Extract DNA

FROM STRAWBERRIES

ESTIMATED LENGTH: 70-95 MIN*

AMGEN® Foundation
biotech101
FOR THE CLASSROOM

In this activity, ELEMENTARY SCHOOL students will use simple household materials to extract DNA from strawberries. They will learn that all living organisms are made of cells that contain DNA. An organism's DNA acts as a blueprint, determining how it develops, looks, and functions.

ATTENTION: This activity includes the use of food. Please discuss the potential of student allergies with teacher before running this activity.

* These time estimates don't include the cleanup and the material shopping.

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Volunteer Background Information

Volunteer topical information to feel confident with the science concepts in this activity.

All living things come with a set of instructions stored in their **DNA**, short for **d**eoxyribo**n**ucleic **a**cid. Whether you are a human, rat, tomato, or bacterium, each cell will have DNA inside of it (with some rare exceptions, such as mature red blood cells in animals). DNA is the blueprint for what happens inside the cell of an organism, and almost every cell has a copy of the same set of instructions inside their cell nucleus. The DNA is made up of individual building blocks called nucleotides. In a DNA molecule, these nucleotides are linked together in a long chain. In fact, the DNA molecule is composed of two nucleotide chains that coil around each other to form a double helix (Figure 1).

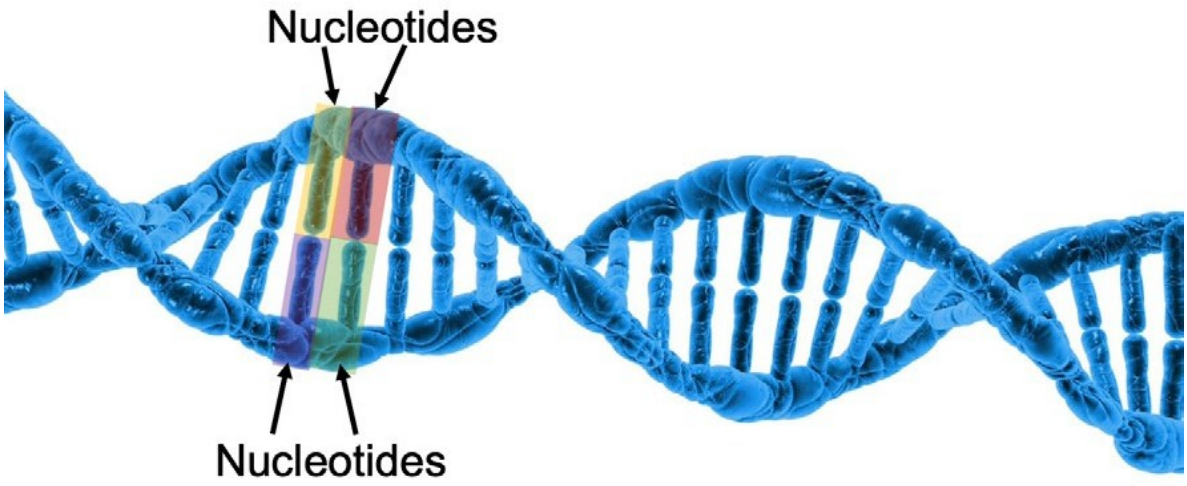

FIGURE 1. DNA double helix consisting of two nucleotide chains.

The instructions on how an organism functions are stored in the sequence of nucleotides within a DNA strand. Certain nucleotide sequences encode a gene. A gene codes for a molecule that has a specific function in our body, such as a protein. The long DNA strands are usually coiled up into structures called chromosomes. The full set of DNA or chromosomes an organism has is called its genome.

Studying the DNA and its nucleotide sequence is the basis of biotechnology. Scientists for example use DNA to search for DNA mutations that cause certain diseases, thus, enabling them to develop new drugs for such genetic diseases. They can modify the DNA of organisms such as crops, so they become resistant to insects. They can also use DNA to figure out the identity of the suspect in a crime and even use ancient DNA to reconstruct evolutionary histories.

To study the DNA of an organism, the DNA first has to be separated from the organism's cells. This process is called DNA extraction. There are many DNA extraction kits available from biotechnology companies for scientists to use in the lab. These kits contain all the chemicals necessary to extract the DNA as shown in Table 1. Common chemicals in a DNA extraction kit.

TABLE 1.

Ingredient	**Purpose**
Detergent	The detergent solubilizes the lipids that are part of the cell membrane similar to how it dissolves fats and grease from dirty dishes. As a result, the cell membranes break apart and the cells pop open.
Salts (sodium acetate, ammonium acetate, sodium chloride)	Salts help to remove DNA-associated proteins and make the DNA molecule less soluble, which makes it more likely to fall out of solution.
Alcohol (ethanol, isopropyl alcohol)	The alcohol causes the DNA to pre-cipitate as the DNA is insoluble in alcohol. When DNA comes out of solution if tends to clump together, which makes it visible.

In this activity, students will use household materials to extract DNA from strawberries. Strawberries are the perfect choice when extracting DNA for the first time. This is because some types of strawberries, for example the one we usually eat *(Fragaria x ananassa)*, have eight copies of their genome in each of their cells. These so-called octoploid strawberry species are products of polyploid evolution. This means that they were formed by the fusion and interactions among genomes from four diploid ancestors a long time ago. Today there are many different strawberry species, and they vary in the amounts of chromosomes. Although there are seven basic types of chromosomes that all strawberry species share, some species have 2, 4, 6, 8, or even 10 sets of these 7 chromosomes in their cells. An octoploid organism has a lot more DNA per cell than an organism that only has two sets of chromosomes. Using DNA from octoploid strawberries will help students have a successful DNA extraction. Normally, individual strands of DNA are so thin that they are microscopic and cannot be seen with the naked eye. However, the clumping of many strands makes strawberry DNA plainly visible!

Further Reading

- Deoxyribonucleic Acid (DNA) Fact Sheet
- DNA, Genes and Chromosomes
- DNA, RNA, and Protein Extraction: The Past and the Present
- Genetics of Strawberry Plants
- Origin and evolution of the octoploid strawberry genome

Vocabulary

Depending on the age of your students, you might want to introduce some of these terms during the activity.

- **Chromosome:** threadlike structure of coiled up DNA present in the cell nucleus.
- **DNA:** abbreviation for deoxyribonucleic acid, carrier of genetic information in almost every cell.
- **Genome:** the complete set of genetic information in a cell or organism.
- **Extraction:** the action of removing something or taking something out.

- **Lysis:** the breaking apart of a cell by breaking its cell wall.
- **Molecule:** a tiny particle that is made up of different components.
- **Nucleotide:** the building blocks of the DNA chain.
- **Precipitation:** the process of a solid coming out of a solution.
- **Protein:** a molecule that carries out a specific function in our cells.

Real World Relevance

DNA plays a central role in health and disease. The DNA within our body stores all the instructions for how we are built and function. Differences in a person's DNA can cause a variety of differences between people. Some of these DNA differences result in differences in the way people look, but others can result in differences in the way people react to medications or can even cause a person to have a disease. Some examples of diseases or disorders that are caused by mistakes in the DNA are certain types of cancers, lactose intolerance, Huntington's disease, sickle cell anemia or cystic fibrosis. Amgen's scientists use the knowledge they gain from differences in people's DNA to develop new tools, medications, and therapies.

Materials

For each student group:

- Three strawberries
- Resealable plastic sandwich bag
- Cheesecloth
- Funnel
- Two tall plastic cups (16 oz)
- Spoon
- Wooden skewer
- Paper towels
- Wet wipes

Materials the educator needs during the activity:

- 4 cups of water (calculated for 10 student groups)
- 6 teaspoons of salt (calculated for 10 student groups)
- 3/4 cup dishwashing soap (calculated for 10 student groups)
- Wooden spoon
- Measuring cup
- Measuring spoons
- Pitcher or large bowl for mixing
- Small plastic cups, 2 oz. (two per student group)
- Ice-cold, chilled isopropyl alcohol, 70% (1/2 cup per student group)

Safety Tip(s)

Before you start the activity, please take note of the following safety tips.

- Make sure to label any flask that contains isopropyl alcohol properly, so students don't mistake it for water.
- Remind students to be careful with the isopropyl alcohol, so they don't splash it. In case of contact with eyes or skin, flush the eyes or skin with plenty of water.
- Emphasize that students should not put any of the materials into their mouths at any time.

Prep Work

1. Chill the rubbing alcohol in a freezer for several hours before the activity. It needs to be very cold for the activity to work well. If transporting, move it from the freezer to a cooler with ice or dry ice and keep it on ice until used.
2. Cut the cheesecloth so it fits into the funnels.
3. Prepare one set of materials for each group of students and set up an individual workstation for each group ahead of class. This way, each student group has their materials ready to go for the extraction.
4. Several days before your class visit, send the teacher these video links and ask that he or she ensure they can be shown in class during your visit. Bookmark the videos, so you can access them quickly in class.

- Cells and the human body
- DNA

Procedure

ENGAGE

1 **Start by explaining that every living organism is made from cells (including our bodies).**

- *Have you ever wondered what we are made from? What do you think?*
- Have students share their ideas. They might bring up that we have different body parts (hands arms, feet, hair, etc.), or they might mention blood, skin, bones, the brain, or flesh. Tell that this is right. Then challenge them with a follow-up question.
- *What if you would have a closer look into our bodies? What is our blood, our bones, or our skin made of?*
- Listen to student's responses. Then show students the video Cells and the human body.

2 **Review the video with your students.**

- *What did the video tell you about what we are made from?*
- Let one or two students summarize what they have learned from the video. Make sure students understand that our bodies are made from cells. Different body parts are made from different cells. Every living organism is made of cells.

3 **Introduce the DNA as an organism's blueprint.**

- *That means I'm made of cells, you are made of cells, a frog is made of cells and a banana is made of cells. If we are all made of cells, why do we all look different? Why are we not all the same?*
- Listen to students' ideas. Use their replies to point out that every life form is made based on a specific blueprint. This blueprint is called DNA (deoxyribonucleic acid) and is stored inside almost every cell inside our body. DNA contains the instructions for how every one of us is built and how we function. Augment your explanation with the video DNA (start at 0:26 and end at 2:26). Then continue to explain that the differences in our DNA are the

reason why we are all different. There are lots of DNA differences between a human and a banana, so we look very different. There are fewer differences between individual humans, so we look more similar.

4. **Optional: Introduce "genome" as a vocabulary word. The genome is the complete set of DNA (genetic information) in a cell.**

5. **Tell students, that today they will do an experiment that will allow them to look at the DNA more closely. The procedure you will do together is called a DNA extraction and you will extract the DNA out of a strawberry. This means that you are taking the DNA out of the strawberry cells. Show students the strawberries.**

   ? *How do you think we can get to the DNA that is inside the cells of these strawberries?*

   Let students share their ideas. Elicit responses that mention that you have to break open the strawberry cells to get the DNA out.

6. **Explain that getting the DNA out of the strawberry cells is not enough. There are several steps involved in separating (or extracting) the DNA out of a cell and making it visible. You will go through all these steps together.**

7. **Briefly discuss the scale of DNA.**

   ? *If DNA is so small how will we able to see it once we have extracted it from the strawberry cells?*

   Again, let students share their ideas. Then explain that whereas individual strands of DNA are invisible to our eyes, many DNA strands clumped together become visible. Strawberries are special because they have lots of DNA in their cells. This is why we can see it after the extraction.

8. **Make groups of 2-3 students and direct each group to one of the stations with the prepared materials.**

EXPLORE

Especially when working with elementary school students, it is important to demonstrate a step, pause and let them do the step, then demonstrate the next step. While demonstrating and discussing, make sure that students understand the purpose of each step in the DNA extraction process. Guiding them in this way will help make sure everyone is successful. Stop in between steps to ask for student's predictions, explain the next step, wait for other groups or share observations. This section is written with this classroom strategy in mind.

While students are working, walk around and check in with them. The teacher can help you with that. Listen to their discussions and provide support where needed. Where indicated below, engage students by asking them about their observations or predictions during the extraction. Ask the teacher to help you with making sure every group is following the DNA extraction steps properly. Also, keep in mind that students will be working with liquids, so be prepared for potential spills. Have wet wipes and paper towels ready to clean up spills if they happen.

1 **Walk the students through the general extraction process before starting the experiment.**

a. Say, *"we said earlier that we have to break open the cells of the strawberry to get to its DNA. We will crack the strawberry cells using a detergent (soap)"* (show the liquid detergent to the students). Explain that the detergent reacts with certain components (the lipids) that make up the walls of the cells and thus breaks the cells open.

b. Explain, *"when we have broken the cells and released the coiled-up DNA, the next step we have to do is to break up the coiled-up structure of the DNA, so we get many long DNA strands. To do this we will add salt to the extraction solution (show the salt to the students). The salt helps to release the DNA strands by breaking up the coiled DNA by removing the pieces (proteins) that hold the DNA together."*

c. Say, *"in the last step we have to make the DNA visible. We use ice cold rubbing alcohol (isopropyl alcohol) to do that (show the alcohol to the students). The DNA is not soluble in isopropyl alcohol and thus will come out of solution (precipitate). As the many DNA strands tend to clump together when coming out of solution, we will be able to see them with our eyes."*

2 **Tell your students that it is now time to get started. First, lead the group to prepare the extraction liquid that contains the detergent, water, and the salt ingredients for the extraction. Make one large batch in front of the class and ask individual students to come up and help. Students can, for example, add the individual ingredients to the pitcher or stir the solution.**

a. Add 4 cups water, 6 teaspoons salt, and ¾ cup dishwashing liquid to the pitcher. This will be enough for 10 groups of students. With each ingredient you add, ask students to remind you what it is needed for (see Table 1).

b. Use a wooden spoon to mix the ingredients until the salt is dissolved.

c. Set the mixture aside for now and tell students that you will add the liquid to your strawberries later.

3 **Tell your students that before you add the extraction liquids to the strawberries, you first have to smash the strawberries.**

Why do you think we have to smash the strawberries first before adding the extraction liquid?

Listen to student's responses. Point out that smashing up the strawberry breaks the strawberry up into its individual cells. This makes it easier for the detergent and salt in the extraction liquid to interact with every cell in the strawberry. Otherwise the ingredients would not be able to get inside of the strawberry.

4 **Let the students remove and discard the leafy green tops from the strawberries (3 strawberries per group). Have them put all three strawberries in a resealable plastic sandwich bag and push out all of the extra air. Remind them to seal the bag tightly.**

5 **Tell your students that they should now smash the strawberries inside the bag. They should take turns to squeeze and smash the bag with their hands to puree the strawberries for about two minutes.**

6 **While students are smashing the strawberries, fill one small (2 oz.) cup with 3 tablespoons of prepared extraction liquid for each group. With the help of the teacher, pass one filled cup out to each group.**

How do the smashed strawberries look?

The smashed strawberries should look like regular strawberry puree (see Figure 2). Remind students that you have now broken each strawberry up into its individual cells.

FIGURE 2. Smashed strawberries before adding the extraction solution

Now that we have the strawberry broken up into its individual cells, what do we have to do next?

Pick one student to explain the next step, which is breaking open the individual strawberry cells to release the DNA. Ask students to name the ingredient in the extraction buffer that breaks open the cells (the detergent/soap).

7 **Tell students to add the whole cup of extraction liquid to the strawberries in the bag. Again, ask them to push out all of the extra air and reseal the bag. Have students squeeze the strawberry mixture with their fingers for another minute.**

How do the smashed strawberries look now? Can you tell that the cells have been broken?

Students will most likely see bubbles form in the bag, due to the detergent in the extraction buffer (Figure 3). However, they won't be able to tell that the strawberry cells have been lysed.

FIGURE 3. Mashed strawberries after mixing with the extraction solution.

What other ingredient did we add to the extraction liquid? Do you remember why we added it?

Listen to students replies. Remind them that they also added salt to the extraction liquid. The salt helps remove proteins that hold the DNA together, so the DNA is converted into many single strands of DNA.

8 **Tell students that your next step is to remove the broken cells and strawberry pulp from the liquid that contains the DNA. They will do this by filtration. Instruct them to place a cheesecloth into their funnel. Then have them put the funnel into one of the tall (16 oz) plastic cups (Figure 4).**

FIGURE 4. Prepared funnel with cheesecloth for filtering the mashed strawberries.

9 **Let students carefully pour the strawberry mixture from the bag into the funnel. If students struggle with this step, you or the teacher can provide help where needed. Tell students to let it drip through the cheesecloth and into the tall plastic cup until there is very little liquid left in the funnel (only wet pulp remains). Mention that they may need to be patient as it can take some time for the liquid to filter through. Point out to students that they have to make sure to not to let any pulp go around the cheesecloth and end up in the cup below. If this happens, they will need to pour the liquid through the cheesecloth cloth again, into a new plastic cup.**

10 **If your students get impatient or the filtration takes too long, students can also twist the cheesecloth at the top to secure the strawberry mixture inside, and then carefully squeeze the cheesecloth with their fingers as shown in Figure 5. They might need assistance with that step. Be careful that they do not let any pulp into the cup below. If students end up with foam on their filtered strawberry liquid, have them remove the foam with a spoon.**

FIGURE 5. Squeezing the cheesecloth can speed up the filtration process.

11 **Once all the liquid has gone through and only wet strawberry pulp remains in the cheesecloth, ask.**

Where is our strawberry DNA now – in the cheese cloth, or in the solution?

Remind students that the DNA is in the solution. The stuff in the cheese cloth consists of the pulp and the broken cells of the strawberry.

12 **Ask students to discard the cheesecloth with the pulp in the regular trash and then look at the filtered solution more closely.**

How does the filtered strawberry liquid look? Do you see any DNA, yet?

The filtered strawberry liquid should have the same color as before. The liquid should be thinner since the pulp has been removed (see Figure 6). Students should not be able to see any DNA, yet.

FIGURE 6. Filtered strawberry liquid without foam.

Now that we have the DNA strands swimming in the liquid and separated from the pulp, what is the next step to make the DNA visible?

Have one student recall the last step of the extraction procedure which is adding the alcohol to make the DNA come out of the solution.

13 **Have one student from each group come up with a fresh tall (16 oz) plastic cup. Fill each cup with ½ cup of ice cold 70% isopropyl alcohol and have students carry the cups back to their tables.**

14 **Students will need adult assistance for the following step. With the help of an adult, have students tilt the cup with the strawberry liquid and very slowly pour the cold isopropyl alcohol down the side of the cup. The alcohol will form a layer on top of the strawberry liquid. Let students pour until the alcohol layer is approximately the same height as the strawberry liquid. Students may not need all of the ½ cup of alcohol. Tell students that they should NOT let the strawberry liquid and alcohol mix (Figure 7).**

FIGURE 7. The alcohol forms a layer on top of the strawberry liquid. You can see the white gooey strawberry DNA strands in the alcohol layer.

15 **Ask students to study the mixture inside of the cup. The strawberry DNA will appear as gooey clear or white stringy strands.**

Do you see anything in the jar that might be strawberry DNA? If so, where in the cup is it?

When you add the cold rubbing alcohol to the filtered strawberry liquid, the alcohol makes the DNA clump together and come out of the liquid. Students should be able to see white/clear gooey DNA strands in the alcohol layer, as well as between the two layers as shown in Figure 7. Remind students that a single strand of DNA is extremely tiny, too tiny to see with the naked eye, but because the DNA clumps together they are be able to see the DNA of the strawberry.

16 **Tell students to dip the wooden skewer into the cup where the strawberry liquid and alcohol layers meet, and then pull up the skewer (Figure 8). Encourage students to feel the DNA with their fingers.**

Can you spool any DNA onto the skewer? How does it look or feel?

Students should be able to spool some DNA onto the skewer as shown in Figure 8. The DNA looks like white/clear goo and feels a little slimy.

FIGURE 8. The DNA becomes visible as white or clear gooey strands in the alcohol layer, as well as between the two layers.

REFLECT AND WRAP UP

1 **Ask students to share their observations from the experiment. Guide their discussion by asking:**

- *Were you able to get some DNA from the strawberry?*
- *What did the extracted DNA look like?*
- *Did you expect the DNA to look like that?*
- *How were you able to get the DNA out of the strawberry cells?*
- *What was difficult or easy about the extraction experiment?*

Responses might differ between groups. However, the strawberry DNA extraction protocol is usually very robust, so most of the groups should have been able to extract the strawberry DNA successfully. You might want to recount the extraction protocol once more with the help of the students to assess if they have understood the extraction procedure.

2 **Continue the discussion.**

Why would scientists want to extract the DNA, for example, from humans? What would they need it for?

Scientists study DNA for many reasons. For example, scientist at Amgen use DNA to figure out how errors in the DNA instructions can result in a disease. They can also use DNA to make new medicines or modify the DNA to change some of its instructions.

3 **If applicable, give examples of how your work at Amgen is related to DNA, the manipulation of DNA, or diseases caused by DNA mutations. Then conclude the activity by having students summarize what they did and what they learned about cells and DNA. Ideally, they should leave class with the following knowledge:**

- All living organisms are made from cells.
- The DNA inside our cells is the blueprint for how an organism is built and functions.
- DNA can be extracted from the cells of organisms in order to study it.
- Detergent, salt and alcohol are needed for a DNA extraction. Each ingredient has a specific purpose (Table 1).

Cleanup

Pour the alcohol/strawberry liquid mixture down the drain. Ideally, choose a sink in a room that is well ventilated, to avoid inhaling alcohol fumes as you pour. Run plenty of cold water to flush the mixture through the pipes.