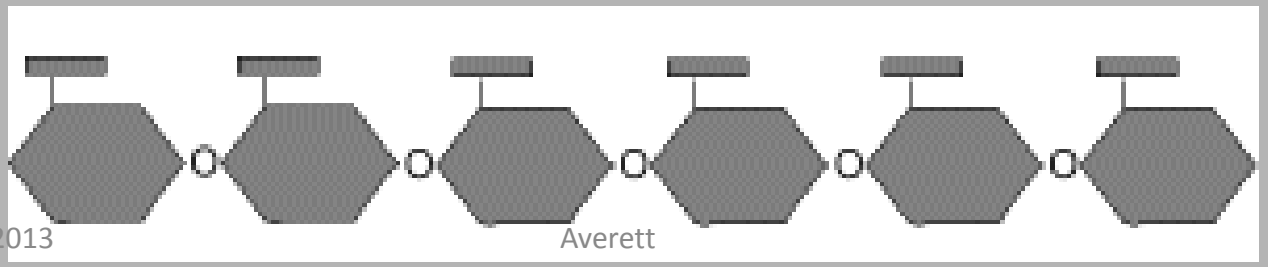
Macromolecules

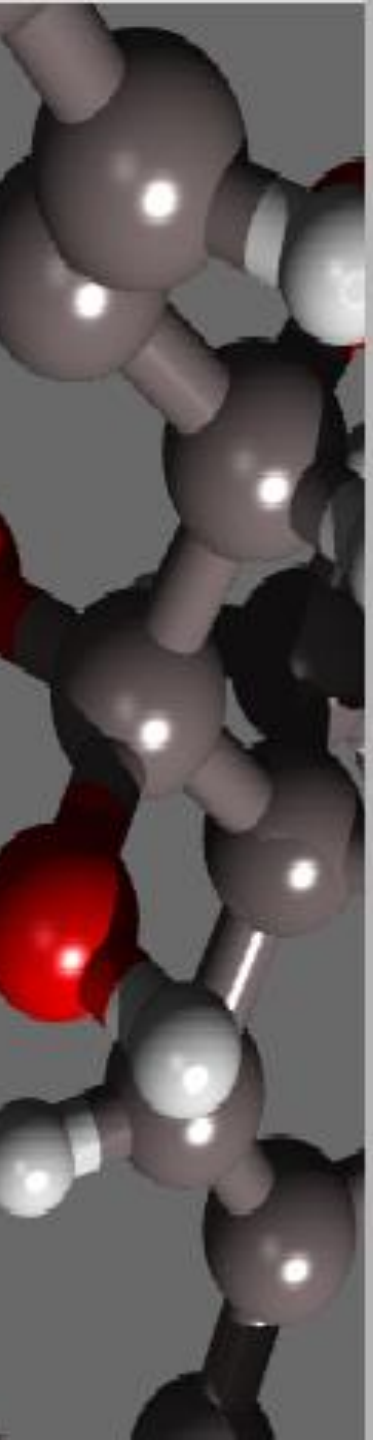
- **Macromolecules are "giant" molecules**
  - **The prefix macro means giant.**
  - **Macromolecules are found in living cells and are made up of thousands of smaller molecules called polymers**
- **Macromolecules are created by a process called polymerization**
  - **2 or more polymers that bond together form macromolecules**
    - **Monomer + monomer + monomer → polymer**
    - **Polymer + polymer → macromolecule**



Polymerization

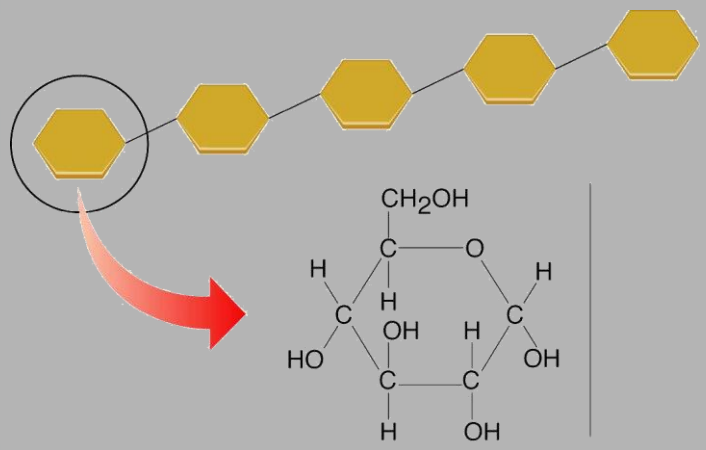
- **In many carbon compounds, the molecules are built from smaller simpler molecules called monomers**
  - **Monomers are the molecular subunits of a polymer, they are the small molecules of the same type that join together to make polymers**
    - **“poly” = many**
    - **“mono” = single**
    - **“meris” = part**

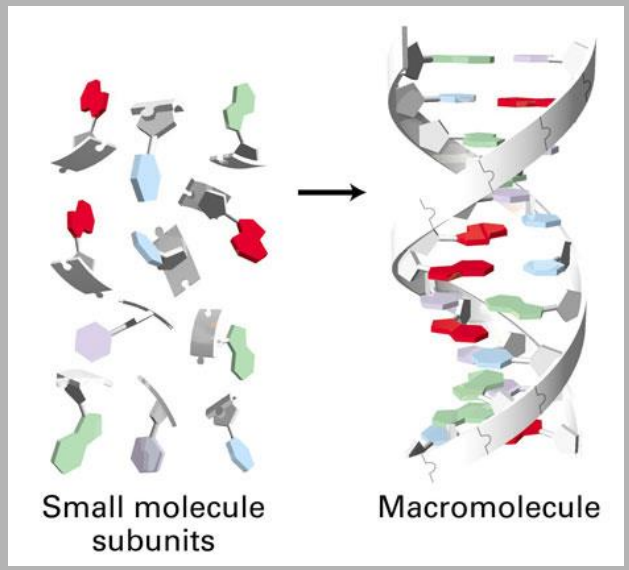


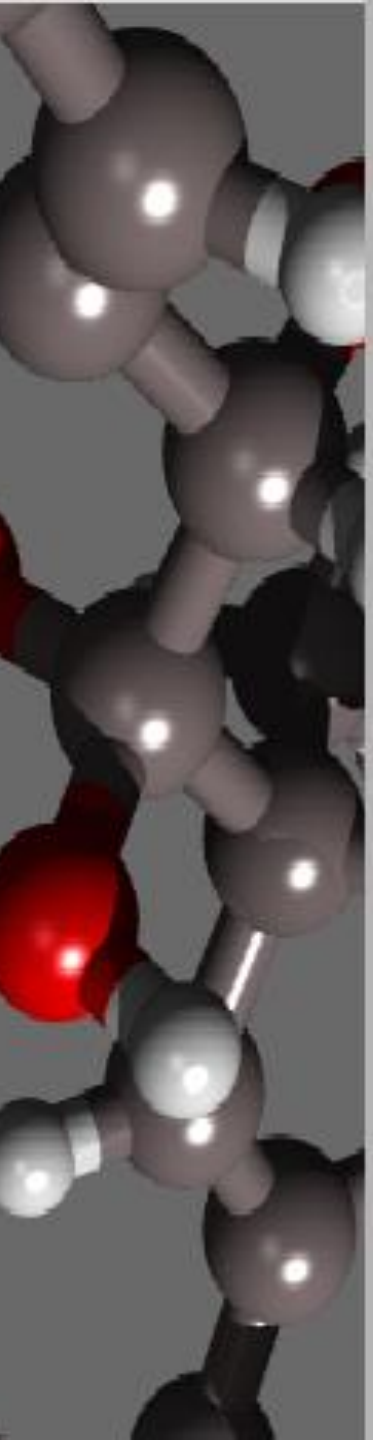


Polymerization

- **Polymerization is the process of monomers bonding together to form polymers**

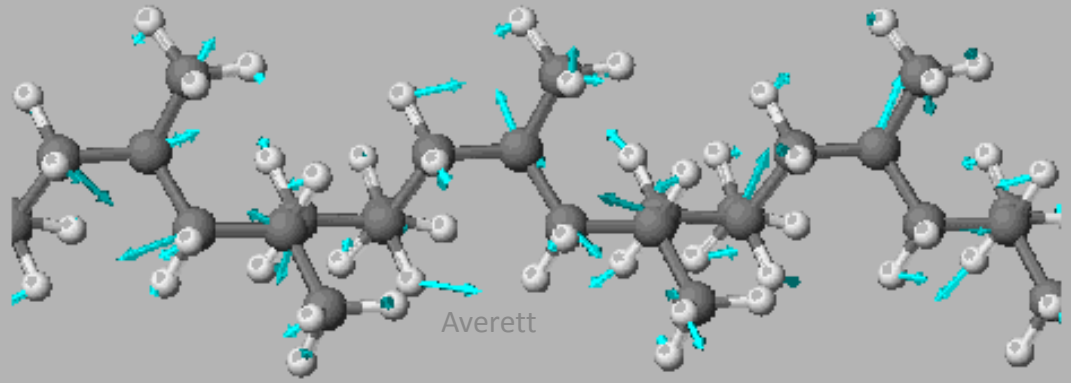


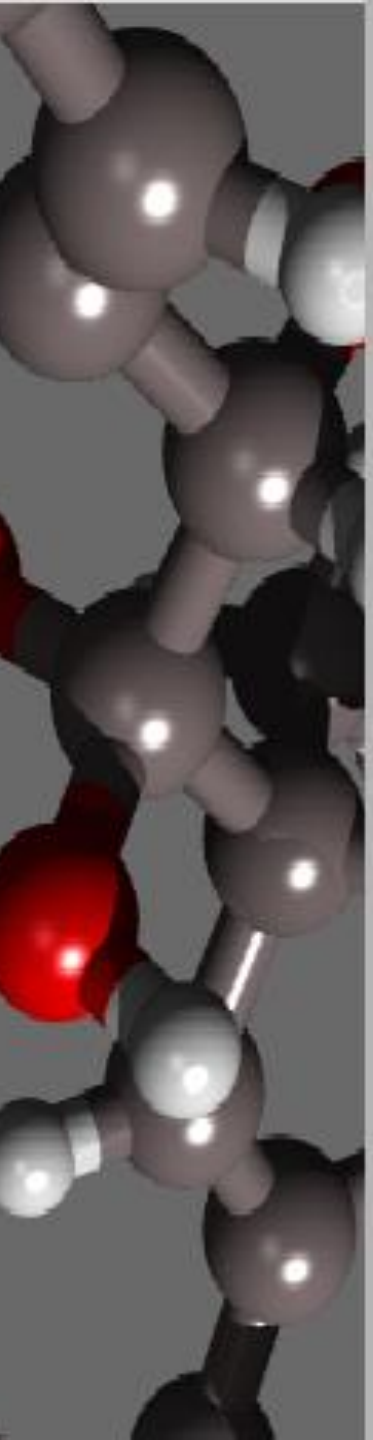




Polymerization

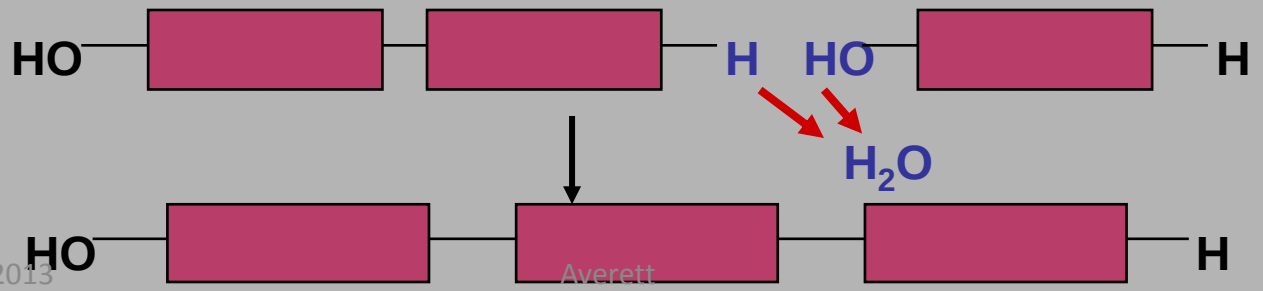
- **Multiple monomers bond together form polymers**
  - **Polymers are large compounds formed by the bonding together of many smaller parts called monomers**
    - **“poly” = many**
    - **“meris” = parts**
  - **Each polymer has its own type of monomer**

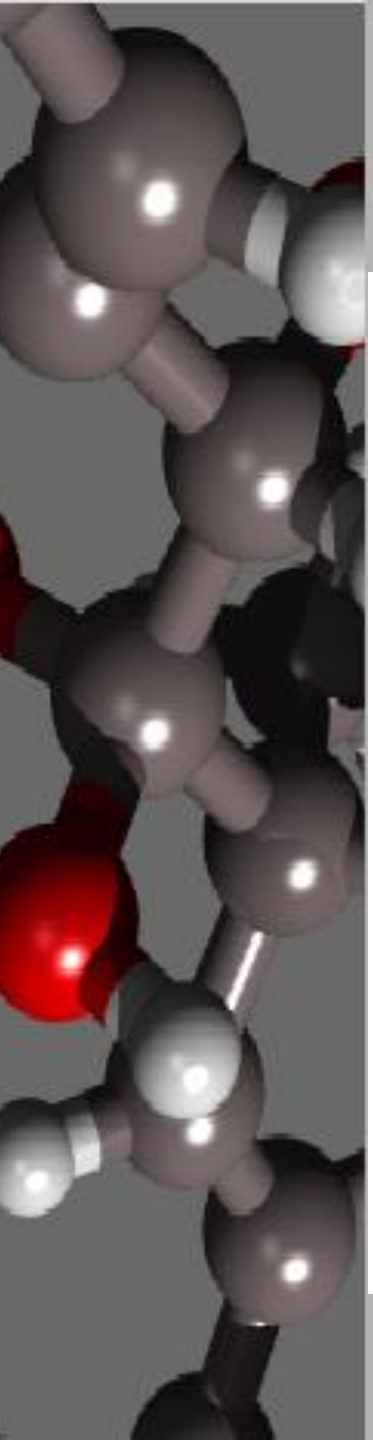




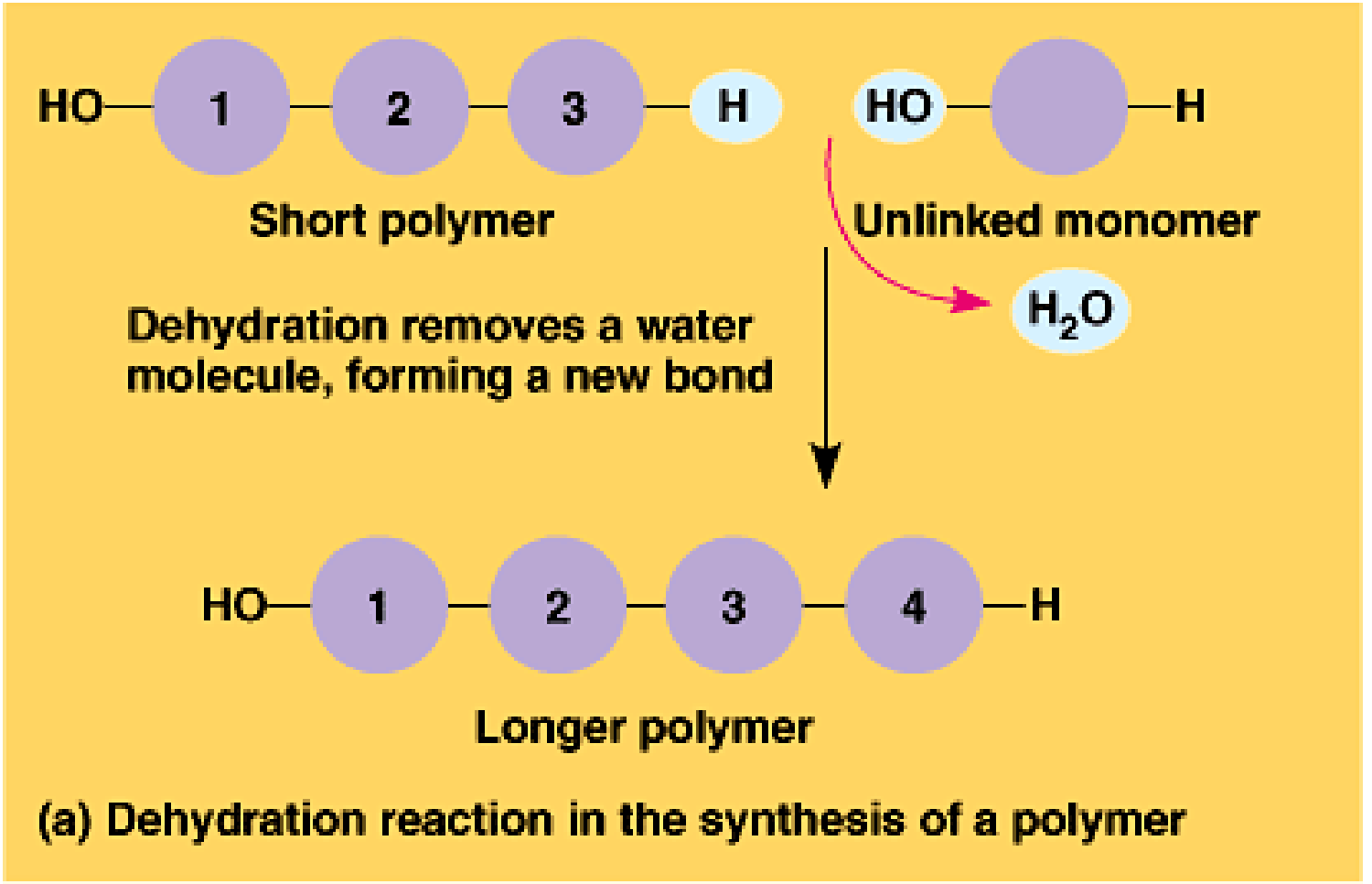
Polymerization

- **Condensation reaction**
  - **Also called dehydration synthesis because a water molecule is lost.**
    - **When a bond forms between two monomers, each monomer contributes part of the water molecule that is lost:**
      - **One molecule provides a hydroxyl group (--OH), while the other provides a hydrogen (--H)**
      - **This process can be repeated as monomers are added to the chain one by one, making a polymer.**

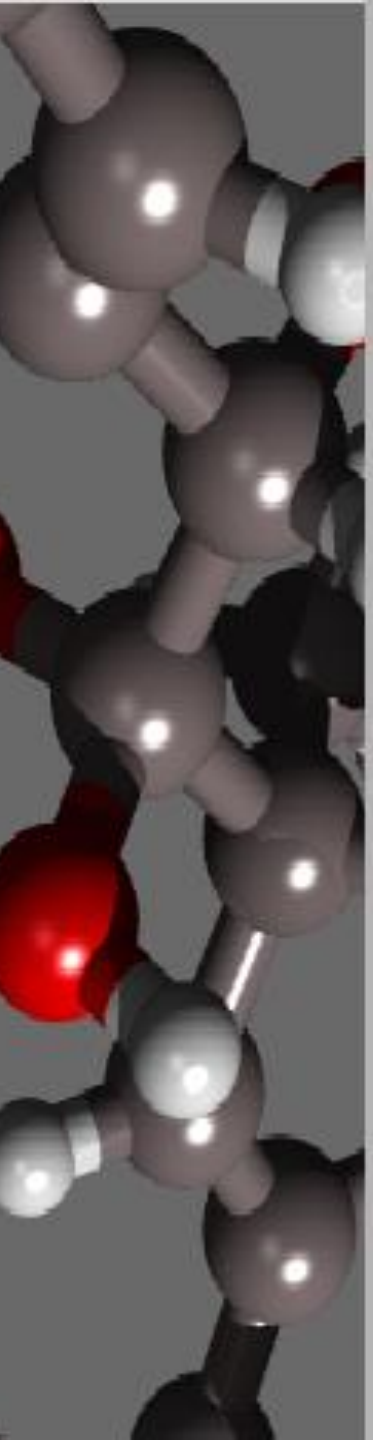




Polymerization

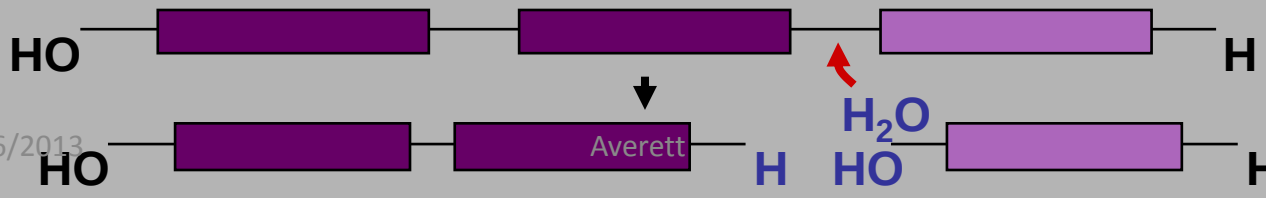


(a) Dehydration reaction in the synthesis of a polymer

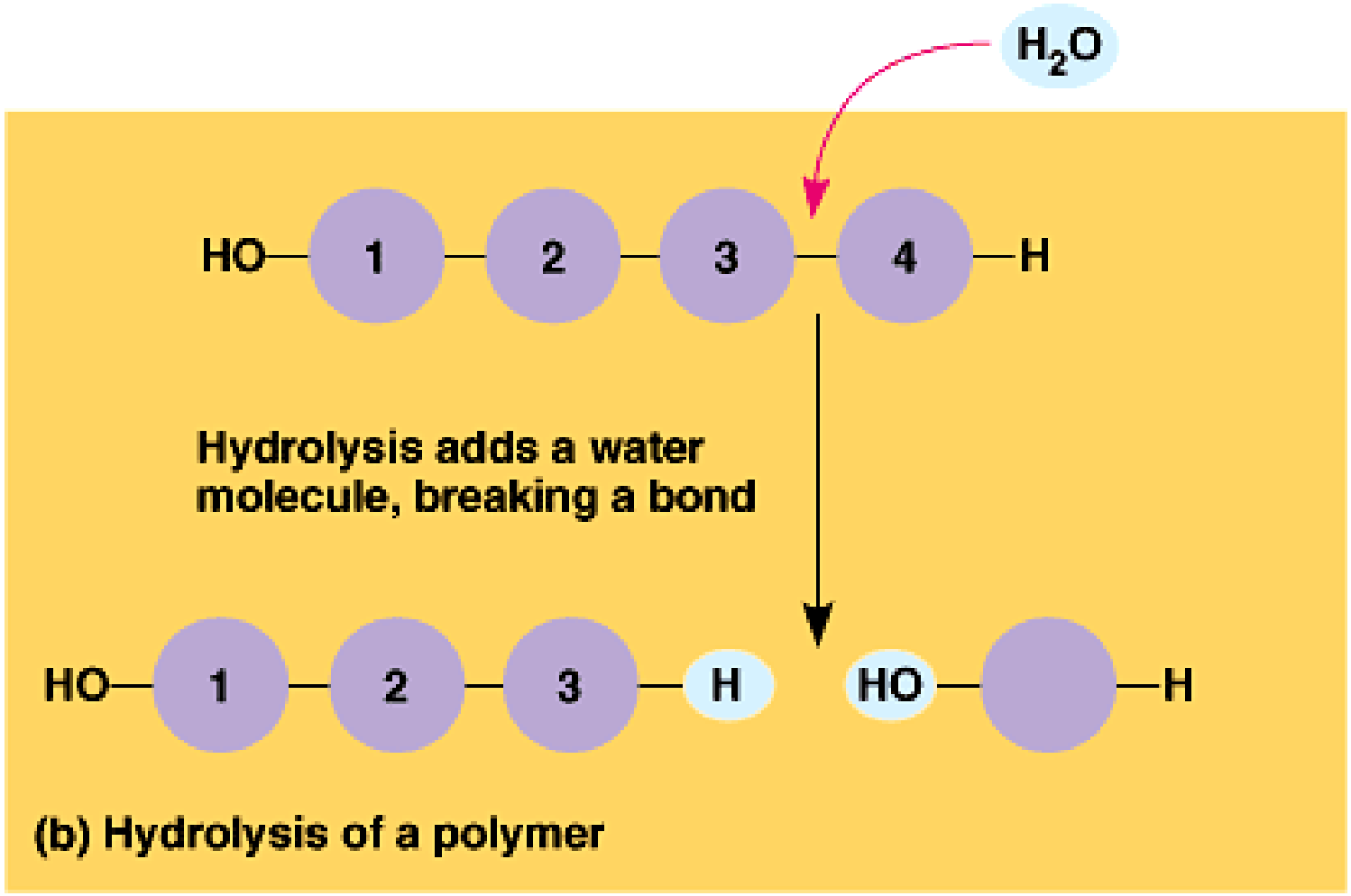


Polymerization

- **Polymers are disassembled to monomers by hydrolysis, a process that is essentially the reverse of dehydration reactions**
  - **"hydro" = water "lysis" = break**
  - **Bonds between monomers are broken by the addition of water molecules, with a hydrogen from the water attaching to one monomer and a hydroxyl group attaching to the adjacent monomer.**
    - **Example: digestion of food**

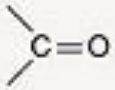
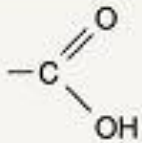
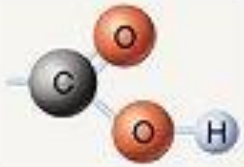
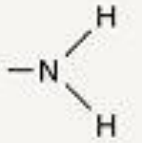
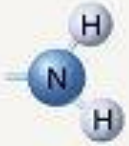
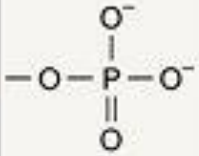


Polymerization

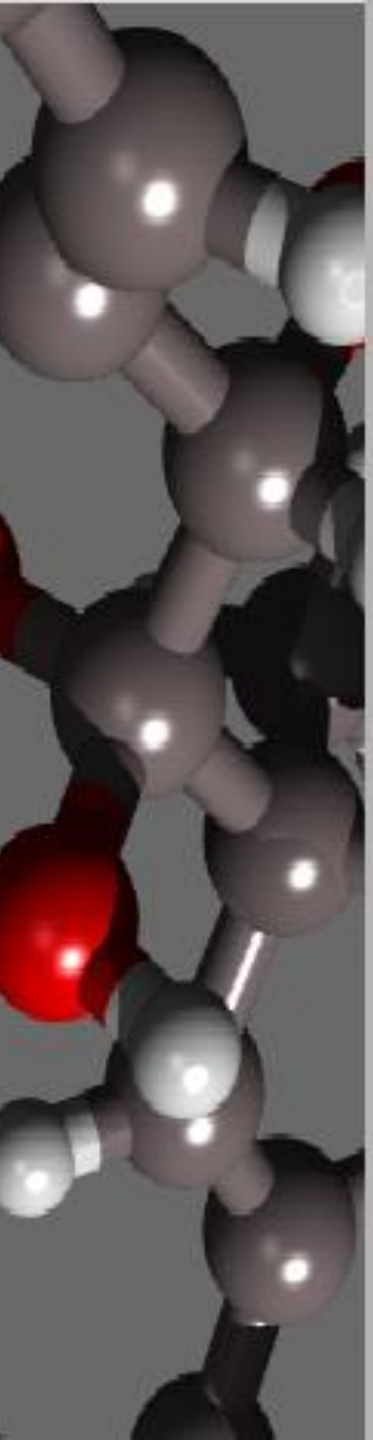


Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

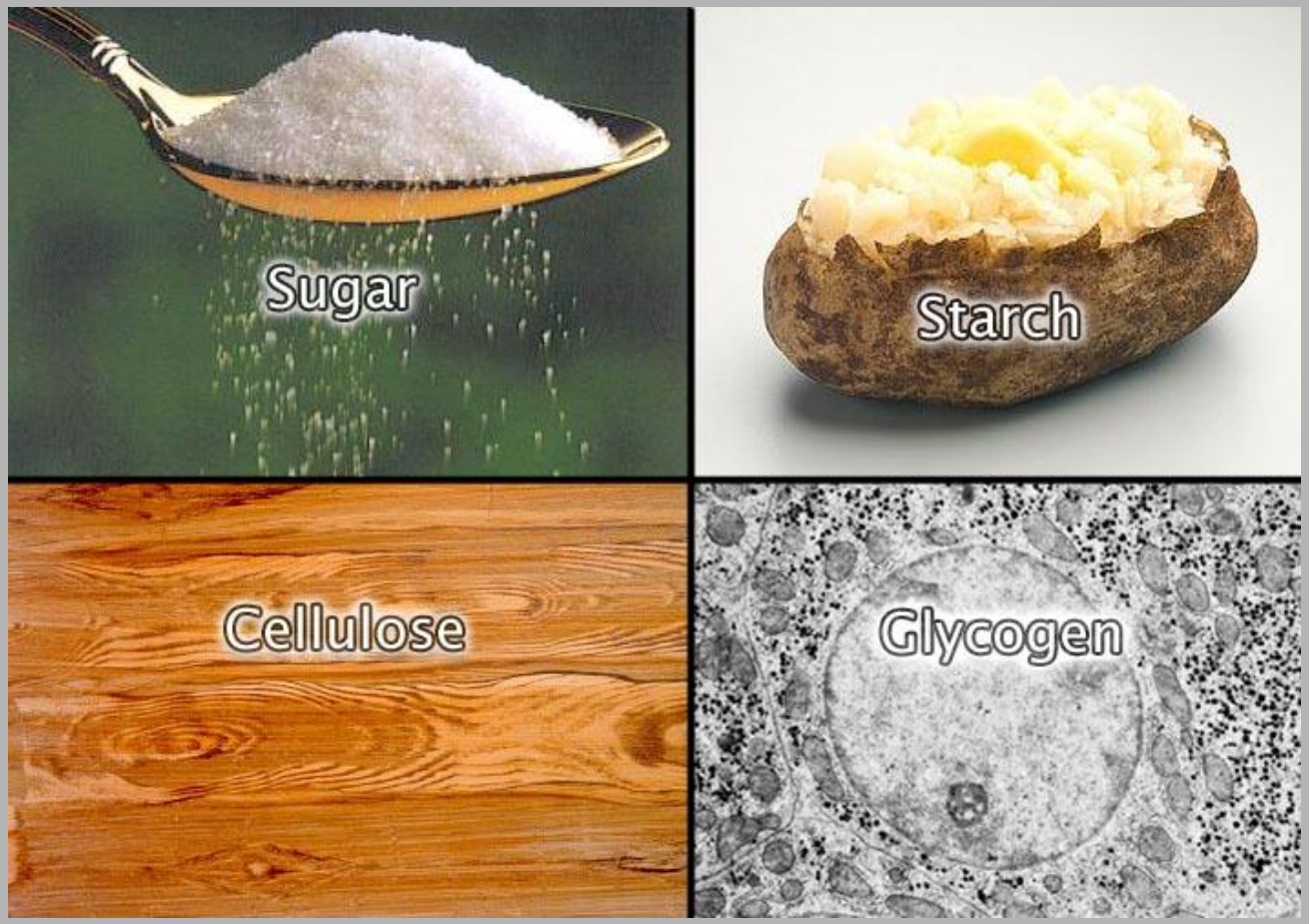
Functional Groups

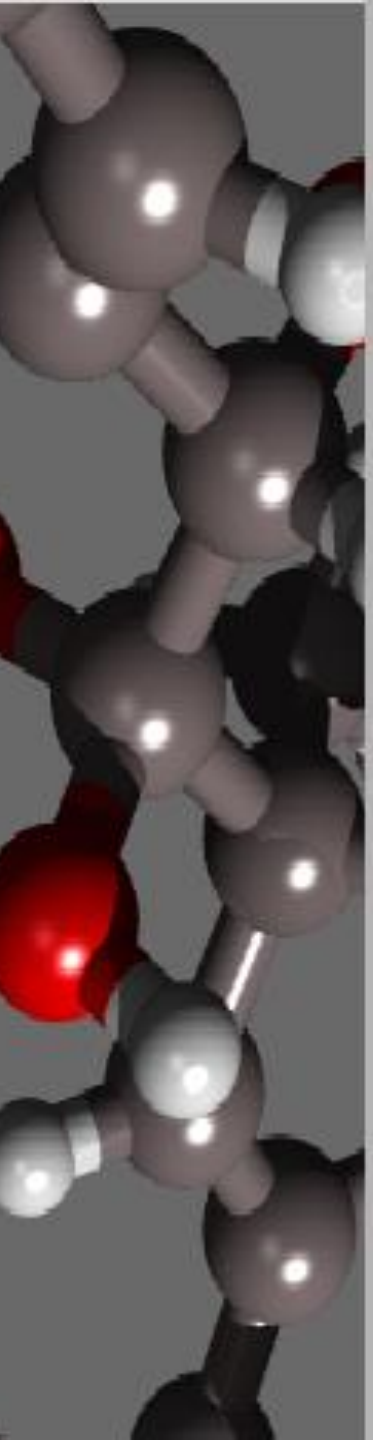
Group	Structural Formula	Ball-and-Stick Model	Found In
Hydroxyl	—OH		Carbohydrates
Carbonyl			Lipids
Carboxyl			Proteins
Amino			Proteins
Phosphate			DNA, ATP

- **Functional groups are groups of atoms found within molecules that are involved in the chemical reactions characteristic of those molecules.**
  - **Give compounds their characteristic properties.**
  - **Focus attention on the important aspects of the structure of a molecule**

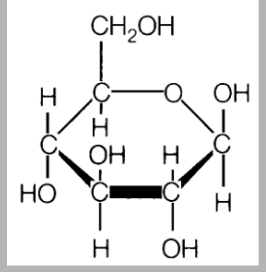


Carbohydrates

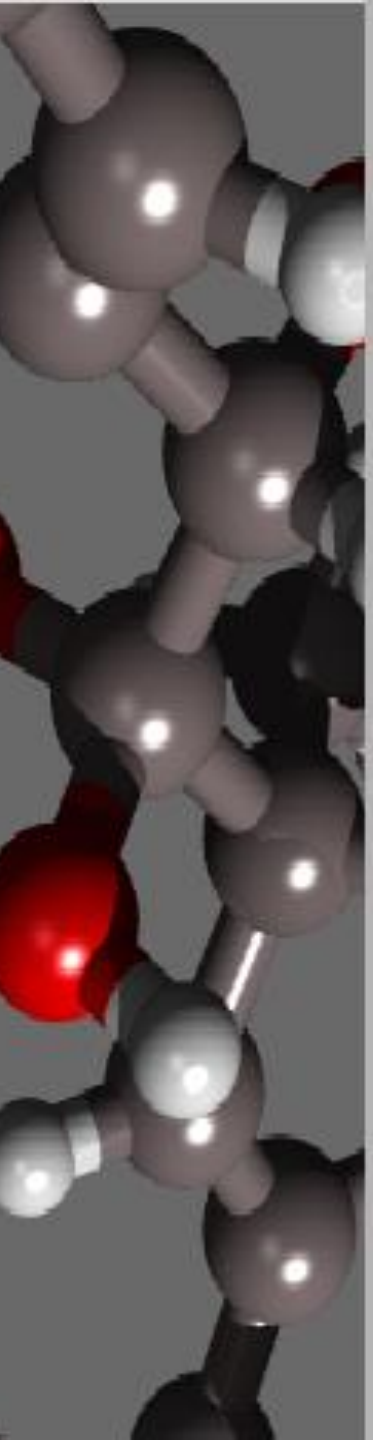




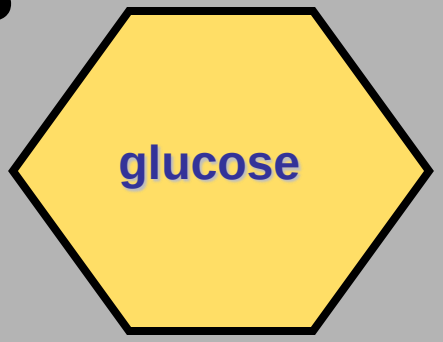
Carbohydrates



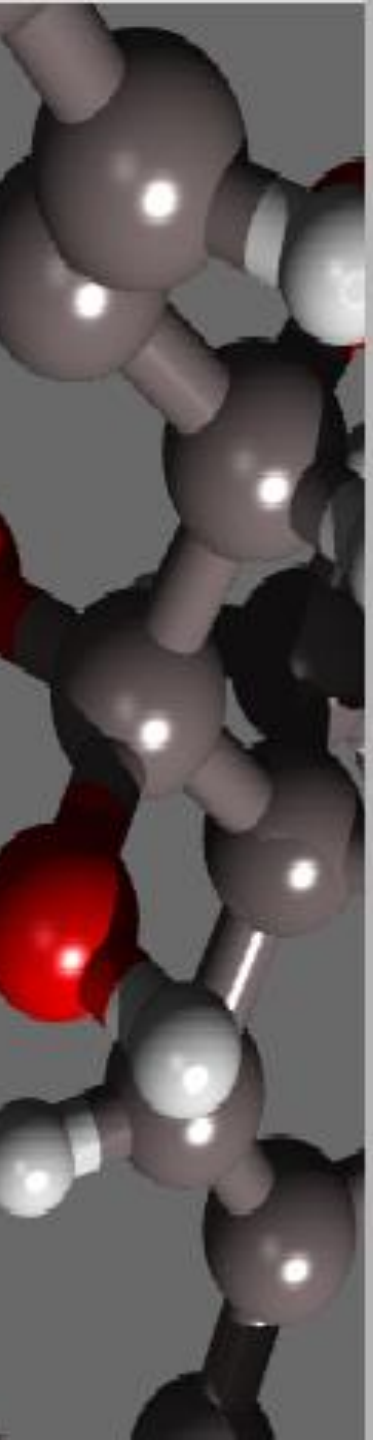
- **Elemental composition**
  - **Contains Carbon, Hydrogen and Oxygen**
    - **General formula is multiples of CH_2O**
      - **1:2:1 ratio**
  - **Contains hydroxyl groups (-OH) and carbonyl groups (>CO) .**
- **Functions:**
  - **The main source of immediate energy for most organisms – store and transport it.**
  - **Used for structural support in plants and some animals**
- **3 main types include monosaccharides, disaccharides, polysaccharides**



Carbohydrates



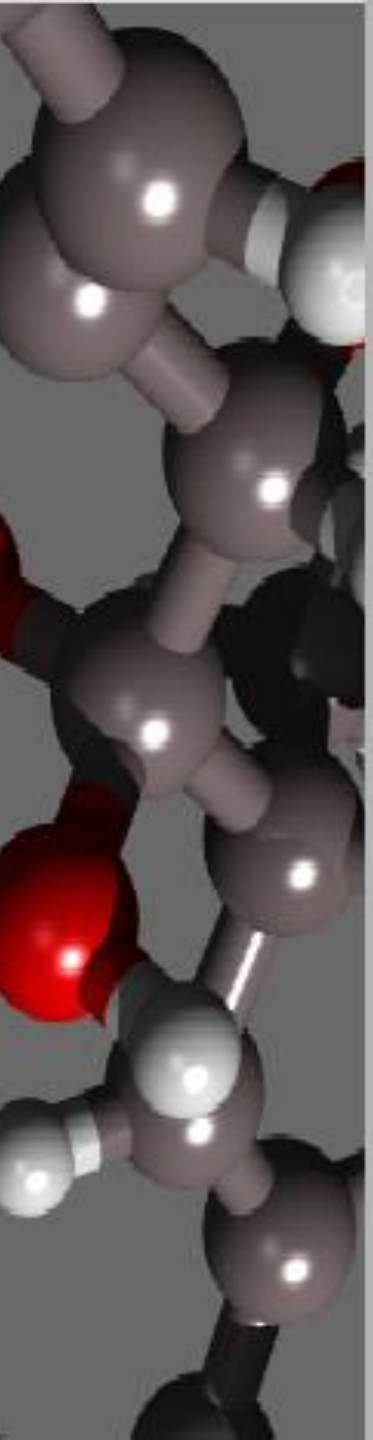
- **Monosaccharides**
  - **Monomers of carbohydrates**
    - **mono = one**
    - **Saccharide = sugar**
  - **provides immediate energy**
  - **Usually contains 5-6 carbon atoms**
  - **Simple enough to serve as raw materials for other organic molecules such as amino acids and fatty acids**



Carbohydrates

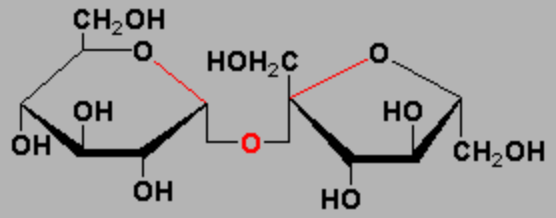
- Common monosaccharides
  - Glucose
    - Produced during photosynthesis and used in cellular respiration; main source of energy for ALL living things
  - Fructose
    - Found in fruits; sweetest of monosaccharides
  - Galactose
    - Found in milk; usually found in combination with glucose and fructose
  - Ribose, Deoxyribose
    - Found in RNA, DNA

Honey is composed of glucose and fructose monosaccharides

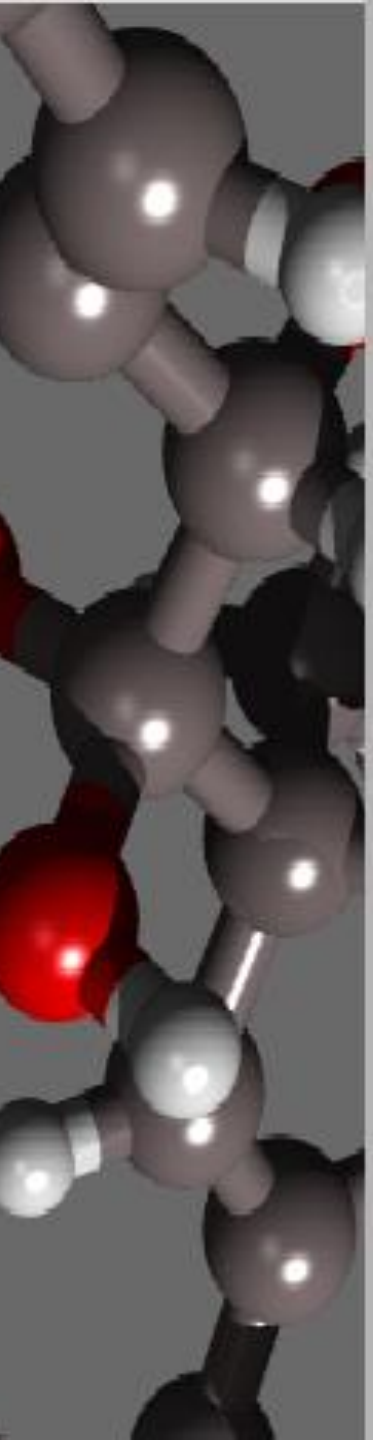


Carbohydrates

- **Disaccharides**
  - **Short chains of 2 monosaccharides**
    - **Di = two**
    - **Saccharide = sugar**

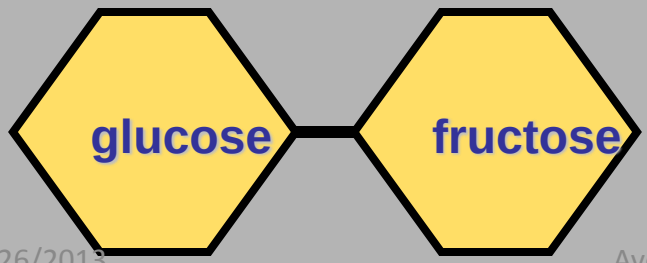


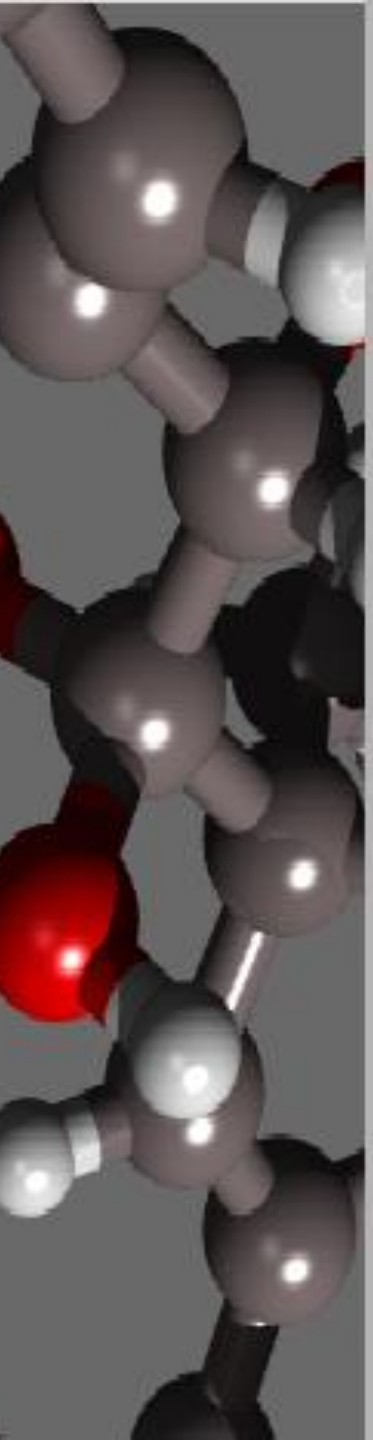
  - **Consists of two monosaccharides joined by a glycosidic linkage**
    - **a covalent bond resulting from dehydration synthesis**
  - **Provide immediate energy**



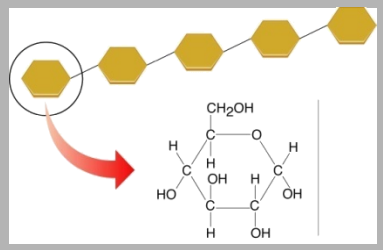
Carbohydrates

- **Common Disaccharide**
  - **Sucrose**
    - **Made up of fructose and glucose and it found in sugarcane/sugar and beets**
  - **Lactose**
    - **Made of glucose and galactose; found in milk**

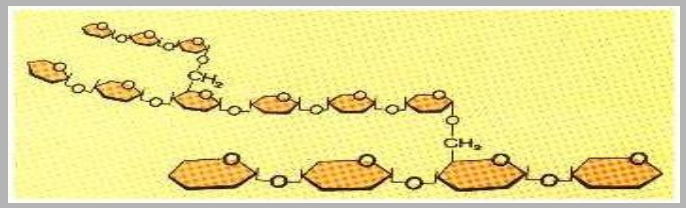




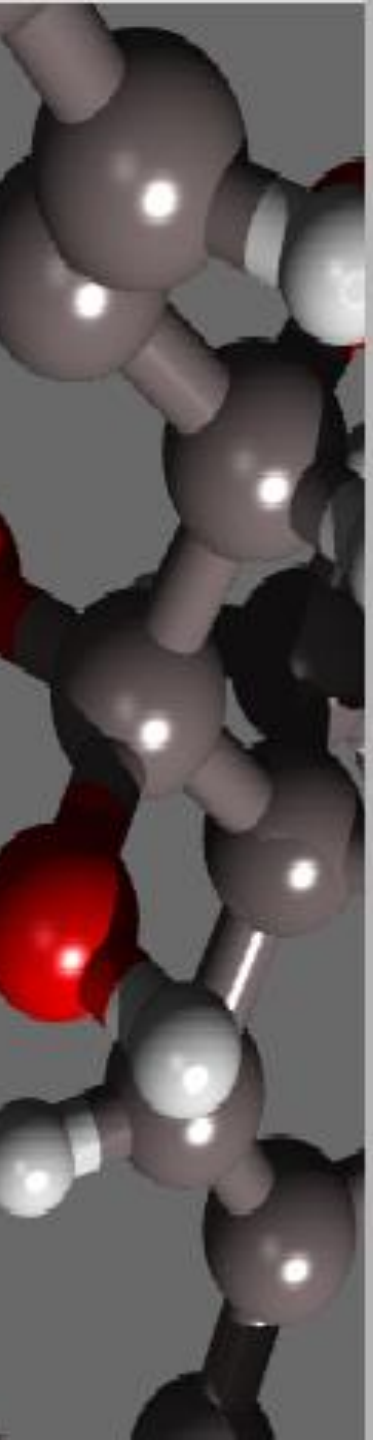
Carbohydrates



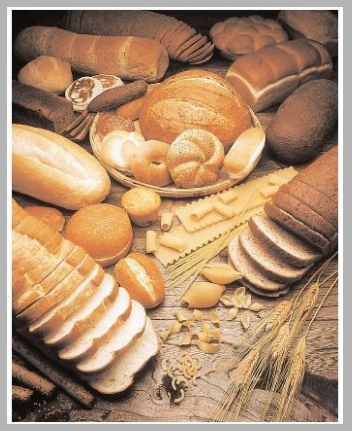
- Polysaccharides
  - Polymers of carbohydrates
    - Combine to form the macromolecules of sugars
  - Long chains of many sugar molecule
    - Hundreds to hundreds of thousands of monosaccharides bonded together
    - Do not always follow 1:2:1 ratio
    - Poly = many
    - Saccharides = sugar



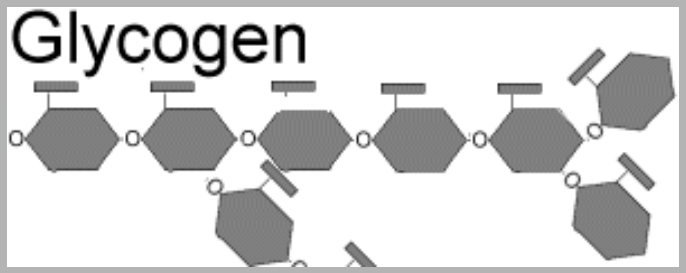
  - Connected by glycosidic linkages
  - Provides immediate energy reserves or structural support

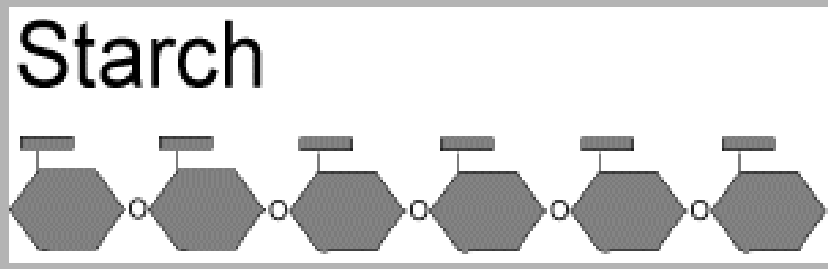


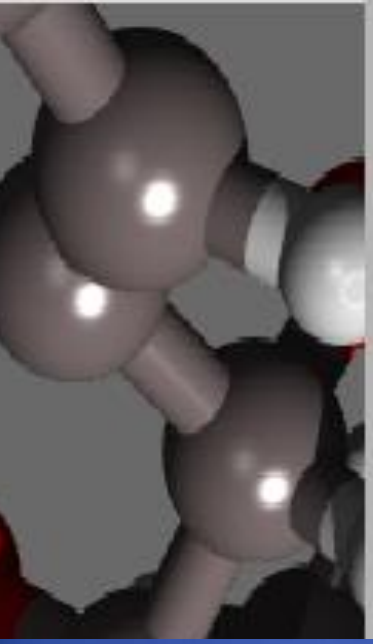
Carbohydrates



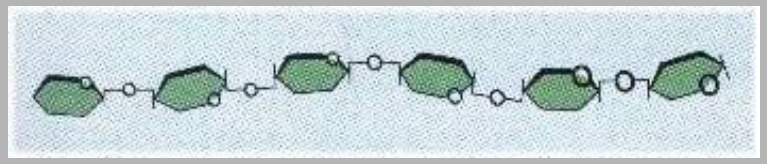
- **Common polysaccharides**
  - **Starch – storage form of carbohydrates**
    - **Glycogen (animal starch)**
      - **Storage form of glucose for animals; stored in the liver and muscle tissue**
    - **Amylose (plant starch)**
      - **Plant storage form of carbohydrates; very good sources of energy**



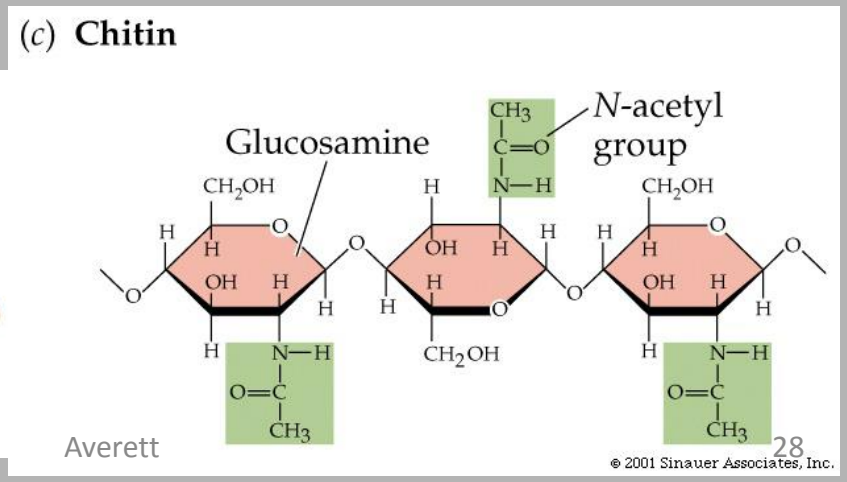


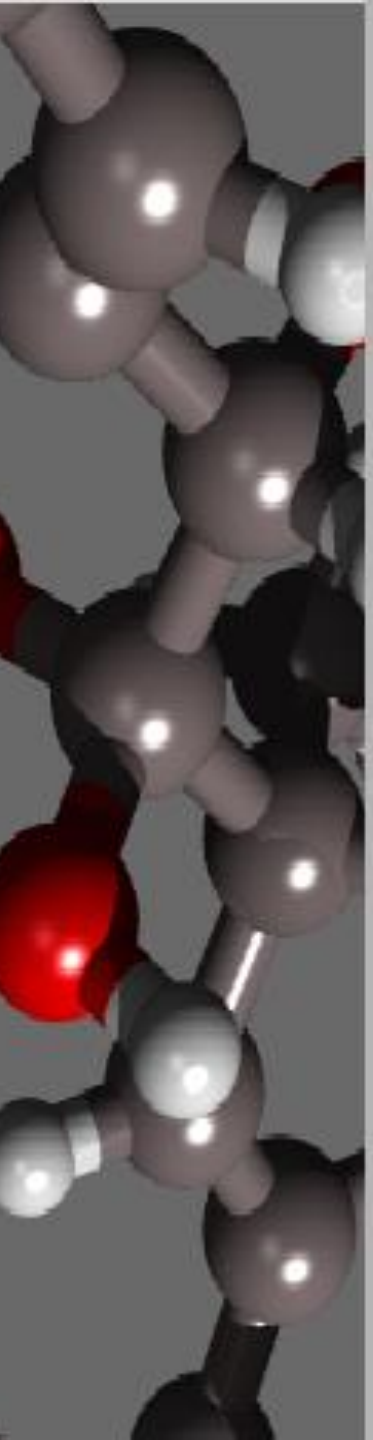


Carbohydrates



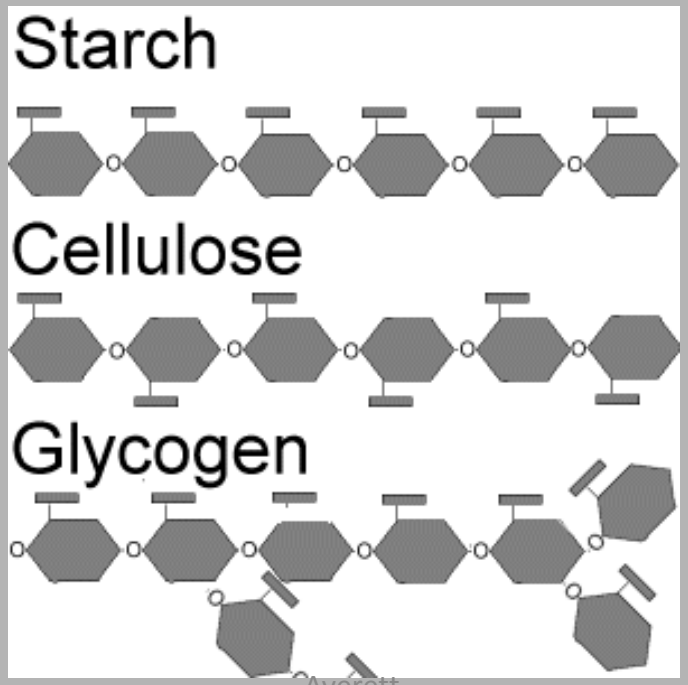
- Cellulose
  - Structural support in plants; gives strength and rigidity to plant cells; major component of wood
- Glucosamine in Chitin
  - Structural support in exoskeleton of some animals and cell walls of fungi
  - One of the most abundant substances on earth

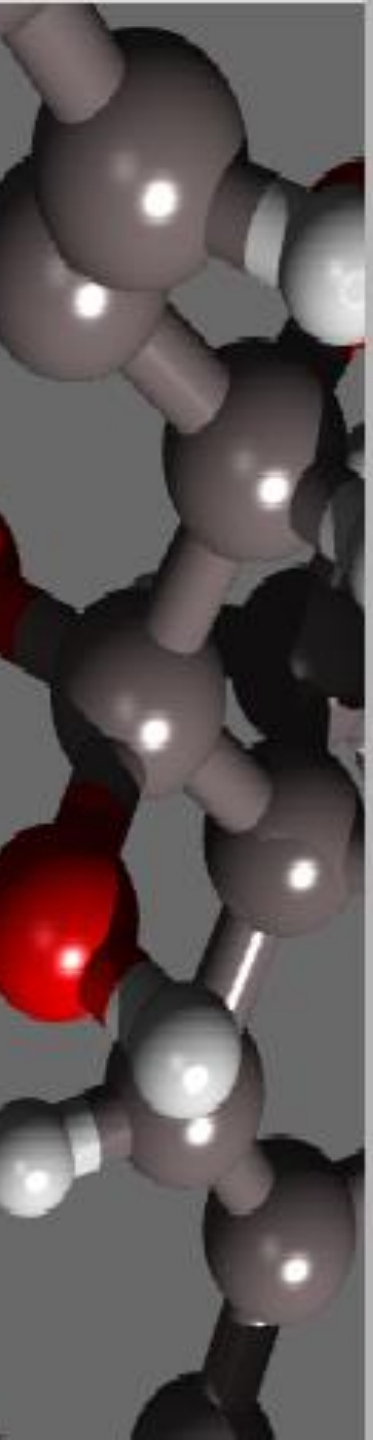




Carbohydrates

- **Glycosidic linkages bond monosaccharides together.**
  - **Specific linkages can vary…**

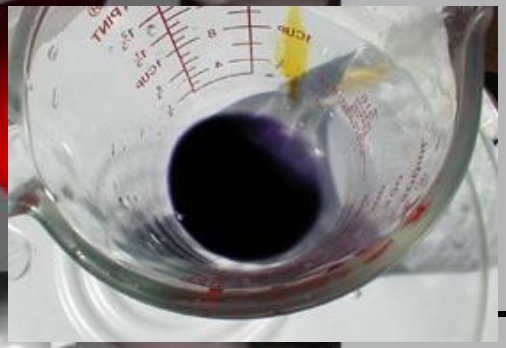




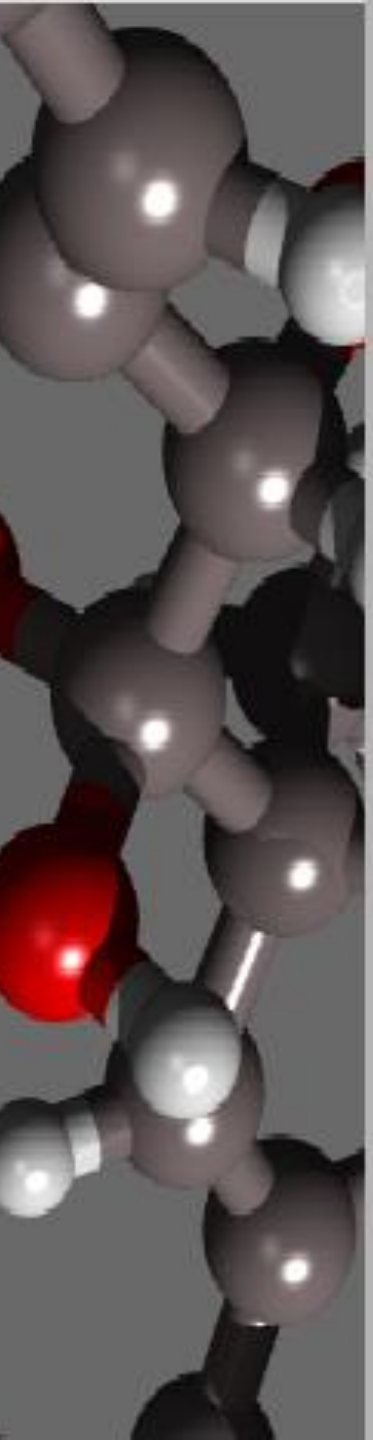
Carbohydrate

- Organic sources of carbohydrates
  - Pasta
  - Potatoes
  - Rice
  - Wheat
  - Shellfish
  - Wood
  - cotton

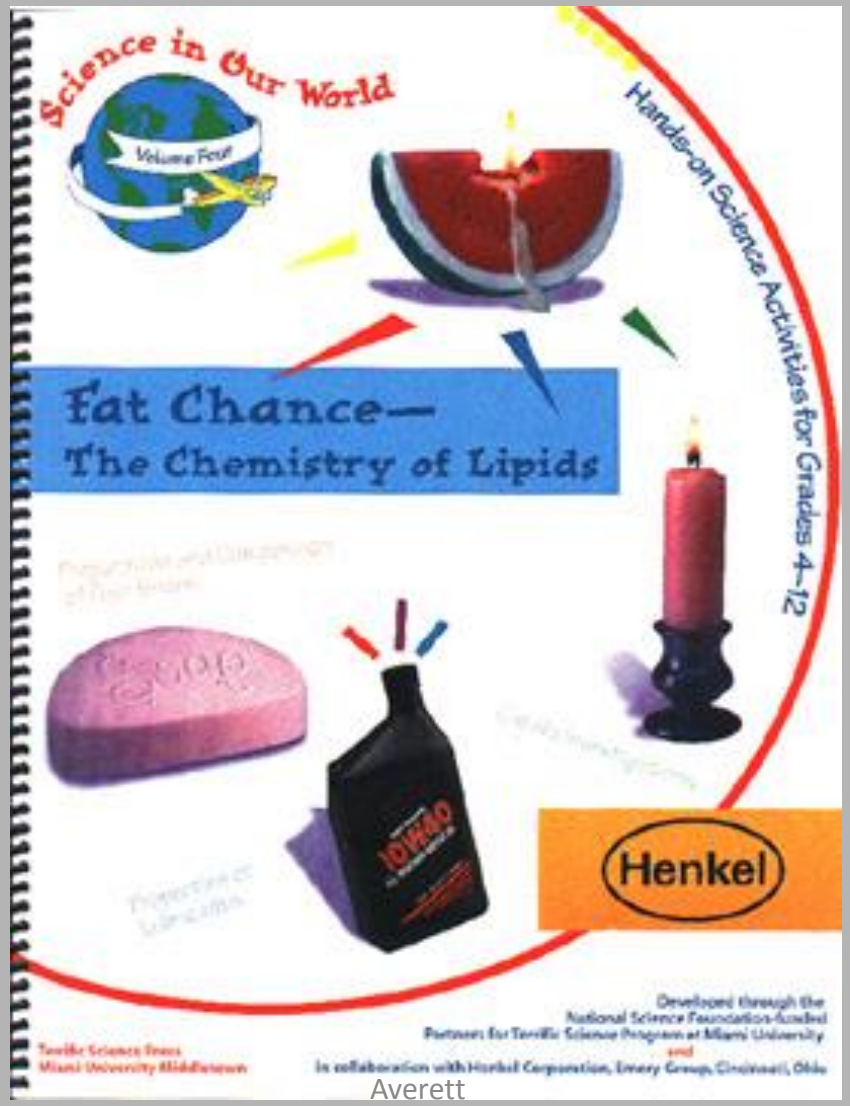
Carbohydrates

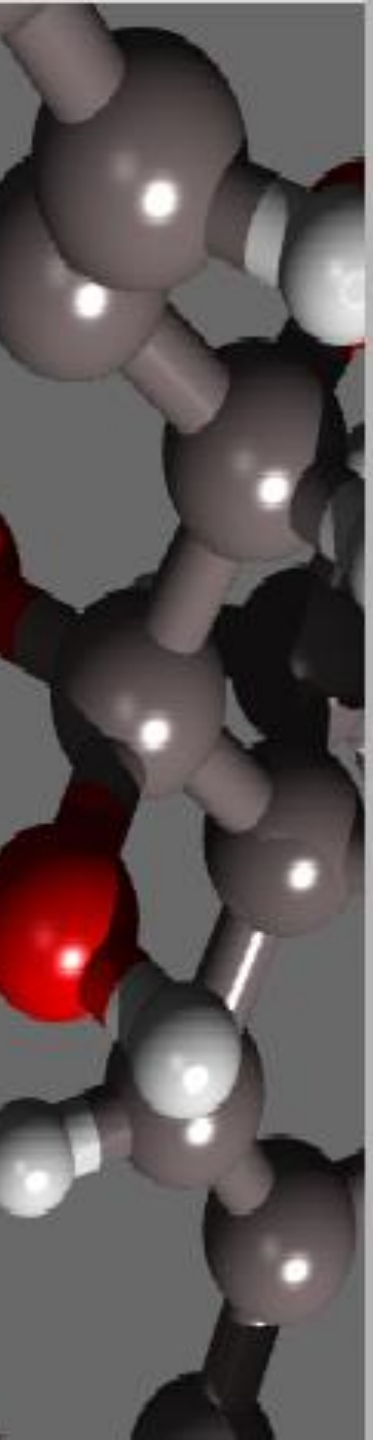


- Testing for carbohydrates
  - Benedict's solution
    - Shows a positive test for simple sugars with a color change that ranges from green to yellow or orange. Tests for monosaccharides
  - Lugol's solution/Iodine
    - Shows a positive test for starch if there is a color change to blue-black. Tests for polysaccharides
  - Process of elimination
    - If no reaction with above then a disaccharide is present



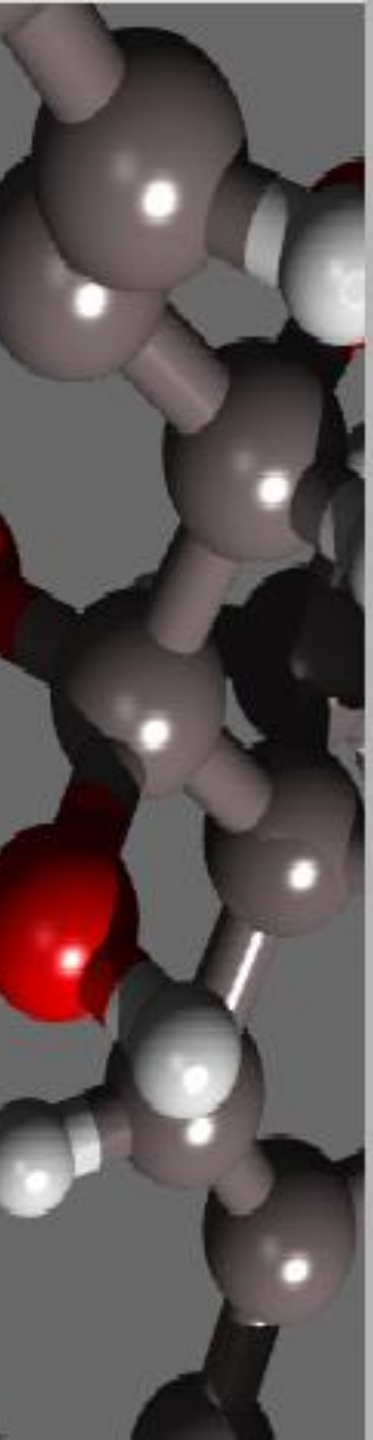
Lipids


Science in Our World
Volume Four
Hands-on Science Activities for Grades 4–12
Fat Chance—
The Chemistry of Lipids
Henkel



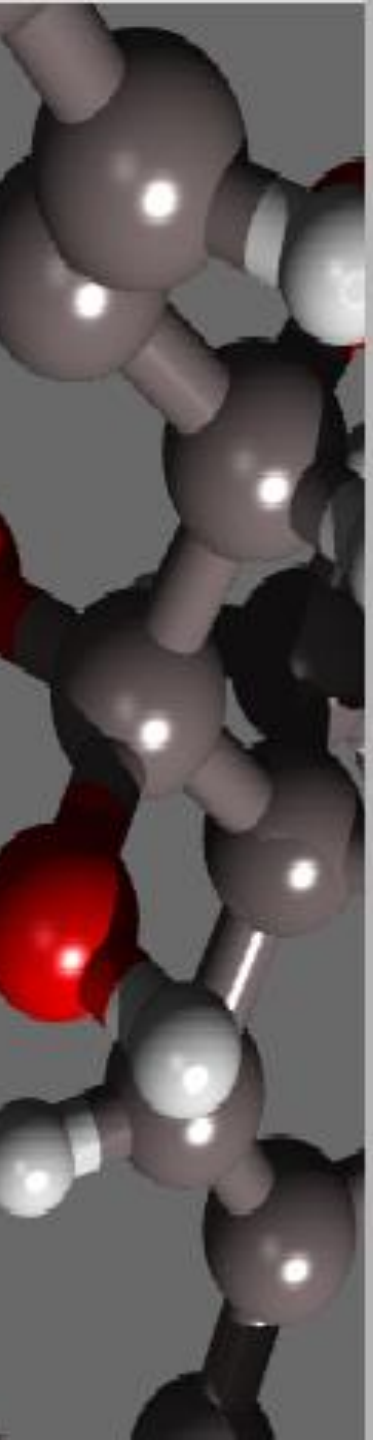
Lipids

- Chemical composition
  - Contains Carbon, Hydrogen and Oxygen
    - But NOT in a 1:2:1 ratio; few or no O
  - May contain phosphate groups
- The main source of long term energy for most organisms
  - 1 gram of fat stores twice as much energy as 1 gram of polysaccharide
- Used for energy, waterproof coverings, structural, and to deliver chemical messages
- Also include vitamins and carotenoids

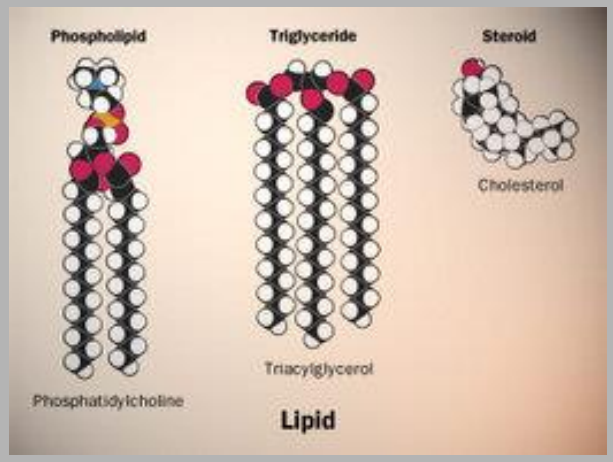


Lipids

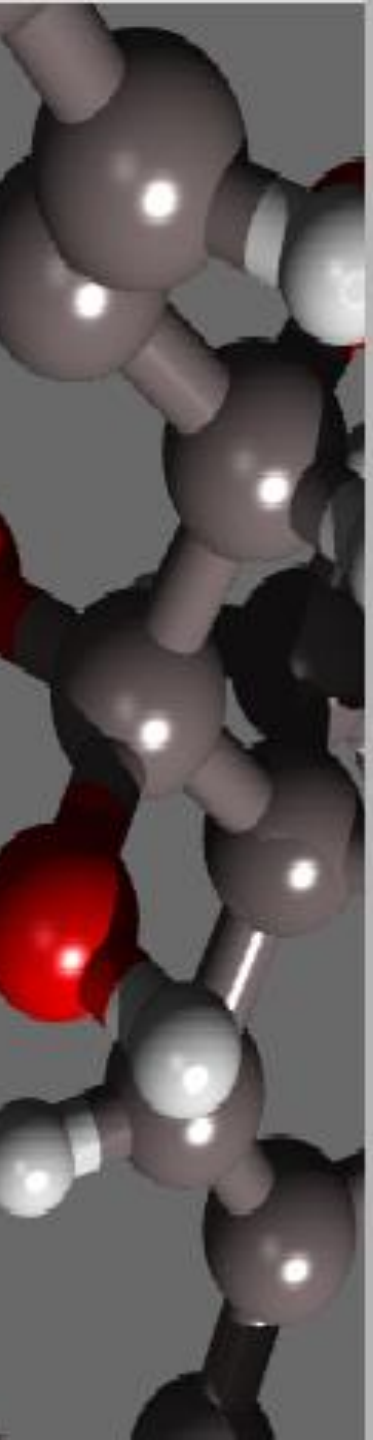
- **Non-polar therefore hydrophobic**
  - **Lipids do not dissolve in water so they are said to be insoluble**
    - **Due to many nonpolar covalent bonds of hydrogen and carbon**
    - **Lipids aggregate away from water, which is polar, and attract to each other via weak, but additive, van der Waals forces.**
  - **Can form barriers between aqueous environments inside and outside of cells**



Lipids



- **5 main groups:**
  - **Triglycerides, phospholipids, waxes, steroids/carotenoids, and vitamins**
  - **Monomers include glycerol molecules and fatty acid chains**
  - **Lipids are held together by ester linkages**
    - **a covalent bond resulting from dehydration synthesis**



Lipids

- **Glycerides**
  - **Glycerol molecule backbone**
  - **One or more fatty acid tails attached**
    - **Monoglyceride**
    - **Diglyceride**
    - **Triglyceride**

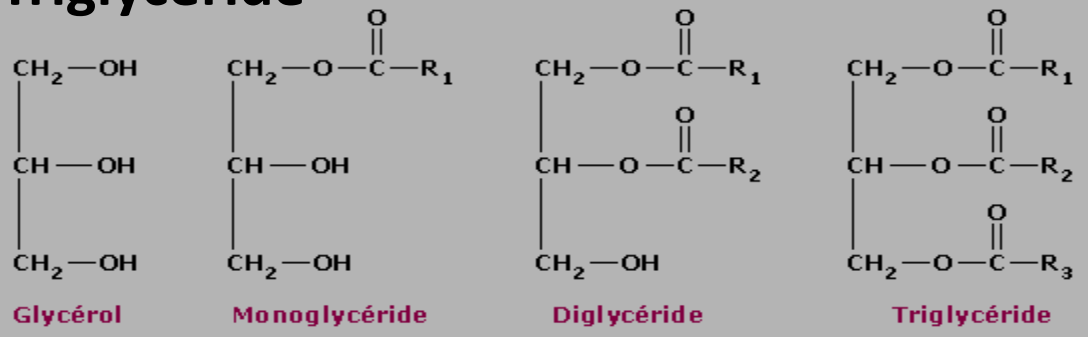
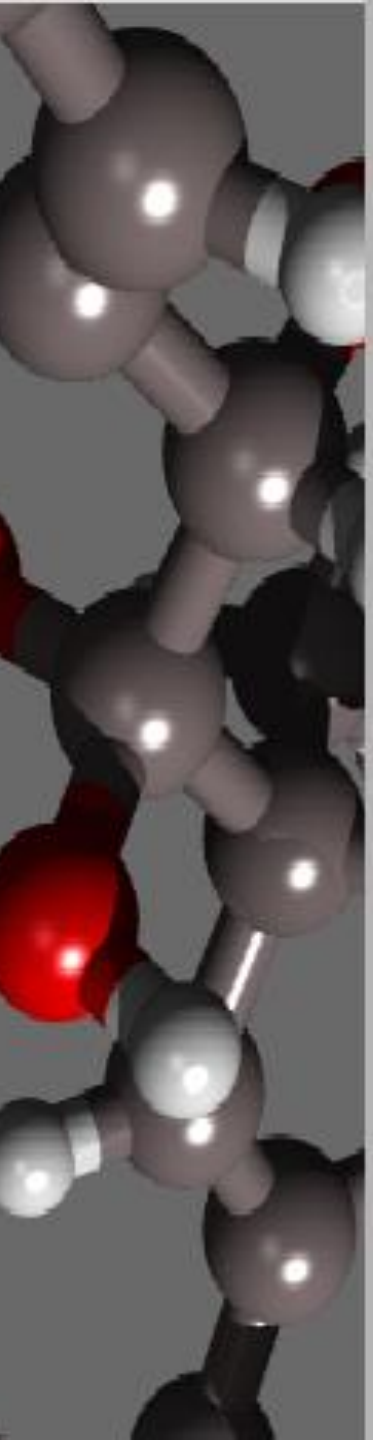


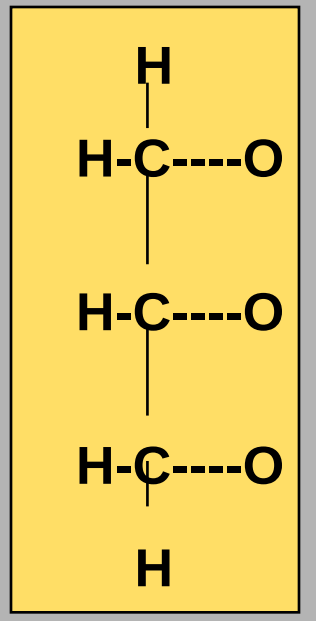
Figure 4 : Glycérides

  - **Triglycerides** are the main constituents of animal fats and vegetable oils (95%).
  - **Monoglycerides**and **diglycerides** are much less abundant than **triglycerides.**

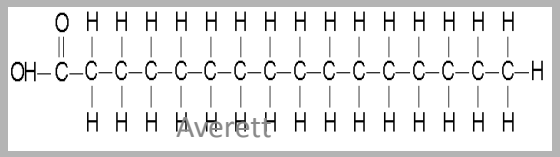


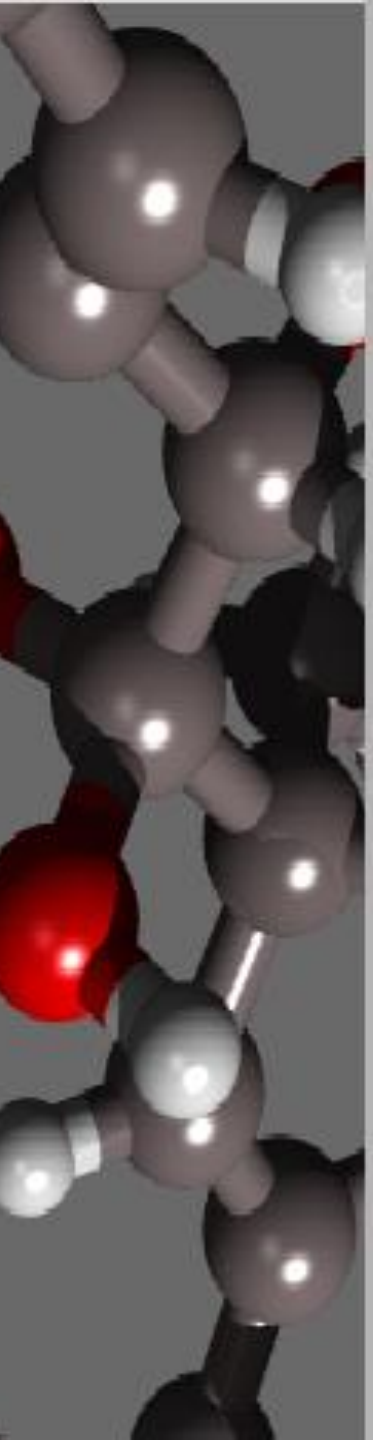
Lipids

- **Triglycerides**
  - **Made up of 1 glycerol molecule and 3 fatty acid molecules**
    - **Joined by a ester linkages resulting from dehydration synthesis**
  - **Glycerol or glycerin**
    - **A three carbon molecule**
  - **Fatty acid chain**
    - **Long hydrocarbon chains**
    - **4-24 carbons**
    - **Saturated or Unsaturated**



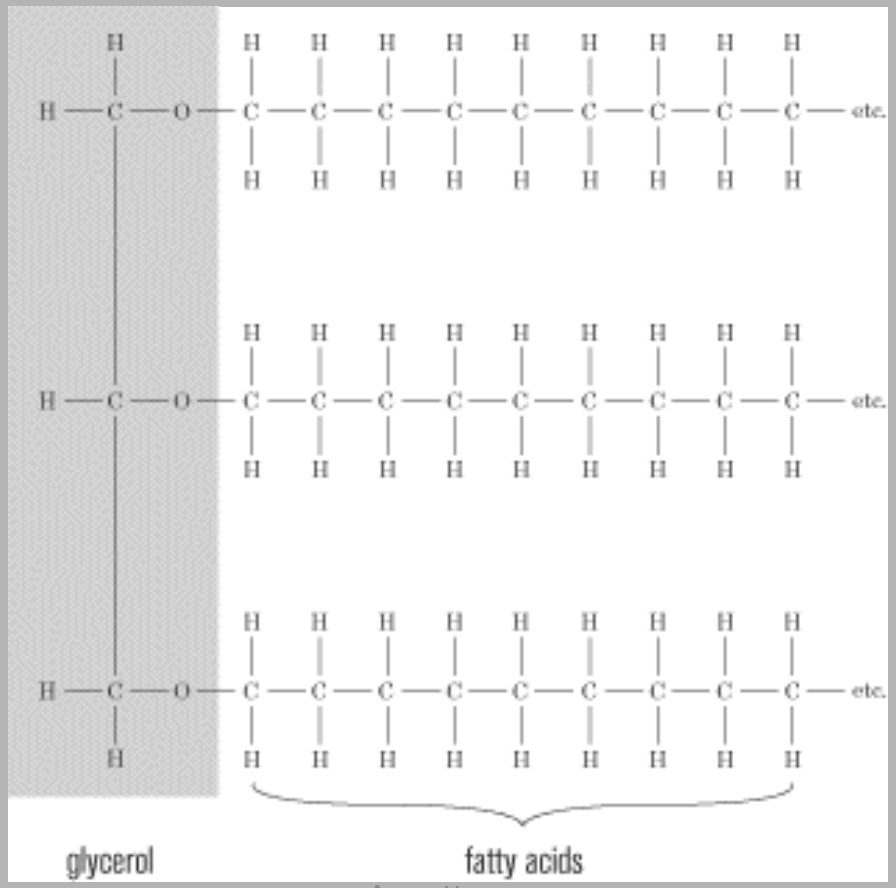
glycerol

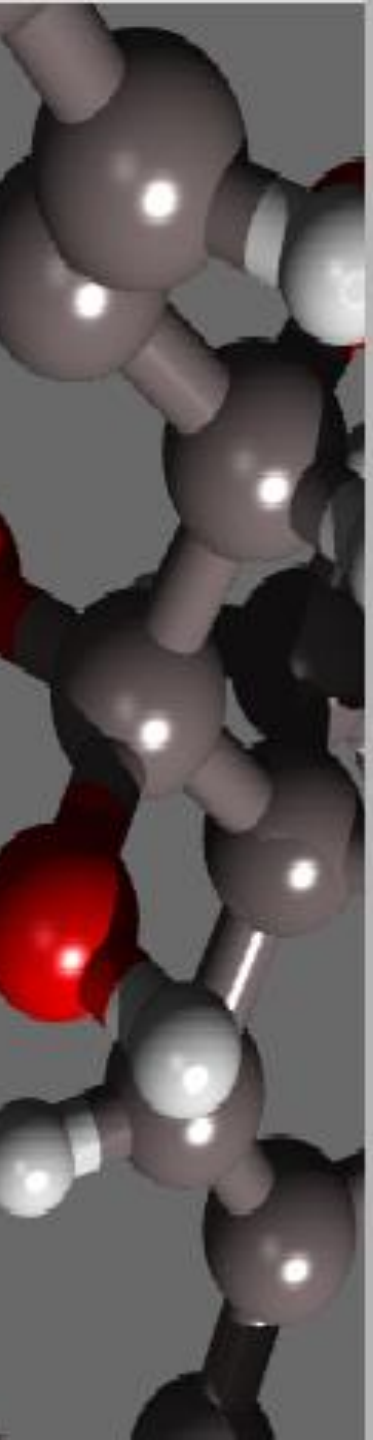




Lipids

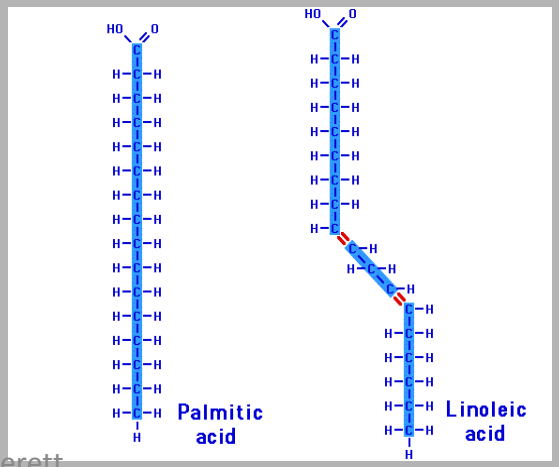
- **Triglyceride**





Lipids

- 2 types of Triglycerides
  - Saturated
  - Unsaturated
- Saturation depends on the number of hydrogen atoms in the fatty acid chains (tails)

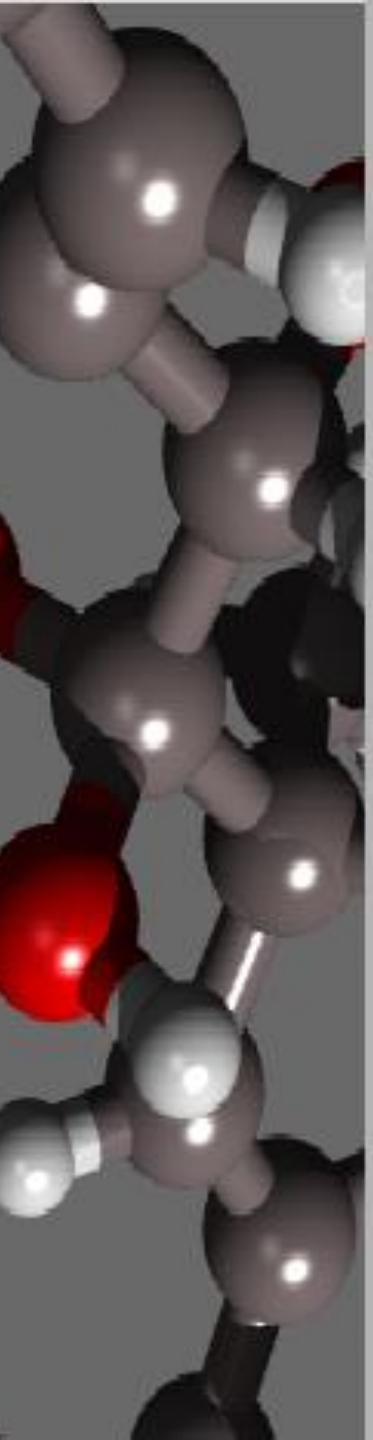


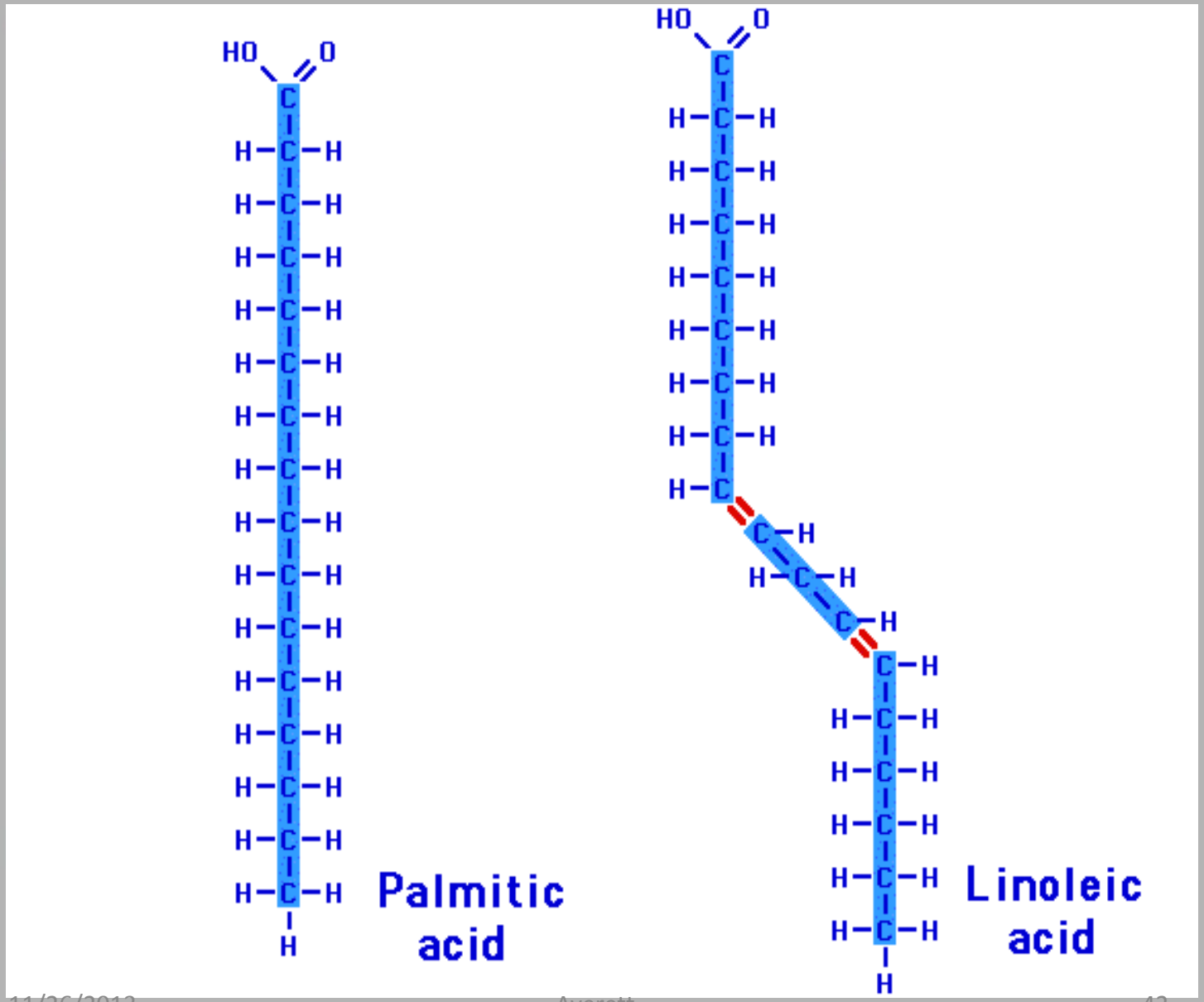
Lipids

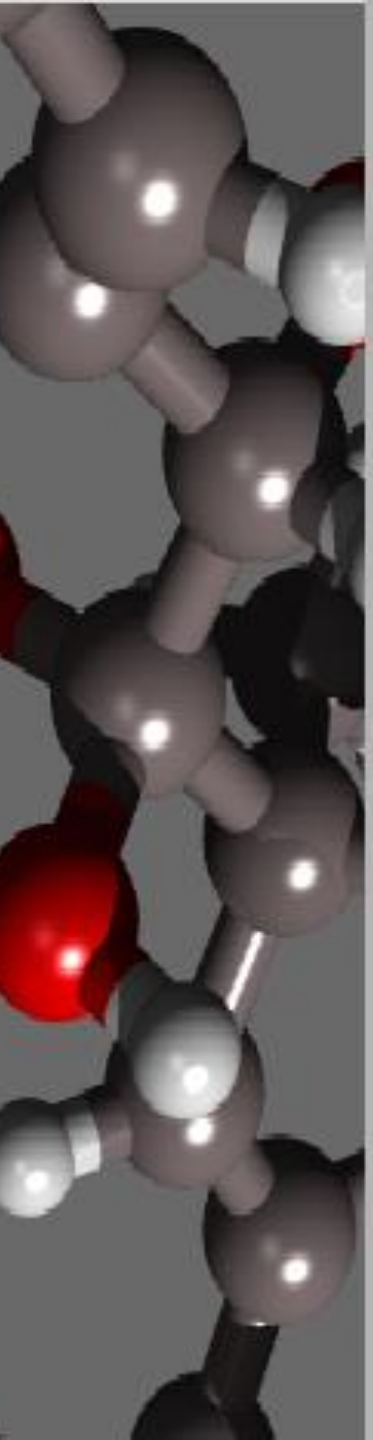
- **Saturated Fats**
  - **The fatty acid chains in the triglyceride are "saturated" with hydrogen atoms**
    - **Contain the maximum number of hydrogen atoms possible**
    - **All single bonds between carbon atoms**
  - **Solid at room temperature**
    - **Majority of fat found in animals**
    - **Fats – butter, lard, bacon grease**
  - **Unhealthy type of fat**
    - **More difficult to break down**
    - **Believed to contribute to heart disease, causes plaque to build up in blood vessels blocking flow of blood**

Lipids

- **Unsaturated fats**
  - **The fatty acid chains in the triglyceride are not "saturated" with hydrogen atoms**
    - **One or more double bonds between carbon atoms**
  - **Liquid at room temperature**
    - **Found in seeds and commonly refe as plant oils**
      - **Oils – olive oil, vegetable oil, etc.**
  - **Healthier type of fat**
    - **More easily broken down**

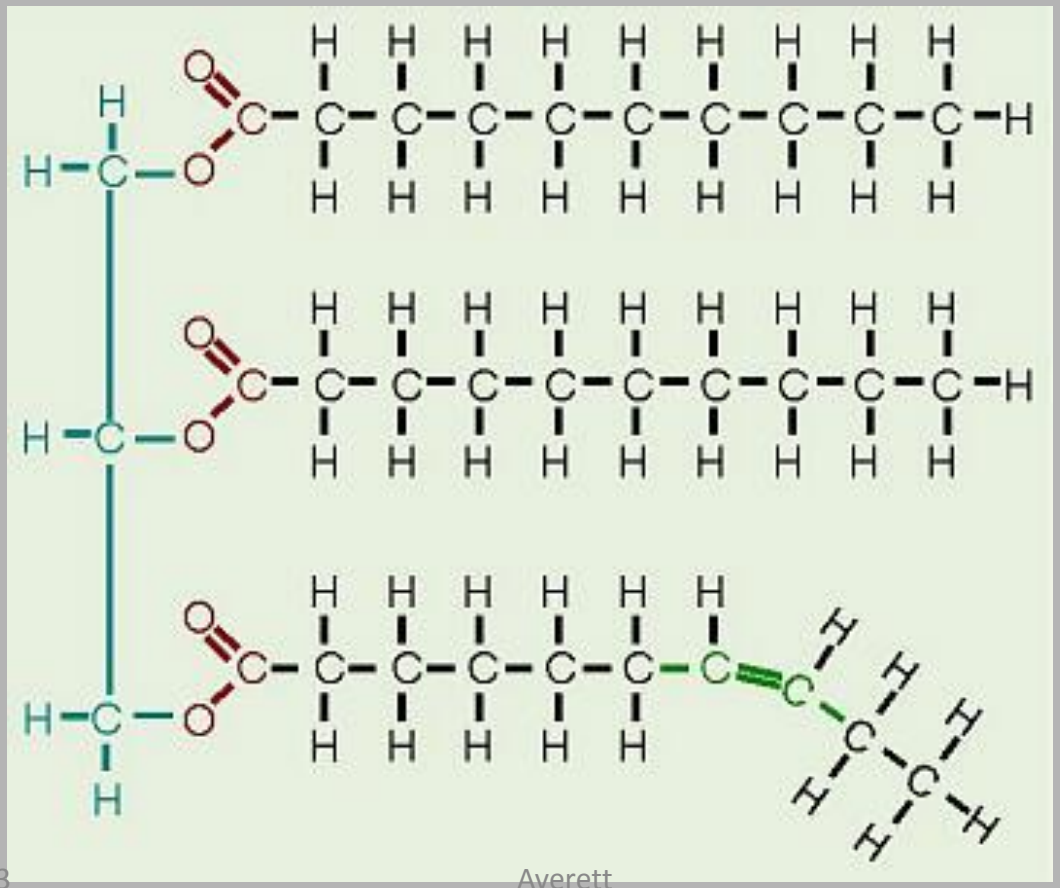



Palmitic acid
Linoleic acid



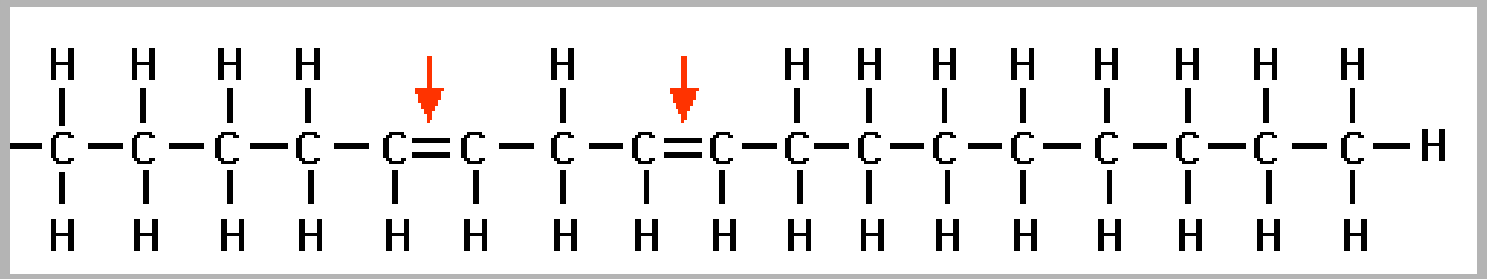
Lipids

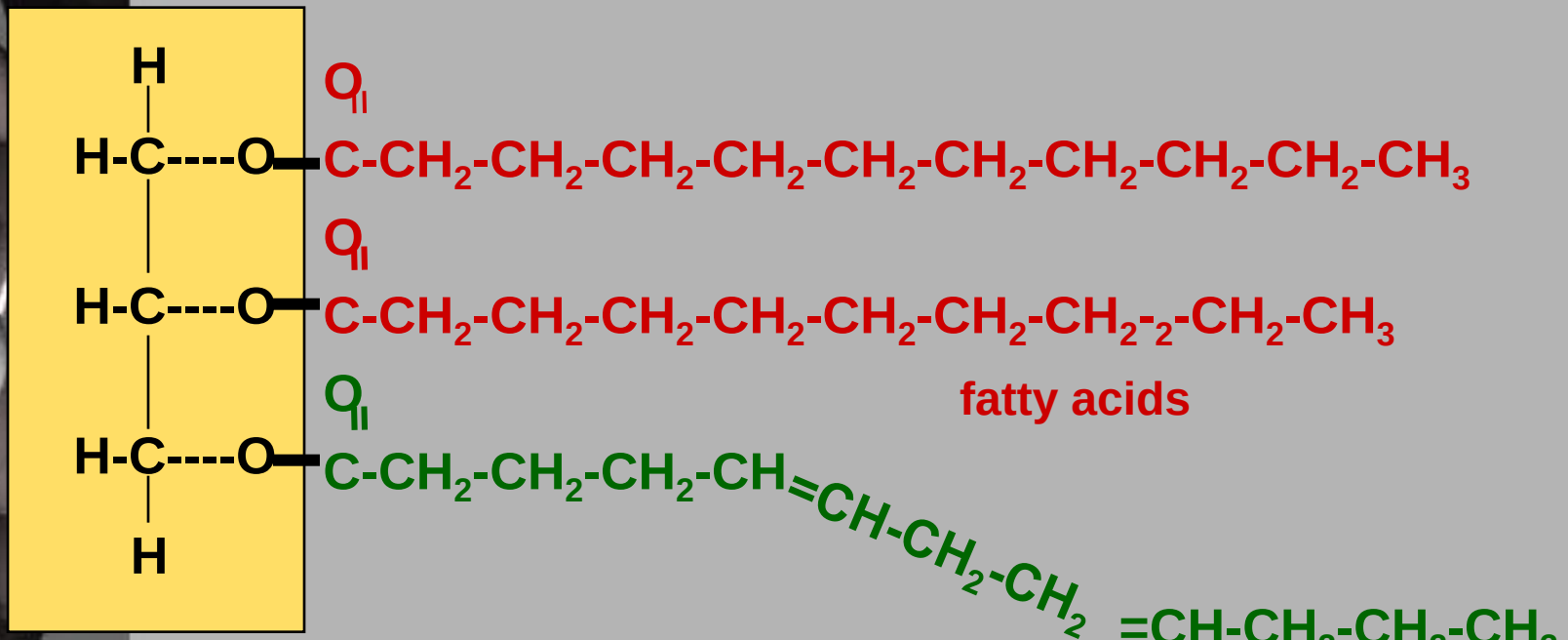
- **Monounsaturated fats**

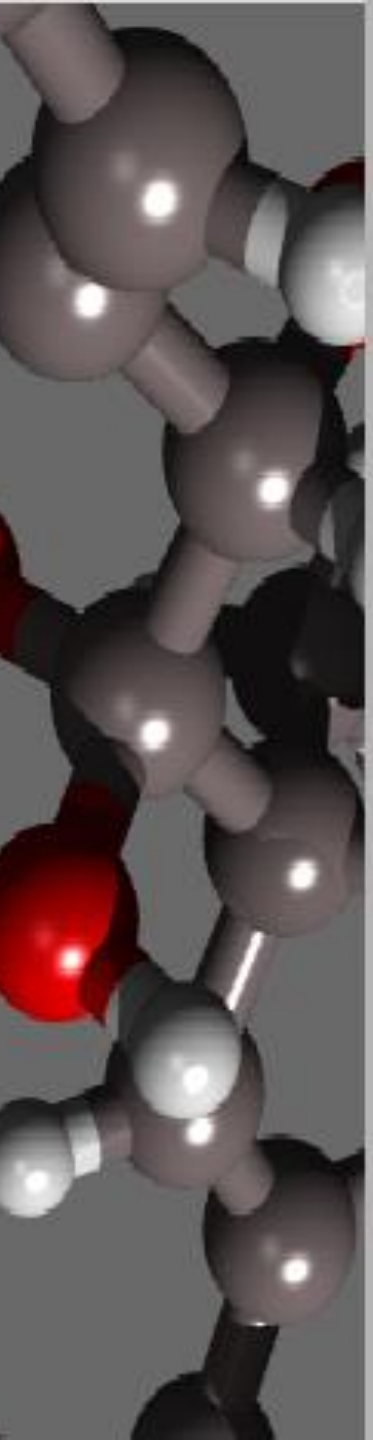


Lipids

- **Polyunsaturated fats**

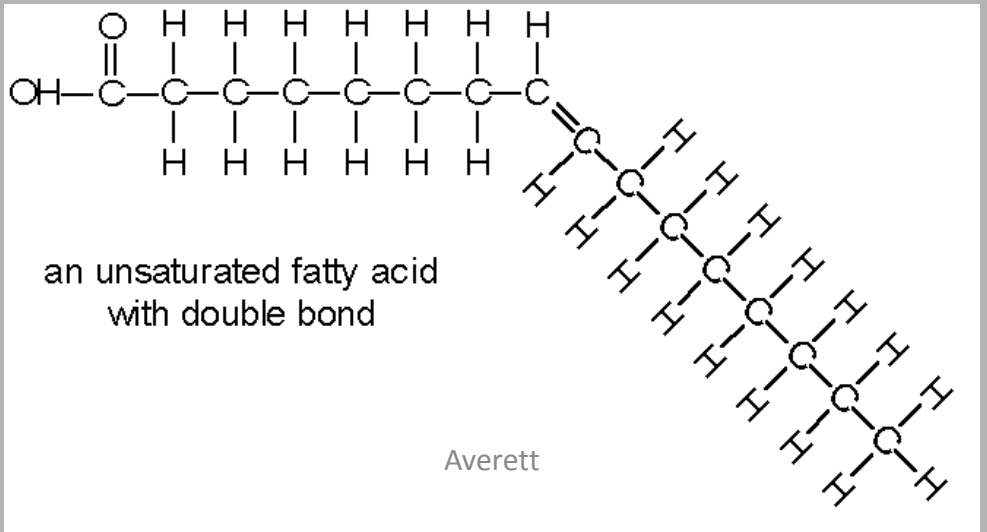


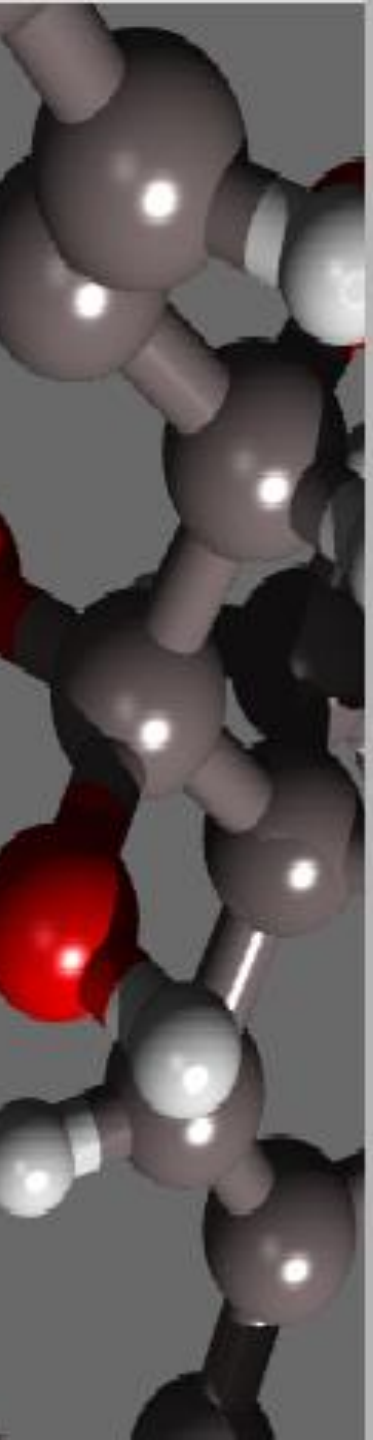




Lipids

- **Double bonds cause a molecule to bend slightly. This prevents the molecule from packing together tightly and forming a solid. As a result the lipids have a lower density and they are more likely to remain liquid at room or body temperature**





Lipids

Nutrition Facts

Serving Size 1 cup (236ml)
Servings Per Container 1

Amount Per Serving	
Calories 120	Calories from Fat 45
	% Daily Value*
Total Fat 5g	8%
Saturated Fat 3g	15%
Trans Fat 0g	
Cholesterol 20mg	7%
Sodium 120mg	5%
Total Carbohydrate 11g	4%
Dietary Fiber 0g	0%
Sugars 11g	
Protein 9g	17%

Vitamin A 10% • Vitamin C 4%
Calcium 30% • Iron 0% • Vitamin D 25%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

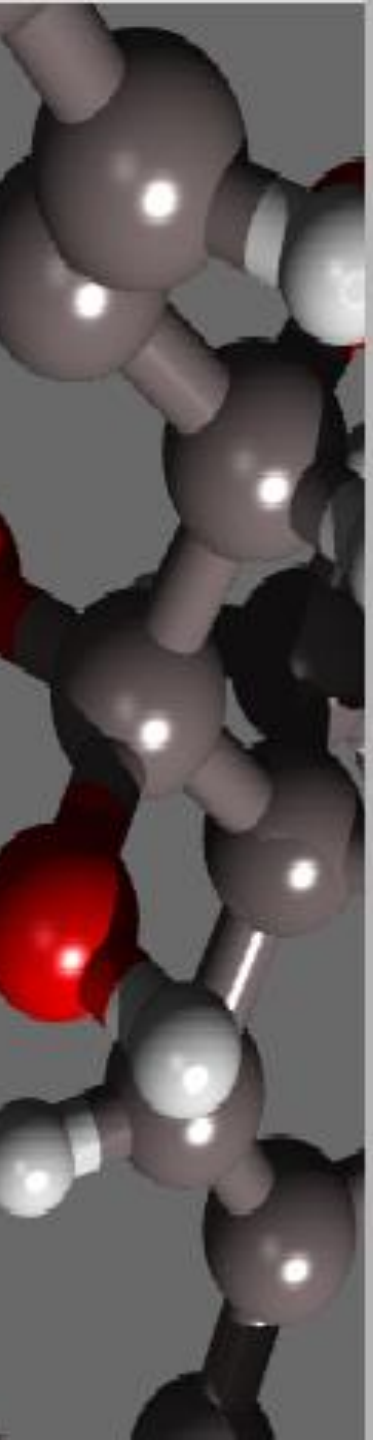
Nutrition Facts

Serving Size 1 cup (236ml)
Servings Per Container 1

Amount Per Serving	
Calories 80	Calories from Fat 0
	% Daily Value*
Total Fat 0g	0%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol Less than 5mg	0%
Sodium 120mg	5%
Total Carbohydrate 11g	4%
Dietary Fiber 0g	0%
Sugars 11g	
Protein 9g	17%

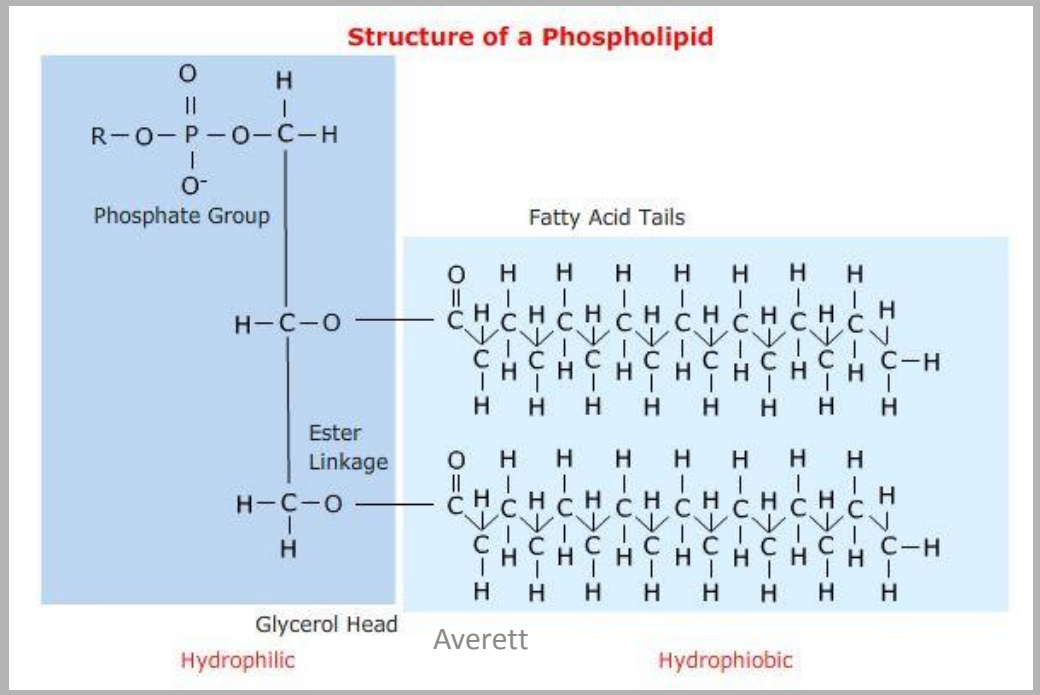
Vitamin A 10% • Vitamin C 4%
Calcium 30% • Iron 0% • Vitamin D 25%

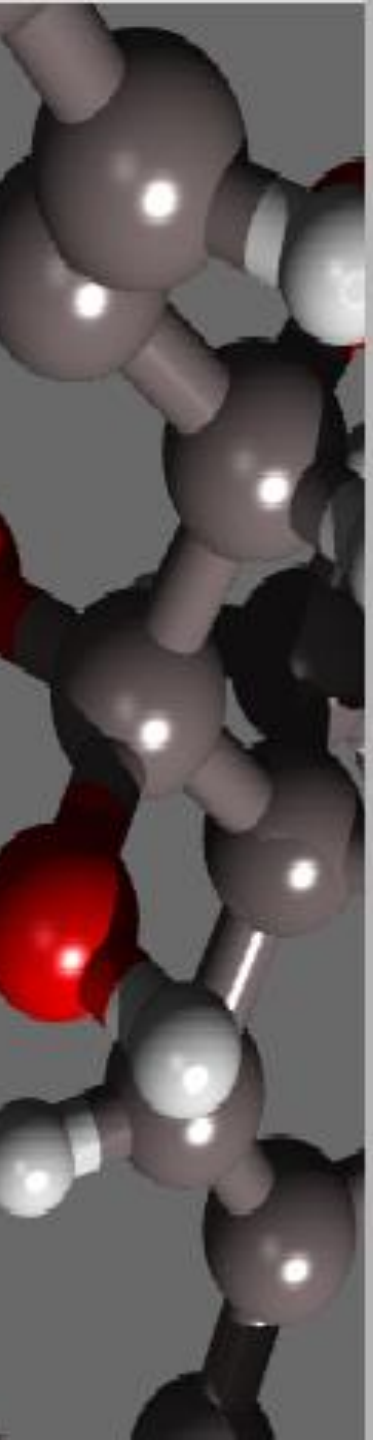
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:



Lipids

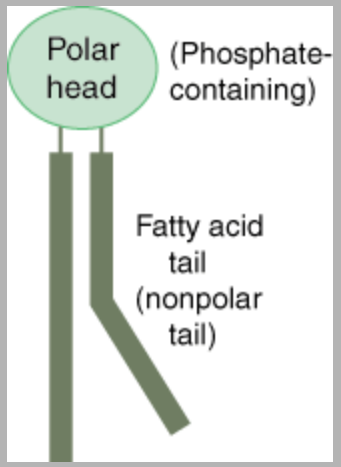
- **Phospholipids**
  - **Similar to triglycerides except one fatty acid chain is removed and replaced with a phosphate group**

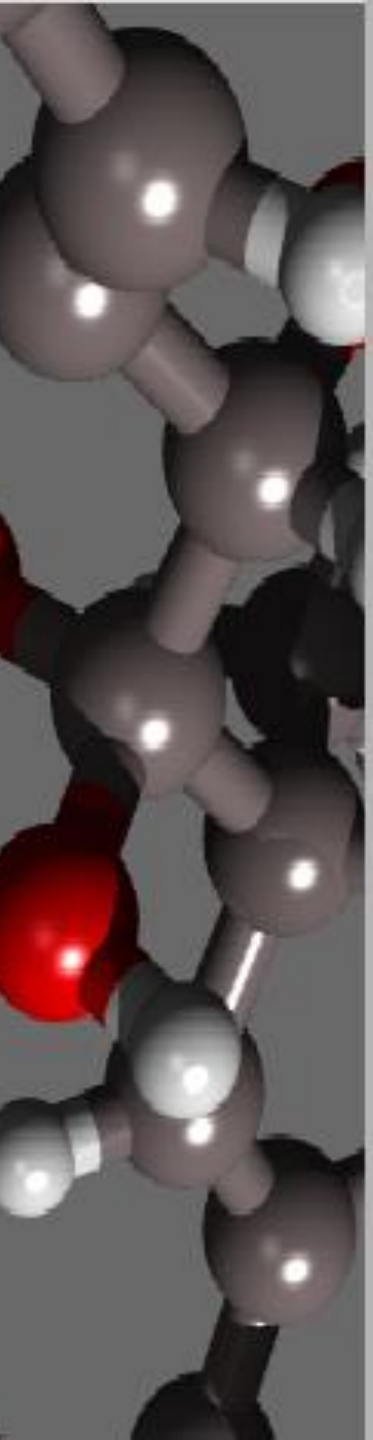




Lipids

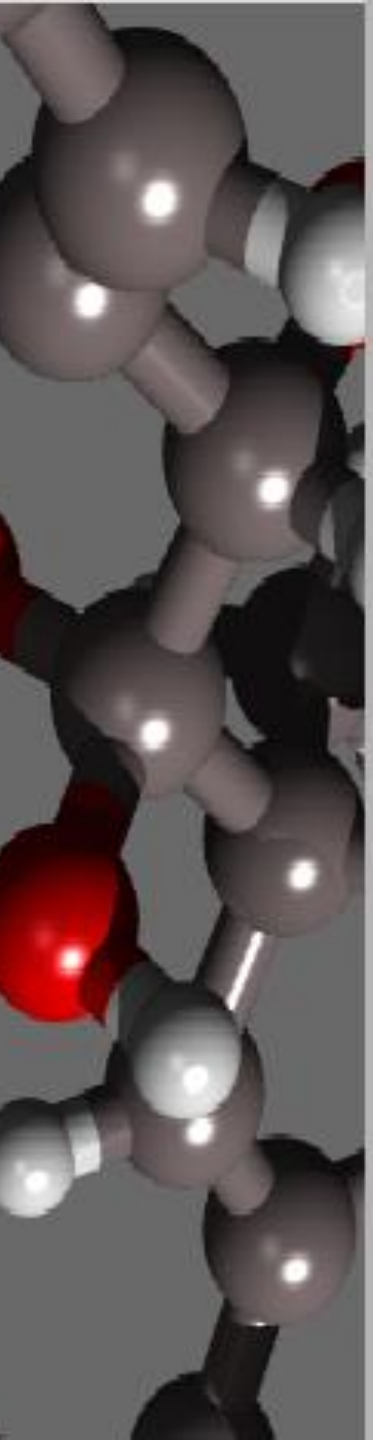
- Two parts of a phospholipid
  - Hydrophobic tail
    - Hydro = water
    - Phobic = fearing
    - Non-polar, fatty acid tails point in one direction and repel water.
  - Hydrophilic head
    - Hydro = water
    - Philic = loving
    - Polar phosphate group and glycerol molecule point in opposite direction of tails and attract water





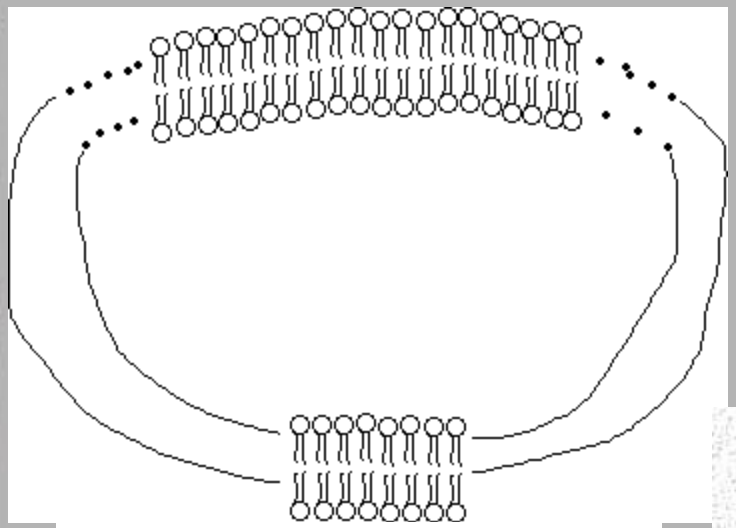
Lipids

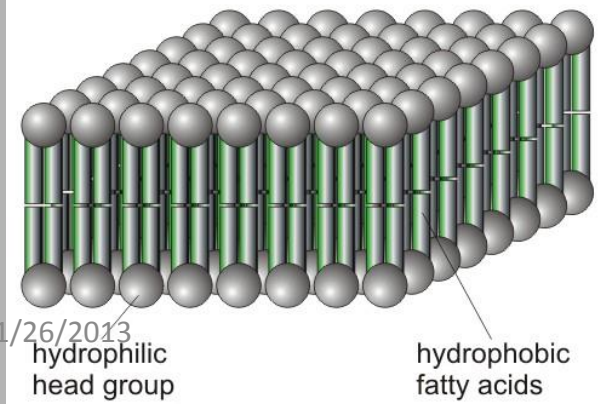
- **Phospholipids provide structural support by forming cell membranes**
  - **Hydrophilic side of a phospholipid is near water, outer surface of cell membrane**
  - **Hydrophobic side of phospholipid is away from water, inside cell membrane**
    - **The hydrophobic and hydrophilic ends allow the membranes to form by flipping in on themselves**
    - **Each cell membrane is really two layers of phospholipids**

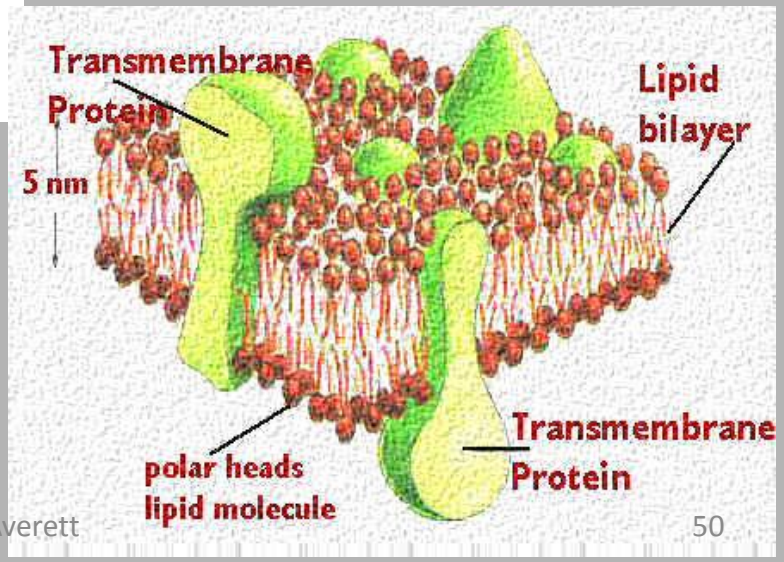


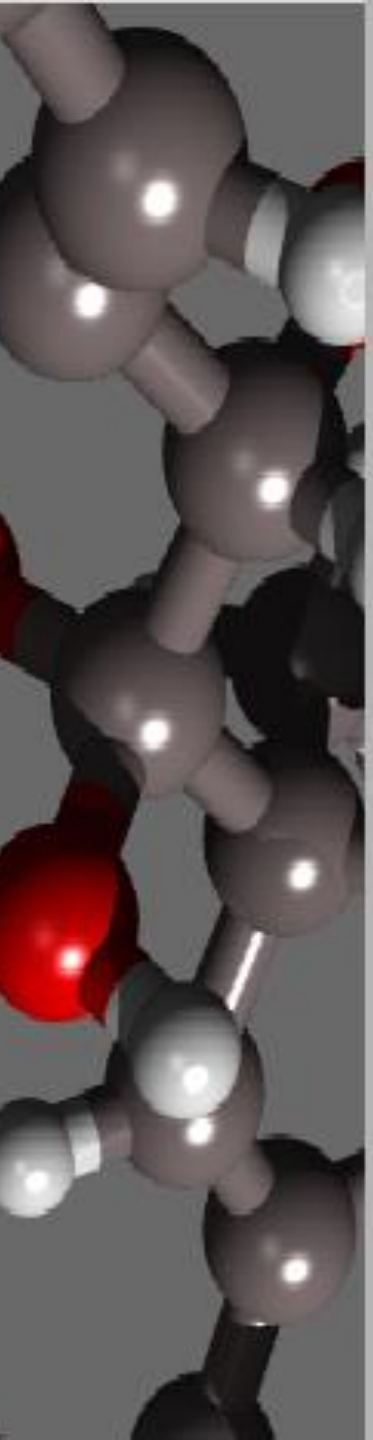
Lipids

- **Phospholipid cell membranes**



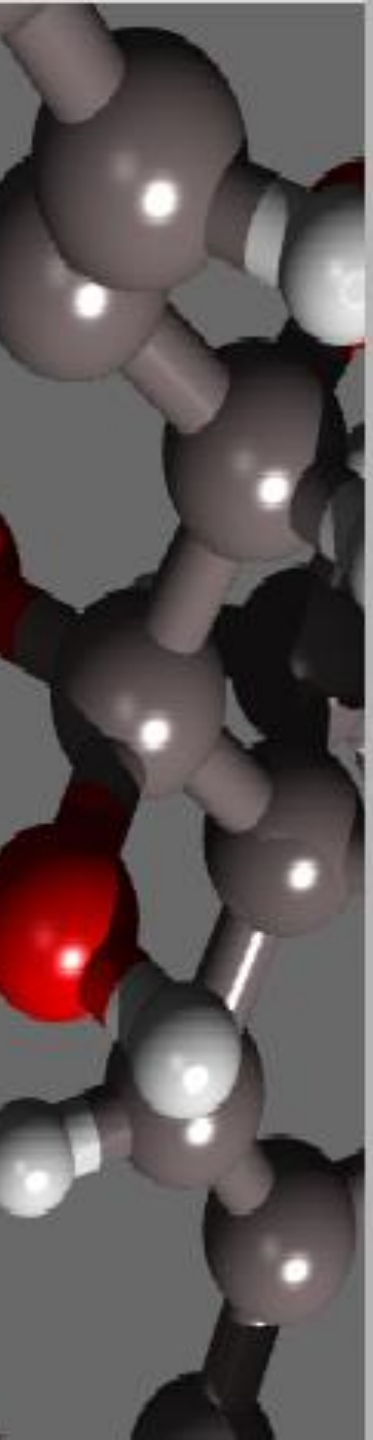




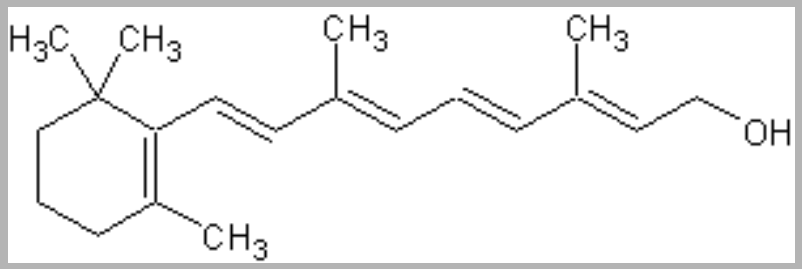


Lipids

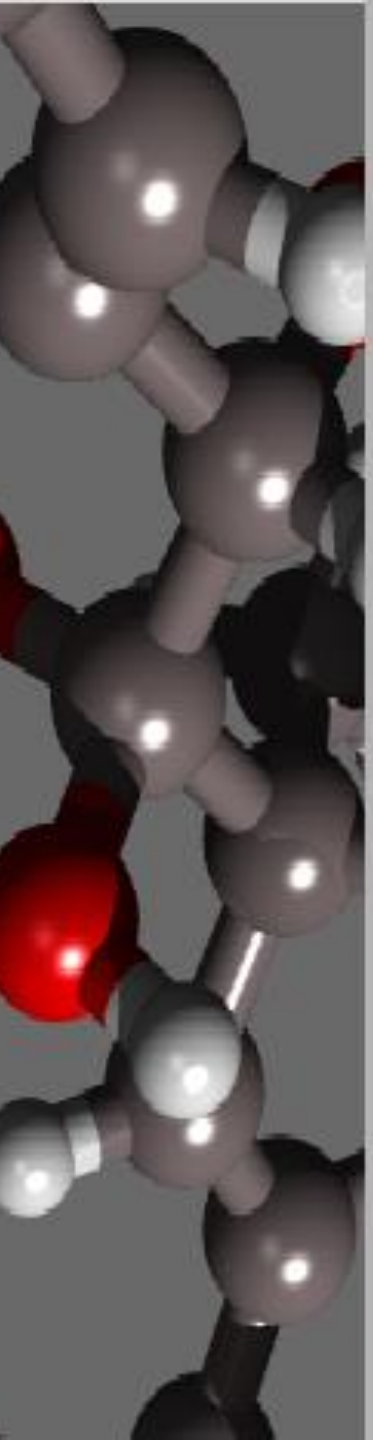
- **Waxes**
  - **Long fatty acid chains hooked together in the middle**
  - **Used for structural support**
    - **Example: Beeswax used to make beehives**
  - **Used for protection**
    - **Highly waterproof**
    - **Examples: ear wax, waxy covering on plant leaves**



Lipids

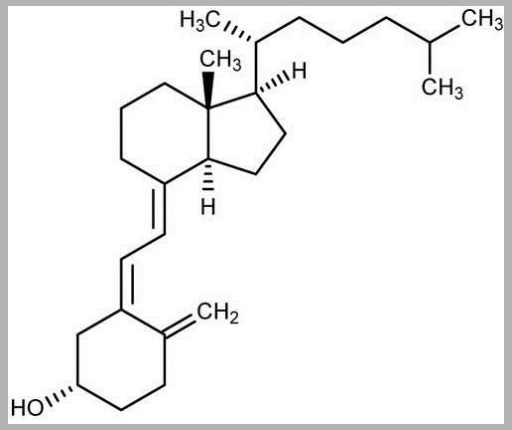


- **Vitamins**
  - **Vitamins are small organic molecules essential to health**
    - **Vitamin A is made from Beta-carotene.**
      - **It is important for normal development, maintenance of cells, and night vision.**
    - **Vitamin D is important for absorption of calcium in the intestines.**
    - **Vitamin E is an antioxidant. It protects membranes.**
    - **Vitamin K is a component required for normal blood clotting.**

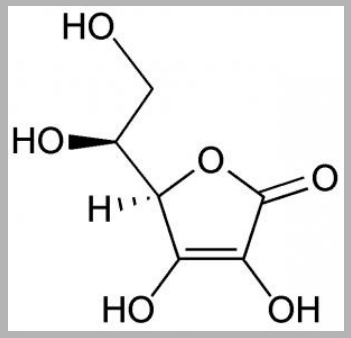


Lipids

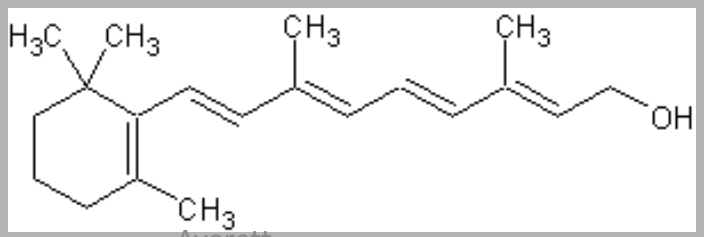
- **Vitamins molecular structure**
  - **Vitamin D**

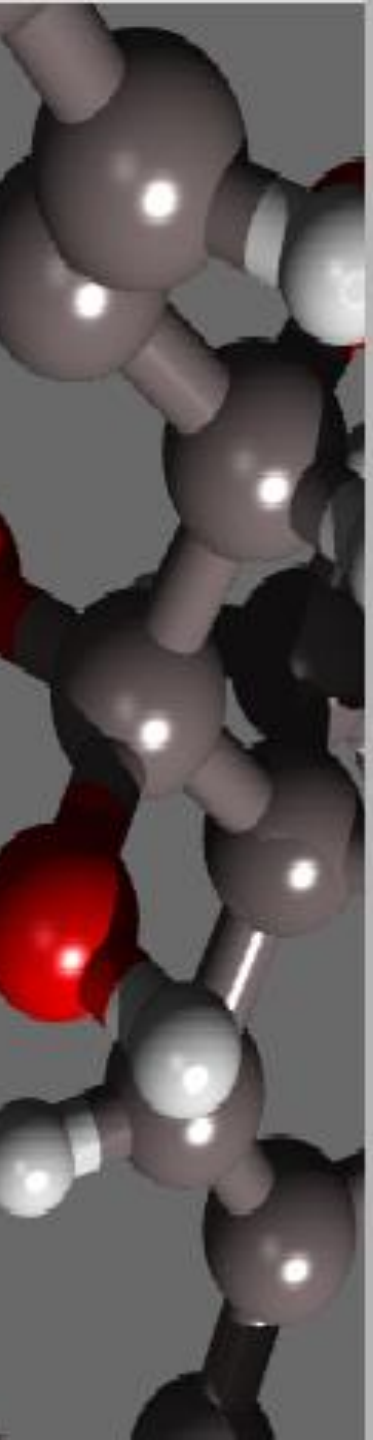


  - **Vitamin C**

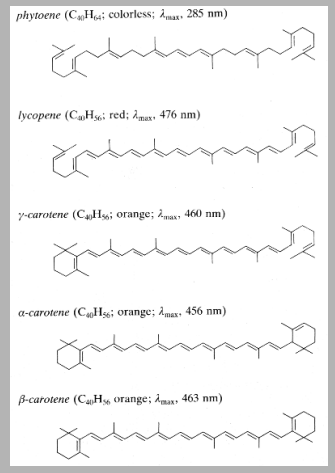


  - **Vitamin A**

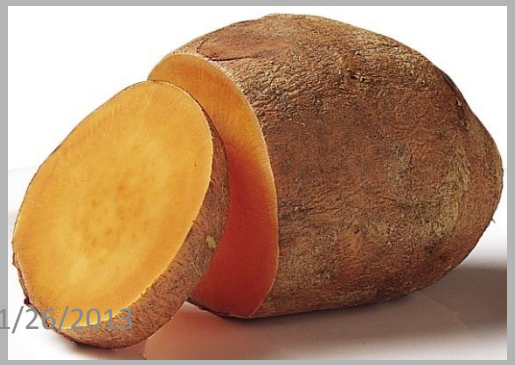


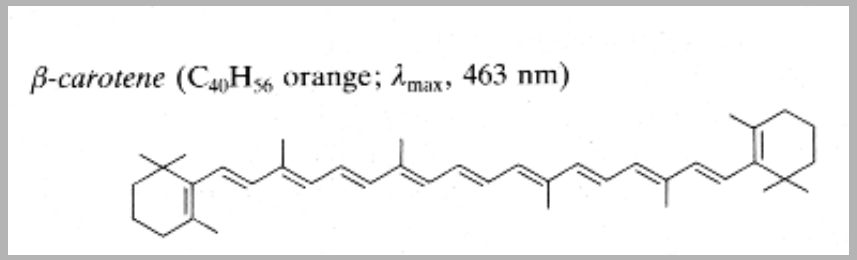


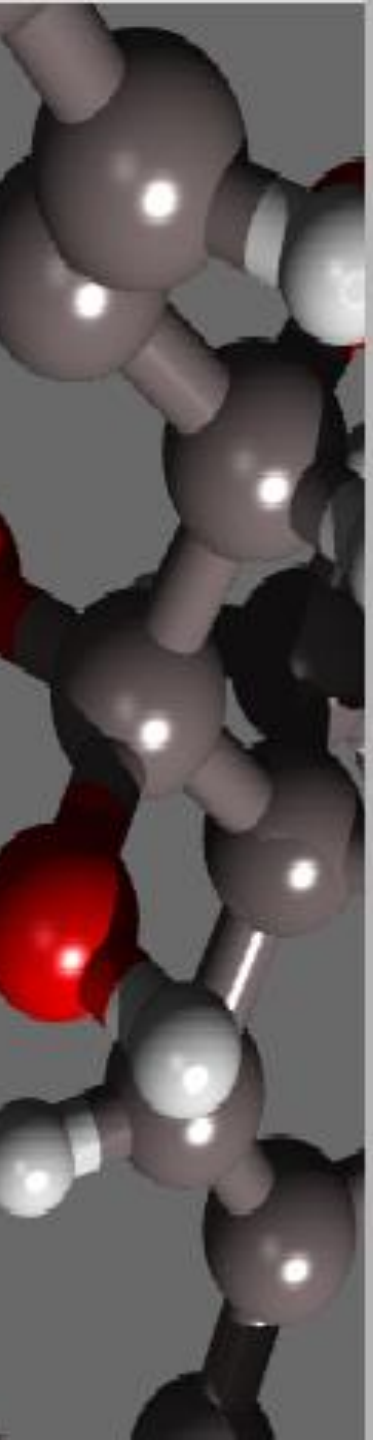
Lipids



- **Carotenoids**
  - **Light absorbing pigments found plants and animals.**
  - **β- carotene is a plant pigment used to trap light in photosynthesis**
    - **In animals, this pigment , when broken into two identical pieces becomes vitamin A and is required for vision.**

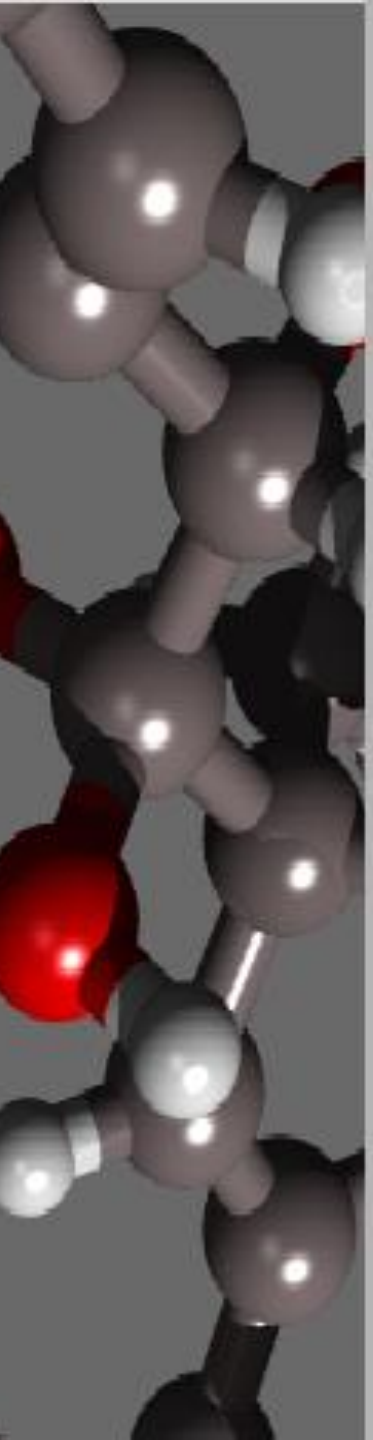




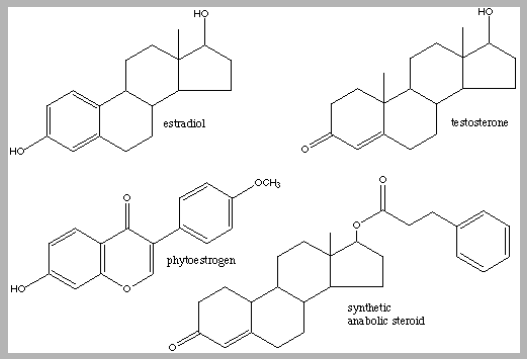


Lipids

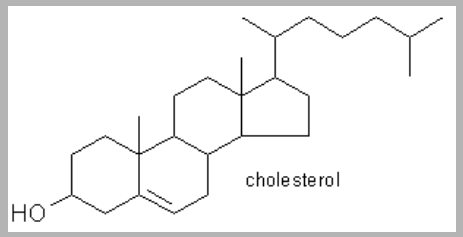
- **Steroids**
  - **Specialized lipids with chemical structures that are different from other lipids.**
    - **Series of fused rings**
  - **Found in hormones, nerve tissue, toad venom, plant poisons**
    - **Used as a signaling molecules to provide chemical messages in organisms.**



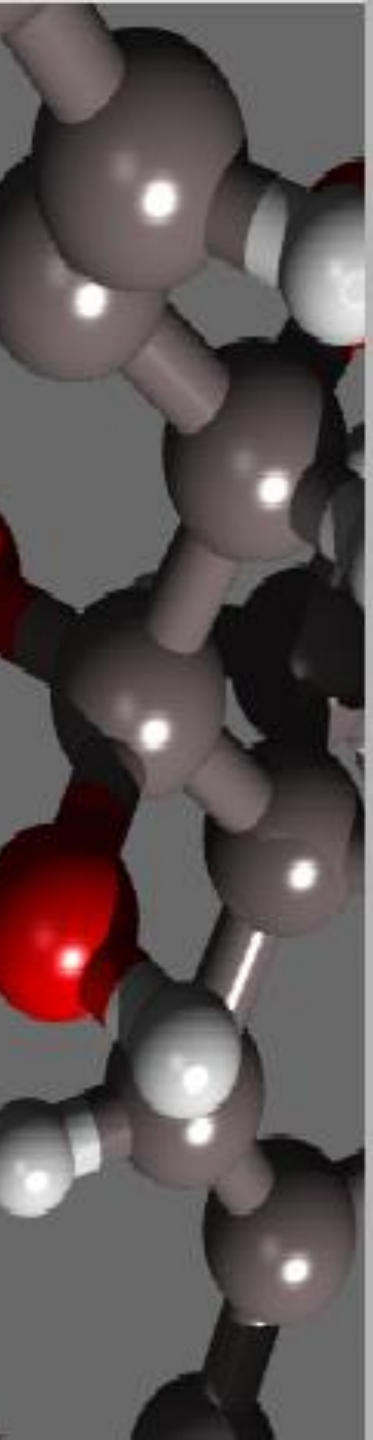
Lipids



- **Steroids**
  - **Series of fused rings.**
    - **No fatty acid tails, instead hydrogen, carbon and some oxygen atoms form interlocking ring structures**
    - **Usually 4 rings**
  - **Example: cholesterol**

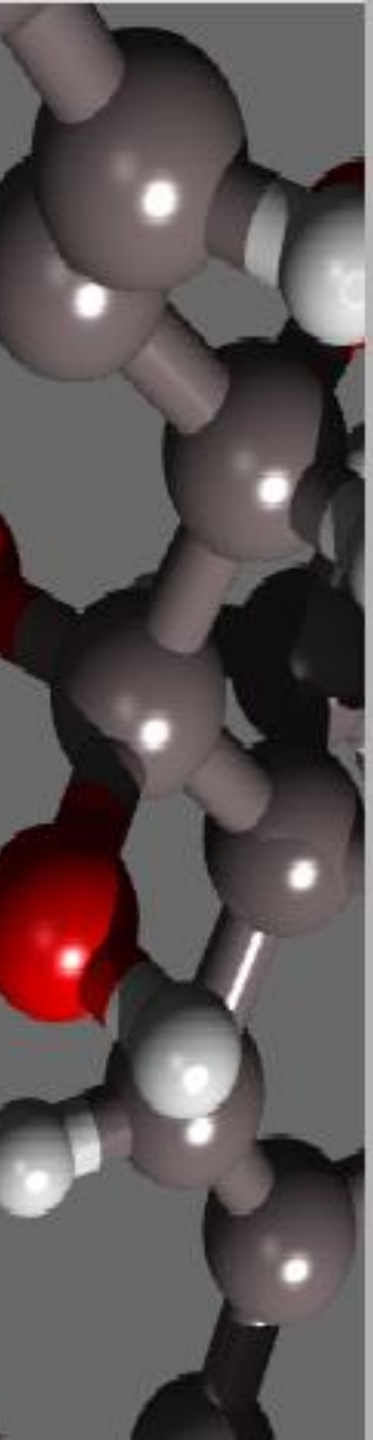


    - **Common part of animal cell membranes**
    - **Absorbed from food and synthesized in the liver**
    - **Also an initial substrate for synthesis of the hormones testosterone and estrogen.**

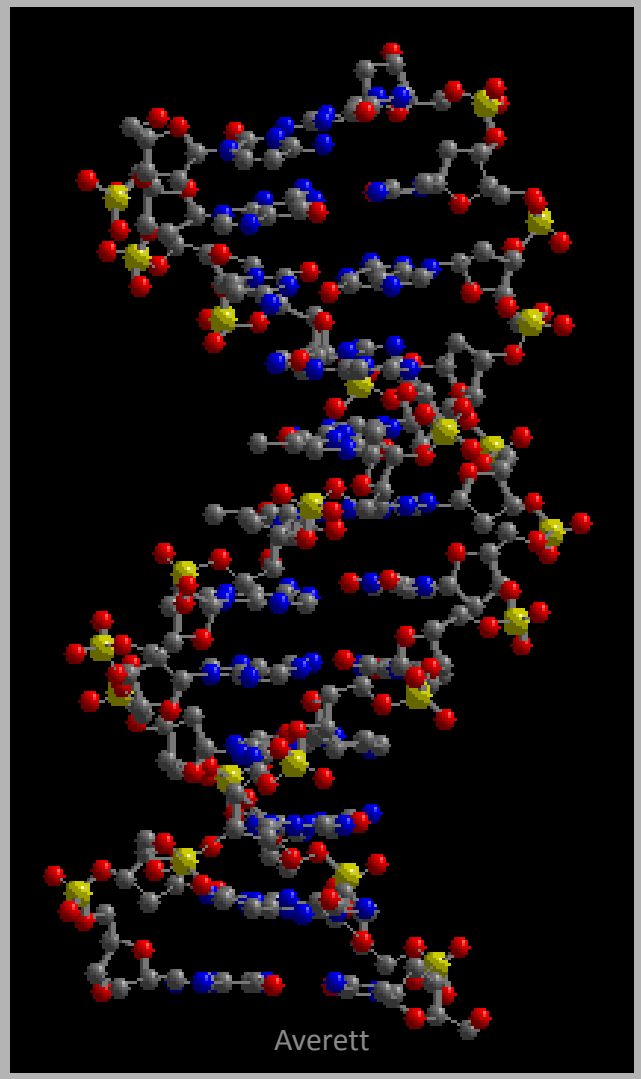


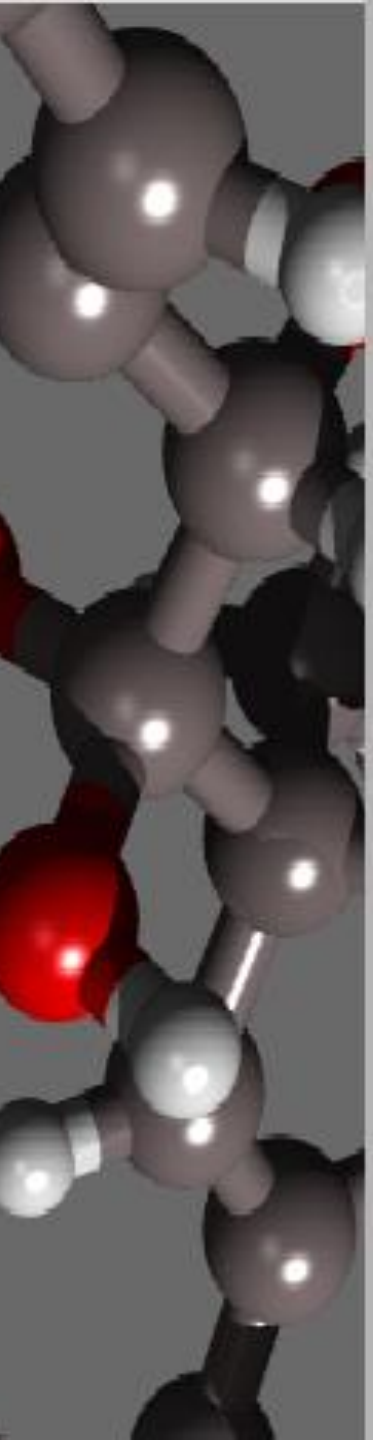
Lipids

- Testing for lipids
  - Translucence Test
    - Lipids leave a semi-transparent spot on brown paper (non-lipids do not)
  - Solubility Test
    - Lipids are insoluble in water and soluble in organic solvents (like lighter fluid)
  - Sudan III Test
    - Lipids stain red in Sudan III; non-lipids do not stain (and if it is a solution, the non-lipid solution will look pink due to the dilution of the Sudan III)



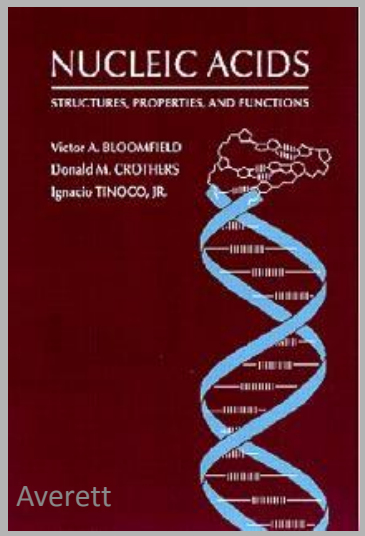
Nucleic Acids

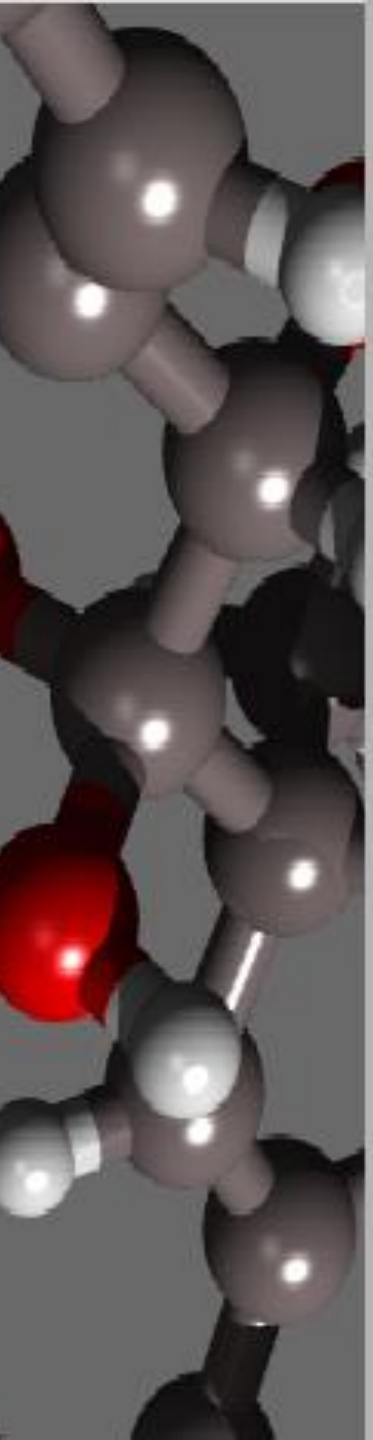




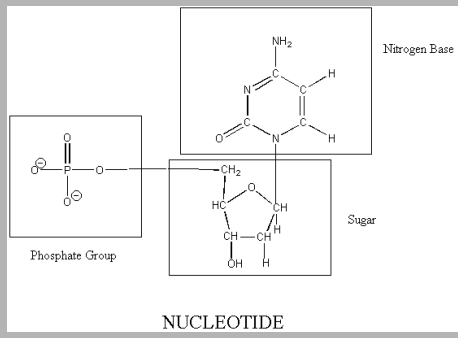
Nucleic Acids

- **Chemical composition**
  - **Contains Carbon, Hydrogen, Oxygen nitrogen, and phosphorus**
- **Storage and transfer of genetic information; involved in protein synthesis**

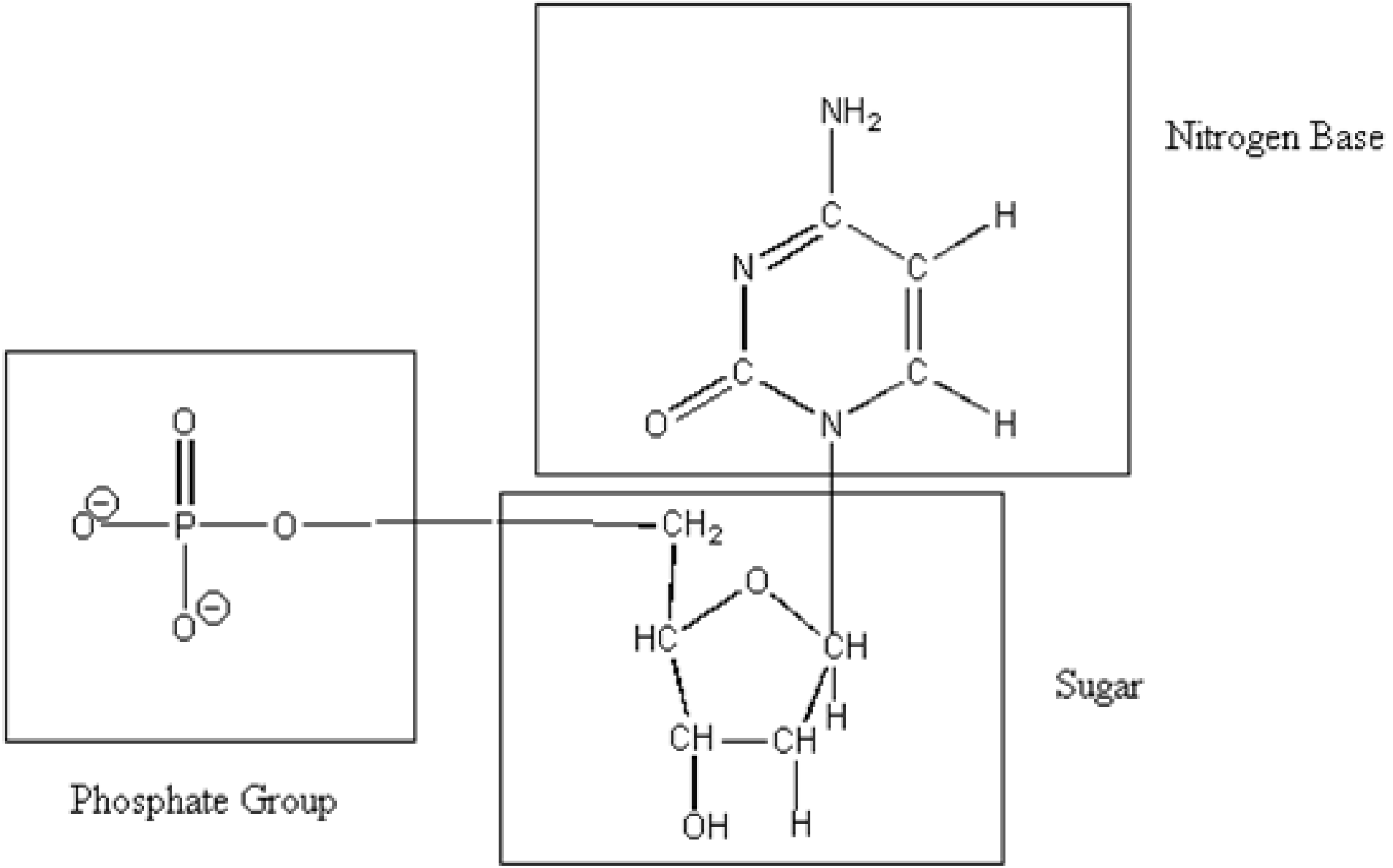




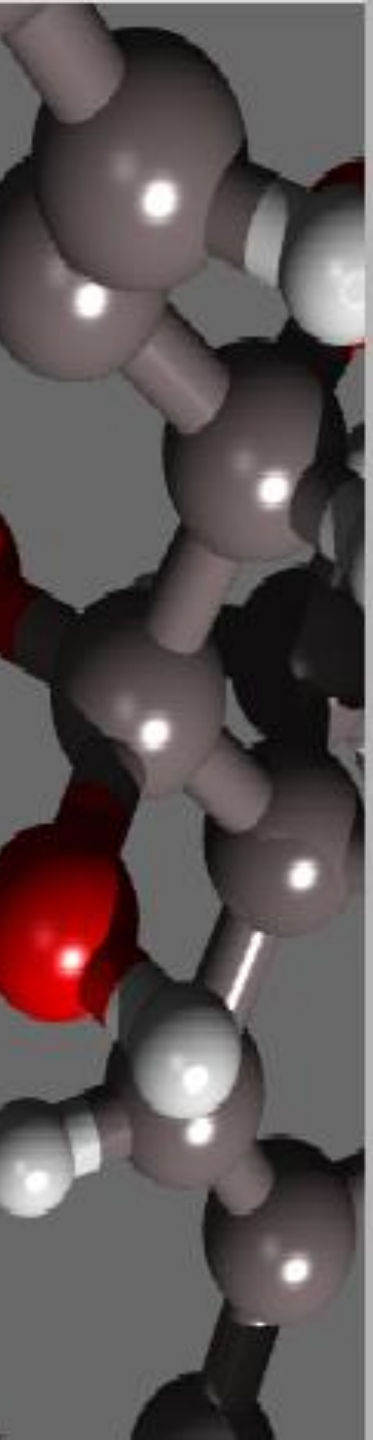
Nucleic Acids



- **Nucleotides**
  - **Monomers of nucleic acids**
  - **Made up of a pentose sugar, a phosphate group, and a nitrogenous base**
    - **More than 130 million nucleotides are found in just one human chromosome of average length**
  - **Phosphodiester bonds link one nucleotide to another**
    - **These linkages are formed between carbon 3 of the sugar and a phosphate group that is associated with carbon 5 of the sugar.**

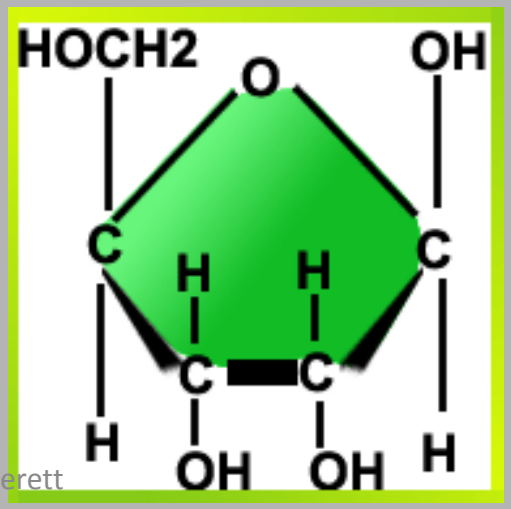


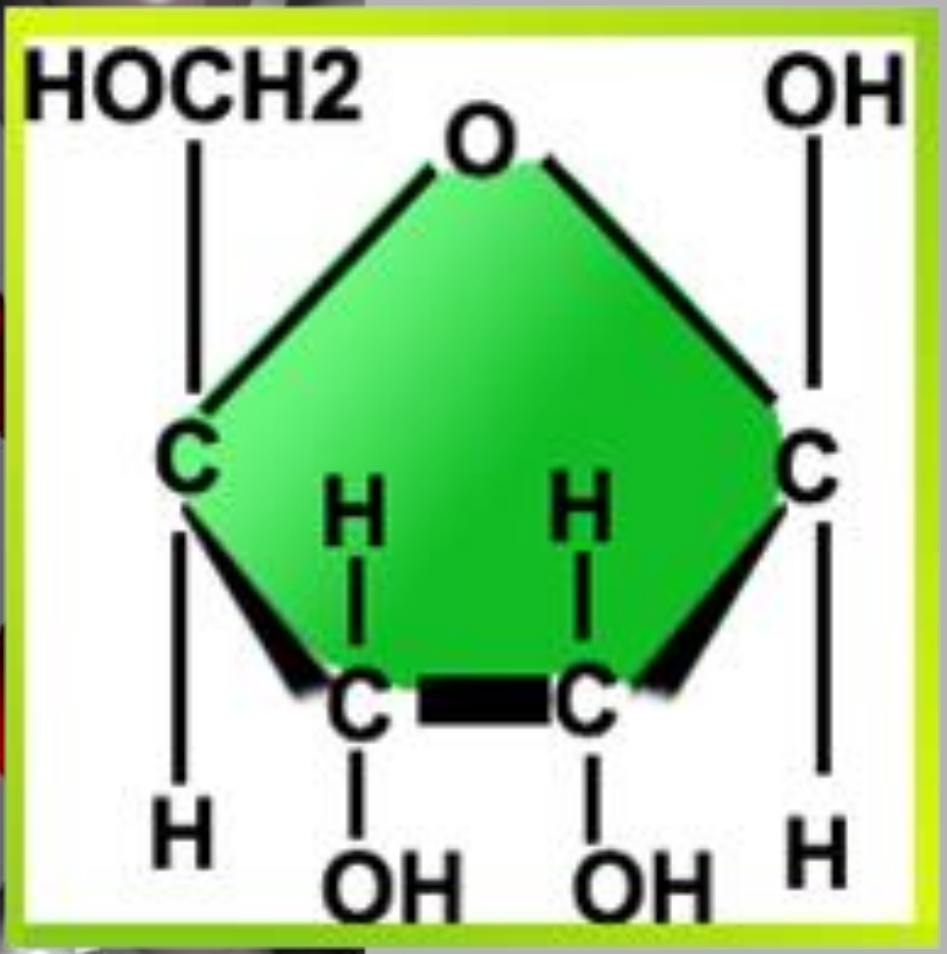
NUCLEOTIDE

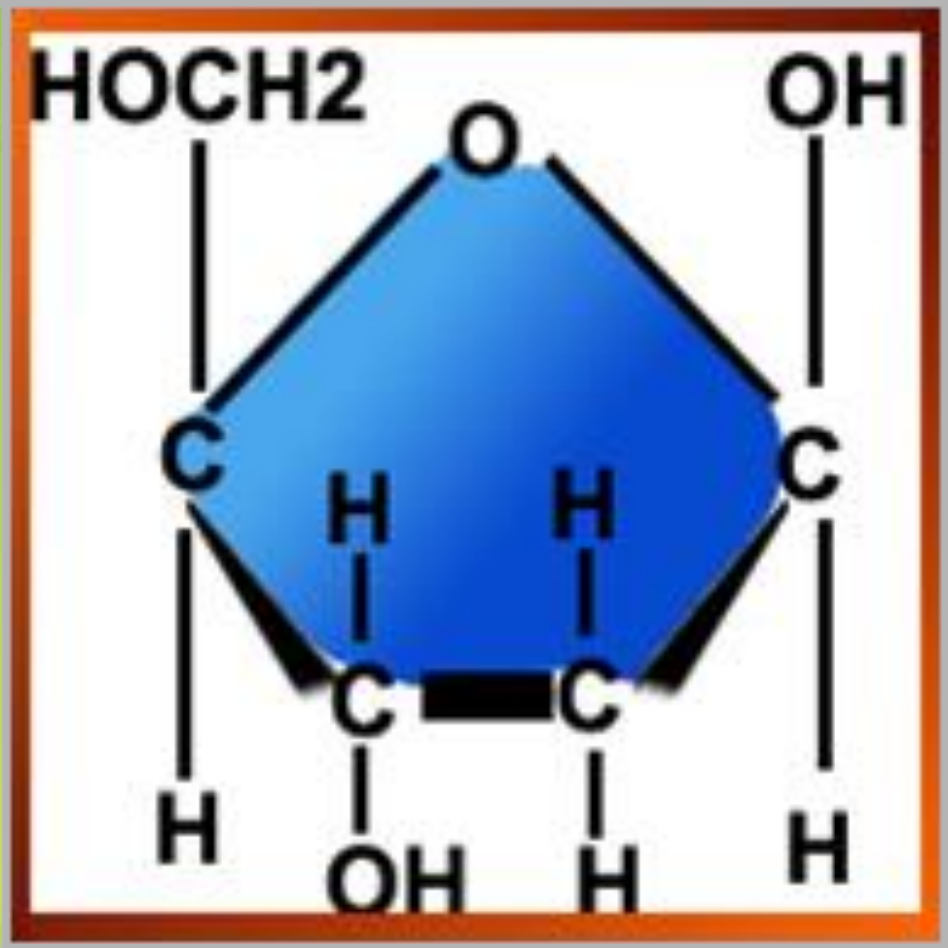


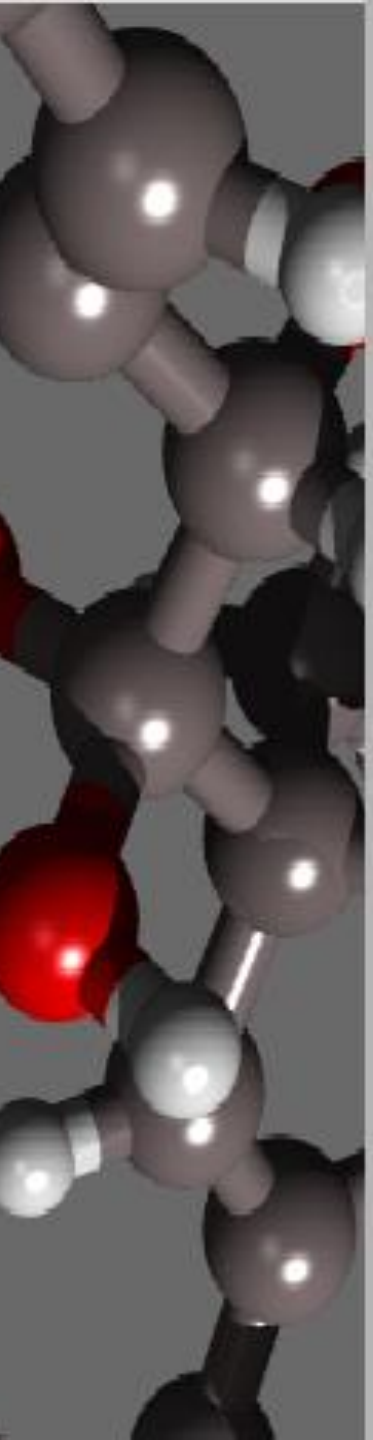
Nucleic Acids

- Pentose sugars
  - 5 sided ring structure
  - 2 types found in nucleic acids
    - Ribose
    - Deoxyribose
      - Missing an oxygen (de-oxy)



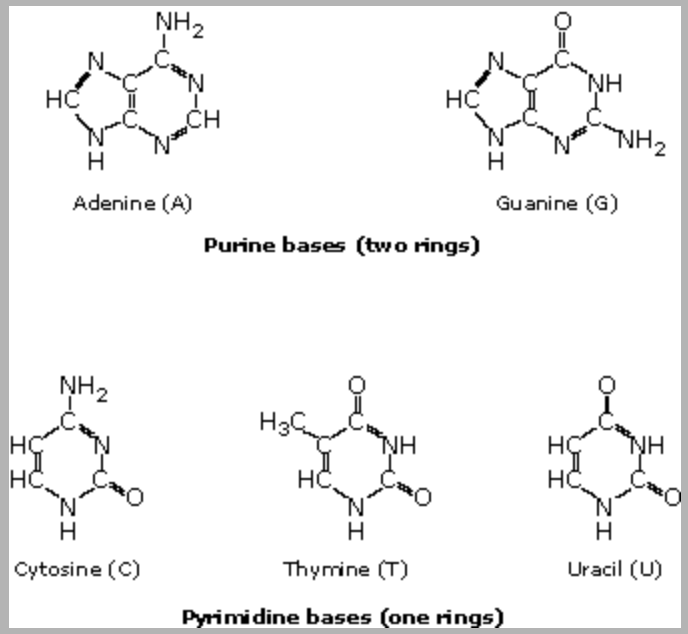

HOCH2
OH
O
C
H
H
C
C
C
H
OH
OH
H


HOCH2
OH
O
C
H
H
C
C
C
H
OH
H
H

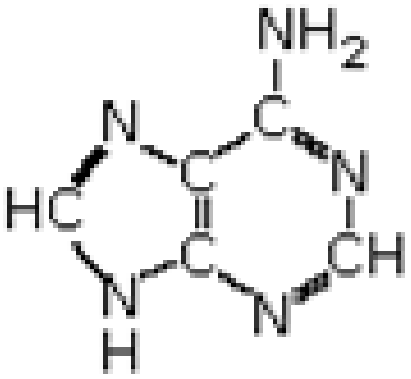


Nucleic Acids

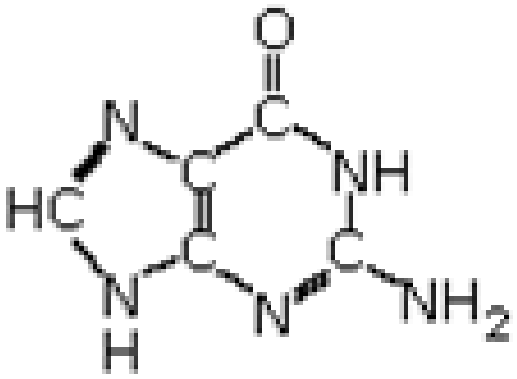
- 5 types of nitrogenous bases
  - Adenine
  - Cytosine
  - Guanine
  - Thymine
  - Uracil



- Purines have 2 rings
- Pyrimidines have 1 ring

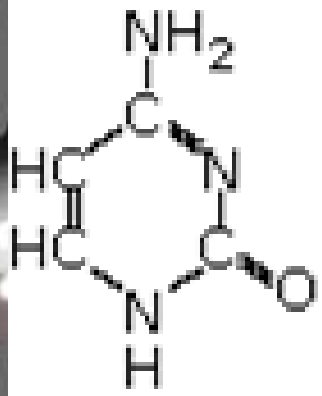


Adenine (A)

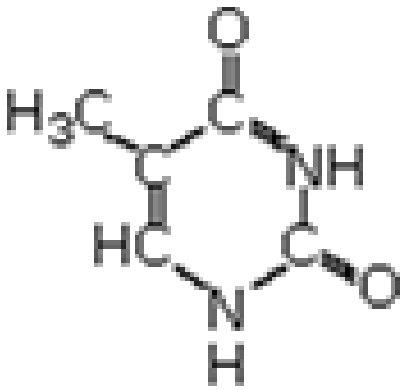


Guanine (G)

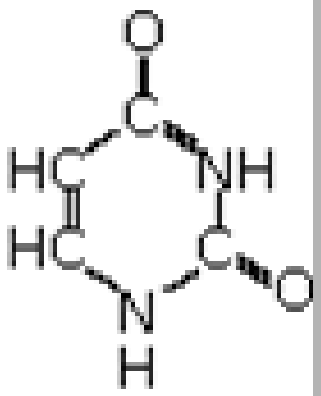
Purine bases (two rings)



Cytosine (C)

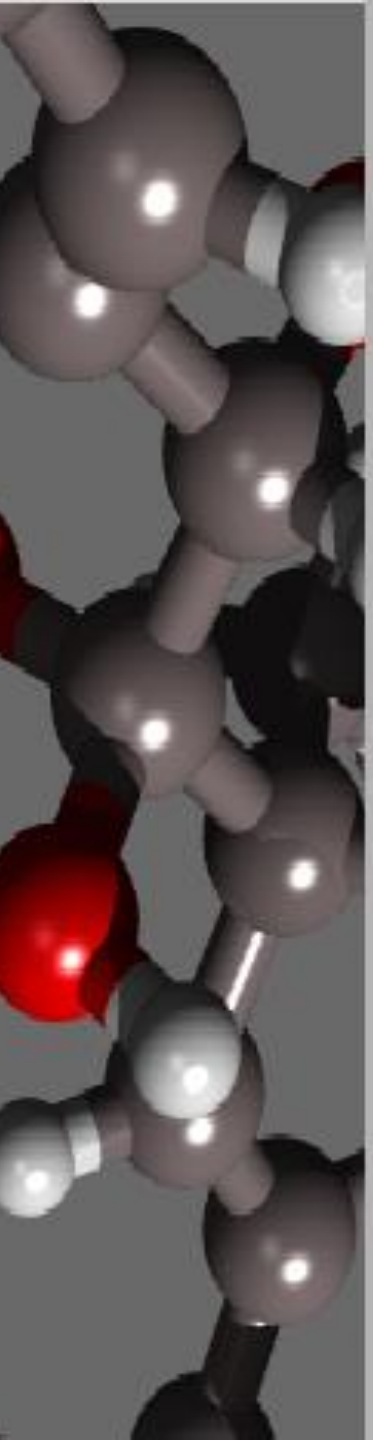


Thymine (T)



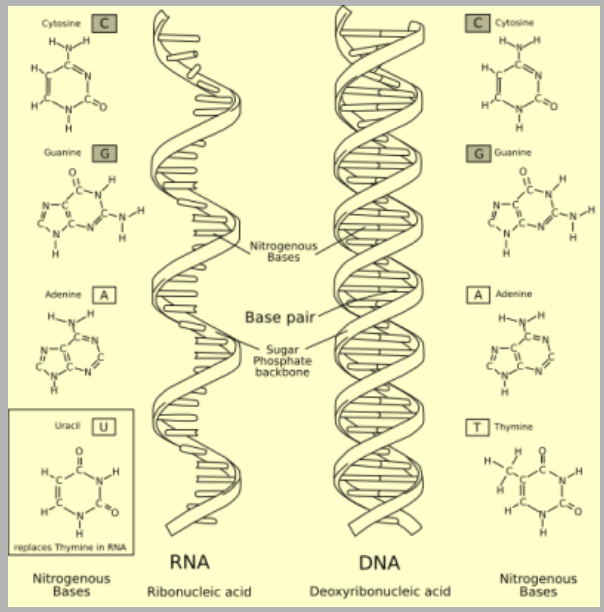
Uracil (U)

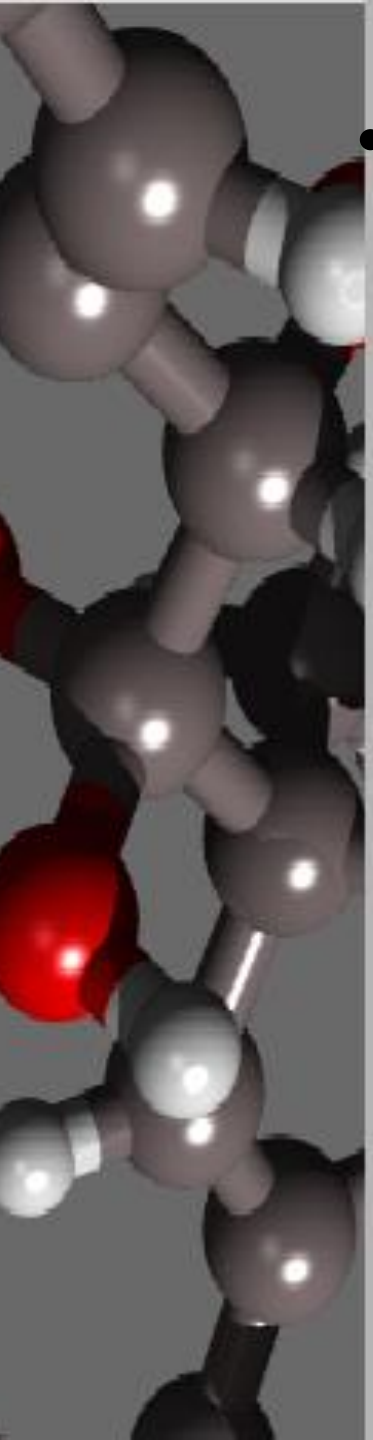
Pyrimidine bases (one rings)



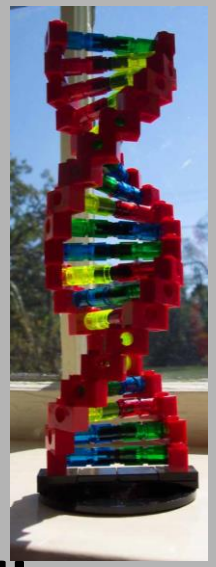
Nucleic Acids

- **Nucleic Acids**
  - **Polymers of nucleotides**
- **2 main types**
  - **DNA**
    - **Deoxyribonucleic Acid**
  - **RNA**
    - **Ribonucleic Acid**

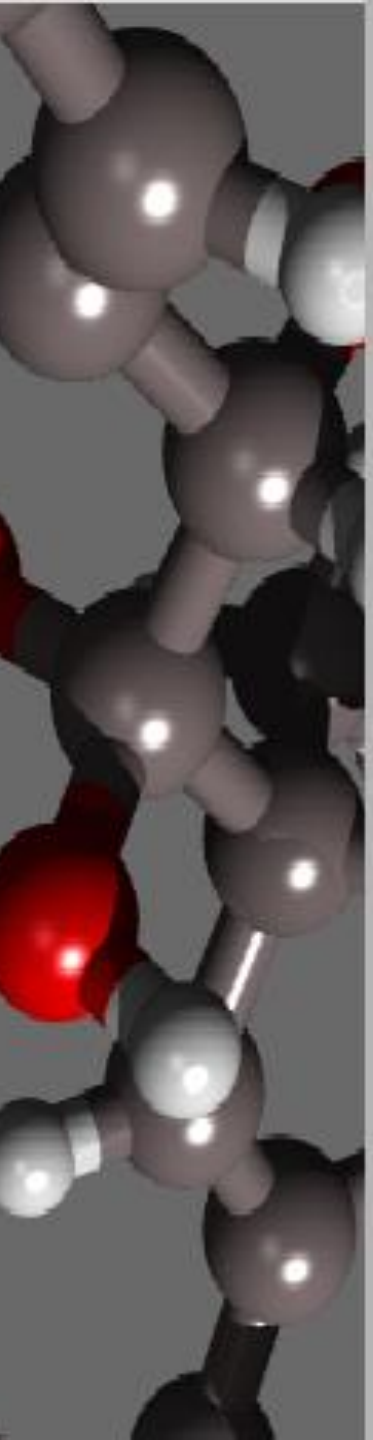




Nucleic Acids



- DNA
  - Deoxyribonucleic Acid
    - Deoxyribo
      - deoxyribose is the type of sugar in DNA
      - Deoxy = missing an oxygen
  - Primarily found in the nucleus of a cell
  - Nitrogenous bases in DNA
    - Adenine (A), Guanine (G), Cytosine (C), Thymine (T)
  - Stores genetic information in the order of the four different bases
    - Controls the production of proteins within the cell by coding for RNA molecules
      - Closely related living species have DNA base sequences that are more similar than distantly related species

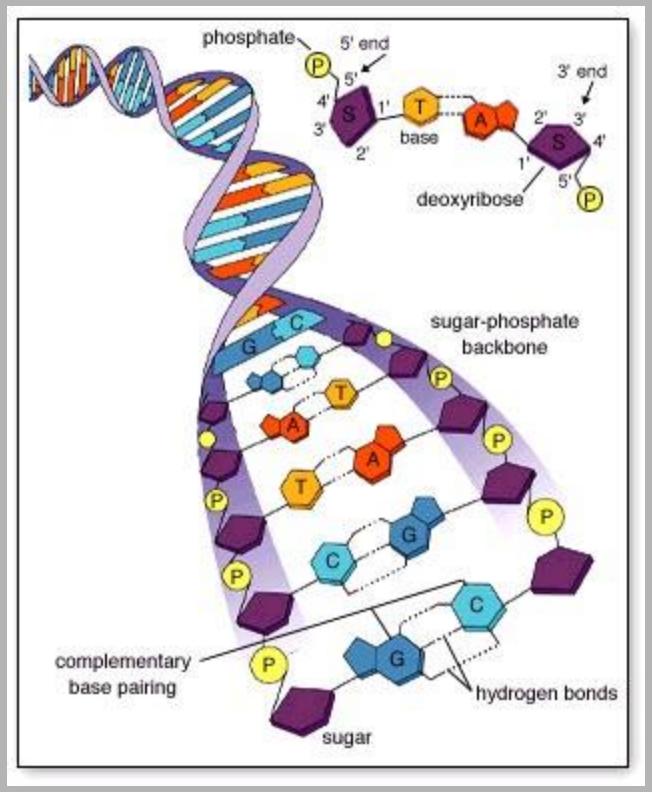


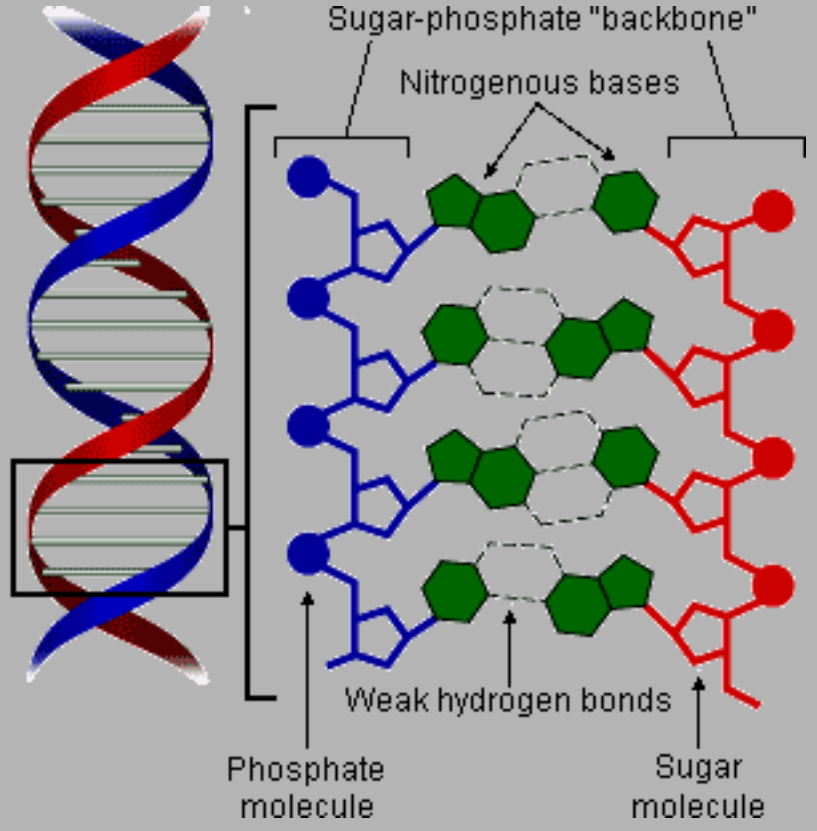
Nucleic Acids

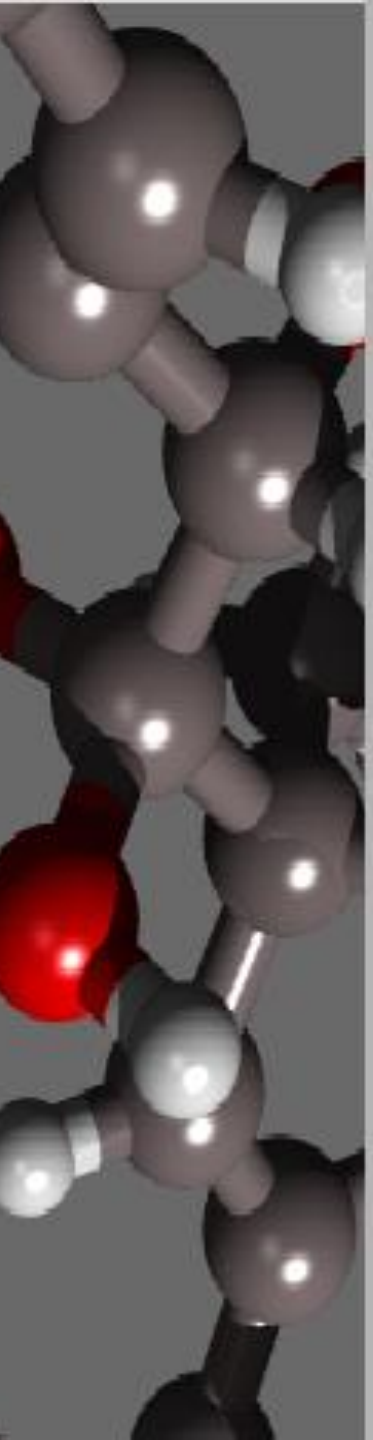
- Double stranded
  - At each position where a purine is found on one strand a pyrimidine is found on the other
    - This maintains three rings in the center of the molecule, so the backbones of the 2 strands maintains a constant distance apart
  - The two strands are held together by the attractions formed my nitrogenous bases in the center of the double stranded molecule
    - The attractions are hydrogen bonds
  - Chargaff's Rule
    - Where A is found on one strand, a T is found at the same point in the complementary strand.
    - Wherever a G is found on one strand, a c is found on the other
    - It is between these bases that hydrogen bonds form, linking the two complementary strands.

Nucleic Acids

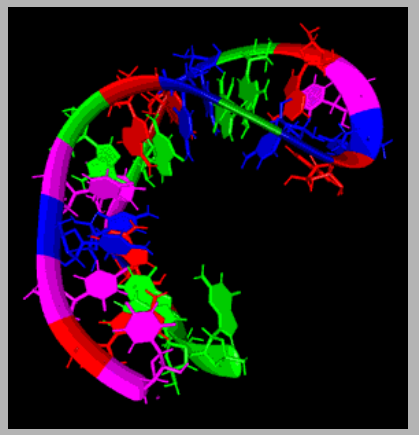
- **DNA molecule**



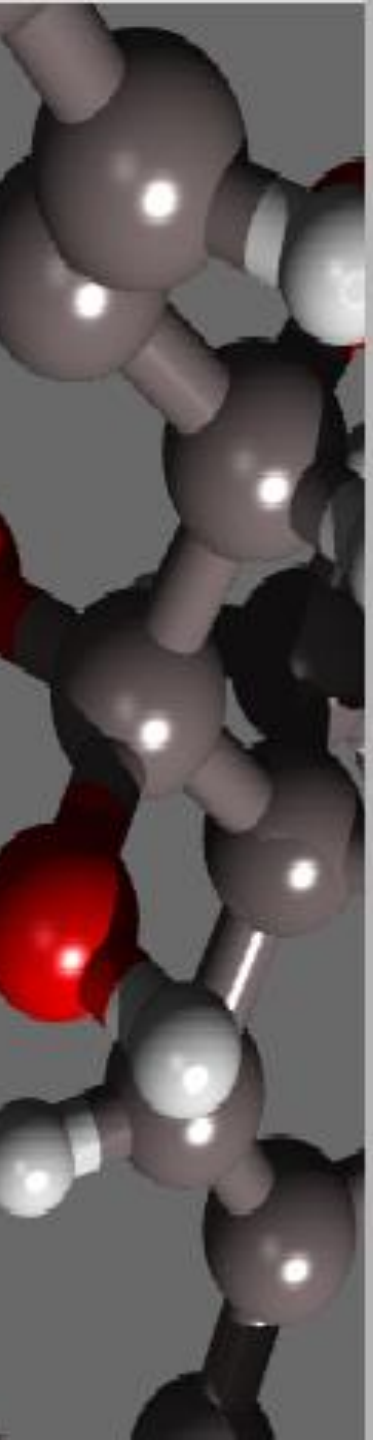




Nucleic Acids

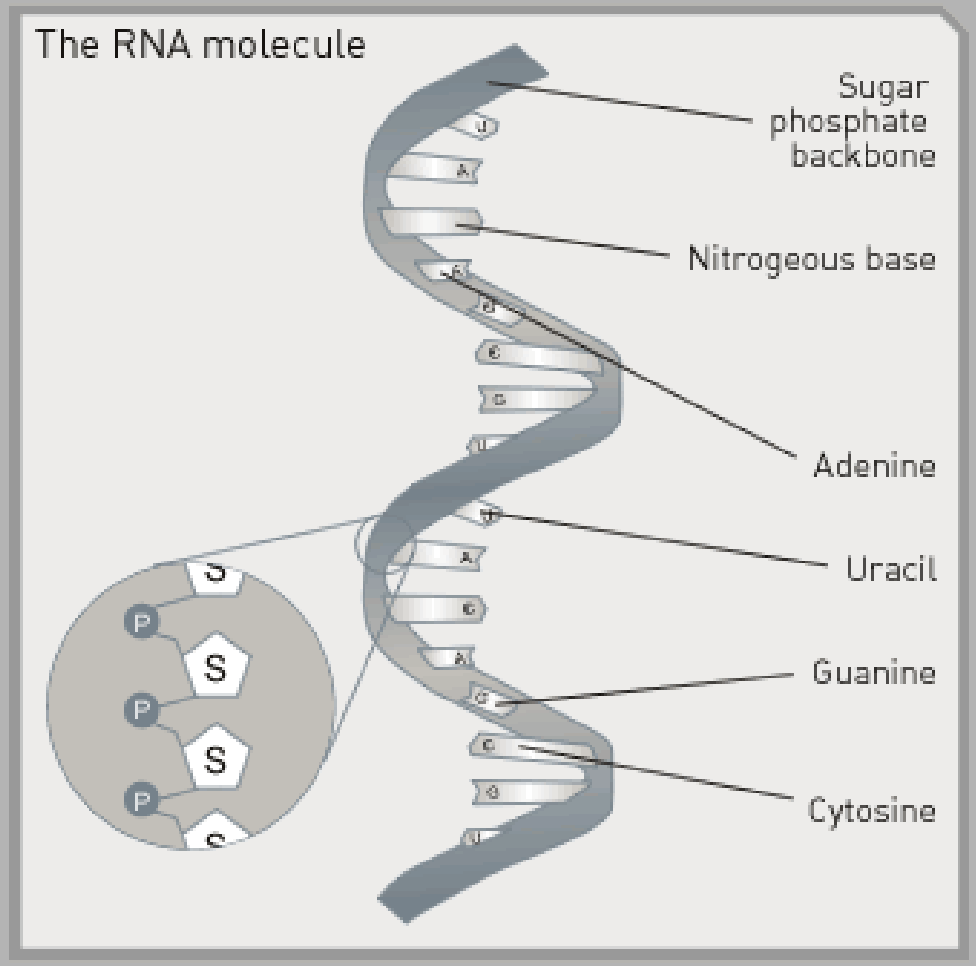


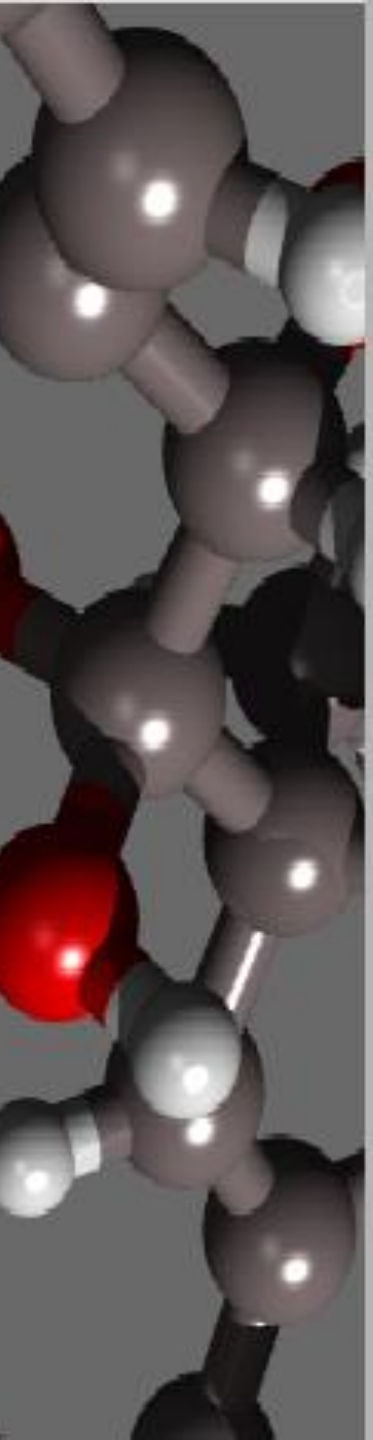
- RNA
  - Ribonucleic Acid
    - Ribo
      - Ribose is the type of the sugar in RNA
  - Nitrogenous bases in RNA
    - Adenine, Guanine, Cytosine, Uracil (U)
  - Stores and transfers genetic information
    - Found in the nucleus and cytoplasm
  - The information in RNA molecules is decoded to specify the sequence of amino acids in proteins (protein synthesis)
  - 3 types; mRNA (messenger), tRNA (transfer), rRNA (ribosomal)



Nucleic Acids

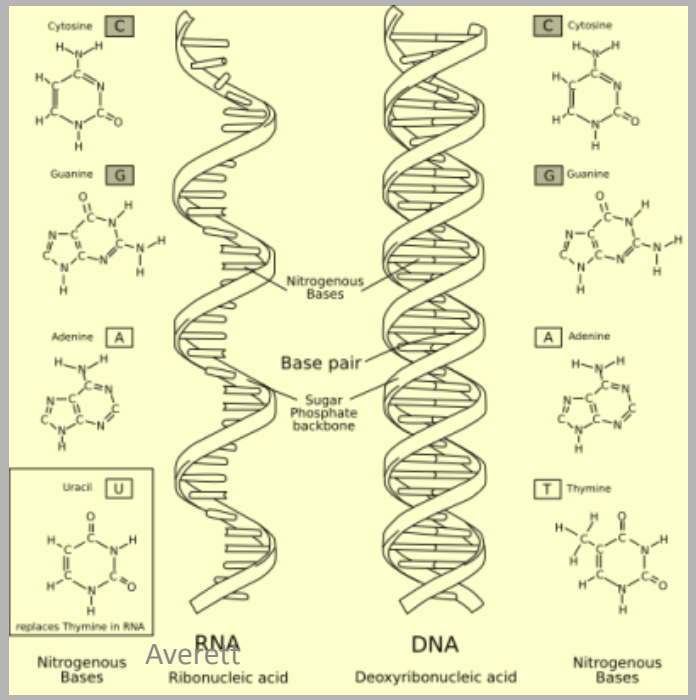
- **RNA**

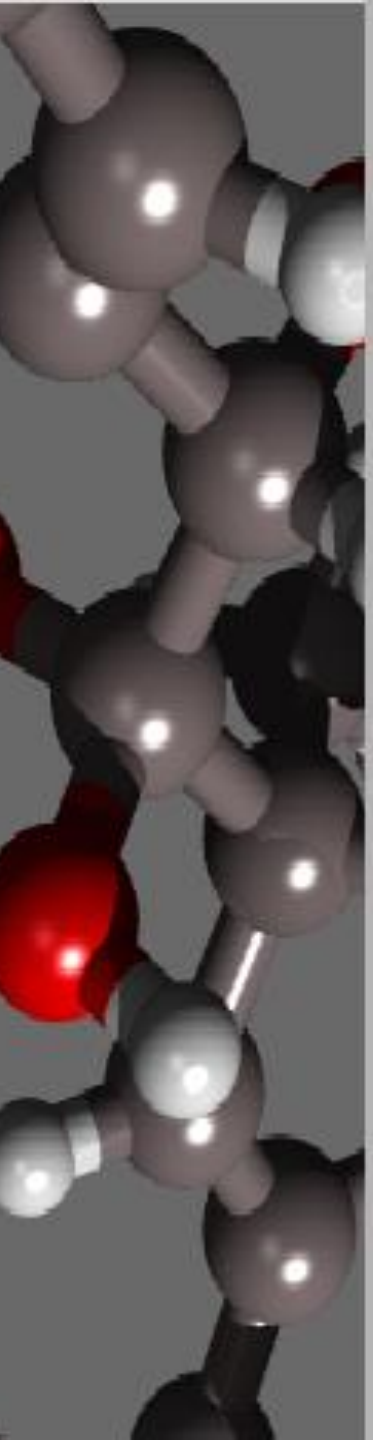




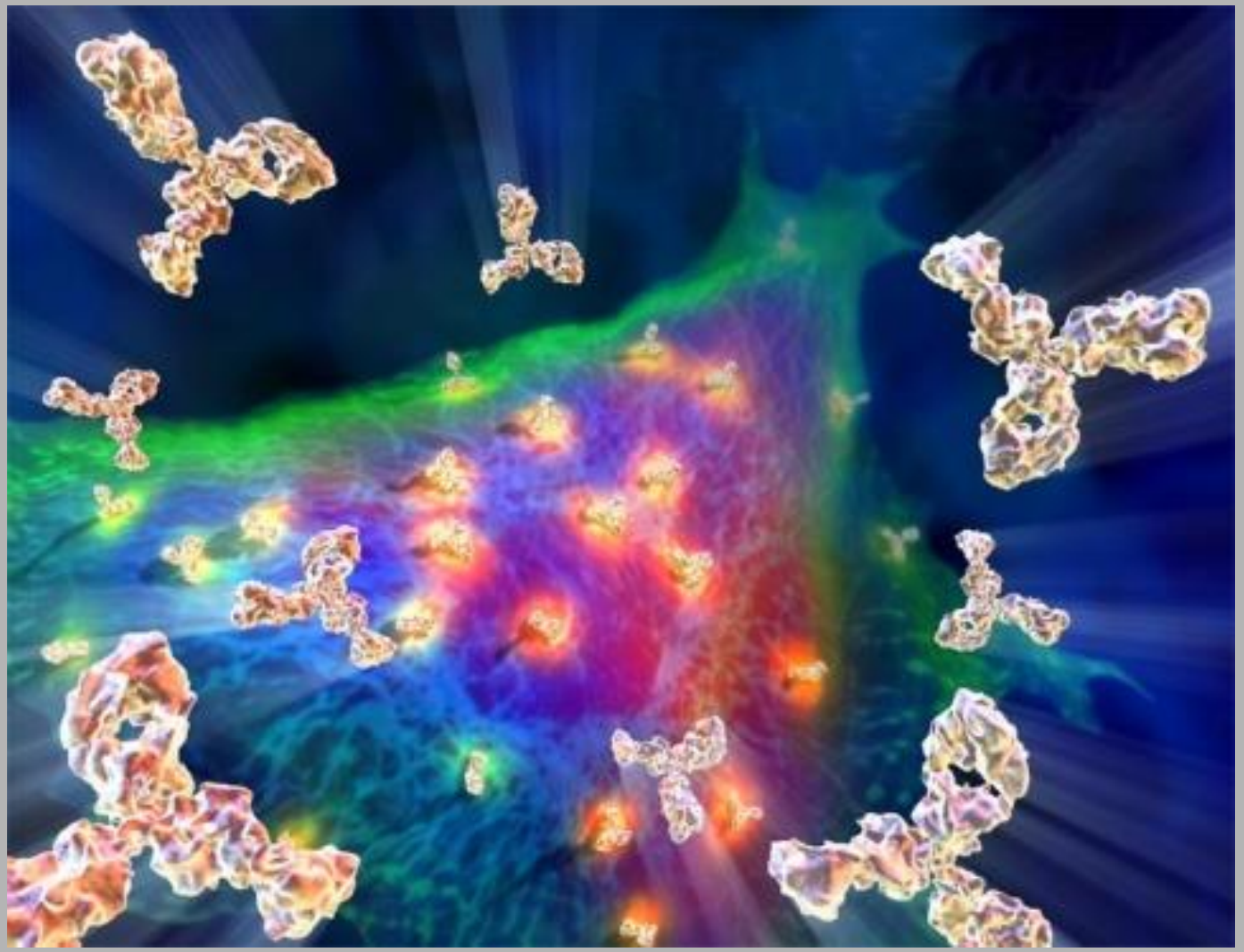
Nucleic Acids

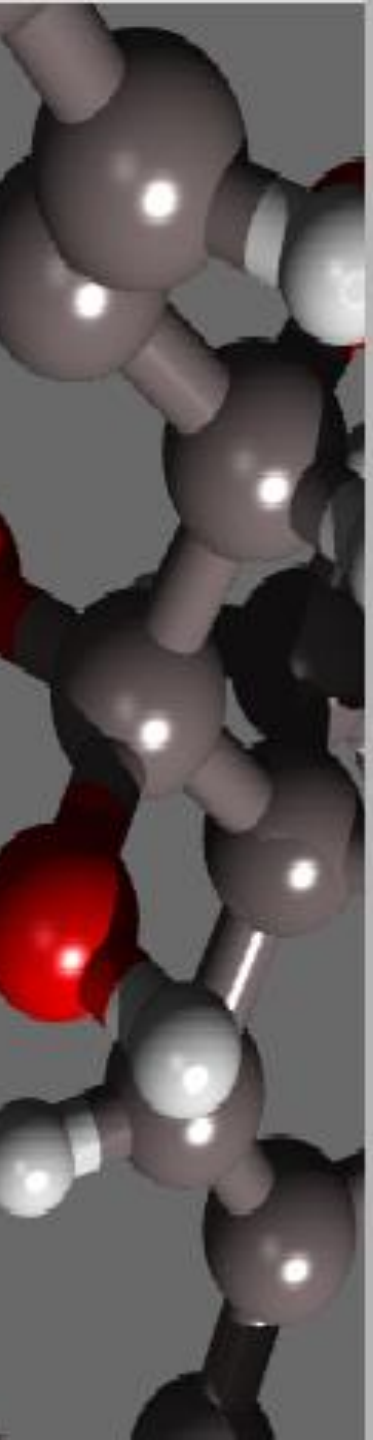
- Compare DNA and RNA
  - Deoxyribose versus Ribose
  - Thymine versus Uracil
  - DNA is a double strand, RNA is a single strand
  - Functions





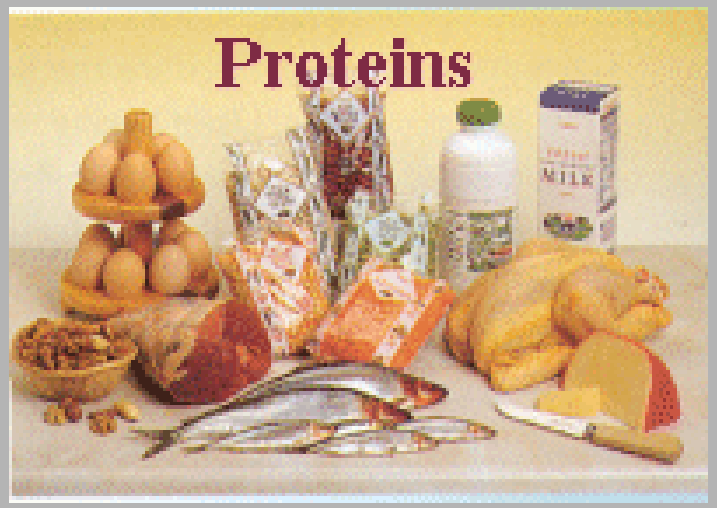
Proteins

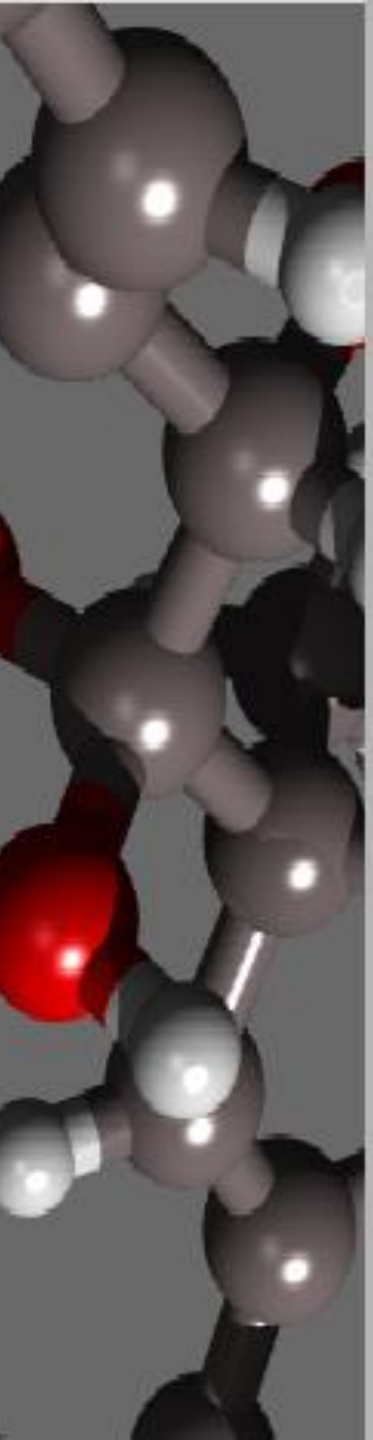




Proteins

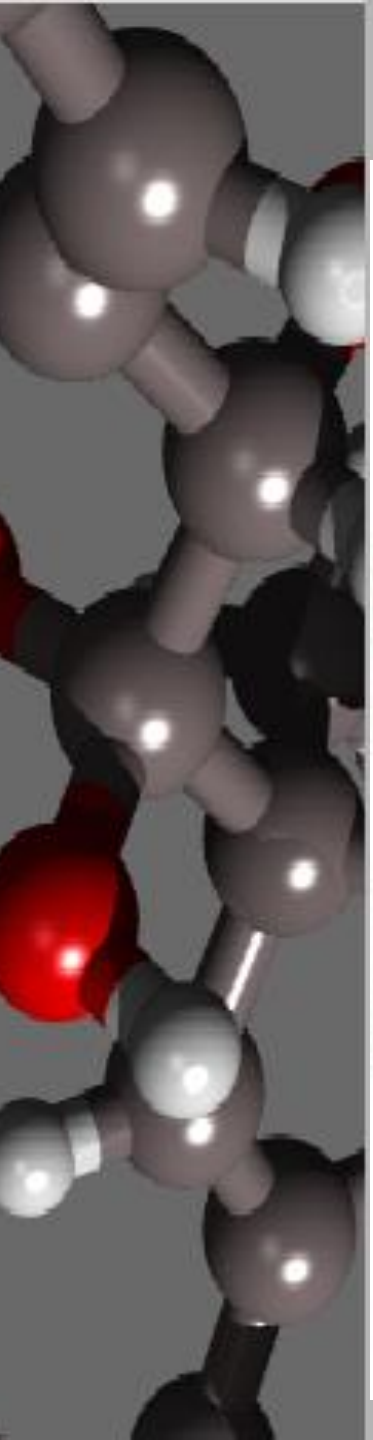
- Chemical composition
  - Contains Carbon, Hydrogen, Oxygen, Nitrogen and Sulfur
- Common sources
  - Milk products
  - Eggs and poultry
  - Meat
  - Fish and shellfish
  - legumes





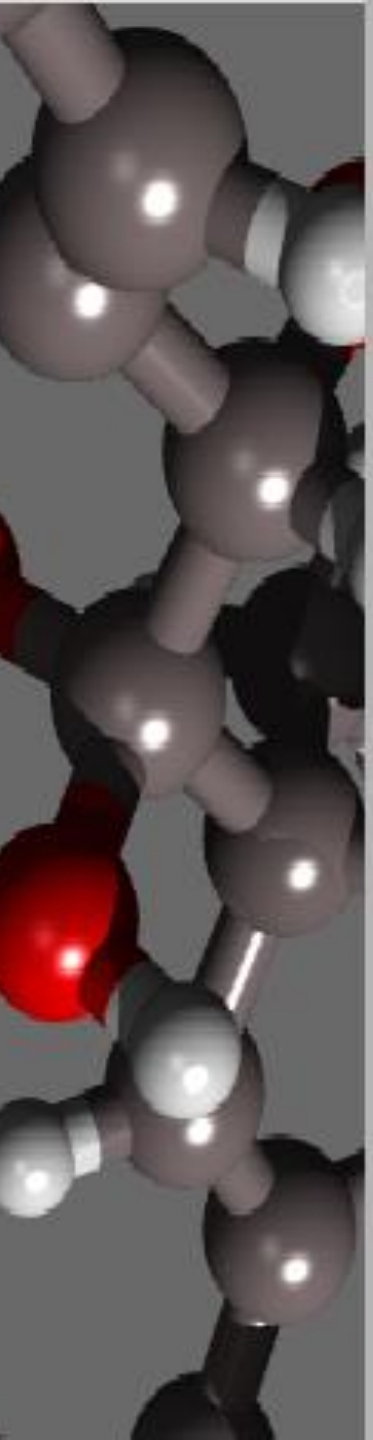
Proteins

- **Proteins are molecules with diverse structures and functions.**
  - **Structural support in tissues outside of the cell including bones, cartilage, tendons, ligaments, and collagen**
  - **Help store and transport other substances**
  - **Help defend the body against foreign substances (bacteria, viruses, etc) in the form of antibodies**
  - **Help speed up certain chemical reactions in the cell in the form of enzymes.**
  - **Help maintain homeostasis and regulate cell processes in the form of hormones.**
  - **Found in muscle tissue and aid in movement.**



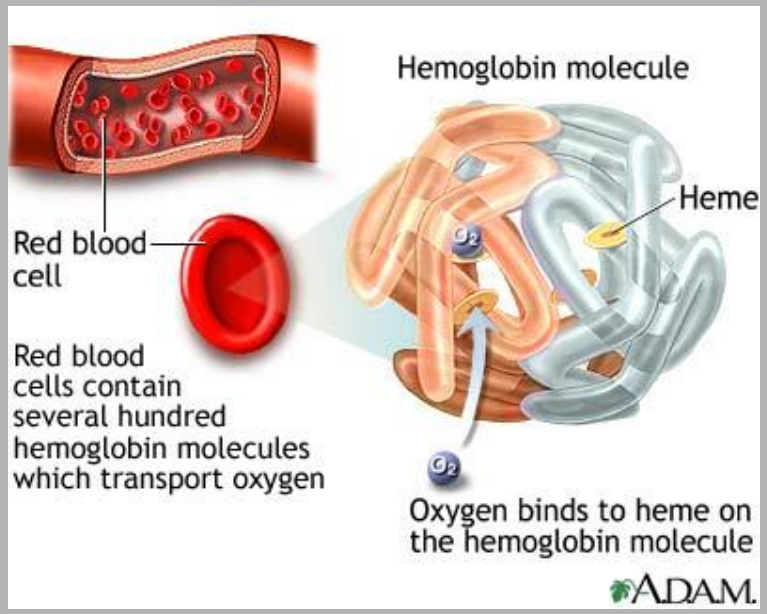
Proteins

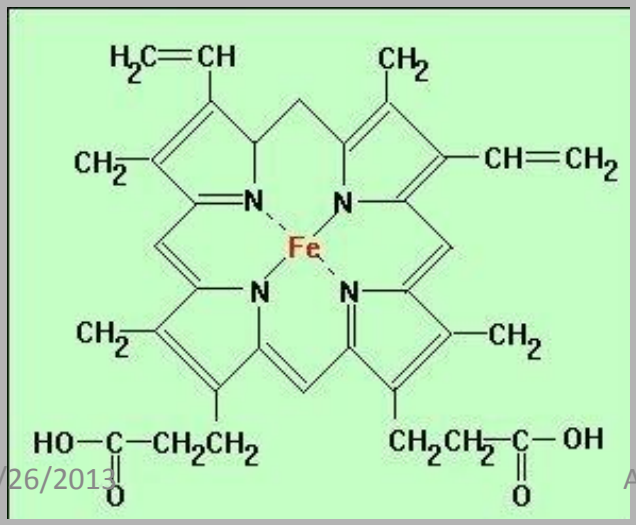

Hair and Nails
A protein called alpha-keratin forms your hair and fingernails,and also is the major component of feathers, wool, claws, scales, horns, and hooves.
Blood
The hemoglobin protein carries oxygen in your blood to every part of your body.
Muscles
Muscle proteins called actin and myosin enable all muscular movement—from blinking to breathing to rollerblading.
Brain and Nerves
Ion channel proteins control brain signaling by allowing small molecules into and out of nerve cells.
Cellular Messengers
Receptor proteins stud the outside of your cells and transmit signals to partner proteins on the inside of the cells.
Enzymes
Enzymes in your saliva, stomach, and small intestine are proteins that help you digest food.
Antibodies
Antibodies are proteins that help defend your body against foreign invaders, such as bacteria and viruses.
Cellular Construction Workers
Huge clusters of proteins form molecular machines that do your cells' heavy work, such as copying genes during cell division and making new proteins.

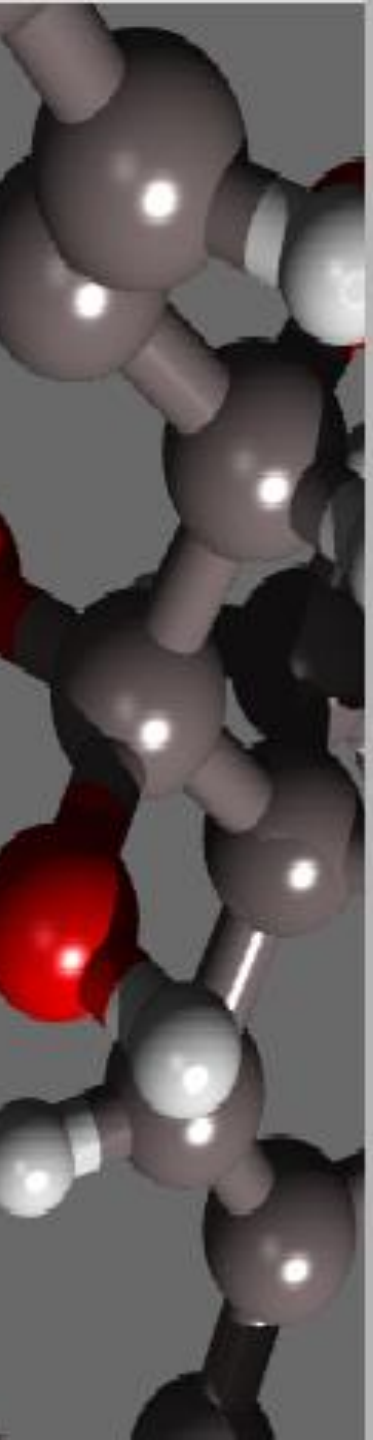


Proteins

- **Common examples:**
  - **Blood**
  - **Insulin**
  - **Mucus**
  - **Keratin**

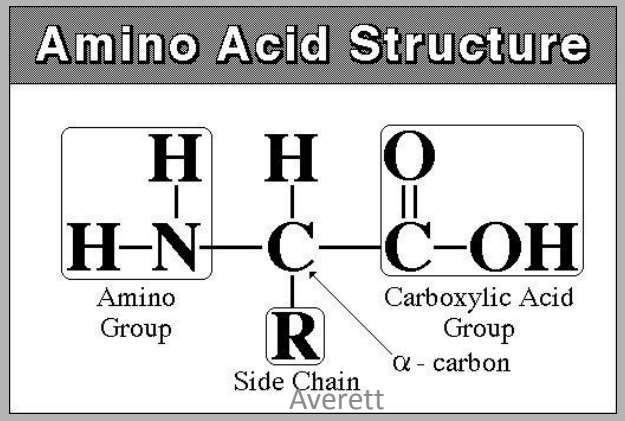




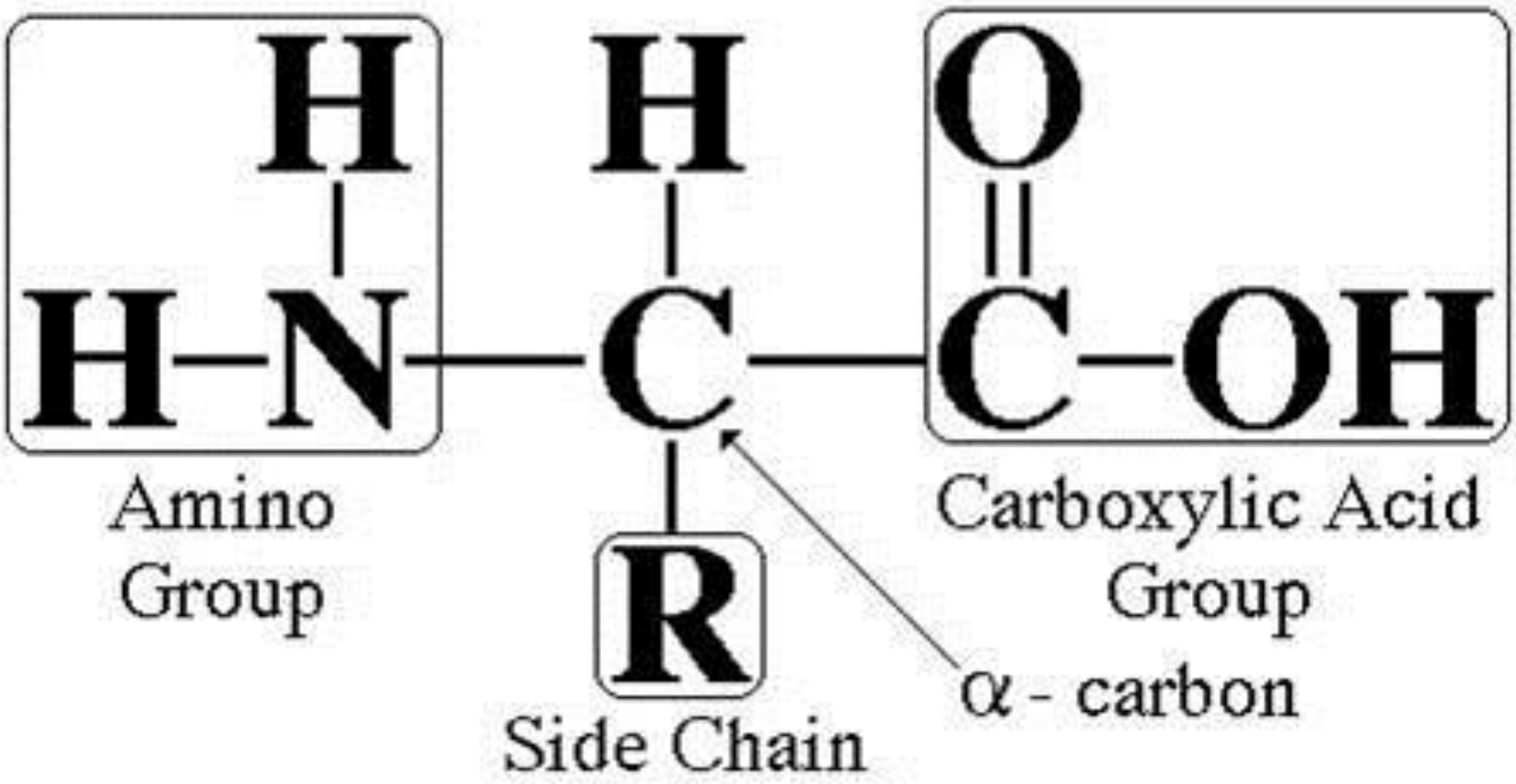


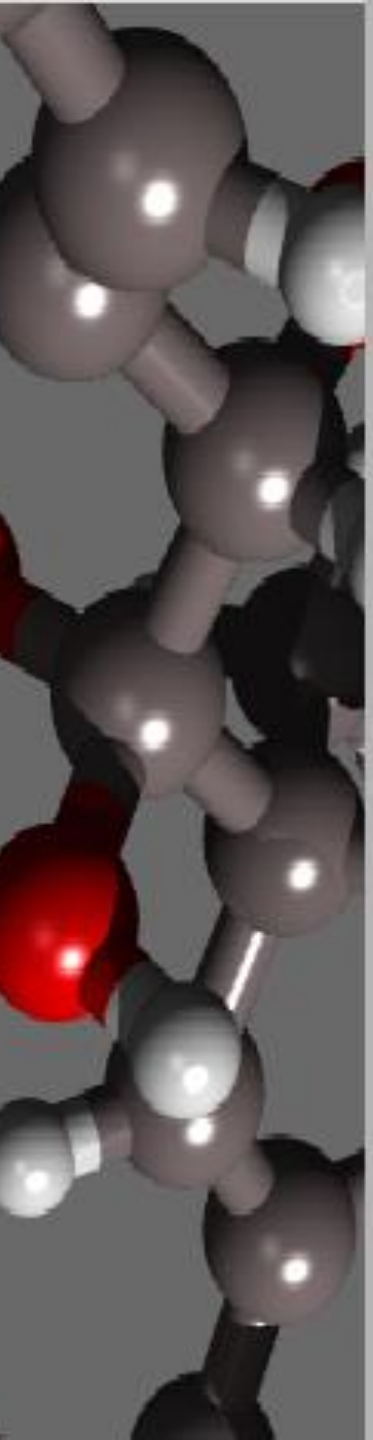
Proteins

- **Amino Acids**
  - **Monomers of proteins**
  - **20 different types – only the "R" side chain changes**
  - **All have same basic structure**
    - **A hydrogen atom, an amino group, a carboxyl group, and an "R" group are bonded to a central carbon.**



Amino Acid Structure



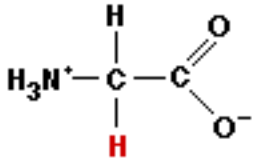


Proteins

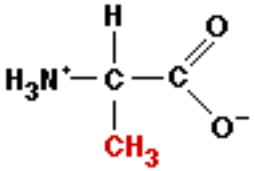
- **Functional groups include**
  - **Amino group**
    - **Nitrogen containing part of an amino acid**
    - **(NH_3^+)**
  - **Carboxyl groups**
    - **The acid part of an amino acid is a carboxyl group**
    - **(COO^-)**
  - **Sulfhydryl groups**
    - **Form disulfide bonds between amino acids in polypeptides**
    - **(SH)**

Proteins

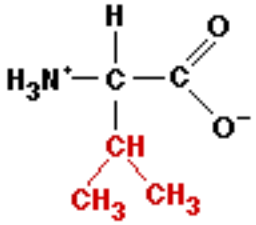
- **Amino acids**



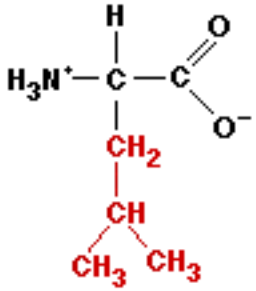
Glycine (Gly)



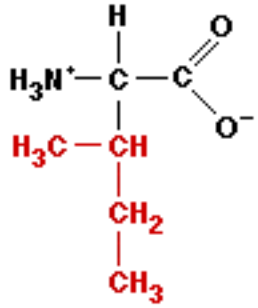
Alanine (Ala)



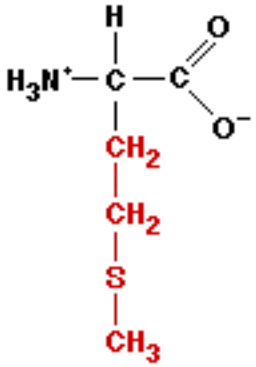
Valine (Val)



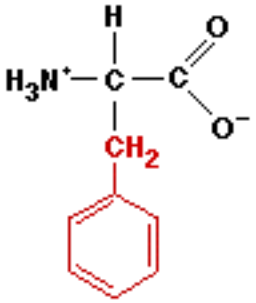
Leucine (Leu)



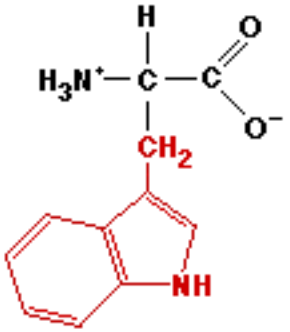
Isoleucine (Ile)



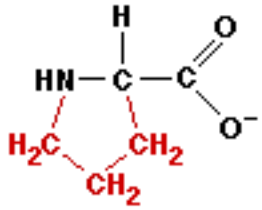
Methionine (Met)



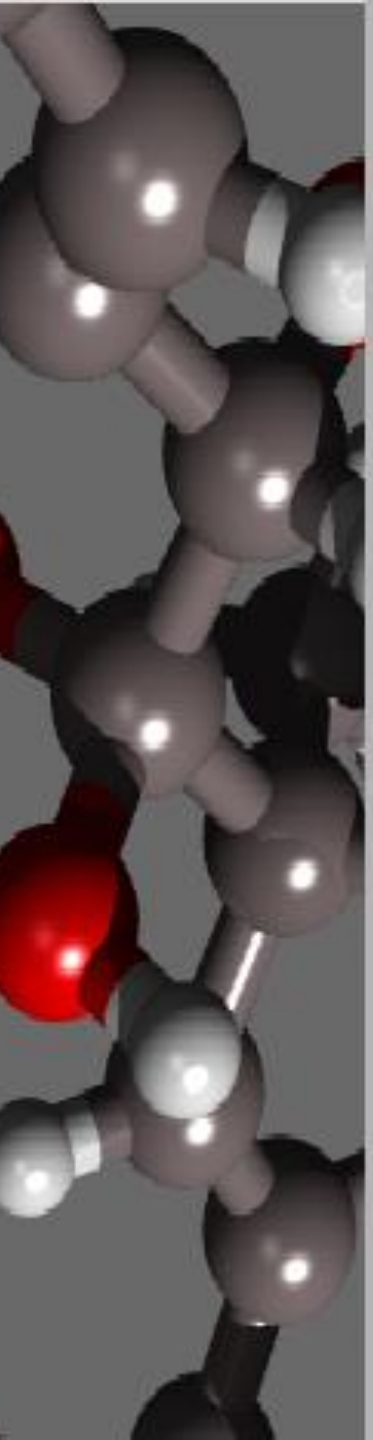
Phenylalanine (Phe)



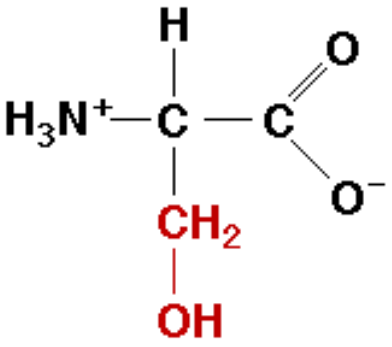
Tryptophan (Trp)



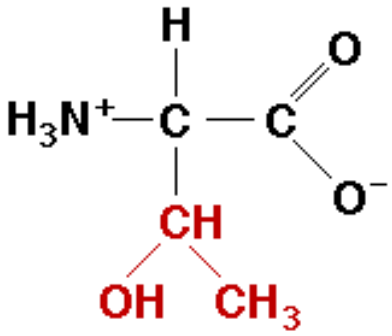
Proline (Pro)



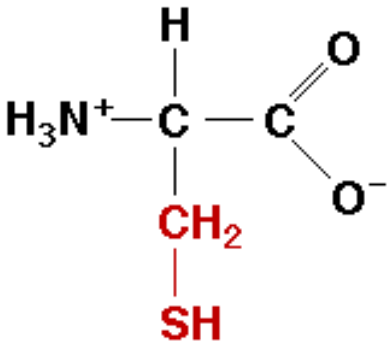
Proteins



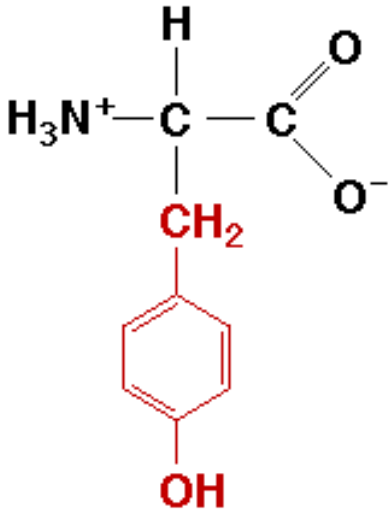
Serine (Ser)



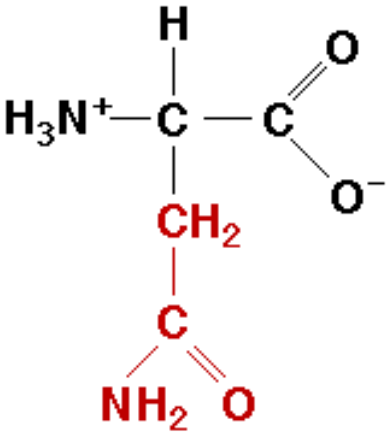
Threonine (Thr)



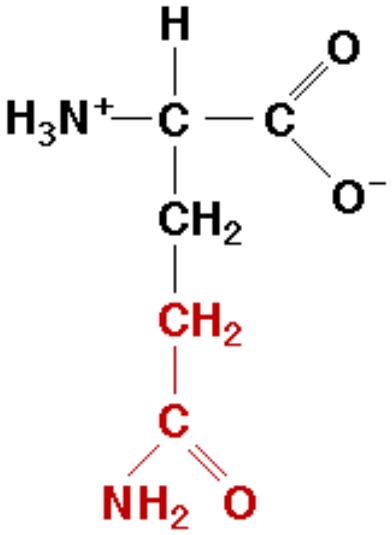
Cysteine (Cys)



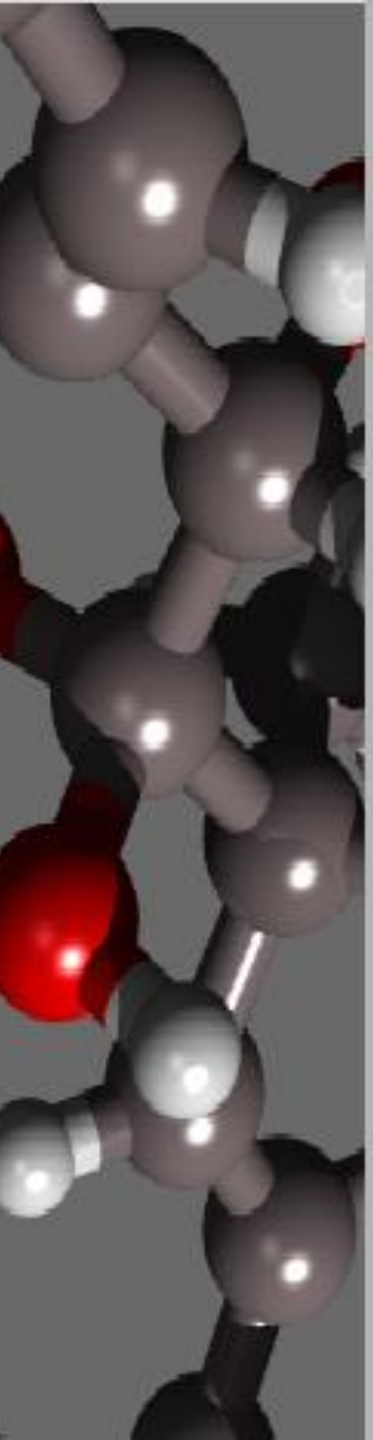
Tyrosine (Tyr)



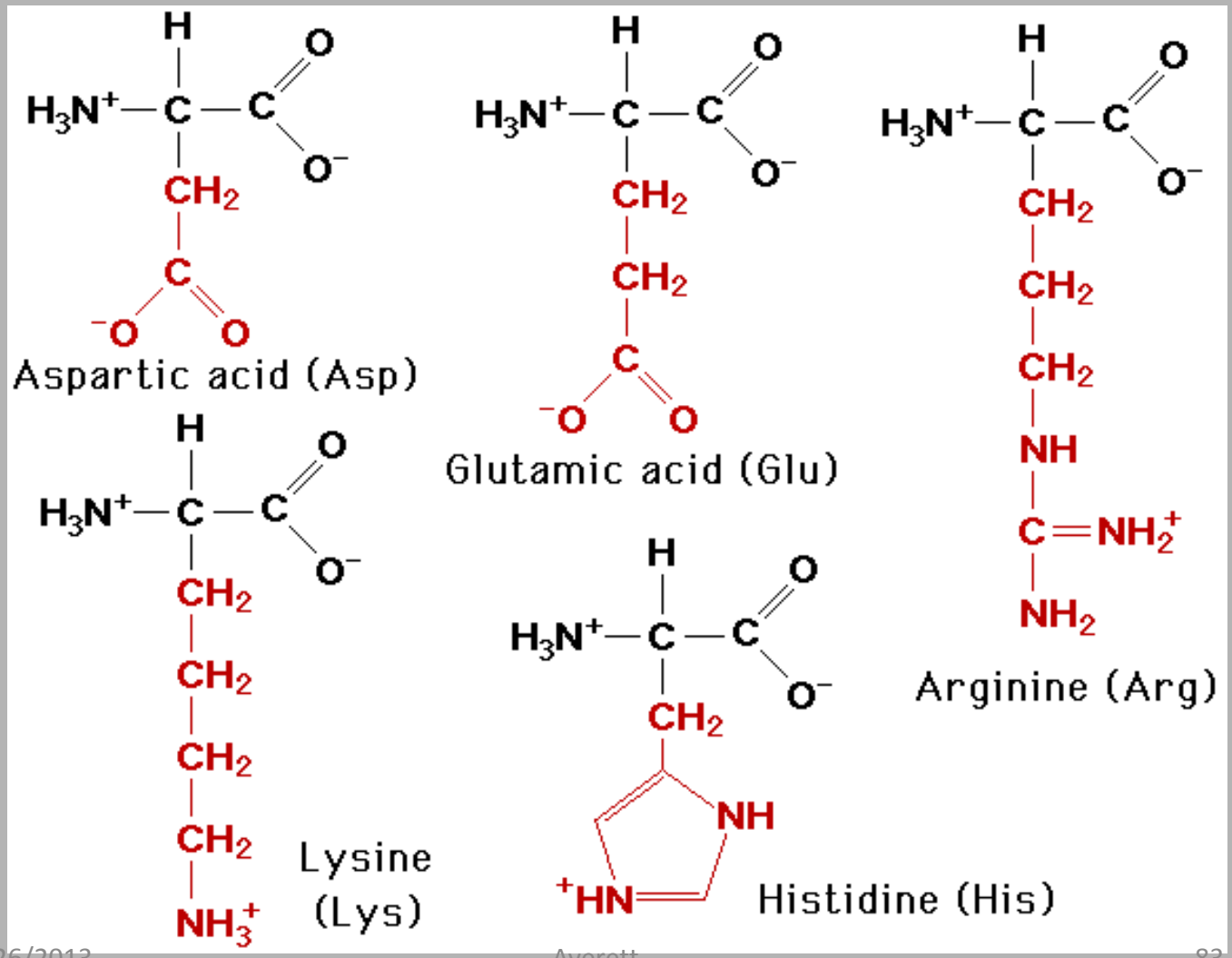
Asparagine (Asn)

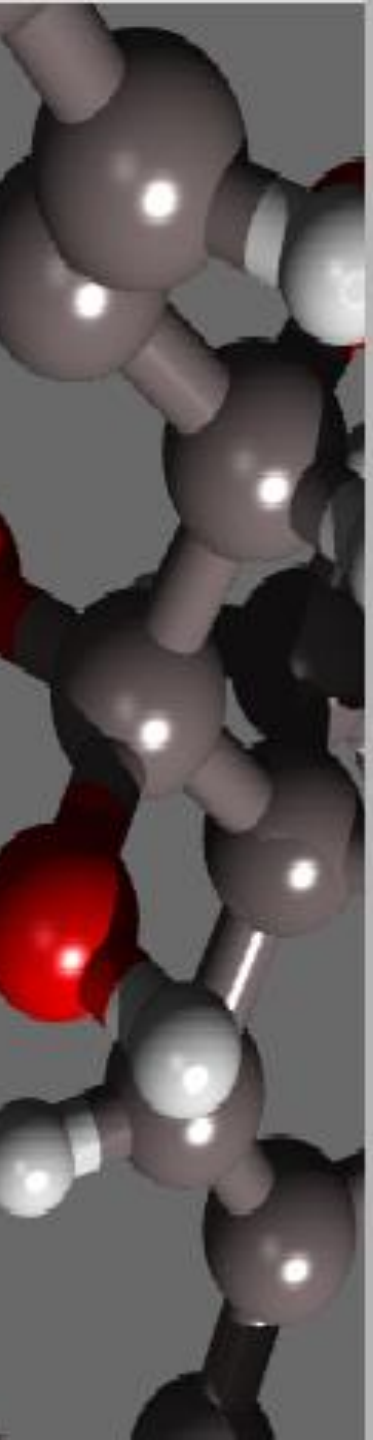


Glutamine (Gln)



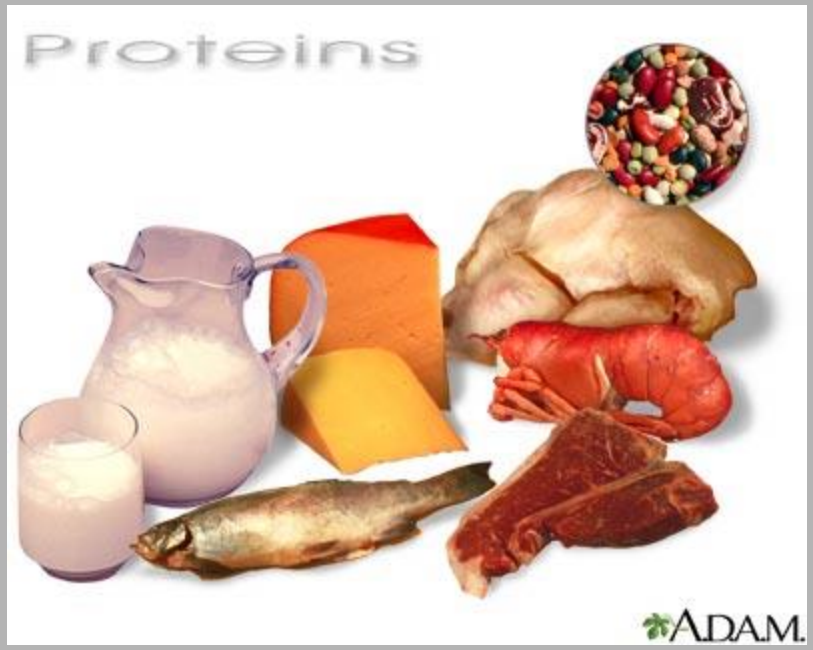
Proteins


Aspartic acid (Asp)
Glutamic acid (Glu)
Arginine (Arg)
Lysine (Lys)
Histidine (His)

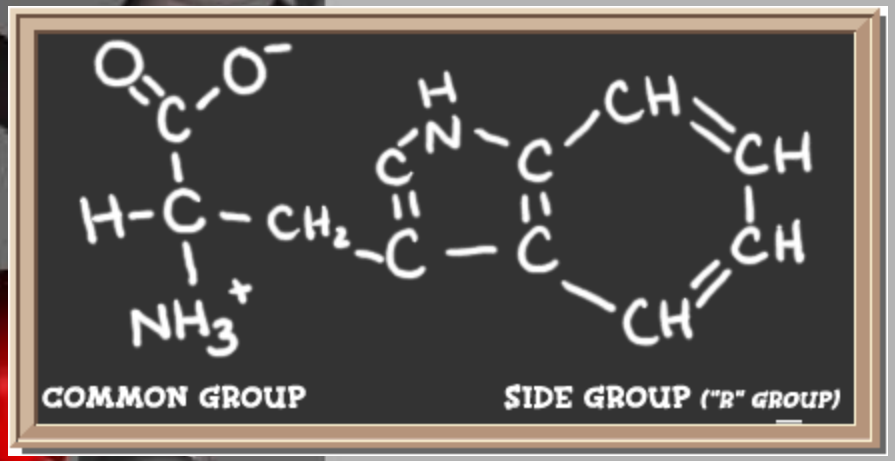


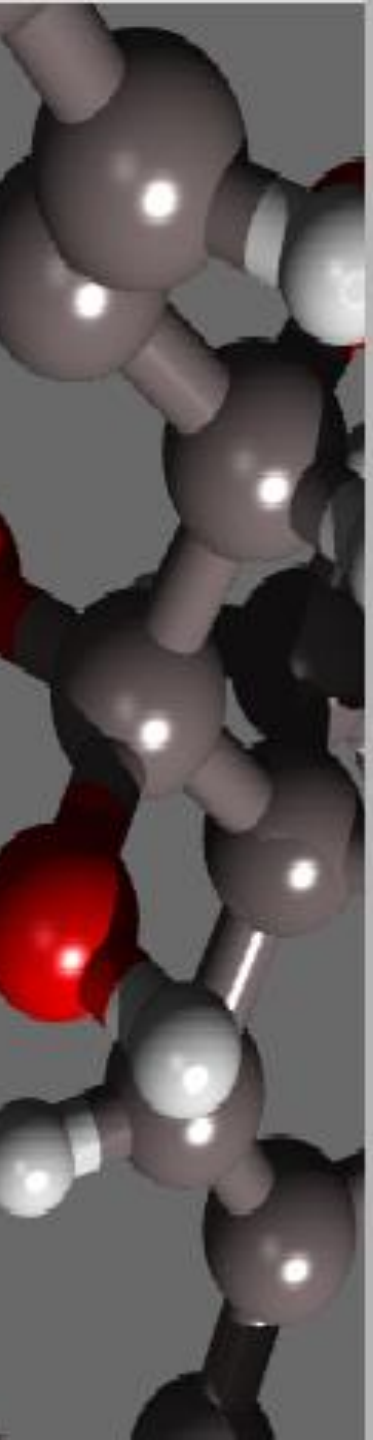
Proteins

- **Eight essential amino acids for humans:**
  - **All come from combination of grains (1-6) and legumes (3-8)**
    - **Tryptophan**
    - **Methionine**
    - **Valine**
    - **Threonine**
    - **Phenylalanine**
    - **Leucine**
    - **Isoleucine**
    - **Lysine**



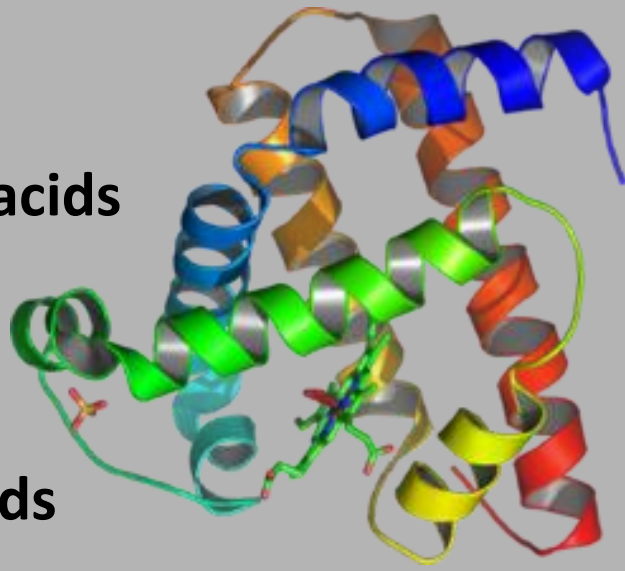
- **Amino Acid examples**
  - **Tryptophan**

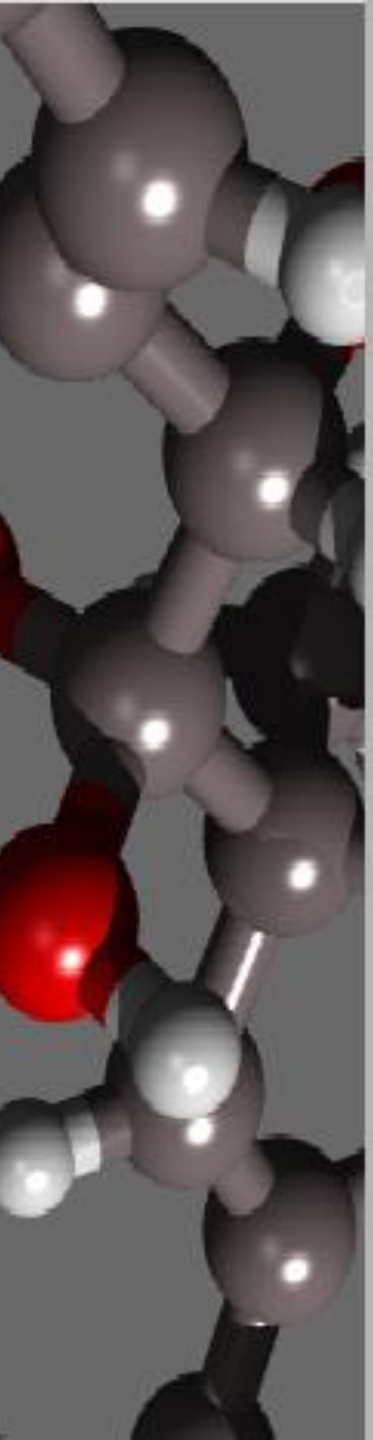




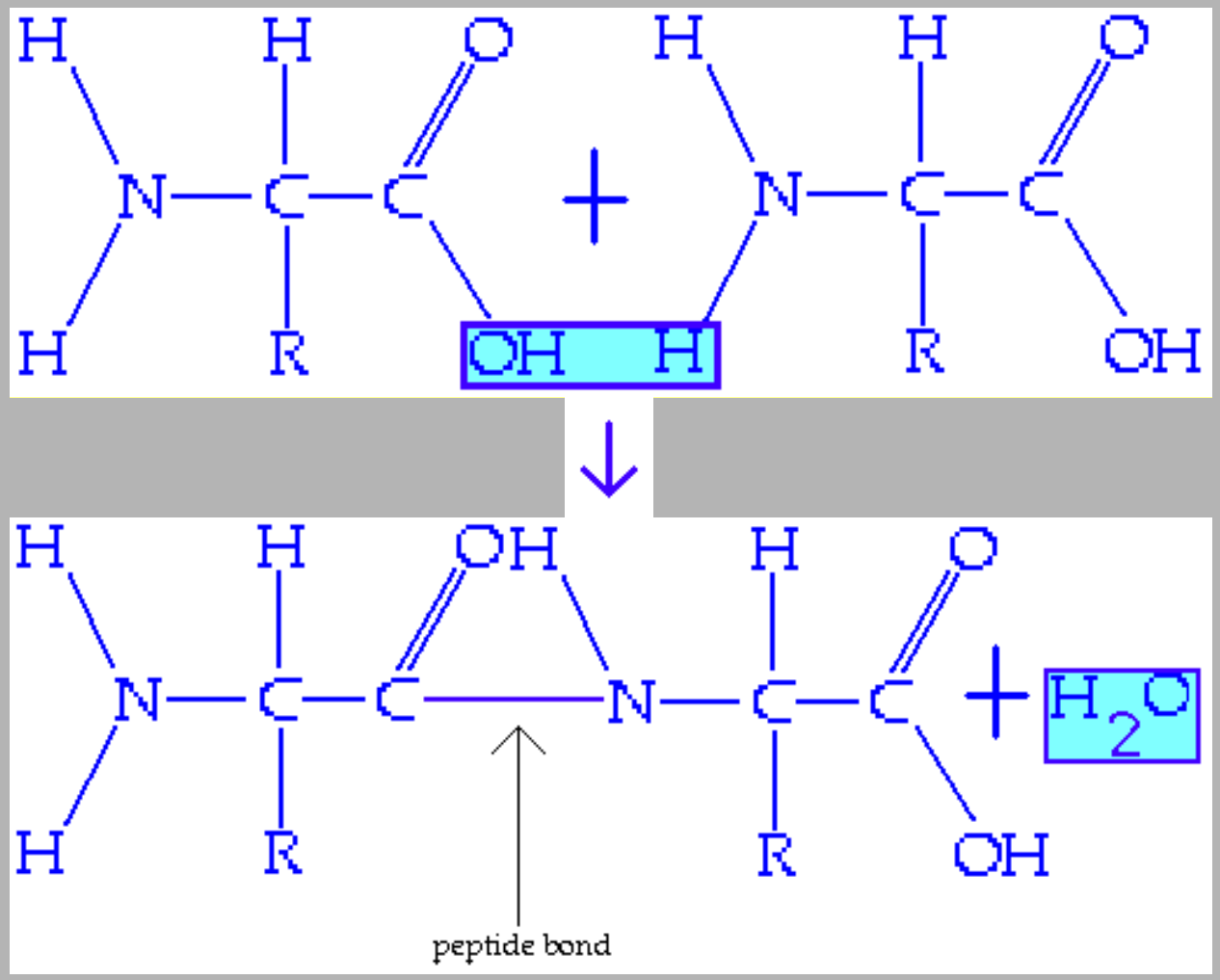
Proteins

- Amino acids are linked together by peptide bonds
  - Condensation reaction between the amino group of one amino acid and the carboxyl group of another
- Dipeptides
  - Short chains of 2 amino acids
- Polypeptides
  - Polymer of amino acids
  - Long chains of amino acids

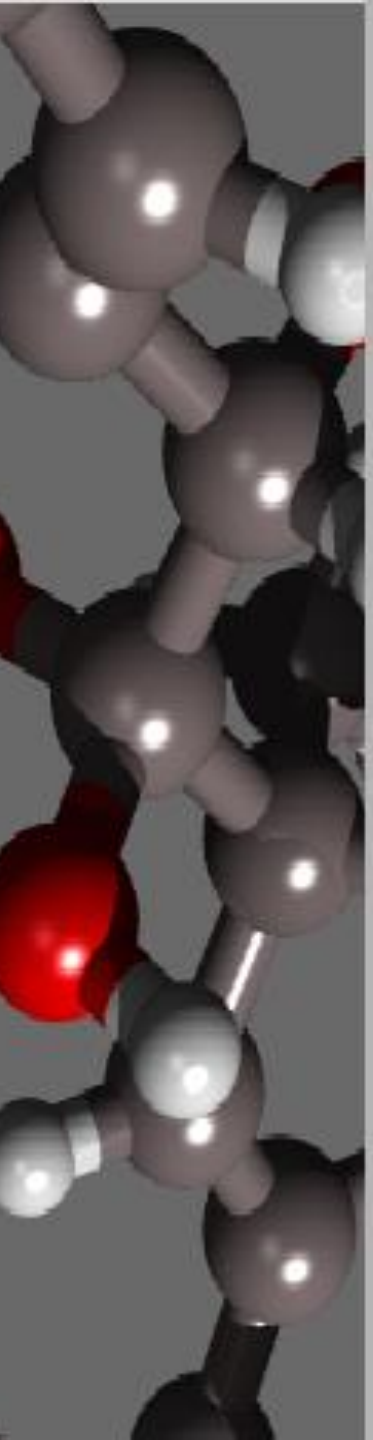




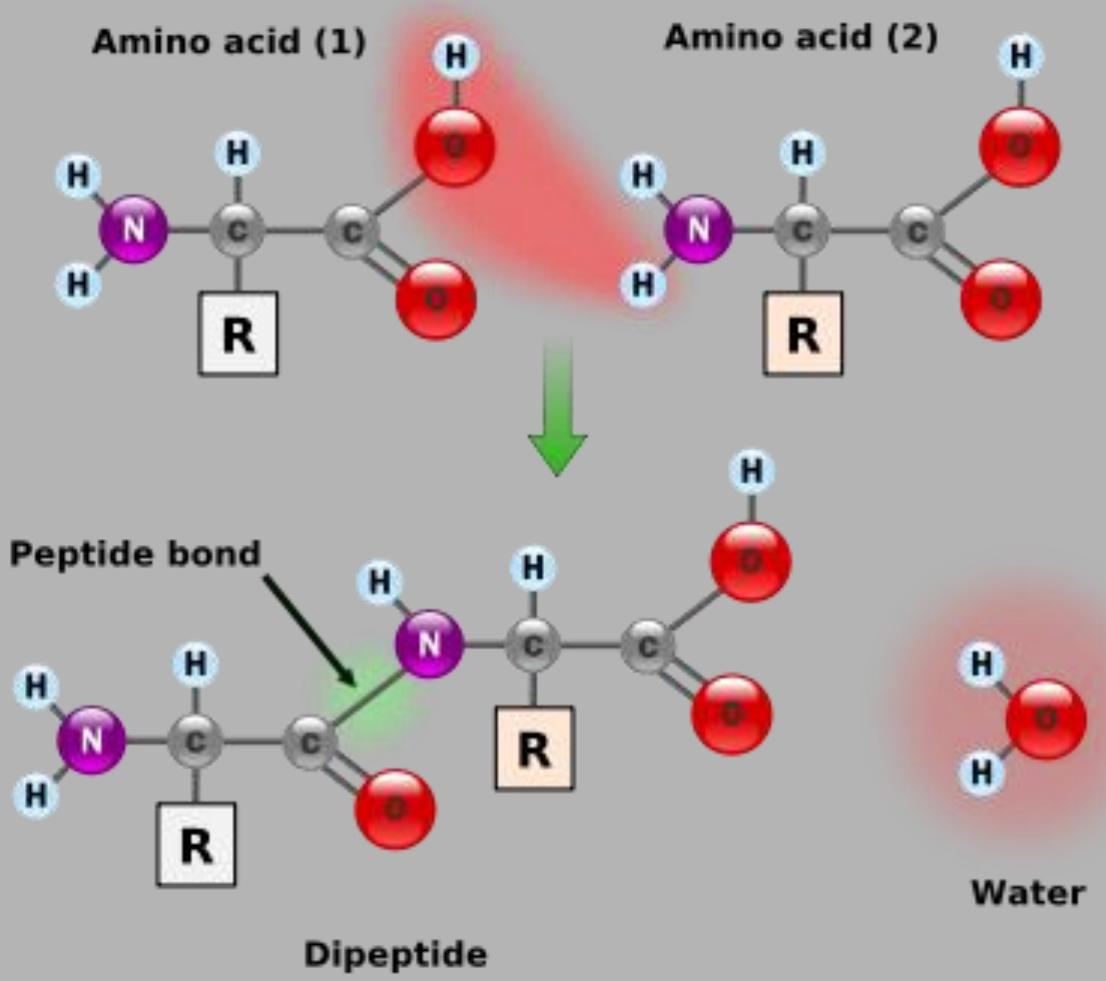
Formation of a Dipeptide

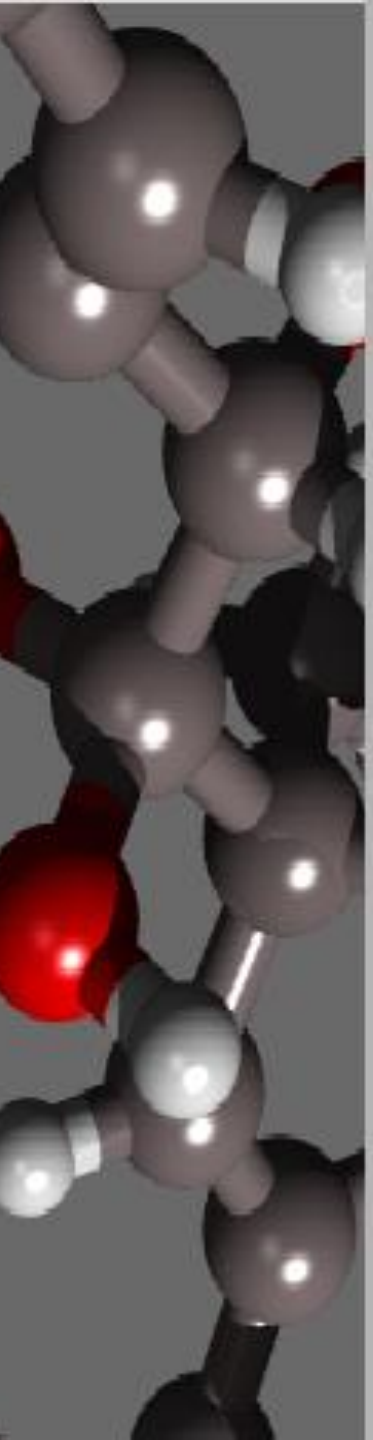


Dehydration synthesis



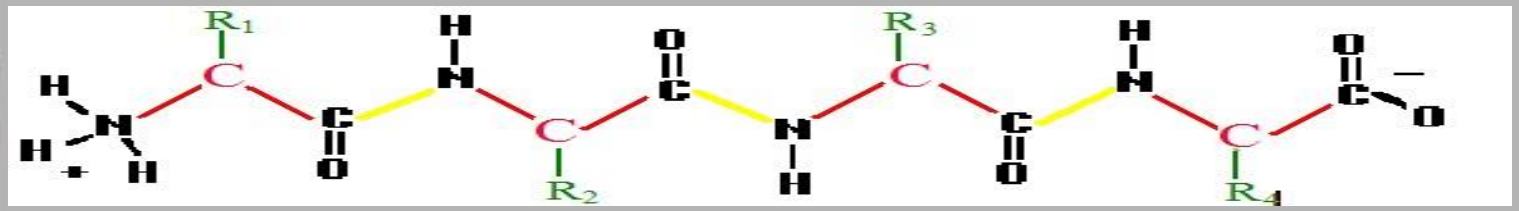
Proteins

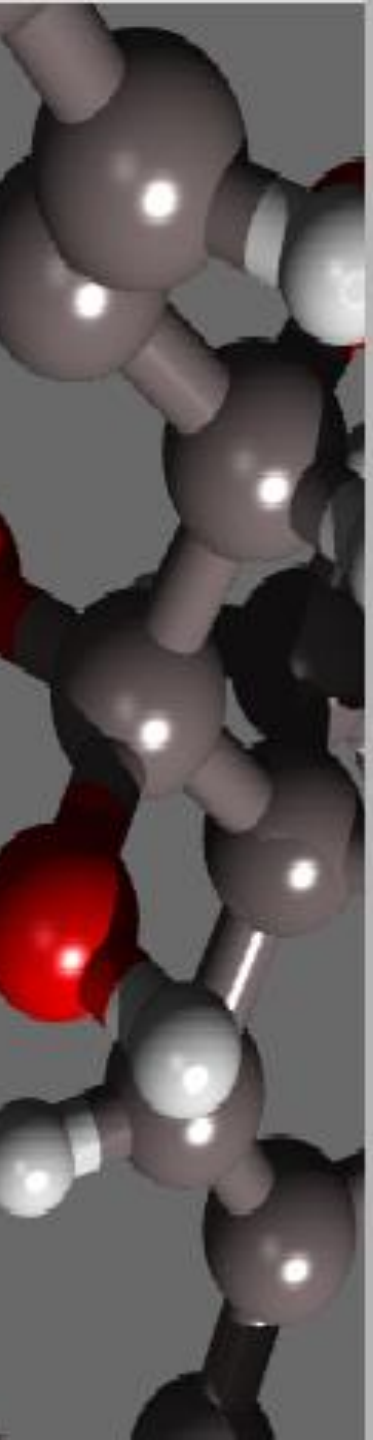




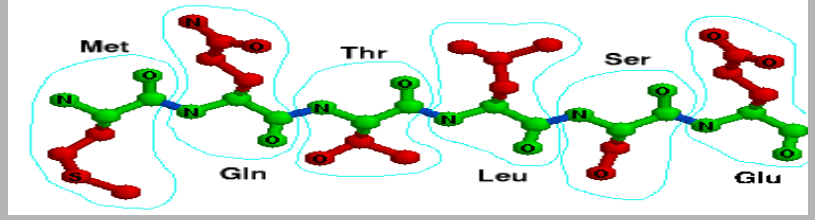
Proteins

- **Proteins range in size from a few amino acids to thousands**
  - **Some proteins are composed of a single chain of amino acids**
  - **Other proteins have more than one polypeptide chain.**
  - **Each type of protein has a characteristic amino acid composition and order**





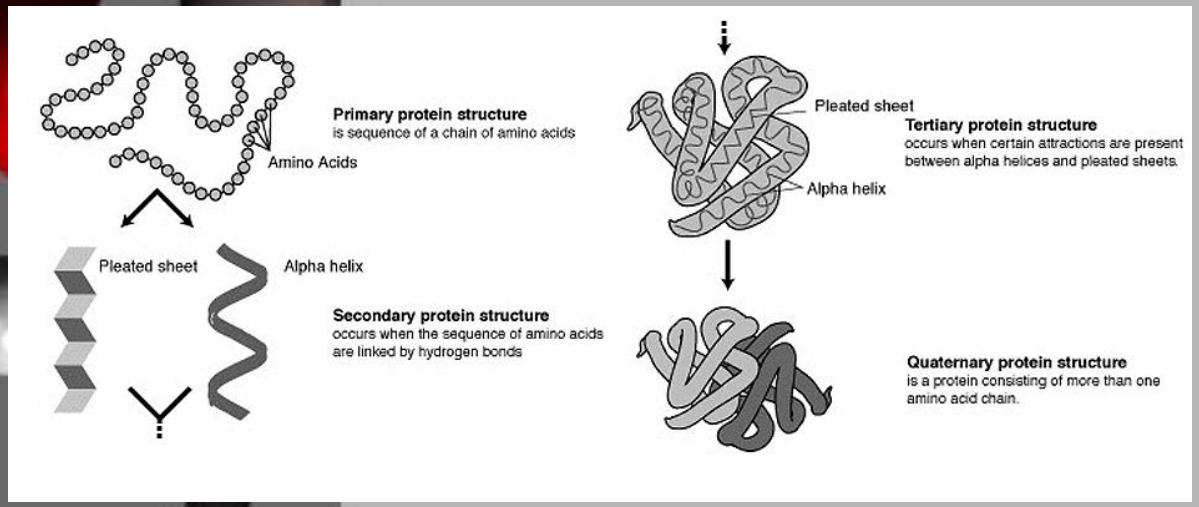
Proteins

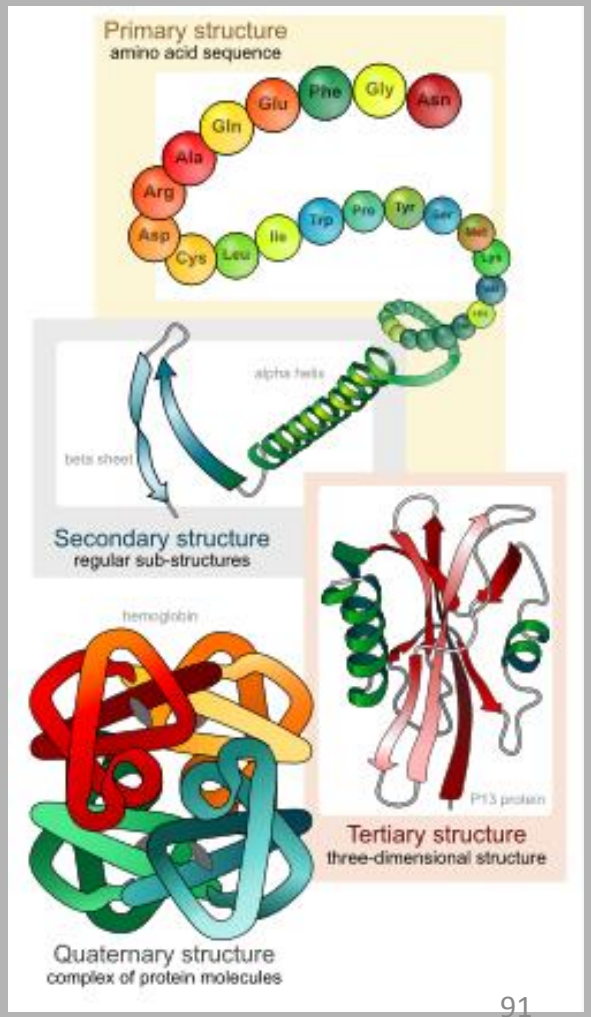


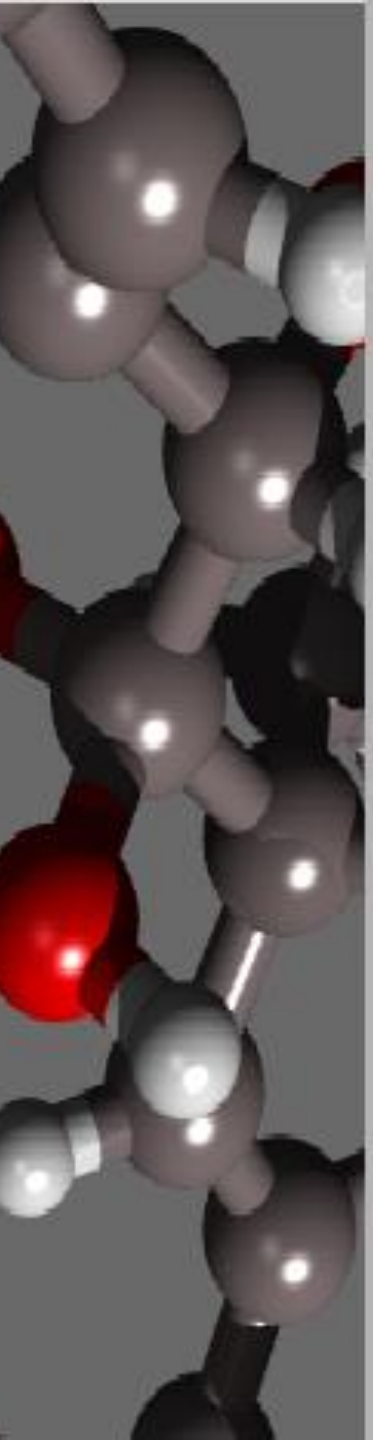
- The type of protein being made is determined by the order of the amino acids in the chain
  - Amazing numbers of different proteins are possible
    - With 20 amino acids, 400 different dipeptides are possible
    - There are 20^{100} different possible proteins that are made up of just 100 amino acids
    - Proteins can also be made up of fewer or greater than 100 amino acids, with makes the number of different proteins mind-boggling.
- The order of the amino acids is determined by your DNA

Proteins

- **4 levels of Protein Structure**
  - **Primary structure**
  - **Secondary structure**
  - **Tertiary structure**
  - **Quaternary structure**

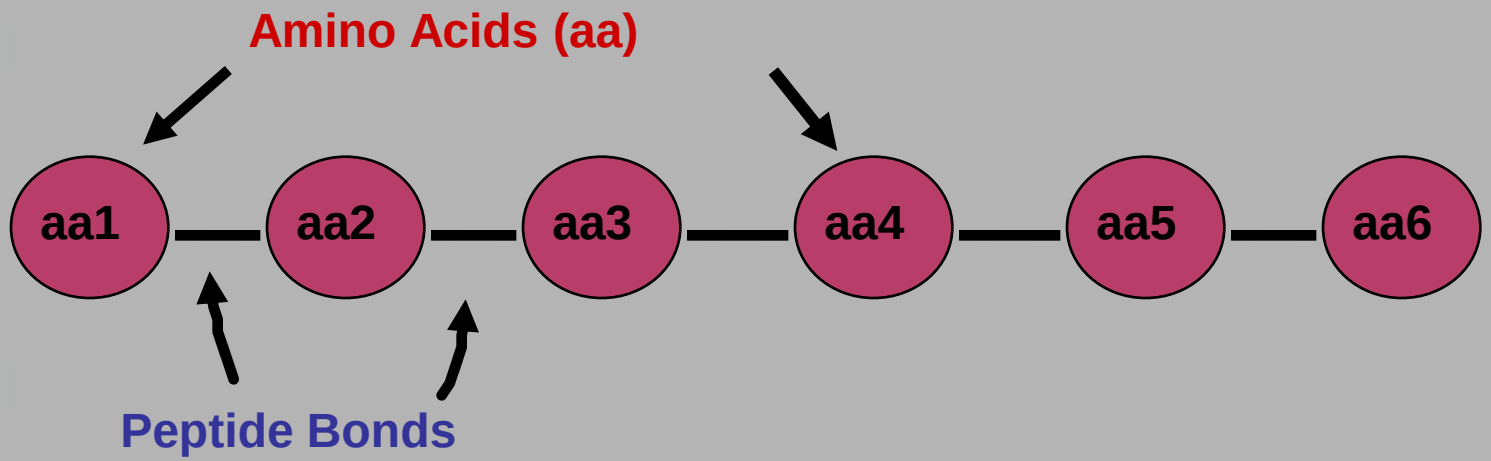


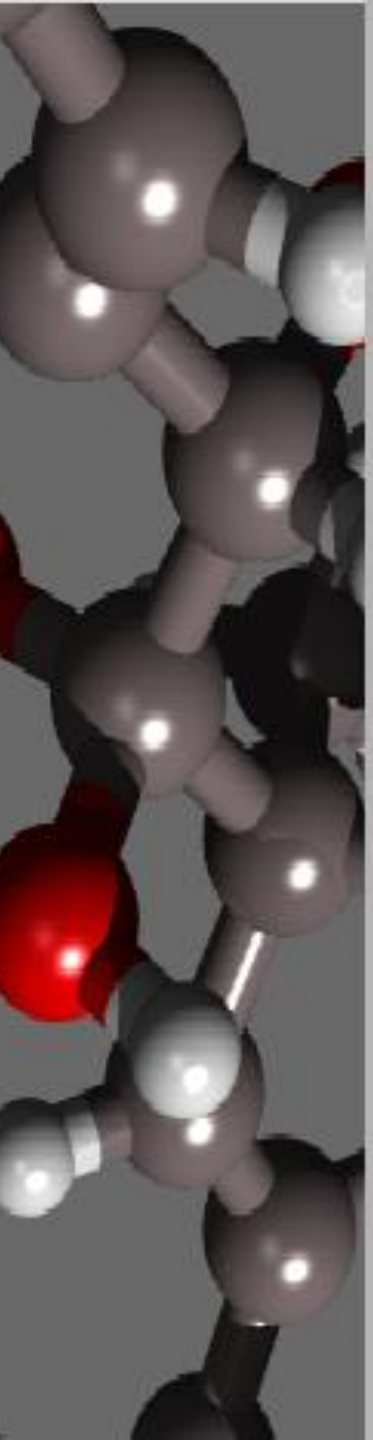




Proteins

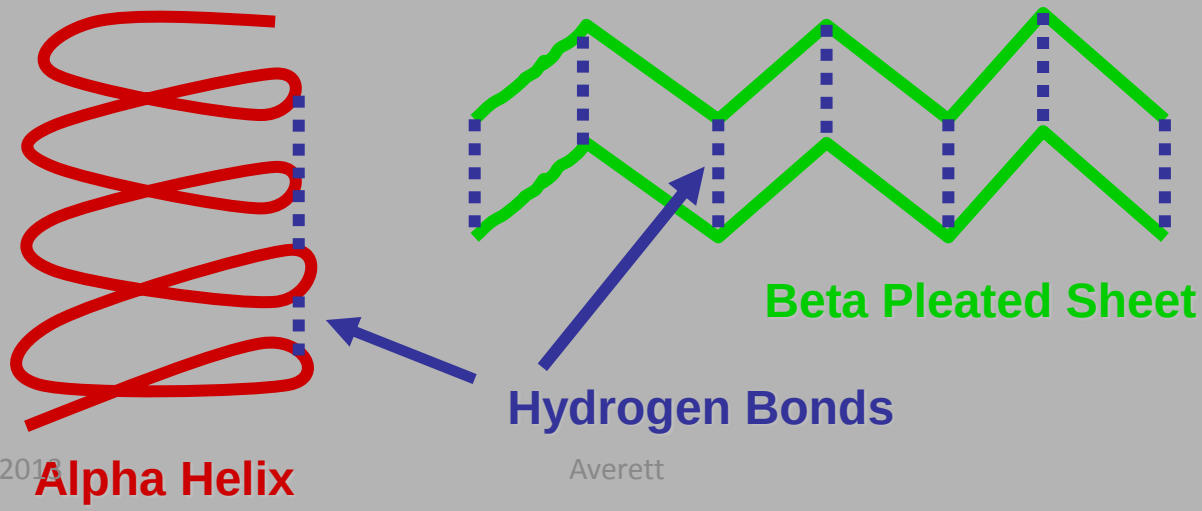
- **Primary Structure**
  - **The precise sequence of amino acids bonded together by peptide bonds to form chains.**

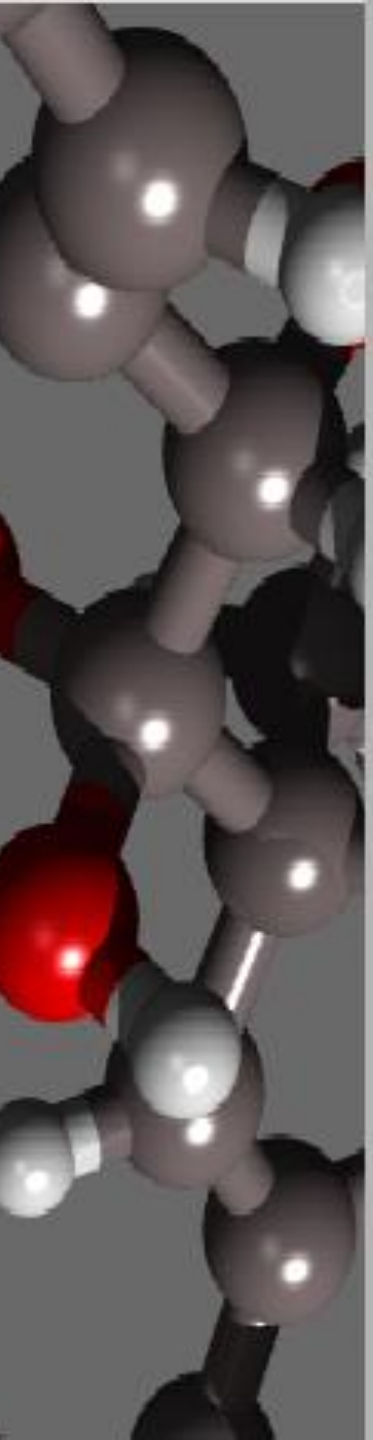




Proteins

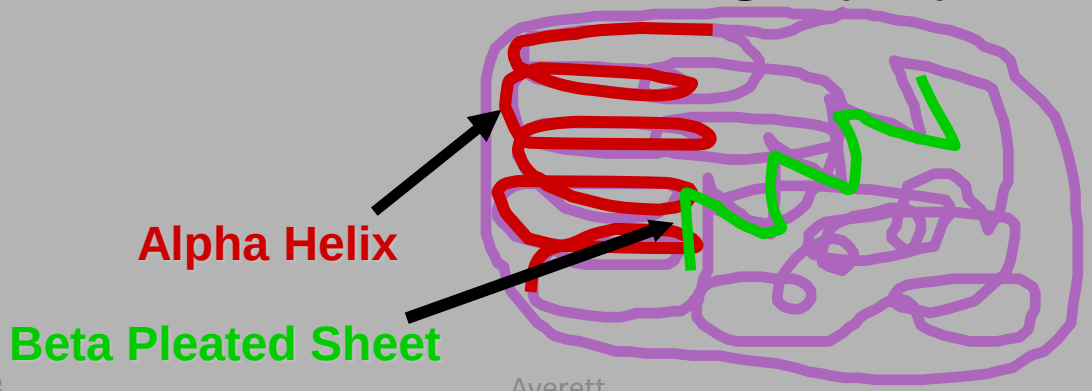
- **Secondary Structure**
  - **The shape that results from different regions of the polypeptide folding or coiling.**
    - **The folding and coiling is due to hydrogen bonds**
      - **This shape is determine by the sequence of amino acids.**
      - **Two common secondary structures**

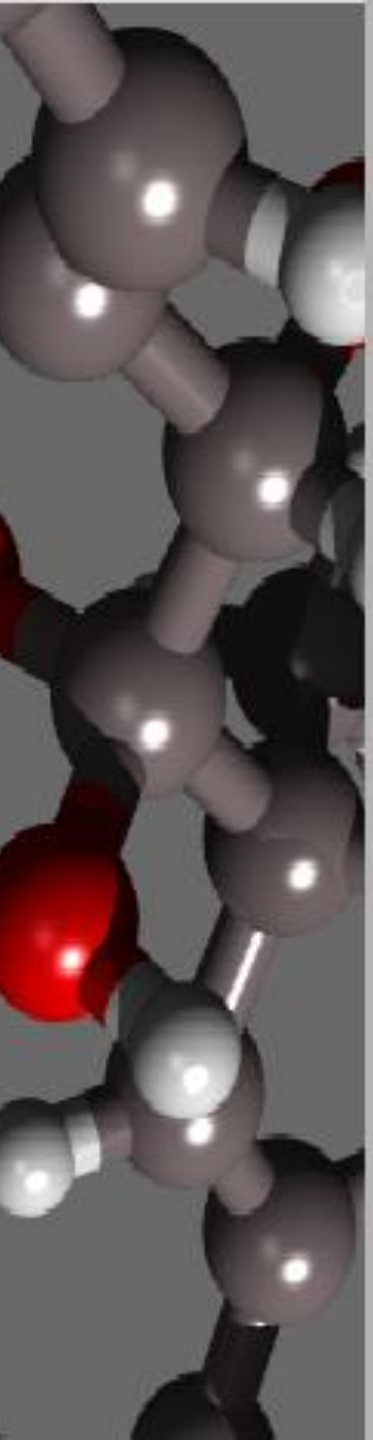




Proteins

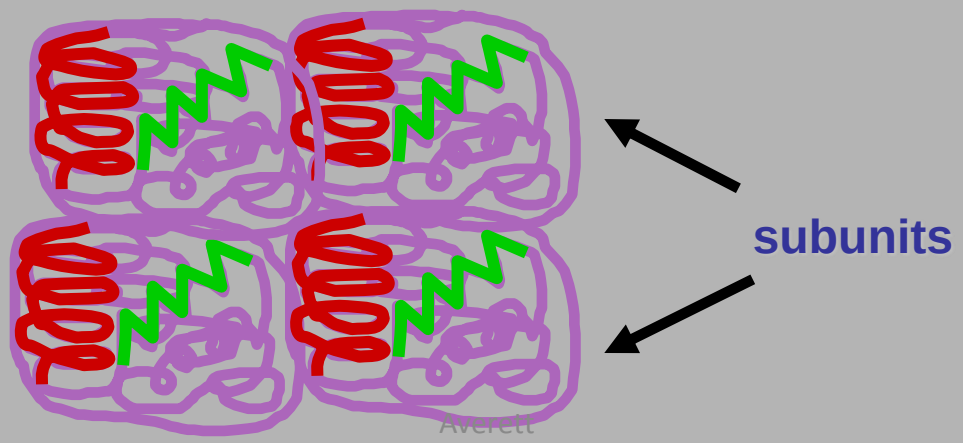
- **Tertiary Structure**
  - **The 3D shape of the polypeptide due to <u>additional</u> bending and folding after the coils and pleats are formed**
    - **Structure folds even more due to attractions between the coiled parts and the pleated parts to form a subunit as well as interactions of the R groups**
    - **Held together by hydrogen bonds, ionic bonds and disulfide bridges (S-S)**

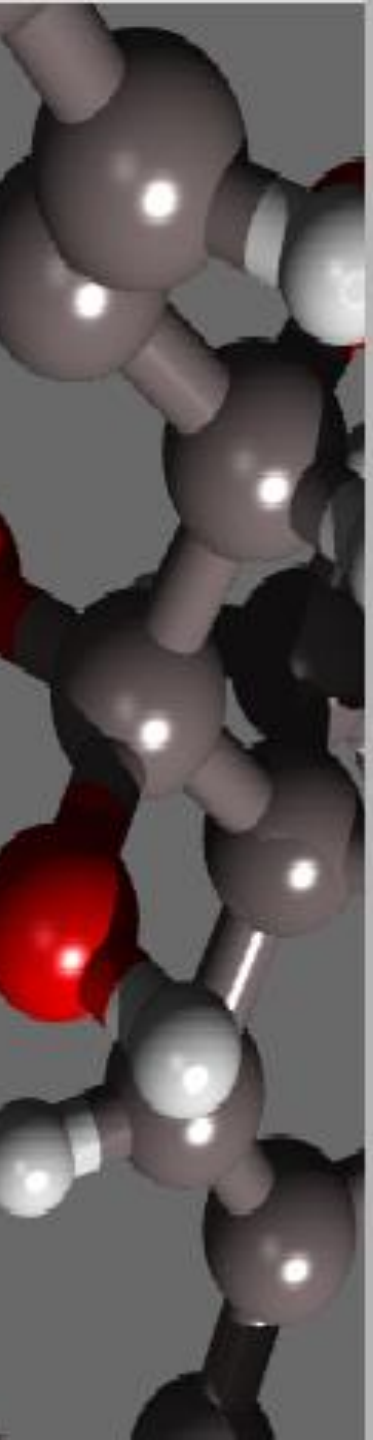


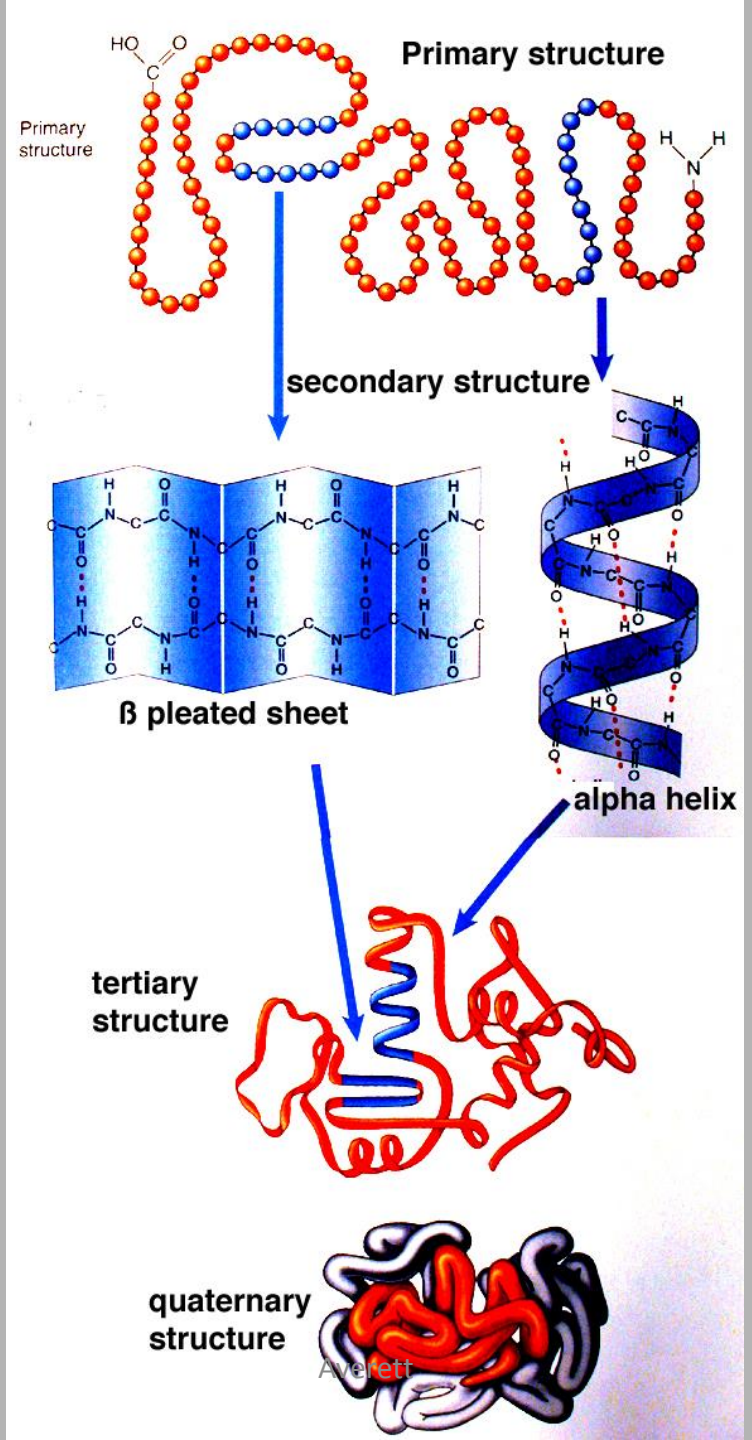


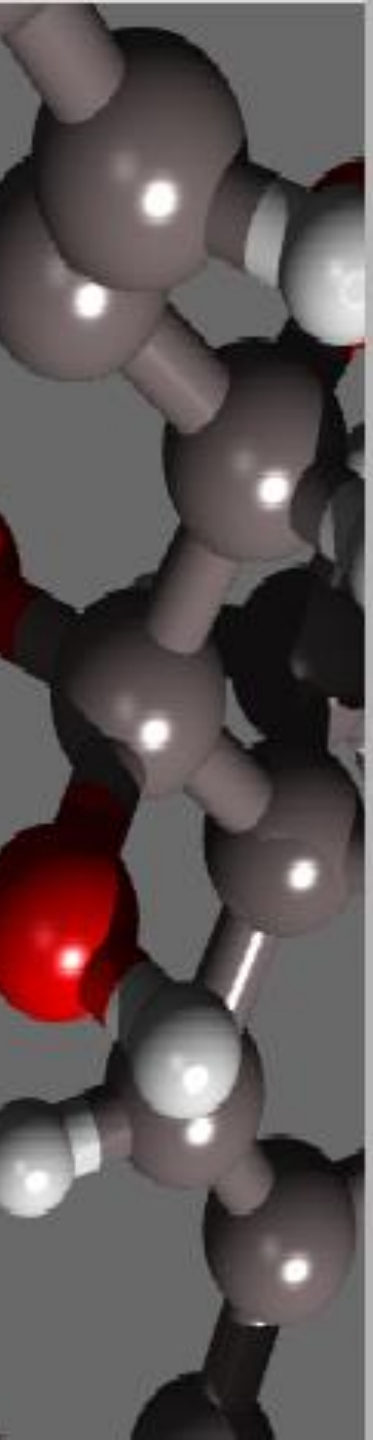
Proteins

- **Quaternary Structure**
  - **The combination of multiple polypeptide chains into a functional protein**
    - **Most proteins are made up of more than one amino acid (polypeptide) chain**
  - **This adds to the 3D shape and results from how the different peptide chains bind together and interact**





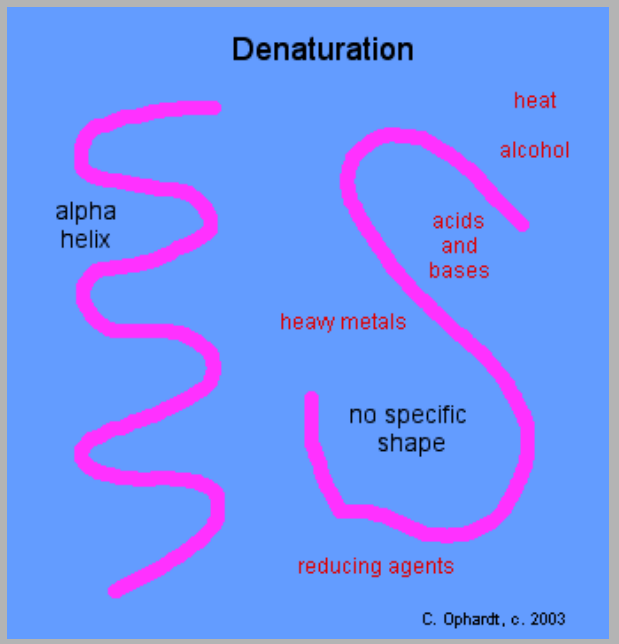

Primary structure
Primary structure
secondary structure
ß pleated sheet
alpha helix
tertiary structure
quaternary structure

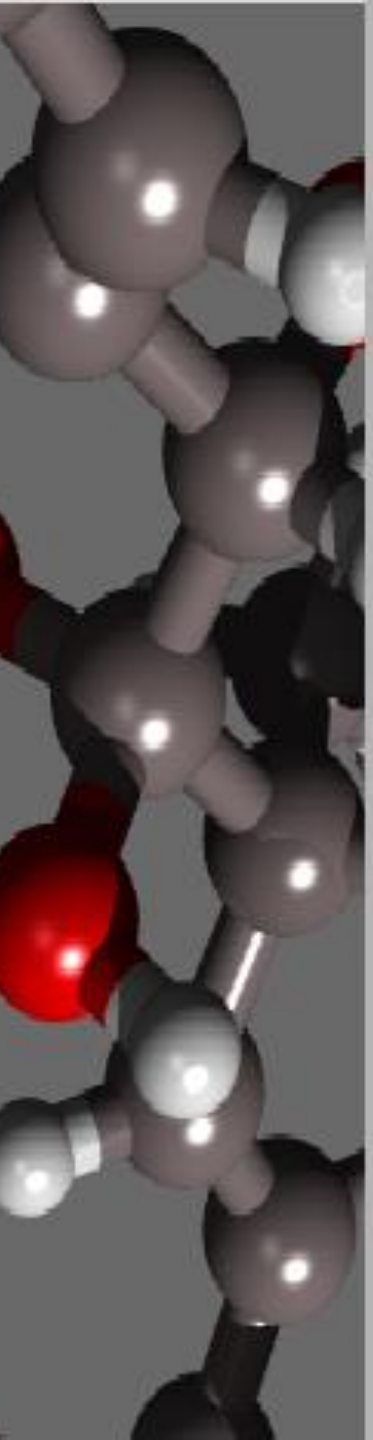


Proteins

- **Denaturation of Proteins**
  - **Denaturation changes the shape of the protein**
    - **Disrupts the bonds**
    - **Causes the protein to lose its ability to function**
  - **Caused by changes in homeostasis**
    - **Temperature, pH, salt, presence of alcohol**

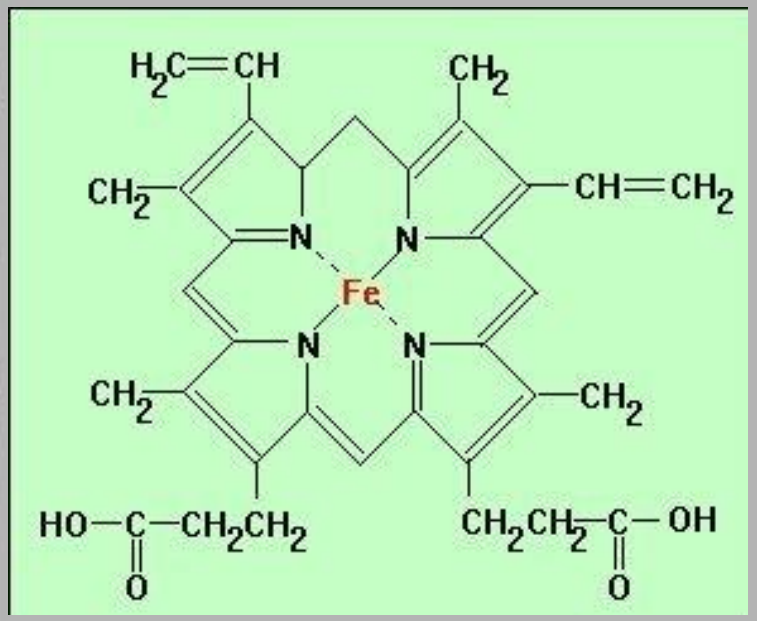
Albumin in egg whites

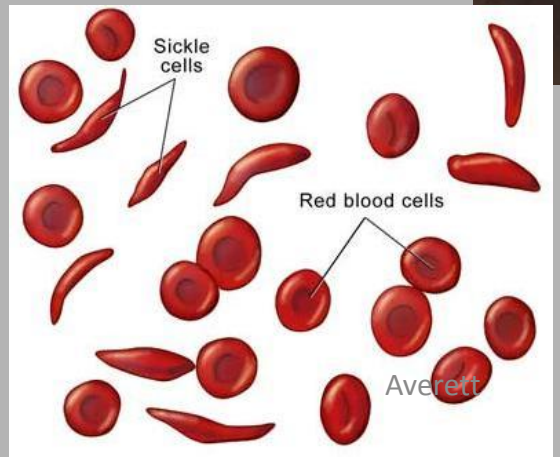


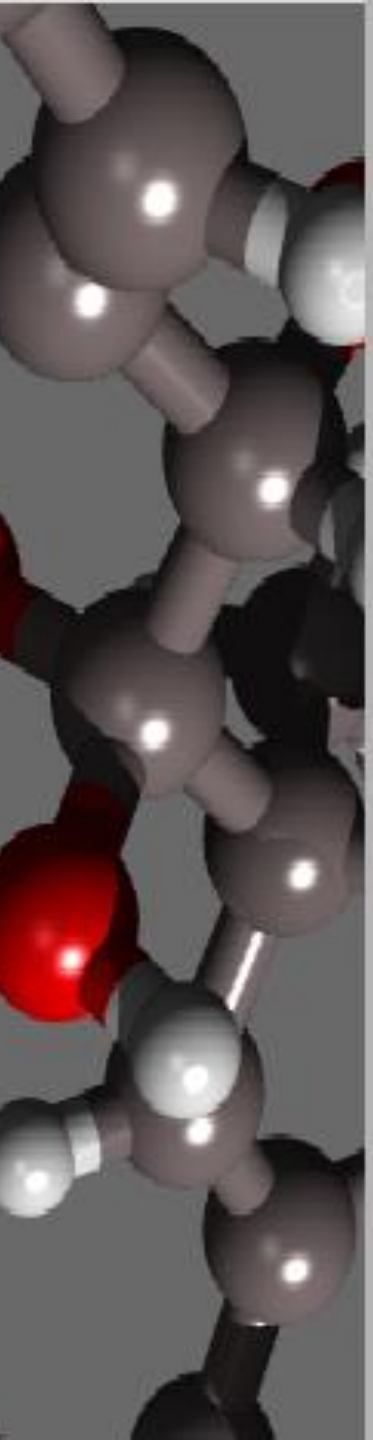


Proteins

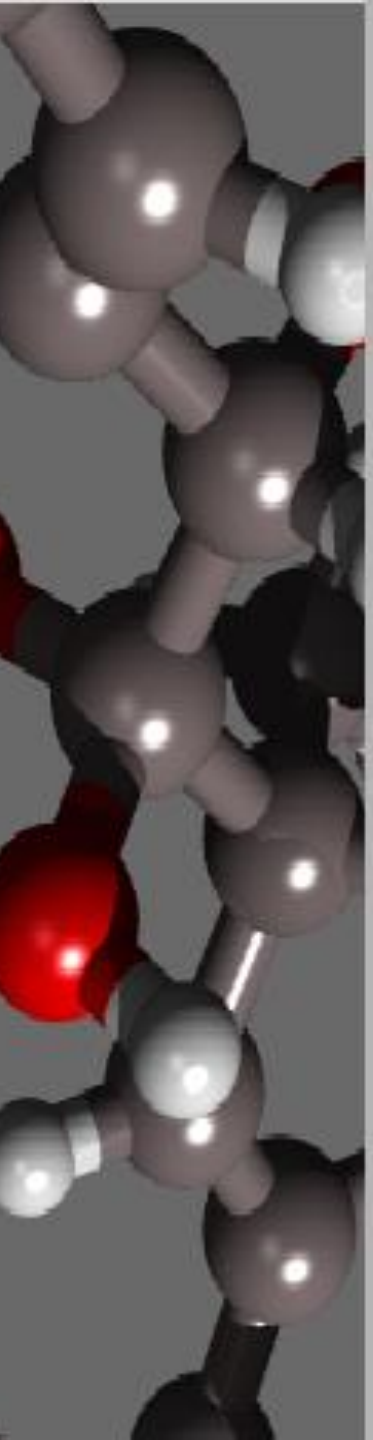
- Example of denaturation
  - Hemoglobin in Sickle Cell Anemia





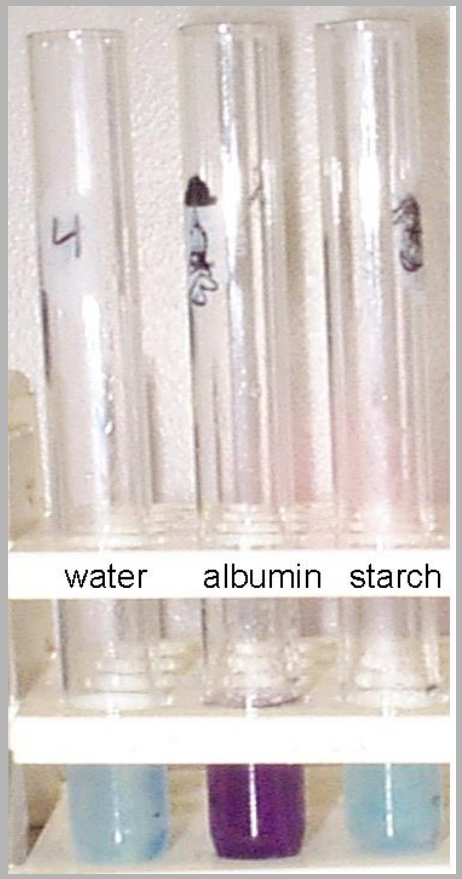


- Sickle cell anemia is a genetically-inherited condition that is characterized by abnormal, sickle-shaped red blood cells (erythrocytes).
- Symptoms can start to show at as early as four to six months of age, but are more usual between the ages of one and two years.
- Symptoms experienced throughout childhood and adulthood can include: fatigue, breathlessness, jaundice, paleness, susceptibility to infections, hand and foot swelling, painful joints, hands, arms, legs, and back, chest syndrome (pain in the chest wall), priapism (prolonged, painful erections), anemia and “pain crises”.
- Children as young as eight can experience strokes as a result of their sickle cell condition as well.
- Patients with sickle cell anemia usually only live into their mid-40s.



Proteins

- **Testing for Proteins**
  - **<u>Biuret Solution</u>- test gives a pink-to-purple reaction in the presence of protein.**
    - **Biuret powder can be used to demonstrate this classic color reaction as well.**



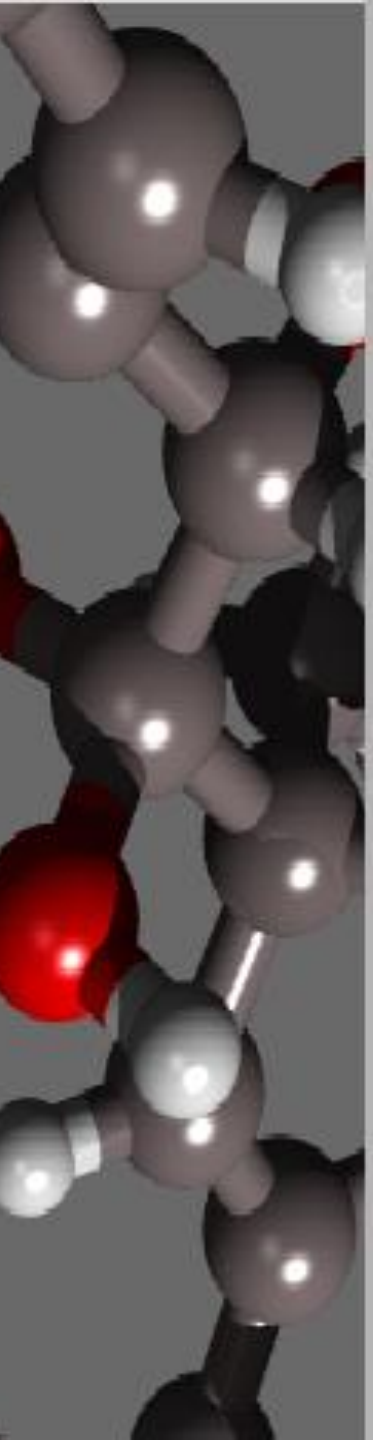


TABLE 4.1 MACROMOLECULES

Monomer	Polymer	Cellular structure
Amino Acid	Polypeptide	Intermediate filament
Nucleotide	DNA strand	Chromosome
Monosaccharide	Starch	Starch grains in a chloroplast
Fatty acid	Fat molecule	Adipose cells with fat droplets

TABLE 4.1 MACROMOLECULES

Monomer	Polymer	Cellular structure
Amino Acid	Polypeptide	Intermediate filament
Nucleotide	DNA strand	Chromosome
Monosaccharide	Starch	Starch grains in a chloroplast
Fatty acid	Fat molecule	Adipose cells with fat droplets