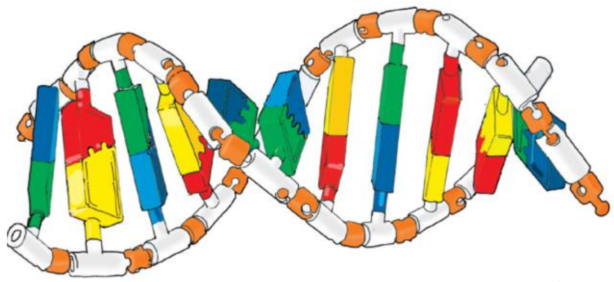
Lesson 2

Atoms to Information:
Shape Matters



Level: 9th grade and up

Correlation:
Nat'l Standards
    LSC1,2,3,5
    K-12

Middle School
Standard A - Understanding about Scientific Inquiry
Standard C - Life Science- Structure and Function, and Reproduction and Heredity
Standard E - Understanding about Science and Technology
Standard G - Science as a Human Endeavor and Nature of Science)

Purpose:
Part I
To describe the components of a nucleotide
To discover the consistency of G – C A –T base pairing
To discover how nucleotides bond to make DNA and RNA.
To discover the two different kinds of bonds in DNA – weak and strong (hydrogen and covalent)
To discover how the double helix 'unzips' due to the relative strength of the bonds.
To use a scientific model for demonstrating how DNA copies itself by strand separation and laying down of new nucleotides.
To discover and discuss the usefulness of the helical nature of the nucleic acids.
To discover that the two elements of the helix are anti parallel.
To discuss how a molecule's structure determines its function
To emulate the historical steps in the discovery of the structure of nucleic acids
To emulate the scientific process of:
    Making and recording observations
    Making predictions/stating hypotheses
    Testing hypotheses
To use a variety of resources at research tools

Background

Students should already have a basic understanding of the structure and function of eukaryotic cell organelles.

This lesson allows the students to emulate Chargaff's 1949 discovery that while samples of DNA taken from different organisms- animals plants, yeast or bacteria contained differing amounts of the four nucleotides. The amount of A in each sample always equaled the amount of T, and the amount of G always equaled the amount of C and raised the question : What structure could account for this property?

The discovery of the shape of the nucleic acid molecule transformed our understanding of its function. Students can discover this form/function relationship through manipulation of a model.

Timeline of discovery:

This occupied roughly the first half of the 20^{th} century. (For more information, consult the excellent book by Horace Judson, "The Eighth Day of Creation" republished in 1998 by Cold Spring Harbor Press.).

Johann Friedrich Miescher
First isolation / of DNA (1869)

Sir Lawrence Bragg
X-ray diffraction crystals/
structural analysis (1912)

Frederick Griffith
Discovery of transforming/
principle (1928)

George Beadle / Art Tatum
Biochemical / genetics (1940)

Max Delbrück / Salvador Luria
Phage biology / (1943)

William Astbury
First published fiber diffraction/
pattern of DNA (1943)

Avery, MacLeod & McCarty
Transforming principle/ is DNA (1944)

Erwin Chargaff
Equimolar A&T/ G&C in DNA (1948)

Linus Pauling
Principles of macromolecular/
structure (1951)

Jerry Donohue
Correct base / tautomers (1951)

Alfred Hershey / Martha Chase
The genetic material / is DNA (1952)

Rosalind Franklin / Maurice Wilkins
Definitive fiber diffraction / DNA (1952)

James Watson/ Francis Crick
Deduced the structure of DNA (1953)

Time: 2 class periods

Materials:
Per cooperative group of 2-5
Package labeled 'Nucleus' containing separated nucleotides - 5 G, 5 C, 3 A, 3 T
The Way Life Works
Access to a variety of biology texts
Per student
Observation notebooks
Activity sheet 'Mystery Molecule'

Important terms:

DNA	Nucleus	Ribose	Thymine
Double helix	Nucleic acid	Phosphate	Adenine
Covalent bond	Nucleotide	Mutation	Uracil
Hydrogen bond	Base	Guanine	Replication
Organelle	Deoxyribose	Cytosine	Base pairing

Procedure:

Part I

Divide the class into six cooperative groups.
Give each student the activity sheet and have him or her read the introductory paragraph
Give each cooperative group the package labeled 'Nucleus'.

- Have each group remove one nucleotide from the 'Nucleus'.
- In their notebooks, students should draw the nucleotide and label its parts using the biology reference materials available.
- Students remove the rest of the nucleotides from the 'nucleus' and note any similarities or differences among them.
- Students will then draw the remaining three types of nucleotides in their notebooks and name all four bases using the letters on the nucleotides as clues.
- Student will complete Part I of the Mystery Molecule activity sheet.
- Students should discover that the double helix formed protects the base pairs" weak bonds from breaking apart.
- Have groups disassemble their molecules by first 'unzipping' them, and return both strands to the package labeled 'Nucleus"

Part II

Have one of the groups reconstruct the double helix.
Have the remaining groups disassemble the strands into their component nucleotides.

- While all groups watch, the group with the double helix will 'unzip' it and, starting with the pop bead end to left, record the order of nucleotides in each strand on the board.
- Ask the following questions and discuss.

Why was it easy to 'unzip' the helix?
Is the order of nucleotides in one strand the same as in the other?

- Have this first group hand each single strand to two other groups. Now, groups 2 and 3 have a single strand and 14 nucleotides.
- These groups will build new double helices from the existing strand and loose nucleotides. (They will end up with 7 unused nucleotides)
- Have these groups 'unzip' their helices and hand single strands to each of the remaining groups.
- This process can continue until all loose nucleotides have been constructed into double helices with a total of 6 double helix molecules constructed. Give one of these to the first team.
- Have students answer Activity sheet Part II questions.

Activity sheet: Mystery Molecule

Your distinguished scientist-grandfather was working on a project that might reveal how information is passed on from generation to generation of cells and organisms. He has left you TWO packages in his will. The first (labeled ‘Nucleus’) appears to contain models of four different types of fairly simple small molecules: fragments of a large molecular model he was working on at the time of his death. Today you will be using this package. He hoped that you might be able to complete the model and possibly decipher its function(s).

Part I
Building the model

1. Identify the parts - bases, phosphate, and sugars - in the model. Draw and give a short description of each (include color, shape and connector differences).

Sugar-Phosphate =

Thymine (T) =

Cytosine (C) =

Guanine (G) =

Adenine (A) =

2 Which bases can be paired?

3. What might the pop-bead connections between the sugar and phosphate parts represent?

4. What might the connectors between the bases represent?

5. What bonds are “weak”? Which are “strong”?
<u>Hypothesize and test</u> why this model might have both strong and weak bonds.
Weak =
Strong =

Take these seven nucleotides from our package: 3Gs, 1A, 2Ts, and 1C
In any order, assemble a strand by connecting the sugars to phosphates.
With the remaining nucleotides, pair a complementary base to each of the bases on your strand.
Connect the sugars to the phosphates on the second strand. (This may be more challenging than you think!).
Notice the direction of the pop bead end of each sugar in the opposite strands.

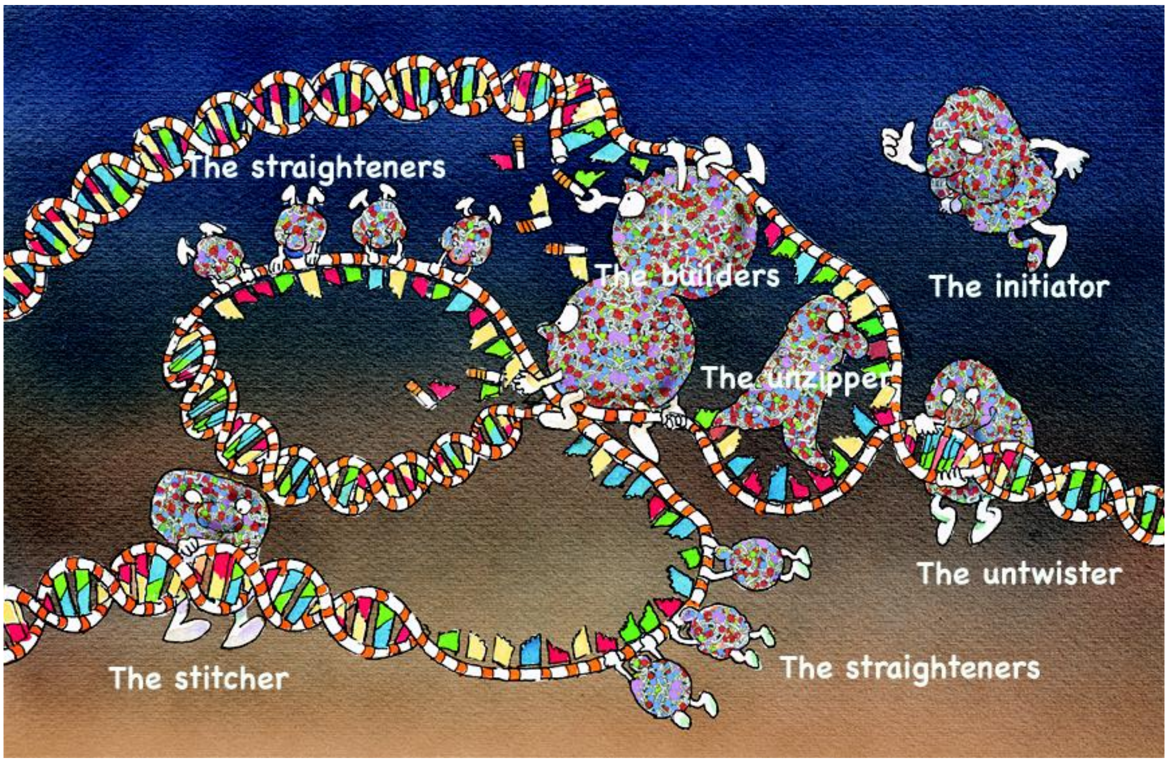
6. After you have assembled the model, record your base pairing as shown below

___ - ___
___ - ___
___ - ___
___ - ___ … etc

7. What is the shape of the reconstructed molecule?

8. What might be some advantages of this shape?

Part II
Replication (this could be extended to mitosis/meiosis modeling)



One student group has a double helix molecule and the other groups a bunch of loose nucleotides.
The DNA molecule group will 'unzip' the double helix and record the order of nucleotides in each strand on the board, starting with the pop bead end of the sugar to the left.

The DNA molecule group will then hand a single DNA strand to each of two neighboring groups who in turn will construct a double helix from the single strand and then ‘unzip’ it. This process will continue until 6 double helices are constructed. The first team will be given one of these.
Each team will unzip its model once again and record the order of nucleotides in each strand on the board.

All teams answer the following questions:

1. What can you say about the order of nucleotides in the six models?

2. If there were any differences, how could you explain them?

3 DNA is often called the ‘information molecule’ because it is the ‘recipe’ for building important cell structures. Why might it be important for this molecule to copy itself accurately?

Describe your work using as many of these words as possible:
Energy
Strong bond
Weak bond
Direction of complementary DNA strands
Shape
Angle
Parts
Covalent bonds
Ionic bonds
Order
Sequence
Copy
Complement

Parts identification
Sugar, phosphate, base, nucleotide,
deoxyribose, ribose, nucleic acid
helix, A T G C