The “Earth & Space Science Expo Investigation Handbook” was created to assist volunteers with presenting science activities to the third-, fourth-, and fifth-grade students attending the annual Science Expo presented by the UC Davis Tahoe Environmental Research Center. Teachers that have scheduled participation at this year’s annual Science Expo event may also benefit by learning more about the science presented at the Science Expo for follow-up discussions and reflection with their students.

The design and format of the handbook is as follows: Each page details a specific Earth or space science investigation. Investigations are divided into three categories: Space Science, Geology & Earth System Science, and Weather & Climate. Each investigation uniquely considers various aspects of Earth or space science including weather, air pressure, cloud formation, stream modeling, ground water modeling, geology, fossils, space science and more. Activity descriptions include the learning objective or “Passport Question,” “Materials List,” “Procedure” and “Talking Points.” The Science Expo is held annually each March and rotates between Earth & space science, life science and physical science thematic activities.

This handbook is designed to meet the intellectual needs of students enrolled in grades three through five as well as particular curricular standards that are determined and designated by individual state departments of education. Procedures that are outlined in the “Earth and Space Science Expo Investigation Handbook” are for student use.

Activities were gathered and described by Kelsey Poole (Space Science), Kristen Reichardt (Earth Science & Geology), and Kylee Wilkins (Climate and Weather); AmeriCorps members with the UC Davis Tahoe Environmental Research Center. For other questions or comments, please contact Heather Segale, UC Davis Tahoe Environmental Research Center education and outreach director at hmsegale@ucdavis.edu or 775-881-7562.
Geology and Earth System Science

Just Around the Riverbend

Passport Question: What process moves particles (such as sand) in the stream?

Passport Answer: Erosion

Supplies:

- Streambed Table Model (with variable flow valve) – EM river2
- Water
- Bucket

Background information:

- By looking at a stream model we can better understand how streams and rivers shape the Earth’s landscape.
- Water always flows downhill, but never in a straight channel. Though a stream might begin as a seasonal stream and only carry rainfall, as it collects speed and larger volumes of water it creates rivulets and eventually more permanent channels. Erosion occurs and sediment is carried downstream.
- A stream is a body of water with a current, confined within a bed and stream banks.
- Streams are important as conduits in the water cycle, instruments in groundwater recharge, and corridors for fish and wildlife migration.

Parts of a stream:

- Confluence: The point at which the two streams merge. If the two tributaries are of approximately equal size, the confluence may be called a fork.
- Run: A somewhat smoothly flowing segment of the stream.
- Pool: A segment where the water is deeper and slower moving.
- Riffle: A segment where the flow is shallower and more turbulent.
- Channel: A depression created by constant erosion that carries the stream's flow.
- Floodplain: Lands adjacent to the stream that are subject to flooding.
- Stream bed: The bottom of a stream.
- Waterfall or cascade: The fall of water where the stream goes over a sudden drop.
- Mouth: The point at which the stream discharges, possibly via an estuary or delta, into a static body of water such as a lake or ocean.

Landforms Vocabulary:

- Alluvial fan: A fan-shaped landform deposited at the end of a steep canyon where the slope becomes flatter.
- Canyon: A V-shaped valley cut by a river or stream.
- Dam: A construction or wall across a river that holds back the water flowing through the river, creating a reservoir or lake.
- Delta: A fan-shaped (triangular) deposit of earth materials at a mouth of a stream.
- Deposition: The process by which eroded earth materials settle out in another place.
- Drainage basin/Watershed: A system of rivers and streams that drains an area like the Colorado Plateau.
- Erosion: The breakdown and removal of soil and rock by water, wind, or other forces.
- Flash flood: A flood that rises and falls rapidly with little or no advance warning. Flash floods can be caused by sudden heavy rainfall, dam failure, or the thaw of an ice jam.
- Flood: A very heavy flow of water, which is greater than the normal flow of water and goes over the stream’s normal channel.
- Landform: A shape or feature of the Earth’s surface, like a delta or canyon.
- Levee: A natural or artificial wall of earth material along a river or sea that keeps the land from being flooded. Artificial levees are built to control flooding.
- Meander: A curve or loop in a river.
- Plateau: A large, nearly level area that has been lifted above the surrounding area.
- Sediment: Tiny bits of rock, shell, dead plants, or other materials transported and deposited by wind, rain, or ice.
- Slope: The angle or slant of a stream channel or land surface.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Prediction: What shape is the water going to make in the land form?</td>
</tr>
<tr>
<td>2 Observe formation and flow of a stream or river.</td>
</tr>
<tr>
<td>3 What happens if the volume of flow changes?</td>
</tr>
<tr>
<td>4 Identify the streambed channel, an alluvial fan, erosion, V–shaped valley, and meander.</td>
</tr>
<tr>
<td>5 Give an example of where you might find something similar to what you are observing in nature.</td>
</tr>
</tbody>
</table>

**Discussion:**

- Where is erosion occurring? How would an increase in foliage affect the flow and shape of the stream? What’s the difference in the size of the sediment pieces left in the streambed and those that have run off?
- Have you seen examples of this in real life? Where? How might erosion affect Lake Tahoe?
Groundwater Explorations

Passport Question: What do you call water stored naturally underground?
Passport Answer: Groundwater

Supplies:
- Groundwater Model/ Watershed Model
- Water
- Bucket (5 gal)

Background information:
The water flowing in streams, rivers and lakes is surface water and the water that is stored beneath the earth’s surface is called groundwater. Although people tend to forget about groundwater, it is an important part of the water cycle.

The top layer of soil contains varying amounts of water but is never saturated, or completely full. Beneath this is the saturation zone where all available spaces between sand and gravel are filled with water. The top of the saturation zone is called the water table.

An area that holds a lot of water—enough to be pumped with a well for human use—is called an aquifer. Groundwater is clean but can be polluted from leaking tanks that hold gasoline, landfills, or excessive use of pesticides and fertilizers.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

Discussion:
- Is groundwater a renewable resource?
- Where does the water that you use on a daily basis come from? Has this water been polluted? How is it filtered naturally/mechanically?
Quakes and Plates

Passport Question: This model demonstrates stress and tension which leads to _______ in real life faults?
Passport Answer: Earthquakes

Supplies:
Wooden sandpaper blocks with rubber bands
Plate Tectonics Wooden Demo
Convection Currents Demo

Background information:
What causes earthquakes? Pieces of the earth’s crust can break or fracture which releases energy. Crustal blocks can also “stick” and “slip” along a fault. When a large block “slips” it releases energy, causing an earthquake. This can be demonstrated using the following wooden blocks activity.

Types of tectonic plate boundaries:
- Convergent: This type of plate boundary occurs where two plates are moving toward each other. Crust is destroyed as one plate dives under another. At continental-continental boundaries, mountains are formed from the uplift of continental crust. At oceanic-continental boundaries, the oceanic plate dives under the continental plate. At oceanic-oceanic boundaries, one of the oceanic plates dives under the other.

- Divergent: This plate boundary occurs along spreading centers where plates are moving apart and new crust is created by magma pushing up from the mantle.

- Transform (Strike-Slip): A plate boundary where two plates are sliding past one another.

- Elastic Rebound: As rocks on either side of a fault shift in relation to each other, they build up energy until their internal strength is overcome and sudden fault movement occurs. This release of accumulated energy is called elastic rebound.

- Friction: This is the force resisting the relative motion of solid surfaces.
**Discussion:**

- Tension and stress build until they overcome friction, at which point the block will move.
- We saw the blocks release energy when they slid. Earthquakes occur because of energy being released in the crust.
- How does this model represent how a real earthquake releases energy?

| **Procedure** |  
|---------------|-------------------------------------------------|
| **1** | Arrange the kids in competition style, paired against each other. |
| **2** | Give each student a block and place block sandpaper-side down on the carpet. |
| **3** | Slowly pull the rubber band (attached to the wooden block) away from the block parallel to the carpet. Do not lift the block up. The block should stick and eventually slide. |
| **4** | Make it a competition between the students to see how far you can pull the rubber band (how much tension can be created) before the energy releases. |
Modeling Convection Currents in the Mantle
(de demo linked with Quakes and Plates)

**Passport Question:** Where does the heat that creates the convection currents come from?

**Passport Answer:** Core of the Earth

**Supplies:**
- Glycerin
- Glitter
- Beaker
- Heat Source (like a single flame)
- Crushed Ice

**Background information:**
This demo shows how convection currents are responsible for tectonic plate movement. This relates to other activities such as the Earthquake Machine, Quakes and Plates, and the 3D Earthquake Viewer as the cause of plate movement and earthquakes.

The upper mantle is made of a much denser, thicker material than the mantle underneath and because of this the plates "float" on it like oil floats on water. Geologists believe that the mantle "flows" because of convection currents.

Convection currents are caused by the very hot material at the deepest part of the mantle rising to the upper mantle, then cooling. The cool material sinks back into the deep mantle where it is once again heated and rises, repeating the cycle over and over. When the convection currents flow in the mantle they also move the crust and the tectonic plates on it. A conveyor belt in a factory moves boxes like the convection currents in the mantle moves the plates of the Earth.

**Procedure**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Place heat source underneath the glycerin/glitter mixture. The crushed ice on top will help the glitter to move back down the beaker so that the current can be observed.</td>
</tr>
<tr>
<td>2</td>
<td>Give the glycerin a minute or two to heat up and observe the moving glitter.</td>
</tr>
<tr>
<td>3</td>
<td>Discuss how this model is like the convection currents happening within the mantle of</td>
</tr>
</tbody>
</table>
the Earth.

Discussion:

- Where does the heat that creates the convection currents come from (center of the Earth)?
- How does the plate movement create earthquakes? Link back to building up tension that eventually releases as an earthquake.
- Discuss what could happen if the convection currents were to stop.
The Break Down

**Passport Question:** _______ and Chemical are the two types of weathering

**Passport Answer:** Physical

**Supplies:**
- Craft Stick
- “Elmer’s” Glue
- Large Shallow Plastic Container of various sized granite pieces and sand
- Sand Slides
- Tahoe Map
- Hand lenses
- Microscope

**Background information:**
Weathering is the breakdown of the Earth’s rocks, soils, and minerals caused by the Earth’s atmosphere. Erosion causes the same break down from the movement of rocks, soils, and minerals from forces like water, ice, wind, and gravity. There are two types of weathering: Physical and Chemical.

Physical weathering causes changes through processes such as thermal stress, frost or pressure. Wind, ice and water are also mechanisms for physical weathering because they transport materials that scour and weather other rocks.

Chemical weathering changes the composition of rocks by dissolution from acid rain, hydrolysis of silicates and carbonates, and oxidation.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Observe the rock pieces within a plastic container to observe the process of mechanical weathering (bigger pieces are becoming smaller). How?</td>
</tr>
<tr>
<td>2</td>
<td>Select several rocks of different sizes and shapes and arrange them in order of size.</td>
</tr>
<tr>
<td>3</td>
<td>Using glue, attach rocks in order of size onto provided craft stick.</td>
</tr>
<tr>
<td>4</td>
<td>Using the hand lens and microscope, observe the different sizes of rock. Look at the sand particles around the different areas of the lake. Why are they different?</td>
</tr>
<tr>
<td>5</td>
<td>Discuss how, in nature, rocks change size, shape, and form.</td>
</tr>
</tbody>
</table>
Discussion:

- If you were looking at these rocks on a beach, what size rocks would you find closest to the water’s edge?
- How does mechanical weathering occur in real life?
- Why do different areas of the lake have such different sand types?
Rock Detective

Passport Question: After completing your experiments, what type of rock did you discover?

Supplies:
- Complete Rock Mineral Testing Kit
- Magnifying Glasses
- Safety Goggles
- Crystal Display
- Geodes

Background information:
There are 3 main types of rocks.
- **Igneous** rocks like obsidian, pumice, granite and basalt are formed through the cooling and solidification of magma or lava.
- **Sedimentary** rocks like limestone, sandstone, and shale are formed by the **lithification** (compaction) of sediment layers under great pressure. Sedimentary rocks compose 5% of the volume of the earth’s crust.
- **Metamorphic** rocks such as marble and quartzite have been changed from existing sedimentary rock types, limestone and sandstone respectively, and require heat and pressure.

A mineral is a natural occurring solid with a unique and definite chemical composition. Rocks are aggregates of one or more minerals. Rocks and minerals can be identified by testing their hardness, luster, color, streak, cleavage, fracture, and specific gravity.

Many rocks look alike. Geologists use a variety of methods to identify a rock, which students will use in this experiment:

a. **Mohs Scale Scratch Test** rates mineral hardness; diamond is the hardest mineral and talc is the least hard.
b. **Acid or “Fizz” test**. Rocks that contain calcium carbonate (limestone, oolitic limestone, coquina and marble) should “fizz” in acid. The bubbles are telling you that your rock contains calcite, like limestone.
c. **Float Test** gives an idea of the rock’s relative density
d. **Streak Tests** on ceramic plates give clues to the rock type based on the presence of a streak and the color

Problem: Which rocks are which? We’ve mixed up our rocks (limestone, talc, pumice, quartz, calcite, and granite) and we need you to identify what type of rock they are!
Hypothesis: We think if we use our fingernail, an iron nail, an acid reaction test, a buoyancy test,
and a streak test then we can determine which rock is which.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

7   (optional) | Select your favorite rock and write out observations from the test, hand lens and eye observations. Be very detailed. Return your rock to the pile. |

8   (optional) | Exchange observation cards with a friend and try to find each other’s rocks based on their observations. |

<table>
<thead>
<tr>
<th>Rock</th>
<th>Fingernail</th>
<th>Nail</th>
<th>Acid Reaction</th>
<th>Floats or Sinks?</th>
<th>Streak?</th>
<th>What rock am I?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>Fingernail</td>
<td>Nail</td>
<td>Acid Reaction</td>
<td>Floats or Sinks?</td>
<td>Streak?</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
<td>------</td>
<td>---------------</td>
<td>------------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td>No scratch</td>
<td>X</td>
<td>X</td>
<td>Sinks</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Talc</td>
<td>X</td>
<td>X</td>
<td>None</td>
<td>Sinks</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Pumice</td>
<td>No scratch</td>
<td>X</td>
<td>None</td>
<td>X</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>No scratch</td>
<td>No scratch</td>
<td>None</td>
<td>Sinks</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td>No scratch</td>
<td>X</td>
<td>X</td>
<td>Sinks</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Granite</td>
<td>No scratch</td>
<td>X</td>
<td>None</td>
<td>Sinks</td>
<td>Grey</td>
<td></td>
</tr>
</tbody>
</table>

**Discussion:**

- Which was the hardest/softest?
- What happened when you conducted an acid test?
- What observations did you make using the hand lenses?
- Why is this information useful?
- Were you successful in determining your rock’s type?

**If Optional Steps were done:**

- What made it easy/hard to find your partner’s rock?
- How do detailed notes help scientists in the field?
- What observations did you make about your rock?
Birdseed Mining

Passport Question: Name one positive and one negative result of mining.

Passport Answer:
- Positive: necessary minerals are collected for use in many applications and product, mining creates jobs, supports economy
- Negatives: environmental impacts and health impacts for miners

Background information:
Mining is a complex process in which relatively small amounts of valuable (gold) or useful (coal) minerals or metals are extracted from very large masses of rock. This activity will illustrate how this “needle in a haystack” process works. Students will be able to experience the difficulty that miners face in locating valuable mineral deposits. They will also learn a simple lesson in economics- a less valuable commodity may be more profitable because it is more abundant. Students will be shown the importance of clean, environmentally conscious mining, and will learn that all mining operations must pay for reclamation work.

Supplies:
- Wild Bird Food- any birdseed mix that contains sunflower seeds and at least 2 other seed varieties
- Shallow Pans
- Small Beads (approximately 2mm) in blue, gold, and silver
- Medium Beads (approximately 4-6mm) in white

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pour approximately one pound of birdseed in each pan.</td>
</tr>
<tr>
<td>2</td>
<td>Mix two gold beads, four silver beads, eight copper beads, and three white beads into each pan of birdseed.</td>
</tr>
<tr>
<td>3</td>
<td>Search through the seed mixtures and separate out or “mine” beads, sunflower seeds, and other grain products, making piles of each. Allow your group two to three minutes to finish mining.</td>
</tr>
<tr>
<td>4</td>
<td>Count the sunflower seeds, blue beads, green beads, marbles, and Styrofoam from your piles and calculate your earnings based on the values given above. Note your earnings in the spreadsheet. Also, pay special attention to any environmental...</td>
</tr>
</tbody>
</table>
damage that was done because of the mining. You will be fined for a messy table!

| 5 | Total the dollar value of the mining operation, subtracting the environmental damage fines and reclamation costs. |

**Discussion:**

- What happened when you mined in a “messy” way? Was it worth it? What would you do differently the next time? How can you maximize your profit?
- Why do we need mining? What do we use these materials for?
- What “environmental impacts” did you see in your model? What would these impacts look like in real life?
- Why should we pay for reclamation?
Magnetic Earth

Passport Question: True or False: The Earth has a magnetic field that protects it.
Passport Answer: True

Supplies:
- Magnetic Field Poster
- Magnetic Earths
- Staples or Paper Clips

Background information:
Right at the heart of the Earth is a solid inner core, two thirds of the size of the Moon and composed primarily of iron. At 5,700°C this iron is as hot as the Sun’s surface, but the crushing pressure caused by gravity prevents it from becoming liquid.

Surrounding this is the outer core is a 2,000 km thick layer of iron, nickel, and small quantities of other metals. Lower pressure than the inner core means the metal here is fluid.

Differences in temperature, pressure and composition within the outer core cause convection currents in the molten metal as cool, dense matter sinks while warm, less dense matter rises. The Coriolis force, resulting from the Earth’s spin, also causes swirling whirlpools.

This flow of liquid iron generates electric currents, which in turn produce magnetic fields. Charged metals passing through these fields go on to create electric currents of their own, and so the cycle continues. This self-sustaining loop is known as the geodynamo.

The spiraling caused by the Coriolis force means that separate magnetic fields created are roughly aligned in the same direction. Their combined effect produces one vast magnetic field engulfing the planet.

The Earth’s magnetic field (magnetosphere) extends several tens of thousands of kilometers into space. This region protects the Earth from cosmic rays and solar wind (a stream of charged particles emanating from the sun) that would otherwise strip away the upper atmosphere, including the ozone layer that protects the earth from harmful ultraviolet radiation. The loss of Mars’ magnetic field caused a near-total loss of its atmosphere.

Studies of the alignment of crystals in ancient volcanic rocks (which oriented themselves relative to the Earth’s magnetic field when they solidified) have shown that the magnetic poles periodically trade places.
TINS bringing in birds and talking about migration patterns linked with magnetic field

Discussion:

- Why do we need the magnetic field?
- Have you used a compass before? Discuss your experience/ how it helped/ how you think it could be useful for others.
Fossil Dig

Passport Question: ________ are evidence of past life on Earth.

Passport Answer: Fossils

Supplies:

- Diatomaceous Earth gathered from Fernley, Nevada
- Fossil Samples
- Kiddy Pool (or large tarp area)
- Tools (putty knives, paint brushes)
- Safety Goggles

Background Information:

**What is Diatomaceous Earth (or Diatomite)?** It is a bright white, very light rock. It is composed nearly entirely of the skeletal remains of tiny diatoms ("microscopic skeletons of unicellular aquatic algae"). The diatomite formed in a large freshwater lake about 9 - 10 million years ago (Miocene geologic age).

**Diatomaceous Earth (Diatomite)** is mined in Fernley, Nevada, among other places. Diatomaceous earth consists of fossilized remains of diatoms, a type of hard-shelled algae.

**What is Diatomaceous Earth used for?** It is used as a filtration aid, as a mild abrasive, as a mechanical insecticide, as an absorbent for liquids, as cat litter, as an activator in blood clotting studies, and as a stabilizing component of dynamite. As it is also heat-resistant, it can be used as a thermal insulator.

**Paleontology** is the study of prehistoric times through the discovery and interpretation of fossils. Paleontologists search for and collect fossilized clues to piece together a picture of the environment and ecosystems of the distant past. As a historical science, paleontology incorporates mainly biology (the study of plants and animals) and geology (the study of rocks) to puzzle together facts to explain the past. In contrast, experimental scientists conduct experiments in order to disprove hypotheses.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td><strong>3</strong></td>
</tr>
<tr>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>
**Discussion:**

- What is diatomaceous earth? Where does it come from?
- How and why were these organisms fossilized? What types of organisms so you see? Where have you seen organisms like this before?
- Why are aquatic fossils in the middle of the desert? (This must have been under water at some point)
- **You found a fossil?** There are “Fundulus nevadensis” fish fossils found in the Nevada Diatomite. These fish from the historic Pliocene era are visible in the Diatomite rocks. Their burnt orange color contrasts well against the off-white color of the diatomaceous earth plate.
**All About Fossils (Demo Paired with Fossil Dig)**

**Supplies:**
- Water tight container (such as a milk carton)
- Sand and gravel
- Fine Sand
- Other types of sediments for layering
- “Fossils” for inside the sediment
- Plaster of Paris and Water (3T of plaster to 1/2c water)
- Tags for labeling sediment layers

**Background information:**
Students will use this station in conjunction with the ‘Fossil Dig’ as a way to learn how fossils get to where they are. This model will be used to connect students to where the diatomaceous fossils they dig for actually came from.

When animals, plants and other organisms die, they typically decay completely. But sometimes, when the conditions are just right, they're preserved as fossils. Fossils are remnants of once living things.

There are four main ways that fossils form:

- **Preserved organisms.** In preserved organisms, the actual organism is basically unaltered and stays intact, e.g., mammoths that have been found in ice and frozen ground. The soft body parts are preserved as well as the hard parts. Preserved organisms have been found in tar pits and amber. Amber is formed when the soft resin from conifers and tropical flowering plants hardens. Organisms such as insects, spiders, leaves, flowers, mosses, and even frogs have been found in amber. Organisms trapped in this resin may experience a degree of decomposition, but because resin has a strong antibiotic component the decay of the organism is minimal.

- **Mineral replacement (Permineralization).** This is the most common kind of fossil. In this type of fossil the organism is buried in sediment, and the soft parts decay quickly. Bones, teeth, claws, and other hard parts decay more slowly. Water seeps through the sediment and passes through the bone. The seeping water dissolves the bone, and minerals in the water replace the bone one cell at a time. The minerals eventually form a stone in the exact shape as the bones. The same process happens in wood (petrified wood) except that wood is often covered with volcanic ash instead of sediments. The ash prevents the wood from rotting, and as rainwater falls on the ash over many years it seeps through the ash into the wood. The mineral replacement makes an exact replica of the original organism.

- **Impression fossils.** These fossils may show detailed outlines of thin plants or small animals, e.g., leaves, feathers, and fish, which die in sediment. As they decay, they leave
a carbon deposit that shows as a dark print of the organism. Impression fossils also include tracks, tail prints, body outlines, teeth marks, and burrows.

- Cast and Mold Fossils. Molds and casts are impression fossils made by larger organisms. When the organism dies it is covered by sediment. The organism decomposes slowly and leaves a mold (hole) in its place. If the mold is later filled with sediment, it produces a cast that will physically look like the outside of the original organism. If an organism completely dissolves in sedimentary rock, it can leave an impression of its exterior in the rock, called an external mold. If that mold gets filled with other minerals, it becomes a cast. An internal mold forms when sediments or minerals fill the internal cavity of an organism, such as a shell or skull, and the remains dissolve.

Be aware that students may become confused by pseudo-fossils. If they are excavating their “fossil”, they need to be aware of the fact that this is not how it would actually look. They may observe a mold that was made by the organism.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

**Discussion:**

- What evidence do we have that fossils represent things from the past? Where they are in the rock/soil column? Is there anything that looks like this today?
- Ask students about the layering of sediments and why older fossils are trapped deeper underneath the Earth than newer ones.
Volcano Loco

**Passport Question:** Which type of volcano erupts most violently?

**Passport Answer:** Composite cone volcanoes have a much more violent eruption.

**Supplies:**
- Dry Ice
- Brown Paper
- Scotch Tape
- Warm Water
- Scissors
- Small beaker or cups
- Gloves
- Pictures of volcano types

**Background information:**
**Earth’s Layers:**

a) **Crust:** This is not what we walk on. The layers of dirt and silt that cover the crust are normally considered to be separate from it. The crust comprises the continents and ocean basins. It has a variable thickness, anywhere from 35-70 km thick in the continents and 5-10 km thick in the ocean basins.

b) **Mantle:** Just under the crust is the mantle. It is composed mainly of ferro-magnesium silicates (iron, magnesium and silicon). It is about 2900 km thick and is separated into the upper and lower mantle. This is where most of the internal heat of the Earth is located. Large convective cells in the mantle circulate heat and may drive plate tectonic processes.

c) **Inner and Outer Core:** There are two very distinct parts of the core: the outer and the inner core. The outer core is 2300 km thick and the inner core is 1200 km thick. The outer core is composed mainly of a nickel-iron alloy, while the inner core is almost entirely composed of iron. The outer core contains as much as 10% lighter elements than iron alloy. The inner core is thought to rotate at a different speed than the rest of the Earth and which contributes to the presence of the Earth’s magnetic field.

**Volcano Formation:** Sometimes high temperatures and pressure cause the mantle to melt and become magma. When a large quantity of magma forms, it moves up to the surface through the crust, and then releases pent-up gas and pressure that makes the volcano erupt. Once magma escapes to the Earth’s surface, air or water turns the magma into lava.

**Magma Types:** There are many different types of magma. They produce different types of lava ranging from fluid, fast moving basalt to slower and much thicker lava. Since rocks are made of
different materials that melt at different temperatures, the type of rock that is melted in the mantle will affect the magma that results.

**Types of Volcanoes:** There are 3 main types of volcanoes: Composite Cone, Cinder Cones, and Shield Cones. Each type is different because of the way they erupt or the types of materials they erupt.

* a) **Composite Cone Volcanoes** (Strato volcanoes) have some of the most explosive eruptions. The volcano is built of lava, cinders and ash, and the overall size of the volcano tends to increase after an eruption. Strato volcanoes have very steep sides and serve as a transportation system for magma to rise to the surface from deep within the Earth’s crust. Sometimes, as in the case of Mount St. Helens in Washington, the eruption can be so powerful that part of the volcano can be blown away, causing the mountain to be reshaped.

* b) **Cinder Cone Volcanoes** are so named because they were formed by lava fragments called cinders. This type of volcano only has one vent in which the magma can flow, unlike the composite and shield volcanoes. Since there is only one vent from which the magma can escape, the lava fragments burst into the air and then fall around the vent of the volcano. Cinder cone volcanoes also have steep sides, but they are not as large as composite or shield volcanoes.

* c) **Shield Cone Volcanoes** got their name because they look like shields due to their gentle sloping sides. These gentle slopes are caused by the volcanoes’ eruptions. Shield volcanoes’ eruptions usually have fluid lava flows, causing the lava to spread out slowly over great distances. The lava flows not only from the top of the volcano but also through cracks in the ground. However, since the lava travels so slowly when these volcanoes erupt, there is usually enough time for animals and people to move to safety. Because of the way Shield Volcanoes erupt, they are some of the largest volcanoes in the world.

**Volcano Vocabulary:**

* a. Active Volcano: An erupting volcano or a volcano that has erupted before and will likely erupt in the future.
* b. Ash: Fragments of volcanic rock that explode from the vent of a volcano in solid or molten form.
* c. Conduit: The passage that the magma follows through a volcano.
* d. Dormant Volcano: A volcano that is currently inactive, but may erupt again.
* e. Eruption: The process that ejects solid, liquid, and gaseous materials onto the Earth’s surface and into the atmosphere by volcanic activity. These eruptions can range from violent explosions to quiet overflow of magma.
* f. Lava: Magma that is exposed to air or water on the Earth’s surface.
* g. Magma: Hot, molten rock that forms beneath the Earth’s surface.
* h. Magma Chamber: The chamber where the rising magma is collected before a volcano erupts.
* i. Pumice: A type of volcanic rock that forms during an eruption.
j. **Pyroclastic Flow**: Avalanche of material that comes down from the side of a volcano during some eruptions. Contains hot ash, pumice, rock fragments, and volcanic ash.

k. **Vent**: An opening from which volcanic material is released.

l. **Volcanic Gases**: Gases that are released from the magma during an eruption. These gases include H2O (water as steam), CO2 (carbon dioxide), SO2 (sulfur dioxide) and HCl (hydrogen chloride).

m. **Volcano**: A vent in the Earth’s surface in which magma, gases, and ash erupt and form a structure that is usually cone-shaped.

### Procedure

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>Put on safety goggles.</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
<td><strong>Using paper, scissors, and tape make cones of varying sizes to model conic and shield volcanoes. Use images as examples. Use laminated volcanoes as examples or for quick use.</strong></td>
</tr>
<tr>
<td><strong>3</strong></td>
<td><strong>Prediction: How will the shape of the volcano affect the pressure and amount of matter that comes out of the opening?</strong></td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>Place paper cone over beaker with dry ice and warm water to test predictions.</strong></td>
</tr>
</tbody>
</table>

### Discussion:

- **Observations**: What do you observe about the eruption? Why do you think they look different based on the shape of the volcano?
- **Composite Cone Volcanoes (Strato volcanoes)** are steep sided and have some of the most explosive eruptions.
- **Cinder Cone Volcanoes** only have one vent in which the magma can flow, unlike the composite and shield volcanoes. Since there is only one vent from which the magma can escape, the lava fragments burst into the air and then fall around the vent of the volcano.
- **Shield Cone Volcanoes** have gentle slopes that are caused by the volcanoes’ eruptions. Shield volcanoes’ eruptions usually have fluid lava flows, causing the lava to spread out slowly over great distances. The lava flows not only from the top of the volcano but also through cracks in the ground. However, since the lava travels so slowly when these volcanoes erupt, there is usually enough time for animals and people to move to safety.
Earthquake Machine

Passport Question: What is the name of the instrument used to measure earthquakes?

Passport Answer: Seismograph

Supplies:
- Index cards
- Tape
- Paper Clips
- Coffee Stir Sticks
- Glue
- Playdough
- Earthquake Machine
- Earthquake Damage Poster
- Seismograph Images

Background information:
Earthquakes are a sudden motion that results from a release of built up energy within the Earth. Seismologists can record the energy in seismic waves from earthquakes by using an instrument called a seismograph. The greater the amount of energy, the more the needle on the seismometer jumps to make “pulse-like” patterns. When we think of earthquakes, we often think of the damage that occurs as a result of the quake. Depending on the magnitude, earthquakes can cause devastating damage to buildings and structures.

In this investigation, students will learn how different magnitudes of earthquakes affect structures differently. Depending upon how a structure is built, the damage done to the structure can vary. They will also see the homemade seismograph and real seismograph images to further understand how earthquakes are measured.

- Seismic Wave: There are two types of seismic waves that move through the earth’s crust and upper mantle as a result of seismic activity. Primary waves (P waves) are compressional waves that are longitudinal in nature, meaning the wave’s energy travels in the same direction as the wave itself. Secondary waves are shear waves that are transverse in nature, meaning that they move perpendicular to the direction of energy transfer. P waves travel at about twice the speed of secondary waves (S waves) and can travel through both liquids and solids, while S waves can only travel through solids.
- Seismograph: An instrument that continuously measures the movement of the earth, including those generated by seismic waves.
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On a cardboard base, build a model of any type of structure using index cards, coffee stir sticks, tape and playdough.</td>
</tr>
<tr>
<td>2</td>
<td>Make predictions about how well your structure will hold and what makes it more or less stable.</td>
</tr>
<tr>
<td>3</td>
<td>Shake Earthquake Machine in intervals of 5-10-15-20 second intervals (demo of a small scale earthquake).</td>
</tr>
<tr>
<td>4</td>
<td>Discuss with the rest of the group what happened. Did your building stay standing? Why or why not?</td>
</tr>
<tr>
<td>5</td>
<td>Shake as hard as you can to see what a large scale/ catastrophic earthquake can do.</td>
</tr>
<tr>
<td>6</td>
<td>Re-Test with paper clips/ tape as reinforcement.</td>
</tr>
</tbody>
</table>

**Discussion:**

- Was your building more or less resistant than it was for the first shaking tests? Why was that?
- How do you think you could make your structure stronger and more stable?
- What did you have to do to keep your structure from falling down?
- What differences did you see in testing the reinforced structure compared to the non-reinforced structure?
- How can your models resemble and demonstrate what happens to real buildings during an earthquake?
- If you had to design a building to withstand an earthquake, what would you do to make sure it was strong enough, and why?
- Describe to your friend or volunteer what you observed on the seismograph.
3-D Earthquake Viewer

Passport Question: Where do most earthquakes occur?
Passport Answer: Along plate boundaries

Supplies:
   Clean 3-D Glasses

Docent Manual for Background, Procedure and Discussion
Weather and Climate

Air is Everywhere

Passport Question: Does air take up space?

Passport Answer: Yes

Background Information:
When air is heated up it expands and when air is cooled it contracts. For example, on a really cold day your car’s tires may look flat because the air is cold and has contracted and is exerting less pressure on its container, the tire. If air is not in a container the change in pressure from temperature change can go unnoticed. This experiment will let us see this change in pressure from change in temperature.

Supplies:
- Glass pan
- Erlenmeyer flask
- Water, with food coloring
- Tea candles
- Lighter

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

Discussion:
- The candle flame heats the air in the vase, and this hot air expands. Some of the expanding air escapes out from under the vase — you might see some bubbles.
- When the flame goes out, the air in the vase cools down and the cooler air contracts. The cooling air inside of the vase creates a vacuum. This partial vacuum is created due to the low pressure inside the vase and the high pressure outside of the vase. We know what you're thinking; the vacuum is sucking the water into the vase right? You have the right idea, but scientists try to avoid using the term "suck" when describing a vacuum. Instead,
they explain it as gases exerting pressure from an area of high pressure to an area of low pressure.

- A common misconception regarding this experiment is that the consumption of the oxygen inside of the bottle is also a factor in the water rising. While there is a possibility that there would be a small rise in the water from the flame burning up oxygen, it is extremely minor compared to the expansion and contraction of the gases within the bottle. Simply put, the water would rise at a steady rate if the oxygen being consumed were the main factor, rather than the rapid rise when the flame is extinguished.
**Stubborn Balloon**

**Passport Question:** Does hot air or cold air take up more space?

**Passport Answer:** Hot Air

**Background information:**
Air pressure is the force exerted on you by the weight and motion of air molecules (tiny particles of air). Although air molecules are invisible, they still have weight and take up space. Since there's a lot of "empty" space between air molecules, air can be compressed to fit in a smaller volume. “Stubborn Balloon” displays the force associated with air pressure and its relationship with temperature and pressure.

**Supplies:**
- Hurricane Vase
- Newspaper
- Lighter
- Water Balloon
- Water
- Safety Goggles

<table>
<thead>
<tr>
<th><strong>Procedure</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Put on safety goggles!</td>
</tr>
<tr>
<td>2</td>
<td>Place the water balloon on top of the jar and ask a student volunteer to try and push it into the jar. They will be able to push it in a little but it will always pop back out. (Make sure they don’t push too hard or the balloon will pop!)</td>
</tr>
<tr>
<td>3</td>
<td>Remove the balloon. Wad up a piece of newspaper, light it on fire and drop it in the jar. When you are sure it is burning well, put the balloon back on the opening of the jar. The balloon may bounce up and down a couple times and will disappear into the jar.</td>
</tr>
<tr>
<td>4</td>
<td>After the appropriate applause, ask the students if they want you to do it again (expect a yes!). Hand the jar to a student volunteer and ask them to pull out the balloon. They won’t be able to do it.</td>
</tr>
<tr>
<td>5</td>
<td>After a sufficient number of tries hand them a straw. Ask them to hold the straw inside the jar, next to the edge, using their other hand pull out the balloon. The balloon should pop right out.</td>
</tr>
</tbody>
</table>

**Discussion:**
- How does this work? It’s all about air pressure. The balloon wouldn’t go into the jar the first time because the air in the jar was pushing back up on the balloon as the student tried to cram it in. The air compresses slightly but not enough to allow the balloon to enter the jar.
- To understand how we got the balloon into the jar, we have to think about equilibrium. Air molecules will move from areas of high pressure to areas of low pressure to maintain a balance of pressure.
• When you place the burning paper into the jar, two opposing actions begin to take place. First, the fire begins to heat up the air inside, which makes it more energetic. The energetic air molecules try to find a way out of the jar, but the balloon resting on the top acts as a valve blocking the only exit. As the air continues to heat, the pressure builds inside the jar up until it is strong enough to lift the balloon (opening the valve) just enough to let out a “burp” of air from the inside. Once the jar burps, the pressure is reduced inside so that the balloon once again seals it off (the valve closed). The burping action can occur several times in rapid succession, which makes the balloon look like it is dancing a jog on top of the jar.

• Until now the air pressure inside was higher than the pressure outside, evidenced by the fact that the air kept trying to get out. Remember though, two different actions are taking place inside the jar. The other action is that the fire is burning and consuming oxygen, which has the effect of trying to reduce air pressure. Eventually, the paper burns out when there is not enough oxygen to keep it lit. After this happens, the gases inside the jar begin to cool. As they cool, they lose energy and slow down, which reduces the pressure inside the jar. Because the atmospheric pressure is greater than the pressure inside the jar, the balloon is pushed into the jar by the outside air pressure.

• When we try to get the balloon back out of the jar, we again have the one-way valve problem. As the balloon is pulled to the bottom of the jar, the air inside is trapped behind the balloon. The minute this happens there is a balance of forces both inside and out. This balloon is not going to go anywhere when this happens: just ask the student trying to get it out! By inserting the straw you allow air to pass by the balloon. If the air can get into the jar, the forces never get a chance to balance and the balloon can be pulled from the jar very easily.

• When it's compressed, air is said to be "under high pressure." Air at sea level is what we're used to; in fact, we're so used to it that we forget we're actually feeling air pressure all the time!

• Air pressure contributes greatly to atmospheric stratification. In general as atmospheric height increases air pressure and density decrease. Temperature helps distinguish atmospheric layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere.
Automatic Balloon Inflator

Passport Question: Which takes up less space? Hot or cold air?

Passport Answer: When placed in hot water, the gases/air inside the bottle are/is heated, expands, and the balloon inflates. When placed in the cold water, the air inside the bottle is cooled, contracts, and deflates the balloon.

Background information:
We can’t see air, yet it is all around us. Air takes up space and can expand and contract. During this experiment we will see what happens to air when it is heated up or cooled down.

Supplies:
- 2 liter bottles
- Balloons
- Bin of hot water
- Bin of cold water

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set up 1 bottle with a balloon on top.</td>
</tr>
<tr>
<td>2</td>
<td>Ask students what they think will happen to the balloon when you put the bottle in the hot and cold water.</td>
</tr>
<tr>
<td>3</td>
<td>Test their hypothesis: Put the bottle in the hot water, and the balloon expands.</td>
</tr>
<tr>
<td>4</td>
<td>Let the balloon shrink back slowly in room temperature.</td>
</tr>
<tr>
<td>5</td>
<td>Put the bottle in the hot water again, letting the balloon expand.</td>
</tr>
<tr>
<td>6</td>
<td>Quickly transfer the bottle from the hot water to the cold water and see that the balloon shrinks faster than in room temperature air.</td>
</tr>
</tbody>
</table>

Discussion:
As shown in the above figure, the pressure exerted by the air is directly related to the temperature. The higher temperature the more pressure is exerted. This is because higher temperatures “excite” the molecules and make them move faster. The faster the air molecules move, the more energy they have with which to do work and push against their surroundings. This energy is kinetic energy, the energy of motion. The hotter the air, the more kinetic energy the air molecules have.

This is the principle behind the automatic balloon inflator. When you place the bottle in hot water, it heats the air inside the balloon, giving the molecules more energy and expanding the balloon. As the bottle and the balloon cool, the air molecules lose energy and the balloon deflates. Placing the bottle in cold water causes the air molecules to lose energy more quickly, creating a more dramatic deflation of the balloon.
The Power of Words

Passport Question: 14.7 pounds per square inch of this is exerted on you at all times.
Passport Answer: Atmospheric Pressure

Background information:
Atmospheric pressure is the force exerted on you by the weight of tiny particles of air. Earth’s atmosphere is pressing against every square inch of you with a force of 14.7 pounds per square inch. So, the more surface area something has, the more atmospheric pressure is exerted on it.

Supplies:
Newspaper
Ruler
Rubber “Atmospheric Mat”

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td><strong>3</strong></td>
</tr>
<tr>
<td><strong>4</strong></td>
</tr>
<tr>
<td><strong>5</strong></td>
</tr>
<tr>
<td><strong>6</strong></td>
</tr>
<tr>
<td><strong>7</strong></td>
</tr>
<tr>
<td><strong>8</strong></td>
</tr>
<tr>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

Discussion:
- How does this work? Atmospheric pressure is exerting a downward force on the single sheet of newspaper. The area of a single sheet of newspaper is fairly large; therefore the
downward force of the atmospheric pressure exerted on the newspaper is strong enough to counter the upward force of hitting the ruler. It didn't work with the folded-up newspaper because the surface area over which the atmospheric pressure could act was far too small and air was able to be in the space under the folded up newspaper.

- Similarly, the rubber mat is held down by atmospheric pressure, which is 14.7 pounds per square inch. A quick calculation leads to a total pressure of 1,620 pounds per square inch of pressure pushing down on the mat. Here is the simple calculation on the mat that measures 10.5” x 10.5”:

\[10.5 \text{ inches} \times 10.5 \text{ inches} \times 14.7 \text{ pounds/inches}^2 = 1,620.7 \text{ pounds per square inch}\]

No wonder it seems like the mat is “glued” to the table! Even the smallest of pebbles under the mat can lead to leaks and breaks in the seal. That’s why it is so easy to lift the mat by grabbing it on the edge or the corner in order to break the seal. Unlike suction cups, the atmospheric mat does not require you to put force or push down on it to make it work. There’s no air to push out as in the case of a suction cups, so unsuspecting spectators are even more amazed.
**Cartesian Divers**

**Passport Question:** Molecules of gas compress easier than molecules of liquid. T or F?

**Passport Answer:** True

**Background information:**
When you build a Cartesian diver, you are exploring three scientific properties of air:

1. Air has weight
2. Air occupies space
3. Air exerts pressure (this is our focus)

Generally speaking, an object will float in a fluid if its density is less than that of the fluid (density*mass/volume). If the object is denser than the fluid, then the object will sink. For example, an empty bottle will float in a full bathtub if the bottle is less dense than the water. However, as you start filling the bottle with water, its density increases and its buoyancy decreases. When it has enough water in it the bottle will sink.

The Cartesian diver, consisting of a plastic medicine dropper and a metal hex nut, will float or sink in the bottle of water depending on the water level in the bulb of the dropper. When pressure is applied to the outside of the bottle, water is pushed up inside the diver, and the air inside the bulb is compressed into a smaller space. **Molecules of gases are more easily compressed than molecules of liquids.** The more water that is inside the diver, the denser it becomes and the diver sinks. When the pressure on the outside of the bottle is released, the compressed air inside the diver expands and this pushes some of the water back out of the diver. As the water level inside of the diver drops, the diver loses density and floats to the top.

The Cartesian diver activity represents the way a mercury barometer works. This type of barometer is made of a glass tube upright in a base of mercury. When atmospheric pressure is high, it pushes more mercury up the tube. Low atmospheric pressure means the mercury level in the tube is lower.

**Supplies:**

- 1 or 1.5 liter bottles
- Plastic pipettes
- Hex nuts
- Hook and sinker
- Squidy

**Procedure**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To make a diver:</td>
</tr>
<tr>
<td></td>
<td>1. The standard Cartesian diver is made from a plastic medicine dropper known as a pipette and a hex nut. Screw the hex nut onto the base of the</td>
</tr>
</tbody>
</table>
pipette. Several turns of the hex nut should be sufficient to hold it in place.

2. Cut off all but 1/4 of an inch of the pipette stem. This is the standard diver.

3. Place the diver in a cup of water, making sure that the water in the cup is at least four inches deep. Notice that the diver floats. Why? While the diver is still in the water, squeeze the bulb of the pipette to force air out and release pressure to draw water up into the diver. Continue squeezing air out and drawing water up into the diver until the pipette is about half full of water. Let go of the diver and see if it still floats in the water. When properly adjusted, the diver should just barely float in the cup of water. If the diver sinks to the bottom, squeeze out a few drops of water and re-test.

2 Divers will be all premade, but if one malfunctions try the above tactics to fix it.

3 Students can make their own Cartesian Diver (hex nut and pipette) to take home and try in a bottle.

<table>
<thead>
<tr>
<th>Procedure 1: Classic Cartesian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure 1: Squidy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure 1: Hook and Sinker</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure 1: Counting Cartesian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>
| **4** | You can have quite a bit of fun with this just in the way you present it to the students. “Here is a bottle with five trained Cartesian Divers. What? You don’t believe me? I’ll show you. Watch as I command diver #1 to sink.” Hold the bottle up and gently squeeze to make diver #1 sink to the bottom. Don’t let
anyone know you are squeezing the bottle.

“Now, it’s #2’s turn.”

Secretly squeeze the bottle a little harder and make the second diver sink. Divers #3 through #5 are more difficult to sink because they have less water and may require the use of the special pump. Lift the top of the pump and push it back down. The pump forces a small amount of air into the bottle and this, in turn, increases the pressure on the air in the divers. By repeating the pumping action, it is very easy to make all of the divers sink. Loosen the cap just as you would when you open a bottle of soda and the divers will jump back up to the top.

Diver #1 contains the greatest amount of water because you adjusted the water level inside so that it would just barely float. Since diver #1 has the most water, it has the smallest pocket of air. When you squeeze the bottle, this diver will descend first. On the other end of the scale, diver #5 contains the least amount of water and has the largest pocket of air. Diver #5 is the most buoyant of the five divers and should be the last one to sink.

The divers will progressively sink in the order 1 to 5 if the densities of the divers are properly adjusted. You will also notice that you have to squeeze harder and harder to get each successive diver to sink. In essence, you have created a strength tester. One person may only be strong enough to sink three divers while someone else may have the strength to sink all five. How strong are you?

**Discussion:**

- **How Does It Work?** The Cartesian diver, named after French philosopher and scientist René Descartes, works because of several factors.
- When you squeeze the sides of the bottle, you are increasing the pressure on the liquid inside. That increase in pressure is transmitted to every part of the liquid. That means you are also increasing pressure on the pipette itself.
- Squeeze hard enough and you will push some more water up inside the dropper. The air inside the pipette squeezes tighter as more water is forced in.
- **Increasing the Density:** Now, water is much denser than air. So when you push more water inside the pipette, you increase its overall density. Once its density is greater than that of its surroundings, it will sink.
- Release the pressure on the bottle’s sides and you stop forcing water inside the pipette. The air inside it will now push out the extra water again, and the pipette will rise. That’s the Cartesian Diver!
Kissing Balloons

Passport Question: Does a low pressure weather system bring sunny or stormy weather?

Passport Answer: stormy

Background information:
Air pressure is the force exerted on you by the weight of tiny particles of air. These air molecules are invisible, but they still have weight and take up space. Changes in temperature affect how many molecules are packed into the atmosphere.

Warm air = low-pressure systems:
Warm air expands so there are fewer air molecules in the atmosphere. Low pressure systems usually bring clouds and rainy days.

How low-pressure systems create clouds and rain:
In the Northern Hemisphere, a low-pressure system forces winds to spiral counterclockwise. Air is forced toward the center of this spiral and has nowhere to go but up. As the air rises, it cools (because the atmosphere gets colder as altitude increases). Cold air can’t hold as much water vapor as warm air, so the water condenses or comes together, to form clouds. When the water droplets join together and get too heavy, they may fall as rain or snow (which meteorologists call “precipitation”).

Cool air= high-pressure systems:
Cooler air contracts, which means air molecules become smaller and take up less space (so more of them can be packed into the atmosphere). High-pressure systems usually bring sunny days.

How high-pressure systems create clear skies:
In the Northern Hemisphere, high-pressure system winds spiral clockwise, moving from the center outward. To replace the air that flows out of the storm’s center, more air is sucked down from up higher in the atmosphere. This air warms up as it is pulled down. The warm air expands, and any clouds or precipitation that had formed disappear.

Supplies:
Balloons
String
Rod

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tie the strings to the rod, make sure the balloons are at the same height.</td>
</tr>
<tr>
<td>2</td>
<td>Ask the student: What happens if you blow between the balloons? Where will they go?</td>
</tr>
<tr>
<td>3</td>
<td>Blow in between the balloons. Were your predictions correct?</td>
</tr>
</tbody>
</table>
Discussion:

- Why do the balloons blow together instead of apart? In your experiment a low pressure area is created between the balloons when you blow in between them. The faster the air moves between the balloons, the lower the air pressure in that space.
- Meanwhile, the air surrounding the balloons now has higher pressure so it pushes the balloons together. This is an example of how low pressure systems cause air molecules to expand, and then condense into clouds.

Follow up: test students weather prediction skills! Print out weather isobar weather maps indicting H and L pressure systems.

a) Where is their potential for rain?
b) Where is it probably sunny?
Homemade Barometer

Passport Question: Does a low pressure weather system bring sunny or stormy weather?
Passport Answer: stormy

Background information:
An important characteristic of the Earth’s atmosphere is its pressure as it often determines wind and weather patterns across the globe. Atmospheric or air pressure is the force per unit of area exerted on the Earth’s surface by the weight of the air above the surface. The force exerted by an air mass is created by the molecules that make it up and their size, motion, and number present in the air. These are important factors because they determine the temperature and density of the air and thus its pressure.

Molecules are significant for measuring air pressure because if the number of air molecules above a surface increases, there are more molecules to exert pressure on a surface and total atmospheric pressure increases. By contrast, if the number of molecules decreases, so too does the air pressure.

Today, air pressure is measured with a mercury or aneroid barometer. A mercury barometer measures the height of a mercury column in a vertical glass tube. As air pressure changes, the height of the mercury column does as well- it drops when pressure falls and rises when it increases. An aneroid barometer uses a coil of tubing with most of the air removed. The coil then bends inward when pressure rises and bows out when pressure drops. Using instruments such as these, scientists have set the standard of normal sea level pressure at about 1013.2 millibars (mb) (force per square meter of surface area).

Low and High Pressure
Air pressure is not uniform across the Earth. The normal range of the Earth’s air pressure is from 980 mb to 1050 mb. These differences are the result of low and high air pressure systems which are caused by unequal heating across the Earth’s surface and the pressure gradient force.

A low pressure system, or "low," is an area where the atmospheric pressure is lower than that of the area surrounding it. Lows are usually associated with high winds, warm air, and atmospheric lifting. Because of this, lows normally produce clouds and precipitation (rain and snow).

A high pressure system, or "high," is an area where the atmospheric pressure is greater than that of the surrounding area. High pressure areas are normally caused by a phenomenon called subsidence, meaning that as the air in the high cools it becomes denser and moves toward the ground. Pressure increases here because more air fills the space left from the low. Subsidence also evaporates most of the atmosphere’s water vapor so high pressure systems are usually associated with clear skies and calm weather.
Supplies:
- Mason Jar
- Balloon
- Straw
- Rubber Bands
- Scissors
- Paper/Pen

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The barometer will be set up on the table.</td>
</tr>
<tr>
<td>2</td>
<td>Show the students. Where is the barometer is reading (sunny/high pressure, stormy/low pressure, cloudy/somewhere in between)?</td>
</tr>
</tbody>
</table>
| 3         | Quiz the students!  
1) If a high pressure system came through the atmosphere, which way would the straw move? Imagine if air was pressing down on the balloon. The straw would go up because the balloon would be pressed or sucked in.  
2) If a low pressure system came through the atmosphere, which way would the straw move? Imagine the air pressure decreasing outside the jar so that the molecules inside want to escape. The straw would go down because the balloon would expand. |
| 4         | Look at the maps provided. Ask the students what they think the weather is at different spots. H= sunny L=cloudy/stormy. |

Discussion:
- Barometers are used to measure air pressure, which has a direct correlation to high or low pressure weather systems. By seeing if the air pressure is greater than 1013.2 or less than 1013.2 at a certain time you can predict what the weather will be.
- Show the students the Galileo weather barometer as an example of another way to measure the ambient air pressure. How does this compare to the homemade one?
- About the Galileo weather barometer: The water-filled glass barometer was invented in the 17th century and used to predict bad weather. It's also called a storm glass. The typical storm glass looks like an exaggerated teapot; it's a hollow glass globe or other rounded
shape with a long spout attached. To set up the barometer, water is drawn into it in good weather (High Pressure). The air in the globe is effectively sealed off from the air outside by the water, so the air pressure within the globe stays constant. If the outside air pressure barometer changes drastically, the water level in the tube rises or falls. The water goes high up the spout in low pressure (stormy weather), and lower in the spout during high pressure (sunny weather).
Cloud in a Bottle

Passport Question: What causes clouds to form?

Passport Answer: The cloud inside our bottle, as well as clouds in the atmosphere, form by 1) adding **water vapor** to the air and 2) a change in **air pressure** from air rising, expanding, and cooling. As the warm water vapor rises through the air, a cooling process begins that forms tiny water droplets (condensation). All of these droplets expand together and form visible clouds that we see in the sky.

**Background Information:**
A cloud is a visible mass of liquid droplets made of water, suspended in the atmosphere above the earth’s surface. They are formed by two processes: cooling the air or adding water vapor to the air. Often these processes act together to form clouds.

There are several different types of clouds, classified by their shape, altitude (height in the atmosphere), and density. Latin roots are used to indicate the shape and density, with prefixes occasionally used to indicate altitude:

<table>
<thead>
<tr>
<th>Latin Root</th>
<th>Translation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>cumulus</td>
<td>heap</td>
<td>fair weather cumulus</td>
</tr>
<tr>
<td>stratus</td>
<td>layer</td>
<td>altostratus</td>
</tr>
<tr>
<td>cirrus</td>
<td>curl of hair</td>
<td>cirrus</td>
</tr>
<tr>
<td>nimbus</td>
<td>rain</td>
<td>cumulonimbus</td>
</tr>
</tbody>
</table>

Cumulus clouds are the big, fluffy type; stratus clouds appear in layered sheets; cirrus clouds take the form of thin wisps; and nimbus clouds are the thick, dark types that often produce precipitation.

**Supplies:**
- 1-liter clear plastic bottle with cap
- Foot pump with rubber stopper attached
- Water
- Rubbing alcohol

**Procedure**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ask the students what they know about clouds. How are they formed? What are they made of? Explain that water molecules are in the air all around us. These airborne water molecules are called water vapor. When the molecules are bouncing around in the atmosphere, they don’t normally stick together. Clouds are formed when the water vapor cools and compresses into visible droplets. We’ll explain this</td>
</tr>
</tbody>
</table>
a bit more after making a cloud of our own!

2. Place a few drops of rubbing alcohol in the bottom of the 1-liter bottle. We use rubbing alcohol instead of water because it volatilizes quickly and works better in this demo. You don’t have to tell the students you’re using rubbing alcohol.

3. Swirl the alcohol around in the bottle, making sure to coat the sides. Then put the rubber stopper in the bottle.

4. Pump the foot pump 10 times while making sure that the stopper doesn’t pop off the top of the bottle.

5. When you are done pumping, pull out the stopper. You should see a cloud form in the bottle!

**Discussion:**

- Pumping the bottle forces the molecules to squeeze together or compress. Releasing the pressure allows the air to expand, and in doing so, the temperature of the air becomes cooler. This cooling process allows the molecules to stick together - or condense - more easily, forming tiny droplets. Clouds are nothing more than groups of tiny water droplets!

- The reason the rubbing alcohol forms a more visible cloud is because alcohol evaporates more quickly than water. Alcohol molecules have weaker bonds than water molecules, so they let go of each other more easily. Since there are more evaporated alcohol molecules in the bottle, there are also more molecules able to condense. This is why you can see an alcohol cloud more clearly than a water cloud.

- Clouds on Earth form when warm air rises and its pressure is reduced. The air expands and cools and clouds form as the temperature drops below the dew point. Invisible particles in the air in the form of pollution, smoke, or even tiny particles of dirt help form a nucleus on which the water molecules can attach.
Blue Skies, Partly Cloudy: A Cloud Model

Passport Question: The cumulonimbus brings what type of weather?

Passport Answer: storms

Background Information:
A cloud is a visible mass of liquid droplets made of water, suspended in the atmosphere above the earth’s surface. They are formed by two processes: cooling the air or adding water vapor to the air. Often these processes act together to form clouds.

There are several different types of clouds, classified by their shape, altitude (height in the atmosphere), and density. Latin roots are used to indicate the shape and density, with prefixes occasionally used to indicate altitude:

<table>
<thead>
<tr>
<th>Latin Root</th>
<th>Translation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>cumulus</td>
<td>heap</td>
<td>fair weather cumulus</td>
</tr>
<tr>
<td>stratus</td>
<td>layer</td>
<td>altostratus</td>
</tr>
<tr>
<td>cirrus</td>
<td>curl of hair</td>
<td>cirrus</td>
</tr>
<tr>
<td>nimbus</td>
<td>rain</td>
<td>cumulonimbus</td>
</tr>
</tbody>
</table>

Cumulus clouds are the big, fluffy type; stratus clouds appear in layered sheets; cirrus clouds take the form of thin wisps; and nimbus clouds are the thick, dark types that often produce precipitation.

Supplies:
- Materials
  - Blue Cardstock
  - Elmer’s Glue
  - Cotton Balls
  - Cloud Diagram
  - Mechanical Pencils
  - Colored Pencils

Procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Look at the cloud diagram. Ask the students to describe the differences they see between the different types of clouds.</td>
</tr>
<tr>
<td>2</td>
<td>Have the students create different types of cloud shapes by gluing cotton balls on a piece of blue cardstock.</td>
</tr>
</tbody>
</table>
Discussion:

- **Stratus clouds** occur below 6,000 feet. These clouds look like flat sheets of clouds and mean an overcast or rainy day. These clouds are usually a uniform color of gray and cover most of the sky.

- **Cumulus clouds** are also below 6,000 feet, and look like big fluffy balls of cotton. They usually mean that the weather will be nice; however, sometimes they can get very tall and turn into thunderheads. These clouds are usually flat on the bottom, but have very lumpy tops. Cumulus clouds usually form alone, and there is a lot of blue sky between each cloud.

- Wispy **cirrus clouds** usually form above 18,000 feet and are often called “horse tail” clouds. Cirrus clouds generally move from west to east. They form when water vapor forms ice crystals, and they are so thin because of the height at which they form. There is very little water vapor above 18,000 feet, so big thick clouds cannot form. They sometimes appear before a front and indicate changing weather.

- These are the three main types of clouds that can form; however, there can be many combinations of clouds. One example is **cumulonimbus**, which is a dense towering vertical cloud associated with thunderstorms and atmospheric instability, forming from water vapor carried by powerful upward air currents.
**Fog in a Jar**

**Passport Question:** At what elevations does fog form? Low or High?

**Passport Answer:** Low

**Background information:**
Fog is a collection of liquid water droplets or ice crystals suspended in the air at or near the Earth’s surface. While fog is a type of stratus cloud, “fog” is typically distinguished from "cloud" in that fog is low-lying, and the moisture in the fog is often generated locally (such as from a nearby body of water, like a lake or the ocean, or from nearby moist ground or marshes). Fog, in its simplest sense, is just a form of cloud that lies low on or near ground level. This proves that clouds don’t form only at very high altitudes. There are times of the day and certain seasons that are ideal for fog formation. As the environment gets more humid and the surface of the Earth becomes cooler, condensation takes place at lower levels.

**Supplies:**
- Large Mason jar
- Matches
- Water, with food coloring
- Gallon Ziploc bag
- Ice
- Dark construction paper

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fill one third of the jar with colored warm water.</td>
</tr>
<tr>
<td>2</td>
<td>Light the match and hold it over the jar opening.</td>
</tr>
<tr>
<td>3</td>
<td>After a few seconds, drop the match into the jar and cover the top of the jar with the bag of ice.</td>
</tr>
<tr>
<td>4</td>
<td>Observe what is happening inside the jar (fog should be forming).</td>
</tr>
</tbody>
</table>

**Discussion:**
- Why does the fog form? The warm water heats the layer of air that it touches. Some of the water evaporates into the air forming water vapor. The warm air containing water vapor rises, and then cools as it comes in contact with the air cooled by the ice. When the water molecules cool, they slow down and stick together more readily. The particles of smoke act as nuclei for “bunches” of water molecules to collect on. This process is called condensation.
- What does this have to do with weather? As the air cools, water vapor suspended in the atmosphere condenses into water droplets around condensation nuclei (such as tiny particles of dust, ash, pollutants, and even sea salt).
Thermal Spirals

Passport Question: What causes the air to rise?
Passport Answer: heat

Background information:
We feel the wind every day. The air is almost always in motion. One day it may be from the north and the next day from the south. There are many sources for wind: mechanical sources such as fans and, in nature, falling rain as it drags air along. But what is the origin of wind on the earth?

Supplies:
Paper plates
Scissors
Colored pencils/crayons
Toaster or other heat source

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turn the toaster on to allow the unit to heat.</td>
</tr>
<tr>
<td>2</td>
<td>Ask the student where wind comes from.</td>
</tr>
<tr>
<td>3</td>
<td>Ask the students if a toaster can create wind.</td>
</tr>
<tr>
<td>4</td>
<td>Hold the spiral paper plates (10-15 inches) over the top of the toaster. What happens?</td>
</tr>
<tr>
<td>5</td>
<td>Turn the toaster off.</td>
</tr>
</tbody>
</table>

Discussion:
- Students may say clouds or trees cause the wind and that toasters cannot produce wind. They will quickly see that toasters do produce wind. Explain that wind is just air molecules in motion.
- We have all heard that “heat rises,” but why? The glowing coils in the toaster produce infrared radiation, heating the toaster. The heated metal then warms the air in the toaster, making the air less dense. Less dense air rises and cooler, denser air moves in to take its place, creating wind that spins the paper spiral.
- The source for the earth's heat is the sun. The radiation from the sun heats the ground. The ground, in turn, heats the air and we know that hot air rises. As it rises, cooler air comes in to replace the rising air. We feel this as wind.
- The faster the air rises, the faster the wind blows to take its place. Every time we feel the wind, regardless if it is from the north, south, east, or west, somewhere else around the world the air is rising. The term for this rising air is convection. The wind patterns we experience have their source in convection.
**Tornados!**

**Passport Question:** A ________ is a violent rotating column of air extending from a thunderstorm to the ground.

**Passport Answer:** Tornado

**Background information:**

**What is a tornado?**
A tornado is a violent rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of up to 300 mph. They can destroy large buildings, uproot trees and hurl vehicles hundreds of yards. They can also drive straw into trees. Damage paths can be in excess of one mile wide to 50 miles long. In an average year, 1000 tornadoes are reported nationwide.

**How do tornadoes form?**
Most tornadoes form from thunderstorms. They need warm, moist air from the Gulf of Mexico and cool, dry air from Canada. When these two air masses meet, they create instability in the atmosphere. A change in wind direction and an increase in wind speed with increasing height create an invisible, horizontal spinning effect in the lower atmosphere. Rising air within the updraft tilts the rotating air from horizontal to vertical. An area of rotation, 2-6 miles wide, now extends through much of the storm. Most strong and violent tornadoes form within this area of strong rotation.

**When are tornadoes most likely to occur?**
Tornadoes can happen at any time of the year and at any time of the day. In the southern states, peak tornado season is from March through May. Peak times for tornadoes in the northern states are during the summer. A few southern states have a second peak time for tornado outbreaks in the fall. Tornadoes are most likely to occur between 3 p.m. and 9 p.m.

**Where are tornadoes most likely to occur?**
The geography of the central part of the United States, known as the Great Plains, is suited to bringing all of the ingredients together to form tornadoes. More than 500 tornadoes typically occur in this area every year and are why it is commonly known as "Tornado Alley." Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Iowa, Missouri, Arkansas and Louisiana all make up Tornado Alley.
**Supplies:**

2 liter bottles  
Tornado tubes  
Water  
Food coloring  
Sparkles

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turn the tornado maker, so that the bottle with the water is on top.</td>
</tr>
<tr>
<td>2</td>
<td>Swirl the bottle in a circular motion. Most tornadoes form counter-clockwise in the Northern Hemisphere.</td>
</tr>
<tr>
<td>3</td>
<td>A tornado will form in the top bottle as the water rushes into the bottom bottle.</td>
</tr>
</tbody>
</table>

**Discussion:**

- A tornado tube works the same way a real tornado does. In our tornado tube, heavy water is above the much lighter air. The air needs some way to get up to the top bottle, and the water needs some way to get down to the bottom bottle. The fastest way is a tornado!
- In a real tornado, a cold and a warm front meet. Layers of the cold heavy air wind up on top of the warm, wet, lighter air. The cold air wants to go down and the warm air wants to rise. Sometimes, just like our tornado tube, the fastest way to do that is a tornado!
**Mini Greenhouse Effect**

**Passport Question:** What greenhouse gas is released in this experiment?  
**Passport Answer:** CO₂

**Background information:**
Earth’s atmosphere is composed of a mixture of gases: 78% nitrogen, 21% oxygen, >1% argon and trace amounts of other gases, including carbon dioxide. Some gases absorb and re-radiate infrared energy that we sense as heat. These heat-absorbing gases are often referred to as greenhouse gases. Human activities have been adding carbon dioxide and other greenhouse gases to the atmosphere. How will earth’s atmosphere respond to this increase in the amount of greenhouse gases? Scientists create physical models or experiments to compare how systems respond to changing conditions.

In this experiment students will observe two model atmospheres: one with normal atmospheric composition and another with an elevated concentration of carbon dioxide. These two contained atmospheres will be exposed to light energy in a sunny window or from a lamp.

**Supplies:**
- Vinegar
- Baking Soda
- Erlenmeyer flask
- Test tube
- Stoppers
- Connector Tubes
- 2 thermometers
- Black paper
- Light/heat source
- 2 large mason jars
- BTB

**Procedure**

<table>
<thead>
<tr>
<th>Step</th>
<th>Intro Questions:</th>
</tr>
</thead>
</table>
| 1    | Explain to students that air is a mixture of many different gases, including some greenhouse gases that absorb infrared energy.  
2. Ask students if they know any greenhouse gases and their sources. (Answers may include: Water Vapor; naturally present from evaporation and transpiration. Carbon dioxide; burning fossil fuels, burning forests. Methane; rice agriculture, digestive systems of cattle, decaying organic matter. Nitrous oxide; agriculture through the use of nitrogen based fertilizers, livestock waste).  
3. Ask Students: What human activities have been changing the concentration of these gases in our atmosphere? (Answers: see above.) Tell students that over the past 200 years, the concentration of these gases increased from approximately 278 ppm (parts per million) in 1800 to 385 ppm in 2008.  
4. How does that happen? Use carbon poster and black “carbon” dots to tell the
story of where carbon is emitted and where is it stored.

- Carbon stored (plant mass (through photosynthesis), soil carbon, fossil fuels, oceans)
- Carbon released (plant respiration, decomposition, burning fossil fuels)
- The earth has had an increase in CO₂ release from burning fossil fuels and now there is a lot more carbon in the atmosphere.
- Ask students: If we burn fossil fuels what is released? And where do it end up?

5. Show graph of CO₂ increase.

2

Assemble the flask, stopper, and tubing as seen in the illustration.

3

Remove the stopper and have a student place 100 ml of vinegar into the flask and another student add a half teaspoon of baking soda, then replace the stopper.

4

Place the flexible tubing into the BTB solution and notice the color of the liquid as the gas bubbles through the indicator solution. What color change do you notice? (Answer: Blue to Yellow)

5

Discuss what gas is being produced; CO₂ is a byproduct of the reaction between vinegar and baking soda.

6

Add 2 teaspoons to the flask to keep reaction happening. Now put the flexible tube into one of the jars. Allow the tubing to stay in the jar for a minute or so. Ask students what invisible gas we are adding into the jar? (Answer: CO₂)

7

Keep one control (the jar without added CO₂) identical to other jar but without added gases.

8

Record both temperatures every 10 minutes in the table on the white board.

9

Once a few data points have been collected, begin graphing temperature vs. time on the other white board. Continue this throughout the session.

10

Data collection and graphing will continue with first jar you did the experiment with. You can continue to show the vinegar and baking soda and BTB experiment to the
students as they come by, but there won’t be enough time to collect new data.

**Discussion:**

- As one can see from this controlled experiment, greenhouse gases absorb heat. Our control jar and our CO\textsubscript{2} jar were exposed to the same amount of heat from the light and are identical in every other way. The only difference is the CO\textsubscript{2} addition.
- Ask students how they can reduce their carbon footprint!
**CO₂ Removal**

**Passport Question:** Do plants take in or release carbon dioxide?
**Passport Answer:** take in, during photosynthesis

**Background information:**
The carbon cycle is a fundamental Earth process. Carbon moves continuously through the atmosphere, plants and animals, soils, the ocean, and the rocks of the solid Earth, in time-spans ranging from hours to tens of millions of years. Throughout Earth's history, the balance of carbon in those various reservoirs has kept the atmosphere's carbon dioxide (CO₂) level—and Earth's temperature—within relatively narrow ranges.

In this experiment, students will observe a natural process that removes carbon dioxide (CO₂) from Earth's atmosphere. This process is a part of the carbon cycle and results in temperature suitable for life.

**Supplies:**
- Baby food jars
- Elodea (water plant)
- BTB
- Straws
- Balloons
- Erlenmeyer flask
- Water

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Explain to students that air is a mixture of many different gases (e.g., nitrogen, oxygen, and other trace gasses). Ask: What gases do animals breathe in and breathe out? What gases do plants take in and release through photosynthesis? (Answer: Animals' bodies use oxygen and produce carbon dioxide; breathing out, or exhaling, releases carbon dioxide. Through the process of photosynthesis, plants do the opposite: they take in carbon dioxide for building their cells and release oxygen. Animals and plants are, then, dependent on each other for survival.)</td>
</tr>
<tr>
<td>2</td>
<td>Instruct the student to half fill an Erlenmeyer flask with a pre-mixed mixture of water and BTB (the mixture should be about 6 drops of BTB to 8 ounces of water). This step will insure that the liquid in all the jars is a uniform blue color.</td>
</tr>
<tr>
<td>3</td>
<td>Ask a student volunteer to blow up a balloon almost full.</td>
</tr>
<tr>
<td>4</td>
<td>Take the balloon and pinch the end, stick a straw through and slowly bubble out the student’s air into the BTB mixture in the flask. The solution should turn from blue to yellow. Explain that BTB is a chemical indicator, something that shows when a particular chemical is present. BTB turns yellow in the presence of carbon dioxide.</td>
</tr>
<tr>
<td>5</td>
<td>Ask students how we can get the CO₂ out of the water once it is sealed in with a lid. Lead discussion on how all plants use CO₂, even plants in water!</td>
</tr>
<tr>
<td>6</td>
<td>Reveal pre-made jars from under cardboard box! It shows a jar that had CO₂</td>
</tr>
</tbody>
</table>
added to it (yellow), and one that had CO₂ and a water plant (elodea) added to it (blue). The water plant used up the CO₂ in the water for photosynthesis, turning the BTB back to blue.

**Discussion:**
- Show and discuss with students the Carbon-Oxygen Exchange diagram (Figure 2).
- Ask students: "What do you think will happen to the carbon dioxide levels in the air if a forest is cut down and burned?" (Answer: CO₂ would increase.)
- Ask: What effect do you think this would have on Earth’s climate? (Answer: Since trees and other plants build their cells using carbon from the carbon dioxide they absorb, cutting and burning them releases this carbon back to the atmosphere as carbon dioxide, increasing its concentration in the air. Since carbon dioxide is a greenhouse gas, more CO₂ in the atmosphere causes warm temperatures and the possibility of global warming.)
Homemade Thermometer

Passport Question: What do thermometers measure?
Passport Answer: Temperature

Background information:
What is temperature? Temperature is a degree of hotness or coldness that can be measured using a thermometer. It’s also a measure of how fast the atoms and molecules of a substance are moving. Temperature is measured in degrees on the Fahrenheit, Celsius, and Kelvin scales.

Supplies:
Clear, plastic bottle (11 oz. water bottle works)
Water
Rubbing alcohol
Clear plastic drinking straw
Modeling clay
Food coloring

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fill about 1/4 of the bottle full with equal parts of water and rubbing alcohol.</td>
</tr>
<tr>
<td>2</td>
<td>Add a few drops of food coloring.</td>
</tr>
<tr>
<td>3</td>
<td>Put the straw in the bottle, but don’t let it touch the bottom.</td>
</tr>
<tr>
<td>4</td>
<td>Use the modeling clay to seal the neck of the bottle, so the straw stays in place. (Make sure the straw does not touch the bottom of the bottle!)</td>
</tr>
<tr>
<td>5</td>
<td>Hold your hands on the bottom of the bottle and watch the mixture move up through the straw.</td>
</tr>
</tbody>
</table>

Discussion:
- Why does this happen? Just like any thermometer, the mixture expands when it is warmed. This makes the mixture no longer fit in the bottom of the bottle. As the alcohol expands the colored mixture moves up through the straw. If the bottle were to get extremely hot, the mixture would come out the top of the straw.
- Point out the Galileo thermometer and compare it to the homemade thermometer. How does the Galileo thermometer work?
- After the weighted tags are attached to the bubbles, each differs very slightly in density (the ratio of mass to volume) from the other bubbles, and the density of all of them is very close to the density of the surrounding water.
- An object immersed in a fluid experiences two major forces: the downward pull of gravity and the upward push of buoyancy. It is the downward force of gravity that makes this thermometer work.
- The basic idea is that as the temperature of the air outside the thermometer changes, so does the temperature of the water surrounding the bubbles. As the temperature of the
water changes, it either expands or contracts, thereby changing its density. So, at any given density, some of the bubbles will float and others will sink. The bubble that sinks the most indicates the approximate current temperature.
Lightning Room!

Passport Question: Lightning is an example of _____ electricity.
Passport Answer: static

Background information:
What is lightning?
Lightning is a bright flash of electricity produced by a thunderstorm. All thunderstorms produce lightning and are very dangerous. If you can hear thunder, then you are in danger from lightning. Lightning kills or injures people between 75 to 100 people each year; more than hurricanes or tornadoes.

What causes lightning?
Have you ever rubbed your feet across carpet and then touched a metal door handle? If so, then you know that you can get shocked! Lightning works in the same way. Lightning is an electric current. Within a thundercloud high in the sky, many small bits of ice (frozen raindrops) bump into each other as they move around in the air. All of those collisions create an electric charge. After a while, the whole cloud fills up with electrical charges. The positive charges or protons form at the top of the cloud and the negative charges or electrons form at the bottom of the cloud. Since opposites attract, that causes a positive charge to build up on the ground beneath the cloud. The ground’s positive electrical charge concentrates around anything that sticks up, such as mountains, people, or single trees. The charge coming up from these points eventually connects with a charge reaching down from the clouds and - zap - lightning strikes!

Supplies:
Fluorescent light bulbs
Balloons
Mints (cut up in ¼)

<table>
<thead>
<tr>
<th>Procedure: Balloons and Light Bulbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Have students grab a blown-up balloon.</td>
</tr>
<tr>
<td>2 Pass out light bulbs, one per student or pairs depending on the number of students.</td>
</tr>
<tr>
<td>3 Have students rub the balloon on their heads.</td>
</tr>
<tr>
<td>4 Turn off the lights and have students press the balloon on end of light bulb.</td>
</tr>
<tr>
<td>5 The light bulb lights up!</td>
</tr>
<tr>
<td>6 Repeat if students want to do it again.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure: Mints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pair up students, or hand out mirrors.</td>
</tr>
<tr>
<td>2 Hand each students a portion of a mint; tell them not to put it in their mouth yet.</td>
</tr>
<tr>
<td>3 On a count to three…have students quickly put mint in mouth and chew hard with mouth open.</td>
</tr>
<tr>
<td>4 A small flash should appear in their mouth!</td>
</tr>
</tbody>
</table>
**Procedure: Van de Graff**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crank the Van de Graaff generator by hand to produce static electricity. While cranking the generator place the big wand within proximity of the large ball at the top of the generator and notice the arc current between the 2 balls.</td>
</tr>
</tbody>
</table>

**Discussion:**

- The **Van de Graaff generator** is an electrostatic generator which uses a moving belt to accumulate very high electrostatically stable voltages. Look at how the rubber belt rubs against the wheel at the bottom of the generator – as the rubber and wheel come in contact with each other they produce electrons (negatively charged particles) that are captured by the ball; this is also known as static electricity. The small wand is capturing protons (positively charged particles.) Why does your hair stand on end? Because the generator is charging you with electrons and each of the strands of your hair have the same negative charge. Like charges repel each other, so each of your hair strands want to move away from each other.

- **Rubbing the balloon** generates static electricity the same way as the Van de Graaff generator. Friction can separate positive and negative charges. As negative charges build up on the balloon, they attract the positive charges on the wall. The balloon will stay against the wall until all the static electricity is dispersed. Similarly, the fluorescent bulb
lights up because of the electrical charge that is conducted from the static electricity, from your hair, and into the bulb.

- The Winter Green Mints also light up! This effect is called triboluminescence, which is similar to the electrical charge build-up that produces lightning, but on a much smaller scale. Triboluminescence is the emission of light resulting from something being smashed or torn. When you rip a piece of tape off a roll, it will produce a slight glow for the same reason.

- Triboluminescence occurs when molecules, in this case crystalline sugars, are crushed, forcing some electrons out of their atomic fields. These free electrons bump into nitrogen molecules in the air. When they collide, the electrons impart energy to the nitrogen molecules, causing them to vibrate. In this excited state, and in order to get rid of the excess energy, these nitrogen molecules emit light – mostly ultraviolet (nonvisible) light, but they do emit a small amount of visible light as well. This is why all hard, sugary candies will produce a faint glow when cracked.

- When you bite into a Wint-O-Green Life Saver, a much greater amount of visible light can be seen. This brighter light is produced by the wintergreen flavoring. Methyl salicylate, or oil of wintergreen, is fluorescent, meaning it absorbs light of a shorter wavelength and then emits it as light of a longer wavelength. Ultraviolet light has a shorter wavelength than visible light. So when a Wint-O-Green Life Saver is crushed between your teeth, the methyl salicylate molecules absorb the ultraviolet, shorter wavelength light produced by the excited nitrogen, and re-emit it as light of the visible spectrum, specifically as blue light – thus the blue sparks that jump out of your mouth when you crunch on a Wint-O-Green Life Saver.
Space Science
The Fabric of Space-Time

Passport Question: What is the difference between the gravity model and the actual Solar System?
Passport Answer: The gravity model has friction that slows down the marbles, but in space there is no friction.

Background Information:
How do the planets stay in orbit around the sun? The key is gravity. Every object with mass (made of matter) has some gravity. When I hold a pencil, I am pulling on the pencil with my gravity and the pencil is pulling on me with its gravity. However, since the mass of both me and the pencil is very small, our gravitational pull is too small to have any real effect. The sun, though, has a lot of mass and therefore a lot of gravity to pull on the planets with! This gravity model allows students to experiment with planetary motion. This activity is more of a guided exploration than a lesson. The goal is that students see that the marbles fall in a circle around the weight, representing the planets orbiting the sun.

NOTE: the model is NOT accurate, as the marbles eventually fall into the center and the planets don’t! The difference is friction—the spandex slows down the marbles, but in space there is no material to slow the planets down so they orbit continuously.

Supplies:
7 36” 1.25” PVC pipes
14 PVC T-connectors
14 34” .75” PVC Electrical Conduit
28 .75” to 1.25” Connector (PVC-1 D2466 IPS 1 x 1/2)
~ 72” x 72” piece of Lycra/spandex (Comes in 48” width rolls)
20 clamps
2 1lb weights
Marbles
Other small spheres (ping pong balls, Styrofoam balls, etc.)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lay out the ground rules for this activity: Students must be gentle with the marbles and the model, and they cannot go underneath the model for safety reasons.</td>
</tr>
<tr>
<td>2</td>
<td>Place one weight in the center of the model. Ask for predictions of what the marbles will do when rolled onto the sheet.</td>
</tr>
<tr>
<td>3</td>
<td>Demonstrate how to roll the marbles: they should be rolled gently but with speed toward the edge of the model (it may take some practice to get it down!).</td>
</tr>
<tr>
<td>4</td>
<td>Allow students to explore what they can do with the model. If they seem stuck,</td>
</tr>
</tbody>
</table>
prompt them with these ideas:
What if we use spheres of different sizes?
What if we roll marbles in opposite directions?
What if we add a second weight to the model?
What if we roll a small sphere and a big sphere together?

Discussion:

- If everything with mass has gravity, then wouldn’t the planets pull on the sun too? They do! The sun has a slight “wobble” due to the pull of the eight planets around it. However, since the sun has so much more mass than the planets, the effect is very small.
- Why do the planets orbit the sun instead of the sun orbiting a planet? Because of mass and gravity, the object with less mass always orbits the object with more mass.
- Why do the planets stay in orbit? Newton’s first law of motion says that an object in motion will stay in motion unless something pushes or pulls it. The planets stay in orbit because there is nothing in space to push or pull them, unlike the marbles in our model that are pushed against by friction.
- If the sun’s gravity is pulling on the planets, why don’t they fall into the sun? In addition to falling toward the sun, the planets are moving sideways—VERY fast! The force of the sun’s gravity and the speed of the planets are balanced. Amazingly, the planets are falling towards the sun but because they are moving so fast that they “overshoot” the sun and travel in a circular path.
How Big is the Moon?

**Passport Question:** A solar eclipse happens when the moon passes between the ________ and the ________.

**Passport Answer:** A solar eclipse happens when the moon passes between the Earth and the Sun.

**Background Information:**
The moon looks big in our sky, but how big is it really when compared to the Earth and the rest of the solar system? The moon is only 1/50 the size of Earth, a fact that may surprise the students. A solar eclipse happens when the moon passes in between the Earth and the sun, blocking the sun's light and casting its shadow on the Earth. The moon looks so big in the sky and can eclipse the far larger sun because of how close it is to our planet. It’s all a matter of perspective!

**Supplies:**
- Play-Doh
- Small Zip-Loc Bags
- Plastic Knives (5)
- Stencil for cutting
- Image of solar eclipse
- Image of Sun to place on the wall

**Procedure**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Ask the students how big the moon is. How big is it compared to the Earth? The sun?</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Take a piece of play-doh and roll it into a long cylindrical shape. Set the play-doh against the stencil and cut it at the grey square. One piece represents 49 units and the other 1.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Roll each of the pieces into spheres. The large piece is the Earth and the small piece is the moon. Are you surprised?</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>What is an eclipse? Has anyone seen an eclipse before? Show the picture of the solar eclipse. A solar eclipse is when the moon crosses between the Earth and the sun, blocking the sun’s light. On this scale, the Sun would be the size of 400 pieces of play-doh. How can our tiny moon block the giant sun in an eclipse?</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Tell students to block the sun on the wall using either their Earth or moon models (NOTE: This part of the activity is not to scale—the big difference in size makes using a true scale very difficult. The sun would actually be much larger than the picture, but the scientific concept still holds). Allow them to experiment and figure out how to eclipse the sun. Then have them switch models and try again.</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Which model is easier to block the sun with? What do they have to do to eclipse the sun with the play-doh moon? What can you guess about how far away the sun is?</td>
</tr>
</tbody>
</table>
Discussion:

- The average distance between Earth and moon is 250,000 miles. For comparison, the next closest object is Venus with an average distance of 25 million miles. In astronomical terms, the moon is right on top of us!
- The current theory on how the moon formed is that about 4.45 billion years ago, while the Earth was still forming, an object about the size of Mars hit the Earth at an angle. The impact threw debris into space from the Earth’s mantle and crust. The object itself melted and merged with the Earth, and the debris came together to form the moon.
- Solar eclipses are very rare—they are only possible when the moon is crossing Earth’s orbital plane, which only happens twice a year, AND is in the new moon phase.
- The sun is 93 million miles from the Earth and the moon on average. Light, the fastest thing in the universe, takes 8 minutes to get to the Earth from the sun. That’s how the little moon can block the giant sun!
Pocket Solar System

Passport Question: What is our Solar System mostly made of?
Passport Answer: Space!

Background Information:
What does our solar system look like? Building scale models of the solar system is a challenge because of the vast distances and huge size differences involved. This is a simple little model to give you an overview of the distances between the orbits of the planets and other objects in our solar system. NOTE: While the distances are to scale, the planet images we use are not.

Supplies:
1 meter per person of paper tape, such as adding machine or receipt paper
Meter stick
Planet sheet
Scissors
Glue sticks
Recycling bin

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ask the students, what does our solar system look like?</td>
</tr>
<tr>
<td>2</td>
<td>Give each student a meter length of paper, a sheet of planets, scissors and a glue stick. Students can cut them all out at the beginning or as they do the activity. Have them place the Sun at one end and Pluto at the other end. (Note: they may need to cut the Sun image smaller to make it fit once the paper has been creased.)</td>
</tr>
<tr>
<td>3</td>
<td>Fold the tape in half, crease it, and open it up again. Which planet is in the middle of our solar system? Many will be surprised that it is Uranus! (Note: pronounce this planet “your-in-us”)</td>
</tr>
<tr>
<td>4</td>
<td>Fold the tape back in half, then in half again. Unfold and lay it flat. Now you have the tape divided into quarters with the Sun at one end, Pluto on the other and Uranus in the middle. Place Saturn at the quarter mark (closer to the Sun) and Neptune at the 3/4 mark (closer to Pluto).</td>
</tr>
<tr>
<td>5</td>
<td>Stop and inspect your work. Which part of the solar system has filled 3/4 of your tape? That’s right; you’ve only been mapping out the places for the 3 most distant planets and Pluto. That means that you’ve still got 5 plus the asteroid belt to fit into the quarter between the Sun and Saturn! Let’s keep going to see how this will work.</td>
</tr>
<tr>
<td>6</td>
<td>Fold the Sun up to Saturn and crease it. Unfold and lay flat again. Place Jupiter at the 1/8 mark (between the Sun and Saturn). If you take a look, you’ve got the four gas giants and Pluto all on there. For the remaining bodies in the Solar System, you’ll only need 1/2 of the first 1/8th! That’s the inner 1/16th of your tape length!</td>
</tr>
<tr>
<td>7</td>
<td>Fold the Sun out to meet Jupiter to mark the 1/16th spot. A planet does not go here, but the Asteroid Belt does.</td>
</tr>
<tr>
<td>8</td>
<td>At this point, things start getting a little crowded and folding is tough to get precise</td>
</tr>
</tbody>
</table>
distances. Fold the Sun to the Asteroid Belt mark and crease it. Place Mars on this fold (between the Sun and Asteroid Belt).

9 How many more planets do we need to place? Three. Fold the Sun up to meet the line for Mars. Leave it folded and fold that section in half. Unfold the tape and you should have three creases. Place Earth on the crease nearest Mars, Venus on the middle crease and Mercury on the crease closest to the Sun.

10 Smooth out your model and admire your work. Are there any surprises when you look at the distances between the planets this way? Many people are unaware of how empty the outer solar system is (there is a reason they call it space!) and how crowded the inner solar system is (relatively speaking).

Discussion
- Our Solar System is made up of planets, moons, asteroids, comets and any other objects that orbit the Sun.
- There are eight planets in the Solar System. Pluto, the former ninth planet, was renamed a "dwarf planet" in 2006 due to its small size (it’s smaller than our moon!).
- Although we usually think of the Solar System as planets, there are many other objects orbiting the Sun. The Asteroid Belt is a loose collection of rocky asteroids orbiting between Mars and Jupiter. Astronomers believe they are leftover materials from the formation of the Solar System that never came together to form a planet or moon.
Cooking Up Comets

Passport Question: Name two ingredients of comets.
Passport Answer: Ice, frozen gases, rocks, dust, organic material

Background Information:
Comets are small objects that orbit the sun and are made of water, frozen gases such as ammonia, methane and carbon dioxide, and dust. In this activity you will “cook” a comet to show what one might look like up close.

Supplies:
- Water
- Dry Ice
- Sand
- Ammonia
- Molasses or dark corn syrup
- Cooler
- Hammer
- Heavy Duty Yard Trash Bag
- Construction Gloves
- Metal Bowls (2)
- Large Metal Spoon
- Measuring cup
- Goggles

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Put on safety goggles and gloves! This activity involves dry ice and students must not touch the comet with their bare hands.</td>
</tr>
<tr>
<td>2</td>
<td>Have all ingredients and utensils arranged in front of you. Cut open a garbage bag and use it to line your mixing bowl.</td>
</tr>
<tr>
<td>3</td>
<td>Place 1 cup of water in mixing bowl. Add one spoonful of sand, stirring well. Add a dash of ammonia and a dash of corn syrup, stirring until well mixed.</td>
</tr>
<tr>
<td>4</td>
<td>Place approximately 1 cup of dry ice in 3 garbage bags that have been placed inside each other. Be sure to wear gloves while handling dry ice to keep from being burned. Crush dry ice by pounding it with hammer.</td>
</tr>
<tr>
<td>5</td>
<td>Add the dry ice to the rest of the ingredients in the mixing bowl while stirring vigorously. Continue stirring until mixture is almost totally frozen. Lift the comet out of the bowl using the plastic liner and shape it as you would a snowball. Unwrap the comet as soon as it is frozen enough to hold its shape.</td>
</tr>
</tbody>
</table>
| 6         | Observe your comet! As the comet begins to melt, the students may notice small jets of gas coming from it. These are locations where the gaseous carbon dioxide is escaping through small holes in the still frozen water. This is also detected on real
comets, where the jets can sometimes expel sufficient quantities of gas to make small changes in the orbit of the comet.

**Discussion:**

- Comets have several distinct parts:
  - a nucleus made of ice, frozen gases, dust, small rocks, and organic material, usually 1-10 km in diameter;
  - a coma which is a dense cloud of water and gases that have evaporated from the nucleus;
  - hydrogen envelope;
  - a long dust tail made of tiny particles evaporated from the nucleus, which reflects sunlight and is the most visible part of the comet; and
  - a very long ion tail composed of electrically charged gas molecules pushed away from the nucleus by solar wind.
- The sun releases a powerful “wind” of energy and particles called the solar wind. The tail of a comet comes from the solar wind, not from how fast it’s traveling—the tail always points away from the sun.
- Comets are invisible most of the time except when they are near the sun.
- Most comets have elongated elliptical orbits that take them close to the sun for a part of their orbit, and then out into the further reaches of the Solar System for the remainder.
- Some scientists believe that comets were the source of Earth’s water and possibly organic compounds during our planet’s early formation approximately 4.5 billion years ago.
**Meteor Impact!**

**Passport Question:** Name one variable that affects the size and shape of a crater  
**Passport Answer:** Size of meteor, angle of impact, speed of meteor

**Background Information:**
A *crater* is the remains of a collision between an asteroid, comet, or meteorite and a planet or moon. Craters can be found on many planets including Mercury, Venus, Earth and Mars. The size, speed, and angle of the falling object determine the size, shape, and complexity of the resulting crater. Small, slow objects have a low energy impact and cause small, simple craters. Large, fast objects release a lot of energy and form large, complex craters. Very large impacts can even cause secondary cratering, as ejected material falls back to the ground, forming new, smaller craters. In this activity students will experiment to see how craters of different shapes and sizes are formed.

**Supplies:**
- 9" Pie Pans (6)  
- Flour (~5 lbs. per day)  
- Cocoa Powder (2-3 containers)  
- Fine Sifter  
- Hand Strainer  
- Golf Balls (6)  
- Marbles (6)  
- Rulers (6)  
- Bucket (3 gal)  
- Drop Cloth  
- Meteor Impact! Data sheets  
- Images of Moon’s surface

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Set up the moon model: In a pie pan create the surface of the moon by filling the pan first with sifted flour (about half of the large sifter) and then sifting cocoa powder (about half of the small strainer) over the top to create contrast.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Make hypotheses about how the various “meteors” will impact the surface of the “moon.” Students can measure the size of the crater and observe its shape (circle, oval, etc.). Vary independent variables such as the height the meteor is dropped (implying speed), the angle of impact, and the size (marble or golf ball). Students may choose to test one variable or all three. Have the students make hypotheses before dropping any “meteors.”</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Begin the experiment! Use a ruler to measure the drop height and the diameter of the crater. Be sure to record the results!</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Were the students’ hypotheses correct? Why or why not? What have they learned about how craters are formed?</td>
</tr>
</tbody>
</table>
Compare the surface you created to the pictures of the surface of the moon. Using what you now know about craters, what can you tell from looking at these images?

**Discussion:**

- Meteors hit at a wide range of speeds, but average about 12 miles per second (20 kilometers per second).
- Erosion from wind and water on Earth has worn away existing craters, making them less visible.
- The surface of the moon is scarred with millions of impact craters. There is no atmosphere on the moon to help protect it from potential impactors (most objects from space burn up in the Earth’s atmosphere). Since there is no erosion and little geologic activity to wear away these craters, they remain unchanged—until another object hits!
- Most of the craters on the moon are circular. The few craters that are not circular, like Messier and Messier A in the Mare Fecunditatis, are mysteries. Scientists do not know exactly how these oddly-shaped craters were formed.
One Shift, Two Shift, Red Shift, Blue Shift

Passport Question: What evidence do scientists have to show that the universe is expanding?
Passport Answer: Redshift

Background Information:
How do scientists know how big the universe is? The answer is very sophisticated, but this activity provides a simple foundation. It has to do with the Doppler effect of waves, which will be demonstrated in two activities.

Supplies:
- Doppler ball
- Concentric paper rings
- Image of redshift and blueshift galaxies

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ask students if they have ever heard a fire truck or ambulance pass. What did it sound like? Encourage the class to imitate the noise, or do it yourself, making sure to emphasize a change in pitch as the vehicle would pass.</td>
</tr>
<tr>
<td>3</td>
<td>To work the Doppler ball, leave the buzzer inside the slot (it is loud!). When you are ready to use it, clip the battery onto the buzzer and push it inside. Once you are finished with the ball take out the battery.</td>
</tr>
<tr>
<td>4</td>
<td>Give students the Doppler ball and let them play for a bit. How can they recreate the sound of the siren? They should eventually note that the sound gets “lower” as they throw it away and “higher” as it is thrown back to them.</td>
</tr>
<tr>
<td>5</td>
<td>To demonstrate what is happening with the Doppler ball, show the students concentric rings arranged one inside the other to look like ripples in a pond. Place your finger in the center and explain that it is the “source” of the sound and the rings are the sound waves. Slowly move your finger towards the students without removing it from the table. The rings will gather in the direction of movement. Question students and have them explain that this shows that a moving source of sound has sound waves closer together in front of it, and sound waves farther apart behind it. Ask them what they would hear standing in front of it, and what they would hear standing behind it.</td>
</tr>
<tr>
<td>6</td>
<td>What does this have to do with space? Light travels in waves just like sound. Blue is a short light wave and red is a long light wave. The spectrum of light can appear “shifted” in one direction or the other. Demonstrate the paper rings again, this time as a light source. If the light source is moving towards you, will it appear more blue or red? What if it is moving away from you? Show students the image of the shifted galaxies to see if their predictions were correct.</td>
</tr>
<tr>
<td>7</td>
<td>Scientists have done a lot of research and found that almost every galaxy in the universe is redshifted. Are they moving toward us or away from us? What does that tell you about the universe?</td>
</tr>
</tbody>
</table>
Discussion:

- The **Doppler effect** of sound is something that we are familiar with from our everyday experience. When something making a loud noise (e.g., a car horn, a fire truck siren or a train whistle) moves past us quickly, the sound changes because the sound waves reach us differently than if everything was sitting still. This effect happens with all types of waves, and is a very useful tool.

- The image illustrates the Doppler effect of light. On the top of the image we see that if the source, such as a galaxy, is still, an observer will see the light as it was given off by the galaxy. However, in the middle and bottom of the image we see what happens if the galaxy is moving. As the galaxy moves, the light waves ahead of the source are crowded together, just like the example with the rings. To an observer ahead of the source this will make the galaxy’s light appear to be shorter and it will shift towards the blue end of the rainbow. This change is called a **blueshift**. However, if the observer is behind the moving galaxy, then the opposite will happen. The waves will be spread out, the light will appear to be longer and it will shift towards the red end of the rainbow. This change is called a **redshift**.

- The shifts in a galaxy’s light can be found with an instrument called a spectrograph. Using this tool, astronomers have found that almost all the stars and galaxies we can see are moving away from us—giving us scientific evidence that the universe is expanding.
Jumping on Jupiter

Passport Question: Our weight changes on other planets because each planet has a different ________ which affects its __________.

Passport Answer: Our weight changes on other planets because each planet has a different mass which affects its gravity.

Background Information:
How far you can jump and how much you weigh depend on gravity. Gravity depends on a planet’s mass—or how much STUFF it’s made of. Smaller planets usually have less mass and therefore less gravity so you weigh less and can jump farther than you can on Earth. Larger planets usually have more mass and more gravity so you weigh more and can’t jump as far as you can on Earth. Students will demonstrate this with some simple calculations and a demo with spheres of different masses.

Supplies:
Scale
Tape Measure
“Jumping on Jupiter” worksheet
Pencils
Calculators (6)
String
Large and small spheres
Solar System poster

Procedure

1. Show students the solar system poster. On which planet do you think you can jump the farthest? Why?
2. See how far you can jump on Earth!
3. Look at the “Jumping on Jupiter” handout and complete the chart to determine how far you can jump on each planet.
4. Based on what you just learned, on what planet do you think you would weigh the most? Why?
5. See how much you weigh on Earth.
6. On the opposite side of “Jumping on Jupiter” handout you can calculate your weight on each planet by completing the chart.
7. On what planet could you jump the farthest? On what planet did you weigh the most? Were your predictions correct?
8. If your body stays the same, why does your weight change on each planet? Hint: what do you notice about the planets where you weigh more?
9. To further illustrate the concept that more mass means more gravity, have the students (carefully!) swing the spheres on the rope. Which one is easier to swing? Why? Because the larger sphere has more mass, it is heavier and harder to swing.
than the smaller sphere.

10 Bonus question: What do you think you would weigh in space?

Discussion:

- What is the difference between weight and mass? We often use the words "mass" and "weight" as if they were the same, but to an astronomer or a physicist they are completely different things. The mass of a body is a measure of how much matter it contains. Matter is anything that takes up space—it can be a solid, liquid or gas. You, me, the lake, the air, the Earth, they are all made of matter and have mass.
- Weight is related to mass. Simply put, weight = mass x gravity. You can measure your weight by standing on a scale—the force of Earth’s gravity pulling on you is your weight!
- So what is the difference between mass and weight? Your mass is always the same no matter where you are, but your weight changes depending on the gravity of planet you’re on.
- Space by definition is empty—it has no matter. Without matter it can’t have mass or gravity. In space, your weight would be zero!
Solar Sensations

Passport Question: Using a telescope, make an observation of the Sun and write it down.
Passport Answer: Answers will vary.

Background Information:
The Sun is a star at the center of the solar system. Like all stars, it is mostly made of hydrogen and helium. The Sun is huge – over 100 times the diameter of Earth. Today students will be able to safely make observations about this star.

WARNING: Never look directly at the sun through a scope without appropriate filter! Looking at the Sun without a filter, even for an instant, can permanently damage your eyes.

Supplies:
- Hydrogen Alpha Telescope
- 10” Dobsonian Telescope with Solar Filter
- Images of sunspots and solar flare

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Look at sun through scopes. Be sure to follow the facilitator’s instructions carefully.</td>
</tr>
<tr>
<td>2</td>
<td>What do you see?</td>
</tr>
</tbody>
</table>

Discussion:
- The Sun has a diameter of 1,392,000 km and is on average 149,600,000 km away from the Earth. It has the greatest mass of any object in our Solar System. Its gravity pulls the planets into orbit around it.
- The Sun gives off different kinds of electromagnetic energy (heat and light in different spectrums.) The Earth’s atmosphere filters harmful light ultraviolet (UV) light that comes from the Sun. UV light is the spectrum that causes sunburn and eye damage.
- Do you see any sunspots? These are areas of dark, cooler gas on the Sun’s outermost layer. If you’re lucky, you might see gases rise from the surface in an arch called a solar prominence. You may even see an explosion of gases on the surface, a solar flare!
- Energy from the Sun warms the Earth, drives the weather and supports life. Although the Sun is very special for us, there are millions of stars just like it throughout the universe. Do you think those others suns could support life too?
Moon Dance

Passport Question: An object spinning around on its axis is __________. An object circling around another object is ______________.
Passport Answer: An object spinning around on its axis is rotating. An object circling around another object is orbiting.

Background Information:
A rotation is an object spinning around on what is called an axis (an imaginary line down the middle). An orbit is when an object circles another object, such as the Earth going around the sun. Just as the Earth orbits the sun, the moon orbits the Earth. The moon doesn’t make any of its own light—it only reflects light from the sun. In this activity we will see how this reflected light causes the phases of the moon.

Supplies:
Flashlights (1 for each pair of students)
Styrofoam spheres
Toothpicks

<table>
<thead>
<tr>
<th>Procedure 1—Rotation, Orbit and Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before beginning the main activities, there are three important concepts to make sure everyone knows.</td>
</tr>
</tbody>
</table>

1. Have the students stand in a circle around you in the room. Tell them to turn around in place. What is a scientific word for what you are doing? Rotation.

2. If you could draw a line down the center of your rotation, where would it be? They should indicate down the center of their bodies. This time, hold your right arm straight over your head and then rotate. What does your arm represent? Your axis, the imaginary line right down the middle of a rotation.

3. Now, ask the students to walk around the circle. What is a scientific word for this? It’s an orbit. An orbit is when an object circles around another object regularly.

4. What does this have to do with space science? Does the earth rotate on an axis and orbit? What about the moon?

<table>
<thead>
<tr>
<th>Procedure 2—Moon Dance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ask students why the moon looks different every night. What makes it full? What makes it new?</td>
</tr>
</tbody>
</table>

2. Group the students in pairs and give each pair a flashlight and a sphere. The person with the flashlight is the sun, the person with the sphere is the Earth, and the sphere is the moon.

3. Give directions to the students: Each pair stands facing each other a few feet apart. The Earth holds the moon in front of them at arm’s length and a little above their head. The sun holds the flashlight a little above their head and shines it straight at the moon.
4 Ask the Earths to describe what the moon looks like to their partner.

5 Tell the Earths to rotate very slowly to their left, holding the moon in the same position. The suns should stand still and continue shining the light straight at the moon. Ask the Earths to stop every two small steps and describe what the moon looks like. What do they see?

6 Once the Earths have rotated all the way around, they switch roles with their partners. The new Earths do the same activity, describing the moon as they slowly rotate.

7 Why does the moon’s appearance in the night sky change?

Discussion:

- As the moon orbits our planet the amount of sunlight it reflects changes. When the moon is on the far side of the Earth the sun’s light hits the side facing us, causing a full moon. When the moon is between the Earth and the sun, the side facing us is dark, causing a new moon.

- When the moon is less than half full is it a crescent; half full is a quarter (because it is ¼ through its cycle); and more than half full is called gibbous. As the shape grows from new to full it is waxing, and as it shrinks back to the new moon it is waning.

- Why do we always see the same side of the moon? The moon orbits the Earth because it is pulled by the planet’s gravity. Earth’s gravity “drags” the moon so that it rotates at the same speed as it orbits (both of which take about 27 days). So we always see the same side! The “dark” side of the moon is the side that we never see from Earth, although it’s not actually dark—it’s lit up during the new moon.
Time of the Seasons

**Passport Question:** What causes seasons on Earth to change?  
**Passport Answer:** The tilt of the Earth’s axis

**Background Information:**  
We all know that it is cold in the winter and hot in the summer, but have you ever thought about why that is? People hold a lot of misconceptions about what causes the seasons and this activity will teach the scientific reason for the seasons.

**Supplies:**  
Lamp  
4 large Styrofoam spheres  
4 dowels  
4 rubber bands  
4 stands  
4 thumbtacks  
Protractor  
Station markers labeled December 21, March 21, June 21, and September 21  
North Star image

**Procedure**  

<table>
<thead>
<tr>
<th></th>
<th>Students have just learned about rotation, axis and orbit and how the sun’s light creates the phases of the moon. Now they will see how the sun cause the seasons.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ask the students what they know about the seasons. Why do we have seasons? Let students answer without correcting them.</td>
</tr>
<tr>
<td>2</td>
<td>Divide the students into four groups and give them an Earth model. On this model the sphere represents the Earth, the dowel is the axis, and the dot is our location in Tahoe. Where is the Earth’s axis? What do you notice about it?</td>
</tr>
<tr>
<td>3</td>
<td>Place the model near the sun (the lamp) and with the axis pointing toward the image of the North Star. Have each group slowly turn the straw so that the earth spins to the left for one rotation. Ask them to make observations about the dot with their group.</td>
</tr>
<tr>
<td>4</td>
<td>They should see that the dot is in light (day) for about half of the rotation and is in shadow (night) for about half of the rotation. This rotation is called a day!</td>
</tr>
<tr>
<td>5</td>
<td>Now place one group at each of the dates: December 21, March 21, June 21, and September 21 (see setup below). Have each group model a day at each position, making sure that the Earth’s axis is tilted towards the North Star. Students should make observations with their group.</td>
</tr>
<tr>
<td>6</td>
<td>For what fraction of the day is the dot in the light? More than half? Less than half? About half? How is the light from the sun striking the dot? Is it direct or at an angle?</td>
</tr>
<tr>
<td>7</td>
<td>After a couple of minutes, move the groups to the next date and have them discuss the same questions. Do this until they are back at the date they started at. It is very</td>
</tr>
</tbody>
</table>
## Discussion:

- Many people think the seasons are caused by variations in our distance from the sun. While the earth’s orbit is slightly elliptical, it’s very close to circular, and the variation in distance between the earth and sun is not enough to account for our seasons.
- The seasons are caused by the tilt of the earth’s axis. The earth holds its tilt fixed in space as it moves around the sun. Our planet is tilted at 23.5 degrees and is “pointing” towards the North Star, Polaris.
- In the summer, the Northern Hemisphere tilts toward the sun. It’s warmer because there are more hours of daylight, providing us with more heat energy, and the midday sun shines more directly head on, increasing the amount of solar energy the earth receives.
- In the winter, when the Northern Hemisphere tilts away from the sun, the sun’s rays strike the earth at a lower angle, and the energy from the sunlight is spread out over a larger area, which reduces its effectiveness at heating the ground. Combined with shorter daylight hours, the temperatures are cooler in winter.
- Because of the tilt, the seasons in the Northern and Southern Hemispheres are opposite. Summer in California is winter in Brazil!
- In winter, the Earth is tilted so that sunlight never reaches the North Pole. It is dark there for 24 hours each day. In summer, the opposite happens, and the North Pole has 24 hours of sunlight each day.