Strawberry Breeding and Genetics
Teacher Resources

Summary
In this standards-aligned, 5-E lesson plan, students will learn about DNA by extracting it from strawberries. Students also analyze the similarities and differences of their extraction process to those of the web-based educational module, Genetic Engineering: The Journey of a Gene. Students learn about how genetic testing (including DNA extraction) is useful in breeding new varieties of strawberries.

Grade Level
9-12

Content addresses the following Next Generation Science Standards

- HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

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Background

Standards

Next Generation Science Standards

- HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Common Core

CCSS.ELA-LITERACY.RST.9-10.3

- Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.9

- Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Estimated Time

One, 60-minute class period

Student Materials

Each group of students will need:

- 1 strawberry
- mortar and pestle
- masking tape and markers
- 2 plastic cups (150mL or more)
- coffee filter
- rubber band
- dish detergent (Dawn)
- salt (non-iodized)
- 91% Isopropyl alcohol (cold)
- tray or tub of ice
- popsicle stick or coffee stir stick
- 1 worksheet per student
- Computer with internet access

Vocabulary

- **band:** when many copies of the same DNA fragment move together through an electrophoresis gel
- **centrifuge:** a machine that spins tubes really fast so that the solid components form a pellet in the bottom of the tube
- **chromosome:** a coiled strand of DNA containing many genes
- **DNA replication:** the copying of a DNA molecule or a portion of it

- **extraction buffer:** a salt solution that helps break down cell membranes so the DNA can be released into the solution
- **gel electrophoresis:** a technique which uses electricity to separate molecule fragments according to size so they can be studied
- **PCR (polymerase chain reaction)**: a method for making lots of copies of a particular gene or sequence of DNA in the lab
- **Precipitate:** the solid that forms when a chemical is added to a solution
- **plant breeding:** the purposeful interbreeding of related plants to produce new varieties with desirable properties or traits

Key STEM Ideas

DNA is the hereditary material in humans and nearly every other organism. This lesson introduces a very theoretical and abstract subject of nuclear genetics and allows students to actually see DNA from a food crop that many enjoy, strawberries. This lab-based experience not only allows students to complete the DNA extraction within a period, but also to compare/contrast their methods to that of an actual DNA analyst scientist.

Students' Prior Knowledge

High school students should understand that DNA is present in cells of living organisms and contains the instructions necessary for growth and function by coding for proteins. This lesson will expand students' knowledge of DNA by having students extract DNA from a familiar food. Students will begin to discuss how traits of an organism are determined by their DNA.

Connections to Agriculture

Strawberries are a tasty and nutritious agricultural crop grown in every state in the U.S. The U.S. produces 30 percent of strawberries grown globally. In order to produce new varieties of strawberries with attractive traits for both growers and consumers, plant breeders are using genetic information to make better breeding decisions. Genetic information about strawberries is becoming more widely available as the strawberry genome was sequenced in 2010.

Essential Links

Web-based education module: Genetic Engineering: The Journey of a Gene

- http://passel.unl.edu/ge/step-4-dna-testing/dna-extraction/
- http://passel.unl.edu/ge/step-4-dna-testing/in-the-lab/

NOVA | Extract Your DNA | PBS

- https://www.youtube.com/watch?v=DaaRrR-ZHP4

Sources/Credits

- http://passel.unl.edu/
- http://www.nclark.net/BERRYteacDNA.pdf
- http://ffanewhorizons.org/farm-facts-about-strawberries/
- DNA diagram: http://www.bbc.co.uk/schools/gcsebitesize/science/images/gatewaysci_32.gif
- Strawberry image by Leslie Land: http://leslieland.com/wp-content/uploads/2008/07/strawberry-sizes-1.jpg

Lesson Procedures

Engage

1. Show students picture (embed image of strawberry-sizes-1 here) of wild strawberries (on the bottom) and cultivated strawberries (on the top).
2. Ask students how the wild variety is different from the strawberries from the store (cultivated strawberry). List noticeable differences on the board.
3. Review and complete the entire lesson yourself so you can get a feel for the concepts and sequence. Jot down notes that will help the lesson flow smoothly with your students.
4. Hand-out the lab and give students time to read the procedures before getting started.
5. Demonstrate the procedures of what they will be doing while reading through the lab as a class (but don't actually complete the lab). Make sure to stress that students should at no point eat the strawberries as chemicals and lab equipment are in use.

Lab Tips:

- Encourage students to grind the mixture very well as this mechanical pulverization helps to break the cell walls.
- Use masking tape and markers to label beakers and test tubes.
- If the liquid from the mixture is not filtering through the coffee filter during step 6, you can gently squeeze the coffee filter to help strain the liquid. Make sure not to break the coffee filter.
- Allow students some time to observe on step 10.
- Put links to videos on class website.

Explore

Activity 1: DNA Extraction Lab

6. Divide students into lab pairs and allow each group to complete the lab procedures:
   a Place one strawberry into the mortar and grind it with the pestle.
   b Add water, dish detergent, and salt to the mortar. Be sure the solution covers the strawberry. Continue to grind the mixture.
   c Label a beaker with your name. Place a coffee filter inside the beaker and use a rubber band to hold it in place.
   d Pour the strawberry mixture into the filter and place the beaker in the tray of ice. It's important to keep the mixture COLD while it slowly filters.
   e While waiting for the mixture to filter, watch Video 1: DNA Extraction from Part 2 of your worksheet. Answer follow-up questions 1-4.
   f After the mixture has filtered, SAVE the filtered liquid (which contains the DNA) in the beaker. Discard the coffee filter and strawberry remains in the trash.
   g Label a test tube with your name. Pour the filtered liquid from the beaker into the labeled test tube.
   h Gently add twice the volume (5-10 mL) of 91% isopropanol (rubbing alcohol) to the test tube. Remember to layer the isopropanol on top of the clear liquid rather than mixing the two layers together. Watch and wait. Bubbles will begin to form and a white stringy substance will become visible.
   i Place the test tube back into the ice tray and check on it in 10 minutes. If you don't stir the layers, a large "glob" of strawberry DNA will form. (Leave the tube in the ice for as long as possible.)

- j While waiting for the DNA to precipitate, clean your lab station and equipment and watch Video 2: In the Lab from Part 2 of your worksheet. Answer follow-up questions 5-10.

7. Monitor student work continuously and engage students in reflection of what they are doing in each step of the procedures and why.
8. Make sure that students see the DNA product at the end of the class period.

Explain
Part 2: Videos

9. It is suggested that you let each group view the videos on their own devices when they are ready. This is best accomplished during appropriate wait time in the lab procedures (steps 5 and 10), however, videos can be played at the front of the classroom at designated times.
10. Lab pairs will complete the follow-up questions after viewing each video in Part 2.
11. Lead a whole class discussion to compare and contrast how the student DNA extraction procedures are similar to and different from the DNA analyst in video.

Explain
Part 3: Reflections and Analysis

12. After students have completed the lab in groups, have lab groups compare their findings.
13. Direct students to work individually or in pair to complete the post-lab reflection and analysis.
14. Facilitate whole class discussion about why a scientist would want to extract DNA. Discuss with students that being able to extract DNA from a strawberry (or any other organism) is only a first step to examining its genetic make-up. A useful FAQ section (copied below) is found at http://learn.genetics.utah.edu/content/labs/extraction/howto/faq/ discussing how extracted DNA is applied.
    - a "What can be done with my extracted DNA?
        - i. This sample could be used for gel electrophoresis, for example, but all you will see is a smear rather than a band. The DNA you have extracted is genomic, meaning that you have the entire collection of DNA from each cell. Unless you cut the DNA with restriction enzymes, it is too long and stringy to move through the pores of the gel.
        - ii. A scientist with a lab purified sample of genomic DNA might also try to sequence it or use it to perform a PCR reaction. But, your sample is likely not pure enough for these experiments to really work.
    - b How is DNA extraction useful to scientists? When do they use such a protocol, and why is it important?
        - i. The extraction of DNA from a cell is often a first step for scientists who need to obtain and study a gene. The total cell DNA is used as a pattern to make copies (called clones) of a particular gene. These copies can then be separated away from the total cell DNA, and used to study the function of that individual gene."

Extend
Part 4: Applying Genetic Testing to Agriculture

15. Read the article "Breeding Strawberries" (http://fruitgrowersnews.com/article/breeding-strawberries/). Assign students into groups of three. Each student must play the role of either strawberry breeder, strawberry grower, or strawberry consumer. Answer the questions and discuss Part 4 of the worksheet.
16. Work with students to construct an accurate diagram of relationships between chromosomes, genes, DNA, proteins, and traits which illustrates their understanding of how genes of a seedling result in

genetic traits of the plant. (*At its most basic, the diagram should indicate that chromosomes are made up of DNA, short sections of this DNA make up genes, genes code for proteins, and proteins determine traits of the plant.*)

Strawberry Breeding and Genetics Answer Key

Part 1: Strawberry DNA Extraction Lab

DNA carries the genetic code for all living organisms, including humans and strawberries. Each cell in a plant or animal has a nucleus with multiple chromosomes. Each chromosome contains DNA with multiple genes. In this lab you will extract from a red, juicy, sweet food crop (strawberries) and compare/contrast your methods to that of an actual DNA analyst scientist.

Materials Needed

- 1 strawberry
- mortar and pestle
- 10 mL (2 tsp) dish detergent
- 125 mL (1/2 cup) water
- 5 g (1 tsp) salt (non-iodized)
- rubber band
- coffee filter
- 2 plastic cups
- tray of ice
- masking tape and marker for labeling
- 91% cold isopropanol (rubbing alcohol)
- popsicle stick or coffee stir stick

Lab Procedures

1. Place one strawberry into the mortar and grind it with the pestle.
2. In a cup, mix the water, dish detergent, and salt. Add the solution to the strawberry in the mortar. Continue to grind the mixture.
3. Label a second cup with your name. Place a coffee filter inside the cup and use a rubber band to hold it in place.
4. Pour the strawberry mixture into the filter and place the cup in the tray of ice. **It's important to keep the mixture COLD while it slowly filters.**
5. While waiting for the mixture to filter, watch Video 1: DNA Extraction from Part 2 of your worksheet. Answer follow-up questions 1-4.
6. After the mixture has filtered, **SAVE** the filtered liquid (which contains the DNA) in the cup. Discard the coffee filter and strawberry remains in the trash.
7. Gently add an amount of isopropanol (rubbing alcohol) equal to the amount of filtered liquid to the cup. Remember to layer the isopropanol on top of the clear liquid rather than mixing the two layers together. Watch and wait. Bubbles will begin to form and a white stringy substance will become visible. This precipitate (the solid that forms when a chemical is added to a solution) is the DNA!
8. Place the cup back into the ice tray and check on it in 10 minutes. If you don't stir the layers, a large "glob" of strawberry DNA will form. (Leave the cup on ice for as long as possible.)
9. Pick up the DNA using a popsicle stick or coffee stir stick.
10. Clean your lab station and equipment and watch Video 2: In the Lab from Part 2 of your worksheet. Answer follow-up questions 5-10.

Part 2: Lab Video Questions

Video 1: DNA extraction found here: http://passel.unl.edu/ge/step-4-dna-testing/dna-extraction/

This video describes the process of DNA extraction from plant cells in the lab.

1. What type of tissue is best used from plants for DNA extraction?
   Young leaf tissue that has been frozen
2. In what ways are the cells broken up in order to release the DNA from the nucleus? (Hint: there are two methods listed in the video.)
   Cells are crushed using a tool resembling a drill and a solution made of buffer, salt, and detergent is added.
3. In what substance is DNA soluble (definition: able to be dissolved)?
   Water
4. Alcohol and water mix, but alcohol and DNA do not mix. What happens as a result?
   DNA molecules will precipitate (come out of solution) and form a solid material inside the test tube.

Video 2: In the Lab found here: http://passel.unl.edu/ge/step-4-dna-testing/in-the-lab/

This video features Justin Rosenbohm, a DNA analyst, as he demonstrates the techniques used in his lab for DNA extraction of plant material. His process of extraction can be summarized into four steps. Answer the questions below while watching the video. Hints are given as to the video times for each step.

5. What was the first step in DNA extraction by the DNA analyst? Did you do anything like this? Explain. (Hint: 0:00- 0:38)
   He uses a shaker to emulsify, pulverize, or puree the leaf tissue. This breaks down the cell walls to access the DNA. Students did this by crushing the strawberry in the mortar.
6. What was the second step? Did you do anything like this? Explain. (Hint: 0:38- 1:13)
   He loads the leaf tissue into the centrifuge to separate the solid components from the liquid. Students did this by pouring the mixture in a filter and waiting for the liquid to drain out.
7. What was the third step? Did you do anything like this? Explain. (Hint: 1:15- 1:26)
   He adds isopropanol to the lysate (the fluid made of the lysed cells) to help precipitate out the DNA. Students did this when they added rubbing alcohol to the filtered liquid.
8. What was the fourth step? Did you do anything like this? Explain. (Hint: 1:27- 1:50)
   He adds metal beads to the sample. These will be used as a handle to move the DNA around. Students used a popsicle stick or coffee stir stick to manipulate their DNA.
9. What is the end goal of PCR? (Hint: 2:30-3:01)
   PCR amplifies the DNA or makes copies of sections of the DNA.
10. What process does the DNA analyst use to see the bands of DNA?
    He uses gel electrophoresis to view bands of DNA that are present in the sample.

Part 3: Post-Lab Reflections and Analysis

1. Compare your results with other groups. Did you notice any differences? Describe what you observed and hypothesize what could have resulted in the differences.
   Answers may vary depending on the differences observed, if any. Differences may result from differences in the size of the strawberry, how fully it was crushed, different methods of filtration, adding alcohol, etc.

2. What did the DNA look like?
   Answers may vary. Ideally, it formed a white or cloudy mass that stuck together.
3. Describe what happened when the isopropanol came in contact with the strawberry mixture.
   Answers may vary. Ideally, the water and the isopropanol separated in the cup and the DNA came out of solution (precipitated) to form a white substance.

4. A person cannot see a single cotton thread 100 feet away, but if you wound thousands of threads together into a rope, it would be visible at some distance. How is this statement an analogy to our DNA extraction?
   Answers may vary. DNA in one cell is similar to a single cotton thread which is difficult to see. In our experiment, we extracted the DNA from many cells which is similar to winding thousands of threads together to make a rope. This made the DNA of the strawberry easier to see.

5. Would the DNA be the same in any cell in the strawberry? Explain. (Hint: Remember that strawberry started out as one fertilized cell.)
   Yes, the strawberry developed through a process of cell division. A single fertilized cell divided into two identical daughter cells, each with the same genetic material. This process repeated for the growth and development of the strawberry. All cells will contain the same blueprints for growth and development known as DNA.

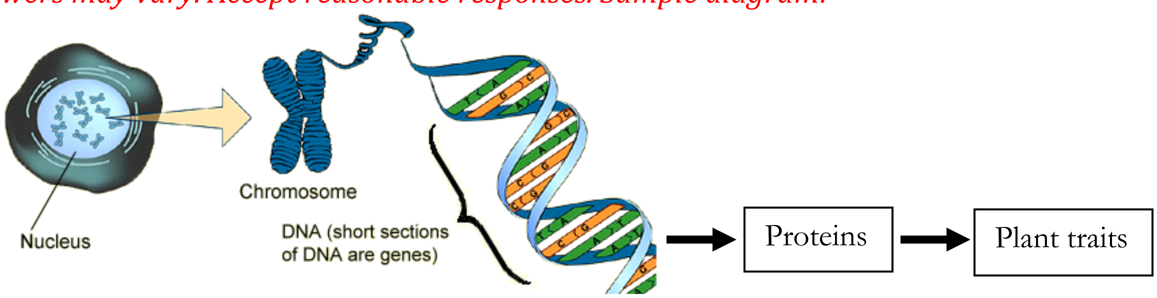
6. Why would a scientist want to extract DNA? Give three reasons.
   Answers may vary. Accept all reasonable answers.

Part 4: Applying Genetic Testing to Agriculture

So we've extracted DNA from a strawberry, but how is this process used in the real world? Often DNA extraction is just one of many steps that researchers use to breed better agricultural crops like strawberries. RosBREED is a research project focused on developing and applying modern DNA tests and related breeding methods to deliver new cultivated varieties of rosaceous crops (including strawberries) in 22 U.S. breeding programs.

Read the article "Breeding Strawberries" (http://fruitgrowersnews.com/article/breeding-strawberries/) and discuss the following questions. Think critically as answers are not always found directly in the article.

1. How is genetic testing beneficial to strawberry <u>breeders</u>?
   Breeders benefit from genetic testing by making the breeding process less expensive, less time-consuming, and less laborious.
2. What are three traits that would be beneficial for strawberry <u>growers</u>?
   Growers would want disease- or drought-resistant strawberry plants, those that can withstand harvest, flower for longer periods of time, produce more fruit, etc.
3. What are three traits that would be beneficial for strawberry <u>consumers</u>?
   Consumers want a strawberry that tastes better, is more nutritious, lasts longer, etc.
4. Draw and label a diagram showing the relationships between chromosomes, genes, DNA, proteins, and traits which illustrates your understanding of how genes of a seedling result in genetic traits of the plant.
   Answers may vary. Accept reasonable responses. Sample diagram:



   Chromosomes are made up of DNA, short sections of this DNA make up genes, genes code for proteins, and proteins determine traits of the plant.

5. Why do you think is it valuable to incorporate genetic material from wild strawberries when breeding new cultivated varieties?
   The variation in the wild population is a genetic resource. From this diverse genetic pool of plants, we can select for plants with vastly different traits (such as plants with genes that make them drought or disease tolerant, do better under different moisture conditions, have different colors, flavors, nutritional value, flowering time, or other traits important to consumers or growers.