**Atoms and Chemical Bonds**

**atom** - makes up all matter and all substances in the universe

* can be seen indirectly w/ tech such as tunnel microscopy
* electrons - (-) charge; revolves around the nucleus
* neutrons - no charge; in the nucleus
* protons - (+) positive charge; in the nucleus; determines the atom's atomic number
* mass - amount of substance
* weight - force gravity exerts on a substance
* **atomic mass** - equal the combined mass of neutrons/protons; measured in **daltons** (6.02\*10^23 daltons=1 gram)

**isotopes** - atoms of an element w/ different numbers of neutrons

* elements - same atomic number, same chemical properties
* **radioactive isotope** - isotopes that decay due to unstable nuclei; decay is constant
* **half-life** - time is takes 1/2 of the atoms to decay; can be used to determine age of biological material
* released subatomic particles could cause mutations in genes

**electrons** - determines the charge in each atom

* neutral atoms - not net charge, same number of electrons/protons
* **ions** - atoms in which the number of electrons is different from the number of protons
* **cation** - ion with positive charge
* **anion** - ion with negative charge

**orbital** - area where an electron is most likely to be found

* each can't contain over 2 electrons
* electrons determine the atom's chemical behavior because the nuclei never interact
* electrons contain potential energy based on their position
* **oxidation** - loss of electron
* **reduction** - gain of electron
* **energy level** - based on an electron's distance from the nucleus; different from orbitals

**periodic table** - developed by Dmitri Mendeleev

* elements' chemical properties repeated themselves in groups of 8
* **valence electrons** - electrons on the outermost energy level; basis for the atoms' chemical properties
* noble gases - elements w/ filled outer levels; are inert and nonreactive
* halogens - elements w/ 7 electrons in outer levels; extremely reactive
* **octet rule** - atoms tend to completely fill their outer levels

**chemical bonds** - connects atoms in a molecule and molecules in a compound

* **ionic bonds** - forms between atoms of opposite charge; exists between an ion and all oppositely charged ions in the area
* **covalent bonds** - forms between 2 specific atoms when electrons are shared; has no net charge or free electrons
* single bond - 1 electron is shared
* double bond - 2 electrons are shared
* triple bond - 3 electrons are shared
* structural formulas - shows elements in a compound and their bonds
* molecular formulas - shows only the elements in a compound
* atoms can form many covalent bonds (ex. carbon)
* **chemical reaction** - forming/breaking of chemical bonds
* reactants - original molecules before the reaction
* products - resulting molecules after the reaction

**factors influencing reactions**

* higher temperature increases reaction rate
* temperature must not be so high that it destroys molecules
* more reactants exposed to each other increases reaction rate
* **catalyst** - substance that increases reaction rate; proteins called enzymes act as catalysts in organisms

**Water**

**chemistry of water** - no organism can survive/reproduce w/o water

* carries no net charge or unpaired electrons
* can form weak chemical associations w/ a fraction of covalent bonds' strength
* oxygen atom portion has partial negative charge
* hydrogen atoms portion have partial positive charge
* **polar molecules** - has charge separation and partially charged poles
* **hydrogen bonds** - very weak bonds that last for a short while between hydrogen atoms
* **cohesion** - attraction between water molecules
* **adhesion** - attraction between water molecules and other molecules
* surface tension - causes water to cling together, allowing some insects to walk on it
* capillary action - water rises in very narrow tubes due to adhesion

**heat storage in water** - temperature measures how fast the molecules move

* **specific heat** - energy needed to change 1 gram of a substance by 1 degree C
* heats up more slowly than most compounds, holds heat longer
* **heat of vaporization** - energy needed to change 1 gram of liquid into gas
* 586 calories needed to change 1 gram of water into water vapor; causes cooling on the surface
* ice is less dense than liquid water because hydrogen atoms space out the molecules

**water as a solvent** - forms hydrogen bonds to break up ions or polar molecules

* **hydration shell** - formed around molecules to prevent it from associating with other molecules of its kind
* **hydrophobic** - nonpolar molecules that don't form hydrogen bonds w/ water
* **hydrophilic** - molecules that readily form hydrogen bonds w/ water
* hydrophobic exclusion - tendency for nonpolar molecules to group together in water

**ionization** - separationg of H20 into hydrogen ion and hydroxide ion

* ph scale - based on the hydrogen ion concentration
* each ph level is 10 times as much acidic/basic than the surrounding levels
* **acids** - increases hydrogen ion concentration; ph values below 7
* **bases** - lowers hydrogen ion concentration; ph values above 7
* **buffer** - minimalizes pH changes; acts as a resevoir for hydrogen ions

**Carbohydrates**

**carbohydrates** - molecules w/ carbon, hydrogen, oxygen in ratio 1:2:1

* empirical formula - (CH2O)n
* releases energy from C-H bonds when oxidized
* sugars - most important energy-storage carbohydrate

**monosaccharides** - simplest of the carbohydrates

* can contain as few as 3 carbon, but most contain 6
* C6H12O6, or (CH2O)6
* usually forms rings in aqueous environments (but can form chains)
* **glucose** - most important energy-storing monosaccaride; has 7 C-H bonds for energy

**disaccharide** - "double sugar"

* 2 monosaccharides joined by a covalent bond
* play roles in transporting sugars (so that it is less rapidly used for energy during transport)
* only special enzymes located at where glucose is to be used can break the bonds
* normal enzymes along the transport route can't break apart disaccharides
* sucrose - fructose + glucose; used by plants to transport glucose
* lactose - galactose + glucose
* maltose - glucose + glucose

**polysaccharide** - macromolecules made of monosaccharides

* insoluble long polymers of monosaccharides formed by dehydration synthesis
* **starch** - used to store energy; consists of linked glucose molecules
* cellulose - used for structural material in plants; consists of linked glucose molecules
* amylose - simplest starch; all glucose connected in unbranched chains
* amylopectin - plant starch; branches into amylose segments
* **glycogen** - animal version of starch; has more branches than plant starch

**sugar isomers** - alternative forms of glucose

* same empirical formula, but different atomic arrangement
* fructose - **structural isomer** of glucose; oxygen attached to internal carbon, not terminal; tastes sweeter than glucose
* galactose - **stereoisomer** of glucose; hydroxyl group oriented differently from glucose

**structural carbohydrates**

* alpha form - where glucose bonds w/ the hydroxyl group below the plane of the ring
* beta form - where the glucose bonds w/ the hydroxyl group above the plane of the ring
* starch contains alpha-glucose chains
* **cellulose** - contains beta-glucose chains; cannot be broken down by starch-degrading enzymes; serves as structural material
* a few animals use bacteria/protists to break down cellulose
* **chitin** - structural material in arthropods/fungi; modified cellulose w/ nitrogen group added to glucose units

**Carbon and Functional Groups**

**carbon** - component of all biological molecules

* molecules w/ carbon can form straight chains, branches, rings
* **hydrocarbons** - molecules containing only carbon and hydrogen; energy-rich, makes good fuels (ex. propane gas, gasoline); nonpolar
* **macromolecules** - large, complex assemblies of molecules; separated into proteins, nucleic acids, lipids, carbohydrates
* polymers - long molecules built by linking together smaller chemical subunits
* **dehydration synthesis** - takes a -OH group and a H from 2 molecules to create a covalent bond between them, forming water as a byproduct
* catalysis - positioning and stressing the correct bonds; done by enzymes
* **hydrolysis** - adding water to break a covalent bond in a macromolecule

**polymer macromolecules**

* amino acid >> polypeptide >> intermediate filament
* nucleotide >> DNA strand >> chromosome
* fatty acid >> fat molecule >> adipose cells w/ fat droplets
* monosaccharide >> starch >> starch grains in chloroplasts

**functional groups** - specific atomic groups added to a hydrocarbon core



**Nucleic Acids and Lipids**

**nucleic acids** - information storage devices of cells; 2 varieties

* can serve as templates to create exact copies of themselves
* **deoxyribonucleic acid** (DNA) - the hereditary material
* **ribonucleic acid** (RNA) - used to read DNA in order to create proteins; used as a blueprint to create amino acid sequences
* finally able to be seen w/ scanning-tunneling microscope

**nucleotides** - subunits of nucleic acids

* contains 5-carbon sugar, phosphate group, organic base
* **purine** - large, double-ring molecules; adenine, guanine (both in RNA/DNA)
* **pyrimidine** - smaller, single-ring molecules; cytosine (in RNA/DNA), thymine (in DNA only), uracil (in RNA only)

**DNA**

* made of difference combinations of 4 types of nucleotides (adenine, guanine, cytosine, thymine)
* 2 chains wrap around each other like a staircase (**double helix** shape)
* hydrogen bonds hold 2 chains together
* adenine only complementary to thymine (in DNA), uracil (in RNA)
* cytosine only complementary to guanine

**RNA**

* uses ribose sugar instead of deoxyribose (in DNA)
* has hydroxyl group where a hydrogen is in DNA >> stops double helix from forming
* uses uracil in place of thymine (has 1 more methyl group than uracil)
* usually single-stranded (differentiates itself from double-stranded DNA); serves as a transcript of the DNA
* evolved into DNA to protect the hereditary material from single-strand cleavage
* "central dogma" of molecular biology - flow of info from DNA to RNA to protein

**ATP** - adenosine triphosphate (contains adenine, a nucleotide)

* energy currency of the cell
* tinamide adenine dinucleotide (NAD+), flavin adenine dinucleotide (FAD) both carry electrons to make ATP

**lipids** - insoluble in water

* most familiar forms are fats/oils
* very high proportion of nonpolar carbon-hydrogen bonds
* can't fold up like proteins
* spontaneously exposes polar parts and moves nonpolar parts within when placed in aqueous environment

**phospholipids** - form the core of all biological membranes

* **glycerol** - 3 carbon alcohol; forms the phospholipid's backbone
* **fatty acid** - long chains of CH2 groups, ending in a carboxyl; 2 chains
* **phosphate group** - attached to an end of the glycerol; usually has an organic molecule attached to it
* phosphate group serves as the polar "head"; fatty acids serve as the nonpolar "tails"
* **micelle** - spherical forms w/ the tails pointed inward
* **phospholipid bilayer** - 2 phospholipid layers w/ the tails pointed towards each other; basic framework of biological membranes

**fats** - do not have a polar end like phospholipids

* contains 3 fatty acids
* aka triglyceride, triacylglycerol
* fatty acids don't need to be identical
* energy stored in the C-H bonds of fats
* clump together in water to form globules since they lack polar ends
* **saturated fats** - carbon atoms in fatty acids each bonded to at least 2 hydrogen
* **unsaturated fats** - has double bonds between 1+ carbon atoms
* **polyunsaturated fats** - has more than 1 double bond; have lot melting points (usually liquid at room temperature)
* **terpene** - long-chain lipids usually found in chlorophyll and visual pigment retinal
* **steroid** - has 4 carbon rings; can function as hormones
* **prostaglandins** - about 20 lipids acting as chemical messengers, with 2 nonpolar tails attached to a five-carbon ring

**fats as energy-storing molecules**

* fats contain about 40 carbon atoms
* ratio of C-H bonds to carbon atoms in fats is 2x the ratio of carbohydrates
* animals produce mostly saturated fats
* plants produce mostly unsaturated fats
* adding hydrogen can convert an oil into solid fat
* hydrogenating oils into solids turns unsaturated fats into saturated
* excess carbohydrates get converted into fats, starch, glycogen
* plaque - deposits of fatty tissue found on blood vessel lining; broken pieces can cause strokes, block blood flow

**Proteins**

**proteins** - have 7 main functions

* **enzyme catalysis** - faciliates/speeds up certain chemical reactions; ex. enzymes
* **defense** - recognizes foreign microbes; forms the center of the immune system; ex. immunoglobulins, toxins, antibodies
* **transport** - moves certain small molecules/ions; ex. hemoglobin, proton pump
* **support** - structural role; ex. fibers, collagen (most abundant protein in vertebrates), keratin, fibrin
* **motion** - contracting muscles; ex. actin, myosin
* **regulation** - receives/sends information to regulate body functions; ex. hormones
* **storage** - holds molecules such as calcium and iron; ex. ferritin

**amino acid** - 20 different kinds used in specific orders to form proteins

* molecule consists of an amino group, carboxyl group, hydrogen atom, and side group (determines the molecule's characteristics) connected to a central carbon atom
* nonpolar amino acids have CH2 or CH3 as side group
* polar amino acids have oxygen or hydrogen as side group
* charged amino acids have acids/bases as side group
* aromatic amino acids have organic rings w/ alternating single/double bonds as side group
* special-function amino acids have unique individual characteristics
* **peptide bond** - bonds between amino acids; forms between the hydrogen and carboxyl groups
* **polypeptide** - protein composed of 1+ long chains

**protein structure** - shape determines function

* shape found through x-ray diffraction
* internal amino acids are generally nonpolar
* most polar/charged amino acids are found on the surface
* 6 levels of structure - primary, secondary, motifs, tertiary, domains, quaternary
* **factors of protein shape** - hydrogen bonds between amino acids, disulfide bridges between side chains, ionic bonds, Van der Waals attractions (weak attractions due to electron clouds), hydrophobic exclusion (polar portions gather on the outside, nonpolar portions go towards the interior)

**primary protein structure** - specific amino acid sequence

* determined by nucleotide sequence that codes for the protein
* any of the 20 different amino acids can appear at any position in a protein
* side groups play no role in peptide structure, but important in primary structure

**secondary protein structure** - determined by hydrogen bonds

* folds the amino acid chain
* alpha helix - forms when hydrogen bonds form in a chain
* beta helix - when parallel chains are linked into a pleated shape

**motif** - aka "supersecondary structure"

* combining parts of the secondary structure into folds and creases
* beta alpha beta motif - creates a fold
* Rossmann fold - beta alpha beta alpha beta motif
* beta barrel - beta helix folded to form a tube
* alpha turn alpha - used by proteins to bind DNA double helix

**tertiary structure** - positions the motifs/folds into the interior

* final folded shape of the globular protein
* protein goes into the tertiary form due to hydrophobic exclusion
* can be unfolded (denatured) and still return to original shape
* no holes in the protein interior
* close nonpolar chains are attracted together by van der Waal's forces
* change in any amino acid can affect how they stay together in a protein

**domain** - structurally independent functional unit; ex. exons in genes

* independent of all other domains
* if severed from the protein, would still maintain the same shape
* connected to other domains by single polypeptide chains

**quaternary structure** - 2+ polypeptide chains connecting to form a functional protein

* arrangement of the subunits
* subunits connect to each other in nonpolar areas
* altering a single amino acid can affect the entire structure

**chaperone protein** - helps new proteins fold correctly

* w/o, proteins would fail to fold/function correctly
* over 17 types, mostly **heat shock proteins** (high heat causes proteins to unfold)
* gives wrongly folded proteins a chance to fix itself and fold correctly
* deficiency in this protein may cause various diseases like Cystic Fibrosis or Alzheimer

**denaturation** - unfolding of proteins

* can occur if pH, temperature, or ionic concentration is changed
* leads to biologically inactive proteins (venoms, made of proteins, stop working in high temperature or in presence of acids/bases)
* salt-curing/pickling used high concentrations of salt/vinegar to stop the enzymes of microorganisms from working
* most enzymes can only function well in very specific conditions
* usually, only smaller proteins can fully refold themselves after being denatured
* **dissociation** - different from denaturation; subunits can dissociate and still go back to their quaternary structure

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[Biology](http://www.course-notes.org/Subject/Science/Biology) [1]

Subject X2:

[Biology](http://www.course-notes.org/Subject/Science/Biology) [1]

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**Biologically Important Molecules**

**organic compounds** - macromolecules made of subunits in living organisms

* carbohydrates, proteins, lipids, nucleic acids
* **dehydration synthesis** - water molecule removed to bond 2 subunits
* **hydrolysis** - exothermic reaction where water is added to break bonds between subunits
* different structures and arrangments give compounds different characteristics

**controlled experiments** - has controls used for comparison

* unknown solution - may or may not contain the substance that is being tested for
* positive control - contains the substance that is being tested for; shows what a positive test should look like
* negative control - doesn't react in the test; shows what a negative result should look like

**carbohydrates** - molecules made of C, H, and O in ratio 1:2:1

* monosaccharides - simple sugars
* disaccharides - paired monosaccharides
* polysaccharides - linking together 3 or more monosaccharides
* reducing sugars - monosaccharides that have free adlehyde (-CHO) or ketone (-C=O) groups that reduce weak oxidizing agents
* **Benedict's test** - identifies reducing sugars that can reduce the cupric ions in Benedict's reagent into cuprous oxide
* **iodine test** - iodine-potassium iodide reacts w/ coiled molecules of starch to become bluish black; doesn't react w/ other carbohydrates as much

**proteins** - made of amino acids

* each amino acid has amino group, carboxyl group, and variable side chain
* **peptide bond** - forms between amino group and carboxyl group of 2 amino acids
* **Biuret test** - peptide bonds of proteins produce a violet color when in contact w/ the copper II found in Biuret reagent; individual amino acids do not react

**lipids** - nonpolar molecules w/ many C-H bonds

* dissolve in nonpolar solvents
* **fats** (triglycerides) - made of glycerol and 3 fatty acids
* tests based on lipid's ability to change color w/ fat-soluble dyes (ex. Sudan IV)
* grease-spot test - lipids produce translucent grease-marks on unglazed paper

**nucleic acids** - made of nucleotide subunits

* either DNA or RNA (differences in sugar structure and organic bases)
* **Dische diphenylamine test** - makes deoxyribose into another molecule that bonds w/ diphenylamine to make a blue color

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**Enzymes**

**enzymes** - proteins that control most reactions in cells

* biocatalysts - speeds up metabolic reactions to biologically useful rates
* lowers activation energy needed for reaction to start
* **substrate** - reacting molecules that binds to the enzyme to make **enzyme-substrate complex**
	+ active site - where substrate attaches to the enzyme
* provides **energy of activation** to form the **transition state** (making substrate more reactive)
* completes reaction when product formed, enzyme goes back to original shape
* structure/shape determines enzyme’s function
* **denaturation** - structural change to enzyme, can destroy its effectiveness
* optimal conditions - the environmental conditions under which the enzyme works the best
* phosphate-carrying molecules like ATP turn enzymes on/off through phosphorylation

**effect of temperature on enzyme activity**

* heat usually increases rate of most chemical reactions (puts energy into the system)
* extreme temperatures may denature enzymes

**catechol oxidase** - plant enzyme converting catechol to benzoquinone

* benzoquinone responsible for brown color in bruised fruit
* catechol >> catechol oxidase >> benzoquinone
* no reaction if either catechol oxidase or catechol missing
* low temperatures >> slower reaction
* moderately high temperatures (about 40° C) >> fast reaction
* extremely high temperatures (about 80° C) >> denatured enzyme, no reaction

**effect of pH on enzyme activity**

* H+ and OH- groups from acids/bases react w/ side groups of enzyme molecules
* lower pH >> more H+ ions
* higher pH >> more OH- ions
* can change enzyme shape enough to change active site

**catalase** - enzyme in plants/animals, speeds up hydrogen peroxide breakdown

* 2 H2O2>> catalase >> 2 H2O + O2
* no reaction if either catalase or hydrogen peroxide missing
* works best in neutral pH
* adding acid/base/buffer can change the pH

**effect of inhibitors on enzyme activity**

* **competitive inhibition** - inhibitors that compete for the same active site as a substrate
	+ makes enzyme unavailable for substrate
* can also bond to allosteric site and shut off enzyme

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