Percent Composition

Contributors

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Intended Audience

<table>
<thead>
<tr>
<th>K-4</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>5-8</td>
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<tr>
<td>9-12</td>
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Intended Audience

<table>
<thead>
<tr>
<th>Classroom Setting</th>
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<tbody>
<tr>
<td>Requires special equipment</td>
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<tr>
<td>Uses hands-on manipulatives</td>
<td>X</td>
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<tr>
<td>Requires mathematical skills</td>
<td>X</td>
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<tr>
<td>Can be performed individually</td>
<td>X</td>
</tr>
<tr>
<td>Requires group work</td>
<td></td>
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<tr>
<td>Requires more than one (45 min class) period</td>
<td>X</td>
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<tr>
<td>Appropriate for special needs student</td>
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</tbody>
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Introduction

Description

Students will examine whether or not candy DNA models often used in introductory biology courses are compositionally accurate in terms of the percent weight composition of each component to the overall chemical weight of a normal DNA molecule.

Abstract

The goal of this activity is to introduce the concept of percent composition to students in a fun, interesting manner. Many introductory biology activities involve making DNA models, in some cases out of candy. Here the students will begin by doing that same modeling activity, using licorice as the backbone, and marshmallows on toothpicks as bases. Once they successfully construct their model they will then deconstruct the complete model and weigh each component, then determine what percentage weight of the total model each component is. Finally they will compare the observed model percent composition to the percent composition of each component in real DNA, and calculate the percent error from the DNA model to the theoretical percentages of each component found in DNA.

Core Themes Addressed

<table>
<thead>
<tr>
<th>The Cell</th>
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<tbody>
<tr>
<td>Molecular Basis of Heredity</td>
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<tr>
<td>Biological Evolution</td>
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<td>Interdependence of Organisms</td>
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<td>Matter, Energy, and Organization in Living Systems</td>
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<tr>
<td>Other – Chemical Reactions</td>
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</tbody>
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Keywords

DNA, percent composition, percent error

Learning Objectives

By completing this activity, students will be able to:

1. Explain what percent composition is
2. Explain what percent error is
3. Determine whether or not DNA models are compositionally accurate
National Science Education Standards Addressed

Teaching Standard A: Science as inquiry

- Through conducting their own experiment, students are learning how to ask and answer valuable questions pertinent to the experiment at hand
Student Prior Knowledge

Students should have the following prior knowledge before completing this activity:
1. Know what percent composition is
2. Know the basic structure of DNA and how bases pair
3. Know what % error is and how it is calculated
A PowerPoint can be given to cover these basic concepts.

Teacher Background Information

Percent composition is a basic property often used to describe different mixtures of compounds. Fundamentally it is often used in analytical chemistry to determine things such as the identity of an unknown compound based upon the percent composition of various atoms, however it is also used in many other analyses, including water quality and safety reports. In order to introduce this potentially dry concept, this lab utilizes candy DNA models as a medium to introduce percent composition. A common practice in biology classrooms, these models are good for introducing the concepts of base pairing and basic DNA structure. However, as a scientific model they fall short, as their percent composition is not a good representation of the percent composition of DNA itself. The students will explore this assertion by first building the models, reviewing concepts from basic biology, and then determining for themselves whether or not the model compares to theoretical numbers from DNA. In addition, students will not only determine if the model is inaccurate, but also by how much the model is inaccurate using percent error calculations.

Class Time

This activity will require a minimum of one 90 minute class period
1. Percent Composition Presentation - 15 min
2. Model Building – 20 min
3. Model Weight – 15 min
4. Questions and calculations – 20 min
5. Class discussion/wrap-up– 15min
Teacher Preparation Time

This lesson will require approximately 15 minutes of preparation time.

1. Prepare baggies of materials for each group – 15 min

Materials and Equipment

Per Lab Group (2 students/group)
- 6 pieces of licorice
- 16 toothpicks
- 8 pink marshmallows
- 8 yellow marshmallows
- 8 green marshmallows
- 8 orange marshmallows
- 6 paperclips
- Masking Tape

Per Class
- 1 Scale per group

Methods

Elephant toothpaste
Wash your hands thoroughly and bring back enough paper towels to cover most of your desk.

2. Start building your double stranded DNA molecule with the licorice as the DNA backbone and the marshmallows as the 4 chemical bases (key above).
   You will use the toothpicks to pair A with T, and G with C (look at the example to the right). Each base should get its own toothpick but complementary bases should be touching or close to it.

3. Once you are done, use paper clips and masking tape to label the following: backbone #1, backbone #2, 1 adenine, 1 thymine, 1 cytosine, and 1 guanine.

4. Raise your hand when you are done so your teacher can come inspect and make sure each piece is labeled properly. Now draw the correct structure below. (Be sure to label nucleotides and the DNA backbone).
Tips/Suggestions

Percent composition

- When building the models, students should use a different toothpick for EACH base, including those that are pairing with one another. That way when they have to deconstruct the model, they will be able to do so easily. They can show that the bases are paired by simply making the touch one another in the middle of the model, and assign to strand by which strand is closer (picture provided)
- It helps to have a model preconstructed for the students to observe before beginning
- When using licorice, it helps to have a brand that is solid and not hollow. Twizzlers work fine, but other generic brands have fallen apart during the deconstruction process as they were too hollow.

References

- Adapted from http://gslc.genetics.utah.edu

Answers to Student Worksheet - Elephant Toothpaste

Part 1 - Percent Composition
1. Licorice was the backbone, green marshmallows were adenine, pink thymine, yellow cytosine, and orange guanine
2. Will vary across groups
3. Will vary across groups
4. The candy model was not an accurate representation of DNA, the percent error from the model composition to the composition of actual DNA was very high.
5. C= 35.5%, A=14.5%, T=14.5%
Student Background Knowledge

Creating models of DNA allow scientists to better understand how it is chemically structured. However, are DNA models accurate not only on structure but also in percent composition? In this lab students will create candy models to understand DNA’s chemical structure. In addition, by comparing composition of candy DNA to real DNA, students will determine if the DNA model that they have created is actually an adequate representation, in terms of percent composition, of real DNA. This lesson will show students the advantages and disadvantages of using models to better understand molecules.

When isolated from a cell and stretched out, DNA looks like a twisted ladder. This shape is called a double helix. The sides of the DNA ladder are called the backbone and the steps (also called rungs) of the ladder are pairs of small chemicals called bases. There are four types of chemical bases in DNA: Adenine (A), Cytosine (C), Guanine (G), and Thymine (T). They form pairs in very specific ways: Adenine (A) always pairs with Thymine (T) and Cytosine (C) always pairs with Guanine (G). DNA is composed of sugars, phosphates, and nucleotide bases. Adenine = 135.13 g/mol, Guanine = 151.13 g/mol, Cytosine = 111.10 g/mol, Thymine = 126.1134 g/mol, Dioxyribose = 268.26 g/mol, Phosphate group = 189.14 g/mol.

Vocabulary

Percent Composition: is a measure of what percentage of a whole and individual part or many parts comprises

Percent Error: a measure of how inaccurate an observed value is from a true value, can be used to assess how accurate an experiment or representation is

Base Pairing: the pairing of the nitrogenous bases as observed in the macromolecule DNA
Materials Checklist

<table>
<thead>
<tr>
<th>Item</th>
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<tbody>
<tr>
<td>6 pieces of licorice</td>
</tr>
<tr>
<td>16 toothpicks</td>
</tr>
<tr>
<td>8 pink marshmallows</td>
</tr>
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<td>8 yellow marshmallows</td>
</tr>
<tr>
<td>8 green marshmallows</td>
</tr>
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<td>8 orange marshmallows</td>
</tr>
<tr>
<td>6 paperclips</td>
</tr>
<tr>
<td>Masking Tape</td>
</tr>
</tbody>
</table>

Procedure

Building a Model
1. Wash your hands thoroughly and bring back enough paper towels to cover most of your desk.

2. Start building your double stranded DNA molecule with the licorice as the DNA backbone and the marshmallows as the 4 chemical bases (key above).

3. You will use the toothpicks to pair A with T, and G with C (look at the example to the right). Each base should get its own toothpick but complementary bases should be touching or close to it.

4. Once you are done, use paper clips and masking tape to label the following: backbone #1, backbone #2, 1 adenine, 1 thymine, 1 cytosine, and 1 guanine.

5. Raise your hand when you are done so your teacher can come inspect and make sure each piece is labeled properly. Now draw the correct structure below. (Be sure to label nucleotides and the DNA backbone).
Candy DNA Models: Biologically Accurate?

Today’s Sequence: TACGTagc – strand 1

Your DNA Model
1. In this exercise which candy represented the DNA backbone and what candy represented bases? (Fill in the table below)

2. Weigh each of your components. What was the % composition for all of the components in the DNA strand? (Fill in the table below)

<table>
<thead>
<tr>
<th>DNA component</th>
<th>What does it represent?</th>
<th>Weight (in grams)</th>
<th>% composition of total DNA strand</th>
<th>Percent error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licorice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green marshmallow and toothpick</td>
<td></td>
<td></td>
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<tr>
<td>Pink marshmallow and toothpick</td>
<td></td>
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<tr>
<td>Yellow marshmallow and toothpick</td>
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<tr>
<td>Orange Marshmallow and toothpick</td>
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</tbody>
</table>

3. Theoretically, DNA is 27.34% sugar backbone, 13.7% Adenine, 15.4% Guanine, 11.32% Cytosine, and 12.85% Thymine. Perform percent error calculations between the percent compositions of candy DNA to real DNA by using the percent error calculation below.

\[
\text{% error} = \left(\frac{\text{% composition actual} - \text{% composition theoretical}}{\text{% composition theoretical}}\right) \times 100
\]

4. Explain, with evidence from the percent error calculations, if the candy DNA model is an accurate representation of DNA’s percent composition.

5. In a sample of alligator DNA, 35.5% of the bases are Guanine (G). Predict the approximate percentages of C, A, and T.