**Chapters 2-5 (Campbell 8th edition) AP Bio Outline Review**

**NOTE: This guide is NOT all inclusive! Chapter 1 is not included in this outline. For ALL chapters: READ YOUR BOOK and TAKE NOTES; GO OVER ACTIVITIES/ASSIGNMENTS; etc.**

***Basic Chemistry/Water:***

1. Matter – anything that takes up space and has mass.
   1. **Element** – a substance that cannot be broken down to other substances.
      1. Nitrogen, oxygen, carbon, and hydrogen (N, O, C, H) make up 96% of living matter.

B. **Compound** – a substance consisting of two or more elements in a fixed ratio.

C. **Atom** – the smallest possible amount of an element.

D. Subatomic particles

1. **neutron** – electrically neutral, mass of 1 dalton = 1 atomic mass unit (amu) (in nucleus)

2. **proton** – electrically positive, mass of 1 dalton (in nucleus)

3. **electron** – electrically negative, mass of 1/2000 dalton (orbit around nucleus-clouds)

1. **Atomic number** – the number of protons. (*e.g.* 6C) Determines the number of electrons present in the atom and therefore the chemical character of the atom.
2. **Mass number** (atomic mass) – mass of the protons plus mass of the neutrons. (*e.g.* 12C)
3. **Isotopes** – atoms that have the same atomic number but different mass numbers. (**All isotopes of a given element behave the same way chemically because they all have the same number of electrons**.) Radioactive isotopes are unstable; they break down into more stable elements with lower atomic numbers by releasing particles and energy. The rate of decay is constant.
4. Electrons determine how molecules behave.
   1. Atoms are electrically neutral because the number of electrons equals the number of protons. (Therefore, the negative charges cancel out the positive charges.)
   2. If an atom gains or loses one or more electrons, it becomes electrically charged and is called an **ion**.
   3. The volume of space around the nucleus where an electron is likely to be found is called an orbital. Each orbital can hold a maximum of two electrons.
   4. The farther out from the nucleus an electron is, the more energy it has. (It would take more energy to move it farther out, and energy would be given off if it moved closer to the nucleus.)
   5. If an atom loses an electron, it is said to be **“oxidized”**. If an atom gains an electron, it is said to be **“reduced”**. These two always go together (*i.e.* if one atom loses an electron, another one must pick it up).
      1. Important point – when an electron is transferred between atoms in this way, it keeps the same energy it had.
      2. Memory aid – **OIL RIG** – oxidation is loss (o-i-l), reduction is gain (r-i-g) or LEO GER
   6. Electrons can only be found at certain distances from the nucleus, called energy shells or energy levels. The maximum number of electrons that can be held in the outermost level is eight (with the exception of the first energy level which can only hold two). This is the most stable arrangement of electrons, and therefore atoms will tend to react with other atoms in order to fill their outer energy levels with eight electrons.
5. Chemical bonds – attractions holding atoms close together.
   1. **Covalent bond** – formed by the sharing of a pair of valence electrons (outer energy level electrons) by two atoms.
      1. **Molecule** – two or more atoms held together by covalent bonds.
      2. **Polar covalent bond** – forms when two atoms share electrons unequally because one is more electronegative than the other. This results in a partial negative charge at one end of the molecule and a partial positive charge at the other end.
   2. **Ionic bond** – force created by the attraction that exists between oppositely charged ions (the force is non-directional). Compounds formed by ionic bonds are called ionic compounds, or salts.
   3. **Hydrogen bond** – forms when a hydrogen atom is covalently bonded to an electronegative atom (like oxygen or nitrogen) and therefore has a partial positive charge. This partially positive hydrogen can then be attracted to a partially negative charge on another similar molecule. Hydrogen bonds are very weak.
   4. Van der Waals interactions – form because electrons are constantly in motion and therefore a molecule may have positively and negatively charged regions even if the bonds themselves are nonpolar. These attract over very short distances.
   5. Hydrophobic interactions – form because substances that do not mix readily with water are pushed together to form droplets (like oil in water). Once these molecules are close together, Van der Waals interactions reinforce the hydrophobic interactions.
6. The chemistry of water (makes life possible)
   1. Molecular structure: H2O Atoms joined by polar covalent bonds. Molecule bent at a 104o angle.
   2. Oxygen is more **electronegative** and pulls the electrons toward it. This causes the oxygen to have a partial negative charge and leaves the hydrogens with a partial positive charge. This allows water to form hydrogen bonds which is very important because it gives water several unique properties which are crucial for life to exist.
   3. Unique properties of water:

1. Water sticks to itself (by forming hydrogen bonds); called cohesion. Allows water to be able to be pulled up to the leaves of plants. Also results in surface tension.

2. Water sticks to other polar molecules (hydrophilic molecules) as well. This is called adhesion and is also a result of hydrogen bonding. This causes capillary action which also helps transport water in plants. Water is taken up by porous hydrophilic materials like paper or a sponge because of adhesion. This is how seeds take up the water that triggers them to germinate.

3. Water has a high specific heat (amount of heat that must be absorbed or released to change the temperature of one gram of a substance by one degree Celsius). Heat is the total quantity of kinetic energy in a substance due to molecular motion. Temperature is a measure of the intensity of the heat due to the average kinetic energy of the molecules (when the average speed of the molecules increases, the temperature goes up). Heat always moves from an object of higher temperature to an object of lower temperature (i.e. molecules in the cooler object speed up at the expense of kinetic energy from the warmer object).

a. Water has a high specific heat because energy that is absorbed must be used to break hydrogen bonds before the molecules will speed up and thereby increase the temperature of the water. Also if the temperature of water drops slightly, many more hydrogen bonds form, which releases heat to the surroundings and helps stabilize the temperature.

b. Water’s high specific heat helps organisms and the environment to resist changes in temperature.

4. Water has a high heat of vaporization (amount of heat a liquid must absorb for one gram of it to enter the gaseous state). The fastest molecules of a liquid may have enough energy to break out of the liquid into the gaseous state. That means only the "hottest" molecules escape, which means the liquid left behind is on the average cooler than before (evaporative cooling). This allows organisms to cool down by sweating or panting.

5. Water expands as it freezes (is less dense). More hydrogen bonds form as the water gets colder, which actually holds the water molecules farther apart from each other than in liquid water. Therefore, ice floats and lakes and oceans don't freeze solid. The floating ice insulates the liquid water below.

6. Water is a good solvent. Water is attracted to any molecule that carries a charge (either an ion or another polar molecule). Therefore it forms a shell of water molecules (hydration shell) around the other molecules and causes them to dissolve. The chemical reactions that occur within cells take place in solution (the reactants having been dissolved).

7. Water organizes nonpolar molecules. Water tends to form the maximum number of hydrogen bonds possible. It therefore excludes nonpolar molecules (hydrophobic molecules) and forces them together where they will disrupt the hydrogen bonding the least. This helps shape many biological molecules (e.g., DNA, proteins, etc.).

D. Aqueous solutions (solutions in which water is the solvent).

1. Solute concentration: a mole of a substance is Avogadro's number of molecules of that substance. Its mass in grams is equal to its molecular weight (e.g. a mole of water weighs 18 grams.) If a liter of solution contains one mole of solute dissolved in it, it is called a 1 molar solution (1 M) (2 moles/liter = 2 M etc.)

2. Acids, bases, and pH.

a. Occasionally, a water molecule will spontaneously dissociate (that means it separates into a hydrogen ion and a hydroxide ion (i.e. H2O  H+ + OH ). The concentrations of these two ions will be equal in pure water (each is 10 7 M).

1) An acid is a substance that increases the H+ concentration of a solution. (e.g. HCl  H+ + Cl )

2) A base is a substance that decreases the H+ concentration of a solution. (e.g. NH3 + H+ 4+)

3) A solution in which the H+ and OH concentrations are equal is said to be neutral.

4) The pH scale measures the concentration of H+ in a solution.

5) pH = log [H+] (For example, for a neutral solution, [H+] is 10 7, so log 10 7 = ( 7) = 7 (pH = 7)

6) In any solution, the product of [H+] and [OH ] is always equal to 10 14 M.

3. A buffer is a substance that minimizes changes in pH. It works by accepting hydrogen ions from the solution when they are in excess and donating them to the solution when they have been depleted.

For example: H2CO3  HCO3- + H+

H+ donor H+ acceptor

(acid) (base)

V. Versatility of carbon in molecular architecture

A. Electron configuration is the key.

1. Carbon has four electrons in its outer electron level (valence shell), therefore it has little tendency to gain or lose electrons to form ionic bonds. Instead it shares electrons with other atoms to form four covalent bonds.

2. Carbon acts as an intersection point from which a molecule branches off in up to four directions.

3. The electron configuration of carbon gives it covalent compatibility with a greater number of different elements than any other type of atom.

B. Isomers – compounds with the same molecular formula but different structures and therefore different properties.

1. Structural isomers – differ in the covalent arrangement of the atoms in the molecules (e.g. glucose and fructose).

2. Geometric isomers – have the same covalent partnerships but have different spatial orientations (e.g. glucose and galactose).

3. Enantiomers – molecules that are mirror images of each other.

VI. Functional groups – groups of atoms with definite chemical properties.

A. Hydroxyl group – hydrogen atom covalently bonded to an oxygen atom which is bonded to the carbon skeleton of an organic molecule.

1. The covalent bond is polar; therefore water molecules are attracted to it which helps to dissolve compounds containing such groups (e.g. sugars).

2. Compounds containing hydroxyl groups are called alcohols.

B. Carbonyl group – carbon atom double bonded to an oxygen atom. (If found at the end of a carbon skeleton, the compound is called an aldehyde, if not at the end of a carbon chain, the compound is called a ketone.)

1. Sugars are characterized by having both hydroxyl and carbonyl groups.

C. Carboxyl group – oxygen atom double bonded to a carbon atom that is also bonded to a hydroxyl group.

1. Compounds that contain carboxyl groups are called carboxylic acids.

2. Carboxyl groups have acidic properties because the two electronegative oxygen atoms pull electrons away from the hydrogen atom which can then dissociate (come off) as a hydrogen ion and thus raise the [H+] (lower the pH).

D. Amino group – nitrogen atom bonded to two hydrogen atoms and to a carbon skeleton.

1. Compounds that contain amino groups are called amines.

2. The amino group acts as a base (the nitrogen has a pair of unshared electrons which can bond to a hydrogen ion and remove it from solution).

3. Amino acids are compounds that contain both an amino group and a carboxyl group.

E. Sulfhydryl group – sulfur atom bonded to a hydrogen atom.

1. Compounds that contain sulfhydryl groups are called thiols (and smell like rotten eggs)

2. Sulfhydryl groups help to stabilize the intricate structure of many proteins by forming disulfide linkages. (The amino acid cysteine has a sulfhydryl group.)

F. Phosphate group – an anion formed by the dissociation of the inorganic acid called phosphoric acid (H3PO4). Organic compounds may contain a phosphate group consisting of a phosphate ion attached by one of its oxygen atoms to a carbon skeleton.

1. The dissociation of phosphoric acid leaves the phosphate with two negative charges.

2. Phosphate groups function in the transfer of energy between organic molecules.

***Structure and Function of Macromolecules:***

I. Polymer – a large molecule consisting of many identical or similar subunits strung together. Subunits that serve as the building blocks are called monomers.

A. Monomers get linked together by a process called a condensation or dehydration synthesis. One monomer loses a hydroxyl group and the other one loses a hydrogen atom. These combine to form water and the process leaves the two monomers attached by a covalent bond.

1. The opposite reaction is called hydrolysis. The bond between the two monomers is broken by adding a water molecule (e.g. digestion of food molecules).

II. Carbohydrates – include sugars and polymers of sugars. (Names of most carbohydrates end in ose).

A. Monosaccharides are simple sugars consisting of a single sugar unit. They have molecular formulas that are some multiple of CH2O (1:2:1 C:H:O ratio). Monosaccharides are a major source of energy for cells because of their great number of energy storing C H bonds (e.g. glucose, fructose, galactose).

B. Disaccharides consist of two monosaccharides joined by a glycosidic linkage (the bond formed between two sugar monomers by a dehydration synthesis). Disaccharides are generally less readily metabolized than monosaccharides and are therefore used as a transport form of carbohydrate (e.g. sucrose, maltose, lactose).

C. Polysaccharides are macromolecules that are polymers of hundreds or thousands of monosaccharides linked together.

1. Some polysaccharides are energy storage material and are hydrolyzed as needed to provide sugar for the cell. They are insoluble in water and therefore can be deposited in specific storage areas in the organism.

a. Starch is a polymer consisting entirely of glucose. Amylose is the simplest form and is unbranched. Pectins are branched starches (e.g. amylopectin). Animals store an even more highly branched polysaccharide called glycogen (stored primarily in the liver and in the muscles).

2. Other polysaccharides serve as building material for protective structures and include cellulose and chitin.

a. Like starch, cellulose is a polymer of glucose. However, unlike starch, the subunits alternate back and forth between two different orientations. Therefore, enzymes that can hydrolyze starch are unable to do so to cellulose. Very few organisms have enzymes that can digest cellulose.

1) Parallel cellulose molecules are held together by hydrogen bonds and are arranged into units called microfibrils. Several microfibrils intertwined form a cellulose fibril and several of these fibrils can be twisted together. The resulting cables are very strong and make excellent building material. Plant cell walls are composed of cellulose.

b. Chitin is a modified form of cellulose in which a nitrogen group has been added to the glucose units. It is used by arthropods to build their exoskeletons, and also by fungi in their cell walls.

III. Lipids – diverse group of compounds that are all insoluble in water because they are nonpolar.

A. Fats – made up of three fatty acids attached to a glycerol molecule. All the fatty acids can be the same or they may be different. The hydrocarbon tails contain numerous C H bonds (proportionally many more than in carbohydrates) and therefore fats serve primarily as a compact energy storage compound. Fats also serve as cushioning for internal organs (e.g., kidneys) and as insulation.

1. Saturated fats have no double bonds between carbon atoms in the fatty acid tails (therefore they are "saturated" with hydrogen).

2. Unsaturated fats contain double bonds between carbons and therefore contain less than the maximum number of hydrogens possible.

a. The double bonds in unsaturated fats put kinks in the fatty acid tails and don't let them pack closely together. They are therefore usually liquid at room temperature as opposed to saturated fats which are able to pack more tightly and form solids at room temperature.

B. Phospholipids – are structurally related to fats but only have two fatty acid chains attached to the glycerol molecule. The third carbon of the glycerol is bonded to a phosphate group (which has negative charge). Phospholipids therefore have unique behavior in water. The hydrocarbon fatty tails are nonpolar and therefore hydrophobic, and the phosphate group is hydrophilic.

1. This structure makes them well suited to their major function which is as a major component of cell membranes. Phospholipids form bilayers in water, the fatty acid tails are forced toward the center away from water, and the phosphate group heads remain toward the outside.

C. Steroids – are lipids characterized by a carbon skeleton consisting of four fused rings. Different steroids have different functional groups attached to the rings. Cholesterol in an important steroid found in animal cell membranes. It is also a precursor from which many other steroids are formed (e.g. sex hormones like estrogen and testosterone).

IV. Proteins – make up over 50% of the dry weight of a cell are have a variety of important functions including structural support, storage, transport of other substances, signaling from one part of the organism to another, movement, defense against foreign substances, and, as enzymes, catalysts for specific chemical reactions.

A. Proteins are polymers of amino acids linked together by peptide bonds formed by dehydration syntheses. An amino acid consists of a central carbon atom bonded to four different covalent partners.

1. Each amino acid has:

a. a hydrogen atom

b. a carboxyl group

c. an amino group

d. a variable R group or side chain which makes the 20 kinds of amino acids different from each other. The physical and chemical properties of the side chain determine the unique characteristics of each amino acid.

2. Amino acids are grouped according to the properties of their side chains. One group has nonpolar R groups, and is hydrophobic. Another group has polar side chains, and therefore is hydrophilic. The members of the acidic group of amino acids generally have carboxyl groups on their R groups and therefore carry a negative charge (because the H is usually dissociated at cellular pH). Basic amino acids have amino groups on their side chains and carry a positive charge. (Both acidic and basic amino acids are hydrophilic because of their ionic nature.)

3. Chains of amino acids, which are linked together by peptide bonds, are called polypeptides.

B. Important: The function of a protein is determined by its three dimensional shape (its conformation) which is a consequence of the specific sequential order of its amino acids. This conformation is based on three superimposed levels of architecture:

1. Primary structure – this is the order of the amino acids in linear sequence (and is determined by the genetic information).

2. Secondary structure – is caused by hydrogen bonding between the polypeptide backbones of nearby amino acids. Results in formation of shapes such as the alpha helix, and the beta pleated sheet.

3. Tertiary structure – consists of irregular contortions of the protein due to bonding between the R groups of the various amino acids.

a. Hydrophobic interactions between nonpolar side chains in the nonaqueous interior of the protein help shape the tertiary structure.

b. Other types of bonds that are important in tertiary structure include:

1) Hydrogen bonding between certain side chains.

2) Ionic bonds between positively and negatively charged side chains.

3) Disulfide bridges which are strong covalent bonds which form when two cysteine amino acids with sulfhydryl groups on their side chains are brought close together by folding of the protein.

4. Quaternary structure – results when the functional protein consists of two or more polypeptide chains. Each polypeptide chain is called a subunit of the protein.

C. Changes is pH, salt concentration, temperature, or other aspects of the environment can cause the bonding in the protein to be changed which results in the protein losing its native conformation in a process called denaturation.

V. Nucleic acids – two types: DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Store information and enable organisms to reproduce their complex equipment from one generation to the next.

A. Nucleic acids are polymers of monomers called nucleotides.

1. Each nucleotide is made up of three parts:

a. a nitrogenous base

b. a 5 carbon sugar (a pentose) – either deoxyribose (in DNA) or ribose (in RNA)

c. a phosphate group.

2. There are two families of nitrogenous bases: pyrimidines (cytosine, thymine, and uracil (which is found only in RNA)) which are characterized by a single 6 membered ring; and purines (adenine and guanine) which are characterized by a 5 membered ring which is joined to a 6 membered ring.

3. The pentose is connected to the nitrogenous base and to the phosphate group.

4. The nucleotides are joined together by phosphodiester bonds between the phosphate group of one nucleotide and the sugar of the next one. This results in a backbone with a repeating pattern of sugar phosphate sugar phosphate etc.

B. DNA is composed of two chains of nucleotides which are spiraled around to form a double helix. The sugar phosphate backbones are toward the outside (they are hydrophilic), and the nitrogenous bases are toward the center (because they are hydrophobic). The two chains are held together by hydrogen bonds between the paired nitrogenous bases (adenine always pairs with thymine, and cytosine always pairs with guanine).

**\*\*BE SURE to go over Chapter 1, which is not included on this guide. This includes the scientific method, overview of natural selection, and feedback loops.**