Vanderbilt Student Volunteers for Science

https://studentorg.vanderbilt.edu/vsvs/
VOLUNTEER INFORMATION

Team Member Contact Information

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Teacher/School Contact Information

School Name: ___________________________ Time in Classroom: __________________

Teacher’s Name: ___________________________ Phone Number: __________________

VSVS INFORMATION

VSVS Educational Coordinator:
Paige Ellenberger 615-343-4379
paige.ellenberger@vanderbilt.edu

VSVS Office: Stevenson 5234

Co-Presidents: Carli Needle carli.d.needle@vanderbilt.edu
Meghana Bhimreddy meghana.bhimreddy@vanderbilt.edu

Secretaries: Emily Chuang emily.a.chuang@vanderbilt.edu
Derek Lee lynn.lee.1@vanderbilt.edu

Vanderbilt Protection of Minors Policy: As required by the Protection of Minors Policy, VSVS will keep track of the attendance – who goes out when and where.
https://www4.vanderbilt.edu/riskmanagement/Policy_FINAL%20-%20risk%20management%20v2.pdf

Before You Go:
The lessons are online at: https://studentorg.vanderbilt.edu/vsvs/lessons/
• Email the teacher prior to the first lesson.
• Set a deadline time for your team. This means if a team member doesn’t show up by this time, you will have to start the lesson without them.
• Don’t drop out from your group. If you have problems, email Paige or one of the co-presidents, and we will work to help you. Don’t let down the kids or the group!
• If your group has any problems, let us know ASAP.

Picking up the Kit:
• Kits are picked up and used for lessons in the VSVS Lab, Stevenson Center 5234.
• The VSVS Lab is open 8:30am – 4:00pm (earlier if you need dry ice or liquid N₂).
• Assign at least one member of your team to pick up the kit each week.
• Kits should be picked up at least 30 minutes before your classroom time.
• If you are scheduled to teach at 8am, pick up the kit the day before.
• There are two 20 minute parking spots in the loading dock behind Stevenson Center. Please do not use the handicap spaces – you will get a ticket.

Just relax and have fun!
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### CLASSROOM ETIQUETTE

Follow Metro Schools’ Dress Code!
- No miniskirts, shorts, or tank tops.
- Tuck in shirts if you can.
- Please dress appropriately.

Metro student standard attire guideline:

### COLLEGE Q&A SESSION

VSVS members should be candid about their experiences and emphasize the role of hard work and a solid body of coursework in high school as a means to get to college.

- Email the teacher prior to the first lesson.
  - They may want to have the students write down questions prior to your lesson.
  - They may also want to have a role in facilitating the discussion.
- Finish the experiment of the day and open up the floor to the students.
- Remind them of your years and majors and ask if they have specific questions about college life.
- If they are shy, start by explaining things that are different in college.
  - Choosing your own schedule, dorm life, extracurricular activities, etc.
  - Emphasize the hardworking attitude.

The following are some sample questions (posed by students):

- When is bedtime in college? Does your mom still have to wake you up in college?
- How much does college cost?
- What do you eat in college and can you eat in class in college?
- How much homework do you have in college?
Volunteer FAQ

→ What is VSVS?
   VSVS stands for Vanderbilt Student Volunteers for Science.
   Members of this organization volunteer to teach hands-on science lessons to 5th-8th grade classrooms in the Metro Nashville School District.

→ How often are lessons?
   Each team teaches 1 lesson per week for 4 consecutive weeks throughout a semester.

→ What is the time commitment?
   Relatively low!
   Depending on your position, you'll attend between 1-3 training sessions at the beginning of the semester, and each of the 4 lessons take about 1.5 hours (30 minutes to run through each lesson beforehand and 1 hour to teach it).

→ Who will I be teaching with?
   All volunteers are put into groups of up to 3 (based on availability) and assigned to a classroom.
   If you have friends that you'd like to be partnered with, be sure to have one group member fill out a separate Partner Application so you can be appropriately matched!

→ Where will I be teaching?
   Your team will be teaching your students over some virtual platform from the same room.
   Team leaders will be responsible for finding their respective team’s own place to “meet” their class and will be shown how to book rooms to teach from through Vanderbilt’s room booking website. VSVS will also be pointing out common spaces on campus as well as providing the VSVS side room first come, first serve. Social distancing rules and sanitation protocols will be enforced.

→ What are the lesson dates?
   At the beginning of each semester, we send out a group assignment email that contains all of the relevant information for your group. It will have your teachers name and contact information, as well as the names and contact for all of your group members, and the date/time of your lessons.

→ What if I need to quit VSVS?
   If you can no longer fulfill your commitment to VSVS, please reply to one of the emails we've sent you ASAP and let us know so that we can adjust accordingly.

→ Can graduate students participate in VSVS?
   Yes -- you can either join as a regular volunteer and be assigned to a team and classroom OR you can serve as a floating volunteer (that is, if your schedule is very irregular but you know that you’ll be available for at least a few of our weeks!). Just note which option you’d like in your application!

For additional questions, feel free to contact the VSVS Educational Coordinator at paige.ellenberger@vanderbilt.edu.
DIRECTIONS TO SCHOOLS

H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD  
615-353-2020  
HG Hill School will be on the right across the railroad lines.

HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE  
615-329-8160  
The parking lot on the left to the Johnston Ave.

J.T. MOORE MIDDLE SCHOOL: 4425 GRANNY WHITE PIKE  
615-298-8095  
From Lone Oak, the parking lot is on the right, and the entrance into the school faces Lone Oak, but is closer to Granny White.

MEIGS MIDDLE SCHOOL: 713 RAMSEY STREET  
615-271-3222  
Going down Ramsey Street, Meigs is on the left.

ROSE PARK MAGNET SCHOOL: 1025 9th AVE SOUTH  
615-291-6405  
The school is located on the left and the parking is opposite the school, or behind it (preferred).

WEST END MIDDLE SCHOOL: 3529 WEST END AVE  
615-298-8425  
Parking is beside the soccer field, or anywhere you can find a place. Enter through the side door.

EAST NASHVILLE MAGNET MIDDLE SCHOOL: 2000 GREENWOODAVE  
615-262-6670

MARGARET ALLEN MIDDLE SCHOOL: 500 SPENCE LN  
615-291-6385  
From West End down Broadway, take 1-40E to exit 212 Rundle Ave. Left on Elm Hill to Spence Lane.
**Chemistry in a Ziploc Bag**

**Mini Lesson**

**Fall 2020**

**Goal:** To have students observe changes during a chemical reaction.  
**Introduces/reinforces TASS: 5.PS1.4** Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties.

**VSVS Lesson Outline**

_____I. Introduction: Explanation about the importance of observations in science experiments. This lesson aims to teach students how to make observations like a scientist.

_____II. Experiment: Students work in pairs. Students study the reaction when a solution of phenol red in water is added to baking soda and record their observations. They then record what happens when calcium chloride is added to the mixture.

_____III. Observations and Explanations: Review the observations students make. Explain what observations indicate that a chemical change has occurred.

_____IV. VSVS Background Information on Chemical Equations

**Look at the Video Before You Go Out to Your Classroom**

https://studentorg.vanderbilt.edu/vsvs/lessons/

*Use the PPT and video to visualize the materials used in each section.*

1. In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

   1) Why are scientific observations important? Why do they need to be recorded?
   2) What is a hypothesis?
   3) How was the phenol red indicator made?
   4) What needs to be prepared during the Introduction?
   5) When do students need to record observations?
   6) What are some of the possible student observations? How can they be explained?
   7) What are some signs of a chemical change?

2. Use these fun facts during the lesson:
   - Why is baking soda used in baking? Baking soda reacts with acids in cake or cookie mixes to create carbon dioxide (similar to this experiment!) which creates bubbles that make the batter expand (“rise”).
   - Baking soda is sodium bicarbonate, and is used for neutralizing both acids and bases. It is also used to treat indigestion, heartburn, and burns and used in some fire extinguishers.
   - Phenol Red is used to monitor the pH of cells in cell culture. An excess of waste or bacterial contamination will cause acidification of the media and the phenol red will turn yellow.
   - Calcium chloride is put on roads in winter because it lowers the freezing point of water, preventing ice from forming.

Students use their own pencils and paper to record observations.
I. Introduction

Learning Goals: To introduce students to the nature of scientific observations and experimentation

Why is the science in this lesson important?
Observation is an important skill in many different careers, including medicine and forensics. Doctors have to take detailed observations on symptoms and illnesses in order to properly select medicine and treatments for patients. In forensics, scientists have to make detailed observations on evidence found at crime scenes in order to draw conclusions on cases.

Explain to the students about the importance of making careful observations and recording them. This is how scientists do experiments. New discoveries and advances in science depend on having a careful and accurate record of observations made while doing an experiment. After the experiment is over, scientists think about the observations and data they have collected and try to come up with an explanation for what happened.

NOTE: Phenol red indicator solution was made by dissolving a small amount of phenol red powder in water, so when you add the phenol red solution you also must consider the effect of the water on the reactions.

II. Experiment

Learning Goals: To give students the opportunity to record color and temperature-based observations during chemical reactions

Give each pair one Ziploc bag containing baking soda, one 2 oz cup containing 15 mL of phenol red solution, and one plate. Tell students to have a piece of paper to write down their observations.

Instruct the students that one person will be holding the bag while the other will write down all observations possible.
Students should write down:
   A. Everything they observe after the phenol red is added to the Ziploc bag containing baking soda.
   B. Everything they observe after the calcium chloride is added to the Ziploc bag.

Tell students to:
1. Hold the bag upright over the plate and add the 15 mL of phenol red solution to it.
2. Seal the bag. Feel the bag (while keeping it upright) and record ALL observations about the color of the mixture and the temperature of the bag.

3. Write their observations on the board.

   At this stage, observations should include:
   (1) When phenol red solution is added to the baking soda bag, it remains red.
   (2) The bag feels cold.

4. Tell students to be ready to open the bag when a VSVS member comes to add a spoonful of anhydrous calcium chloride to the mixture.

5. Seal the bag as quickly as possible after the calcium chloride is added.
   Keep the bag upright and sealed while gently shaking the bag back and forth to mix the contents.

6. Observe what happens after the calcium chloride was added – color changes, whether the bag is cold or warm (or both since there can be localized heating), foaming, gas given off, change in bag size, ...

7. The reaction takes about three minutes.

   NOTE: There is no danger of the bag exploding if the correct amounts of chemicals are used. Since everything is pre-measured, you should have no problems. In the event one does explode or leak, use paper towels to clean up any mess. Assure the students that the chemicals are safe.

III. Observations and Explanations

   Learning Goals: To provide students with information that can help them identify key indicators of the occurrence of chemical reactions.

   Write student’s observations on the board. Possible student observations:
   (1) When phenol red solution is added to the baking soda bag, it remains red.
   (2) The bag feels cold.
   (3) When the calcium chloride is added, the phenol red turns yellow. Students may feel a short-lasting warming while the anhydrous calcium chloride dissolves in water.
   (4) The bag fills up with gas and continues to feel cold.

   Explanation for students:
   For purposes of your classroom discussion, you can mention the following points (Equations for the chemical reactions are for VSVS team information only).
   1. Phenol red is an acid-base indicator, which turns red in basic and yellow in acidic solutions.
   2. The bag feels cold because baking soda absorbs heat when it dissolves in water.
   3. When the anhydrous calcium chloride is added to the ziploc bag, the mixture becomes warm at first because anhydrous calcium chloride gives off heat when it dissolves in water. (This may not be noticed because the bag is warm for a very short time.)
   4. The phenol red solution turns yellow which indicates an acidic solution. This happens because the bag fills with carbon dioxide gas. The CO₂ dissolves in water to produce an acidic solution.

Your Notes:
a. The calcium ion (Ca\(^{2+}\)) reacts with the bicarbonate ion (HCO\(_3^-\)) to form insoluble calcium carbonate and hydrogen ion (H\(^+\)).

\[
\text{Ca}^{2+} (aq) + \text{HCO}_3^- (aq) \rightarrow \text{CaCO}_3 (s) + \text{H}^+ (aq)
\]

5. The bag fills with carbon dioxide gas because the hydrogen ion formed in the reaction of calcium ion and bicarbonate reacts with remaining bicarbonate ion to give carbon dioxide gas. This is similar to the reaction that happens when vinegar is added to baking soda.

\[
\text{H}^+ (aq) + \text{HCO}_3^- (aq) \rightarrow \text{CO}_2 (g) + \text{H}_2\text{O (l)}
\]

\[
\text{CO}_2 (g) + \text{H}_2\text{O (l)} \rightarrow \text{H}_2\text{CO}_3 (aq) \rightarrow \text{H}^+ (aq) + \text{HCO}_3^- (aq)
\]

6. The bag continues to feel cold because heat is being absorbed.

**Ask students:** *How can you tell when a chemical change has occurred?*

*Possibilities include: a gas given off, color change, temperature change, explosion, burning*

Note: The 5\(^{th}\) graders may not have covered this topic. In that case, tell students what evidence to look for to determine if a chemical reaction occurs: *a color change, a gas given off, temperature change, or the formation of a precipitate.*

**Ask the students what evidence for chemical changes did they observe in today’s experiment?**

**Answers:** A color change; a gas given off; a temperature change.

**Clean-up:** The VSVS team should collect all ziploc bags and used cups and put them in the trash bag. Make sure the ziploc bags containing the reaction mixture are sealed before you put them in the trash bag. Return trash bag and kit to the VSVS lab.

### IV. VSVS Background Information on Chemical Equations

The equations for the reactions that occur when anhydrous calcium chloride is added to the sodium bicarbonate solution are given below.

Baking soda is sodium bicarbonate (NaHCO\(_3\)) and is weakly basic (pH of 8.4), and so the solution of phenol red indicator remains red when it is added to the baking soda.

\[
\text{HCO}_3^- (aq) + \text{HOH(l)} \rightarrow \text{H}_2\text{CO}_3 (aq) + \text{OH}^- (aq)
\]

(Equilibrium reaction which produces 0.00025% OH\(^-\))

The bicarbonate ion (HCO\(_3^-\)) is a weak acid and partially ionizes in solution.

\[
\text{HCO}_3^- (aq) \rightarrow \text{H}^+ (aq) + \text{CO}_3^{2-} (aq)
\]

Calcium ion (Ca\(^{2+}\)) from calcium chloride reacts with sodium bicarbonate to give insoluble calcium carbonate.

\[
\text{Ca}^{2+} (aq) + \text{CO}_3^{2-} (aq) \leftrightarrow \text{CaCO}_3 (s)
\]

The removal of the carbonate ion from solution shifts the bicarbonate equilibrium (1) to the right, releasing more H\(^+\), which reacts with more HCO\(_3^-\) to produce CO\(_2\) gas and H\(_2\)O.

\[
\text{H}^+ (aq) + \text{HCO}_3^- (aq) \rightarrow \text{CO}_2 (g) + \text{H}_2\text{O (l)}
\]

The indicator changes color (around pH 6.8) because the carbon dioxide dissolves in water to produce an acidic solution.

\[
\text{CO}_2 (g) + \text{H}_2\text{O (l)} \rightarrow \text{H}_2\text{CO}_3 (aq) \rightarrow \text{H}^+ (aq) + \text{HCO}_3^- (aq)
\]


Adapted by: Dr. Melvin D. Joesten, Department of Chemistry, Vanderbilt University

Pat Tellinhausen, Program Director of VSVS

**Your Notes:**

________________________________________________________________________________________

________________________________________________________________________________________
Goal: To investigate the properties of substances at extremely cold temperatures (referred to as cryogenic temperatures). To illustrate that changes in phases of matter are physical changes. **Introduces/reinforces TASS:**

- **5PS1.1** Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.
- **5PS1.2** Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.

**VSVSer Lesson Outline**

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**I. Introduction**
Discuss the meaning of the word cryogenics and the properties of nitrogen. Also discuss physical and chemical changes.

**Discussion of the Cold Temperature of Boiling Nitrogen**
Give each pair of students one of the diagrams (in binder) of a thermometer and use this to help students understand how cold liquid nitrogen is by comparing the markings for the boiling point of water, freezing point of water, the sublimation temperature of dry ice, and the boiling point of liquid nitrogen.

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**II. Demonstration of Liquid Nitrogen**
Put on gloves and goggles. Pour some liquid nitrogen into a clear 10 oz cup. Use a glove to hold the cup high enough for students to see. Ask them to write down their observations on the observation sheet. Draw a picture of the cup on the board and discuss the students’ observations.

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**III. Demonstration - Hammering a Nail with a Banana**
**Note:** Never place any objects in the liquid nitrogen dewar since it is going to be used to make ice cream. There is a small dewar (one made from two clear plastic bottles with packing peanuts for insulation.) Pour liquid nitrogen from the large dewar into the smaller insulated container. Even if you are wearing gloves, the temperature is too cold for these to protect you. Attempt to hammer a nail into a piece of wood with a banana. Then freeze the bottom half of the banana in the small dewar that has been filled with liquid nitrogen. After the banana has been in the liquid nitrogen for several minutes, use the banana to pound a nail into the piece of wood.

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**IV. Demonstration - Rubber Tubing in Liquid Nitrogen**
Demonstrate the loss of elasticity of rubber by bending the middle of two pieces of split rubber tubing and putting the bent middle portion in the small dewar used for the banana. After removing the pieces of rubber tubing from liquid nitrogen, take one piece and quickly and forcefully hit the cold end against the top of the table. This should shatter the tubing. Allow the other piece of rubber tubing to warm up to show the flexibility of the rubber returns.

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**V. Demonstration - Shrinking a Balloon and Whistling Tea Kettle**
Blow up a balloon, place it in the bowl, and pour liquid nitrogen over it. Do not use an excessive amount of liquid nitrogen in order to have about one-third of the liquid nitrogen left for making ice cream. Put a small amount of liquid nitrogen into a tea kettle and explain the whistling.

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**VI. Demonstration - Making Ice Cream**

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**VII. Review**

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.
1. Before the lesson:
In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.
1. What is Cryogenics? Answer in introduction
2. What happens to liquid nitrogen when placed in a cup? Answer in first demo
3. What is a physical change? Answer in introduction
4. What is a chemical change? Answer in introduction

2. During the Lesson:
Here are some Fun Facts
Liquid Nitrogen:
- Liquid nitrogen boils at 77 K (−195.8°C or −320.4°F).
- Nitrogen is non-toxic, odorless, and colorless.
- It can be used for freezing and transporting food products.
- Used for preservation of biological samples
- Gaseous nitrogen makes up about 78% of air.
- Your body is about 3% nitrogen by weight.
- Liquid nitrogen is used in medicine. (Dermatologists use liquid nitrogen to remove warts and moles.)

Unpacking the Kit

Unpacking the kit and Set-Up:
Part I. Observation Sheets and thermometer diagrams
Part II. 10oz clear cup, liquid nitrogen dewar, gloves
Part III. Banana, small dewar, nail, board, gloves
Part IV. Goggles, gloves, rubber tubing (2 pieces), small dewar
Part V. Small dewar, tea kettle, balloon, gloves
Part VI. Large dewar, mixing bowl, spoon, ice cream mix, milk, taster spoons, tasting cups, gloves

Safety Precautions: Team members pouring liquid nitrogen and doing experiments with liquid nitrogen need to wear safety goggles. Always pour from the large nitrogen dewar to small containers. Never try to fill a small container by dipping it in the large dewar. You risk frostbite if your skin is exposed to liquid nitrogen. The cotton gloves are provided only for use when pouring and will not provide protection.

Full Materials List
- 1 large dewar of liquid nitrogen
- 1 small dewar
- 1 10 oz cup
- 1 mixing bowl
- 1 mixing spoon
- 1 quart of milk
- 1 pair of gloves
- 1 pair of goggles
- 1 box of ice cream mix
- 1 banana
- 1 nail
I. Introduction

One VSVS team member should write the following vocabulary words on the board while another member leads the introduction:

**Cryogenics, chemical change, dry ice, condensation, physical change, liquid nitrogen**

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### Learning Goals:

- Students understand that different materials have different freezing and melting points.
- Students identify physical and chemical changes, and make observations about how they change the properties of matter.

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Ask students if they have ever heard of **cryogenics**.
- If they have, ask them to share what they know.
- *If they haven’t, share some of the following information with them:*
  - Cryogenics is a branch of physics that deals with the production and effects of very low temperatures.
  - Substances such as liquid nitrogen that are used for cooling things to very low temperatures are called cryogens.
  - The derivation of the word cryogen is from the Greek "kryos”, meaning "icy cold”.
  - Cryogens represent special hazards since contact with cryogens produces instantaneous frostbite, and structural materials such as plastics, rubber gaskets, and some metals become brittle and fracture easily at these low temperatures.
  - Cryogenics is used by companies to make some metal tools more durable and less likely to break under stress.

Ask students: **What do you know about nitrogen?**

*Include the following points in the discussion:*

- Nitrogen is a gas that makes up **78% of the air**. Oxygen makes up 21%, and the rest is made up of other gases such as argon, carbon dioxide, water vapor, and trace amounts of neon and krypton.
- Nitrogen liquefies at -196° C or -320° F.
- Liquid nitrogen is used in medicine. (Dermatologists, skin doctors, use liquid nitrogen to remove warts and moles.)
- Since nitrogen is not reactive, liquid nitrogen has found wide use in frozen food preparation and preservation during transit to grocery stores. “Dippin Dots” ice cream is prepared using liquid nitrogen.

Ask students: **What are some examples of physical and chemical changes?**

*Include the following points in the discussion:*

- Physical change
  - Physical change is a change in the state of matter without any change in composition. Examples include melting, boiling, sublimation, and condensation.
- Chemical change
  - Chemical change is a change in composition of matter. Examples include rusting, burning, and decay.
Physical changes involve changes in the phase of a substance. Examples: Liquid water freezes to form ice or boils to change to water vapor gas. All three forms are chemically the same and have the same formula, $H_2O$.

Chemical changes involve the reaction of two substances to create a new substance with a different formula and may be evidenced by a color change, the formation of a gas or precipitate.

DISCUSSION OF THE COLD TEMPERATURE OF BOILING NITROGEN

Give each pair of students one of the thermometer diagrams and use this diagram to help students understand how cold liquid nitrogen is by comparing the markings for the boiling point of water, freezing point of water, the sublimation temperature of dry ice, and the boiling point of liquid nitrogen.

II. Demonstration #1: Liquid Nitrogen

Learning Goals: Students identify physical and chemical changes, and make observations about how they change the properties of matter

Materials:
1. 10 oz. clear plastic cup
2. Large dewar of liquid nitrogen
3. Pair of gloves
4. 32 Observation Sheets

- Give each student one of the observation sheets.
- Pour liquid nitrogen into the 10 oz. clear plastic cup so that it is half full.
- Use a glove to hold the cup up high enough so students can see the liquid nitrogen. Then set the cup on the front desk (well away from any students to avoid skin contact).
- Have the students look at the liquid nitrogen, but do not allow them to touch it. Liquid nitrogen is not toxic, but the temperature is so cold that it will hurt the skin.
- Ask the students to draw a cup on their observation sheet and write down what they see happening in and around it.
- Draw a picture of the cup on the board and ask the students to tell you what happened. Write these observations around the drawing. Students may not have observed all of the following. If not, point them out.
  1. Liquid nitrogen boils.
  2. Fog is formed which goes down when it gets to the air outside the cup.
  3. Frost is formed on the side of the cup
Ask students: What is happening to liquid nitrogen and is this a physical or chemical change?

*Include the following points in the discussion:*

1. Liquid nitrogen boils (changes from a liquid to a gas) because the temperature of the room (about 25 °C) is much higher than the boiling point of liquid nitrogen (−196°C). *This is a physical change.*

2. Fog forms above the liquid nitrogen. *This is a physical change.*
   - The fog is not liquid nitrogen but solid water (ice particles) suspended in the cold nitrogen gas above the liquid nitrogen.
   - Gaseous nitrogen is colorless as evidenced by the fact that we can’t see air, which is 78% nitrogen.
   - The fog goes down after it leaves the cup because the cold nitrogen gas contains crystals of water, which makes the fog heavier than air. Remind students that this is why regular fog is close to the ground – fog contains air mixed with small drops of water.

3. Condensation on the outside of the plastic cup is water vapor (gas) from the air, changing to liquid water.
   - The water droplets are quickly frozen by the low temperature of the liquid nitrogen to form solid water (frost or ice). *These changes are also physical changes.*
   - Most students will report only seeing the frost since the water droplets are only observable for a brief time before they turn to solid water (frost).

*Note:* Tell students that the next few experiments will show some of the things that can be done with liquid nitrogen. *Ask them to decide whether each experiment involves a chemical or physical change and to underline their choice on their Observation Sheet.*

**III. Demonstration #2: Hammering with a Banana**

**Learning Goals:**
Students identify physical and chemical changes, and make observations about how they change the properties of matter.
Students observe, describe, and explain physical changes that occur at cryogenic temperatures

**Materials**
1 piece of wood

**Your Notes:**
1 nail
1 banana
1 large dewar of liquid nitrogen
2 small dewar - small plastic insulated bottle
1 pair of gloves

**Note:** Do not place any objects in the large liquid nitrogen dewar since it is going to be used to make ice cream. There is a small dewar (one made from two clear plastic bottles with packing peanuts for insulation) for freezing the banana and rubber tubing.

- Show students the nail and piece of wood.
- Tell them that you forgot your hammer so you think you’ll just use the banana.
- Ask students if they think you can hammer the nail into the piece of wood with the banana.
- Attempt to hammer the nail into the board with the banana. **Watch out! This can be messy.**
- Tell the students that you think the banana needs a little help.
- Fill the small dewar about two-thirds full with liquid nitrogen.
- Put the banana in the small dewar.
- Wait 2-3 minutes for the liquid nitrogen to cool the banana. Ask the next two questions while you wait.
  - Ask students to predict what the banana will look like when it comes out of the liquid nitrogen. Ask the students if they think you will be able to hammer a nail into the board this time.
- When 2-3 minutes have passed, use a glove to pull the banana out of the liquid nitrogen and hammer the nail into the board.

**Note:** Please dispose of banana at the school, before the box is returned to the VSVS lab.

**IV. Demonstration #3: Rubber Tubing in Liquid Nitrogen**

**Learning Goals:**
Students identify physical and chemical changes, and make observations about how they change the properties of matter.
Students observe, describe, and explain physical changes that occur at cryogenic temperatures

**Materials:**
2 pieces of rubber tubing or bicycle inner-tube (tubing must be slit down the middle to avoid the possibility of liquid oxygen collecting)
1 small dewar (made from plastic bottles) of liquid nitrogen
1 pair of gloves
1 pair of tongs

**Important Safety Note:** The VSVS team member performing this demonstration must wear safety goggles.

- Use the small dewar of liquid nitrogen from Demonstration #2.
- Hold up a piece of split rubber tubing and demonstrate how flexible it is by bending it back and forth.

Your Notes:
• Take the two pieces of split rubber tubing and bend in half at the middle (not kinked but a little rounded) and while holding the pieces of tubing together at the open ends, immerse the bent middle portions into the small dewar containing the liquid nitrogen for about one minute.

• While the middle of the rubber tubing is in the liquid nitrogen, ask students what they think the cooling in liquid nitrogen will do to the rubber tubing. **Accept logical responses.**

• Take the pieces of rubber tubing out of the liquid nitrogen, and put one piece aside to warm up to room temperature. **Caution: Have safety goggles on for this part.** Take the other piece and quickly and forcefully hit the cold end against the top of the table. This should shatter the tubing.

**Explanation:** Rubber is made up of long chains of molecules that are loosely coiled. The elasticity of rubber is caused by coiling and uncoiling of these long chains. At liquid nitrogen temperatures the molecular motion is slowed down enough that the coils are locked into one position.

• Pick up the rubber tubing that was allowed to warm to room temperature and show the students that it is flexible again.

**Explanation:** When the temperature of the rubber becomes warmer, the elasticity of the rubber returns because the molecular motion increases again and allows the coiling and uncoiling of the polymer chains.

• Ask the students: Are the changes in elasticity with temperature a physical or chemical change? **Physical because the rubber recovers its elasticity when it warms up.**

**V. Demonstration #4: Whistling Tea Kettle and Shrinking a Balloon**

<table>
<thead>
<tr>
<th>Learning Goals:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students identify physical and chemical changes, and make observations about how they change the properties of matter.</td>
</tr>
<tr>
<td>Students observe, describe, and explain physical changes that occur at cryogenic temperatures</td>
</tr>
</tbody>
</table>

**Materials:**
- 1 inflated balloon (tied off)
- 1 dewar of liquid nitrogen
- 1 large stainless steel bowl
- 1 pair of gloves (Put On!)
- 1 whistling tea kettle
- 1 ladle

A. **Whistling Tea Kettle**
Ask the students if they know what happens when water is boiled in a whistling tea kettle. *The whistle makes a loud whistling noise when water boils.*

Ask – what causes the whistle? *The boiling water (liquid) creates steam (a gas).*

*Pressure builds up and the steam has nowhere to go, except through a hole in the lid. (Show the students the hole.)*

*When enough steam has been created so that it rushes through the hole, vibrations are set up, causing the kettle to whistle.*

Use the ladle to put some liquid nitrogen into the kettle. Ask the students to explain why the kettle is whistling.

*The liquid nitrogen is boiling, producing nitrogen gas, which is forced out through the hole, setting up vibrations, in the same way the steam from the boiling water was.*

Your Notes:
B. Shrinking a Balloon

- Show an inflated balloon to the class.
- Ask students to predict what will happen to the balloon when you pour liquid nitrogen over it. Accept logical responses.
- Put the bowl in a spot where students can see it.
- Place the inflated balloon in the bowl.
- Tell students to watch and to be very quiet so they can hear what happens.
- Pour a small amount of liquid nitrogen over the balloon.
- The balloon will shrink and crackle as it gets cold.
- Ask students to predict what will happen when you pull the balloon out of the bowl. Accept logical responses.
- Use a glove and remove the deflated balloon from the bowl.
- As you hold the balloon in the air, the students will be able to observe the balloon inflate and return to its original state.

Explanation

Gases contract when cooled and expand when heated. The volume of a gas is directly related to the temperature. Therefore, the balloon was larger in the warmer air of the room and smaller in the coldness of the liquid nitrogen. This can be explained by the molecular motion of the gas molecules. They move faster at higher temperatures and as a result, take up more room (volume). When the molecules of gas are cooled, they slow down and take up less room (volume).

Ask students: Are these chemical or physical changes? *Physical*

VI. Demonstration: Making Ice Cream with Liquid Nitrogen

Materials:
1 stirring spoon or spatula  
1 quart of whole milk  
1 box of ice cream mix  
1 large dewar of liquid nitrogen  
1 large stainless steel bowl  
32 small paper cups for ice cream  
32 taster spoons for ice cream  
2 pairs of gloves (have handy in case they are needed)

- Make sure you have goggles and gloves on.
- Tell students that liquid nitrogen is great for making a quick batch of ice cream.
- Pour all (1 quart) of the whole milk into the bowl.
- Open the ice cream mix and sprinkle it on top of the milk. Stir to mix.
- Have one VSVS volunteer *slowly* pour about 1 pint of liquid nitrogen into the bowl while another volunteer holds the bowl still and stirs the mixture.
- *Slowly* add more liquid nitrogen.
- *Stop* if any of the liquid turns solid. If ice cream becomes too hard, wait a few minutes for it to soften.
- Put a small amount in enough cups to serve everyone. Pass these out with the taster spoons.

Your Notes:
VIII. Review
Chemical and Physical Changes:
- Review the physical and chemical change responses on the students’ observation sheets. See answer sheet.

Cryogenics
- Cryogenics is a branch of physics that deals with the production and effects of very low temperatures.
- Substances such as liquid nitrogen that are used for cooling things to very low temperatures are called cryogens.
- The derivation of the word cryogen is from the Greek "kryos", meaning "icy cold".
- Containers used to hold cryogens are large vacuum-walled bottles much like the thermos used to carry hot soup or coffee.

Liquid Nitrogen:
- Nitrogen is a gas that makes up 78% of the air. (Oxygen makes up 21%, argon 0.9%, and the rest is made up of other gases such as carbon dioxide, water vapor, and trace amounts of neon and krypton.)
- Nitrogen liquefies at -196°C or -320°F.
- Liquid nitrogen is used in medicine. (Dermatologists use liquid nitrogen to cool a localized area of skin prior to removal of a wart or mole.)
- Since nitrogen is not reactive, liquid nitrogen has found wide use in frozen food preparation and preservation during transit to grocery stores.

Hazards Associated with Cryogenics:
Cryogens represent special hazards since contact produces instantaneous frostbite, and structural materials such as plastics, rubber gaskets, and some metals become brittle and fracture easily at these low temperatures.

Share this information about the Challenger Explosion
The tragic explosion of the space shuttle Challenger in January, 1986 was caused by the effect of cold temperatures on a rubber gasket. The rubber gasket was used to seal joints in the booster

Clean-Up: Throw away the banana and the milk carton. Empty the water/dry ice bottle – make sure there is no cap on it. Discard pieces of broken balloon and small pieces of rubber tubing. Put the bowl and spoon back in the trash bag and place it in the kit. Be sure to return both the liquid nitrogen dewar and the kit to the VSVS lab.

Note: If there is any liquid nitrogen left at the END of the lesson you can pour some on the floor to allow students to watch it roll around.

BE SURE TO ASK THE TEACHER BEFORE YOU DO THIS!

Note: The slower the liquid nitrogen is added, the better the consistency of the ice cream. Pour the liquid nitrogen at about the rate of a drip coffee machine for about 20 to 30 seconds. Then stop and look. Continue pouring the liquid nitrogen at a slow rate. Have the stirrer check every 20-30 seconds for the consistency of soft serve ice cream.
rockets to prevent contact with the hydrogen fuel tanks. The cold launch temperature on that January day made the rubber gasket lose some of its elasticity. This allowed flames from the booster rocket to burn through the hydrogen fuel tank and cause the explosion that killed the astronauts and the teacher-in-space, Christa McAuliffe.

**Share this information about the news article “Company puts freeze on metals to extend use” (in binder).**

Read the article before going to the class so you can share the information with students. Highlights from the article are listed below:

- Cryo-Processing of Tennessee freezes metal items - drill bits, saw chains, punch tools, musical instruments, guitar strings - at temperatures hundreds of degrees below zero, and then quickly reheats them, to strengthen their molecular structure.
- This process makes these items more durable and less likely to break under stress.
- This means less cost for the company or individual forced to spend precious time replacing or repairing the items. A company has increased production due to decreased downtime to replace the tools.
- The company in the article cryo-processes twice a week for 48 hours each time. They also do some quick heat processing - called "sweetening" - before they put it in the "fridge".
- This technique was developed by a Decatur, Illinois firm called 300 Below. It uses a chest-freezer-sized piece of equipment to hold parts while liquid nitrogen gradually cools the air surrounding them.
- Cryo-Processing can treat golf clubs and golf balls to give an increased driving distance. Tennis rackets and aluminum baseball or softball bats can be treated cryogenically.
- The cost of cryo-processing varies according to volume. One to five pounds cost $49.50 per pound. 10 pounds drops to $9.75 per pound. A ton of cryo-processed equipment will cost $2.54 a pound.
- Old tires can be frozen in liquid nitrogen to make them so brittle that they can be ground to a fine powder and then used in paints, coatings and sealants. These products then take on some of the qualities of rubber – they are more elastic and impact resistant. (Time, March 3, 2008).

If time permits, use the insert in the article (“Just pop it in the fridge”) and draw the molecules on the board. Share the explanation in the article with the students to show what happens to the molecules before, during, and after cryogenic treatment.

Lesson written by Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Director of VSVS, Vanderbilt University
Dr. Todd Gary, former Coordinator of VSVS, Vanderbilt University
Susan Clendenon, Teacher Consultant, Vanderbilt University

Your Notes:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Demonstration #1 – Liquid Nitrogen – The VSVS team adds liquid nitrogen to a clear cup.

Draw a cup like the one being used and write down everything you see happening in and around the cup. (List of possible observations and labeled cup given on page 5 of lesson.)

Are the following physical or chemical changes? Circle your response.

<table>
<thead>
<tr>
<th>Physical Change</th>
<th>Chemical Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling liquid nitrogen</td>
<td>Physical</td>
</tr>
<tr>
<td>Formation of fog</td>
<td>Chemical</td>
</tr>
<tr>
<td>Condensation</td>
<td>Chemical</td>
</tr>
<tr>
<td>Freezing and thawing of banana</td>
<td>Chemical or Physical</td>
</tr>
<tr>
<td>(You may get both responses here. Since the banana skin turns brown, this would indicate a chemical change. However, the banana still tastes like a banana, although the part that was frozen is mushy.)</td>
<td></td>
</tr>
<tr>
<td>Cooling and warming rubber tubing</td>
<td>Chemical</td>
</tr>
<tr>
<td>Shrinking and inflating balloon</td>
<td>Chemical</td>
</tr>
<tr>
<td>Making ice cream</td>
<td>Chemical</td>
</tr>
<tr>
<td>(The ice cream mix contains flavor and sugar; mixing and freezing this with milk is a physical change.)</td>
<td></td>
</tr>
</tbody>
</table>
Fossils
Fall 2020

Goal: To introduce students to the geological time scale, the fossil record, index fossils, and the uses of fossils.

Introduces/reinforces TASS: 5.ESS1.7 Use evidence from the presence and location of fossils to determine the order in which rock strata were formed. 5.LS4.1 Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct.

I. Introduction – Fossils and Paleo environments
II. Types of Fossils

III. Sedimentary Rock Layers/Columns
   A. Sedimentary Rocks
   B. Creating a Model of Sedimentary Rocks
   C. Explaining the Columns
   D. Dating with Index Fossils
   E. Usefulness of Fossils
   F. Looking at Real Fossils

Materials:
1 cylinder containing the larger string timeline
10 laminated timeline mats
10 jars containing fossils and sedimentary rocks
1 container with copralite, crinoid sample,
5 large versions of timeline table
32 observation sheets
10 plates,
10 models of rock layers with fossils encased in boxes
10 jars of water
10 sets of jars containing sand and “fossils” (stones)
   Jar 1: Pale yellow sand (limestone) with rocks representing containing trilobites and brachiopods
   Jar 2: Brown sand (sandstone) with rocks representing brachiopods, shark’s teeth, crinoids
   Jar 3: White sand (limestone) with rocks representing ammonites, shark’s teeth and brachiopods

Materials for VSVS demo
1 plate
1 column container
1 bottle of water
3 jars of sand and “fossils” (pebbles)

Why is the science in this lesson important?
An understanding of sedimentary layers is useful for understanding when and how life originated on Earth, as well as for studying evolution and historical changes in Earth’s ecosystems.
I. Introduction – Fossils and Paleo environments

a. What are Fossils?

- Pass out the model of rock layers with fossils encased in boxes, 1 per 3-4 students.
- Point out the fossils as they are referred to in this section.
- Q. What is the definition of the word “fossil”?
  - It is a preserved piece of ancient life. It may look like the original life form, or it may be a piece of evidence that a creature lived. It takes millions of years to form.
  - Stress that in most cases, a fossil is not the actual flesh and bone (or stem/leaf) of the organism. Fossilized organisms look like the original form, but the parts have been replaced with rocks or minerals that took the shape of the organism’s remains.
- The oldest fossil found is dated at 2.2 billion years old – but we know that the earth is close to 4.6 billion years old, so we don’t have fossils spanning earth’s entire history.

b. Paleoenvironments

- Q. Ask students if they have ever found a fossil around home or anywhere in Nashville?
  - If they say yes, ask them what type; ideally they will have found something that looks like a seashell.
  - Rocks in Nashville have many fossils of brachiopods (clam-like animals), crinoids, and corals that are 400 million years old. Tell students to look at the brachiopods and crinoids in the rock layer model.
  - 400 million years ago, when these fossils were formed, what was the environment like? Hint – where do clams, crinoids, and corals live today?
    - Underwater in shallow oceans.
  - Fossils don’t move from where an organism lived, so what does this say about Tennessee’s location 400 million years ago?
    - Underwater in a shallow ocean!
- In Antarctica, dozens of fossil tree stumps have been discovered. Antarctica is covered mostly by ice today and no trees.
  - Q. What must be true about Antarctica’s past climate?
    - It was much warmer and supported large plant life like trees.

II. Types of Fossils

There are 2 main types of fossils:

- **Trace fossils** include tracks, burrows, or dung from animals – any evidence that the animal lived that isn’t an actual part of the animal’s body. They form because an empty animal burrow or track can be preserved.
  - Examples are animal burrows, dinosaur poop, ripples in land, tracks,
  - Show students the trace fossil copralite.
  - Tell students that copralite is fossilized poop. It is millions of years old. Coprolites are the fossilized feces of animals that lived millions of years ago. They are trace fossils, meaning not of the animal's actual body. Scientists can look inside coprolites to see what they contain. If there are bone fragments, the animal was a carnivore.

Your Notes:
Tooth marks on the fragments, if present, can reveal how the animal ate its prey. Seeds, leaf remains, pollen or bark found in a coprolite suggest that the animal it came from ate plants.

- **Body fossils** are the mineralized hard remains of an organism or an imprint left from the remains. In these fossils, we should see actual features of the living organisms.
  - Q. Which parts of animals are preserved as fossils? Hint: many fossils are teeth, bones, or shells – how are these different from other parts of the body?
  - *Hard parts of animals’ bodies have the ability to be preserved as fossils. Soft parts of their bodies are almost never preserved as fossil because they decompose too quickly.*
  - Show students the crinoid fossils

<table>
<thead>
<tr>
<th>Question 1: What parts of an organism can turn into a fossil?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard parts like teeth, bones, or shells</td>
</tr>
</tbody>
</table>

### III. Sedimentary Rock Layers/Columns

#### Learning Goals:
- Students understand how sedimentary rocks are formed.
- Students experiment with forming sedimentary layers and understand that fossils are deposited at the same time as the sediment.
- Students understand that sediments are deposited in **horizontal** layers.
- Students understand that older layers are at the bottom in a sedimentary layer, while younger layers are at the top.

#### a. Reviewing Sedimentary Rocks

- Q. Ask students what they know about sedimentary rocks. If these answers aren’t given, go over them briefly:
  - Most sedimentary rocks are formed from sediments deposited in oceans, lakes or rivers.
  - Sediments form layers that pile on top of each other, which compress over time to create rock.
  - Types of sedimentary rock include sandstone (primarily from sands), limestone (primarily from shells), and shale. (primarily from mud).
  - Tell students to look at the sedimentary rocks in their jar.

- Q. Ask for a show of hands of which students have seen rock layers on the sides of the highway while driving around Nashville – this is sedimentary rock! Ask if anyone knows what type of rock this is.
  - *Limestone*
- Tell students that we are going to create a model of sedimentary rock layers.

#### b. Creating a Model of Sedimentary Layers

Materials for VSVS demo
1 plate, 1 column container, 1 bottle of water, 3 jars of sand, and “fossils” (pebbles)

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Your Notes:
Materials for students, per group:
1 plate, 1 column containers (jars containing water), 1 model of rock layers with fossils encased in boxes, 1 set of numbered jars of sand, with different colors of sand representing different types of sedimentary rock and pebbles representing fossils

   Jar 1: Pale yellow sand (limestone) with rocks representing trilobites and brachiopods
   Jar 2: Brown sand (sandstone) with rocks representing brachiopod shark’s teeth crinoids
   Jar 3: Pale Yellow sand (limestone) with rocks representing ammonites, shark’s teeth and brachiopods

32 observation sheets,

- Set up at the front of the class the apparatus to create the sedimentary rock column demonstration
- One VSVS member should draw a large diagram on the board to represent the column, based on the diagram on this page.
  - Do not draw the entire finished diagram. Start with the open-top rectangle representing the column (bolder lines). As each jar of sand is added, draw the layer line and write the color of the sand and “fossils” (rocks).
- Other VSVSers should pass out the columns (jars with water), jars of sand, and plates (1 per group of 2-3 students).
  Put the column on the plate to catch spills.

Tell students to look at the model of sand and fossils in a case.

- The model represents fossils buried in layers of rock.
- Tell them that the sand represents the type of sedimentary rock pale yellow is limestone and brown is sandstone).
- The fossils in the model are real.

Tell students they are going to create sedimentary layers that are represented in the model.
- Demonstrate how to create the column and have the students do each layer after you do.

1. Pour the container of water into the column, reminding students that sedimentary rocks form when sediments settle out of water and form layers.

2. Explain to students that we are using different colors of sand to represent different types of sedimentary rock, and different color pebbles to represent fossils. **Point out that the fossils (pebbles) get deposited at the same time as the sand.**

3. Pour all of the sand and “fossils” from container #1 into the column. Wait until each layer settles (~30 seconds) before pouring the next layer. Make sure students are adding the jars of sand to the column in the correct order (#1 first ...)

4. When settled, pour all of container #2’s contents into the column and wait for it to settle. Then container #3’s contents. Make sure to update the drawing on the board as new layers are added.

**c. Explaining the Column**

- Q. Ask students to describe what happened when they poured each layer of sand.
  - Sand settles through the water to make a flat layer at the bottom of the column.
  - This is similar to sediment settling out of water to form layers; over millions of years the sediment is compressed and turns into rock.

Your Notes:
o Explain that sediment is deposited in horizontal layers, and it stays that way unless something disturbs it.

o **Have students answer Question 2a on their observation sheet.**
  1. Sediments settle and form rocks in horizontal layers.

o Fossils are deposited at the same time the rock material is deposited. Therefore the ages of the fossil and rock in which it is found are the same.

o **Have students answer Question 2b on their observation sheet.**
  2. What is the age of a fossil relative to the rock in which it is found? **The same**

- Tell students to imagine that the process of creating their sand columns took millions of years to occur.
- Tell students that different rock layers represent different periods of time.
  o Q. Ask students which layer is the oldest in the column. Answer question 2c.
    - The bottom layer; it was deposited first and other layers were deposited on top of it.
  o Q. Ask students which layer is the youngest in the column. Answer question 2d.
    - The top layer; it was deposited last, on top of all other layers.
  o How old are the middle layers? (You can’t tell for sure! But they are older than the top layer and younger than the bottom layer.)
  o Fossils succeed each other in a definite order – the oldest fossils in a series of layers will be in the lowest layer.

### IV. Usefulness of Fossils

- Q. Why are fossils useful?
  o Answers will vary, but they should focus on fossils telling us how earth has changed over time. Besides the answers below that we will go over, they might say something about figuring out what organisms ate in the past or where organisms migrated from.

- Tell students that fossils are useful for:
  o Finding the age of rocks.
  o Learning what type of environment once existed in a region.
  o Showing evidence that species evolve over time.

### b. Looking at Real Fossils – Timeline placemat

Materials - Fossils Placemat, jars of fossils

- Tell students to look at their observation sheet and point out the 4 eons.
- The **geologic time scale** covers earth’s entire history.
  It is divided into eons, which are further divided into eras.
  o Eons and eras are not of equal length, but are based on events/organisms in certain time periods (eons) and when major extinctions happened (eras).

- Tell students we are going to focus on the last eon – the Phanerozoic Eon
- Briefly explain the layout of the timeline mat:
  o The top rectangle is the time scale of the Phanerozoic Eon in millions of years before present with 0 being present day (denoted by the stick figure at the end).
  o The different colors (pink, green and yellow) show the different **ERAS**.

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
The thick black lines represent mass extinctions from catastrophic events.
The other rectangles below the time scale correspond to the life spans of the organisms in the rectangles.
The pictures are the fossils of the organisms that the rectangle represents and images of what the organisms would have looked like.

- **ERAS** are characterized by unique advanced life forms and end with mass extinctions.
  - Q. What is meant by extinction? (*The last remaining members of a species have died out.*)
- Identify the **pink section** of the time scale as the **Paleozoic Era**. During this era:
  - Invertebrates such as trilobites, brachiopods, and crinoids, flourished in this era. Direct students to the images on the timeline to see what trilobites, crinoids & brachiopods look like.
    - Q. Does anyone know what makes an animal an invertebrate?
      *The lack of a backbone.*
      *Animals are vertebrates (like us) if they have a backbone.*
  - Early fish develop (direct attention to placemat for sharks).
  - Early land plants develop (direct attention to placemat for early ferns).
  - Early reptiles developed.
  - The biggest mass extinction occurred at the end of this era – 90% of all species became extinct. (Emphasize the magnitude of this extinction to students – tell them to imagine 90% of all animals on earth right now dying out.)
- Identify the **green section** of the time scale as the **Mesozoic Era**:
  - This is known as the Age of Reptiles, since many major reptile groups were dominant life forms.
  - Dinosaurs, birds, small mammals, flowering plants, and flies flourished.
  - Another mass extinction occurred at end of this era – 50% of all species became extinct, including dinosaurs.
  - Q. Does anyone know the current theory as to why the dinosaurs went extinct?
    - *Many scientists agree that it was likely due to the impact of a large meteorite near Mexico.*
- Identify the **yellow section** of the time scale as the **Cenozoic Era**:
  - Cenozoic means “recent life” – it continues up until today.
  - This is the Age of Mammals.
  - Some mammals are already extinct (woolly mammoth, saber-toothed cats), but another mass extinction hasn’t occurred yet.

**DO NOT PASS OUT THE JARS CONTAINING FOSSILS AND SEDIMENTARY ROCKS UNTIL YOU HAVE DONE THE FOLLOWING:** Count the number of fossils. There must be 6 in each. These fossils are expensive and the jars must be returned with all 6 fossils.

- Tell the students that we will now look at real fossils of past organisms.
  - Hand out the jars of fossils (1 jar per group).
  - Tell students to identify each fossil and put it in the correct place on the timeline, using the pictures as a guide.
  - Some images are at the right for your reference
  - Walk around helping students as needed, and interact with the students to see

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
what questions or thoughts they have about the fossils.

- Tell students to look at your placemat and tell you the name of the oldest fossil
  - Answer question 3. What are the oldest fossils? *Trilobite*

- What fossils are now extinct?
  - Answer question 4. *Trilobites and Ammonites*

### c. Dating with Index Fossils
- Tell students that fossils can be used to determine the age of rock layers - these are called **index fossils**.
  - Not all fossils are index fossils.
  - Fossils are chosen to be index fossils if they:
    - Lived only a short time.
    - Are found in many areas worldwide.
    - Are easy to find (abundant).
    - Are easy to identify.
- Students should now look at the placemat AND their model of rock layers with fossils encased in boxes and predict which fossils are index fossils. Make sure they understand that MYA means “millions of years ago,” and that the horizontal bars represent the length of time fossils of this type existed.
- Q. Ask students which fossils are index fossils and which are not. For the ones that are index fossils, what time period are they useful for dating the rocks from?
  - Brachiopods, Crinoids, Ferns and shark’s teeth are not index fossils because they are in almost every time period.
  - Ammonites and trilobites are index fossils because they lived for just a short time and then became extinct. Trilobites can be used to date rocks 540 – 490 million years old. Ammonites can be used to date rocks 100 – 65 million years old.

### Question 6: Which fossils on your timeline are used as index fossils? *Ammonites and trilobites*

- After students are finished putting the fossils in their correct locations, tell them to return all of their fossils to the box and to leave the lid off.
  - Go to each group and count the fossils (make sure they are all different and are actually the fossils).
  - If the set is complete, put the lid on the box and place it in the kit.
  - If any fossils are missing and students say they do not know where they are, tell the teacher immediately and have him or her help you find the missing fossils.

Leave the placement map on the student’s desk.

DO NOT CONTINUE UNTIL ALL FOSSILS ARE ACCOUNTED FOR

### V. Geologic Time – Optional (time permitting)

**Materials:**
1 cylinder containing the larger string timeline

**a. Introduction**

Your Notes:
Q. Does anybody know how old the earth is?
   o 4.6 billion years old. Write the number out in full on the board so they understand how much time this is (4600,000,000).

Q. Tell the students to think about how much of the earth’s history humans have been around for, but tell them we will come back to this later. (For about 1.5 million years.)

b. Time Scale Model

Point to the different eons and eras as you go through the timescale. This is on the students observation sheet. A large version is in the binder.

Have students answer the questions as a class.

Hold up the time scale model (the cylinder) with just a small piece of string pulled out so that all students can see it.

Tell students:
- The string represents the timeline of earth’s history.
- The string covers the complete geologic time scale over a time of 4.6 billion years.
- The string is divided into the 4 eons, and the last eon is divided into eras.

Note – the string is 19 feet long, so make sure you have enough room to “spread”.
   a. One VSVS member or student volunteer will hold the string and another will hold the container and walk away while removing each eon and stopping when a knot is reached.
   b. A VSVS member will describe each eon to the students, while another writes names of eons and eras on the board as they are introduced.
   c. The string must be kept taught in a straight line so that the students get the concept of the length of time taken for each eon.

1. Pull the first (camouflage-colored) section of the string out, and stop as soon as you get to the first knot (between color changes).
   **Tell students:**
   a. This first section represents the **Hadean Eon** lasting from 4.6-3.8 billion years ago (write time ranges of eons on board).
   b. **Major event:** No organisms living during this eon, but the earliest known rocks were formed.
   c. The oldest earth rock is dated at 4.03 billion years old and was found in the Canadian Rockies. The only rocks found that are older come from meteorites and the moon.1.
   d. Q. How do we know the rocks are this old? *Scientists use radiometric dating with radioactive isotopes (elements like uranium) in the rocks to figure out their age."

2. Pull the second (tan) segment of the string until the second knot is reached.
   a. This represents the **Archean Eon** lasting from 3.8-2.5 billion years ago.
   b. **Major event:** During this eon, the first single-celled organism evolved.

3. Pull the third (white) segment of string until the third knot is reached.
   a. This represents the **Proterozoic Eon** lasting from 2.5 billion years ago - 540 million years ago.
   b. **Major event:** Multi-celled organisms evolved during this eon.
   c. The earliest multi-celled fossil is from Michigan and is dated at 2.2 billion years old.

Your Notes:
4. Display the black end of the string.
   
   a. This last section represents the **Phanerozoic Eon** lasting from 540 million years ago - now.
   
   b. **Major event**: Life evolves from multi-celled organisms to plants, fish and animals as we know them today.
   
   c. Q. Have you been thinking about how long humans have existed? *Humans only existed in the very last knot of the rope. (See the dangling skeleton!) This is an extremely short time in the history of the earth.*

This eon is subdivided into 3 smaller time intervals called **eras**. These eras are color coded with colored string twisted around the black cord.

These are the eras studied with the Timeline Placemats.

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We gratefully acknowledge the assistance of Dr. Molly Miller, Professor of Earth & Environmental Sciences, Vanderbilt University.

Fossils Observation Sheet - Answers

1. What parts of an organism can turn into a fossil?
   
   **Hard parts like teeth, bones, shell, skeletons**

2. Observe the sediments as you add them to the water. Are the following statements true or false?
   
   a. Sediments settle and form in horizontal layers  
      **True**
   
   b. Fossils are the same age as the rock it is found in  
      **True**
   
   c. The oldest layer is at the bottom  
      **True**
   
   d. The youngest layer is at the bottom  
      **False**

3. Look at your placemat. What are the oldest fossils? **Trilobites**

4. Look at your placemat. What fossils are now extinct? **Trilobites and Ammonites.**

5. Which fossils on your timeline can be used as index fossils?
   
   **__Trilobites and Ammonites__**

   How old is the earth?

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<table>
<thead>
<tr>
<th>Eon:</th>
<th>Hadean Eon</th>
<th>Archean Eon</th>
<th>Proterozoic Eon</th>
<th>Phanerozoic Eon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years:</td>
<td>4.6-3.8 billion years ago</td>
<td>3.8-2.5 billion years ago</td>
<td>2.5 billion years ago - 540 million years ago</td>
<td>540 million years ago - now</td>
</tr>
<tr>
<td>Major Events:</td>
<td>Oldest earth rocks form</td>
<td>Single-cell organisms evolve</td>
<td>Multi-cell organisms evolve</td>
<td>Advanced organisms like plants, mammals, and fish</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Era:</th>
<th>Paleozoic Era</th>
<th>Mesozoic Era</th>
<th>Cenozoic Era</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant Organisms:</td>
<td>Invertebrates (trilobites, crinoids, ammonites, brachiopods)</td>
<td>Dinosaurs, birds</td>
<td>Mammals</td>
</tr>
</tbody>
</table>
GOAL: To introduce the concept of intensity/direct light to students in reference to the Earth’s tilt.

Introduces/reinforces TASS: 5.ESS1.5 Relate the tilt of the Earth’s axis, as it revolves around the sun, to the varying intensities of sunlight at different latitudes. Evaluate how this causes changes in day lengths and seasons.

VSVSer LESSON OUTLINE

1. Introduction
2. Experiment
3. Graphing
4. Observations and Explanations

USE THE PPT AND/OR VIDEO ON WEBSITE TO VISUALIZE THE MATERIALS USED IN EACH SECTION BEFORE TEACHING THIS LESSON.

1. In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

   1. Why do different areas of the planet experience different intensities of sunlight?
   2. What is the difference in degrees between the northern and southern hemispheres?
   3. What about the earth's movement causes us to have seasons?

Full Materials List:

- 1 globe (with 5 marked locations)
- 1 globe lamp
- 1 collapsible hula hoop
- 11 example two-line graphs (laminated)
- 3 VSVS data collection sheets (half sheets)
- 32 observation sheets
- 11 instruction sheets
- 11 stacks (1 per group) 3 similarly sized textbooks (students provide)
- 11 flashlights
- 11 protractors
- 11 bags markers (containing 1 green, 1 blue, 1 purple, 1 orange, 1 black, and 1 brown)
- 11 sets 7 pages graph paper
- 11 rulers
- 11 clipboards
I. Introduction
   a. Why is the science in this lesson important?
   b. Demonstrating the Earth’s tilt.
      i. Show the students the provided globe. Explain that the Earth is tilted on its axis at 23.5 degrees and the axis is always tilted in the same direction as it orbits the sun. Show this by holding the globe in front of your body and moving it in a circle without turning it (the axis should stay pointing at the same wall through the entire circle).
      ii. Demonstration.
         ● Place the lamp in the center of the room with the hula hoop on the floor around it.
         ● Allow one student to walk around the “sun” while holding the globe with the axis always facing the same direction. (This means that their body should not turn the entire time they walk around the circle – the axis should always point to the same all, so at times their left or right side may face the lamp and at others the front or back of their body will face it.)
         ● If possible, allow students to turn the globe on its base to show Earth’s rotation as well.
      iii. Focus the sun’s rays and how they hit the Earth at a given position. Using the marked locations on the globe, guide students to consider that, while the Earth’s surface is spherical, each ray of sunlight hits only one place on Earth. The activity they are about to complete will focus on the area where the sun’s energy actually hits the surface of the Earth.

Unpacking the kit and Set-Up:
   Organize students in groups of three. Tell students to have a pencil and five similarly sized textbooks ready.
   Remove all items from kit box.
   While one VSVS member gives the introduction, other VSVS members should set up the demo using the globe, desk lamp, extension cord, and loop.
   Set aside other materials in 10 group sets and keep one for demonstration purposes. Borrow five similarly sized textbooks from the teacher or students for demonstration purposes.

II. Experiment
   a. Set-up.
● Pass out 1 flashlight, 1 protractor, 1 roll masking tape, 1 bag markers, 1 set graph paper, 1 instruction sheet, and 3 observation sheets to each group.

● Instruct students to set up their station according to the guide (figure 1) on the instruction sheet and choose a role for each group member (figure 2). VSVS members should circulate through the room and assist students with set-up or to help solve issues with role assignment (some groups will easily agree on roles, others may need direction such as “Why don’t you try playing a game of rock, paper, scissors to determine who will be the XXX today?”).

● VSVS group members should also set up their demo station at the front of the room so all students can see it. This will make it easier to instruct students through the experiment portion. (VSVSer note: If you have groups larger than three, you may assign another role and have one student be in charge of changing out the paper on the clipboard and making sure it is lined up properly.)

b. Review using a protractor to determine angle.

● Use the protractor diagram on the student instruction sheet to quickly refresh students on how to determine the angle of the clipboard throughout their experiment.

● Review the parts of the protractor and ask students where each part of their angle should be lined up with (one line should always be lined up with the base line, the vertex should be lined up with the center, and the other line of the angle will be lined up with one of the numbers on the inner or outer scale).

● Tell students that they will be using the inner scale to measure their angles because they will be leaning the clipboard backwards to create obtuse angles.

● They should start with the clipboard at 90 degrees, but note that while we will use the protractor as a measurement tool, we will refer to the first vertical position as 0 degrees. The other locations will follow a similar pattern (10°, 20°, 30°, and 40°).

<table>
<thead>
<tr>
<th>Choose a Role!</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurer</strong></td>
</tr>
<tr>
<td>Hold the graph paper on the clipboard vertical throughout the experiment. Adjust its angle when needed and be sure to hold it steady!</td>
</tr>
<tr>
<td><strong>Checker</strong></td>
</tr>
<tr>
<td>Check the protractor to ensure that the angle of the clipboard doesn't waiver during the experiment! Also, double check that each adjustment is correctly measured on the protractor</td>
</tr>
<tr>
<td><strong>Tracker</strong></td>
</tr>
<tr>
<td>Outline the most intense circle of light on the graph paper with the correct colored marker.</td>
</tr>
</tbody>
</table>

**Do not switch roles during the experiment!**
c. **Note.** Be sure to specify that the system we are viewing is only our sun (the flashlight) and Earth (the clipboard). We do not consider the movement of Earth or the sun within our galaxy or our galaxy within the universe.

d. **Instruct students to line up the protractor next to the side of the clipboard with the graph paper attached.**
   
i. **Step #1** - They should place the flashlight on the book 1 inch from the edge, then turn on the flashlight and trace the intense circle of light on the graph paper with the green marker. Be sure to tell them to try to keep the clipboard and flashlight as stable as possible while the area of light is being traced.

   ii. **Step #2** – Students will replace the graph paper on the clipboard and reset. They should lean the clipboard back 10 degrees and trace the most intense light with the blue marker.

   iii. **Steps #3-5** – Students will repeat the above step with purple, then orange, then brown, leaning the clipboard back another 10 degrees with each step (figure 3). Be sure to instruct students to turn off their flashlights anytime they aren’t using it to outline the circle of light. Each group should finish with five circles of light traced on pieces of graph paper (not shaded in!).

III. **Graphing**

   a. **Count.** Have students count the number of squares within each outlined area and record on their observation sheets (be sure to have them add each portion of a square rounded to the nearest fourth as a decimal – you may need to draw a few examples on the board to show them how to do this). VSVS members should circulate through the room collecting information on the VSVS Data Collection Sheet to create class averages for each data point.

   b. **Write the class averages for each datapoint on the board.** Instruct students to fill them in on their observation sheet before attempting their two-line graph.

   c. **Pass out example two line graphs (figure 4).** Explain that students should start with one data set (either the class average or their group’s data) and individually plot each point before connecting it with a line. They can use whichever color they like for their group data, but instruct them to make the class average black for consistency across the classroom!
IV. **Observations and Explanations**

a. Discuss the experiment as it relates back to the Earth. Different areas on the planet will receive a different intensity of sunlight depending on the angle the light hits it and how much direct sunlight it receives.

b. Note each of the marked locations on the globe. Each corresponds to a different angle measurement you used in the experiment today. Show students each of the locations and tell them the angle measurement (0°, 10°, 20°, 30°, 40°) for each.

c. Ask students what they notice about each location on the globe and the light intensity information they found for it during their experiment.

d. Explain that the tilt is why we have seasons! Move the globe around the sun (globe light) once more and direct students to look at which portion of the globe is receiving more direct sunlight at various points in it’s orbit. (Recreate the diagram below, stopping to explain each place or ask students to guess which season we would be in!)

- In the diagram below, position 2 represents summer in the northern hemisphere because it is receiving the most direct sunlight.
- Position 3 represents fall in the northern hemisphere because both hemispheres are receiving equal amounts of direct sunlight.
- Position 4 represents winter in the northern hemisphere because it is receiving less direct sunlight.
- Position 1 represents spring in the northern hemisphere because both hemispheres are receiving equal amounts of direct sunlight.
- Direct students to focus on the northern hemisphere while you do this (because that’s where we live!) but be sure to tell students that at each point the southern hemisphere would be the exact opposite!

**Seasonal Configuration of Earth & Sun (from the Northern Hemisphere)**