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An Excellent DNA Model

Robert B. Ketcham

University of Delaware, Department of Biology, 048 McKinly Lab, Newark DE 19716 USA (**rketcham@udel.edu**)

Students manipulated a model of DNA. They started with phosphate, deoxyribose, and two nitrogenous bases to assemble one nucleotide pair. They then built a DNA molecule having 12 base pairs. They measured several emergent features and record the sequence of bases along one strand. They ended by deliberating on how four kinds of nitrogenous bases can code for twenty amino acids. A group of students submited their responses on an Activity Sheet.

Keywords: DNA, molecular model

Introduction

3D Molecular Designs has produced a model of DNA that is a pleasure to handle. It reliably pulls the viewer's attention into a contemplation of this all-important molecule, whether the viewer is the student or the instructor. For many students, the experience of building the model seems to make sense of thousands of instructor words.

The model is sturdy but it can be damaged by someone who attempts to disassemble it as their first interaction with it. For this reason, we start by giving each group of students two small trays, one containing the pieces of a GC pair and the other containing the pieces of an AT pair. This requires the instructor to pull the phosphates and the deoxyriboses off each nitrogenous base before handing them out, about a 10 minute job for 6 groups. Students can assemble the full nucleotide pair without damage to the model.

Once students have done this first assembly, they figure out, by trial and error, how to link one nucleotide pair to another. They then build a 12 nucleotide pair sequence on a special stand provided with the model kit. We have students measure aspects of the model and record its sequence. They do this on a Group Activity Sheet. The last question has them consider the problem of how four nucleotides can specify twenty amino acids.

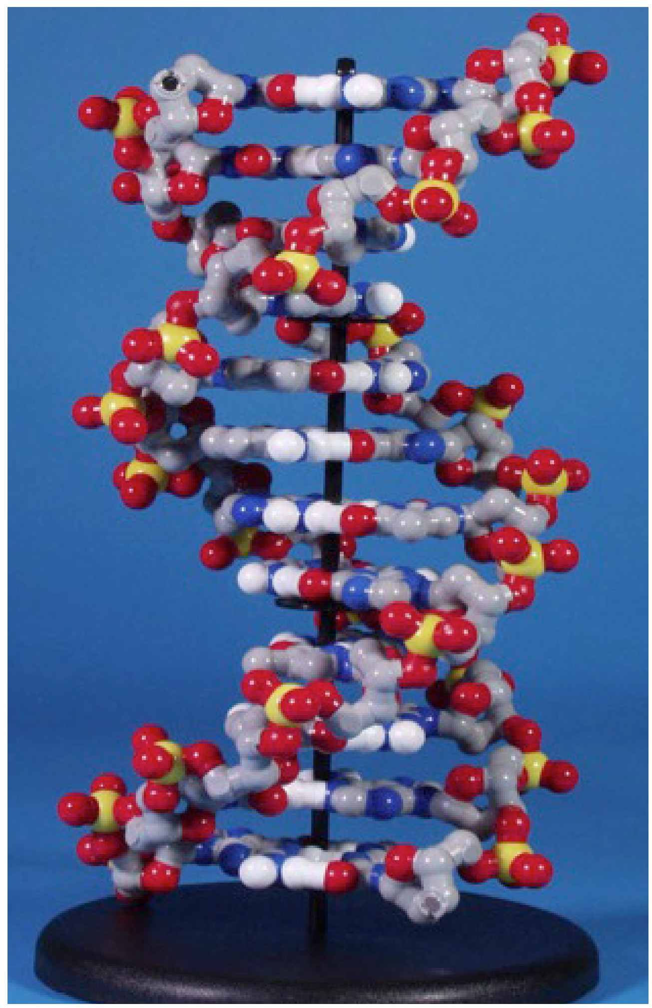


Figure 1.DNA Discovery Kit.

Student Outline

Learning Objectives

When you have finished this lab, you should be able to do the following things:

1. Explain how an individual nucleotide is assembled from three components: phosphate, the sugar deoxyribose, and a nitrogenous base.
2. Explain how multiple nucleotides are connected to each other to give a DNA molecule its characteristic shape.
3. Discuss how information can be stored in a DNA molecule.

Introduction

As all of you know, we live in the midst of a revolution in the way we handle information. Figuring out how to store information on a silica chip was the key event in getting this digital revolution started, and the World Wide Web is just one example of how we've changed the way we collect, store, and transmit information.

This digital age of ours is not the first information revolution on Earth. The first one enabled life, as we know it today, to exist. The key to that first revolution was an organic molecule we call DNA.

Watson and Crick published the structure of DNA (DeoxyriboNucleic Acid) in 1953. This amazing molecule has become very famous in the years since. Here are some of the things you should understand about DNA.

- In the final analysis, DNA is what is passed from one generation to the next.
- The information for making proteins is stored in the sequence of nucleotide bases in DNA.
- If the DNA molecules in one of your cells were stretched out in a single line, it would be about 6 feet long. Each of your cells contains that much DNA.
- That much DNA contains about 6 billion pairs of nucleotide bases.
- Inside a eukaryote nucleus, DNA molecules are highly coiled and wrapped around special protein molecules.
- Every person has very similar DNA but the sequence of nucleotide bases in each person's DNA is unique to some extent.
- Each species is unique in the sequence of its bases; these differences are greater than differences among individuals within each species.

It is time to learn more about the DNA molecule.

Nucleotides – What Are They?

DNA is made of units called nucleotides. One molecule of DNA can have a really huge number of these units. The Y chromosome, for instance, which is well known because its presence leads an individual to develop into a male instead of a female, contains a relatively short piece of DNA that has about 57 million pairs of nucleotides.

A single nucleotide is made of three smaller parts: a phosphate molecule, a sugar molecule, and a molecule called a nitrogenous base. We will look at each of these in turn. As you will see, the phosphate and sugar are identical in all nucleotides, but there are four different nitrogenous bases and this little bit of variation is what makes it possible for DNA to store information.

Phosphate

Look at the model of the phosphate molecule. It has one phosphorus atom (yellow) and four oxygen atoms (red). Phosphorus is chemical element #15 in the chemists' periodic table; oxygen is element #8. As you can see, a phosphate molecule has a beautiful tetrahedral symmetry.

In our model two of the oxygen atoms are not smooth and round. They have a tab or a magnet,so you can attach them to the rest of the DNA model.

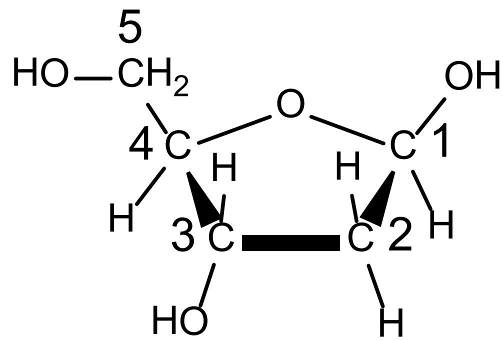
Sugar

Sugars are familiar chemicals. You probably recognize fructose, glucose, and sucrose as sugars; there are many others, such as lactose, maltose, galactose, arabinose, etc. The sugar that is part of DNA is called deoxyribose.

Sugars are short chains of carbon atoms; most of them have 5 or 6 carbons (element #6). Each carbon atom, besides being bonded to other carbon atoms, is also bonded to a hydrogen and to an oxygen-hydrogen combination. So a typical carbon unit in a sugar looks like H – C – O – H (ignoring its bonds to other carbons).

Notice that H – C – O – H can easily be rewritten as $C – H_20$. Can you see how early chemists came up with the name *carbo – hydrate* for the group of organic molecules that includes sugars?

The other feature that characterizes a sugar is that the chain of carbons is closed into a ring. A ring is formed because two carbon atoms, the C at one end and the next-to-last C at the other end, are bonded to the same oxygen atom. The 5-carbon ring of deoxyribose, missing its oxygen at carbon #2, looks like this:



Look at the piece of the model that represents deoxyribose. The carbon atoms are gray and the oxygen atom is red. Hydrogen atoms and the other oxygen atoms are not represented, to keep the model simple. Notice that the ring structure is almost flat, except for the 5th carbon, which stands out from the plane of the ring.

Attach the phosphate to the deoxyribose sugar. There are two ways to do this. Try them both, but end up using the tab connection rather than the magnet connection.

Nitrogenous Bases

Put the phosphate-sugar pieces aside and look at what you have left.

Notice several things:

- there are atoms colored blue;
- there are atoms colored white;
- some of the white atoms are distinctively barrel-shaped;
- the molecule is very flat;
- there are rings, one by itself, and two fused together.

The blue atoms are nitrogen (element # 7). The white atoms are hydrogen (element #1). The barrel-shaped white atoms represent hydrogen bonds. A hydrogen bond is a hydrogen atom being shared between two other atoms – in your model the atoms being held together by hydrogen bonds are either oxygen (red) or nitrogen (blue).

Some of your models have two barrel-shaped hydrogen bonds; others have three. This little bit of variety among the nitrogenous bases is critical to the way DNA works as an information-storing molecule.

Notice that you can flex the models at the hydrogen bonds. Do this now so each one separates into two pieces. Each piece is actually one nitrogenous base; what you started with was a pair of bases held together by their hydrogen bonds.

One of your bases has a single ring and the other base has two fused rings. This is the way bases always pair up in DNA: a double ring paired with a single ring. There are two different kinds of pairs, however, the one with two hydrogen bonds and the onewith three hydrogen bonds. All this is summarized in Table 1, which also gives the names of the four nitrogenous bases found in DNA.

Table 1. The nitrogenous bases of DNA.

		Ring	
		Double	**Single**
Hydrogen Bonds	2	Adenine (A)	Thymine (T)
	3	Guanine (G)	Cytosine (C)

Join each nitrogenous base piece to a sugar-phosphate piece so you have two complete nucleotides.

Assembling DNA

The individual nucleotides snap together readily to make a model of DNA. The fun of learning from models comes from discovering things through trial and error. Play with this assembly problem within your group.

Each group can assemble a dozen nucleotide pairs on a special stand made for this purpose. Every 4th nucleotide pair will rest on one of the circular ledges that are part of the post, to support the weight of the growing model.

Consult with other groups to see what they figure out.

Answer the first and second questions on the group Activity Sheet.

Before you finish with your DNA molecule, record the sequence of nucleotides you created as you put it together. Directions are in question #3 on the Activity Sheet.

Answer the last question on the Activity Sheet below.

Group Activity Sheet - DNA Models

Names: **Lab Section:**

DNA Models

1. You see some features of DNA only after you have put several nucleotide pairs together. Describe two features that are like this – they show up when the model is fully assembled.

2. Can you measure something about each of those features? Make the measurements and record the results here.

3. Copy down the sequence you created in your model. Let the nucleotide at the top of the model, the one with its phosphate projecting up, be your first base, then the one below it, etc. You can disassemble your model as you go, returning the nucleotides to their container.

Position	1	2	3	4	5	6	7	8	9	10	11	12
Nucleotide base												

4. The information in DNA is the information a cell uses to make its proteins. A protein is a long chain of amino acids connected one to the next:

$$AA_1 – AA_2 – AA_3 – AA_4 – AA_5 – AA_6 – AA_7 – \; .....$$

There are 20 different amino acids found in proteins in living things.

Discuss in your group the problem of how information in DNA can specify the sequence of amino acids in a protein. What aspect of your DNA model might contain information? How could this specify sequences of 20 different amino acids?

Materials

- DNA Discovery Kit.One per group of students.
- Rulers
- Containers to facilitate distribution to students
- Copies of Activity Sheet, one per group

The DNA Discovery kit can be purchased from 3D Molecular Designs for $252.

3D Molecular Designs
1050 Market Street
Suite CC130A
Milwaukee WI 53202
414 774-6562

About the Authors

Robert Ketcham is a Laboratory Coordinator in the Biology Department at the University of Delaware.

Mission, Review Process & Disclaimer

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