Growing Agriscience in Louisiana

Agritech Laboratory Manual
Supported by the Agriculture and Food Research Initiative’s Professional Development for Agricultural Literacy Program [award no. 2020-67037-31046] from the USDA National Institute of Food and Agriculture.
Acknowledgements and Introduction:

This work is supported by the Agriculture and Food Research Initiative’s Professional Development for Agricultural Literacy Program [award no. 2020-67037-31046] from the USDA National Institute of Food and Agriculture

Introduction to the Agritech Laboratory Guide

This lab guide was developed to assist teachers in delivering hands-on laboratories and activities with content tied to the Agritech Curriculum Guide. This guide is also not intended to be the limit to what you can develop for your courses and we hope that you will supplement this guide with content that is most appropriate for your overall program.

This guide begin with several activities for you to share information related to the scientific method and the Four Question Research Strategy which can be used to introduce the concept of scientific inquiry to your students. We hope that one or both of these methods will help you introduce the concept of incorporating science more directly into your agriculture curriculum.

In addition to this guide, a wide variety of resources which tie into the Agritech curriculum can be found at the Louisiana Ag in the Classroom Resources web page, including several that were too expansive to include in this guide. You can also save activities that you use to a customized binder so they are easy to find and use. Check out more at the Louisiana AITC web page: https://aitcla.org/.

We hope this guide is helpful and provides you with classroom laboratories which will help your students gain an understanding of science within agriculture!

Dr. Kristin Stair
We would like to thank the following individuals for their development of the laboratory guide and its content:
Abigail Greer, Katie Denova Madelyne Easley, Lana Myers, Regina Smart, and Dr. Kristin Stair
# Table of Contents

- Importance of the Scientific Method 5
- Steps in the Scientific Method 6
- Supporting Students with the Four Question Strategy 7
- Review of the Four Question Strategy 11
- The Four Question Research Strategy 13
- Chewing Gum Science Lab 15
- Are Double Stuf Oreos Really Double Stuffed? Lab 27
- Strawberry DNA Extraction 35
- Microbiology: What’s Growing Around Us? 39
- Soil Erosion Bottle Science Lab 46
- Plant Nutrients: Can We Have Too Much of a Good Thing? 51
- Floating Photosynthesis 59
- Compost Cups 67
- Arable Land Apple Slice Activity 72
- Mining For Fossil Fuels 73
- Goo-Be-Gone: Cleaning Up Oil Spills 79
- Soy Plastic in a Bag 87
- Counting Calories: Food Calorimetry 91
- Milk-Curdling: A Cheesy Science Lab 99
- Classroom Dairy Science 106
- Owl WHAT?!?!: Animal Anatomy and Forensics Using Owl Pellets 116
- Wetlands and Water Filtration Simulation 122
- Desktop Aquaponics Raft Design Challenge 128
- Time Value of Money Blog 135
- Selling Environments in Louisiana Agriculture 139
- Why AgriSCIENCE? Classroom Activity 140
- Additional Lab Activities/Resources For Your Classroom 181
Importance of the Scientific Method
Teacher Information

The ability to function in a scientific setting has been identified as an essential skill for high school students moving into agricultural careers. For most of the labs in this guide, it is recommended that before you begin using them, you spend some time with your classes introducing the scientific method and then allowing students to use the scientific methods as part of the laboratory design.

What is the Scientific Method?
The scientific method is a process for experimentation that is used to explore observations and answer questions. Does this mean all scientists follow exactly this process? No. Some areas of science can be more easily tested than others. For example, scientists studying how stars change as they age or how dinosaurs digested their food cannot fast-forward a star's life by a million years or run medical exams on feeding dinosaurs to test their hypotheses. When direct experimentation is not possible, scientists modify the scientific method. In fact, there are probably as many versions of the scientific method as there are scientists! But even when modified, the goal remains the same: to discover cause and effect relationships by asking questions, carefully gathering and examining the evidence, and seeing if all the available information can be combined into a logical answer.

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an iterative process.

Whether you are doing a science fair project, a classroom science activity, independent research, or any other hands-on science inquiry understanding the steps of the scientific method will help you focus your scientific question and work through your observations and data to answer the question as thoroughly as possible.
Handout: Steps in the Scientific Method

The scientific method is a process for experimentation that is used to explore observations and answer questions. Does this mean all scientists follow exactly this process? No. Some areas of science can be more easily tested than others. For example, scientists studying how stars change as they age or how dinosaurs digested their food cannot fast-forward a star’s life by a million years or run medical exams on feeding dinosaurs to test their hypotheses. When direct experimentation is not possible, scientists modify the scientific method. In fact, there are probably as many versions of the scientific method as there are scientists! But even when modified, the goal remains the same: to discover cause and effect relationships by asking questions, carefully gathering and examining the evidence, and seeing if all the available information can be combined into a logical answer.

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an iterative process.

Whether you are doing a science fair project, a classroom science activity, independent research, or any other hands-on science inquiry understanding the steps of the scientific method will help you focus your scientific question and work through your observations and data to answer the question as thoroughly as possible.

1. Ask a Question
   The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where? For a science fair project some teachers require that the question be something you can measure, preferably with a number.

2. Do Background Research
   Rather than starting from scratch in putting together a plan for answering your question, you want to be a savvy scientist using library and Internet research to help you find the best way to do things and ensure that you don't repeat mistakes from the past.
3. Construct a Hypothesis
A hypothesis is an educated guess about how things work. It is an attempt to answer your question with an explanation that can be tested. A good hypothesis allows you to then make a prediction: "If _____ [I do this] ______, then _____ [this] ____ will happen." State both your hypothesis and the resulting prediction you will be testing. Predictions must be easy to measure.

4. Test Your Hypothesis by Doing an Experiment
Your experiment tests whether your prediction is accurate and thus your hypothesis is supported or not. It is important for your experiment to be a fair test. You conduct a fair test by making sure that you change only one factor at a time while keeping all other conditions the same.

You should also repeat your experiments several times to make sure that the first results weren't just an accident.

5. Analyze Your Data and Draw a Conclusion
Once your experiment is complete, you collect your measurements and analyze them to see if they support your hypothesis or not.

Scientists often find that their predictions were not accurate and their hypothesis was not supported, and in such cases they will communicate the results of their experiment and then go back and construct a new hypothesis and prediction based on the information they learned during their experiment. This starts much of the process of the scientific method over again. Even if they find that their hypothesis was supported, they may want to test it again in a new way.

6. Communicate Your Results
The final step will be to communicate your results to others in a final report and/or a display board. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster or during a talk at a scientific meeting.

Content and additional activities available from:
Science Buddies
https://www.sciencebuddies.org
Supporting students with the Four Question Strategy

BY SUSAN GERMAN

The Four Question Strategy is a series of tests designed to identify experimental variables and help students generate an experimental procedure (Cothron, Giese, and Rezba 2000). The four questions are:

1. What materials are available to do investigations regarding the (object or phenomenon)?
2. How does the (object or phenomenon) act?
3. How can I change the set of materials in question 1?
4. How will I measure the response of the (object or phenomenon)?

Students and I work through each question as a class. Typically, the four questions take students about half of a 50-minute class period to get through. As students become more proficient with the Four Question Strategy, they are able to answer the questions more independently.

In my classroom, students use the Four Question Strategy to design, construct, and test the performance of hand warmers. (Safety note: This investigation requires the use of indirectly vented chemical splash goggles.) To fully understand the science behind the function of hand warmers, students first complete lessons regarding chemical and physical changes and heat transfer. Students then determine which substances produce heat while undergoing change. At this point, the class discussion shifts to the investigative question: How does the temperature vary during a physical or chemical change? From this question, students determine how the amount of calcium chloride impacts the final temperature of the system. This information is used in the final design of the hand warmer. Finally, students use the Four Question Strategy to create their experimental procedure (see Figure 1).

The function of the four questions

Each question helps students identify the variables and constants for the investigation and determine how to measure the dependent variable. For example, Question 1 asks students to brainstorm...
possible independent variables for the investigation. (Any item listed in Question 1 that is not chosen as the independent variable becomes a constant.) Question 2 helps students define the response, or dependent variable, that the object or event demonstrates. (The dependent variable provides evidence that supports or refutes the hypothesis to the investigative question.)

Question 3 asks students to list ways that the variables can be changed. Prior to selecting an independent variable, students must evaluate all answers that were generated for Question 3 to make sure that they have selected the most appropriate variable to test. In the example from my classroom, students must rule out items such as the plastic bag and plastic cup, both of which have no impact on the physical change because of their nonreactive properties. After thinking about the purpose of each variable, students better understand how to determine the procedure for their investigation.

Students determine how to measure the dependent variable with Question 4. When choosing the dependent variable, students need to consider if measuring temperature or measuring reaction rates (generated from Question 2) answers the question: How does the temperature vary during a chemical or physical change?

The experimental design diagram

After students have completed the Four Question Strategy, they choose one independent variable from Question 3 and explain how they will change it. Next, they use Question 4 to decide how to measure the change demonstrated by the dependent variable. Any variables listed in Questions 1 and 3 not chosen as the independent variable are identified as constants. Students record this information on an experimental design diagram by Cothren, Giese, and Rezba (2000) (see Online Supplemental Materials). The diagram asks students to identify the scientific question, write a hypothesis, and identify the independent variable and its levels (changes to the independent variable), the dependent variable and how it will be measured, and any constant variables. Students also identify the control group by adding an asterisk to the level of the independent variable.

A completed version of the diagram used in my classroom example is shown in Figure 2. Using the information generated by the Four Question Strategy, students chose the independent variable and recorded how it would change. The diagram also asks students to specify the number of independent variable levels and trials, showcasing the overall structure of the investigation.

The identified control group (marked by an asterisk) is identified to use as a standard for comparison. This investigation is an example of an experimenter-selected control because all levels of the independent variable receive treatment. One gram of calcium chloride is chosen because it is the smallest amount of calcium chloride that students investigate, and the hypothesis claims more calcium chloride produces increased temperatures. Some investigations use a no-treatment control, while other investigations require the experimenter to select the control because all levels of the independent variable within the

**FIGURE 2: Experimental design diagram**

**Scientific question:** How does the temperature vary during a physical or chemical change?

**Hypothesis:** Increasing the amount of calcium chloride mixed with water increases the final temperature of the reaction because each molecule of calcium chloride dissolved produces heat, so more calcium chloride means more heat.

**Independent variable:** amount of calcium chloride

<table>
<thead>
<tr>
<th>Levels of independent variable</th>
<th>1 gram</th>
<th>2 grams</th>
<th>5 grams</th>
<th>10 grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trials</td>
<td>5 trials</td>
<td>5 trials</td>
<td>5 trials</td>
<td>5 trials</td>
</tr>
</tbody>
</table>

**Dependent variable:** Final temperature [degrees Celsius]

**Constants:** Size of plastic bag, size of plastic cup, particle size of calcium chloride, amount of water, temperature of water

July 2018 27
investigation receive treatment.

The experimental design diagram allows teachers to easily assess student thinking and provide formative feedback and to quickly scan for errors, such as misalignment between hypothesis and variables. Teachers may also use it to see whether the design is reasonable. For example, a student wanting to use 100 grams of calcium chloride is not cost-effective. Once I approve the experimental design diagram, students can start their investigation. Students can wait until after the investigation to determine the optimal amount of calcium chloride.

**Conclusion**

The Four Question Strategy is an effective scaffold for teaching how to plan and carry out an investigation. If you are interested in using the Four Question Strategy, start small and look into changing a previous activity where students confirm knowledge. An example of an activity is rolling different massed spheres down a ramp into a cup and measuring the distance the cup traveled. Those activities, which are simple and have an associated procedure, are typically easy to modify into a student-led investigation by providing students with the investigative question but not the procedure and leading students through the four questions so they can design their own investigation. You can find more information about the Four Question Strategy and its use in implementing scientific inquiry by examining Julia Cothron’s books (see References).

**REFERENCES**


Susan German [sgeron@hollsville.org] is a science teacher at Hollsville R-IV School District in Hollsville, Missouri.
A Review of the Four Question Research Strategy


**Step 1. Identifying the Independent Variable**
An independent variable is the part of an experiment that the experimenter changes on purpose. In Question 3, you listed several potential ways to change your research materials. You need to select one of the ways you listed in Question 3. This will be your independent variable in your experimental design. All the other variables will need to be held constant in order to have a fair test.

In the popcorn example, you might choose to vary the amount of oil used to pop the popcorn. The **amount of oil** is your independent variable.

**Step 2. Deciding on the Levels of the Independent Variable**
Once you have decided on the variable you will change (IV), you need to decide how you will change it. Here is where you decide on the number of levels and the amount of each level.

In the popcorn example, you chose to vary the amount of oil used to pop the popcorn. Here is where you decide on how many different amounts of oil you want to use (the levels). So, you might decide to have five levels for your independent variable and use 0 ml, 10 ml, 20 ml, 30 ml, and 40 ml of oil.

**Step 3. Establishing a control group**
Here you need to identify a comparison group where the independent variable is not changed.

In the popcorn example, the control group is the set of popcorn kernels that receive no oil (0 ml).

**Step 4. Identifying the Dependent Variable**
In Question 4, you identified several possibilities for what you can observe in your experiment as you change the level of the IV — these observations are the dependent variables. Here is where you select one (or more) of the kinds of observations you can make.

In the popcorn example, you might choose to count the number of kernels popped. This will become the dependent variable for your experimental design. You could also time how long it took for the kernels to pop, calculate the kernels popped per minute…. The observations are only limited by how many you can collect.

A part of Step 4 is operationally defining, if need be, your dependent variable. For instance, In the popcorn example, you will need to define exactly what you consider a "popped kernel" to be, i.e. how do you count a partially popped kernel? Some dependent variables just need to have units attached, such as time (minutes, seconds?), length (inches, cm, mm).

**Step 5. Composing a Hypothesis**
A hypothesis is a prediction of the effect that changing the independent variable will have on the outcome of your experiment (i.e., what you observe as your dependent variable). For continuous IV variables, the hypothesis can be written as an "if-then" statement in the following way: If the [independent variable] changes [in this way], then the [dependent variable] will [respond this way]. This ‘formula’ doesn’t work for categorical variables (gender, race, brands, etc.)

In the popcorn example, a possible hypothesis might be: If the amount of oil (IV) is increased (how the IV is deliberately changed) when popcorn is popped, then the number of popped kernels (DV) will increase (how the DV will respond to the change in the IV).

**Step 6. Identifying Constants**
In Step 3, you brainstormed all the potential independent variables you could choose from. Since you chose one of those variables as your independent variable, all the others should be held constant. To change a potential independent variable to a constant, you need to assign it a specific value — amount, time, brand, etc.

In the popcorn example, you would need to identify the brand of popcorn, amount kernels used, the age of the popcorn, popcorn storage, type/kind of oil, brand of popper, heating and cooking time.
Step 7. Repeated Trials
You need to decide how many times to gather data for each level of independent variable. Here you need to consider the amount of variation in the object you are researching and the consequences of coming to a wrong conclusion. The more trials for each level of independent variable, the more confident you can be in your results and conclusion.

In the popcorn example, three trials at each of the independent variable levels would give better results than only one trial with each amount of oil. Of course, 10 trials would even be better because there can be variability in how many kernels of popcorn may pop during each trial.

Step 8. Identifying Safety Concerns/Procedures
You need to identify how you will conduct your experiment safely.

In the popcorn example, the kernels will be extremely hot immediately after popping, so you should identify how you will handle the kernels safely… perhaps wear gloves and perhaps goggles.
The Four Question Research Strategy
From: Cothron, Giese, and Rezba, Students and Research, 2000.

Identify your area of research interest: _____________________.

1. What materials and tools are readily available for conducting experiments on __________________?  
   Response:  
   Materials:  
   Tools:  

2. How do(es) _________ act? What do(es) it do? What can you observe about ____?  
   Response:  

3. How can you change the set of materials to affect the action of _________?  
   Materials:  
   one per column  
   What can vary the material/tool to change the action of your research interest?  

4. How can you measure or describe the response of your research interest to the change? Keep in mind the materials and tools you have on hand to make measurements.  
   Response:  

** Remember to describe how you will define your qualitative variables.

5. What tools do you have available to observe and measure your research interest’s response? [Dr. Blanchard’s additional question]  
   Response:  


**Experimental Design Diagram**

*Based on Cothron, Giese, and Rezba, *Students and Research*, 2000.*

The Experimental Design Diagram is a concise way to describe an entire experiment.

**Title:** The Effect of ________________ (IV) on ________________ (DV)

**Hypothesis for a continuous variable:** If ________________ (IV) is ________________ (change, ↓↑), then ________________ (DV) will ________________ (change, ↓↑).

**OR**

**Hypothesis for a discontinuous (or discrete) variable:**

Independent Variable: ________________ (unit of measure: _______)

Levels of Independent Variable, Including the Control

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
</table>

How many repeated trials for each of the IV levels

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
</table>

Dependent Variable: ________________ (unit of measure: _______)

**Constants:**

<table>
<thead>
<tr>
<th>Potential Variable</th>
<th>Level held constant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential Variable</th>
<th>Level held constant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Measurement Tools Needed:**

**Safety Considerations:**
Background:
The purpose of this lesson is to introduce students to the scientific method. The main purpose will be for students to follow the scientific process as they work so that they can apply this process to other activities throughout the year or get a start on an Agriscience fair project.

Students are learning about how to create a lab report and follow the seven basic steps of the scientific method. They are given background information on bubble gum and from that, they are asked to create lab reports that should be written in a manner so that another scientist could replicate it if necessary.

When conducting this lab, I give no written procedures that they should follow, each student is responsible for creating their own procedure to try to solve/answer the question, “Does gum lose or gain mass when you chew it?”

The seven steps all students must complete are as follows:
1. Problem or Question (What are you trying to solve?)
2. Hypothesis (An if/then statement on what you will be testing)
3. List of Materials (All materials used in this lab)
4. Procedure (All of the steps that you use to complete your lab)
5. Observations - qualitative (what you observe such as texture, sight, smell, etc.) and quantitative (your measurements and data in a table or chart)
6. Analysis- A graph or visual representation of the quantitative data from the previous step
7. Conclusion – What did you learn from your study?

Each student is to write the question, hypotheses, materials, and procedure with a partner. These four steps must be completed before any data collection can begin. The lab is then to be conducted together with that partner, typically, I have each person in the group chew their own gum, but they will follow the same procedure and help each other stay on task following their written procedures as accurately as possible. Each student is responsible for writing their own final copy for turning in.

Students are given enough class time to conduct three trials of their procedure. They are to record and document all of their observations (data). Both qualitative and quantitative observations are required. The former can be written in note format, the latter should be displayed in a data table that the students create with proper headings and labels. Students will complete the results section of their lab report by plotting all their data in a graph and analyze. The conclusion should restate whether their hypothesis was correct or incorrect, give reasons why and support the conclusion with data they collected.
Materials:
- Multiple packs of gum (Different types and flavors, some should be sugar free). Or ask students to bring in their favorite types of gum for analysis.
- Digital scales
- “Chew on This” Article
- Paper to place on scales

Preparation:
Set-up lab stations with a selection of different gums and one digital scale at each station. Print out student laboratory sheets
Chewing Gum Science
Background Information

**Chew On This!**
Written by [Science Meets Food](#)

When you really think about it, chewing gum is a very odd invention. We voluntarily and consistently chew to chew on a flavored gum with no intention of swallowing or gaining any nutritive value. Why do we partake in such behavior? When did it start? And why do we continue? Could there be some added benefit to our compulsion to chew?

**Gum – origins?**

We have been chewing gum for quite some time, but it did not start out as the product you might keep in your pocket today. Historically, gum consisted of elements like tree resin or sap. Ancient peoples chewed gum for a number of reasons including enjoyment, teeth cleaning, and fresh breath, just like we do today. Specifically chicle, a resin from the sapodilla tree, retained its flavor well and played a role in popularizing what has now become chewing gum.

In the process of researching chewing gum, I had the opportunity to speak with IFTSA Immediate Past President, Amy DeJong. DeJong, a PhD student researching chewing gum, says chicle from trees is rarely, if ever, used in modern gum formulations because it is not very sustainable and can be quite variable. Companies now use synthetic gum base, because it is more sustainable, easier to work with, and brings less food safety concerns, like insects or tree particulates contaminating chicle during harvest. Modern day chewing gum, though, is not as sustainable as DeJong would wish, saying that it would be great if...
we could figure out how gum would degrade if disposed of inappropriately on the street, yet not dissolve during chewing.

The first commercial gum was created by John B. Curtis in 1848 and called State of Maine Spruce gum. Fun fact: the first commercialized gum was pink! Why? Coincidence — pink happened to be the only color Curtis had at the time. However, the first patented chewing gum did not come along until a little over 20 years later in 1869. Ironically, it was developed by dentist William Semple of Mount Vernon, OH. William Wrigley Jr. was the first to actually advertise commercial chewing gum in 1920’s, which helped make Wrigley’s spearmint and Juicy Fruit the mega-popular brands they are today.
Now, How is gum made?

Gum is formed using four main ingredients: a gum base, sweetener, flavor, and color. The following steps are the basic process of how gum is made today.

1. Gum base ingredients are melted and filtered
2. Sweeteners and flavors are added until mix forms into dough
3. Extruders blend, smooth and form the gum
4. Gum is formed into sticks or molded into shapes
5. Gum is sprinkled with powders or other substances to prevent from sticking to packaging
6. Gum is cooled for up to 48 hours in order to properly set
7. Gum is wrapped and packaged, ensuring fresh delivery!

A gum base and something to chew on is exciting, but not quite as epic as flavored gum.
To this day, spearmint, peppermint, and cinnamon are considered the most popular gum flavors. However, a quick perusal of the candy aisle or grocery checkout line will yield many other flavors to choose from including fruit flavors and variations of mint. Some brands focus solely on mint variations and title these flavors something unique or representative of a feeling or experience. Ever chewed flavors like “Ascent,” or “Solstice”? Other innovative flavors include rainbow ice and birthday cake. The possibilities are endless...!

De Jong also commented that lasting flavor and sweet sensations are some of the chewing gum industry’s largest challenges. She says companies are constantly trying to improve flavor release; often gum seems to lose its flavor, however, flavor compounds are often still there stuck in the gum base, unreleased.

With the excitement of such innovative flavors, it might be hard to imagine that there are additional benefits to that delicious chewy treat. Chewing gum boasts functional benefits associated with some of its flavors as well as the actual chewing motion.

For example, research has found that chewing gum enhanced performance on standardized tests for working and episodic memory but not attention.³ It is suggested the act of chewing aids memory via action of insulin stimulated from chewing, making the body anticipate a ‘nutritional load.’ Authors hypothesized that the more metabolically active cells would improve glucose uptake, since glucose has been found to improve memory recall.⁴ Additionally, theories also suggested increased bouts of oxygenated blood reaching the brain obtained through chewing helped facilitate memory improvement.⁵
Chewing gum also has been found to moderate stress in multiple ways. One study found increased alertness during multitasking. Others found reduced levels of cortisol (i.e., a hormone associated with stress) during stressful tasks, in addition to lower self-rated reports of stress when chewing gum. More than one theory on the mechanism of gum-related stress reduction exists, including effects on vasodilation. It has been suggested short-term stress reduces vasodilation and with chewing gum’s effect on cerebral blood flow, may counter this stress reaction, helping to minimize blood flow reduction. It has also been suggested that gum-related stress reduction may be due in part to chewing gum’s ability to facilitate better task performance, indirectly lowering stress levels. More research is needed to be conclusive on the exact mechanisms and outcomes of chewing gum. It also complicates studies when positive effects cannot be differentiated from the action of chewing versus the presence of particular flavor profiles, such as mint. With all these potential benefits and mouth-watering flavors, why not choose to chew?

http://www.clipartkid.com/bubble-gum-bubble-cliparts/
References

Chewing Gum Science
Student Information

Background:
The purpose of this lab is to introduce you to the scientific method. To do this, you will be responsible for creating your own procedure to try to solve/answer the question, “Does gum lose or gain mass when you chew it?”

The seven steps all students must complete are as follows:
1. Problem or Question (What are you trying to solve?)
2. Hypothesis (An if/then statement on what you will be testing)
3. List of Materials (All materials used in this lab)
4. Procedure (All of the steps that you use to complete your lab)
5. Observations - qualitative (what you observe such as texture, sight, smell, etc.) and quantitative (your measurements and data in a table or chart)
6. Analysis - A graph or visual representation of the quantitative data from the previous step
7. Conclusion - What did you learn from your study?

You will be given class time to conduct three trials of your procedure. You are to record and document all of your observations in the student data sheet. Both qualitative and quantitative observations are required. The former can be written in note format, the latter must be displayed in a data table that you will create with proper headings and labels. You will then complete the results section of the lab report by including all your data to analyze. The conclusion, must restate whether your hypothesis was correct or incorrect, give reasons why and support the conclusion with data you collected.

Materials:
- Three different types of gum
- Digital scales
- “Chew on This” Article
- Paper to place on scales
Chewing Gum Science
Student Data

1. Question: Does gum gain or lose mass when you chew it?

2. Hypothesis: If I chew gum, then it will ____________ (gain or lose) mass because:

3. Materials List:

4. Procedure: Write the steps for your experiment here
5. Qualitative Observations: Write at least five qualitative observations below: texture, color, taste, appearance, flavor, etc.

6. Quantitative Observations: Create a data table or charts for your research
7. Analysis: Create a chart or graph based on your data

8. Conclusion:
Are Double Stuf Oreos Really Double Stuffed?

Teacher Information

Background:
The purpose of this lesson is to introduce students to the scientific method. The main purpose will be for students to follow the scientific process as they work so that they can apply this process to other activities throughout the year or get a start on an Agriscience fair project.

Students are learning about how to create a lab report and follow the basic steps of the scientific method. They are given background information on Oreos and from that, they are asked to create lab reports that should be written in a manner so that another scientist could replicate it if necessary.

When conducting this lab, I give no written procedures that they should follow, each student is responsible for creating their own procedure to try to solve/answer the question, “Are Double Stuf Oreos Really Double Stuffed?”

The seven steps all students must complete are as follows:
1. Problem or Question (What are your trying to solve?)
2. Hypothesis (An if/then statement on what you will be testing)
3. List of Materials (All materials used in this lab)
4. Procedure (All of the steps that you use to complete your lab)
5. Observations - qualitative (what you observe such as texture, sight, smell, etc.) and quantitative (your measurements and data in a table or chart)
6. Analysis - A graph or visual representation of the quantitative data from the previous step
7. Conclusion – What did you learn from your study?

Each student is to write the question, hypotheses, materials, and procedure with a partner. These four steps must be completed before any data collection can begin. The lab is then to be conducted together with that partner, typically, each student is responsible for writing their own final copy for turning in.

Students are given enough class time to conduct three trials of their procedure. They are to record and document all of their observations (data), this is step 5 of the lab report. Both qualitative and quantitative observations are required. The former can be written in note format, the latter must be displayed in a data table that the students create with proper headings and labels. Students will complete the results section of the lab report by plotting all their data in a line graph to analyze. The conclusion, must restate whether their hypothesis was correct or incorrect, give reasons why and support the conclusion with data they collected.
Materials:
- Regular Oreos (at least 6 per group)
- Double Stuf Oreos (at least 6 per group)
- Digital scales
- “All About Oreos” Background Information
- Paper to place on scales

Preparation:
Set-up lab stations one digital scale and papers for weighing at each station. Print out student laboratory sheets
Are Double Stuf Oreos Really Double Stuffed?

Background Information

Many people have grown up with Oreo cookies. The "twist or dunk" debate has been around for decades, with one side claiming that the chocolate sandwich cookie is best separated into two halves and eaten as such and the other side claiming that the treats are meant to be enjoyed by dunking them straight into a glass of milk. Whatever camp you are a part of, it is safe to say that most find the cookie delicious.

Oreos have become an icon of 20th-century culture. From Oreo-based dessert recipes spreading on the internet to festival favorites featuring the beloved cookie, it is clear that the world has a soft spot for this famous snack, and the cookie has only grown in popularity since it was invented in 1912, propelling it to the rank of best-selling cookie in the United States.

Oreos Are Introduced
In 1898, several baking companies merged to form the National Biscuit Company, also called Nabisco. This was the beginning of the corporation that would create the Oreo cookie. In 1902, Nabisco rolled out Barnum's Animal Crackers for the first time, making them famous by selling them in a little box designed like a circus animal cage that featured an attached string so that the box could be hung on Christmas trees.

In 1912, Nabisco had an idea for a new cookie, though it wasn't exactly its own—two chocolate disks with a creme filling in between had been done already by the Sunshine Biscuits company in 1908, which called the cookie Hydrox. While Nabisco has never named Hydrox as its inspiration, the Oreo cookie invented four years after the world was introduced to Hydrox closely resembled the biscuit that preceded it: two decorated chocolate discs with white creme sandwiched between them.

Despite its potentially suspicious origination, the Oreo made a name for itself and quickly surpassed the popularity of its competitor. Nabisco made sure to file for a trademark on the new cookie soon after its creation on March 14, 1912. The request was granted on August 12, 1913.

The Mysterious Name
When the cookie was first introduced in 1912, it appeared as an Oreo Biscuit, which changed in 1921 to an Oreo Sandwich. There was another name change in 1937 to Oreo Creme Sandwich before the company settled on the name that was decided upon in 1974: Oreo Chocolate
Sandwich Cookie. Despite the roller coaster of official name changes, most people have always referred to the cookie simply as an "Oreo."

So where did the "Oreo" part even come from? The people at Nabisco aren't quite sure anymore. Some believe that the cookie's name was taken from the French word for gold, or (the main color on early Oreo packaging).

Others claim the name stemmed from the hill-shaped test version that never even made it to store shelves, inspiring the cookie prototype to be named the Greek word for mountain, oreo.

Some speculate that the name is a combination of taking the "re" from "cream" and sandwiching it, just like the cookie, between the two "o"s in "chocolate"—making "o-re-o."

Still others offer the bare explanation that the cookie was named Oreo because it was short, fun, and easy to pronounce.

Though the true naming process may never be revealed, that has not affected Oreo sales. As of 2019, it was estimated that 450 billion Oreo cookies have been sold since 1912, planting it firmly at the top of cookie sales and winning over the hearts of millions.

Changes to the Oreo
The original recipe and signature look of the Oreo has not changed much, but Nabisco has been pumping out limited new looks and flavors for years, right beside the classic. The company started selling various versions of the cookie as its popularity grew. In 1975, Nabisco released its celebrated Double Stuf Oreos. A few of the other most welcomed varieties and themes created over the years include:

1974 - Double Stuf Oreo – Introduced as a variety with double the normal amount of crème filling as the original.
1987: Fudge covered Oreos introduced
1991: Halloween Oreos introduced
1995: Christmas Oreos introduced

Through ambitious new flavors of the cookie, the design of the chocolate discs has been a constant, outside of color changes. The wafer design that has stuck around for the longest and was brought into existence in 1952 has remained much the same since then. As far as the recipe of the Oreo goes, the delicious filling that has contributed to the success of the cookie has evolved very little. It was created by Nabisco's "principal scientist" Sam Porcello, who is often referred to as "Mr. Oreo." His recipe for the classic creme has been only slightly altered since 1912, outside of primarily limited-edition flavors.

Nabisco and the world agree that the Oreo recipe and design are far from broken, so there is no need to fix them. Oreos are well-loved just as they are and are sure to be around for many years to come.

Ingredients in an Oreo
The Oreo ingredients are: unbleached enriched flour (wheat flour, niacin, reduced iron, thiamine mononitrate {vitamin b1}, riboflavin {vitamin b2}, folic acid), sugar, palm and/or canola oil,
cocoa (processed with alkali), high fructose corn syrup, leavening (baking soda and/or calcium phosphate), salt, soy lecithin, chocolate, artificial flavor.

Oreo lists the ingredients on the back of the package, but the order of ingredients doesn't distinguish between cookie and filling. That being said, filling is likely made of sugar, palm and/or canola oil, high fructose corn syrup, soy lecithin, and artificial flavor.

The omission of one particular ingredient is glaringly obvious: cream. Because there are no dairy products used in Oreo cookies, the FDA does not allow Nabisco to call their filling cream. The easy get-around? They spell it "creme".

References:


Are Double Stuf Oreos Really Double Stuffed?

Student Information

Background:
The purpose of this lab is to introduce you to the scientific method. To do this, you will be responsible for creating your own procedure to try to solve/answer the question, “Are Double Stuf Oreos really double stuffed?”

The seven steps all students must complete are as follows:
1. Problem or Question (What are you trying to solve?)
2. Hypothesis (An if/then statement on what you will be testing)
3. List of Materials (All materials used in this lab)
4. Procedure (All of the steps that you use to complete your lab)
5. Observations - qualitative (what you observe such as texture, sight, smell, etc.) and quantitative (your measurements and data in a table or chart)
6. Analysis- A graph or visual representation of the quantitative data from the previous step
7. Conclusion – What did you learn from your study?

You will be given class time to conduct three trials of your procedure. You are to record and document all of your observations (data), this is step 5 of the lab report. Both qualitative and quantitative observations are required. The former can be written in note format, the latter must be displayed in a data table that you will create with proper headings and labels. You will then complete the results section of a lab report by plotting all your data to analyze. The conclusion, must restate whether your hypothesis was correct, give reasons why and support the conclusion with data you collected.

Materials:
- Regular and Double Stuf Oreos
- Digital scales
- “All about Oreos” Background information
- Paper to place on scales
Are Double Stuf Oreos Really Double Stuffed?
Student Lab Sheet

1. Question: Are Double Stuf Oreos really double stuffed as compared to regular Oreos?

2. Hypothesis:

3. Materials List:

4. Procedure: Write the steps for your experiment here
5. Observations: Write at least five qualitative observations below: texture, color, appearance, etc.

6. Quantitative Observations: Create a data table or charts for your research
7. Analysis: Graph or use a chart for your data here.

8. Conclusions:
Strawberry DNA Extraction
Teacher Information

Background:
The purpose of this lesson is to provide students the opportunity to observe, first-hand, the DNA of a strawberry. Strawberries are perfect for this activity because they are easy for students to handle individually and also because they have more DNA than any other fruit. Strawberry DNA is octoploid which means that there are eight copies of each type of chromosomes. In comparison, humans are diploid, meaning there are two copies of each chromosome.

An extraction solution is pre-made and contains a clear (not cloudy) soap, salt and water. The soap in the extraction solution helps to dissolve some of the layers of the cell membrane and organelles. The salt in the solution breaks up protein chains around the nucleic acids.

Finally, ice cold alcohol is added to cause the DNA to precipitate out of solution. Ethanol is ideal, but isopropyl may be used. You can also use Everclear that has been transferred to a plastic container. At least a 95% solution is recommended. DNA is not soluble in alcohol and the colder the alcohol, the less soluble it is. Keeping the alcohol in the freezer or on ice until used will work the best.

Materials:
- Zip-top bags (one for each student)
- Strawberries (one for each student)
- Extraction Solution (per class)
  - 900 mL water
  - 100 mL dishwashing liquid or clear shampoo without conditioner
  - 2 teaspoons salt
- Graduated cylinders (to measure extraction solution)
- Cheese cloth or coffee filter
- Plastic cup
- Rubber band
- 50 mL vial or test tube (one for each student)
- Alcohol (ethanol or isopropyl – 95% - 20 mL per student)
- Wooden coffee stirrer, tooth pick or glass stirring rods (one for each student)

Preparation:
Prepare the extraction solution in advance of class. In a container, add 900 mL water, then 100 mL dishwashing soap or shampoo, and finally, 2 teaspoons salt. Carefully mix the solution, taking care not to cause foaming. Place the Ethanol on ice or store in the freezer in advance of this lab. It should be kept cold at all times for best results.

Extension:
Use different fruits and compare and contrast the yield of DNA to the ploidy level of each fruit or vegetable. Use varying amounts of alcohol to determine how concentration affects DNA yield.
DNA Extraction Lab

Student Information

Background:
All living things have DNA in the nucleus of every cell. These long fibers store the information needed for carrying on all life functions. Strawberry DNA can be extracted (taken out) using a few simple, everyday materials. An extraction solution is used to assist the extraction. This solution contains dishwashing soap to help break down fat in the cell wall and membranes. Salt in the solution helps break up chains of protein that surround the DNA. Using this solution will help us draw the DNA out of the cells of the strawberry.

Pre-Lab Questions:

1. What do you think the DNA will look like?

2. Where is DNA found?

Materials:
- 1 zip-top bag
- 1 strawberry
- 10 mL DNA extraction solution (this mixture contains salts, soaps and water)
- 1 square of cheesecloth or 1 coffee filter
- 1 plastic cup
- 1 rubber band
- 50 mL vial or test tube
- 1 Wooden coffee stirrer, toothpick or glass stirring rod
- 20 mL alcohol

Lab Procedure:
1. Place one strawberry into a zip-top bag.
2. Smash/grind up the strawberry, using your fingers, for 2 minutes.
   Be very careful not to break the bag!
3. Add the extraction solution to the bag.
4. Squish the mixture in the bag for 1 minute.
5. Assemble a filtration device by placing your filter on top of the cup and secure with a rubber band.
6. Pour the strawberry mixture into the filtration device and let it drip directly into your vial/test tube. This may take a few minutes.
7. Remove and dispose of the filter and the strawberry that is left on top, being careful not to spill any of the filtered strawberry solution into the cup.
8. SLOWLY pour the cold alcohol so that it runs down the side into the cup of your filtered solution. Observe.
9. Slowly stir the mixture using your stirring device. Observe
Conclusions and Analysis:

1. What did the DNA look like?

2. Explain what happened when alcohol was added to the mixture.

3. A person cannot see a single cotton thread 100 feet away, but if you wind thousands of threads into a rope, it could be seen from much further away. Compare this example with what happened to the strawberry DNA.

4. Why do you think it is important for scientists to be able to remove DNA from an organism?
Microbiology: What’s Growing Around Us?  
Teacher Information

Background:
Bacteria is all around us. Some areas collect more bacteria than others. This lab allows students to explore areas which areas collect the most bacteria. Typically, students will think about areas they consider “dirty” like bathrooms and weight rooms, however it is often areas that don’t get cleaned as often like their phones, keyboards or doors that might surprise them. Encourage students to swab a wide variety of areas so you can see bacteria growth in a large variety of areas.

For this lab, you will need several different materials that will need to be prepared in advance, plates can be prepared a day in advance and sealed until ready to use.

You can purchase prepared plates, but it is usually cheaper to buy the materials and make the plates yourself.  
Some examples of media can be found here:
Nutrient Agar Plates  
Dried Nutrient Agar Media

The examples above are from Carolina Biological, but can also be purchased from Amazon, Lab-Aides, or any other lab or science source. Make sure that you purchase nutrient agar for bacterial growth.

Materials needed:
Plastic Petri dishes  
Nutrient Mix Agar Media (Premade or Powdered)  
Cotton tipped swabs  
Tape or Parafilm

Prepare agar powder according to directions. Melt and pour agar can be heated gently in the microwave by loosening the lid and heating for 30 second intervals swirling gently each time until all of the media is melted completely. Powdered media must be mixed with distilled water, heated and stirred repeatedly until completely dissolved. **Do not pour or dispose of agar in sinks or drains.**

Once media is prepared, lay out your petri dishes, open them up only long enough to pour the media into petri dishes filling approximately 1/4 of the plate, making sure the bottom of the plate is completely covered. Cover quickly with the lid and allow it to cool.

Seal the plates until ready to use. If preparing more than a day in advance, place petri dishes upside down in the refrigerator. By placing them upside down, condensation will gather on the lid and not the gel.

Give each student or group one prepared plate, cotton tipped swabs (I prefer the long stick lab swabs but sterile cotton swabs can be used as well), ziplock bags, and sharpie markers to label the bags and document their location.
Lab Clean-up:
Once the lab is completed, the samples will be smelly and will likely have significant bacteria growth. Open each plate, spray thoroughly with bleach or alcohol and throw away. **Do not allow agar to be poured into the drains. The agar can solidify and block drains and pipes.**

Extension:
This lab can be further extended by taking samples of antibacterial products and having student soak paper punch circles into each product.

Prepare plates as usual. Have students soak the circles in different antibacterial products. Swab plates with one bacterial sample then quadrant the plates and place one circle with an antibacterial sample in the middle of each quadrant. As bacteria begins to grow, students can observe which areas repel bacterial growth the most.
Microbiology: What’s Growing Around Us?
Student Information
Background information from: Teach Engineering: Bacteria are Everywhere
https://www.teachengineering.org/activities/view/nyu_bacteria_activity1

Have you ever noticed blobs of mold or strangely colored microorganisms around your house? These strange organisms might have shown up in suspicious looking food or in a pink ring around the water in a (dirty) toilet bowl. Well, microorganisms are all around us, and we can even study how quickly they grow.

When we study bacteria closely, we find that they fascinating organisms. They have special features that make them ideal organisms for scientists and engineers to use in a wide range of applications ranging from medicine to environmental and energy engineering. One of these features is that bacteria grow very quickly. On average, bacteria reproduce every 20 minutes, which each bacterium does by splitting into two identical copies of the parent. That means that one bacterium turns into two, those two split into four, which then split into eight, and so on. If each split takes only 20 minutes, it does not take long before we have millions of bacteria. Scientists use this knowledge to their advantage to grow large quantities of these organisms for a variety of purposes. Another important feature of bacteria is that they do not need much to thrive: all they need for growth is air, water and a carbon source (such as sugar). Different strains of bacteria have adapted to survive in very harsh climates, such as high altitudes, deep in the ocean, and at very cold or hot temperatures. All of these features allow scientists and engineering to use them in a wide range of applications.

Not only do these organisms affect the exterior and interior of our bodies, but bacteria such as *E. coli* are also used by biochemists and engineers to produce important proteins for therapeutic purposes through *biosynthesis*. Biosynthesis refers to the process by which cells, such as bacteria, put together simple molecules to make more complex ones. It is the process of biosynthesis that *E. coli* use to make new proteins that pharmaceutical companies then sell as treatments for various illnesses.

Engineers also add bacteria to biofuel to create useable energy and remove waste from fermentation by-products while generating electricity. Scientists and engineers modify different types of bacteria to act as clean-up agents for oil spills: the bacteria are able to break down oil compounds to simplify its removal from seas and oceans.

This activity demonstrates that bacteria are found *everywhere*, and maybe thrive in areas where you wouldn’t suspect.
1. Carefully draw 4 segments on the bottom of your petri dish. Label those segments 1-4.
2. Use your cotton tipped swab to collect 4 samples, being sure to cover the entire surface of your with the sampled area.
3. Place each used swab in an individual plastic bag after collection.
4. Label each bag with the area that was swabbed.
5. When you receive your plate, open the dish and gently swab each sample onto one of the gel segment. Be careful when swabbing, pressing too hard will tear the gel. Be careful to rotate the swab gently so that the entire surface comes in contact with the gel. Close quickly after each swab, taking care not to touch or contaminate the gel.
6. Document which sample is being applied to each segment of the gel.
7. Seal with tape or parafilm and place in the area indicated by your teacher.
8. Observe over the next few days. and document the growth of each sample.
1. Question: Which locations contain the most bacteria?

2. Hypothesis:

3. Materials List:

4. Procedure: Write steps for your lab here
5. Qualitative Observations: Write qualitative observations below: color, appearance, etc.

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. Quantitative Observations: Create a data table for your study.

7. Analysis: Graph or chart your data and describe your results here.

8. Conclusions:
Soil Erosion Bottle Science
Teacher Information

Background:
Some researchers estimate that Louisiana loses the equivalent of one football field of wetlands every 100 minutes. It is estimated that the state has lost roughly 2,000 square miles of land since the 1930s. Soil erosion greatly affects the agricultural industry in Louisiana and other coastal states and presents a unique challenge to develop agricultural methods that help to prevent erosion.

The purpose of this lesson is to provide students with the opportunity to observe soil erosion and explore factors that may impact erosion rates.

Materials:
- Three plastic water bottles per group (2-liters work best)
- Garden soil or potting mix
- Mulch, bark chips, pins straw or dead leaves
- Grass seed or 3-4 seedlings per group
- 1 pair of scissors per group
- Three plastic cups per group
- Wooden blocks, dowel rods or other materials to raise the back of the bottles at an angle
- Hole punch
- String

Preparation:
This lab can be completed in stages to allow students to grow their own grass from seed first before performing their experiments, or seedlings can be added to the soil if you want to preform the lab in a shorter time frame. You can also have students dig up top-soil with grass already established. It can be difficult to round up enough bottles by yourself, so it is helpful to have students start bringing them into class or collect them in advance of the lab.
Soil Erosion Bottle Science Lab

Student Information

Background:
Some researchers estimate that Louisiana loses the equivalent of one football field of wetlands every 100 minutes. It is estimated that the state has lost roughly 2,000 square miles of land since the 1930s. Soil erosion greatly affects the agricultural industry in Louisiana and other coastal states and presents a unique challenge to develop agricultural methods that help to prevent erosion.

Pre-Lab Questions:

1. What do you think causes erosion?
2. What factors do you think impacts the rate of soil erosion in Louisiana?

Materials:
- Three plastic water bottles with caps
- Garden soil or potting mix
- Mulch, bark chips, pins straw or dead leaves
- Grass seed or 3-4 seedlings
- 1 pair of scissors per group
- Three plastic cups
- Wooden blocks, dowel rods or other materials to raise the back of the bottles at an angle
- Hole punch
- String

Lab Procedure:
1. Carefully cut a large square out of the side of each bottle leaving the top of the bottle intact.
2. Fill all three bottles 3/4 full with your soil media
3. In bottle 2, add mulch or other organic materials provided by your teacher.
4. In bottle 3, plant your seeds or seedlings, being sure to plant them firmly within the soil in the bottle.
5. Punch holes on either side of three plastic cups and tie a string through the top so that the cup can hang from the tops of the bottles
6. Place your wooden blocks or dowel rods under the back of the bottles so they will be tilted at an angle and water will be able to drain from the bottle into the cups.
7. Remove bottle caps
8. Slowly pour two cups of water over each bottle. Taking care to pour the water over the entire surface of the soil.
9. Observe
Soil Erosion Bottle Science
Student Lab Sheet

1. Question: What soil components best prevent erosion?

2. Hypothesis:

3. Materials List:

4. Procedure: Write steps for your lab here
5. Qualitative Observations: Write qualitative observations below: color, appearance, etc.

6. Quantitative Observations: Create a data table for your study
7. Analysis: Graph or chart your data and describe your results here.

8. Conclusions:
Background:
Plants require 17 essential chemical elements for successful growth and reproduction. Carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium are required in relatively large quantities. These elemental nutrients are obtained from the air and from water in the soil. Nitrogen (N) is known as the builder. Nitrogen is needed to make proteins and to carry out photosynthesis. Phosphorus (P) is known as the energy supplier and is needed for energy transfer in photosynthesis and is important for seed germination and efficient water use. Potassium (K) is known as the regulator because it plays an important role in catalyzing chemical reactions involved in plant growth and protection from stress. Eleven other elements must also be available to plants in smaller amounts.

The soil is like a “grocery store” for plants. The plant roots go “shopping” in the soil to get the nutrients they need. Similar to people, if plants do not get all the nutrients they need, they do not stay healthy. Conversely, if the concentration of nutrients is too high, plants can be damaged or killed.

A perfect soil will have good texture and structure that provide spaces for air, water, and roots and also contains the proper nutrients in the correct concentrations. Most soil must be amended or improved in some way to give crops or garden plants what they need to be healthy and abundant year after year.

A fertilizer is any substance that is added to the soil or water to increase the amount of nutrients available to a plant. Fertilizers can be manufactured from natural substances in factories or can be substances that go through little processing before being used on the farm or garden. Manure, fish emulsion, composted plant materials, and store-bought commercial materials are all considered to be fertilizers. Commercial fertilizers contain a mixture of nitrogen, phosphorus, and potassium in known quantities that can be immediately used by plants.

As the human population continues to increase, farmers face the challenge of growing more food on the same amount of land. As food crops grow, they take up nutrients from the soil. When the crops are harvested, the nutrients that they have assimilated are also removed from the soil. Farmers must replace nutrients in the soil to continue to grow healthy crops. Research is needed to continue to improve agricultural efficiency.

Directions for preparing and applying liquid and solid fertilizers should be followed carefully. Extensive research has been done to determine the best application that provides the proper amounts of nutrients to your plants. Applying too much fertilizer can harm a plant and applying...
too little can result in nutrient deficient plants that are unhealthy. The experiment that follows will allow students to explore the effects of applying different fertilizer concentrations on plants.

Materials:
- Six, 6 packs of one type of vegetable or flower seedling from a nursery
- Sand or perlite for potting seedlings
- Plastic or wax lined paper cups with a hold in the bottom for planting seedlings
- Liquid fertilizer
- Distilled water
- Jars or beakers that can hold 300 ml of liquid
- 500 ml graduated cylinder or other measuring device
- Wax marking pencil or masking tape
- Too Much of a Good Thing? Student Data Sheets (one per student)

Preparation:
The fertilizer mixtures can be developed in advance, or you can alter the lab to have students prepare them. If students prepare the solutions, care should be taken for students to wear gloves and safety goggles to prevent accidents or injuries as a result of handling concentrated fertilizers.

Procedures:
It may be helpful to try this experiment ahead of time, especially preparing the solutions and determining how far away the light source should be from the plants for optimal outcome. Consider how often, and how much, the plants will need to be watered in the classroom environment. Evaluate how many of your students can participate in set-up.

1. Designate a well-lit area of the classroom for the plants. An optional grow light or a fluorescent fixture can improve results.
2. Prepare the fertilizer mixtures ahead of time for each student group (or modify the lab to allow them to prepare their own)
3. Label sets of four jars or beakers for each group with a wax marking pencil or piece of tape at the 300 ml mark. Label one container in each set with the fertilizer concentrations: 0%, 0.5%, 1%, and 2%. Use the following directions to prepare the concentrations of fertilizers:
   a. 0% solution: Fill jars or beakers, labeled 0%, with distilled water. No fertilizer is to be added to these jars.
   b. 0.5% solution: Put 1.5 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 0.5%.
   c. 1% solution: Put 3 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 1%.
   d. 2% solution: Put 6 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 2%.
   e. When time permits, make a reserve stock of each of the same solutions to use during the experiment to replenish the solutions. Keep the solution jars covered and away from heat and possible contamination.
4. Divide the students into groups of four. Each group will carry out the experiment using the scientific method. At the completion of the experiment each individual student will write a lab report.

5. Review the Scientific Method and the components of a properly written lab report with the students. Give students a reference for lab report expectations by providing examples that range from high to low quality.

6. Guide the students in the proper set up of their experiment. Check each student’s hypothesis prior to beginning the lab experiment. Monitor their process and reinforce the concept of having only one variable. Have the student’s take detailed notes and use them to write their final reports. They should include their notes as an attachment to the final report.

7. Complete the following activity with your students. Give as much or as little instruction as appropriate for the class. You can give your students detailed instructions or this experiment can be done as a Design-Your-Own-Experiment.

8. Discuss the results of the experiment as a class. What did your students learn about fertilizers? What are some examples of fertilizers? Why are fertilizers important to farmers? Why are they important to the students? What should a farmer or home gardener know before applying fertilizers?

Concept Elaboration and Evaluation:
After conducting these activities, review and summarize the following key concepts:

- Plants are an important element in our food supply. Plants grow in soil and require specific levels of nutrients for healthy growth.
- Fertilizer can be used to supplement needed nutrients, however, it must be applied at the proper time, place, and rate.
- Over or under fertilizing can have negative impacts.

Variations
- Do the experiment as a class with just one set of plants.
- Have each group produce one lab report and put it on a poster board for display.
- Have the students follow directions to mix the various fertilizer solutions for their own group.
- Grow plants from seeds as a class project.
Plant Nutrients: Can We Have Too Much of a Good Thing?

Student Information

Background:
Plants require 17 essential chemical elements for successful growth and reproduction. Carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium are required in relatively large quantities. These elemental nutrients are obtained from the air and from water in the soil. Nitrogen (N) is known as the builder. Nitrogen is needed to make proteins and to carry out photosynthesis. Phosphorus (P) is known as the energy supplier and is needed for energy transfer in photosynthesis and is important for seed germination and efficient water use. Potassium (K) is known as the regulator because it plays an important role in catalyzing chemical reactions involved in plant growth and protection from stress. Eleven other elements must also be available to plants in smaller amounts.

The soil is like a “grocery store” for plants. The plant roots go “shopping” in the soil to get the nutrients they need. Similar to people, if plants do not get all the nutrients they need they do not stay healthy. Conversely, if the concentration of nutrients is too high, plants can be damaged or killed.

A perfect soil will have good texture and structure that provide spaces for air, water, and roots and also contains the proper nutrients in the correct concentrations. Most soil must be amended or improved in some way to give crops or garden plants what they need to be healthy and abundant year after year.

A fertilizer is any substance that is added to the soil or water to increase the amount of nutrients available to a plant. Fertilizers can be manufactured from natural substances in factories or can be substances that go through little processing before being used on the farm or garden. Manure, fish emulsion, composted plant materials, and store-bought commercial materials are all considered to be fertilizers. Commercial fertilizers contain a mixture of nitrogen, phosphorus, and potassium in known quantities that can be immediately used by plants.

As the human population continues to increase, farmers face the challenge of growing more food on the same amount of land. As food crops grow, they take up nutrients from the soil. When the crops are harvested, the nutrients that they have assimilated are also removed from the soil. Farmers must replace nutrients in the soil to continue to grow healthy crops. On-going research is being conducted to improve agricultural efficiency.

Directions for preparing and applying liquid and solid fertilizers should be followed carefully. Extensive research has been done to determine the best application that provides the proper amounts of nutrients to your plants. Applying too much fertilizer can harm a plant and applying too little can result in nutrient deficient plants that are unhealthy. The experiment that follows will allow you to explore the effects of applying different fertilizer concentrations on plants.
Procedures:
1. Your teacher will provide your group with four labeled plants. These should be potted in the same type of soil using directions given by your teacher.

2. Make detailed beginning observations of each plant. Take measurements of each plant and use descriptive words and sketches. During the experiment you will be watering these plants with different concentrations of fertilizers to see the effect of fertilizer concentration on the plants.

3. Make notes of all the materials you use and the procedure you follow.

4. Write a hypothesis prior to the start of the experiment. Take detailed notes on observations of your plants throughout the experiment.

5. You will be watering each plant with one of four concentrations of liquid fertilizer that your teacher has prepared for you.
   a. Plant A will have a 0% fertilizer concentration. This is your control.
   b. Your teacher will tell you how much and how often to water the plants.
   c. Be careful to give each plant the same concentration of fertilizer that has been designated for that plant throughout the experiment.
   d. Water them the same amount each time. For example, you will always water Plant A with the 0% fertilizer solution and you will give it the measured amount specified by your teacher each time you water it.

6. On the last day of the experiment make your final observations and analyze the results.

7. When using fertilizers on the farm or in a garden, instructions need to be followed carefully and precisely for best results. See below for an example of a complete fertilizer.

---

Guaranteed Fertilizer Analysis Statement for Super-Gro

Total N = 8%
Available Phosphate = 12%
Soluble Potash = 4%

Directions: Add one tablespoon per gallon of water. Mix until dissolved. Apply to plant foliage and soil. Repeat monthly. Do not apply during heat of day.
Plant Nutrients: Can We Have Too Much of a Good Thing?

Student Lab Sheet

1. Question(s): Which fertilizer solutions will be best for overall plant health? Will higher concentrations of fertilizer be better or will lower concentrations be better?

2. Hypothesis:

3. Materials List:

4. Procedure: Write the steps for your lab here
5. Qualitative Observations: Write five qualitative observations below: color, appearance, etc.

6. Quantitative Observations: Graph or chart your data and describe your results here.
7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusion:
Background:
Photosynthetic organisms capture energy from the sun and matter from the air to make the food we eat, while also producing the oxygen we breathe. In this activity, oxygen produced during photosynthesis makes leaf bits float like bubbles in water.

Plants occupy a fundamental part of the food chain and the carbon cycle due to their ability to carry out photosynthesis, the biochemical process of capturing and storing energy from the sun and matter from the air. At any given point in this experiment, the number of floating leaf disks is an indirect measurement of the net rate of photosynthesis.

In photosynthesis, plants use energy from the sun, water, and carbon dioxide (CO2) from the air to store carbon and energy in the form of glucose molecules. Oxygen gas (O2) is a byproduct of this reaction. Oxygen production by photosynthetic organisms explains why earth has an oxygen-rich atmosphere.

The equation for photosynthesis can be written as follows:

$$6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

In the leaf-disk assay, all of the components necessary for photosynthesis are present. The light source provides light energy, the solution provides water, and sodium bicarbonate provides dissolved CO2.

Plant material will generally float in water. This is because leaves have air in the spaces between cells, which helps them collect CO2 gas from their environment to use in photosynthesis. When you apply a gentle vacuum to the leaf disks in solution, this air is forced out and replaced with solution, causing the leaves to sink.

When you see tiny bubbles forming on the leaf disks during this experiment, you’re actually observing the net production of O2 gas as a byproduct of photosynthesis. Accumulation of O2 on the disks causes them to float. The rate of production of O2 can be affected by the intensity of the light source, but there is a maximum rate after which more light energy will not increase photosynthesis.

To use the energy stored by photosynthesis, plants (like all other organisms with mitochondria) use the process of respiration, which is basically the reverse of photosynthesis. In respiration, glucose is broken down to produce energy that can be used by the cell, a reaction that uses O2 and produces CO2 as a byproduct. Because the leaf disks are living plant material that still require energy, they are simultaneously using O2 gas during respiration and producing O2 gas during
photosynthesis. Therefore, the bubbles of O2 that you see represent the net products of photosynthesis, minus the O2 used by respiration.

When you put floating leaf disks in the dark, they will eventually sink. Without light energy, no photosynthesis will occur, so no more O2 gas will be produced. However, respiration continues in the dark, so the disks will use the accumulated O2 gas. They will also produce CO2 gas during respiration, but CO2 dissolves into the surrounding water much more easily than O2 gas does and isn’t trapped in the interstitial spaces.

Materials:
- Baking soda (sodium bicarbonate)
- Gram scale
- Water
- Liquid dish soap
- Spoon or other implement (for mixing solution)
- Soda straw or hole punch
- Spinach leaves
- 10-mL syringe (without a needle)
- Clear plastic cup (1-cup size) or 250-mL beaker
- Incandescent or 100-watt equivalent lightbulb in fixture or a grow light
- Timer
- Notepaper and pencil (or similar) to record results
- Optional: ring stand, foil, thermometer, ice, hot water, colored gel filters

Preparation:
If you have a grow light, it will work well for this lab, if not, an incandescent light bulb that is clamped so that it is stationary will also allow for you to see results.

Extension:
Try changing other factors that might affect photosynthesis and see what happens. How long does it take for the disks to float under different conditions? For example, you can compare the effects of different types of light sources—lower- or higher-wattage incandescent, fluorescent, or LED bulbs. You can change the temperature of the solution by placing the beaker in an ice bath or a larger container of hot water. You can increase or decrease the concentration of sodium bicarbonate in the solution or eliminate it entirely. You can try to identify the range of wavelengths of light used in photosynthesis by wrapping and covering the beaker with colored gel filters that remove certain wavelengths.

Teaching Tips:
This experiment is extremely amenable to manipulations, making it possible for students to design investigations that will quantify the effects of different variables on the rate of photosynthesis. It is helpful to have students familiar with the basic protocol prior to changing the experimental conditions.

Ask your students to think carefully about how to isolate one variable at a time. It is important to hold certain parts of the experimental setup constant—for example, the distance from the light source to the beaker, the type of light bulb used, the temperature of the solution, the height of the solution, and so on. Certain treatments may eliminate photosynthesis altogether—water with no bicarbonate, very low temperature, and total darkness.
A typical way to collect data in this assay is to record the number of disks floating at regular one-minute time intervals. This is easily graphed, with time on the x-axis and number of floaters on the y-axis.

To make comparisons between treatments, the number traditionally used is the time point at which half of the disks in the sample were floating, also known as the E50.
Background:
Photosynthetic organisms capture energy from the sun and matter from the air to make the food we eat, while also producing the oxygen we breathe. In this activity, oxygen produced during photosynthesis makes leaf bits float like bubbles in water.

Plants occupy a fundamental part of the food chain and the carbon cycle due to their ability to carry out photosynthesis, the biochemical process of capturing and storing energy from the sun and matter from the air. At any given point in this experiment, the number of floating leaf disks is an indirect measurement of the net rate of photosynthesis.

In photosynthesis, plants use energy from the sun, water, and carbon dioxide (CO2) from the air to store carbon and energy in the form of glucose molecules. Oxygen gas (O2) is a byproduct of this reaction. Oxygen production by photosynthetic organisms explains why earth has an oxygen-rich atmosphere.

The equation for photosynthesis can be written as follows:
\[ 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

Materials:
- Baking soda (sodium bicarbonate)
- Gram scale
- Water
- Liquid dish soap
- Spoon or other implement (for mixing solution)
- Soda straw or hole punch
- Spinach leaves
- 10-mL syringe (without a needle)
- Clear plastic cup (1-cup size) or 250-mL beaker
- Incandescent or 100-watt equivalent light bulb in fixture or a grow light
- Timer
- Notepaper and pencil (or similar) to record results
- Optional: ring stand, foil, thermometer, ice, hot water, colored gel filters

Preparation:
1. Make a 0.1% bicarbonate solution by mixing 0.5 grams baking soda with 2 cups (500 mL) water. Add a few drops of liquid dish soap to this solution and mix gently, trying to avoid making suds in the solution.
2. Using the straw or hole punch, cut out 10 circles from your leaves
3. Remove the plunger from the syringe, and remove the cover from the tip, if there is one. Put the leaf disks into the barrel of the syringe, and tap them down to the tip. If you have a straw, you can blow the discs gently into the plunger.
4. Replace the plunger into the syringe, being careful not to touch or damage the leaf disks.
5. Pour 150 mL of bicarbonate solution into the cup. Try to avoid making suds.
6. Draw about 6–8 mL of bicarbonate solution into the syringe. The leaf disks should float in the solution.
7. Hold the syringe with the tip up, and expel the air by gently pushing on the plunger.
8. Plug the tip of the syringe tightly with your finger, and gently pull on the plunger, creating a slight vacuum. You should see tiny bubbles coming out of the leaf disks. Hold the vacuum for a few seconds, and then release the plunger, letting it snap back. Some of the disks should begin to sink.
9. Repeat the previous step several times, until all of the disks have sunk to the bottom of the solution. You may need to tap on the plunger to release the bubbles in order to make all the leaf disks sink.
10. When all the leaf disks have settled to the bottom of the solution, carefully remove the plunger and pour the disks and solution into the cup. They should settle to the bottom of the cup. If any leaf disks float, remove them from the beaker.
11. Set up your light fixture so that it is suspended about 12 inches (30 cm) above the table. You may want to use a ring stand for this.
12. Place the beaker under the light fixture provided by your teacher.
13. Start a timer, and watch the leaf disks at the bottom of the cup. Observe what happens to the leaves.
14. Observe the leaves at 5, 10, 15 and 20 minutes. Record your observations.
15. Remove the light and place your cup in a dark area. Record your observations after 10 minutes.
1. Question: What factors impact photosynthesis?

2. Hypothesis:

3. Materials List:

4. Procedure: Write the steps for your lab here
5. Qualitative Observations: Write five qualitative observations below: texture, color, appearance, etc.

6. Quantitative Observations: Record data from your observations
7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusions:
Prior Knowledge:
Prepare your students for this lab by teaching the basics of sustainability, soil science, and decomposition.

Materials:
Collect organic materials for this lab around your household or school campus. Consider contacting your school cafeteria to save you supplies.
Take it a step further… You may wish to have different students/groups test the composting rate of different organic materials in order to spark more discussions and comparisons.

What will happen?
The warm environment of the cup increases the activity of the microbes inside. These bacteria and fungus go to work breaking down the organic matter in the cup. The added water and oxygen from the shaking keep the process going. Within a day or two you can see this happening. Given enough time, you’ll be able to see the organic matter turn into dark, nutrient rich compost that can be added to garden soil. Consider starting this experiment on a Friday so the students can see significant changes when they return to school Monday.
Background:
Have you ever wondered what happened to that pile of leaves you raked up during the fall? That’s easy, they composted.

Composting is the process in which organic material is broken down into simpler forms of matter. It's natural recycling! When leaves fall and plants and animals die, they start this process of breaking down or decaying. Insects, bacteria, and fungus all help to carry out decomposition. In the end, dead matter decays and is turned back into soil. That’s what happened to the piles of leaves from last fall.

Composting creates nutrient rich soil that can be put back into the garden. You can easily create a compost bin or pile at your house where your yard, garden, and kitchen waste can be decomposed. In this lab, you will create a compost cup in order to compare and contrast the rate that organic items decompose.

Materials:
- 16 ounce plastic cup
- Organic items such as grass clippings, kitchen scraps (no meat or dairy), leaves, coffee grinds, bark, etc.
- Plastic wrap
- 1 tablespoon water
- 1/4 cup soil
- Rubber band or tape

Procedures:
1. Place organic material, dirt, and water in the plastic cup.
2. Cover the cup with plastic wrap and seal with a rubber band or tape. Give it a good shake and place it in a warm, sunny place like a window or safe spot outside where it won’t be disturbed.
3. Every couple of days add another tablespoon of water and give it a shake. Note what is happening to the organic matter on your student lab sheet.
1. Question: How long does it take organic matter to compost back into soil?

2. Hypothesis:

3. Materials List:

4. Procedure: Write Steps for your lab here.
5. Qualitative Observations: Write qualitative observations below: texture, color, appearance, etc.

<table>
<thead>
<tr>
<th>Materials Before Compost Cup Creation</th>
<th>During/Immediately After Creating Compost Cup</th>
<th>1 Day After Experiment Begins</th>
<th>1 Week After Experiment Begins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Quantitative Observations: Record data from your observations

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Amount of Water Added</th>
<th>Temperature</th>
<th>Mass of Compost Cup</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day ___</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day ___</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day ___</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day ___</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week ___</th>
<th>Amount of Water Added</th>
<th>Temperature</th>
<th>Mass of Compost Cup</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week ___</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusions:
Arable Land Apple Slice Activity
Interest Approach or Class Activity
Developed by Katie Denova

Use this activity as a hook at the beginning of an Environmental Science Unit/Lesson

While people don’t often think about it, fertile soil is one of our most valuable resources. Without it, we would not be able to grow the crops and plants we need to feed all the people and animals on earth. So, just how much of the earth is made up of land that is suitable for growing food? Try this project to find out.

First, get a large, unpeeled apple to represent the earth.

Slice the apple into 4 equal slices. Since ¾ of the earth is covered in water, set 3 of the slices aside. The remaining slice represents all of the land on earth. Now, cut that slice in half

One of those slices represents land that is not suitable for farming (swamps, deserts, arctic regions, etc), so set that piece aside.

That leaves you with ⅛ of an apple which represents all of the land on earth where people can live and grow crops

Now, cut that slice into 4 equal pieces:
Piece 1 represents land that is too rocky to farm, so put that one aside
Piece 2 represents land that is too wet to farm, so put that one aside
Piece 3 represents land that is too hot to farm, so put that one aside
The remaining piece (1/32 of the entire apple) represents all of the land on earth that can be used for farming
Background:
Discuss where we get the majority of the energy that we use. How do power plants create electricity? What is an example of fossil fuel? What does it mean to be renewable? Are fossil fuels renewable? What does our society get from fossil fuel mining? Discuss jobs, economic benefits, and energy.

Students will use cookies to explain how mining affects the earth and it’s inhabitants

Essential Question: How does fossil fuel mining affect the Earth and its inhabitants? Introduce the essential question by telling students that we will be investigating how mining for fossil fuels affects the Earth and its inhabitants.

Fossil Fuels Cookies Recipe:
Recipe from: https://sarasglobalcooking.blogspot.com/2012/01/blog-post.html

Yields: 26 Cookies
Beat together:
● 1 stick butter, softened
● 1/2 c. sugar
● 1/2 c. brown sugar
● 1 egg (2 Tbs. water, 1 Tbs. oil, 2 tsp. baking powder)
● 1 tsp. salt
● 2 tsp. vanilla Next, add:
● 1 c. + 2 Tbs. flour
● 1/2 tsp. baking soda
● After that is all mixed together, stir in:
● 1 c. chocolate chips
● 3/4 c. raisins
● 3/4 c. chopped walnuts

Bake at 375F for 8 minutes

***You could also use store bought cookies that have at least 3 chopped ingredients. ****
Background:
Fossil Fuels - Fossil fuels like coal, oil, and natural gas present environmental problems starting with their extraction and going all the way through to their use. They are all different in their properties and uses, but they have some similarities. Fossil fuels all come from fossilized plant or animal material and are all nonrenewable resources; they take millions of years to form and do not regenerate on the timescale of a human life. All fossil fuels go through similar processes on their path from being extracted from the ground to serving as fuels for human beings. We use fossil fuels for most of our energy needs today. Coal, natural gas, and oil accounted for 87 percent of global primary energy consumption in 2012, and they meet 82% of U.S. energy demand (Worldwatch Institute, 2013; Institute for Energy Research, 2014).

Mining - Mining is the process of extracting coal, oil, and natural gas from the ground. Strip mining (also known as open cast, mountaintop, or surface mining) involves scraping away earth and rocks to get to coal buried near the surface (Greenpeace, 2010). This often has a significant impact on the surrounding land, plants, and animals. As plants and topsoil are removed from an area, it destroys landscapes and wildlife habitats. Soil erosion follows, leading to destruction of agricultural land. As topsoil is disturbed, sediments wash into waterways, damaging fish habitats and causing changes to river channels which lead to flooding. There is an increased risk of chemical contamination of groundwater when minerals in upturned earth seep into the water table, and watersheds are destroyed when disfigured land loses the water it once held. Besides providing energy, coal mining, including strip mining, provides jobs and revenue. Coal is mined in over 50 countries, employing approximately seven million people worldwide (World Coal Association, 2015). Large mines are often the largest source of jobs and income for some communities. For example, coal mining in the Appalachians is one of the main sources of income in rural West Virginia. Over six thousand residents are employed as coal miners, and thousands more are indirectly employed because of the coal industry (National Mining Association, 2015). When we face sustainability issues, it is important to also bear in mind the economic factors at hand.

Energy Conservation - As global supplies of cheap fossil fuels steadily decline and fossil fuel related greenhouse gases accumulate in the atmosphere, energy conservation is becoming a critical topic of discussion. Climate change is an important reason for people to reduce their fossil fuel consumption via conservation, efficiency measures, and switching to renewable energy sources.

Some of these technologies include: wind energy, biomass energy, carbon capture and underground storage, methane capture and use, geothermal energy, energy-efficient buildings and solar energy. These technologies are explained in detail here.
Materials:

- One fossil fuel cookie
- Toothpick
- Napkin

Procedures:
Your teacher will provide you with a cookie. The cookie represents a land area that may contain deposits of coal (represented by raisins), oil (represented by pieces of nuts), or natural gas (represented by chocolate pieces). You will also be provided with a toothpick, which represents the mining and drilling equipment used in obtaining the coal, oil, and natural gas.

Your job is to try to remove as much of the coal, oil, and natural gas from the land as possible, with as little damage to the environment as possible.

Imagine that the top surface of the original cookie is an area of land on which hundreds of plants and animals live. (DO NOT “peek” at the underside of the cookie to see the deposits.) Record the amounts of the various resources you obtain during minding and the amount of “waste” generated. Record your findings on the data table and analyze the results!
1. Question: How much “waste” is generated when mining for fossil fuels?

2. Hypothesis:

3. Materials List:

4. Procedure: Write Steps for your lab here
5. Qualitative Observations: Sketch the cookie surface below, before and after mining: texture, color, appearance, etc.

<table>
<thead>
<tr>
<th>Before Mining</th>
<th>After Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Quantitative Observations: Record data from your observations.

___% Coal
___% Natural Gas
___% Oil
___% Waste
7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusions:
Goo-Be-Gone: Cleaning Up Oil Spills

Teacher Information
Developed by Katie Denova
Adapted from https://www.sciencebuddies.org

Terms and Concepts Students need to Know:
Petroleum oil
Sorbent
Absorptivity

Discussion Questions:
• What characteristics make a good sorbent?
• Is a sorbent enough to clean up an oil spill?

Tips:
• To save time and resources, divide students into groups or partners. Have each group test a different solvent. Compare the results as a class.
• Consider using a live google document so that students can easily compare results. Prepare and measure sorbents prior to class time.
  o Cut large sorbents into small, thumb-sized pieces so that they can easily fill a measuring cup. Prepare at least three cups of each sorbent you want to test this way.
  o Use caution when crushing or smashing coconut husks. Wear eye protection and gloves, and cover the coconut with a large towel or place it in a burlap bag before smashing it. Be sure to only smash the coconut on a surface that you have permission to hammer on.

Variations:
This science project let you investigate which sorbent was the best based on the volume of oil and water it absorbed. Which sorbent is the best by mass? Figure out a way to do this by weighing the liquids and sorbents you used (before and after soaking the sorbents in the water and oil mixture), and then give it a try!

Do some sorbents work faster than others? Investigate which sorbent is the best by time.

Does shape impact absorptivity? For the same weight, what happens when you twist or roll a sorbent tightly? What if you leave it in big pieces or chop it up? Devise a way to figure this out and then give it a try!
Goo-Be-Gone: Cleaning Up Oil Spills

Student Information
Developed by Katie Denova
Adapted from https://www.sciencebuddies.org

Background:
Stop, look down, and wiggle your toes. Are you wearing shoes? If you are, chances are good that some part of those shoes is made from petroleum oil. Now look at the fabric of your clothes, chair cushion, bedsheets, mattress, carpet, and drapes. Many of these fabrics were made from oil. Wander into the kitchen for a glass of milk or soda. The wax in that milk carton and materials in the soda bottle were made from oil. Open up the fridge and look at all the fruits and vegetables—those were grown with the help of fertilizers and pesticides, also oil-containing products. Check out your cupboards. All the packaging you see is made from oil, and the canned goods have additives made from oil, too. Next, head to the bathroom and take a look at all the make-up, medicines, lotions, toothpaste, shampoos, and bandages made from oil. The laundry room also has oil-derived detergents to keep all those oil-made fabrics clean. And even the roof that keeps you dry needs oil to make it waterproof. Seems like everywhere you look around your home, from the ink in your pen to your movie DVDs, you see something that was made from oil.

Oil products are everywhere, including the outdoors: car tires, roads, fuel that powers cars and ships, and heats homes. As you can tell, oil continues to be a very important product in our society, despite climate change fears. Because oil is used in so many ways, great amounts of it are carried long distances to the factories and plants all over the world that use it to make the products that keep our society running. Every day, millions of barrels of oil are moved around, mostly on big ships, called oil tankers. Each tanker can carry more than 200,000 tons of oil.

Occasionally, these tankers have accidents—they hit other ships or scrape against rocks or ice and their hulls break open, spilling oil into the sea. Oil spills can also happen when oil rigs are damaged. The spilled oil can contaminate water resources and devastate wildlife nearby.

One way environmental engineers try to clean up the oil spills before they kill wildlife and damage habitats is with sorbents — materials that are good at absorbing liquids. If you have ever used a sponge, paper towel, or kitty litter, you have used a sorbent.

Materials:
- Newspaper
- Large plastic garbage bag
- Liquid measuring cup, 4-cup size; the angled, read-from-the-top types are easiest to use. These types of measuring cups are available at some grocery stores or through online suppliers such as Amazon.com.
- Four or more sorbents that you want to test (3 cups of each)
Examples include: cotton, hair, fur, straw, coconut husks, corn cobs, corn husks, polypropylene pads, shop towels, and bird feathers. Barber shops or pet groomers are good places to get hair or fur. Shop towels and polypropylene pads can be purchased in the automotive section of many stores.

- Scissors, if sorbent needs to be cut into smaller pieces
- If you are using a coconut husk as one of your sorbents, you will need the following materials:
  - Gloves and eye protection
  - Hammer
  - Large towel or burlap bag
- Paper or glass bowls, 12-oz size (need three bowls for each sorbent you are testing)
- Vegetable oil (1 gallon)
- Pitcher of water
- Dry measuring cup, 1-cup size
- Reusable mesh coffee filter. It should fit easily inside the 4-cup liquid measuring cup; available at stores that sell coffee supplies, such as some grocery stores, or through online suppliers such as Amazon.com.
- Stopwatch, timer, or clock that shows seconds
- Liquid soap
- Lab notebook
- Graph paper

Procedures:

1. Spread newspaper onto your work surface, to make cleanup easier.
2. Open your garbage bag and put it close to the liquid measuring cup.
3. Divide your sorbent into three piles of 1 cup each and place each pile in a glass or paper bowl.
4. Pour 3 cups of water into the liquid measuring cup.
5. Slowly add 1 cup of vegetable oil. Do the oil and water separate or mix?  
   **Note:** In some trials, a layer of bubbles may form between the water and oil layers. If this happens, wait a few minutes until the bubble layer mostly disappears.
6. Put 1 cup of your sorbent into the reusable mesh coffee filter. Lower it slowly into the water-oil mixture and gently move it from side to side for a few seconds until the sorbent is completely submerged, as shown in Figures 3 and 4. You may need to slowly lower the filter below the surface of the liquid in the measuring cup for liquid to easily get into the filter.
7. After the sorbent has been submerged in the liquid, start your stopwatch or timer (or note what time it is on your clock).
8. After 30 seconds, lift the filter with the contents of the sorbent inside and hold it just above the surface of the water-oil mixture for 30 more seconds to drain.
9. Dump the contents of the mesh coffee filter into the plastic garbage bag.
10. Get down level with the liquid measuring cup and read and record the total water and oil level (measure A, as shown in Figure 4).
11. Measure and record the remaining water level (measure B, as shown in Figure 4).
12. Wash out the mesh coffee filter and measuring cup with soap and water.
13. Repeat steps 6–12 for the remaining piles of your sorbent.
14. Then repeat step 6–12 for the rest of the sorbents you chose.
15. Now calculate the remaining oil after removing the sorbent (by subtracting B from A) for each trial and record it in your data table.
16. Calculate the ratio of remaining water to remaining oil for each of the trials and record it in your data table.
1. Question: Can ______________ sorbent absorb enough oil to clean up an oil spill?

2. Hypothesis:

3. Materials List:

4. Procedure: Write Steps for your lab here
5. Qualitative Observations: Write qualitative observations below throughout the lab: texture, color, appearance, etc.

6. Quantitative Observations: Record data from your observations.

<table>
<thead>
<tr>
<th>Sorbent Name (for example, Fur)</th>
<th>Total Water and Oil Level (A)</th>
<th>Remaining Water Level After Removing Sorbent (B)</th>
<th>Remaining Oil Level After Removing Sorbent (A-B)</th>
<th>Ratio of Remaining Water Divided by Remaining Oil (B / (A-B))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 (using first cup of sorbent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2 (using second cup of sorbent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3 (using third cup of sorbent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
After each group has tested their sorbents, compare the average ratios for each sorbent as a class and fill in the data table below. Average the ratios for each sorbent (for the three trials for each sorbent) and record them in a new data table, like Table 2, below.

<table>
<thead>
<tr>
<th>Sorbent Name</th>
<th>Average Ratio of Water to Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Sorbent</td>
<td>3</td>
</tr>
</tbody>
</table>

7. Analysis: Graph data, create a chart, or describe your results here. Make a bar graph of your results. Plot the average water-to-oil ratios (on the y-axis, or the vertical axis) vs. the sorbents you tested (on the horizontal axis, or the x-axis). Make a bar for each sorbent the class tested.
8. Conclusions:
   Analyze your results. The higher the ratio, the better the sorbent was at removing oil.
   1. Are any sorbents less than the starting ratio of 3? This means that the sorbent absorbs
      more water than oil and would not be a good candidate for cleaning up oil spills.

2. Which sorbents have the highest average water-to-oil ratio? These would be the best
   sorbents for oil out of the different sorbents you tested.
Plants impact our daily lives in many ways, beyond providing us with food and oxygen. Biodegradable plastics, ink, and packaging help reduce the amount of waste we produce and the amount of valuable resources that we consume. For example, soybeans can be used to produce plastics, ink, oils, industrial materials, and even crayons.

The purpose of this lab is to allow students to explore the process of making plastics using plant based materials.

Caution should be taken during this lab since plastics will be hot when they are removed from the microwave. Make sure students are following all instructions and using caution when working with hot plastics.
Plants impact our daily lives in many ways, beyond providing us with food and oxygen. Biodegradable plastics, ink, and packaging help reduce the amount of waste we produce and the amount of valuable resources that we consume. For example, soybeans can be used to produce plastics, ink, oils, industrial materials, and even crayons!

Objective: Explore how soybeans can be made into biodegradable products.

Materials: Cornstarch, soybean oil, sandwich sized-sealable bag, food coloring (liquid), microwave, water, pipette or eye dropper, tablespoon measuring spoon.

Safety Notes:
- CAUTION! The bags and plastic will be HOT after time in the microwave.
- The mixture must be thoroughly mixed or plastic will be chalky.

Procedure:
1. Place 1 Tbs of cornstarch into the plastic bag
2. Add 2 drops of soybean oil
3. Add 1 Tbs of water
4. Close bag and knead it, mixing the contents
5. Add two drops of food coloring
6. Seal bag leaving a corner of the bag open to vent the contents
7. Heat bag in the microwave for 20–25 seconds on high
8. CAUTION: Bag will be HOT!
9. Remove the cornstarch and oil mixture and see what shapes you can form

What’s the Science behind this?
The chemistry is that the starch in the cornstarch is binding with the soybean oil, when exposed to heat which forms the plastic. This is considered a bioplastic because it is produced from a biological source.

Lab Questions:
1. What are other sources of bioplastic in everyday household items you use?
2. How did Henry Ford (Creator of Ford Automotives) contribute to the Soybean industry?
3. This is chemistry at work. How do you think the plastic was formed?
4. What contribution do you think bioplastics will make to the environment?
1. Question: How can soybeans be made into biodegradable products?

2. Materials List:

3. Procedure: Write the steps for your lab here
4. Qualitative Observations: Write five qualitative observations below: texture, color, appearance, etc.
7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusions:
Background:
People who check nutrition labels to make informed decisions about which foods to eat and which to avoid often base those decisions solely on the number of calories per serving. A calorie, like a joule, is a unit of energy. The International System of Units (SI) unit for energy is the joule; however, the calorie is commonly used for a unit of food energy. A calorie is equal to the amount of energy per unit mass required to raise the temperature of 1 g of water by 1° C. One calorie is the equivalent of 4.18 joules. Food calories, as read off a nutrition label, are actually kilocalories (often denoted as “Calories” with a capital C). There are 1,000 calories in a kilocalorie, or food Calorie. Animal nutrition is very important to ensure that animal are getting the amount of calories that they need to be healthy and gain adequate weight for meat production.

A calorimeter is a piece of equipment designed to measure the energy released or absorbed during a chemical reaction or phase change. Food calorimetry allows us to determine the number of calories per gram of food. In this activity, a piece of food is burned and the released energy is used to heat a known quantity of water. The temperature change (ΔT) of the water is then used to determine the amount of energy in the food. In this lab, calories will be compared across common snack foods to determine their calorie content.

Materials:
For each group
- Soda Can (empty)
- Stirring Rod
- Ring Stand and Ring
- Cork
- Thermometer
- Graduated Cylinder, 100 mL
- Large Paper Clip
- 2 Twist Ties
- 3 Food Samples with Nutrition Labels (2 to 3 g each of samples such as nuts, marshmallows, or soft chips, e.g., cheese puffs)
- Water
- Matches
- Aluminum Foil (multiple small piece to catch ash or pieces of burnt food)
- Digital Scale (can be shared by multiple groups)
- Pot holders, leather gloves or towels to move the foil, cork, paperclip and food item (Caution! items may be hot, care should be taken when moving items to the scale.)
Important Safety Recommendation:
Use safety glasses or goggles and be cautious with the matches and burning food samples. Check for food allergies before using food samples. Allergic individuals should not participate in any activities that may result in exposure. Never eat or drink the materials used in the lab.
Counting Calories: Food Calorimetry

Student Information

Background:
People who check nutrition labels to make informed decisions about which foods to eat and which to avoid often base those decisions solely on the number of calories per serving. A calorie, like a joule, is a unit of energy. The International System of Units (SI) unit for energy is the joule; however, the calorie is commonly used for a unit of food energy. A calorie is equal to the amount of energy per unit mass required to raise the temperature of 1 g of water by 1° C. One calorie is the equivalent of 4.18 joules. Food calories, as read off a nutrition label, are actually kilocalories (often denoted as “Calories” with a capital C). There are 1,000 calories in a kilocalorie, or food Calorie. Animal nutrition is very important to ensure that animal are getting the amount of calories that they need to be healthy and gain adequate weight for meat production.

A calorimeter is a piece of equipment designed to measure the energy released or absorbed during a chemical reaction or phase change. Food calorimetry allows us to determine the number of calories per gram of food. In this activity, a piece of food is burned, and the released energy is used to heat a known quantity of water. The temperature change (ΔT) of the water is then used to determine the amount of energy in the food. In this lab, calories will be compared across common snack foods to determine their calorie content.

Materials:
For each group
- Soda Can (empty)
- Stirring Rod
- Ring Stand and Ring
- Cork
- Thermometer
- Graduated Cylinder, 100 mL
- Large Paper Clip
- 2 Twist Ties
- 3 Food Samples with Nutrition Labels (2 to 3 g each of samples such as nuts, marshmallows, or soft chips, e.g., cheese puffs)
- Water
- Matches
- Aluminum Foil (small piece to catch ash or pieces of burnt food)
- Digital Scale (can be shared by multiple groups)
- Safety glasses or goggles
- Pot holders, leather gloves or towels to move the foil, cork, paperclip and food item (Caution, items may be hot, care should be taken when moving items to the scale.)
Procedures:
1. Using the graduated cylinder, obtain 150 mL of water and carefully pour it into the soda can.
2. Determine the mass of water and record your finding in the data table (hint: density of water = 1 g/mL).
3. Hold the paper clip horizontally and bend the outer end upwards until it is at a 90° angle to the rest of the paper clip. Push the bottom end of the paper clip into the cork, using it as a stand to hold your sample and paperclip.
4. Obtain a 2- to 3-g food sample.
5. Place the food sample on the paper clip's upward-extending end and place on a piece of aluminum foil. The sample should be freestanding, supported by paper clip inserted into the cork. Determine the initial mass of the food sample, paper clip, foil and cork. Record your findings in the data table.
6. Insert the stirring rod through the soda can tab and position the can in the ring stand so the stirring rod supports it.
7. Adjust the ring stand until the can is approximately 4 cm above the food sample.
8. Suspend the thermometer inside the can a few centimeters above the can's bottom. Secure with 2 twist ties. Ensuring the thermometer isn’t touching the bottom of the can will prevent inaccurate temperature readings.
9. Determine the initial temperature of the water in the can and record this value in the data table.
10. Carefully light a match and use it to light the food sample.
11. Allow the lit sample to heat the water in the can. Gently stir the water periodically with the thermometer.
12. Monitor the temperature change of the water and record the highest observed temperature in the data table.
13. Once the food sample has been completely consumed, find the mass of the remaining food sample and paper clip. Record this value in the data table.
14. Repeat steps 1 through 14 for each of the remaining food samples, changing out water and cooling off the can between food samples. Make sure to record mass of each sample of water as well as the initial temperature.
1. Question: What snacks have the highest caloric energy?

2. Hypothesis:

3. Materials List:

4. Procedure: Write steps for your lab here
5. **Qualitative Observations:** Write qualitative observations below: texture, color, appearance, etc.

6. **Quantitative Observations:** Record data from your observations

<table>
<thead>
<tr>
<th></th>
<th>Sample #1</th>
<th>Sample #2</th>
<th>Sample #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Food Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Paper Clip, Foil and Cork</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Water Temperature (°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Water Temperature (°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Mass of Food Sample, Foil, Cork and Paper Clip After Burning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Calories (see formula below)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Calculations for each food sample**

1. Determine the mass of food that actually burned. (Initial Mass of Food Sample and Paper Clip, Foil and Cork – Final Mass of Food Sample and Paper Clip, Foil and Cork) ___________ g
2. Determine the change in temperature of water, $\Delta T$. ___________ °C
3. Calculate the energy (in calories) released by the burning food sample and absorbed by the water.

\[ Q = mC_p \Delta T \]

\( Q \) = heat absorbed by water, \( m \) = mass of water in grams, \( C_p = 1 \text{ cal/g} \cdot ^\circ\text{C} \), \( \Delta T \) = change in temperature

\[ Q = \text{__________} \text{ calories} \]

4. Determine the number of kilocalories (food Calories) released by the burning food sample (1 kilocalorie, or Calorie = 1,000 calories).

5. Calculate the energy content of the food in kilocalories/gram.

6. Using information on the nutrition label of the food sample, calculate the kilocalories/gram. (Divide Calories per serving by the number of grams in a serving.)

7. Compare your experimentally determined energy content (in kilocalories/gram) to the calculated value from the nutrition label. Calculate the percent error for your experiment.

7. Analysis: Graph data, create a chart, or describe your results here.

8. Conclusions:
Milk-Curdling: A Cheesy Science Lab
Teacher Information
Developed by Madelyne Easley

Introduction:
Have you ever poured yourself a cup of milk and instead of a smooth liquid, all you get is clumps? This is usually a sign that the milk has gone bad. And if it smells sour, it probably has. But the physical process of what happened to the milk is called coagulation, which is the mechanism that occurs when proteins in the milk clump. Although you do not necessarily want this in your milk, without coagulation (or curdling) there would be no cheese or yogurt, which is why it is a very important process in the food industry. This activity uses chemicals to make milk curdle and allows students to explore the process of milk coagulation.

This activity would probably be used best in a Food Science and Biotechnology Unit. This is a fun hands-on activity where they can see chemical reactions and breakdowns right in front of them with different fruit juices.

This activity can be completed in groups of 4 having students each take a responsibility-Supplies Runner, Recorder, Time Keeper, Janitor to keep messes to a minimum.

Analysis of Expected Results:
Did students see clump formation in the milk? Whereas regular milk looks smooth and white, it changes very fast when you add a teaspoon of lemon juice. It almost immediately gets thicker in consistency, and you see white clumps forming that stick to the cup wall when you swirl the milk slightly. The clumps, or curd, consist of casein proteins that are usually in solution where they form micelle structures. These structures are very fragile, and when you change the conditions of the solution, they can easily break up and form clumps of casein proteins. This can happen if you change the pH, or acidity, of the milk, which means making it sourer. Lemon juice is very acidic, and that is why you see the casein proteins clumping once you add it. Heating the lemon juice does not affect its acidity, which means when you added heated lemon juice to your milk, the exact same reaction should have occurred.

Pineapple juice, on the other hand, is not acidic enough to break the micelle structure of the casein proteins. Your milk still clumps when you add it, however. This time, it is not the acidity but special enzymes within the pineapple that make the milk curdle. The pineapple contains an enzyme extract called bromelain, which contains a protease enzyme that chops up the casein proteins, destroying their micelle structure. You might have noticed the curdling did not happen as quickly with pineapple juice as with lemon juice—the enzymes need some time to activate—but within five minutes the milk should have looked very clumpy. Many enzymes are deactivated when heated. When you put the pineapple juice in the microwave, the enzymes will not work anymore. This is why no milk curdling occurs when you added the heated pineapple juice.

Filtering out the curd through a cheesecloth results in a whitish-yellow solution called whey, which consists of about 94 percent water and four to five percent lactose and whey proteins. The solid part, the curd, looks like cottage cheese—and it actually is!
Milk-Curdling: A Cheesy Science Lab
Student Information
Developed by Madelyne Easley

Introduction:
Have you ever poured yourself a cup of milk and instead of a smooth liquid, all you get is clumps? This is usually a sign that the milk has gone bad. And if it smells sour, it probably has. But the physical process of what happened to the milk is called coagulation, which is the mechanism that occurs when proteins in the milk clump. Although you do not necessarily want this in your milk, without coagulation (or curdling) there would be no cheese or yogurt, which is why it is a very important process in the food industry. Wonder how you can make milk curdle—without having it be spoiled? Try this activity to find out!

Background:
Humans have turned milk into a multipurpose liquid. By itself, milk is a nutrient-rich beverage. But when you start treating milk in various processes, all kinds of other products can be created such as butter, yogurt, buttermilk and cheese. Milk mostly consists of fat, protein, lactose (a kind of sugar) and water. The milk fat is suspended in the water as fine droplets, which makes it an emulsion. Milk also contains a lot of proteins that, in this case, are mostly whey and casein. Because casein is poorly soluble in water, its proteins build spherical structures called micelles that allow them to stay in suspension as if they were soluble.

With both fat and proteins in suspension, the milk is a white liquid as we know it. The micelle structures, however, can easily be disrupted or changed, and once altered they cannot be reformed. Because the micelle holds the casein protein in suspension, without it the micelles will clump together and the casein comes out of the solution. The result of this process of milk coagulation, or curdling, is a gelatinous material called curd.

The processes for making many other dairy products such as cottage cheese, ricotta, paneer and cream cheese start with milk curdling. This is why cheese producers want the milk to curdle. There are different ways to start milk coagulation. You can do it with acid or heat as well as by letting the milk age long enough or with specific enzymes (which are proteins that perform a specific chemical reaction). Chymosin, for example, is an enzyme that alters the casein micelle structure to make milk curdle. Proteases are other enzymes that disrupt the casein micelle structure by chopping up proteins, causing milk to curdle. In this activity you will try two different methods of making milk curdle—and produce some cheesy results!

Helpful Videos:
https://www.youtube.com/watch?v=g2N1eZPOcCk - The Science of Cheese
https://www.youtube.com/watch?v=amyaYsJLjss&t=44s - What do Enzymes in Pineapple do to Milk?
Materials:
- Milk
- Lemon (fresh)
- Pineapple (fresh)
- Lemon squeezer
- Food grater, juicer or blender
- Teaspoon
- Tablespoon
- Knife
- Cutting board
- Two pieces of cheesecloth or cotton fabric
- 10 small transparent and microwavable cups (that each hold about two ounces)
- Paper towels
- Microwave
- Permanent marker
- Workspace that can tolerate spills
- Timer (optional)

Preparation:
- Mark four of the small cups with the labels “pineapple juice,” “pineapple juice (heated),” “lemon juice,” and “lemon juice (heated).”
- Take a fresh pineapple and with the help of an adult cut off the rind on a cutting board. Only use about one fifth of the pineapple. Cut the flesh in smaller pieces and grate it. Alternatively, you can use a juicer or blender. Then, place the grated fruit in a piece of cheesecloth and squeeze at least one teaspoon of juice into each cup that you labeled with “pineapple juice.”
- Put the cup that you labeled “pineapple juice (heated)” into the microwave and heat it just long enough to get it boiling (about 10 to 20 seconds). When it starts to boil, carefully take it out of the microwave and let it cool down.
- Take a fresh lemon and use the lemon squeezer to make lemon juice. Add at least one teaspoon of juice into each cup that you labeled with “lemon juice.”
- Again, put the cup labeled “lemon juice (heated)” into the microwave and heat it for 10 to 20 seconds. Once it starts boiling, carefully take it out and let it cool down.
- Label four of the remaining cups “1” to “4.” Fill each of these cups with about one tablespoon of milk. Label the last two cups “curd” and “whey.”

Procedures:
1. Place the cup that you labeled “1” in front of you. It should contain one tablespoon of milk.
2. Use a clean teaspoon to add one teaspoon of the freshly squeezed lemon juice to your milk in cup 1. Swirl the cup slightly.
3. Take your second cup of milk and this time add one teaspoon of the heated lemon juice.
4. Use your third cup of milk, and with a clean teaspoon add one teaspoon of pineapple juice to the milk. Observe what is happening for about five minutes.
5. To the fourth cup of milk add a teaspoon of heated pineapple juice and swirl the cup slightly. Again, observe the cup for about five minutes.
6. Choose the cup with milk that gave you the greatest amount of curd. Then, place your second cheesecloth over the cup labeled “whey” and carefully pour the curdled milk mixture onto the cloth. Fold the cloth over the curdled milk and squeeze the liquid from the mixture into the cup.

7. Once you have squeezed out all the liquid, open the cheesecloth and scoop the curd into the cup labeled “curd.”

8. If you want (and only if you used clean materials!), you can taste a little bit of the whey and curd. Does it taste similar to milk? Is it sweet, sour, creamy or salty? Does it remind you of a particular food?
1. Question: What changes does milk undergo when curdling?

2. Materials List:

3. Procedure: Write the steps for your lab here
4. Observations: Write qualitative observations do you observe at each check point: how does the color, texture, appearance, etc. change over time?

<table>
<thead>
<tr>
<th>Cup 1</th>
<th>Cup 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Cup 3</td>
<td>Cup 4</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Cup 5</td>
<td>Cup 6</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Analysis: Graph data, create a chart, or describe your results here.

6. Conclusions:

What changes did the milk undergo at each stage?
Background:

Did You Know?
- It takes approximately 2 and 1/2 gallons of milk to make 1 pound of butter.
- It takes approximately 1 gallon of milk to make 1 pound of cheese
- The average cow in the United States produces 6-8 gallons of milk per day

Milk & Food Processing

Processing is a term used to describe steps that are taken after the product leaves the farm, and before it is ready for retail sale. Many foods undergo various food processing procedures. Examples include curing Pork to make ham and bacon, turning apples into applesauce or cider, and squeezing oranges for orange juice. Food processing is a benefit to consumers. Food processing provides a greater variety of food to eat as well as food that is safer for human consumption. Without food processing our diets would consist of whole, raw foods exactly as they were produced on the farm and only in the season or shelf life of the food item. In addition, without food processing, consumers are at a greater risk of food-born illnesses.

Milk undergoes processing after it leaves the dairy farm. The fluid milk we drink and the milk that is used to make other dairy products such as ice cream, yogurt, and cheese is typically produced by cows on a dairy farm. In the United States, goats only provide a very small portion of milk for specialty markets. Milk leaves the dairy farm and must be processed prior to being sold to consumers. Fluid milk in the United States is pasteurized, homogenized, fortified, and standardized before it is sold to consumers.

Pasteurization is a process originally created by Louis Pasteur in the mid 1800's. During pasteurization, milk (or another liquid) is heated to destroy microorganisms. As pasteurization practices became more common and eventually mandatory, milk borne diseases such as typhoid fever, scarlet fever, diphtheria, and diarrheal diseases were virtually eliminated. These diseases were especially devastating to young children and infants. Today, each state administers its own laws as to whether milk can be sold without pasteurization.

Homogenization breaks up or shears the fat molecules (cream) in milk so that they are the same size and density of the rest of the milk. This results in a uniform texture and stops the cream from separating and rising to the top of the milk.

Fluid milk in the United States is often fortified with Vitamin A and D. Vitamins A and D are found naturally in milk, however, they are fat-soluble vitamins. Milk with reduced fat levels (2%, 1% or skim) does not contain adequate levels of vitamin A without fortification. Vitamin D is critical to calcium absorption. Adequate calcium in our diet for healthy bones and teeth is only valuable when accompanied with vitamin D.
An important component of milk is fat. The percentage of fat found in milk depends on the species and breed of the animal that produced it. Other factors such as the animal's nutrition and the stage of lactation affect fat content. Most cattle produce milk with 3-5% milk fat. Consumers desire milk that is consistent in flavor and texture each time they purchase it. Consumers also desire lower fat milk products. Standardization is the process of removing fat from milk and adding it back to achieve the desired fat content. Whole milk (3.25%), 2%, 1% and skim (<.1%) milk are the result. Once milk is pasteurized and homogenized it can be used to make many different food products. Each process requires milk to undergo a physical or a chemical change.

Physical changes can occur without altering the chemical composition of a substance. Physical changes can include changing the color, shape, state of matter, or volume of a substance. With many physical changes, the process can be reversed and return the product to its original state.

Chemical changes occur when bonds between atoms are made or broken. A new chemical substance is formed as a result and the process is permanent.

For Making Butter

Materials (per group or individual):
- Small baby food sized glass jars (one for each person or group)
- Heavy whipping cream (approximately 1/4 cup for each jar enough that jars can be 1/2 to 2/3 full with plenty of room at the top)
- Crackers or bread for tasting (optional)

Procedure:
1. Fill jar approximately 1/2 to 2/3 full of cream
2. Close jar tightly
3. Shake for 5 – 10 minutes, opening the lid to observe every 2-3 minutes.
4. Note the changes in state that occur at each time point. NOTE: Whipping cream is made before butter forms. You can have students note when it becomes the consistency of whipped cream. At this point they could add vanilla and powdered sugar and it would be a third product to demonstrate.
5. Continue shaking until a solid lump of butter forms in the jar.
6. Pour off the buttermilk and add salt if desired.

For Making Ice Cream

Materials (per group or individual):
- Measuring spoons and measuring cup
- 1 quart zippered plastic bag
- 1/4 cup sugar
- 1/2 teaspoon vanilla
- 1 cup 2% milk
- 1 cup half & half
- Duct tape
- 1 gallon zippered plastic bag
- 2 lbs. ice
- 1/2 cup water
- 1 cup rock salt
- Paper towels
- Scissors
- Plastic spoons
- Flavorings and toppings (optional)

Procedure:
1. In the quart sized plastic bag, place sugar, vanilla, and milk half & half.
2. Close the bag and massage bag gently until contents are mixed. Open one corner of the bag and squeeze the air out completely. Reseal bag and cover the seal with duct tape.
3. Place quart bag in the larger gallon bag. Add ice around the small bag then rock salt and water.
4. Seal the bag with duct tape.
5. Toss the bag gently in your hands for approximately 10 minutes until the mixture in the smaller bag is frozen. Use paper towels to protect your hands from the cold as well and prevent the mixture from warming.
6. Cut the large bag and dispose of the saltwater and ice.
7. Remove the smaller bag and wipe with a paper towel.
8. Cut the corner of the smaller bag and squeeze to release a serving size of ice cream.

Additional materials needed:
Phones or computers with access to the internet to research questions for the conclusions section of the student lab data sheet. You can also have students guess the process and then discuss it in more detail later in class.
Classroom Dairy Science
Student Data

Background:
Did You Know?
- It takes approximately 2 and 1/2 gallons of milk to make 1 pound of butter.
- It takes approximately 1 gallon of milk to make 1 pound of cheese
- The average cow in the United States produces 6-8 gallons of milk per day

Milk & Food Processing
Processing is a term used to describe steps that are taken after the product leaves the farm, and before it is ready for retail sale. Many foods undergo various food processing procedures. Examples include curing Pork to make ham and bacon, turning apples into applesauce or cider, and squeezing oranges for orange juice. Food processing is a benefit to consumers. Food processing provides a greater variety of food to eat as well as food that is safer for human consumption. Without food processing our diets would consist of whole, raw foods exactly as they were produced on the farm and only in the season or shelf life of the food item. In addition, without food processing, consumers are at a greater risk of food-born illnesses.

Milk undergoes processing after it leaves the dairy farm. The fluid milk we drink and the milk that is used to make other dairy products such as ice cream, yogurt, and cheese is typically produced by cows on a dairy farm. In the United States, goats only provide a very small portion of milk for specialty markets. Milk leaves the dairy farm and must be processed prior to being sold to consumers. Fluid milk in the United States is pasteurized, homogenized, fortified, and standardized before it is sold to consumers.

Pasteurization is a process originally created by Louis Pasteur in the mid 1800's. During pasteurization, milk (or another liquid) is heated to destroy microorganisms. As pasteurization practices became more common and eventually mandatory, milk borne diseases such as typhoid fever, scarlet fever, diphtheria, and diarrheal diseases were virtually eliminated. These diseases were especially devastating to young children and infants. Today, each state administers its own laws as to whether milk can be sold without pasteurization.

Homogenization breaks up or shears the fat molecules (cream) in milk so that they are the same size and density of the rest of the milk. This results in a uniform texture and stops the cream from separating and rising to the top of the milk.

Fluid milk in the United States is often fortified with Vitamin A and D. Vitamins A and D are found naturally in milk, however, they are fat-soluble vitamins. Milk with reduced fat levels (2%, 1% or skim) does not contain adequate levels of vitamin A without fortification. Vitamin D is critical to calcium absorption. Adequate calcium in our diet for healthy bones and teeth is only valuable when accompanied with vitamin D.

An important component of milk is fat. The percentage of fat found in milk depends on the species and breed of the animal that produced it. Other factors such as the animal's nutrition and the stage of lactation affect fat content. Most cattle produce milk with 3-5% milk fat. Consumers desire milk that is consistent in flavor and texture each time they purchase it. Consumers also
desire lower fat milk products. Standardization is the process of removing fat from milk and adding it back to achieve the desired fat content. Whole milk (3.25%), 2%, 1% and skim (<.1%) milk are the result.

Once milk is pasteurized and homogenized it can be used to make many different food products. Each process requires milk to undergo a physical or a chemical change.

Physical changes can occur without altering the chemical composition of a substance. Physical changes can include changing the color, shape, state of matter, or volume of a substance. With many physical changes, the process can be reversed and return the product to its original state.

Chemical changes occur when bonds between atoms are made or broken. A new chemical substance is formed as a result and the process is permanent.

For Making Butter:
Materials (per group or individual):
- Small baby food sized glass jars (one for each person or group)
- Heavy whipping cream (approximately 1/4 cup for each jar, enough that jars can be 1/2 to 2/3 full with plenty of room at the top)
- Crackers or bread for tasting (optional)

Procedure:
1. Fill jar approximately 1/2 to 2/3 full of cream
2. Close jar tightly
3. Shake for 5 – 10 minutes, opening the lid to observe every 2-3 minutes.
4. Note the changes in state that occur at each time point.
5. Continue shaking until a solid lump of butter forms in the jar.
6. Pour off the buttermilk and add salt if desired.
For Making Ice Cream:
Materials (per group or individual):
- Measuring spoons and measuring cup
- 1 quart zippered plastic bag
- 1/4 cup sugar
- 1/2 teaspoon vanilla
- 1 cup 2% milk
- 1 cup half & half
- Duct tape
- 1 gallon zippered plastic bag
- 2 lbs. ice
- 1/2 cup water
- 1 cup rock salt
- Paper towels
- Scissors
- Plastic spoons
- Flavorings and toppings (optional)

Procedure:
1. In the quart sized plastic bag, place sugar, vanilla, and milk half & half.
2. Close the bag and massage bag gently until contents are mixed. Open one corner of the bag and squeeze the air out completely. Reseal bag and cover the seal with duct tape.
3. Place quart bag in the larger gallon bag. Add ice around the small bag then rock salt and water.
4. Seal the bag with duct tape.
5. Toss the bag gently in your hands for approximately 10 minutes until the mixture in the smaller bag is frozen. Use paper towels to protect your hands from the cold as well and prevent the mixture from warming.
6. Cut the large bag and dispose of the saltwater and ice.
7. Remove the smaller bag and wipe with a paper towel.
8. Cut the corner of the smaller bag and squeeze to release a serving size of ice cream.
1. Question: What changes does milk undergo when making dairy products?

5. Materials List:

6. Procedure: Write the steps for your lab here
7. Observations: Write qualitative observations for both butter and ice cream below for each check point: how does the color, texture, appearance, etc. change over time?

<table>
<thead>
<tr>
<th>Butter</th>
<th>Ice Cream</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Analysis: Graph data, create a chart, or describe your results here.

6. Conclusions:

What changes did the milk undergo to make butter? To make ice cream? Are the changes physical, chemical, or both?
How do you think this process was completed before mechanization?

How would the process used to make these products look in a modern food production facility?

Draw a diagram, map, or flowchart of the steps for milk or butter to get from the cow to your home.
Owl WHAT?!?!: Animal Anatomy and Forensics Using Owl Pellets

Teacher Information

From Biology Corner
Additional directions and materials can be found at:
https://www.biologycorner.com/worksheets/owlpellet.html

Background:
Despite what your students will probably assume, owl pellets are NOT owl excrement. Owl pellets are masses of bone, teeth, hair, feathers and exoskeletons of various animals preyed upon by raptors, or birds of prey. Pellets are produced and regurgitated not only by owls, but by hawks, eagles and other raptors that swallow their prey whole or in small pieces. Owls feed early in the evening and regurgitate a single pellet approximately 20 hours after eating. Unlike snakes, the protein enzymes and strong acids which occur in the digestive tract of raptors do not digest the entire meal. The relatively weak stomach muscles of the bird form the undigested fur, bones, feather etc. into wet slimy pellets. In this process even the most fragile bones are usually preserved unbroken.

Owl pellets themselves are ecosystems, providing food and shelter for communities which may include clothes moths, carpet beetles and fungi. Clothes moth larvae are frequently abundant in pellets, feeding on fur and feathers. The black spheres about the size of periods (.) that are found in the pellets are the droppings of the caterpillars. The larvae metamorphose near the surface of a pellet in cocoons made of fur.

Materials:
- Dissection tray, cardboard or paper plates
- Separate plate or paper for moving bones onto once found
- Dissection kits or tweezers and toothpicks
- Owl pellets (can be purchased easily online or found locally)
- Copies of the Owl Pellet Bone Chart for each group
- Non-latex gloves
- Small bowls of water if needed for soaking pellets if they are tightly packed together or muddy

Teaching Tips:
Owl pellets can be used in a variety of ways. They can be used to teach nutrition, anatomy, or even used as an animal forensics type of lab. This can also be a one-class lab or take multiple class periods depending on how much time you wish to dedicate to it. Sorting through the bones can be intensive. If you would like the lab to move quickly, have students identify major bones and then try to identify species. If you want to take more time and focus on anatomy, you can have students work more extensively on pulling out all of the bones, then soak and bleach the bones. They can then be laid out to form partially complete skeletons.
Owl WHAT?!?!: Animal Anatomy and Forensics Using Owl Pellets
Student Information

Background:
Owl pellets are NOT owl excrement. Owl pellets are masses of bone, teeth, hair, feathers and exoskeletons of various animals preyed upon by raptors, or birds of prey. Pellets are produced and regurgitated not only by owls, but by hawks, eagles and other raptors that swallow their prey whole or in small pieces. Owls feed early in the evening and regurgitate a single pellet approximately 20 hours after eating. Unlike snakes, the protein enzymes and strong acids which occur in the digestive tract of raptors do not digest the entire meal. The relatively weak stomach muscles of the bird form the undigested fur, bones, feather etc. into wet slimy pellets. In this process even the most fragile bones are usually preserved unbroken.

Owl pellets themselves are ecosystems, providing food and shelter for communities which may include clothes moths, carpet beetles and fungi. Clothes moth larvae are frequently abundant in pellets, feeding on fur and feathers. The black spheres about the size of periods (.) that are found in the pellets are the droppings of the caterpillars. The larvae metamorphose near the surface of a pellet in cocoons made of fur.

Materials:
- Dissection tray, cardboard
- Separate plate or paper for moving bones onto once found
- Dissection kits or tweezers and toothpicks
- Owl pellet
- Copy of the Owl Pellet Bone Chart

Procedures:
1. Put on gloves and get an owl pellet from your teacher
2. Using the tools provided, gently pull apart the pellet to begin to expose the bones. The bones will be packed in tightly so you may need to soak the pellets in water to help pull them apart. Care should be taken to make sure not to miss bones or other materials found in the pellet.
3. Separate bones onto a separate plate for analysis
4. Once most of the pellet has been pulled completely apart, use the owl pellet chart to identify the most likely species.
## Owl Pellet Bone Chart

<table>
<thead>
<tr>
<th></th>
<th>Rodent</th>
<th>Shrew</th>
<th>Mole</th>
<th>Bird</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td><img src="image1" alt="Skull Rodent" /></td>
<td><img src="image2" alt="Skull Shrew" /></td>
<td><img src="image3" alt="Skull Mole" /></td>
<td><img src="image4" alt="Skull Bird" /></td>
</tr>
<tr>
<td>Jaw</td>
<td><img src="image5" alt="Jaw Rodent" /></td>
<td><img src="image6" alt="Jaw Shrew" /></td>
<td><img src="image7" alt="Jaw Mole" /></td>
<td><img src="image8" alt="Jaw Bird" /></td>
</tr>
<tr>
<td>Scapula</td>
<td><img src="image9" alt="Scapula Rodent" /></td>
<td><img src="image10" alt="Scapula Shrew" /></td>
<td><img src="image11" alt="Scapula Mole" /></td>
<td><img src="image12" alt="Scapula Bird" /></td>
</tr>
<tr>
<td>Forelimb</td>
<td><img src="image13" alt="Forelimb Rodent" /></td>
<td><img src="image14" alt="Forelimb Shrew" /></td>
<td><img src="image15" alt="Forelimb Mole" /></td>
<td><img src="image16" alt="Forelimb Bird" /></td>
</tr>
<tr>
<td>Hindlimb</td>
<td><img src="image17" alt="Hindlimb Rodent" /></td>
<td><img src="image18" alt="Hindlimb Shrew" /></td>
<td><img src="image19" alt="Hindlimb Mole" /></td>
<td><img src="image20" alt="Hindlimb Bird" /></td>
</tr>
<tr>
<td>Pelvic Bone</td>
<td><img src="image21" alt="Pelvic Bone Rodent" /></td>
<td><img src="image22" alt="Pelvic Bone Shrew" /></td>
<td><img src="image23" alt="Pelvic Bone Mole" /></td>
<td><img src="image24" alt="Pelvic Bone Bird" /></td>
</tr>
<tr>
<td>Rib</td>
<td><img src="image25" alt="Rib Rodent" /></td>
<td><img src="image26" alt="Rib Shrew" /></td>
<td><img src="image27" alt="Rib Mole" /></td>
<td><img src="image28" alt="Rib Bird" /></td>
</tr>
<tr>
<td>Vertebrae</td>
<td><img src="image29" alt="Vertebrae Rodent" /></td>
<td><img src="image30" alt="Vertebrae Shrew" /></td>
<td><img src="image31" alt="Vertebrae Mole" /></td>
<td><img src="image32" alt="Vertebrae Bird" /></td>
</tr>
</tbody>
</table>
1. Question: What types of animal are owls most likely to eat?

2. Hypothesis:

3. Materials List:

4. Procedure: Write the steps for your lab here
5. Qualitative Observations: Write five qualitative observations below about the pellets or what you found in your pellets: texture, color, appearance, etc.

6. Quantitative Observations: Record what you found from your observations (number of bones, feathers, other materials, etc.)
7. Analysis: Using the bone chart, what species can you identify that your owl consumed?

8. Conclusions:
Background:
In this lesson, students learn more about how the wetland plays a role in maintaining healthy marine environments. Through participation in a lab simulation that will demonstrate how water filtration occurs in a wetland, students will discover why it is important to preserve our wetlands.

While preservation of wetland ecosystems is important for the protection of endangered species and endangered habitats, there are other important reasons to preserve our wetlands. They are productive ecosystems harboring a variety of species of microbes, plants, insects, amphibians, reptiles, fish, birds, and mammals. They provide refuge and food to these organisms, many of which live some, or part, of their life cycle in a wetland. Wetlands trap sediments and excess nutrients from surface water run-off before it reaches open water, acting as a natural filter in maintaining water quality.

Wetlands are important in flood protection, acting as sponges that slowly release surface water, rain, and snowmelt to the surrounding environment, controlling flood heights. Wetland plants hold soil in place with their roots, absorb wave energy, and break up the flow of rivers and streams, therefore, protecting shorelines and riverbanks from erosion. The wetlands have a big job because they serve as a natural water filtration device that protects the delicate marine ecosystems of the ocean. The filtration process begins as surface water flows through a wetland area and moves around plants, which cause the water to slow down. Once this happens, the sediment carried by the water begins to drop out and settle on the wetland floor. Plant roots usually absorb nutrients from fertilizer application, manure, and local sewage that are dissolved in the water. Other pollutants that may be in the water stick to soil particles. In many cases, the wetland filtration process removes much of the water’s nutrient and pollutant load by the time it leaves a wetland, therefore, allowing quality water to enter the ocean.

Materials:
1. Gloves and goggles for each participant
2. 2 cups or bowls that can each hold 1 liter of water
3. 2 cups of sphagnum moss packed
4. One mesh strainer
5. One 2-liter (2.11 quarts) bottle of turbid water (mixture of water and 1/4 cup of soil)

Preparation:
1. Shake the turbid water in its bottle for 30 seconds, mixing all of the solids in the water together, avoiding allowing the solids to gather at the bottom.
2. Pour the turbid water into one bowl.
3. Note how clear the water is in a chart, adding detailed descriptions of how cloudy the water is.
4. Pack the sphagnum moss into the mesh strainer and hold it above the second bowl, while pouring the turbid water through the moss into the second bowl.
5. Note the level of turbidity in the water in your data chart, noting how the turbidity changes after pouring the water through the moss.
6. Repeat steps 4 and 5 until one of these two things happens: the water becomes totally clear (has low turbidity), or you have poured the water through the moss 25 times.
7. Record your observations with each pour.
Wetlands and Water Filtration Simulation
Student Information Sheet

Background:
In this simulation, you will observe how the water filtration that occurs in certain types of wetlands. Part of the water cycle involves a certain amount of water flowing into, and through, wetland areas. This includes rainwater and surface water, such as streams and rivers. Sphagnum moss is one of the plants that grow in a bog. A bog is a soft, spongy, water-saturated area. It usually has acidic soil in an area full of dead plant material. Sphagnum moss is also called peat moss because it is often found in a type of bog called a peat bog. Sphagnum moss can hold large quantities of water inside its cells, sometimes holding up to 20 times its dry weight in water. How much water would you hold if you were a Sphagnum moss plant? 20 x your weight = _____. That’s a lot of water! Wetlands are home to many plants that have special adaptations that allow them to thrive in water-saturated environments. In this lab, you will find out just how wetland plants play a role in filtering water that flows through the wetlands.

Turbidity is a word that describes how clear or cloudy water can be. You would describe clear water as having low turbidity and muddy water has having high turbidity. In this simulation, you will be monitoring water turbidity and how the wetlands affect it

Materials:
1. Gloves and goggles for each participant
2. 2 cups or bowls that can each hold 1 liter of water
3. 2 cups of sphagnum moss packed
4. One mesh strainer
5. One liter bottle of turbid water (mixture of water and 1/4 cup of soil)

Preparation:
1. Shake the turbid water in its bottle for 30 seconds, mixing all of the solids in the water together, avoiding allowing the solids to gather at the bottom.
2. Pour the turbid water into one bowl.
3. Note how clear the water is in a chart, adding detailed descriptions of how cloudy the water is.
4. Pack the sphagnum moss into the mesh strainer and hold is above the second bowl, while pouring the turbid water through the moss into the second bowl.
5. Note the level of turbidity in the water in your data chart, noting how the turbidity changes after pouring the water through the moss.
6. Repeat steps 4 and 5 until one of these two things happens: the water becomes totally clear (has low turbidity), or you have poured the water through the moss 25 times.
7. Record your observations with each pour.
Wetlands and Water Filtration Simulation
Student Lab Data Sheet

1. Question: What impact do wetlands have on water quality?

2. Materials List:

3. Procedure: Write the steps for your lab here
4. Qualitative Observations: Write five qualitative observations below about the water during your trials (color, particulates, etc)

6. Quantitative Observations: Record what you found from your observations (number of water quality approximate measurements, etc.)
7. Analysis: What impact did moss have on the water quality? What impact do wetlands have on water quality in our state? What other implications can you make from what you learned in this lab? What would happen if there were no wetlands?

8. Conclusions:
Background:
The purpose of this lab/activity is to challenge your students to design a part of a small-scale aquaponics system for your classroom. By starting from scratch, you can involve your students in scouting materials, construction, and maintenance of the system, but there is also a simple ‘recipe’ included at the end of this document should you choose to remove the design challenge element. This small system will help display basic principles of aquaponics and is a great jumping off point for students interested in larger aquaculture or sustainable hydroponics practices.

Materials (purchasing these should not exceed $50):
For this lab, materials are variable, but you will need the following at minimum:

- A 10-gallon glass fish tank (can be larger, see notes at end of lab for more information)
- Fish tank filtration system with fine mesh filter (NOT charcoal)
- Several small, tolerant fish such as goldfish, koi, or even fancy varieties of goldfish, anything from the carp family that can be purchased from a pet store will work
- Gravel or another aquarium substrate
- Fish food
- Buoyant, flat materials such as foam board insulation, science fair tri-fold foam board, classroom jigsaw foam toys, pool noodles, or even a sheet of Styrofoam
- Rockwool plugs or something similar such as Oasis Rootcubes, cotton balls, floral foam, or even Miracle Grow hydroponics inserts
- Small plastic containers such as yogurt cups or small soda bottles
- Soil-less media such as perlite, gravel, aquarium gravel, expanded clay substrate, lava rock, etc.
- Hot glue gun
- Non-fruited plant seeds (herbs, lettuces, etc.)
- Fishing weights, pennies, or something similar to aid in raft design
- Scissors or box cutters if permitted
- A variety of materials students can use in the construction of their raft such as fishing line, string, hot glue, zip ties, twist ties, wire, duct tape, etc.
- Rulers
- Permanent Markers

Preparation:
This lab will be an ongoing activity that will likely take around one month to see true progress after initial construction. Construction of the system can be done quickly if materials are pre-gathered but can also be parsed out across several days depending if you’d like to truly do this from scratch or emphasize the raft design challenge in this activity. Since so many materials are substitutable, gather what is best for you and your budget.
Teaching Tips:

- This system can be maintained like a regular fish tank after plants are ready for harvest, or you can continue to start new plants with occasional tank cleanings.
- Certain materials for this activity can be found cheaper in less conventional locations. Items such as fish tanks and filters can be found at thrift stores, while aquarium hobby stores may have less expensive food and gravel. Some materials can even be recycled, such as the raft material and the starter plugs. Do what is best for your budget but also consider choosing unconventional materials to up the ante for the design challenge.
  - The plants recommended for this lab are all leafy, non-fruiting plants. These will have lower sunlight and nutrient demands overall, but you may realize your plants need a grow light because you cannot move a fish tank too close to a window! An unconventional place to find low to no cost grow lights can be your sheriff’s department. Always worth asking to see what they have!
- This lab is designed in a way that students will first research aquaponics design, plan their raft, troubleshoot, and eventually finalize their design. The lab can be shortened in several ways, whether it’s providing the research materials instead of allowing broad searching or limiting design trials, cut where you see necessary or allow students to linger on certain steps if they’re really taking off with it!
- With smaller aquaponics systems, around 10 gallons or less, you may not need to worry about adding an air stone or bubbler to your tank, especially if your filter waterfalls the water and/or causes a current. However, with larger tanks, a filter alone will not create the necessary surface agitation to facilitate oxygen diffusion into the water and a bubbler or air stone will be necessary for the survival of your fish.
- See the accompanying how-to sheet at the end of this activity to see how to construct an easy, cheap aquaponics system from start to finish. This bare-bones guide can be used with any raft design your students create to construct a small system.
Basic Aquaponics Setup:

Materials:
- Fish Tank
- Goldfish
- Filter appropriate to size of tank
- UV Light
- Warm weather, non-fruiting plant seeds
- Fish food, pelleted is best
- Sheet insulation
- Rock wool

Procedure:
1. Fill fish tank with water and allow it to cycle through filter for several days to ensure water is dechlorinated.
2. Add appropriate amount and sized fish to tank. Allow them to establish themselves for a few days, noting how much they can eat without leaving excess food behind. Establish regular feeding practice.
3. Cut sheet insulation in a way that it fits in the tank with little wiggle room but ensure it does not cover more than 75% of the water’s surface.
4. Cut holes the size of your rockwool plugs in the insulation, allowing about 4-5 inches between each hole. Do not place holes close to edges of insulation, this will make the raft unstable.
5. Place seeds into rockwool starts and place starts into holes in raft.
7. Before plants establish significant roots, use carbon insert in the water filter. Once roots have begun to appear, switch filter to a physical filter that will not remove nutrients from the water. Using carbon until plants can take nitrates out of the water will ensure fish do not die before plants are established. Switching to a physical filter will in turn not remove nutrients from fish waste that plants will need as they mature.
9. Top of water as needed, taking care to only use dechlorinated water.
Desktop Aquaponics Raft Design Challenge

Student Information
Developed by Abigail Greer

Background:
The purpose of this lab is to design a raft for a small aquaponics system with the materials provided, and then maintain the system throughout the lifecycle of the plants and fish living within it. By designing an aquaponic system raft from scratch, you will be able to better maintain the system and troubleshoot common issues. Designing a raft out of unconventional materials can help you repurpose common items and learn how to test different design principles.

Required Materials:
- Fish tank, filled with water
- One floating material of choice
- One medium for root growth of choice OR Plastic cups and soil-less substrate
- One of the following:
  - Zip ties
  - Twist ties
  - String
  - Wire
  - Duct tape
- Weights to simulate the weight of a mature plant
- Scissors
- Ruler
- Permanent Marker
- Hot Glue Gun

Procedures:
1. Research the following two types of raft systems, noting the necessary components of each:
   a. Aquaponics floating raft technique
   b. Aquaponics media bed technique
2. Measure the fish tank your class will be working with before designing your raft.
3. Investigate the different materials available to you, making note of which you think will be best in the system and why.
4. Design and draw a labeled plan for your raft on your lab sheet complete with measurements.
5. Collect materials needed to create your raft.
6. Construct your raft using only the quantities of materials specified above.
7. Test your raft design by placing it in the fish tank. Add weights to your raft to simulate the weight of a mature plant.
8. Record positives and negatives of your initial raft design. Re-design as necessary.
9. Repeat raft trials until you create a functioning raft for your aquaponics system.

Cautions or Safety Procedures:
Be careful when cutting any materials during this lab. Should you decide to create your own plastic net cups, carefully use the hot glue gun to melt small holes in your cups instead of trying to cut holes with scissors.

Measure twice and cut once—materials are not unlimited!
1. Guiding Questions: How can I use what I know about different aquaponics designs to create a raft for the classroom system? What are the best materials for my design and why? How can I improve my design between trials? What would make this design be easy to maintain and repair?

2. Research:
   a. Aquaponics floating raft technique
   b. Aquaponics media bed technique

3. Materials List: Edit this as needed between trials
4. Raft Design with measurements and material labels:

5. **Trial 1 Observations:** What went well? What could be done differently or be improved?

**Trial 2 Observations:**

**Trial 3 Observations:**
6. Final Raft Design Diagram:

7. Conclusions: What ultimately worked? Do you think this would be affected if you scaled it up or down for different systems? How has your raft performed over time? What would you change after seeing it in use?
For this activity, students will locate three articles pertaining to time value of money, discounting, compounding, interest, inflation, etc. Use MSN Money, CNN Money, or Yahoo Money to begin your search. After reading and taking notes over all three articles, students will write a blog post about the key information in the articles. Include how they feel about the information, tips shared in the article, and how they plan to use the information in their life.

Once all student blog posts are complete, each student will be assigned two blog posts with which to read and respond in a short blog comment. This response should pertain to an agreement of the blog post, an opposition to the blog post, personal past experiences pertaining to the blog post, and/or how they personally might use this information in his/her life. Blog comments simply stating, “I agree,” “I disagree,” “Good point,” etc. will not be accepted. Blog comments must recall information learned from reading the initial blog post.
# Time Value of Money Blog

**Blog Evaluation Rubric**

Developed by Lana Myers

<table>
<thead>
<tr>
<th></th>
<th>10 points</th>
<th>7 points</th>
<th>4 points</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
<td>Blog post provides comprehensive insight, clear understanding, and reflective thought about the topic. It builds a focused argument around the issue, poses questions to the reader and/or makes an opposing statement supported by personal experiences.</td>
<td>Blog post provides moderate insight, clear understanding, and reflective thought about the topic.</td>
<td>Blog post provides minimal insight, understanding, and reflective thought about the topic.</td>
<td>Blog post lacks insight, understanding and reflective thought about the topic.</td>
</tr>
<tr>
<td><strong>Viewpoint Created</strong></td>
<td>Blog post presents a focused viewpoint supported by examples from articles read and content learned in lesson to enhance blog viewpoint.</td>
<td>Blog post presents a focused viewpoint supported by examples from articles read and content learned in lesson, but does not enhance blog viewpoint.</td>
<td>Blog post presents a focused viewpoint, but is not supported by articles or content from the lesson.</td>
<td>Blog post lacks a focused viewpoint.</td>
</tr>
<tr>
<td>Creativity in Writing</td>
<td>Blog post is creatively written and easily stimulates dialogue and comments.</td>
<td>Blog post is creatively written and can somewhat stimulate dialogue and comments.</td>
<td>Blog post is brief and unimaginative, lacking the ability to easily connect with readers.</td>
<td>Blog post does not stimulate dialogue and comments.</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Citations</td>
<td>Quotations and comments directly from articles are used effectively and cited correctly.</td>
<td>Quotations and comments directly from articles somewhat enhance the blog post and are cited correctly.</td>
<td>Quotations and comments directly from articles do not enhance blog post and/or cited incorrectly.</td>
<td>Quotations and comments directly from articles are not used in blog post.</td>
</tr>
<tr>
<td>Quality of Writing</td>
<td>Free of grammatical, spelling, and punctuation errors.</td>
<td>1-2 errors</td>
<td>3-4 errors</td>
<td>5 or more errors</td>
</tr>
</tbody>
</table>
You will locate three articles pertaining to time value of money, discounting, compounding, interest, inflation, etc. Use MSN Money, CNN Money, or Yahoo Money to begin your search.

After reading and taking notes over all three articles, write a blog post about the key information in the articles. Include how you feel about the information, tips shared in the article, and how you plan to use the information in your own life.

Once all posts are complete, you will be assigned two blog posts with which to read and respond in a short blog comment. This response should pertain to an agreement of the blog post, an opposition to the blog post, personal past experiences pertaining to the blog post, and/or how they personally might use this information in his/her life.

Blog comments simply stating, “I agree,” “I disagree,” “Good point,” etc. will not be accepted. Blog comments must recall information learned from reading the initial blog post.
Agriculture involves a variety of buyer and seller markets, in this activity, you will explore different selling markets that are being used in Louisiana Agriculture.

Use this website: [http://la.foodmarketmaker.com/](http://la.foodmarketmaker.com/) to identify three Louisiana agricultural businesses for each type of selling environment listed below.

<table>
<thead>
<tr>
<th>Retail Sales</th>
<th>Wholesale Sales</th>
<th>Processing/Industrial Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>1)</td>
<td>1)</td>
</tr>
<tr>
<td>2)</td>
<td>2)</td>
<td>2)</td>
</tr>
<tr>
<td>3)</td>
<td>3)</td>
<td>3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direct Sales</th>
<th>Web Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>1)</td>
</tr>
<tr>
<td>2)</td>
<td>2)</td>
</tr>
<tr>
<td>3)</td>
<td>3)</td>
</tr>
</tbody>
</table>
Why AgriSCIENCE?

Read your assigned article. Once you have completed your article, please answer the following questions:

Part 1:
1. For your article, what areas of agriculture are represented?
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________

2. What connections do you see in your article that are directly related to science? To the scientific method?
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________

3. How does the technology or issue in your article affect traditional production agriculture?
__________________________________________________________________________________
__________________________________________________________________________________
4. What future careers will be responsible for managing the technology or issues addressed in your article?

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

5. What skills will high school students need in order to be prepared for these careers?

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

____________________________________________________________________________________________________________________________________________________

Part 2:
Partner with other teachers who have different articles. Summarize your articles and then share your answers with each other. Once you have shared your information, as a group discuss the following questions:
How are your programs already preparing students for these skills and careers?
How can our programs improve?
Ditching farm pollution — literally

Reducing fertilizer runoff benefits both farmers and the environment

March snowdrifts blanket both levels of Shatto Ditch outside Mentone, Ind. This ditch is a demonstration project to cut the runoff of farm pollution during spring snowmelts and rains.

K. M. KOWALSKI.

By Kathiann Kowalski

April 17, 2015 at 6:15 am

A ditch shrouded in snow may look serene. But soon it will begin funnelling potentially toxic pollution from nearby farm fields into nearby lakes and streams. Scientists are now looking to reshape those ditches to keep farm chemicals and soils where they’ll do the most good: on the farm.

Farmers often construct ditches along natural drainage paths. These channels carry away excess rain that might otherwise flood fields. Many ditches also have tile drains. These run under fields to remove rainwater that might waterlog the roots of crops.
Most farm ditches in the American Midwest have a trapezoidal design. Two sides slope down to a flat bottom that is parallel to the field level. As winter snows melt, lots of water will flow off fields and down those ditches. Spring rains will soon follow, carrying away soil and fertilizer applied to croplands. Environmental scientists refer to this water and the stuff it picks up as it flows across and through soils as runoff.

Those ditches “move water very quickly off the landscape,” notes Jennifer Tank. “And a lot of [soil] and nutrients come with it.” Tank is a stream ecologist and field biologist at the University of Notre Dame in South Bend, Ind. At Shatto Ditch outside Mentone, Ind., Tank is working to show how a two-tiered ditch design and other steps can keep valuable soil and polluting chemicals out of lakes and streams. “A demonstration project is really useful to show that something can work in the ‘real world’ under real-world conditions,” she says. Her partners are farmers and researchers with The Nature Conservancy and the local Soil and Water Conservation District. Their goal: Reduce runoff.

**The problem**

Fertilizer costs farmers lots of money. But it’s worth it, because it helps their crops grow bigger and faster. Pesticides can keep plants healthy by deterring the growth of weeds or insects and other pests that eat leaves, roots and crops. But once those chemicals leave the farm, they no longer help. They’re simply pollutants. And they can harm species elsewhere.

For example, Shatto Ditch empties into the Tippecanoe River. The endangered clubshell mussel lives there, along with other species. Pollutants in runoff can poison them.

Washed-away fertilizer that was meant for crops can also feed other organisms, including harmful algae and bacteria. If they grow out of control, they can create a harmful ‘bloom.’
Such blooms can kill fish and other water-dwelling creatures. That happens because the numerous algae and bacteria eventually die and decompose. That process sucks up oxygen and creates low-oxygen “dead zones.”

Algal blooms also can produce poisons. Last August, an algal bloom in Lake Erie shut down the public water supply for Toledo, Ohio. City officials found a toxin called microcystin (MY-kroh-sIS-tin) at levels above one part per billion. This toxin can harm a person’s liver and nervous system. And people aren’t the only organisms that can suffer from this. Wildlife will too.

Even the runoff of soil can harm the environment. In the case of American’s biggest amphibians, the hellbenders, that sediment can cloud the rivers that these salamanders call home. In extreme cases, it can suffocate them.

In hopes of heading off these problems, researchers have been working on new approaches to runoff control.

How the two-tier ditch works

The part of Shatto Ditch used for Tank’s demonstration project stretches 0.8 kilometer (0.5 mile). The project rebuilt that stretch as a two-stage ditch. Land on each side slopes down to a middle level almost 2 meters (nearly 6 feet) wide. The ditch sides slope down again to the ditch’s main channel below.

Land at the middle level acts like the floodplains that often build up from silt when streams overflow their banks. Plants and soil microbes at that level help trap soils and catch nutrients, such as phosphorus and nitrate. The design also slows water flow under most conditions.

Tank’s team has done chemical testing on water samples from Shatto Ditch since 2007. Compared to a trapezoidal ditch upstream, the two-stage ditch has clearer water flowing out. That means less soil is flowing away. That water also has lower nutrient levels.

“There are water quality benefits,” stresses Tank. The Shatto Ditch project is short compared
to all the ditches and streams in the Midwest. But even small improvements in water quality can add up over thousands of miles in a river system.

**That’s not all**

The Shatto Ditch project includes other conservation practices as well. Some nearby farmers leave dead plants and stalks on the ground instead of plowing them up each fall. This so-called no-till practice helps prevent erosion of valuable crop soil.

Most farmers around the project also plant winter cover crops, such as annual rye grass. The green tops die off after snow falls and grow again in early spring. But long roots reach down into the soil the whole time. “The roots are holding nutrients on the land and not letting them run off into the water,” Tank says. At planting time, farmers kill the grass or other cover planting. Then they sow corn, soybeans or other crops.

Tank’s team sampled tile drains along Shatto Ditch throughout the year before widespread planting of winter cover crops began in the fall of 2013. They continued sampled drains throughout the following year. Levels of nitrates, one of the chemicals in fertilizer, dropped almost 40 percent. The samples also had lower levels of another fertilizer component, a form of phosphorus.

“These data are preliminary,” Tank notes. Other scientists still need to review the findings. But the results seem promising. Her team plans to publish its research soon.

**The benefits**

Local Indiana farmers are find value in adopting these practices. Mike Long of Warsaw and Jamie Scott of Pierceton say their farms need less fertilizer since they began taking part in the Shatto Ditch project. They believe that’s because fewer nutrients from soils and previous
fertilizer applications wash away. Spending less on fertilizer saves money now.

Over time, ditch maintenance could cost them and other farmers less as well. Silt builds up on the bottom of ditches, so most ditches need to be dug out every few years. With the two-stage ditch design, any soil that washes off fields tends to stay on the middle level. The bottom shouldn’t fill up as quickly.

The project offers environmental benefits too. “Projects like these are a huge step towards controlling heavy phosphorus loads in the face of these heavy rain storms that we seem to be getting in the springtime,” says Justin Chaffin. He’s a limnologist — someone who studies inland waters — at Ohio State University’s Stone Laboratory at Put-in-Bay. Chaffin is not part of the Shatto Ditch project.

“I applaud Tank’s approach to look at multiple practices in combination,” adds Jonathan Witter. He’s an agricultural engineer at Ohio State’s Agricultural Technical Institute in Wooster. Although not working on the Shatto project, he has experience studying other two-stage ditches. Stacking or combining practices, such as the two-stage design and winter cover crops, “is going to be a necessity,” he says. Otherwise, runoff pollution will continue, and the environmental problems it causes could get worse.

A demonstration project like Shatto Ditch can be “a real catalyst for other people adopting this strategy,” Witter stresses. “They can see it. They can watch it.” And by seeing it work they can be encouraged to try it on their own farms, he says.

Indeed, Tank hopes more farmers will start stacking conservation strategies. Reducing fertilizer runoff makes sense for the environment, as well as offering “dollars and cents” benefits to farmers, she says.
CITATIONS


*Questions for Ditching Farm Pollution.*
As infections ravage food crops, scientists fight back

Everything from chocolate to wheat to citrus fruits are at risk from devastating diseases.

Melese Tsegaye, a farmer in Kulumsa, Ethiopia, holds seed heads taken from stalks of wheat. Wheat is one of many crops that have suffered from disease outbreaks.

PETER LOWE/CIMMYT/Flickr (CC BY-NC-SA 2.0)

By Kathryn Hulick
August 15, 2019 at 5:45 am

You'll never see a tree barf or a flower sneeze. Still, plants get sick, much as we do. Their symptoms just look different. Their leaves may curl or drop. Their stems can break out in spots. Their fruit might shrivel.

One such plant sickness is called swollen shoot disease. Over the past two decades, it's swept through cacao trees in Ivory Coast, a country in West Africa. Cacao is the main ingredient in chocolate. Hundreds of thousands of these trees have sickened or died. "We saw this rapid, rapid death. Trees were dying in one year," Judy Brown says of the epidemic.
Romain Aka (left) looks for signs of disease on a cacao tree. This plant pathologist works at the National Center for Agricultural Research in Ivory Coast. Together with Judy Brown, he studies swollen shoot disease.

**Getting to know the enemy**

Fighting any epidemic begins with understanding the disease. “You have to know who your enemy is,” Brown says. The foe she's working to understand is swollen shoot disease.

It gets its name from one of its symptoms. Young branches of an infected tree will develop thick bulges. “We think those areas might be little virus factories,” she says. Inside the bulge, viruses may be multiplying rapidly. Leaves of infected trees grow smaller than normal, and often turn yellow or brown.
Different viruses can cause swollen shoot disease. Brown wanted to identify them. Scientists do this by reading a virus's genome (GEE-nohm). That's the complete pattern of nucleotides that tells a living thing how to grow. Nearly all living things have genomes made of DNA. Some viruses instead use a similar molecule, called RNA.

Each viral species has its own unique genome. Before Brown and her colleagues began working on the swollen shoot problem, they had identified seven viruses that cause the disease. Her team has turned up dozens of new ones. Today, the grand total stands at 84. Her team also has found that in some cases, more than one of these viruses has infected the same tree.

Identifying microbes by their DNA is a long, involved process. First, Brown collects an infected leaf. She separates the viral genetic material from all of the other molecules in the sample. Then she uses techniques similar to the ones police use to identify criminals. She makes many copies of the viral DNA (or RNA) so that it is easier to study. Computer programs then read through these copies, matching patterns to build up a complete readout of the genes.

For now, all of this happens in a lab. And it can take several weeks or longer. Brown wishes you could put a leaf into a handheld device to find out whether a tree was sick, even before any symptoms showed.

**Heading into the field, literally**

No such handheld tool yet exists. But another researcher, working on a different disease, has made a portable DNA sequencing lab that fits inside a suitcase. Sequencing means finding the pattern of genes and other genetic material in a sample.

Diane Saunders works at the John Innes Centre in Norwich, in England. This plant pathologist specializes in a group of diseases that attack wheat. They're known as rusts. Their common names are leaf rust, stripe rust and stem rust. All make their host plants
break out in reddish-brown or yellow spots or stripes. They get their names from the fact that these lesions look a bit like rust on metal.

The reddish-brown splotches on this wheat leaf reveal that the plant is infected with stem rust. Microbes called fungi cause the sickness.

Thousands of years ago, the Romans believed that the god Robigus was responsible for wheat rust. They threw a festival in his honor each year on April 25th. The festivities involved sacrificing an animal with reddish fur. Supposedly, this would please the god and protect the wheat.

Now scientists know that single-celled fungi cause plant rusts. Farmers can spray chemicals called fungicides on a field to kill the microbes. But that’s expensive. And sometimes the crop dies anyway, notes Ruth Wanyera in East Africa. She’s a plant pathologist at the Kenya Agricultural and Livestock Research Organization (KALRO) in Njoro.

She thinks a better approach is to plant crops that naturally withstand the fungal infection. Certain genes toughen plants up so they can fight off various types of fungus. But no wheat variety resists every type of disease. To choose which variety to plant, farmers must know which rust-causing microbes live in their region.

Until recently, the only way to figure out the identity of a fungus was to mail a sample to a lab. Getting a result would take “many, many months,” says Saunders. In fact, analysis would take longer than it took for the wheat to ripen. Farmers would have to plant their next crop
before finding out which diseases had attacked the previous crop.

Diane Saunders and a technician from the Ethiopian Institute of Agricultural Research try out the MARPLE tool in the back of a car. Here, they are cleaning a sample to remove everything except DNA.

So Saunders’ team put together a tool they call the Mobile And Real-time PLant disEase diagnostic kit, or MARPLE for short. (The name is a nod to Miss Marple, the British detective in a famous series of mystery novels by Agatha Christie). It’s like a miniature laboratory. To use the kit, someone first mashes up plant material and puts it through a series of steps very similar to what Brown does in her lab. After just a few days, a laptop computer spits out genetic information. It’s not the entire genome. But it’s enough information to identify a fungus.

The kit doesn't need constant electricity or internet access. So researchers can bring it into wheat fields anywhere in the world. That’s exactly what Saunders did during a test of the technology in Holeta, Ethiopia last year. Her team worked with the Ethiopian Institute of Agricultural Research to test rust from real farmers’ fields. At the end of the 10-day trip, the group shared a list of the fungi they had found. “It was the earliest warning they’ve ever had about what strains they have in their country,” says Saunders. The team has submitted its research for publication.

So far, the tool can identify only strains of stripe rust. But Saunders hopes to one day add
the ability to identify stem rust.

**Breeding plants for battle**

In the late 1990s, a new and very aggressive strain of stem rust appeared in Uganda. Named Ug99, it devastated farm fields in Africa and the Middle East. “It can turn a wheat field in a matter of days into nothing,” says Maricelis Acevedo. She is a plant pathologist at Cornell University in Ithaca, N.Y.

Realizing the crisis it posed, the scientific community began hunting for wheat genes that could resist the new disease. Acevedo studied one resistant plant, called Montenegrin spring wheat. She started with a genetic map of the plant. The map didn’t cover the plant’s complete genome, just a general outline of it. She also had the genetic map for a different wheat variety that easily died from the disease.

She bred the two types of wheat together. Some of the offspring inherited resistance to Ug99. Others didn’t. Acevedo repeated this process again and again over several generations. At the same time, she compared all the plants’ genetic information, hoping to puzzle out which genetic material made a plant resistant.

It was slow work. Each time she had to wait for a new generation of wheat plants to grow up before she could assess their resistance. After four years, however, her team showed that multiple genes work together to protect Montenegrin spring wheat from Ug99.

“Now we’re in the process of identifying if all these genes are fully necessary or if one or two genes provide most of the resistance,” says Acevedo. When her results are final, she’ll share them with breeders. From there, it may take up to 10 more years to produce a variety that’s ready for farmers’ fields.
Ruth Wanyera (at center) teaches students and colleagues at KALRO Njoro about rust diseases. Here, she's demonstrating how to judge the severity of an infection.

Ten years is a long time to wait for better wheat plants. In the meantime, climate change is causing more extreme weather around the world. When the weather is warmer, wetter or drier than normal, plants have trouble coping. That makes it harder for them to fight an infection.

In addition, new diseases or new strains of known diseases will continue to emerge. A plant that resists Ug99 may not fare as well against a slightly different strain of wheat rust. “The disease is windborne and keeps on mutating,” notes Wanyera. “Scientists have to be awake all the time.” The faster scientists can identify resistant genes and develop stronger wheat plants, the better.

The quickest way to create a stronger plant is by directly “editing” a plant’s genes in the lab. This is called genetic modification, or GM. Once scientists have identified all the genes they want in a plant, they can cut and paste them together. They don’t have to wait for many
generations of thousands of baby plants to grow. “We know we can do it,” says Acevedo. “We have proof that it works.”

But the idea of changing a living thing’s genes makes many people nervous. Any technique that involves adding, deleting or altering genes in a lab is a form of genetic modification. A food that has gone through this type of process might be called a genetically modified organism, or GMO.

In the United States and Europe, many food products boast the label “non-GMO.” It means that none of the ingredients in the food contain genes that were modified in a lab. Scientific studies have shown that GM foods are safe to eat, concluded a massive 2016 review by the National Academy of Sciences. Still, many people refuse to buy products that contain such ingredients. So Acevedo and many others tend to breed crops using traditional, slower methods.

**Animals for oranges**

Genetic testing and modification aren’t the only way to find and fight crop diseases. Some researchers have recruited animals to join the battle.

The company F1K9 in Yalaha, Fla., trains dogs to sniff out bombs, drugs — and diseases. They’ll work with “any [dog] that’s got a nice, long nose and the desire to please,” says William Schneider. He is a molecular biologist with the company. Dogs he has helped train have been sniffing out citrus greening disease. (This plant ailment also goes by the name of huanglongbing, or HLB.)

Citrus greening disease affects all citrus fruit. That includes oranges, grapefruit, tangerines, lemons and limes. A sick tree produces skinny branches with tiny leaves. The small, hard fruit it produces also fall off before ripening. Eventually, an infected tree will die.

The disease arrived in Florida in 2005, then spread rapidly. Today, around four out of every five citrus trees in Florida have the disease. Citrus growers in the state now produce less than half of the fruit that they used to. In 2012, citrus greening disease made it to California, though the sickness has not yet spread to large orchards there.
A genetic test for citrus greening disease exists. But scientists sample just a few leaves at a time. So their testing might not catch the disease very soon after a tree is infected, a time when most of leaves show no symptoms. Yet even though it doesn’t appear sick, this tree can still infect its neighbors.

However, Schneider says, his dogs smell the entire tree at once. They often can detect the disease before genetic testing or human eyes identify a problem. Schneider’s company has brought their trained dogs to farmers’ groves in Florida and California. When the dogs find disease, farmers cut the infected trees down. This may help save the grove.

The disease the dogs are sniffing out is a bacterial infection. But the bacteria that cause citrus greening disease can’t hop between trees on their own. They move by hitching a ride on a tiny flying insect called the citrus psyllid (SILL-id). It sucks sap from trees. When this insect feeds on a sick tree, it picks up the bacteria. The next tree it visits may now become infected. In the United States, citrus psyllid is an invasive species. And it has no native predators.

Farmers can treat their trees with chemical insecticides. But in cities and backyards, these chemicals may not be safe to use. Another bug might be a better weapon.

The wasp *Tamarixia radiata* lays an egg on a young citrus psyllid. When the egg hatches, her young will devour its host.

In Asia, the original home of citrus trees, a tiny wasp called *Tamarixia radiata* hunts and eats psyllids. This wasp is as small as a grain of sand and harmless to people. It lays its eggs on
young psyllids, called nymphs. Later, a baby wasp will hatch out of each egg and “eat the nymph alive,” notes David Morgan. He works for the California Department of Food and Agriculture in Riverside. As an entomologist, he studies insects.

Morgan and his colleagues, Mark and Christina Hoddle, wondered if wasps could help hunt psyllids in the United States. The Hodddles are a husband-and-wife team of entomologists who work at the University of California, Riverside. They’ve been raising baby *T. radiata* wasps for several years.

The researchers made sure that the wasps wouldn't harm any native insects. Then in 2011, the Hodddles released several hundred wasps into the wild in California for the first time. Since then, they sent some 13 million of the tiny warriors in search of psyllids. In some places, this has brought down the population of citrus psyllids by almost 70 percent, says Morgan. Fewer psyllids means the chance that citrus greening disease will spread also is lower.

Dogs and wasps are joining scientists in the war against many diseases that threaten important crops. Cacao, wheat and citrus aren’t the only foods at risk. Epidemics of fungus affect *banana*, coffee and rice plants. When it comes to keeping food on our plates, every bit of help counts.

**CITATIONS**


AGRICULTURE

Robots will control everything you eat

Technology is changing the way your food is grown — and prepared

Some farmers have begun to enlist drones — robotic aircraft — to precisely map their fields, their crops and crop threats (such as insects and excessive thirst). One day soon, robots may also be picking crops, driving them to market and more.

ILZE79/ISTOCKPHOTO

By Terena Bell

January 25, 2018 at 6:45 am

It starts with a seed. That seed — maybe it’s a tomato seed — gets planted into the ground. Then it grows. And grows. Slowly, the plant pierces through the soil, emerging into the light. Weeks to months later, this seed becomes a plant, waist-high, bearing dozens of ripe tomatoes. Someone picks the fruit and packs it into a box. Someone else ships those boxes to warehouses where a restaurant or grocery buys the tomatoes. Later, a cook will take one, cut it up and put it in a salad.

Today, this process is still pretty low tech. Sure, there are cars and trucks involved, but
robotics? Not as much. People are still key players at every step. But that may change, and soon.

“There are major technologies coming in the next 10 years to make each part of farming more efficient, more productive and hopefully healthier and less expensive,” says Dan Steere. He heads up a company called Abundant Robotics in Menlo Park, Calif.

In other words, robots increasingly are going to play roles in growing and preparing our food.

By time the time kids in middle school become adults, the entire food cycle may be robotic. Even now, robots help farmers. Some plant fruits, vegetables and grains in a more efficient way. Soon, they’ll help harvest that food more quickly. Some food warehouses already have self-driving trucks. Robots will even help get that food onto our plates. In fact, a robot named Sally is already doing just that. The goal is to make the way food is produced and prepared faster, easier and more efficient.

**Getting seeds in the ground**

Every field has some areas that are naturally less fertile than others. Farmland may not be level, either. It can have areas that rise or are lower than their surroundings. There may even be ditches. Plowing evens out the ground somewhat, but never completely. If a creek runs through a field, there’s always going to be land near that creek where it’s difficult — or impossible — to plant. Soil quality also varies throughout a field.

All of these things can impact how much food the land can produce and how good that food will taste. And the amount of food produced affects how much money a farmer makes.

Math helps farmers calculate how many seeds to plant and where. But land also changes over time, so these calculations must be done over and over again every year.
Theo Pistorius is head of a company called DroneClouds. It’s in Cape Town, South Africa. His is one of many companies using drones to help farmers know where to plant. *Drone* is slang for *unmanned aerial aircraft* — a flying robot. The craft that DroneClouds uses has five cameras. Pistorius says each camera “is essentially [like] a camera on an iPhone.” But not a normal iPhone. He says think of each as “a very specialized, aerial iPhone, with a very specialized, calibrated camera.”

As the drone’s cameras fly overhead, they take pictures of the land. These show field size and the different lays of the land. They also reveal soil variation and any irrigation problems. They even show where insects and fungus might cause problems.

Next, DroneClouds processes those images to create a map of the field and what’s growing in it. “We then do analyses to interpret it for the farmer,” explains Pistorius. If the images come from an apple orchard, for instance, they might look at how the trees are growing. They’ll note where tall weeds might cause a brand new tree to struggle.
To pinpoint problems, analysts compare these pictures to others of the same crop. This is called *comparative analysis*. Pistorius says it's like running a race, then comparing your time today to what it was earlier in the season. That lets you measure how much you've improved. But runners also compare their time against other runners. So farmers compare pictures of their field to those of other farmers. This is known as a *signature-based analysis*.

“The ideal pictures come from labs all across the world,” Pistorius says. “Every four years, scientists from the Agricultural Research Commission [in South Africa] meet with labs [in the United States], and take a bunch of signatures.” This way farmers in both countries can help each other.

**Picking fruit**

Consistently monitored, the little plants grow. Day after day, the sun rises and falls. Sometimes it shines, other times there's rain. Finally, harvest time arrives. And with it comes new, cutting-edge work in farm robotics.

For two years, Abundant Robotics has been developing a robot that picks apples. Two years? Isn't picking apples easy?

Not if you’re a robot.
To understand why apple picking is hard for a machine, let’s break down the process. When you see an apple hanging on a tree, your eyes send a signal to your brain. The brain processes the data in this signal — such as the apple’s color and where it is on the tree. Instinctively, you’ll know when the apple’s ready to pick. Your brain then tells your arm to reach out and your hand to pull the fruit away from its branch. You hold the apple like you would a bird — gently enough not to bruise it, but firmly enough that it doesn’t fall away.

For people, picking an apple is so easy, even a kid can do it. But for robots, this simple activity used to be impossible.

BUBUTU-JISTOCKPHOTO

When you pick an apple, you make all these decisions quickly. But if you needed to pick an entire field’s worth of apples, it would take a very, very long time. After you picked one apple, you’d have to put it in a basket. The next apple would go in there, too, and the next, until your basket was full. Then down the ladder you’d go, where you’d have to empty your basket before climbing back up to start again.

Doing this for hundreds of trees would be incredibly time consuming. That’s why people are seeking help from robots. When Abundant Robotics is done, farmers will be able to plant more trees. And they won’t be worried about part of their crop rotting in the field because people weren’t able to pick it all in time.

The first problem Abundant Robotics had to solve was acquiring the right signals. “If you don’t have a good pair of eyes, it’s hard to do a lot of tasks in the real world,” Steere says. So the company had to give their robot what Steere calls “a better pair of eyes.” This system — and how it connects to a robot’s brain — is known as computer vision. Computer vision helps
the robot see “every surface of an apple,” says Steere, in addition to judging its size, color and weight. It can even scout for any defects in the fruit. Such systems are rapidly improving what robots can do.

Yet even with super eyes, the apple robot still had to learn how to physically pick the fruit without hurting it. In robotics, movement is called animation. Steere says, “Heavy animation damages the fruit.” If it bruises the apple or cuts through the skin, the fruit may look bad and likely won’t sell. Rough handling also can damage trees.

So the robot must coordinate its vision and motor skills. Think back to the apple-picking process: You have to know which apple to pick. You have to pick it quickly and gently. But what else? You can’t disturb apples on the tree that still need time to grow. “The vision has to ... recognize fruit,” Steere says, and “recognize whether it’s ripe or not.” And it has to do all that in a fraction of a second.

“People have wanted to automate this type of agriculture for decades. It’s just never been possible,” he says. Even after two years, his team’s work still is not done! Abundant’s robot won’t go on sale until later this year. Developing great tech is like farming — it takes patience.

**Sorting the harvest**

![Coffee berries come in many colors. A new robot can quickly sort the good ones from the bad.](BONGA1965/ISTOCKPHOTO)

Once the crop been picked, good fruit must be sorted from the bad. That’s what a company
called bext360 does. Instead of apples, its robot works with cocoa, nuts, cardamom (a spice) and coffee cherries (the fruit that holds coffee beans). Daniel Jones heads the company, based in Denver, Colo.

Take those coffee cherries. “The farmers would harvest their coffee and place it in our machine,” Jones explains. “Then the machine drops [the fruit] through a visioning system.” Picture a waterfall of cherries falling. That’s what the machine stares at, all the while taking pictures of the passing fruit. The robot then uses those pictures to sort good coffee cherries from bad.

Machine vision and computer vision are essentially the same thing. Abundant and bext360’s robots do different tasks. Still, the same core technology helps both of them do it.

Both robots also need more than computer vision to succeed. Vision can tell bext360’s robot how to sort, but then the robot actually has to do it. Farmers harvest coffee cherries — up to 30 kilograms (66 pounds) — from one section of their field at a time. Then they load cherries holding some 18,000 beans into a chute on top of the robot.

Within about 3 minutes, the robot will have individually sorted every cherry. To do that, the
robot has to take a picture of each one. Then it analyzes them all in a mere 22 milliseconds or so. “We’ll know everything about them in that split second that they fall through [the chute],” says Jones. Puffs of air then push the cherries into different bins — one for good fruit, another for rejects.

After the coffee cherry falls, the robot shares its analysis with the farmer. “The main things [the robot measures] are size and color and density,” says Jones. It also checks the inside and outside of the cherry for signs of rot or disease. This is why farmers only put cherries from one part of their field in at a time. This information helps them know if something they tried in one part of a field worked better than something they tried elsewhere.

The robot from bext360 is still new: Sales only started about six months ago.

**Onto the plate**

Picked, analyzed and sorted, a harvest now goes to a warehouse. One day, it might get there in a self-driving semi-truck. And a self-driving forklift might move the pallets off the truck and onto another that is destined for a restaurant or store. Amazon already has a grocery store just for employees that doesn’t have any human stockers or check-out clerks: They’re all robots.

![Forklift](https://commons.wikimedia.org/wiki/File:Forklift%2C_Ansa%2C_Brussels.png)

This forklift doesn't need a driver. It can drive itself.

* STRASSENBAHN/WIKIMEDIA COMMONS (CC-BY-SA 3.0)

Finally, the food might end up with our last robot: Sally. Sally makes salads. From the outside, she looks like a box. There’s a touchscreen and a hole where a bowl can be placed.
Inside, though, this robot's more complicated. “Sally is a box with the robotic components on the inside,” notes Deepak Sekar. He heads up Chowbotics, in Redwood City, Calif. It’s the company that makes Sally.

“There are cylinders inside the robot that are filled with prepped ingredients,” Sekar explains. People activate Sally by pressing the touchscreen. Diners can customize their salads by calorie count and ingredients.

At $30,000 per robot, Sally isn’t designed to be used at home. Chowbotics sells the robot to schools and offices, which use Sally in cafeterias and breakrooms. Observes Sekar: “We hear all the time that students in schools don’t like eating from salad bars.” Why? Sekar claims they’re gross. “Because all the ingredients are inside Sally, you don’t have to wonder if someone sneezed on the tomatoes an hour ago — ew!,” he says. “Your salad is always fresh and healthy.”

Robots aren’t in every part of the field-to-plate process yet. But soon they will be. This will make the food process cooler for us. Even more importantly, robots could one day even out the world’s food supply. Think about it: Today, DroneClouds helps farmers know how to plant more. bext360 helps them know how to plant more efficiently. Abundant Robotics helps growers harvest more quickly — which means farmers can plant more. Then Chowbotics stores that produce in a healthier way.

Says Steere, “If there was ever a time [for] a young person going into farming — this has gotta be one of the most amazing times in history. The kind of things that automation can do is going to continue to change and to evolve quickly.”

*Note: This story was updated on January 26, 2018 to correct the spelling of Deepak Sekar’s name and the location of Chowbotics’ headquarters.*

**CITATIONS**

*Questions for ‘Robots will control everything you eat’*

*Wordfind*
ECOSYSTEMS
Soggy coastal soils? Here’s why ecologists love them
At risk from climate change, these wetlands could actually cut some climate-change impacts

Coastal wetlands like this one in South Carolina are not only beautiful — they’re also functional. They can help counter some of the impacts of climate change and intense storms.

KEITHBRILEY/ISTOCK/GETTY IMAGES PLUS

By Alison Pearce Stevens
September 17, 2020 at 6:30 am

Katrina. Harvey. Laura. Sandy. Maria. For some people, these might be merely names. For others, they’re reminders of utter devastation. Some of the most damaging storms to hit North America bear these names. Each one did billions of dollars of damage to buildings, roads and other property. People died in their floodwaters. Many coastal areas have yet to recover.
A storm’s destructive power stems from its winds. Powerful gusts not only blow objects around, they also churn up massive waves called storm surges. This is a rapid rise water that rushes onshore, sweeping away trees, cars and almost anything else in its path. Storm surges can flood buildings, trapping people inside or forcing them onto roofs, where they wait for rescue.

What if there were a way to slow those storm surges, to prevent them from scouring the coastline with their raw power? Turns out, there is — if we allow nature to do its thing.

Coastal wetlands hold the key to damping big waves. They provide flood control and critical habitat for young fish and other marine creatures. They help stabilize climate by trapping carbon. And they’re critical for coasts dealing with rising sea levels.

**Standing up to storms**

*Wetlands* are more than just wet land. They are ecosystems of plants and animals thriving in areas that flood at least part of the year. Coastal wetlands are often grassy marshes. Warmer areas may support mangroves. These trees grow right along the coastline, their long, stilt-like roots stretching down into the water. Those roots provide critical habitat for fish, shrimp and other marine animals. They also trap silt and other sediment, protecting it from erosion and building up the shoreline.
Anna Armitage is a marine biologist at Texas A&M University at Galveston. There, she studies coastlines along the Gulf of Mexico. Hurricanes regularly hit this area. She and her team have created study plots with randomly placed patches of marsh and mangrove. As temperatures have been warming, mangroves have been spreading. The team wanted to learn about the ecological changes that take place when mangroves overtake a marsh. But in 2017, their plots took a direct hit from Hurricane Harvey. A category 4 storm at the time, Harvey’s winds raged up to 217 kilometers (135 miles) per hour. The event offered a unique opportunity to study how different types of wetlands survive a big storm.

Marshy wetlands came through quite well, researchers found. The storm surge covered the grasses completely. This protected them from damaging winds. “There was erosion right along the shoreline,” Armitage says. But just 10 meters (33 feet) in, the marsh plants were fine. If they were submerged for longer, the plants might have drowned, Armitage notes. But Harvey’s storm surge didn’t last long enough to kill those plants.

High water also protected the shorter, scrubbier mangroves. But trees more than 2.5 meters (8.2 feet) tall, which grew right along the water’s edge, weren’t completely submerged. High winds broke branches above the water and stripped off their leaves. Those areas began to regrow within two months of the hurricane. But they still haven’t completely regrown. “It appears that full mangrove recovery will take longer than two growing seasons,” Armitage says.
Mangrove roots form a thicket along the waterline, which supports a wide variety of marine life. During storms they can also diminish an oncoming surge of high waves.

Both marshes and mangroves help reduce inland flooding. “Mangroves may reduce [storm] surge more because they are taller,” Armitage says. “But their height also makes them more vulnerable to storm damage.” The benefits are about equal between the two types of wetland, she concludes.

Coastal wetlands are essential for flood protection during big storms, says Siddharth Narayan. He’s a coastal engineer at East Carolina University in Greenville, N.C. He and a team of researchers from around the world used a computer model to understand just how much of a difference marshy wetlands make. (A computer program, such a model uses math to predict how a complex real-world event might unfold.)
They ran their program using Hurricane Sandy as their model storm. This superstorm hit the Northeastern United States in 2012. It killed 72 people and its flooding alone caused $50 billion in damage.

The computer model looked at property damage that Sandy caused along the Atlantic coast from Maine to North Carolina. The team ran the model twice: first with wetlands as they exist now, and a second time with all these wetlands removed. Without those wetlands, the U.S. East Coast “would have experienced $625 million more in damages,” Narayan now reports. Areas upstream from coastal wetlands also benefited in the model — even if they no longer had nearby wetlands. That’s because coastal wetlands would sop up the excess water, slowing the surge upstream.

Wetlands could actually cause a few areas to flood more, according to the model. That’s because homes here had been built between the wetlands and ocean. Those homes wouldn’t get any benefit from wetlands soaking up the storm surge. What’s more, the wetlands would prevent some of that water from moving inland, so flood levels around those homes would rise higher.

**Wetlands under threat**
Storms bring extremely high tides and large surges of water that can overwhelm seawalls. Wetlands can sop up some of that bonus water to limit flooding — and in some cases even prevent it.

MOOREFAM/ISTOCK/GETTY IMAGES PLUS

Narayan’s model didn’t include wetlands as they existed 100 years ago. Those were much larger than today’s. Coastal wetlands have been shrinking around the world for the last century. Anything that interrupts the way they interact with their surroundings can pose risks to them, Narayan says. That can include changes in the flow, temperature or saltiness of water, he notes. That last one is a major problem. If too much freshwater — or salty seawater — gets into the wetlands, it can kill off plants that need just the right amount of salt to thrive.

Wetland sediment also erodes from the constant wash of waves. In the past, spring floods replaced that missing sediment, Narayan says. Swollen rivers carried sediment downstream, depositing it along the way. This rebuilt the sandy base for wetlands along rivers. It also built the broad deltas that form where rivers meet the sea.

But people have altered rivers to prevent floods. Dams hold back sediment, trapping it higher up the river. Riverbanks are often reinforced with concrete, to prevent them from eroding. These changes have stopped the essential flow of nutrient-rich sediment to the river’s deltas and the wetlands they support.

Other threats to wetlands are more direct. People fill them in to build homes, restaurants or hotels. They use chemicals that kill weeds and pests. These can then wash downstream,
harming plants and animals along the way. Building roads can cut off the flow of water. Severe storms can kill wetland plants by carving channels that let seawater move too far inland. Other times, Narayan points out, storm surges can be surprisingly helpful, depositing sediment that helps wetlands extend out into the ocean.

To survive, coastal wetlands need space to shift, Narayan explains. Wetland plants need specific amounts of salt in the water — too much or too little will kill them. That creates another problem: As Earth’s climate changes, sea levels are rising, pushing saltwater farther inland.

Wetland plants respond to rising sea levels “by growing vertically and also by shifting landward,” Narayan says. They try to “stay in the same tidal range that they’re used to.” But this requires space, he notes. And in many places, human-built barriers prevent a wetland’s ability to move. “As a result, these living wetlands end up getting squeezed against a hard shoreline and drowned,” he says, as the seas rise.
Exactly how sea-level rise will affect coastal wetlands has been a bit of a mystery. But a recent study by Australian researchers offers hope. Kerrylee Rogers is a coastal scientist at the University of Wollongong. It’s in New South Wales, Australia. Rising seas can play a role in fighting climate change, her team finds. They do this, Rogers explains, by forcing coastal wetlands to store carbon below ground and within the living plants.

The team compared the carbon stored in the sediments of 345 coastal wetlands. They were on every continent except Antarctica. Some were where sea level is rising rapidly. In others, water levels had been largely stable. Where seas had been rising, they found, coastal wetlands collected more sediments and carbon. “As long as the plants can survive, the sediment will continue to store carbon as seas rise,” Rogers concludes. “This will help coastal wetlands to adjust to sea-level rise.” It also could help slow climate change, she notes, by storing more carbon where it can’t be released into the air.

**Bringing wetlands back**

![Photo of wetlands](image)

*After Hurricane Sandy in 2012, water flooded — and badly damaged — the Prime Hook National Wildlife Refuge beach road in Delaware, seen here.*

USFWS/Flickr
People around the world are starting to recognize the important role of coastal wetlands in flood control. And in supporting the fisheries that feed us. Many organizations are now working to restore coastal wetlands. However, those efforts face challenges. Some new wetlands haven’t worked as well as the wetlands they replaced. But with every setback, researchers learn what doesn’t work — and what does. This helps guide their next efforts.

Allowing the flow of water through coastal areas to return to normal seems key. That’s the lesson from Prime Hook National Wildlife Refuge. Home to sand dunes and marsh, it sits along the coast of Delaware. From 2006 to 2012, a series of storms broke through the dune barriers. Saltwater washed into an area that had been freshwater only, killing 4,000 acres of vegetation — an area equal to more than 3,000 football fields. In 2012, Hurricane Sandy blasted through the remaining dunes, completely flooding what had once been a thriving ecosystem.

The next year, the U.S. Fish and Wildlife Service began studying how to best rebuild the refuge. After studying computer models of natural water flow — both saltwater and fresh — they begin a massive restoration project. Bartholomew Wilson led the effort at this government agency.

His team dredged sand from Delaware Bay, using it to rebuild two miles of beach. They dug channels through the former wetland to let both freshwater and salty tides flow through it as they had in the past. Mud from the channels built soil up so that it was higher than the water line. On those mud flats, a team of 12 people planted more than a half million marsh
plants to help anchor the sediment in place. A plane dropped about 4,500 kilograms (10,000 pounds) of seeds to further boost plant growth. And a new road along the shoreline now includes a bridge and four pipes that let tidal waters flow freely into the wetland on the other side.

Dredges at Prime Hook in Delaware brought up mud from beneath the floodwaters, spraying it onto nearby areas. This created channels for water flow.

RICHARD WEINER/USFWS/Flickr

It was a massive project — and that was the biggest challenge, Wilson says. “We had a beach being rebuilt with one very large dredge and six bulldozers.” Those moved enough sand to fill 424 Olympic swimming pools. At the same time, three smaller dredges dug 25 miles of channels through the wetlands. “This is the largest restoration project ever on the East Coast,” Wilson says. It’s also one of the most successful, he adds.

By 2018, Prime Hook was a thriving ecosystem again. Many plant and animal species again call it home. These include bird species such as piping plovers, least terns and American oystercatchers. All three species are endangered, and the restored wetland provides habitat
that may help boost their populations.

Endangered American oystercatchers rely on coastal wetlands for food and nest sites.

RABBITT/IStock/GETTY IMAGES PLUS

What’s more, the area has held up well to storms. “We had four storms last year in a few-week period,” Wilson told Science News for Students. And Prime Hook experienced “only minor erosion,” he says. No hurricanes like Sandy have yet tested the area’s resiliency. But one nor’easter brought a near-record storm surge — and it had very little impact on the restored refuge. (Nor’easters are a type of big, intense storm that can strike the northeastern United States.)

Wetland restoration benefits human communities, too. “Before the project, several of the roads leading through the refuge would flood every month or two,” Wilson says. The project finished in 2016. Since then, these roads haven’t flooded once.

Prime Hook is just one example of a restored coastal wetland. Many others are also underway around the world. Organizations and government agencies often work together, says Narayan of East Carolina University. They might move a road to give nearby wetlands more space. Or they might nourish them with sand or mud that, for a while, had been prevented from reaching the area. Adding culverts (openings) under roads can allow tidal flow in and out of a wetland that’s been disconnected from the ocean. It’s a big task, but many teams are up to tackling it.
“People are trying to figure out how we can work with nature to improve the health of these wetlands,” Narayan says. There is no one right answer on how to do this. And the solutions will vary with the site. But in the end, he says, such efforts can pay big benefits to both the environment and human communities.

CITATIONS


OPINION: The New Agriscience: Beyond 'Cows and Plows'

Education Nation //Oct. 1, 2010 // 8:00 AM

Education Nation invited an array of contributors to share their views and ideas on a wide variety of education topics. If you’d like to contribute, contact us at educationnation@nbcuni.com.

When I became a Delaware Agriscience teacher just over seven years ago, I was asked "Do kids still take ‘Ag’ in high school? Nobody is farming anymore." Friends laughed at the career path I’d chosen - teaching about "cows and plows."

No response to critics of Agriscience education works better than posing one simple question to them: "Well, you like to eat don’t you?" The simple fact is that without agriculture we would have nothing to eat - yet many Americans in 2010 cannot connect the food that they buy at the grocery store to the source it once was. If children do not know where their food comes from today, how can we expect them to feed the world tomorrow? This is the value of Agriscience education.

Every student in grades K-12 would benefit from a curriculum that has roots in agriculture. Agriscience education is no longer just about teaching America’s youth to raise livestock, plow fields, and fix tractors. We also teach students about genetically altering crops to produce higher yields, while reducing the amount of pesticides. We have students researching Colony Collapse Disorder and how decreased numbers of honeybees could impact food production worldwide. We have students comparing efficiency rates of fossil fuels versus biofuels such as crop-based ethanol and soy biodiesel.

Today’s ‘Ag’ curriculum has evolved to include complex scientific and ethical topics such as the release of transgenic organisms into the environment, and the relationship between animal genetic engineering and human organ transplants. Students in Agriscience classes use all aspects of STEM - science, technology, engineering and mathematics - to learn about issues impacting our world. And because Agriscience students are applying what they learn everyday, they don’t ask "when will I ever use this?"

Our children will face an unprecedented challenge: how to feed the world’s growing population on less land than ever before, while simultaneously meeting the world’s growing energy demands. Today’s agriculturalists are helping to meet these challenges; students with a foundation in agriculture will be the leaders meeting those challenges tomorrow.
How many of those students are there? Visit the National FFA Convention held every year in late October (Oct. 20-23 this year, in Indianapolis). Talk to any one of the more than 50,000 students dressed in the signature FFA Blue Jacket, and ask them why agriculture is important. Our students know that our country’s roots and world’s future prospects are in agricultural production; that agriculture’s past, present, and future is more important now than ever before. That is why I teach Agriscience. I believe in the future of agriculture and it is my hope to inspire others to as well.

*Kellie Michaud is an Agriscience Teacher and FFA Advisor at Smyrna High School in Delaware.*
Additional Lab Activities/Resources for Your Classroom!

Agriscience Lab Activities:
- National Ag in the Classroom - https://www.agclassroom.org/teacher/matrix/search_result.cfm

Other Resources:
NAAE Communities of Practice
Facebook Ag Ed Discussion Lab
Science News for Students: https://www.scientificnewsforstudents.org/topic/agriculture
LSU Coastal Roots Program: https://www.lsu.edu/coastalroots/index.php

Lab Kit Resources:
Wards Natural Science: http://wardsci.com/
Carolina Biological: http://www.carolina.com/
Lab Aides: https://lab-aids.com/