DNA Extraction

Learning Objectives: *Students learn about DNA, cell structure, and basic chemical separations.*

GRADE LEVEL

4–8

SCIENCE TOPICS

Solutions and Mixtures
Techniques
Organic and Biochemistry

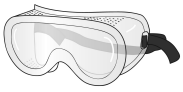
PROCESS SKILLS

Describing and Defining
Explaining
Evaluating

GROUP SIZE

1–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students extract DNA from strawberries.

STUDENT SUPPLIES

see next page for more supplies

strawberries
sealing plastic bags
dish soap
salt
meat tenderizer
isopropyl alcohol, etc.…

ADVANCE PREPARATION

see next page for more details

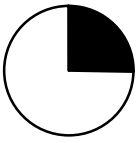
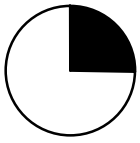
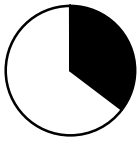
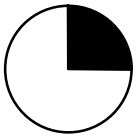
dilute soap
mix tenderizer and salt together, etc.…

OPTIONAL EXTRAS

DEMONSTRATION
Modeling the Procedure (p. C - 22)

EXTENSIONS
Animal DNA (p. C - 29)
Other DNA Sources (p. C - 30)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes the day before	**15 minutes**	**20 minutes**	**15 minutes**

SUPPLIES

Item	Amount Needed
strawberries	1 per group
sealing plastic bags (e.g., Ziploc™)	1 per group
liquid dish soap	½ teaspoon per group
99% isopropyl alcohol (or lower, e.g., 70% rubbing alcohol)	¼ cup per group
meat tenderizer **OR** papaya or pineapple juice	1 tablespoon per class **OR** ¼ cup juice per class
salt	1 tablespoon per class
tall, clear, narrow plastic cups (8 oz. or 12 oz.)	2 per group
plastic spoon	1 per group
pop-top squeeze bottles (e.g., water or sports drink)	1 per group
freezer or bucket of ice	1 per class

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Strawberries:

- Purchase fresh or thawed, green tops on or off.

Isopropyl alcohol:

- 99% isopropyl alcohol is best.
- 90% or 70% (rubbing alcohol) will work also.

CAUTION: Isopropyl alcohol is flammable and poisonous. Keep away from heat and open flames.

Soap solution:

- Dilute liquid dish soap with water: one part soap or detergent to two parts water.
- If possible, leave the soap mixture in a refrigerated place until immediately before use.

Either—meat tenderizer/salt mixture:

- Mix 1 tablespoon salt with 1 tablespoon powdered meat tenderizer in a plastic cup.

Or—papaya or pineapple juice:

- Use 1 cup of fresh, frozen (diluted as directed), or canned juice.
- Make sure juice contains raw, uncooked fruit juice.

Notes and Hints

- Keep the isopropyl alcohol very cold—use the freezer or ice bucket. Give to students as close to the start of the activity as possible.
- Pass out the pinches of meat tenderizer/salt mixture yourself or put the container at a central location for students. In the same way, you may pass out the juice samples yourself or make the juice, with a ⅛ teaspoon measure, available to all the students.
- Tall, narrow cups work best to see the layers of alcohol and strawberry mixture.

SETUP

For each group

- 1 sealing plastic bag
- ¼ cup **cold** isopropyl alcohol in a plastic cup
- 1 strawberry
- ¼ cup soap solution in pop-top squeeze bottle
- 1 teaspoon measure
- 1 clear plastic cup (6 oz. or larger, tall and narrow works best)

At a central location (or with the teacher)

- sponges and towels for clean up
- a bucket of ice or access to a freezer
- **Either—**meat tenderizer/salt mixture (2 tbsp) in a plastic cup
  Or—papaya or pineapple juice (1 cup) in a plastic cup, with
- ⅛ teaspoon measure

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will explore some of these questions by looking at the DNA from strawberries.

What do you think of when you hear the term "DNA"?
Most likely students have heard the term in daily life through newspapers, radio, or television. It may come up in stories related to crime solving, inheriting traits, treatments for disease, or identifying remains after an accident.

What sorts of things have DNA?
All living things have DNA, including plants, animals, fungi, bacteria, etc. Some viruses have DNA. Rocks, water, clouds, and other non-living things do not have DNA.

What characteristics of people does DNA influence?
DNA is in charge of physical attributes like height, hair color, eye color, etc. Dyed hair, colored contacts, tattoos, etc., are not determined by DNA. Things like interests, hobbies, and weight can be influenced by DNA but are also affected by how people grow up. Many scientists are still researching exactly which characteristics of people are determined by DNA and what are influenced by their environment.

Where do people/living things keep their DNA?
Many answers are possible, but students should know that a copy of DNA is kept in each cell in a living organism. Cells are surrounded by protective barriers (cell walls and membranes, see Explanation) that help organize and keep the DNA safe.

If we want to get the DNA out of living things to a place where we can see it, what do we need to do?
The DNA needs to be taken out of the cells. We need to get a source of DNA (i.e., something living), break down its cell walls and membranes, and then separate the DNA out from everything else in the cell. Students do this in this experiment.

What do you think DNA looks like with the naked eye?
Students can draw pictures, or write a sentence or two. The double helix structure might come up, or the "x" like structure of a chromosome. Individual molecules of DNA are too small to see even with microscopes (scientists use X-rays). On the other hand, thousands of strands of DNA all clumped together are visible even to the naked eye.

TEACHER DEMONSTRATION

Modeling the Procedure
For younger students, it is a good idea to model the steps in this reaction, especially layering the alcohol on top of the squished strawberry mixture without letting them mix.

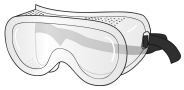
To layer the alcohol, tilt the strawberry cup and pour the alcohol SLOWLY down the side of the cup so it doesn't disturb the mixture. Alcohol and water readily mix together, so take care to pour the alcohol slowly onto the strawberry mixture.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page C - 34, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.



DNA Extraction

SCIENTIFIC PROCEDURE

This handout is on p. C - 34.

1. Place a strawberry in a plastic bag. Close the bag tightly. Smash and squish the strawberry until it forms a smooth paste.
   - What does the strawberry look like?
2. Open the bag.
3. Add one spoonful of the soap mixture into the bag.
4. Add a pinch of the mixture of meat tenderizer and salt into the bag.
5. Close the bag tightly and squish the contents until completely mixed.
   - How has the strawberry mixture changed?

Running Suggestions:

- The colder the alcohol is, the more DNA it will extract. It can be stored in the freezer without freezing solid.
- During the activity, you might pour out ¼ cup of cold alcohol to each group. This is safer than letting students walk around the room with alcohol and also allows the alcohol to stay cold longer.
- Make sure the plastic bag is closed tightly between steps.
- **The hardest step is layering the alcohol.** Make sure students DO NOT pour alcohol directly on top of the strawberry mixture at the bottom of the cup. They should tilt the cup and pour the alcohol SLOWLY so it flows down the side of the cup and floats on top of the strawberry mess. If the alcohol and water layers mix, the DNA will not precipitate out.

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by dirty hands or poisons in the lab.

Ongoing Assessment

- Why do we need to squish the strawberry? (To free the DNA. *Squishing breaks cell walls and releases the contents of the cell.)*
- Does anyone have a guess what the soap and tenderizer is for? *(The soap dissolves the cell and nuclear membranes that protect the DNA. The meat tenderizer and salt help control enzymes in the cells and keep the DNA structurally intact.*)
- Now that we have added soap and tenderizer, we have the DNA out of the cell. Why can't we see it? *(It's still dissolved in the water from the cell.)*

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Caution students to never put lab supplies into their mouths. Even if they are foods, they may be contaminated from other things in the lab.
- Waste isopropyl alcohol should be kept away from all sparks and flames. The small amounts used in this experiment may be poured down the sink drain with lots of water. All other materials can be thrown away as solid waste.

CAUTION: Isopropyl alcohol is flammable and poisonous.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

What happened when you added the alcohol?
Snot, goo, white clumpy stuff, etc., came out of the strawberries and floated on top.

If this is DNA from the strawberries, does it look like what you expected?
Students will have various answers—some may have expected to see double helices or long ropy strands. In fact, people can't see those microscopic features. Instead, the thousands of strands of DNA from the strawberries look like white goo. NOTE: Some of the white, clumpy material may be coagulated protein mixed with the DNA.

Why would scientists want to extract DNA from cells?
This has a large number of answers, such as:

- *To change the DNA. Creating genetically modified foods, for example, could create crops that are resistant to certain pests/insects or that grow larger or faster.*
- *To analyze the DNA. Some diseases are linked to differences in people's DNA, so studying DNA can help scientists find cures and create vaccines.*

- *To identify the DNA. Since everyone has different DNA, it can be used to identify him or her. Forensic scientists, for instance, can identify criminals from DNA samples left at crime scenes. In the same way, biochemists can perform paternity tests or identify people from their remains after accidents.*

Could the DNA we extracted be used to identify or study the strawberries?
Unfortunately, DNA is quite fragile and the methods used in this experiment tend to break it apart. Scientists therefore use special chemicals and procedures to protect DNA. For example, they add chemicals to control the acidity of the solution. Scientists use other chemicals to cut DNA apart very precisely to look at one part at a time. This process can take several days to several weeks—not like on TV!

What other things could we extract the DNA out of?
In principle, scientists can extract the DNA from any living thing, and many spend their careers doing just that. (Students are encouraged to try the other foods mentioned in the Extensions to this activity.)

Note that although any living thing has DNA that can be extracted, the method in this activity is crude and quick and works well for only a few living objects. DNA is fragile and it is difficult to extract a whole DNA molecule (a chromosome) intact. Scientists use other methods to extract DNA from different organisms.

EXPLANATION

This background information is for teachers. Modify and communicate to students as necessary.

In this activity, students extract the DNA from strawberries using only salt, soap, and alcohol. Students may be very surprised at how much DNA is recovered in this simple procedure. Strawberries are used in this activity because they have a lot of DNA that comes out easily and is very visible.

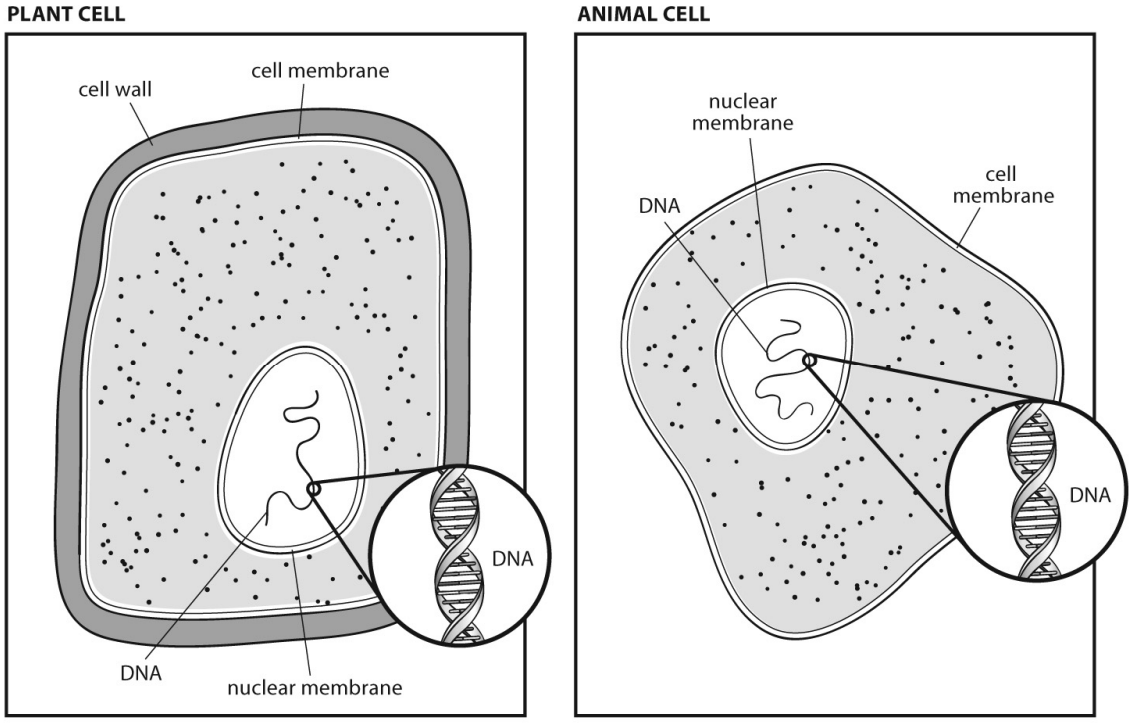
BACKGROUND FOR ALL GRADES:

All living things are made of cells, and each cell contains a molecule called **DNA**. DNA carries the genetic information that determines gender, physical appearance, vulnerability toward disease, and many other parts of who we are. Every cell in our body contains DNA. Even though cells can only be seen under a microscope, an uncoiled piece of DNA can be 2.8 inches (7.2 centimeters) long!

Getting at the DNA
Plant and animal cells store their DNA in the **nucleus**, a small compartment inside each cell that is surrounded and protected by the **nuclear membrane** (see Figure 1 below). A **membrane** is a flexible, thin film that only water and a few special chemicals can pass through. The **cell membrane** surrounds and protects the entire cell. Adding detergent or soap breaks the nuclear and cell membranes, releasing the DNA.

Plant cells, but not animal cells, also have a rigid **cell wall** around the outside of the cell. The students must smash the strawberry in the bag to break the cell walls and expose the membranes inside to the soap or detergent.

Once the DNA has been released, the meat tenderizer (or pineapple or papaya juice) helps untangle and unfold the DNA from the other parts of the cell.



Protecting the DNA
Breaking the nuclear membrane exposes the DNA to reactive and possibly dangerous chemicals in the cell. To slow down these chemical reactions, which might damage or chop up the DNA, students use cold ingredients and add cold alcohol.

Separating Out the DNA
Although it is free to float around, the DNA is still dissolved in water after it escapes the membranes and cell wall. Students add alcohol, which floats on top of the water, to lift the DNA out of the water and to separate it from the rest of the cell debris. Since the DNA does not dissolve in alcohol, it **precipitates** (turns to a solid) in the alcohol layer. It is visible as a kind of white goo.

EXTRA BACKGROUND FOR 6–8 GRADES:

Lipid Structure of Cell Walls and Membranes

In this activity, students add soap to **lyse** (break open) the cell and nuclear membranes and release the DNA. Soap dissolves these membranes because they are basically layers of oil that surround the cell.

In other words, dish soap destroys cell membranes in the same way that it cleans oil off dishes and pans. Cell membranes and oil are both made of molecules called **lipids.** Lipids are large molecules that have two parts: a small, compact **hydrophilic** head and a long, dangling **hydrophobic** tail. (Hydrophilic means attracted to water, and hydrophobic means repelled by water.) In lipids, most of the molecule (the tail) is repelled by water, while the tiny head is attracted to water.

This head and tail structure of lipids allows them to arrange as large, two-layer sheets when they are in water. The sheet structure allows the hydrophilic, water-loving heads to be exposed to the water, while the hydrophobic, water-hating tails can be tucked into the interior of the sheet. The cell and nuclear membranes are such sheets of lipids, each with the water-attracting heads on the outside and the water-repellant tails on the inside.

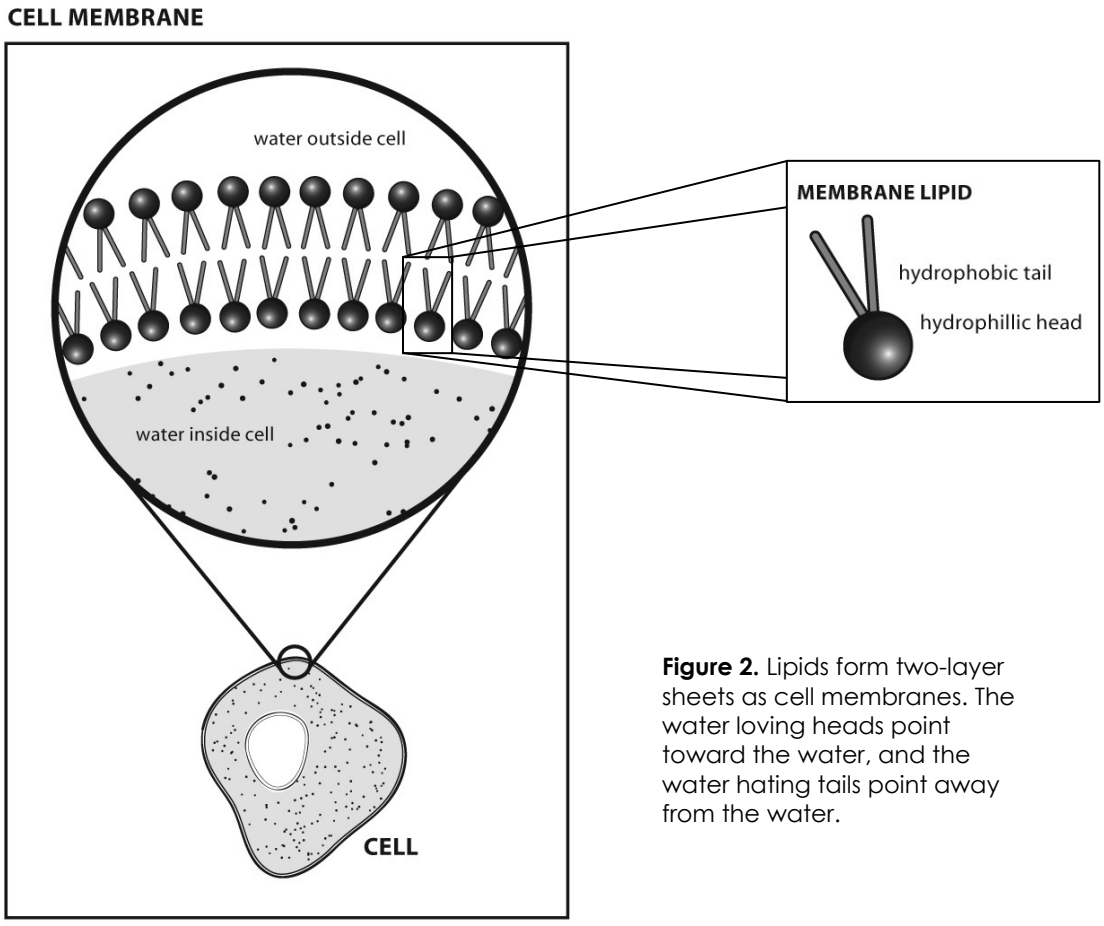


Figure 2. Lipids form two-layer sheets as cell membranes. The water loving heads point toward the water, and the water hating tails point away from the water.

Soap molecules are also lipids, just like the molecules in the membranes, but with one key difference: their hydrophilic, water-loving head is more able to dissolve in water—yet they still have a bit of a hydrophobic, water-hating tail. This means that they are still "lipid enough" to mix with the lipids in the cell membrane, but also "water enough" to mix with the water around the membrane. Because they can mix with lipids and water, soaps and detergents move into the membranes and break them apart into greasy, soapy bubbles (see the picture below).

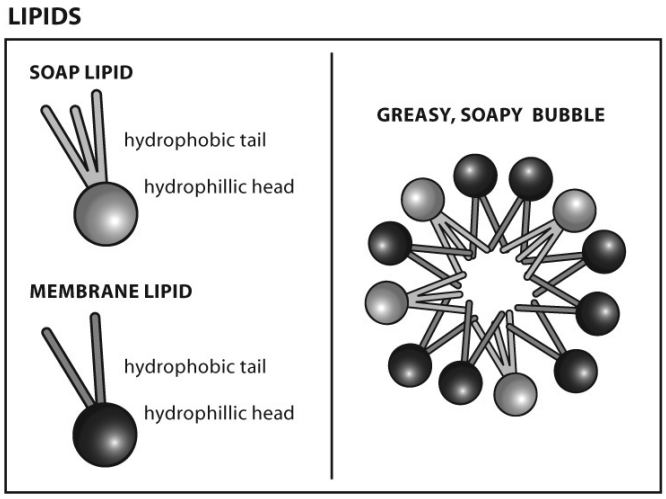


Figure 3. Lipids have two parts: a hydrophobic (water hating) tail and a hydrophilic (water loving) head.

Soaps are lipids and so are the membranes in cells.

Soap lipids are different from membrane lipids because their hydrophilic "heads" are more "water loving" and more able to mix with water.

The membrane lipids and the soap lipids form little droplets with the membrane molecules broken up between soap molecules.

Protecting the DNA

To prevent **viruses** and **bacteria** from invading the cell with their DNA, cells have **enzymes** (called **DNase enzymes**) that chop up any DNA floating around outside the nucleus. Once the strawberry DNA is out of the nucleus, it becomes vulnerable to these enzymes. The students use cold ingredients to protect the DNA from DNases. Since reactions are slower at lower temperatures, using cold alcohol and other cold ingredients slows down the DNase reactions that break down DNA.

Meat tenderizer also helps to protect the DNA. Meat tenderizer contains another two enzymes, **bromelain** and **papain**, which are extracted from pineapples and papayas, respectively. (Pineapple and papaya juice perform the same function in this experiment as meat tenderizer.) When DNA is packaged in the nucleus, it is wound tightly around **proteins**. Bromelain and papain enzymes break down these proteins and release the DNA with minimal breakage.

Separating the DNA
DNA is **soluble** in water, but not in salty water. All the other cell contents are soluble in water and salt water. This difference in solubility allows students to separate DNA from the rest of the cell. Students add salt to the mixture to force the DNA out of the solution of water, strawberries, and soap.

For more information on this process of separating substances according to their solubility, see the activity ***Salting Out***.

DNA is not soluble in alcohol. When the DNA leaves the salty water mixture, it comes into contact with the alcohol and cannot dissolve. When DNA comes in contact with alcohol, it uncoils and **precipitates** (turns into a solid that forms from a liquid solution). All the other cell contents stay in the salty water solution.

Strawberries Have a Lot of DNA
Strawberries are **octoploid**, which means they have eight copies of their genetic material. (As a comparison, humans are **diploid**, since we have two copies of our genetic material.) This large volume of DNA ensures that even if the procedure is not very accurate, or if mistakes are made, enough DNA can still be extracted to be visible.

EXTENSIONS

Extension A: Animal DNA
Extract DNA from animal cells and compare it to the extraction from plant cells.

Extra Supplies
- source of animal DNA (calf liver or thymus work well)—about 1 tablespoon per group
- blender

Extra Instructions
- Use the same procedure as the regular activity, but puree the liver or thymus in a blender just before class. (These items don't squish in bags very well.) Students should receive a strawberry-size amount of the animal source.
- After the procedure, compare the animal DNA to the plant DNA from strawberries. How is it the same and different?

CAUTION: Advise students using these raw meat products to wash their hands thoroughly with soap and warm water after handling them.

Explanation

Animal DNA may separate more cleanly than plant DNA. Plant cells have cell walls, which can separate out in the solution and be visible as a third layer. Because animal cells lack cell walls, this layer doesn't appear.

Extension B: Other DNA Sources
Students can try to extract DNA from other living things using the same procedure as for strawberries.

Extra Supplies
- other sources of DNA (some good ones are: wheat germ, spinach, peas, onions, broccoli, bananas, and zucchini)—use about 1 tablespoon of each per student group. Frozen foods work fine.
- blender—1 per class

Extra Instructions
Follow the same procedure as before but with the following changes:
- Firm sources (wheat germ, broccoli, onions, or zucchini) should be pureed in a blender or food processor immediately before use.
- If possible grind the wheat germ in a coffee grinder first. Then soak in warm water 5–10 minutes before blending.

CROSS-CURRICULAR CONNECTIONS

SOCIAL STUDIES

Genetically Modified Organisms
Find articles about genetically modified organisms (GMOs). What products contain GMOs? What are the advantages and disadvantages to GMOs? Since this is a controversial topic, stress to students the importance of getting scientific summaries and not just information from advocacy groups.

Discovery of DNA's structure
Scientists knew information was somehow stored and passed on between generations but didn't know details. Use one of the books listed in the Resources section to learn about how DNA's structure was discovered.

BIOLOGY

Cell Biology
Discuss the parts of the cell and their functions.
Discuss the differences between animal and plant cells.

RESOURCES

Web – http://learn.genetics.utah.edu/units/activities/extraction/
This site has excellent pictures of the extraction process with diagrams of how detergent breaks apart fats and cell membranes, as well as where in the cell the DNA is stored. The Frequently Asked Questions section has additional information.

Web – http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The *Journal of Chemical Education* publishes online lesson plans for high school students on multiple topics. Under the topic, "Biochemistry," the lesson "Liver and Onions" uses a more complicated procedure to extract DNA.

Balkwill, Frances R., *DNA is Here to Stay*
Reading level: kindergarten to 4th grade
This gives a simple explanation of what DNA is and what it does in the body. This author also writes a series called "Enjoy Your Cells." This book is scientifically accurate and good for all ages.

Walker, Richard, *Genes and DNA*
Reading level: 4th to 8th grade
This book explores modern genetics, from an investigation of genes and their function to forensics, gene therapy, and cloning.

Claybourne, Anna et al., *Usborne Internet Linked Introduction to Genes and DNA*
Reading level: 4th to 8th grade
Beautiful artwork takes you deep inside a cell. This book also explains genetically modified foods, the Human Genome Project, gene therapy, designer babies, and DNA testing.

Watson, James D., *The Double Helix: A Personal Account of the Discovery of the Structure of DNA*
Reading level: 10th to 12th grade
This is an autobiographical account from one of the discoverers of the structure of DNA. Tends to be a bit dramatic.

Maddox, Brenda, Rosalind Franklin: The Dark Lady of DNA
Reading level: 10th to 12th grade
Rosalind Franklin conducted crucial research that led to the discovery of the double helical structure of DNA. Because of her unpublished data and photographs, Francis Crick and James Watson were able to publish their work on the structure of DNA.

VOCABULARY

bacteria: very small organisms each made of just one cell

bromelain: enzyme from pineapples that cuts up proteins

cell membrane: a thin barrier that surrounds the contents of plant and animal cells; provides structure and organization to the cell and controls the passage of water and other chemicals both into and out of the cell

cell wall: the rigid outermost barrier that surrounds the cell membrane; found in all plants and some algae, bacteria, and fungi; absent from all animal cells

diploid: having two copies of genetic material

DNA: **D**eoxy-ribo**N**ucleic **A**cid; a long molecule found in the nucleus of a cell and shaped like a double helix; associated with the transmission of genetic information

DNase: an enzyme that breaks down DNA; "-ase" stands for enzyme

enzyme: complex protein produced by cells; acts to speed up a specific biochemical reaction

hydrophilic: attracted to water; easily absorbs water and dissolves in water

hydrophobic: repelled by water; unable to absorb water or dissolve in water

lipids: group of organic molecules that includes oils, fats, and waxes; lipids, carbohydrates, and proteins make up the main structures of cells

lyse: to break open or split

membrane: a thin film that forms a barrier

nuclear membrane: similar to the cell membrane; surrounds the contents of the nucleus, separating it from the rest of the cell

nucleus: a compartment inside the cell that contains the cell's genetic information

octoploid: having eight copies of genetic material

papain: enzyme from papayas that cuts up proteins

precipitate: to come out of a liquid solution as a solid

proteins: a large, complex biological molecule found throughout the body; hormones, enzymes, and antibodies are all proteins, as are many of the structural parts of the body

soluble: able to dissolve in a particular substance

virus: a simple, small infectious agent made from genetic material with a thin protein coat; cannot live without entering a cell so is not considered living

DNA Extraction

SCIENTIFIC PROCEDURE

1. Place a strawberry in a plastic bag. Close the bag tightly. Smash and squish the strawberry until it forms a smooth paste.
   - What does the strawberry look like?

2. Open the bag.

3. Add one spoonful of the soap mixture into the bag.

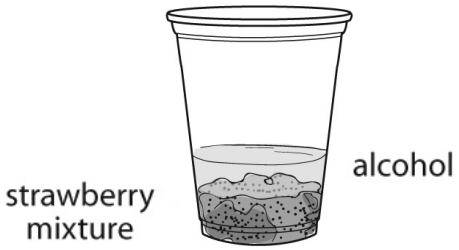
4. Add a pinch of the mixture of meat tenderizer and salt into the bag.

5. Close the bag tightly and squish the contents until completely mixed.
   - How has the strawberry mixture changed?

6. Open the bag and pour the contents into a clear plastic cup.

7. SLOWLY pour alcohol so it runs down the side of the cup and gently floats on top of the strawberry mixture.
   - **You can tilt the strawberry cup to make this easier. Continue to carefully pour until about 1" of alcohol is on top of the strawberry mixture.**

8. Put the cup down and wait 30–60 seconds.
   - What is happening to the strawberry mixture?



9. Clean up your area.
   - Follow your teacher's instructions.

SUPPLY WORKSHEET

This worksheet is available online at **www.omsi.edu/k8chemistry**.

DNA Extraction

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
strawberries	1 per group		
sealing plastic bags (e.g., Ziploc™)	1 per group		
liquid dish soap	½ teaspoon per group		
99% isopropyl alcohol (or lower, e.g., 70% rubbing alcohol)	¼ cup per group		
meat tenderizer **OR** papaya or pineapple juice	1 tablespoon per class **OR** ¼ cup juice per class		
salt	1 tablespoon per class		
tall, clear, narrow plastic cups (8 oz. or 12 oz.)	2 per group		
teaspoon measure	1 per group		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
freezer or bucket of ice	1 per class		
Extension A			
source of animal DNA (calf liver or thymus work well)	½ cup per class		
blender	1 per class		
Extension B			
other sources of DNA (wheat germ, spinach, peas, onions, broccoli, bananas, zucchini)	1–2 cups per class		
blender	1 per class		
Teacher Demonstration			
no extra supplies needed