Study Guide: Biochemistry

A. **Hydrophilic vs Hydrophobic**. Since biological chemistry occurs largely in an aqueous environment, the interaction of a biological molecule with water is very important. That interaction is influenced by two primary causes: size and polarity (charge). The smaller a molecule is, the more likely it is to be willing to associate with water (dissolve). Also, the more polar and/or charged a molecule is, the more likely it is to be willing to associate with water. Since biological molecules are often very large, it is common for the different parts of the molecule to interact differently in water. For instance, a protein, which is composed of many different amino acids which have a large variety of characters, may be hydrophobic in part of its sequence and hydrophilic in other parts.

Hydrophilic (hydro=water; philios=love): Hydrophilic molecules or parts of molecules will dissolve in (interact with) water.

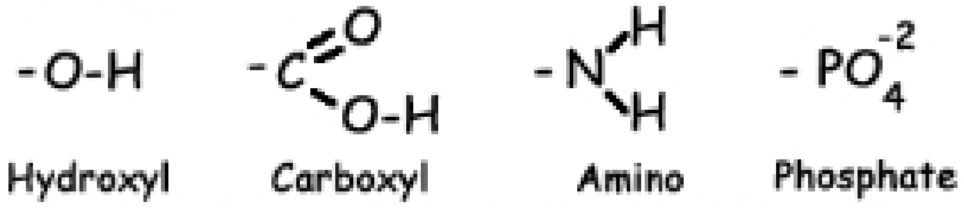
Hydrophobic (hydro=water; phobio=fear): Hydrophobic molecules or parts of molecules will refuse to interact with water. If sufficiently hydrophobic, a molecule or part of a molecule will actively repel or exclude water.

Hydrophilic/phobic characters are not an all-or-none phenomenon. Molecules fall along a scale, somewhere between extremely hydrophobic and extremely hydrophilic. Changing the parts of a molecule will often shift it more toward the hydrophobic or the hydrophilic end of the scale (depending upon the change).

B. **Hydrocarbons**. The basic skeletons of organic molecules are composed of hydrocarbon. Hydrocarbon is made only of the elements carbon and hydrogen. Since carbon atoms all have the same electronegativity, and the electronegativity of hydrogen is only slightly different than that of carbon, the bonds in hydrocarbons are all non-polar. Thus, hydrocarbons tend to be hydrophobic, especially if they are more than a few carbons in size.

The many, many different organic molecules are formed by attaching a variety of functional groups to hydrocarbon skeletons. Each functional group has its own characteristic behavior, and the combinations of the behaviors of a molecule's functional groups and the effects of the hydrocarbon skeleton create the overall nature of the molecule. Classes of organic molecules are largely characterized by their functional groups.

C. **Important Functional Groups**



1. **Hydroxyl Group** (found in alcohols and carbohydrates). This is a polar functional group due to the polar covalent bond between oxygen and hydrogen. Molecules whose most influential functional group is a hydroxyl group are called alcohols, and their systematic names end in –ol. Example: ethanol.

2. **Carboxyl Group** (found in organic acids). The carboxyl is sometimes written –COOH. The H on the OH dissociates easily in appropriate circumstances, thus liberating H^+ (a hydrogen ion) and creating $-COO^-$. This makes this functional group a proton donor, and thus acidic. It also makes the carboxyl group a strong hydrophilic force. Molecules whose most influential functional group is a carboxyl group are considered to be organic acids; their systematic names end in –ate. Example: acetate.

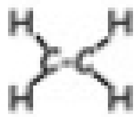
3. **Amino Group**. The amino is sometimes written $-NH_2$. The amino group is polar, due to the polarity of the N-H bond. It also tends to pick up an extra hydrogen ion (due to the negative character or the N, and the pair of uninvolved valence electrons), thus becoming NH_3^+. This makes it a hydrogen acceptor, and thus alkaline in character. It also makes it a strong hydrophilic influence. Molecules whose most influential functional group is an amino group are organic bases, and their names end in –amine. Example: diphyenylamine.

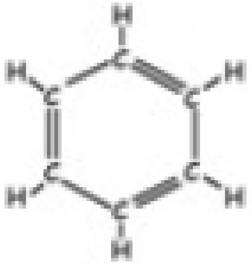
4. **Phosphate Group**: This functional group is always charged, either -1 or -2. This makes it strongly hydrophilic in nature and influence. Phosphates may be attached to organic molecules (organic phosphate) or unattached (free or inorganic phosphate). When diagramming the structures of phosphate-containing organic molecules, the organic phosphate is often abbreviated as a P inside a circle. Free phosphate is often abbreviated P_i (i for "inorganic).

D. **Structures of Important Classes of Biological Molecules**

1. **Hydrocarbon**: [hydro=hydrogen; carbon=carbon] These are molecules consisting of only hydrogen and carbon They come in many sizes and arrangements. They may be saturated (contain only single covalent bonds) or unsaturated (containing at least one double covalent bond). They are very non-olar, since the C-C bond and the C-H bond are both completely non-polar. Most carbohydrates are quite hydrophobic.

Examples: ethane benzene

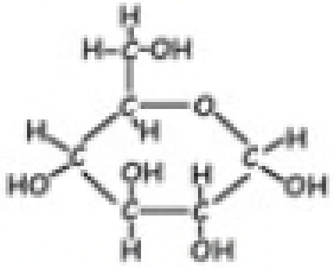


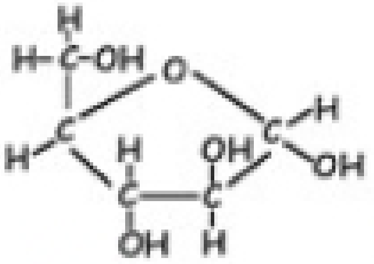


2. **Carbohydrates**: [carbo=hydrogen; hydrate- with water] Carbohydrates are molecules consisting only of carbon and the components of water (hydrogen and oxygen). In common language, most carbohydrates are sugars (saccharides) and their relatives. They fall into several categories.

   a) **Monosaccharides** (mono=one). These molecules are composed of single sugar units. They come in a variety of sizes, depending upon the number of carbons in the sugar. The most common of the sizes is the hexose (hexa=six), which has six carbons. Also of biological importance is the pentose (penta-five), which has five carbons. There are several different hexoses and several different pentoses, and several may actually have the same molecular formula, since the details of the arrangement of the hydrogen and the hydroxyls on the ring is important in the identity of the sugar. Sugars are usually depicted in a ring form, though they also have open chain forms.

   Examples: glucose (a hexose) ribose (a pentose)





   b) **Disaccharides** [di=2]. These sugars are made of two monosaccharides covalently bonded together. The building of the linking bond is accomplished by dehydration synthesis (the removing of the components of water from the two sugars to be bonded together for the purpose of providing unpaired electrons for the formation of the new bond). Examples: sucrose (glucose-fructose) and maltose (glucose-glucose)

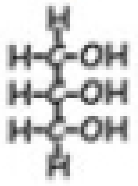
   c) **Polysaccharides** [poly=many]. These molecules consist of long chains (polymers) of monosaccharides linked together by covalent bonds (again, formed through dehydration synthesis). The long chains may branch. Examples: starch, glycogen, cellulose—all glucose polymers

3. **Lipids** (fats and oils). These molecules are essentially all hydrophobic or partially hydrophobic. There is quite a variety of structure among the lipids, but the two best known examples are the steroids and the glycerides. The steroids include such substances as cholesterol, testosterone and estrogen. The glycerides include the triglycerides(primary storage lipids) and phospholipids (also called phosphoglycerides, the major component of all biological membranes).

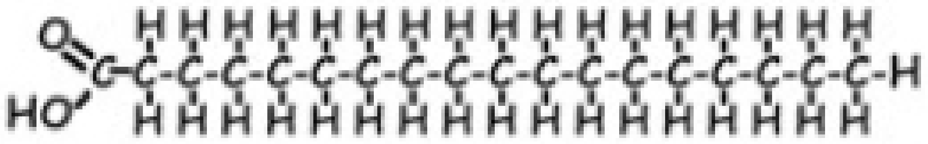
   a) **Steroids** are complex structures with four interlocking rings. There are a number of them which have very significant biological roles. Your text can enlighten you on the structures and roles of the various steroids.

   b) **Glycerides** come in at least two types. All glycerides have as part of their structure the trialcohol glycerol, as well as two to three fatty acids (long hydrocarbon chains which terminate with carboxyl groups). The chemical nature of a glycerides is somewhat contradictory—especially the phospholipids. The glycerol part of the molecule is at least somewhat polar, while the hydrocarbon tails contributed by the fatty acids are highly non-polar. The fatty acids are attached to the glycerol through dehydration synthesis between the hydroxyls of the glycerol and the carboxyls of the fatty acids, creating an ester linkage. The formation of this connecting bond destroys most of the polarity of both the hydroxyl and the carboxyl. The completed glyceride has a polar head with two or three long non-polar tails.

Example: Glycerol

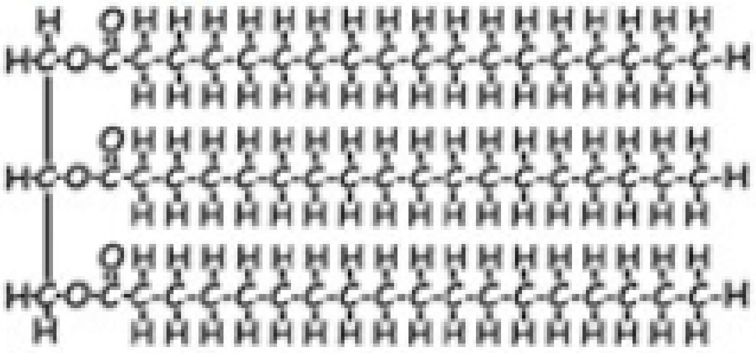


Fatty Acid



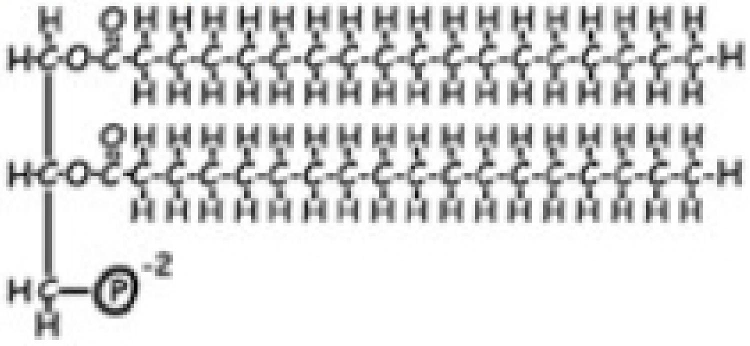
(i) **Triglycerides** are constructed out of one glycerol and three fatty acids. The heads of these molecules have very little polarity left, and the tails are very non-polar. As a result, all triglycerides are at least mildly hydrophobic; most are very hydrophobic. The degree of hydrophobicity is determined by the lengths of the hydrocarbon tails from the fatty acids. The primary function of triglycerides is long-term carbon and energy storage.

Example: Triglyceride



(ii) **Phospholipids** (phosphoglycerides) are very much like triglycerides, except that one of the fatty acids is replaced by a phosphate functional group. This affects the behavior of the molecule in two significant ways. First, it decreases the number of hydrophobic tails from three to two, thus weakening the overall force for hydrophobicity in the molecule. Second, since the phosphate functional group is small (and thus functionally part of the head of the molecule) and negatively charged, it is a very powerful force for hydrophilicity. Because of this arrangement, phospholipids spontaneously form bilayers in water, with the hydrophobic tails sequestered between the two layers of hydrophilic heads. The tails create a water-free environment between the two layers. This is the structural basis for all biological membranes. The membrane is a fluid mosaic composed of proteins of various sorts "floating" in a phospholipid bilayer.

Example: Phospholipid



4. **Proteins** are long, unbranched chains (polymers) of smaller biological molecules called amino acids, linked together by a special covalent bond called a **peptide bond**. A peptide bond is a covalent bond between an amino group and a carboxyl group. Peptide bonds are formed by dehydration synthesis in a process called **translation**, which is performed by the ribosomes of the cell.

a) **Amino acids** come in about twenty varieties. (Actually, there are a few more than twenty, and most come in two different stereoisomers, but since the translation process only specifies codes for twenty, those are the most significant in this context.) All of these amino acids have the same core structure—a carboxyl and an amino group with a single carbon between them—but each has a different **R group** (or side chain, sometimes called a "residue") attached to that central carbon. R groups vary from a simple hydrogen (glycine) to complex ring structures (tryptophan). Some are polar, some non-polar; some are neutral, some acidic, some basic; some are small, some very bulky. As a typical protein might be between 150 and 500 amino acids long, this makes the possible variety in protein behavior very vast.

Example: Amino Acid