DNA Structure, Function and Replication

DNA molecules contain our genes. Genes influence our characteristics and provide the information to make the many proteins needed for our bodies to function. In this activity you will learn how:

- the structure of DNA contributes to its function
- genes influence our characteristics
- DNA is copied, so each cell gets a complete set of genes.

DNA is a long molecule that consists of two strands of nucleotides twisted together in a long spiral called a double helix.

1. Each nucleotide contains a sugar, a phosphate, and one of the four bases: 
   \((A = \text{adenine}, \quad \_ = \text{cytosine}, \quad \_ = \text{guanine}, \text{or} \quad \_ = \text{thymine})\).

2. DNA stands for deoxyribose nucleic acid.
   Draw a circle around a deoxyribose sugar in the backbone of one of the strands of DNA. Draw a rectangle around the nucleotide that contains this deoxyribose sugar.

3. Each base in one strand of the DNA double helix pairs with a base in the other strand of the double helix. The base-pairing rules describe which bases pair together in a DNA double helix.
   
   - A in one strand always pairs with \_ in the other strand.
   - C in one strand always pairs with \_ in the other strand.

Since all the nucleotides in DNA are the same except for the base they contain, each nucleotide is given the same symbol as the base it contains (A, C, G, or T).

4. A polymer consists of many repeats of a smaller molecule.

   DNA is a polymer of ____________________________.

   A protein is a polymer of ____________________________.

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1 By Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania, © 2017; Teachers are encouraged to copy this Student Handout for classroom use. A Word file (which can be used to prepare a modified version if desired) and Teacher Notes (with learning goals, instructional suggestions, and suggested alternative and follow-up activities) are available at http://serendip.brynmawr.edu/exchange/bioactivities/DNA
Function

Each DNA molecule contains many genes. Each gene is a segment of DNA with a sequence of nucleotides that provides the instructions for making a protein. A cell needs many different types of proteins to function. For example, a cell needs:

- protein enzymes to carry out the chemical reactions needed for life
- transport proteins to move ions and molecules into and out of the cell and to move substances around inside the cell
- structural proteins.

5. All living organisms, including bacteria, plants, humans and other animals, are made up of one or more cells. Explain why all living organisms need to have DNA. Include the words genes and proteins in your explanation.

Genes influence an organism’s characteristics by determining which types of proteins the organism makes. The flowchart shows an example in humans.

<table>
<thead>
<tr>
<th>Gene in DNA</th>
<th>→</th>
<th>Protein</th>
<th>→</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Gene" /></td>
<td>→</td>
<td><img src="image" alt="Protein" /></td>
<td>→</td>
<td><img src="image" alt="Characteristic" /></td>
</tr>
<tr>
<td>One version of the gene gives instructions to make normal protein enzyme.</td>
<td>→</td>
<td>Normal enzyme makes the pigment molecule in skin and hair.</td>
<td>→</td>
<td>Normal skin and hair color</td>
</tr>
<tr>
<td>The other version of this gene gives instructions to make defective enzyme.</td>
<td>→</td>
<td>Defective enzyme does not make this pigment molecule.</td>
<td>→</td>
<td>Albinism (very pale skin and hair)</td>
</tr>
</tbody>
</table>

How does a gene give the instructions to make a protein?

The sequence of nucleotides in the DNA of a gene determines the sequence of amino acids in a protein which determines the structure and function of the protein which influences the characteristics or traits of the organism.

6. Explain how a difference in the sequence of nucleotides in a gene could result in one boy being albino and the other boy having normal skin and hair color.
7. For most people, when a blood vessel is injured, several types of clotting proteins work together to make a blood clot which prevents excessive bleeding. A person with hemophilia has a defective version of one type of clotting protein, so blood clots do not form normally and the person bleeds excessively when injured.

Complete this chart to describe how a person's DNA determines whether he has hemophilia. (Hint: begin by completing the bottom box in the protein column.)

<table>
<thead>
<tr>
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<th>→</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>→</td>
<td></td>
<td>→</td>
<td>Normal formation of blood clots prevents excessive bleeding.</td>
</tr>
<tr>
<td></td>
<td>→</td>
<td></td>
<td>→</td>
<td>Hemophilia (excessive bleeding because clots do not form normally because one type of clotting protein is defective)</td>
</tr>
</tbody>
</table>

DNA Replication

Our bodies need to make new cells to grow or to replace damaged cells. New cells are formed by cell division which occurs when a cell divides into two daughter cells. Before a cell can divide, the cell must make a copy of all its DNA; this is called DNA replication.

8. Explain why a cell needs to replicate its DNA before the cell divides into two daughter cells.

During DNA replication, the two strands of the DNA double helix are separated. Each old strand provides the information needed to make a new matching strand. Each nucleotide in the new strand is matched to a nucleotide in the old strand using the base-pairing rules.

The enzyme DNA polymerase helps to make each new matching strand. DNA polymerase:
- adds matching nucleotides one-at-a-time and
- joins each new nucleotide to the previous nucleotide in the growing DNA strand.

DNA replication results in two new DNA molecules that are identical to the original DNA molecule.
This drawing shows a short segment of DNA which separates into two strands in preparation for replication.

- Your job is to play the role of DNA polymerase and create the new matching strands of DNA to produce two pieces of double-stranded DNA. Add matching nucleotides one-at-a-time, using the base-pairing rules and the nucleotides and tape provided by your teacher.

9. Do both of these two new double-stranded pieces of DNA have the same sequence of nucleotides as the original double-stranded piece of DNA?
   yes ___  no ___

10. Why is it important that both copies of the DNA molecule have the exact same sequence of nucleotides as the original DNA molecule?

11. Based on the function of DNA polymerase, explain why each part of the name DNA polymerase (DNA, polymer, -ase) makes sense.

12. Explain how DNA polymerase, the double helix structure of DNA, and the base-pairing rules work together to produce two identical copies of the original DNA molecule.