DNA Worksheet

Name_____________________________ Day/Time_________________________

Refer to Chapter 5 and Chapter 16 (Figs. 16.5, 16.7, 16.8 and figure embedded in text on p. 310) in your textbook, Biology, 9th Ed, for information on DNA and its structure

DNA Structure
The structure of DNA was first determined in 1953. This exercise will explore the structure of DNA, beginning with nucleotide structure, through hydrogen bonding of base pairs and the structure of the sugar-phosphate backbone to the DNA double helix.

Nucleotide Structure
Look at models of the four nucleotides. These are labeled as follows:

A = adenine
C = cytosine
G = guanine
T = thymine

These models are based on X-ray crystallographic structures and are built to scale. X-ray crystallography does not permit the identification of hydrogen atoms, so these are not shown on the model, except in the case of hydrogen bonds between base pairs. These are shown in white, and are held together using magnets. The remaining colors used in the model are standard CPK colors, as follows:

Carbon atoms: grey
Oxygen atoms: red
Nitrogen atoms: blue
Phosphorous atoms: yellow

Each nucleotide consists of three parts:
- Phosphate group (PO₄) is connected to the sugar group, and lies perpendicular to the plane of the nitrogenous base. This portion of the molecule is identical in all four nucleotides.
- Deoxyribose is a 5 carbon sugar, lying between the phosphate group and the nitrogenous base. This forms a ring structure, and the carbons are numbered starting with the carbon attached to the nitrogenous base. Note that because the numbers 1-9 are used to number the atoms in the nucleotides, sugar atoms are numbered 1’ (read ‘one prime’) to 5’ to distinguish them from the atoms in the base. The 1’ carbon (attached to the base) is always adjacent to the ring oxygen (a red atom). The 4’ carbon lies in the sugar ring, and the 5’ carbon is the link between the sugar ring and the phosphate group. This structure is also identical in all nucleotides in DNA.
- The base is the portion of the molecule that varies among the four nucleotides. Adenine and guanine are purines, consisting of two fused rings. Cytosine and thymine are pyrimidines, consisting of a single ring. Hydrogen bonds form between base pairs. (These are indicated with the use of magnets.)
Below is the structure of the deoxyribose. Number the carbons (1’ to 5’) and place an asterisk (*) on the 3’ carbon.

For each of the nitrogenous bases, label the atoms as carbon (C), oxygen (O) or nitrogen (N). Draw dotted lines to indicate where the hydrogen bonds form with the complementary base.
Once you have drawn each nucleotide, determine which bases are most likely to hydrogen bond together. Remember that the width of the DNA helix is the same for each base pair. This can only be achieved with a purine (double ring) pairing with a pyrimidine (single ring). Note that in order for the bases to hydrogen bond, one of the bases in each pair must be flipped upside down.

Based on your drawings, record your prediction as to which bases pair with which:
__________ pairs with _________ and __________ pairs with _________.

Test your hypothesis by aligning the base pairs in the model. When done correctly, the magnets (representing hydrogen bonds) will hold the base pair together.

**Review**

Indicate which of the bases (A, C, G and T) goes with each of the following terms. Some descriptions will require more than one answer.

__ __ purines
__ __ pyrimidines
__ pairs with A
__ pairs with C
__ pairs with G
__ pairs with T
__ __ has three hydrogen bonds
__ __ has two hydrogen bonds
__ __ __ __ attaches to the 1’ carbon of deoxyribose

**Orientation of the Chains**

Take a base pair, and rotate it so that the plane of the bases is on edge and the sugar groups are facing you. It should look like this:
Label the oxygen (O) on both sugar molecules. Also label the 3’ carbon of the sugar (hint: they each have a magnet, facing you). As you observe the structure, complete the following statements, circling the appropriate word from the choices given.

- The oxygen of the sugar molecule on the left side lies (above, below) the plane of the nucleotides.
- The phosphate group on the left side lies (above, below) the plane of the nucleotides.
- The oxygen of the sugar molecule on the right side lies (above, below) the plane of the nucleotides.
- The phosphate group on the right side lies (above, below) the plane of the nucleotides.
- Thus, the red oxygen atoms in the sugar molecules serve as a pointer, pointing in the direction of the (phosphate group, 3’ carbon of the sugar).
- Relative to the base on the left, the base on the right is (in the same orientation, upside down).

**Double Helix**

Next, work with other students to assemble the base pairs into a double helix. The 3’ carbon (on the sugar) of one base attaches to the phosphate group (attached to the 5’ carbon) of the adjoining base. As a shortcut, we label these the 3’ (sugar or OH) and 5’ (phosphate or P) ends of the molecule.

Assemble the helix on the stand. Label the order of the bases (circles) on the helix and indicate the phosphate (5’) and sugar (3’) ends of the strands (boxes). It may be useful to draw the bases on one strand upside down, to remind you that two strands run in opposite directions.
Look carefully at the structure of the double helix. Imagine the structure is a spiral staircase. If you were walking UP the staircase, which hand would be on the outside rail? _______________

This determines the handedness of the helix. DNA is therefore often called a _______ -handed double helix.

Note the grooves in the helical structure. Trace the deep groove (called the major groove) and see how it twists with the helix. The major groove is where many regulatory proteins bind. The narrow groove (called the minor groove) is the site of binding to the nucleosome, which is involved in packaging the DNA in the cell.

**Post Lab Questions**

1. Explain the meaning of each of these terms which describe the structure of DNA:
   a. complementary base pairing
   
   b. antiparallel

   c. sugar-phosphate backbone

   d. double helix

2. Chargaff determined that in DNA the concentration of guanine was the same as cytosine, and adenine was the same as thymine (G=C and A=T). Explain how this correlates to the structure of DNA.

3. Take measurements of the diameter of the DNA helix that you have assembled in class (for each take at least 3-5 measurements). Why does this support purine-pyrimidine binding but not purine-purine or pyrimidine-pyrimidine binding?