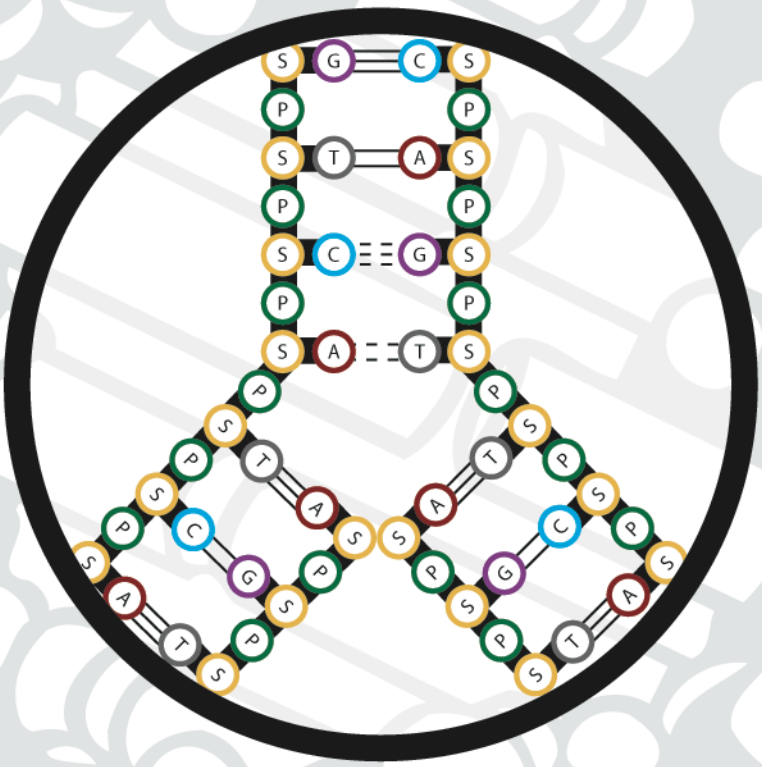
Dolan
DNA Learning Center
www.dnalc.org

DNA Structure



Background

DNA is called the code of life, possessing the hereditary information for all living things. Genes determine many of the traits and functions that we find in different organisms. All living things are composed of cells that contain DNA and follow genetic instructions to make proteins. For example, human skin cells use the instructions in a gene to produce the protein melanin that gives the trait of skin pigmentation.

The chemical structure of DNA is basically the same in all organisms. DNA, or deoxyribonucleic acid, is a molecule made of the elements phosphorous, nitrogen, carbon, hydrogen, and oxygen. DNA is a nucleic acid, one of the types of organic compounds necessary for life.

The shape of DNA is a ladder, twisting in a clockwise direction to form a double helix shape. If the double helix is "untwisted" into a ladder, each side of the ladder, or helix, is called a "backbone" made of alternating sugar and phosphate molecules. The "rungs" of the ladder consist of pairs of nitrogenous (containing nitrogen) bases. These base pairs are attached at either end to a sugar molecule in the backbone. The sugar molecules are connected to each other by phosphate groups and held together by very strong covalent bonds.

The four nitrogenous bases that make up the genetic code are Adenine (A), Thymine (T), Guanine (G) and Cytosine (C). In the DNA molecule, Adenine and Thymine are bound together as a base pair, and Guanine and Cytosine are bound together as a base pair. A weak hydrogen bond holds the base pairs together. Adenine and Guanine are grouped as Purines and Thymine and Cytosine are grouped as Pyrimidines. Purines and Pyrimidines are molecules that are very similar in their chemical make up and chemical shape. This allows Adenine to pair up easily with Thymine and Guanine to pair up easily with Cytosine, as pieces of a puzzle fit together. If DNA is separated down the middle between the bases ("unzipped"), the two strands contain complimentary bases. For example, if one strand has the sequence ATTGCA, its complement would have the sequence TAACGT.

Nitrogenous bases make up the code of DNA by forming different combinations or sequences. Every gene has a specific sequence of A, T, G, C that ultimately codes for amino acids, the building blocks of proteins. The combination of amino acids determines what protein is produced. The Human Genome Project is a collaborative effort of many scientists decoding the 3 billion base pairs in the human genome (the DNA contained in a human's chromosomes). It is estimated that the human genome contains 30,000-50,000 genes.

P.A. Levene was a biochemist in the 1920's that figured out the chemical makeup of the DNA molecule. Later, in 1953, James Watson and Francis Crick were the scientists who worked together to develop a model of DNA in Cambridge, England. According to a study done by Erwin Chargaff in the 1940's, a double strand of DNA has the same number of Adenine and Thymine molecules and the same number of Guanine and Cytosine molecules. Watson and Crick used these calculations to conclude that Adenine/Thymine and Guanine/Cytosine are pairs. Rosalind Franklin, who worked under Wilkins, photographed the DNA molecule using X-ray crystallography to determine the helix shape. Chargaff and Franklin's contributions led the way for Watson and Crick's discovery. In 1962, Watson and Crick were awarded the prestigious Nobel Prize for Physics and Medicine along with Maurice Wilkins (Rosalind Franklin's boss) for their discovery of the double helix shape of DNA.

Watson and Crick proposed that the structure of DNA allows it to replicate during mitosis. Other discoveries by scientists supported this theory. Each base pair is held together by a weak hydrogen bond. Before a cell divides, an enzyme called helicase untwists the double helix and separates the two complimentary strands by breaking that hydrogen bond. A different enzyme, DNA polymerase, rebuilds each strand by matching the missing nucleotides. The result is two daughter strands identical to the original.

Description of Activity

In this one-hour activity, children in grades 5-8 learn about the structure of the DNA molecule. They will discuss base pairing and learn how information in DNA is copied to make new DNA molecules. Students will produce a 3-dimensional model of DNA using craft store materials.

Learning Outcomes

Students will:

- learn the genetic code (A, T, C, G).
- understand the structure and function of the DNA molecule.
- discuss the process of DNA replication.
- produce a model of DNA.

Assumptions of Prior Knowledge

Students should know that all living cells contain DNA. They should be able to identify and define the role of cells and their structures, and understand the relationship between chromosomes and DNA.

Misconceptions

Students often believe that DNA is a living thing. They may also think that different cells within an organism contain different DNA. It is not uncommon for students to think that only animal cells contain DNA.

Lesson

Materials and Equipment

- Molecular model kit
- Periodic table of elements
- Large 3-D model of DNA

Per student:

- 2 – ¾" x 13" black and white striped foam strips
- 18 - ¼" wooden dowels cut into:
    - 1" pieces, painted orange and green
    - 2" pieces, painted yellow and blue
- 18 upholstery tacks
- 9 - ¼" x 1" clear vinyl tubing pieces

Purchasing Information

- Wooden dowels- local lumber retailer
- Vinyl tubing (20')- Home Depot
- Foam sheets (Foamies)- Sunshine Crafts
- Boardwalk contact covering-local hardware store
- Upholstery tacks- Home Depot
- Large 3-D DNA model – Henry Kosloski (413) 786-6934

Before Class

- Photocopy the corresponding student worksheets.
- Review the history of the DNA molecule on the DNA Interactive Internet site at: www.dnai.org < Code

During Class

- Review the history of the discovery of the DNA molecule. If you have internet access in the classroom you can show them the following some clips from the following section of the DNA Interactive website, http://www.dnai.org/a/index.html.
- Explain how organisms can grow from a single cell through the process of cell division and that DNA replicates within cells when they divide.
- Using a 3-D model of DNA, discuss the double helix shape, and why it is called a double helix. Point out that the model has 6 different colors on it, and each color represents a small molecule that is one part of the whole molecule.
- If students have never seen a periodic table, it can be fun to talk about atoms, elements and molecules, and the fact that DNA is not alive. It is a molecule, just like glucose or water, but it is a molecule with special instructions for a cell. The DNA in a cell can be compared to a recipe book, and the genes to individual recipes for traits and characteristics. Without the machinery in a cell, the DNA cannot function, as it should.
- Using the DNA Molecule handout, examine the chemical structure of the DNA molecule. Start with the backbone, which is made of repeating molecules of deoxyribose sugar and phosphate groups.
- Ask the students why this part of the molecule is called the backbone. They might notice that deoxyribose sounds familiar because the acronym DNA is short for Deoxyribonucleic Acid. Many

times molecules are named for their chemical components and characteristics. Ask students why the molecule is called a *nucleic* acid.

- Focus next on the four bases, which comprise the rungs of the DNA ladder. Read the chemical names, and explain that many times they are called A, T, G and C for short. Point out that they have partners. A is bound to T, and G is bound to C. An easy way to remember is the saying:
  At **T**he
  Grand **C**anyon, they fell in love.
- Using an alphabet analogy, illustrate how a simple four-letter code can carry information for all living organisms. For example, using the three letters C, A, and T, how many words can you make? The alphabet has 26 letters, and by simply rearranging the order of letters, or adding/taking letters away, we can make new words.
- Genes are specific ATGC sequences that carry information to make proteins. The DNA in a cell is the "cookbook" and genes are the individual "recipes".
- Demonstrate how to construct a DNA model using the materials supplied. The black and white striped foam pieces represent the backbones and the wooden dowels represent the four bases. Each base pair is held together by a piece of vinyl tubing, and the pairs are held to the white squares on the backbone with upholstery tacks. Each student should try to create a unique pattern of bases, just like the unique patterns we see in our own genes.

Analysis and Discussion

- Discuss how different genes can vary in sequence and length.
- Ask the students to propose a method of DNA replication, just as Watson and Crick did in 1953. Help the students to demonstrate the process of DNA replication using their models.
- Discuss how a mutation in the genetic code can be produced, and how that mutation might affect specific traits in an organism.
- Explore scientific theories relating to the formation of the DNA molecule and the beginning of life on earth using the film "The Birth of Earth and Ancient Oceans" by the Discovery Channel.

Further Explorations

Students can design their own unique DNA model using creative materials to represent each component of the molecule. They should be displayed in the classroom along with interesting facts about the double helix.

Students can research historical events and discoveries in history that were possible because of the knowledge we have regarding the structure of the DNA molecule. Encourage your students to be creative with their research.

Students can bring in examples of the double helix that are present in pictures, periodical clippings, and movies. It would be an interesting way to generate discussions about the importance of DNA, and how the DNA molecule has become a part of our everyday lives.

Resources

http://www.dnaftb.org/dnaftb/
The DNA Learning Center's Internet site.
Use this site to explore various genetic concepts from inheritance to genetic engineering.

http://www.ygyh.org/
The DNA Learning Center's Internet site.
Use this site to learn about the connection between genes and health.

www.dnai.org
The DNA Learning Center's Internet site.
Use this site to learn about the past, present and future of DNA science.

Films:
"The Birth of Earth and Ancient Oceans"
Discovery Communications, Inc., 2002.

Correlations

New York State
NYS Standard 4: Science
The Living Environment

- Living things are both similar to and different from each other and nonliving things.
- Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.
- The continuity of life in sustained through reproduction and development.

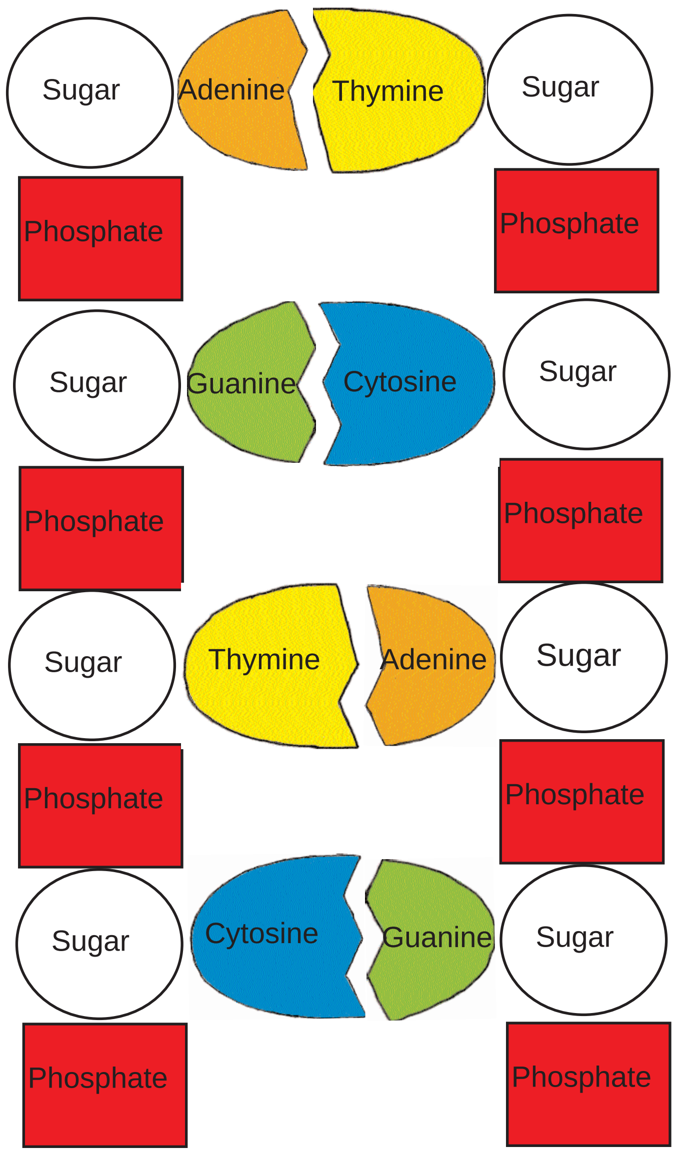
National
Content Standard C: Life Science
Reproduction and Heredity

- Every organism requires a set of instruction for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Heredity information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and other result from interactions with the environment.

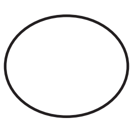
AAAS Benchmarks
Standard B: Heredity

- In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.

The DNA Molecule

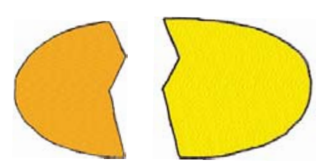


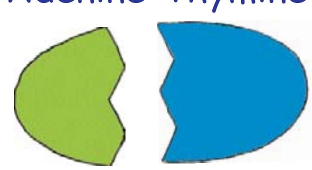
The DNA molecule is made of six parts:


A sugar, called deoxyribose

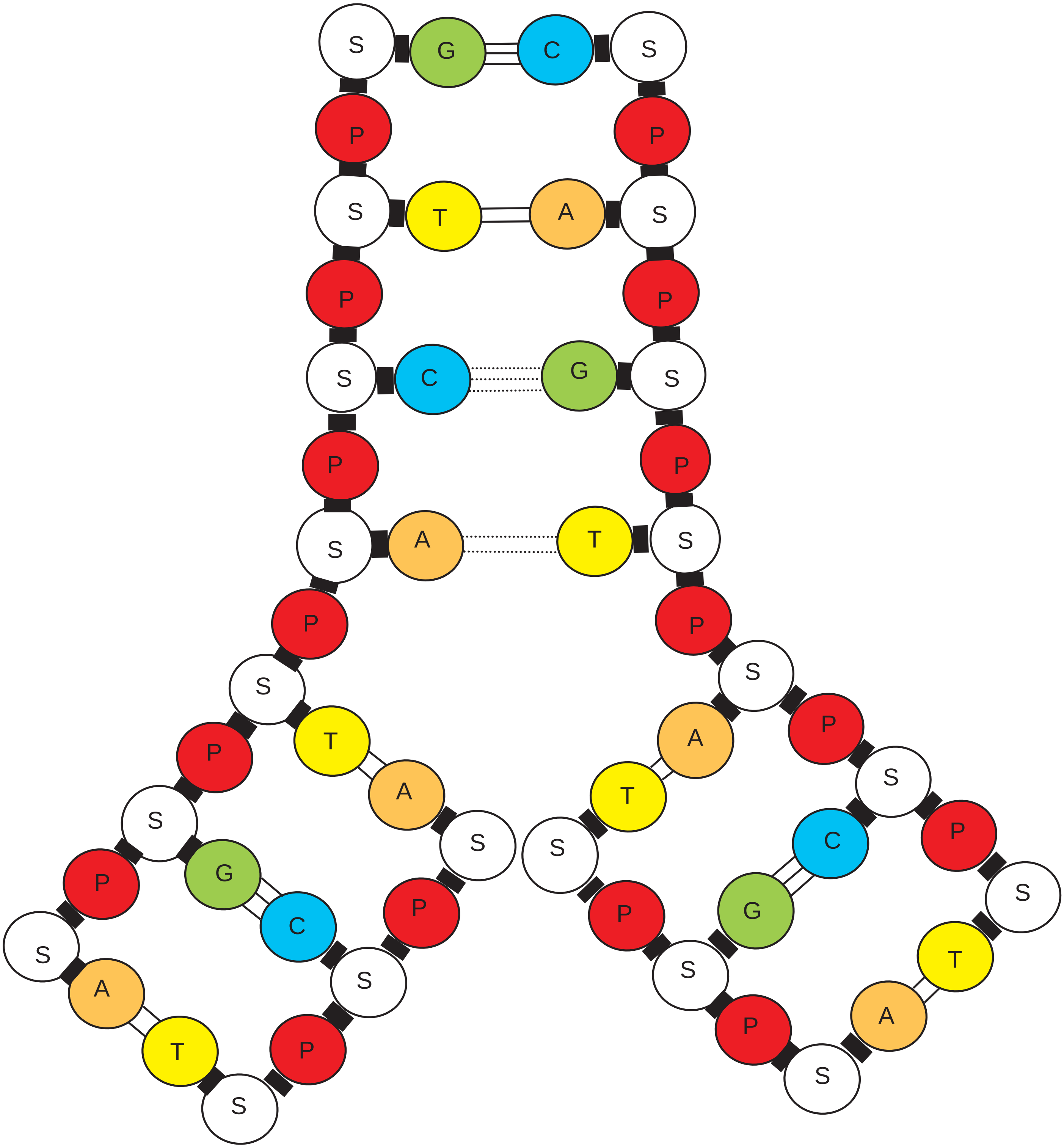

A phosphate group

Four bases:


Adenine Thymine


Guanine Cytosine

DNA Replication



To replicate, the DNA molecule unzips. This separates each base from its partner and forms two single stranded molecules. Then, the correct partner for each base is attached to re-form two new double-stranded molecules. This makes two identical copies of the original DNA strand.