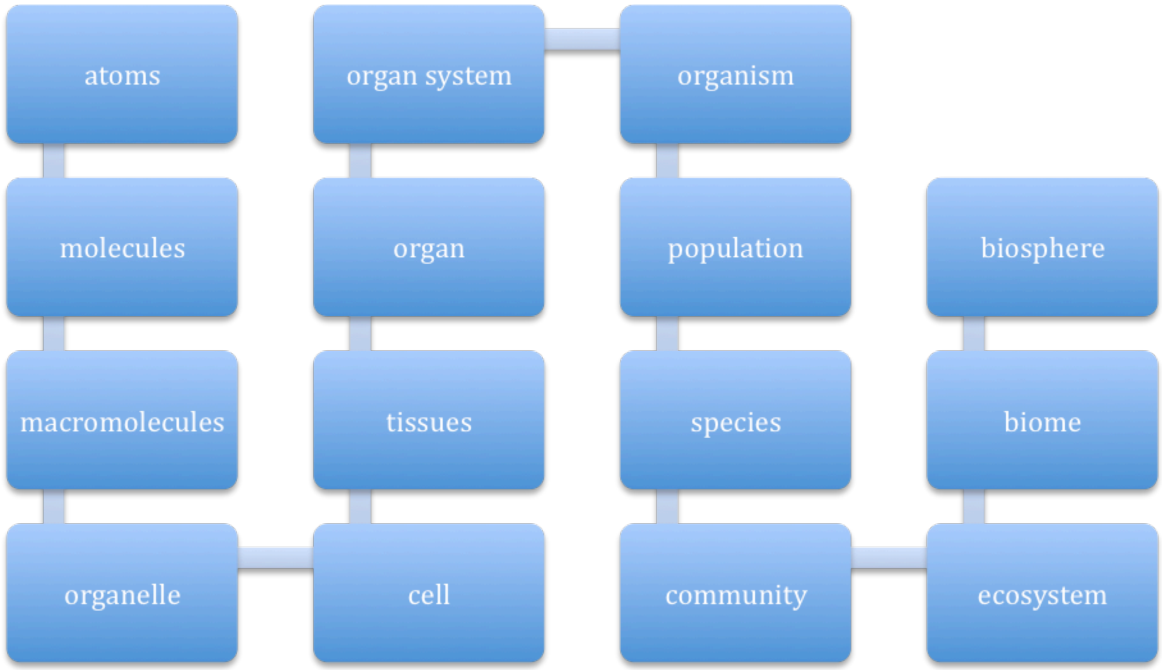


The Chemistry of Life

- Organisms are chemical machines
- Any substance in the universe that has mass and occupies space is comprised of matter
- all matter is made up of atoms

<u>Atoms</u>

All atoms have the same structure

- at the core is a dense nucleus comprised of two subatomic particles
- protons (positively charged)
- neutrons (no associated charge)

- orbiting the nucleus is a cloud of another subatomic particles electrons (negatively charged)

Atoms are characterized by # of protons it has or by its overall mass

- atomic number : # of protons in the nucleus
  atoms w/ same atomic # exhibit the same chemical properties and are considered to belong to same element

- mass number (atomic mass): # of protons + # of neutrons in nucleus. electrons have negligible mass. Defines the isotope

Electrons determine the chemical behavior of atoms

these subatomic components are the parts of the atom that come close enough to each other in nature to interact

- Electrons are associated with energy
- electrons have energy of position, called potential energy
- the field of energy around an atom is arranged as levels called electron shells
- within this volume of space, orbitals are where electrons are most likely to be found

Electron shells have specific numbers of orbitals that may be filled with electrons

- atoms that have incomplete electron orbitals tend to be more reactive
- atoms will lose, gain, or share electrons in order to fill completely their outermost electron shell
- these actions are the basis of chemical bonding
- as electrons move to a lower energy level, closer to the nucleus, energy is released
- moving electrons to energy levels farther out from the nucleus requires energy

Ions and Isotopes

Ions – atoms that have gained or lost one or more electrons

Isotopes – atoms that have the same # of protons but different # of neutrons. most elements in nature exist as mixtures of different isotopes

- Some isotopes are unstable
- break up into particles w/ lower atomic numbers
- this process is known as radioactive decay

Radioactive isotopes have multiple uses

1. nuclear medicine: Can be used as tracers to study how the body functions. Short-lived isotopes decay rapidly and do not harm the body
2. dating fossils: rate of decay of a radioactive element is constant. By measuring the fraction of radioactive elements that have decayed, scientists can date fossils
   the older the fossil, the greater the fraction of its radioactive atoms that have decayed

Molecule:
A group of atoms held together by energy called a chemical bond

<u>3 principal types of chemical bonds</u>
1.ionic
2.covalent
3.hydrogen

IONIC	COVALENT	HYDROGEN
•attraction of opposite electrical charges •Molecules comprised of these bonds are often most stable as crystals	•form between 2 atoms when they share electrons •the # of electrons shared varies depending on how many the atom needs to fill its outermost electron shell •covalent bonds are stronger than ionic bonds	•are weak bonds that form due to covalent bonds where one nucleus attracts the shared electrons more than another nucleus •this attraction for electrons by a nucleus is called the atom's electronegativity •e- from H more strongly attracted to the O nucleus than its own H nucleus. This causes a strong – charge by the O nucleus and a more + charge near the H nucleus. •POLAR molecule

Hydrogen bonds

- form in association with polar molecules
- each atom with a partial charge acts like a magnet to bond weakly to another polar atom with an opposite charge
- H bonds have cumulative strength
- Hydrogen Bonds Give Water Unique Properties

Water is essential for life. The chemistry of life is water chemistry.
Water is a polar molecule
water can form hydrogen bonds

This hydrogen bonding confers on water many different special properties

<u>5 Unique Properties of Water</u>

1. Heat Storage: water temperature changes slowly and holds temperature well

2. Ice Formation: few hydrogen bonds break at low temperatures water becomes less dense as it freezes because hydrogen bonds stabilize and hold water molecules farther apart

3. High Heat of Vaporization: at high temperatures, hydrogen bonds can be broken. Water requires tremendous energy to vaporize because of all the hydrogen bonds that must be broken

4. Water molecules are sticky

- cohesion – when one water molecule is attracted to another water molecule
- adhesion – when polar molecules other than water stick to a water molecule

5. The last unique property of water is that it is <u>highly polar</u>

- in solution, water molecules tend to form the maximum number of hydrogen bonds

•hydrophilic molecules are attracted to water and dissolve easily in it
–these molecules are also polar and can form hydrogen bonds
•hydrophobic molecules are repelled by water and do not dissolve
–these molecules are non-polar and do not form hydrogen bonds

Water Ionizes

- The covalent bond within a water molecule breaks spontaneously
- This produces two ions in a process called ionization
- because of the great strength of covalent bonds, this does not occur too often

The amount of ionized hydrogen from water in a solution can be measured as pH

pH Scale

- The pH scale is logarithmic, which means that a pH scale difference of 1 unit actually represents a 10-fold change in hydrogen ion concentration
- Pure water has a pH of 7 (there are equal amounts of [H+] relative to [OH-]
- Acid – any substance that dissociates in water and increases the hydrogen ion concentration
- acidic solutions have pH values below 7
- Base – any substance that combines with [H^+] when dissolved in water
- basic solutions have pH values above 7
- The pH in most living cells and their environments is fairly close to 7
- proteins involved in metabolism are sensitive to any pH changes
- metabolic activities & dietary intake and processing creates acids and bases
- Organisms use buffers to minimize pH disturbances

Buffer – a chemical substance that takes up or releases hydrogen ions

- buffers don't remove the acid or the base affecting pH but minimize their effect on it
- most buffers are pairs of substances, one an acid and one a base

4 types of Macromolecules (polymers)

Proteins

Nucleic Acids

Carbohydrates

Lipids

Monomers: single unit that repeats to make up a polymer.

Organic Molecule: any molecule that has a carbon based core with special groups attached.

- These special groups give the molecule it's identity.

How are Macromolecules Made & Destroyed?

Enzymes are required.

Making a Macromoledule	Dehydration Synthesis	Remove a $H2O$ (H from one and OH from another)
Destroying a Macromolecule (polymer)	Hydrolysis	Add a $H2O$ molecule

1. Proteins (a chain of AA) Protein structure is complex

- the covalent bond linking two amino acids together is called a peptide bond
- the assembled polymer is called a polypeptide
- AA are small molecules with a simple basic structure, a carbon atom to which three groups are added
    - an amino group ($-NH_2$)
    - a carboxyl group (-COOH)
    - a functional group (R)

The functional group gives amino acids their chemical identity
there are 20 different types of amino acids

the order of the AA that form the polypeptide is important
the sequence of the amino acids affects how the protein folds together

the way that a polypeptide folds to form the protein determines the protein's function
some proteins are comprised of more than one polypeptide

<u>There are four general levels to protein structure</u>

1. Primary: the sequence of AA in the polypeptide chain

2. Secondary: folded

3. Tertiary: 3d

4. Quaternary: Multiple polypeptide chains

The shape of a protein affects its function

- changes to the environment of the protein may cause it to unfold or denature

- increased temperature or lower pH affects hydrogen bonding, which is involved in the folding process

- a denatured protein is inactive

- Enzymes are globular proteins that have a special 3-D shape that fits precisely with another chemical which causes the chemical that they fit with to undergo a reaction

catalysis : process of enhancing a chemical reaction:

Proteins fold specifically

- the folding process is helped by special proteins called chaperone proteins
- these proteins somehow correct a misfolded protein
- defective chaperone proteins may play a role in certain genetic disorders that involve defective proteins
- Cystic fibrosis
- Alzheimer's

2. Nucleic Acids: 2 types

Nucleic acids are very long polymers that store information
Monomers: nucleotides

each nucleotide has 3 parts

1. a five-carbon sugar
2. a phosphate group
3. an organic nitrogen-containing base

There are 5 different types of nucleotides

- information is encoded in the nucleic acid by different sequences of these nucleotides
- 2 types of nucleic acids
  - Deoxyribonucleic acid (DNA)
  - Ribonucleic acid (RNA)

RNA is similar to DNA except that

a. it uses uracil instead of thymine
b. it is comprised of just one strand
c. it has a ribose sugar

DNA STRUCTURE

1. The structure of DNA is a double helix because there are only two base pairs possible

- Adenosine (A) pairs with thymine (T)
- Cytosine (C) pairs with Guanine (G)

2. the bond holding together a base pair is hydrogen bond

3. a sugar-phosphate backbone comprised of phosphodiester bonds gives support

4. The structure of DNA helps it to function

5. The hydrogen bonds of the base pairs can be easily broken to unzip the DNA so that information can be copied

Each strand of DNA is a mirror image so the DNA contains two copies of the information
Having two copies means that the information can be accurately copied and passed to the next generation

3. Carbohydrates

Carbohydrates are monomers that make up the structural framework of cells and play a critical role in energy storage

a carbohydrate is any molecule that contains the elements C, H, and O in a 1:2:1 ratio
the sizes of carbohydrates varies

- simple carbohydrates – made up of one or two monomers
- complex carbohydrates – made up of polymers

Simple carbohydrates are small

- monosaccharides consist of only one monomer subunit
I e: glucose ($C_6H_{12}O_6$)
- disaccharides consist of two monosaccharides
  Ie: sucrose, which is formed by joining together two monosaccharides, glucose and fructose

Complex carbohydrates are long polymer chains

- because they contain many C-H bonds, these carbohydrates are good for storing energy
- these bond types are the ones most often broken by organisms to obtain energy

long chains are called polysaccharides

Plants and animals store energy in polysaccharide chains formed from glucose

- Storage polysaccharide in plants is starch
- Storage in animals as glycogen.

Some polysaccharides are structural and resistant to digestion by enzymes

- plants form cellulose cell walls . Cellulose is a polysaccharide in cell walls.
- some animals form chitin for exoskeletons. Chitin is a polysacch. In external skeletons of insects.

4. Lipids

Lipids – fats and other molecules that are not soluble in water
lipids are non-polar molecules

lipids have many different types

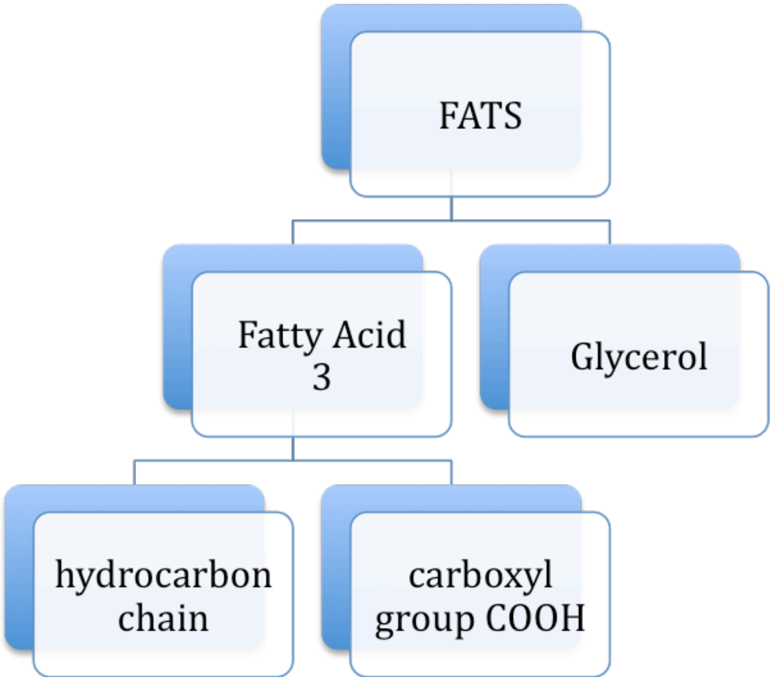
fats	steroids	waxes
oils	rubber	pigments

TYPES OF LIPID MOLECULES

Fats	3 Fatty Acids + Glycerol	Aka triglycerides Can be saturated or unsaturated
Phospholipid	2 Fatty Acids + Glycerol + Phosphate group FA tails are NONpolar (&flexible) Other end is polar	Found in plasma membrane
Steroids	Ie: cholesterol Complex ring structures	

Other examples of biological lipids:

- rubber
- waxes
- pigments (like chlorophyll) and retinal (found in your eyes, detects light_



Fats are converted from glucose for long-term energy storage
fats have two subunits
1.fatty acids
2.glycerol

Fat Molecules: a 3 C glycerol + 3 FA tails

Animal Fats	SATURATED: each carbon has the max # of hydrogen's bonded to it.	Butter Solid at room temperature Hard
Plant Fats	UNSATURATED: contain double bonds	Oil Liquid at room temperature

Name ____

HOMEWORK # 1

Test your knowledge. Use your text, lecture notes or publisher's webpage.

There are 3 types of bonds discussed in chapter 3. Which type of bond is

a) the strongest: ____________________

b) the weakest: ____________________

c) most commonly found in the human body: ____________________

d) responsible for the unique properties of water: ____________________

List one molecule that illustrates each type of bond.

a) covalent: ____________________

b) ionic: ____________________

c) hydrogen: ____________________

For each macromolecule (polymer) below, identify its monomer.

a) carbohydrate: ________________________________

b) lipids: ________________________________

c) proteins: ________________________________

d) nucleic acids: ________________________________

Define:

❖ Chaperone protein:

❖ Catalysis:

Which macromolecule above serves as the greatest storage of energy? ____________