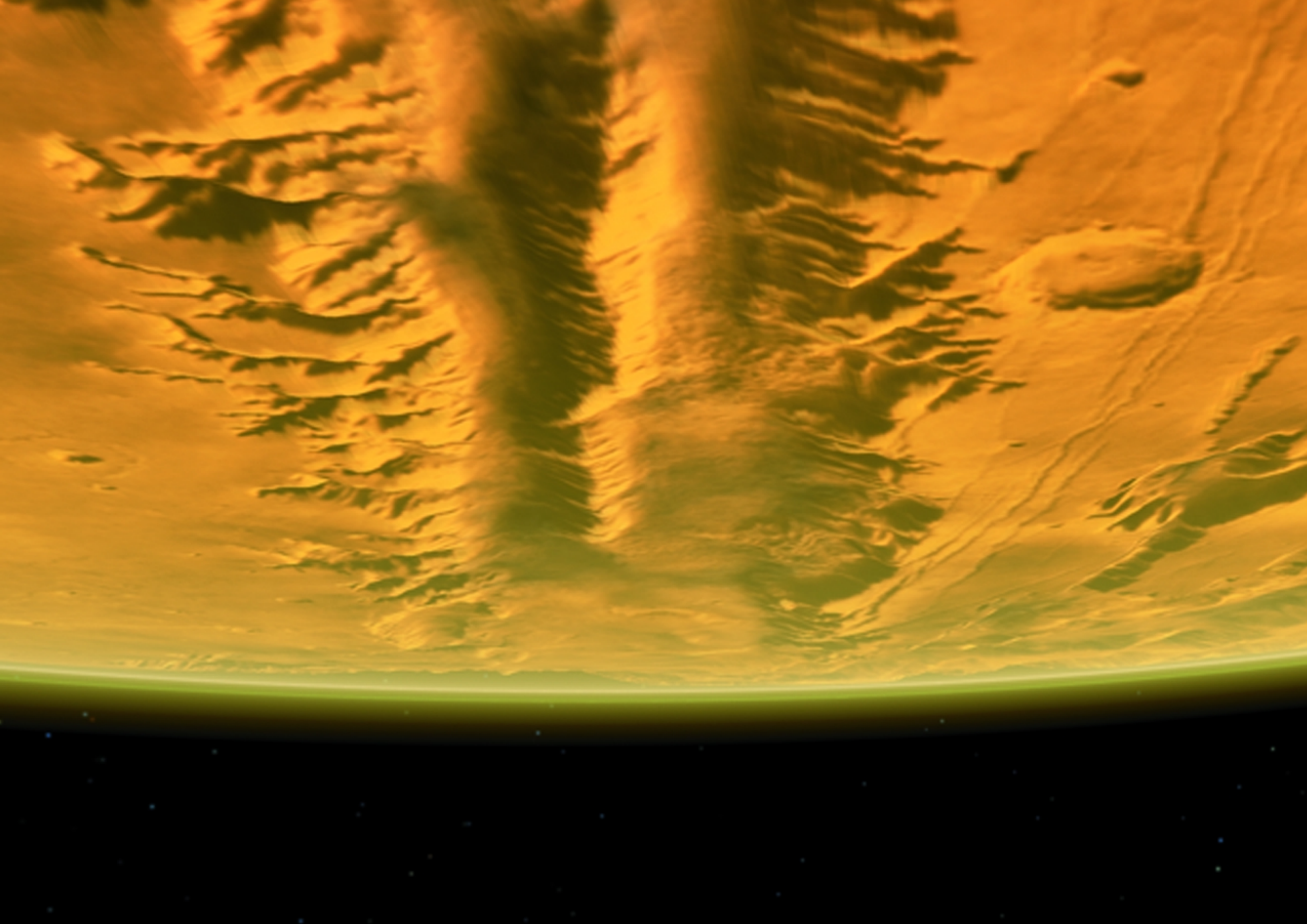


the search for life
are we alone?

An Educator's Guide

INSIDE

- ACTIVITIES YOU CAN DO WITH YOUR STUDENTS **BEFORE** YOUR VISIT
- MUST-READ **INFORMATION** TO HELP YOU PREPARE
- **WHAT TO DO** WHEN YOU GET TO THE MUSEUM
- **CONNECTIONS** TO OTHER PLACES IN THE MUSEUM
- TIES TO **NEW YORK STATE STANDARDS**
- PRE-, DURING-, AND POST-VISIT **ACTIVITIES**

FOR FURTHER INFORMATION AND ACTIVITIES, VISIT OUR WEB SITE AT WWW.AMNH.ORG/RESOURCES/PROGRAMS/SEARCHFORLIFE

AMERICAN MUSEUM OF NATURAL HISTORY

the search for life are we alone? synopsis

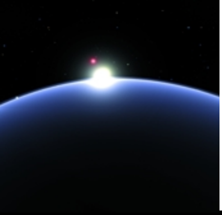
The Search for Life: Are We Alone? is an immersive journey. It whisks audiences from the bottom of the ocean to the edge of the universe to learn about the possibilities for life beyond our planet. The journey begins by listening: A sound collage of terrestrial life surrounds us, leading us into a view of the brilliant night sky, where we ponder the possibility that someone might be out there wondering if *we* exist. We then descend to the bottom of the ocean, exploring a world where life thrives without sunlight. A deep sea hydrothermal vent is one of the many recent discoveries that leads us to think that if life can exist in harsh environments here on Earth, then perhaps it can do the same in space as well. From here, we burst through the ocean's surface to learn that the one thing on Earth that all life needs is liquid water. Understanding these parameters for life on Earth, we are ready to launch into space, to search for life on other planets in our solar system – and then beyond.

Mercury and Venus have no water – and no life – so our first stop is Mars. Mars is a lot like Earth, with regular seasons, polar ice caps, and a 24-hour day. But the surface of Mars is a barren desert, and there is no life above ground. Underground, however, there may be enough heat and pressure to keep water in its liquid state and to support microbial life. If we do find life here – on a place in many ways like Earth – then perhaps life is common elsewhere in the universe. We next land on Europa, one of Jupiter's moons. Europa's icy surface covers a deep ocean of water – organisms live here in conditions much like those we saw at the bottom of the ocean back on Earth.

If there is life *inside* our own solar system, we may find it soon. But what about life *outside* it? The stars are millions of times farther away than the planets of our solar system. Could there be planets orbiting those faraway stars? We journey out among those other suns to learn that, indeed, there are planets out there – and lots of them. In fact, these so-called exoplanets may well outnumber the stars. And where did all these planets come from? These exoplanets formed the same way Earth did some 5 billion years ago. We fly outside our galaxy, and into the past to view the birth of our planet, from its beginnings as a swirling mass of gas and dust, to a rotating disk of ice and rock, and then finally to a planet teeming with life.

If the process that made the Earth has made perhaps billions of other worlds, what are the chances that our planet is the only one with life? We fly to an imaginary extra-solar system to see a world lit by two suns – a small terrestrial moon circling a great gas giant planet like our own planet Jupiter. Our radio, television, and radar waves have been spreading out into space at the speed of light for the last century or so. If there is somebody living on a planet like this, perhaps they have picked up our signals already. We ourselves have also been listening for their signals. So far we have heard nothing, but we keep listening.

As we travel out of our galaxy once more and into a vast expanse of galaxies, we ruminate on the idea that, with so many billions – and possibly trillions – of worlds in our galaxy, multiplied by the billions of galaxies in the known universe, the possible number of worlds that may support life is staggering. We conclude by returning to Earth, where we reflect on the uniqueness of our planet and the need to protect it and the spectacular diversity of life found here.

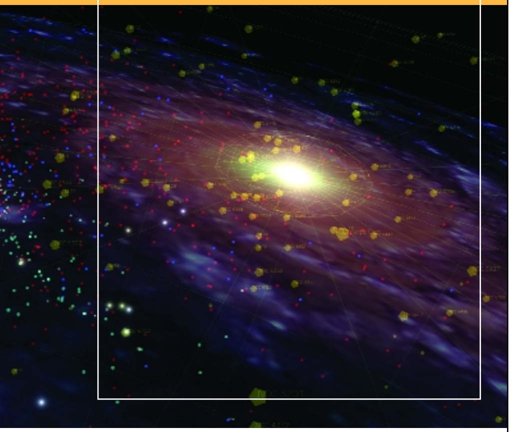


key concepts and orientation

come prepared !

The Space Show at the Hayden Planetarium at the Rose Center for Earth and Space uses cutting-edge technology to communicate cutting-edge science. A high-definition playback and production system projects video on the theater's 67-foot-wide dome, and every seat has an amazing view. It is an "immersive environment" in which you feel as if you are participating in the action that is taking place on screen. The journey you are about to embark on may seem like science fiction, but it is all based on scientific theory and data.

If students feel dizzy during the show, they should simply close their eyes and let the feeling pass. Please encourage your students to remain as quiet as possible during the show.



Investigating the possibility of life elsewhere in the universe demands an interdisciplinary approach. The Space Show encompasses the Physical, Earth and Planetary, and Life sciences. *The Search for Life: Are We Alone?* draws on perspectives from each of these scientific disciplines to consider where extraterrestrial life might exist, and in what form.

PHYSICAL SCIENCE

There appears to be a staggering number of possible planets outside our solar system.

- **Stars** are enormous spheres of hot gas that produce light and energy through nuclear reactions in their cores. Many stars may have **planets**, or large bodies that **revolve** (orbit) around them, held in orbit by their parent star's **gravity** – an attractive force between two bodies due to their masses.
- Our **solar system** consists of the Sun (a star), the planets, asteroids, and other bodies under the influence of the Sun's gravity.
- Stars reside in **galaxies**, that is, collections of hundreds of billions of stars revolving around a common center. All the stars in our sky, including the Sun, are part of the Milky Way galaxy.
- The first **exoplanet**, a planet orbiting a star other than our Sun, was discovered in 1995. Exoplanets provide possible habitats for extraterrestrial life. Some may orbit at just the right distance from their star to retain an atmosphere with temperatures and pressure that permit liquid water to exist. Exoplanets may also have **moons**, or natural satellites, on which conditions suitable for life may exist.
- Astronomers searched for and discovered exoplanets by observing that some stars exhibit a tiny wobbling in their motion. This wobbling is caused by the gravitational influence of the exoplanets on the star. Scientists obtained this data by studying the **light**, or electromagnetic waves, emitted by the star.
- New York State Science Standards covered:
  - The Earth and celestial phenomena can be described by the principles of relative motion and perspective.
  - Observe and describe the transmission of various forms of energy.

EARTH AND PLANETARY SCIENCE

The same process that formed Earth formed other worlds.

- Two processes were involved in the Earth's formation: condensation and accretion. **Condensation** occurs when gas cools and changes to liquid. The liquid molecules stick to dust grains and form solid particles. **Accretion** takes place when dust-sized or larger particles clump together to form increasingly massive objects.
- All life as we know it needs liquid water to survive, so good places to look for life in our solar system are places where we may find water.
- Liquid water can only exist on the surface of worlds not too close or too far from a star – too close and water evaporates, too far and water freezes.
- Water cannot exist in liquid form on the surface of Mars for an extended period of time. However, water may exist in liquid form within the Martian crust. Liquid water may also exist under the frozen surface of Europa, a moon of Jupiter.
- New York State Science Standards covered:
  - Energy and matter interact through forces that result in changes in motion.
  - Describe current theories about the origin of the universe and solar system.

LIFE SCIENCE

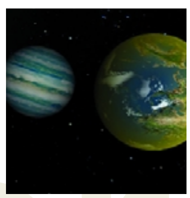
Life is tougher than we thought.

- Microbial life has existed on Earth longer than animal and plant life. It is the most common type of life on Earth.
- Extraterrestrial life may likely be microscopic.
- Known living organisms require liquid water and a source of energy.
- Life survives in environments in which humans would not be able to exist.
- The evolution of terrestrial life is intimately connected to the evolution of Earth.
- New York State Science Standards covered:
  - Living things are both similar to and different from each other and nonliving things.
  - Individual organisms and species change over time.
  - Organisms maintain a dynamic equilibrium that sustains life.

background

The investigation of life on other worlds embraces concepts drawn from the Physical, Earth and Planetary, and Life sciences. What is life? What are the requirements for life? How do living things survive? What kinds of environments – on Earth or elsewhere – are suitable for life? Where in the universe should we look for life? *The Search for Life: Are We Alone?* invites viewers to ask these questions and begin to formulate answers. Presented below is background on some significant topics from the Space Show.

PHYSICAL SCIENCE

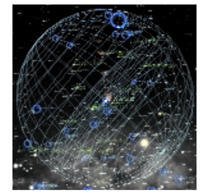


Detection of Exoplanets

Until 1995, scientists had speculated about the existence of exoplanets, but had not discovered any. Now astronomers are finding them at the rate of one per month, which suggests that exoplanets are quite common.

Exoplanets are too small and faint to be observed directly, so astronomers look instead for their effect on the motion of the stars they orbit. All objects with mass exert a gravitational force on each other, so not only does a star keep a planet in orbit, but a planet also pulls on its parent star. When we detect a planet orbiting a star, the exoplanet sometimes pulls the star slightly toward us, sometimes slightly away from us. Astronomers can detect this "wobble" by studying the light from the star. Thus far, the exoplanets discovered are giants (at least the size of Jupiter). Better technology may enable us to detect planets and moons of sizes approximating Earth or Europa.

Earth's Radio Emissions

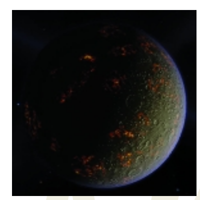


The expanding sphere of our civilization's radio waves has already reached many of the exoplanets we have discovered. If intelligent life exists on these worlds, our signals could be detected there.

All electromagnetic radiation, which includes light, radio, television, and radar waves, possesses certain characteristics. It travels at the speed of light, 300,000 kilometers or 186,000 miles per second, along a linear path. A radiation source emitting in all directions creates a "bubble" of radiation spreading outward at the speed of light. Several decades of radio emissions from Earth have created just such a bubble – expanding into space and washing over many exoplanets.

Distances to other stars, and their planets, are tremendous. To make the numbers easier to manage, astronomers use light years. A light year is the distance light travels in one year, about 9.5 trillion kilometers (5.9 trillion miles). The distance to the brightest star, Sirius, is nine light years. In other words, the light from Sirius reaching us today left that star nine years ago.

EARTH AND PLANETARY SCIENCE



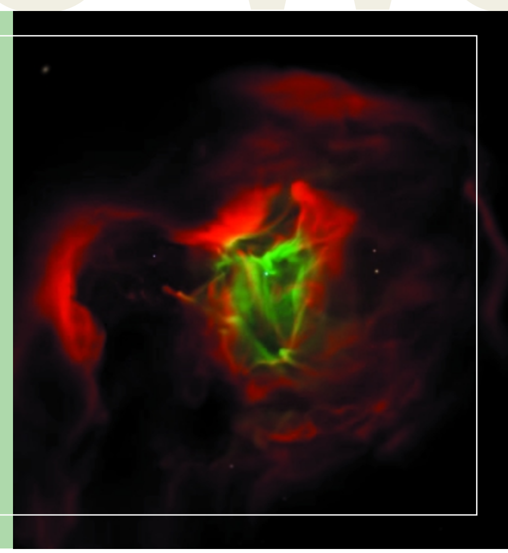
Solar System and Earth Formation

Dense regions of interstellar clouds can collapse, becoming denser and hotter and possibly forming stars and planetary systems.

Earth and the rest of the solar system began as a rotating cloud of hydrogen and helium, with trace amounts of heavier elements, dust, and ice grains. Gravity collapsed the cloud inward. As the cloud shrank, it began to spin faster and flattened into a disk with a central bulge. Planets would eventually form in the disk.

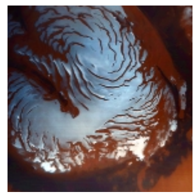
before your visit

- Students may have many ideas about extraterrestrial life. Some concepts to address include what life is, where and how to look for extraterrestrial life, how it might look, and how we might communicate with it. Conduct a poll of students' opinions regarding these concepts. Post their ideas in the classroom for further discussion after their visit.
- Have students brainstorm what life is. Place several numbered items on a table. Include some items clearly living and some not. Have students categorize each item as living or nonliving, giving their reasons. List on the board characteristics that all living things possess.
- Ask what living things need to survive. List student suggestions. Then have students choose living things from within the classroom and test if these things have these needs. Add to the list as needed.
- To demonstrate how exoplanets are detected by the "wobble method," mark an X on the floor. Then join hands with a student smaller than you and spin with the X in between the two of you. Most students will note that the student is revolving around you (possibly even with you on the X), but acute observers may notice that you are also describing a slight circle – the wobble.
- Review all vocabulary in bold.



Collisions in the bulge raised its temperature. When the central temperature became high enough to fuse the hydrogen in the bulge, the Sun ignited. Meanwhile, temperatures in the disk away from the Sun were cool enough to allow heavier elements and compounds such as iron and silicates to condense into solids. These particles in the disk began to accrete, forming small planet-like bodies called **planetesimals**, which then merged together to form larger bodies, culminating in Earth and the other bodies of the solar system. Our current Earth is the result of 4.6 billion years of planetary evolution from the time of its formation.

Comparative Planetology

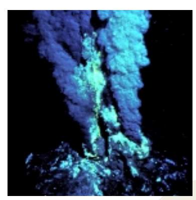


Mars was probably more like our own watery blue planet in the past, but now its surface is a barren desert.

Both Earth and Mars orbit at a distance from the Sun at which water can exist as a liquid. However, the more massive Earth is better able to retain its atmosphere than the less massive Mars. Earth's greater gravitational pull prevents heavier molecules such as nitrogen and oxygen from escaping its atmosphere. Thus, Earth's atmosphere is relatively dense, making its temperature and pressure high enough to support liquid water. The present Martian atmosphere is less dense, and thus its atmospheric pressure and atmosphere are too low for liquid water to exist stably on the surface. Data returned from the Mars *Odyssey* spacecraft indicates that huge amounts of water ice lie within the upper regions of soil around the Martian South Pole (see photo at right). This finding supports the possibility of life existing on Mars – not on its surface, but beneath it.

LIFE SCIENCE

Life Fills Every Niche



Earth's ocean floor seems to be as alien as another planet, yet life exists there.

Basically, something is alive if it carries on life processes with the aim of sustaining itself and its species: A living thing obtains energy, responds to its environment, grows, and reproduces. The information on how to carry on life processes is encoded in DNA (deoxyribonucleic acid) found in fundamental units called cells. Scientists know that life can thrive even in the most inhospitable environments, such as around "black smokers" – sulfide chimneys formed near hydrothermal vents on the sea floor. (Hydrothermal vents were discovered in 1977. In 1998, the Museum mounted an expedition to collect sulfide chimneys – now on display in the Hall of Planet Earth.) Certain types of microbes, which form the food-chain base, convert energy from the hot, mineral-rich hydrothermal fluids to food as it mixes with seawater. Microbes that live below Earth's surface obtain their energy from Earth's interior, rather than from the Sun. These microbes may be the most common life form on Earth. Microscopic organisms arose on Earth much earlier than plants and animals and thrive in places where plants and animals cannot survive. Hence, it is reasonable to hypothesize that microbial life could exist in similar, seemingly hostile environments beyond Earth.

Does All Life Look Alike?

Could there be living forms on other worlds that don't need or can't stand water, but instead need something else?

We have seen that life is resilient. But what forms might life on other worlds take? Although extraterrestrial life in movies and on television often resembles humans, this depiction is limiting. Life may not need to be based on DNA, for example. Or perhaps not even carbon–based, but silicon-based. Some scientists have theorized that liquids other than water, such as ammonia, methane, and ethane, could possibly sustain life on other planets. These life forms, however, would be different chemically from those on Earth. Thus, the criteria used to search for life on other worlds should reflect the understanding that our conception of life is based on a single example – the life that arose here on Earth.

while you're at the museum

In addition to the Space Show, the Museum provides other opportunities for students to reinforce, enrich, and extend their knowledge.

Rose Center

- In **Scales of the Universe**, students compare models of various physical structures in the universe, from superclusters of galaxies to subatomic particles to the size of the Hayden Planetarium Sphere. Where do life forms fit on this scale? How do humans compare in size to other forms referenced along the Scales of the Universe?
- As students walk down the **Cosmic Pathway**, they can gain a sense of the universe's history, from its birth 13 billion years ago to the present day. They should note that animal life is a recent entry onto the stage and that the span of human history is brief when compared with that of the universe.
- In the **Hall of Planet Earth** students can observe dramatic black smoker sulfide structures and images of life forms that inhabit the surrounding area, including a video of the sulfide chimneys at the ocean floor. Students can compare the energy source of this ecosystem – Earth's internal heat – with that of the Sun.

Hall of Biodiversity

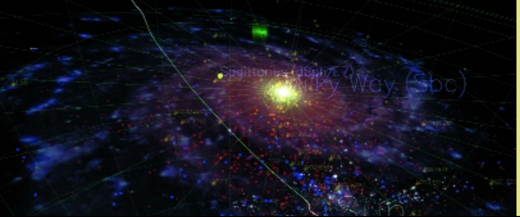
- This Hall offers many opportunities to investigate the conditions life requires for survival. It also shows the immense diversity of life forms that evolved as organisms adapted to changing conditions on the planet. Invite students to compile a list of various characteristics that life forms have developed in order to survive.

The Dinosaur Halls

- The Halls of **Saurischian Dinosaurs** and **Ornithischian Dinosaurs** help students trace the evolution and history of the dinosaurs. Ask students to identify similarities among the dinosaurs in each hall and to infer what these animals needed to survive. Students should include any adaptations that they notice.

The Cultural Halls

- To learn how other people think about the creation of Earth, the universe, and the cosmos, visit the **Hall of Mexico and Central America**, Students may observe the Aztec Stone of the Sun, which represents the Sun as the source of all life. They may also observe evidence of the calendrical, mathematical, and astronomical expertise of the Maya. In the **Hall of South American Peoples** students will find information on native Amonzonia mythology connected with the constellations.



back in the classroom

Physical Science

- Poll students' ideas about extraterrestrial life as you did in the Before Your Visit section. Then refer students to the poll taken before their visit. Have they changed their views? In what ways? Students can chart their opinions before and after their visit to the Museum.
- How many worlds might sustain life? Use the Drake Equation formula to estimate the number of Earth-like worlds in the Milky Way. Visit http://www.astronomy.com/Content/Dynamic/Articles/000/000/000/937mkdgp.asp for an interactive Drake Equation tool.
- Compare the speed of light with the speed of sound by having students list the times they saw something before they heard it. (Possible answers include lightning and thunder, or seeing a baseball hit before hearing the crack of the bat.)

Earth and Planetary Science

- Have students discuss the formation of the Earth. What factors make a world suitable for life? Where in our solar system might we look for life?
- Have students discuss what they saw as they walked down the Cosmic Pathway. What scale model did they find the most interesting in the Scale of the Universe display? Have students create a "Scale of the School" in which students compare the size of different objects around the school (erasers, pets, classrooms, teachers, the entire building, etc.) to themselves. More advanced students can make models or draw scaled diagrams of their comparisons.

Life Science

- To illustrate the difficulties inherent in searching for extraterrestrial life, do the following demonstration or make setups for groups of four students. Label each of three clear plastic glasses #1, #2, and #3. Into each glass, place 1 teaspoon sugar and 3 tablespoons sand. Into Glass #1 add nothing; into Glass #2 add 1 heaping teaspoon of yeast; into Glass #3 add 1 crushed antacid tablet. Ask students to make observations by touching or smelling, not tasting. Now carefully pour just enough hot water into each cup to cover each sample. Have students record their observations (#1 no activity; #2 release of bubbles after about five minutes; #3 immediate fizzing). As a class, discuss all results and conclusions. Which of these cups gave evidence for life? How could you tell? Reveal the contents of each jar. How could you show that the yeast in #2 is alive and the antacid tablet in #3 is not? For example, what does the yeast do that the antacid does not? What kinds of follow-up tests might you devise to give you the data necessary to support your answer? Compare the yeast and antacid the next day. Is there evidence of growth? Have students extrapolate to the search for extraterrestrial life.

Related Web Sites:

http://www.amnh.org/rose/mars/ch5img.html
This Web site explores the question of life on Mars.
http://www.amnh.org/rose/hope/index.htm
The Web site for the Hall of Planet Earth.
http://www.amnh.org/nationalcenter/expeditions/blacksmokers/
This Web site chronicles the expedition by Museum scientists to collect black smoker sulfide chimneys.
http://astrobulletin.amnh.org/
Review the American Museum of Natural History's latest feature stories about astronomy.

REFERENCES

Conselice, Christopher J. "Astrobiology: The New Astronomy," *Mercury*, May/June 2002, p. 9.

Cowen, R. "Planetary System in the Making?" *Science News*, June 22, 2002, pp. 388-389.

DeGrasse Tyson, Neil. *Universe Down to Earth*, Columbia University Press: New York, 1994.

Ferris, Timothy. *Life Beyond Earth*, Simon & Schuster: New York, 2001.

Lemonick, Michael D. and Andrea Dorfman. "How Life Began," *Time Magazine*, July 29, 2002.

Long, Michael E. "Surviving in Space," *National Geographic*, January 2001, pp. 6-29.

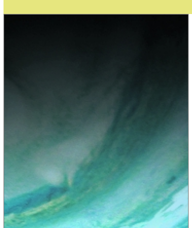
Mercury, March/April 1999, Special Issue on Extraterrestrial Life.

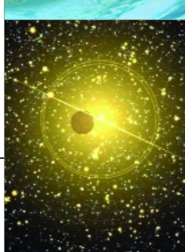
Naeye, Robert. "Opening the New-Planet Floodgates," *Astronomy*, September 2002, pp. 20, 22.

Reed, Christina. "Revisiting the First Hydrothermal Vents," *Geotimes*, July 2002, p. 7.

Soter, Stephen and Neil deGrasse Tyson, eds. *Cosmic Horizons: Astronomy at the Cutting Edge*: American Museum of Natural History/The New Press, New York, 2001.

Svitil, Kathy A. "Field Guide to the New Planets," *Discover*, March 2000, pp. 48-55.





Credits:

The Search for Life: Are We Alone? was developed by the **American Museum of Natural History** in collaboration with the **National Aeronautics and Space Administration (NASA)**, and is made possible through the generous support of **Swiss Re**.

This guide was produced with support from the **The Horace W. Goldsmith Foundation**.

This guide was developed by the Education Department and the National Center for Science Literacy, Education, and Technology.

Project Team: Paisley Gregg, Rachel Connolly, Ryan Wyatt, Caroline Nobel, Rosamond Kinzler, Adriana Aquino, Eric Hamilton, Sharon Simpson, and Donna Sethi.

Written by: William L. Siletti

Thanks to: Michael M. Shara and Anthony Braun

Designed by: Amanda Kavanagh, Ark Design

American Museum of Natural History