Chemical Basis of Life

2

Unit One

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URLs to print and study for this chapter

This site covers information on carbohydrates, fats, & proteins. It also discusses cholesterol. Explore it all.
http://home.howstuffworks.com/food.htm

Carbohydrates.
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/Carbohydrates.html#disaccharides

Proteins
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Proteins.html

Good explanation of cholesterol
http://home.howstuffworks.com/cholesterol.htm

I. Introduction

A. Chemistry deals with the composition of substances and how they change.

B. A knowledge of chemistry is necessary for the understanding of physiology.

C. Body functions depend on chemical changes within cells.

D. Biological chemistry, or biochemistry, is the study of the chemistry of living organisms.

II. Structure of Matter

MATTER

Anything that has weight and takes up space

A. Elements and Atoms

*elements combine to form compounds

*bulk elements – compose 95% of body (by weight)
(some are C, H_2, O_2, N, S, & P)

*trace elements – required in small amounts
(important parts of enzymes = Co, Cu, F, I, Fe, Mn, Zn)

*ultratace elements – required in very small amounts
(As = vital in very small amounts)

****Major elements in body:
Know these:
O, C, H, N, Ca, P, K, S, Cl, Na, Mg

MATTER

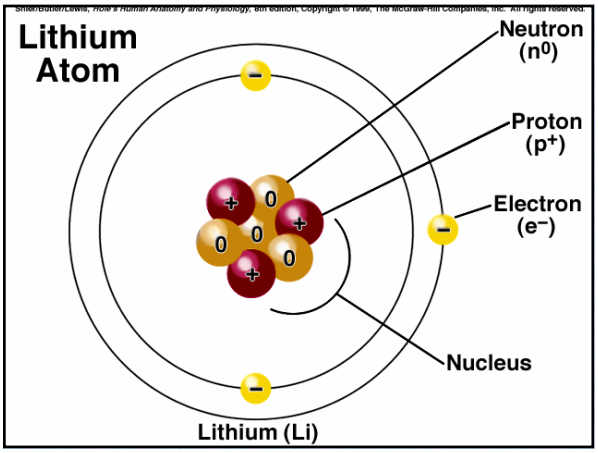
B. Atomic Structure

*nucleus – central portion;
contains protons (p^+) and neutrons (n^0)

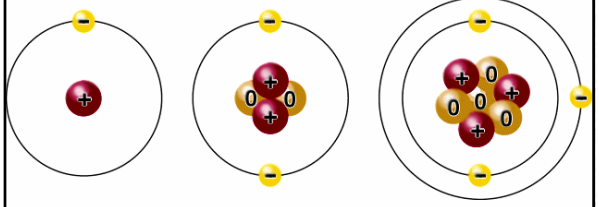
* electrons – (e-) outside orbitals

* atomic number = # of protons

* atomic weight = # protons plus # neutrons



Hydrogen, Helium, and Lithium Electrons



Hydrogen (H) Helium (He) Lithium (Li)

MATTER

C. Isotopes

isotopes - atoms with the same atomic number & differing atomic weights (ex.) oxygen=always 8 protons, it can have 8, 9, or 10 neutrons

***The number of electrons in the outer orbital (shell) determines how atoms interact with each other.

***radioactive isotopes - have nuclei that are unstable. They decompose & release E. This is atomic radiation.
- 3 kinds: alpha, beta, & gamma.
- gamma radiation is similar to X-radiation and is the most penetrating of these forms

MATTER

D. Bonding of Atoms

*bonds – form when atoms combine

*atoms gain, lose, or share electrons to form bonds

*electron configuration – electrons in shells

*atoms (He) that have outer shell full are stable (inert) & cannot form chemical bonds

*atoms that have incomplete outer shells tend to gain, lose, or share electrons to fill outer shells and form chemical bonds

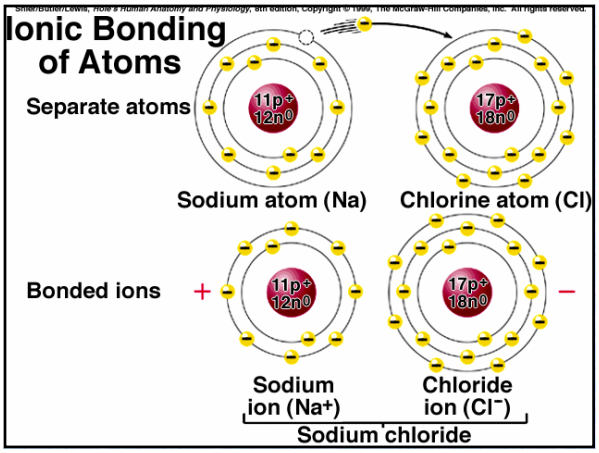
MATTER

*ion - When atoms gain or lose electrons they become electrically charged.
*ionic bond – formed when atoms lose electrons
*covalent bond – formed when atoms share electrons;
-single and double covalent bonds

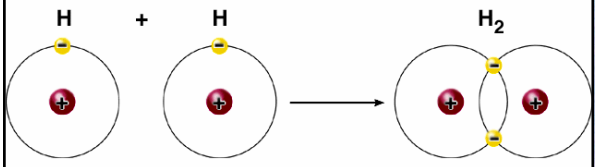
E. Molecules and Compounds

*molecule – 2 or more atoms combined
*molecular formula – tells #s and kinds of atoms
*compound – result of atoms combining

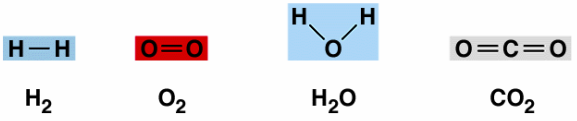
Ionic Bonding of Atoms



Covalent Bond

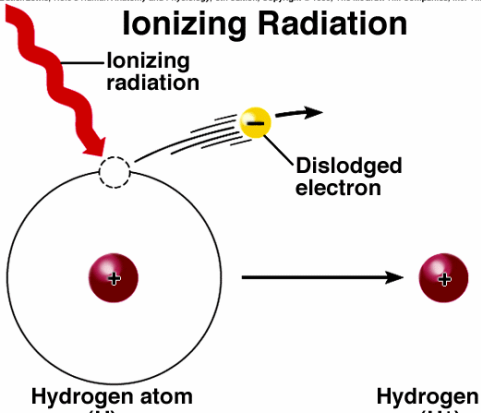


Structural Formulas



H_2 O_2 H_2O CO_2

Ionizing Radiation



MATTER

F. Chemical Reactions - 4 KINDS

*$2H_2 + O_2$ -> $2H_2O$ (synthesis reaction)

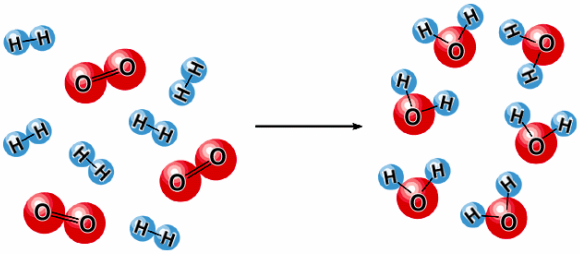
reactants product A + B -> AB

*AB -> A + B (decomposition reaction)

*AB + CD -> AD + CB (exchange reaction)

*A + B >< AB (reversible reaction)

Water Molecules



MATTER

G. Acids, Bases, & Salts

*What happens to compounds when they react with water?

They ionize and become ions that are electrically charged.

They will conduct an electric current, release ions in water, and are called electrolytes.

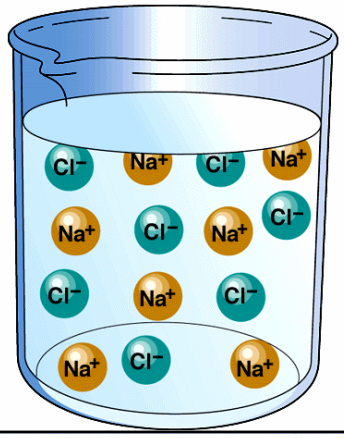
ACIDS = electrolytes that release H+ ions in water HCL->H+Cl

BASES = electrolytes that release OH+ ions that combine with H (can form water) NaOH->Na+OH

SALTS = acids and bases can react together to form salt + H_2O

HCl+NaOH -> H_2O + NaCl

Ionization of NaCl



H. Acid and Base Concentrations

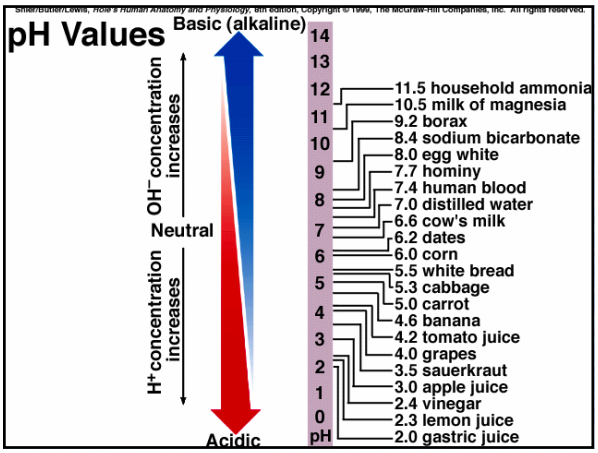
Life processes are affected by chemical reactions>illness.

*pH scale – represents the concentration of (H+) and (OH-) ions in a solution (pH 0 to pH 14.0)
pH below 7 is acidic; pH above 7 is basic; pH 7.0 is neutral

*Normal blood pH is 7.35 to 7.45

*alkalosis – condition when blood pH rises 7.5 to 7.8
-results from stomach acid becoming too low

*acidosis – condition when blood pH falls to 7.0 to 7.3
-results from small intestinal contents becoming too acidic



III. Chemical Constituents of Cells

Metabolic reactions in the body's cells involve chemicals that are either organic or inorganic.

*ORGANIC – compounds containing C and H_2 atoms;

usually are nonelectrolytes – do not dissolve in H_2O and will dissolve in ether or alcohol

*INORGANIC – all other molecules;

usually are electrolytes – will dissolve in H_2O and react with H_2O to release ions

A. Inorganic Substances

B. BODY = water, oxygen, carbon dioxide, inorganic salts

Water: * most abundant compound; *2/3rds of body; *90% of blood
*most abundant compound in cells; *causes chemical reactions (hydrolysis); *transports chemicals and heat; *helps release body heat

Oxygen:*releases energy from nutrient molecules (food) which drives the cell's metabolic activities; *necessary for survival of an organism

Carbon Dioxide:*produced as a waste product when energy is released during metabolic processes CO_2 is released from the body by the respiratory organs

Inorganic Salts:*play important role in metabolic processes; >>>>

Electrolytes: Na, Cl, K, Ca, Mg, PO_4, CO_3, HCO_3, and SO_4 are inorganic salts that must be present to maintain homeostasis

Carbon

The element of life!

CARBON

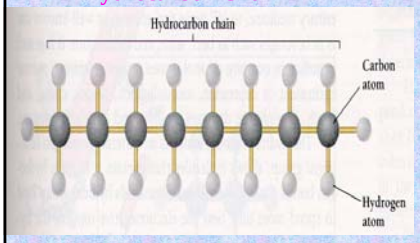
Inorganic Organic Biochemistry

Importance of carbon:
1- atomic #6
2- can form a total of 4 covalent bonds with other atoms
3- can also form double or triple bonds with other carbon atoms forming stable compounds
4- is the world's best electron sharer-----
this allows carbon to form the molecules that make life possible--- MACROMOLECULES ---
5 - the carbon cycle

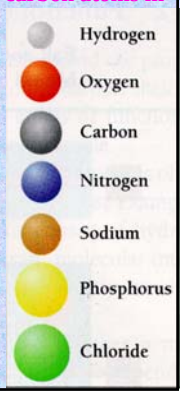
MATTER

Carbon atoms frequently form single covalent bonds with other carbon atoms in chains

Hydrocarbon Chain



Octane - 8 carbons & 18 hydrogens

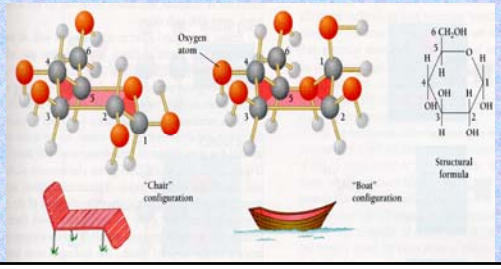


MATTER

Carbon atoms in rings:

The glucose ring bends into a "chair" structure or a "boat" structure.

GLUCOSE

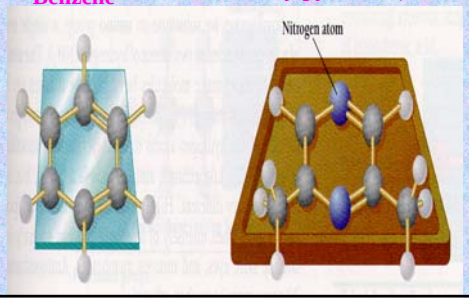


MATTER

Carbon atoms in rings: these lie flat

Benzene

Dimethylpyrazine (chocolate)



MATTER

BUILDING A CARBON CHAIN: It is possible to think of carbon atoms as a flexible "skeleton" that can be used to construct just about any type of molecule - there can be one to thousands of carbons in the chain

PRACTICE:

CH_4 - METHANE

C_2H_6 - ETHANE

C_3H_8 - PROPANE

Chemical groups can be attached to the chain

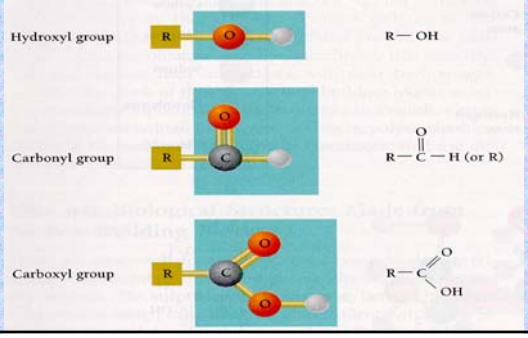
MATTER

CARBON ATOMS can assume complex shapes including:
CHAINS, BRANCHES AND RINGS

FUNCTIONAL GROUPS: groups of atoms attached to the carbon backbone that determine the characteristics and chemical reactivity of the molecules

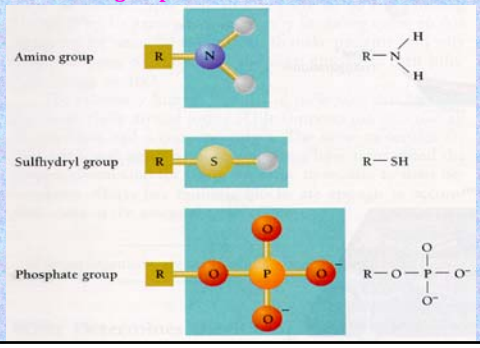
MATTER

functional group model structural formula



MATTER

functional group model structural formula



MATTER

How Do Organisms Use Biological Molecules To Build?

How Big Are Biological Molecules?

If we analyze the sizes of all the molecules in a cell, we discover a surprising thing. Cells have many small molecules, with molecular weights less than 300, and many large molecules, with molecular weights greater than 10,000. But cells have very few molecules with intermediate sizes.

Terms to remember:

subunit, monomer, polymer, macromolecule

MATTER

Remember this:

Biological Molecules are Joined Together or Broken Apart by Adding or Removing Water:

dehydration synthesis - to form by removing water
hydrolysis - to break apart with water

Biological molecules are one of the following:

CARBOHYDRATES LIPIDS
PROTEINS NUCLEIC ACIDS

MATTER

Macromolecules

MATTER

Organic Substances

MACROMOLECULES

Carbohydrates - provide energy

Lipids -provide energy, building materials, & insulation to protect some organs

Proteins -provider materials for growth & repair, & they form enzymes that control chemical changes in the body

Nucleic Acids -provide the molecules of life

MATTER

CARBOHYDRATES

CARBON + WATER

MATTER

CARBOHYDRATES AND POLYSACCHARIDES
-are compounds that contain one O atom and one H_2 atom for every carbon atom (1 H_2O per C)

SUGARS
STARCHES
GLYCOGEN
CELLULOSE
CHITIN

SUGARS - Important energy storage molecules in cells. They are composed of carbon, hydrogen, and oxygen.
- 1:2:1 ratio or $(CH_2O)_n$; n = # of carbons in the backbone

Monosaccharides - simple sugars of one sugar unit
Animals store energy for important use in glucose.
-may contain from 3 to 7 carbon atoms
Disaccharides - 2 or more monosaccharides linked together
Plants use sucrose. (glucose and fructose linked together with a hydroxyl unit attached) - sucrose $C_{12}H_{22}O_{11}$ is table sugar
Polysaccharides - carbohydrate macromolecules formed by linking many simple sugars (monosaccharides)
Most carbon atoms are attached to both a H atom and an OH group. Each group forms H bonds with a H_2O molecule; so they will dissolve in water easily

MATTER

GLUCOSE - most common Monosaccharide
All cells use special adaptations to keep glucose at a constant concentration. $C_6H_{12}O_6$

Subunits of glucose form polysaccharides; it is a 6 carbon atom (hexose and pentose)

Glucose can exist in several forms: chains and rings
- fructose and galactose - rings

Ribose and deoxyribose have 5 carbons - pentose sugars
****They are parts of the genetic molecules DNA and RNA.**

MATTER

Dissacharides: 2 single sugars linked by dehydration synthesis; often used for short-term energy storage by plants

Sucrose = glucose + fructose

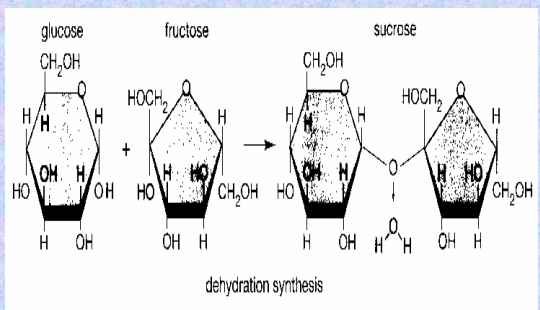
Lactose = glucose + galactose

Maltose = glucose + glucose

Hydrolysis breaks up dissacharides when energy is needed by the cells.
Dehydration synthesis – connects monosacharides to form di- and polysacharides

MATTER

DEHYDRATION SYNTHESIS OF A DISACCHARIDE



Matter

Polysaccharides: Starch and Cellulose and Chitin

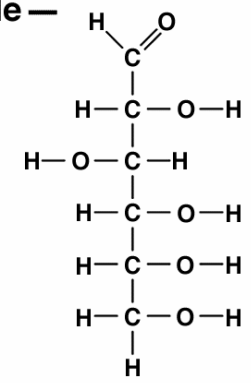
Needed for long term energy storage.
Glucose molecules join together forming starch (plants) or glycogen (animals)

STARCH - formed in plants (roots and seeds)
- glycogen (starch formed in animals)

CELLULOSE - cell walls of plants

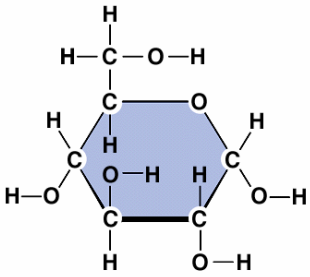
CHITIN - exoskeletons of insects, crabs

Monosaccharide — Glucose (1)

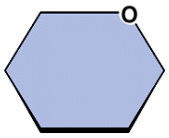


Straight chain of carbon atoms

Monosaccharide — Glucose (2)

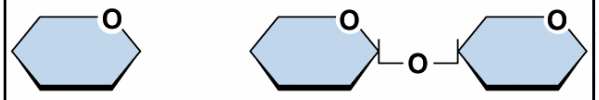


Ring structure



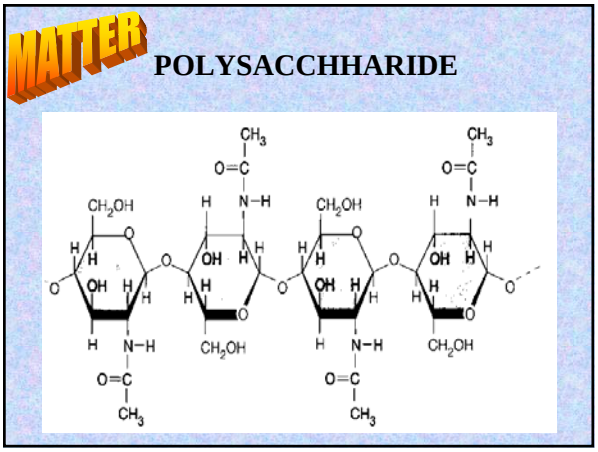
Symbol of glucose ring structure

Monosaccharide and Disaccharide Molecules

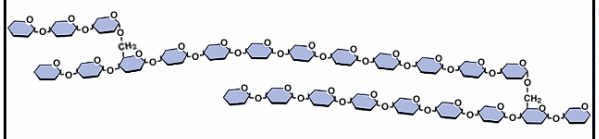


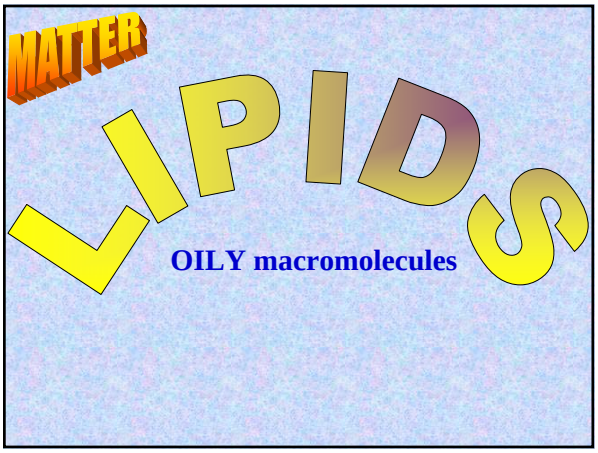
Monosaccharide

Disaccharide



Polysaccharide Molecule





MATTER

LIPIDS include a variety of nonpolar compounds

1) Oils, fats, and candle wax are found at home.
2) contain more chemical energy per gram than other biological molecules
3) often serve as energy stores; form structural basis for cell membranes; can be used as chemical messengers
4) composed of long chains of C atoms totally surrounded by H; dissolve in nonpolar solvents (gasoline, acetone)

MATTER

5) nonpolar - no charge differences to allow them to form hydrogen bonds to H_2O
6) some are amphipathic - they contain a polar functional group as well as nonpolar chains of C and H atoms. SOAP - has one part that interacts with oil and one that interacts with water; 18 carbon stearic acid = soap
7) fatty acids are the building blocks of LIPIDS; lipids are FATS
8) Lipids are hydrophobic and insoluble in water
9) Lipids have a smaller proportion of O_2 than occurs in carbohydrates

MATTER

Saturated - when hydrocarbon chain with single bonds of stearic acid has the maximum # of hydrogens per carbon (butter); solid at room temperature

Unsaturated - double bonds between some of the carbon atoms (so there are fewer hydrogens) (oils); liquid at room temperature

Polyunsaturated - 2 or more double bonds between carbon atoms - used to describe margarine and cooking oils

(Saturation determines how the body is able to use food containing fatty acids)

MATTER

LIPIDS ARE **FATS - contain C, H, and O**

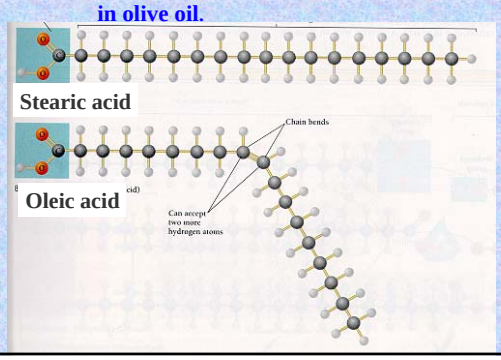
FATTY ACIDS: have a hydrocarbon (hydrophobic) chain + a carboxyl (hydrophilic) functional group at the end - (-COOH); normally do not have ring structure

- fatty acids differ from each other in 2 ways
  1) # of carbon atoms
  2) # of carbon to carbon double bonds

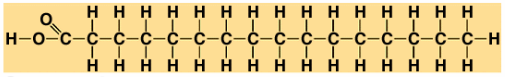
FATS and OILS - formed by dehydration synthesis from 3 fatty acid subunits and one molecule of Glycerol = a short, 3 carbon molecule with one hydroxyl group (-OH) per C

MATTER

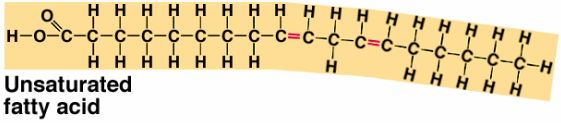
Saturated fatty acids, like stearic acid in beef fat, pack together more closely than unsaturated fatty acids, such as the oleic acid in olive oil.



Fatty Acid Molecules



Saturated fatty acid



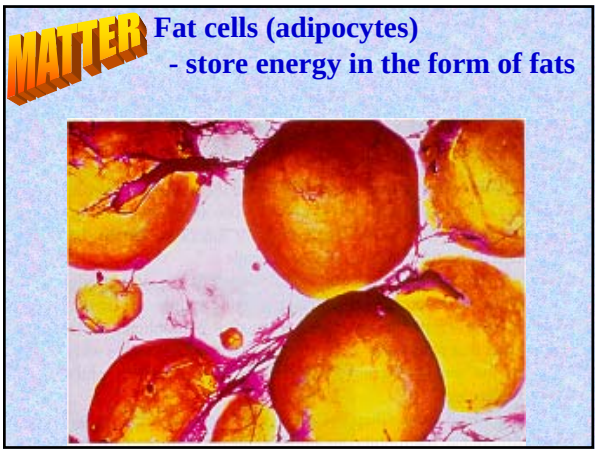
Unsaturated fatty acid

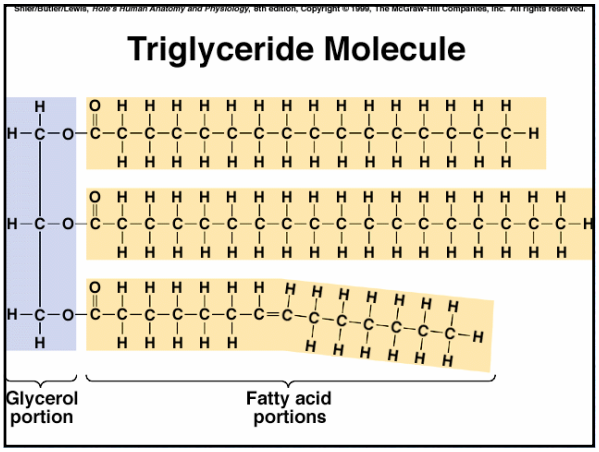
3 Important groups of LIPIDS:

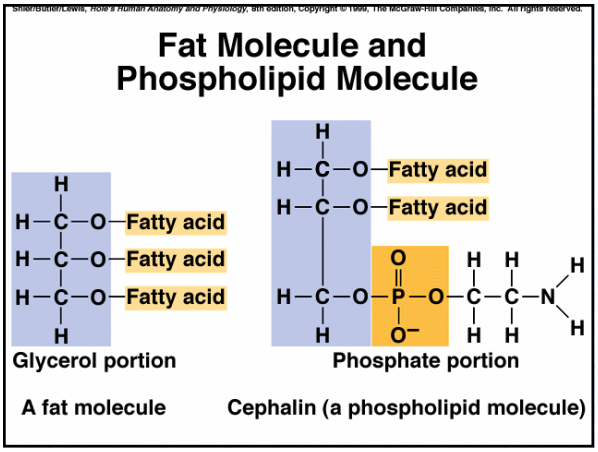
1) triglycerides - (chemical name of fats and oils) a form of lipid found in fat cells and used for food storage in plants and animals; are nonpolar and have no charge; are made of 3 connected fatty acids and a glycerol - made of 3 (-OH) groups and is soluble in H_2O

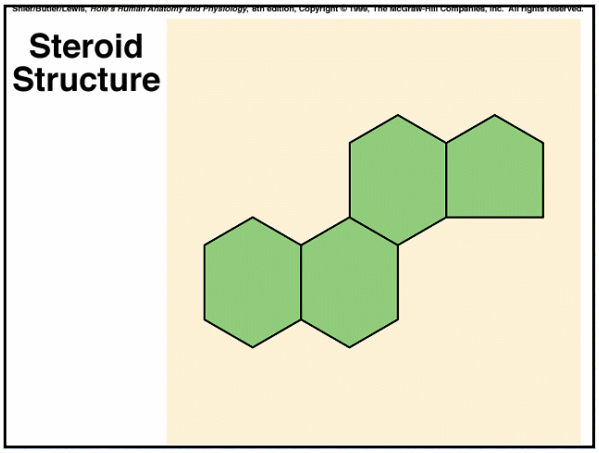
2) phospholipids - a molecule of glycerol bonded with 2 fatty acids and a molecule of phosphate; used to form biological membranes (plasma)

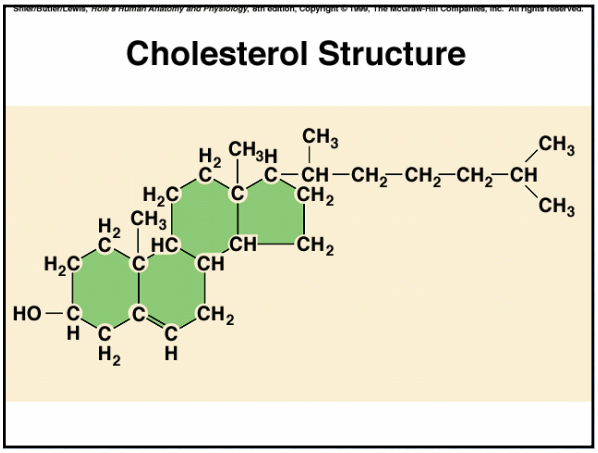
3) steroids - composed of 4 rings of carbon fused with different functional groups; Cholesterol is a steroid- aids in assembly of cell membranes; others regulate cell activities throughout the body with hormones











MATTER

PROTEINS

MATTER

Proteins are involved in every activity in the cell; they pump molecules across cell membranes

Structural Proteins - KERATIN - form hair, skin, and fingernails, - ELASTIN - gives skin elasticity.

Chemical messenger Proteins - INSULIN - hormone secreted by the pancreas

Oxygen transport carriers - HEMOGLOBIN - iron containing; gives color to blood cells; MYOGLOBIN – does the same for muscle cells

Chemical catalysers (enzymes) - AMYLASE - found in saliva; breaks starch down into simple sugars.

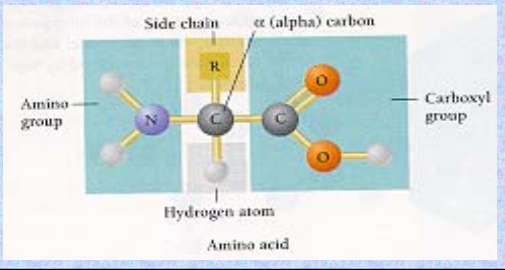
PROTEINS - formed by the polymerization of amino acids; (20 amino acid building blocks)

All amino acids have the same fundamental structure:
a central CARBON bonded to 4 different functional groups:
1) a nitrogen-containing amino group ($-NH_2$)
2) a carboxyl group (-COOH)
3) a hydrogen group (-H)
4) a variable group (-R)

-R groups differ among amino acids and give each its distinctive properties. There is much amino acid diversity. R groups determine this diversity.
-Amino acids are connected by peptide bonds.

MATTER

An amino acid includes a carboxyl group, an amino group, a hydrogen atom, and a side chain (R). All 4 are attached to a single, central carbon atom, called the α carbon



MATTER

AMINO ACIDS and their -R GROUPS

-R groups can be polar and hydrophilic; others are nonpolar and hydrophobic
-R groups can have SULFUR in the -R group (cysteines); and can form bonds with other cysteines = linked protein chains
The resulting bonds are called disulfide bridges.
-R groups of amino acids determine chemical and physical properties: size, water solubility, electrical charge

MATTER

DEHYDRATION SYNTHESIS - makes it possible for amino acids to bond together and form proteins. (covalent)
Nitrogen($-NH_2$) of one amino acid is joined to the carbon of the (-COOH) group of a second amino acid

PROTEIN SYNTHESIS FORMS:
PEPTIDE BOND = chain of 2 amino acids is called peptide

Amino acid chains can be as long as several 1,000
protein and polypeptide refer to longest chains (50 or more) of amino acids
peptide - term for shorter chains

MATTER

Proteins are highly organized molecules that come in a variety of shapes. They may have up to 4 levels of 3-D structure.

4 structural levels: conformation

primary structure - sequence coded by genes

secondary structure - coiled, helix; hair, keratin

tertiary structure - 3 dimensional

quaternary structure - huge proteins

Within a protein, the exact type, position, and number of amino acids, bearing specific R groups determine both the structure of the protein and its biological function. This is the conformation of a protein.

***A protein's conformation determines its function.

MATTER

denature – conformation breakdown of a protein caused by breaking the hydrogen bonds (ie) hair perm, frying an egg

**5 ways a protein can lose its conformation by being denatured:

high temperature, radiation, pH changes, chemicals, & electricity

enzymes - large molecules, almost always proteins, that accelerate the rate of a chemical reaction; they are not consumed in the reaction.

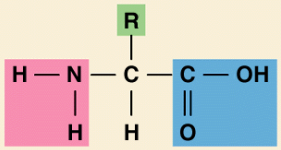
Enzymes are catalysts in living systems.

Amino Acid Structure

R group

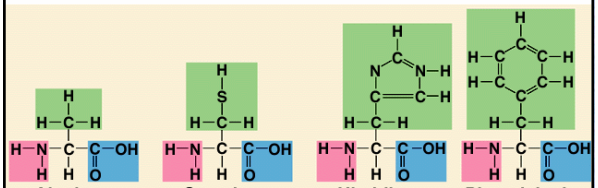
Amino group

Carboxyl group



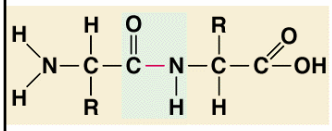
Amino acid

Structural Formulas of Various Amino Acids

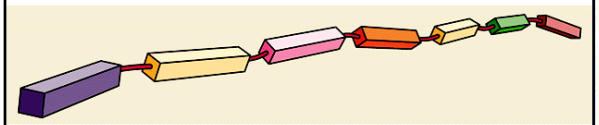


Alanine Cysteine Histidine Phenylalanine

Primary Structure of a Protein

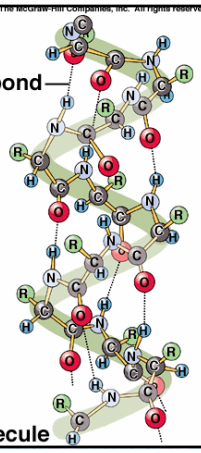


Peptide bond

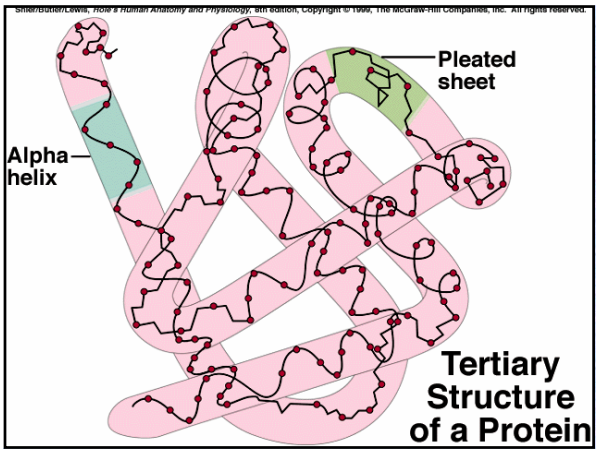


Amino acid sequence

Secondary Structure of a Protein



Portion of a protein molecule



MATTER

NUCLEIC ACIDS

MATTER

Nucleic Acids are MACROMOLECULES that carry genetic information.

NUCLEOTIDES - building blocks of 2 kinds of information carrying molecules; DNA & RNA (nucleic acids are polymers of nucleotides)

3 part structure:

1) a five-carbon sugar; ribose or deoxyribose
2) a phosphate group
3) a nitrogen containing base that differs among nucleotides

MATTER

Two types of NUCLEOTIDES:

RIBOSE - contains the sugar ribose

DEOXYRIBOSE - contains the sugar deoxyribose

RIBOSE - bonds to 4 types of bases:
adenine, guanine, cytosine, and uracil

DEOXYRIBOSE - bonds to 4 types of bases:
adenine, guanine, cytosine, and thymine

Nucleotides may be strung together in long chains as nucleic acids, with the phosphate group of one nucleotide covalently bonded to the sugar of another.

DNA and RNA are Nucleic Acids, & are the molecules of HEREDITY.

Deoxyribose nucleotides form chains millions of units long called deoxyribonucleic acid or DNA.

DNA, found in the cell's chromosomes; contains the genetic information needed to construct proteins.

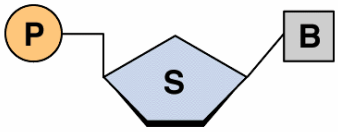
RNA, found in the cell's nucleus; is copied from DNA, and moves into the cytoplasm and directs the construction of proteins there.

MATTER

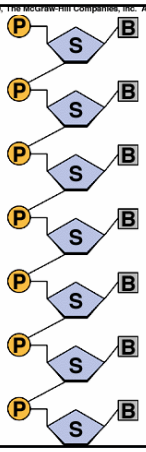
Some nucleotides like adenosine triphosphate or ATP have extra phosphate groups and carry energy from one place to another within cells.

Other nucleotides called coenzymes help vitamins assist enzymes in their functions.

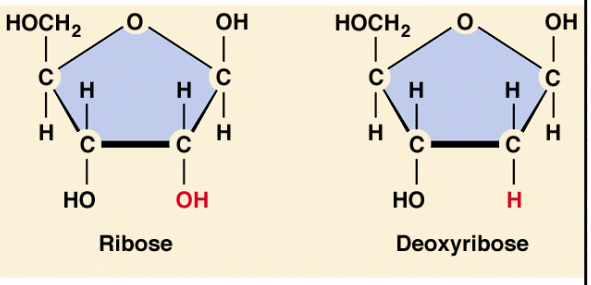
Nucleotide



Polynucleotide Chain



Ribose and Deoxyribose



What are the building blocks for macromolecules?

Remember – At the end of the chapter is a Chapter Summary that is your Study Guide for the Chapter 2 test.