

Key Teaching Points for DNA Discovery Kit®

Overall Student Learning Objective: The structure of DNA allows for fidelity in replication as well as opportunities for variation over time.

- DNA consists of four **nucleotides**: adenine, guanine, cytosine, and thymine.
- Adenine and guanine are **purine** molecules, each with a double ring structure.
- Cytosine and thymine are **pyrimidine** molecules, each with a single ring structure.
- Each nucleotide has a variable **nitrogenous base** and an identical backbone consisting of **deoxyribose** (a sugar) and a **phosphate** group.
- The identical backbone portions of each nucleotide can be joined together to make a long strand of DNA.
- These strands are oriented from the 5' phosphate (beginning) to the 3' hydroxyl (OH) group on the sugar (end).
- DNA consists of two strands, running in opposite directions (**antiparallel**), so the 5' end of one strand is base-paired to the 3' end of the second strand.
- **Base pairing** between the two strands always pairs a purine with a pyrimidine: adenine pairs with thymine and guanine pairs with cytosine.
- The two strands are twisted into a right-handed helix, which has a larger, **major groove** and a smaller, **minor groove**.
- Each of the two strands of DNA serves as a template for the other strand.

★ We recommend that you allow students to discover the *concepts* related to DNA structure before introducing the *vocabulary*.

Nucleotide Structure

Pre-class preparation: disassemble each nucleotide into sugar, phosphate and nitrogenous base and place in zippered snack bag. Bundle four bags (one of each nucleotide) together with a rubber band.

Give each group of four students a set of nucleotides; each student should get one bag. Have students compare their three parts with their group and identify which parts are identical and which parts are different. Identify the identical parts (sugar, phosphate).

Ask students what color is predominant in the parts they have that differ – blue. Blue represents nitrogen atoms. These are nitrogenous bases.

1. Why do you think these are called nitrogenous bases?

Have students take their nitrogenous bases and form two groups with similar characteristics.

2. How did you group your bases?

Some students may group the bases by size. Use this type of grouping to introduce the terms purine (a double ring structure – for A and G) and pyrimidine (a single ring structure – for T and C).

Other students may group the bases by the number of hydrogen bonds. Use this grouping to discuss base pairing, and that a purine always pairs with a pyrimidine.

If students all group their nucleotides in the same way, ask:

3. Is there another way you could group the nucleotides based on similar characteristics?

Nucleotide Composition and Base Pairing

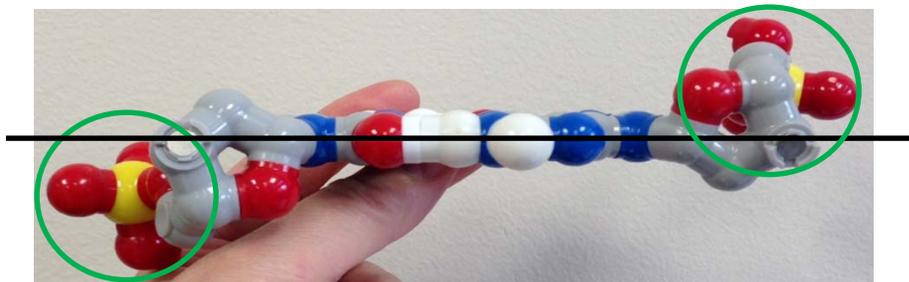
Have students assemble their nucleotide by joining the three pieces using only the pegs and holes (no magnets). Next have students form base pairs by joining a purine and a pyrimidine using only the hydrogen bonds on the nitrogenous bases. A correct base pair will use all bonds on *both* nucleotides and will join two different bases.

4. What nucleotide binds with A? G? T? C?

5. How many hydrogen bonds join a G-C base pair? An A-T base pair? Which do you think is a stronger interaction? Why?

Antiparallel Strands

Have students hold their base pair so that the sugar rings are facing them and the nucleotides lie in a horizontal plane:



6. Where do the two phosphate groups lie in relation to the plane of the bases?

Students should see that the two phosphate groups (circled in green in the image) lie on opposite sides of the plane of the bases (black line in the image), one above and one below the plane.

DNA strands are created by joining the sugar-phosphate backbone of adjacent nucleotides, so the backbone alternates phosphate-sugar-phosphate-sugar-phosphate-sugar. The nucleotides in any given base pair have the sugar and phosphate oriented in opposite directions, so the sugar-phosphate backbones of the two strands run in opposite directions, much like the cars on a road. This parallel but opposite direction is termed **anti-parallel**.

Double Helix

Students should join base pairs together by connecting the sugar of one nucleotide to the phosphate of another nucleotide using magnets. By stacking the plane of the nucleotides and twisting one relative to the other, they can connect the sugar to the phosphate on both sides of the structure. Additional base pairs should be added to construct a portion of a double-stranded DNA molecule.

7. What is the shape of the DNA molecule?

Have students imagine that the bases are a set of spiral stairs, and they are walking up the staircase. The railing in a spiral staircase is always on the outside.

8. Which hand is on the railing? Does your hand change if you walk up the DNA staircase starting from the other end?

Students will discover that, regardless of which way they walk up the staircase, their right hand will be on the railing. This makes DNA a **right-handed helix**. Because there are two strands of DNA, and they are intertwined, DNA is a **right-handed double helix**. This structure is often described as a twisted ladder, with the nitrogenous bases forming the rungs and the sugar-phosphate backbone forming the rails of the ladder.

Intertwining of DNA Strands

You may wish to begin discussing how each strand of DNA is a complement (not a copy) of the other, and that if you know the sequence of one strand; you could infer the sequence of the other. Watson and Crick suggested in their second paper (May, 1953) that this complementarity of the two strands suggests a way that the DNA might replicate. In order for DNA to be copied, the two strands must be separated. Using the toober model of DNA that comes with the DNA Discovery Kit[®], have a student try to separate the two strands. They will discover that the two strands are intertwined. (The technical term for two intertwined helices is **plectonemic**.) In order to separate the two strands, they must be untwisted. With a little practice, you can untwist the strands, creating a replication bubble. This is a nice introduction to the process of DNA replication.

Major and Minor Grooves

Note that although the overall shape of DNA is like a long cylinder, there are two spiral indentations, called the **major** and **minor grooves**. The major groove is large enough for the alpha helix of a protein to fit and interact with the edge atoms of the base pairs. These interactions are typically sequence-specific; proteins such as transcription factors often bind in the major groove.

The minor groove, on the other hand, is only large enough to accommodate an amino acid sidechain. Very often, positively-charged arginine or lysine residues interact with the phosphate groups in the minor groove. Because each nucleotide contains an identical phosphate group, these interactions are non-specific. Proteins binding in the minor groove typically interact with the DNA regardless of DNA sequences. As an example, histone proteins interact with DNA in the minor groove to form nucleosomes involved in packaging DNA in the nucleus.

9. Write a description of the structure of DNA using your own words.

You may wish to have students review their paragraphs, inserting the terminology that describes DNA structure where they have described the terms in their words. This paragraph will then serve as a description plus definition of terms they can use to review DNA structure.

! Caution – Note This Limitation in the Model - This activity has students construct DNA from nucleotide to base pair to double helix. DNA is not replicated in this manner; instead, the double stranded DNA is unwound, then each strand is used as a template to build a second strand. We suggest you use the DNA Starter Kit[®] or the Flow of Genetic Information Kit[®] to address the process of DNA replication.



For more detailed lesson plans and activities, please visit

<http://www.3dmoleculardesigns.com/Education-Products/DNA-Discovery-Kit.htm>

The DNA Discovery Kit[®] can be borrowed from the MSOE Model Lending Library (<http://cbm.msoe.edu/teachRes/library>) or purchased from 3D Molecular Designs (www.3dmoleculardesigns.com).