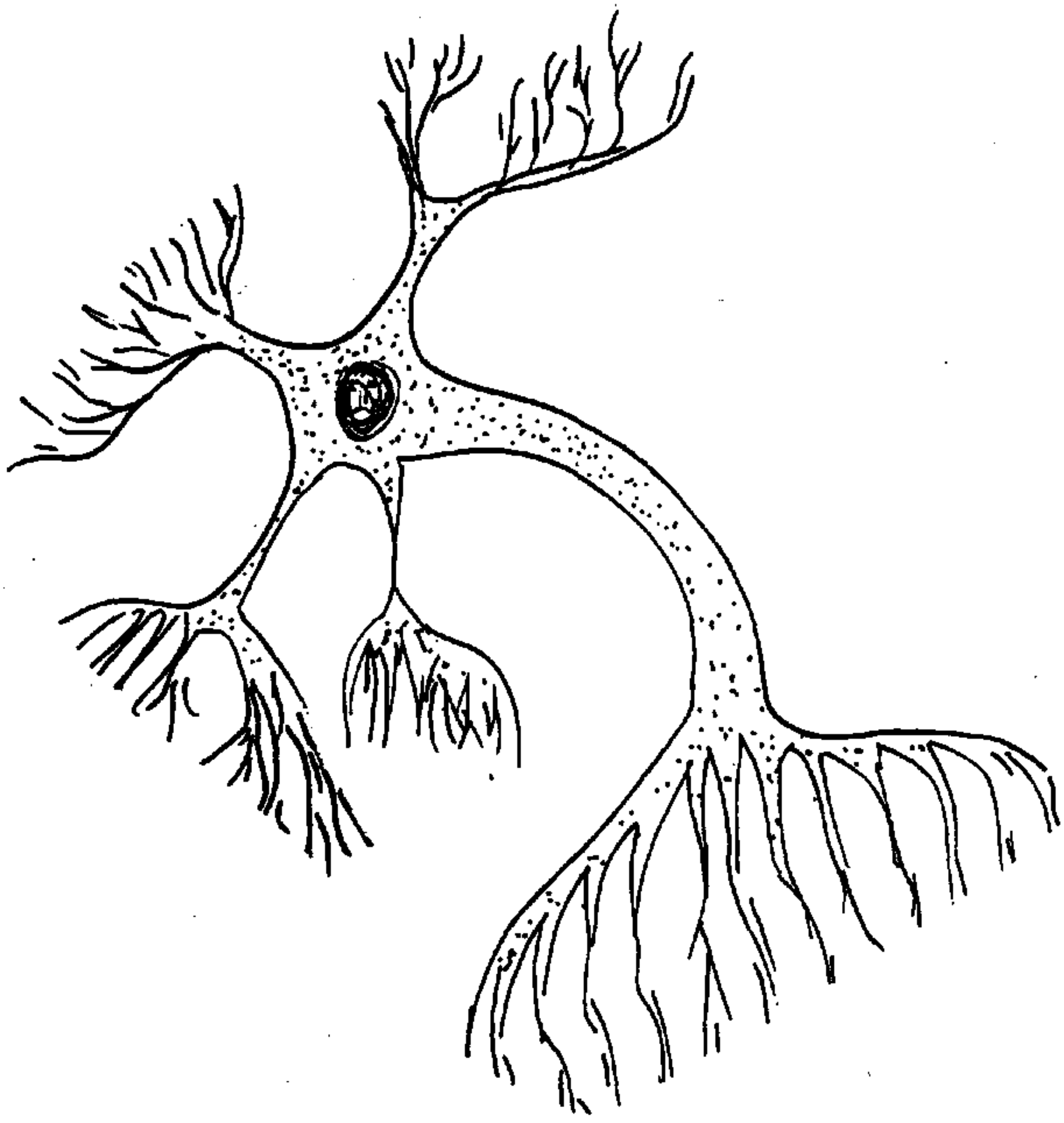
UNIT 2

CELLULAR DIVERSITY: BIOCHEMICAL AND CELL ORGANIZATION



CLASS SESSION: BIOCHEMISTRY - BASIC ELEMENTS

A. Atomic Structure (description) - atoms may be viewed as the basic structural units of matter which are composed of sub-atomic particles, which include charged electrons (-), charged protons (+), and neutral neutrons (0); other subatomic particles are known that include: muons (+/-) positrons (+); neutrinos (o); pions(+/-/o); antiprotons (-); antineutrons (o); and photons.

1. electron cloud model (description) - a more current view of atomic structure describes electrons (-) not in distinct ring-like orbits around the nucleus, but the orbits form an "electron cloud" around the nucleus that electrons occupy; orbits form shells or energy levels

B. Elements (description) - refers to a type of matter composed of one kind of atom with a stable or constant number of protons, neutrons, and electrons; letters of the alphabet are used to represent the different elements

1. common elements in organisms (examples):

H = hydrogen	I = iodine	Fe = iron
O = oxygen	Na = sodium	Cl = chlorine
N = nitrogen	Mg = magnesium	Ca = calcium
C = carbon	S = sulfur	K = potassium
P = phosphorus	Pb = lead	Cd = cadmium

2. atomic weight (characteristic of an element) - refers to the relative mass of the total number of protons and neutrons in the nucleus of an atom of a given element; also called the atomic mass

3. atomic number (characteristic of an element) - refers to the total number of protons in the nucleus of an atom of a given element

a. isotopes (definition) - defined as a different form of an atom of a given element that has the same atomic number or number of protons in its nucleus, but has a different atomic weight because of more neutrons in the nucleus of the atom

1. radioactive isotopes (description) - some isotopes of some elements are not stable and naturally breakdown into other forms; radioactive process described as the spontaneous and uncontrolled decay of an atomic nucleus

element	C^{12}	C^{14}	O^{16}	O^{18}	I^{127}	I^{131}
atomic #	6	6	8	8	53	53
atomic wt	12	14 *isotope	16	18 *isotope	127	131 *isotope

CLASS SESSION: BIOCHEMISTRY - COMPOUNDS AND MIXTURES

A. Compounds (description) - defined as the units of matter formed by the chemical combination of two or more elements; compounds are unique substances with properties that are different from those of the individual elements that compose it; symbols used to represent the elements are also used to represent the combination and ratios of the elements chemically combined in compounds (eg. H_2O; CO_2; O_2; and $C_6H_{12}O_6$

1. molecule (definition) - defined as one or the smallest amount of a given compound as formed by its atomic or element combination; (for example, one molecule of water is H2O composed of 2 atoms of hydrogen and 1 atom of oxygen; one molecule of the sugar glucose is C6H12O6 composed of 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen)

(description) AP

2. chemical bonds - elements combine in specific ratios to form compounds; the ratios and combinations are determined by the arrangement of electrons in the outermost orbits or shells of the elements; to become electrically stable some elements can share electrons or transfer their electrons to other elements to form covalent or ionic chemical bonds

a. covalent bond (definition) - defined as a chemical bond between atoms of different elements formed by the sharing of electron pairs in their outer orbits; compounds are formed when atoms share electrons to form covalent bonds

b. ionic bond (definition) - defined as a chemical bond between atoms of different elements formed by the transfer of electrons from the outer orbit of one element to that of another element; the atom that loses the electron in the transfer becomes charged (+ ion) and the atom that gains the electron becomes charged (- ion); the attractive force between the (+ ion) and the (- ion) forms the bond and a substance known as an ionic crystal

1. ions (definition) - defined as a charged atom of an element due to gaining or losing electrons; if an atom of an element gains electrons it becomes a negatively charged (-) ion; if an atom of an element loses electrons it becomes a positively charged (+) ion

Example: NaCl - sodium chloride is an example of an ionic crystal (salt) formed by attractive forces between Na^+ ions and Cl^- ions; the Na atoms become Na^+ ions as the atoms transfer (lose) electrons over to Cl atoms which accept (gain) the electrons to become Cl^- ions

Example: H_2O - a water molecule ionizes to form a H^+ ion as one H atom loses an electron, and to form a OH^- ion as the remaining OH (hydroxyl) part of the molecule gains an electron

Note: Chemical reactions are defined as the chemical interactions between different elements or compounds in which chemical bonds are broken and new bonds formed to produce new compounds; the starting compounds or elements are referred to as reactants and the new compounds produced are called products. Chemical equations are representations of reactants and products in a chemical reaction using chemical formulas of the compounds in balanced ratios.

B. Mixtures (description) - may be defined as the physical combination of two or more substances which may be liquid, solid, or gaseous; in a mixture chemical bonds are not broken or formed and the molecules retain their properties and can be physically separated; defined according to the state, size, and distribution of the molecules that form the mixture

1. homogeneous mixture (definition) - defined as a mixture in which the molecules are approximately the same size and uniformly distributed

a. solution (a homogeneous mixture) - refers to a mixture in which the substances are evenly dissolved in liquid; solvent part of a solution refers to the liquid substance that forms most of the mixture and is usually water; solute part of a solution refers to solids, liquids, or gases that are dissolved in the solvent and are usually salts

2. heterogeneous mixture (definition) - defined as a mixture in which the substances are unequal in size and not uniformly distributed

a. suspension (a heterogeneous mixture) - refers to a mixture in which substances or solutes do not dissolve in the liquid solvent, but usually settle out; (eg. sand and water)

1. colloidal dispersion (definition) - also referred to as a colloid or colloidal suspension; described as a mixture intermediate between solutions and suspensions in which the size of the particles are too large to dissolve and too small to settle so they become dispersed unevenly through the mixture; substances forming a colloid may be liquids, gases, or solids

a. cytoplasm (colloid description)) - described as a colloid or colloidal dispersion because molecules of organic and inorganic compounds, ions, and organelles are dispersed unevenly throughout the liquid (water) medium

CLASS SESSION: BIOCHEMISTRY - BIOGEOCHEMICAL CYCLES
Reference

A. Biogeochemical Cycles (description) - refers to elements that are essential for life and part of ecosystem dynamics; elements circulate through the environment in different chemical states (gas, liquid, solid); elements of environmental significance include phosphorus, lead, mercury, cadmium, and chromium

1. phosphorus (natural cycle) - primary reservoir of P is phosphate (PO_4) in soil and rocks; rocks erode to release phosphate into environment; phosphates are absorbed by plants and passed to animals in food chain; animals excrete excess phosphate in feces (guano); plants/animals decay P compounds are degraded and released by microorganisms back into environment; environmental concern - phosphates dumped or washed in excess into streams and lakes promote algae overgrowth which depletes oxygen supplies

2. sulfur (natural cycle) - found as sulfur (S), sulfides (SO_2), sulfur monoxide (SO) and sulfates (SO_4); sulfur compounds available in soil are absorbed by plants and passed to animals in food chain; as plants/animals die/decay aerobic microorganisms decompose sulfur compounds to sulfates while anerobic forms form hydrogen sulfide (H_2S); sulfates and sulfides become available to plants in soil; environmental note - industrial combustion of sulfur compounds (in coal and oil) releases sulfur dioxide (SO_2) and other sulfur compounds into the atmosphere; sulfur products react with O_2 to form sulfur trioxide (SO_3) which in turn reacts with H_2O to form sulfuric acid (H_2SO_4) leading to acid rain/snow

3. lead (natural cycle) - lead sulfide in rocks/ soil; plants absorb Pb from soil, water, and air; animals obtain Pb from food, water, and air; recycled through decomposition; environmental note - high Pb levels released into air and water from leaded fuels and industry; in humans can be absorbed by the lungs and cause disruptions of enzymes, neurological processes, hemoglobin synthesis, kidney function, and causes "intoxication effects"

4. cadmium (natural cycle) - occurs as constituent of zinc, copper, and lead ores in rocks and soils; cycled through plants, food chains, and decomposition; environmental note - used in alloys, paints, plastics, rubber products, metal plating; disposed as an industrial waste causing contamination of food and water sources; in humans associated with hypertension, bone decalcification, arteriosclerosis, emphysema, and kidney dysfunction

5. chromium (natural cycle) - found in low levels in soils; cycled by plants to animals in food chains, and decomposition returns chromium compounds to soil; environmental note - used to coat metals and other materials as an anticorrosive; released/dumped as waste; released into atmosphere in small amounts during combustion of coal and wood; in humans can be ingested or inhaled and is associated with skin lesions, gastrointestinal ulcers, and lung cancer

CLASS SESSION: INORGANIC COMPOUNDS - WATER
Supplement with Audiovisuals

A. Inorganic Compounds (definition) - defined as compounds that do not involve the element carbon (except carbon dioxide and calcium carbonate); inorganic compounds are structurally and functionally important in organisms and in the interactions of organisms with the environment; important inorganic compounds include water, gases, acids, bases, and salts

1. polar molecules (description) - in some compounds formed by covalent bonds the atomic nuclei of the elements involved have different degrees of attraction for electrons; the electrons tend to spend more "time" around the nuclei of the element with the greater attraction giving these nuclei a slight negative (-) charge and the other nuclei where the electrons spend less time a slight positive (+) charge; the unequal sharing of electrons form polar covalent bonds and such molecules are described as polar; water is a polar molecule with the H end being slightly (+) and the O end being slightly (-)

B. Water (H_2O) (description) - described as the most abundant inorganic compound in the structure of organisms and of great importance in the biochemical reactions of organisms

1. biological functions of water (description) - the functions of water in living systems include the following:
- water serves as a general solvent for biochemical reactions
- water serves as a general solvent for dissolution of salts and gases
- water serves as the general component of cell cytoplasm and forms approximately 50% to 90% of weight in living organisms
- water is a chemical agent in hydrolysis or chemical digestion
- water serves as a medium for circulation and transport
- water serves as a medium for reproductive processes
- water serves as a medium for developmental processes
- water serves to stabilize temperature of habitats
- water forms aquatic and marine habitats
- water is a medium upon which the flow of energy and the cycling of nutrients depend in aquatic and marine habitats

C. Properties of Water (description) - the physical and chemical properties of water molecules account for the biological importance of water in organisms; water is described as a polar molecule which accounts for its biological significance

1. hydrogen bonds in water (description) - the polar nature of water molecules allows for the formation of attractive bonds known as hydrogen bonds between the negative zones and positive zones of one water molecule and the oppositely charged zones of other water molecules; each H_2O molecule can form such bonds with four other water molecules; hydrogen bonds are continually breaking and shifting which makes water liquid at ordinary temperature and pressure

a. <u>water as a solvent</u> (description) - refers to water as a universal solvent due to the polarity of water molecules; polar water molecules tend to separate ionic molecules as water molecules cluster around and segregate the charged ions; water molecules also separate the polar covalent molecules into positive and negative ions

1. <u>hydrophilic molecules</u> (description) - refers to ionic and polar molecules that readily dissolve in water; the partially charged regions of polar molecules attract water molecules as much or more than eachother; called "water-loving"

2. <u>hydrophobic molecules</u> (description) - refers to non-polar molecules that interact to cluster in water and not readily dissolve; the hydrogen bonds of water act as an exclusion force

b. <u>high specific heat of water</u> (description) - refers to heat capacity and the amount of heat required to raise the temperature of 1 gram of a substance 1 degree C; water is described as having a high specific heat (1 calorie per gram) due to its hydrogen bonds; capable of storing tremendous quantity of heat with a relatively small rise in temperature; results in stable temperature of oceans and large bodies of water; allows ponds, lakes, and seas to warm slowly in the Spring and cool off slowly in the Fall which prevents seasonal fluctuations in aquatic habitats and moderates the environment; helps maintain internal temperature of terrestrial plants and animals

c. <u>heat of vaporization of water</u> (description) - refers to the amount of heat required to change a given amount of a liquid to a gas; water has a high heat of vaporization or evaporation (540 calories per gram) due to hydrogen bonding; results in cooling effect of evaporation as water molecules carry off heat as they become vapor; significant in temperature control of terrestrial plants and animals

d. <u>heat of fusion of water</u> (description) - refers to the amount of heat needed to convert a given amount of a solid to a liquid; water requires 79.7 calories per gram to convert melt ice; heat needed to melt ice is drawn from surroundings thereby cooling the surroundings and same amount of heat is released as water freezes; large amounts of heat must be removed before water can change from a liquid to solid state (freeze) and must absorb a considerale amount of heat before ice can be converted to liquid (melt); results in ice/snow serving as a temperature stabilizer especially during seasonal transitions

1. <u>freezing of water</u> (description) - water displays unusual property during transition from liquid state to solid state; the <u>density</u> of water molecules increases as water cools to 4 degrees C, but then the molecules move slightly apart to maintain maximum hydrogen bonding in a stable structure; ice at freezing temperature of 0 degrees C takes more volume and is less dense than liquid water and "floats"; results in protection of aquatic life from freezing on the bottom of aquatic habitats

e. <u>viscosity of water</u> (description) - water has high viscosity, a property that resists changes in shape or arrangement during the liquid's flow; greatest flow at the center with decrease towards sides due to internal friction (can be seen in waterflow of a stream or river where the streamsides seem still and the swift current is evident towards the center); there are viscosity factors which create turbulence horizontally and vertically which serve as sources of frictional resistence for objects (organisms) moving through the water (adaptations to reduce this friction (eg. streamlined body shape, mucus coating)

f. <u>surface tension of water</u> (description) - water molecules at the surface display surface tension as a result of cohesion (holding together of molecules of same substance); surface tension forms a "skin of water" which can be a support or barrier for aquatic organisms and also these forces function as water is drawn through the pores of soil and through the vascular networks of plants

g. <u>capillary action of water</u> (description) - refers to cohesion and adhesion (holding together of molecules of different substances) forces that allow water to move upward or through very fine spaces or "tubes"; significant in water movement nthrough pores of soil and vascular networks of plants

D. <u>Water in the Environment</u> (description) - at any given time the water on earth is distributed as follows: 94% in marine habitats, 4% inaccessible aquifers, 1.5% polar ice, and .5% circulating-fresh water

1. <u>water biomes</u> (description) - water serves as a basis for marine and freshwater ecosystems and associated habitats

a. <u>marine biome</u> (description) - the oceans, seas and gulfs form the marine ecosystem; consideration of marine habitats includes the shore communities, salt marshes, tidal flats, and estuaries

b. <u>aquatic biome</u> (description) - the relatively small, separate bodies of lakes, ponds, rivers, streams, and brooks form freshwater ecosystems; consideration of aquatic habitats includes groundwater, underground streams and inland wetlands such as swamps, marshes, bogs, and springs

2. <u>hydrologic (water) cycle</u> (description) - water cycles through ecosystems in physical interactions that involve evaporation, condensation, and precipitation

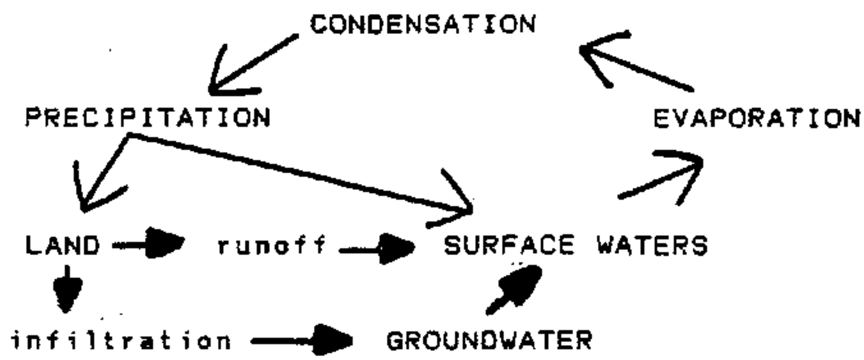
a. <u>evaporation</u> (definition) - defined as the process of water being converted from the liquid state to the gaseous state; occurs from the seas, rivers, lakes and land surfaces to add water/vapor to the atmosphere

1. <u>transpiration</u> (definition) - defined as the process by which plants lose water from their leaves through the stomates to add water to the atmosphere

b. condensation (definition) - defined as the process by which water changes from the gaseous to liquid state; moisture in the air cools to form water droplets or ice crystals; air must contain small particles known as condensation nuclei (salts, dust, particulates) on which water vapor collects

c. precipitation (definition) - defined as process in which condensed water falls back towards earth's surface as rain, snow, sleet, or hail; water accumulates on ground and there is runoff to rivers, streams and lakes; some water filters into the ground (infiltration) to replenish ground water or become available for plants

Diagram: Hydrologic (Water) Cycle



Note: Water Pollution is a major environmental concern in both industrialized and developing nations. Water pollutants include various inorganic and organic compounds in high concentrations that are generated directly from point sources (eg. factories; power plants; sewage plants..) and indirectly by runoff from non-point sources (eg, croplands; forests; urban areas; roadways..). Organic pollutants (from feedlots, sewage treatment plants, paper mills, meat packing plants) accelerate aerobic bacterial growth which depletes dissolved oxygen and leads to fish kills. Further anerobic bacterial action on organic pollutants produce toxic methane and hydrogen sulfide gases. Similar effects occur from algae blooms and dieoff associated with inorganic pollutants such as nitrates and phosphates from fertilizers and detergents that stimulate algae growth. Other water pollutants with negative effects on fishes and aquatic organisms include toxic inorganics (metals, acids, salts, and chlorine derived from industrial dumping, urban runoff, mining, soil erosion, sewage effluents, and air pollution fallout); infectious agents (pathogenic bacteria, viruses, protozoans, and parasites from untreated raw sewage and animal wastes in fields and feedlots near waterways); synthetic organics (PCBs and phenols from industrial dumping); sediment (from increased erosion and runoff from deforestation, agriculture, ranching, mining; and construction); and thermal effects (rapid changes in water temperature from release of hot or cold waters into streams from hydroelectric and nuclear plants, steelmills, refineries, and paper mills).

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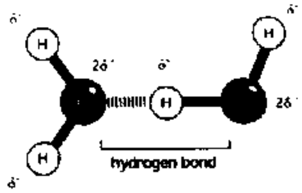
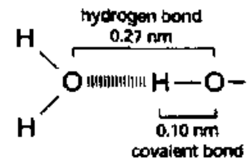
Chemical Properties of Water - Part 1

HYDROGEN BONDS

Because they are polarized, two adjacent H_2O molecules can form a linkage known as a hydrogen bond. Hydrogen bonds have only about 1/20 the strength of a covalent bond.

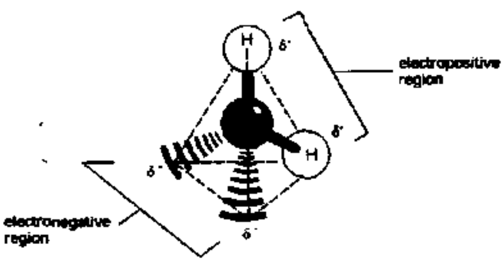
Hydrogen bonds are strongest when the three atoms lie in a straight line.





WATER

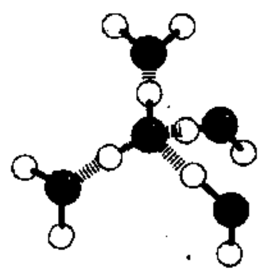
Two atoms, connected by a covalent bond, may exert different attractions for the electrons of the bond. In such cases the bond is polar, with one end slightly negatively charged (δ^-) and the other slightly positively charged (δ^+).



Although a water molecule has an overall neutral charge (having the same number of electrons and protons), the electrons are asymmetrically distributed, which makes the molecule polar. The oxygen nucleus draws electrons away from the hydrogen nuclei, leaving these nuclei with a small net positive charge. The excess of electron density on the oxygen atom creates weakly negative regions at the other two corners of an imaginary tetrahedron.

WATER STRUCTURE

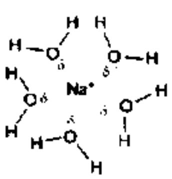
Molecules of water join together transiently in a hydrogen-bonded lattice. Even at 37°C, 15% of the water molecules are joined to four others in a short-lived assembly known as a "flickering cluster."

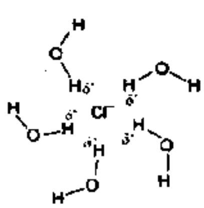


The cohesive nature of water is responsible for many of its unusual properties, such as high surface tension, specific heat, and heat of vaporization.

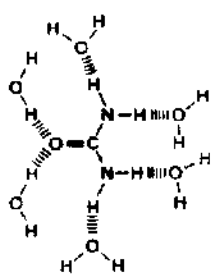
HYDROPHILIC MOLECULES

Substances that dissolve readily in water are termed hydrophilic. They are composed of ions or polar molecules that attract water molecules through electrical charge effects. Water molecules surround each ion or polar molecule on the surface of a solid substance and carry it into solution.





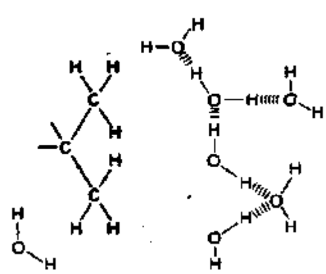
Ionic substances such as sodium chloride dissolve because water molecules are attracted to the positive (Na^+) or negative (Cl^-) charge of each ion.



Polar substances such as urea dissolve because their molecules form hydrogen bonds with the surrounding water molecules

HYDROPHOBIC MOLECULES

Molecules that contain a preponderance of nonpolar bonds are usually insoluble in water and are termed hydrophobic. This is true, especially, of hydrocarbons, which contain many C–H bonds. Water molecules are not attracted to such molecules and so have little tendency to surround them and carry them into solution.



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Chemical Properties of Water - Part 2

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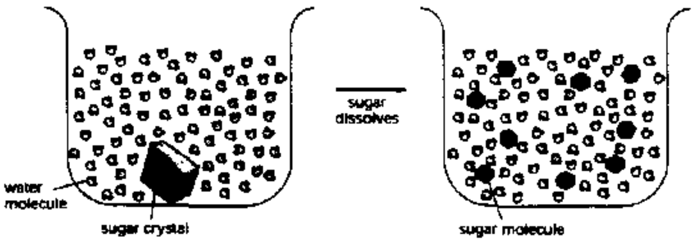
WATER AS A SOLVENT

Many substances, such as household sugar, dissolve in water. That is, their molecules separate from each other, each becoming surrounded by water molecules.



When a substance dissolves in a liquid, the mixture is termed a solution. The dissolved substance (in this case sugar) is the solute, and the liquid that does the dissolving (in this case water) is the solvent. Water is an excellent solvent for many substances because of its polar bonds.

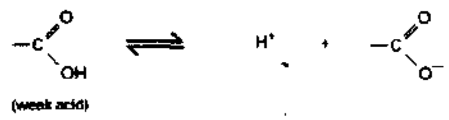
ACIDS

Substances that release hydrogen ions into solution are called acids.

$$HCl \longrightarrow H^+ + Cl^-$$

hydrochloric acid (strong acid) — hydrogen ion — chloride ion

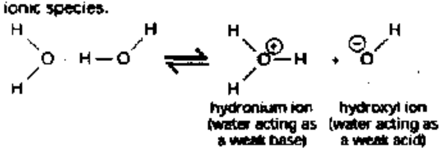
Many of the acids important in the cell are only partially dissociated, and they are therefore weak acids—for example, the carboxyl group (–COOH), which dissociates to give a hydrogen ion in solution



Note that this is a reversible reaction.

HYDROGEN ION EXCHANGE

Positively charged hydrogen ions (H^+) can spontaneously move from one water molecule to another, thereby creating two ionic species.



often written as: $H_2O \rightleftharpoons H^+ + OH^-$

hydrogen ion — hydroxyl ion

Since the process is rapidly reversible, hydrogen ions are continually shuttling between water molecules. Pure water contains a steady state concentration of hydrogen ions and hydroxyl ions (both 10^{-7} M).

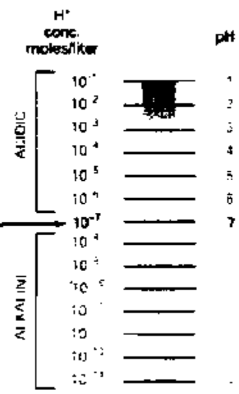
pH

The acidity of a solution is defined by the concentration of H^+ ions it possesses. For convenience we use the pH scale, where

$$pH = -\log_{10}[H^+]$$

For pure water

$[H^+] = 10^{-7}$ moles/liter



BASES

Substances that reduce the number of hydrogen ions in solution are called bases. Some bases, such as ammonia, combine directly with hydrogen ions.

$$NH_3 + H^+ \longrightarrow NH_4^+$$

ammonia — hydrogen ion — ammonium ion

Other bases, such as sodium hydroxide, reduce the number of H^+ ions indirectly, by making OH^- ions that then combine directly with H^+ ions to make H_2O.

$$NaOH \longrightarrow Na^+ + OH^-$$

sodium hydroxide (strong base) — sodium ion — hydroxyl ion

Many bases found in cells are partially dissociated and are termed . This is true of compounds that contain an amino group ($-NH_2$), which has a weak tendency to reversibly accept an H^+ ion from water, increasing the quantity of free OH^- ions.

$$-NH_2 + H^+ \rightleftharpoons -NH_3^+$$

CLASS SESSION: BIOACTIVE INORGANIC COMPOUNDS
Supplement with Audiovisuals

A. Gases (definition) - defined as a state of matter of a compound in which it can expand indefinitely or completely fill its container; described as a vapor state; described as not liquid or solid; includes gases of oxygen and nitrogen formed by covalent bonds between two atoms of the same element (diatomic molecules) as well as carbon dioxide that are part of biochemical reactions and cycles

1. oxygen gas (O_2)(description)- diatomic gas molecule of two oxygen atoms used in aerobic cellular respiration reactions that produce ATP energy; formed as a product of photosynthesis

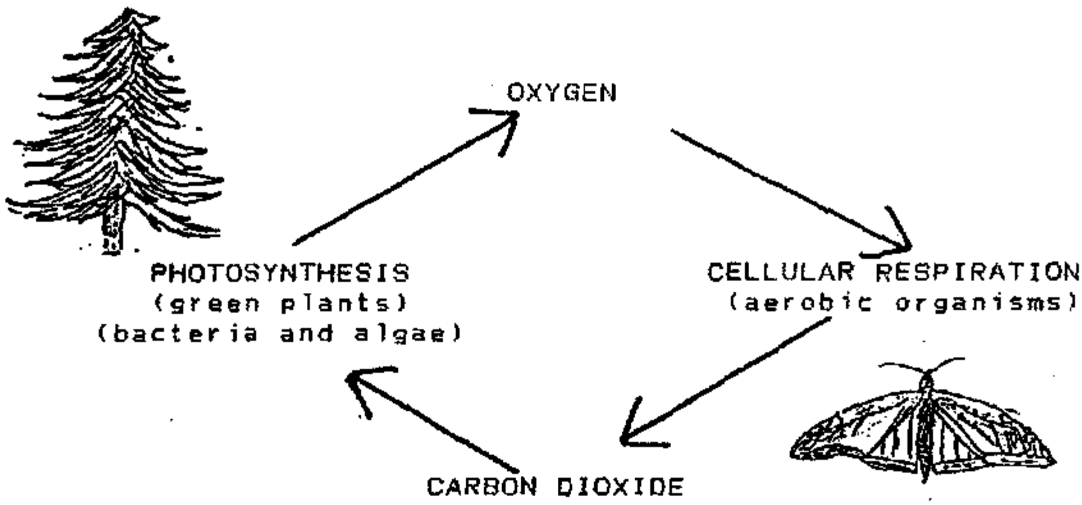
Note: Ozone is a gaseous molecule formed by the chemical combination of three oxygen atoms (O_3). Ozone molecules combine to form a protective ozone layer that occupies the outer two-thirds of the stratosphere (12-30 miles or 20-50 km). Ozone screens out 99% of harmful ultraviolet radiation and protects against the uv mutagenic and carcinogenic effects. A current environmental issue deals with depletion of the ozone layer due to the destruction of O_3 molecules by certain air pollutants that include nitrogen oxides; methyl chloride; and freons (chlorofluoromethanes and CFCs). As an example, freons (CFCs) undergo photodissociation by ultraviolet radiation in the stratosphere to produce a highly reactive chlorine free radical that reacts with and destroys ozone (1 freon generated radical destroys 100,000 ozone molecules). Sources estimate an ozone depletion of 1/2 to 1% has already occurred, and projections are made of 16-30% depletion by 1994-2000. Environmental concerns include increases in skin cancers; damage to plant leaves; inhibition of photosynthesis; and mutagenic effects in plants.

2. carbon dioxide gas (CO_2)(description) - gas molecule formed by one carbon and two oxygen atoms needed for photosynthesis reactions to produce glucose and formed as a product of cell respiration and alcohol fermentation

a. carbon-oxygen cycle (description) - refers to the inter-relationship of carbon dioxide and oxygen that occurs through the metabolic processes of photosynthesis and aerobic cellular respiration

1. CO_2 (-) O_2 exchanges (description) - represents a cycle between the exchanges of carbon dioxide and oxygen gases through reactions of photosynthetic green plants and algae that use carbon dioxide and release oxygen; aerobic organisms basically use oxygen in cellular respiration and release carbon dioxide

Diagram: Carbon-Oxygen Cycle



Note: Global Warming is an environmental issue that involves atmospheric CO_2 levels. Daily solar radiation heats the earth's surface and is slowly radiated back into the atmosphere as infrared radiation, which normally escapes back into space. Carbon dioxide naturally absorbs infrared radiation escaping from the earth's surface and radiates it back to the surface to help maintain temperature levels on earth in a "greenhouse effect". Over the past one hundred years, global levels of CO_2 have increased due to the combustion of fossil fuels, and are expected to increase further as a result of increased combustion of fossil fuels; deforestation; and agricultural burning. In addition, other "greenhouse gases" that trap infrared in the lower atmosphere include CH_4 (methane), which is produced during processes such as digestion by bacteria (produced in digestive tracts, swamps, wetlands, landfills), and chlorofluorocarbons (CFCs), which are synthetic byproducts from the manufacture of chemicals used in refrigeration, aerosols, and plastics. Environmental concerns focus on an increase in average global temperature with effects on melting of polar ice packs and glaciers with subsequent increases in sea level (a 1 foot rise in sea level would have a sea encroachment of 100 feet inland). Small changes in global temperature could have significant effects on climate and major shifts in weather patterns (droughts, storms, heat waves, floods..).

3. <u>nitrogen gas</u> (N_2)(description) - diatomic gas molecule formed by two nitrogen atoms; needed as a source of nitrogen; nitrogen is a significant element in biological systems because it is part of the chemical structure of bioactive compounds that include the nucleic acids of DNA and RNA which are molecules that form the genetic machinery of cells and organisms, and proteins including enzymes, which control biochemical reactions in cells and organisms

a. nitrogen cycle (description) - nitrogen is not usable to most organisms in its atmospheric form of N_2; the nitrogen cycle involves bacterial forms that have the enzyme machinery to utilize nitrogen or to convert the element into forms that can be absorbed and metabolized by plants, animals, and microorganisms

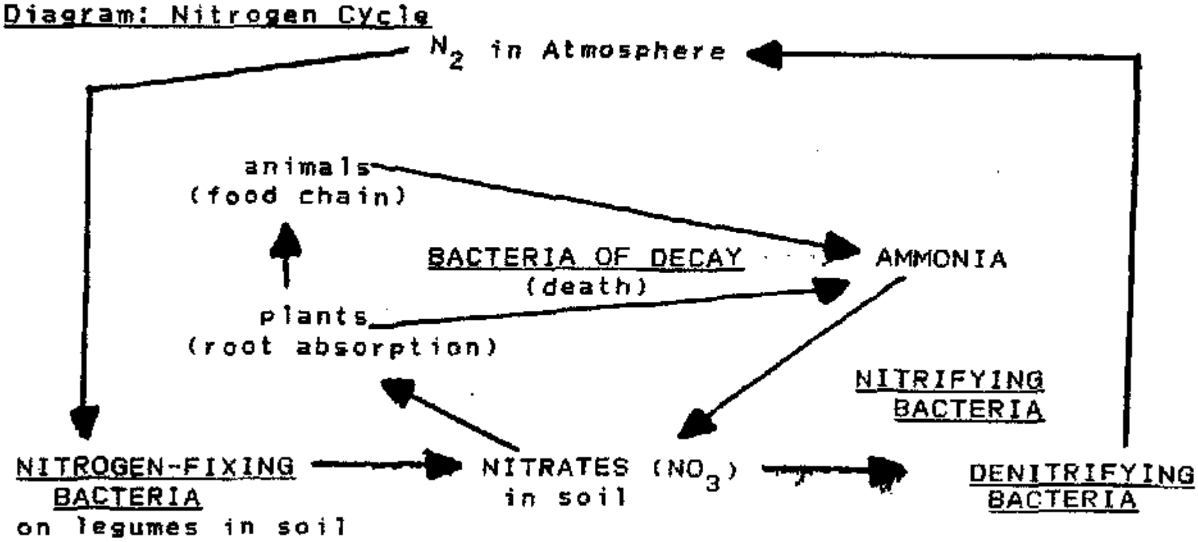
1. nitrogen fixing bacteria (function) - refers to bacteria (along with some forms of fungi and blue-green bacteria) that can use atmospheric nitrogen and convert it to ammonia (NH_3) which is then converted to nitrates (NO_3) in the soil; these microbes live symbiotically on the roots of legumes (alfalfa, clover, beans, pea family)

2. denitrifying bacteria (function) - refers to bacterial forms (along with some fungi) that convert ammonia and nitrates to atmospheric nitrogen; function opposite to nitrogen-fixing bacteria

3. bacteria of decay (function) - refers to aerobic and anaerobic bacteria (along with fungi) that decompose dead plant and animal matter to produce ammonia compounds which are then converted by other organisms to nitrites and nitrates

4. nitrifying bacteria (function) - involves several forms of bacteria that metabolize intermediate nitrogen compounds and ammonia that are formed by bacteria of decay to produce nitrates which are absorbable by plants or converted to atmospheric nitrogen by denitrifying bacteria

Diagram: Nitrogen Cycle



8. Ionization (description) - in liquid water there is a tendency for a H atom to "jump" from the O atom to which it is covalently bonded to an O atom to which it is hydrogen bonded; this produces hydronium (H^+) and hydroxide (OH^-) ions in an equilibrium reaction; ionic substances dissolved in water may offset the H^+ (=) OH^- equilibrium forming acidic or basic solutions

Note: The pH Scale is used to indicate the acidity or basicity of a solution. The pH scale measures the H^+ ion concentration in a solution, which is greater for an acid and lower for a base (bases have a greater OH^- ion concentration). The pH scale ranges from 1 to 14 with 1 to 6 being acidic (1 is strongly acidic and 6 is slightly acidic); 7 is neutral; and 8 to 14 being basic (8 is slightly basic and 14 is strongly basic).

1. acids (definition) - defined as any compound that forms an excess of H^+ ions when dissolved in water; described as electron acceptors or proton donors in chemical reactions; examples of inorganic acids include H_2SO_4 (sulfuric acid), HNO_3 (nitric acid), and HCl (hydrochloric acid); include pH scale 1 to 6

a. biological importance of acids - in many organisms acids are a source of H^+ ions which are needed for homeostasis and proper control of acid/base balance in cytoplasm and body fluids; in addition, some acids are needed for biochemical reactions such as HCl in chemical digestion in the stomach

Note: Acid Precipitation is a current environmental concern. Normal rainwater is slightly acidic with a 5.6 pH. Acid rain or snow is defined as precipitation with a pH of less than 5.6 (change of 1 unit on the pH scale represents a 10 fold change in the level of acidity). Air pollutants that include sulfur oxides and nitrogen oxides react with atmospheric water to form sulfuric and nitric acids, respectively. The formed atmospheric acids fall to the surface by wet deposition. The acid precursors and acids remain airborne for days and are carried by winds. Sources of sulfur and nitrogen oxides include volcanoes; forest fires; and bacterial decay as well as burning fossil fuels, especially coal. Environmental concerns center on the acidification of surface waters (lakes), which kills fishes and other aquatic organisms; damages to crops; alteration of soil fertilizers; and the destruction of human structures built with sandstone and marble.

2. <u>bases</u> (definition) - defined as any compound that forms an excess of OH^- ions when dissolved in water; described as an electron donor or proton acceptor in chemical reactions; examples of inorganic bases include NaOH (sodium hydroxide), KOH (potassium hydroxide), and NH_4OH (ammonium hydroxide)

a. <u>biological importance of bases</u> - bases are important in homeostasis for the control and regulation or proper acid/base balance in cytoplasm and body fluids; also needed in intestine to neutralize acidic contents from the stomach

3. <u>buffers</u> (description) - described as combinations of H^+ donor and H^+ acceptor forms of weak acids or weak bases to prevent changes in pH in solutions; maintain pH by tendency to combine with H^+ ions and remove them from solution as H^+ ions increase in concentration and release them as their concentration decreases

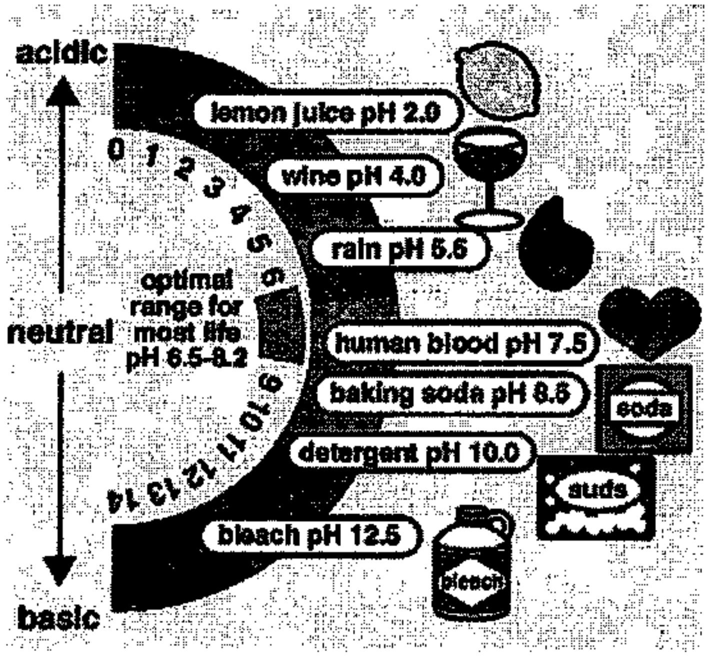
a. <u>biological importance of buffers</u> - buffers are important in the maintenance of homeostasis since pH influences the rate of chemical reactions in cells; allow cells and organisms to resist sudden changes in pH of body fluids

1. <u>example of buffer system</u> - in human blood there is a system of H2CO3 (hydrogen donor) and $HCO3^-$ (hydrogen acceptor) to maintain a pH of 7.4; if H^+ ions enter the blood they combine with the H^+ acceptor ($HCO3^-$) to form H2CO3; if OH^- ions enter the blood they combine with H^+ to form H2O and the H2CO3 ionizes to replace the used H^+ ions

C. <u>Salts</u> (definition) - defined as compounds produced as a result of a chemical reaction between an acid and a base known as neutralization; ionic crystals formed by ionic bonds between the negative ions from the acid and the positive ions from the base

<u>examples of inorganic salts</u>:
NaCl = sodium chloride (Cl^- from HCl and Na^+ from NaOH)
Na_2SO_4 = sodium sulfate ($SO4^{--}$ from H_2SO_4 and Na^+ from NaOH)
$CaCO_3$ = calcium carbonate (CO_3^{--} from H_2CO_3 and Ca^{++} from $CaOH_2$)

1. <u>biological importance of salts</u> - salts are biologically important because they are a source of ions and elements which are needed for a great variety of cell and body reactions; for example, Ca^{++} is needed for blood clotting and muscle contraction; Na^+ is needed for nerve impulses and salt balance; and Fe^{++} is needed for oxygen transport in blood cells with hemoglobin



Exercise will result in the production of CO2, which will acidify the blood. Explain the buffering system that minimizes blood pH changes.

Identify and describe two other buffering systems that function in body systems.

CLASS SESSION: BIOCHEMISTRY - CARBOHYDRATES AND LIPIDS

A. Organic Compounds (definition) - defined as compounds that involve bonds with the element carbon (with the exception of carbon dioxide and calcium carbonate); electron structure of carbon allows for each carbon atom to form a total of 4 bonds with atoms of other elements; carbon compounds display a variety of bonds that include single and/or double bonds between carbons and other atoms; biologically important organic compounds include the carbohydrates, proteins, enzymes, lipids, and nucleic acids

Note: Structural formulas for inorganic and organic compounds can be represented by "showing" the covalent or ionic bonds formed between the atoms of the elements that form the compound as dash-lines between the atoms (- shows a single bond formed by sharing 1 pair of electrons or by transfer of an electron) (= shows a double bond formed by sharing 2 pairs of electrons).

1. process of condensation (description)-

B. Carbohydrates (definition) - defined as organic compounds that contain the elements C, H, and O with H and O in a ratio of 2 to 1 (H_2O); includes the sugars and starches; basic building molecules are saccharide units or monosaccharides

1. monosaccharides (description) -

Diagram: Structural Formulas of Monosaccharides (Isomers)

Alpha-Glucose	Galactose	Fructose
($C_6H_{12}O_6$)	($C_6H_{12}O_6$)	($C_6H_{12}O_6$)

Note: In solution glucose exists as alpha- and beta-glucose ring structures that are in equilibrium. Beta-glucose differs from alpha-glucose at carbon #1 where the OH (hydroxyl) group attaches above the plane of the ring.

2. glycosidic bond formation (description) -

a. disaccharides (description) -

1. formation of maltose by condensation:

reactants:

a-glucose	+	a-glucose
$C_6H_{12}O_6$	+	$C_6H_{12}O_6$

products:

	maltose	+	water
---->	$C_{12}H_{22}O_{11}$	+	HOH

b. polysaccharides (description)- described as the chemical combinations of many saccharide units linked in long chains by the process of dehydration synthesis or condensation; saccharide units (simple sugars) bond to form polysaccharides

1. starch (description) - refers to the polysaccharide forms stored in plants; includes amylose and amylopectin; amylose may contain one thousand or more alpha-glucose units linked from carbon #1 to carbon #4 in a single unbranched chain that forms a helix; amylopectin may contain from one to six thousand linked alpha-glucose units with short alpha-glucose side branches (24 to 36 units)

2. glycogen (description) - refers to the polysaccharide form stored in animals; structure is similar to amylopectin with more numerous and shorter side branches (16 to 24 units); glycogen is formed in the liver when glucose is in excess

3. cellulose (description) - refers to the principal structural polysaccharide in plants; forms the fibrous part of plant cell wall; formed as a polymer of beta-glucose units joined in carbon #1 to carbon #4 linkages; structure allows for hydrogen bonds between neighboring OH groups resulting in bundles of parallel chains (difficult for enzymes to breakdown)

4. chitin (description) - refers to a modified polysaccharide found in the exoskeletons of insects and crustaceans; also found in cell wall of fungi; polymer of modified monosaccharides similar to glucose, but with a nitrogen group ($-NHCOCH_3$) replacing an OH group on carbon #2

3. biological importance of carbohydrates - the sugars serve as basic fuels in the reactions of cell respiration to produce energy molecules; sugars serve as building blocks for more complex starch and polysaccharide molecules which are important as energy storage compounds and also part of cell structures such as the cell wall

C. Lipids (triglycerides) (description) - refers to organic compounds that are formed by C, H, and O; soluble in fat solvents and alcohols, but insoluble in water; hydrophobic nonpolar; includes the fats, phospholipids, oils, and waxes;

1. lipid structure (building molecules) - lipids are defined as a chemical combination of fatty acids and glycerol by condensation; there are variations in the glycerol component and the number of fatty acids

glycerol   a fatty acid

a. lipid formation by condensation (description) -

glycerol + 3 fatty acids (reactants)

----) 1 lipid (fat) + 3 waters (products)

Note: Lipids are described as saturated fats if fatty acids in their structure (such as stearic acid) have no double bonds. Unsaturated fats involve fatty acids (such as oleic acid) in which the carbon atoms have double bonds and so have the potential to form additional bonds with other atoms.

2. oils (description) -

3. waxes (description) -

4. phospholipids (description) -

a phospholipid

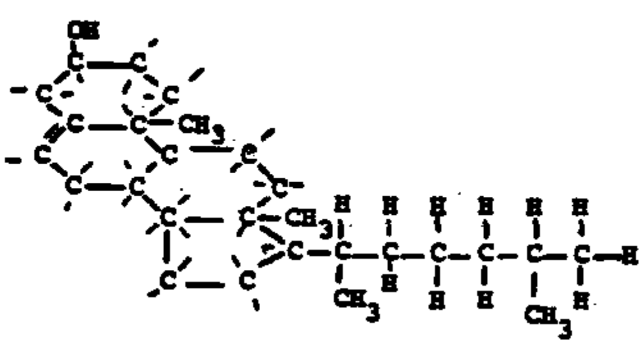
5. glycolipids (description) -

6. biological importance of lipids -

D. Steroids (description) - refers to lipid-like insoluble organic compounds; all steroids have 4 linked carbon rings; some also have a carbon tail and/or OH alcohol functional groups; examples include cholesterol, sex hormones and adrenal cortex hormones

1. cholesterol (description) -

steroid: cholesterol



CLASS SESSION: BIOCHEMISTRY - PROTEINS AND ENZYMES

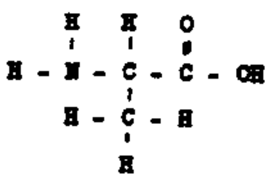
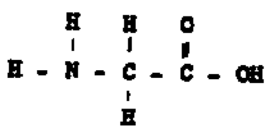
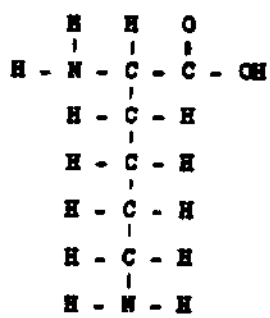
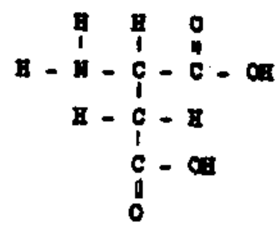
A. <u>Proteins</u> (description) - refers to organic compounds that involve the elements C, H, O, N, and S; described as globular or fibrous compounds formed by combinations of peptides or amino acids; includes the enzymes

1. <u>peptide unit</u> (building molecule) -

<u>structural formula of a general amino acid</u>:

<u>Note</u>: The <u>R side group</u> varies with each of the twenty amino acids. The R groups may be nonpolar and hydrophobic; may have polar regions and be uncharged or become charged in acidic or basic solutions; or may be weak acids or bases and be negatively or positively charged.

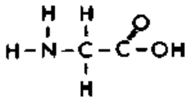
	(...............at pH 7	....................)	
<u>alanine</u>	<u>glycine</u>	<u>lysine</u>	<u>aspartic acid</u>
(nonpolar)	(polar)	(basic)	(acidic)
	(uncharged)	(+)	(-)

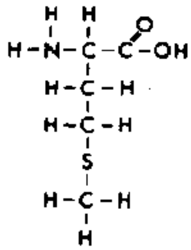
2. <u>formation of peptide bond</u> (description) -

AMINO ACIDS 1. Essential

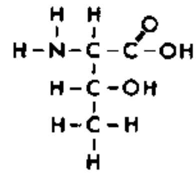
Glycine



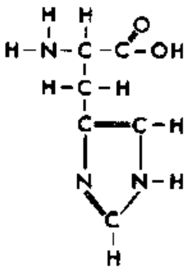
Methionine



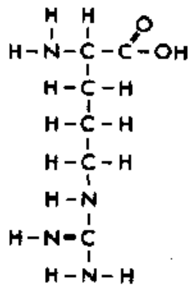
Threonine



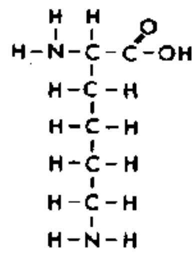
Histidine



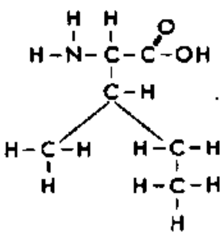
Arginine



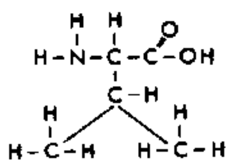
Lysine



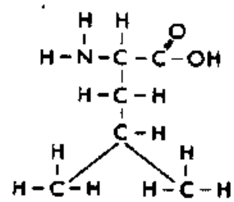
Isoleucine



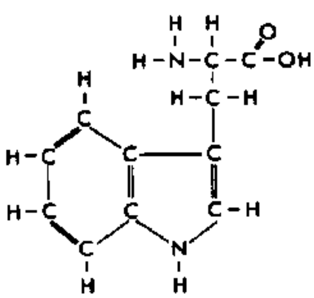
Valine



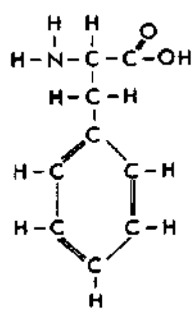
Leucine



Tryptophan



Phenylalanine



Carolina Biological Supply Company, Burlington, North Carolina 27215

structural representation of peptide bond formation:

amino acid #1 + amino acid #2 --> dipeptide + water

a. polypeptides (description) -

1. primary structure (description) -

2. secondary structure (description) -

3. tertiary structure (description) -

4. quaternary structure (description) -

3. biological importance of proteins -

a. fibrous proteins (description) - refers to structural proteins that are insoluble and have a polypeptide chain that is regular with a repeated sequence of amino acids along one dimension; the chains interact to form sheet-like or cable-like structural units; form the main structural composition of most animal tissues; examples include collagen, keratin, silk, and elastin

b. globular proteins (description) - refers to proteins that have a tertiary structure involving a three dimensional folded shape; characterized by having complex, irregular amino acid sequences; some are structural proteins forming microtubules and others have various bioactive functions such as enzymes, antibodies, myoglobin, and hemoglobin

1. hemoglobin (structure) - described as a globular protein that is carried in erythrocytes and has the capacity to bind loosely with oxygen; primary structure involves the sequence of about 150 amino acids that form two identical alpha chains and two identical beta chains; secondary structure involves the helical shape assumed by any part of each of these polypeptide chains; tertiary structure involves of globular folding of each chain - each of which is connected to a heme group (composed of Fe and four nitrogen-containing rings known collectively as a porphyrin ring); quarternary structure involves the combination of all four chains into a functional protein molecule

a. defective hemoglobin (sickle cell anemia) - refers to disease in which defective hemoglobin molecules result in abnormally shaped and dysfunctional red blood cells; defective hemoglobin differs from normal hemoglobin by the specific location in each beta chain of the amino acid valine instead of glutamic acid

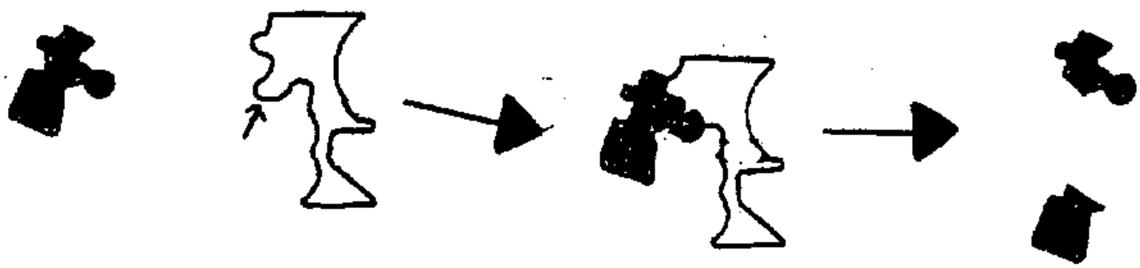
B. Enzymes (specific proteins) (description) - refers to globular proteins designed to serve as organic catalysts which function to regulate the rate of a chemical reaction, but are not changed during the reaction; the enzymes as catalysts control the biochemical reactions of cells; enzymes lower the energy of activation required for a reaction by forming temporary complexes with reactants known as substrates; enzymes allow reactions to occur at relatively low temperatures and fast speeds within the physiological limits of cell activity

1. enzyme active site (description) - refers to the location or region on the surface of the enzyme into which the substrate molecule or molecules "fit" and where the substrate reactions occur; the active site is associated with the tertiary structure of the globular protein in that the folding forms a three dimensional groove or pocket on the enzyme surface that is specific for the substrate; the active site also directs the position of the substrate by having complementary binding sites related to electric charge and hydrophilic or hydrophobic interactions

a. <u>induced-fit concept</u> (description) - refers to the interaction of the enzyme and substrate at the active site; the active site displays specificity in forming an enzyme-substrate complex and also displays flexibility to alter its conformation to induce a closer binding between the enzyme and the substrate which facilitates the reaction; updates the concept of lock and key analogy

<u>Diagram: Enzyme Action:</u>

substrate + enzyme --> enzyme-substrate complex --> products
(induced-fit)

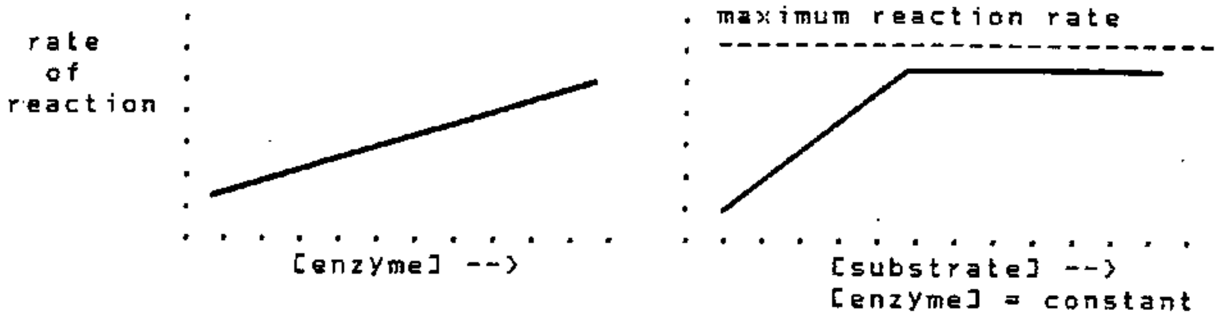


2. <u>rate of enzyme action</u> (factors) - a number of factors affect the rate of an enzyme controlled reaction that include temperature, pH, and the concentration of both substrate and enzyme

a. <u>effect of temperature</u> (description) - enzymes function within a low to high range of temperatures below which and above which enzyme action is inhibited; generally, enzyme activity increases with an increase in temperature; above the high temperature range the enzyme may be <u>denatured</u> or destroyed by losing its tertiary structure

b. <u>effect of pH</u> (description) - enzymes function within a range of acid and/or base pH levels below which or above which enzyme activity is inhibited

c. <u>effect of concentration</u> (description) - the relative amounts of substrate and enzyme each affects the rate of the reaction; generally, the reaction rate will increase with an increase in enzyme concentration; generally the reaction rate will increase as the substrate amount increases until a maximum balanced rate is achieved and the rate becomes constant (as long as the enzyme concentration is constant)



3. enzyme pathway systems (description) - refers to biochemical reactions described as a series of reactive steps; each step in the pathway is regulated by a specific enzyme; allows groups of related enzymes to be segregated within the cell; allows for little accumulation of intermediate products which are used in subsequent reactions of the series and removes products of each step reaction from the system so that equilibrium is not attained moving the reactions forward

a. cofactors in enzyme systems (description) - refers to nonprotein inorganic molecules or ions required by some enzymes for catalysis of reactions; examples include enzymes that require Mg^{++}, Ca^{++}, or K^{+} ions for their functions

1. coenzymes in enzyme systems (description) - refers to nonprotein organic molecules that function as cofactors in enzyme activity; bind to the enzyme close to the active site; some function as electron acceptors in oxidation - reduction reactions; includes vitamins and related electron carrier molecules such as NAD and FAD that function in cellular respiration

4. allosteric feedback inhibition - refers to inhibition of an enzyme that has an active site and a second site for a molecule referred to as an allosteric effector which binds and alters the shape of the enzyme affecting its function; one of the products (usually the last in the series) of an enzyme pathway acts as an allosteric effector to alter and inhibit one of the enzymes (usually the first) in the pathway

a. competitive inhibition (description) - refers to inhibition of enzyme activity by molecules other than the substrate temporarily binding to the active site; the inhibitory molecule competes with the substrate for the active site; inhibition is reversible and depends on the concentrations of substrate and inhibitor that are available; example of sulfur drugs used to treat bacterial infections that combine with and inhibit the enzyme that normally converts PABA, an intermediate product, to folic acid needed by the bacteria

Note: Some chemical substances disrupt enzyme structure and activity by binding to the enzyme at a location other than the active site producing a noncompetitive inhibition. Lead binds to enzymes that include the amino acid cysteine deactivating them and causing the symptoms of lead poisoning.

VOCABULARY REVIEW: BIOCHEMISTRY

Class Sessions: ----->

atomic structure	protons	electrons
neutrons	electron cloud model	element
atomic weight	atomic number	isotopes
radioactive isotope	compound	molecule
chemical bond	covalent bond	ionic bond
ionic crystal	ion	chemical reaction
reactant	chemical equation	mixture
homogeneous mixture	solute	solvent
heterogeneous mixture	solution	suspension
colloidal dispersion	biogeochemical cycle	phosphorus cycle
sulfur	chromium	lead
cadmium	inorganic compound	polar molecule
polar covalent bond	hydrogen bond	hydrophilic
hydrophobic	specific heat	heat of fusion
heat of vaporization	density	viscosity
surface tension	capillary action	water biome
hydrologic cycle	evaporation	transpiration
condensation	precipitation	water pollution
infiltration	runoff	gases
oxygen gas	ozone	carbon dioxide
carbon-oxygen cycle	global warming	greenhouse effect
nitrogen gas	nitrogen cycle	nitrogen fixation
denitrifying bacteria	nitrifying bacteria	bacteria of decay
ionization	pH scale	acids
acid precipitation	bases	buffers
salts	neutralization	

organic compounds	structural formula	organic polymers
condensation reaction	dehydration synthesis	carbohydrates
saccharide unit	monosaccharide	alpha glucose
beta glucose	fructose	galactose
ribose	deoxyribose	glycosidic bond
disaccharide	maltose	lactose
sucrose	polysaccharide	starch
glycogen	cellulose	chitin
lipid	triglyceride	fatty acid
glycerol	saturated fat	unsaturated fat
oils	waxes	phospholipids
glycolipids	steroids	cholesterol
protein	peptide unit	amino acid
peptide bond	polypeptide	primary structure
secondary structure	alpha-helix	tertiary structure
quaternary structure	insulin	fibrous protein
collagen	keratin	globular protein
myoglobin	antibodies	hemoglobin
heme group	porphyrin ring	sickle cell anemia
enzyme	energy of activation	substrate
active site	induced fit concept	denatured
enzyme pathway system	cofactors	coenzymes
allosteric feedback	allosteric effector	
competitive inhibition		
noncompetitive inhibition		