NARRATED BY RICHARD DORMER

BIRTH OF PLANET EARTH

EDUCATOR GUIDE

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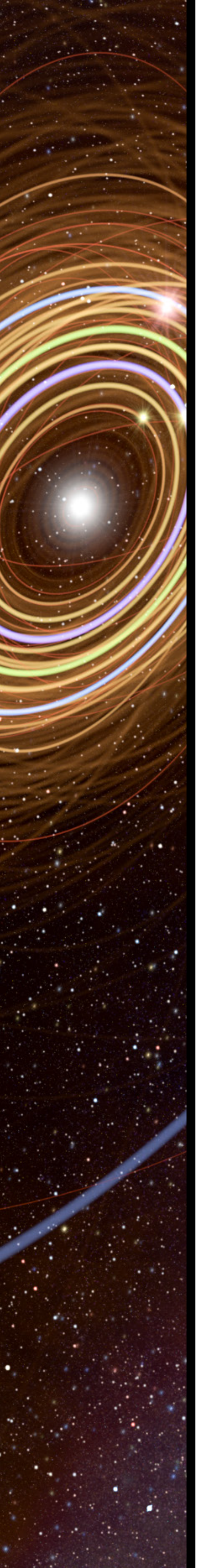

About This Guide

This Educator Guide is designed for use with students in grades 7–12 in conjunction with a viewing of the planetarium show. It supplements the documentary by offering classroom resources that address and reinforce the topics covered in the show: solar system formation, comets, geological time, photosynthesis, and how Earth became a living planet. The guide includes content overview, five inquiry-based labs, a glossary of terms and related reference guides.

We have also included links to video interviews with Kevin Walsh and Robin Canup, research scientists who contributed to the production of several visual sequences seen in the show. These short format "Making Of…" mini-documentaries explore the science behind the visualizations, and hope to pull back the curtain by focusing on the methods behind the technologies, visualizations, big data, and the science itself.

Birth of Planet Earth was designed for fulldome theaters in museums, planetariums, and science centers. It features English language narration by actor Richard Dormer. The show was produced by Spitz Creative Media, NCSA's Advanced Visualization Lab, Thomas Lucas Productions, Inc., in association with Tellus Science Museum. The project is supported by the Commonwealth of Pennsylvania and the Greater Philadelphia Film Office, and was funded in part by the National Science Foundation. Additional information, news stories and more: https://www.spitzcreativemedia.com/shows/birth-of-planet-earth/.

The movie is distributed by Spitz, Inc. (www.spitzinc.com) and Evans & Sutherland (www.es.com).

TELLUS SCIENCE MUSEUM

This Educator Guide was written by David Dundee, Astronomer, Lynn Avery, Educator, and José Santamaria, Director, of the Tellus Science Museum in Cartersville, GA. Editor: Inna Leonov-Kenny, Spitz, Inc.

Formation Of The Solar System *(left):* A dense, rotating clump within a giant cloud of gas and dust, collapsing under its own gravity, starts the formation of our Sun and its planets. Visualization by Advanced Visualization Lab, National Center for Supercomputing Applications, U. of Illinois.

SECTION I
Overview

Meteor Impact, Early Earth *(left)*: Meteor impacts brought massive amounts of water to early Earth. Visualization by Spitz Creative Media.

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Scientists now believe that our galaxy is filled with solar systems, including up to a billion planets roughly the size of our own. Birth of Planet Earth *employs advanced, data-driven visualizations to explore some of the greatest questions in science today: How did Earth become a living planet in the wake of our solar system's violent birth? What does its history tell us about our chances of finding other worlds that are truly Earth-like?*

Data-Enabled Scientific Discovery

Birth of Planet Earth is the second fulldome show produced under the banner of the CADENS project. Led by Dr. Donna Cox, CADENS (The Centrality of Advanced Digitally ENabled Science) is a National Science Foundation-supported project to increase digital literacy and inform the general public about computational and data-enabled scientific discovery.

According to Dr. Cox: "One of the reasons that *Birth of Planet Earth* is unique is because of the production-quality data visualizations developed by the NCSA's Advanced Visualization Lab (AVL). Our AVL team worked iteratively with teams of scientific researchers to transform billions of numbers from computational data into stunning visual scenes for the *Birth of Planet Earth*."

Located at the University of Illinois at Urbana-Champaign, the AVL, under Cox's direction, is known for taking computational data and redefining it into high-resolution, cinematic-quality visuals for public consumption. As *Birth of Planet Earth's* director Thomas Lucas describes it, "The visualization of science through supercomputing resources provides a level of detail and dynamism that's ideally suited for fulldome presentation."

Over a half of the show's visuals were created by visualizing actual numerical data, including an early form of photosynthesis, and the violent collision which resulted in the creation of our Moon.

Lucas sums up the film this way: "One of the big revelations of the search for extra-solar planets is that most solar systems don't look like ours. There are lots of Neptune-sized planets, for example, within the inner solar systems. In this modern age of planet hunting, there's a question many people don't ask: Is our Earth a commonplace planet in a galaxy teeming with life, or is it a rare oasis in a barren universe?"

SECTION II
Education Goals

Early Volcanic Islands *(left)*: Oceans and volcanic activity created an environment suitable for development of life. Visualization by Spitz Creative Media.

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Next Generation Science Standards (NGSS)

Middle School

Earth Science

Earth's Systems

ESS1.A: The Universe and Its Stars
Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe (MS-ESS1-2)

ESS1.B: Earth and the Solar System
The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.(MS-ESS1-2)

ESS2.A: Earth Materials and Systems
The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

Physical Science

Motion and Stability: Forces and Interactions

PS2.A: Forces and Motion
For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

PS2.B: Types of Interactions
Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)

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Life Science

From Molecules to Organisms: Structures and Processes

LS1.C: Organization for Matter and Energy Flow in Organisms
Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)

High School

Earth Science

Earth's Place in the Universe

ESS1.B: Earth and the Solar System
Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)

ESS1.C: The History of Planet Earth
Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS-ESS1-6)

Life Science

From Molecules to Organisms: Structures and Processes

LS1.C: Organization for Matter and Energy Flow in Organisms
The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

Main Questions and Answers

What role did the planet Jupiter play in the evolution of the solar system?

In order to understand the complexities of terrestrial planet formation, new modeling techniques are needed to explain the difference in size and mass between the Earth and Mars. Dr. Kevin Walsh, a Senior Research Scientist at Southwest Research Institute, relies on supercomputers to study these models of planetary formation that not only explain the smaller size of Mars, but also the rapid formation of larger planets like Jupiter and Saturn.

The "Grand Tack"
Among the sequences visualized by the NCSA's Advanced Visualization Laboratory, Dr. Kevin Walsh and his collaborators simulated a theoretical chain of events known as the "Grand Tack" (named after the sailing term for the action a boat takes as it turns its bow into the wind), in which Jupiter—the first planet in our solar system to

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be formed—migrated for a brief period into the inner solar system, disrupting the orbits of the developing inner planets.

During the Grand Tack, Jupiter's gravitational pull caused a number of the inner planets to be ejected from the solar system, while others collided and broke apart. These effects reduced the mass of the inner solar system, ensuring that smaller planets would survive and dominate. Later, the gravitational tug of other large planets, such as Saturn, helped bring Jupiter back into its current orbit.

Play the interview with Dr Walsh here (Planet Formation in the Early Solar System clip): https://vimeo.com/369876547.

How was the Moon created?

Early in its formation, just as its crust was beginning to solidify, Earth suffered a catastrophic collision with Theia, a proto-planet about the size of Mars. Theia was pulverized by the impact, while Earth had close to a third of its total mass stripped away. The resulting debris mixed together, and eventually formed what we now know as the Moon. Scientists believe that by exerting gravitational pull on our planet, the Moon helped stabilize both the Earth's tilt and its rotation. At the same time, Moon's gravity created the tides, which assisted in the evolution of life.

In the last decade, scientists like Dr. Robin Canup of the Southwest Research Institute, have been using the new generation of powerful supercomputers to test a number of predictive models of the Giant Impact Theory which describes the origin of our Moon. In this video, she explores the ideas behind the theory and showcases the results of those tests (Collision That Formed the Moon): https://vimeo.com/369874665.

How did water appear on our planet?

Water was always part of our planet's chemical makeup, ever since the Earth first formed, along with the rest of the solar system, inside a giant cloud of dust and gas. Originally, though, water remained chemically bonded to rocks that comprised the Earth. Many thousands of years later, volcanic activity and meteor bombardment allowed the water to separate, and maintain liquid form.

Why was the Earth in danger of losing its water?

Early Earth was subject to frequent bombardments by coronal mass ejections, which carried solar particles down to the Earth's atmosphere. Whenever a solar particle hit a water molecule, the water molecule would split into its component gases: oxygen and hydrogen. The lighter hydrogen would then waft out into space, while oxygen drifted down to the ground and bonded with surface rocks. If not replenished, the majority of the Earth's water supply would eventually disappear.

What role did living organisms play in helping the Earth retain water?

As living organisms began to appear on Earth, they used photosynthesis to convert sunlight into energy, releasing oxygen as a by-product. These new oxygen molecules would bond with hydrogen to form water, thus keeping hydrogen from escaping into space and preserving the Earth's water reserves.

SECTION III
Inquiry Based Labs, Experiments and Activities

Early Photosynthesis *(left)*: Ultimately, our goal is to find a planet outside our solar system that is hospitable to life. Visualization by Spitz Creative Media

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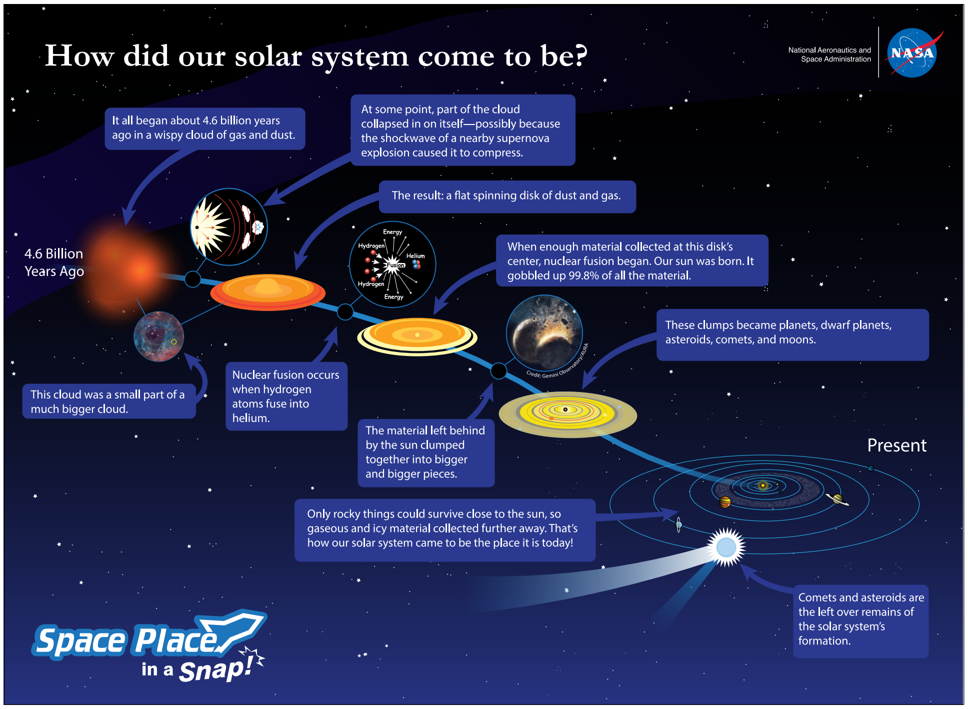
Solar System Formation Flowchart

This Solar System Formation Flowchart comes from the NASA education site https://spaceplace.nasa.gov/solar-system-formation/en/. It presents the formation of our solar system in chronological order.



How did our solar system come to be? *NASA.*

Vocabulary: nebula

Length of time: 1–2 class periods

Materials:

- script copy per student
- large sheets of bulletin board paper
- crayons
- markers
- internet

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Instructions

1. Play the embedded YouTube video on this site for the students. Discuss afterwards. Then tell them their task is to design a flow chart of the formation of our solar system with their group of 4–6. Pass out the handout with the script and have them reread it and discuss any questions they have.
2. Have the students discuss in their groups the main things that they want in their flowchart and have the students highlight them. Let them research examples of flowcharts from the internet if they're not sure what their possibilities are. They may want to find pictures of nebulas.
3. Pass out the materials they may use. Have them divide up the main ideas with each being responsible for at least two parts. Let them discuss their layout and let them work.
4. When finished let them display their work in the hall and let them make written observations about each team's flowchart. A rubric could be given ahead of time for them to use.

Script of YouTube Video of Formation of the Solar System

The solar system is a pretty busy place. It's got all kinds of planets, moons, asteroids, and comets zipping around our Sun. But how did this busy stellar neighborhood come to be?

Our story starts about 4.6 billion years ago, with a wispy cloud of stellar dust. This cloud was part of a bigger cloud called a nebula.

At some point, the cloud collapsed—possibly because the shockwave of a nearby exploding star caused it to compress. When it collapsed, it fell in on itself, creating a disk of material surrounding it.

Finally, the pressure caused by the material was so great that hydrogen atoms began to fuse into helium, releasing a tremendous amount of energy. Our Sun was born!

Even though the Sun gobbled up more than 99% of all the stuff in this disk, there was still some material left over.

Bits of this material clumped together because of gravity. Big objects collided with bigger objects, forming still bigger objects. Finally, some of these objects became big enough to be spheres—these spheres became planets and dwarf planets.

Rocky planets, like Earth, formed near the Sun, because icy and gaseous material couldn't survive close to all that heat. Gas and icy stuff collected further away, creating the gas and ice giants.

And like that, the solar system as we know it today was formed.

There are still leftover remains of the early days though.

Asteroids in the asteroid belt are the bits and pieces of the early solar system that could never quite form a planet. Way off in the outer reaches of the solar system are comets. These icy bits haven't changed much at all since the solar systems formation. In fact, it is the study of asteroids and comets that allows scientists to piece together this whole long story.

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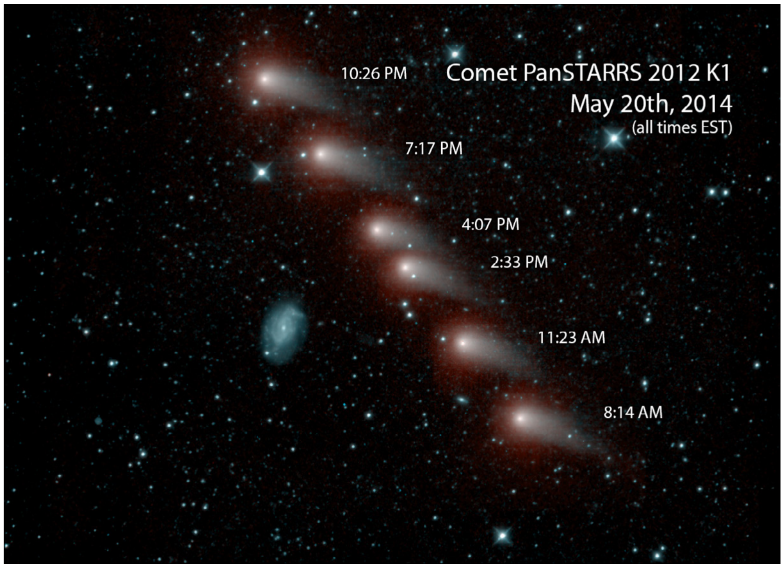
Make a Comet

Since the study of comets has given us so much information about the birth of our planet, our next activity comes from https://www.noao.edu/education/crecipe.html.

A dramatic and effective way to begin a unit on comets is to make your own comet right in front of the class. The ingredients for a comet are not difficult to find and watching a comet being "constructed" is something the students will remember for a long time.

You and your students will follow the path of a comet as it makes its way through space. You will also simulate the heat and gravitational effects of the Sun in this fun science lesson for kids.



Comet. *NASAJPL-Caltech.*

The "ingredients" for a six-inch comet are:

- 2 cups of water
- 2 cups dry ice (frozen carbon dioxide)
- 2 spoonful of sand or dirt
- a dash of ammonia
- a dash of organic material (dark corn syrup works well)

Other materials you should have on hand include:

- an ice chest
- a large mixing bowl (plastic if possible)
- 4 medium-sized plastic garbage bags
- work gloves
- a hammer, meat pounder, or rubber mallet
- a large mixing spoon
- paper towels
- safety goggles

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Dry ice is available from ice companies in most cities (look under “ice” in the Yellow Pages for a local source). Day-old dry ice works best, so you might want to buy it the afternoon before the day you do the activity. Keep the dry ice in an ice chest when transporting it and in your refrigerator's freezer compartment overnight.

Most ice companies have a minimum on the amount of ice they will sell (usually 5 pounds). But having extra dry ice on hand will be useful because some will evaporate and also because it is advisable to practice this activity at least once before doing it with the class.

Instructions

1. Cut open one garbage bag and use it to line your mixing bowl. Have all ingredients and utensils arranged in front of you.
2. Place water in mixing bowl.
   a. Add sand or dirt, stirring well.
   b. Add dash of ammonia
   c. Add dash of organic material (e.g. corn syrup), stirring until well mixed.
3. Place dry ice in 3 garbage bags that have been placed inside each other. Be sure to wear gloves while handling dry ice to keep from being burned.
4. Crush dry ice by pounding it with hammer.
5. Add the dry ice to the rest of the ingredients in the mixing bowl while stirring vigorously. Continue stirring until mixture is almost totally frozen.
6. Lift the comet out of the bowl using the plastic liner and shape it as you would a snowball.
7. Unwrap the comet as soon as it is frozen sufficiently to hold its shape.

Now you can place the comet on display for the students to watch during the day as it begins to melt and sublimate (turn directly from a solid to a gas—which is what carbon dioxide does at room temperature and comets do under the conditions of interplanetary space when they are heated by the Sun).

The comet is reasonably safe to touch without getting burned by the dry ice, but it is still best to have a spoon or a stick for the students to use while examining it. As the comet begins to melt, the class may notice small jets of gas coming from it. These are locations where the gaseous carbon dioxide is escaping through small holes in the still frozen water. This type of activity is also detected on real comets, where the jets can sometimes expel sufficient quantities of gas to make small changes in the orbit of the comet.

After several hours, the comet will become a crater-filled ice ball as the more volatile carbon dioxide sublimates before the water ice melts. Real comets are also depleted by sublimation each time they come near the Sun. Ultimately, old comets may break into several pieces or even completely disintegrate. In some cases, the comet may have a solid, rocky core that is then left to travel around the comet's orbit as a dark barren asteroid.

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Driving through Geologic Time

Our next activity, Driving through Geologic Time—An Analogy by Eric M. Baer, Geology Program, Highline Community College, comes from https://serc.carleton.edu/quantskills/activities/drivinggeologictime.html.

The scale of geologic time is presented by comparing it to a cross-country drive. The rough distance between Washington DC and Seattle, Washington is 4560 km, so each kilometer can be used to represent one million years of Earth's history. This analogy can be used as a springboard to talk about the limits of personal perceptions and experiences when drawing conclusions.

Goals:

- Gain familiarity with the metric system
- Make basic scaling calculations
- Increase knowledge of large numbers
- Become familiar with an order and rough age of major events in Earth's history
- Consider the scale of human events compared to geologic events

This activity is part of the On the Cutting Edge Peer Reviewed Teaching Activities Collection.

Context for Use

"Driving through Geological Time" can be presented in a lecture-type format. It can take a minute, or be extended into a long discussion of what one may see through a hypothetical car window as one drives through the Earth's history. The analogy is appropriate for studying physical geology, geologic hazards, geomorphology and environmental geology; it sets up students for understanding that slow processes (tectonic uplift, river erosion, fault displacement etc.) can create massive changes in the environment.

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Teaching Notes and Tips

It may be helpful, in conclusion of the "cross-country drive" analogy, to discuss the limits of our view of time. If following the 1km = 1 million Earth years model, then an average student would have only seen the last few centimeters of the entire trip (10 centimeters for a 100-year-old student!).

The question for the students would then be: "Imagine if you were stuck in one place for your entire life and could only see a few centimeters in front of your face. Then someone tells you about all the amazing things that exist in the United States—the Grand Canyon, Mount Rainier, even a large field of corn! There's no way you would believe them!

The same thing happens when geologists talk of mountains rising, seas opening and closing, and the evolution of species. People disbelieve because it doesn't fit into their worldview". This analogy sometimes helps the students to question their world view a little bit.

Teaching Materials

Geologic Drive (PowerPoint 74kB Feb16 05) is a PowerPoint illustration of what this analogy.

Assessment

This lesson can be assessed in a traditional manner, using tests or quizzes. For example, students may be asked to place a variety of events in order, or estimate what percentage of Earth's history saw the existence of life, fish, humans etc.

Related Links

Deep Time
(https://serc.carleton.edu/quantskills/methods/quantlit/DeepTime.html)

Big Numbers
(https://serc.carleton.edu/quantskills/methods/quantlit/BigNumbers.html)

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Photosynthesis Demonstration

Because photosynthesis plays such a key role in our planet's history, the next activity comes from Thoughtco.com at https://www.thoughtco.com/floating-spinach-disks-photosynthesis-demonstration-604256.

Dew on Plant. *Sofie Vanborm.*

Watch Leaves Perform Photosynthesis

Watch spinach leaf disks rise and fall in a baking soda solution in response to photosynthesis. The leaf disks intake carbon dioxide from a baking soda solution and sink to the bottom of a cup of water. When exposed to light, the disks use the carbon dioxide and water to produce oxygen and glucose. Oxygen released from the leaves forms tiny bubbles that cause the leaves to float.

Materials:

You can use other leaves for this project besides spinach. Ivy leaves or pokeweed or any smooth-leaf plant work. Avoid fuzzy leaves or areas of leaves that have large veins.

- Fresh spinach leaves
- Single hole punch or a hard-plastic straw
- Baking soda
- Liquid dishwashing detergent
- Plastic syringe (no needle, 10cc or larger)
- Clear cup or glass
- Light source (bright sunlight works or you can use a light)

EDUCATOR'S NOTES

Procedure:

1. Prepare a bicarbonate solution by mixing 1/8 teaspoon baking soda in 12 oz. of water. The bicarbonate solution acts as a source of dissolved carbon dioxide for photosynthesis.
2. In a separate container, dilute a detergent solution by stirring a drop of dishwashing liquid in about 6 oz. of water.
3. Fill a cup partly full with the backing soda solution. Add a drop of the detergent solution to this cup. If the solution forms suds, add more baking soda solution until you stop seeing bubbles.
4. Use the hole-punch or straw to punch 10–20 disks from your leaves. Avoid the edges of the leaves or major veins. You want smooth, flat disks.
5. Remove the plunger from the syringe and add the leaf disks.
6. Replace the plunger and slowly depress it to expel as much air as you can without crushing the leaves
7. Dip the syringe in the baking soda/detergent solution and draw in about 3 cc of liquid. Tap the syringe to suspend the leaves in the solution.
8. Push the plunger to expel excess air, then place your finger over the end of the syringe and pull back on the plunger to create a vacuum.
9. While maintaining the vacuum, swirl the leaf disks in the syringe. After 10 seconds, remove your finger (release the vacuum).
10. You may wish to repeat the vacuum procedure 2–3 times, to ensure the leaves take up carbon dioxide from the baking soda solution. The disks should sink to the bottom of the syringe when they are ready for the demonstration. Tip: If the disks do not sink, use fresh disks and a bit more detergent.
11. Pour the spinach leaf discs into the cup of baking soda/detergent solution. Dislodge any disks that stick to the side of the container. Initially, the disks should sink to the bottom of the cup.
12. Expose the cup to light. As the leaves produce oxygen, bubbles forming on the surface of the disks will cause them to rise. If you remove the light source from the cup, the leaves eventually will sink.
13. If you return the disks to the light, what happens? You can experiment with the intensity and duration of the light and its wavelength. If you would like to set up a control cup for comparison, prepare cup containing water with diluted detergent and spinach leaf disks that have not been infiltrated with carbon dioxide.

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Oceans from Rocks

Without our oceans, we would not be here. How our oceans form is answered by https://oceanservice.noaa.gov/facts/why_oceans.html.

Over vast periods of time, our primitive oceans formed. Water remained a gas until the Earth cooled below 212 degrees Fahrenheit. At this time, about 3.8 billion years ago, the water condensed into rain which filled the basins that are now our oceans. Most scientists agree that the atmosphere and the oceans accumulated gradually over millions and millions of years with the continual 'degassing' of the Earth's interior.

According to this theory, the ocean formed when water vapor and other gases escaped from Earth's molten rocks into the atmosphere as the planet cooled down. After the Earth's surface had cooled to a temperature below the boiling point of water, rain began to fall—and continued to fall for centuries. As the water drained into the great hollows in the Earth's surface, the primeval ocean came into existence. The forces of gravity prevented the water from leaving the planet.

Ocean. *NASA.*

Release Water out of Rocks

A very simple activity that demonstrates water within an object comes from José Santamaria, Director of the Tellus Museum. He suggests placing a natural sponge (that has been soaked with water and squeezed just enough to appear dry) on a plate. The students are then asked if they know what's inside the sponge. (If anyone is curious, sponges are made of tiny, needle-like splinters, or a mesh of protein called spongin. Some sponges are made of both spicules and spongin. Artificial sponges are made of calcereous or siliceous spicules, and they are therefore soft to the touch. https://en.m.wikipedia.org/wiki/Sponge_(tool)) Afterwards, the teacher squeezes the sponge and—surprise!—water appears. It has been inside all along.

Our last activity from https://universalmodel.com/brooke-e-mckay/rocks-form-water/ will prove that rocks contain water.

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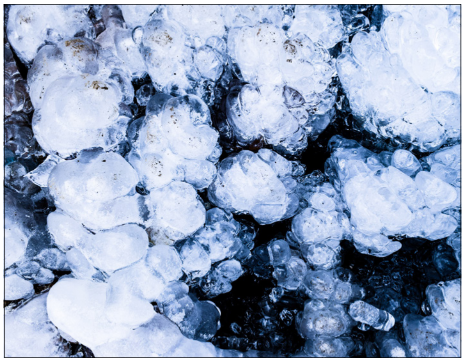
Although generally unknown to the public, researchers have known for decades that rocks and minerals contain water. Trapped inside the rock beyond the limits of visible observation, deep within the molecular or crystal lattice structure, water exists.

Because rocks contain water in their microstructure, when they are heated, the water will expand, vaporize and escape. This can be verified by comparing the weight of a rock prior to heating to the weight of the rock after heating. After the rock is heated and some of the water in the rocks molecular structure is released through steam, it will never weigh the same as it did before heating.

Caution, rocks can pop/explode if they are heated too quickly or at too high a temperature. Also make sure you wait for the heated rocks to return back to room temp before reweighing them. An electric scale that goes to 1000th of a gram will be needed and you can pick one up online for around $20 on eBay or amazon.

Natural sponge. *Morguefile.com.*



Crystal. *Fouad Ghazizadeh, Unsplash.*

Controlled Vocabulary Terms

Subject: Biology:Evolution

Resource Type: Activities:Classroom Activity:Short Activity

Special Interest: Quantitative, 2YC:Geo2YC

Grade Level: College Lower (13–14):Introductory Level

Quantitative Skills: Arithmetic/Computation, Graphs, Units and Unit Conversions, Probability and Statistics: Describing Data Distribution, Models and Modeling

Ready for Use: Ready to Use

Earth System Topics: Evolution

Topics: Time/Earth History, Biosphere: Evolution

Theme: Teach the Earth: Teaching Environments: Intro Geoscience, Two-Year College

APPENDIX A
Glossary of Terms

ATP (Adenosine triphosphate)
A compound present in all living tissue, composed of an adenosine molecule and three phosphate groups. When one of the phosphates breaks off, the compound becomes ADP (adenosine diphosphate). This results in a release of energy, which powers processes necessary to life, such as muscle contraction.

Chlorophyll
The green coloring matter of leaves and plants, essential to the production of carbohydrates by photosynthesis.

Coalesce
To grow together into one body. To unite so as to form one mass. To blend or come together.

Cosmology
The branch of astronomy that deals with the general structure and evolution of the universe.

Galaxy
A large system of stars held together by mutual gravitation and isolated from similar systems by vast regions of space.

Mass
A body of coherent matter, usually of indefinite shape and size.

Nebula
A cloud of interstellar gas and dust.

Orbit
The curved path, usually elliptical, described by a planet, satellite, spaceship, etc., around a celestial body, such as the Sun.

Photon
A quantum of electromagnetic radiation.

Photosynthesis
The complex process by which carbon dioxide, water and certain inorganic salts are converted into carbohydrates using the energy of the Sun.

Solar Flare
A sudden burst of solar material from the surface of the Sun.

Supernova
The explosion of a star, during which the star's brightness increases and most of the star is blown away, leaving behind an extremely dense core.

APPENDIX B
Additional Resources on the Web

http://hte.si.edu

http://jpl.nasa.gov/edu

http://www.sciencekids.co.nz/lessonplans/space/makeaspaceship.html

https://astropix.ipac.caltech.edu/

https://oceanservice.noaa.gov/facts/why_oceans.html

https://universalmodel.com/brooke-e-mckay/rocks-form-water/

https://spaceplace.nasa.gov/classroom-activities/en/

https://universe.nasa.gov/afterschool

https://viewspace.org

https://www.ipac.caltech.edu/outreach/project/universe-unplugged

https://www.jpl.nasa.gov/edu/teach/activity/stem-activities-for-families/

https://www.lpi.usra.edu/education/explore/beyondEarth/activities/newPlanet.shtml

https://www.nasa.gov/

https://www.thoughtco.com/floating-spinach-disks-photosynthesis-demonstration-604256

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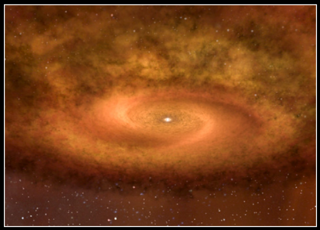
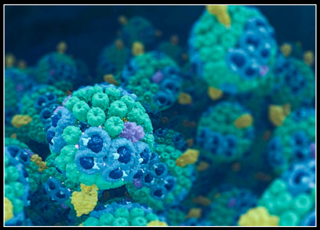


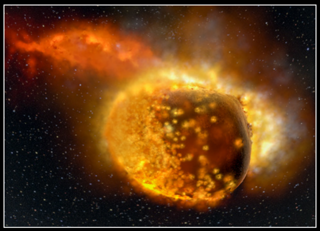


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