How-To-Do-It

A Hands-On Approach to Teaching about DNA Structure and Function

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In light of the ever-increasing importance of genetic research to the ordinary citizen as well as to the biologist, it seems imperative to ensure that our biology students gain a thorough understanding of the structure and function of DNA. This instruction should include the way in which DNA replicates and the process of transcription in which the codes for various proteins are passed on to the ribosomes by the mRNA. We became dissatisfied with the laboratory activities available at the high school level for developing concepts in molecular genetics. The students who appeared not yet able to carry out formal operational thought were having a particularly difficult time conceptualizing the structure of DNA. We thought that a more concrete activity would allow our students to meaningfully visualize the structure and function of DNA. The laboratory investigations illustrated here seemed to accomplish these goals.

Our goal was to develop a manipulative activity using inexpensive but graphic materials. The materials used were two sizes of paper clips, an assortment of colored pipe cleaners, and flat styrofoam sheeting, such as that used for building insulation. Advance preparation consisted only of cutting the pipe cleaners into approximately 5 cm lengths, spray-painting part of the paper clips, and cutting the 2-cm-thick styrofoam sheeting into pieces approximately 3 cm by 7 cm. Be sure to have plenty of paper clips available for each student.

The investigations can be used before or after class discussion of DNA structure, as all the information needed is included in the "Background" section of the paper supplied to the student. The format of the investigations was patterned after the Extending Discretion Approach (Leonard, 1980; 1981), but the steps are very specific in order to make sure the desired results are obtained. Allowing the students to "watch" what happens with the models appears to aid in their understanding of both replication and transcription. The first part of the investigation has the student make model nucleotides and then form them into a model of DNA to show how the nucleotides act as building blocks. Students demonstrate replication using the flat DNA model and free nucleotides and make a somewhat three-dimensional model to visualize the double helix. The flat and twisted DNA models are shown in Photo 1 and Photo 2 respectively.

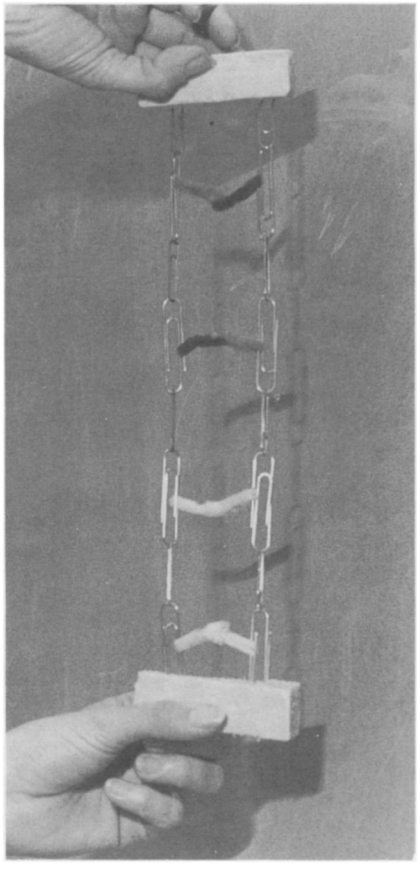

Photo 1. The flat model of DNA creates a concrete visual aid for understanding DNA structure.

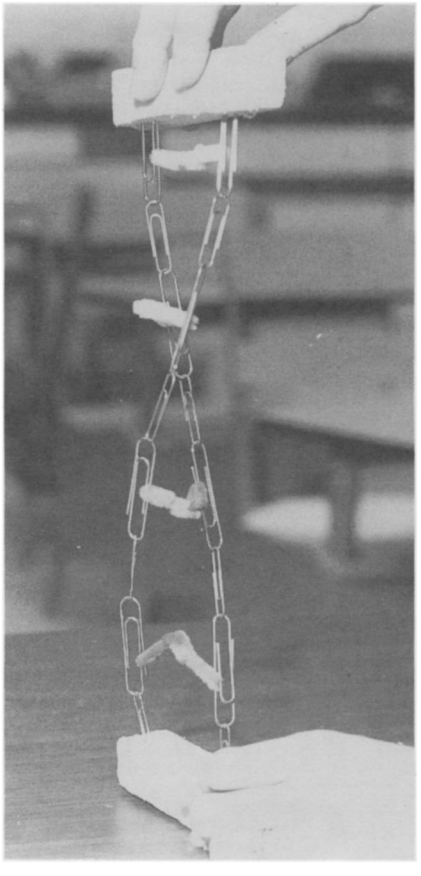

Photo 2. With a twist of the wrist, an idea of the double helix is suggested.

The second part of the lab deals with mRNA and has the students again form nucleotides and make a model using slightly different materials, thus demonstrating the differences between mRNA and DNA. They demonstrate transcription using the flat DNA model and the mRNA nucleotides. Each part of the investigation may take a full class period, so they are separate activities. After completing the investigation, the students write a report summarizing what they have learned about the structure and function of the two compounds. The actual printed laboratory procedures given to the students are shown in Boxes 1 and 2.

In working with the student during

this lab, the teacher must be careful not to tell the students too many answers. The teacher may use a few leading questions to aid the student in verbalizing the basic ideas, however. One point that can be brought out is the relative strength of the different bonds in the molecules. The phosphate bonds represented by the joined large and small paper clips are fairly strong, but the hydrogen bonds between the bases, represented by hooking two pipe cleaners together, are much weaker and more easily broken to allow the processes of replication and transcription to occur.

After following the procedures in this lab, the students seem to have a much clearer understanding of this important part of biology, and have a knowledge base for their later learning about DNA and RNA. Some typical student comments resulting from this activity were:

"I liked the transcription activity with the paper clips. Everytime DNA is mentioned I think about what we did with the paper clips and I understand what happens."

"I learned a lot more than if we had just sat and discussed it."

"The best activity we did was about replication and transcription, because it helped me see how the process works."

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Box 1. MOLECULAR GENETICS PART I: DNA STRUCTURE AND REPLICATION

Goal

To understand the structure of DNA and the way in which DNA duplicates by building simple models of DNA and its components.

Background

DNA consists of a ladder-like structure known as a double helix. The sides are composed of a chain of alternating deoxyribose and phosphoric acid molecules. The bonds between these are strong and not easily broken. The base molecules, guanine, cytosine, thymine and adenine, are attached to the deoxyribose molecules, one to each deoxyribose. The rungs of the ladder are formed by two bases linking together in the center. The bonds linking the bases are fairly weak, which enables them to unhook to perform certain operations, such as replication and transcription. Bases join together only in specific combinations—adenine to thymine, and guanine to cytosine. The actual structure of DNA is a spiral, like a spiral staircase. A nucleotide is composed of one molecule of deoxyribose sugar, one molecule of phosphoric acid, and a base attached to the deoxyribose. Constructing the nucleotide is rather like a building block of DNA. The nucleotides attach together to form the DNA molecule. DNA Replication is a process in which the DNA "unzips," or splits down the center of each rung, allowing the base pairs to separate. This gives two distinct strands of DNA. Free nucleotides come in, match up with the correct bases, and join together to form a complementary strand for each original strand. The result is two identical molecules of DNA.

Steps *Teacher OK*

1. Use materials to form nucleotides, with at least two nucleotides containing each possible base. _____
2. Line up molecules in one row and write down their order, then figure out what the other side of the ladder would have to be to match, and write it down. (Remember which base must match with which.) Mix up the nucleotides and do it again, making at least three different combinations. _____
3. Using the nucleotides you made, make a flat model of DNA. _____
4. Using the flat model, demonstrate the process of replication. (You will have to make more nucleotides.) _____
5. Make a 3-D model of DNA from a flat model. _____
6. Write a short report describing the structure of DNA and the process of replication. _____

Materials

Large and small paper clips, 5 cm lengths of colored pipe cleaners, styrofoam blocks.

Reference: Textbook

Techniques

1. Suggested use of materials:
   Large paper clip to represent deoxyribose sugar
   Small paper clip to represent phosphate group
   Yellow pipe cleaner-adenine base
   White pipe cleaner-thymine base
   Red pipe cleaner-guanine base
   Orange pipe cleaner-cytosine base
2. To form a nucleotide: Hook a large paper clip to a small paper clip. Then take a short piece of pipe cleaner and fasten it to the center of the large paper clip. Remember what each of these represents.
3. To make a flat model of DNA: Using the nucleotides you made, hook half the clips together, making sure the large and small clips alternate, to form one side of the ladder. Using the rest of the nucleotides, match the bases in proper order, hook the clips together, and hook the pipe cleaners together in the center to form the rungs.
4. To show replication: Unhook the pipe cleaner bases from each other to form two chains. Make new nucleotides to match with the bases and fasten the bases and paper clips together to form two DNA molecules.
5. To make a 3-D model: Take two pieces of styrofoam and one of the flat models. Press the two paper clips at each end into one styrofoam strip. Hold a styrofoam strip in each hand, stretch out the model, and twist slightly to give a spiral staircase effect.

Box 2. MOLECULAR GENETICS PART II: mRNA STRUCTURE AND TRANSCRIPTION

Goal

To use the DNA model and to build a model of mRNA which will demonstrate its structure and the way it is formed by transcription.

Background

The structure of mRNA is similar to the structure of DNA. It is also composed of nucleotides in chains. However, mRNA is single-stranded, contains *ribose* sugar instead of deoxyribose, and has one different base. The base *uracil* is substituted for thymine and pairs with adenine in the place of thymine. In the process of *transcription*, the DNA partially "unzips." Then mRNA nucleotides come in to match up with one side of the DNA strand and join together to form one strand of mRNA. The mRNA then breaks loose and travels to the ribosome to help form a protein, while the DNA strands rejoin to form their original structure.

Steps *Teacher OK*

1. Use the materials to form nucleotides of mRNA, at least two with each of the four bases. _____
2. Use the flat model of DNA from Part I and your mRNA nucleotides to demonstrate transcription. _____
3. Write a report describing the structure of mRNA and the process of transcription. Then research the function of mRNA and describe what it does after it is formed. _____

Materials

Models from Part I, the same materials, plus large colored paper clips to represent ribose, and black pipe cleaners to represent the uracil base.

Reference: Textbook pages on mRNA structure and transcription.

Question: Why should your mRNA not contain white pipe cleaners?

References

Leonard, W.H. (1980). An extended discretion approach for high school biology laboratory investigations. *American Biology Teacher, 42,* 228-248.

Leonard, W.H. (1981). Designing an extended discretion laboratory activity. *American Biology Teacher, 43,* 254-266.