FINDING LIFE BEYOND EARTH

Education Collection

NOVA PBS

NOVA Education pbs.org/nova/education, novaeducation@wgbh.org

NOVA's "Finding Life Beyond Earth" script visualized.

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Credits and Acknowledgements

Produced by NOVA's Department of Education, WGBH

Rachel Connolly, Director of Education | NOVA

Chris Randall, Senior Editorial Project Director | WGBH Education Department

Maiken Lilley, Education Coordinator | NOVA

Graham Veth, Education Outreach Coordinator | NOVA

Rachel Gesserman, Production Assistant | NOVA

Advisors

Chris Dietlin, WGBH

Kristen Erickson, NASA

Irena Fayngold, WGBH

Kay Ferrari, NASA/JPL

Rebecca Jaramillo, National Institute of Aerospace

Daniella Scalice, NASA Astrobiology Institute

Harla Sherwood, National Institute of Aerospace

Stephanie Shipp, Lunar and Planetary Institute

Anita Sohus, NASA/JPL

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The "Finding Life" activities were adapted from the following resources:

Activity 1 Make Scale Models of the Planets | Jet Propulsion Laboratory
Appendix Activity 1 from *marsprogram.jpl.nasa.gov/education/modules/webpages/modulesobtain.htm*

Designing a Scale Model of the Solar System | NCESSE
Lesson 2 of the NCESSE's *Journey Through the Universe* guide, grades 3-4.
messenger-education.org/teachers/MEMS_CompPlanetology.php

Activity 2 Astrobiology Education Poster | NASA Astrobiology Institute
From Activity 1 in *Life on Earth … and Elsewhere?*
http://astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/astrobiology-education-poster/

What Is Life? | NASA Astrobiology Institute
Activity 1 from pages 5–10 in *Life on Earth … and Elsewhere?*
http://astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/life-on-earthand-elsewhere/

Activity 3 Impact Craters | Johnson Space Center
From *Exploring the Moon* (pages 61–70). *www.nasa.gov/pdf/180572main_ETM.Impact.Craters.pdf*

Think SMALL in a BIG Way | Jet Propulsion Laboratory
From the Stardust Educator's Guide. *http://stardust.jpl.nasa.gov/classroom/guides.html*

What Can Craters Tell Us About a Planet? | Jet Propulsion Laboratory
Exploring Activity 3 from *marsprogram.jpl.nasa.gov/education/modules/webpages/modulesobtain.htm*

Activity 4 Where Does Life Live? | NASA
Activity 6 in NASA's Astrobiology Science Learning Activities for Afterschool Educator Resource Guide, pages 22–24. Produced by the American Museum of Natural History for NASA.
http://www.nasa.gov/pdf/145916main_Astrobiology.Guide.pdf

Activity 5 Mars Critters | Johnson Space Center
Activity 1 in the *Fingerprints of Life* activity guide.
ares.jsc.nasa.gov/ares/education/program/FPOL/searchingforlife.cfm

Search for a Habitable Planet | Johnson Space Center
Activity 4 in JSC's ARES Modeling Orbits in the Solar System guide.
http://ares.jsc.nasa.gov/ares/education/program/etss/solarsystemscales.cfm

Activity 6 What Makes a World Habitable? | NASA Astrobiology Institute
Activity 3 in the *Life on Earth … and Elsewhere?* (pages 23–36).
http://astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/life-on-earthand-elsewhere/

Activity 7 A Search for Habitable Places | KEPLER - NASA
An assortment of K–16 activities focused on finding planets, including Detecting Planet Transits.
http://kepler.nasa.gov/education/activities/

Stopped Dead in Its Tracks | Johnson Space Center
From the *Fingerprints of Life* activity guide. *ares.jsc.nasa.gov/ares/education/program/FPOL/searchingforlife.cfm*

The Nose Knows | Johnson Space Center
From the *Fingerprints of Life* activity guide. *ares.jsc.nasa.gov/ares/education/program/FPOL/searchingforlife.cfm*

The Search for Another Earth | Jet Propulsion Laboratory
planetquest1.jpl.nasa.gov/resources/pq_activity_guide.pdf

Overview

Introduction to “Finding Life Beyond Earth”

A new era in understanding life has begun

The science of astrobiology is concerned with the question of whether life exists beyond our home planet Earth. To date, there is no definitive proof that life does—or has ever—existed beyond Earth, but it is important to realize that this is still an ongoing investigation. Everything we know about life comes from studying our own planet, so the current strategy is to study life on Earth to find out more about where and how to look for life beyond Earth. Recent discoveries about life forms in extreme environments and about our solar system have renewed scientists' interest in looking for life elsewhere.

NOVA's “Finding Life Beyond Earth” program tells the story of how powerful telescopes and unmanned space missions at the forefront of this search have revealed a wide range of dynamic environments in the solar system. The new data are forcing scientists to expand their ideas about life and what kinds of worlds could support it. It may well be that life is common in the universe—the rule, and not the exception.

NOVA's education collection explores overarching themes

The search for life beyond Earth coalesces around several overarching questions, such as “What is life?” and “Where do we find habitable conditions?” NOVA has developed an education collection with seven hands-on activities that explore questions at the heart of the search for extraterrestrial life. Educators can mix and match the activities to complement museum exhibits and to offer sessions to help kids understand the biology, physical science, technology, and Earth and space science related to the search.

The activities are multipurpose, flexible, and modular

NOVA has adapted several NASA activities so that they work well in a range of educational settings. We've provided an overview, preparation section, procedure, and video collection from “Finding Life Beyond Earth.” You may use the activities in several ways. For example, each one can serve as a stand-alone museum cart activity to highlight a particular element in an exhibit. They can be grouped to fit specific time frames or highlight particular topics. (We suggest several implementation ideas on page 10.) You'll find all the resources you need for each activity on the NOVA website (e.g., the leader notes, activity sheet, image sets). But should you want more detailed background information, additional resources, or ideas for extending the lesson, we've listed the NASA resources on which the “Finding Life Beyond Earth” activities were based.

Overview of Activities

Astrobiology presents young thinkers with intriguing questions about the universe. The activities below provide opportunities for children, ages six to eleven, to explore topics related to the search for life beyond Earth using some of the same strategies that astrobiologists use.

Activity 1. Meet the Planets

Kids will identify the planets in the solar system, observe and describe their characteristics and features, and build a scale model out of everyday materials.

Activity 2. What Is Life?

Kids observe a number of objects, make a list of life's characteristics, and develop a working definition of being alive.

Activity 3. Basic Ingredients for Life

Kids make impact craters to gain insight into how comets and asteroids deliver water and chemicals to the Earth and other places in the solar system.

Activity 4. Extreme Living

Using cards that show extremophiles and some of Earth's extreme environments, kids match a microbe to an extreme environment in which it could live.

Activity 5. Home Sweet Home

Kids choose a card describing one of six possible planetary environments and design a form of life that can thrive in the conditions outlined on the card.

Activity 6. Where to Look for Life

Kids examine environment cards that describe planets and moons in terms of their temperature and atmosphere and the availability of water, energy, and nutrients. They then select the best candidates to search for life.

Activity 7. How to Search

Kids participate in a range of demonstrations that illustrate different techniques for searching for life.

Understanding the Activities

The activities in this collection all have the following components:

The Overview

The activity overview provides a brief summary of the activity, along with an estimate of the amount of time it will take to complete and a description of the learning goal for students.

Preparation

This section lists all the materials and multimedia you will need to complete the activity, along with a description of how to set up the activity. The supplies needed are commonly used items. Most handouts are provided in the appendix, although some images may need to be downloaded from a website (URLs are provided). Presentation slides are provided to accompany the activities, and can be downloaded by clicking *here*. The complete materials list for all the activities can be found on page 9.

The Activity

The activity is presented with easy-to-follow steps and prompts, suggesting how to engage the audience, facilitate the activity, and check for understanding.

Keep Exploring

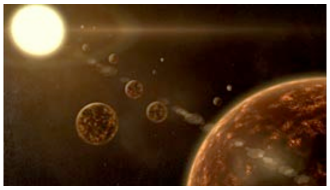
This section provides ideas on how to extend the activity to further explore the overarching question. An estimate of the time needed to complete these extended engagements is included. A suggested cart activity version of the activity is also included in this section for museum educators.

Video Resources

An important aspect of the "Finding Life Beyond Earth" education collection are the video resources adapted from NOVA's "Finding Life Beyond Earth" program. The beautiful imagery and engaging narration make these segments invaluable teaching aids.

Video Resources

These video excerpts from NOVA's "Finding Life Beyond Earth" program complement the activities in this collection.



Video 1: How the Inner Solar System Formed *(Activity 1)*

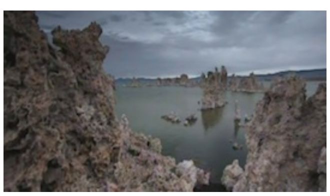
Learn about the process of planet building that formed the four inner planets in the solar system. In the early solar system, asteroids collided to form increasingly large bodies, ultimately producing moon-sized protoplanets. Protoplanets continued the process of planetary billiards to become full-sized planets.

Video 2: Life's Basic Ingredients *(Activity 2)*

Learn what astrobiologists consider to be the three basic ingredients of life—water, organic compounds, and energy. Although Earth has water and energy, scientists are trying to learn the origins of organic molecules. Astrobiologists believe that comets could help us understand how the final ingredients necessary for life arrived on Earth.

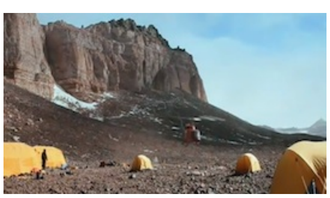
Video 3: Comets Bombard the Early Earth *(Activity 3)*

Learn about the behavior of the four outer planets in the solar system 3.9 billion years ago. As Jupiter and Saturn circled the Sun, gravitational interactions destabilized the orbits of Uranus and Neptune. These planets were sent careening toward the Kuiper Belt, causing comets to be blasted out of their orbits into the solar system in a period known as the "late heavy bombardment."



Video 4: Life's Extreme Environments *(Activity 4)*

Meet organisms that thrive in a wide variety of harsh conditions, such as dry deserts, toxin-laden lakes, dark caves, and acidic rivers. These microbes—dubbed extremophiles—show life's adaptiveness and are broadening scientist's understanding of the diverse environmental conditions life can withstand. Since similar conditions have been detected or inferred on other planets or moons, it is possible that microbes might live there as well.



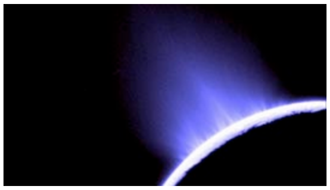
Video 5: Microbial Life in Antarctica *(Activity 4)*

What can one of the most extreme deserts on Earth—the dry valleys of the Antarctic—tell us about life on Mars? Watch as scientists drill into the Mars-like soil and ice, where they discover microorganisms in a film of liquid water at the point where the dirt meets the ice.

Video 6: Thriving on the Arctic Seafloor *(Activity 4)*

Follow biologist Tim Shank as he explores the deep Arctic Ocean, which may be similar to the ocean on Europa. Robots sent to the ocean floor discover a hostile environment that is home to new forms of life that use sulfur, hydrogen, and methane as chemical sources of energy.

Video Resources



Video 7: Life on Enceladus? *(Activity 6)*

Learn about one of Saturn's icy moons, named Enceladus. See real images taken by the *Cassini* spacecraft that reveal jets of ice erupting from the South Pole of Enceladus into space. Upon further investigation, *Cassini* collects particles from the jets and detects some of the basic chemical building blocks of life.

Video 8: Life on Europa? *(Activity 6)*

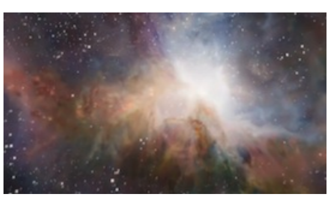
Learn about Jupiter's moon Europa. Images reveal a surface covered with jagged areas of ice in a pattern similar to the one made by sea ice on Earth. Readings of Europa's magnetic field indicate that an electric current is flowing inside, consistent with an ocean of salty, liquid water beneath the icy surface that could be 60 miles deep.

Video 9: Life on Mars? *(Activity 6)*

Learn about the discovery of water ice on Mars. Satellites analyzing radar waves bouncing back from Mars's polar caps reveal that if all the water ice melted, it would cover the entire planet in an ocean more than 80 feet deep. However, just like a piece of dry ice on Earth goes directly from solid ice to vapor without forming a liquid, water ice on Mars behaves the same way because the pressure is so low.

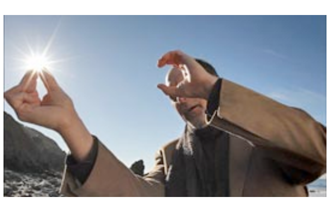
Video 10: Life on Titan? *(Activity 6)*

Learn about Titan, the largest moon of Saturn. Through radar imaging, scientists discover that Titan's surface is covered with hundreds of lakes filled with liquid methane and ethane, making it the only world other than Earth that has a liquid on its surface.



Video 11: Life Beyond the Solar System *(Activity 7)*

Learn how the Hubble Space Telescope is being used to find new stars like our Sun that are being born inside clouds of dust and gas. These gas and dust particles may one day collide and clump together to form new planets and moons in a process similar to how the planets in our solar system could have formed.



Video 12: Planet-Hunting *(Activity 7)*

Learn how scientists search for planets beyond our solar system. Using the highly sensitive Kepler space telescope, scientists can observe a slight dimming of starlight when a planet passes in front of its star. So far, the telescope has discovered thousands of planet candidates, including several similar in size to Earth.

Materials

Activity 1

- Handouts (1 per child): “Solar System Model” and “Planetary Postcard” (in appendix)
- Cotton balls (2 per child)
- Whole coffee beans (2 per child)
- Whole peppercorns (2 per child)
- Pin head–sized beads or seeds (2 per child)
- Cups or paper plates (for distributing beans, beads/seeds, and peppercorns)
- Scotch tape (or white glue, if you have drying time)
- Pencils or pens

Activity 2

- Poster paper and a marker or a drawing board
- A pair of objects per child (or per every two children); for example:
  - A real piece of fruit and a plastic replica (from a flower, Christmas, hobby, or decorator shop)
  - A live flower and a similar kind of silk, paper, or plastic flower
  - A live leaf and a similar kind of silk, paper, or plastic leaf
  - A live tree leaf and a dead tree leaf (the same kind)
  - Live grass and dead grass (the same kind)

Activity 3

(1 per child or per team of 2 to 3 children)

- A shallow box (e.g., medium-sized plastic deli container, pizza box, lid from copy paper box, aluminum pan, etc.)
- White flour (enough to make a layer two inches deep)
- Powdered cocoa (enough to make a thin layer on the flour)
- A flour sifter, sieve, or cheese or spice shaker (for sprinkling cocoa powder onto flour)
- 3 balls of various sizes (1 to 4 cm), such as rubber balls or marbles in a cup

Activity 4

(1 set per team of 2 to 4 children)

- “Can Living Things Live Here?” cards (in appendix)
- “Extreme Life” cards (in appendix)

Activity 5

- “Creature” cards (1 set per team, in appendix)
- “My Creature” handout (1 per team or child, in appendix)
- Markers (for drawing)

Activity 6

- “Habitability” cards (1 set per team, in appendix)
- A drawing board or a chart pack and a marker

Activity 7

Demonstration A

- A plastic drinking straw
- String
- Clay

Demonstration B

- A bright flashlight or small lamp
- A series of balls, ranging in size from large to small (compared to the size of the light)
- String

Demonstration C

- Sealable containers, such as baby-food jars or small plastic storage containers
- Aromatic foods (e.g., diced onion, garlic, and citrus rind, and extracts such as peppermint, vanilla, and citrus fruits)
- Cotton balls

Demonstration D

- 2 clear, sealable plastic bags, one containing a half cup of sugar and the other with a half cup of salt
- 2 ceramic bowls or plates
- A gas match barbecue lighter

Implementation Suggestions

Each core activity, geared toward ages six to eleven, takes 15 to 30 minutes. (See each activity's overview box for a specific time recommendation.) This includes introducing, doing, and wrapping up the activity and watching any related video clips—a powerful, visual way to underscore the lesson's main ideas. Each activity can also be done as a stand-alone activity on a cart or table. Encourage kids to visit related museum exhibits to further their understanding of the subject area whenever possible.

Below we provide suggestions for how you might integrate the activities into a more comprehensive class module, museum workshop, or field trip.

If you have 60 minutes....

Planetary and Earth Sciences

1. Meet the Planets | Activity 1
2. Basic Ingredients for Life | Activity 3
3. Where to Look for Life | Activity 6

Astrobiology and Life Sciences

1. What Is Life? | Activity 2
2. Extreme Living | Activity 4
3. Home Sweet Home | Activity 5

If you have 90 minutes....

Planetary and Earth Sciences

1. Meet the Planets | Activity 1
2. Basic Ingredients for Life | Activity 3
3. Extreme Living | Activity 4
4. Where to Look for Life | Activity 6
5. How to Search | Activity 7

Astrobiology and Life Sciences

1. What Is Life? | Activity 2
2. Extreme Living | Activity 4
3. Home Sweet Home | Activity 5
4. Where to Look for Life | Activity 6
5. How to Search | Activity 7

Activity Standards Alignment

Note: Alignment to standards is conservative to ensure the utility of the collection.

National Science Education Standards Kindergarten through 4th Grade	#1	#2	#3	#4	#5	#6	#7
Science as inquiry							
1. Understandings about scientific inquiry	√	√	√	√		√	√
Physical science							
1. Properties of objects and materials	√	√	√				
2. Position and motion of objects			√				√
3. Light, heat, electricity, and magnetism							√
Life science							
1. Characteristics of organisms		√		√	√		
2. Life cycles of organisms		√		√	√		
3. Organisms and their environment				√	√	√	
Earth and space science							
1. Properties of Earth materials			√				
2. Objects in the sky	√		√			√	√
3. Changes in the earth and sky	√		√				√
Science and technology							
1. Abilities of technological design							√
2. Understandings about science and technology						√	√
3. Abilities to distinguish between natural objects and objects made by humans		√					
History and nature of science							
1. Science as a human endeavor						√	√

National Science Education Standards 5th through 8th Grade	#1	#2	#3	#4	#5	#6	#7
Science as inquiry							
1. Understandings about scientific inquiry	√	√	√	√		√	√
Physical science							
1. Properties and changes of properties in matter	√						√
2. Motion and forces			√				√
3. Transfer of energy			√				√
Life science							
1. Structure and function in living systems		√		√	√		
2. Reproduction and heredity		√					
3. Regulation and behavior		√		√	√		
4. Populations and ecosystems				√	√	√	
5. Diversity and adaptations of organisms				√	√	√	
Earth and space science							
1. Structure of the earth system			√	√	√		
2. Earth's history	√		√				
3. Earth in the solar system	√					√	√
Science and technology							
1. Abilities of technological design							√
2. Understandings about science and technology							√
Science in personal and social perspectives							
1. Natural Hazards	√		√				
2. Risks and benefits			√				
3. Science and technology in society							√
History and nature of science							
1. Science as a human endeavor						√	
2. Nature of science						√	√

1 — Meet the Planets

What's in the solar system?

Overview

Setting the stage for the search for life, kids will identify the planets in the solar system, observe and describe their characteristics and features, and build a scale model out of everyday materials. They will also be introduced to moons, comets, and asteroids.

Time

This activity will take approximately 20 to 25 minutes.

Learning Goal

Kids will understand that Earth is one of several planets that orbit the Sun in our solar system. They will observe the different planets and objects in our solar system and gain an understanding of scale when comparing planet sizes.

Preparation

Materials	Multimedia	Setup
• Handouts (1 per child): "Solar System Model" and "Planetary Postcard" (in appendix) • Cotton balls (2 per child) • Whole coffee beans (2 per child) • Whole peppercorns (2 per child) • Pin head–sized beads or seeds (2 per child) • Cups or paper plates (for distributing beans, beads/seeds, and peppercorns) • Scotch tape (or white glue, if you have drying time) • Pencils or pens	• NOVA solar system poster or another image of the solar system that shows all the planets in size comparison with each other and the Sun • Video 1: *How the Inner Solar System Formed* (optional) • "Meet the Planets" presentation slides (optional, download *here*)	• Put cotton balls, coffee beans, peppercorns, and beads into separate containers. • Make copies of the "Solar System Model" handout and the "Planetary Postcard" handout found in the appendix. • Gather enough tape or glue. • If you have the NOVA solar system poster, post it where everyone can see it.

The Activity

1. Engage

Ask:

- What's the name of the planet that we live on? *(Earth)*
- What are some of the things you know about planet Earth?

Show kids the image of the solar system with all the planets. Point out the Sun and name the planets. Ask:

- What are some things you notice? (*The Sun is huge. The planets are different sizes. The planets look different—Jupiter has stripes; Saturn has a ring; Neptune is blue.)*
- Where do you think it is hottest? *(Near the Sun.)* Coldest? *(Far from the sun.)*

Give each child a "Planetary Postcard." Situate the kids in their place in the solar system by starting locally with what they know and moving outward, filling out the postcards together as you go. Kids can customize their postcard and design a stamp if time allows.

Tell kids that you want them to take home a solar system so they can keep exploring the planets, but you don't know how they will be able to carry around something so large. Do they have any ideas? Ask them if they have things that they like that are too big to carry around and play with. Work toward the idea that you are going to make a model of the solar system—something that is different from the real thing but can be used to learn something about the real thing. The model we will build in this activity is similar in size scale to the planets and Sun of our solar system.

2. Facilitate

The challenge for kids is to reference an accurate image showing the scale of the solar system image, match an object (coffee bean, cotton ball, bead/seed, or peppercorn) to a planet based on size, tape/glue the objects onto the "Solar System Model" handout, and label each planet. This model includes only planets, since moons, comets, and asteroids are too small to be seen at this size scale. (Work from the Sun, in an outward direction, visiting each planet.)

For each planet, ask:

- Who can name this planet?
- It is larger or smaller than its neighbor(s)?
- Which object do you think should represent this planet? *(Cotton balls for Jupiter and Saturn; coffee beans for Uranus and Neptune; peppercorns for Earth and Venus; and beads/seeds for Mercury and Mars.)*

Kids share their ideas and reach a consensus. Everyone works to tape/glue the objects to their "Solar System Model" handout and label it.

3. Check for understanding

Ask: By looking at your models, what can you tell about the differences between the planets? What information does your model *not* tell you? Have you seen other solar system or planetary models? (If a nearby museum or park has a large solar system model, this is a good time to visit and compare the models.)

Keep Exploring

Make planetary observations

(This will add 10 to 15 minutes to the activity.)

Use the presentation slides to further explore each planet by showing detailed images of each of the planets. Work your way through the solar system as children build their models. Guide children to observe and discuss the characteristics of each planet and begin to draw some comparisons between them.

For each planet, ask:

- What do you notice about this planet?
- What tells you if it is made or rock or of gas? *(Craters, ice caps, landforms, cloudiness, etc.)*
- Older children can keep an observation journal or build a table comparing the characteristics of each planet (i.e., size, composition, environment, etc.). They can do further Internet research at *http://solarsystem.nasa.gov/planets/* to build a portfolio or presentation.

Discuss the formation of the solar system

(This will add 10+ minutes to the activity.)

The accompanying NOVA *How the Inner Solar System Formed* video (four minutes long) highlights the processes that were active in shaping the early solar system, with a focus on accretion.

Check out "The Thousand-Yard Model, or Earth as a Peppercorn"

(This will add 30 to 60 minutes to the activity.)

This outdoor activity from the National Optical Astronomy Observatory gives kids a visual demonstration of size and distance in the solar system. Kids make a scale model of the sizes and spacing of the planets using common household materials. It's also a great way to get children outdoors and active! Visit *noao.edu/education/peppercorn/pcmain.html* to learn more.

Cart Version

1. **Show** kids the NOVA solar system poster or images of the planets in size comparison with each other and the Sun. Point out the Sun and name the planets.
2. **Ask** kids to explain things that they notice about each one. *(The Sun is huge. The planets are different sizes. The planets look different—Jupiter has stripes; Saturn has a ring; Neptune is blue.)*
3. **Explain** to kids that they are going to make a model of the solar system—it will be different from the real thing but can be used to learn about the real thing.
4. **Invite** kids to create their own solar system model by matching an object (a coffee bean, cotton ball, bead, or peppercorn) to a planet based on size. They can glue these objects onto the "Sun" handout and label each planet. It is useful to have a model already finished for reference.

2 – What Is Life?

What are the characteristics of life?

Overview

Kids observe a number of objects, make a list of life's characteristics, and develop a working definition of what it means to be alive. Using a confounding example, children test their definition and conclude that one needs multiple characteristics to define and search for life.

Time

This activity will take approximately 15 minutes.

Learning Goal

By understanding the characteristics of living things, scientists can develop appropriate tools to search for life beyond Earth. They will also learn that there is no single indicator of life. To define something as alive, we must look at many characteristics collectively.

Preparation

Materials	Multimedia	Setup
• Poster paper and a marker or a drawing board • A pair of objects per child (or per every two children); for example: - A real piece of fruit and a plastic replica (from a flower, Christmas, hobby, or decorator shop) - A live flower and a similar kind of silk, paper, or plastic flower - A live leaf and a similar kind of silk, paper, or plastic leaf - A live tree leaf and a dead tree leaf (the same kind) - Live grass and dead grass (the same kind)	• Video 2: *Life's Basic Ingredients* (optional) • "What Is Life?" presentation slides (download *here*)	• If you are distributing pairs of objects, put them both in a bag or container.

The Activity

1. Engage

Ask:

- Who is alive? *(All hands go up!)*
- Who can tell if something is alive? *(Most likely, every kid will raise his or her hand.)*
- How do you know something is alive? *(By what it does or how it acts.)*
- What are some things all living things do? *(Grow and develop; consume raw materials [eat and drink], use nutrients, require energy; produce waste; reproduce; respond to changes in the environment; consist of one or more cells; and evolve. Remember to include only those characteristics that make sense for the age group you are working with.)*

2. Facilitate

Give kids an object or pair of objects. Have them look at the object(s) and list observations that indicate whether or not the object is/was alive. (You could also do this as a demo.) Remember that you are working toward a definition or criteria for life. As a group, develop a list of characteristics on a drawing board.

Show kids the presentation slides of living and nonliving things and ask them to call out, "It's alive!" when they see something that is living.

Ask:

- Is a piece of fruit or blade of grass alive? Can you say something is alive if you only have a piece of it and the piece really couldn't survive on its own? *(A piece of something that is/was alive is evidence of life, and would qualify as real evidence for scientists looking for life.*)
- What about fire?—a confounding example. *(This is optional, depending on your time and the audience's age. Point out that a wildfire uses raw materials, moves, grows, produces waste, responds to its environment by changing direction with the wind or going out in the rain, and reproduces by its sparks starting new fires.)*
- What are some things that are true for living creatures but not for fire? *(Organisms are self-contained chemical systems with consistent shapes and predictable behaviors. Importantly, they can produce offspring that exhibit genetic variation.)*

3. Check for understanding

Tell kids to hold up an item that they believe is alive.

Ask: How hard is it to tell which item was real and which was the copy? How did you know?

Conclude by saying that one needs multiple characteristics to detect life. Help the group see that it isn't just one characteristic that defines something as alive. Point out that it is difficult to define something as alive by just one or two characteristics. For example, movement alone doesn't mean something is alive—a ball can roll down a hill. Mention the importance of long-term functions, and that many characteristics occur for a short time period. But to persist, life evolves and adapts to changing conditions over long periods of time.

Keep Exploring

Observe another confounding example, sewer lice

This classic demonstration is an opportunity to observe characteristics often associated with living things exhibited in nonliving materials. *www.flinnsci.com/Documents/demoPDFs/Biology/BF10054.pdf*

Watch *Life's Basic Ingredients*

The accompanying NOVA *Life's Basic Ingredients* video (three minutes long) highlights the three main ingredients that life needs and ends with a mention of comets as a possible key source of organic materials.

Cart Version

1. **Help** kids understand a definition for life by giving them each a pair of objects—a real one and a model.
2. **Ask** them to list some characteristics of each object before categorizing them into "living" and "nonliving" piles.
3. **Discuss** what makes something alive. Stress the point that life involves adapting to changing conditions over a long period of time.
4. **Encourage** kids to go off and determine whether things in the museum are living or nonliving.

3 – Basic Ingredients for Life

How do craters help us in the search for life?

Overview

Kids make impact craters to gain insight into how comets and asteroids deliver water and chemicals to the Earth and other places in the solar system. They identify the basic features of craters and compare the craters they make with those observed in the solar system.

Time

This activity will take approximately 20 to 30 minutes.

Learning Goal

Kids will learn that life as we know it requires energy, water, and organic compounds. Comets and asteroids deliver water and chemicals to planets and moons through collisions. Evidence of these collisions can be found in craters throughout the solar system.

Preparation

Materials	Multimedia	Setup
(1 per child or per team of 2 to 3 children) • A shallow box (e.g., medium-sized plastic deli container, pizza box, lid from copy paper box, aluminum pan, etc.) • White flour (enough to make a layer two inches deep in the box) • Powdered cocoa (enough to make a thin layer on the flour) • A flour sifter, sieve, or cheese or spice shaker (for sprinkling cocoa powder onto flour) • 3 balls of various sizes (1 to 4 cm), such as rubber balls or marbles in a cup	• Video 3: *Comets Bombard the Early Earth* • "Basic Ingredients for Life" presentation slides (download *here*)	• Fill containers two inches deep with flour. • Lay down an unopened trash bag, drop cloth, or large sheet of newspaper at every station. • Cover the flour with a layer of cocoa powder, using a flour sifter, sieve, or shaker to evenly sprinkle a thin dusting. • Add three or more impactors to a cup and set at each station.

The Activity

1. Engage

Ask:

- What kinds of things do you need to keep you alive? *(Humans need food, water, and air. Broadly, life as we know it requires energy, water, and organic compounds.)*
- The Earth didn't always have abundant water and nutrients easily available to living things. What are some ideas for how a good portion of Earth's water and nutrients got here? Here's a hint: something delivered them from outer space. *(They were delivered by comets and asteroids that had a small supply of water and nutrients. When one crashed into Earth, it added a little water and a few nutrients to Earth's supply.)*
- We have to look for clues that collisions like these took place on Earth and in the solar system. What might evidence of a collision look like?

Show presentation slides of the aftermath of other kinds of collisions to get kids thinking about what caused them. End with images of craters so kids can make the connection between craters and collisions. Identify key features (e.g. rim, ejecta, rays, walls, and central peaks).

2. Facilitate

Demonstrate how to make a crater. Explain that the white flour is a fine powder that represents the *lunar regolith*—the layer of loose, heterogeneous material covering the rocky surface of the moon made of dust, soil, broken rock, and other related materials. The cocoa makes the ejecta and rays from the impact much easier to see.

Send each child or team to a cratering station and encourage them to change the drop height, angle of impact, and size of the impactor. As the kids are making their craters, walk around and ask them to identify the rays and rim of their craters.

3. Check for understanding

Show the NOVA *Comets Bombard the Early Earth* video, which explains the role that asteroids and comets played in seeding the solar system with water and chemicals. Discuss comets and impact craters and what we learn from them.

Ask:

- What would happen if a comet hit Earth? *(It would make a crater; break into pieces; make a huge explosion; raise a cloud of dust; add material to Earth; destroy the area it hit.)*

Show presentation slides of some of Earth's craters. Tell kids that all the planets and moons in the early solar system were bombarded by comets and asteroids, and they all got similar supplies of water and nutrients. *(Comets and asteroids are rich in water ice and chemicals needed by life. They delivered these materials when they crashed into the planets and moons.)*

Keep Exploring

Guided cratering lab activity (ages 9 and up)

(This will add 45 minutes to the activity.)

This comet cratering activity is from *Think SMALL in a BIG Way* in the Stardust Educator's Guide (pages 6–12), at *stardust.jpl.nasa.gov/classroom/guides.html*. Tell kids they will find out how craters are formed by doing an experiment. Group kids into teams of three or four. Tell them to follow the procedure on the *Stardust* mission's handout.

Let kids know:

- The knot in the string is at 30 cm.
- To measure the crater diameter, the kids need to carefully remove the ball and measure across the middle, rim to rim. (Optional: Kids can also measure the diameter of the blanket of ejected material.)
- Before testing the next ball, smooth the cratering surface by running a card across the surface layer. If the top is too mottled in color, kids may need to refresh the dusting of cocoa powder.

Make a dry-ice comet

Demonstrate what a comet is made of by making one out of dry ice:

- Find the basic recipe: *http://www.noao.edu/education/crecipe.html*
- NASA's Create a Comet with Dry Ice video: *jpl.nasa.gov/education/videos/playVideo.cfm?videoID=17*
- Comet Basics (from *Stardust* mission): *http://stardust.jpl.nasa.gov/classroom/guides.html* Try these two activities: Cookin' Up a Comet, which uses dry ice (pages 2–4); and Edible Comet, which uses ice cream and toppings (pages 5 and 6).

Cart Version

1. **Ask** kids to list what kinds of things they need to stay alive. *(Humans need food, water, and air. Broadly, life as we know it requires energy, water, and organic compounds.)*
2. **Explain** to kids that Earth didn't always have abundant water and nutrients easily available to living things; in fact, they were delivered by comets and asteroids that crashed into Earth.
3. **Show** kids images of craters in the solar system and explain that these are clues that collisions took place on Earth and on other planets. Identify the key features of the craters (e.g., rim, ejecta and rays, walls, and central peaks).
4. **Invite** kids to make their own craters, experimenting with different drop heights and speeds.
5. **Ask** them to identify features like the rays and the rim on their craters.

4 – Extreme Living

Are microbes living in harsh conditions on Earth models for life beyond Earth?

Overview

Using cards that show extremophiles and some of Earth's extreme environments, kids match a microbe to a place where it could live. They discuss whether life could exist beyond Earth, based on the idea that Earth has organisms that live in conditions comparable to ones found elsewhere in the solar system.

Time

This activity will take approximately 15 minutes.

Learning Goal

Kids will learn that on Earth, microbes thrive in a wide range of environmental conditions. Since similar conditions have been detected or inferred on other planets or moons, microbes might live there as well.

Preparation

Materials	Multimedia	Setup
(1 set per team of 2 to 4 children) • "Can Living Things Live Here?" cards (in appendix) • "Extreme Life!" cards (in appendix)	• Video 4: *Life's Extreme Environments* • Video 5: *Microbial Life in Antarctica* • Video 6: *Thriving on the Arctic Seafloor* • "Extreme Living" presentation slides (optional, download *here*)	• Print the 16 "Can Living Things Live Here?" and "Extreme Life!" cards found in the appendix. • Cut the cards apart.

The Activity

1. Engage

Ask:

- What's the hottest place you've ever been to? Coldest? Saltiest? *(Possible answers include: A place in summer, a hot tub, a hot climate, a desert, a boiler room; a place in winter, a cold climate, a walk-in freezer; the ocean, the Great Salt Lake, a bath with bath salts.)*
- Name some organisms that live in hot, cold, and salty places. *(Plants, animals, microbes)*

2. Facilitate

Tell kids that some organisms thrive in places with amazingly harsh conditions. Some of the hardiest ones are microbes. Microbes are tiny—only as big as one cell. Kids might be familiar with the term *bacteria*, which is one kind of microbe. Most microbes are harmless. In fact, many help us in important ways, like helping us digest our food. We call microbes that make us sick *germs*. In this activity, kids will explore some harsh environments and meet some microbes that live there.

Play the game:

- Give each team a set of "Can Living Things Live Here?" cards. Ask them to sort them into two piles: "Life could live here" and "Life could not live here."
- Once sorted, have teams discuss what pile they assigned each card/location to and why. Are there places that teams didn't agree on?
- Hand out the "Extreme Life!" cards. Have kids match the microbe to its environment.

3. Check for understanding

Ask:

- Which life forms matched up with which environments?
- Did any matches between the environments and life forms surprise you? Why or why not?
- What kinds of organisms seem to be tough enough to live in extreme conditions? *(Microbes)*
- What do you think finding life in these extreme environments on Earth means with regards to where we can look for life on other planets and moons of the solar system?

Show the related NOVA video resources to visit some extreme environments on Earth and join in the search for life.

Keep Exploring

Play concentration

Shuffle two sets of cards and place them face down in rows. The person to the left of the dealer turns over two cards. If the cards show a life form and the environment in which it lives, the person takes the pair and turns over two more cards. If the cards don't match, the person turns them face down again and the person to the left continues the play. Play until all cards have been matched. The winner is the one with the most pairs of cards.

Play the "Life on the Edge" card game from NASA's Astrobiology Institute

This game is similar to "Extreme Living," but it adds a third kind of card—examples of conditions on Mars and Europa that may be similar to conditions on Earth. Kids play concentration, making books of three kinds of cards: an "Organism" card, an "Earth Habitat" card, and a "Possible Extraterrestrial Habitat" card. Find the instructions and cards on pages 45–48 of the Astrobiology Institute's *Life on Earth … and Elsewhere?* Educator Resource Guide at *http://astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/life-on-earthand-elsewhere/*.

Cart Version

1. **Explain** to kids that organisms—especially microbes—thrive in places with amazingly harsh conditions. (Kids might be familiar with the term *bacteria*, which is one kind of microbe.)
2. **Explain** that since similar conditions have been detected or inferred on other planets or moons, microbes might live there as well.
3. **Play** a game of concentration by using the "Extreme Life!" and "Can Living Things Live Here" cards to match life forms with the environments in which they live.
4. **Discuss** how that life form is able to adapt and thrive in that particular environment when a match is made.

5 – Home Sweet Home

How do organisms adapt to living in very different environments?

Overview

Kids choose a card describing one of six possible planetary environments and invent a creature that can thrive in the conditions outlined on the card. Kids will have to be creative in order to invent creatures that can live on some of the planets in our solar system, as some cards describe planets where no life is predicted to exist. However, the goal is to introduce kids to the factors to consider when thinking about the habitability of planets: Is there food to eat, gas to breathe, a comfortable temperature, a way to move, and gravity? Kids will draw their creatures and share the drawings with the group.

Time

This activity will take approximately 30 minutes.

Learning Goal

Kids will understand that living things develop so they can survive in a particular environment.

Preparation

Materials	Multimedia	Setup
• "Creature" cards (1 set per team, in appendix) • "My Creature" handout (1 per team or child, in appendix) • Markers (for drawing)	• "Home Sweet Home" presentation slides (download *here*)	• Print the "Creature" cards and "My Creature" handout found in the appendix. Each child or team will need a card, so duplicate them as many times as necessary • Cut the cards apart.

The Activity

1. Engage

Ask:

- Think about where you and your family live. Is it an apartment? A house? A trailer? What makes a house or an apartment such a good place to live? *(It provides space; protects us from the elements; stores food; keeps the temperature comfortable; there is oxygen that we can breathe.)* Write down the kids' answers, if possible.
- How is the planet Earth like a house or apartment? *(It provides us with food and water; the atmosphere shields us from ultraviolet light C, which can harm our eyes and skin; the magnetic field protects us from cosmic radiation, which can damage our body's cells; the atmosphere circulates oxygen for us to breath and acts like a blanket to protect us from the cold of space.)*

Brainstorm some requirements of life and the related planetary characteristics. Invite each group to share its ideas about the requirements for life. Some groups may list requirements that are not absolutely necessary for survival (such as this requirement for a cat: "someone to take care of it"). Encourage kids to discuss which of their requirements are necessary for basic survival and which add to the quality of life of the living thing.

Optional: Consider putting this information or the titles below on a chart for kids to see, fill in, or discuss (see table).

Life Requirements	Related Planetary Characteristics
Food to eat	Planets need to supply chemicals that creatures can use for energy
"Air" to breathe	A planets atmosphere can supply creatures with important chemicals in gas form (e.g., air)
Comfortable temperature	Planets can be hot, moderate (i.e., Earth), or cold
Ability to move	A planet's surface type (solid, liquid, gas) affects how creatures can move
Gravity	The more massive a planet is, along with its size, determines the pull of gravity on a creature

2. Facilitate

Hand out the "Creature" cards and the "My Creature" handout. Tell kids that you will give each person (or team) a card that describes the kind of food and atmosphere on a planet as well as the planet's temperature. The card also states how creatures move on their planet. The kids' job is to invent, design, draw, and name a creature that can thrive in the conditions listed on the card. After 10 to 15 minutes, they will gather and meet everybody's creature.

- Kids can work individually or as a team. Teams give kids a way to discuss ideas.
- More than one kid or group can use the same "Creature" card.
- Kids can be creative when inventing and drawing creatures that can live on their planet.
- For the temperature, "moderate" means a range of temperatures, like on Earth. "Cold" means much, much colder than Earth, and "hot" means much, much hotter than Earth.

3. Check for understanding

Gather in a circle. Have kids first describe their planet and then talk about their creature's needs and the features that enable it to live successfully on the planet. (Try to keep this moving, because kids will get really involved with their creatures.)

Tell kids that the "Creature" cards relate to planets in the solar system. As kids describe their creature, show an image of the planet from the provided presentation slides. Use the key below:

Creature	Conditions	Match Planets
A	Can live on cold gas planets	Jupiter, Saturn, Uranus, and Neptune
B	Can live on hot solid planets	Venus
C	Can live on a solid, moderate-temperature planet	Earth
D	Can live on cold gas planets that support swimming	Uranus and Neptune
E	Can live on a cold, solid planet	Mars
F	Can live on a solid, moderate-temperature planet	Earth

Note: No creatures can live on Mercury *(it's too hot and there's no atmosphere*).

Emphasize that life is adaptable. Tell kids that Creatures C and F are most like life as we know it. However, scientists are constantly amazed by the discovery of microbes living in places that they never imagined could support life.

The message is that if a liquid, food, and an energy source are available, there is a good chance that life will find a way to develop—life has an amazing ability to exploit resources. And as much as we think we understand life and where it can exist, discoveries of new forms of life thriving in seemingly uninhabitable conditions constantly surprise us and force us to rethink our ideas of life and habitability.

Optional message for older kids: Organisms need protection from extreme temperatures and radiation levels and access to reliable supplies of water, nutrients, and energy. On most planets and moons, they would have to live underground to find all these conditions, meaning they would be microbial.

Keep Exploring

Make a model

(This will add 20 to 30 minutes to the activity.)

Invite kids to build a 3-D model of their creature out of clay or other modeling materials. Put together a gallery display of creatures for children to share.

Cart Version

1. **Help kids brainstorm** several requirements for life: food to eat, “air” to breathe, comfortable temperature, ability to move, and gravity. Explain how planets can provide these requirements to support life. It may be useful to show this information in a chart.
2. **Explain** that life is extremely adaptable, and that scientists are constantly discovering microbes living in places that they never imagined could support life.
3. **Supply** each child with a creature card that describes the kind of food and atmosphere on a planet as well as the planet’s temperature. The card also states how creatures move on their planet.
4. **Ask** kids to design and name their own creature that can survive in the conditions listed on the card. Tell them to be creative when inventing and drawing creatures that can live on their planet.

6 – Where to Look for Life

Which planets and moons in the solar system are potentially habitable?

Overview

Kids examine 12 cards that describe the planets and six moons in terms of their temperature and atmosphere and the availability of water, energy, and nutrients. Based on their assessment of the habitability, kids identify the top candidates for life in the solar system.

Time

This activity will take approximately 20 to 30 minutes.

Learning Goal

Many scientists are convinced that habitable conditions exist beyond Earth and that the solar system offers several possible places that may be (or have been) able to support life.

Preparation

Materials	Multimedia	Setup
• "Habitability" cards (1 set per team, in appendix) • A drawing board or a chart pack and a marker	• Video 7: *Life on Enceladus?* • Video 8: *Life on Europa?* • Video 9: *Life on Mars?* • Video 10: *Life on Titan?* • "Where to Look for Life" presentation slides (optional, download *here*)	• Print the "Habitability" cards found in the appendix. • Cut cards apart. To make them last longer, print them on card stock or laminate them.

The Activity

1. Engage

Ask:

- Who can tell us how to play hide-and-seek? *(Someone hides. Then others try to find that person.)*
- Why might looking for life in the solar system be like a game of hide-and-seek? *(If there is life beyond Earth, it is not obvious. It is probably very small and living underground. Our challenge is to find it.)*

Tell kids that in this activity, they are going to help decide where we should focus our search for life in the solar system.

2. Facilitate

Tell kids that sending spacecraft out to look for life is very expensive. Plus, looking everywhere takes a long time. To decide where to look first, scientists narrow their search by understanding what makes a planet or moon habitable. They look closely at the most habitable places.

Review what life needs and either refer to the list you made in Activity 5, or have kids call out the key requirements, such as food, water, suitable temperatures, and protection from harmful radiation. Make sure kids are aware of food's dual role as a provider of energy and of nutrients.

Distribute the cards and point out that each card has images and evidence for how habitable a planet or moon is by giving information about its temperature and atmosphere and the availability of water, energy, and nutrients.

Prioritize the cards. Have kids use the "Habitability" cards to assess a planet's or moon's chances of supporting life, past or present. Have teams sort the cards into three piles: a likely, an unlikely, or a possible place for life. Ask them to be able to explain the reasoning behind their choices. (Note: For younger kids, consider doing the sorting as a full-group activity.)

3. Check for understanding

Rate each planet and moon by making a chart on a board (see the example on the following page). Go down the list, and have each team report its ranking and reasoning.

Remind kids that:

- The same processes that forged life on Earth are found throughout the universe.
- Except for Earth, each planet or moon currently has major limitations for life, as we know it.
- Looking for habitable conditions is easier than looking for actual organisms.

Ask kids to name their top destination for the next space mission looking for life. (*Europa, Mars, Callisto, Enceladus, and Titan may have or have had habitable conditions.)* Then visit the most promising candidates for life (Enceladus, Mars, Europa, and Titan) by showing one or more of the NOVA video resources.

Planet/Moon	Likely	Possible	Unlikely	Reasoning
Four gaseous planets (Jupiter, Saturn, Uranus, Neptune)			X	They have extreme temperatures, churn violently, and have very little water
Mercury			X	Too hot
Venus			X	Too hot
Earth's Moon			X	Lacks water
Mars	X			Has water, nutrients, and internal heat to melt ice and circulate water
Io			X	Lacks water and is very volcanic
Ganymede			X	Too cold and has no liquid water
Europa		X		May have an ocean beneath its icy surface
Callisto		X		Very cold, but may have an ocean under its surface
Enceladus*		X		Jets of ice suggest water and internal heat
Titan		X		There is liquid methane and ethane on the surface; to evolve and live in such a cold place, it could not be life as we know it—it would be totally new
Pluto (not a planet)			X	Too cold and has no liquid water

*Enceladus is not part of the "Habitability" card collection, but is featured in the NOVA program

Keep Exploring

The search for life

The Search for Life guide from the American Museum of Natural History explains the five components of habitability: distance and energy, a protective shield, proper temperature range, water, and the right ingredients. Further explain these concepts to kids and then discuss how life on Earth would be affected by several changes proposed in the guide, which can be found in the online index at *http://www.amnh.org/exhibitions/permanent-exhibitions/earth-and-planetary-sciences-halls/arthur-ross-hall-of-meteorites/promos/online-educator-s-guide.*

Cart Version

1. **Explain** to kids that scientists can narrow their search for life by understanding what makes a planet or moon habitable.
2. **Have kids brainstorm** some key requirements for life: food for energy and nutrients, water, suitable temperatures, and protection from harmful radiation.
3. **Distribute** "Habitability" cards to each child. These provide evidence for how habitable a planet or moon is by giving information about its temperature, atmosphere, and the availability of water, energy, and nutrients.
4. **Have kids sort** the cards into three piles: a likely, an unlikely, or a possible place for life.
5. **Discuss** with kids their reasoning for placing a card in a particular pile.

7 – How to Search

How do we search for life in our solar system and beyond?

Overview

Kids participate in demonstrations of four different search techniques. Two of the demonstrations show how biomarkers can be used to find life in the solar system, and two feature techniques that can be used to detect planets orbiting other stars. Do one or two of the demonstrations to make the point that we use different methods to search for planets, habitable conditions, and life. Choose and/or modify them according to the age of your audience (demonstrations B and C work best with younger kids; consider demonstrations A and D for kids ages nine and up).

Time

This activity will take approximately 20 minutes per demonstration.

Learning Goal

Technology, such as telescopes and sensors on spacecraft, give scientists powerful tools for looking for extrasolar planets, habitable conditions, and signs of life. To search for life in the solar system, we send spacecraft to explore nearby planets and moons. To search for and learn about planets orbiting distant stars, we use sensitive telescopes.

Preparation

Demonstration A

Materials	Multimedia	Setup
• A plastic drinking straw • String • Clay	• Video 11: *Life Beyond the Solar System* • Video 12: *Planet-Hunting*	• Form the clay into a large ball (e.g., diameter = 1 inch) and a small ball (e.g., diameter = ½ inch). • Poke the clay balls onto the opposite ends of a drinking straw. • Tie a string along the straw so that the two balls balance one another.

Demonstration B

Materials	Multimedia	Setup
• A bright flashlight or small lamp • A series of balls, ranging in size from large to small (compared to the size of the light) • String	• Video 11: *Life Beyond the Solar System* • Video 12: *Planet-Hunting* • "How to Search" presentation slides (download *here*)	• Tape each ball to a string so you can dangle it in front of the light. • Experiment to find the best distance between the light and wall so that the larger balls dim the light.

Demonstration C

Materials	Multimedia	Setup
• Sealable containers, such as baby-food jars or small plastic storage containers • Aromatic foods (e.g., diced onion, garlic, and citrus rind, and extracts such as peppermint, vanilla, and citrus fruits) • Cotton balls	• Video 11: *Life Beyond the Solar System* • Video 12: *Planet-Hunting*	• Make "scent" jars by either placing small amounts of aromatic foods or cotton balls moistened with a flavoring extract in separate, sealable containers.

Demonstration D

Materials	Multimedia	Setup
• 2 clear, sealable plastic bags, one containing a half cup of sugar and the other with a half cup of salt • 2 ceramic bowls or plates • A gas match barbecue lighter	• Video 11: *Life Beyond the Solar System* • Video 12: *Planet-Hunting*	• Set out all your materials on a table where kids will be able to see them.

The Activity

1. Engage

Tell kids:

- I'm going to describe a scene. Based on what I tell you, what do you think happened? One evening, you visit a park. No one is there. A balloon is caught in a tree branch. The trash barrels are filled with cups, paper plates, and wrapping paper. A piece of a broken piñata hangs on a string from a branch. *(There was a birthday party earlier in the day. People broke open a piñata, ate food, drank beverages, opened presents, and cleaned up.)*

Ask:

- Why might you need to think like a detective to find life in the solar system? *(If there is life beyond Earth, it is not obvious. People need to collect hints and figure out what they tell us.)*

2. Facilitate

Demonstration A — Astrometric measurement: Planets make stars wobble

Tell kids that the large clay ball represents a star, the small clay ball represents a planet, and the straw represents the gravity that keeps the balls in position relative to one another. Point out that these two objects form a system. Spin the system. When the system rotates, both objects are affected. Explain that the point of rotation is not the big "star," but is a point along the straw where the string balances the balls. This is the center of the system.

Ask:

- Does the star stay in one place or does it move? Tell kids to close one eye and hold up a finger at arm's length between their open eye and the spinning system.
- Now that you have your finger as a reference point, can you see the star move back and forth? (*All planets have gravity and pull on the stars they orbit. The pull makes the star wobble back and forth. The bigger the planet, the greater its gravity. And the greater its gravity, the bigger the star's wobble. Telescopes like NASA's Space Interferometry Mission look for the wobble of stars, which tells scientists that there is a planet orbiting it*.)

Demonstration B — Transits: Planets can dim a star's light

Introduce the idea of a planet transiting a star by passing your fist in front of a light and by showing the images of the transit of Venus in the presentation slides. Aim a flashlight or small lamp at a wall, projecting a circle of light on it. Tell kids that the light is a star, and that you will pass a series of different-sized balls (i.e., planets) between the star and the wall. Their job is to figure out the smallest ball that dims the star's light. (Variables include the distance between the light and wall, the size of a ball, and how far you hold it from the light. For best effect, pass each ball close to the light.) Start with the largest ball.

Ask:

- Did this planet dim the star? *(All balls will dim the light, though most people's eyes are not sensitive to minor dimming.)*
- Why does a ball dim the light? *(It blocks some of the light.)*
- Which ones caused noticeable dimming?

Explain that telescopes like the Kepler space telescope are very sensitive. Scientists detect planets by finding stars that repeatedly dim and brighten as the planet orbits the star.

Demonstration C – Biomarkers: Our senses work like sensors on a spacecraft

Pass around the scent jars. Ask kids to tell you what's in each jar. Tell them that their noses can detect tiny bits of the food items that are present in each container. This helps them figure out what it is even though they can't necessarily see it.

Explain that one way to find life is to look for telltale signs that organisms leave behind.

Demonstration D – Biomarkers: Life has a special chemistry

Show kids the plastic bags of salt and sugar. Ask them to describe what's inside. *(Similar-looking white, granular powders.)* Pour a teaspoon of salt onto one ceramic plate and a teaspoon of sugar onto another. Using a gas match, try to light the salt. *(It won't light.)* Repeat with the sugar. *(It will turn black and burn.)*

Ask:

- Which powder came from something living? How do you know?

Explain that salt is a mineral that contains no carbon. Carbon is an essential molecule of life. Since carbon compounds burn, the fact that salt doesn't burn suggests that it contains no carbon and is not a product of a living organism. Sugar comes from plants. It contains carbon, which turns black when burned. (Mention burned toast and meat.) Life uses carbon in so many ways that scientists think that all life will use carbon. As a result, spacecraft and rovers looking for chemicals associated with life look for carbon-based compounds.

3. Check for understanding

Ask:

- Which of these techniques is good for detecting life in our solar system? And a distant solar system? *(C and D can be used in our solar system because they rely on sampling rather than on analyzing a star, as with A and B. D can also be used to analyze distant planets. Astronomers analyze atmospheres of distant planets, looking for gasses associated with life, such as oxygen and methane.)*

Point out how scientists work like detectives, designing experiments, instruments, and missions to collect hints that can help them solve the riddle of whether there is life beyond Earth. Then use NOVA's video resources to show how scientists conduct the search for life within and beyond the solar system.

Keep Exploring

Finding worlds that look like stars

Use this NASA activity to demonstrate a method to discover new objects or changes in the sky. By overlaying positive and negative images of the sky, kids will be able to view stars awaiting discovery. You can find the activity under "Asteroids" at *saturn.jpl.nasa.gov/education/EDUCATION58Program/edu58kitchen/*.

Cart Version

1. **Create** scent jars filled with aromatic foods (e.g., diced onion, garlic, citrus rind, and extracts like peppermint and vanilla.) You can either place small amounts of the foods in a jar or moisten cotton balls with a flavoring extract.
2. **Explain** to kids that finding life in the solar system is like being a detective, and that if there is life beyond Earth, it is not obvious. People need to collect hints and figure out what they tell us.
3. **Ask** kids to smell the scent jars and tell you what they think is in each jar. (Make sure to ask about any allergies beforehand.)
4. **Explain** that their noses can detect tiny bits of the food items even though they can't necessarily see them. Their noses are working just like a sensor on a spacecraft.

Common Misconceptions

Below is a list of some of the possible misconceptions about the solar system and its components that educators should be aware of and possibly proactively address.

The Sun is yellow.

Fact: The Sun gives off a complete visible spectrum, in addition to nonvisible light, and is essentially white.

The planets of the solar system lie in a straight line (as seen in many images).

Fact: The planets move around the Sun in nearly circular orbits. As the planets orbit, they pass each other, but rarely do more than two of them sit on a straight line out from the Sun—which is called a "conjunction."

The planetary orbits are very elliptical (as seen in many images).

Fact: The planets move around the sun in nearly circular orbits.

The planets all sit on the Sun (like the model).

Fact: The planets are many millions of miles away from the Sun in the solar system. When closest to the Sun, the planet Mercury is still over 28 million miles away.

The solar system is made up of just the Sun and eight planets.

Fact: Although the Sun makes up almost the entire mass of the solar system (over 99 percent), the solar system also consists of gas, dust, ices, moons, meteoroids, asteroids, comets, Kuiper Belt objects, etc.

Where's the planet Pluto?

Fact: To learn more about Pluto's reclassification as a dwarf planet, watch NOVA's "The Pluto Files" at *http://www.pbs.org/wgbh/nova/space/pluto-files.html*.

Comets, asteroids, and meteorites are all the same.

Fact: These terms are often interchanged. When teaching younger children, it's best to focus on the distinction between the comets being icy and the asteroids being rocky or metallic.

Related Resources

Interactives

Eyes on the Solar System | NASA

A 3-D environment full of real NASA mission data.
http://solarsystem.nasa.gov/eyes/

Extreme Planet Makeover | NASA

Beautiful interactive that lets you design your own interactive.
http://planetquest.jpl.nasa.gov/system/interactable/1/index.html

Build a Solar System | Space Science Institute

Try and build the perfect solar system. See how different planets react with one another and see how some planets are important in keeping the solar system stable.
http://www.alienearths.org/online/starandplanetformation/planetfamilies.php

Tour the Solar System | NOVA

Explore the planets, visit the moon, and gaze at the stars in this 3-D interactive of the solar system.
http://www.pbs.org/wgbh/nova/space/tour-solar-system.html

Let's Make a Microbe | NOVA

Build an animated microbe to investigate key traits that distinguish a living organism from something that is not alive.
http://www.pbs.org/wgbh/nova/tech/make-microbe.html

Other Activities and Materials

Products & Resources | NASA Astrobiology Institute

A collection of resources for teachers about astrobiology.
http://astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/

Messenger For Teachers | NASA

Kids plot how temperature varies with distance from the Sun and identify a theoretical habitable zone. They then see how factors, such as atmosphere and ice sheets, can extend the habitable zone. *messenger-education.org/teachers/MEMS_CompPlanetology.php*

Mars for Educators | NASA

JPL's main Mars website with dozens of educator resources (ERGs, activities, programs, links, etc.)
http://mars.jpl.nasa.gov/participate/marsforeducators/

Mars and Earth | NASA

ERG with nine activities especially for elementary and informal settings. *http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Mars_and_Earth_Educator_Guide.html*

Video

Origins of the Solar System | NOVA

Combining evidence from meteorites with the latest computer simulations, scientists show how our solar system formed from a cloud of dust and gas (good for older kids or for background information).
http://www.pbs.org/wgbh/nova/space/origins-solar-system.html

Where Did We Come From? | NOVA

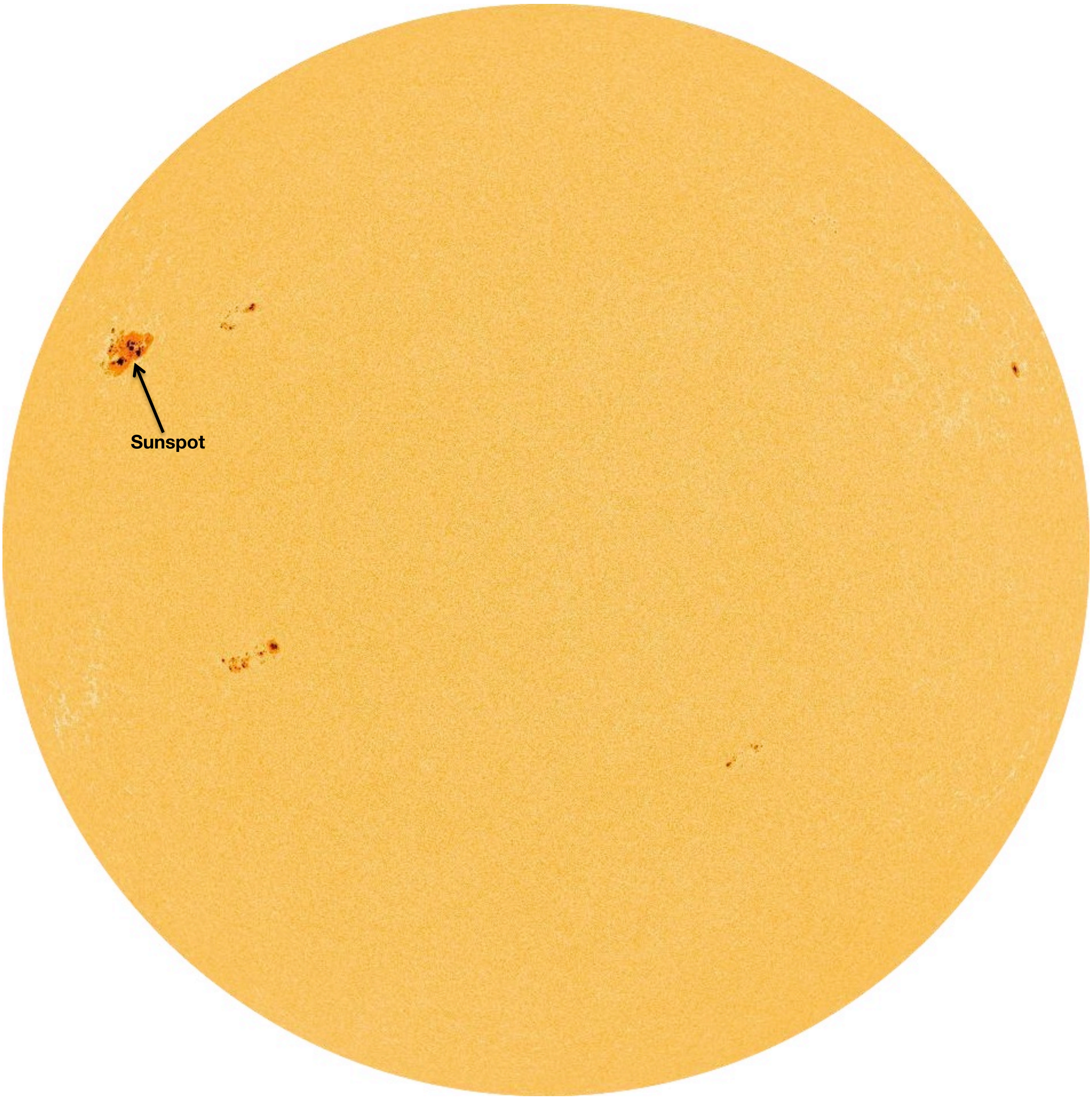
Explore the origin of our solar system, the start of life itself, and more (good for older kids or for background information).
http://www.pbs.org/wgbh/nova/evolution/where-did-we-come-from.html

Is There Life on Mars? | NOVA

The decades-long search for life on the Red Planet heats up with the discovery of frozen water.
pbs.org/wgbh/nova/space/is-there-life-on-mars.html

Appendices

_________________'s Solar System Model



My favorite planet is _________________

Can Living Things Live Here?

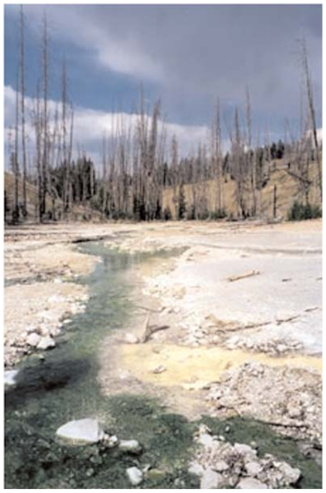


Image by Kathy Shehan
Courtesy of Micro*scope http://microscope.mbl.edu

Lemonade Spring in Yellowstone park has acidic (acid-like) water that can burn your skin.

Can Living Things Live Here?

Photograph by: Kristan Hutchison
National Science Foundation

McMurdo Dry Valleys in Antarctica have average temperatures of -20°C (-4°) and get less than 10 cm (4 inches) of rain each year.

Can Living Things Live Here?

Image by Linda Amaral-Zettler Courtesy of Micro*scope
http://microscope.mbl.edu

Rio Tinto (River of Fire) in Spain is one of the most naturally acid-like rivers in the world.

Can Living Things Live Here?

National Park Service
U.S. Department of the Interior

Hot springs in Yellowstone. Water underground can be heated to boiling by nearby magma (the word for lava that's underground).

Can Living Things Live Here?

Photo by Brett Leigh Dicks Courtesy of Micro*scope
http://microscope.mbl.edu

Mono Lake in California is two and a half times saltier than the ocean.

Astrobiology: Science Learning Activities for Afterschool

Can Living Things Live Here?

OAR/National Undersea Research Program (NURP); NOAA

Under water volcanoes known as black smokers add extremely hot water (as high as 400°C, 725°F) to the ocean environment.

Astrobiology: Science Learning Activities for Afterschool

Can Living Things Live Here?

NASA Image Exchange

Salt domes in Iran. These domes of salt are usually found over underground stores of oil and gas.

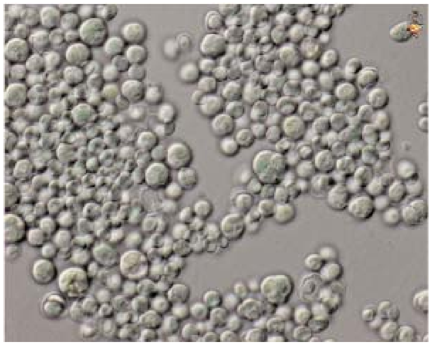
Astrobiology: Science Learning Activities for Afterschool

Can Living Things Live Here?

Radiation is a kind of energy that can be harmful to people in large doses. In space, radiation from the Sun is stronger than on Earth and spaceships must be built to protect astronauts.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!



Courtsey of Micro*scope http://microscope.mbl.edu

This algae was found in acidic (acid-like) springs in Yellowstone National Park. They can live in water acidic enough to burn human skin.

Astrobiology: Science Learning Activities for Afterschool

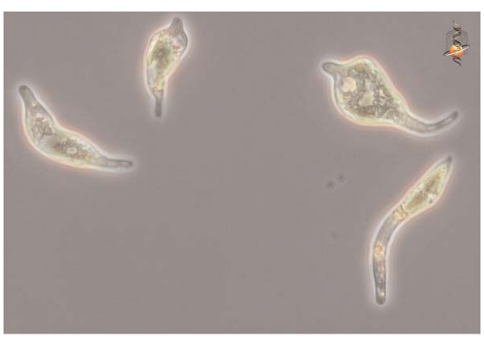
Extreme Life!

Courtsey of Micro*scope http://microscope.mbl.edu

Algae can be found under the ice in lakes in the Arctic and Antarctica.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!



Courtsey of Micro*scope http://microscope.mbl.edu

These microscopic creatures, known as euglenia mutablis, were found in the acid-like Rio Tinto in Spain.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!

Courtsey of Micro*scope http://microscope.mbl.edu

Some bacteria, like these found in Yellowstone National Park, can live in boiling water (100°C, 212°F).

Extreme Life!

Courtsey of Micro*scope http://microscope.mbl.edu

This microscopic life form, Artemia monica, can be found in the "hypersalinic" (high salt to water ratio) waters of Mono Lake.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!

NOAA

Tube worms like these grow near hydrothermal vents in the ocean.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!

U.S. House of Representatives Committee on Resources http://resourcescommittee.house.gov/subcom mittees/emr/usgsweb/

Very old bacteria has been found living inside salt crystals.

Astrobiology: Science Learning Activities for Afterschool

Extreme Life!

NASA

Deinococcus radiodurans (shown on an agarplate) can survive radiation levels thousands of times greater than what would kill humans.

MY CREATURE'S NAME IS: ____________________

MY NAME IS: ____________________

Creature A

- Eats gas for food
- Moves around by flying
- Lives in a cold place

Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.

Creature B

- Eats rocks for food
- Moves around by flying
- Lives in a hot place

Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.

Creature C

- Eats plants for food
- Moves around by walking
- Lives in a moderate place

Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.

Creature D

- Eats gas for food
- Moves around by swimming
- Lives in a cold place

Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.

Creature E

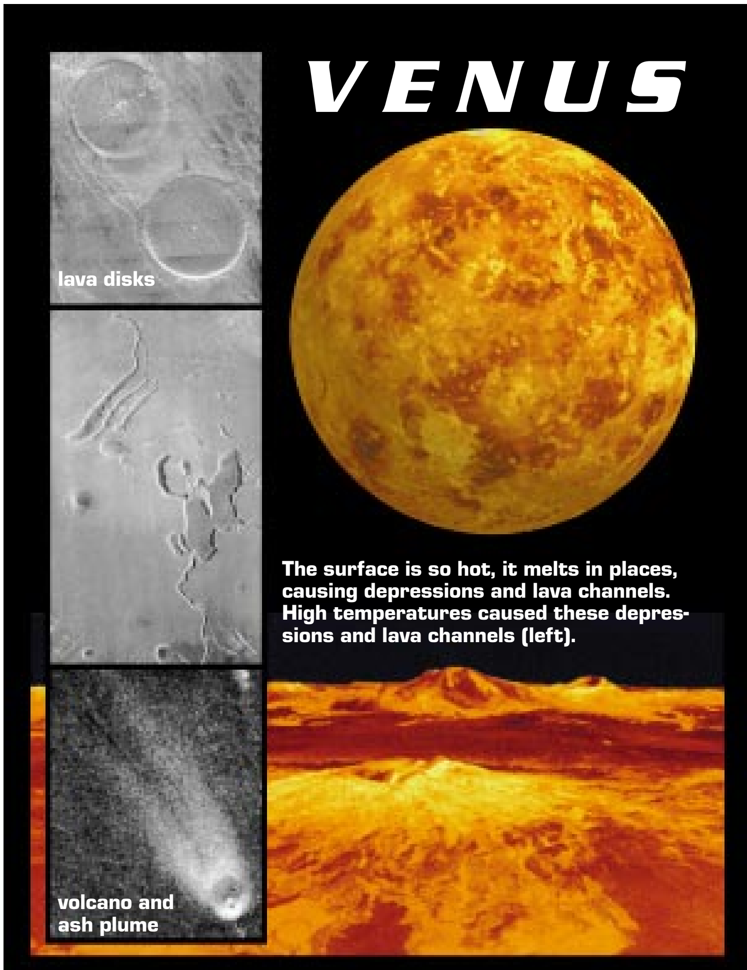
- Eats rocks for food
- Moves around by flying
- Lives in a cold place

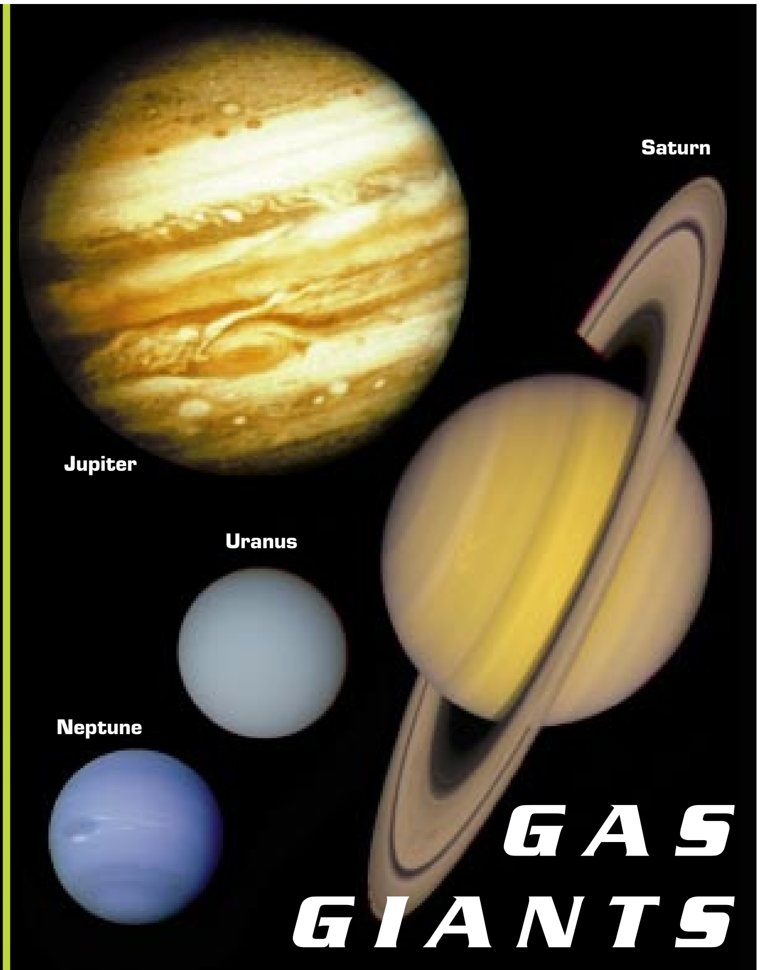
Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.

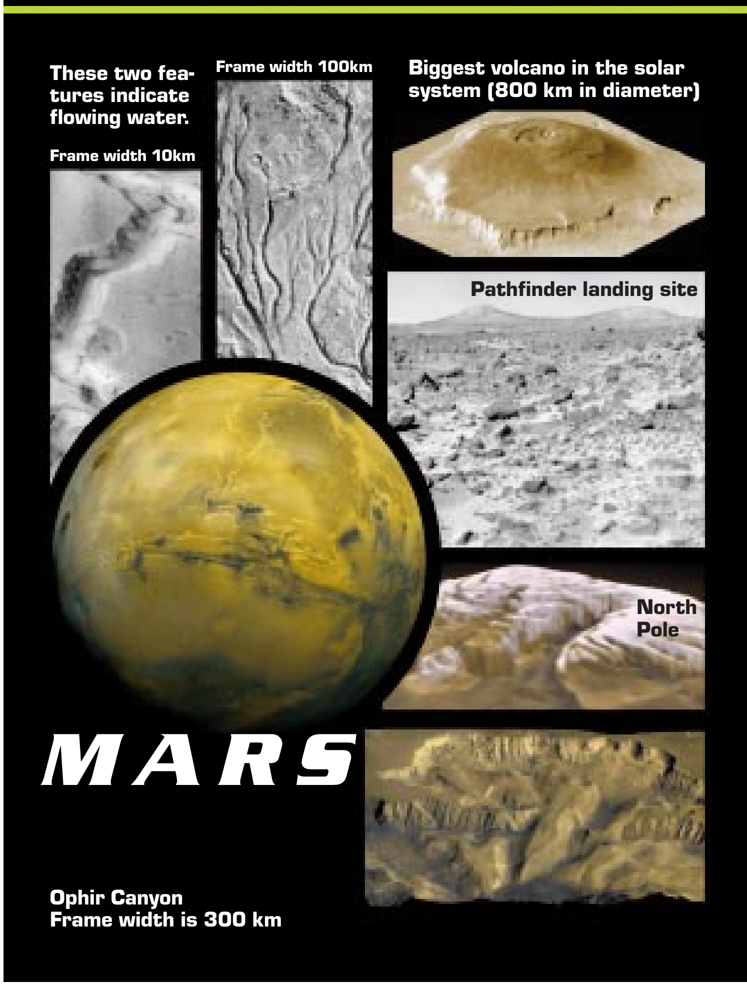
Creature F

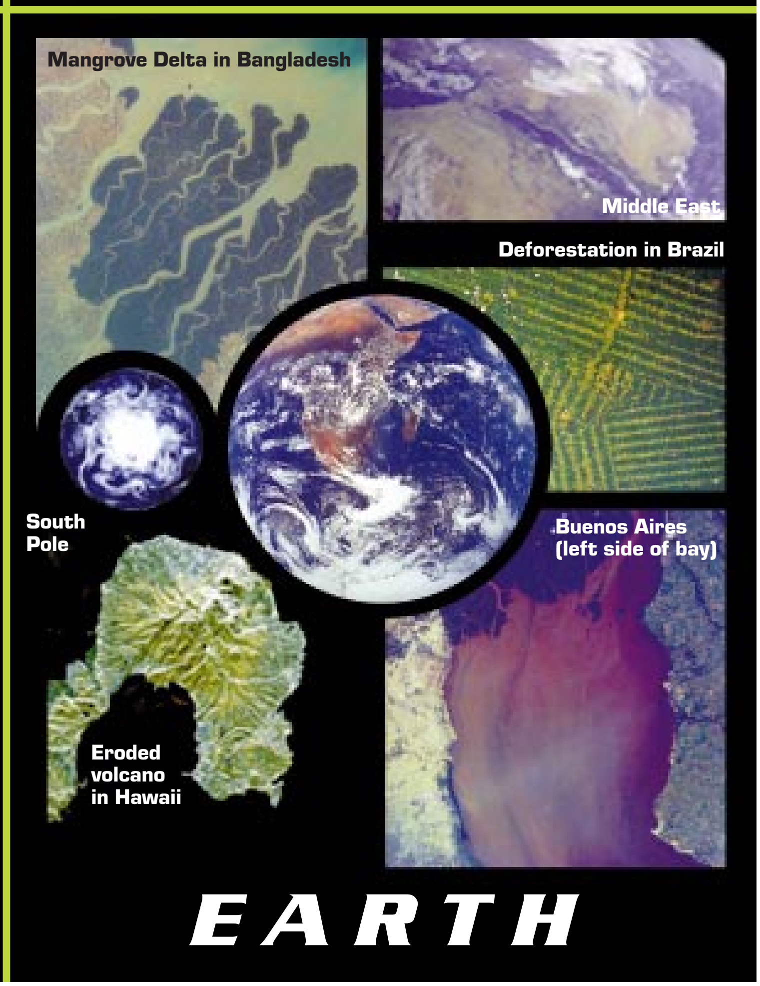
- Eats rocks for food
- Moves around by swimming
- Lives in a moderate place

Instructions:
1. Design a creature that fits the above description.
2. Give it a name.
3. Introduce it and explain how it meets its needs for life.


VENUS
lava disks
The surface is so hot, it melts in places, causing depressions and lava channels. High temperatures caused these depressions and lava channels (left).
volcano and ash plume


Saturn
Jupiter
Uranus
Neptune
GAS GIANTS


These two features indicate flowing water.
Frame width 100km
Biggest volcano in the solar system (800 km in diameter)
Frame width 10km
Pathfinder landing site
North Pole
MARS
Ophir Canyon
Frame width is 300 km


Mangrove Delta in Bangladesh
Middle East
Deforestation in Brazil
South Pole
Buenos Aires (left side of bay)
Eroded volcano in Hawaii
EARTH

fast facts THE GAS GIANTS

JUPITER
SATURN
URANUS
NEPTUNE

The temperature at the cloud tops is –200°C while the interior temperatures reach tens of thousands of degrees. The churning of the atmosphere causes temperatures of the circulating gasses to change greatly over short distances and periods of time.

The gas giants are made almost entirely of hydrogen and helium, with very small amounts of water.

Gas giants release large amounts of their own energy, keeping internal temperatures high and causing their atmospheres to circulate constantly. The violent storms created by this circulation would subject life to rapid and extreme changes in temperature and pressure.

Sunlight is dim but may be a viable energy source. Obtaining sufficient amounts of chemicals in a gaseous environment is difficult, making chemical energy an unlikely energy source.

A gas environment is too diffuse to concentrate nutrients and make them available in a predictable, reliable way. Having life arise or survive in such a constantly changing environment is highly unlikely.

fast facts VENUS

Venus has a thick carbon dioxide atmosphere that traps heat efficiently. The average surface temperature is 464°C.

There is no surface water. The atmosphere has trace amounts of water vapor (30 parts per million or 0.0000003%).

Venus's atmosphere is 92 times that of Earth's. It is 97% carbon dioxide.

The thick clouds prevent much sunlight from reaching the surface, so any life would have to depend on chemical energy. Sulfuric acid clouds provide a potential source of chemical energy.

In general, Venus and Earth have the same chemical composition, and Venus is volcanically active, giving it a way to cycle chemicals important to life.

fast facts EARTH

The average surface temperature is 15°C. Earth's maximum temperature is 51°C (Libya) and its minimum is –89°C (Antarctica).

On Earth, water exists in all three states. The water cycle delivers water to nearly every part of Earth.

Earth's atmosphere shields the surface from harmful ultraviolet radiation and most meteorites, insulates the Earth, and serves as a source of nutrients such as nitrogen and carbon.

Plants capture sunlight and make possible the food chain. High oxygen levels in the atmosphere enable life to use high-energy, carbon-based energy sources (e.g., sugar). Many microbes live off the chemical energy in inorganic compounds such as iron and sulfur.

Everything organisms need to build and maintain their bodies is already on Earth. Earth has processes such as plate tectonics to cycle chemicals important to life.

fast facts MARS

Even though the surface temperature can reach room temperature for a few minutes at mid latitudes, the average surface temperature is –63°C.

Though there is no surface water, features suggest that Mars once had flowing surface water. There are also indications of thick layers of permafrost, soil locked in water ice. The Northern and Southern ice caps contain water ice.

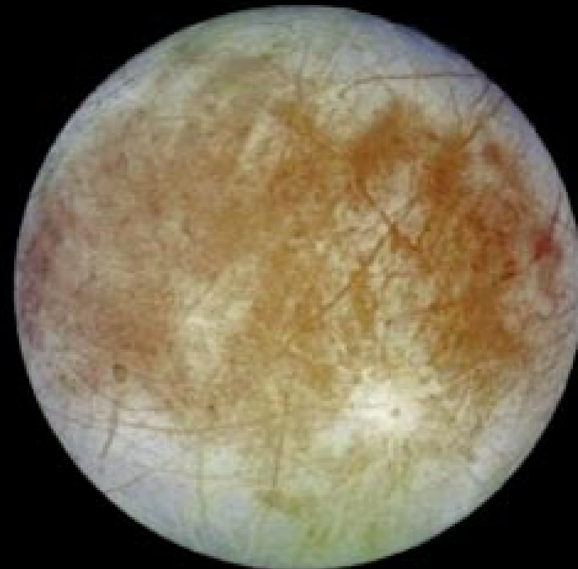
The Martian atmosphere is 95% carbon dioxide. The atmospheric pressure is so low (one-thousandth that of Earth's) that surface water quickly boils away. The atmosphere is too thin to protect or insulate the surface of Mars significantly.

Mars is on the edge of the Habitable Zone, making sunlight a possible energy source. Chemicals made available by volcanic activity early in Mars's history may once have been a possible energy source.

Mars and Earth have the same general chemical composition. Mars was volcanically active for its first two to three billion years, giving it a way to cycle chemicals important to life.

The bright patches are a highly reflective material such as ice that oozed from the interior. Ganymede is Jupiter's largest moon.

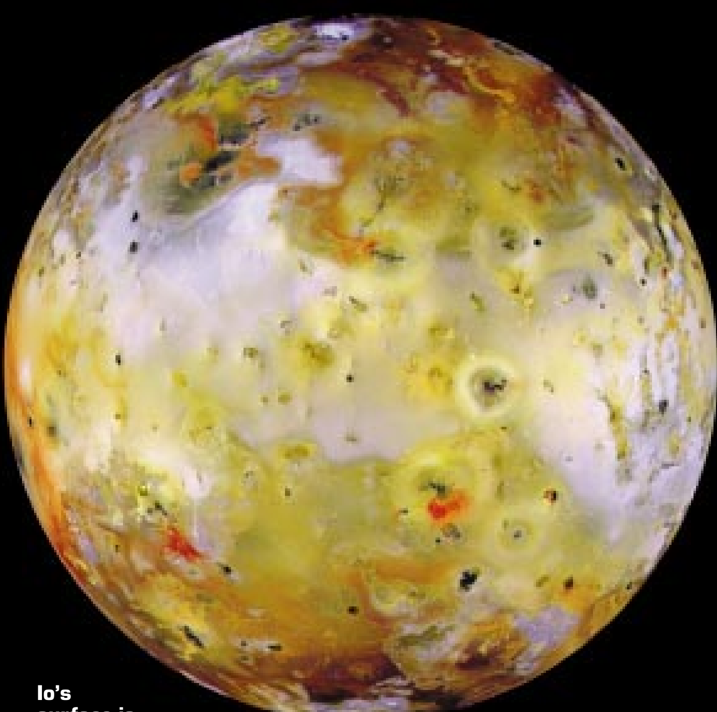
GANYMEDE



EUROPA

Surface close-up. Frame width is 50 km.

IO



Io's surface is discolored by sulfur compounds from volcanic eruptions.

Computer-generated surface view.

CALLISTO

Callisto is the most heavily cratered object in the solar system.

fast facts EUROPA JUPITER'S MOON

At noon on the equator, the average surface temperature is –145°C.

Europa is covered with a one- to ten-kilometer-thick crust of water ice. There is strong evidence that this crust may cover a 60–100-km deep ocean of water. An ocean of this size would hold more water than there is on Earth!

There is no atmosphere.

Sunlight may be a viable energy source. Scientists think Europa's core is hot enough to have volcanic activity beneath its ocean. Such activity might make energy-rich compounds such as sulfur compounds available. Europa's ice crust is also thickly dusted with another potential energy source, sulfur compounds from Io's eruptions.

Europa is a solid body and the materials for life are likely to be present. Possible volcanic activity and a large ocean provide several ways to cycle chemicals important to life.

fast facts GANYMEDE JUPITER'S MOON

At noon on the equator, the average surface temperature is –121°C.

Ganymede's surface and upper layers are an even mixture of rock and water ice. There is no known source of heat to melt the ice.

There is virtually no atmosphere.

Sunlight may be a viable energy source. There are no known geologic processes to make chemicals available to organisms that rely on chemical energy.

Ganymede is a solid body and probably has the necessary materials for life. However, Ganymede seems to lack any processes that are necessary to cycle chemicals important to life.

fast facts CALLISTO JUPITER'S MOON

At noon on the equator, the average surface temperature is –108°C.

Callisto appears to be an ice-rock mix through and through. Its low density suggests that it contains large amounts of water ice. Some scientists think there is a salt-water layer beneath the surface.

There is virtually no atmosphere.

Sunlight may be a viable energy source. If there is a salt-water layer beneath the surface, organisms may be able to rely on chemical energy.

Callisto is a solid body and probably has the necessary materials for life. However, Callisto seems to lack any processes that are necessary to cycle chemicals important to life.

fast facts IO JUPITER'S MOON

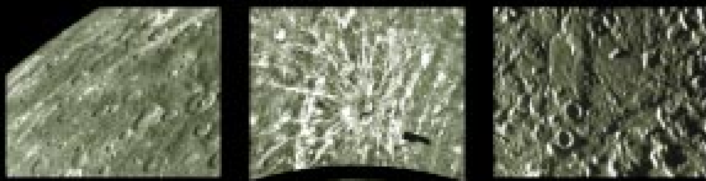
At noon on the equator, the average surface temperature is –150°C. In areas with volcanic activity, the lava flowing across the surface can reach 1,250°C.

Io experiences almost constant volcanic activity, making it the most active volcanic body in the solar system. This activity and the hot interior drive out any water, and there is no known liquid water or water ice on Io.

There is essentially no atmosphere. A thin cloud of sulfur compounds from Io's constant volcanic activity surrounds Io.

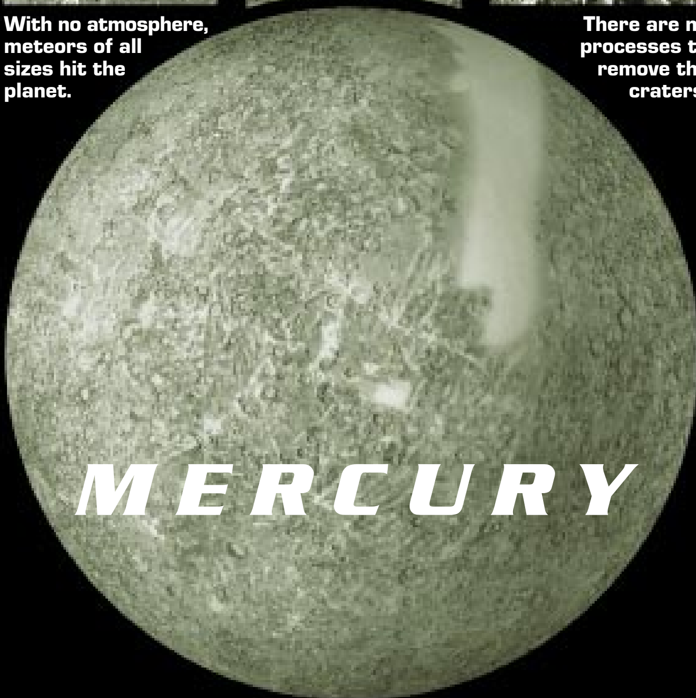
Sunlight may be a viable energy source. Volcanic activity has coated Io's surface with compounds such as sulfur and sulfur dioxide. On Earth, many microbes use such compounds as an energy source.

Io is a solid body and the materials for life are likely to be present. Volcanic activity could cycle chemicals important to life.



With no atmosphere, meteors of all sizes hit the planet.

There are no processes to remove the craters.



MERCURY

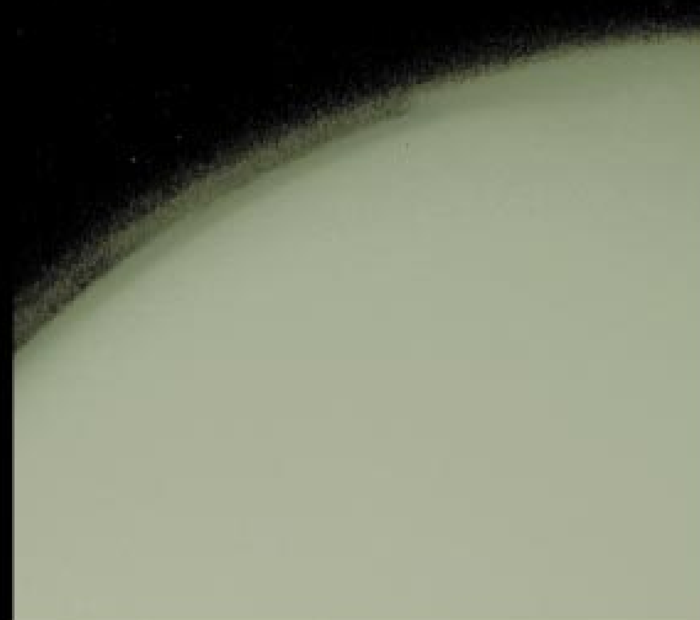
Because no spacecraft has ever visited Pluto, this computer-generated image based on telescopic observations is among the most accurate depictions we have of Pluto.

PLUTO

EARTH'S MOON

TITAN

A thick, hazy atmosphere envelops Titan. The closest a spacecraft has come to Titan is about 400,000 km.



fast facts PLUTO

The average surface temperature is −225°C.

All water is permanently frozen as ice.

There is essentially no atmosphere.

At this distance from the sun, sunlight is too dim to be a viable energy source. Organisms would need to rely on chemical energy.

Pluto and Earth have the same general chemical composition, but Pluto lacks any processes that are necessary to cycle chemicals important to life.

fast facts MERCURY

The temperature on the side facing the sun is 252°C. On the dark side, it is −183°C.

There is no surface water or water in the atmosphere.

There is essentially no atmosphere.

Living on or near the surface is impossible, so life would have to live underground and depend on chemical energy.

Mercury and Earth have the same general chemical composition, but Mercury lacks the processes that are necessary to cycle chemicals important to life.

fast facts TITAN SATURN'S MOON

The average surface temperature is −179°C.

Water-ice icebergs might float in an ocean of ethane-methane liquid or slush. There is virtually no water in the atmosphere.

Titan has an atmospheric pressure 1.5 times that of Earth. It is 90–97% nitrogen and 3–10% methane, a composition more like Earth's than the carbon dioxide atmospheres of Mars and Venus.

At this distance from the sun, sunlight is too dim to be a viable energy source. Organisms would need to rely on chemical energy.

Sunlight-driven reactions can turn methane into amino acids, the building blocks of life. They could join into large, complex molecules and rain down on the surface. There, they could accumulate, covering the surface with thick, gooey deposits of hydrocarbons. These conditions may be similar to those on early Earth.

fast facts EARTH'S MOON

There is no atmosphere to moderate temperatures, and temperature depends entirely on how much sunlight falls on the surface. While the overall average surface temperature is −23°C, the daytime average is 107°C and the nighttime average is −153°C.

There is no known liquid water on the moon. In 1998, NASA's Lunar Prospector spacecraft detected water ice at each of the moon's poles.

There is no atmosphere. Without an atmosphere, the surface experiences large and rapid temperature swings, which are hard for organisms to cope with.

The moon receives the same amount of sunlight as Earth, making the sun a viable energy source. Chemicals made available by volcanic activity early in the moon's history may once have been a possible energy source.

The moon and Earth have the same general chemical composition, but the moon lacks any processes that are necessary to cycle chemicals important to life.