

Berries...with a side of DNA?

A DNA Extraction Lab for High School

Maryland Loaner Lab Teacher Packet



Written and developed by Towson University.

Berries...with a side of DNA?

Table of Contents

TEACHER MATERIALS

Introduction & Learner Goals	3
Materials and Supplies	5
Facilitation Guide	6
Background Information	8
Laboratory Preparation & Instructions	11
DNA Extraction Steps and Notes	14
Answer Keys to Student Worksheets	15

STUDENT ACTIVITY HANDOUTS AND LABORATORY PROTOCOL

Pre-Laboratory Exploration	S-1	<i>Used in the Pre-laboratory Activity</i>
DNA Model	S-3	<i>Used in the Pre-laboratory Activity</i>
Background Reading	S-5	<i>Used in the Pre-laboratory Activity</i>
Laboratory Activity	S-8	<i>Used in the Laboratory Activity</i>
Steps Activity	S-9	<i>Used in the Laboratory Activity</i>
Post Laboratory Activity	S-11	<i>Used in the Post-Laboratory Activity</i>

APPENDIX

Why Did I...? Extension Activity	A-1
Next Generation Science Standards	A-6
Video and Online Resources	A-9

Berries...with a side of DNA?

Introduction & Learner Goals for Teachers

Towson University's Center for STEM Excellence

Towson University's Center for STEM Excellence (TUCSE) provides three services to educators and students. The Maryland Loaner Lab program develops inquiry-based, student centered, hands-on activities and lab kits aligned with state education standards. Curricula and supplemental resources are available for FREE on our website or by contacting program staff. The SciTech Student Learning Laboratory is housed in Columbus Center in Baltimore's Inner Harbor and offers students the opportunity to experience biotechnology and Bay ecology first-hand in our dedicated student laboratory led by an expert instructor. TUCSE's Professional Development opportunities allow educators to expand their knowledge and experience in areas such as biotechnology, lab activities for students, Next Generation Science Standards and other areas. Please visit www.towson.edu/cse for more information or to register for any of our programs.

Overview

All living things are made of cells, and with the exception of mammalian red blood cells, all cells contain DNA. *Berries...with a side of DNA?* invites students to explore cell structure and the presence of DNA in living cells, especially in the cells of foods we eat.

This activity is divided into three parts, a **pre-laboratory**, a **laboratory** exercise, and a **post laboratory** activity. The pre-laboratory exercise encourages engagement by asking students, "What is DNA?" and then asking students to build models of DNA. The introductory activities include a short video which introduces cell theory and some cell structures to students, and concludes with students reading an article and problem-solving ways to work through the challenges encountered in extracting DNA. The laboratory exercise begins with students extending their problem-solving ideas by correctly ordering the steps involved in DNA extraction. The actual laboratory activity allows students to determine if DNA is in the food we eat by attempting to extract DNA from foods such as strawberries, onions, and bananas. The post laboratory activity asks students to analyze and interpret their data, then construct an explanation using a Claim-Evidence-Reasoning framework.

Inquiry based instruction promotes exploration before explanation, encourages greater student engagement, and facilitates depth of learning. Inquiry based instruction incorporates a student-centered, student-driven approach to teaching. This **structured inquiry** lab activity provides support for students new to inquiry or new to developing lab procedures while still encouraging them to explore and inquire early in this learning experience. Instead of following a list of numbered steps to complete the lab, students are asked to read a series of un-numbered steps and use reasoning skills to put the steps in the appropriate sequence before completing the investigation.

Investigation Design

This lab investigation encourages students to review the basic elements of investigation design. In traditional laboratory experiments, scientists manipulate **independent variables** to determine the effects on the **dependent variables**. Other elements of the experiment remain consistent, and are termed "**constants**". However, scientists need a reference point to compare their results. Specifically,

Berries...with a side of DNA?

Introduction & Learner Goals for Teachers

they need to know what a “negative” result looks like and how it compares to a “positive” result.

Controls serve as points of comparison for the investigation. In this investigation, a positive control shows what the sample will look like if DNA is extracted and isolated from the sample while the negative control lacks DNA.

Food Samples

Foods like strawberries, bananas, kiwis, raspberries, and onions work particularly well in this lab. DNA can be isolated and extracted from other foods such as meats, other produce, and even processed foods such as corn chips and crackers. Teachers and classes can choose to attempt isolations from a variety of foods, but the suggested produce is recommended because they provide reliable results with a high volume of DNA.

***Berries...with a side of DNA?* Learning Goals:**

1. Use a model to understand that nucleotides sequences in DNA determine the proteins translated, and that differences in the sequence can lead to difference in the proteins. (Pre-lab, Post-Lab Extension activities)
2. Use a model to understand the structure and function of DNA. (Pre-lab, Post-Lab Extension activities)
3. Plan and carry out a laboratory investigation to determine if cells, including cells in our food, have DNA in them. (Pre-lab and Laboratory)
4. Analyze and interpret data collected during an investigation on DNA extraction from food. (Laboratory activity)
5. Construct an explanation using evidence collected during an investigation to answer the driving question, does our food contain DNA? (Laboratory activity/Post Lab)

Thank you for using Maryland Loaner Lab’s *Berries...with a side of DNA?* in your classroom! We sincerely hope you and your students enjoy this lab activity!

Berries...with a side of DNA?

Materials and Supplies for Teachers

SAFETY: The classroom teacher must instruct students with basic laboratory safety rules and provide gloves and goggles for student use with the laboratory activity.

Supplied by the Teacher:

Description	Quantity	Comments
Fruit/Vegetable	varies	Per student group - ½ of a medium or large strawberry, ½-inch slice of banana, ¼ of a kiwi or the equivalent
Isopropyl or Ethyl Alcohol (70%)	80 ml per class	8 ml per group. Best if used chilled. Note: 70% isopropyl or ethyl alcohol will work, but 90% is preferred.
Zip-lock bag	10	1 for each group to prepare experimental sample
Distilled H ₂ O	90 ml/class	9 ml/lab station

The teacher must ALSO supply all of the materials for all non-lab activities associated with this investigation.

Contained in the Maryland Loaner Lab kit:

Description	Quantity	Comments	Must be Returned
Pipette pumps	10	Pump used with pipettes to measure liquids	Return
Plastic pipettes: -10 "DNA Buffer" -10 "Alcohol" -10 "Experimental" -10 "dH ₂ O"	40	Size: 10 ml; Each student group needs 4 pipettes – one of each	Discard
DNA Buffer	10 tubes	8 ml per "DNA Buffer" tube, 1 for each group	Discard
Empty 15 ml "alcohol" tubes	10 tubes	Fill with 8 ml of alcohol, 1 for each group	Discard
Empty distilled water (dH ₂ O) tubes	10 tubes	10 ml per tube, 1 for each group	Discard
Wooden sticks	10	1 for each group	Return unused only
Strainers	10	1 for each group	Clean, dry and return
Styrofoam racks	10	1 per group	Return
Test tubes	30	(empty tubes) 1-2 for food sample, 1 "-" for negative control and 1 "+" for the salmon cell positive control	Clean, dry and return
Container Disinfectant Wipes	1		Return
Sharpies	10	1 for each group	Return
Salmon cells for positive control	2 tubes	Each group gets 2 ml in "+" tube (Keep refrigerated)	Discard
Plastic 250 ml beakers	10	1 for each group	Clean, dry and return

Berries...with a side of DNA?

Facilitation Guide for Teachers

A PowerPoint presentation on DNA Extraction to support this activity is available on the Maryland Loaner Lab page (<https://www.towson.edu/fcsm/centers/stem/loanerlab/index.html>).

Pre-laboratory Activity – 40 minutes (Engage and Explore):

1. Ask students some questions to engage thinking about DNA, such as “What is DNA?” “What does it do?” “Where is it found?”
2. *Exploration “What is DNA?”:* Tell students they’ll begin their exploration with the shape and structure of DNA. Have students construct a simple paper model of DNA. Depending on their understanding of DNA structure, students may initially pair the DNA bases based on the shapes of the images, then add the appropriate labels after watching the video in Step 3. Or, students can label the bases as they construct the model and correct the models as they watch the video.
3. *Exploration “What does DNA do?”* Have students watch the video (<https://www.youtube.com/watch?v=zwiBgNGe4aY>) and answer the questions. The two primary goals of this section is to a) connect the function of DNA to protein production and b) connect different nucleotide sequences result in different proteins. There is an extension activity which further explores and explains protein translation.
4. *Exploration “Where is DNA found?”* Make sure the students recognize the cell layers between DNA and the outside of the cell.
5. *Background Reading:* This step sets students up for the driving question, “Is DNA in our food?” First, ask where students find cells and DNA. Then have students read the background reading and brainstorm ways to get through the cell layers to extract DNA.
6. The Background Reading ends with a brief discussion about hypotheses and controls. Students are asked to write a hypothesis and identify a positive control (beef or salmon cells) and a negative control (distilled water) before moving on to the Laboratory Activity.

Lab Activity – 20 min plus 40 min for lab procedure (Explore):

7. Distribute the Laboratory Activity with a chart to write in the sequenced steps and invite students to review their hypotheses or predictions. Students should copy their prediction/hypothesis in the space provided at the top of the Laboratory Activity Worksheet.
8. Tell students that Dr. Meischer left his protocol for them to use, but that the students will need to figure out the order. Before class, print pages S-8 and S-9. Ask students to cut out the steps on page S-9 (they are out of order on page S-9) and then paste those strips in the correct sequence in the chart on page S-8. (Hint: have them think about what they read about with critical pieces for DNA extraction consideration).
9. Teachers may choose to confirm that the class has the strips in order or proceed with the students using the order they determined.

Berries...with a side of DNA?

Facilitation Guide for Teachers

10. Move through the steps of the procedure. Each group of students should use one fruit. Fruit can be frozen and thawed or fresh. Strawberries, bananas, kiwis, and raspberries work very well. Students can also try other fruits and vegetables if you choose.

Post Lab – 15 min (Explain):

11. The post-lab consists of a Claim-Evidence-Reasoning (CER) chart and follow up questions to assist students in arguing with the evidence.

The CER is a claim-evidence-reasoning chart. For this piece, students should answer the question “Does food have DNA in it?” as the claim statement. They then use evidence from their investigation to support their claim. They must then provide the reasoning for how their evidence supports the claim. Many students find making the claim and finding the evidence relatively easy, but students may struggle with the reasoning piece. Alternatively, the post lab questions 1-3 also serve to have students answer the question and provide the evidence and reasoning for their answers.

Extension Activities – time varies with activity:

12. Students can explore transcription and translation using a modeling activity such as that written by Lynn Marie Wartski (<https://migrc.org/Resources/ViewResource.aspx?rid=665>) or this online activity by University of Utah (<http://learn.genetics.utah.edu/content/molecules/transcribe/>).
13. Students can explore DNA sequencing activities, such as this one available through PBS (http://www.pbslearningmedia.org/asset/biot09_int_dnasequencing/).
14. Students can complete the Why Did I...? papers. Ask students to connect the lab procedures to the cell structures or DNA characteristics encountered during DNA extraction. These papers can be completed during the five minute wait period during the lab procedures or any point after the lab. Resources are available in the Extension Activity section.

Berries...with a side of DNA?

Background Information for Teachers

Cells form the basic unit of life. Living things may consist of a single cell or a collection of many cells organized into tissues, organs and organ systems that function together to form a multicellular organism. Bacteria and some fungi, such as yeast, are unicellular. Plants, animals, and other fungi like mushrooms are all multicellular. Organisms are classified into two very broad categories depending on cell type. **Prokaryotic** cells are smaller, simpler cells with circular DNA that is not contained in a nucleus. Prokaryotes lack membrane-bound organelles and are frequently unicellular. Larger, more complex cells which contain a nucleus and other membrane-bound organelles are **eukaryotic** cells. Plants, animals, and fungi are all eukaryotic organisms.

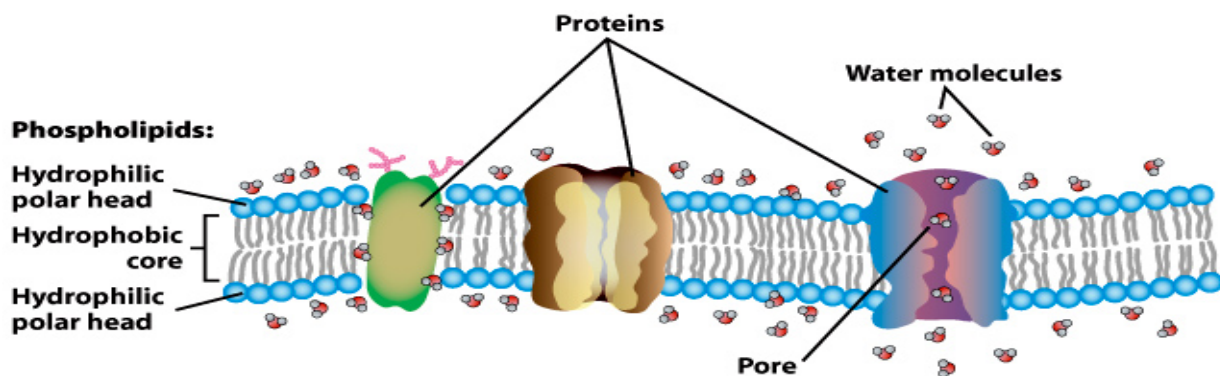
While significant differences exist between prokaryotic and eukaryotic cell structures, both cell types meet all of the requirements for the characteristics of life. Both contain the three primary parts of a cell. These three primary parts are

- **Cell membrane**, which serves as the barrier separating the cell from the outside world, regulates substances entering and leaving the cell, and communicates between the cell and the outside world.
- **Cytoplasm**, a jelly-like substance which fills the interior of the cell, and contains organelles and/or cell structures and dissolved substances necessary for cell functioning.
- **Deoxyribonucleic acid** or **DNA** is the genetic material that controls everything that happens in a cell.

Cell Membrane

The cell membrane consists of a phospholipid bilayer with proteins embedded in and on the surface of the membrane. Each phospholipid consists of a hydrophilic (polar, water-loving) head and a hydrophobic (non-polar, water-fearing) tail region. The hydrophobic tails orient towards each other to avoid the highly aqueous environment found in organisms. The embedded proteins serve broad purposes. They can be cellular markers to identify the cell type, channels which regulate entry and exit of substances across the membrane, or receptors which bind to chemicals outside the cell to communicate external environmental conditions to the cell.

Eukaryotic cells also have a nuclear membrane. The nuclear membrane has the same basic structure as the cell membrane, but instead regulates what enters and leaves the nucleus. This provides an extra layer of protection for the eukaryotic cell's genetic material.



www.rise.duke.edu

Berries...with a side of DNA?

Background Information for Teachers

Cytoplasm

All cells have a jelly-like substance called cytoplasm which fills the cell and suspends internal structures in the cell. Cytoplasm is highly aqueous with a water concentration of 65-95% depending on a variety of factors. Proteins, fat droplets, solid inclusions and dissolved substances necessary for cellular growth and functioning comprise the rest of cytoplasm's content.

DNA

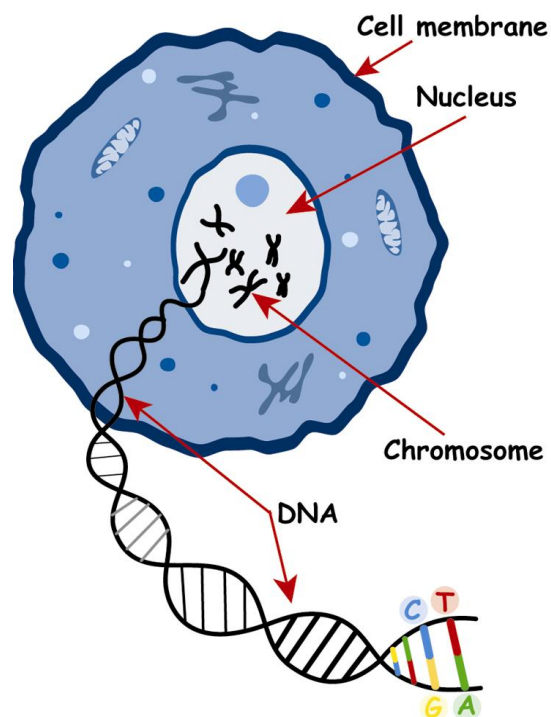
DNA is the largest known molecule. A single unbroken strand can contain millions of atoms. DNA is made of two strands that wind around each other like a twisted ladder. The rungs of the ladder are made of the four nucleotides adenine (A), thymine (T), guanine (G) and cytosine (C). These nucleotides pair together, A-T and C-G. Different organisms have different sequences of these four nucleotides, but the pairings are consistent across all living things. The nucleotides "spell" out different genes, which are instructions to make particular proteins. Genes are organized on chromosomes; all of the chromosomes in a cell make up the organism's genome.

DNA determines which proteins are made and directs all activities in the cell. Therefore, it also directs the entire multicellular organism. Prokaryotic cells possess a region of the cytoplasm called a nucleoid where the DNA is found. The nucleoid is not separated from the surrounding cytoplasm by a nucleus. In contrast, eukaryotic cells have a membrane-bound nucleus which contains the genetic information. This nucleus is generally found near the center of the cell, surrounded by cytoplasm.

DNA is found in all living cells except for mature mammalian red blood cells. During the maturation process, mammalian red blood cells lose their nucleus in order to accommodate a larger area for carrying hemoglobin for oxygen and carbon dioxide transport.

Isolating and Extracting DNA

Because DNA is essential in cells, it is not surprising that cells evolved ways to protect the genetic material. The process of extracting and isolating DNA requires that it be released from the cell. All cells have a cell membrane. Plant cells have an extra protective layer surrounding them called the cell wall. Mechanical destruction of the cell wall will readily remove it. Detergents and soaps break down cell membranes and proteins so that the DNA can be released. Protein enzymes of **proteases** like those in contact lens cleaner or "Ultra" forms of laundry detergents can be used to degrade proteins in cells and cell membranes.



2002 Mary S. Gibbs

Berries...with a side of DNA?

Background Information for Teachers

When DNA is released from a cell it typically breaks into tiny fragments. These tiny fragments have a slightly negative electric charge. Salt ions, common in many solutions, are attracted to the negative charges of the DNA fragments and prevent them from adhering to one another. By controlling the salt concentration of the solution containing the DNA fragments, DNA can remain fragmented or become very “sticky” and form large globs of molecular material.

Once the DNA fragments are released into solution, the DNA can be spooled together by using ice-cold alcohol. A small layer of alcohol is added to the top of the solution containing cellular fragments. The DNA will collect at the interface between the alcohol and the cell solution. The DNA can then be captured or spooled onto a wooden stick or glass rod. The alcohol allows the DNA fragments to stick together once again and you have a blob of DNA to examine. Although this method is effective at isolating DNA, the DNA is by no means pure. Other materials like protein and cell fragments are carried along. Additional steps can be completed to remove proteins and cellular debris, thereby purifying the isolated DNA. DNA purification steps are not a part of this lab.

Berries...with a side of DNA?

Laboratory Preparation & Instructions for Teacher

Prepare Student Stations (10):

- 3 empty, unlabeled test tubes
- 3 labeled 15 ml tubes with the following:
 - DNA Buffer: 8 ml
 - Distilled Water (dH₂O): 10 ml
 - Alcohol: 8ml
- Plastic pipettes labelled “DNA Buffer”, “Alcohol”, “Food”, and “dH₂O”
- 1 pipette pump
- Fruit/vegetable sample
- 1 zip-lock bag
- 1 250 ml plastic beaker
- 1 strainer
- 1 wooden stick
- 1 test tube rack

Preparing Food Samples (fruit/vegetable): Fruits that work the best are strawberries, raspberries, kiwis or bananas. Soft, ripe fruit will give the best results. While the activity directs the students to prepare the fruit/vegetable solution, the teacher may prepare this in advance if there is a time constraint.

Provide the students with one of the following: ½ of a medium to large strawberry, ½-inch slice of banana, ¼ of a kiwi, or an equivalent amount of the fruit of your choice. Make sure students remove all of the air from the zip-lock bag while fruit is being crushed and mixed well with distilled water and DNA buffer. A mortar and pestle can be used instead of a zip-lock bag. **Make sure the fruit is well mashed;** you really want a fruit pulp liquid without solid chunks. Students will pour off ONLY the liquid (no solid parts) into a small beaker or cup (this mixture could be filtered through two layers of cheesecloth in a funnel if desired). Students will label one unmarked test tube “E”, then pipette 2 ml of this liquid into the “E” tube while trying to avoid seeds and/or solid pieces of fruit.

Negative Control: Distilled Water

Students will mark one unmarked test tube “-” and will be used for the negative control. Each student group will pipette 2 ml of distilled water into their negative DNA control tube.

Positive DNA Control Sample: Salmon Sperm Cells

The Maryland Loaner Lab will provide teachers with a salmon cell solution. Two capped conical tubes will contain approximately 15 ml of salmon cells. This will be used by the students as a positive control (keep refrigerated until ready to use). The teacher will add 2 ml of the salmon cells to 10 unmarked test tubes (1/student group). Students should label this positive control tube with a “+” at the beginning of the lab period.

Your MDLL kit provides enough salmon solution and buffer for the number of class sets indicated on your reservation. The following directions are provided in the event that you would like to run an additional positive control or need additional buffer.

Berries...with a side of DNA?

Laboratory Preparation & Instructions for Teacher

Salmon cell substitutions:

Place four one-inch cubes of calf thymus or beef liver in a blender. Add 90 ml of DNA Buffer and 210 ml of dH₂O and blend until the mixture is almost smooth. This step breaks apart the sample; the smoother the mixture, the better the DNA isolation results.

DNA Buffer:

Add the following into the dH₂O and stir well.

- 5 ml dishwashing liquid (Palmolive™ is recommended)
- 1.5 g salt (NaCl, non-iodized)
- 5 g baking soda (NaHCO₃)
- 120 ml distilled water (dH₂O), available at most grocery stores

DNA Isolation

The students will add 1 ml of DNA buffer to each food sample and to each control tube. Mix the contents well by “flicking” the tubes 2 or 3 times.

When adding the 2 ml of alcohol, pipette it slowly down the side of each test tube to form a layer that floats on top of the sample. It is best to add the alcohol while the tube is held at a slight angle. **DO NOT MIX OR INVERT THE TUBES** after adding alcohol. Gently place tubes in rack.

If there is DNA present in any of the samples, it should precipitate out at the interface between the two layers. Look for white or clear clumps; it may look like cobwebs or threads. There are often bubbles attached to the DNA. Students may use the wooded stick to spool the DNA clumps and place them on black paper for observation.

Results and Analysis

The students should record their observations after each step and their results. All produce samples should contain DNA. The salmon cells or beef liver extract sample should contain DNA and serve as the positive control. The distilled water sample should not contain DNA and is the negative control.

Students should refer to the initial investigative question and use the data collected from the lab to answer the question. A Claim-Evidence-Reasoning worksheet and follow up questions are provided in the post-lab to assist students with analyzing and interpreting their results. Have the students answer the investigation question, and ask them to consider if other foods would also contain DNA and why or why not.

Helpful Hints on using a Pipette Pump:

Secure the plastic pipette into the pump by using a pushing and twisting motion. Use the wheel to draw liquid into the pipette by rolling it forward; reverse the wheel's direction to expel the liquid. Always hold the pipettes upright when attached to the pump to prevent contamination and volume loss.

The 10 ml plastic pipettes have two scales on them, which run in opposite directions. When measuring liquid, use the scale that has the “1 ml” at the bottom of the tip and “10 ml” at the top. Also make sure

Berries...with a side of DNA?

Laboratory Preparation & Instructions for Teacher

to use the bottom of the meniscus (the curved part of the liquid in the pipette) to determine the volume level.

When transferring liquid, make sure the container you are transferring the liquid into is physically close to the container from which you are extracting the liquid. Liquids will sometimes drip out of the pipette tip, so the transfer must take place quickly.

The labeled pipettes should be used only with the corresponding liquids (they can be reused with the same liquid only), otherwise the pipettes and samples risk contamination and inaccurate results may be obtained. To further prevent contamination, the tip of the pipette should not touch the inside of the tubes when expelling liquid.

Berries...with a side of DNA?

Laboratory Preparation & Instructions for Teacher

This steps sheet is for the teacher's use and should not be photocopied and distributed to students. This is the correct sequence for the steps that the students sort in the pre-lab activity. Teacher notes follow each step.

Step Number	Lab Step	Teacher Notes
1	<ul style="list-style-type: none">-Label one empty test tube “-“, and the other one “E”.-Put the experimental sample in the zip-lock bag- Add 7ml of “dH₂O” (distilled water) to the bag.	Fruit samples can be frozen and thawed. Softer, ripe fruits work well.
2	<ul style="list-style-type: none">- Use a clean pipette and add 3mL of DNA Buffer to the bag.- Remove the air from the bag and seal it.	
3	<ul style="list-style-type: none">- Keeping the bag closed, gently mash up the food sample with the water and DNA buffer.	Students are often enthusiastic about mashing their fruit samples. Remind them to mash carefully or the bag may break.
4	<ul style="list-style-type: none">- Carefully open the bag and pour off all of the liquid into the cup or beaker. Avoid getting any food chunks in the cup.	Use the strainers to catch solids left after mashing the fruit.
5	<ul style="list-style-type: none">- Use a clean pipette to transfer 2 ml of food liquid from the cup or beaker to a clean test tube marked “E” for experimental sample.	
6	<ul style="list-style-type: none">- Transfer 2 ml of “dH₂O” to a test tube and mark it “-“.- Note that 2 ml of positive control are already in the test tube. Mark it “+“.	Students will need to pipette the dH ₂ O into the positive control. The teacher should aliquot the negative control prior to class.
7	<ul style="list-style-type: none">- Use a clean pipette to add 1 ml of DNA buffer to each test tube (food sample and both controls).- Mix gently by “flicking” them.- Wait 5 minutes.	
8	<ul style="list-style-type: none">-After 5 minutes, slowly pipette 2 ml of alcohol into each test tube. Do NOT mix the test tubes. Watch for formation of a white or cloudy substance.	Add the alcohol gently so it does not mix with the bottom layer. Cold alcohol works best, but room temperature will also work.

Answer Keys to Student Worksheets

Today we are going to investigate the questions below! What do you already know about these questions?

What does DNA do?

What is DNA?

Where is DNA found?

Exploration: What is DNA?

DNA Modeling Activity. Complete the modeling activity then use your model to answer the questions below.

1. Name the bases in DNA.
Adenine (A), Guanine (G), Cytosine (C), Thymine (T)
2. How do the bases pair? Is there flexibility in how they pair?
No flexibility in how they pair. In DNA, A must always pair with T and C must always pair with G. RNA lacks T, so A pairs with Uracil (U) and C still pairs with G.
3. Why are the “rungs” of the ladder equal in length?
In each base pair, one of pairs is a pyrimidine and the other is a purine. So the total length of the “rung” is always the same.
4. DNA is double stranded and the two strands are said to be “antiparallel”. Look at the phosphate-sugar backbone of your model. How is DNA antiparallel?
One side of the structures starts with a phosphate group and ends with a sugar group. The parallel strand is opposite, so starts with a sugar group and ends with a phosphate group. One side is labeled as running from the 5' to the 3' and the parallel strand runs 3' to 5'. Hence, antiparallel.
5. DNA in a cell is actually in a helical shape. How can you make your model helical?
Twist the model so it become helical.
6. What limits exist in your model?
Answers will vary. For example, some answers might include the following:
 - Once glued together, you can't separate it to illustrate transcription or replication.
 - The model consists of only a few nucleotides and real DNA includes many, many base pairs.
 - The helical twist isn't truly in our model, and twisting might not produce an even twist, like in real DNA.
 - The DNA model doesn't have any other organization features like histones.

Answer Keys to Student Worksheets

Exploration: What does DNA do?

DNA controls the cell and provides all instructions for the cell's functioning. How does it do this? Check out this video to learn more about DNA, what it does, and how it connects to proteins (<https://www.youtube.com/watch?v=zwiBgNGe4aY>).

After watching the video,

- Use symbols like arrows and equal signs to connect the terms below. The flow of information described by these three terms is called the Central Dogma in biology and is retained in all domains and kingdoms of living organisms.

DNA → **mRNA** → **protein**

- Refer back to your DNA model. Compare your model to the other models built by people around you. Are the nucleotides in the same order? If the nucleotide order changes, what else would change if the cell transcribed then translated this section of DNA? Why?

Nucleotides will probably not be in the same order. If the nucleotide order changes, then the transcribed RNA will also change, and this can change the protein that's made by this section of DNA.

Exploration: Where is DNA found?

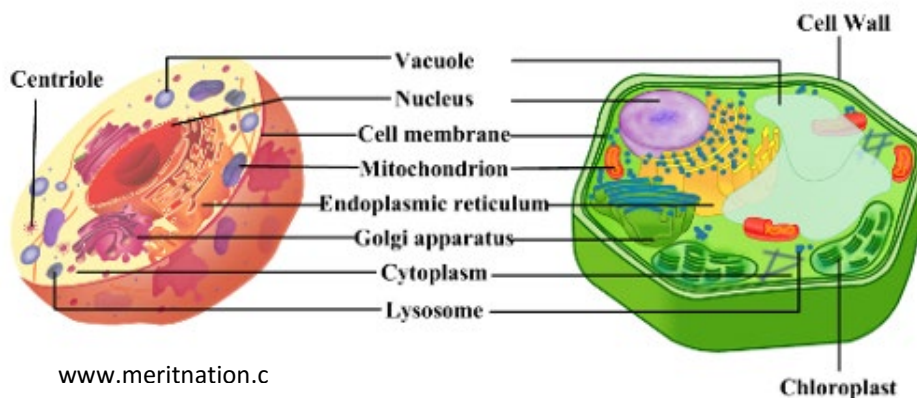
Based on its role in the cell, it is safe to say that DNA is very important to the cell! In fact, the DNA determines the type of cell and the things that particular cell can do! DNA is so important that cells have evolved ways to protect the DNA while keeping it available for it to function.

- Where would you find DNA in each cell below?

In the nucleus

- What are the layers you'd need to go through if you wanted to access the DNA?

For both, cell and nuclear membranes and cytoplasm. Plants also have a cell wall.



Answer Keys to Student Worksheets

Let's try to find DNA! Questions to consider as we try to find DNA: Do all cells have DNA? Do all organisms have DNA? Where could we find samples of DNA?

Driving question:

Does food have DNA in it?

Background Information: Back in 1869, Johann Friedrich Meischer developed a way to extract DNA from cells. He tested his procedures on salmon and beef cells and successfully extracted DNA. To extract DNA, scientists must break up each of the protective layers of the cell and carefully pull out the DNA hidden inside the nucleus. Each step of the extraction process either breaks up one of the layers or works with DNA to make it condensed, so the DNA is visible and thick enough to recover from the cell. It is kind of like a miniature mining mission!

Below are some considerations about extracting DNA from cells.

1. Plant cells have an extra layer on them that animal cells lack. This extra layer, called a cell wall, is a hard surface that helps protect the cell and maintain its shape. This layer must be broken down, but even in cells without a wall, the cells must be broken open so the inside contents are accessible. (See Figure 1.)

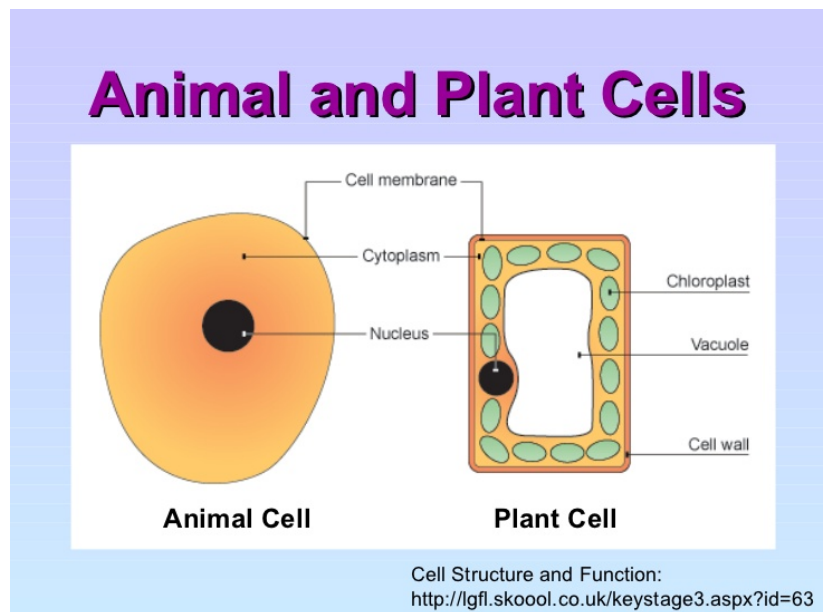


Figure 1. Which structures are common to both plants and animal cells? Which are only found in plant cells?

Question: How could you get through the cell wall?

Answers will vary, but students should recognize that they need to mechanically break up the cell wall for plant cells.

Answer Keys to Student Worksheets

2. All cells have cell membranes. Membranes serve as a gateway for molecules leaving and entering the cells, and for communicating with the world outside of the cell. The membrane consist primarily of a double layer many molecules called phospholipids. The heads of the phospholipids are hydrophilic and associate with water. The tails of each phospholipid are hydrophobic and avoid water, instead associating with oils. Detergents consist of molecules which resemble a phospholipid. Detergents break up the phospholipid bilayer and disrupt the membrane. (See Figure 2).

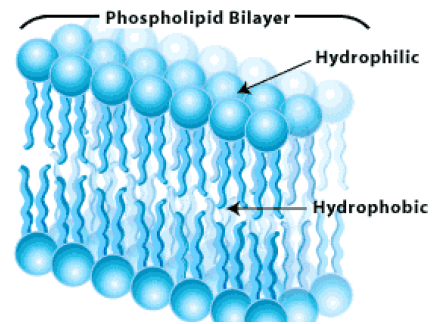


Figure 2. Why are the hydrophilic heads facing outside of the cell membrane?

Question: How could you get through the cell membrane?

Students should recognize that adding detergents would disrupt membranes.

3. Cells contain DNA, protein, carbohydrates, and other components. Successfully extracting the DNA means that the DNA is separated from the other cell components. Dr. Meischer discovered that adding salt to a mixture of DNA and cellular components causes the components to clump together and sink to the bottom of the test tube. DNA remains in suspension (stays in the liquid) until exposed to alcohol. (See Figure 3.)



Figure 3. The white or cloudy substance is DNA in the alcohol layer floating above an extract.

Question: Do you think you could add salt and alcohol in the same steps or in different steps? If you added them in different steps, which would you add first?

Students should recognize that salt must be added first, and alcohol second in order to make this work correctly. Our DNA buffer includes both salt and detergent.

Answer Keys to Student Worksheets

YOUR Investigation:

After learning about their research topic, scientists make a prediction or **hypothesis** about what they think will happen in their experiment. Since you are a scientist investigating DNA in food, write your prediction or hypothesis about the presence of DNA in the food samples your class will test.

Answers will vary.

Experimental Design:

In order to know if you successfully extracted DNA, you'll want to compare your results to a known sample. You'll also want to know what it looks like if DNA is NOT successfully extracted. **Controls** are samples you run with known results. For example, your positive control will have DNA in it and your negative control will not have DNA in it. You do all of the same steps with your controls as you do with your **experimental samples** (the food you are testing for DNA).

What could you use as a negative control?

Distilled water because water is not living, so does not consist of cells nor contain DNA.

What could you use as a positive control?

Since Dr. Meischer used salmon and beef cells to test his protocol and successfully extracted DNA from both, we could use salmon or beef cells as our positive control.

Answer Keys to Student Worksheets

Answers will vary. This is a possible answer for students.

Driving Question: *Does food have DNA in it?*

Claim (answer the question): *All foods may have DNA in them, but fruit and meat does have DNA in it.*

Evidence (What did you see in the lab to support your claim?):

DNA was successfully extracted from several fruit samples including strawberries, kiwi, and raspberries. DNA was also extracted from salmon cells in our lab and beef cells from Dr. Meischer's lab. We saw a white, cloudy substance in each of the test tubes with fruit or animal-based samples, and this substance was DNA. This is the evidence we have to support the claim.

Reasoning (Why does this evidence support this claim?):

We learned in our reading and videos that all living things are made of cells, and cells contain DNA. Therefore, food which was once living is made of cells and should contain DNA. The foods we tested were once living and are made of cells, and we successfully extracted the DNA, demonstrating that the DNA is still present in these foods when we would eat them. We did not test all foods, such as processed foods and fungi (mushrooms), so we cannot be certain if ALL foods contain DNA.

Questions: After completing the lab activity answer the following questions.

1. Did you successfully extract DNA from your sample? How did you know?

Yes, we saw the white, cloudy substance in the alcohol layer.

2. Did your investigation today support that ALL of the food you eat has DNA in it? Why or why not?

We can hypothesize that all foods that were once living contain DNA because so far, all food that was once living has had DNA in it. However, we did not test processed foods or mushrooms or vegetables, so we might want to test those before we can say that all foods contain DNA.

Pre-Laboratory Activity

Today we are going to investigate the questions below! What do you already know about these questions?

What does DNA do?

What is DNA?

Where is DNA found?

Exploration: What is DNA?

DNA Modeling Activity. Complete the modeling activity then use your model to answer the questions below.

11. Name the bases in DNA.
12. How do the bases pair? Is there flexibility in how they pair?
13. Why are the “rungs” of the ladder equal in length?
14. DNA is double stranded and the two strands are said to be “antiparallel”. Look at the phosphate-sugar backbone of your model. How is DNA antiparallel?
15. DNA in a cell is actually in a helical shape. How can you make your model helical?
16. What limits exist in your model?

Pre-Laboratory Activity

Exploration: What does DNA do?

DNA controls the cell and provides all instructions for the cell's functioning. How does it do this? Check out this video to learn more about DNA, what it does, and how it connects to proteins

(<https://www.youtube.com/watch?v=zwibgNGe4aY>).

After watching the video,

17. Use symbols like arrows and equal signs to connect the terms below. The flow of information described by these three terms is called the Central Dogma in biology and is retained in all domains and kingdoms of living organisms.

DNA

mRNA

protein

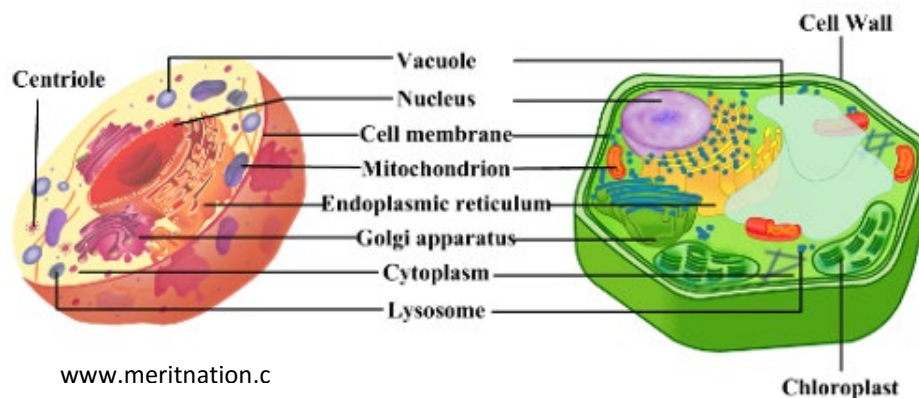
18. Refer back to your DNA model. Compare your model to the other models built by people around you. Are the nucleotides in the same order? If the nucleotide order changes, what else would change if the cell transcribed then translated this section of DNA? Why?

Exploration: Where is DNA found?

Based on its role in the cell, it is safe to say that DNA is very important to the cell! In fact, the DNA determines the type of cell and the things that particular cell can do! DNA is so important that cells have evolved ways to protect the DNA while keeping it available for it to function.

19. Where would you find DNA in each cell below?

20. What are the layers you'd need to go through if you wanted to access the DNA?

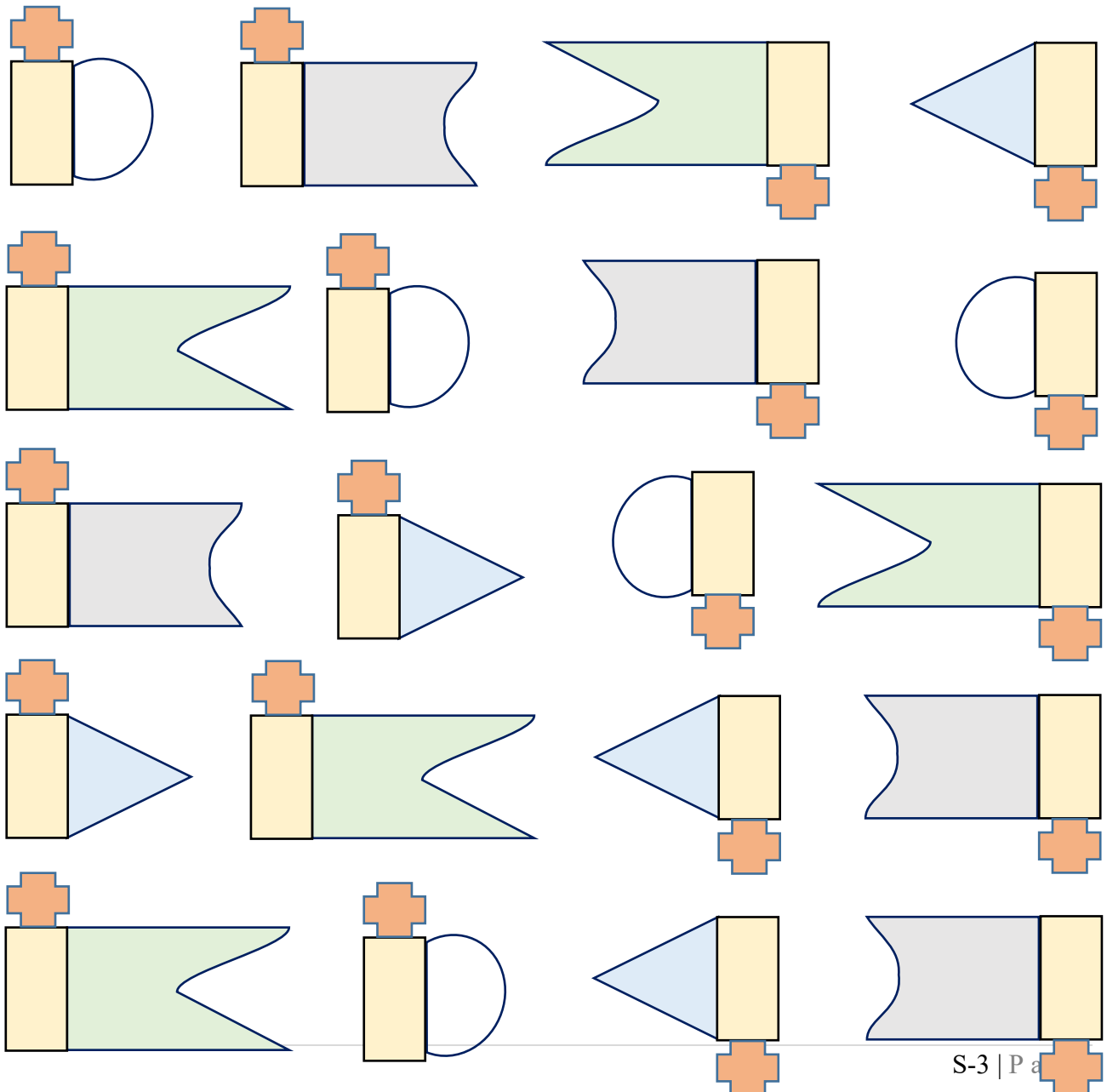


Pre-Laboratory Activity

DNA Model

Directions to make DNA model

1. The white shape represents guanine (G) and the blue triangular shape represents thymine (T). Label the gray shape and the green shape with the appropriate nitrogenous base.
2. The yellow and orange shapes represent the phosphate-carbohydrate (sugar) backbone. The sugar in DNA is deoxyribose. Deoxyribose binds to the nitrogenous base and to the phosphate group. The phosphate group actually binds to the sugar of the next nucleotide. Now label the yellow and orange shapes.
3. Cut out and tape the model together to make a double-stranded DNA molecule.



Background Reading for Students

Let's try to find DNA! Questions to consider as we try to find DNA: Do all cells have DNA? Do all organisms have DNA? Where could we find samples of DNA?

Driving question:

Does food have DNA in it?

Background Information: Back in 1869, Johann Friedrich Meischer developed a way to extract DNA from cells. He tested his procedures on salmon and beef cells and successfully extracted DNA. To extract DNA, scientists must break up each of the protective layers of the cell and carefully pull out the DNA hidden inside the nucleus. Each step of the extraction process either breaks up one of the layers or works with DNA to make it condensed, so the DNA is visible and thick enough to recover from the cell. It is kind of like a miniature mining mission!

Below are some considerations about extracting DNA from cells.

- Plant cells have an extra layer on them that animal cells lack. This extra layer, called a cell wall, is a hard surface that helps protect the cell and maintain its shape. This layer must be broken down, but even in cells without a wall, the cells must be broken open so the inside contents are accessible. (See Figure 1.)

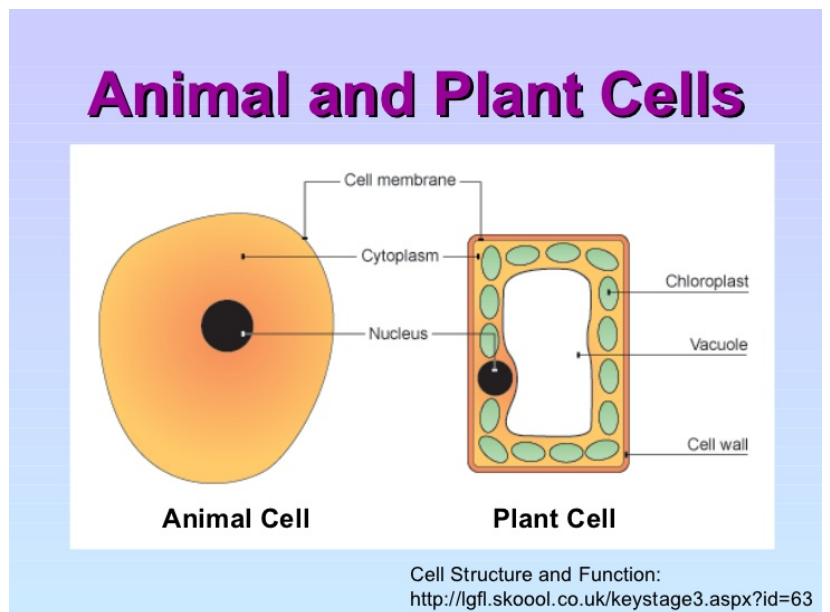


Figure 4. Which structures are common to both plants and animal cells? Which are only found in plant cells?

Question: How could you get through the cell wall?

Background Reading for Students

5. All cells have cell membranes. Membranes serve as a gateway for molecules leaving and entering the cells, and for communicating with the world outside of the cell. The membrane consist primarily of a double layer many molecules called phospholipids. The heads of the phospholipids are hydrophilic and associate with water. The tails of each phospholipid are hydrophobic and avoid water, instead associating with oils. Detergents consist of molecules which resemble a phospholipid. Detergents break up the phospholipid bilayer and disrupt the membrane. (See Figure 2).

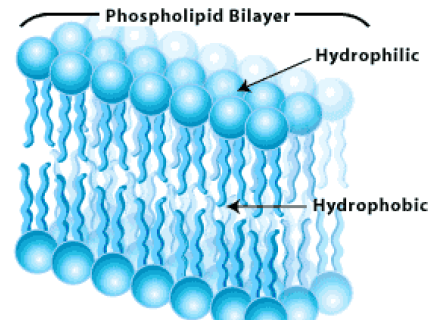


Figure 5. Why are the hydrophilic heads facing outside of the cell membrane?

Question: How could you get through the cell membrane?

6. Cells contain DNA, protein, carbohydrates, and other components. Successfully extracting the DNA means that the DNA is separated from the other cell components. Dr. Meischer discovered that adding salt to a mixture of DNA and cellular components causes the components to clump together and sink to the bottom of the test tube. DNA remains in suspension (stays in the liquid) until exposed to alcohol. (See Figure 3.)

Question: Do you think you could add salt and alcohol in the same steps or in different steps? If you added them in different steps, which would you add first?



Figure 6. The white or cloudy substance is DNA in the alcohol layer floating above an extract.

Background Reading for Students

YOUR Investigation:

After learning about their research topic, scientists make a prediction or **hypothesis** about what they think will happen in their experiment. Since you are a scientist investigating DNA in food, write your prediction or hypothesis about the presence of DNA in the food samples your class will test.

Experimental Design:

In order to know if you successfully extracted DNA, you'll want to compare your results to a known sample. You'll also want to know what it looks like if DNA is NOT successfully extracted. **Controls** are samples you run with known results. For example, your positive control will have DNA in it and your negative control will not have DNA in it. You do all of the same steps with your controls as you do with your **experimental samples** (the food you are testing for DNA).

What could you use as a negative control?

What could you use as a positive control?

Laboratory Activity for Students

DNA Extraction Procedure & Observations: Copy the steps in the correct order below. Write your observations in the Observations box after you complete each step.

Your hypothesis:

Step Number	Lab Step	Observations
1		
2		
3		
4		
5		
6		
7		
8		

Steps Activity for Students

Directions: Use this activity with the Laboratory Activity for Students chart. Cut the following blocks out. Read each step and put the blocks in order to complete the DNA extraction activity.

<p>- Keeping the bag closed, gently mash up the food sample with the water and DNA buffer.</p>
<p>- Use a clean pipette to add 1 ml of DNA buffer to each test tube (food sample and both controls). -Mix gently by "flicking" them. -Wait 5 minutes.</p>
<p>- Use a clean pipette to transfer 2 ml of food liquid from the cup or beaker to a clean test tube marked "E" for experimental sample</p>
<p>- Use a clean pipette and add 3mL of DNA Buffer to the bag. - Remove the air from the bag and seal it.</p>
<p>- After 5 minutes, slowly pipette 2 ml of alcohol into each test tube. Do NOT mix the test tubes. Watch for formation of a white or cloudy substance.</p>
<p>-Label one empty test tube "-", and the other one "E". -Put the experimental sample in the zip-lock bag - Add 7ml of "dH₂O" (distilled water) to the bag.</p>
<p>- Transfer 2 ml of "dH₂O" to a test tube and mark it "-". - Note that 2 ml of positive control are already in the test tube. Mark it "+".</p>
<p>- Carefully open the bag and pour off all of the liquid into the cup or beaker. Avoid getting any food chunks in the cup.</p>

Post Laboratory Activity for Students

Driving Question: *Does food have DNA in it?*

Claim (answer the question):

Evidence (What did you see in the lab to support your claim?):

Reasoning (Why does this evidence support this claim?):

Questions: After completing the lab activity answer the following questions.

3. Did you successfully extract DNA from your sample? How did you know?

4. Did your investigation today support that ALL of the food you eat has DNA in it? Why or why not?

Extension Activities for Students

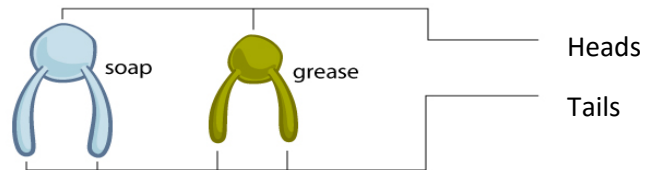
Why Did I.....?

DNA BUFFER (DETERGENT)?

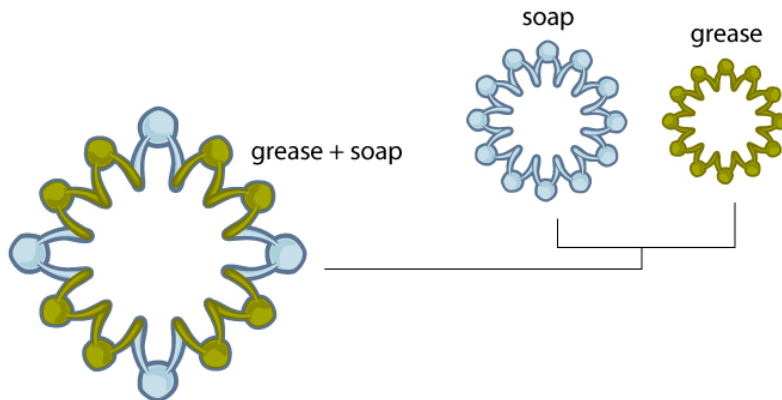
Each cell is surrounded by a sack (the cell membrane). DNA is found inside a second sack (the nucleus) within each cell. To see the DNA, we have to break open these two sacks. We do this with detergent. Why detergent? How does detergent work?

Think about why you use soap to wash dishes or your hands. To remove grease and dirt, right? Soap molecules and grease molecules are made of two parts:

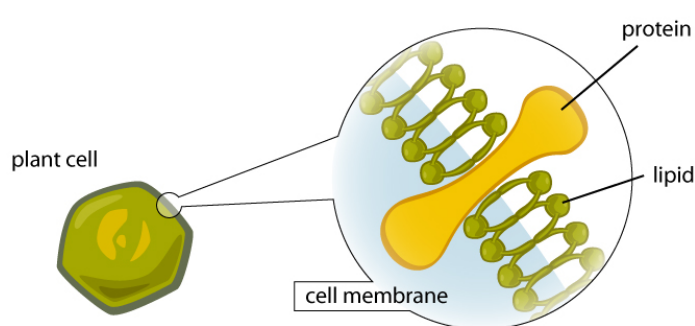
- 1) Heads, which like water.
- 2) Tails, which hate water.



Both soap and grease molecules organize themselves in bubbles (spheres) with their heads outside to face the water and their tails inside to hide from the water.

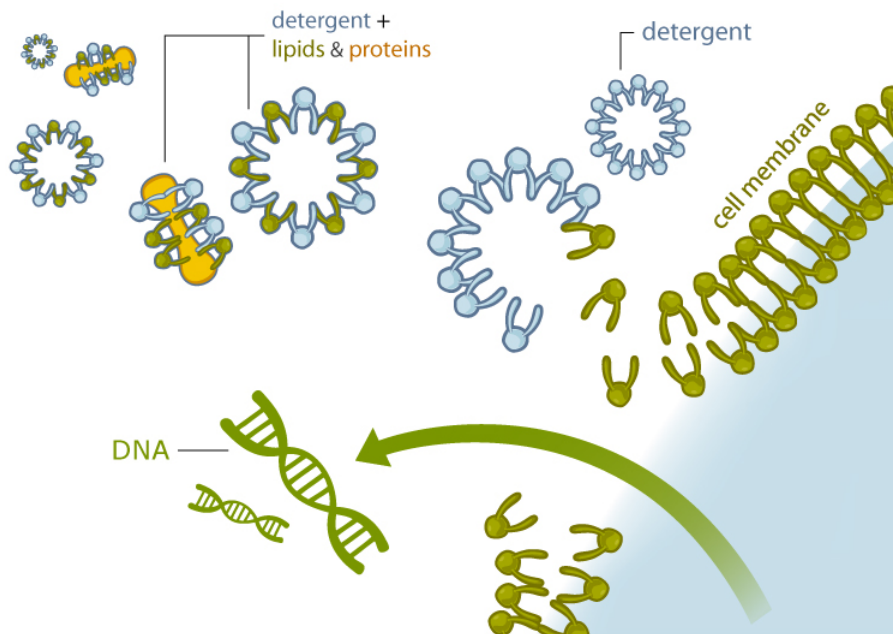


When soap comes close to grease, their similar structures cause them to combine, forming a greasy soapy ball.



A cell's membranes have two layers of lipid (fat) molecules with proteins going through them. When detergent comes close to the cell, it captures the lipids and proteins. After adding the detergent, what do you have? The cell and nuclear membranes break apart, releasing the DNA from the cell.

Extension Activities for Students



© 2010 | 15 North 2030 East, Salt Lake City, Utah 84112-5330, (801) 585-3470

(From: <http://learn.genetics.utah.edu/content/labs/extraction/howto/detergent.html>)

WHY DID I ADD SALT (NaCl)?

The salt then separates the proteins and other cellular debris from the DNA by causing them to clump together and sink to the bottom of the tube, while the DNA remains suspended in the liquid.

WHY DID I ADD ALCOHOL?

The addition of alcohol allows the DNA to precipitate, or fall out of solution, and form clumps that look like goey globs or cobwebs.

Questions:

1. In your own words, explain why DNA Buffer (detergent) is added to your samples. (What did the detergent do?)

Extension Activities for Students

2. In your own words, explain why a salt solution was added to the sample.

3. In your own words, explain the purpose of the alcohol added to your sample.

Berries...with a side of DNA?

Maryland Science Curriculum Standards

These classroom and laboratory activities meet several of the Maryland Science Content Standards:

Goal 1.0 Skills and Processes

1.4.9	Use analyzed data to confirm, modify, or reject a hypothesis.
1.2.1	The student will identify meaningful, answerable scientific questions.
1.2.2	The student will pose meaningful, answerable, scientific questions.
1.2.3	The student will formulate a working hypothesis.
1.2.3	The student will test a working hypothesis.
1.2.6	The student will identify appropriate methods for conducting an investigation (independent and dependent variables, proper controls, repeat trials, appropriate sample size, etc.).
1.3.1	The student will develop and demonstrate skills in using lab and field equipment to perform investigative techniques.
1.3.2	The student will recognize safe laboratory procedures.
1.3.3	The student will demonstrate safe handling of the chemicals and materials of science.
1.3.4	The student will learn the use of new instruments and equipment by following instructions in a manual or from oral directions.
1.5.1	The student will demonstrate the ability to summarize data (measurements/observations).

Goal 3.0 Concepts of Biology

3.1.1	The student will be able to describe the unique characteristics of chemical substances and macromolecules utilized by living systems (specifically DNA).
-------	--

Berries...with a side of DNA?

Next Generation Science Standards

Performance Expectations: Students’ abilities to complete the following performance expectations will be supported by participation in this activity.

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.

Dimension	NGSS code or citations	Corresponding student task in activity
Practice	Planning and Carrying Out Investigations <ul style="list-style-type: none"> Plan an investigation individually and collaboratively, to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effect and evaluate the investigation’s design to ensure variables are controlled. 	Students use reasoning skills to sequence the steps of the protocol to carry out the investigation to answer the driving questions, “Does food have DNA in it?” Students identify positive and negative controls, and write their hypotheses for their investigation. Students will conduct their investigation to test whether fruit contains DNA.
	Analyzing and Interpreting Data <ul style="list-style-type: none"> Analyze data using tools, technologies, and/or models (e.g. computation, mathematical) in order to make valid and reliable scientific claims. 	Students analyze and interpret data from their and the class’s DNA extractions to determine if food has DNA in it.
	Constructing Explanations <ul style="list-style-type: none"> Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations peer review) and the assumption that theories and laws that describe the natural work 	Students construct a scientific explanations using reasoning and evidence from their investigation to answer the driving question “Does food have DNA in it?”.

Berries...with a side of DNA?

Next Generation Science Standards

	<p>operate today as they in the past and will continue to do so in the future.</p> <ul style="list-style-type: none"> Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena. 	
Disciplinary Core Ideas	<p>LS1.A Structure and Function</p> <ul style="list-style-type: none"> All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. <p>LS3.A Inheritance of Traits</p> <ul style="list-style-type: none"> Each chromosome consists of a single very long DNA molecule, and each gene on a chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. 	<p>Students conduct an investigation in which they attempt to extract DNA from a variety of foods to determine whether food cells have DNA. They then construct an explanation regarding if all foods have DNA, based on evidence from the investigation and background readings.</p> <p>The transcription-translations activities in the extension activities provide online models and simulations for DNA and the protein products.</p> <p>Students construct a paper model of DNA in the pre-laboratory activities. Teachers can expand on this modeling activity so students can illustrate difference between DNA sequences and what that means.</p> <p>The transcription-translation activities in the post-lab extension activities provide another model of the length of DNA molecules and the differences in sequences.</p>
Crosscutting Concepts	<p>Structure and Function</p> <ul style="list-style-type: none"> The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the 	<p>Students are asked to explore if all cells would have DNA in them, and specifically test if food has DNA in it. Students construct an explanation that food does have DNA in it because food has cells and all cells have DNA,</p>

Berries...with a side of DNA?

Next Generation Science Standards

	<p>molecular substructures of their various materials.</p>	<p>and students know this because of the evidence they gather in the investigation.</p> <p>The post-lab extension activities, particularly the ones for transcription-translation, model the strong connection between structure and function in the DNA molecule.</p>
	<p>Systems and System Models</p> <ul style="list-style-type: none"> Models (e.g. physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows-within and between systems at different scales. 	<p>Students construct a paper model of DNA and use it to understand the molecule they are extracting from fruit during the laboratory investigation.</p>
<p><u>Nature of Science</u></p> <ul style="list-style-type: none"> Scientific investigations use a variety of methods <ul style="list-style-type: none"> New technologies advance scientific knowledge. Scientific knowledge is based on empirical evidence 		
<p><u>Connections to Common Core State Standards</u></p> <p><u>English Language Arts</u></p> <p><i>RST.9-12.3</i></p> <p><i>RST.11-12.9</i></p> <p><i>SL.9-10.1</i></p> <p><i>SL.9-10.4</i></p> <p><i>WHST.9-12.2</i></p> <p><i>WHST.9-12.2</i></p> <p><i>WHST.9-12.9</i></p>		

Berries...with a side of DNA?

Video and Online Resources

Other Video Resources:

Discovery Video – Cells (<https://www.youtube.com/watch?v=u54bRpbSOgs>)

What is a cell? - <https://www.youtube.com/watch?v=3BZEA4areBM>

What is DNA? How Does it Work? - <https://www.youtube.com/watch?v=zwibgNGe4aY>

Organelle Songs:

The Cell Song by Mr. W: <https://www.youtube.com/watch?v=rABKB5aS2Zg>

The BEST Cell Rap – with Lyrics: <https://www.youtube.com/watch?v=CdGpsDF2Ci8>

Class Rap: <https://www.youtube.com/watch?v=-zafJKbMPA8>

Online Resources:

BioMan: <http://www.biomanbio.com/GamesandLabs/Cellgames/Cells.html>

CellsAlive: http://www.cellsalive.com/cells/cell_model.htm

DNA Sequencing: <http://www.pbs.org/wgbh/nova/body/sequence-DNA-for-yourself.html>

Transcribe and Translate a Gene: <http://learn.genetics.utah.edu/content/molecules/transcribe/>