Name: Key

Pattern Matching: Part II

Chemists and other scientists use a variety of representational styles or conventions for drawing molecules, and they shift easily between them.

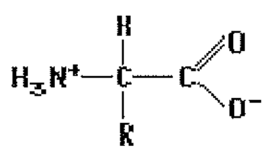
Take out your response to Part I of this exercise. As you read and answer the questions, check your groups of molecules against the grouping given here. At the same time, (a) learn a bit about how to read and interpret the various types of molecular formulas and (b) learn about the different groups of organic molecules.

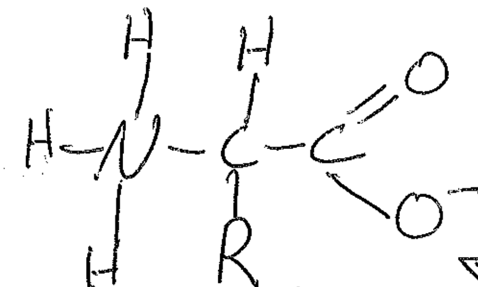
Group 1: Amino Acids - Building Blocks of Proteins

Amino acids are the building blocks of proteins - molecules that play many important roles in the body (including muscle structure, enzymes, hormones, antibodies, hemoglobin for carrying oxygen, other transport proteins for carrying molecules across cell membranes, toxins, and chemical messengers in the nervous system).

Figure 1 shows a "generic" amino acid. Another (more compact) way to represent the same molecule is: "NH_3+ -- CHR -- COO-" or "NH_3+ -- CHR -- COOH".

Figure 1. "Generic" Amino Acid



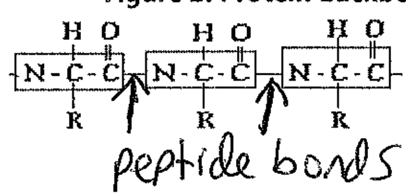


On the left side of the generic amino acid in Figure 1, there is a functional group, NH_3, known as an **amine group.**

1. The bonds between the nitrogen and the hydrogen atoms of NH_3 are not shown in Figure 1. In the space to the right of Figure 1 to redraw the amino acid showing all of bonds between the atoms.

The "-N-C-C-" in the center of the molecule is known as its backbone and is a defining feature of amino acids. The backbones are linked together in a linear chain when amino acids are combined to form a protein. The bonds that link the amino acids together are called **peptide bonds.** A typical protein chain may contain 300 - 1000 or more amino acids.

Figure 2. Protein Backbone

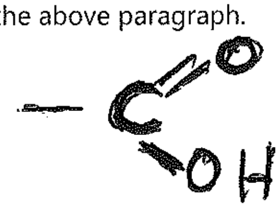


2. LABEL the peptide bonds on Figure 2.

3. Take a look back at Figure 1. Which atom has a negative charge? Oxygen

The negative charge arises when a **hydroxyl group** ("-OH") gives up a positively charged hydrogen atom ("H+"), leaving the negatively charged oxygen atom ("O-"). The entire group, "- COOH" or "-COO-", is known as a **carboxyl group**. The amine and carboxyl groups and the "N-C-C-" backbone are defining features of amino acids.

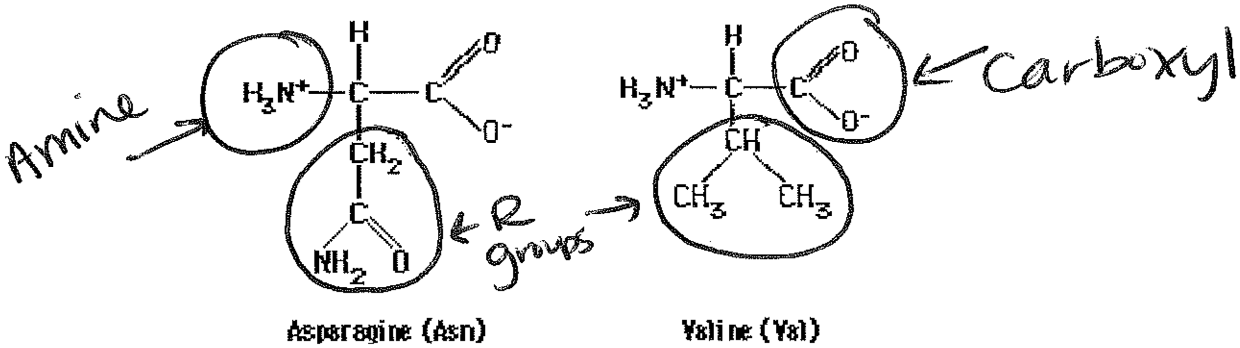
4. The bonds between the carbon and oxygen atoms are not shown in the above paragraph. Draw the molecular structure of a –COOH group (show all bonds).



5. Does the carbon atom bond the same way to both oxygen atoms in the carboxyl group? How do you know?
Double bond b/t single oxygen; single bond to hydrox group

Each amino acid has a different side group that is represented by "R" in Figures 1 and 2. Two amino acids with their particular side groups are shown below.

Figure 3. Side Groups in Asparagine & Valine



6. CIRCLE the R groups on Asparagine and Valine in Figure 3. Then, LABEL the amine and carboxyl groups.

7. Which elements/atoms are found in ALL amino acids? C, H, O, N

There are twenty common amino acids that are used to build protein molecules. Cells string amino acids together end-to-end as shown in Figure 2.

8. With 20 amino acids to choose from, how many different combinations are there for a **polypeptide** three amino acids long (show your work)? Note: a **polypeptide** is what we call a shorter strand of amino acids!

$(20)^3 = 8{,}000$ 20-20-20

9. Consider that you learned that proteins are typically hundreds to thousands of amino acids long. From the calculations above, explain how a cell can potentially make millions of different proteins.

- There are so many possible combinations of 20 different amino acids.
- When they are 100-1,000 long, even more combinations.

10. Using this information, determine which molecules are **amino acids**. Paste them below.

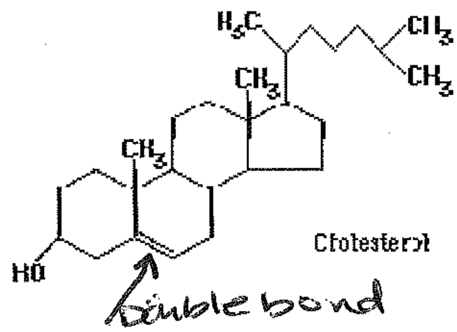
3, 5, 11, 13, 23, 24, 26, 29, 30, 31
33, 34, 35, 36

14 total

Group 2: Steroids - Type of Lipid

One thing that all lipids have in common is that they do not dissolve in water.
Cholesterol, shown below, is a steroid. Steroids are one type of molecule in the class of compounds known as lipids. Cholesterol plays an important role in cell membrane formation. They also form the basis for many hormones, including estrogen and testosterone, in addition to being a component of bile, and a precursor to vitamin D.

Figure 4. Cholesterol



Steroids can be recognized by their multiple rings of carbon atoms connected together. "But wait," you say, "I don't see any carbon atoms in the four rings in the cholesterol molecule!" Believe it or not, they are there.

Organic chemists use many shortcuts in drawing complex molecules. Because organic molecules include so many carbon atoms, chemists often do not include the letter C for carbon. In the cholesterol molecule above, there is a carbon atom (not drawn in most cases) at every point of each of the four rings and in the side chain. The bonds between the carbons are shown. In all but one case the carbon atoms are connected to one another by a single bond (one pair of shared electrons). In one ring there are two carbon atoms connected by a double bond.

11. DRAW AN ARROW to point at the double bond in Figure 4.

12. Paste your steroids below.

14, 22, 37

Group 3: Fatty Acids – Another Type of Lipid

Fatty acids are the building blocks of oils and fats. There are two fatty acids (bilayer) in each of the millions of phospholipids that make up your cell membranes.
Fatty acids have long hydrocarbon chains with a carboxyl group at one end. One of the defining features of these hydrocarbon chains is the absence of oxygen except in the one carboxyl group at one end of the molecule.

Figure 5. Three Representations of the same Fatty Acid (Lauric acid)

a.) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$

b.) $CH_3(CH_2)_{10}COOH$

c.)
```
  H H H H H H H H H H H
  | | | | | | | | | | |
H-C-C-C-C-C-C-C-C-C-C-C-C-OH
  | | | | | | | | | | | ||
  H H H H H H H H H H H O
```

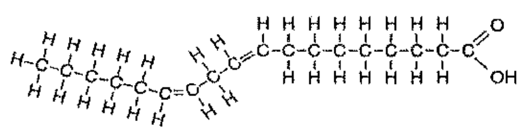
13. Using the representations of fatty acids in Figure 5, count the number of each atom (carbon, hydrogen, and oxygen) and list below:
    a) $C_{12}H_{24}O_2$
    b) $C_{12}H_{24}O_2$
    c) $C_{12}H_{24}O_2$

14. Using your answer to #13, describe the amount of hydrogen compared to carbon and oxygen.
    There is double the amount of Hydrogen as Carbon. Only oxygen in carboxyl group.

Fatty acids that contain no double bonds are called **saturated fatty acids**. An **unsaturated fatty acid** contains one or more double bonds (Figure 6).

Figure 6. Unsaturated Fatty Acid

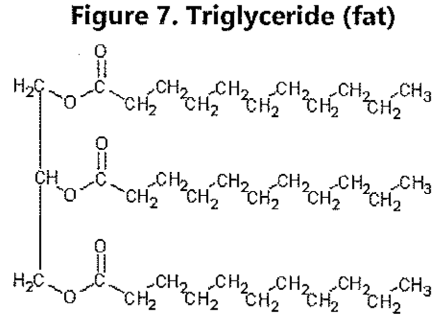
$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$



Linoleic acid (polyunsaturated fatty acid)

Fats are the most concentrated energy source in our diets, furnishing about 2.5 times the energy that sugar does, gram for gram. We store energy for future use in fats. Fats also insulate and protect the body and many internal organs. Figure 7 illustrates a fat molecule, also known as a **triglyceride**, which consists of 3 fatty acid molecules joined to a glycerol.

Figure 7. Triglyceride (fat)



A fat made from saturated fatty acids is called a **saturated fat**. Most animal fats are saturated. Saturated fatty acids can be packed tightly together because without double bonds the molecule is quite flexible. As a result, saturated fats (such as butter) are solid at room temperature. The fats of plants and fishes are generally unsaturated, meaning they are built of one or more types of unsaturated fatty acids. An **unsaturated fat** is liquid at room temperature because the kinks where double bonds are located prevent the molecule from packing closely together.

15. Is the fat shown in Figure 7 a saturated or unsaturated fat?

16. How many saturated fatty acids do you have in your collection? 2 = (17+19)

17. If a monounsaturated fatty acid has one double bond in its hydrocarbon chain, how do you think you would define a polyunsaturated fatty acid?

Many double bonds

18. How many of your molecules are monounsaturated fatty acids? 1 (#18)

19. Paste your fatty acids below.

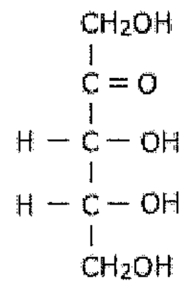
17, 18, 19

Group 4: Sugars - Building Blocks of Carbohydrates

Sugars are the building blocks of carbohydrates. They are literally hydrates of carbon, having the general formula "$C_n(H_2O)_n$". Sugars are burned (oxidized) to release energy in cellular respiration and they play an important role in homeostasis. Your body maintains the level of the sugar **glucose** in your blood within a very narrow range. Glucose is the immediate source of energy for your cells.

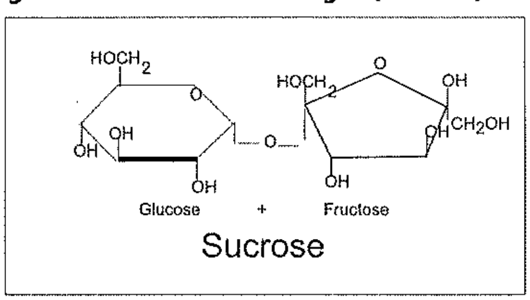
Sugars occur as ring structures. They can be **monosaccharides** (single rings) such as glucose, **disaccharides** (double rings) such as sucrose, and longer chains such as starch, glycogen, and cellulose. In solution, single rings can dynamically change from straight chains to rings and back to straight chains. A straight chain sugar is shown below (Figure 8). Notice that every carbon has an oxygen attached to it.

Figure 8. Straight Chain Representation of a Sugar (ribulose)



20. How many straight chain sugars do you have in your set? 6 (2, 12, 15, 28, 32, 39)
21. Based on what you know so far, which elements are contained in sugars? C, H, O
22. How many monosaccharides are in your molecule set? (2) single ring + (6) straight chains #7 & 21
23. How many disaccharides are in your molecule set? (2) # 25 & 38

Figure 9. Common table sugar (sucrose)



24. One of the disaccharides, sucrose is shown in Figure 9. Sucrose is formed when two monosaccharides, glucose and fructose, are joined together in the process of **dehydration synthesis**. Based on what you learned in chemistry, which atoms are removed during the bonding of the two monosaccharides? H_2O

Sugars can be joined together in long chains to form macromolecules called starch, cellulose, and glycogen (animal starch). Starch (in plants) and glycogen (in animals) are easily broken down into sugars for energy. Cellulose, on the other hand, which is made in plants, can be broken down only by a few organisms in the world (primarily the bacteria in the guts of termites). Yet all three types of macromolecules are made of long chains of sugar, and cellulose differs only by a small change in the connecting bond between each pair of sugars.

25. In the space below, paste all your sugars, including straight chain sugars, monosaccharides, and disaccharides. LABEL the monosaccharides, and disaccharides

2, 7, 12, 15, 21

25, 28, 32, 38, 39

monosaccharide
Straight chain = 6

monosaccharide rings = 2

disaccharide rings = 2

Group 5: Nucleic Acids -- Single & Double Ring Molecules Containing Nitrogen

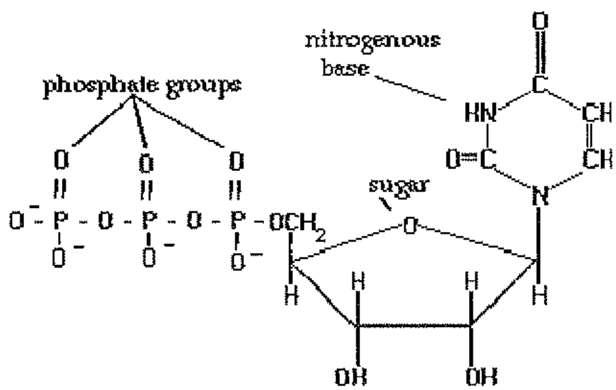
So far we have identified three of the four major classes of molecules in living things:

- **proteins** and their subunits amino acids
- **lipids** including fats and oils with their subunits, fatty acids, and steroids
- **carbohydrates**, including starch, cellulose, and glycogen (animal starch) with their subunits, sugars.

You probably recognize these three types of molecules as major food groups as well as major classes of biological molecules. In contrast, **nucleic acids**, the fourth and last major group of molecules, are not a major food group. Nucleic acids include two kinds of molecules, **RNA** (ribonucleic acid) and **DNA** (deoxyribonucleic acid), and their subunits. In most organisms, DNA contains the genetic blueprint for the organism and is reproduced in its entirety in every cell of its body. RNA helps to translate the information in DNA into the production of thousands of different kinds of proteins, which in turn control development of the organism.

The subunit of a nucleic acid is called a nucleotide. A nucleotide has three parts, a nitrogenous base, a five-carbon sugar, and 1 to 3 phosphate groups (Figure 10).

Figure 10. Parts of a Nucleotide (Uracil triphosphate)



26. Which elements are contained in nucleic acids? C, H, O, N, P

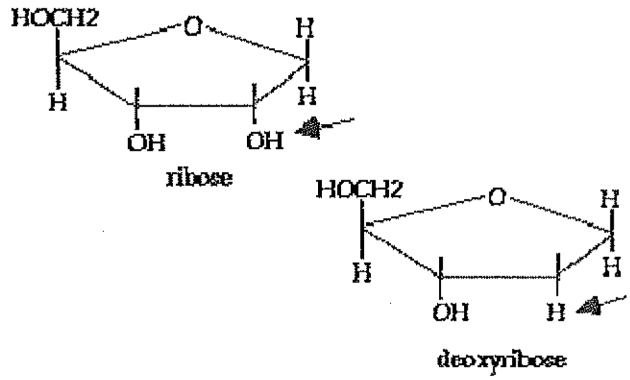
The nitrogenous bases consist of single or double rings, and each ring contains two nitrogens. DNA contains four nitrogenous bases: adenine (**A**) , guanine (**G**), cytosine (**C**), and thymine (**T**). RNA contains three of these, **A**, **G**, and **C**, and a fourth base, uracil (**U**).

27. Paste your nitrogenous bases below. Remember <u>nitrogenous bases</u> are only one part of a nucleotide.

1, 6, 9, 14, 27

A nitrogenous base is combined with a five-carbon sugar, either ribose (for RNA) or deoxyribose (for DNA), as shown below. The arrows in Figure 11 point to the single structural difference between ribose and deoxyribose.

Figure 11. Ribose and Deoxyribose



28. How many molecules do you have that contain <u>both</u> a nitrogenous base and a five-carbon sugar? These are called **nucleosides** (free nucleotides are called nucleosides--it's weird). Paste them below.

4, 8, 10, 20

Nucleosides can combine with one, two, or three phosphates. The greater the number of phosphates, the greater the energy contained in the molecule. Adenosine triphosphate (**ATP**) is a major energy carrier in living systems.

29. Paste the remaining molecules below, there should be three total. LABEL each as Mono-, Di-, or Triphosphate.

40, 41, 42

Di phosphate — Mono phosphate — Triphosphate