BLUEPRINT FOR LIFE (2 Hours)

In this activity, students will explore DNA as a code for biological traits and extract samples of DNA from the interior of living cells.

Topic: DNA as the blueprint for a living cell

Real World Science Topics:

- An exploration to discover how biological information is stored
- An exploration of DNA, the molecule used to store biological information

Objective

Students will learn that DNA encodes the information necessary for specifying biological traits.

Materials Needed for Demonstration:

chalkboard or overheard projector
multicolored chalk or pens

Materials Needed for Each Student:

blank paper
colored markers or pencils
1 T raw wheat germ
1 t dish detergent
4 T rubbing alcohol
bowl of ice
4 T warm water (50–60° C)
2 clear plastic beverage cups
permanent marker or masking tape and a pen (for labeling the cups)
coffee stirrers
bent paper clip (see illustration)
measuring spoons (teaspoon and tablespoon)

STEPS FOR *BLUEPRINT FOR LIFE*

1. **Warm-up Activity:** Write the following on the board:

8 5 12 12 15

Tell students that it is a greeting and ask them if they can figure out what it says. Lead students to recognize that you have written the word “hello” in code. Each letter is represented as a number, with a = 1, b = 2, c = 3, and so on.

Ask students if they know that the cells in their bodies contain molecules that code for information. Provide a few examples of the type of information encoded by these molecules in a human: blue eye color or curly hair, for example. Ask for volunteers to suggest what molecule might contain this information. Lead students to suggest DNA as the information-carrying molecule in a cell.

Draw a circle on the board to represent a cell. Draw another circle within the first to represent the cell nucleus. Inside the nucleus, draw a simple sketch of DNA as two straight strands with connecting “rungs” like a ladder. Explain that the DNA represents a code for molecules called proteins, much like the series of numbers represents a code for the word hello. Draw an arrow from the DNA to the cytoplasm portion of the cell (outside the nucleus) and write the word *proteins* at the end of the arrow. Explain that the sequence within the DNA is like a code that tells the cell the specific proteins to make in the cytoplasm. Different DNA sequences make different proteins.

Tell students that they are going to decode the DNA of some plant seeds to predict what the plants will look like after they have grown. Explain that the activity is only a simulation to show how a code can work. DNA uses a code that is different than the code students will use in the simulation.

2. Distribute the *Blueprint for Life* handout and materials to each group of two to four students.

3. Students should first decide how they will decode their DNA. They are given a clue in the strand of DNA on their handout: the word *start* is associated with the first five letters in the sequence and the word *stop* is associated with the last four letters. Do not tell students this; only provide them with the hint that they have all of the information necessary to decode their DNA sequence. Circulate among groups to assist if necessary, but allow teams enough time to discuss and solve the problem themselves.

4. Once each team has figured out the key to the code, have the team members divide up their DNA sequence so that each student translates the coded sequence of one portion. Teams should work together to collect all the decoded sequences into one complete decoded sequence.

5. The translated sequence will provide the team the information necessary to identify the traits their plant will have when it grows to adulthood. Have the team create a picture of their plant and give it an inventive name of their choice.

6. **Lab activity:** Have students extract DNA from fresh wheat germ or another plant source. Tell students that DNA is present in all living cells, so a similar procedure could be used to extract DNA from their cells.

7. Before students get started on the extraction, go back to the drawing of the cell on the board. Ask students what will have to happen to remove DNA from a cell. Lead students to understand that cells will have to be

broken open in order to allow the DNA to be removed. In animals, cells are surrounded by a cell membrane; plant cells have both a cell membrane and a cell wall.

8. Explain to students that detergent will help disrupt the cell membranes and cell walls of the plant cells they will be working with. When they add detergent to the wheat germ mixture, the detergent molecules mix with the cell wall and cell membrane molecules, causing them to move away from one another.

9. Once the DNA is released into the detergent solution, it must be isolated from the other cell material. DNA tends to clump together and come out of solution if alcohol is added. Students will carefully add ice-cold alcohol as a layer on top of their wheat germ mixture as a way to do this. It is important that they do this carefully so that the water and alcohol do not mix too much. It is at this stage that students can actually see evidence of the DNA—it turns the alcohol layer milky white. If the alcohol and water are mixed together, no DNA precipitate will be formed and the students will not be able to see the DNA. It is advisable to demonstrate this step to help guide students to avoid this potential problem.

10. Have students begin by getting two plastic cups, labeling them "1" and "2," and preparing them as follows:
   a. Leave cup 1 alone for now. Later, students will place ice-cold rubbing alcohol in it.
   b. To cup 2, add 1 T raw wheat germ and 4 T hot water (50–60° C). Mix these together with a coffee stirrer.

11. To cup 2, add 1 teaspoon (t) of dish detergent. Mix very gently every minute for five minutes. Caution students not to mix the solution too vigorously; if they mix it too hard, the DNA will break into many small fragments, and the final step will not work properly.

12. To cup 1, add 4 tablespoons (T) of ice-cold rubbing alcohol. Tip cup 2 at an angle of about 45° and very slowly pour the chilled alcohol from cup 1 down the side of cup 2 so that it forms a layer on top of the wheat germ/detergent mixture. Do not allow the two liquids to mix. Slowly return the cup to an upright position and place it on the desk or table for a few minutes. Observe any signs of DNA precipitation (formation of a milky white substance) where the two liquids meet.

13. After a few minutes, students should observe a milky white swirl of DNA in the alcohol layer. Dip the bent paper clip into the alcohol and carefully pull the white precipitate out of the cup. This thick blob contains mostly DNA, along with some proteins and other cellular material.

14. Explain to students that this extraction procedure is similar to the procedure used by a forensic scientist when he or she isolates DNA from human cells. However, the forensic scientist must perform several more steps to remove all proteins and other cell debris before sequencing the DNA.

Blueprint for Life **Extension Activity**

Students on each team can create their own code and develop blueprints for alien life forms. Teams can challenge one another to decode their creations. Encourage students to be creative in their codes—for example, they might use shapes or colors instead of numbers or letters. Each team should first create a key for its code, to ensure that the translation is accurate.

What is DNA?

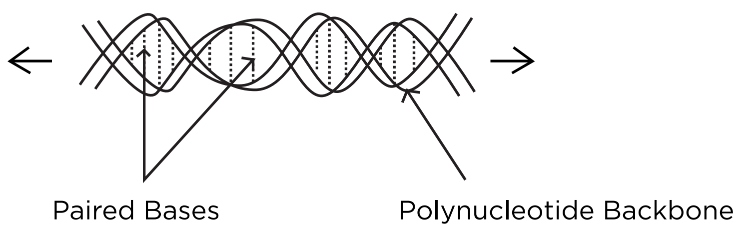
DNA is an enormous molecule made up of a series of individual units called nucleotides. Each nucleotide contains a portion called a base. There are four possible bases: cytosine, guanine, adenine, and thymine. It is the specific sequence of these bases along a strand of DNA that provides the information necessary for the cell to construct the proteins it needs for its various functions.

DNA is double-stranded, meaning that it is composed of two strands of nucleotides. The two strands are complementary because every cytosine is paired up with a guanine and every adenine is paired up with a thymine in the final double-stranded DNA molecule. The two strands twist into a helix structure, as shown below:

DNA contains two complemetary strands:

Strand 1: <-G-C-T-A-C-G-A-A-T-G-C->

Strand 2: <-C-G-A-T-G-C-T-T-A-C-G->



It may be easier to visualize DNA as a ladder with the base pairs lined up along the rungs of the ladder. If you then hold on to the top and bottom of the ladder and twist, you get a double-stranded helix that resembles DNA.

How large is a DNA molecule?

In a human, DNA is distributed among 23 pairs of chromosomes. Each chromosome contains one strand of DNA. Normally, these strands of DNA are tightly coiled into compact structures held in place by proteins that bind and stabilize them. However, if all 46 pieces of human DNA were uncoiled and laid end to end, the resulting molecule would be about 2 meters long.

Do humans have more DNA than other organisms?

No. There are a little more than 3 billion pairs of nucleotides in the DNA in a single human body cell, but many animals and plants have significantly more than that. Scientists are still trying to determine why this is. One thing is known: Not all DNA codes for proteins, so the total amount of DNA is not an indication of the numbers of proteins that an organism can produce. DNA is much more complicated, with some sections regulating the expression of other portions.

Do we know the full sequence of human DNA?

Yes. The total sequence of a representative human DNA sample—the human genome—was completed in May 2006. However, with the exception of identical twins, each person's specific DNA sequence is unique. The "human genome" is considered a representative example of a complete human DNA sequence, but the tiny differences in that sequence make each person unique.

Key Vocabulary

DNA: deoxyribonucleic acid; the molecule that encodes biological information necessary for the cell to carry out life functions
extraction: a chemical process used to separate substances in a mixture
trait: a physical characteristic, such as hair color
nucleus: the portion of an animal or plant cell where DNA is located
cytoplasm: the portion of a cell surrounding the nucleus
cell membrane: the structure that encloses a cell and creates a barrier between the cell interior and the surrounding environment
cell wall: the structure that encloses a plant cell; plant cells also have a cell membrane inside the cell wall
gene: the sequence of DNA that codes for one protein
chromosome: a tightly packed strand of DNA held in its packed form by proteins
protein: a large molecule made up of a linear strand of units called amino acids and coiled in a series of twists and turns to create a spherical shape
nucleotide: a small molecule that can be bonded to others like it to form a long strand of DNA
base: the portion of a DNA molecule used for encoding biological information; each base acts in a fashion that is analogous to letters in an alphabet

STUDENT HANDOUT FOR *BLUEPRINT FOR LIFE*

The sequence below represents a strand of DNA that codes for specific traits in a plant seed. As a team, work together to determine the key to the code using only the information provided.

Start

HGZIGYILZWOVZUHGLKHGZIGGZOOHGLKIVWUOLDVIHHGLKHGZIGGSLIMBHGL

KHGZIGHDVVGHXVMGHGLKHGZIGGIZMTFOZIOVZUHSZKVHGLK

Stop

Once your team has determined the key to the code, divide the sequence into portions and allow each team member to decode his/her portion. Assemble all of the decoded sequences to determine the specific traits that will be produced in your plant.

Use the information to draw a picture of an adult version of your plant. Choose an inventive name for your plant.

1. How did you determine the key to the code?

2. Did the DNA sequence contain information other than trait descriptions? If so, what other information was present?

3. Why is it important for a seed to have information encoded in its DNA?

4. If all plants contain DNA, why do different types of plants (such as pine trees and orchids) look so different from one another?

5. Do you think that your DNA is more similar to your friend's DNA or to the DNA of one of your parents? Why?

TEACHER HANDOUT FOR *BLUEPRINT FOR LIFE*

The sequence below represents a strand of DNA that codes for specific traits in a plant seed. As a team, work together to determine the key to the code using only the information provided.

Start

HGZIGYILZWOVZUHGLKHGZIGGZOOHGLKIVWUOLDVIHHGLKHGZIGGSLIMBHGL

KHGZIGHDVVGHXVMGHGLKHGZIGGIZMTFOZIOVZUHSZKVHGLK

Stop

[STARTBROADLEAFSTOPSTARTTALLSTOPSTARTREDFLOWERSSTOPSTART
THORNYSTOPSTARTSWEETSCENTSTOPSTARTTRIANGULARLEAFSHAPESTOP]

[Note: the key is a reverse alphabet. Z=A, Y=B, X=C, and so on.]

Once your team has determined the key to the code, divide the sequence into portions and allow each team member to decode his/her portion. Assemble all of the decoded sequences to determine the specific traits that will be produced in your plant.

Use the information to draw a picture of an adult version of your plant. Choose an inventive name for your plant. [Students should draw pictures of what they think the plant might look like.]

1. How did you determine the key to the code?

[We used the start and stop sequences to figure out that the code was the alphabet run in reverse. Z=A, Y=B, X=C, and so on.]

2. Did the DNA sequence contain information other than trait descriptions? If so, what other information was present?

[Yes. The sequence also contained start and stop signals in between the trait descriptions.]

3. Why is it important for a seed to have information encoded in its DNA?

[The seed needs to know what proteins to make as it grows. It will acquire its traits as it grows.]

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4. If all plants contain DNA, why do different types of plants (such as pine trees and orchids) look so different from one another?

[Plants differ in their DNA sequences. Those sequences determine the proteins that each plant makes and these differences result in different traits that we see.]

5. Do you think that your DNA is more similar to your friend's DNA or to the DNA of one of your parents? Why?

[My DNA would be more similar to my parent's DNA because my cells came from my parents.]