



New ideas for teaching science

Modeling DNA Structure & the Process of Replication

INVESTIGATION

#20-2193

OBJECTIVES

- *Assemble* models to demonstrate base pair structure
- *Model* the components of nucleotides
- *Model* DNA synthesis and replication by assembling nucleotides into double-stranded DNA
- *Demonstrate* DNA double helix structure

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New ideas for teaching science

Background

Modeling DNA structure and the process of replication allows students to build 3-dimensional models of the DNA bases and construct a model of the DNA double helix using the plastic manipulatives included in the kit.

The atoms consist of plastic centers with prongs set at the correct bond angles. The centers are color-coded according to the element and the bonds between each atom and between the DNA base pairs are made with flexible plastic straws.

Safety Information

This lab activity uses small parts which may represent a choking hazard. Be sure that students follow your directions and take proper precautions when working with these parts.

Kit Materials List

6 Sets of the Following Components:

- 10 Carbon, black (3 prongs)
- 1 Carbon, black (4 prongs)
- 7 Hydrogen, white (1 prong)
- 5 Hydrogen, white (2 prongs)
- 2 Nitrogen, blue (2 prongs)
- 6 Nitrogen, blue (3 prongs)
- 2 Oxygen, red (2 prongs)
- 1 Oxygen, red (1 prong)
- 8 Phosphate, yellow (2 prongs)
- 1 Silver (4 prongs)
- 32 Straws, white, 3.5cm flexible plastic
- 2 Straws, gray, 3.5cm rigid plastic
- 2 Straws, blue, 3.5cm rigid plastic
- 3 Straws, white, 3.5cm rigid plastic
- 3 Straws, red, 3.5cm rigid plastic
- 1 Straw, green, 20cm rigid plastic

Time Requirements

Pre-lab preparation and discussion:	30 Minutes
Activity 1:	30 Minutes
Activity 2:	30 Minutes
Activity 3:	20 Minutes
Analysis of Results and Discussion:	30 Minutes

Pre-lab Setup

Divide your class into 6 groups and provide each group with one set of the molecular model components. Copy a set of the Student's Guide for each student.

Pre-lab Discussion

This lab is designed to complement and enrich a unit on the structure and function of DNA and DNA replication. Students should have a basic understanding of the concepts presented in this investigation.

ACTIVITY

1

Constructing DNA Base Pairs

What you need

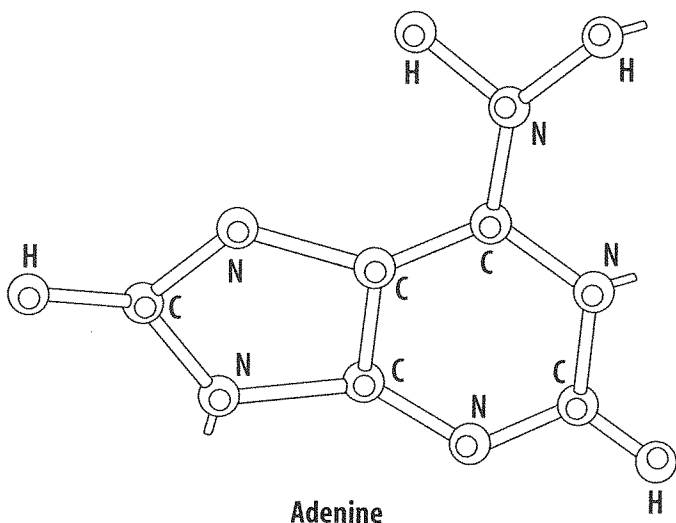
(per group)

- 9 Carbon, black (3 prongs)
- 1 Carbon, black (4 prongs)
- 7 Hydrogen, white (1 prong)
- 5 Hydrogen, white (2 prongs)
- 2 Nitrogen, blue (2 prongs)
- 6 Nitrogen, blue (3 prongs)
- 2 Oxygen, red (2 prongs)
- 1 Oxygen, red (1 prong)
- 32 Straws, white, 3.5cm flexible plastic

What to do...

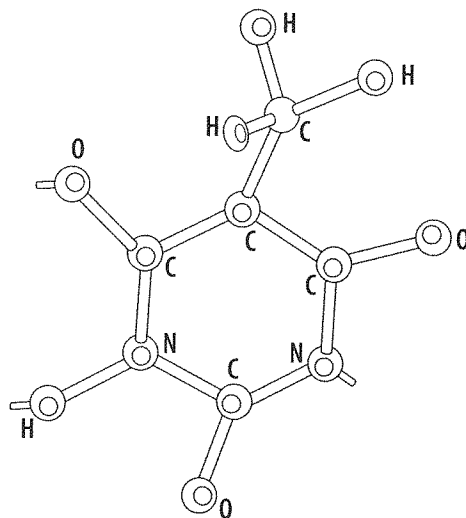
Step 1

Students should construct a model of the base adenine using the illustration below as a guide:



Step 2

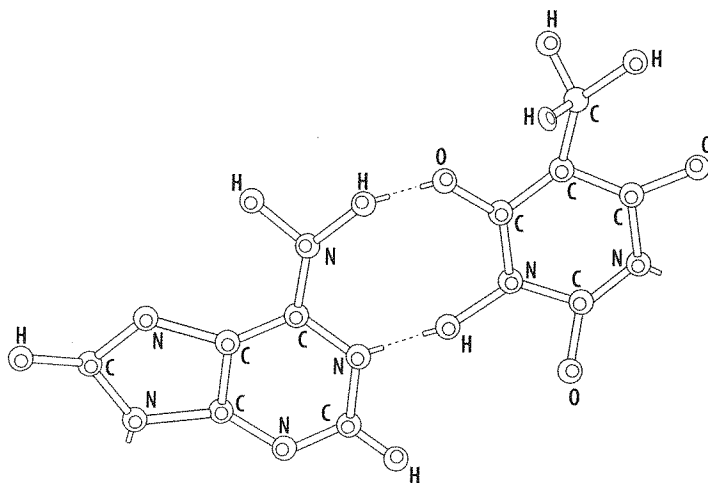
Students should construct a model of the base thymine using the illustration below as a guide:



Thymine

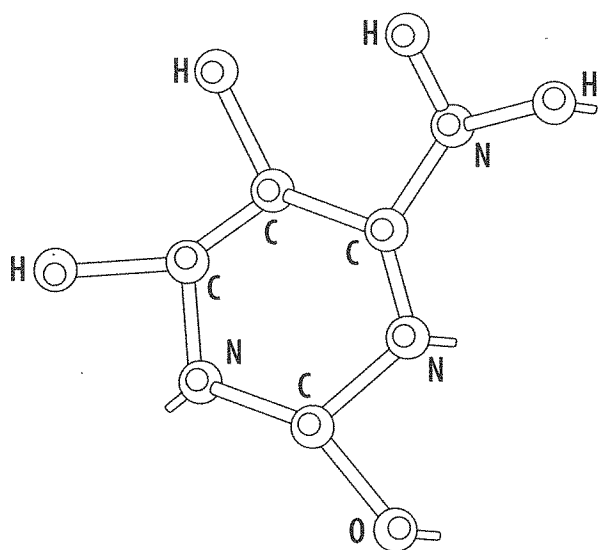
Step 3

Thymine and adenine are complementary bases, in that they can bond together via hydrogen bonds. Note to students that there are two hydrogen bonds that hold the adenine and thymine bases together. Have them use the illustration below to pair adenine and thymine.



Step 4

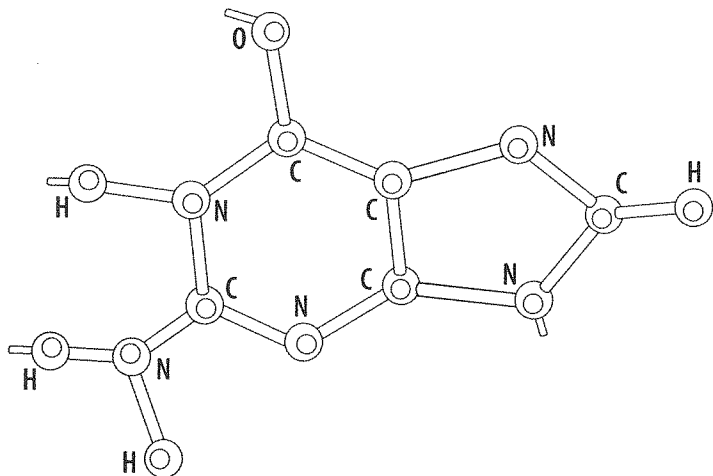
Have students disassemble the thymine and adenine base models constructed in the previous steps and construct a model of the base cytosine using the illustration below as a guide:



Cytosine

Step 5

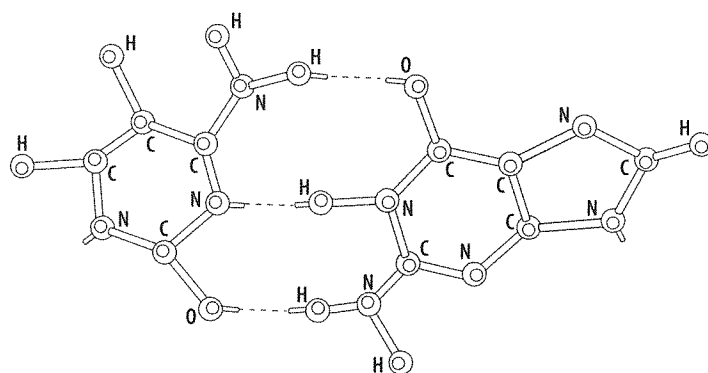
Students should construct a model of the base guanine, complementary base to cytosine, as shown in the illustration below:



Guanine

Step 6

Note to your students that there are three hydrogen bonds that hold the guanine and cytosine bases together. Have them use the illustration below to pair up guanine and cytosine.

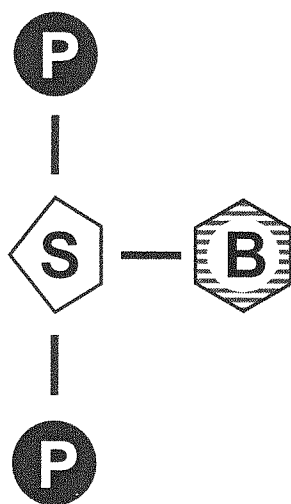


ACTIVITY

2

DNA Replication

A nucleotide consists of a nitrogen-containing base, a sugar group and a phosphate group held together by covalent bonds.



Note that the bases are represented by colored straws, the sugar group by a 4-prong carbon atom and the phosphate group by a 2-prong yellow manipulative. Nucleotides are the building blocks of DNA. Complementary bases are held together by hydrogen bonds.

Remember the base pair matching rules:

Guanine always pairs with **Cytosine**

Thymine always pairs with **Adenine**

Use the following color scheme:

Adenine = Blue
Thymine = Gray
Guanine = Red
Cytosine = White

What you need

(per group)

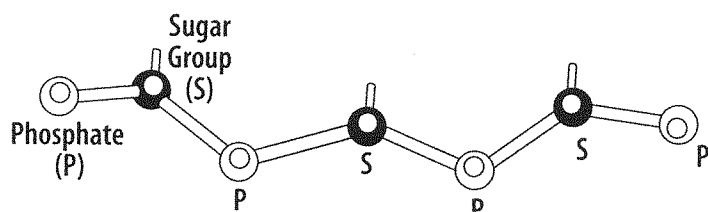
- 5 Hydrogen - Hydrogen bonds, white (2 prongs)
- 8 Phosphate groups, Yellow (2 prongs)
- 16 Straws, white, 3.5cm flexible plastic
- 3 Straws, red, 3.5cm rigid plastic
- 3 Straws, white, 3.5cm rigid plastic
- 2 Straws, gray, 3.5cm rigid plastic
- 2 Straws, blue, 3.5cm rigid plastic
- 10 Sugar groups - Carbon, black (3 prongs)

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What to do...

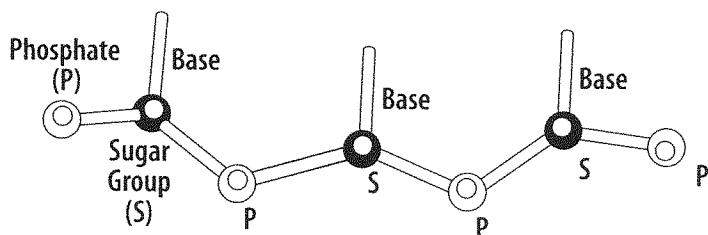
Step 1

Students should construct the "backbone" of the DNA by linking the phosphate groups with the sugar groups as shown in the illustration below:



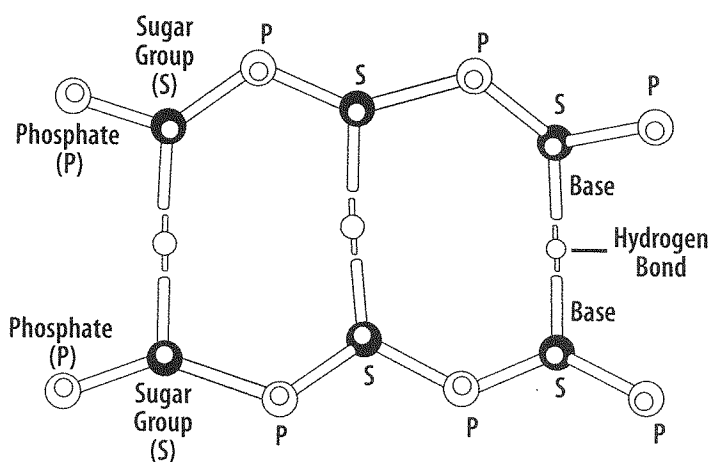
Step 2

Students should attach a base to the prong of each sugar group.



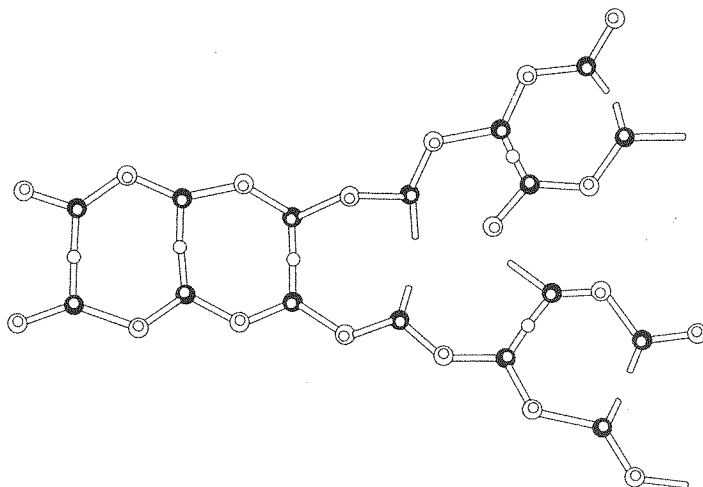
Step 3

Students should construct complementary nucleotides and join them to the single-stranded DNA you assembled in Steps 1 and 2. Students should join the complementary bases using the hydrogen bond connectors as shown below:



Step 4

Discuss with students the process of DNA replication. During DNA replication, the double-stranded DNA molecule unwinds and unzips. As it unzips, each single-stranded DNA replicates forming two complete double DNA strands.



ACTIVITY

3

DNA Double Helix

What you need

(per group)

Assembled double-stranded DNA from Activity 2

- 1 Silver (4 prongs) to form base
- 3 Straws, white, 3.5cm for legs on base (rigid plastic)
- 1 Straw, 20cm

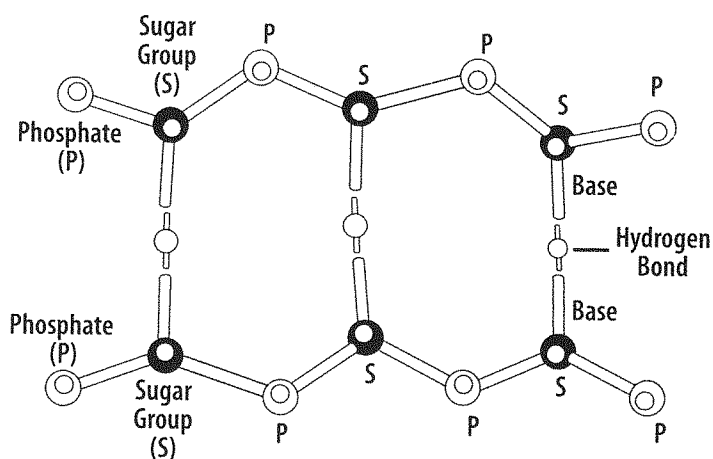
What to do...

Step 1

The secondary structure of DNA is a double helix, with hydrogen bonds bridging the two strands. Have students insert the long straw through the hydrogen bonds of the DNA double-stranded molecule that they assembled in the previous activity.

Step 2

Have students twist one of the rungs of the ladder counter clockwise to form the double helix structure.



Step 3

To support the DNA double helix model, students should prepare a base. They insert a 4 prong silver plastic manipulative on one end of the long straw and then attach a 3.5cm piece of straw to each of its four prongs.



Questions

1. What does the term "complementary" mean in base-pairing?

It means that like bases don't pair together – that is, no A-A or T-T or C-C or G-G pairs occur. Complementary pairing means that each base pairs with another that "complements" its structure.

2. Why isn't it possible for adenine to pair with cytosine or guanine?

Adenine is a purine (i.e. two rings), which can form two hydrogen bonds with another base. Guanine is also a purine, so pairing guanine with adenine would make that part of the DNA molecule too wide. In addition, guanine - like cytosine - can form three hydrogen bonds, so the "fit" with adenine would not be close.

3. What type of chemical bond is found between the phosphate group, sugar group, and base of a nucleotide?

Covalent bonds form between the components of a nucleotide.

4. What type of chemical bond is found between the strands of the DNA molecule?

Hydrogen bonds form between the polar regions of adjacent, complementary bases within the DNA molecule.

5. What is a strand of DNA which functions as a section of the genetic code called?

A strand of DNA on a chromosome which functions as a unit of the genetic code is called a gene (codes for a polypeptide).

6. What makes one gene different from the next gene within a chromosome?

The linear sequence order of bases determines what the gene codes for; for example, a DNA section of AGTCTAACG may code for a different product than a DNA section with AGTATCCGA.

7. What do you think must happen to the double strand of DNA when a cell makes a copy of itself?

It must "unzip" along the hydrogen bonds to make copies of itself.

Assessment

Ask the students to perform the following:

- Describe and/or use the model to illustrate the following:

- Nucleotide
- Nucleic Acid
- Gene
- Chromosome
- Pentose sugar
- Nitrogen-containing base
- Base pairing
- Complementary strand

- Use the model to create a "gene" which is 5 base pairs in length.
- Use the model to create a complementary strand of DNA for the 5 base pair gene.

Cross Curricular Integration

Language arts

One of the major differences between RNA and DNA is the type of sugar used to build them. Ask the students to speculate about this difference based on what they know about suffixes and root words.

History

Ask the students to research the discovery of the structure of the genetic material, including the competing proposals of protein versus nucleic acids, and the competing international teams of scientists working on the puzzle.

Biotechnology

Discuss the Human Genome Project with your students. Ask them to think of ways in which this type of information may be useful to scientists, physicians and lawyers. Assign groups to study different techniques used in studying DNA and/or medical uses of information from the Human Genome Project.

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