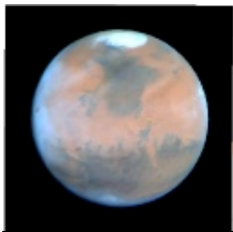


Life: What is it? Where is it?

Grades 6-8

Lesson Summary
Students will describe characteristics of and necessary conditions for life to develop. They will use logic and evidence to explain why studying extreme environments on Earth is important in the search for extraterrestrial life.

Prior Knowledge & Skills
Basis understanding of how life is defined and how living things grow, evolve, reproduce, and consume

AAAS Science Benchmarks
The Nature of Science
Scientific Inquiry

NSES Science Standards
Science as Inquiry
Abilities Necessary to Do Scientific Inquiry

Teaching Time: 45 – 90 minutes

Materials
- Handout of "Examples of Earthly Extremophiles" (included)
- Image set of "Examples of Earthly Extremophiles" (included)

Advanced Planning
Preparation Time: ~10 minutes
Review the lesson plan and the different examples of Earthly Extremophiles

Recommended Reading: (for teachers)
Student handout entitled "Examples of Earthly Extremophiles."

Produced by the NASA Astrobiology Institute
http://nai.arc.nasa.gov/poster/

LASP
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS

Activity 1
Life: What is it? Where is it?

Learning Objectives:
Students will be able to:

- Explain the characteristics of living things and the conditions needed for life.
- Use logic and evidence to explain why the study of extreme environments on Earth is important to the search for life on other planets.

Standards Addressed:
As a result of this activity, students should develop the following understanding about scientific inquiry:

- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.

Student Prerequisites:
Before beginning this activity, students should have a basic knowledge of how life is defined – living things grow, reproduce, and evolve in response to changes in the environment, consume raw materials for energy, and produce waste products.

Student Misconceptions:
Students may think "life" means intelligent, human-like life and/or familiar forms of life such as plants and animals. According to Benchmarks for Science Literacy (p. 341): Elementary- and middle-school students typically use criteria such as "movement," "breathing," "reproduction," and "death" to decide whether things are alive. Thus, some believe fire, clouds, and the Sun are alive, but others think plants and certain animals are nonliving. … High-school and college students also mainly use obvious criteria (e.g., "movement," "growth") to distinguish between "living" and "nonliving" and rarely mention structural criteria ("cells") or biochemical characteristics ("DNA"). This activity specifically addresses this misconception.

Activity:

1. Ask students if they think there is life elsewhere in the universe. Probe to see why students think there is or is not life. (Answers will vary). Explain that there is a field of science called astrobiology (write the word on the board and explain what it means – the study of the origin, evolution, distribution, and future of life in the universe; refer to the Science Background for more information about astrobiology). Explain that astrobiologists are studying ways to look for life on other planets and moons, and in order to do that they need to understand the nature of life.

2. Write the following question on the board: How do you know if something is alive? Encourage an open brainstorming session, steering the discussion to include the idea that living things: consist of one or more cells; grow and develop; evolve; respond to changes in the

environment; consume raw materials (eat) for energy; produce waste products; and reproduce. Write these characteristics of living things on the board. Note that these characteristics define scientifically observable behaviors of living things. Do not exclude other responses from the list, but rather go over them one by one, recognizing that it isn't just one characteristic that defines something as alive. For example, movement alone doesn't render something as living; an empty bottle can roll down the hill. Point out that it is difficult to define something as alive by just one or two of these characteristics. For example, a wildfire appears to grow and produce waste products (CO2) as it consumes raw materials (trees and brush) and appears to respond to its environment (changing direction with the wind), but fire is not a living thing. To define something as alive, one must look at many characteristics collectively.

3. Ask students under what conditions living organisms can exist. Students will likely respond with the conditions at the surface of the Earth – a moderate, narrow temperature range, oxygen to breathe, liquid water to drink, sunlight, moderate atmospheric pressures like those on the surface of the Earth, and a steady source of food. List these responses on the board, noting that these conditions define where one would find the life forms with which students are probably most familiar, such as trees, humans, and elephants. When finished, title the list "Conditions for Familiar Life."

4. Probe to see if students think life is possible in more extreme conditions, such as very cold places (e.g., the interior of Antarctica), very hot places (hot springs), in rocks deep underground (no sunlight, no air), or at the bottom of the sea (high pressures, no sunlight). Have students justify their responses.

5. Distribute the handout "Examples of Earthly Extremophiles." Explain that scientists have indeed discovered and begun to study life (microorganisms) in the most extreme environments on Earth. Read aloud or have students read aloud the information on the handout. Note that some of the thumbnail pictures on the handout are the same images as appear on the front of the poster. Larger versions of the thumbnail pictures can be downloaded from http://nai.arc.nasa.gov/poster.

Discuss as a class how the life forms mentioned in each extreme environment meet the characteristics of life discussed earlier – What would they eat? What would they use for energy? Do they reproduce? Refer to the science background on the back of the poster for more information to support this discussion, if needed. Make a second list on the board titled "Conditions for Extreme Life." With student input based on the handout, list descriptions of the conditions in which extremophiles live (for example, very hot and very cold temperatures, very little rain, no sunlight, "crushing" pressures, no air/oxygen, broad range of pH, presence of liquid water, etc.).

6. On the board, draw a circle around each list, making sure they overlap in the middle as in a Venn diagram. Referring to the two lists, ask students what the extremophiles' conditions have in common with each other and with other "familiar" life, like us (all require liquid water). Explain that all life on Earth requires liquid water at some point during its lifetime. Please refer to the science background narrative (on the back of the poster or downloadable) for information to support this discussion. Use the space created by the overlapping circles in the Venn diagram

to illustrate that both familiar and extreme life require liquid water. If desired, have students create the Venn diagram on the back of the handouts, comparing and contrasting the conditions that support familiar and extreme life on Earth.

Point out that for extremophiles, the conditions that we consider “extreme” are “normal.” To them, the conditions at the surface of the Earth – moderate temperatures, sea level air pressure, and oxygen in the air – are extreme and toxic and potentially deadly. “Extreme” is a relative term. If desired, collect students’ Venn Diagrams for assessment at the end of class.

7. Explain that the existence of extremophiles has changed the way scientists think about life and where it can exist. They have had to modify their theories and expand their view of what types of environments are habitable based on the new information presented by the existence of extremophiles. Discuss as a class how studying extremophiles influences the search for life on other planets. Steer the discussion to include the following points: 1) understanding how life survives in earthly extreme environments can help scientists better understand how life might survive on other planets and moons; 2) conditions that we think of as “extreme” on Earth are similar to what is “normal” elsewhere in the Solar System; 3) knowing that life can exist in more extreme conditions than previously thought means there are more extraterrestrial environments that could potentially support life; and 4) researchers can use Earthly extreme environments to test equipment and techniques they might someday use to search for life on another planet or moon.

Point out that the discovery and study of extremophiles helped spur the development of the field of astrobiology, illustrating the need for an interdisciplinary approach to the questions: what is life and where is it.

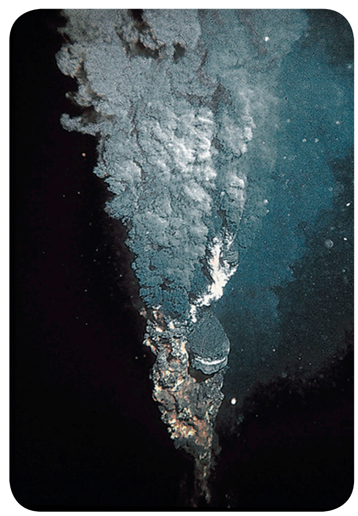
8. Have students write a paragraph, either in class or as homework, addressing the question: Why is the study of extremophiles on Earth important to the search for life on other planets? Students should mention the four points listed above.

Examples of Earthly Extremophiles

Cold – The McMurdo Dry Valleys in Antarctica are some of the coldest, driest deserts on Earth, with average annual temperatures of -20^{O}C (-4^{O}F) and less than 10 centimeters (4 inches) of precipitation a year. Scientists have found bacteria in liquid water pockets embedded about twelve feet deep in "solid" lake ice. Some of these bacteria use chemical nutrients from particles of dirt in the ice and use energy from sunlight for photosynthesis.

Hot – Large concentrations of microbes thrive in Yellowstone National Park's Grand Prismatic Springs, a hot spring with water temperatures up to 90^{O}C (188^{O}F). Other hot springs in Yellowstone are extremely acidic, yet are home to many different kinds of bacteria and microbes. Many of these microbes use chemical nutrients in the waters and energy from sunlight for photosynthesis.

Deep underground – Scientists have discovered bacteria living in groundwater 5 kilometers below the surface in deep gold mines of the Witwatersrand Basin in South Africa. These microbes thrive in cavities and cracks in rocks. Scientists are also are investigating life within and below permafrost in northern Canada.



Bottom of the sea – Scientists have found abundant life clustered around hydrothermal vents on the ocean floor, including bacteria, mussels, clams, shrimp, and giant tubeworms that can reach ten feet in length. Water pouring out of the vents in the complete darkness thousands of feet under the surface of the sea can reach temperatures of 113-120^{O}C (235-248^{O}F). The high pressures keep the water from boiling. Bacteria use chemicals in the vent's water, primarily hydrogen sulfide, as their energy source instead of sunlight. Other creatures survive by eating the bacteria or each other.

High Acidity – The water in the Rio Tinto in southwestern Spain is very acidic, a result of chemical reactions between the water, and iron and sulfur minerals in the ground. The river has a deep red color, like wine, because of iron dissolved in the water. Microbes living in the water use chemical reactions with iron and sulfur minerals to generate the energy they need. Products from these metabolic reactions contribute to the low pH in the environment. Many algae and fungi also live in the acidic waters.