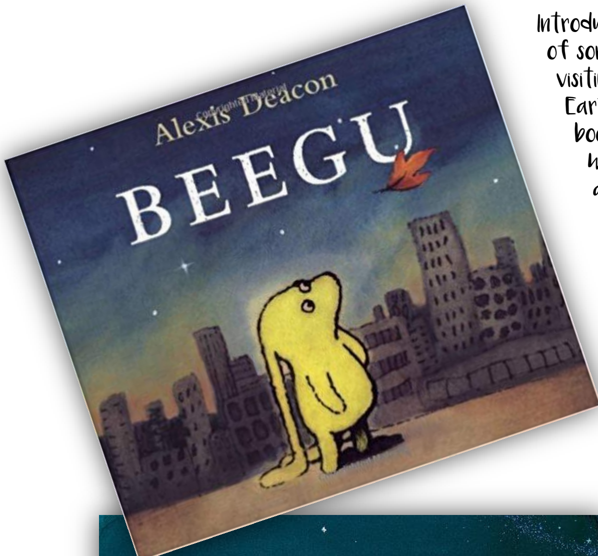
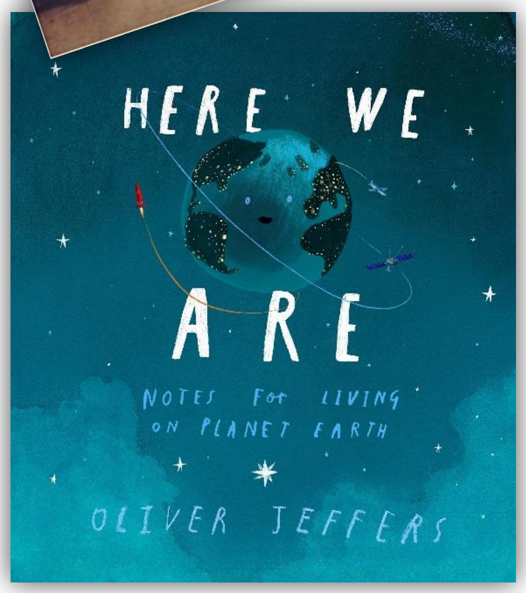
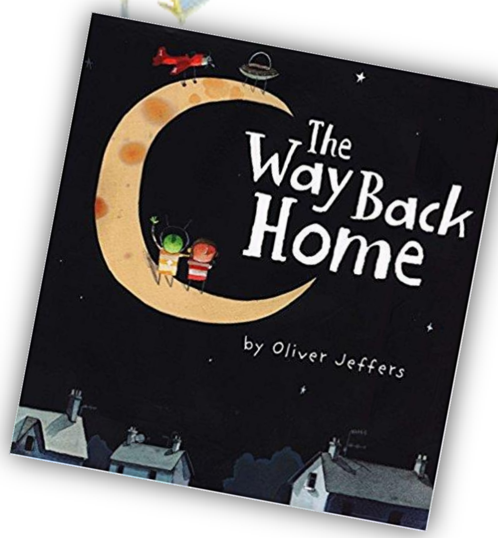
There's No Place Like Home



Introduce the idea of someone visiting us on Earth with picture books such as *The Way Back Home* and Here We Are Oliver Jeffers' users guide to life on Earth by Oliver Jeffers and *Beegu*, by Alexis Deacon. Beegu's spacecraft is stranded on Earth. Now she is lost and wandering. Waiting for a rescue signal from her mother, she begins to explore. This simple, bittersweet picture book shows us our world through the three eyes of an innocent outsider with the help of stylish art and a wry, understated text.

Have students view the front cover and give their initial thoughts on the cover. What is happening? What is the setting? Who is Beegu and why is she there?





Ever been on a trip and seen something that changes the way you think about things? The pictures are never good enough, the words fall short. Now, imagine that trip was through space. For thousands of years we've looked up and asked questions, now we have the opportunity to look down and explore even more.

Ask students why people (and aliens like Beegu's family) explore. Cluster students' answers on chart paper or the blackboard. Group their comments so that you can lead them to the major reasons for exploration (increasing knowledge, economics, national glory, and adventure). Examples of typical responses you might get. "Because it's interesting." "They want to know about another world." "There might be gold or diamonds there." "We want to be there first." "It would be fun to discover new things and meet new creatures."

Point out that the students have identified the same motivations for early explorers had for coming to the New World and that scientists have for exploring today. The basic motivations for exploring remain the same for us today, and in the future.

Explorers face all kinds of great challenges and the motivations for exploration that existed in the past are the same as those that exist today (increasing knowledge, economics, national glory, and adventure).

One Odd Rock

Captains Log #546.57

The Commander got back a report from one of our Exploratory Survey Teams today. After two years of exploring Alpha Centauri Team 10 has finally landed on a planet! Each member of the team sent their reports concerning the possibility that this planet can be successfully colonized. That we might have finally found that rarest of things. A true 'goldilocks planet.' A world thats not too hot and not too cold. But their reports left the Commander, and myself, utterly confused! Its hard to have hope after so long, but were determined to try.

The reports from the Initial Surveyors are as follows:

First Report: This is a dry and barren planet. It is very hot in the daytime and frigid cold at night. Only a few strange plants and odd animals grow here. There is no water.

Second Report: There is a cold, white, powdery substance falling from the sky. It piles up on the surface of the planet. There are no plants and no animals except for a huge, white furry creature. The extreme cold makes this planet uninhabitable.

Third Report: I cannot believe what a perfect planet this is for colonization. The abundance of vegetation and variety of animals would ensure a plentiful food supply. The temperature remains moderate for the planets entire day.

Fourth Report: There is no solid ground. The planet is made entirely of a liquid containing numerous salts, minerals, oxygen, and hydrogen. Many life forms and vegetation are supported inside the liquid. However, the cost of creating a suitable habitat capable of supporting a colony in this environment would be outrageous. [1]

Im assigning the Alpha Team to this one as a special assignment. This elite team will be responsible for working with Earthlings who will act as their guides as they gather data and submitting reports to the Commander. We need to learn more and explore the wonder of this planet - from all reports its one of the most peculiar, unique places in the universe!

Captain Rick con Oytr, Star Date 26546.3

Display a large world map or globe and ask where each person from the survey team might have landed. Have students discuss in small groups.

Have the groups report out to the class, explaining their theory of where each surveyor might have landed and what information supports this decision.

Discuss why the survey personnel might have had such divergent views. Tie this into the findings of the early explorers. (i.e., Early maps show California as an island.)

[1] https://www.scholastic.com/content/dam/teachers/lesson-plans/migrated-files-in-body/unit_exploration_alienlanding.pdf

Earth Expedition Discovery Journals

These journals will be our closest companions while were explaining our world to our new friends! Make sure to keep track of your thoughts, ideas, and your own discoveries about Earth as we delve deep to help our new alien friends learn more about our amazing home!

Materials

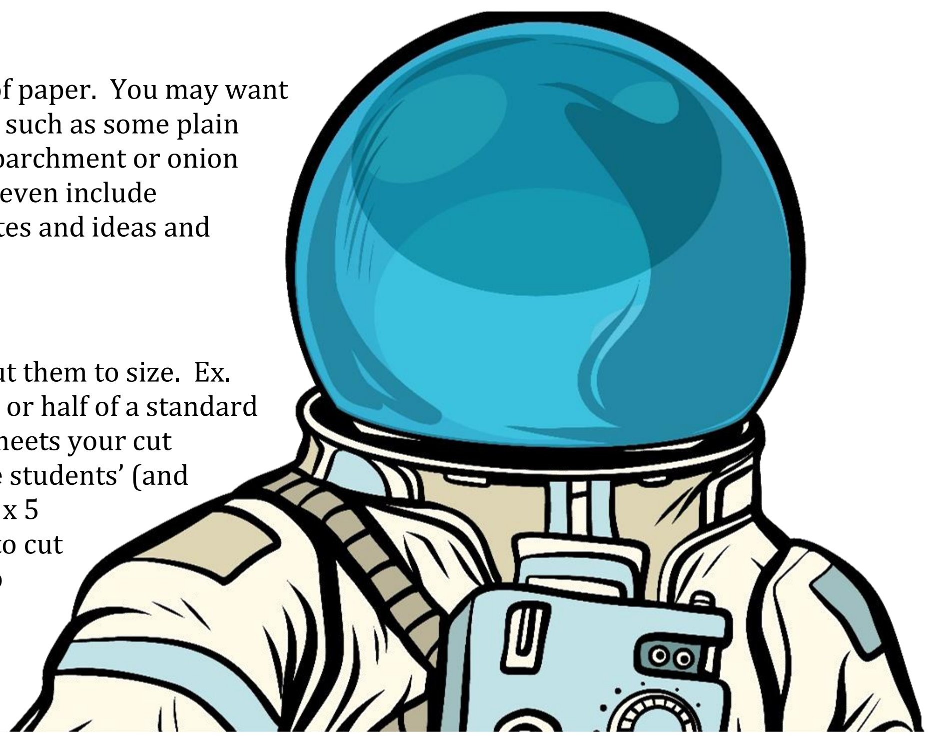
- Paper (white, graph, parchment, tissue, card stock, brown paper bags, envelopes, etc.)
- Maps
- Push pins or other pin, such as a tiny awl
- Dental floss or embroidery thread
- Binder clips
- Glue
- Packing tape
- Clear tape
- Cardboard (to protect your work surface!)

Procedure:

While a classic notebook will work perfectly fine, this is a fun variation that will help students feel even more 'authentic' as explorers. As they take an active part in 'making and doing,' throughout the 'expedition' their questions begin to build the structural base for later scientific thinking.

Assemble Your Papers

To start, you'll need a handful of paper. You may want to use a combination of papers, such as some plain computer paper, graph paper, parchment or onion skin, and tissue paper. You can even include envelopes to be able to tuck notes and ideas and samples inside!



Cut Your Paper

Once you've got your papers, cut them to size. Ex. You may want to do a full sheet or half of a standard sheet of paper. If you use half sheets your cut pages will be 8 ½ x 5 ½ and the students' (and instructor's) finished book 4 ¼ x 5 ½. For fun you may also want to cut some graph paper extra-long to make fold-out pages.

Option: Cut down some maps and brochures to the same size.

Use at least 10 sheets of paper to make a good-sized book (if students need additional pages during the 'expedition' then they can make/get another book or stuff them in, like real explorers do!) Cut them, fold them individually, and then stack them together. If some pieces aren't quite as big as your other pages, that's okay—the little tabs add interest and work themselves into your student's drawings and note taking in fun ways.

Add a cover, ex. a piece of brown cardstock, and then clip the stack together to hold everything in place.

Bind Your Papers into the Discovery Journal

To bind the pages, poke three holes in each book with a push pin. You may want to put some cardboard underneath to protect the table. Then sew the pages together using dental floss. It's strong and the waxy coating makes the knots stay in place. (And it can help with a dental emergency while we're on the planet.) Use a three-hole pamphlet stitch (**illustrated step-by-step instructions here**) or easy Saddle Stitch with the knot on the inside.

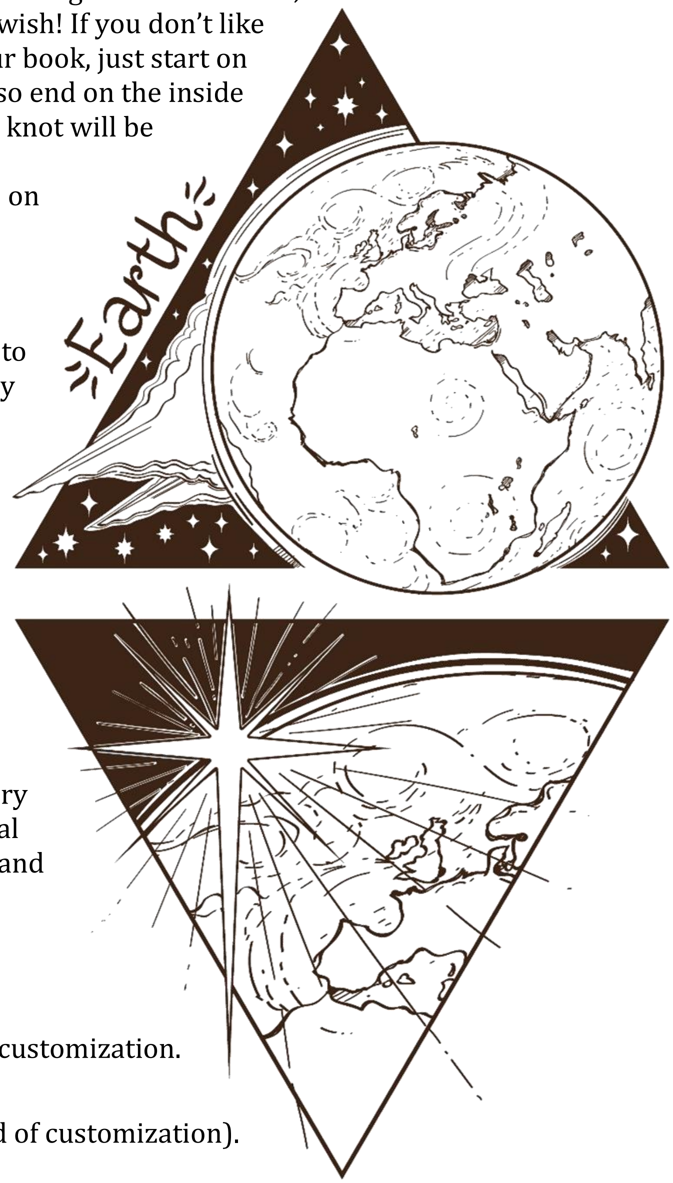
Check out the video for an easy tutorial for saddle stitching books.

Three Hole Pamphlet Stitch Basics:

1. Starting on the inside, put the needle through the middle hole. Pull it almost all the way through, just leaving a tail on the inside (enough to tie a knot when you're done, but don't make any knots right now!) You may want to lightly tape the tail
2. Now on the outside, put the needle through one of the other holes (doesn't matter which one) and pull it all the way through until it is snug (but make sure you don't pull the tail through).
3. Now with the needle back on the inside, put it through the last hole (the only one you haven't used yet) and pull it all the way through until it is snug.
4. Now the needle has to go back through the middle hole. Don't pierce the other thread that is already through this hole (if you pierce the other thread then you won't ever be able to tighten the sewing, so don't do it). Go beside the other thread, not through it!
5. Pull the needle and thread all the way through until all the sewing is snug.
6. Before you tie a knot, make sure that the two ends of your thread are on either side of the thread that is along the spine. Make sure the thread is snug on the inside and the outside, then tie a square knot (right over left, left over right).

7. You can do whatever you want with the ends of the string – cut them short, or make a bow, or attach shells and feathers if you wish! If you don't like the ends of the string hanging on the outside of your book, just start on the inside of the fold. When you do that, you will also end on the inside so you can trim the ends of the string short and the knot will be hidden inside your book.

There are also many visual tutorials on this easy technique on YouTube, such as [this one] and [this one] (for 4th graders).



Add a Map/Image to the Cover

Gluing a map of or image of planet earth (such as this one) to the front cover works but for additional sturdiness you may want to pull out a classic middle-school trick for 'laminating': packing tape. You may want to laminate the front and back covers with tape.

Use weights or a press to help the pages lay flat.

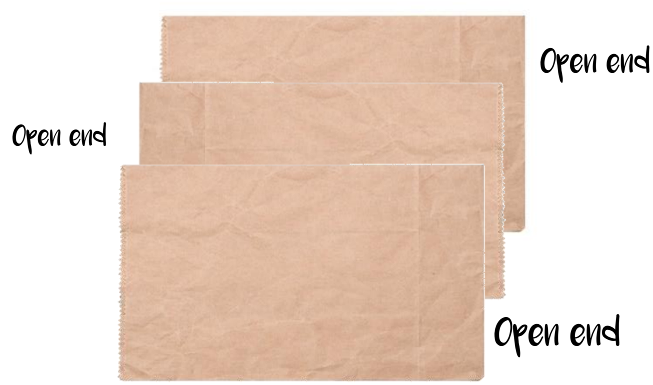
Brown Paper Bag Variation for very young students:

Materials:

- Brown paper lunch bags (the amount needed will vary depending on how many pages you want your journal to have. 2 bags will make 8 pages INCLUDING front and back cover.
- Scissors for cutting your paper pages.
- Glue OR Tape
- Hole Puncher OR Scissors (depending on method of customization. There are a few different options).
- Ribbon OR Washi Tape (again, depending on method of customization).

Procedure:

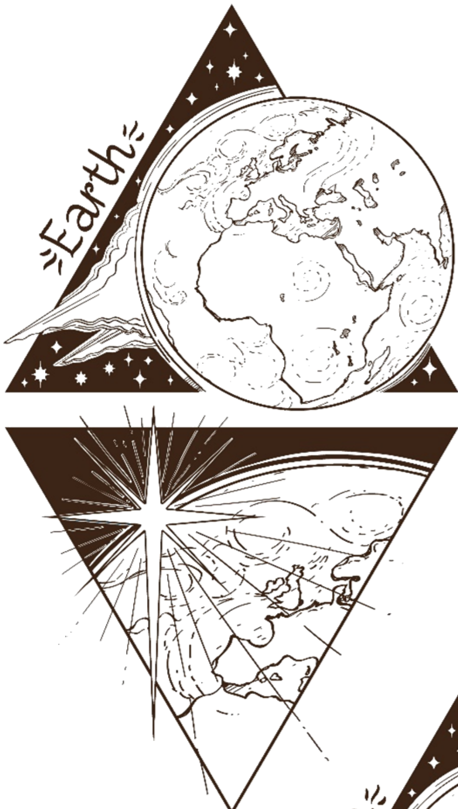
1. Tape or glue down the flaps on each bag (what would open up to be the base of the bag). If you will be taping down journal pages over it you don't want it flapping up. Note: Some instructors use these flaps by pasting questions on the top and then pasting answers under the flap.
2. Stack however many bags you are using in alternating directions directly on top of each other. (One bag will have its opening to the left. The one on top will have it's opening to the right. And repeat as you stack – one directly on top of the other)



3. Take your stacked pile and fold over, forming the book shape.
4. Here is where you can determine the way you want to secure your book. *Ex. hole punch and lace with ribbon or twine, then tie.*
5. If you're looking for a quicker, easier option stapling is the best choice. You can still dress it up quickly by placing washi tape over the front edge (and staples) and wrapping it around to the back edge – creating the appearance of a binding.

6. Now, put on your cover!
7. Optional: The pages act as pockets to store notes and more. If you think you may want a way to secure your items from sliding out of the little pockets, you can always hole punch the very front and very last page, then loop ribbon through – tying together to secure the book closed.[2]

[2] http://www.simplyrachelbyrachel.com/2015/04/14/nature-journals-for-kids/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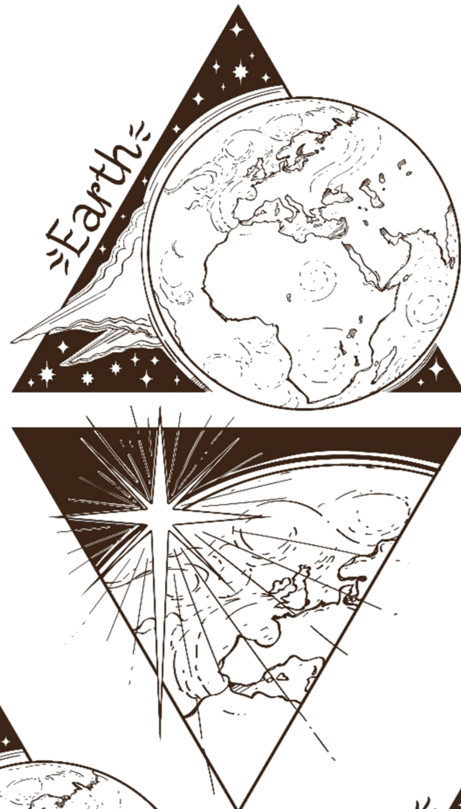
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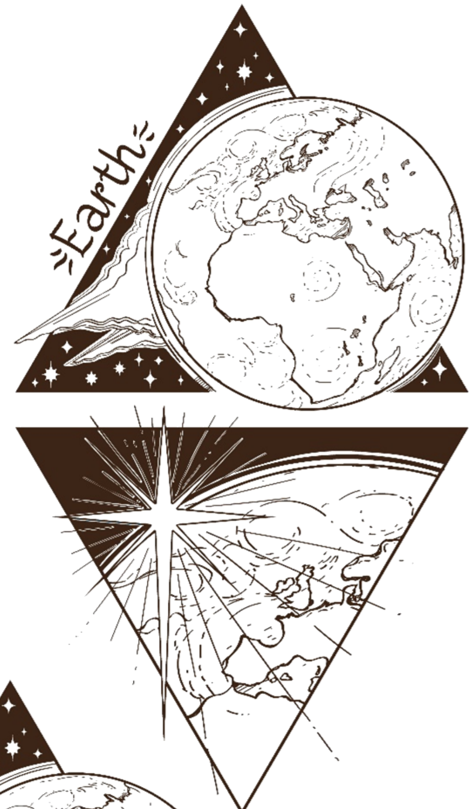
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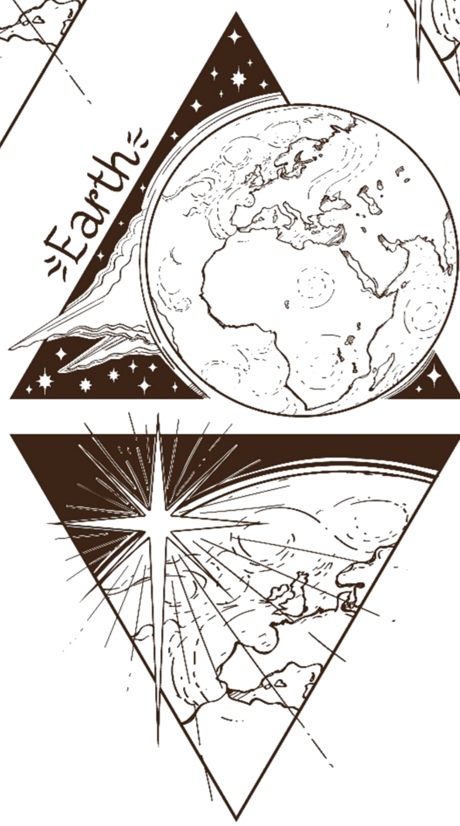
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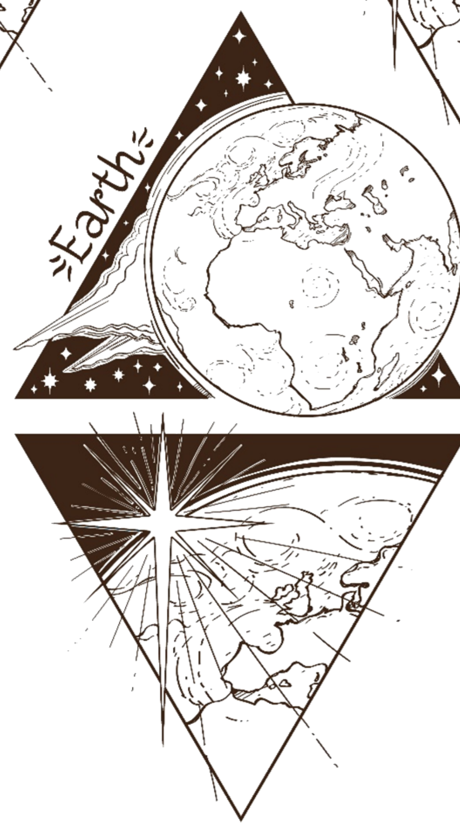

Earth

Breathe: The Thin Blue Line

There's something that we all do without thinking about it. Something nearly every organism takes for granted. We breathe. 16 breaths a minute. 23,000 breaths a day.

Looking down at this planet (show students the Live Feed from the ISS) you can hardly see any atmosphere at all. It's only when you look at the horizon that you can see a thin delicate blue line. A delicate line that shows the gravity of the planet is pulling down all those molecules of oxygen and holding them down, but the higher up you go the thinner it gets. It gets less and less the higher you go. What's surprising is how quickly that happens. The planet's atmosphere is so thin, you can walk to where the oxygen starts to run out.

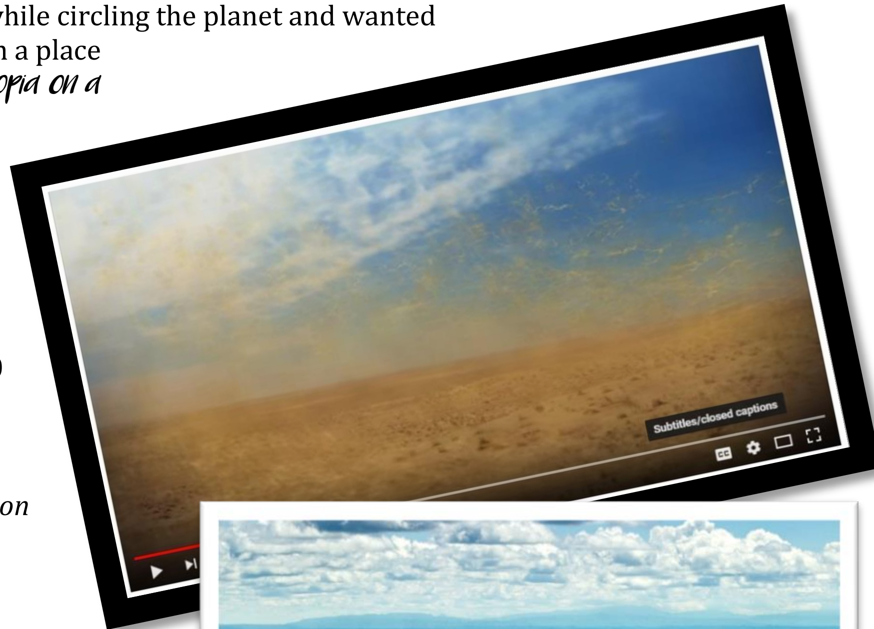
Our team needs to help our alien friends know more and explore the unlikely and unexpectedly interconnected systems that allow life on our strange planet to breathe. There's nothing more natural than breathing. Yet, as far we know this is the only planet [we've found] where that happens. The only planet with an oxygen-rich environment. Without that, life on this planet would be something very different indeed.

Every time we breathe in oxygen mixes with the food we eat and releases energy. Power that enables larger more complex creatures to exist. This planet is covered in living organisms. So, how is there enough oxygen for everything?

Let's find out. It's time to teach our new friends more. They're about to land their vessel on this strange place and explore a bit more. Remember to keep notes about what we learn in our discovery journal!

Option: Play clips entry into Earth footage, such as this video from a GoPro inside a fairing from a recent Falcon 9 flight

They spotted an incredible dust storm while circling the planet and wanted to follow it. So, we'll start in the desert in a place called Ethiopia. *Have students find Ethiopia on a map.* A very salty desert. The people here rely on this desert. The whole world does. But, not because of the salt.



Sands from the Saharan desert were being blown across the ocean to South America. Every year about 27 million tons of that dust – enough to fill 104,980 semi-trucks – drops out of the sky into the Amazon Basin. It turns out, it's the perfect fertilizer. *Watch here as a NASA satellite tracks Saharan dust to the Amazon in 3-D.*

As they grow the plants and trees turn carbon dioxide into oxygen. One single tree can produce enough oxygen to support two people and the Amazon Rainforest is ten times the size of Texas. Producing 20x more oxygen than all the people on the surface of the planet could consume.

You might think, or have heard, that this incredible rainforest is the 'lungs' of this planet. But, not one breath of all that oxygen leaves the Amazon. There are so many animals living in the Amazon basin that the life there uses all that oxygen up. Sure, it makes a lot of oxygen, but it uses it all.

The rainforest helps us breathe, but not because of air. There's a surprising discovery our climatologist has made and a surprising way that this rainforest helps this planet breathe. There's a river in the Amazon. Not the one on the ground. It's a river in the sky.

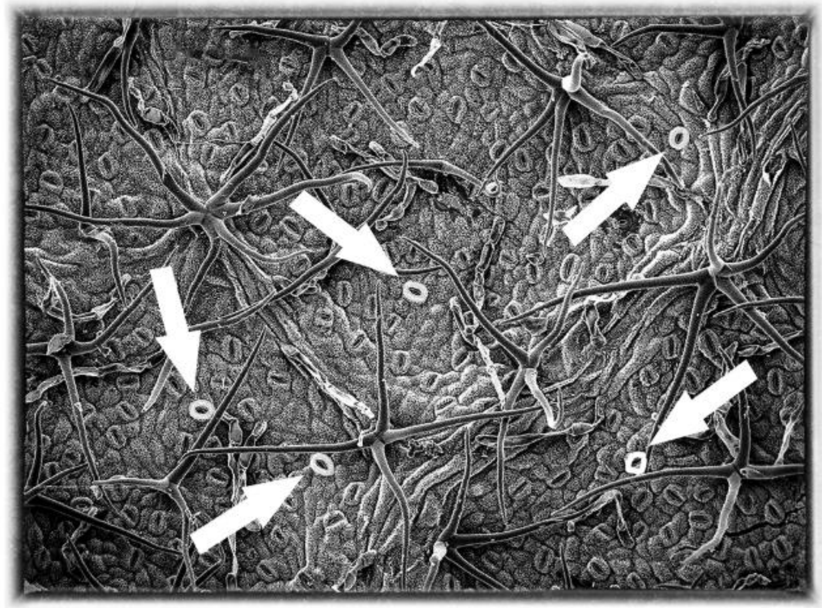
If you could look inside the trees you could see water sucked up from the forest floor. We all know that plants need water. However, it only uses a small amount. The rest is lost by transpiration (about 99%!)

How does transpiration work? Leaves have pores all over them that you can see if you look closely on the bottom side with a magnifying glass.

Try it. Look closely at any oak leaf or any leaf (or, for that matter, the surface of any green plant, even a blade of grass) with a magnifying glass. You'll find little breathing tubes called stomata. That's "mouth" in Greek, because, like mouths, they're openings that allow outside air in. You might also think of them like lungs, often with squeezable openings.

The plants open their stomata to let in carbon dioxide and water comes out of the pores in the process. It cools the plants, but it is also a critical part of the water cycle. In just one year, every leaf on earth can send out much more than its own weight in water. In fact, a large oak tree can contribute 40,000 gallons of water a year to the air!

That's where the carbon dioxide gets in and the oxygen slips out. Photographer Robert Dash used a scanning electron microscope to magnify the surface of an actual oak leaf 150 times, and all those little cheerio-like openings you see there? There are so, so many of them! On, say, a square millimeter of leaf—that's one thousandth of a square inch—you might find a hundred to a thousand little lungs.



Photograph by Robert Dash

From Root to Tip

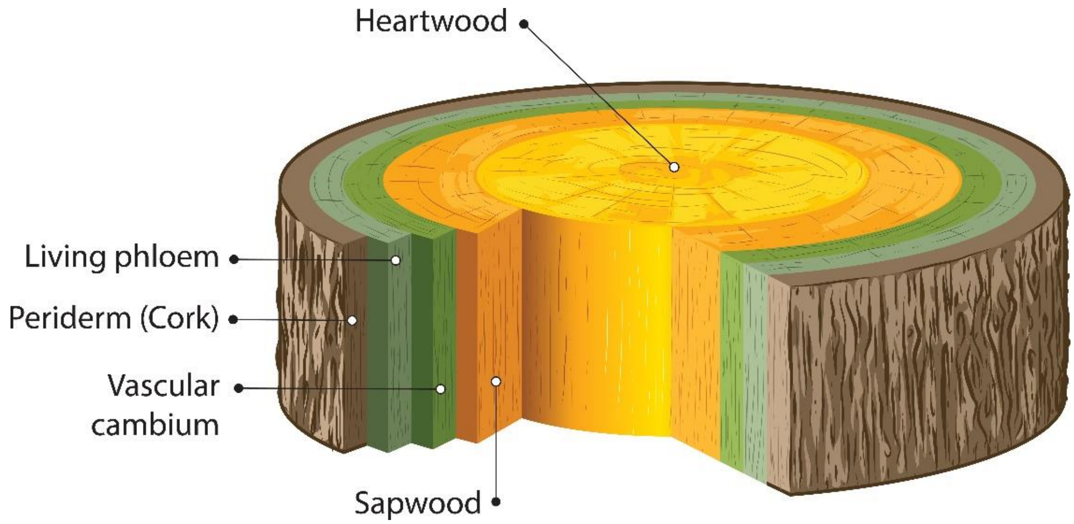
To understand water transport in plants, one first needs to understand the plants' plumbing.

Plants contain a vast network of conduits or channels, which consist of xylem and phloem tissues. Xylem and phloem are the names for the special pipe-like system that allows water and food to get delivered to all parts of a plant.

So how exactly does this system work? The parts of the plants above the ground--the stem or trunk, leaves and branches--absorb the sunlight during a process called photosynthesis. This is when the plant turns light into food in the form of sugar. Watch how it happens!

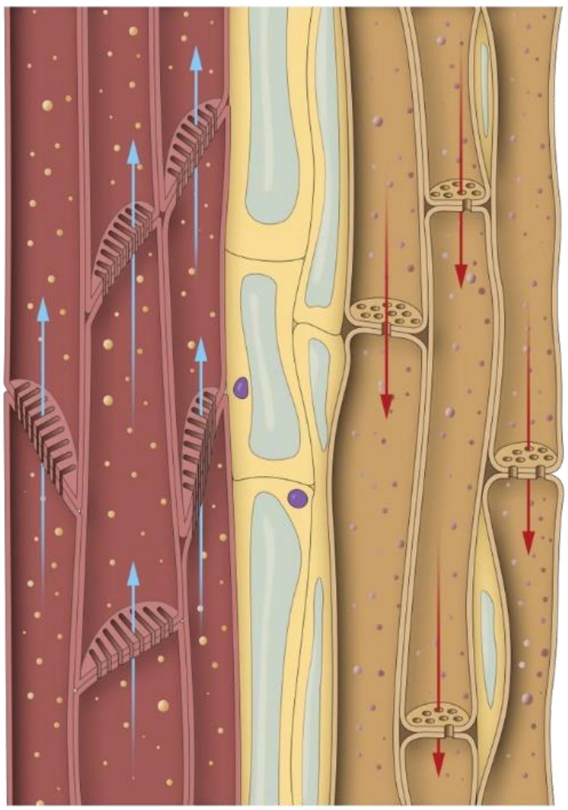
Underground, the plant's root system is busy absorbing water and nutrients from the soil. The xylem and phloem keep it all connected. They help the above-ground parts work with the underground parts and enable the plant to digest the food and liquids.

Scientists have studied the connection between trees and rain in the Amazon before. A 2012 study found that plants help seed the atmosphere for rain by releasing tiny salt particles. But the new study strongly supports the idea that plants play an important role in triggering the rainy season. Plants are more than just passive recipients; to weather and that they instead can play an active role in regulating rainfall. If that's true in the Amazon, climate scientists will need to take into account practices like deforestation when predicting regional changes in weather patterns. And curbing deforestation will be an important step for people to take in preventing drought.



Phloem carries the sugar that's made during photosynthesis from the leaves to the plant's storage areas. These are usually the plant's seeds and fruits. Phloem also carries sugar to parts of the plants that are growing and need energy, such as the roots. Phloem can flow up and down to carry the food through the whole plant.

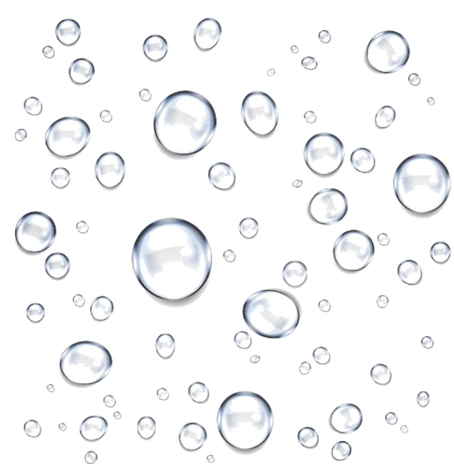
So where is phloem located? You can find this tissue, which is made of tube-like structures, close to the outside part of a stem or trunk (but not exposed to the outside elements). In a tree, for example, it's usually just under the outside coat of bark. In plants, phloem tends to be close to the bottom of the leaves, which is why you often find insects feeding on the underside of leaves.



Xylem, also called sapwood, carries water from the roots to all parts of the tree or plant. The flow of water can only travel in an upward motion.

This pathway of water and nutrient transport can be compared with the vascular (blood vessels and arteries) system that transports blood throughout the human body. Like the vascular system in people, the xylem and phloem tissues extend throughout the plant. These conducting tissues start in the roots and transect up through the trunks of trees, branching off into the branches and then branching even further into every leaf.

The main driving force of water uptake and transport into a plant is transpiration of water from leaves. Transpiration is the process of water evaporation through specialized openings (pores) in the leaves, called stomates.



Water molecules tend to stick to one another; that cohesion/adhesion is why water forms rounded droplets on a smooth surface and does not spread out into a completely flat film.

See cohesion in action!

Materials:

- Liter Bottle
- Expedition Journals
- Pencils
- Thumbtacks
- Water

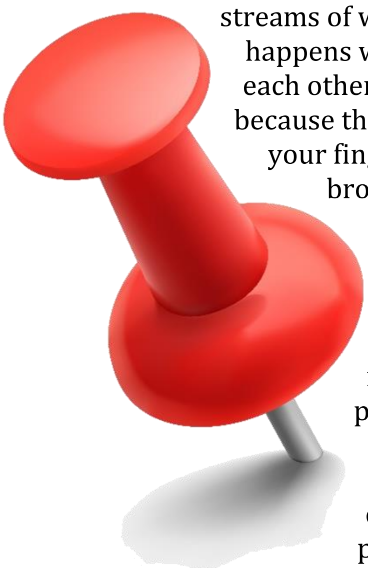
Procedure:

1. Fill a 1-liter bottle with water and screw on the cap.
2. Have expedition members make predictions in their journals of what they think will happen if/when you poke holes in the bottle.
3. Using a thumbtack, make 5 evenly spaced holes on the side of the bottle, near the bottom.
4. Loosen the cap to release the water.
5. Run your finger along the streams of water that are coming from the bottle. What happens each time you run your fingers through the streams?

What's happening?

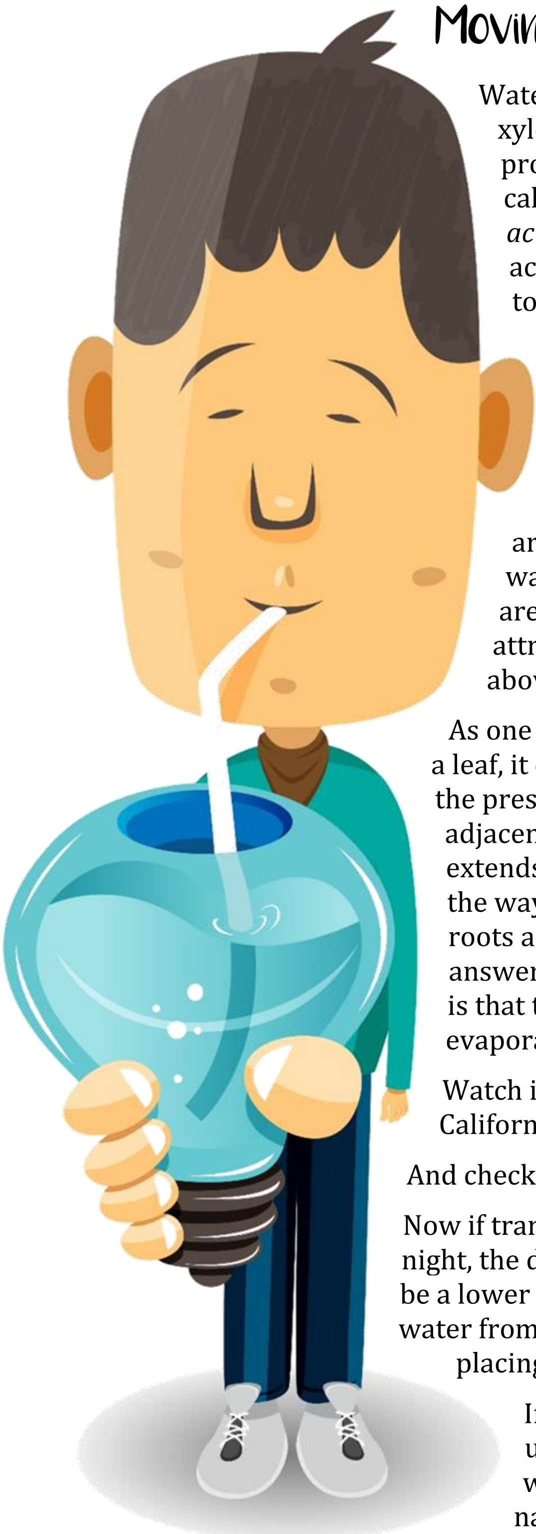
When you poke five, evenly-spaced wholes into the side of a bottle, they come out as five separate streams. That is, until you run your finger through the streams. Like magic, the five streams combine to form one!

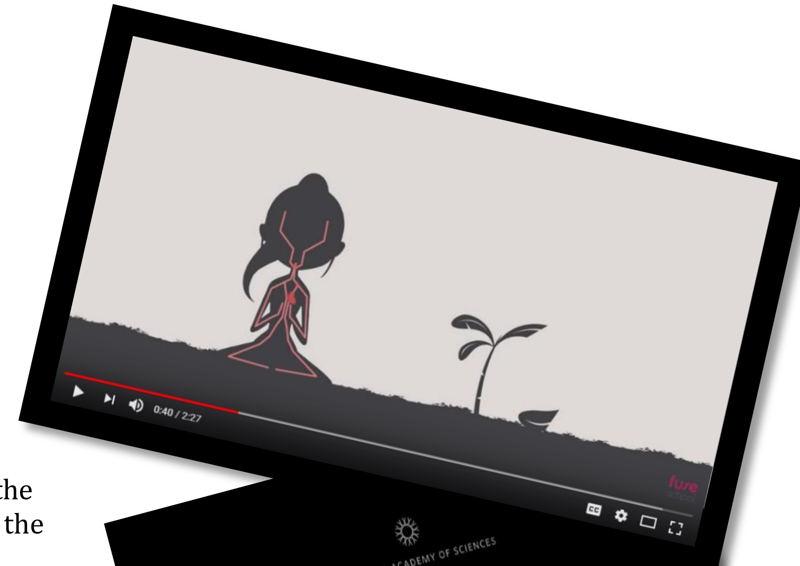
The force at work, when you run your finger through the streams of water, is called cohesion. Cohesion happens when molecules of a substance stick to each other. Water is a very cohesive substance because the molecules are polar. When you run your finger over the stream again, the bonds are broken and the streams resume their separate flows.



Water is the perfect substance to demonstrate cohesion because of the simplicity of a water molecule. Water molecules consist of one oxygen atom, possessing a weak negative charge, and a pair of hydrogen atoms that sport a slightly positive charge. The negative charge of the oxygen attracts the positive charge of the hydrogen atoms and hydrogen bonds are formed. These bonds are strong enough to create cohesion but are easily broken.

Movin' On Up!





Water moves up the xylem through a process called *capillary action*. Capillary action allows water to be pulled through the thin tubes because the molecules of the water are attracted to the molecules that make up the tube. The water molecules at the top are pulled up the tube and the water molecules below them are pulled along because of their attraction to the water molecules above them.[3]

As one water molecule evaporates through a pore in a leaf, it exerts a small pull on adjacent water molecules, reducing the pressure in the water-conducting cells of the leaf and pulling water out of adjacent cells. (Remember, the xylem is a continuous water column that extends from the leaf to the roots.) This chain of water molecules extends all the way from the leaves down to the roots and even extends out from the roots and causes them to pull more water in from the soil. So, the simple answer to the question about what propels water from the roots to the leaves is that the sun's energy does it: heat from the sun causes the water to evaporate, setting the water chain in motion.

Watch it happen: How Do Trees Transport Water from Roots to Leaves? | California Academy of Sciences

And check out Fuse School's awesome Xylem and Phloem video

Now if transpiration from the leaf slows down, like during cloudy weather or at night, the drop in water pressure in the leaf will not be as great, and so there will be a lower demand for water (less tension) placed on the xylem. The loss of water from a leaf (negative water pressure, or a vacuum) is comparable to placing suction to the end of a straw.

If the vacuum or suction thus created is great enough, water will rise up through the straw. If you had a very large diameter straw, you would need more suction to lift the water. Likewise, if you had a very narrow straw, less suction would be required. Think of trying to suck through a coffee stirrer, a drinking straw, a smoothie straw, a hose pipe, or a PVC pipe. Which one would you need to suck hardest/create the most suction on to get water?

This correlation occurs as a result of the cohesive nature (water likes to stick together) of water

[3] http://www.nsta.org/publications/news/story.aspx?id=49197

along the sides of the straw (the sides of the xylem).

Because of the narrow diameter of the xylem tubing, the degree of water tension, (vacuum) required to drive water up through the xylem can be easily attained through normal transpiration rates that often occur in leaves.[4]

Wood is the Star?

Earth wood is amazing stuff! And so is that magical substance of water! It's always fun to use simple materials in simple ways and really surprise people, including our alien friends!, with the results. OK, this one is part science and part Earth magic, but the results are all real. You start out with broken toothpicks and end up with a star-shaped design after just a few drops of water are added. The best part is that Discovery Team Members can watch the change take place right in front of them!.

Materials per team/group :

- 5 wooden toothpicks
- a dropper or a drinking straw
- plastic plates
- water
- Small cups

Option: Watch the video from Steve Spangler science for help before you do the experiment with students.

Procedure:

1. Start with round toothpicks that are brand new and dry. Bend each one at the middle so it cracks **but doesn't break** into two pieces. Press the ends together to widen the split.
2. Place the split middles of the toothpicks together in the center of the plate to form a star shape. The edges of the toothpicks should touch each other. You've made a closed, five-pointed star.
3. Have students make predictions in their expedition journals about what they think is going to happen with the star if you add water.
4. Load some water into the straw (or the eyedropper or the pipette). If you'd like, have students practice releasing small amounts of the water a drop at a time from the straw.
5. Use the straw to add drops of water at the middle of the star where the splits are closest to each other. The goal is to place the water so that all the exposed, broken ends get soaked. However, don't add so much that the toothpicks start to float.

[4] https://www.scientificamerican.com/article/follow-up-how-do-trees-ca/

6. The right amount of water reforms your closed star into an open, recognizable shape in seconds.
7. Ask students if their predictions were correct. Have them give their ideas on why the star spread out when water was added.

What's going on?

The toothpicks you used were probably made of dried birch wood. When you break the toothpicks, you stretch and compress the wood fibers inside them. When you put drops of water in the middle of the closed star formation, the dry wood fibers in each broken toothpick absorb some of it. This causes the fibers to swell and then to expand. The absorption of the water into the toothpick is due to capillary action. Capillaries are microscopic hollow tubes within the wood that draw water along the length of the toothpick. Capillaries normally carry water and food throughout a living plant's stem and leaves.

As the wood absorbs the water, each individual toothpick tries to straighten itself as the soaked fibers expand. This straightening action causes the toothpick ends to push against each other. As the toothpicks straighten and push against each other, the inside of the star opens up into the final star shape.

Testing! Testing!

If you want to take this scientific magic trick a bit further, here are some ideas for you:

- Test whether hot or cold water makes the movement faster or slower. What about salt water or sugar water or something else dissolved in water? What about other types of water like distilled or bottled?
- Find out what surface allows the greatest expansion of the fibers: a plastic tablecloth? a wooden table? a formica countertop? a glass surface? a flat surface? a curved surface? etc.

Just a Bundle of Straws?

Create the following easy-to-make model of a cross-section of a tree trunk to help students and our alien visitors visualize the inner layers of an Earth tree and how they work.

Materials List:

Here is a list of the materials you will need to make this model to represent a tree's component parts:

- 1 toilet tissue tube (or half of a paper towel roll tube) (**Outer Bark, Peridum/Cork**)
- ¼-inch wooden dowel rod cut to 4-inch length (*Heartwood*)
- 15 plastic drinking straws cut to 4-inch lengths (*Phloem*)
- 34 plastic coffee stirrers (or small straws) cut to 4-inch lengths (*Xylem/Sapwood*)
- 1 piece of colored card stock paper, mesh tights, or tissue paper (**Cambium**)
- 1 rubber band
- Ruler
- Scissors
- Scotch tape

Note:

The cambium layer is extremely thin. An adaptation for this model might be to use a thinner layer of paper or fabric (such as tissue paper or mesh tights) in between the layers of the two different sized straws (xylem and phloem).

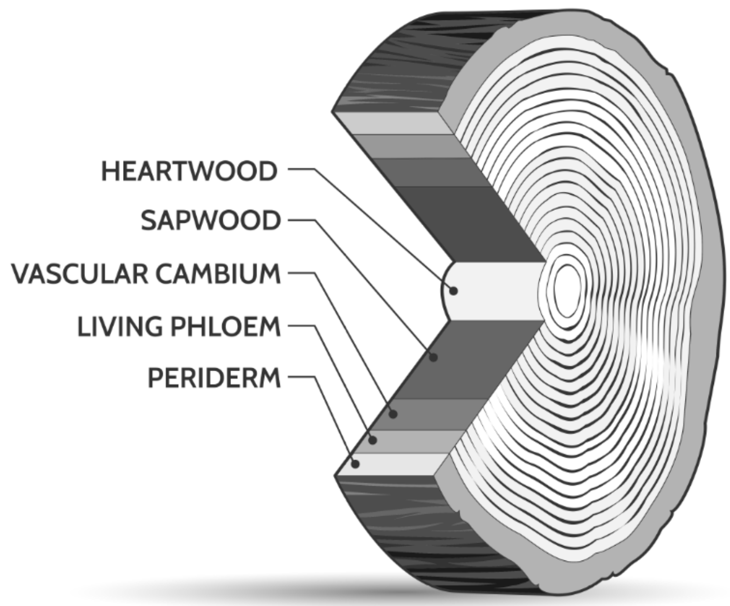
Instructions

1. Cut the ¼-inch dowel into a 4-inch piece (the length of the toilet tissue tube or paper towel roll tube)
2. Cut the card stock, tissue paper, or mesh to measure 3 ¼ inches by 4 inches
3. Cut the plastic drinking straws into 4-inch lengths
4. Cut the plastic coffee stirrers into 4-inch lengths
5. Grip the coffee stirrers in your hand and wrap the rubber band around them
6. Insert the wooden dowel into center of the coffee stirrers
7. Wrap card stock paper around the coffee stirrers and tape the edge tightly
8. Slide the toilet tissue tube over the paper and stirrers
9. Place one row of drinking straws between the card stock paper and the toilet tissue tube
10. Make adjustments where needed to get the appropriate look.

Parts of a Tree

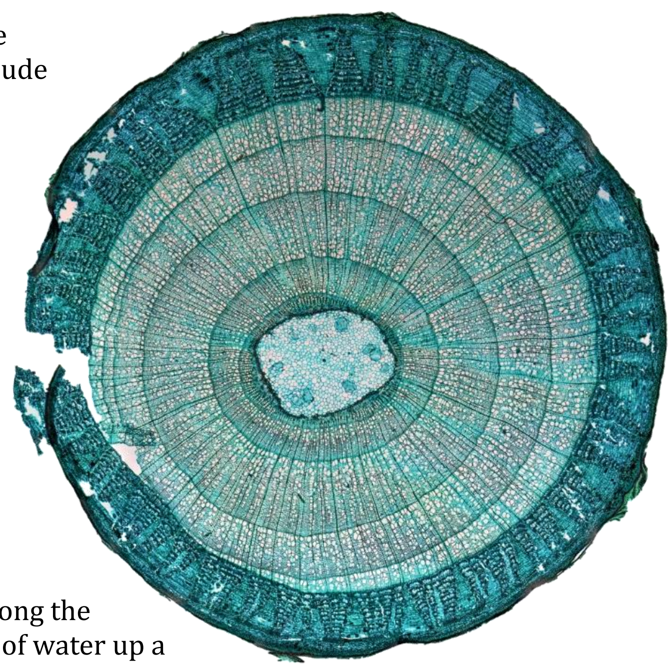
Use your model to explain how xylem and phloem transport water and food. More specifically, these are the functions of each tree part depicted in the model:

- **Heartwood** – forms the central core of the tree. It is made up of dense dead wood, and it provides strength.
- **Xylem** – brings water and nutrients up from the roots to the leaves. Older xylem cells become part of the heartwood and continue to add strength to the tree.
- **Cambium** – a very thin layer of living growing tree tissue. It makes cells that become new xylem, phloem, or cambium.
- **Phloem** – carries sap from the leaves to the rest of the tree. At certain times of the year, phloem may also move stored sugars from the roots up to the rest of the tree.
- **Outer Bark** – protects the tree from injury caused by insects, animals, plants, diseases, and fire. [5]



Note:

The movement of water up the length of the xylem can be modelled using a number of simple apparatus. These include capillary tubing, filter or blotting paper and porous pots.



Capillary Tubing:

Water has the capacity to flow along narrow spaces in opposition to external forces like gravity (capillary action). This is due to a combination of surface tension (cohesive forces) and adhesion with the walls of the tube surface. The thinner the tube or the less dense the fluid, the higher the liquid will rise (xylem vessels are thin: 20 – 200 μm)

Filter Paper:

Filter paper (or blotting paper) will absorb water due to both adhesive and cohesive properties. When placed perpendicular to a water source, the water will rise up along the length of the paper. This is comparable to the movement of water up a xylem (the paper and the xylem wall are both composed of cellulose).

[5] Rob Beadle, *Project Learning Tree*: https://www.plt.org/educator-tips/diy-model-to-explain-inner-tree-parts

Porous Pots:

Porous pots are semi-permeable containers that allow for the free passage of certain small materials through pores. The loss of water from the pot is similar to the evaporative water loss that occurs in the leaves of plants. If the porous pot is attached by an airtight seal to a tube, the water loss creates a negative pressure that draws more liquid[6]

Transpiration & Transportation Projects

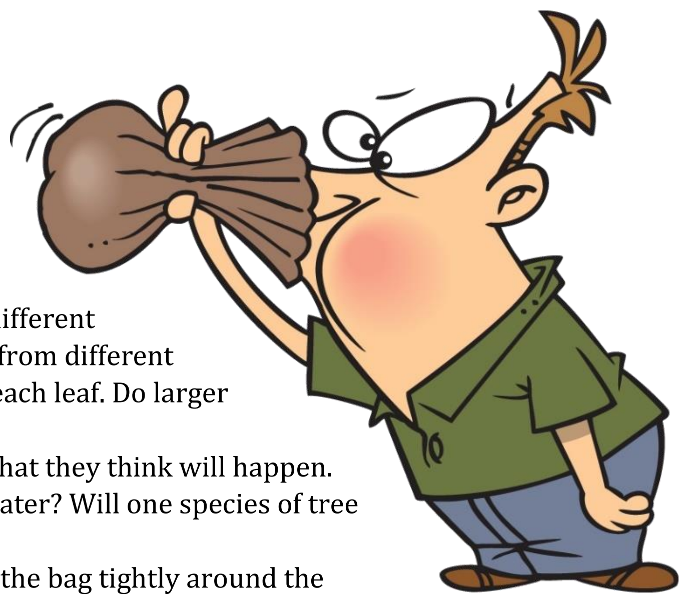
Our Science Team will need to be able to demonstrate how transpiration works to our alien visitors! They won't have seen anything like it on their home world!

Bag of Breath

Materials:

- Sunny Day
- Rubber Bands
- Clear Plastic Bags
- Measuring Cups
- Rulers

Procedure:



1. For a very simple leaf transpiration project, go outside on a sunny day and find a big leaf on a tree, ex. Oak or maple leaf.
2. Measure the leaf with the ruler and record the size.
3. Do a compare and contrast by selecting different sized leaves on the same tree and leaves from different trees. Chart the amount of liquid lost by each leaf. Do larger leaves
4. Have students make predictions about what they think will happen. Will larger or smaller leaves lose more water? Will one species of tree leaf lose more or less water?
5. Cover the leaf with a plastic bag and seal the bag tightly around the branch with a rubber band. After a few minutes you may notice the bag starting to look a big foggy.
6. Leave the bag on the leaf for at least several hours, or even overnight or several days.
7. What do you observe? Are students surprised by the amount of liquid in the bag(s)?

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[6] Plant Experiments. *BioNinja*: http://ib.bioninja.com.au/higher-level/topic-9-plant-biology/untitled-6/plant-experiments.html

8. Measure how much water is in each bag in a measuring cup and record it.
9. Compare the results.
10. Were students' predictions correct?

Further Study:

Would the same leaf release the same amount of water every day? On a cloudy day? What do students hypothesize? Test it out!

Walking Water![7]

Kids of all ages, including our alien friends, will be dazzled by the magic of watching colored water move along a paper towel from a full glass to fill up an empty glass.

Materials per group:

- 6 wide mouth glasses or jars, clear plastic cups, or test tubes in a rack. Smaller jars/cups require less food coloring
- Paper towels {use the kind where you can select a size}
- Food dye or liquid water colors {red, yellow, and blue}
- Paper
- Colored Pencils
- Pencils
- Timer (optional)

Preparation:

1. Get six sheets of paper towel and fold each sheet in thirds lengthwise.
2. Depending on the size of your glasses you may need to cut a few inches off the folded paper towel so it will fit in the glasses.
3. It's a good idea to test your paper towel strip to make sure they fit properly in your glasses. They should be able to go from the bottom of one jar to the next without sticking up in the air too much. The arch/fold should be just above the rims of the classes.

Procedure:

[7] https://www.adabofgluewilldo.com/walking-water-science-activity-kids/

1. Line up the glasses and add a good squirt (approx. 20 drops) of red food coloring or liquid watercolor to the first glass. Add yellow to the third glass and blue to the fifth glass. The other glasses will not get food coloring.
2. Add water to the glasses with color until the colored water almost reaches the top.
3. Move the glasses into a circle.
4. Before you insert the strips, you have the perfect opportunity to make some predictions about what will happen. Have your kids come up with a hypothesis or prediction for their experiment and write it down in their expedition journal. Will the water walk?
   You can start the conversation with…What do you think will happen when we put the towels into the water?
5. Add the paper towels.
6. Starting with the red, add one end of the paper towel and then put the other end in the empty glass next to it.
7. Continue around until the last paper towel is placed into the red glass and you've come 'full circle.'
8. At this point you can set up a stopwatch to make note of how long it takes for the colors to meet and mix.

What will you observe?

We should see the color wick up the paper towel right away. After another several minutes, the colored water will likely have travelled the whole length of each paper towel.

Five minutes later, the water should travel all the way up and then down the paper towel and drip into the empty glass. Ex. The yellow and red water should drip into the empty cup to make orange!

With more time you should see the water level has dropped in the red, yellow, and blue glasses and risen in the once empty glasses as the water continued to travel from the fuller glasses to the less full glasses.

Troubleshooting

If you aren't seeing much movement within a few minutes, it may be that you need to add more water to your colored water glasses. It really needs to be almost at the top for the water to walk quickly. Try topping off those glasses and seeing if that gets things moving.

If you see the water moving up the paper towel but it seems like it's taking forever, it may be the type of paper towel you are using. You want a paper towel that will really hold a lot of water, ex. Bounty Select-a-Size.

It really is worth the extra effort of trying different cups and paper towels to get this activity to work. For further help, check out a video like this one

Tip: Once you have had success, don't throw out those beautifully colored paper towels or the colored water! Gently squeezed out our paper towels and let them dry. You'll end up with gorgeous tie-dyed looking paper towels to use for crafts.

How does it work?

Capillary Action

The colored water travels up the paper towel by a process called **capillary action**. Capillary action is the ability of a liquid to flow upward, against gravity, in narrow spaces. This is the same thing that helps water climb from a plant's roots to the leaves in the tree tops.

Paper towels, and all paper products, are made from fibers found in plants called **cellulose**. In this demonstration, the water flowed upwards through the tiny gaps between the cellulose fibers. The gaps in the towel acted like capillary tubes, pulling the water upwards.

The water is able to defy gravity as it travels upward due to the attractive forces between the water and the cellulose fibers.

The water molecules tend to cling to the cellulose fibers in the paper towel. This is called adhesion.

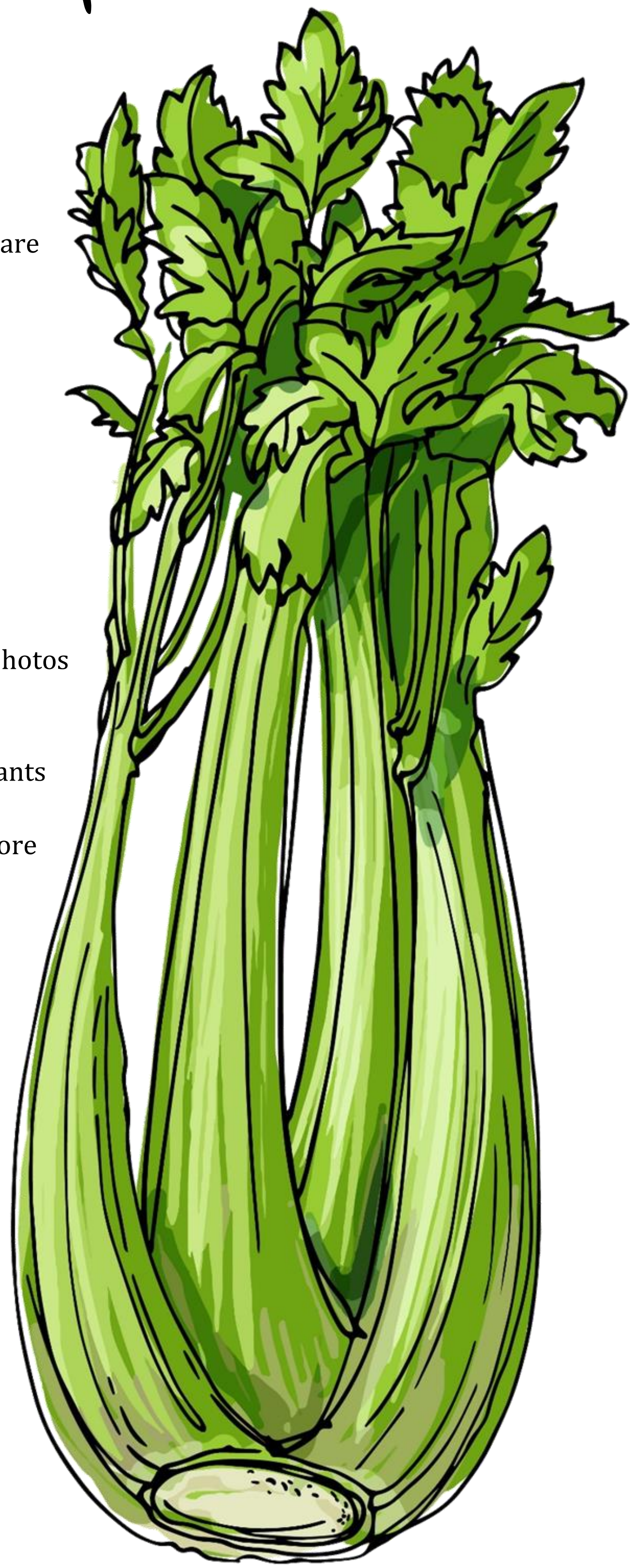
The water molecules are also attracted to each other and stick close together, a process called **cohesion**. So as the water slowly moves up the tiny gaps in the paper towel fibers, the cohesive forces help to draw more water upwards.

At some point, the adhesive forces between the wa ter and cellulose and the cohesive forces between the water molecules will be overcome by the gravitational forces on the weight of the water in the paper towel. When this happens, the water will not travel up the paper towel anymore. That is why it helps to shorten the length that colored water has to travel by making sure your paper towel isn't too tall and making sure you fill your colored liquid to the top of the glass.

Extensions

- Turn this demonstration into a true experiment by varying the water level {volume} you start with and seeing how long it takes the water to reach the empty glass.
- Or start with the same volume of colored water and change the brand, type {single vs double ply, quilted vs not} or length of paper towel to see how long it takes for the water to "walk" to the empty glass.
- You could even use the same volume of water, same length and brand of paper towel but vary the height of the filled glass, by raising them up on books, to see how that affects the speed of the water as it "walks" to the empty glass.
- Have you had enough fun with the paper towels? Try using other paper products to see how the type of paper effects the results. Try toilet paper, printer paper, newspaper, or a page from a glossy magazine. What do you predict will happen?

Stalking Science: What Transpired in the Celery?



Materials:

- Celery stalks of a similar size, washed with bottoms trimmed and leaves still on. (Pale green inside stalks are best)
- Food coloring
- Water
- Clear cups
- Kitchen knife for adult partner
- Metric ruler
- Paper towels
- Pen
- Clock or timer
- Data sheets
- Vegetable peeler
- Tablets, if available, for recording observations and photos

Tips:

- A magnifying glass and a flashlight may help participants better view the celery's xylem.
- Celery that is slightly wilted will take up the water more quickly. Measurements may be taken in 5 minute intervals and total time for the activity may be reduced.
- Make sure that the celery will not knock over the cups. If this seems possible, prop the celery in the cup against something so that it does not fall over and spill the colored water and/or use clay, tape, or museum wax to hold the cups in place.
- This experiment can also be done with carnations, cabbage leaves, etc.

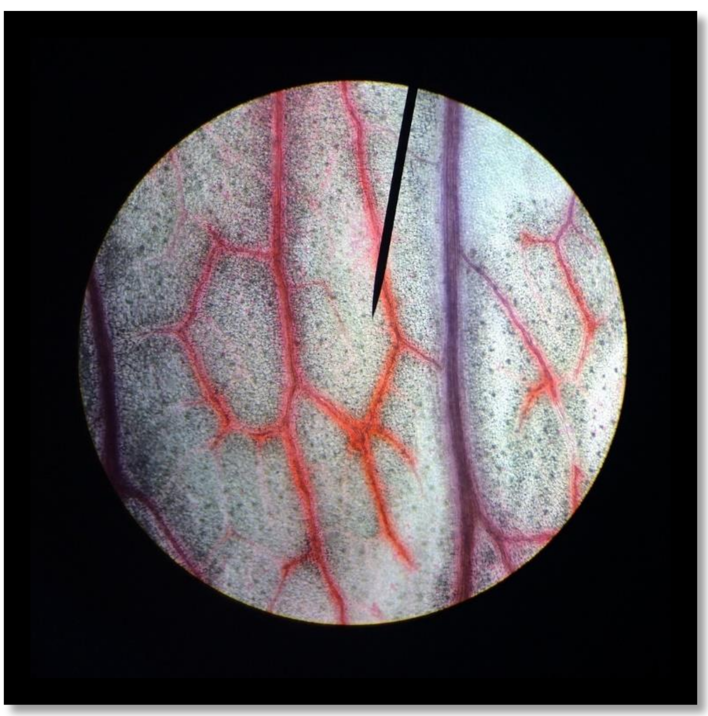
Procedure:

1. Assign each team a different color.
2. Make sure to have a control cup of celery in plain water.
3. Have them follow the directions to fill their containers with a cup (8oz) of water and 20 drops of food dye. Stir until the color is evenly distributed throughout.

4. Ask students to make and record predictions.
5. Cut about 2.5 cm off the bottom of the stalk of celery with the knife and place the celery in the cup with the leaves sticking up.
6. Have students use 'thinkpads' or sheets of paper to note changes, address questions, share thoughts, and formulate conclusions throughout the experiment.
7. Data should be collected hourly/daily through written observations on data sheets. Note, there may be hour-to-hour differences on the very first day.

Discussion Points & Next-Day Follow-up

- What happened to your celery stalk overnight?
- How do you know that the water reached the top of the plant (celery leaves)?
- Remove the celery stalk from the cup and cut another centimeter off the bottom.
- Look for small circles at the bottom of the stalk that are the color of the food coloring you used. (These circles are xylem, the tubes that carry water up the plant.)
- Continue cutting the celery stalk at one cm intervals. Try to follow the path of the colored water all the way up the stalk of the celery to the leaves. Or, have an adult peel the rounded part of the celery stalk with the vegetable peeler. This will let you see how far up the stalk the purple water has traveled. Measure the distance the colored water has traveled up the stalk and record this amount in centimeters.



Dyed veins in a celery leaf under a microscope

What's Happening?

Water has special properties. Water sticks to itself, like when rain falls in drops, and it sticks to other surfaces. These properties are cohesion and adhesion. The cohesion and adhesion of water molecules help them to move up very thin tubes like those in a plant. When water moves into tiny spaces like that, we call it capillary action. In this activity the color in the water moved up into the celery with the water, because the water molecules attached to the coloring and brought it along. In nature, the water moving into a plant brings with it nutrients from the soil. These chemicals can help a plant live, but sometimes they make the plant sick as well.

Did You Know?

The fact that plants bring water and other chemicals from the soil is sometimes used by humans to help them. In Iowa, poplar trees have been shown to reduce levels of nitrates, which come from fertilizers on some farms. In California, mustard plants soak up selenium, and in the Ukraine in Eastern Europe, sunflower roots dangling in ponds near the location of the 1986 Chernobyl nuclear power plant accident draw uranium from the water.

Part Two

As your class draws conclusions following the experiment, students may begin to ask questions they have about the outcomes and variables, ex. food coloring, celery in plain water vs that in colored water, etc. Ask students to share any questions they still have and write them all down. Samples of student questions:

- What if you put the celery stalk in upside down?
- What if you added salt to the water?
- What would happen if you put tape over the bottom of the celery?
- What would happen if you switched the celery from one color to another?
- What if you cut off all of the leaves and only used the stalk?
- What would happen if you split one stalk of celery between two different colors?

They will use these questions to problem solve and design their own experiments.

After brainstorming a list of things they are wondering about from the previous experiment, move the discussion towards what types of tests can be performed to find the answers.

Guide the discussion towards the conclusion that each student or team will only change one of the variables in the next round of experiments: the liquid, container, location, or the celery. If they changed two (or more) variables at a time, it could be tough to figure out which one caused the end result!

Have students fill out the following organizational sheet and, once experiments are approved, use them to create your class shopping list.

Thinking Experimentally: Design Your Experiment

Put this worksheet and your results in your discovery journal!

My Underlying Question-What I want to know:

What kind of experiment could you do to answer your question?

Your Hypothesis: When I what you will do ,

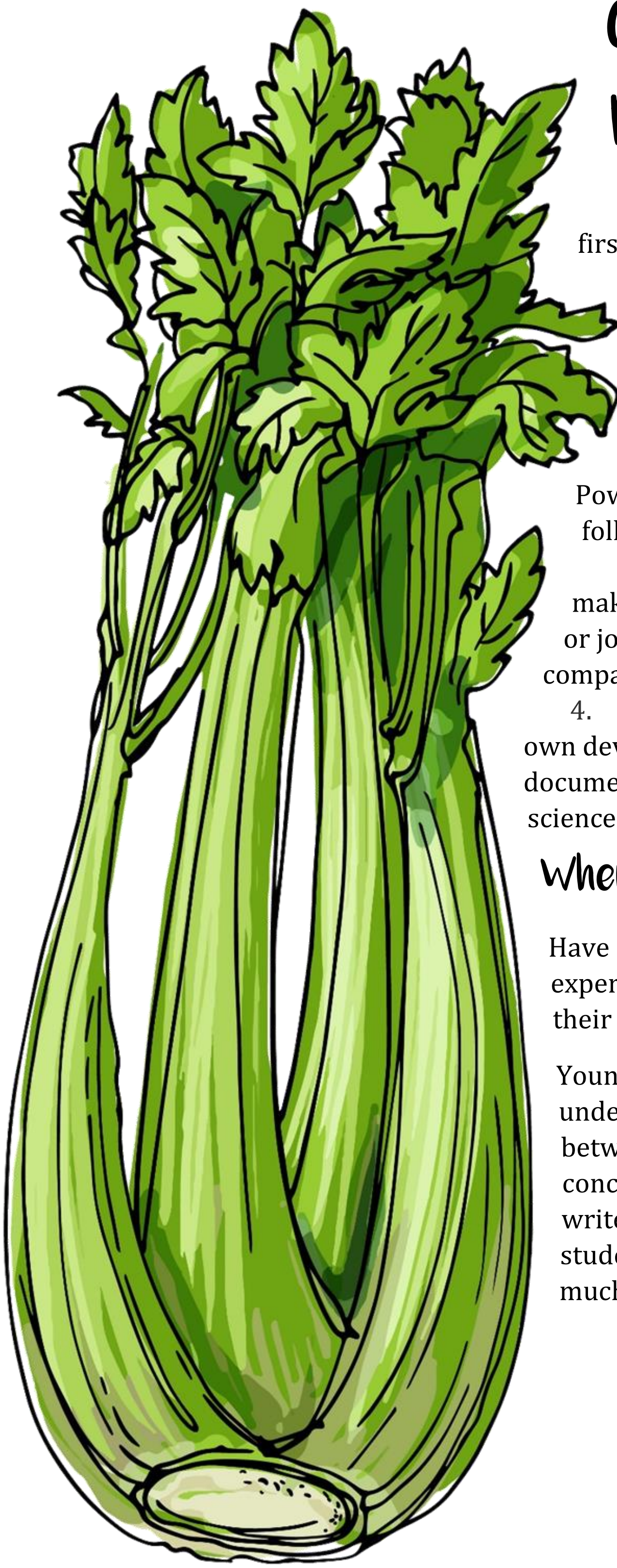
I think what you think will happen

What materials will you need?

What steps would you follow to set up your experiment? Write a numbered list of steps. Remember, the steps should be written clearly enough so that another scientist could easily recreate your experiment.

How will you collect your data? How often, what tools will you use chart, table, drawings, photos?

How long will your experiment take? ____________________



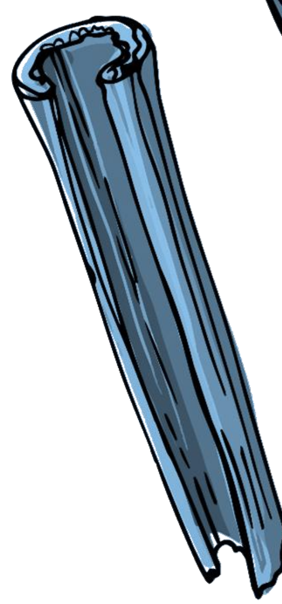
Getting Started with Round 2

1. Because students have already participated in the first round they should need minimal instruction to set up their experiments.
2. If students have tablets available, have each student create a Keynote presentation that they can use to record their observations each day, including photographs that they take with their devices. To help students set up their Keynotes, journals/notebooks, or PowerPoint presentations, give each student an organizer to follow (sample organizer included).
3. Each day students should take or draw pictures and make observations and record them in their Keynotes or journals. They can also onto the day-by-day comparison page and their photo galleries.
4. If students do not have their own devices they can simply document everything in their science notebooks or in PowerPoint.

When your time is up:

Have students conclude the experiment by writing a summary of their findings and drawing conclusions.

Younger students may need guidance in understanding the difference between summaries and conclusions and how to write them, whereas older students may not need as much support.



Documenting Your Experiment: Discovery Journal Entries

Entries	Heading	Include	Done
1		Title /Name/Picture	
2	I Was Wondering	What question did you have that led to this experiment?	
3	So I…	Tell how you planned to get the answer to your question.	
4.	Hypothesis	What are you doing and what do you think is going to happen?	
5.	Materials	Tell what materials you needed. Include picture s .	
6.	Getting Started	In a few sentences, tell how you put your experiment together. Include Pictures.	
7	Day ___/2nd observation Time: ______	Draw or take a picture and write 3-4 sentences of observations.	
8.	Day ___/3rd observation Time: ______	Draw or take a picture and write 3-4 sentences of observations.	
9.	Day __/4th observation Time: ______	Draw or take a picture and write 3-4 sentences of observations.	
10.	Day ___/5th observation Time: ______	Draw or take a picture and write 3-4 sentences of observations.	
12.	Summary	Summarize what you did and what happened over the last __ day s .	
13.	Conclusion	Tell if your hypothesis was correct, what you learned and what you would do differently next time.	
14.	Day-by-Day Comparison	If possible include a photo gallery of day by day changes in your celery.	

A Flying River?

We flew with the dust across the Atlantic Ocean in our alien friends' Discovery Vehicle and discovered something amazing!

When the water hits the top of the trees (through transpiration) a combination of sun and wind turns this moisture into a river. A flying river made of clouds.

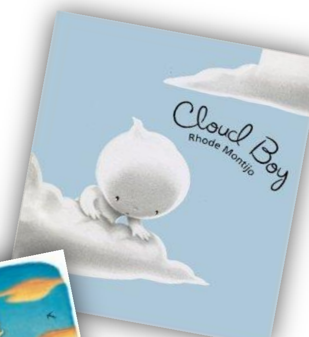
The tallest structure in South America is a tower in the Amazon that is used to measure this river of clouds and how big it really is. If it was a normal river, it would be the largest on the planet. Even bigger than the mighty Amazon River flowing beneath it.

This mighty atmospheric river, fueled by water vapor from the Amazon and heat from the sun, flows across South America until it runs into a brick wall. A wall up 5,500 miles long and up to 4 miles high. The Andes mountain range.

The clouds then condense into raindrops which then race down the slopes of the mountains and flow directly back into the Amazon Basin.

Tree-induced rain clouds could have other domino effects on the weather. As those clouds release rain, they warm the atmosphere, causing air to rise and triggering circulation.

This barrage of rain erodes the rock and turns it into sediment. This sediment flows until all those nutrients and minerals are dumped into the ocean.

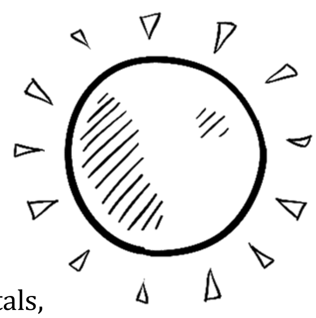


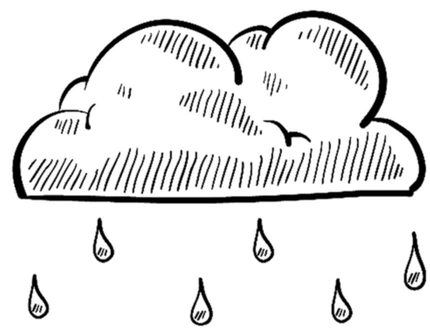
Humans sure love to make shapes out of clouds! Expand on the discussion of Earth clouds or introduce the topic by reading great picture books about clouds such as *The Cloud Spinner*, *Cloudette*, and *Cloud Boy*.

Water + Dirt = Clouds? Clouds are Mud pies in the sky?

Clouds are, in essence, massive collections of tiny water droplets and crystallized water molecules clinging to particles called condensation nuclei or freezing nuclei (also known as aerosols or nucleators). Typically, things like dust particles, sea salt particles and soot from wildfires will serve as nucleators, and the water droplets or ice crystals form around them. Studies show that bacteria -- specifically certain plant bacteria -- can also serve as the focal point for condensation.

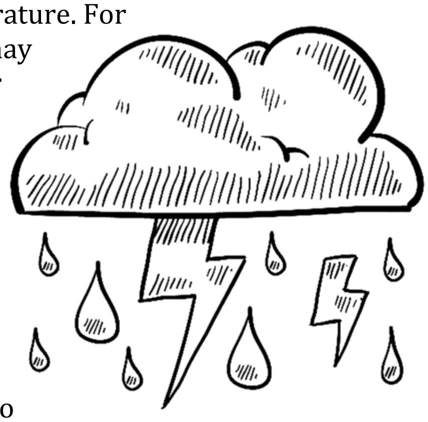
The different shapes, textures and other features of clouds depend largely on the conditions under which they form and later develop. For instance, temperature, humidity and altitude are all factors that affect cloud formation.

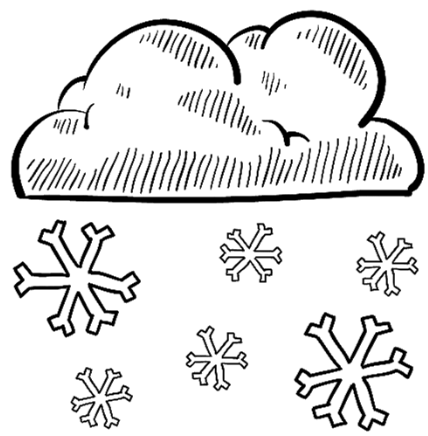




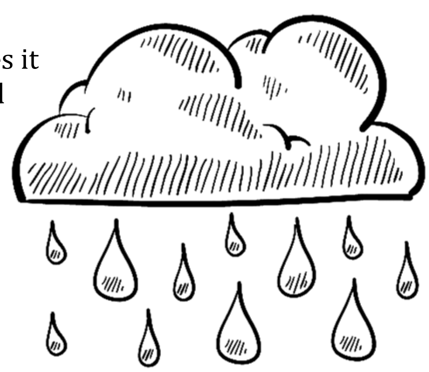
Clouds and Precipitation

A cloud can contain both water droplets and ice crystals, depending on its temperature. For instance, a cloud's top may be cooler than the lower regions, creating a mix of liquid and frozen water.





Gravity causes all this water to fall as rain. [The average size and volume of a cloud droplet is tiny, but, if a cloud droplet manages to attract enough water, the influence of gravity causes it to become a raindrop and fall.]

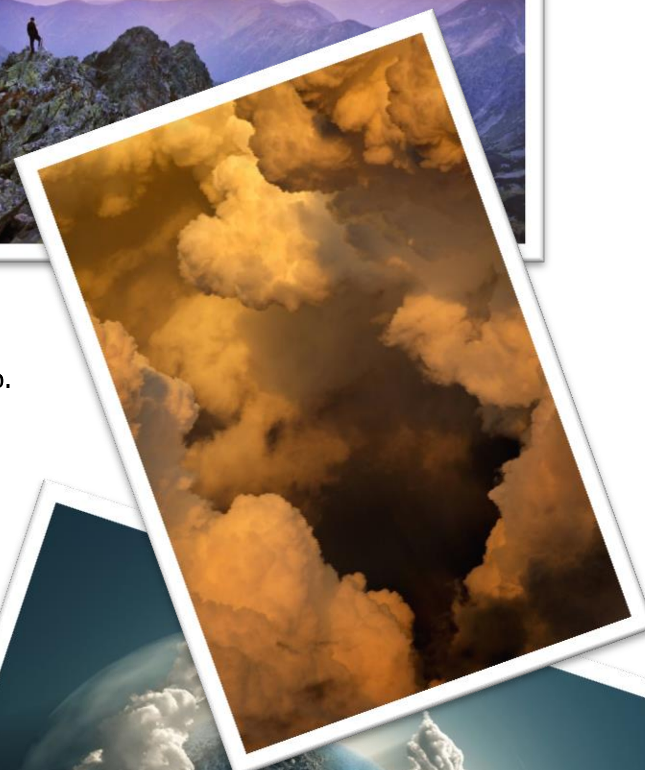


Making our own Clouds

Materials Needed:

- Cotton Balls
- Flat pans or flat containers
- Water

Put about a half inch of water in the pan(s). Give each child a cotton ball. Explain that this will act as their cloud. How does the cloud feel? Light and soft? Talk about how water will "evaporate" or become tiny droplets and will rise up into the sky. Ask them to place their cotton over the water. Can you see the water traveling up into their cotton? How does the cloud feel now? Heavy? As they lift the cotton ball up from the water some "rain" will begin to drip from the clouds. This is exactly how a cloud acts when it is full of water! The water comes back down as rain and ends up in lakes, streams and the ocean (represented by the pan of water). Once their cloud in empty of water, the process can begin again.



Snow happens a lot like rain. As snow crystals condense and clump together, snowflakes form. When they reach the point where they're too heavy to remain aloft, they fall together as snow. Different surrounding temperatures affect what type of snowflakes will develop. Sometimes on the way down, snowflakes melt into rain; other times they fall intact.

The Purpose of Clouds

Clouds have many effects on our climate besides simply hurling down rain and covering us in snow. For example, they serve as barriers for heat moving both in and out of the Earth's atmosphere.

Clouds generally affect the temperature in two ways. Over the surface of the planet, clouds reflect about 20 percent of the incoming heat from the sun back into space. Clouds, water vapor and other atmospheric gasses also absorb about 20 percent of this incoming solar radiation. Low-level clouds reflect the greatest amount of heat, which is why we enjoy cooler temperatures during a cloudy day.

Conversely, a cloudy night is warmer than a cloudless night because clouds also create a blanketing effect. Clouds partially absorb outgoing heat (such as the heat released in the evenings, as the ground cools) and reradiate a portion of that heat back towards the Earth's surface. High-level clouds typically absorb this outgoing heat.

Clouds regularly help shift dust, bacteria and other particles throughout the planet's surface. Clouds carry dust at a rate much faster than you might think. Remember the 27 million tons hauled every year from Africa to South America!

Unfortunately, too much dust in the atmosphere can decrease the amount of rain that falls on a region. This is thought to be because when raindrops form by lots of nucleators, these drops grow smaller and don't become heavy enough to fall. So if a region has a lot of dust in the air, it likely will receive less rain. This can contribute to desertification (where a local climate slowly changes to desert) and is one of the factors scientists believe is behind the landscape changes around central Africa.

Catching a Cloud in a Bottle

Have you ever wondered how clouds form on this planet? Our scientists have discovered that moist air rises in the atmosphere, cools, and water droplets form into clouds. It's going to be hard for our alien friends to take a cloud back to their MotherShip. They all want their own pet cloud. Luckily we've found a way to catch one in a bottle! Sometimes the results are a little hard to see, but practice always makes perfect!

Materials

- Clean 1 or 2 liter clear plastic bottle with cap
- Foot pump (bicycle pump)
- Rubber Stopper/Valve Stem (Can be purchased from auto parts store)
- Water
- Rubbing alcohol
- Safety glasses

Easy Method

Adult supervision is required!

1. Let's start with making the easy cloud first and then you'll know what to do for the tougher version when it's time to demonstrate to the Captain. Wear safety glasses and pour a little alcohol into the bottle so it puddles in the bottom.
2. Swirl the alcohol around inside the bottle. Make sure it coats the lower sides of the bottle.

3. Insert the stopper into the bottle and pump eight to ten times. As you start to pump, you'll notice that the stopper wants to pop out. Hold it tightly in the bottle opening so it doesn't. It may be stronger than you think!
4. When you're ready, quickly remove the stopper and watch the cloud form almost instantly in the bottle. If the cloud is faint or just a small puff of one, you'll need to add more pressure in the bottle before you pop the stopper.

Getting A Little More Realistic

1. Now you have a good idea what to expect when you're making a cloud and it's time to be more realistic. Put on your safety glasses and pour enough warm water into the bottle to cover the bottom. You want more water than you had alcohol.
2. As before, swirl the water around to coat the sides and put the rubber stopper into the opening.
3. Pump about five times. Hang on to the stopper!
4. After five pumps, pull the stopper out of the bottle. You may see a very faint "poof" of a cloud. There probably wasn't enough pressure in the bottle to make a really good cloud – yet.
5. Repeat the pumping but instead of five pumps, go for ten. You'll notice that the more you pump, the harder it is to keep the stopper in the bottle. (OK, say it together: Duh!) Pull out the stopper and you may see a slightly more visible cloud this time.
6. See where this is going? Fill the bottom of the bottle with warm water again and pump about 15-20 times. You want to put about 20 psi (103 cmHg) of pressure in the bottle.
7. When you remove the rubber stopper, you should see a pretty good cloud this time. Yes, it's more difficult to make a cloud using water than alcohol. Have students give some thought as to why that's true.

Note: If you cannot obtain a foot pump and rubber stopper a similar effect can be achieved by adding a bit of smoke from a blown-out match and then capping the bottle and squeezing on the sides of the bottle until you see a cloud form. It won't be as impressive as using the foot pump, and it is notoriously tricky to get to work, but it is possible.

How does it work?

Even though you can't see them (even when it's raining), water molecules are in the air all around you when we're on this planet. These invisible, airborne water molecules are called water vapor. When water vapor is bouncing around in the atmosphere, it has a lot of motion energy and doesn't normally stick together.

Pumping air into the bottle forces water vapor to squeeze together or to compress. Releasing the pressure quickly allows the air in the bottle to expand quickly. In doing so, the temperature of the air in the bottle becomes slightly cooler. This cooling allows the water vapor to stick together – or condense – more easily and form tiny droplets.

Why did we get a better cloud with alcohol?

Rubbing alcohol forms a more visible cloud because alcohol evaporates faster than water. Alcohol molecules have weaker bonds between them than water molecules, so they let go of each other easily. As a result, there are more evaporated alcohol molecules in the bottle that are able to condense at a lower pressure. That's why you see the alcohol cloud more clearly than the water vapor cloud earlier on in the pumping process.

Clouds are nothing more than gazillions of groups of tiny water droplets!

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, salt, smoke, dust, or even tiny particles of dirt, become a nucleus on which the water molecules can attach themselves and go from invisible to visible as a cloud.[8]

Seeding Clouds

There was a time when a farmer would sit out in his field, watching a lonesome cloud float away, taking with it the last hope of a much-needed burst of rain. As humans take control over more and more natural processes, rain too seems to have finally been leashed in.

Water is a valuable resource that affects nearly all aspects of life on earth. It also is limited, so people use a variety of methods to ensure that supply meets demand. Just like a farmer throws seeds on ploughed land to harvest plants, clouds can also be seeded with chemicals to induce rain!

Formation of ice crystals takes a long time. Due to changes in climate, certain areas do not get adequate rain. Lack of rain dries up the land, causing drought. To avoid drought and to increase water resources, scientists have over the years studied cloud formations. They concluded that clouds lack ice nuclei. Therefore, they argue, additional ice nuclei should result in more rain-producing clouds. More nuclei = more rain. Cloud seeding aims to jump-start this process by helping droplets to clump or freeze together when they otherwise wouldn't.

As an experiment, scientists sprayed a chemical called silver iodide (dry ice is also used), onto a cloud formation. The temperature at the cloud layer is already low, compared to the temperature at the surface and may be close to 0◦C, so to achieve significant

[8] Steve Spangler, *Steve Spangler Science*: https://www.stevespanglerscience.com/lab/experiments/cloud-in-a-bottle-experiment/

cooling, something far colder would have to be used. Something that hopefully isn't too toxic! Dry ice has a far greater cooling effect on the air around it than water ice would. Sure enough, because it was so cold, the dry ice induced freezing of the water droplets, and what followed was rain.

The same effect can be observed without dry ice by taking a cold glass out of the refrigerator and watching the water condense on it. The air near the cold glass will not hold as much moisture as the air in the room that is at a higher temperature and droplets will gather.

So the final recipe for rain is: one large cloud, though a bunch of smaller ones would do nicely too; a not too large serving of silver iodide/dry ice (remember, too much and it's called pollution) and the services of a plane. Shower the silver iodide onto the cloud. Blend well and serve cold. We now have rain! [Liquid propane, which expands into a gas, has also been used. This can produce ice crystals at higher temperatures than silver iodide.]

It's important to plan things well. Since clouds don't produce rain until 20 or 30 minutes after they have been seeded, one needs to make sure they deliver at the right place.[9]

The flow of air into the clouds and the liquid water content also suggests if a cloud is likely to produce rain.

Cloud seeding is most commonly done out of airplanes. Planes fly into selected cloud formations and release packets of microscopic silver iodide particles using flares. When the particles meet cool moisture in the clouds, they trigger the formation of ice crystals and raindrops. The amount of silver iodide that is used is small enough to make sure that it doesn't pose a pollution risk.

Another method is to use smoke machines from the ground. The machines send silver iodide particles billowing from the ground into the atmosphere.

The results clearly demonstrate that, at least under certain conditions, it is possible to change the evolution and growth of cloud particles, leading to snowfall that otherwise would not have occurred. The next question is whether cloud seeding can be an effective tool for water managers.[10]

Cloud in a Jar aka Seeding Clouds!

Adult supervision is required!

Supplies Needed

- Clean glass jar with a lid (ex. a pint mason jar works well)

[9] Arti Jalman "What is Cloud Seeding?" *Pitara* https://www.pitara.com/science-for-kids/5ws-and-h/what-is-cloud-seeding/

[10] http://theconversation.com/does-cloud-seeding-work-scientists-watch-ice-crystals-grow-inside-clouds-to-find-out-90903

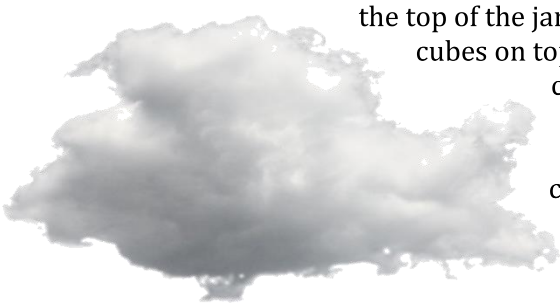
- 1 cup hot water (a glass 2 cup measuring cup is helpful)
- hot pads
- blue food coloring (optional)
- Dark colored paper
- aerosol hairspray or air freshener
- 3-5 cubes of ice

Option: Use food coloring to dye the water blue before pouring it into the jar. This is not required, but it does help distinguish the cloud from the water. Plus, it makes the water look like the sky.

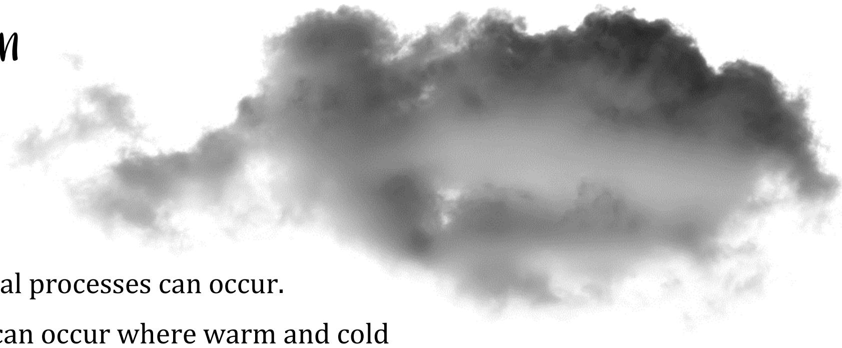
1. Pour 1 cup of hot [some say boiling works best, or at 145F] water into a glass jar. You may want to swirl the hot water on the sides of the jar to warm up the glass, otherwise, condensation will immediately occur.
2. Place the lid on the top of the jar. Place several ice cubes onto the lid and allow it to rest on the top of the jar for about 20 seconds.
3. Remove the lid and quickly spray hairspray into the jar. [The spray gives the water vapor a surface [condensation nuclei or 'seeds']to condense into tiny cloud droplets.]
4. Immediately put the lid onto the jar.
   Tip: This step must be performed quickly, so have the lid handy. It also helps to have multiple people doing the experiment/demonstration. One to spray the hairspray and one to put on the lid.
5. Place 3-5 pieces of ice on top of the lid of the jar.
6. Now hold up the dark colored paper to the glass and look for wisps of cloud to start swirling inside towards the top of the jar.
7. You may also want to shine a flashlight inside the jar to see the cloud better.
8. After observing the cloud in the jar, remove the lid and watch the cloud move out of the jar.

How does it work?

When you add the warm water to the jar, some of it turns to water vapor. The water vapor rises to the top of the jar where it comes into contact with cold air, thanks to the ice cubes on top. Water vapor condenses when it cools down. However, a cloud can only form if the water vapor has something to condense on to. In nature, water vapor may condense onto dust particles, air pollution, pollen, volcanic ash, etc. In the case of this activity, we acted like human scientists/cloud seeders adding silver iodide to the environment and the water vapor condensed onto the hairspray.



Other Forms of Precipitation



You may be asking, "If water droplets and snow crystals make up clouds, how do we get hail, sleet and freezing rain?" The answer is that once cloud droplets and ice crystals condense and reach critical falling mass, a few additional processes can occur.

- Freezing rain, also known as glaze, can occur where warm and cold air fronts meet. A snowflake can fall into cold air, then pass through a layer of warmer air and melt. As it continues to fall and right before it hits, the snowflake passes through a layer of cold air and becomes supercooled. This means that it won't refreeze, but upon impact with a cold object, such as the street or a tree branch, it will immediately turn to ice.
- Sleet starts the same way as freezing rain, but the melted snowflakes have time to refreeze before they hit the ground.
- Hail forms during severe storms. The gusty updrafts produced by high winds may knock snowflakes and raindrops up and down until the supercooled water droplets collect themselves into chunks of ice. This can happen repeatedly, until the heavy hail can no longer be lifted by the storm's powerful updrafts. The resulting ice chunks can be quite large when they're finally released and create quite an impact if they hit objects like the hood of your car

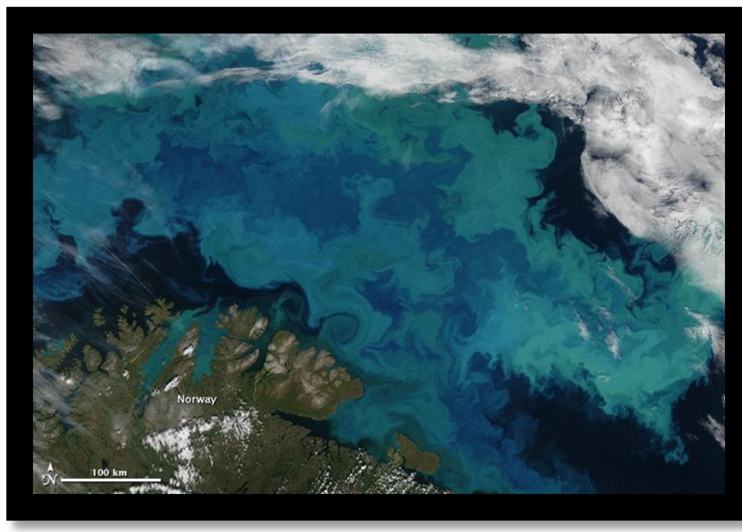
Diatoms are Dynamite*: One-Celled Wonders!

Waiting for those nutrient-filled sediments washed down by all that rain and flowing with the river is an extraordinary organism, four times thinner than a human hair. It's called a diatom.

Diatoms (DIE-a-toms) are one of the most important things you never knew about. They are everywhere there is water. Diatoms are algae that live in houses made of glass. They are the only organism on the planet with cell walls composed of transparent, opaline silica, the main ingredient in glass.

*They Really Are

Diatomaceous earth, or diatomite, is composed by the silica cell walls of diatoms.
Diatomite is a crucial component of dynamite. Alfred Nobel, who patented dynamite in 1867, discovered that nitroglycerin was more stable if it was mixed in diatomite. The mixture allowed for safer handling and transport than nitroglycerin in its raw form.



Diatoms are the secret to this planet's oxygen supply. They use the silica from the sediment to create new shells, which allows them to reproduce. Their population doubles every day. And they begin to photosynthesize. Each one producing oxygen.

One out of every two breaths that we take while on this planet is entirely produced from the photosynthesis of those diatoms. These were the incredible changes of color that we noticed from space. Diatom blooms that reflect the sunlight differently than the water around them, so that they show up from space.

Groups of them can cover hundreds of miles. When swimming in the water we don't notice the microscopic diatoms around us. But, they can be seen from space when they bloom and they're what's keeping us alive.

These dazzlingly beautiful little organisms live in oceans, lakes, rivers, and puddles. . . just about everywhere you find water. There are trillions of them in every ocean. A drop of lake water is packed with them. You probably swallow millions every time you go swimming. These tiny, one-celled life forms populate the world's ponds, rivers, and oceans (and anywhere else that's the least bit wet). They spend their invisible lives quietly using sunlight to turn carbon dioxide and water into food and oxygen. And they can't all rely on flying rivers. So, diatoms around this planet have to get their nutrients in different ways.

Some diatoms are as far from tropical rainforests as you can get. Such as in the bitterly cold oceans near Norway, which are full of glaciers. Glaciers that are slowly moving, crushing rock as they travel. Not fast enough to see, but fast enough to hear. And when ice meets water there is a familiar sound, rather like the snap, crackle, pop of your favorite crispy rice cereal. That's the sound of bubbles escaping as the glacier melts. And as they melt, they crack.

Just one collapse of a glacier face (when a glacier 'calves') dumps thousands of tons of ice into the sea. That powdered rock (that the glacier crushed as it travels) is perfect food for diatoms.

Sometimes glaciers move really quickly, parts break off, and the glacier dumps hundreds (or more) of tons of rock into the sea (this is called calving), sparking a feeding frenzy and a population explosion of diatoms. But then, just as quickly as it's started, the feeding frenzy is over. Sometimes the glaciers might stay dormant for decades. No cracking. No shifting. No food for diatoms.

When the nutrients run out the blooms fade and most of the diatoms die. Diatoms are not only important for what they do while they're alive, but also what they do when they're dead.

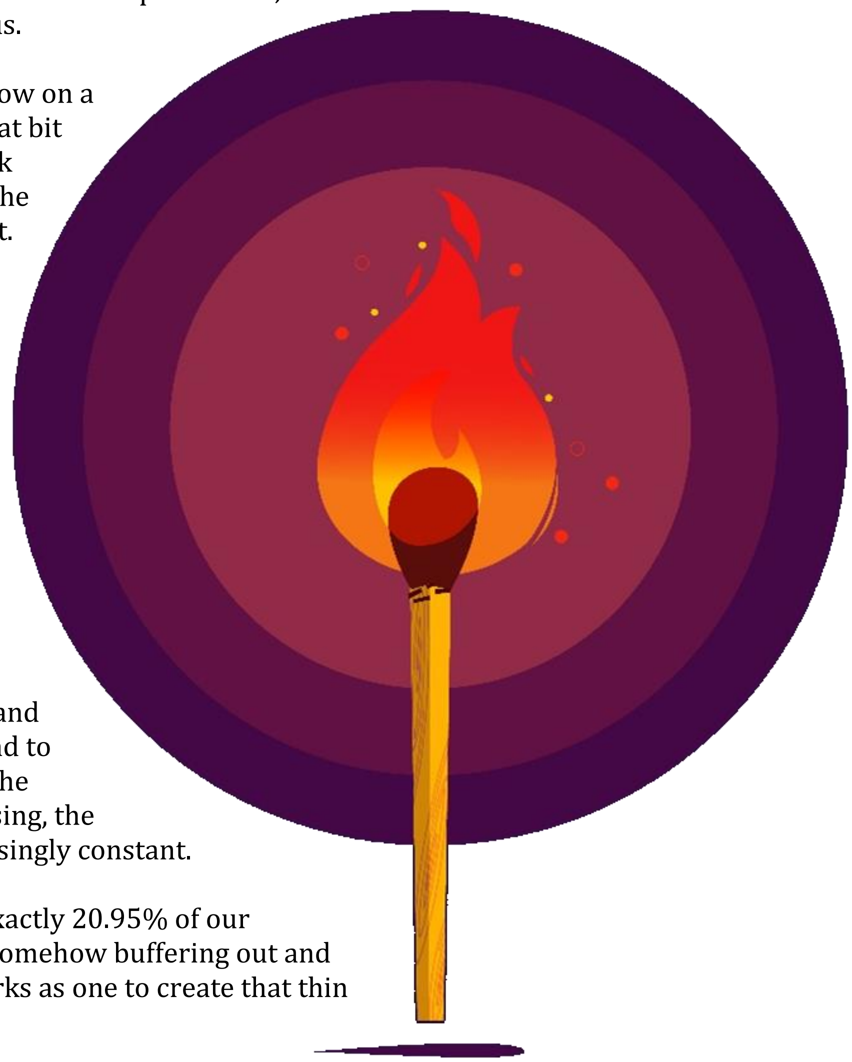
Their carcasses slowly drift down to the ocean floor where they carpet the bottom in a layer ½ mile thick. It's called marine snow and that's exactly what it looks like. Snowflakes drifting down.

Unlike snowflakes diatoms never melt. When diatoms die, their dead bodies pile up by the trillions on the floor of oceans and lakes, forming a chalky mud. This plentiful mud is used as a water filter, an insecticide, and even as an ingredient in some toothpaste. Over millions of years the sea beds rise and ocean levels fall and the ocean floor becomes a salty desert. The desert that blows all the way to the Amazon Basin? That was once a sea bed. And the dust that makes the rainforest grow? Diatom shells.

It's all connected.

It shows us how incredibly interlinked everything is. There's nothing on one side of the planet that isn't connected in some way to the other side. Every single thing on the planet contributes to everything else. Nothing exists in isolation. All the systems must work together in order for us to breathe.

You only have to mess with oxygen a little bit to throw things off. Without enough oxygen human organs can start shutting down and it can happen surprisingly quickly. It's called hypoxia. It's vital that we get enough oxygen while on the planet. But, too much can be just as dangerous.



You see it when you blow on a tiny fire. Just blowing that bit of oxygen turns the spark into a flame. It's exactly the same for the whole planet. A rise in oxygen levels can threaten life on this planet.

300 million years ago there was a lot more oxygen in the atmosphere. So much that the planet burned. Too much oxygen and we burn. Too little and we choke. The planet walks a tightrope with death on either side. The only thing that can save us, just like a tight rope walker, is balance. It's crucial. Interestingly, we don't fully understand how the planet manages to maintain it.
Despite diatoms having to wait for glaciers and South American trees having to wait for wind to blow African dust and despite the fact that the human population has been steadily increasing, the amount of oxygen in the air has been surprisingly constant.

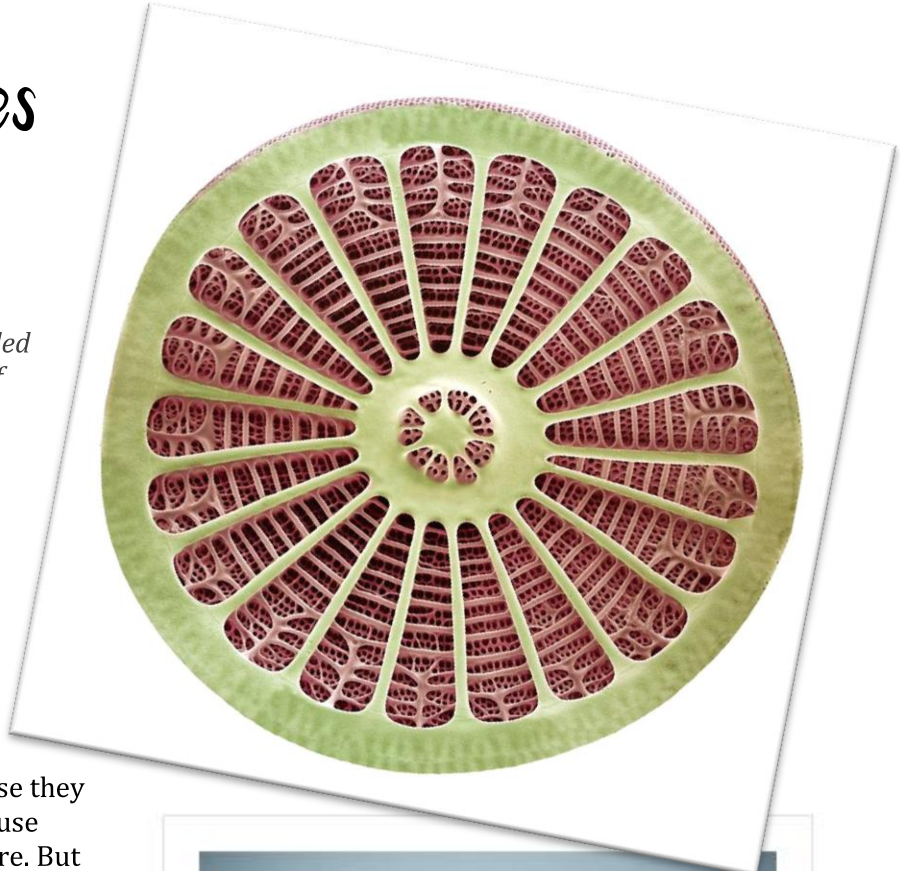
For millions of years oxygen has made up exactly 20.95% of our atmosphere. Exactly 20.95%. Everything's somehow buffering out and keeping things stable. The whole planet works as one to create that thin blue line.

One we've seen nowhere else in the universe.

Living in Glass Houses

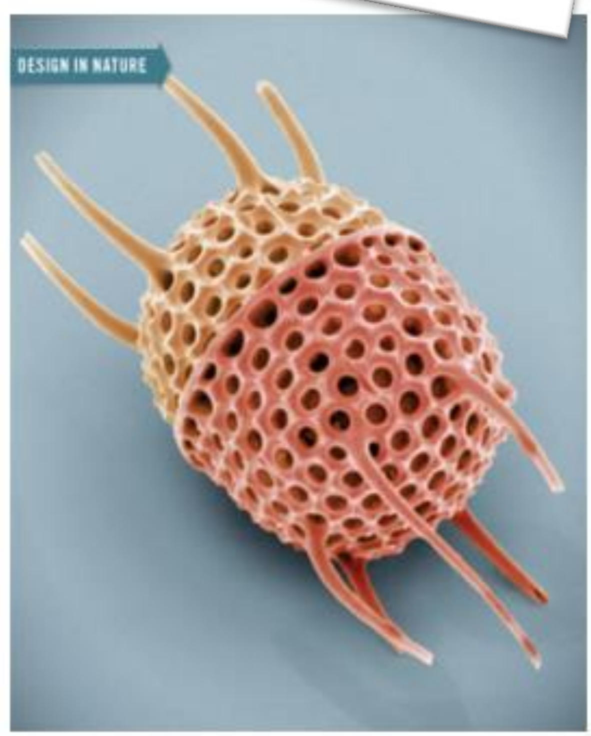
Why bother laboriously creating intricate, microscopic devices when single-celled organisms can do the job for you?

Mankind was not the first to invent glass. Untold trillions of little creatures, called diatoms, have long made their homes out of glass. Now we're enlisting their help to engineer entirely new products for our benefit.



Diatoms range in size from the finest dust up to a millimeter (about the thickness of a U.S. dime). More than 70,000 species have been catalogued as animals, plants, or something midway between.

Scientists have long prized diatoms, photosynthetic algae that abound in marine and freshwater ecosystems, because they remove large amounts of a major greenhouse gas—carbon dioxide—from the atmosphere. But another, unusual trait has recently caught the attention of materials scientists and engineers: The cell wall of this unicellular organism is made entirely of glass. More precisely, diatom shells consist of silica, or silicon dioxide, the primary constituent of glass. Many shells are ornately patterned with features just tens of nanometers in size. To give some perspective, the period at the end of a sentence is 1,000,000 (yep, one million) nanometers wide.



Steve Gschmeissner | Photo Researchers, Inc.

What's more, there are thousands of different species of diatoms, each with a unique shell design. Some look like miniature sieves, others resemble microscopic gears. Others of the microscopic, ornate diatom shells variously resemble chandeliers, cylinders, pillboxes, snowflakes, stars, and crowns. They are treasures of beauty on the smallest scale.

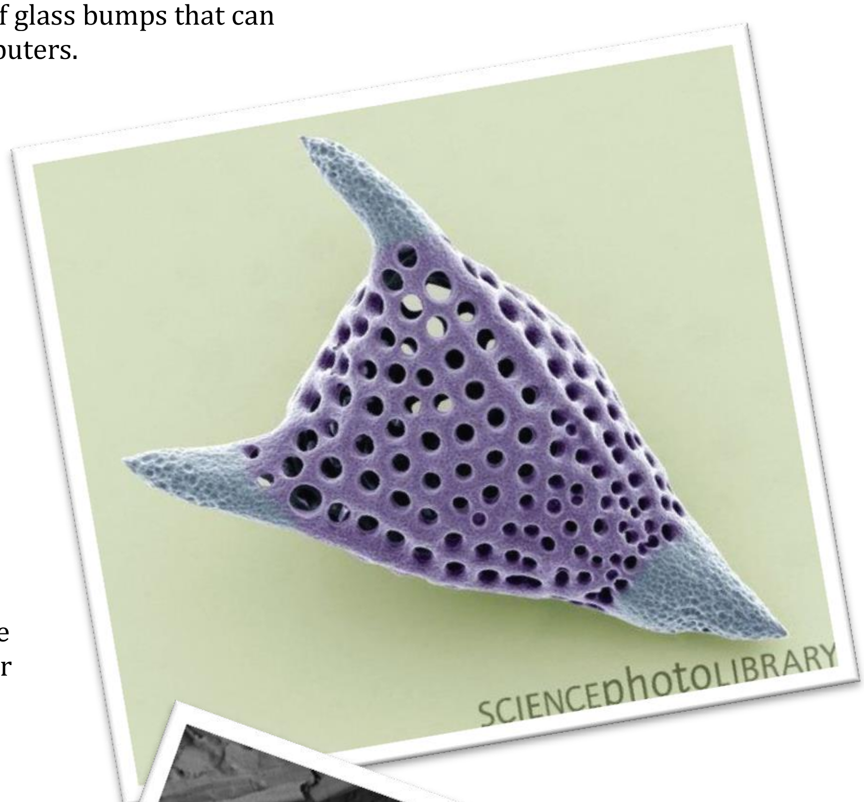
Gallery of Diatom images by Steve Gschmiessner and more

Gallery on Pinterest

Today materials scientists are looking at diatoms to provide them with ready-made components to put into miniature devices on a molecular scale (called nanotechnology).

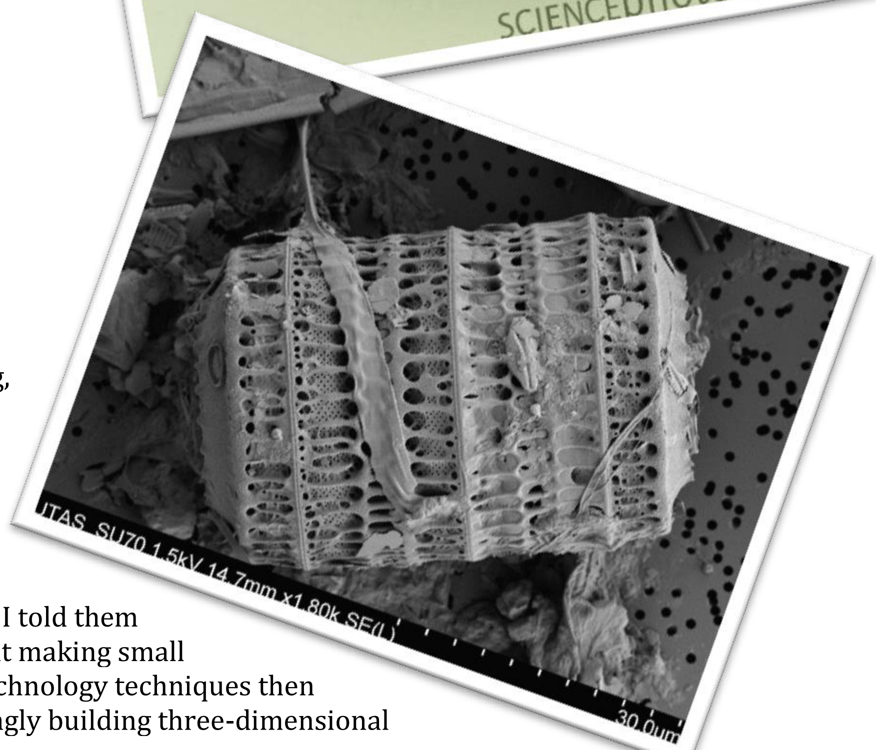
The researchers fabricate small devices for use in electronics, medicine, and optics. Some diatoms have openings, or pores, that provide ready-made filters for chemical separation. Other diatom surfaces are covered with a regular array of glass bumps that can function as focusing lenses for optical computers.

Diatoms also provide components for micro-machines, such as motors, pumps, and valves. Because glass is fragile, specific diatom shapes are made more durable by heating at 1,652°F (900°C) for several hours in the presence of magnesium or titanium vapor. The silica glass vaporizes and is replaced, atom by atom, with tough metal ceramics in exactly the same shape. [11]



Researchers also hope to coax diatoms to grow into new useful shapes called "designer diatoms." For example, diatoms could become capsules for delivering medicines to specific parts of the body. Success thus far is limited because we do not understand how diatoms sculpt their glass palaces, but research continues.

Turning to Nature for Engineering Solutions



[12]Richard Gordon, Professor of Radiology at the University of Manitoba in Winnipeg, Canada, somewhat accidentally laid the foundations of 'diatom nanotechnology' in 1988 when he was invited to give a lecture at an engineering conference. 'I'm not an engineer', explains Gordon, 'but I knew engineers were interested in what was then called microfabrication so I told them about diatoms because they are so good at making small things'. By contrast, says Gordon, 'nanotechnology techniques then and now are tedious, involving painstakingly building three-dimensional structures up layer by layer'.

Such incredibly slow techniques are currently used in the semiconductor industry. Currently

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[11] Philip Cohen, "Natural Glass," *New Scientist* 181, no. 2430 (2004):26–29.

[12] Image by By Jmpost - University of Tasmania Scanning Electron Microscope, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19586796

light waves are used to carve features on circuit boards. However, for the next generation of faster computers, engineers need to get denser features onto computer chips than is possible with light etching. Diatoms are naturally good at etching things at an incredibly tiny size. If we could work out how diatoms create their micro lines of silica, then we may be able to copy how they do it and create incredible microcomputers.

There are other ways in which diatoms could help clumsy humans build nanoscale 'widgets'. Already, engineers are using diatoms to help them build extremely sensitive sensors.

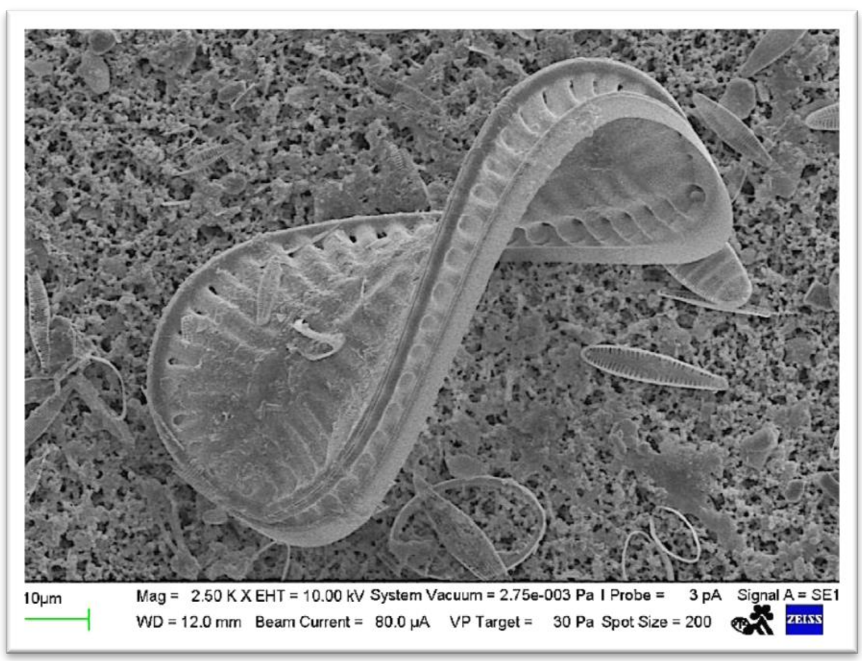
'Information processing technology is moving from electronically to optically based hardware, which allows more information to be carried and stored. Optical systems need materials with regularly repeating structures with features below the micrometre size range. These are very difficult to make by standard manufacturing techniques, but diatoms make structures like this all the time'.

Dr. Diatom?

It might also be possible to use diatom shells as delivery vehicles for drugs. 'They have a uniform nanoscale pore structure and are chemically inert and biocompatible'. Scientists envision loading diatoms with a drug that would then enter the blood stream at a rate dependent on the diatom species used. By incorporating magnetic particles within the diatom structure, it might be possible to use a magnet to guide the drug to the right organ.

Learning from the Little Guys

[13]Diatom structures are not just of interest to people interested in tiny objects. In diatoms, Nature has solved many of the problems that engineers want to solve. For example, diatoms are particularly good at making lightweight but strong structures. Because it is possible to scale static structures like shells, diatoms can teach us how to make lightweight constructions for the aerospace and car industry'.



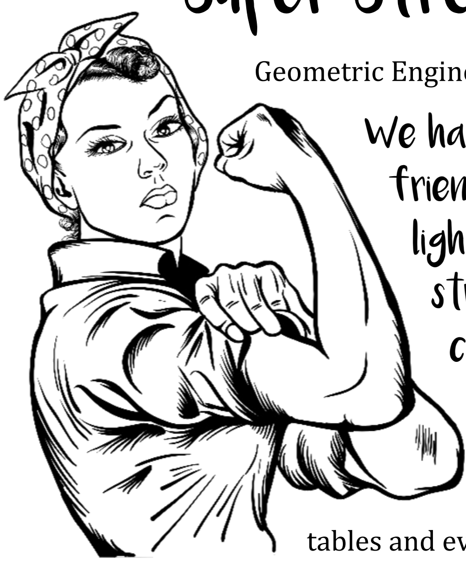
Some of the potential applications of diatoms can be investigated right now, using naturally occurring diatoms. In addition, subtle but important changes can be induced in

[13] Image by By Nicola Angeli/MUSE - This file was derived from: Surirella spiralis - SEM MUSE.tif, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=48428932

diatoms by varying the amount of silica in their environment or changing the water flow. Scientists hope to create a device called a compustat, which would be used to select diatoms for a specific purpose.

However, to make the most of the nanotechnological potential of diatoms, we need to know exactly how diatoms make their shells. Scientists are still working on figuring that secret out.[14]

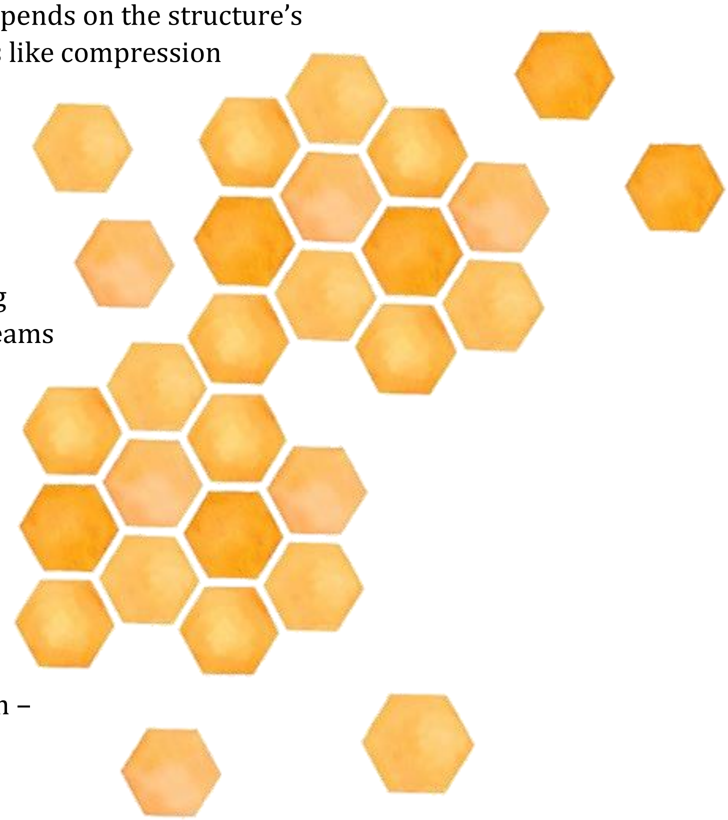
Super Strong! Build Like a Diatom!



Geometric Engineering Challenge:

We have to design the perfect home for our new alien friends to live in on Earth. It needs to be strong, but lightweight! We're going to take inspiration from the strongest builders on this planet! And even if they can't colonize this planet they'll take what we've learned to survive their long journey in space.

Structures are all around us. Take a look. Structures include bridges, buildings, chairs, shoes, spiderwebs, beehives, anthills, tables and even your own body. Structures are made by man and also found in nature. All structures have a definite size, shape, and are capable of holding a load. It's shape, size and the materials it is made of depends on the structure's function. They also determine how strong it is. Forces like compression and tension are always acting on structures. As a result, structures must be strong and stable. Builders, designers and engineers have to ensure that they are safe to live and work in. [Builders of every species.]



Scientists and engineers are always looking for strong materials to build with. A research team that made beams of sawn diatom shells (which they then poked with a diamond-tipped probe until they cracked) have revealed that the microbial armor has the highest strength-to-weight ratio of any known biological material. Well above the values for other strong natural materials including bamboo, mollusk shell, spider silk, bones, teeth and even antlers, all of which are known for being sturdy. That's not to say no known substances exceed this specific strength –

[14] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC521728/

many do, but they are all man-made. Kevlar is one such substance.

According to the scientists who conducted the study, the remarkable toughness of this material is likely due to its honeycomb-like architecture and flawless silica build. [15]

While silica is an inherently resilient material, it's also brittle. It's like glass that will break when you drop it. Shells (or frustrules) made by diatoms, however, are dotted with honeycomb-like holes, and the team believes that their porous surface is the feature that prevents them from cracking and breaking. The presence of the holes spreads out the stress on the structure and makes it able to stand more pressure.

What's so great about honeycomb-style building?

Honeybees are some of nature's finest mathematicians. Not only can they calculate angles and comprehend the roundness of the earth, these smart insects build and live in one of the most mathematically efficient architectural designs around: the beehive. Let's learn with Zack Patterson and Andy Peterson and delve into the very smart geometry behind the honeybee's home with [this video.]

Challenge: Build a structure out of toothpicks--our version of diatom beams and honeycomb wax--that is able to support the weight of a brick!

Planning Ahead: Bee an Engineer with Orthographic Drawings

Materials:

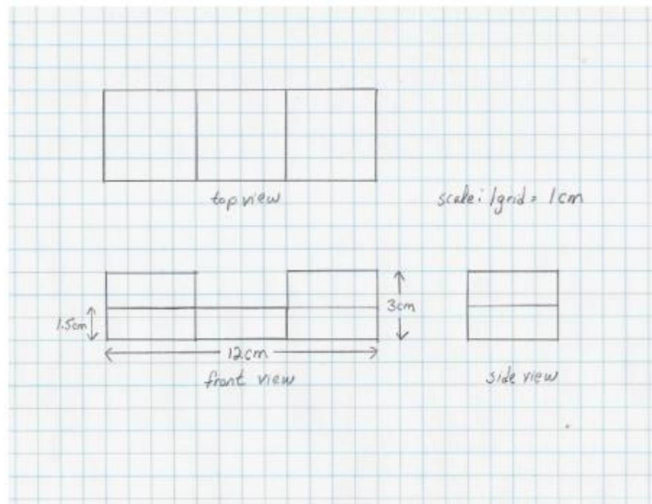
- bag of children's building blocks
- graph paper
- centimeter rulers

[15] Jennifer Frazer "Beams Built of Diatom Boast Record-Setting Strength" *Scientific American* https://blogs.scientificamerican.com/artful-amoeba/beams-built-of-diatom-boast-record-setting-strength/

- box of pencil erasers – the kind that go on the end of the pencil

Orthographic drawings are the standard method used in engineering industry to convey information about parts and structures. They consist of a front, side, and top view of the part.

The students will learn the basics from building blocks, then later apply the skill to their toothpick structures. Start with a simple structure built from children's building blocks, such as pictured below:



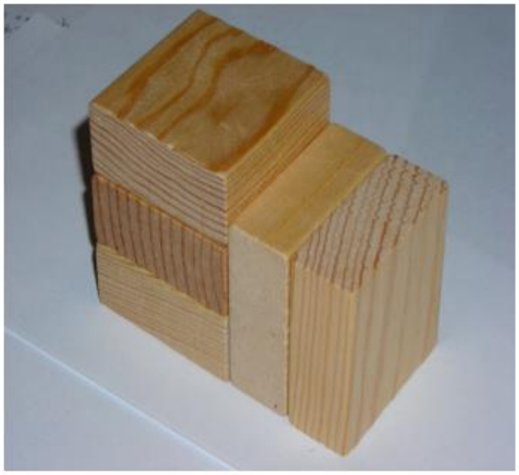
Have the students note the following details:

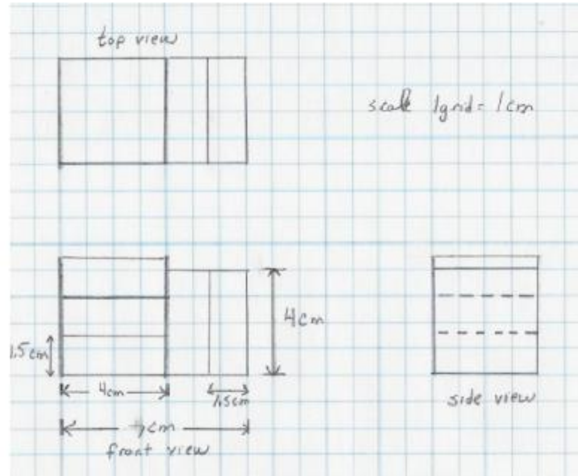
The scale is 1grid = 1cm (actual dimensions are marked, as is customary in orthographic drawings, but you don't have to require the students to do so – making the drawing to scale will be enough)

The views are aligned with each other. The front view is directly underneath the top view, and the edges are aligned (meaning the front view is not to the right or left of the top view, but directly underneath). The side view is to the right (or it can be to the left) of the front view, and its edges are also aligned (the side view is not higher or lower than the front view, but directly across).

Each solid line in the drawing is a line that you see as you look at the blocks.

Next, try a more complicated structure such as:





Have the students note the following:

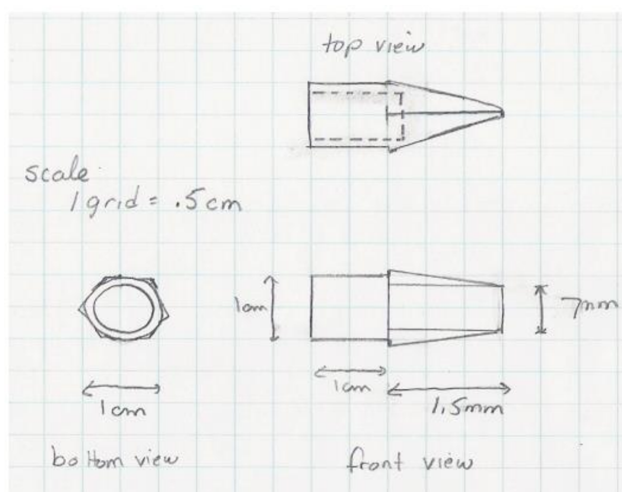
The side view is a bit tricky to understand. A solid line is a line that you can see.

A dashed line means that is a line that you cannot see.

As you look at the structure from the right side, you see a line at the top of the two 'standing up' blocks; this is the second solid line from the top. You do not see the two lines that are created by the pile of three 'lying flat' blocks; that is why they are dashed. (All lines on their structure drawings will be visible; there may be no need for dashed lines. However, these drawings are so prevalent in industry, that it is worthwhile to introduce students to these ideas in this class.)

Set up three or four stations, each with a different structure. Put the students in groups and have them construct drawings for each station. Check their work as they go along, or, have answer keys for each station. Lastly, you can have each group create their own structure with blocks and orthographic drawings. They can switch the drawings with another group's and try to build the structure.

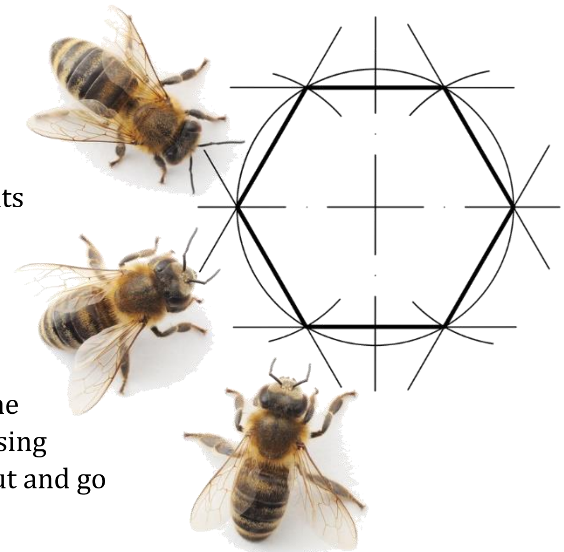
Additional Practice Challenge:



You will need a box of pencil erasers – the kind that go on the end of the pencil. These are inexpensive and are fairly simple to draw. Pass out an eraser and graph paper to each student, along with the following directions: Using graph paper, construct a top view, side view, and bottom view of the eraser. The bottom view is where the hole is in the eraser. Measure in centimeters. Use the scale 1 grid = .5 cm (which is the same as every 2 grids = 1 centimeter). This will make the drawing larger than actual size.[16]

[16] http://nhadulted.org/grants/D35bridgeunit.pdf

Design in Mind?



Show the students sample toothpick planks and columns. Let them know that these will be their construction materials.

Hold up a sample structure or show images – do not let the students look at it too long. They need to have some idea of what they will be doing, but you do not want them to copy the sample structure(s) exactly.

Explain that at the end of the project the structures will be broken/tested to see how much weight they can hold. However, the students will not be able to make the structure strong by simply using a lot of toothpicks or glue; they have to stay within budget. Pass out and go over the basic structure criteria.

Basic Structure Criteria:

- The total budget for the structure is 10 million dollars. We were only able to bring so many resources with us in space! And we're not able to negotiate for more with the humans, yet.
- The toothpicks come in boxes. One box costs $245,000*.
- The glue comes in sets of 2 (1 regular glue/1 small tacky glue) or 1 bottle of tacky glue. One glue costs $205,000*. [Tip: You may want to give out glue in small lidded condiment cups to control use/waste, especially if you are using a mix of glues. They make for easy storage and labeling as well.]
- The labor is 125% of the cost of material.
- The goal is to make a structure that will hold the most weight without collapsing
- The structure must be upright, it must stand, it cannot be flat
- The structures will be weighed, then broken to determine their maximum load. The bridge efficiency will be calculated. The bridge efficiency = load/weight.

*Adjust the budget numbers as necessary to suit your needs and student mathematical abilities.

Assign groups and have each group come up with three structure designs. They will make a decision about which design to use later.

Drawings: Bee Creative!

They can come up with as many tower/structure designs as they would like, but they must pick three for their drawings. You may adjust this requirement to meet the age and abilities of your students. Ex. Younger students may only be required to do one drawing.

Encourage students to get creative with the endless shape possibilities! As we learned from the bees triangles and hexagons are some of the strongest shapes to build with, but if you want to try another hypothesis, go for it!

Think about - what shapes do you think are strong? - what shape do you want for the bottom, for the sides? - where do you think this will fail under load?

Create 3 separate set of drawings, one for each design - for each design create a front, top and side view - use the scale 1 grid = 2 cm - for each design estimate the number of toothpick planks and columns you want to include - write on the drawing any comments or thoughts you might note.

Each group will have the same three designs, but everyone is to have their own drawings. Keep them in your expedition journals.

Extra Challenge: Require older students to test their structure on an angled base!

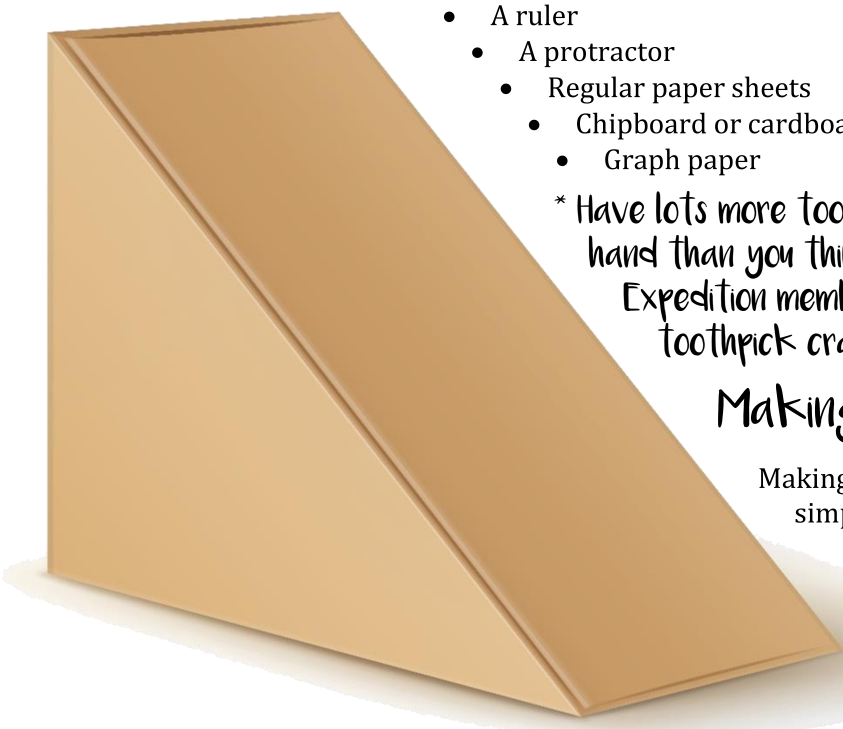
Finalize the Design

Estimate the total number of toothpicks needed, estimate if their structure will stay on budget, and create their final structure drawings. Do a front, top and side view.

Now, the students will build their structures and calculate the actual cost of their structure.

Structure Construction Materials Needed, per group :

- 1-2 packages of regular toothpicks*
- Clear drying glue - a mix of regular and tacky works best
- X-Acto knife or box cutting knife
- Cutting mat
- Wire cutting scissors
- A ruler
- A protractor
- Regular paper sheets
- Chipboard or cardboard boxes- can be any size needed for the base
- Graph paper



* Have lots more toothpicks and glue on hand than you think you'll need! Expedition members tend to go toothpick crazy!

Making the Base

Making the base is very simple. The sample shows an angled base, but feel free to make any type of base (e.g., make or use a regular box base) you would like. First measure out all the sides of your base. If you're going to make an angled base, use the protractor to measure out the angle. Add additional pieces to the inside in order to support more weight towards the middle.

Use your knife to cut the pieces out and then glue them together making sure not to use too much glue. After measuring and cutting the pieces, carefully assemble the base. Be careful not to cut yourself when handling an X-Acto or box cutting knife. Children should ask their instructors for help when cutting with a knife.

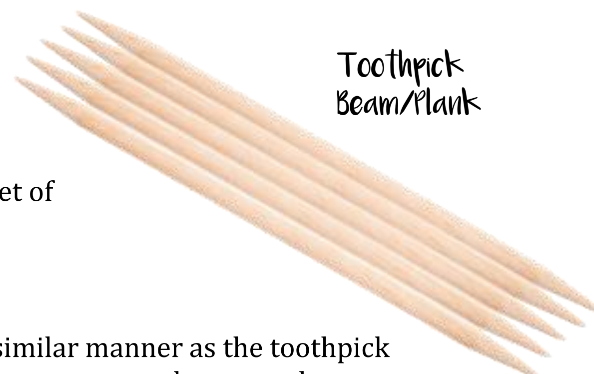
Toothpick Column

Making the Toothpick Structure Pieces

Now time for the fun part! The easiest way to have a successful structure is to think of actual architectural structures such as columns and beams which help to transfer weight to the ground.

Toothpick Columns

1. First create a mixture of tacky and regular glue. Using only regular glue is fine, just expect for it to dry slowly.
2. To make a column of toothpicks, take seven toothpicks and coat them with a generous amount of glue.
3. Using your fingers, gently and carefully make sure to coat all the toothpicks while grouping them together.
4. There should be one toothpick in the middle and six toothpicks surrounding the middle one.
5. Gently place this group of toothpicks on a regular sheet of paper and allow it to dry.



Toothpick Beam/Plank

Toothpick Beams/Planks

Next, make the toothpick beam/planks. These are made in a similar manner as the toothpick columns. Use **five** toothpicks instead of seven and make sure not to group them together.

1. Hold five glue coated toothpicks in one hand between you thumb and your index finger. Be careful not to press too hard because the toothpicks may be sharp.
2. With your other hand, form the five toothpicks **into a plank**, making sure that the toothpicks are touching each other.
3. Carefully slide your fingers across the plank of toothpicks to remove any excess glue and gently place each piece on a sheet of paper to allow them to dry.

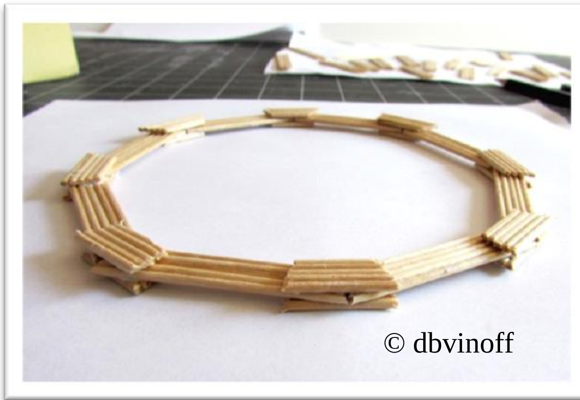
Make sure to make a lot of toothpick columns and beams/planks. Once all the pieces have dried, remove them from their sheets and have them ready for assembly.

Note: Use Caution. The toothpicks may be sharp. If you wish to trim their points off, the instructor may do so with a knife or wire cutter scissors. If after the drying process some toothpick groups haven't fully stuck together, use a little super glue to glue them, just be careful not to use too much and to not get it on your fingers.

Toothpick Structure Assembly

Once all the pieces have dried, use the cutting knife or wire cutting scissors to trim some pieces. **Be careful not to cut yourself when using a knife or wire cutting scissors.** Use the glue mix to attach all the pieces together.

[In the sample by dbvinoff in the photos he/she chose to use an octagon as a primary shape. He/she cut an even angle off of each beam/plank piece for the project. *Go here for more details and step-by-step pictures of the process.*]



Glue the toothpick columns and then brace them with pieces in between. You'll see that it's not very difficult once you start gluing everything together. Allow the pieces to fully dry before testing the structure.

Tip: Sandwiching corners helps the structure stay upright.

Final Testing & Budget Calculations:

For the last step make sure that your structure is fully dry and able to stand on the base properly.

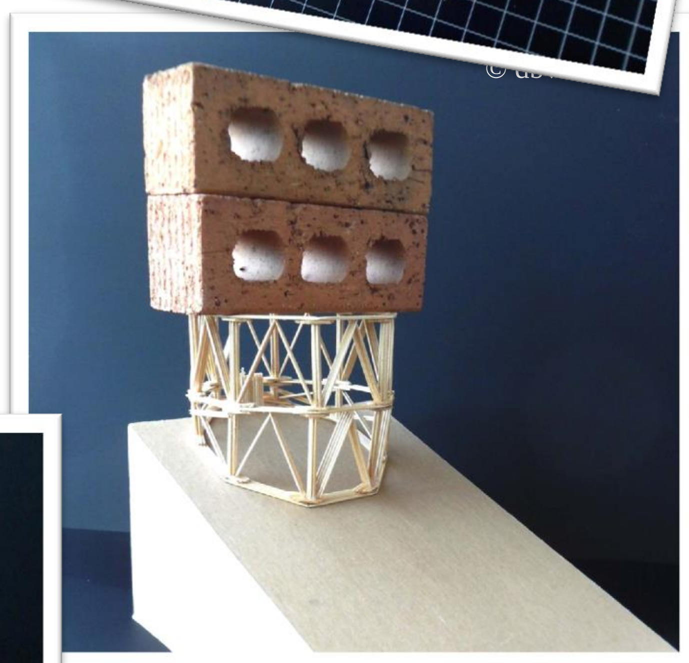
Use a digital scale to weigh each structure.

Have students calculate the final cost of their structure and write it in their expedition journal. Did they stay in budget?

Place each team's structure on the base and see how much weight it can resist. Consider using bricks in order to test the structure's maximum weight.

Have students calculate how much their structure

This sample project was able to withstand the weight of twenty-eight bricks!



Calculate Your Costs

How many boxes of toothpicks did you use total to build your structure?

How many glues did you use?

Add in the cost of labor:

Total cost of project?

Did you stay in budget or go over?

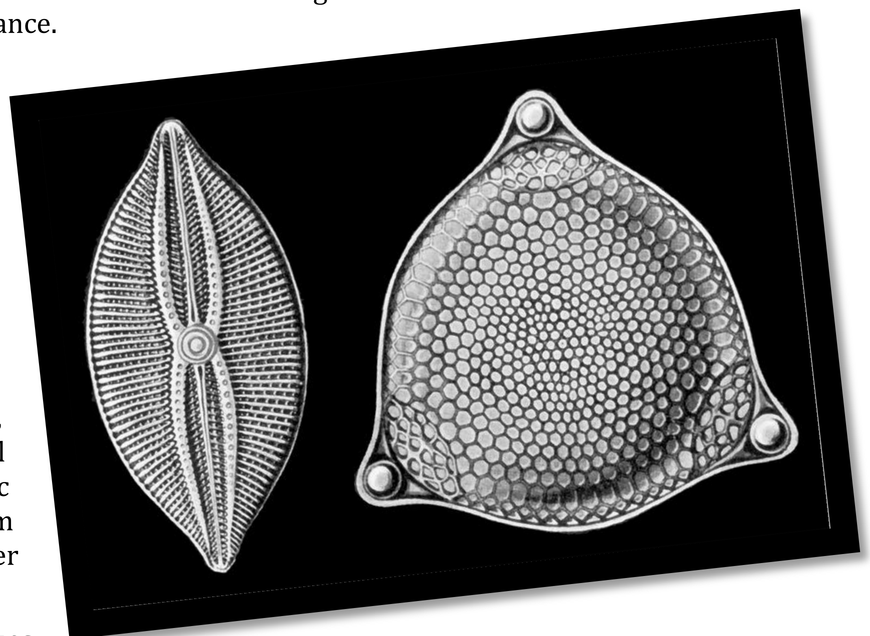
How much does your structure weigh?

How much weight did it hold?

What Does Art Have to Do with Science?:
We're Drawing to Learn

Art and science are intrinsically linked; the essence of art and science is discovery. And for many scientists, the only way to record new discoveries was and is with art! Drawing is not an archaic skill; it is an essential part of the modern scientist's toolkit. Drawing is essential to scientific observation and the once commonplace skill of scientific sketching is as relevant in the digital age as it was in the Renaissance.

Humans have been drawing to record and represent the world around us for thousands of years. The fountain pen and graphite pencil predate compound microscopes and telescopes, all of which scientists used to draw what they observed and invented. Maria Sybilla Merian discovered insect metamorphosis by drawing tropical insects in exacting detail. Leonardo Da Vinci was equally obsessive scientist, inventor, and draftsman. His masterful artworks were based upon scientific knowledge he gained from drawing human anatomy and other natural forms.



Selections from Ernst Haeckel's 1904 *Kunstformen der Natur (Art Forms of Nature)*, showing pennate (left) and centric (right) frustules.

Artists have invented/refined techniques and ways of thinking which spawned a host of technological advancements: pixels, geodesic domes informing virus research, building computer chips, and the nuances of modern camouflage among them.

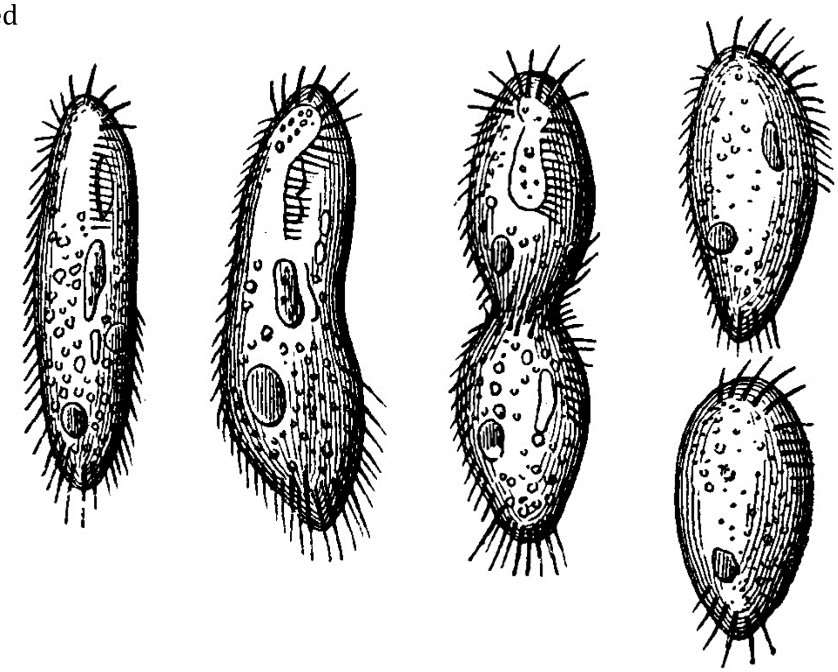
Paleobiologist Anna K. Behrensmeyer writes, “Drawing what you see is more powerful [than photography for learning] about spatial patterns and relationships.” [17]

[18]The importance of observation can be seen in the work of zoologist Ernst Haeckle. From the earliest days of diatom research, specimens have been drawn, either by eye (freehand) or with the help of some kind of drawing aid that is attached to or part of the microscope. The geometric shapes and natural forms, captured with exceptional precision in zoologist Ernst Haeckel's prints, still influence artists and designers to this day. Powerful modern microscopes have confirmed the accuracy of Haeckel's prints, which even in their day, became world famous.

Diatoms don't inspire only biologists and engineers—artists, too, are fascinated by their intricate structures.

[17] Bethann G. Merkle, Why Scientists (Even Nonartists) Should Draw: http://crastina.se/the-crastina-column-july-scientific-sketching/
[18] Public Domain, https://commons.wikimedia.org/w/index.php?curid=483096

During the Victorian age (mid to late 1800s), microscopes were improving and becoming more commonplace. People were fascinated with what everyday objects looked like under a microscope because things looked so different than what people could only see with the naked eye. Some households even had a cabinet of curiosities with prepared slides of items such as bones, insects, feathers, cloth, fossils, and even diatoms. To create diatom art, microscopists would move diatoms around under the microscope with a single human hair mounted on a wooden shaft to create elaborate designs and patterns.[19]



Discuss:

Why and when might scientists draw their observations?

Why is it important to be accurate in drawing?

Why do scientists still need to accurately draw their work?

Diatoms, we just can't resist!

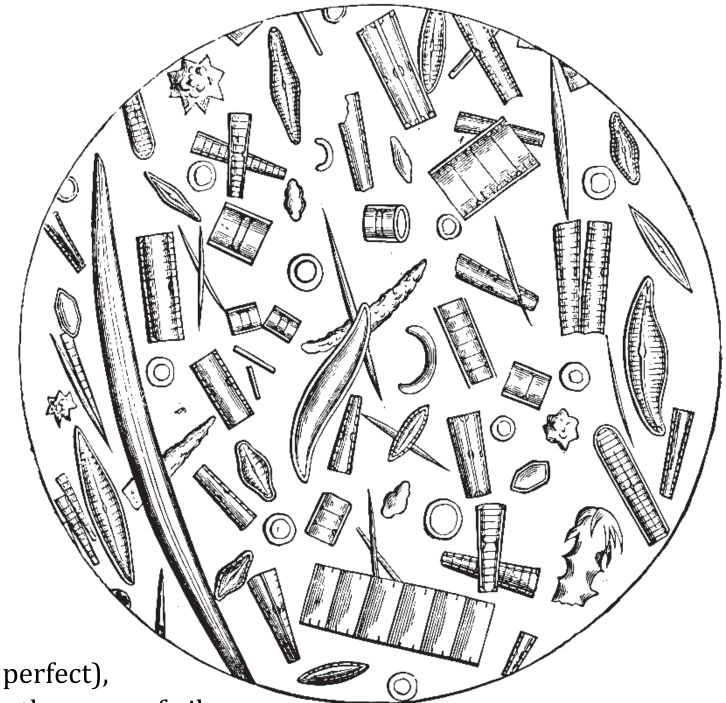
Students will make a painting of diatoms in a drop of water using a watercolor resist technique. Resist means that the crayons will push the paint away from where you draw the lines and they'll show up clearly. To get a clear idea of what resist looks like, check out this video.

We will use a circular format, like we are looking down into a microscope.

[19] Cabrillo Marine Aquarium: http://www.cabrillomarineaquarium.org/_publications/LessonPlan-Diatom-Art.pdf

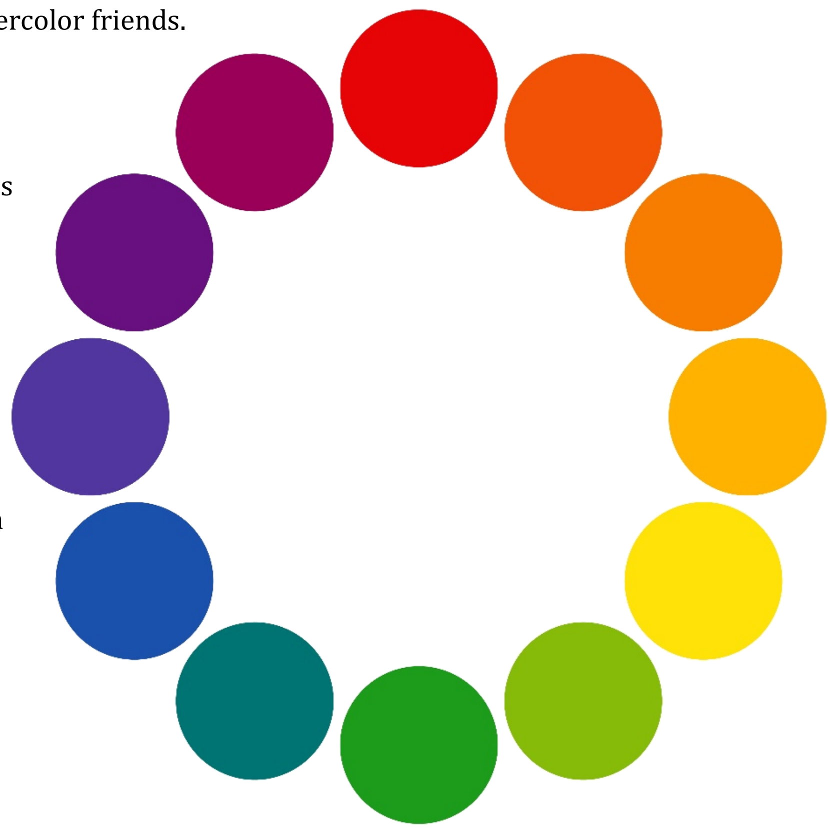
Materials:

- Black crayons or black oil pastels
- Liquid watercolor paints
- White
- Photos of diatoms
- Black Paper (cardstock or construction paper)
- White watercolor paper*
- Glue (sticks)
- Scissors
- Water cups
- Brushes
- Paper towels, for the inevitable spills!
- Concentrated ocean water, if available
- Diatomaceous earth
- Microscope, if available



* With watercolor paper (school-grade 90 lb paper is perfect), the watercolor paint *sits on top* of the surface, avoiding the areas of oil pastels or crayons but blending with their watercolor friends.

Procedure:

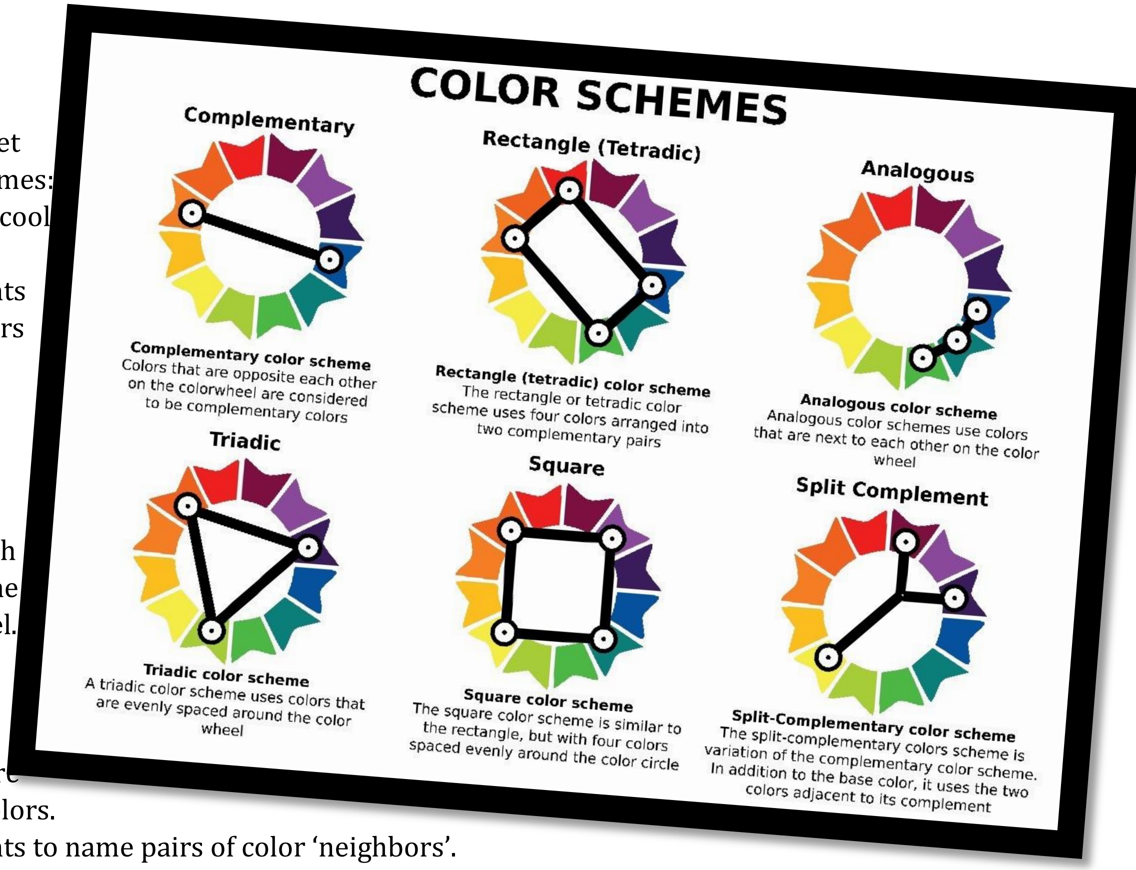


1. Display close-up photos of diatoms.
2. Ask students: Can you find the cell walls in each diatom? The nucleus? Are they symmetrical? Where is the line of symmetry in each?
3. Discuss color. Each of these photographs of diatoms in the unit uses a different color scheme. Which one is a cool color scheme and which one is warm? This color was added by computer and is not the natural diatom color.

Review color and introduce analogous color schemes.

1. Go over basic color theory.
2. Point out and name with students:
3. Primary colors: red, yellow, blue

4. Secondary colors: orange, green, violet
5. Color schemes: warm and cool analogous.
6. Ask students which colors are warm? Cool?
7. Analogous colors are neighbors, next to each other on the color wheel.
8. Many analogous color schemes are just two colors.



9. Ask students to name pairs of color 'neighbors'. RED/ORANGE, RED/VIOLET, VIOLET/BLUE, BLUE/GREEN, GREEN/YELLOW, YELLOW/ORANGE
10. Any two primaries along with the secondary color they create when mixed make a three-color analogous scheme.
11. Point these out on the chart or ask students to try to figure them out and name them RED/YELLOW/ORANGE, BLUE/YELLOW/GREEN, RED/BLUE/VIOLET

Making 'Micro' Art

First! Get out a sheet or two of watercolor paper and a few jars of liquid watercolor paints and give students a quick demo on watercolor resist.

1. Use the included circle template to trace circles onto white multi-media art paper.
2. Cut out the circle and glue it on a backing of black paper (9" x 9" works well)
3. Have students draw diatom shapes on their circles using dark black crayons or black oil pastels.

Remind students to:

- Give diatoms a cell wall and a nucleus.
- Make diatoms symmetrical.

- Add patterns.
- Use lots of variety in shape, size and pattern.
- Let some shapes overlap.
- Let some diatoms go off the edge of the page

4. For younger students, teachers can have different diatom-inspired shapes pre-cut from construction paper or pre-drawn patterns, which students can choose from to arrange in their own radial pattern on their white art paper.

Paint the Background:

1. Paint watery background using wet-on-wet watercolor technique.
2. First, wet a portion of background by carefully 'painting' clean water around diatoms. It should be very wet but not puddled.
3. The waxy black crayon will resist the water and paint, keeping diatoms dry. We'll get to those after we finish the background.
4. Add drops of two analogous colors letting them blend without stroking too much. Use plenty of color, letting it flow into water. Don't worry too much if the colors get muddied or blended. As an art teacher, scientist, and explorer its important to instill a sense of fearlessness in your little artists about using mediums with enthusiasm.

5. Continue wetting portions of the background and adding color until it is complete.

Tip: Be sure to tell your students not to move the paper around a lot when it is wet because the paper may tear easily. They can gently blot (not rub!) with paper towels if necessary.

Paint the Diatoms

1. Encourage students to use contrast to help diatoms stand out. Discuss that that means using a different color scheme (e.g., if students used warm colors for the background, they may want to choose 'cool' colors for their diatoms!) or making them darker than the background.
2. Wait until background is dry to paint diatoms!
3. BUT, if the background is still wet and you don't have time to wait, have students paint the insides of the diatoms first, then go back to the edges. It's important to teach the students to layer the paint by starting out with a light layer (more water than paint) and then building up color if desired.

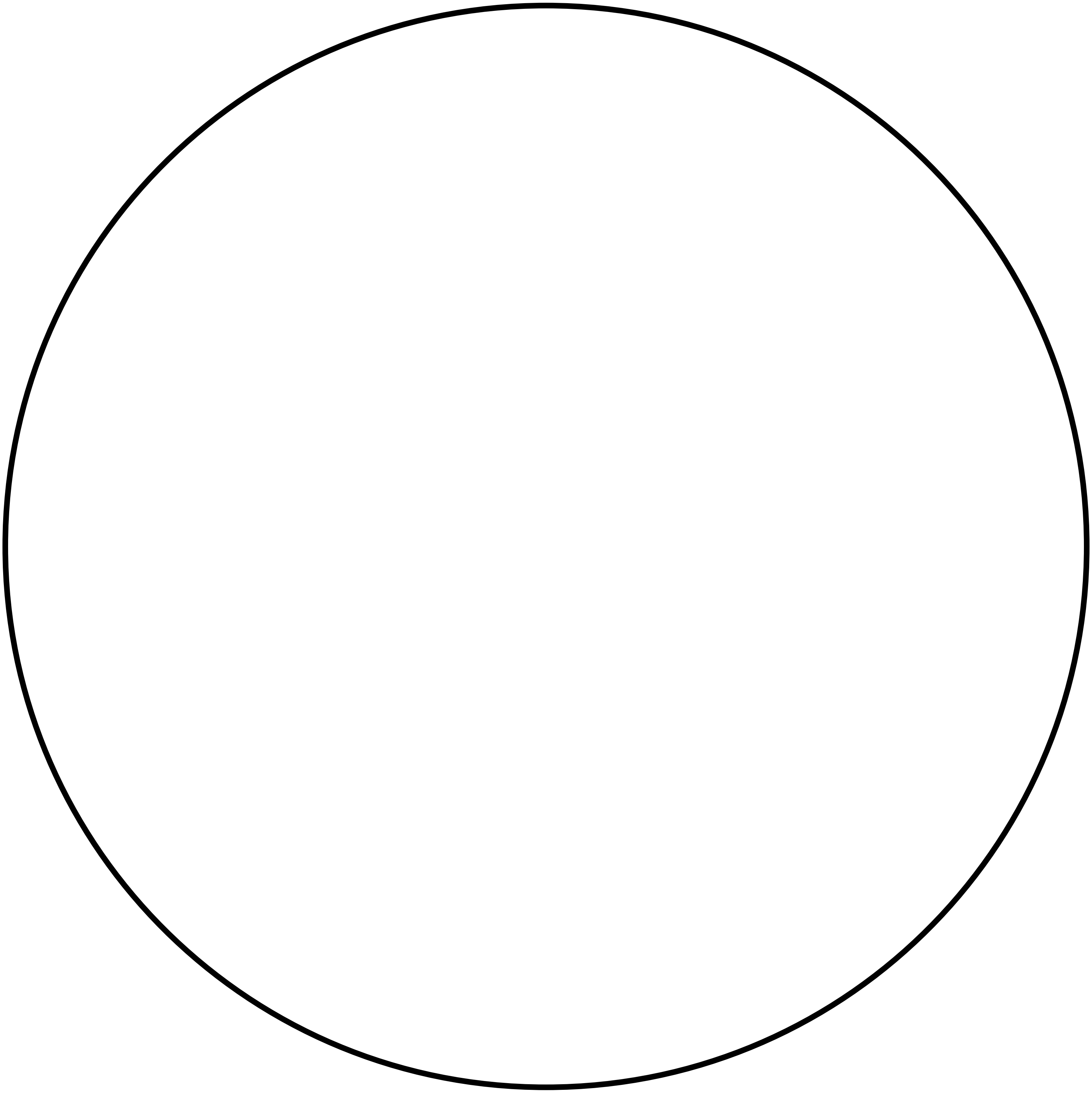
4. Use regular painting technique for painting diatoms, which simply means: Paint on dry paper.

Related Activities:

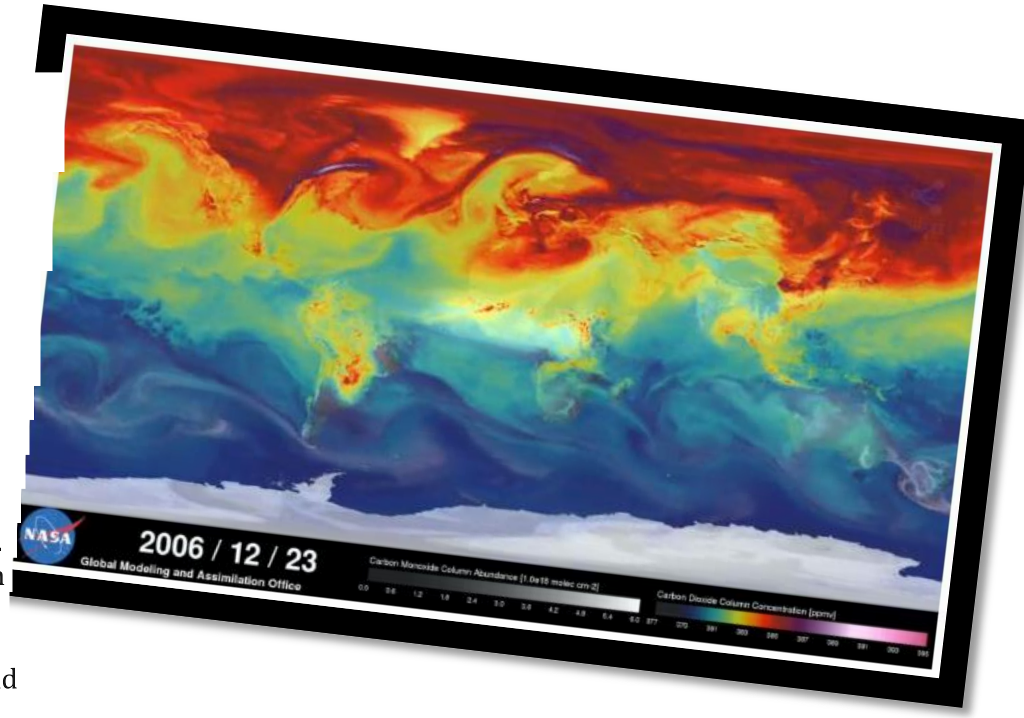
- Have students examine samples of concentrated ocean water under a microscope to look for diatoms.
- Look at food grade diatomaceous earth* under a microscope. Diatomaceous earth forms over a long period of time as millions of these organisms fossilize in lake beds. These lake beds then dry up, exposing the sedimentary deposit that we call diatomaceous earth.

*Inhaling **food grade** DE is no more harmful than inhaling dust. But if you are asthmatic, elderly, smoke, or have small children, be aware that there might be respiratory discomfort or health complications if proper precautions are not taken.

Unlike food grade DE, pool grade diatomaceous earth is dangerous to eat or inhale. This is DE that has been treated at temperatures in excess of 1000°C or 1832°F to change its state to mostly crystalline silica. This increases its effectiveness as a pool filter but makes it unsafe for any other use.



Consider: The Living Planet



What a difference a leaf makes! Well, not just one leaf. We have 3.1 trillion trees on our planet—that's 422 trees per person. If we count all the leaves on all those trees and take a look at what they do collectively to the air around us, the effect is stunning.

If we multiply all those leafy lungs times all those leaves times all those trees and add grasses into the bargain, we're talking about an unimaginably vast planetary breathing system—a giant green machine that pulls enormous quantities of carbon dioxide out of the air, especially in the warmer months.

That's what this NASA video shows us: We get a global view of carbon dioxide. We can see the Green Machine turning on, then, a few months later, turning off. When it's on, when the leaves are out, those ugly, poisonous-looking swirls of orange and red vanish from the sky. The machine works. And this happens every year. It's as though the Earth itself has lungs.

But for all of its lung power, CO_2 concentrations keep building in our atmosphere. Carbon is a building block of life on our planet. It is stored in reservoirs on Earth—in rocks, plants and soil—in the oceans, and in the atmosphere. And it cycles constantly between these reservoirs.

Understanding the carbon cycle is crucially important for many reasons. It provides us with energy, stored as fossil fuel. Carbon gases in the atmosphere help regulate Earth's temperature and are essential to the growth of plants. Carbon passing from the atmosphere to the ocean supports photosynthesis of marine phytoplankton and the development of reefs.

These processes and myriad others are all interwoven with Earth's climate, but the manner in which the processes respond to variability and change in climate is not well-understood yet.[20]

For now, we know that we're apparently pouring so much CO_2 into the sky that the trees can't keep up. Humans emit roughly 30 to 40 billion tons of the greenhouse gas carbon dioxide into the atmosphere each year. If they keep it up, the Earth will continue to heat up and ultimately their way of life will be devastated.

So what can we do about it?

[20] https://www.scientificamerican.com/article/nasa-satellite-will-watch-earth-breathe-from-space/

Most of our scientists agree that we need a way to capture some of that CO_2 to take it out of the atmosphere. One idea is to plant lots of trees. Twelve thousand years ago, a Yale study says, there were twice as many trees on Earth. Trees use CO_2 in order to grow and they also release oxygen, so it's a win-win. Right? It would definitely be helpful! Carbon sequestration through afforestation and reforestation can work as mitigation, together with emission reduction.

But even that can't fix everything. Recent reports indicate that we simply can't grow enough trees to capture the necessary amount of CO_2 to help humans meet the goals set by the Paris Agreement.

We would have to cover the entire US with trees just to capture 10% of the CO_2 humans emit annually.

There's just not enough room on the planet to have the farmland it takes to feed the world plus the space to plant the necessary number of trees. [21]

Watch Earth Breathing:

For 20 years, human NASA satellites have monitored their planet from space, tracking the pulse of life in seasonal patterns as heat moves around the planet, sea ice grows and shrinks, and vegetation blooms and recedes on the continents.

And now, data gathered by a fleet of satellites circling Earth since 1997 have been visualized as a breathtaking time-lapse video of our dynamic planet, capturing the most complete view to date of biology on a global scale, spanning two decades.

Consolidating this data from Earth-orbiting satellites helps scientists to better understand the interconnectedness of all these processes — in the oceans and on land.

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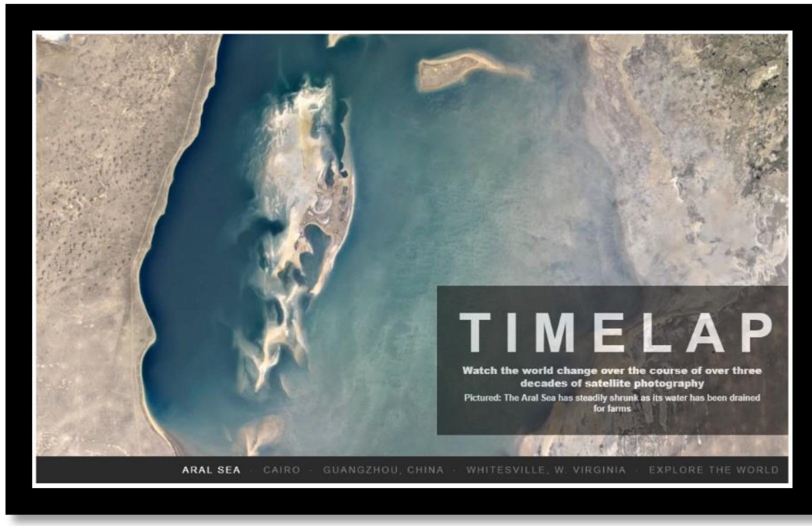
[21] Rob Ludacer and Jessica Orwig, "There's So Much CO2 in the Air that Planting Trees Can No Longer Save Us" *Business Insider* https://www.independent.co.uk/news/science/co2-atmosphere-planting-trees-oxygen-greenhouse-gas-carbon-dioxide-earth-scientists-climate-change-a8116856.html

Take a World Tour (Through Time)

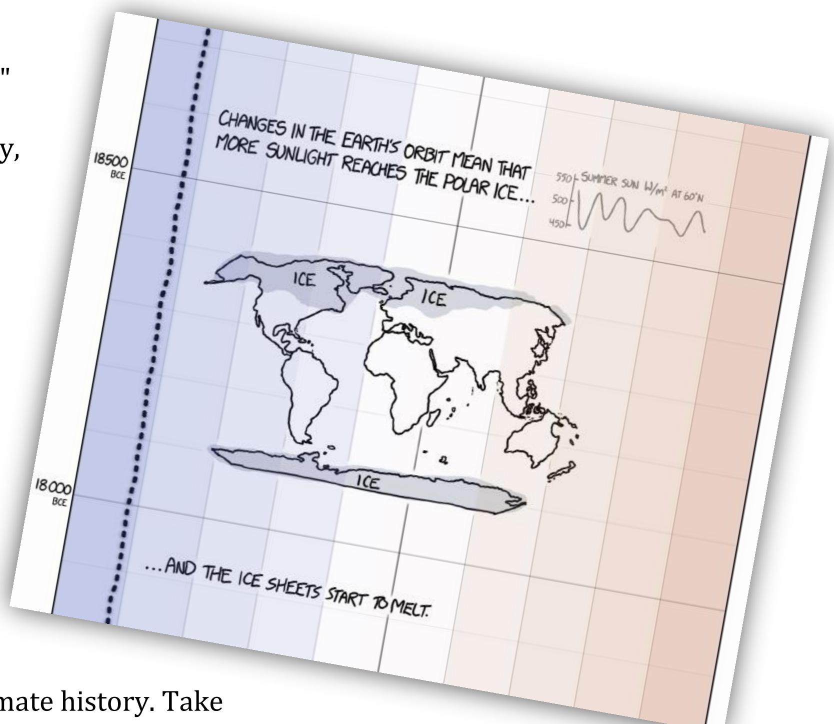


In the years all of the satellites have been flying they've taken millions upon millions of high- definition images, which NASA and the U.S. Geological Survey (USGS) have collated and assembled into something of a flip book that reveals the slow but steady alteration of our world. What the two science agencies started, the folks at Google have finished, turning the usually choppy, sometimes-hazy images into smoothly streaming videos, revealing decades of topographic changes in 10-second sweeps. (Click for source material). Watch the Columbia glacier shrink and disappear and more and more.

When watching these clips what do you notice? What trends do you notice in the data comparisons?

But, it's been warm before!

There's a common line among climate skeptics that "[t]he climate has always changed, so why worry if it's changing now?" The first half of that sentence is undeniably true. Due to orbital wobbles, volcanic activity, rock weathering, and changes in solar activity, the Earth's temperature has waxed and waned over the past 4.5 billion years. During the Paleocene it was so warm that crocodiles swam above the Arctic Circle. And 20,000 years ago it was cold enough that multi-kilometer-thick glaciers covered Montreal, Canada.



Randall Munroe, the author of the webcomic XKCD, has a habit of making wonderfully clear and understandable infographics on otherwise difficult scientific topics. Everyone should check **his take on global warming**. It's a stunning graphic showing Earth's recent climate history. Take some time with it with your students. Stroll through the events like the domestication of dogs and the construction of Stonehenge. Discover that mammoths were still around as the Pyramids were being built. And then ponder the upshot here.

Munroe's comic hits at the "why worry." What's most relevant to us humans, living in the present day, is that the climate has been remarkably stable for the past 12,000 years. That period encompasses all of human civilization — from the pyramids to the Industrial Revolution to Facebook and beyond. We've benefited greatly from that stability. It's allowed us to build farms and coastal cities and thrive without worrying about overly wild fluctuations in the climate.

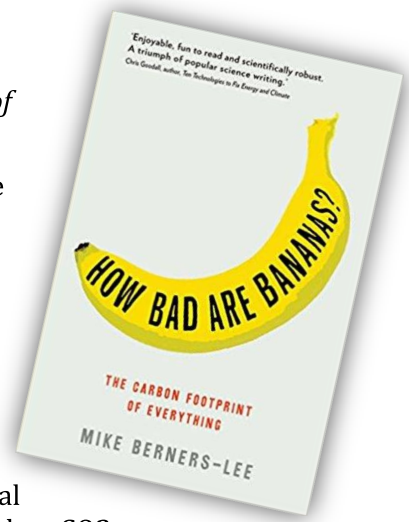
And now Earth is losing that stable climate. Thanks to the burning of fossil fuels and land use changes, the Earth is **heating up at the fastest rate in millions of years**, a pace that could prove difficult to adapt to. Sea level rise, heat waves, droughts, and floods threaten to make many of our habitats and infrastructure obsolete. Given that, it's hardly a comfort to know that things were much, much hotter when dinosaurs roamed the Earth.[22]

What can we do?

The term carbon footprint crops up a lot these days among humans. What exactly does it actually mean? When talking about climate change, footprint is a metaphor for the total impact that something has. And carbon is a shorthand for all the different greenhouse gases that contribute to global warming.

The term carbon footprint, therefore, is a shorthand to describe the best estimate that we can get of the full climate change impact of something. That something could be anything – an activity, an item, a lifestyle, a company, a country or even the whole world.

CO2e? What's that?



Interesting reference guide: *How Bad Are Bananas?: The Carbon Footprint of Everything* ? by Mike Berners Lee

Man-made effects on climate change, or global warming, are caused by the release of certain types of gas into the atmosphere. The dominant man-made greenhouse gas is carbon dioxide (CO2), which is emitted whenever we burn fossil fuels in homes, factories or power stations. But other greenhouse gases are also important. Methane (CH4), for example, which is emitted mainly by agriculture and landfill sites, is 25 times more potent per kilogram than CO2. Even more potent but emitted in smaller quantities are nitrous oxide (N2O), which is about 300 times more potent than carbon dioxide and released mainly from industrial processes and farming, and refrigerant gases, which are typically several thousand times more potent than CO2.

Given that a single item or activity can cause multiple different greenhouse gases to be emitted, each in different quantities, a carbon footprint if written out in full could get pretty confusing. To avoid this, the convention is to express a carbon footprint in terms of carbon dioxide equivalent or CO2e. This means the total climate change impact of all the greenhouse gases caused by an item or activity rolled into one and expressed in terms of the amount of carbon dioxide that would have the same impact.

[22] Brad Plumer "Yes, the climate has always changed. This comic shows why that's no comfort." *Vox* https://www.vox.com/2016/9/12/12891814/climate-change-xkcd-graphic

Beware carbon toe-prints

The most common abuse of the phrase carbon footprint is to miss out some or even most of the emissions caused, whatever activity or item is being discussed. For example, many online carbon calculator websites will tell you that your carbon footprint is a certain size based purely on your home energy and personal travel habits, while ignoring all of the goods and services you purchase.

Direct versus indirect emissions

Much of the confusion around footprints comes down to the distinction between 'direct' and 'indirect' emissions. The true carbon footprint of a plastic toy, for example, includes not only direct emissions resulting from the manufacturing process and the transportation of the toy to the shop: it also includes a whole host of indirect emissions, such as those caused by the extraction and processing of the oil used to make the plastic in the first place. These are just a few of the processes involved. If you think about it, tracing back all the things that have to happen to make that toy leads to an infinite number of pathways, most of which are infinitesimally small. To make the point clearly, let's try following just one of those pathways. The staff in the offices of the plastic factory used paper clips made of steel. Within the footprint of that steel is a small allocation to take account of the maintenance of a digger in the iron mine that the steel originally came from … and so on for ever. The carbon footprint of the plastic toy includes the lot, so working it out accurately is no easy task.

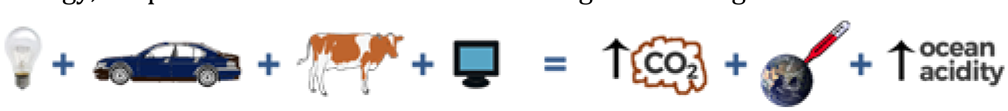
To give another example, the true carbon footprint of driving a car includes not only the emissions that come out of the exhaust pipe, but also all the emissions that take place when oil is extracted, shipped, refined into fuel and transported to the petrol station, not to mention the substantial emissions caused by producing and maintaining the car.

The essential but impossible measure

The carbon footprint is the climate change metric that we need to be looking at. The dilemma is that it is also impossible to pin down accurately. [23]

One of the perennial debates around global warming has to do with the role of individual choices. What responsibilities do individuals have to fight climate change?

Every time we turn on a light, travel by car, eat a meal, switch on a TV, or use anything that requires energy, we produce carbon dioxide and other greenhouse gases that cause climate change.



The challenge involves understanding the causes of climate change and then envisioning and embodying effective solutions so that we, as a planet, can avoid the worst potential consequences.

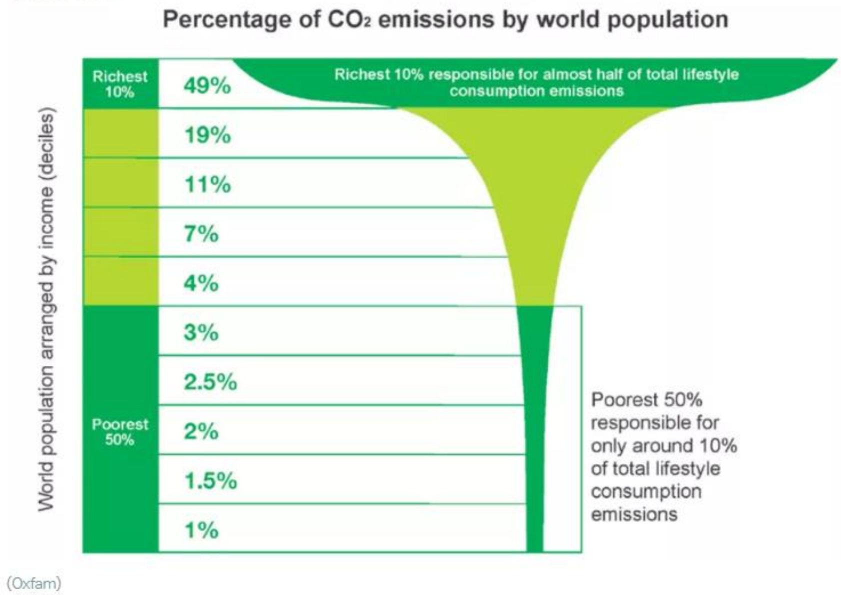
We don't stand a hope of being able to understand how the impact of our bananas compares with the impact of all the other things we might buy instead unless we have some way of taking into account the farming, the transport, the storage and the processes that feed into those stages.

[23] Mike Berners Lee "What is a carbon footprint?" *The Guardian:* https://www.theguardian.com/environment/blog/2010/jun/04/carbon-footprint-definition

First, the global view, which reveals that the wealthiest 10 percent of the population produces almost 50 percent of "lifestyle consumption emissions."

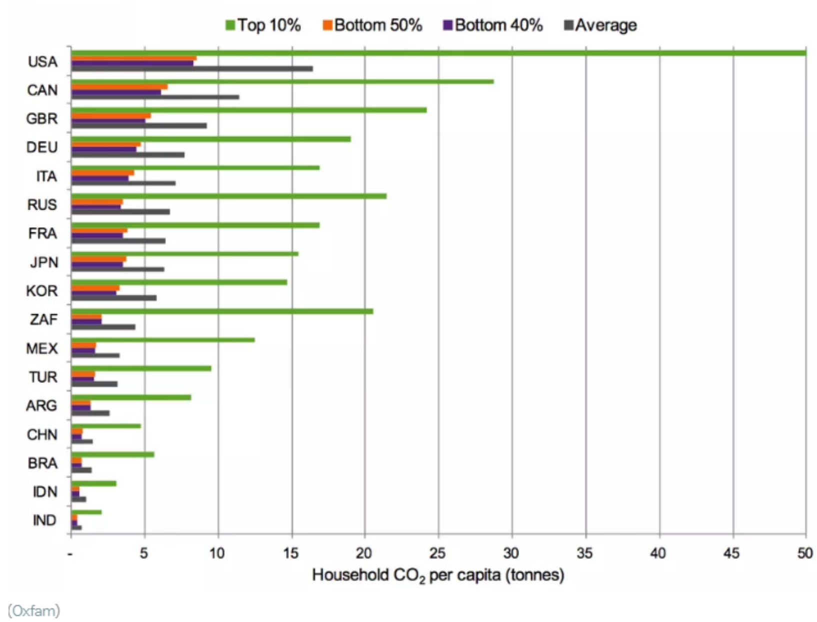
It is rarely stated this way, but it is true nonetheless: Climate change is primarily being driven by the behavior of the world's wealthy. The same disparity holds within countries, none more so than the US. Carbon emissions rise with wealth[24]

Figure 1: Global income deciles and associated lifestyle consumption emissions



[25]Do my choices matter then, if I'm not wealthy? Yes!

Figure 4: Per capita lifestyle consumption emissions in G20 countries for which data is available



Perhaps "Global Warming" or "Climate Change" is still arguable – while other environmental impacts and issues are not. So how should we deal with a situation in which the thing we need to understand is impossibly complex?

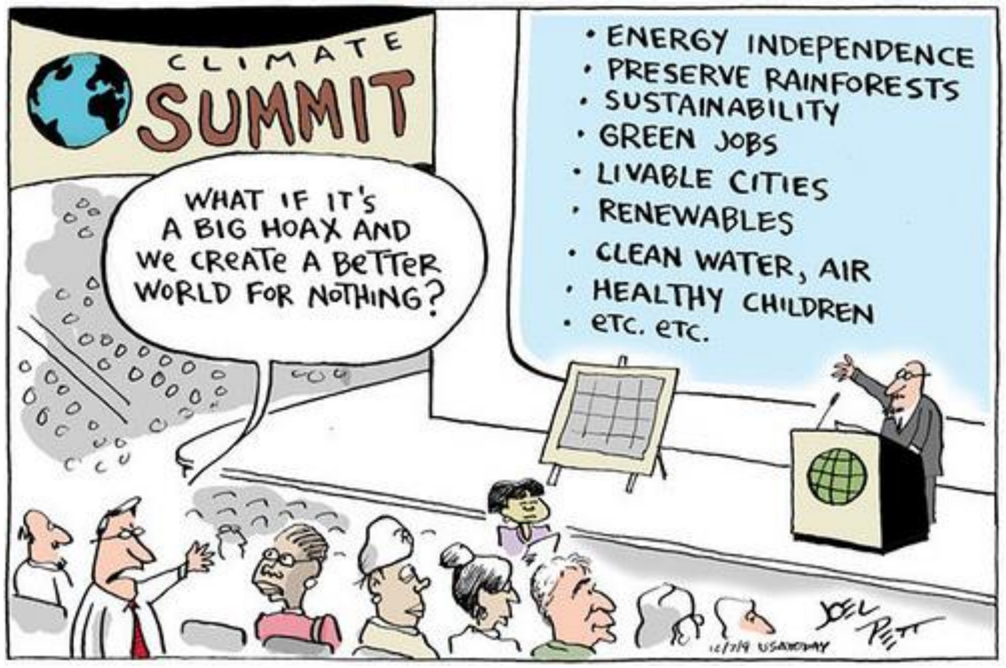
Do the best job we can, despite the difficulties, of understanding the whole picture. Make the most realistic estimates that are possible and practical and be honest about the uncertainty.

What do we want the coming decades and centuries to be like for the 11 billion people who will inhabit the planet by 2100? We want to make this world better by coming here! That much, at least, is up to us. Individual choices are very meaningful with regard to local/regional environmental problems.

[24] David Roberts "The Best Way to Reduce Your Personal Carbon Emissions: Don't Be Rich." Vox.com https://www.vox.com/energy-and-environment/2017/7/14/15963544/climate-change-individual-choices

[25] Comic: Joel Pett, Herald-Leader Cartoonist, First printed USA Today, December 2009: http://www.kentucky.com/opinion/op-ed/article44162106.html

Every individual, by driving less, eating less meat, using less energy, using less water, and producing less consumer waste, can help reduce local/regional air and water pollutants and improve local/regional ecosystems. Being frugal with resources is worthwhile regardless of climate change. Also, those choices are good for your health. Win-win!

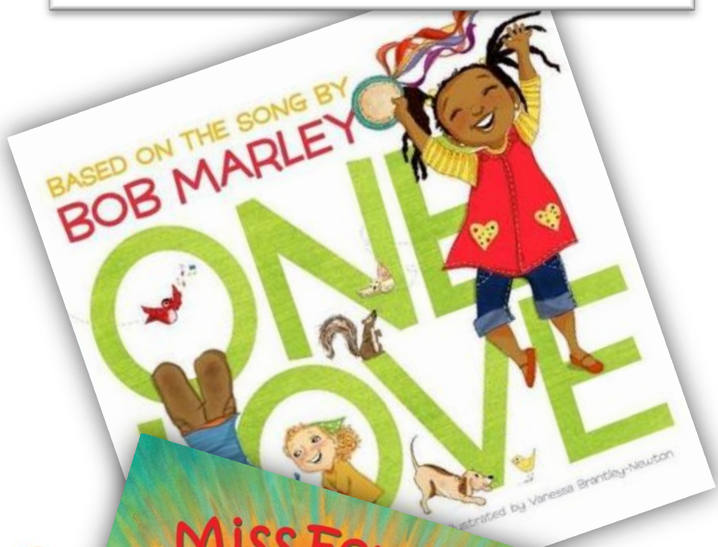


* Another great way to try and reduce carbon emissions is to get involved in politics and policymaking. Just like a global ban on ozone layer killing chemicals is helping heal the ozone layer, global changes to policy can help slow change to the environment.

Go Green!

Our alien visitors have noticed our world is covered in...garbage? They've asked us: How did this happen? And what are we doing about it? Let's see if we can find some answers!

Read books such as *Miss Fox's Class Goes Green* by Anne Kennedy, Here Comes the Garbage Barge by Jonah Winter (based on true history), and One Love by Cedelia Marley, or *The Michael Recycle series* by Ellie Bethel. After the stories, have a class discussion:



Ex. Discuss the way the classroom in the stories went green and how the world, our alien visitors, and our classroom explorers could incorporate some of their strategies and practices.

Use a map and track the travels of the barge with your students and note how many miles the barge actually went while on this great stinking adventure.

Make a plan! Make an impact!

Work with students to create a plan for improving your local environment.

What can we do?

Simple decisions can have an impact, like coloring on both sides of the page, planting a tree, turning off the water when you brush your teeth, or turning out lights when you leave a room.

Others like canceling magazine subscriptions, picking up trash around the playground, river, park, or other area, holding a fundraiser for your favorite environment group, or starting a recycling program can have big impacts too!

Practice the three Rs of conservation: reduce, reuse, recycle. Here are some ideas to get students started.

1. **Reduce: Use Only What You Need!** Here are some easy ways for you to help reduce the trash you create and save natural resources.

- **Use fewer grocery bags!** Bring your own cloth bags to the grocery store when you shop. Or bring back the plastic or paper bags you got the last time.
- **Check it out.** Look for and buy products that have less packaging, ex. Candies that aren't all individually wrapped! But if something you really need comes with packaging (like bottles or cardboard boxes), try to reuse or recycle it.
- **Water matters.** Make an effort to use less water. Figure out how much water each student usually uses to take a shower by trying the Shower Estimation activity. Chart their answers and create a class graph. How many gallons does the class use in total for showers?

  Then come up with ways to use less water like turning off the shower as you wash your hair. You could also ask your parents to install low-flow showerheads or turn off the water while you brush your teeth.
- **Turn it off.** Use less electricity so there's less air pollution. Climb the stairs instead of using the elevator. Turn off the lights, TV, and computer when you're not using them.

2. **Reuse!** Here's a great way to make less waste:

- Be creative and reuse! Find a second use for trash. Can you make something new instead of throwing it away? Can you use a bag a second or third time?

3. **Recycle!** Whenever possible, give an item a second life! Here are some great ways to recycle:

- **Buy recycled products.** Ask your family or school to use recycled paper and other products. You can even buy quality second hand clothes that are often like new at local shops or online at retailers like ThredUp. When you buy recycled products, the message is clear--you want to protect the environment.
- **Be helpful**. Does your town have a recycling center? If so, encourage your family and neighbors to recycle. Paper, plastics, aluminum cans, and glass can all be recycled. If your community or school doesn't have curbside pick-up or a recycling program, write to your elected officials about starting one.

reduce • reuse • recycle

Shower Estimation Activity

1. First, you need to find out how long you spend in the shower. The next time you take a shower, time it. You can use a timer or just look at the clock.

   How long I spent in the shower: __________ minutes

2. Next, find out how much water you used. You can do that by holding a bucket under your showerhead for 30 seconds while you run the water just like you do when you shower.

   Measure how many cups of water are in the bucket:

   I had __________ cups of water in my bucket.

3. Multiply how many cups you have in the bucket by 2 to get how many cups you use in a minute.

   ____________ x 2 = __________ cups of water in one minute

4. Now, multiply your total cups of water (your answer to number 3) by how many minutes you usually shower for (your answer to number 1). That will tell you how many cups you use during your shower.

   _______ cups of water x _________ minutes in the shower = _____________ cups of water while I shower.

5. Divide the answer to number 4 (the number of cups you use while you shower) by 16 to get how many gallons you use.

   _____________ ÷ 16 = __________________ gallons while I shower

6. Bring your completed sheet back to class!

Here's how to start your own clean-up project:

Think of a place that is important to you. It might be a bus stop near your house, your school playground, a nearby beach, or any other place where you like to spend time.

What can you do to help your favorite place look its best? You could pick up trash, remove weeds, add a coat of paint, or donate plants.

Get permission. Get permission before you make big changes, like planting, weeding, or painting. Ask an adult to help you call a city official or the site owner. For example, if you are planting a tree in a park, you should contact the Department of Public Works.

Tell your friends and family. Tell your friends and family about your project and ask if they want to help. Find a day when your helpers will be free.

Mechanical Grabber

Pick up trash without touching it!

ZOOMsci

What You Need

- wire clothes hanger (Use the type with a cardboard tube attached to open-ended wire.)
- string
- rubber bands
- duct tape
- PVC plastic pipe (1 inch in diameter and 3 feet long)
- wooden dowel (1/4 inch in diameter and at least 3 feet long) (You can find duct tape, PVC plastic pipe and wooden dowels at a hardware store.)

1 **Remove** the cardboard tube from the hanger. **Reshape** the two sides to form the "hands" of the grabber.

2 **Straighten out** the hooked part of the hanger (the part that hangs over the rod in your closet).

3 **Attach** a dowel to the straightened hanger with duct tape. **Place** the straightened hanger and dowel into one end of the PVC plastic pipe. The "hands" of the hanger should poke out of one end of the pipe and the dowel should poke out of the other.

4 **Add** rubber bands or duct tape to each of the "hands" of the hanger.

5 **Pull** on the dowel to make the "hands" of the grabber come together and **push** on the dowel to release them.

6 **Try it out.** Can you pick up a piece of paper? A soda can? How can you **improve** your grabber?

Sent In by Girl Scout Troop 2628 of Maynard, MA

ZOOMon

Another simple way to make a grabber is to **create tongs** out of wooden paint stirring sticks (you can get them for free at any paint store), rubber bands, and paper. Which grabber do you think will **work better**? **Try** them both! **Which** would you rather use?

Engineering Scoop

This mechanical grabber makes it easy to **grab trash**. You can lift up trash without bending over. Each **material** plays an important role in the design. The dowel **pulls** the "hands" together to **capture** an item and **pushes** them apart to release it. The duct tape or rubber bands keep the trash from **slipping** off the grabber.

The Weezie Foundation

Collect supplies. Collect clean-up supplies like gloves, trash bags, paper towels, and glass cleaner. Don't forget to make a ***Mechanical Grabber*** or tongs like those by PBS Kids ZOOMSci to help keep your hands clean while you make the Earth cleaner! For tongs all you need are wooden paint stirring sticks (you can get them for free at any paint store), rubber bands, and paper!

Let the clean-up begin! Make sure to bring an adult with you. When your clean-up day arrives, make your favorite place look its best

Safety first. Don't pick up any sharp objects, such as broken glass. If you find something sharp, ask an adult to take care of it for you.

Wait before you throw! If you find any recyclable items like cans or paper bags, don't throw them out! Bring them to your local recycling center instead!

Think about it.

- Who did your clean-up help?
- What did you see and hear during the clean-up?
- How did the clean-up make you feel?
- What did you learn that you did not know before?
- What new questions or ideas do you have?

reduce • reuse • recycle

- Is there anything you would do differently the next time?

Celebrate! Thank everyone who helped you. If you took pictures, you can send some to the friends and family members who volunteered with you. And remember to log your hours and share your story.

Keep helping. Go back to your area once a month to keep it clean. Write a letter to your local newspaper and tell them about your project. Tell them why this place is special to you and what people can do to help take care of it. Remember to send your "before" and "after" pictures, too. [26]

Glacier Dynamics

Glaciers are massive bodies of ice that move across the surface of the Earth like really slow rivers. Glaciers are pretty fascinating things: massive, moving, blue-and-white mountains of ice that destroy nearly everything in their paths, creating landforms such as U-shaped valleys, moraines and kettle lakes, to name a few. For hundreds of thousands of years, the movement of glaciers has shaped land through erosion and deposition.

Glaciers can be as much as 2 miles thick and weigh more than millions of tons. As they move, glaciers can widen and deepen valleys, flatten forests and grind boulders into pebbles. Gravity drives glaciers in 2 ways: by sliding over the bedrock with melt water and by ice building up in the middle, forcing the edges to expand. In the Polar Regions, glaciers are frozen to the bedrock and move very slowly, from 30 feet to a half mile each year. During a surge, glaciers can move as much as 100-250 feet per day for several years before returning to their normal flow. When they move quickly, they develop cracks called crevasses.

Glacier Goo is a really cool way to learn how glaciers transform the earth and literally move mountains—and you don't have to wait a thousand years to see the results.

As glaciers move they change the surface of the Earth by wearing away loose rocks and soil and depositing them somewhere else, ex. In the

[26] http://pbskids.org/zoom/activities/action/way04.html

ocean for diatoms to munch on!

Watch the Fastest Glacier video (running time approximately 5 minutes). Encourage students to take notes as they watch, so they are prepared to discuss the following questions with their classmates.

- How fast does the Jakobshavn Glacier move compared to other glaciers?
- What is the scientists' explanation for the increased speed of the Jakobshavn Glacier?

Materials:

- Two 8-oz. (237 mL) bottles of white glue per batch
- Borax (a powdered soap found in the grocery store)
- Large mixing bowl
- Plastic cup (8-oz. [237 mL] size works well)
- Spoon
- Cookie sheets, plastic trays, and/or PVC pipe ‘chutes’
- Measuring cup
- Dry erase markers/markers
- Blue food coloring
- Plastic drinking straws
- Water
- Paper towel
- Zipper-lock bag (to keep any clean slime in when you’re done)
- Waxed paper
- Spoon
- Graduated cylinder
- Water
- Large bowl
- Gravel
- Sand (or cornmeal*)
- Soil
- Timer
- Sample images of glaciers

Experimental Procedure:

Make Glacier Goo

You’ll make two separate batches of goo—one will be white and the other blue. Measurements do not need to be exact, but it’s a good idea to start with the suggestions below for the first batch.

1. Start with the glue. Empty one 8-oz. (240 mL) bottle of white glue into a mixing bowl. Fill the empty bottle half-full with warm water and shake. Pour the glue-water mixture into

the mixing bowl and use the spoon to mix.
2. Pour the Borax solution into the glue and water and mix into a ball using your hands.
3. Mix the Borax. Measure ½ cup (120 mL) of warm water into the plastic cup and add a heaping teaspoon of Borax powder to the water. Stir. Don't worry if all the powder doesn't dissolve e.
4. Add Borax to glue. While stirring the glue in the mixing bowl, slowly add a little of the Borax solution. You will feel the long strands of molecules start to connect.
5. Abandon the spoon and use your hands to mix. Keep adding the Borax solution to the glue mixture until the goo has a putty-like consistency. You should be able to roll it on the table like dough. Let it rest for a little bit and it will spread itself out.
6. Set that batch to the side.
7. Once combined, the goo should be the consistency of Silly Putty.

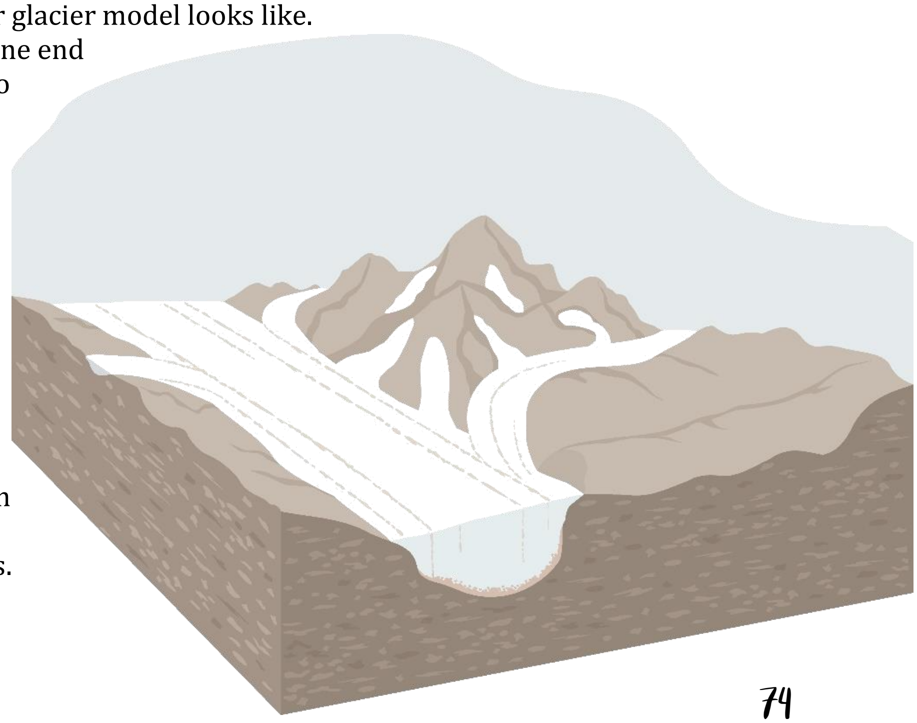
Batch Two: Blue Goo!

1. Repeat the first three steps to make your second batch of goo—but this time, add about 10 drops of blue food coloring to your glue mixture before adding the Borax solution. Try to keep this batch the same consistency as the first.
2. Now it's time to combine the blue and white batches together. There's no right or wrong way, just start twisting and folding the large pieces together until you get a cool swirl of blue and white goo. It's a lot like pulling taffy.

Ice, Ice, Baby! Simulate a Glacier

Create an incline to observe how a glacier moves.

1. Take all of your team's goo and place it at the higher end of your PVC pipe, tray, wax paper, or cookie sheet. Lay the goo out on wax paper on top of a cookie sheet or plastic tray. Press it down so it sticks to the surface.
2. Use a dry erase marker to mark the position of the front end of the glacier (the terminus).
3. Draw a diagram of what your glacier model looks like.
4. Use a few books to prop up one end to create a hillside for the goo to flow down.
5. Start your timer and leave the goo alone while writing down your observations.
6. The Glacier Goo should flow downhill and simulate the movement of a real glacier.
7. Observe how the material behaves. Does it flow? This is much like the way ice deep in a glacier flows. Watch it create some amazing patterns as the mixture flows.



8. Stop your timer when the goo front touches the front of the sheet. Record this time.
9. When it reaches the bottom, pick the blob back up, reshape it into a ball and reset it at the top of the cookie sheet.
10. Compare your time with the rest of the class. What could account for differences? (amount of goo, timer error, location of starting line)

Variation: Going the Distance

1. Place the entire "glacier" at the top of the chute or wax paper on the sheet or tray. Use the dry erase marker to mark the position of the front end of the glacier (the terminus).
2. Use a few books to prop up one end to create a hillside for the goo to flow down.
3. Set your timer for 5 minutes.
4. Mark the new location of the glacier terminus.
5. Measure the distance the glacier traveled from start to finish at the center, the left side, and the right side of the glacier.
6. Determine the rate of flow for all three by dividing distance by time. (Distance glacier traveled (cm) / Time (in seconds))
7. Mark the new location of the glacier terminus.
8. Measure the distance the glacier traveled from start to finish at the center, the left side, and the right side of the glacier.
9. Determine the rate of flow for all three by dividing distance by time. (Distance glacier traveled (cm) / Time (in seconds))
10. Record your results.

Now. Go with the flow! Nice & Slow!

1. Set up the experiment again, marking the terminus of the glacier.
2. Set your timer for 5 minutes
3. Poke the plastic drinking straw through the glacier as close to the top of the glacier as possible.
4. Add 5ml of water through the straw to simulate meltwater seeping down through the glacier.
5. Predict how you think the glacier will flow compared to the first time you ran the experiment.
6. Measure the distance the glacier traveled from start to finish at the center, the left side, and the right side of the glacier.
7. Determine the rate of flow now that you added water and record your results.

Stop & Think:

- What causes glaciers to flow?
- When the glacier initially flowed, what shape did the front of the glacier take?
- What part of the glacier flows the fastest? Why?
- Describe the difference between the flow rates before and after water was added via the straw. Why do you think this change occurs?
- Why is it important for scientists to find out how fast glaciers are moving?

What happens to obstacles in the path of a glacier?

- Place various sizes of rocks on the cookie sheet as obstacles for your glacier. Predict how you think the glacier will flow compared to the first time you ran the experiment. Depending on the size of the rock, it may be picked up and carried downhill or flowed around.
- Sprinkle sand, gravel, and soil in a 1 ½ inch band around the edges of the glacier. Use a marker to mark the perimeter of the band on the waxed paper.

Simulating snowpack:

1. On top of the glacier, place another spoonful of the slime mixture in the center. This is “new snow” over the ice cap during the winter. What do you observe about the perimeter of the glacier?
2. Place one spoonful of the mixture at a time on top of the center of the glacier. After each spoonful, measure how far the ice cap moved. Observe what happens when the glacier reaches the sand. Stop adding “new snow” when the glacier is 1 ½ from the sheet’s edge.
3. Draw a diagram of your glacier. Compare the thickness at its edges and center.

Looking Beneath the Surface/Finding Diatom's Dinner:

Place a second piece of waxed paper on top of the glacier. Carefully turn it over so you can see the bottom of the glacier. Observe and draw a diagram of the bottom. What do you notice about the position of the sand and soil particles?27

Discussion:

• How is glacier goo similar to a real glacier? (Moves slowly, stretches and breaks like glaciers, acts like a solid and a liquid)
• How are they different? (glaciers are compressed snow crystals, goo is sticky, goo does not melt)
• What other variables could you test with glacier goo?
• If a variable was added, what would this experiment serve as? (the control)

The unique, slow-moving properties of the goo simulate the movement of a glacier. At a molecular level, ice is comprised of stacked layers of molecules with relatively weak bonds between the layers. This is similar to the makeup of our goo molecules. Ice can stretch or break depending on the amount of pressure applied. If there is a lot of pressure or a high strain rate, ice will crack or break, causing crevasses in glaciers. When the pressure is lower, or the strain rate is small and constant, ice can bend or stretch.
The steady pressure from the bulk of the ice mass and the pull of gravity cause the glacier to flow slowly (so slowly you can’t see it) downhill, bending like a river of ice.[28]

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[27] https://www.education.com/science-fair/article/glacial-movement-earth-surface/
[28] http://www.mykidsadventures.com/glacier-goo-project/

Related Activities:

Freeze a paper cup filled with water, pebbles and sand. Tear off the paper cup and place the ice on a slanted surface. Observe while the ice is melting and inspect the remains of the glacier (till).

Explore the Interactive Resource Glaciers adapted from the National Park Service:

Shields Up!

The sun. It gives warmth and light. It is the fuel of life on this planet. Without the energy of the sun almost nothing grows, thrives, or lives. People have a fascination with staring at the sun. But the sun was not put there for humanity's benefit. It's not the planet's warm jolly friend. The sun is a monster. A planet killer.

The sun simultaneously gives life and it can destroy life. It's exploding and sending cosmic radiation down at the planet. In fact, given the amount of radiation from the sun there shouldn't be life on the surface of the planet. But there is. Why? How?

The earth's core, the air above, and life itself work to protect the inhabitants. Our star would wipe the planet out in an instant without the incredible planetary shields that work to protect those on the surface. The planet shields those that live upon it with a shield of armor.

In space the temperature degrees are 250 in the sun and -250 in the shade. But even in space we only experience a fraction of the sun's power. It has many weapons it can send our way. Heat, light, and deadly flares that can devastate entire planets.

Take a look at Mars for an example. Scientists think it used to be just like Earth. A potential cradle for life. But radiation from the Sun ravaged it. Solar flares with the destructive power of billions of atomic bombs helped chew away Mars' atmosphere. And the oceans evaporated into space.

Earth is even closer to the sun than Mars. Why is it not dust and ashes? This planet is strong on defense. And every player has a role in that defense. From the edge of space to the deepest of the planet's oceans, everything plays a part in keeping the planet safe.

The Core Truth

What spreads the sea floors and moves the continents? What melts iron in the outer core and enables the Earth's magnetic field? Heat.

Geologists have used temperature measurements from more than 20,000 boreholes around the world to estimate that some 44 terawatts (44 trillion watts) of heat continually flow from Earth's interior into space. Where does it come from?

Scientists have found that studying active volcanoes is one of the best ways to understand what's happening in the center of the Earth and the process that protects us from the sun. Lava is roughly 2,000 degrees. It will burn pretty much anything on contact.

Lava is often radioactive. *[When an atom breaks down, energy is released (causing radiation). An object is radioactive if the atoms that make up that object suddenly become unstable and begin to give off radiation.]*

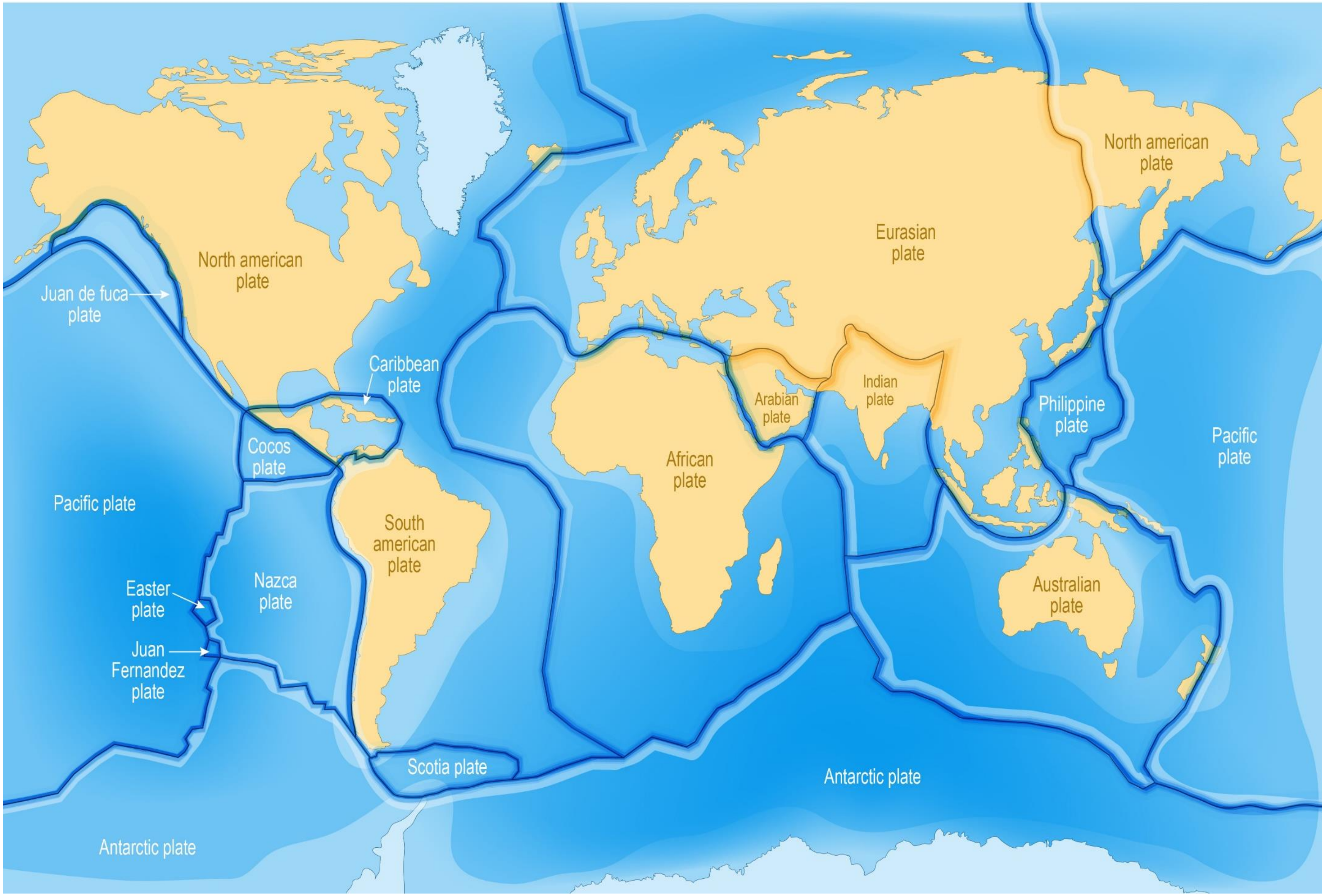
Lava flows can contain uranium and thorium. In 2011 scientists discovered those elements are really important for maintaining the heat of the planet. About 50% of the heat given off by the Earth is generated by the radioactive decay of elements such as uranium and thorium, and their decay products.

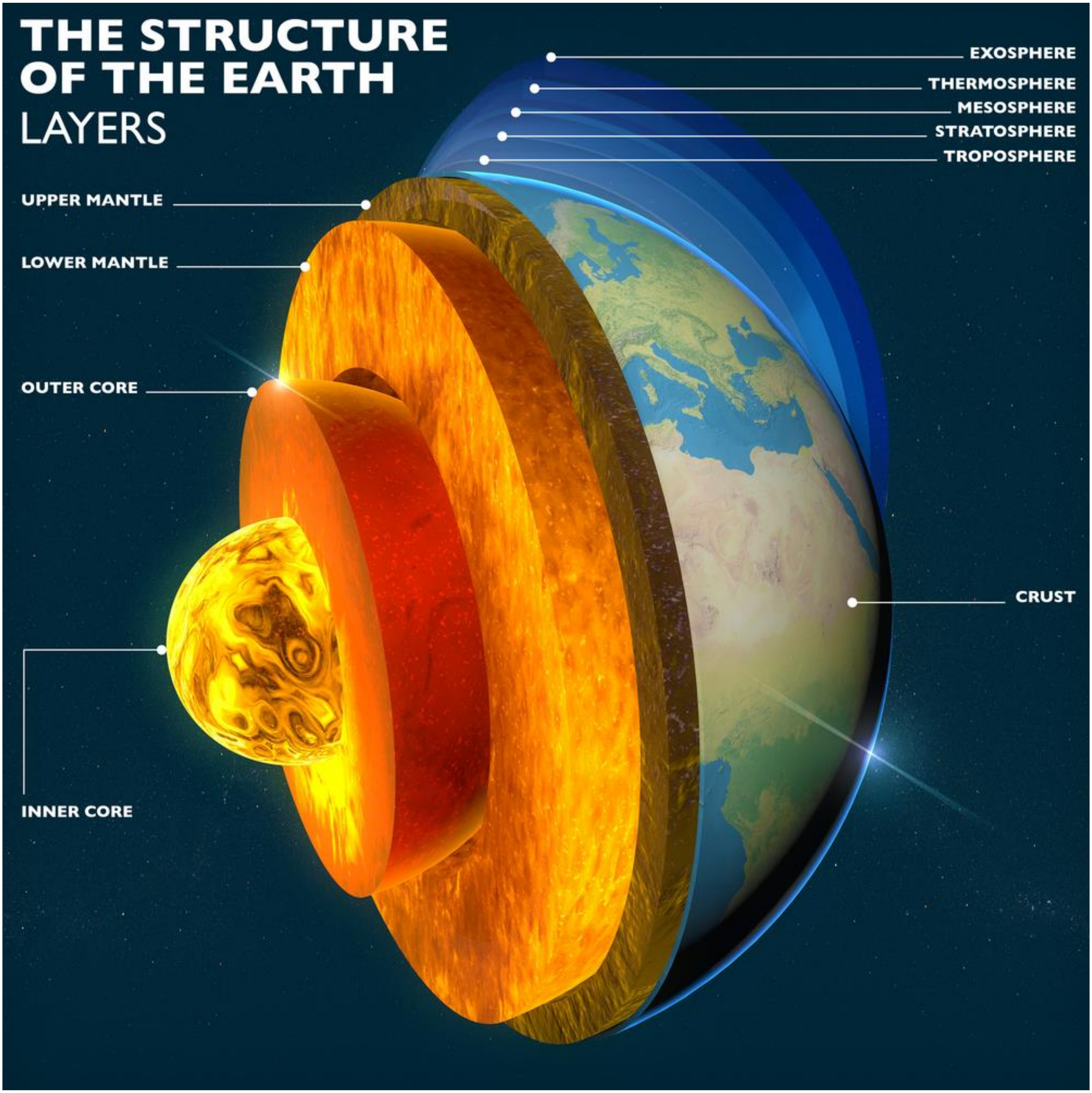
Because radioactive decay proceeds at a known pace, the findings reveal how much heat Earth is losing now and the rate at which it lost heat in the past. In particular, the data may provide insights into how the speeds at which Earth's tectonic plates have moved—movements powered by the planet's heat—may have changed through time.

Eggzactly Like Earth?

Take a hard-boiled egg and crack its shell. Does the egg remind students of anything? The Earth, perhaps? The egg could be seen as a tiny model of the Earth. The thin shell represents the Earth's crust, divided into plates; within the shell is the firm but slippery mantle. Move the pieces of shell around. Notice how the shell buckles in some places and exposes "mantle" in other places. The same thing happens on Earth, but on Earth, this activity results in the formation of mountains, earthquakes, and new ocean floor. Have students put together the plate tectonic puzzle and add it to their discovery journal!

Earth's Plate Tectonics Puzzle: Major and Minor Plates




THE STRUCTURE
OF THE EARTH
LAYERS
EXOSPHERE
THERMOSPHERE
MESOSPHERE
STRATOSPHERE
TROPOSPHERE
UPPER MANTLE
LOWER MANTLE
OUTER CORE
CRUST
INNER CORE

Earth Cracks Us Up!

Expedition members will learn that the crust of the earth is broken into plates and that they move slowly over time. Expedition members will also learn that the effects of plate movement determine various geologic activity on the planet and the current formations of the continents. Have students diagram the various plate movements in their discovery journals.

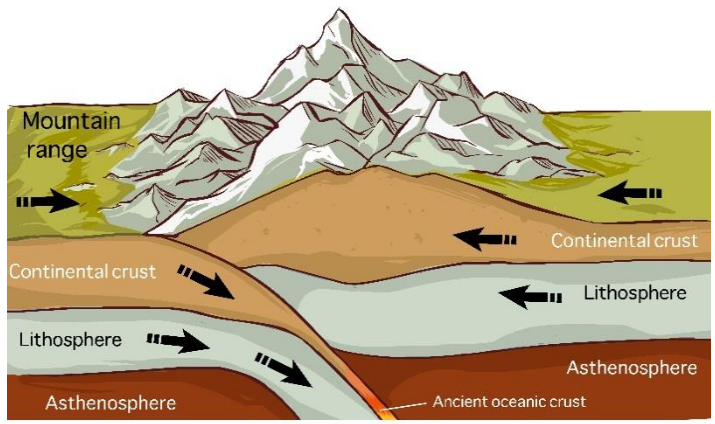
Materials:

- Each student should have ONE double-stuff chocolate cream, ex. Oreo brand, sandwich cookie

Recommended Resource:

Discovering Plate Boundaries
Excellent inquiry-based activity through which students in upper elementary through college can make observations about the patterns of features on Earth's surface – and draw conclusions about Earth's tectonic plates.

Discuss with students how an Oreo cookie might become a model of the Earth. Have them write their ideas in their expedition journal. Remind them of the make-up of the Earth's layers: core, mantle, crust. Focus mainly on the mantle and its semi-liquid molten make-up and the crust (thin layer on the surface of the earth broken into plates). Show the cross-section of the earth's interior, ex. the Oreo.



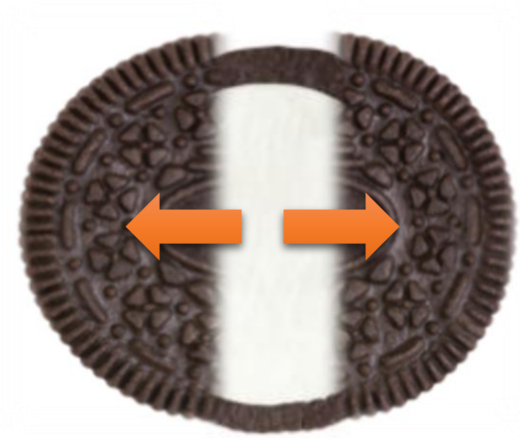
Pass to each student an Oreo and a napkin and explain that they are not to touch or eat them yet. It's best if the Oreo's are room temp/warm so the center is soft .

1. Explain that the plates move upon the semi-liquid mantle around the surface of the earth.
2. The upper cookie is the ***lithosphere***, the creamy filling the ***asthenosphere***, and the lower cookie the ***lower mantle***. (Be sure to get the "Double Stuff" variety, which has adequate asthenosphere)!
3. First, carefully remove the upper cookie (a "twisting" motion is required). Slide the upper cookie over the creamy filling to simulate motion of a rigid lithospheric plate over the softer asthenosphere.

4. Next, break the upper cookie in half. As you do so, listen to the sound it makes. What does that sound represent?

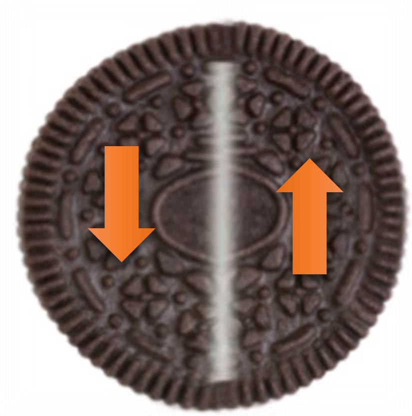
(An earthquake.) Discuss how it takes cold, brittle lithosphere to make earthquakes – earthquakes do not occur in the soft, flowing asthenosphere. Teachable moment tip: some cookies will break in two easily while others may crumble: you can use this to explain that the crust is brittle in some areas and stronger in others.

5. To simulate a ***divergent plate boundary***, push down on the two broken cookie halves and slide them apart. Notice that the creamy filling between the two broken "plates" may tend to flow upward, similar to the rising, decompression, and partial melting of hot asthenosphere at mid-ocean ridges and continental rift zones.
6. Push one cookie piece beneath the other to make a ***convergent plate boundary***. The plates literally, converge, or come together. Note that this is the only situation where the cold, brittle lithosphere extends to great depths, and hence the only place where deep earthquakes occur. The very largest earthquakes are at subduction zones where two plates get stuck together for centuries, then suddenly let go.
7. Simulate a ***transform plate boundary*** by sliding the two cookie pieces laterally past one another, over the creamy filling. You can feel and hear that the "plates" do not slide smoothly past one another, but rather stick then let go, stick then let go. The cracking sound you hear each time is like an earthquake occurring along the San Andreas Fault in California.
8. A ***hotspot*** can be simulated. Imagine if a piece of hot, glowing coal were imbedded in the creamy filling – a chain of "volcanoes" would be burned into the overriding cookie.



Divergent Plate Boundary

Convergent Plate Boundary



Transform Plate Boundary

Plate tectonics is how Earth controls its heat output. And, on average, that heat output also influences geophysical processes such as the overall rate of volcanic activity.[29]

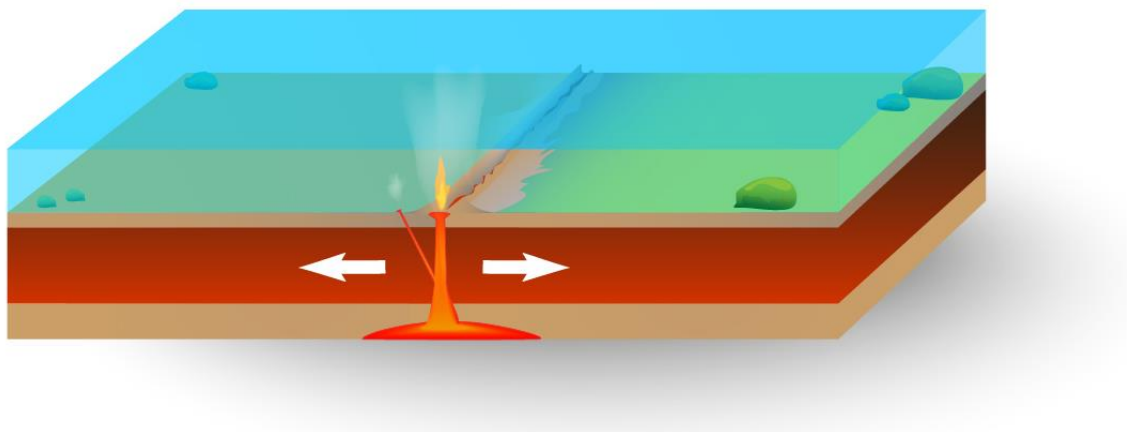
One thing that's at least 97-percent certain is that radioactive decay supplies only about half the Earth's heat. Other sources – primordial heat left over from the planet's formation, and possibly others as well – must account for the rest.[30]

[29] Sid Perkins "Earth Still Retains Much of its Original Heat" *ScienceMag* http://www.sciencemag.org/news/2011/07/earth-still-retains-much-its-original-heat

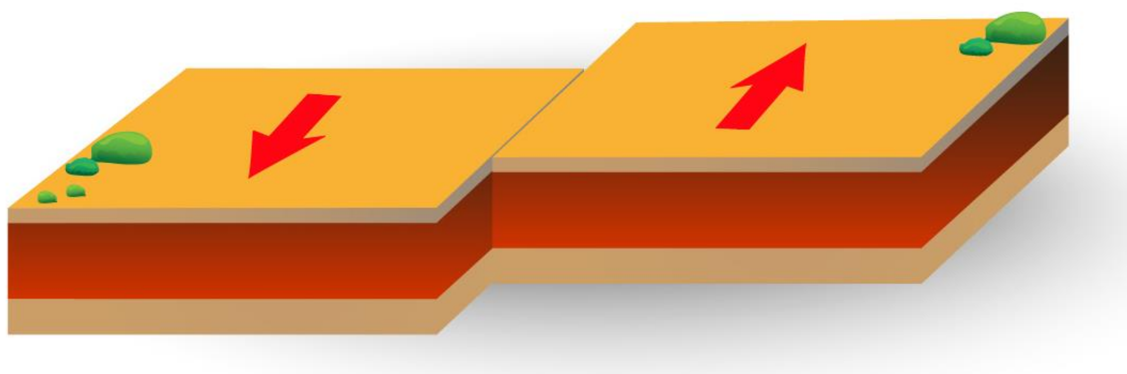
[30] Paul Pruess "What Keeps the Earth Cooking?" *Berkeley Lab* http://newscenter.lbl.gov/2011/07/17/kamland-geoneutrinos/

THREE TYPES OF PLATE BOUNDARY

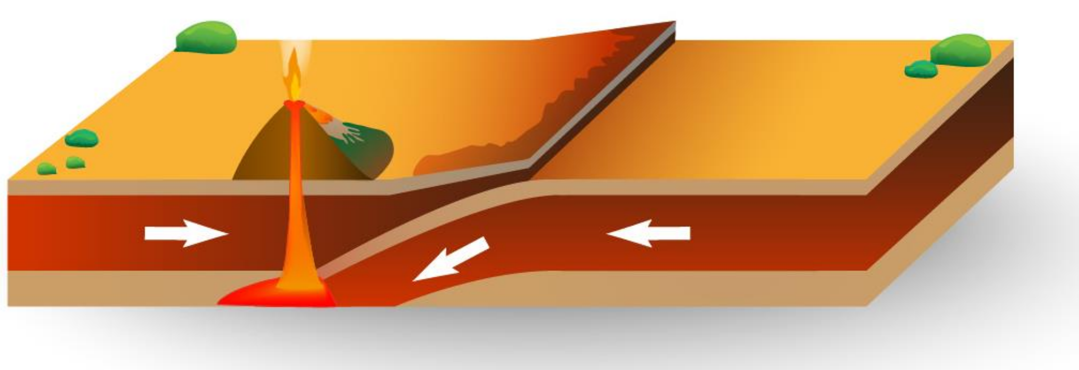
Divergent plate boundary



Transform plate boundary



Convergent plate boundary



Going with the Flow!

Our alien visitors want to know more. After our report about tectonic plates were heading to the Hawaiian Islands to study active volcanoes using Stratigraphy! We have to find it on the map and work in teams to discover more! Keep your journals close and your protective gear on! It's about to get hot!

Materials, per group :

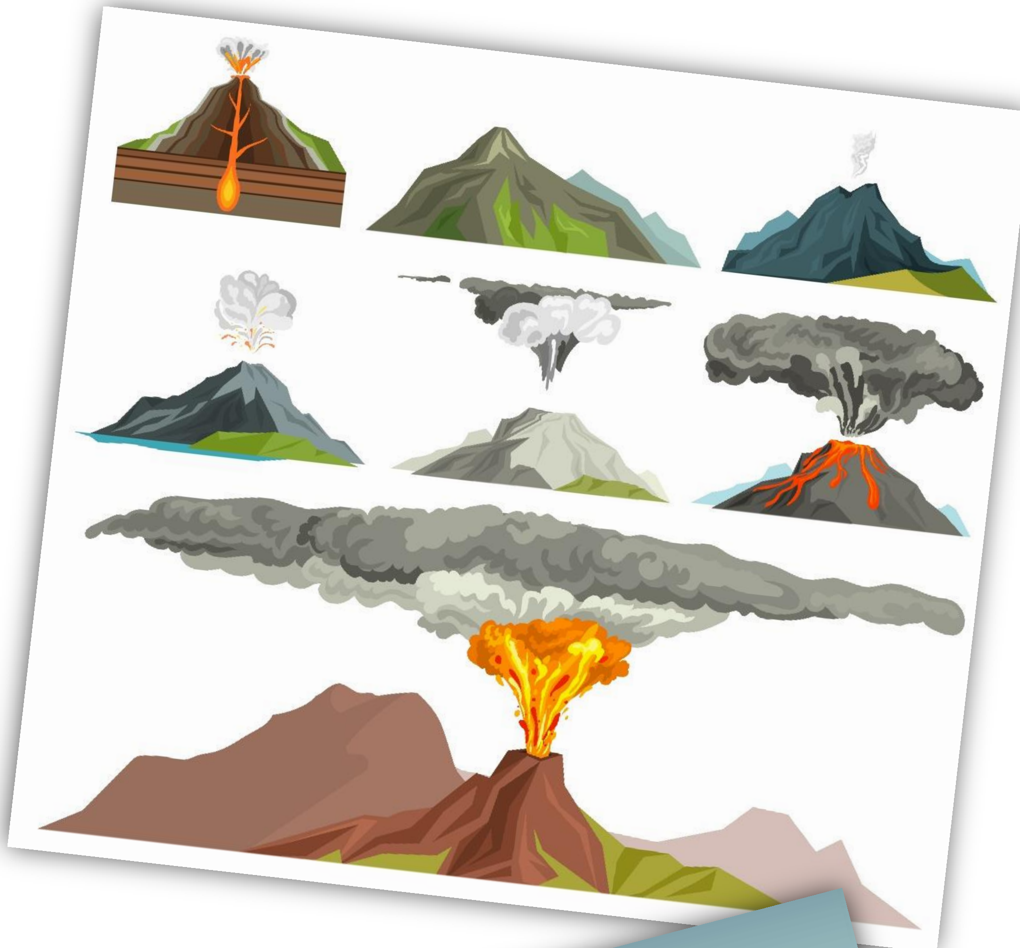
- Short paper cups (4oz size, cut down to a height of 2.5cm)
- 4-7small paper cups (4 oz) or 2 large (6-8 oz) cups
- One sheet of poster-board (per group of four students)
- Cardboard, cookie sheet, or box lid, approximately 45cm2
- Colored pencils (preferably matching the colors of the play dough)
- Plastic spoon
- Plastic knife
- Paper towels
- 1-3 Clear straws cut into 1/3rds
- at least 3, but preferably 4-6 colors of soft clay
- and something to roll the dough flat
- Food coloring
- Vinegar (4-6 oz/100-150 ml) depending on number and size of lava flows
- Baking soda (4-10 spoonfuls, depending on number of lava flows)
- Glue or tape
- Graph paper (2 8.5x11sheets per group)
- Plastic wrap (optional), if done over 2 days

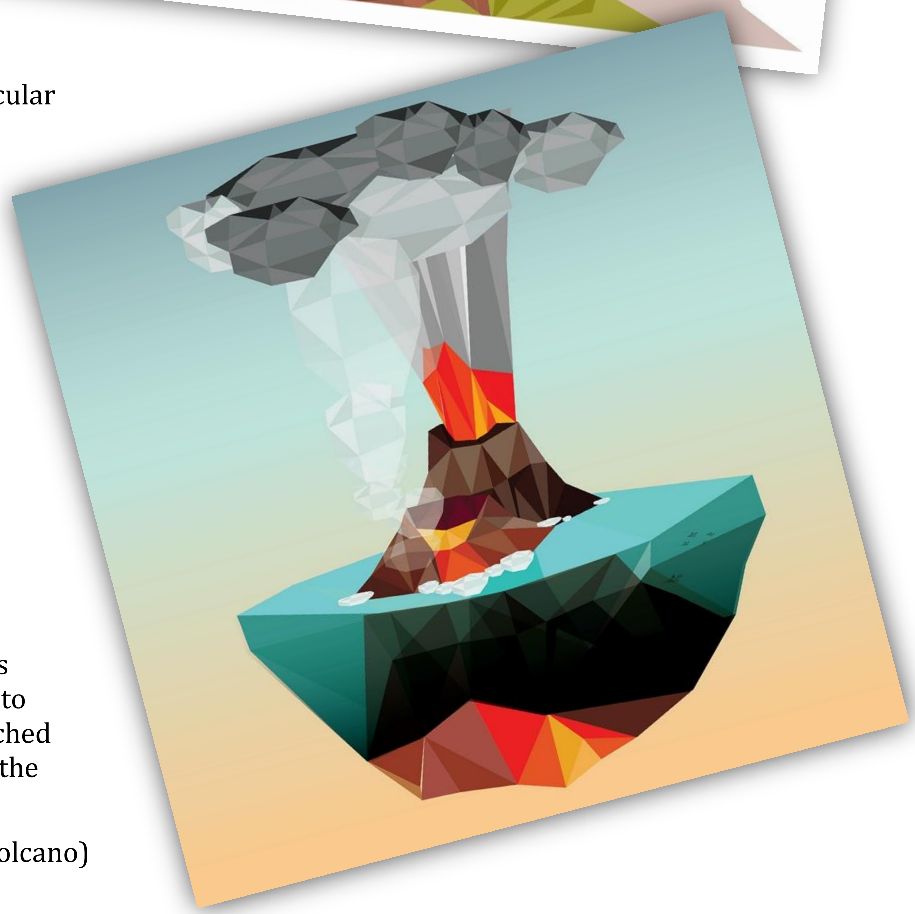
Directions

Have students examine images of volcanoes and discuss what they know about volcanoes.

Sample Questions:

- What is a volcano?
- What are some things that come out of a volcano? (lava, ash, water vapor, carbon dioxide, sulfur)
- Where are some volcanoes on Earth located?
- Are there volcanoes on other planets? (Nearly all the solid planets and moons have some volcanic activity in their history. Some, such as Earth, Venus, and Io are still active.)
- How can we tell volcanoes and craters apart? (Volcanoes have a central crater, raised rims, a circular central opening, and outer edges that are irregularly shaped though roughly circular. However, unlike craters, volcanoes do not have ejecta or an internal central peak. Furthermore, they are raised features while impact craters are low/deep.)
- Does a single volcano form all at once or over a period of time, in stages? (Over time)
- What volcanic features provide hints that it formed in stages? (Stacks of lava layers)





Explain that teams will model lava flows from a homemade volcano. Invite them to examine the poster board with the attached cup (cup having been taped or glued to the poster board).

Ask: What does the cup represent? (A volcano)

Write the following questions (but not the answers!) on a board or chart paper so everyone can see them. The group will discuss them at the end of the activity, so teams should prepare answers as they work.

- Do all the flows occur on top of each other? (Not always)
- How do earlier flows influence the direction of later flows? (Later flows may flow off to the sides of the earlier ones)
- Does anything else influence the path of lava flow? (Direction of flow out of the volcano)
- Where does the oldest layer occur relative to later flows? (On the bottom)

Part One: Volcano Fun!

Have teams:

1. Cut the top of the small paper cup so that the cup is 2.5 cm high.
2. Place the small paper cup in the center of each piece of graph paper and trace around it with a pencil.
3. Secure the small paper cup (right-side up) onto the cardboard using a small loop of tape on the bottom of the cup. This short cup is your eruption source (eventual caldera) and the cardboard is the original land surface.
4. Mark north, south, east, and west on the edges of the cardboard and the graph paper, orienting them similarly on the table.
5. Fill about half of a large paper cup with baking soda.
6. Place one heaping (table)spoonful of baking soda in the short cup.
7. Fill each of the four (to six) small cups with approximately 1/8 cup of vinegar. Optional: Add to each cup three drops of food coloring, making each cup of vinegar a different color (to match the available colors of dough). If you don't have enough food dyes or wish to skip this you can simply put the vinegar in a large cup.

8. You are now ready to create an eruption. Have each team pour one (or part of) of its cups of vinegar into the "volcano." The vinegar and baking soda will react and bubble over the edge of the "volcano."
9. When the "eruption" has quieted, have the children use a pencil to outline the edge of their "lava flow."
10. Dab up the fluid with paper towels.
11. Have the children select their dough color (that matches) to mark the first lava flow. They should flatten the dough into a thin sheet (about the thickness of a clip-board) and place it over the area they marked, covering any area where the lava flow extended. (Trim the dough sheet with the plastic knife to match the lines)
12. On one piece of graph paper, use the colored pencil that matches the play dough color to draw an outline representing the edge of the play dough, being sure to maintain the cardinal orientation (north, south, east, west) of the paper with the orientation of the volcano. Shade in this lava flow drawing. Make a note on the graph paper regarding the order of eruptions (which color came first).
13. Repeat steps 6 - 12 for each color of play dough available. Four to six flows show a good example of a shield volcano, but three flows will be adequate for a simple shield volcano model.
14. Notes: The source cup may be cleaned out as needed. Be sure to mark the entire area of each lava flow – over previous flows and on the cardboard. On subsequent flows, students will need to dig into the underlying play dough with their pencil to mark the flow area.

    Remind the children to be gentle when placing layers of dough on top of each other; **they should not smash the layers together**. The result will resemble a strange layer cake with new flows overlapping old ones.
15. If time is short, cover each volcano with plastic wrap and return to the activity the following day.

Part Two: Switcheroo

Alright teams. We've had time to practice, but our alien visitors want to know more. It's time to divide and conquer. You're headed to a mysterious volcano and it's your job to learn as much as you can. You can even name it. Keep good notes in your expedition journals! *This portion of the lesson is designed to promote the use of higher-order thinking skills and encourages the* questioning, predicting, testing, and interpreting sequence that is important to scientific inquiry.

1. Have teams trade volcanoes so that they can investigate and map a volcano with an unknown history. They may give the volcano a name if desired.
2. Explain to students that they are to act like planetary geologists who have just come upon this volcano and must determine its history and create an accurate map representing its formation.
3. Have students orient and label their blank piece of graph paper to match the cardinal (north, south, east, west) directions of their volcano.
4. Have students draw the visible layer(s) of the volcano to scale on the graph paper using a ruler and colored pencils.
5. Discuss that there is much detail that can't be seen from the surface.
6. Have students answer questions 1-6 on the student worksheet. Note: Some volcanoes may be more complex than others. Each will be different! There may be flows that are completely covered, some flows that have two separate lobes, and some flows for which the sequential relationship cannot be determined at the surface.

Digging Deeper

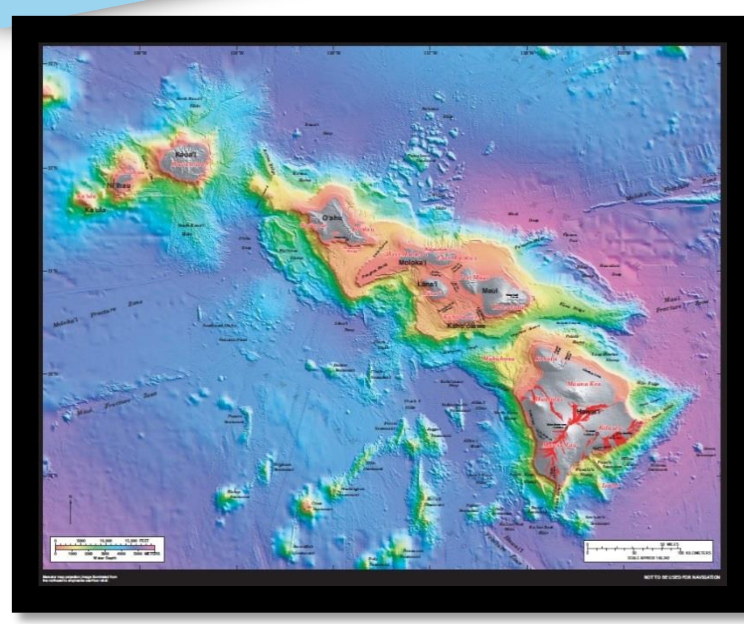
Lead the students to question what they cannot see below the surface. Where do the flows extend under the exposed surface? Ask students to hypothesize how geologists investigate such hidden details. Then discuss various subsurface exposure techniques including core sampling, erosion cuts, road cuts, earthquakes, surface-penetrating radar, etc.

Have your discovery teams make a plan in their journals that shows on their map where they want to investigate the layers of their volcano using the subsurface exposure techniques discussed above. They should indicate how the proposed cores and cuts will maximize the information they might gain from excavations. Limit the number of exposures each group may use, e.g., five drill cores and one road cut and one river erosion.

To make the cuts or cores on the volcano models:

Remove a core sample by pushing a straw vertically into the play dough until encountering the cardboard surface, twisting if necessary, and withdrawing the straw. The various layers of play dough will be visible in the core sample inside the straw. Lay the straw containing the core sample next to the hole from which it was taken.

- **River valleys** may be made by cutting and removing a V-shape in the side of the volcano (open part of the "V" facing down slope).
- To make **road cuts**, use a plastic knife or dental floss to cut and remove a strip about 1-cm wide and as deep as you want from any part of the volcano.
- To make **earthquake exposures**, make a single cut and lift or drop one side of the fault line. Some support will be necessary.



7. Record cuts and cores on the map and in notes. Be sure to use location information, e.g., core No. 2 is located on the blue flow in the northeast quadrant of the volcano.
8. Observe hidden layers. Interpret data and draw dotted lines on the map indicating the approximate or inferred boundaries of the subsurface flows. Color in flow areas.
9. On a separate paper, have students write a short history of the volcano that relates sequence of flows and relative volumes of

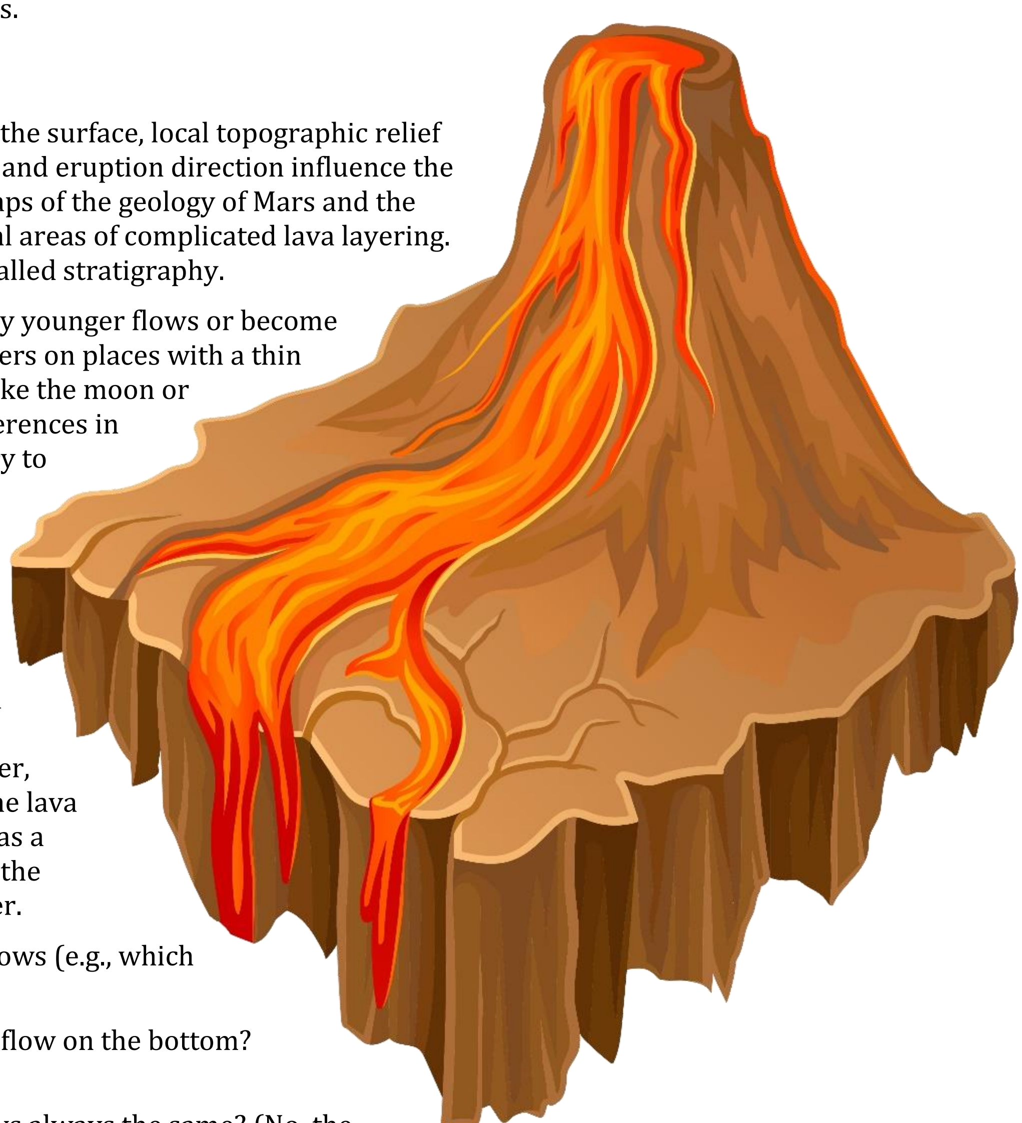
flows (or make a geologic column, a map key showing the history of the volcano with oldest geologic activity at the bottom and youngest at the top). A math challenge would be to try to compute the volume of the various flows.

Compare the history developed through mapping in Part 2 with the original history from the group that made the volcano in Part 1. Have students write how they are similar or different.

Examine **volcano maps** created by geologists. How are these similar to and different from the maps students created for their volcano model?

Option: Allow students to make more cuts or cores (within specified reasons) to see if they are able to better refine their maps.

Discussion Points:



Generally, the overall slope of the surface, local topographic relief (small cliffs and depressions), and eruption direction influence the path of lava flows. Detailed maps of the geology of Mars and the moon from photographs reveal areas of complicated lava layering. The study of rock layering is called stratigraphy.

Older flows become covered by younger flows or become more pocked with impact craters on places with a thin or non-existent atmosphere, like the moon or Mars. Field geologists use differences in roughness, color and chemistry to differentiate between lava flows. Good orbital images allow them to follow the flow margins, channels and levees to try to trace lava flows back to the source area. Core samples, cylindrical sections that show various layers beneath an exposed layer, are obtained by drilling into the lava flows using special drill that has a hollow steel tube allowing for the extraction of subsurface matter.

What is the vertical order of flows (e.g., which is on the bottom, top, etc.)?

What is the relative age of the flow on the bottom? (Oldest)

Is the vertical order of the flows always the same? (No, the model may have locations where a layer is missing)

Is the order always the same in terms of timing? (Yes, older layers are always under younger units)

The study of rock layering is called stratigraphy. One of the rules of stratigraphy is called the principle of superposition. It states that older rocks occur under younger rocks. In other words, the rocks on the bottom were laid down first and then covered by more recent deposits.

Another rule of stratigraphy is the principle of cross-cutting relationships. It states that any feature (fault, crater, intrusion) must be younger than the rock that it "interrupts” because the rock was there first and the fault, crater, or intrusion happened after the rock was formed. You can’t have a crack before a rock.

- What could the expeditionary have done differently to improve the accuracy of their maps?
- In what ways are these model volcanoes similar to real volcanoes?
- In what ways are these model volcanoes different from real volcanoes?

What's your recommendation to our alien visitors? Should they live near active volcanoes?

Going with the Flow Student Worksheet

Directions: Use colored pencils to make a map on graph paper of the volcano model as seen from above. Label flows and features. Keep this sheet in your Expedition Journal.

1. How many flows can you see?

2. In addition to the map, make a list of the lava flows, starting with the youngest flow at the top and finishing with the oldest flow at the bottom. Example: "Top flow is a long, skinny, green flow."

3. Can you easily determine the sequence of flows which came first, which came last or are there some flows where you can't say which are younger or older? Put a question mark by the uncertain flows in the list on the map.

4. Are there parts of any flows that might be covered? Which ones?

5. What would you need to figure out the sequence and shape of each flow? How could you get that information without lifting the play dough? Write down your ideas.

6. Think about what techniques will help you learn more about the interior of your volcano. We're going to have a class discussion about these techniques before you experiment.

Going with the Flow Student Worksheet Continued

Experiment!

1. Document why each proposed experiment will be helpful in revealing information about your volcano. Conduct the experiments and record locations and information gained.

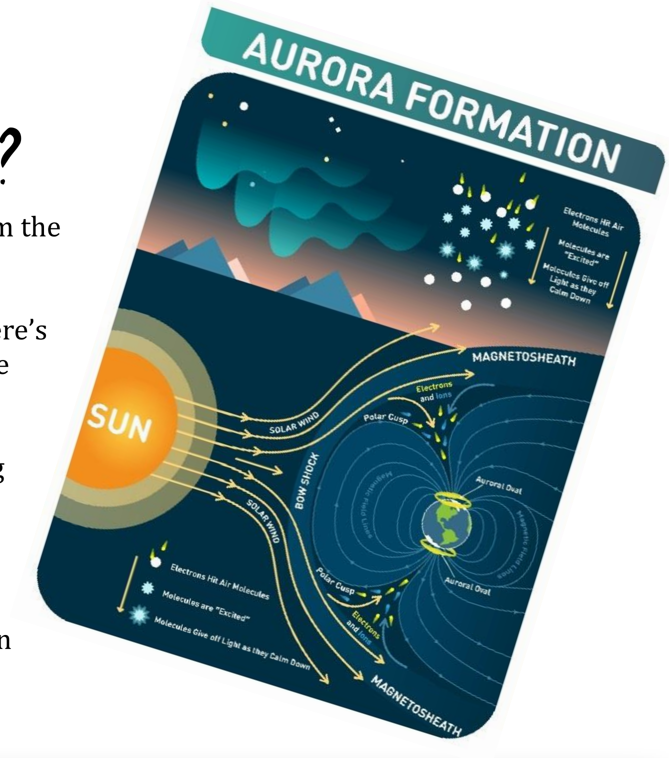
2. Finish your map. On a piece of paper, describe the sequence of flows that tells the history of the volcano. Compare your map and sequence to the map and history documented by the group that originally made the volcano. Was your interpretation accurate? Explain.

3. Why would it be harder to map lava flows on the planet using images taken by our spacecraft?

What do volcanoes prove?

What does any of this have to do with keeping us safe from the Sun?

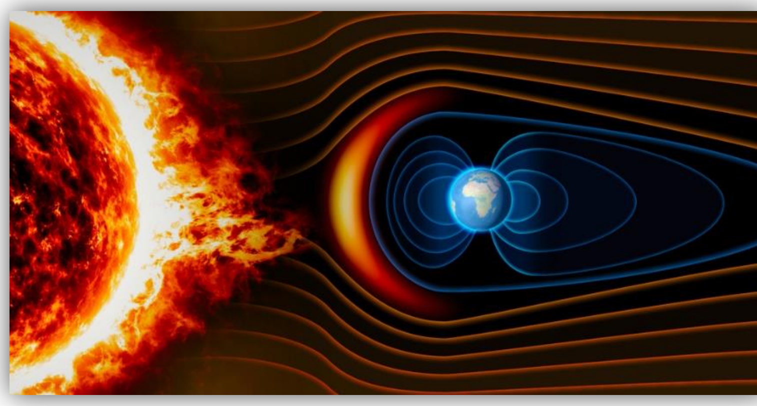
Radioactive lava up at the surface of the planet proves there's a raging nuclear furnace at the heart of the planet. It is one big ball of incredible heat. But that's not all. The molten insides are full of iron and nickel. Rising falling and spinning in a constantly melting furnace. All that churning metal creates its own magnetic field.



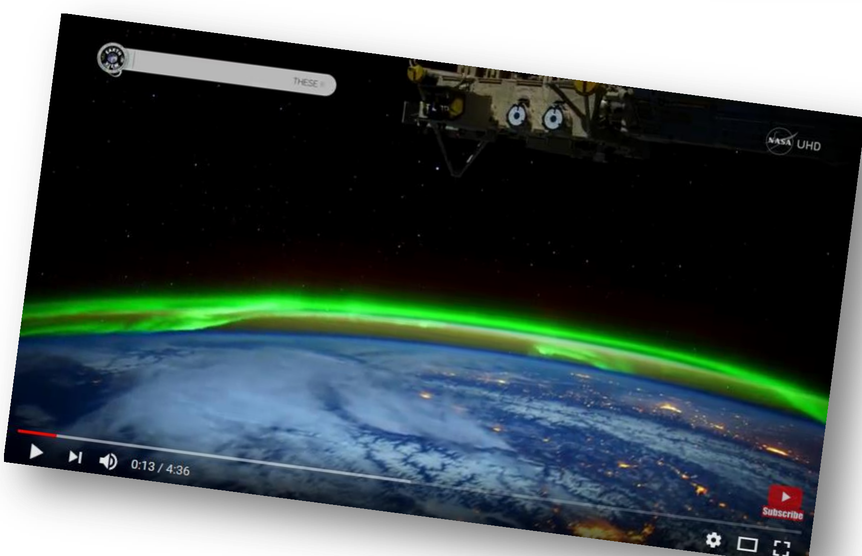
A magnetic field that stretches up to 400,000 miles into space surrounding the entire planet. It works as a massive force field that helps deflect the massive radiation that destroyed Mars.

For the most part the magnetic field is invisible. But when the Sun flares up, we get to see it in action. Humans call it the aurora. From space you see it in a different way. For those that have seen it they say it looks like an enormous ghost of a curtain that's shimmering and dancing.

It takes more than that one shield to keep the planet alive.



Watch the aurora borealis from space with this gallery of videos from NASA!

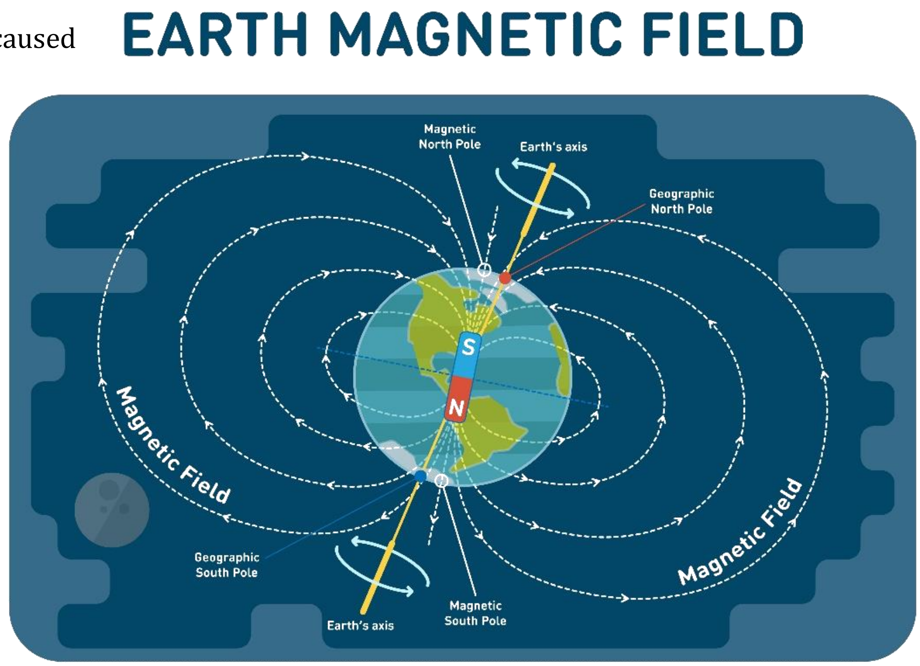


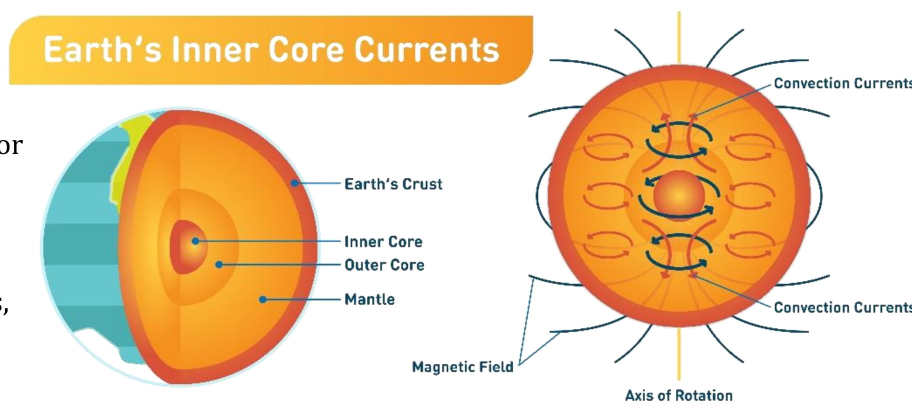
Did You Know?
The mystery behind how birds navigate might finally be solved: it's not the iron in their beaks providing a magnetic compass, but a newly discovered protein in their eyes that lets them 'see' Earth's magnetic fields.

Seeing the Invisible: Taking a Look at Magnetic Fields

Earth's magnetic field is mostly caused by electric currents in the liquid outer core, which is made of conductive, molten iron. Loops of currents in the constantly moving, liquid iron create magnetic fields. From afar, the Earth looks like a big magnet with a north and south pole like any other magnet.

Just like a bar magnet, Earth's magnetic field stretches out into space, in a region called the magnetosphere, and can affect things around it. When energetic particles zooming in from the Sun (the so-called solar wind) interact with Earth's magnetic field, we get amazing auroras in the sky (the northern lights or aurora borealis and the southern lights or aurora australis).

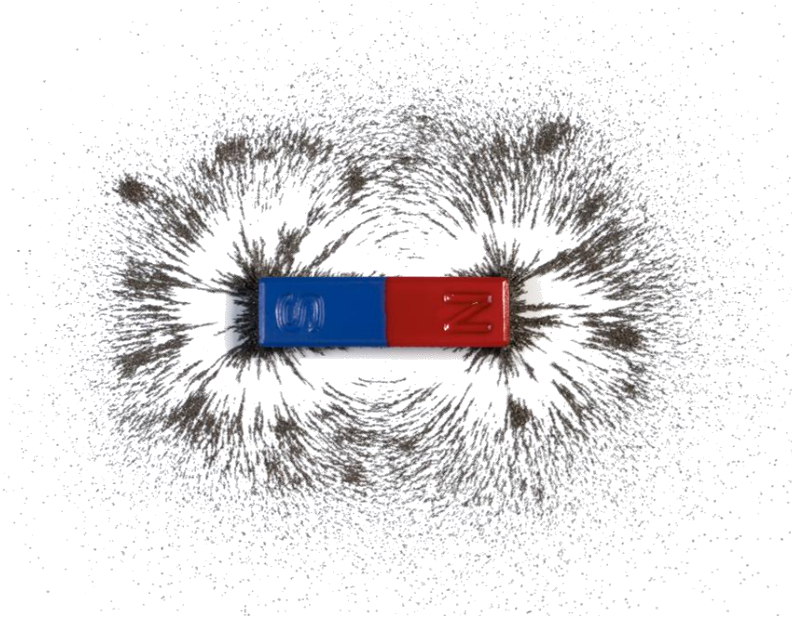




Materials:

- Neodymium, Bar Magnets, or Cow Magnets
- Plastic Disposable Plates with rims
- Iron Filings
- Paper (Graph paper would work well)
- Pencils
- Plastic zip lock bags—to protect the magnet. If you get filings on a neodymium, bar, or cow magnet it is practically impossible to remove them

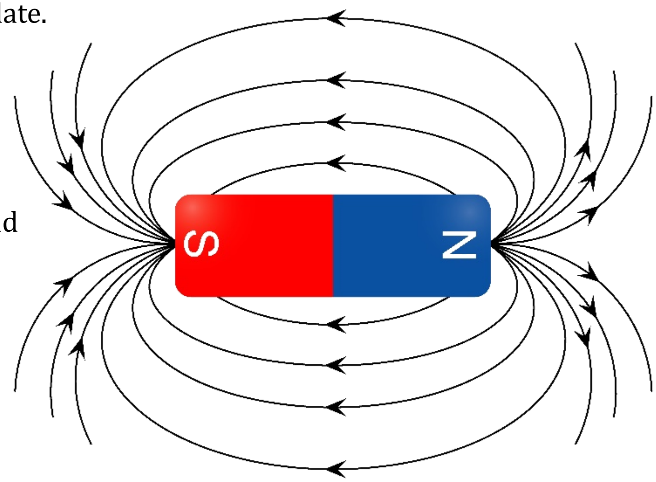
Finding Magnetic Fields



Basics: Magnets (including planet Earth) create magnetic fields. These cannot be seen.
They fill the space around a magnet where the magnetic forces work, where they can attract or repel magnetic materials.
Although we cannot see magnetic fields, we can detect them using iron filings.
The tiny pieces of iron line up in a magnetic field.

1. Pour iron filings on top of the plate.
2. Hold the neodymium magnet **beneath** the plate.
3. What do you see happening?

Drawing magnetic field diagrams

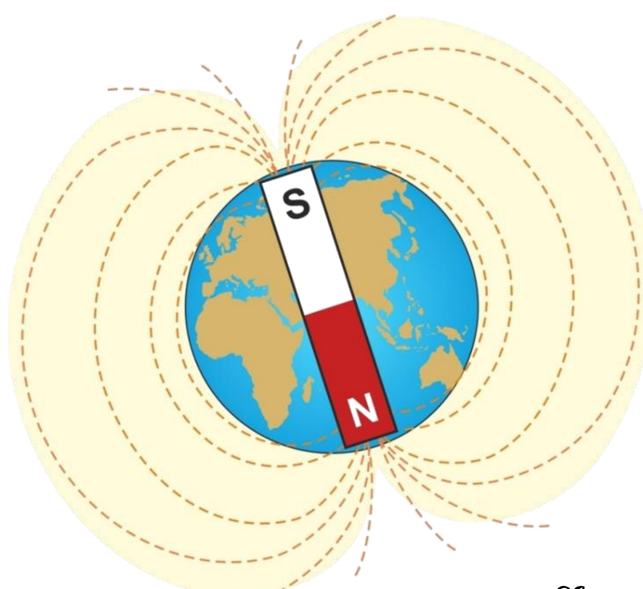


Since it can be challenging to draw every line in the magnetic field showing by the filings, scientists simplify the diagrams and draw simple magnetic field lines.

Draw a diagram of the magnetic field of the magnet and of the Earth in your discovery journal!

Note that:

The field lines should have arrows on them
The field lines should come out of N and go into S
The field lines are more concentrated at the poles.
The magnetic field is strongest at the poles, where the field lines are most concentrated.

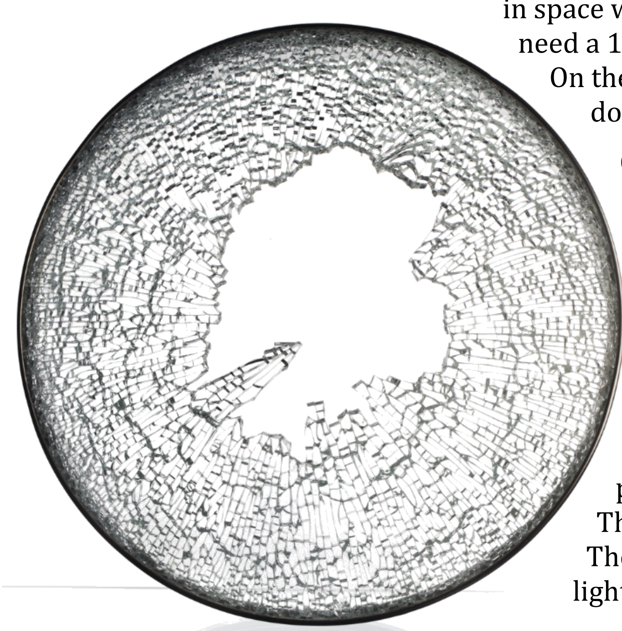


Magnetic fields of the globe. The north geomagnetic pole is actually the south pole of the earth's magnetic field, and the south magnetic pole is the north pole.

Another Tool in Its Arsenal

The Sun has another weapon. Something humans usually think of as their friend. A silent assassin called light. In space we need special protection from light. We see the visible light but there's the unseen spectrum of ultraviolet light. An invisible spectrum that can cause significant damage. Ultraviolet light is vicious. UV radiation breaks down DNA and turns healthy cells cancerous. Its effects can be seen in faded paper, a sunburn, or a cracked hose that has been left out in the sun.

For almost all life on the planet facing the sun as explorers do in space would be ultimately fatal. In space you need a 12 million-dollar space suit for protection. On the surface of the planet just some lotion does the job perfectly fine.

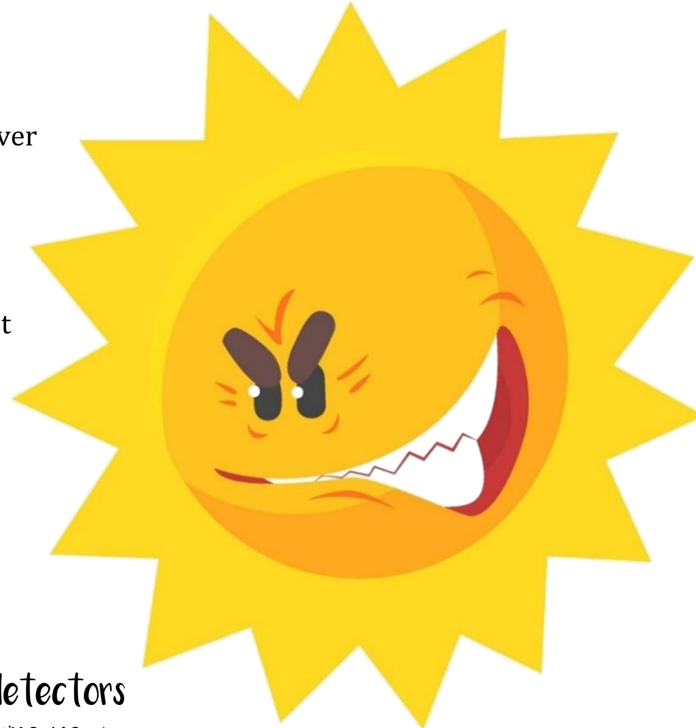


Only about 2% of the truly damaging ultraviolet light gets down to the surface of the planet. If every bit got down to the earth human skin would burn in a matter of seconds. If the planet were hit with the full force of the sun plant life and microscopic life would be sterilized and unable to reproduce. Life on this planet would be unsustainable.

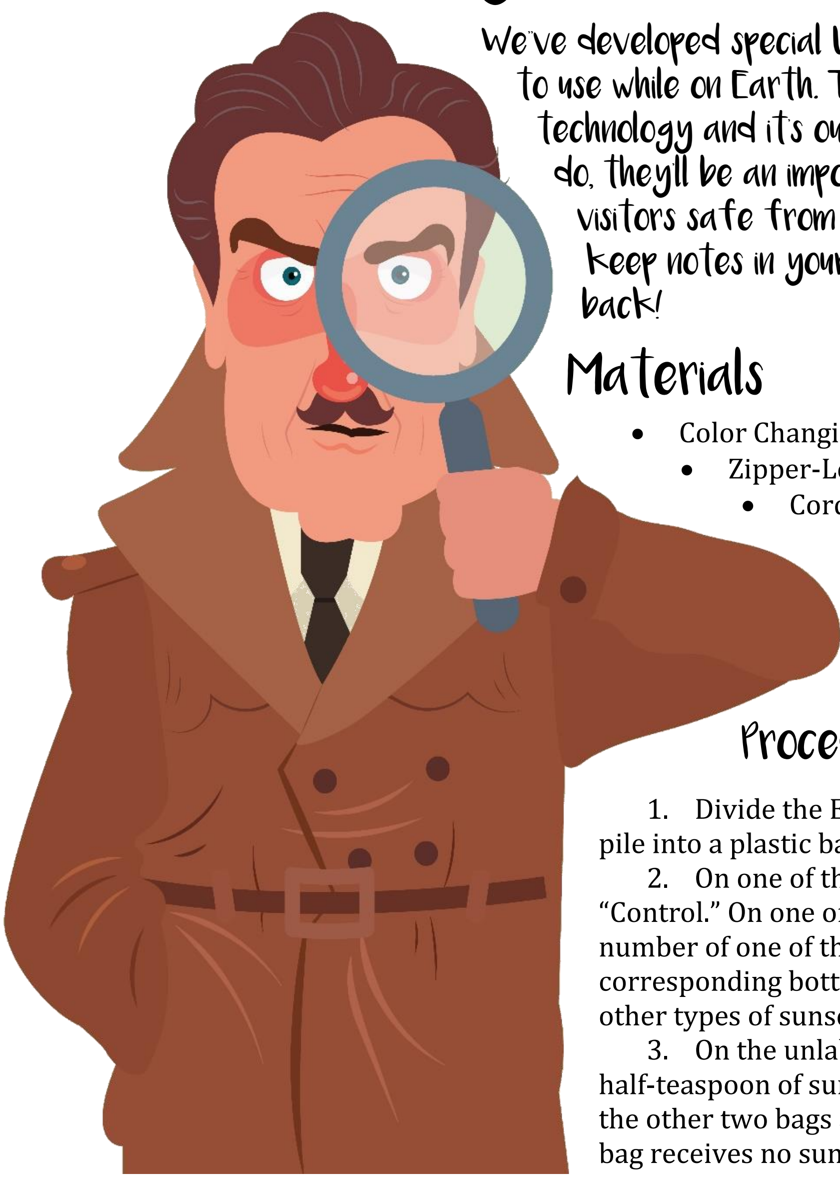
So, what's protecting the planet from this crispy fate? The answer is high above. The sun slings deadly UV light, but most of it is stopped in its tracks by a thin layer of molecules humans call the ozone layer. It's a second shield in the sky, but it's very fragile.

Thirty years ago, humans discovered that chemicals humans use had punched a hole in the ozone layer. Is it fixable or is that hole permanently there, waiting to kill life on the planet? Human scientists are trying hard to figure that out. They're sending gliders, using air rising over the southern Andes to reach incredible heights and take samples at 52,000 feet.

According to the samples they're taking, thanks to a global ban on ozone harming chemicals, it looks like the hole is healing. The shield is slowly regenerating. A planet is not an inanimate object. It's a living thing which can heal. It's an incredibly special shield that has looked after the planet for millions of years.



Do You Detect the Danger?



We've developed special UV detectors to use while on Earth. They're new technology and it's our team's job to see if they work! If they do, they'll be an important tool to keep us and our alien visitors safe from UV rays while on Earth! Make sure to keep notes in your expedition journals! We'll have to report back!

Materials

- Color Changing UV/Energy Beads
- Zipper-Lock Bags
- Cord or white pipe cleaners (for bracelets)
- Sunscreens (a variety)
- Sunglasses
- Markers
- Measuring spoons
- Mailing labels, optional

Procedure:

1. Divide the Energy Beads into four equal piles and dump each pile into a plastic bag.
2. On one of the plastic bags use the marker to write the word "Control." On one of the other bags write the name and the SPF number of one of the products you're testing. Keep the bag with the corresponding bottle of sunscreen and do the same labeling with the other types of sunscreen.
3. On the unlabeled side of a bag, smoothly and evenly spread a half-teaspoon of sunscreen directly onto the bag. Do the same with the other two bags and their corresponding sunscreens. The Control bag receives no sunscreen. Be sure to wash your hands in between

each application so the test is fair. Let the sunscreens dry completely.

4. Go outside. Lay the four bags, labels down, next to each other in direct sunlight and watch them for two to three minutes.
5. Keep the labels down and sort the bags on the cookie sheet by the brightness of the colors you see. Place the brightest colors at the left, palest colors at the right, and the other two bags by decreasing colors in between. Go into the shade (or inside) and turn the bags over to check the labels to see how effective your sunscreens truly are.

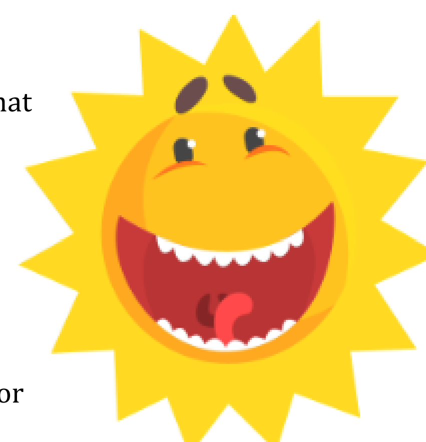
Don't stop there!

While testing the effectiveness of various sunscreens is one great idea, here are a few other ways to create experiments using UV Beads.

Make sure to keep notes in your discovery journal!

- Observe how well the beads change color when exposed to sunlight at different times of the day or in different conditions (like a cloudy or overcast day). Some people believe the clouds will protect them from UV. Is it true? According to your data, what time of day does the sun give off its most intense UV light? Most weather forecasts now include a UV Index so you can tell when it's OK to stay out in the sun a little longer. The UV Index runs from 0 to 11+ and the higher the number, the less time you should be in the sun. The index changes based on the time of day and the season as well as the weather conditions. Your new bead detectors will reveal those changes.

- Test the ability of different sunglasses to block out UV light. Place a few beads in two cups. Cover one of the cups with a lens of the sunglasses and go outside with your cups. If the beads under the sunglasses don't change color, the glasses block harmful UV light from your eyes.
- Test the beads under water!
- Test a variety of glass and plastic containers, or even prescription bottles, to determine which materials might block UV light. Place different transparent materials between a UV light source and the beads. You will find that the front windshield of most automobiles absorbs some UV radiation so the driver gets less eye strain. Usually, the side windows in a car do not have this built-in protection.



- Tube Test: Place a handful of UV beads under a fluorescent light. What color changes do you see in the beads? Based on the intensity of the colors you see, what are the chances you can get a sunburn or a tan by sitting next to a fluorescent light?
- Black Light: Black light (long-wave UV light) can also change the color of the beads. You can purchase a small black light at many specialty or hardware stores that have a large section of light bulbs. Steve Spangler Science also sells mini-versions of them. Sometimes, high intensity lights (e.g. mercury vapor or halogen) found in gyms or

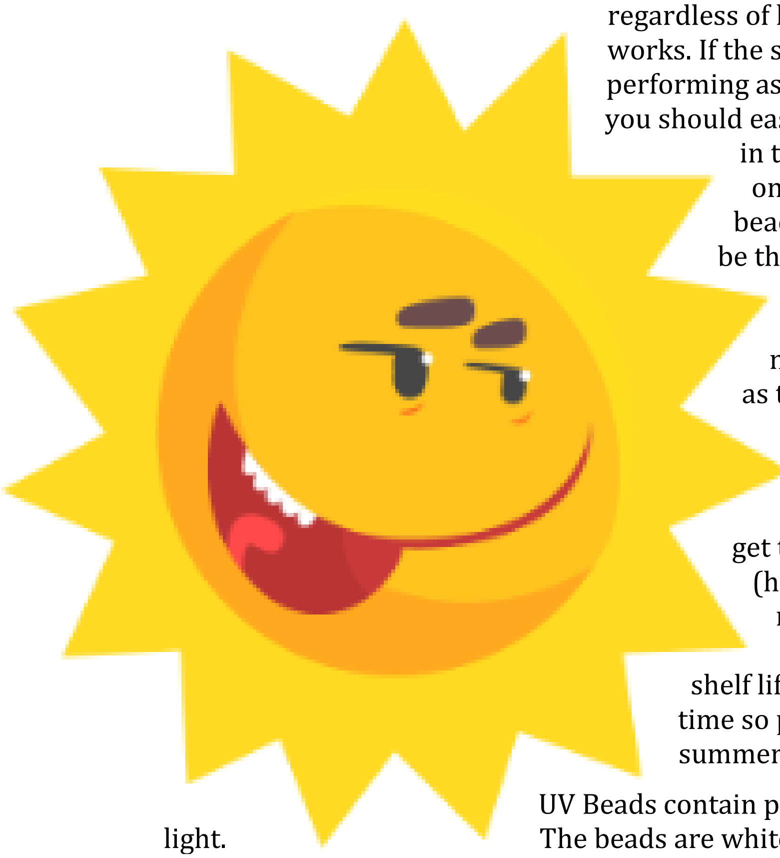
along city streets emit just enough UV light to make the beads change color a little.

These are just a couple of ideas, but you aren't limited to them! Try coming up with different ideas of variables and give them a try. Remember, you can only change one thing at a time. If you are testing different sunglasses, make sure that the other factors remain the same!

Discuss: Ask students which of the materials tested are most effective at keeping you safe from dangerous UV light from the Sun? As a reflection closer, ask students at what times of the day are they most at risk for UV radiation from the Sun? [mid-day] Least at risk? [night, sunrise, sunset]. In which season are they most at risk? We'll need to know if we're going to live on this planet!

How they work:

These beads are very sensitive and will always change color a little regardless of how well a sunscreen works. If the sunscreen products are performing as advertised, however, you should easily see color differences in the bags. The Control bag on the left is full of colorful beads. At the right should be the palest beads under the highest SPF product with lower numbers on the other two bags as the colors get less bright.

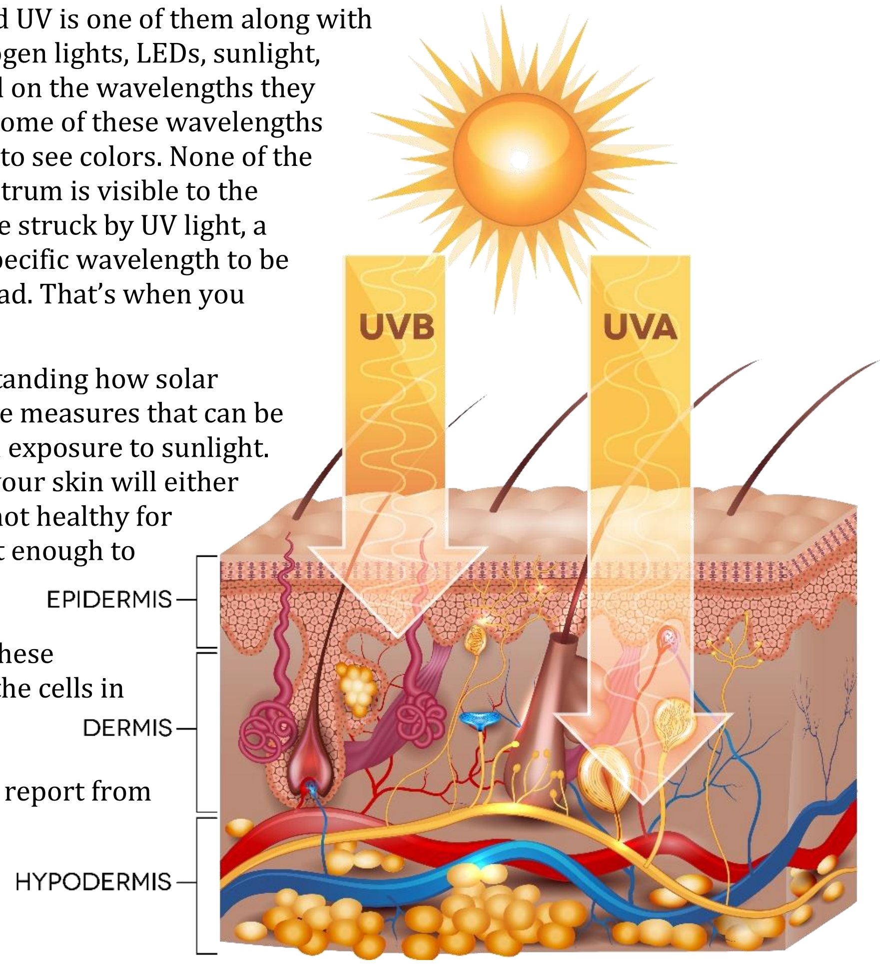


How are the products performing? Their ingredients don't necessarily "block" UV light as much as absorb UV photons so they don't get to your skin at full intensity. As you can see (hopefully), some get through the lower SPFs but many are stopped by the higher SPFs. You didn't see these results? Sunscreen products do have a shelf life and it's not very long. They break down over time so plan on buying a fresh supply of sunscreen each summer.

UV Beads contain pigments that turn colors when exposed to UV light. The beads are white in ordinary, visible light but in UV light, you'll see different colors depending on the pigment added to each bead. The beads will change from white to a color about 50,000 times before the pigment will no longer respond to UV light.

There are many forms of light energy and UV is one of them along with incandescent light, fluorescent light, halogen lights, LEDs, sunlight, neon, and others. They're different based on the wavelengths they produce and how the light is produced. Some of these wavelengths create the visible spectrum and allow us to see colors. None of the energy present in the UV part of the spectrum is visible to the human eye. However, when the beads are struck by UV light, a chemical reaction occurs that causes a specific wavelength to be released so you can see a color on the bead. That's when you know there's UV radiation around you.

UV Beads are the perfect tool for understanding how solar radiation can be harmful and to recognize measures that can be taken to reduce the risks associated with exposure to sunlight. When you expose bare skin to sunlight, your skin will either burn or tan (which doctors warn is still not healthy for you). UV radiation wavelengths are short enough to break chemical bonds in your skin tissue and, with prolonged exposure, your skin may wrinkle or skin cancer may occur. These responses by your skin are a signal that the cells in your skin have been assaulted by UV radiation for a long time. Wear a hat, use sunscreen, and be aware of the UV Index report from your local weather forecaster.[31]



[31] Steve Spangler "UV Reactive Beads" Steve Spangler Science: https://www.stevespanglerscience.com/lab/experiments/uv-reactive-beads/

Life. Under Water

In Earth's battle with the sun, the sun has often had the upper hand. Today the ozone layer protects us, but long ago, it wasn't there. The only safe place for life was under the waves. Scientists believe life on the planet would still only exist under the waves if it wasn't for something new that emerged nearly three billion years ago. Something that found a way to use sunlight to its advantage.

Scientists believe that billions of years ago as ancient organisms first harnessed the energy of the sun they began to produce a waste product. Oxygen. At first it was only a few, but thousands became millions, then trillions, all bubbling up oxygen. When oxygen gas rises high into the atmosphere something amazing happens. It transforms into protective ozone.

Under the protection of this layer more and more plants emerged out of the water and made even more oxygen. This meant even more oxygen was produced further strengthening the ozone layer shield. Protected by a thicker ozone layer than ever before, a whole range of possibilities opened up for life on the planet.

All because of the special layer of oxygen up in the sky.

A Third Weapon

So, that's two shields the planet gives us. That's enough right? No. The sun has a final weapon, perhaps its most dangerous one. Heat.

It's pumping out millions of degrees of powerful burn. A powerful burn intensified by something on the planet itself.

Volcanoes make terrible neighbors, but even if you're on the other side of the planet from it, a volcano can still make you feel the heat.

Volcanoes produce carbon dioxide (CO2). And carbon dioxide is a killer. It traps heat in the atmosphere. And the sun can cook planets wrapped in a warm blanket of carbon dioxide gas.

We found out how dangerous CO2 can be when we stopped by the planet the humans call Venus. Venus, though not the closest to the sun, has the hottest surface temperature of any planet in the solar system. That's purely the effect of too much CO2 in the atmosphere. So, why is this Earth planet not as hot as Venus? It has its own way of dealing with CO2. A way unique to it that can easily go wrong.

A unique defense

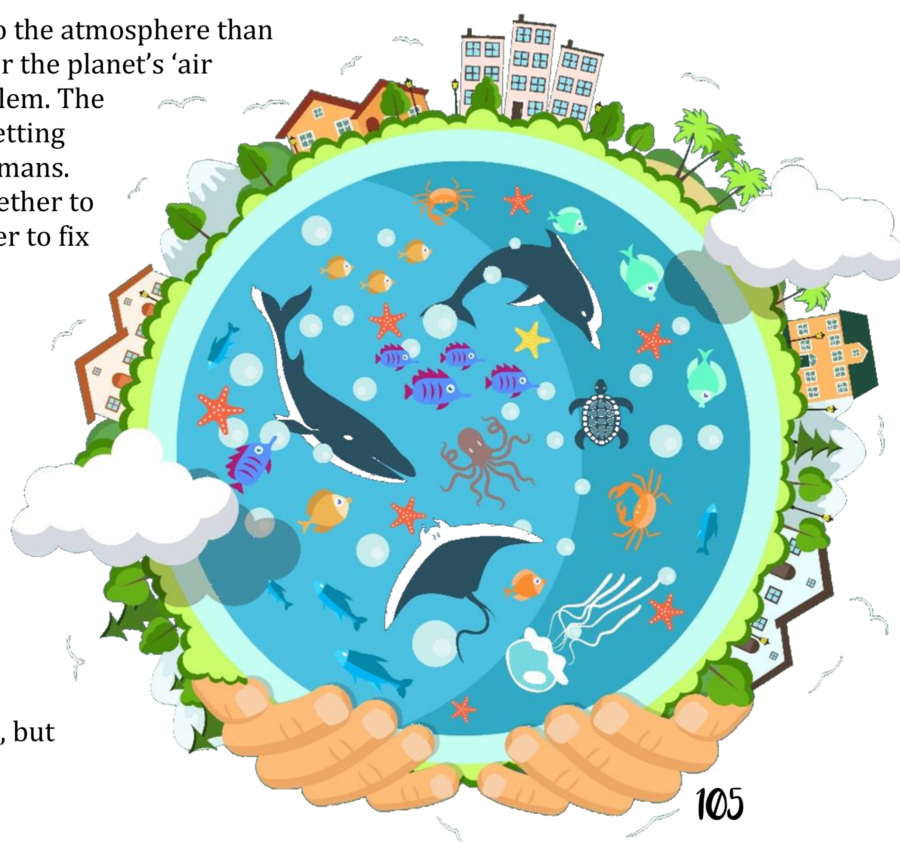
Just like the human body has ways of keeping everything in check, the planet has its own regulatory system to keep itself from being boiled by the sun. The planet starts with something no other planet we've ever found has. An air conditioning system made possible by rain.

Rain isn't pure water coming down out of the sky, it's carrying dissolved carbon dioxide from the atmosphere. This makes it acidic enough to dissolve rocks. Eventually this water, silt, and locked up carbon dioxide gets washed into the planet's rivers. Which then force it into the oceans. This process goes on every day. From space we can see the huge quantities of sediment and locked up CO2 that gets buried at the bottom of the oceans. That helps cool down the planet. Over millions of years the cycle of rain, rivers, and volcanoes has helped balance the CO2 in the atmosphere. Keeping the planet warm in the coldness of space while preventing the planet from being boiled alive by the sun.

A Planetary Partnership

All of these ancient systems (volcanoes, currents in the ocean, etc) are shaping and molding this planet we see and have kept it safe for billions of years. But now they're changing in a very big way.

Humans are pumping 60x more CO2 into the atmosphere than volcanoes and there isn't enough time for the planet's 'air conditioning system' to correct the problem. The repair guy can't keep up. The planet is getting hotter. How much hotter depends on humans. The hope is that if humans can work together to fix the ozone hole, they can work together to fix this.



Our alien visitors aren't the only ones who have been in space! Humans have sent man and machines into space.

Thanks to the human scientist Jeff Hoffman humans have been given a glimpse into the future. A very bright future. He was part of the team that helped the planet see its ultimate fate by fixing the Hubble telescope. Hubble couldn't see straight.

By now, the story is well known: Hubble was launched in 1990 with great fanfare, but soon after the telescope was turned on, mission managers knew something was horribly wrong: Instead of rich and vibrant views of nebulas and galaxies, the images beamed back from Hubble were fuzzy, and seemed out-of-focus. Despite a Herculean effort to test the Hubble before launch, an imperfection in the main mirror caused the resulting images to come out blurry when the telescope should have been able to see in crystal clarity. The media of the time declared Hubble a $1.5 billion-dollar disaster. Comedians made fun of it on late-night television. Congress declared it was a 'techno turkey.'

So fixing Hubble was critical for the future space activities that NASA wanted to carry out.

Astronauts, including Jeff Hoffman, repaired the telescope in 1993 by adding an instrument to correct for the lens aberration — essentially eyeglasses for Hubble. With that single adjustment Hubble went from 'turkey' to triumph. And it's been sending back beautiful and inspiring images of the universe ever since. That was the first of five manned service missions that added new cameras, repaired gyroscopes, and replaced the batteries.

Before and after! An error in the grinding of Hubble's mirror caused it to produce fuzzy images like that of galaxy M100, left. After the addition of a corrective lens, in 1993, Hubble's image of the same galaxy became as clear as promised. Photo: NASA and STScI

The work on Hubble also meant humans could capture images of the moment that a star, like the sun, dies. Around 5 billion years from now, the sun will grow in size and swallow up Earth. In those final moments all matter on the planet, all traces of life, will be torn apart as the planet is enveloped by the sun.

The planet has protected life on its surface for billions of years, allowing it to thrive. As biological creatures, we too will need the Earth to protect us. These shields provide sort of a blanket over us to keep us secure and carefree on the surface of the planet.

Were we just lucky that all these things happen to be in place? If they weren't in place we wouldn't be here.

Next time you take a walk outside think about the iron churning at the heart of the planet's core, the oxygen bubbling out from under the sea, the rain crashing onto the rocks. The systems that allow this little planet to survive the sunbeams. [32]

Hubble is in Trouble! Space Repair, Way Up There?

The Hubble Space Telescope has been orbiting Earth for more than a quarter century. It's sent back some amazing photos during that time, while also expanding humanity's knowledge of the universe. That's an amazing technological achievement. But it wasn't always a smooth ride.

The last Hubble service mission was in 2009, prior to the end of Shuttle flights in 2011. (Dr. Grunsfeld, an astrophysicist and astronaut who worked on three repair missions to the Hubble Space Telescope, described it as "brain surgery" in space!) Hubble has long outlived its original life span, and it's due for replacement soon. The 10 billion-dollar James Webb Space telescope is supposed to launch in the next few months (October 2018), but there's a chance Hubble could get a new lease on life with another service mission. (Another plan that has been discussed is that when the telescope's batteries and gyros finally run out of juice NASA will send a rocket and drop the Hubble into the ocean.)

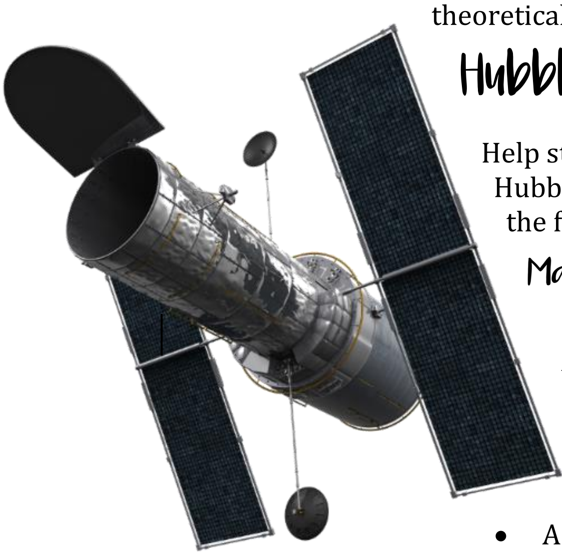
This is still in the early stages, but human officials think that private space firm Sierra Nevada could have a vehicle capable of going on a Hubble refurbishment mission.

Why bother? Keeping Hubble operational would serve two purposes. First, it's a hedge against potential issues with the Webb Telescope. Unlike Hubble, Webb will be positioned far away from Earth at a stable orbital location that keeps the Earth between the telescope and the sun. It will be too far away to service effectively, so making sure the Hubble works as a backup could be smart. There will also be limited time on the Webb Telescope for astronomers, so keeping some observations on Hubble could

[32] http://channel.nationalgeographic.com/one-strange-rock/video-gallery/?sort=recent&filter=episodes

free up time for studies that can only be completed by the more powerful Webb Telescope.

There's still a lot of design and testing that needs to be done before Sierra Nevada's craft, *Dream Chaser*, can take astronauts into space. However, the craft was designed from the start to theoretically support a crew.



Hubble is in Trouble! Space Repair Plan

Help students imagine all that has been involved to secure the success of the Hubble Space Telescope and what might go into fixing it in the future with the following activity.

Materials:

- Objects to fix (one per group): e.g., Battery-operated children's toys that have battery compartments secured by screws (it's ok if the objects aren't all the same), flashlights.
- Batteries of various sizes (enough for every group to change the batteries in their toy)
- A variety of screwdrivers (sizes, types)
- New "components" to be added onto the toy, e.g., Lego blocks, pipe cleaners or twist ties, rubber bands, etc.
- Pairs of thick gloves (ex. kitchen dish washing gloves) or mittens to represent "space suits" (2 pairs per group)
- Optional: Plastic bags
- Optional: Tubs or buckets of water

Preparation:

Place all materials on a desk or table at the front of the classroom and allow students to observe them briefly.

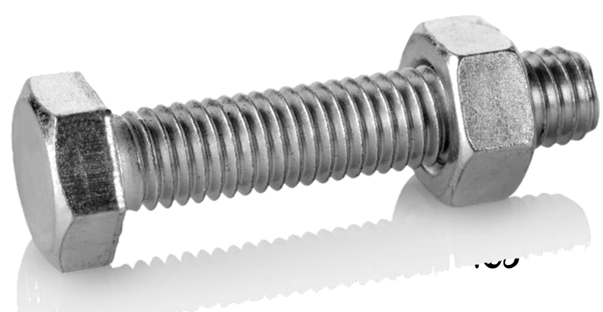
Depending on the materials available to you, you may wish to modify the following tasks. For example, if you have extra screws available, consider having students replace battery-compartment screws as well.

Activity Instructions:

Divide students into small groups.

Tell groups they will have ten minutes to plan their mission and gather materials. With their group, students must come up with a plan to complete the given task in the given time. *Questions are provided to assist you in guiding them through planning their mission.*

Tip: As an activity modification for younger students or as a fun part of astronaut mechanic mission 'training' for students of all ages: Have students wear kitchen gloves and screw large nuts, washers, and bolts together underwater (e.g., in a bowl, bucket, or metal tub) to give them the feel of wearing gloves and doing repairs in space!



The Task:

The Hubble Space Telescope is need of repairs and upgrades. Our team has been selected to be part of a space mission to repair the telescope and demonstrate human skill in space to our alien visitors. While in space, you will have to successfully complete the following tasks (tasks may be modified according to your class' age and skill level):

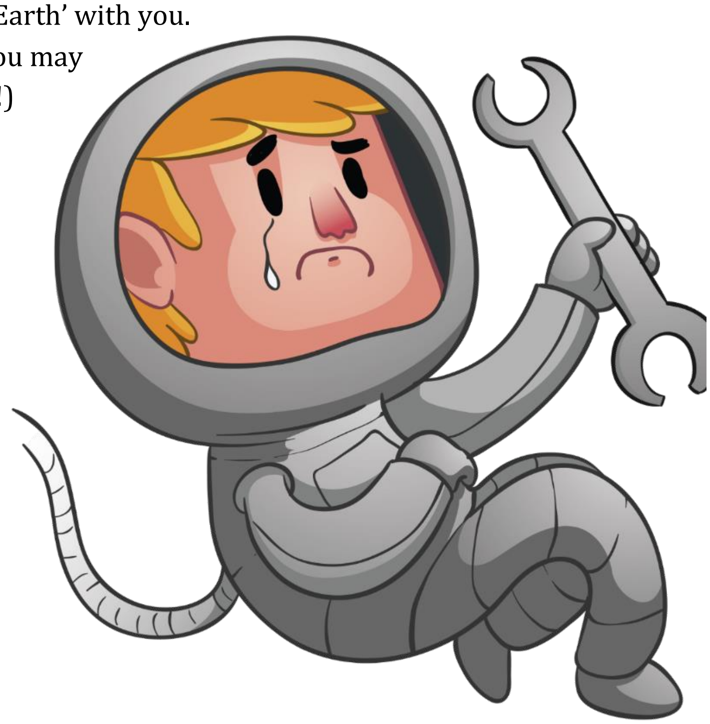
1. Change the batteries.

2. "Fix" a broken part by twisting a pipe cleaner or twist tie around part of the toy 5 times.

3. Install a new component- a Lego block must be attached snugly to the toy with a rubber band.

The Mission Rules:

- You will have 10 minutes to plan and gather the materials necessary to successfully complete all 3 tasks.
- After "take-off" you will not be allowed access to any materials left behind on the Earth.
- Not all group members have to conduct "space walks" to work on the "telescope," but those that do must wear "space gloves."
- All tools and dead batteries must return 'to Earth' with you.
- If you drop any tools or parts on the floor, you may not pick them up. (They floated out of reach!)
- You will only have 5 minutes to complete repairs.



Making a Plan!

Questions for Consideration:

- What role will each group member play?
- What materials will you need to complete the tasks?
- What difficulties are presented by the environment of outer space?
- How will you overcome these problems?
- How will you practice for your mission?
- How will you keep all crew members safe?

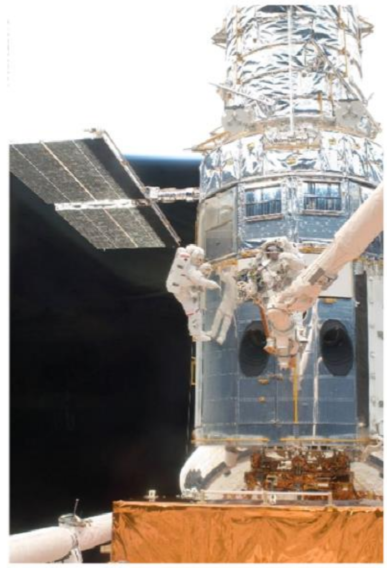
Take-Off!

After ten minutes of planning, tell groups it is time for "take-off." You may wish to create a mock countdown and have students pretend they are traveling to the Hubble Space Telescope.

Fixing the Trouble with the Hubble!

When groups are ready, give students five minutes to complete the 3 tasks to repair their toy. Use a timer or clock to record start and stop times for students to work.

Returning to Earth:



After five minutes, have students stop working, 'return to the ship' and then Earth and discuss how they did as a 'mission debriefing.' Including taking notes in their discovery journals.

Debriefing Discussion:

- Did you successfully complete all tasks? Why or why not?
- What problems, if any, did you encounter?
- How would you prepare differently given more time?
- Have students discuss the similarities and differences between the in-class activity and an actual repair mission to the Hubble Space Telescope. [Option: show The New York Times Audio Slide Show "The Hubble Repairman", NASA's images of repairing the Hubble, and the Hubble history infographic]

Further discussion questions might include:

- What is planned for the Hubble Space Telescope?
- How might have astronauts prepared for this or past repair missions?
- Based on your experience, what is the most challenging part of the repairman's job?
- Why do some human astronomers and the space program want to repair the telescope?
- Do you think the astronauts will be able to successfully complete all repairs?
- Does this mission seem important to you and why or why not? What intrigues you about this mission or about space exploration in general?
- What space mission would you like to plan if possible and why?

Make Your Own Telescope!

We can't make a new Hubble, but there are some we can make and the absolute simplest one is made up of just two lenses. One large lens called an objective and a second smaller lens called an eyepiece and if you follow the directions a point will be reached where everything comes into focus. It is as simple as that. You have a telescope.

Materials per student or group

- Two paper towel tubes
- Scissors
- Masking tape
- Optional: Paint (any color you like)
- 2 convex lenses (you can get these from a pair of magnifying glasses or order them online) with an approximate diameter of 2 inches

Materials Notes: Lenses

Inexpensive lenses are available from a variety of surplus and online stores, at photography shops, or at optics centers, and they generally will only cost a couple of dollars each at the most.

- The diameter of the convex objective lens should be approximately two inches and its focal length should be approximately 18 inches (at least 50 millimeters in diameter and a focal length of between 200 and 300 millimeters.)
- If you can, the eyepiece lens should be smaller than two inches in diameter and have a focal length of approximately two inches (A convex lens that is between 10 and 25 millimeters wide with a focal length of less than 75 millimeters.)
- You can test the focal length of a lens by focusing an image of the sun or lamp onto a white piece of paper, like in the previous project. When the image of the lamp is sharp the distance the lens is away from the paper is the focal length.

Focal Length:

The focal length is the distance it takes the objective (mirror or lens) to bring the light from what the telescope is pointed at into focus. This is usually measured in millimeters. Note: Eyepieces also have a focal length. This also is measured in millimeters.

The size of the objective: The size of the lens or mirror is usually measured in inches or millimeters. This is important because the size of the objective determines what can be seen and how bright the image will be.

Limiting Magnification:

Every telescope has a limited range of useful magnifications. The limiting magnification is quite simply based on the size of the objective lens or mirror. As a rule of thumb the average telescope can handle between 50x and 70x per inch of aperture (opening). So for example a small telescope purchased in a store can really only handle about 100x to 144x magnification. Only 100x! But on my box it says it will work up to 500x? Sorry, but at 500x in a small telescope you would be lucky to see anything at all. The problem is that the telescope does not collect enough light to magnify an image that much. As the magnification powers increase the brightness of the image seen in the telescope will decrease.

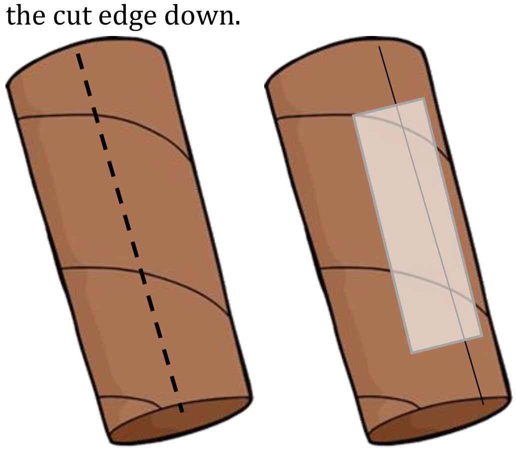
Examples: An average telescope with a 60mm (2.4 inch) objective will work up to about 144x2.4 inch objective x 60 magnification per inch = 144x magnification. An average telescope with a 150mm (6 inch) objective will work up to about 360x.6.0 inch objective x 60 magnification per inch = 360x magnification. So as you see a larger telescope that collects more light allows for a higher magnification.

Preparation:

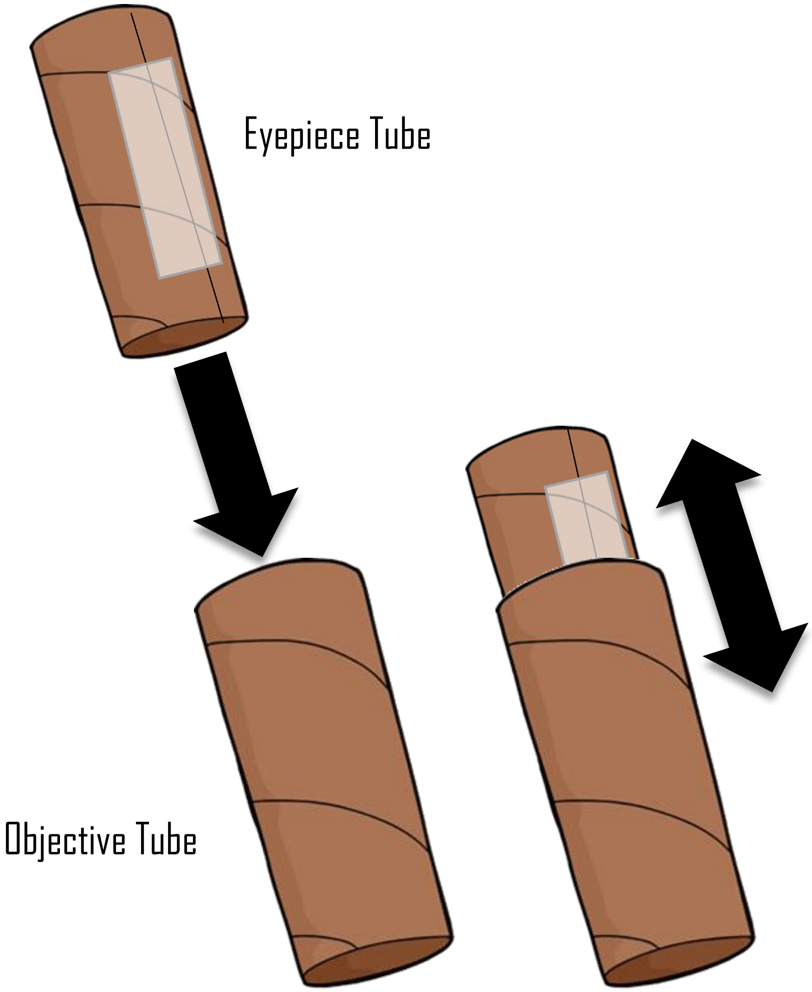
Paint your paper towel rolls and let them dry.

Activity Instructions:

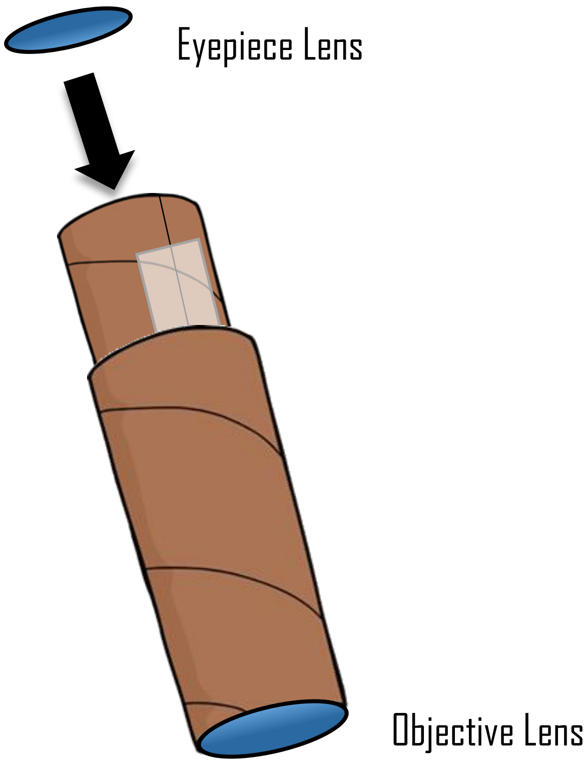
1. Create the inner tube, also called the eyepiece tube, of the telescope. Using scissors, cut one tube lengthwise on one side. Curl one side of the cut edge slightly over the other. Then tape the cut edge down.



2. Insert your inner tube into the second paper towel tube. It should fit snugly into the second tube but still be able to slide in and out. If not, adjust the size of the inner tube.



3. Tape one of the convex lenses to the outer edge of each tube. The larger will go at the end of the objective tube, the smaller will be attached to the top of the eyepiece tube. Make sure to tape only around the rim so you don't cover too much of the lens.
4. Hold the telescope with the inner tube facing your eye. Aim it at an object in the night sky. (Never use a telescope to look at the sun.) You can focus by sliding the inner tube in and out. Note that this simple telescope will show objects to be upside down. Remind students: Do not look at the sun or any other extremely bright light through the telescope.



Student Challenge!

Improving the Design:

How do students think they could improve the telescope design? Have students evaluate the telescope and determine ways to improve the design and then develop an adaptive design and test its effectiveness.

SAMPLE Hypotheses: There are several things I can do to make this telescope even better. First off, I could make a tube out of something more durable than cardboard tubes.

Fixing an Issue: Inverted Images

This type of telescope will invert images so everything appears upside down which is ok for viewing the sky but is very awkward for viewing things on the earth.

How could students solve this problem?

SAMPLE Hypothesis: I can solve this by using a concave lens for the eyepiece rather than a convex lens.

No Place Like Home?

The aliens are about to head back to their ship, but they don't want to leave.
In the following review game students will be put in teams and challenged to answer questions (about the topics you've covered during the unit) in a battle for ownership of the planet!

Materials:

- Board
- Markers
- Questions from the unit
- Masking tape
- Erasers
- Ball or paper wads
- Hoop or clean garbage can

Battle for the Planet!

1. Split your class into 2 to 6 teams, depending on how fast you want the game to go and how many students you have. Option: Some teams can be humans and some can be aliens!
2. Each team gets 10 "X's" on the board.
3. Each group gets a question. If they get it right they automatically get to erase two X's from the board. They can take it from one team or split it. They cannot hurt their own team (take X's from themselves).
4. Before they take off these X's, though, they have a chance to increase their ability to get the other teams to rather dislike them. They get to shoot the ball.
5. Set up two lines with masking tape. One is a two point line while

Sample Game Board

Alien Crew 1	Earthlings 1	Alien Crew 2	Earthlings 2
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X

the other is a three pointer.

6. If they shoot from the two point line and get it in, they can take four X's off the board. If they go from the three point line, and make it in, they can take five off the board. If they don't make it they still get to take the original two off the board.

Sample Board

Alien Crew 1	Earthlings 1	Alien Crew 2	Earthlings 2
X	X	X	X
X	X	X	X
	X	X	X
	X	X	X
	X	X	
		X	
		X	
		X	
		X	

7. When a team is knocked off they still stay active in the game. These teams still take turns. To get back on the board they need to get the question right and make the basket. If they do this they can earn four or five X's back on the board (depending on from where they shoot). This allows them to stay involved, take part in the review and not shut down. Kids will want to make alliances. With really good natured you can let this process naturally happen. If you have an immature or meaner class, try to stop this due to chances of bullying. Note: You will inevitably get one kid that takes the "attacks" personally. Just try to really reiterate that the object of the game is to knock everyone else off and people are going to get upset but that is okay.
8. The team with the most x's left at the end gets the planet! Will it be the humans or the aliens? ;)

Option: If the team whose turn it is gets the answer to the question wrong, give every other team seconds to try to get the correct answer to try to steal points. If any other team gets it correct, they get to shoot the basketball in order to see if they can steal 2 or 3 points from the teams of their choice. If they miss the shot, then they do not get to take away any points. It allows more opportunities for the basketball to get shot and it helps make sure every single team is participating in every problem.[33]

Sample Questions:

1. What are three defenses the planet uses to protect us from the Sun?
2. What was wrong with the Hubble after it was launched?
3. What is transpiration?
4. What are diatoms frustules made of?
5. Why shape are honeycomb cells?

[33] Kara Wilkins "Grudgeball" *Engaging Them All*: http://toengagethemall.blogspot.com/2013/02/grudgeball-review-game-where-kids-attack.html

6. How does water move through a plant?
7. Name two of the ways the sun is trying to kill us.
8. Where is phloem located?
9. Name one of the special properties of water.
10. What is the ‘brick wall’ the Amazon’s flying cloud river runs into?
11. Etc…