LIFE IN ICY PLACES

LESSON DIRECTORY

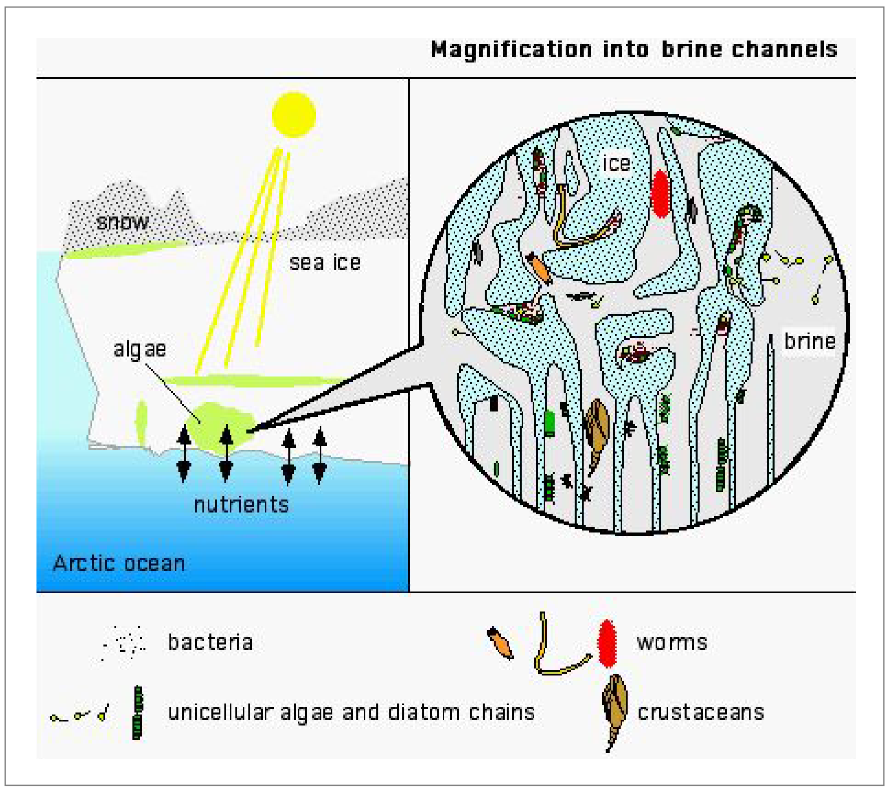
PHOTO GALLERY

This lesson develops pre-cursor understanding about the field of astrobiology, the study of life in the universe and explores how ice can harbor life and preserve evidence of life.

SCIENCE & LITERATURE

Ice plays a significant role in the field of astrobiology, the study of life in the universe. With the discovery that life can flourish in extreme environments, such as ice, scientists have expanded their search of where to look for conditions for life in other places in the Solar System and beyond.

> "Ancient microbes can remain viable through cryopreservation, becoming dormant and then resuming metabolic activity upon thawing after being frozen in glacial ice or permafrost for thousands to millions of years."
>
> — Richard Hoover,
> Astrobiologist at NASA's
> Marshal Space Flight Center



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CONCEPT OVERVIEW

This lesson develops precursor understanding about the field of astrobiology, the study of life in the universe and explores how ice can harbor life and preserve evidence of life.

Concepts:

- Astrobiology
- Extremophiles
- Microbes

This Lesson Provides a Concrete Experience of:

1. How astrobiologists look for evidence of life in icy conditions.
2. Evidence of effects of freezing temperatures on microbial activity.

This lesson connects these experiences to conceptual understanding of how some forms of life can exist in or near icy conditions.

PRE K–2 CONCEPTS

- Some forms of life can survive in extreme conditions.
- Some forms of life can survive freezing cold conditions.
- Ice can harbor microbial life and can preserve signs of life.
- Microbial life may exist in other icy places in the Solar System.
- *Astrobiology* is the study of life in the universe.

GRADE 3–5 CONCEPTS

- Organisms can survive under extreme environmental conditions such as heat, cold, and radiation.
- The term *extremophiles* describes life that flourishes in extreme environments.
- Some forms of life can extract energy to stay alive and grow in very cold and icy places on Earth.
- Ice can harbor life in a dormant phase and can preserve evidence of life processes (biomarkers).
- Microbial life may exist in other icy places in the Solar System.
- *Astrobiology* is the study of life in the universe.

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LESSON SUMMARY & OBJECTIVES

To survive in extremely cold and icy conditions, living organisms must develop effective strategies to extract energy to stay alive and grow.

By looking at how life copes in very cold conditions, we can learn more about the fundamentals of what life is.

Objective 1: Notice that freezing inactivates microbes.
"Spoiling" is caused by the activity of bacteria, yeasts, and molds that decompose food. We keep food in the refrigerator and the freezer to slow down or stop the decomposing process. When energy-extracting activity is inhibited, microbes enter an inactive, or dormant, phase.

Objective 2: Notice that ice can preserve evidence of life processes.
Glacial ice cores preserve signs of the presence of life and can harbor dormant phases of microbial life.

Objective 3: Notice that scientists have discovered icy places where life exists.
Extremophiles are organisms that survive in extreme conditions. By studying life in extremely cold environment, we expand our thinking about the possibility of life arising in similar conditions in other places in the Solar System.

STANDARDS

BENCHMARKS

5A The Living Environment: Diversity of Life
GRADES K–2, PAGE 102

- Plants and animals have features that help them live in different environments.

5C The Living Environment: Cells
GRADES K–2, PAGE 111

- Most living things need water, food, and air.

GRADES 3–5, PAGE 111

- Some living things consist of a single cell. Like familiar organisms, they need food, water, and air; a way to dispose of waste; and an environment they can live in.

5D The Living Environment: Interdependence of Life
GRADES K–2, PAGE 116

- Living things are found almost everywhere in the world. There are somewhat different kinds in different places.

NSES

Content Standard C Life Science: The characteristics of organisms
GRADES K–4, PAGE 129

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

GRADES 5–8, PAGE 156

- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.

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ESSENTIAL QUESTION

Under what conditions can life exist and sustain itself?

What conditions are necessary for life to exist? What are extreme conditions with respect to life? What have astrobiologists discovered about life in extreme conditions? How does this affect our understanding about life?

ACTIVITY QUESTION

What is the relationship between ice and life?

What enables some forms of microbial life to survive freezing? What strategies do extremophiles use to survive in sub-freezing conditions? How do we detect the presence or past-presence of life in extreme cold? How does ice harbor and/or preserve life?

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BACKGROUND

What is Astrobiology?

Astrobiology is the scientific study of the living universe: its past, present, and future. It starts with investigating life on Earth, the only place where life is known to exist, and extends into the farthest reaches of the cosmos. It ranges in time from the big bang and continues on into the future.

Astrobiology draws information from chemistry, geology, astronomy, planetary science, paleontology, oceanography, physics, biology, mathematics…and emerges with a unique perspective.

Astrobiology covers a diverse range of topics that can be categorized under major questions:

- Where did life come from?
- What is its future?
- Are we alone in the universe?

While these questions have been asked for millennia, rapid advances in the sciences and the ability to travel out into space have set the stage for a novel scientific examination. As any such newborn, Astrobiology is growing and maturing rapidly. Breakthroughs and discoveries are routine. But rather than a description of each new research finding, the definition of Astrobiology must be that of a whole, greater than the sum of its parts. It is a collaborative effort; a new practice that leverages and transcends traditional scientific discipline boundaries to create an innovation in interdisciplinary communication.

Source: NASA Astrobiology Institute http://nai.arc.nasa.gov/astrobio/what_astrobio.cfm

Looking for Life in all Extreme Places

Recent research about life in extreme environments has yielded tremendous rethinking about the boundaries of life and the conditions where life can survive. Within the last decades of the twentieth century, scientists have discovered the presence of microbial life in unimaginable extremes of ice cold and fiery heat.

New definitions have emerged about the boundaries of life and understandings about where life can exist. Heat vents breaking through the surface of deep oceans have been revealed as places where life flourishes. The underside of sea ice has been shown to harbor life.

Extreme is in the mind of the beholder. From our human point of view the roiling sulfurous heat vents deep in the ocean and the frigid layers of ice deep in the Antarctic glaciers are extreme. For the forms of life that have adapted to those niches, those conditions are normal. Astrobiologists seek to understand life's ingenious solutions for selecting survival strategies. The findings of the astrobiologists are transforming our view of the boundaries and capabilities of life. As we explore the Solar System and beyond, we are looking for places, extreme as they may seem, where microbial life might take hold.

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Richard Hoover, Astrobiologist at NASA's Marshal Space Flight Center makes the following three points:

- The microbial extremophiles in the Arctic and Antarctic glaciers and permafrost represent analogues for microbes that may someday be found in the permafrost or ice caps of Mars or on other icy bodies of the Solar System.
- Ancient microbes can remain viable through cryopreservation, becoming dormant and then resuming metabolic activity upon thawing after being frozen in glacial ice or permafrost for thousands to millions of years.
- These ancient cryopreserved microbiota may hold clues to the origin and evolution of life on Earth and the distribution of life in the cosmos.

The discoveries of extremophiles have broadened the thinking about the nature of life and the range of conditions that are necessary for life to exist. This has implications across the curriculum, bridging geology, chemistry, biology, and planetary science—and the creation of the field of astrobiology, the search for life beyond Earth. This also plays into the broader fascination about life out there that also stimulates claims that go beyond what scientific evidence has shown.

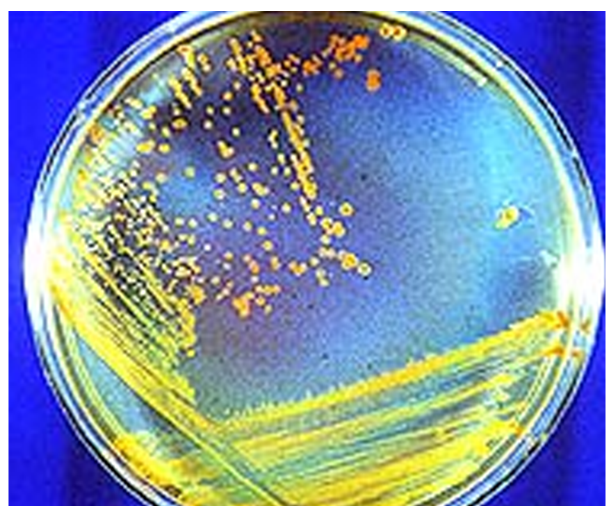
Students need to discern the difference between science and pseudoscience. The distinction is not always very clear, particularly as recent discoveries in astrobiology change our perspectives about the conditions necessary for life.

Hardy Bacteria Could Survive Trip in Space

Microbial life forms that exist in extreme environments are called extremophiles.

Super extremophile, *Deinococcus radiodurans* was discovered in the 1950s. Scientists experimenting with radiation to kill bacteria and preserve food for long periods found that something kept growing back after treatment.

Scientists hypothesize that this hardy strain of bacteria could survive the extremes of space.



Source:
http://science.nasa.gov/newhome/headlines/ast14dec99_1.htm

Can Living Cells Survive Freezing Conditions?

Generally, living cells do not survive freezing. Most often, the expansion that takes place as water freezes breaks cellular walls irreparably. Life can live near ice, at surfaces and edges in meltwater, or in pockets of liquid water within solid ice, but usually life processes are slowed or stopped by ice itself.

Nevertheless, some forms of microbial organisms adapt to freezing conditions and can find a harbor within ice, suspending their bioactivity indefinitely, and then when conditions melt the ice, the organism springs back into life, even after thousands of years. Scientists in the field of astrobiology investigate extremophiles on Earth, anticipating that conditions for life may be present beyond Earth in solar systems around other stars.

How do bacteria survive in icy places?

Multicellular organisms, like mammals, birds, and human beings, cannot endure being frozen, because freezing disrupts their cells, as crystals of ice penetrate the delicate cell membranes and cause them to break open and leak their contents. So how do single-celled organisms like bacteria survive in icy places?

Some bacteria that derive nourishment from plants actually accelerate the formation of frost that breaks down the plants cells. Bacteria have also been found to live in clouds and to travel long distances in the dust and droplets that make up the cloud, and eventually return the ground as falling rain or snow.

In a population of microbes that flourish in the icy cold, many bacteria live as a colony. The freezing and leaking of some individual cells release sugars and proteins that protect the other microbes from freezing. While individuals die, the population as a whole, and the species, survives. How microbes remain viable is not fully understood.

There is some evidence that particles of soil and sand atop the Antarctic ice may absorb solar radiation just enough to melt down through the ice, creating pockets where water may form, providing a niche for bacteria.

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What's the importance of Lake Vostok in Antarctica?

Satellite radar studies have established that an exceptionally large lake, roughly the size of Lake Ontario, exists under more than 4 km (2.4 miles) of ice sheet. Lake Vostok is the largest of over 70 sub-glacial lakes in Antarctica. Estimates of the age of Lake Vostok range from hundreds of thousands to millions of years.

Within ice that covers a salty, liquid Antarctic lake scientists have found and revived microbes that were at least 2,800 years old and possibly as old as 200,000 years. Scientists have discovered teeming microbe colonies that use sunlight filtering through the ice to activate and sustain life when the South Pole tilts toward the sun each year. In fact, the researchers have found surprisingly diverse microorganisms throughout the frozen lake water, supported by the key life-sustaining processes photosynthesis and atmospheric nitrogen fixation. Previously, most investigators thought little or no biological activity could occur within the ice itself.

These discoveries point to probable life within the underground lake and suggest the sort of icy ecosystem that might exist on Mars. NASA astrobiologists also see an analogy between the environment of Lake Vostok and a possible sea environment beneath the ice sheet on Jupiter's Europa.

ACT OUT THE SCIENCE

Whole Group Mime Activity: *Movement Integration Mediating Experience*

This science story plays on the fascinating microbial strategy of individual bacteria releasing sugars and proteins that protect the colony population and leads to species survival. In a sense our own multicellular existence depends on a process of cellular renewal at the boundary of our being. Our outermost layer of skin, hair, nails, are protein structures of cells that shed, individually no longer alive. Our being is a mix of the active living cells and this protective outer coat.

A Psychrophilic Journey: The science story of psychrophilic (cold-loving) bacteria

Narrative	Movement	Concept
There was once a pair of mighty microbes so tiny, you could only see them if you were looking through a microscope. These microbes were ice-loving germs, each one a psychrophilic bacterium. Well, to be generally specific, these bacterium twins have hundreds of ice-loving cousins with names like: Pseudomonas (soo-dó-mo-nas), Halomonas (hal-ló-mo-nas), Hyphomonas (hy-fó-mo-nas), Sphingomonas (sfin-gó-mo-nas), Pseudoalteromonas (soo-do-al-ter-ró-mo-nas), Psychrobacter (sy-kro-bác-ter), Arthrobacter (ar-thro-bác-ter), Planococcus (plan-o-cók-us), and Halobacillus (hal-o-ba-cíl-lus).	Invite all students to participate with partners. Get everyone moving together, showing gestures of being cold, but enjoying it. Have fun with the word psychrophilic, which means cold-loving. Have fun with these genus names, more as sounds and rhythms as students wiggle around like bacteria.	Microbes, germs, microorganisms—small microscopic one-celled forms of life. Bacterium, singular; bacteria, plural. Psychrophilic, meaning cold-loving, referring to species that actively thrive sub-freezing temperatures of ~ 0° to –10° C and survive by becoming dormant encased as spores in temperatures way below freezing.
One cold, shivery day, these two little psychrophilic bacteria were feeling hungry on a dewy leaf of grass. The grass was very tough to munch on. The bacteria didn't have big teeth like a cow or a sheep or a goat or a horse. But they were very clever. Conditions were just right so they could chemically coax the dew to freeze into frost, and the ice crystals crunched the outer leaf cells just enough for the cold-loving bacterium twins to have a feast.	Have partners mime being on a leaf of grass, show being hungry. Move arms to transform the wateriness of the dew toward the iciness of frost. Munch on the leaf.	Some species of bacteria are capable of manipulating near-freezing dew to freeze into frost. The frost breaks down the leaf cells, making it accessible as to the bacteria to obtain nutrients.
Then they split into several more, now there were three and four!	Partners join up to become a foursome. *(Alternatively, tell the whole story with tow students up to this point and then add other students.)*	Generally, the rapid reproduction of bacteria.
All of a sudden, a big storm came in, with wind and snow, and the four bacteria friends were swept into the sky along with dust and debris, up, up, up into the clouds. (continued)	Wild stormy motions, that result in floating cloud motions.	Scientists have discovered that bacteria not only travel in the clouds, but can also live and reproduce during their journeys in the clouds.

Narrative	Movement	Concept
They happened to find a cave in a particle of silicate dust, where they huddled up for the long wild ride.		
Since they loved the cold, they were having a wonderful time. The bacteria had time to each slow themselves down and form an outer coat, a spore case, to survive the bitterly cold journey.	Allow students to invent ways to exude the formation of a relatively rigid outer coat.	Generally, many species of bacteria are capable of forming spore cases around themselves as environmental conditions become critical.
They traveled for hundreds and thousands of miles until they ended up over Antarctica. As the cloud got colder a snowflake began to form around the speck of dust and the bacteria spores.	Let students "float" about and then become the center of a snowflake that drifts to the surface.	Bacteria can become the nucleating particles for snow formation in the clouds.
Along with millions and billions of other snowflakes, they drifted down, down, down, onto to the top of a beautifully cold glacier in the middle of an Antarctic storm. They were buried under mounds of snow and merged into firn.	Let students drift slow-motion, to become seated on the floor.	A quick version of what really takes many seasons of snow to accumulate and form layers of ice.
Then one summery day, when the sun shined for months, not exactly warmly, but just enough to warm a speck of sandy soil that had blown onto the glacier. The speck melted down into the ice, right next to the speck where the bacteria friends were hiding and waiting just for such a moment to spring back to psychrophilic life.	Let students use their hands to show the sunlight, the sand, the warming of the particle and the melting of the particle down into the ice. Let the student stand slowly.	The sunlight strikes the polar region indirectly, just enough to warm some particles on the surface to burrow down 7–8 meters into the ice.
Oh, they loved the cold and feasted on the nutrients brought down by the speck, and they split and split some more, until they formed a whole colony of bacteria, thousands of bacteria all helping each other.	Let the whole group work collaboratively together.	In cold environments, colonies have greater potential for survival.

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Narrative	Movement	Concept
Then a marvelous moment occurred a bacterium found a skinny brook of meltwater gliding between the ice grains. All the bacteria leaped in and like a watery slide, they slid this way and that way, deeper and deeper into the ice.	Let students create movements like a water slide.	Deep in glacial ice, trickles sometimes form at the boundaries of ice grains.
But then it got really cold. Oh, they loved the cold all right, but if it got really, really cold, they huddled together. They all began to transform themselves to spores. The outer group, pressured by the grains of ice, released proteins and sugars to protect the whole colony—and they stayed like this for hundreds, even thousands of years.	Let the outer group of students create a protective coat, while the inner group huddles.	While this is still not fully understood, the outer bacteria sacrifice themselves, allowing their constituent materials to affect the surrounding ice, in effect protecting the whole colony, giving the inner group the time to repair damage and to reproduce.
Then one day a band of psychrophilic astrobiologists drilled down into the ice and in bringing up the ice-core, they also brought up our colony of bacteria. They flew the ice-core back to the astrobiology lab, and to their surprise, the scientists found that not just one, but that over a hundred cold-loving species of bacteria had found a way to thrive and survive in the extremely icy place, deep in the glacier above the frozen lakes of Antarctica! So that's the science story as far as we know of the ice-loving bacteria, the ice-loving astrobiologists and their most psychrophilic journey!	Let students transform themselves from being bacteria to being the team of astrobiologists making this discovery, and completing the psychrophilic journey.	Scientists discovered the phenomenon of ice-loving or psychrophilic bacteria in the ice-cores in both the Arctic and the Antarctic. Life is everywhere it can be.

Small Group Mime Activity: *Movement Integration Mediating Experience*
Invite students to form small groups (about three to five students), create their own imaginative mime and narrated story about a psychrophilic journey, the story of how cold-loving bacteria thrive and survive in freezing cold places. Encourage students to act out a sequence that results in understanding about the nature of life in icy places.

MATERIALS

The activity enables students to collect evidence about the observable effects of freezing on microbial forms of life.

For All Lessons, to Record Reflections, Observations, Calculations, etc.

- Science Notebooks: writing and drawing utensils.

For food freezing exploration

- A collection of different foods that spoil rapidly, such as:
  - Fruit, such as oranges, grapes, strawberries.
  - Vegetables, such as spinach, tomatoes.
- Access to refrigerator and freezer.
- Thermometers (to measure temperature. in room, in refrigerator, and in freezer).
- Sterile Petri dishes, or similar containers & resealable plastic bag.
- Sterile Petri dishes containing nutrient agar.
- Organic materials (bits of food).
- Water.
- Gallery of images and videos of astrobiologists at work in the field.
- Gallery of images of microbial life and effects of microbial activity.
- Gallery of images of extreme environments.
- Resources about extremophiles, biomarkers, biosignatures.
- Access to contact with a microbiologist or astrobiologists.

Access to contact with a microbiologist or astrobiologists is available through the NASA Astrobiology Institute:

- Building Bridges with Astrobiology Researchers: http://nai.arc.nasa.gov/teachers/teacher_topics.cfm?ID=1
- Ask an Astrobiologist: http://nai.arc.nasa.gov/astrobio/index.cfm

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DEMONSTRATION

Through discussion, guide students to express ideas about life and the conditions needed for life to exist, probing especially to draw out their understandings resulting from their personal experience. Show images and videos of astrobiologists at work in the field, connected to their discoveries about life in extreme conditions, especially icy conditions.

PRE K–2

- Invite students to share their own experiences of finding living things in unusual places. For example: Roly-polys under a rock? Spiders in a shed?
- Guide discussion toward inquiry about the notion of *extreme conditions*.
- List the conditions that students say are extreme.
- Build from the student generated list to guide discussion of the range of extreme environments scientists are exploring.
- Ask students to consider how life copes with those conditions.
- Invite students to draw a picture of life in an extreme environment.

3–5

- Invite students to consider the range of conditions for life to exist.
- Guide discussion by asking students to share their own ideas about and experiences of life in unusual and extreme conditions.
- Use these experiences to move toward a discussion of a working definition of *extreme* and *extremophiles* in this situation.
- Invite students to draw, write, and share their own experiences of finding living things in unusual places.

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MAIN ACTIVITY

This activity introduces the notion that ice preserves evidence of life and can harbor some forms of life that suspend and then revive their bioactivity.

PREPARATION

Select a familiar group of samples of food that usually tend to spoil rapidly.

- Fruit, such as oranges, grapes, strawberries.
- Vegetables, such as spinach, tomatoes.

Collect enough Petri dishes to enable each student to have a participatory role (individually or in context of small groups).

Set up astrobiology exploratory zones, which display images of extreme environments and the diversity of extremophile species, especially magnified images of bacteria.

Explain how to handle samples and Petri dishes carefully.

TEACHING TIPS

Explore

Encourage students to probe why we refrigerate and freeze food. Engage student's experiences of spoiled food, sour milk, and consequences of not recognizing spoilage. Encourage students to consider their own experience of cold weather and how to enjoy the cold.

Diagnose

Listen to student ideas about life. What are the conditions needed for life to exist? What kind of evidence do we need to establish the presence of life? How does extreme cold affect biological processes? Listen also to students' understandings about microbial life, germs, their benefits and threat to human life.

Design

Encourage students to work as collaborative teams to pose questions and then to design their ice and life experiment. Help them arrange an interview of a working scientist, in person, over the phone, or via email.

Discuss

Discuss the implications of the experiment with respect to life in extreme environments on Earth and in the Solar System. After speaking directly with a scientist, ideas for further exploration are likely to arise.

Use

This activity applies collaborative research techniques, how to work together to gather information, design an experiment, and pose questions to a scientist, skills that can be applied in other investigations as well.

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WARM-UP AND PRE-ASSESSMENT

Present a sample of something tasty and delightful that has been frozen.

> *Likely reaction: Yum, but we have to wait until it thaws out.*

Present a sample of something tasty and delightful that has been refrigerated.

> *Likely reaction: Yum, we could eat this right now.*

Present a sample of something that once was tasty and delightful, but is now spoiled.

> *Likely reaction: Yuck, this looks awful!*

Follow up with a guided discussion, punctuated by showing related slides or by referring to astrobiology zones. Keep track of and record student ideas.

Evoke comments regarding the reaction to the different samples, using guiding questions such as:

- What distinguishes each of the three samples?
- What caused the changes to the food that spoiled?
- Why do we refrigerate and freeze food?
- Why do you think that we keep food in the refrigerator or the freezer?
- What do you think happens to food that is left out too long?
- What actually happens when food spoils? What causes food to spoil?

Guide the discussion toward the understanding that microscopic forms of life are responsible for the decomposition that they observe. Use the discussion to probe how familiar students are with an understanding of “germs.” Introduce and use the term *microbe* to refer to the whole class of microscopic life forms: bacteria, viruses, fungi, and protozoa.

PROCEDURES

PART 1.

Ice & Life Experimental Activity

Spoil the food and Spare the child

The purpose of this activity is to give students a taste of astrobiology fieldwork, comparing microbial activity in three temperature conditions: room temperature, refrigerated, and frozen.

Teacher-prepared control dishes (optional): for young children in the classroom, working with nutrient agar is sometimes complicated. Nevertheless, if possible, it would be good to have two kinds control dishes:

1. Sterile Petri dishes with nutrient agar NOT EXPOSED to the air; (should remain clear of microbial growth).
2. Sterile Petri dishes with nutrient agar EXPOSED to the air; (should show evidence of microbial growth, bacteria, molds, fungi).

For each small group, or for each exploratory zone:

Prepare several initially sterile Petri dishes, each with a bit of water and a bit of fresh organic material (for example, a piece of lettuce, spinach, grapes, a piece of banana, or other bit of food, something that usually spoils rapidly), expose to air, and then cover. Place one sample in a location at room temperature, one in the refrigerator, and one in the freezer.

Optional: for handling ease, place each dish inside a resealable plastic bag, to avoid the likelihood of the cover coming off as students handle Petri dishes for observation.

Examine each dish daily over the period of several days, or before and after the weekend. Record observations. (Bacteria need about four hours to adapt to a new environment before they begin rapid growth. Evidence of spoilage may happen in several hours.)

- What differences do your observe?
- How do you explain your observations?

As a follow-up, leave the previously frozen sample out at room temperature for several days. Ask questions such as:

- What happens?
- Does spoilage occur? If it does, how do you explain it?
- How do you explain your observations?

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What can we conclude about the effect of freezing on bioactivity?

Astrobiology Note: Astrobiologists freeze microbial cultures for long-term storage of specimens. Freezing slows bioactivity down, but with thawing, the microbes activate again. Frozen specimens in the field can reactivate, too!

Observations and measurements connected to ice and life experiment:

Observations	Measurements
a. Sample at room temperature shows evidence of decomposition	• Daily observations: draw, describe, photograph
b. Sample in refrigerator shows little evidence of decomposition	• Daily observations: draw, describe, photograph
c. Sample in freezer shows virtually no decomposition	• Daily observations: draw, describe, photograph
d. Follow-up: after previously frozen sample is left at room temperature, does evidence of decomposition appear? What does this mean?	• Daily observations: draw, describe, photograph

PART 2.

Exploratory Zones: Life in Icy Places

Assemble a collection of resources in viewing zones around the room: pictures, microscopes and slides, videos, articles that show places where life can exist (sea ice, Antarctic rock outcroppings, deep ocean heat vents, clouds), and recent findings regarding extremophiles in icy environments on Earth.

Invite students to work in small groups to view the collection of materials and to generate questions to pursue in greater detail.

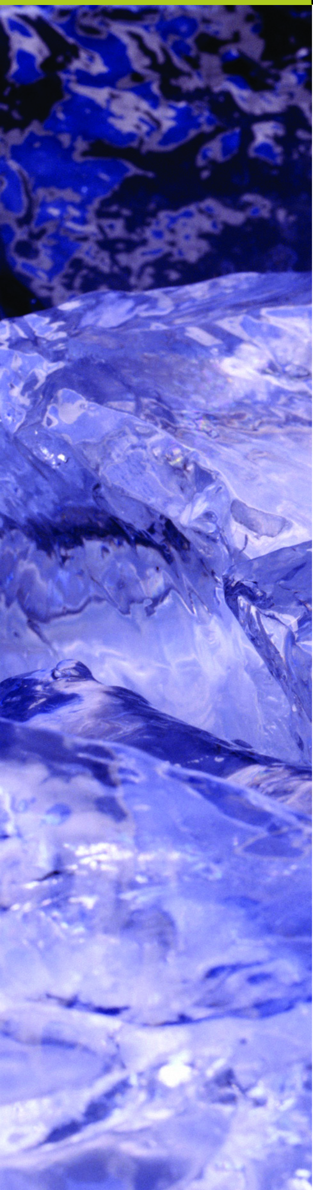
Contact a NASA or local university expert in the field (microbiologist, astrobiologist) to create access for students in a collaborative science learning relationship.

Encourage students to prepare a focused interview, based on specific questions, if they were able to communicate directly with an astrobiologist or microbiologist working in the field.

What have scientists discovered about ice and life?

Research studies connected to ice and life:

Discoveries	Evidence
a. Ice can form around bacteria in the atmosphere	• Cloud chamber experiments • Samples from low-lying clouds
b. Microbes can survive in very cold climates	• Frozen lake & glacial ice cores • Sea Ice, Lake Ice • Ancient ice, once melted, yields culture of microbial life
c. Ice can have occlusions of water where life can exist	• Channels around glacial ice grains • Ice can act to insulate water



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DISCUSSION AND REFLECTION

Does microbial life exist on other planetary bodies in the Solar System?

With new discoveries about life in extreme conditions on Earth, astrobiologists are increasingly open to the possibility of microbial life in other places in the Solar System. For example, here are the lead headlines and first paragraphs from two articles in the New Scientist, a British science magazine:

Acidic clouds of Venus could harbour life

The acidic clouds of Venus could in fact be hiding life. Unlikely as it sounds, the presence of microbes could neatly explain several mysterious observations of the planet's atmosphere.

New Scientist, 10:15 26 September 02

http://www.newscientist.com/news/news.jsp?id=ns99992843

Bacterial explanation for Europa's rosy glow

The red tinge of Europa, one of Jupiter's moons, could be caused by frozen bits of bacteria. Their presence would also help explain Europa's mysterious infrared signal.

New Scientist, 10:34 11 December 01

http://www.newscientist.com/news/news.jsp?id=ns99991647

Lead a discussion among students about the possibilities of life in other places in the Solar System. Guide the students to discern the difference between astrobiology, which is scientific inquiry about life in the universe, and pseudoscience, that projects images of UFOs, aliens, and extraterrestrial beings.

CURRICULUM CONNECTIONS

With the emphasis on microbial life, this lesson connects to social studies and health studies. Infectious diseases caused by microbes such as bacteria and viruses have had major impacts on the lives of people around the world. The pasteurization of milk, for example, protects against the passing of bacterial diseases in milk products. Understanding the role of hygiene is critical in controlling the presence of harmful bacteria and to prevent infection.

Bacteria also play a role in our well being. Bacteria within our digestive system help in the process of breaking down nutrients for our bodies. Managing bacteria for beneficial effects, such as using oil-eating bacteria to clean-up oil spills, has become possible as we grow in our understanding of microbial life.

This lesson also connects to literature. Lead a discussion of how science fiction literature, movies, and video games project imaginative images of life out there. In reality, the life we may first encounter in other places in the Solar System is most likely to be microbial life.

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ASSESSMENT CRITERIA

Exemplary

- Students write and illustrate a personal ice and life experience about life in unusual places and share it dynamically with both a small group and the whole group.
- Students display drawings, constructions, and dynamic kinesthetic models drawn from their science notebooks and web-based research.
- Students identify and extend science questions drawn from direct observation and extended research about ice and life.
- Students explore a rich range of observations about ice and life and relate it to prior shared experiences.
- Students ask a rich and extensive range of questions about ice and life.
- Students extend learning by considering implications of the bioactivity at low temperatures.
- Students relate ideas to whole context of exploring ice in the Solar System.

Emerging

- Students write and illustrate a description of conditions where ice preserves and/or harbors life and share it with both a small group and the whole group.
- Students pose basic science questions drawn from their observations and research of ice and life.
- Students observe examples of life in extreme cold.
- Student display results using a variety of ways to represent examples of ice and life.
- Students ask a rich range of questions about ice and life.
- Students make speculations about possible explanations for ice preserving and/or harboring life.

Formative

- Students recognize that ice preserves life and can harbor life.
- Students identify characteristics of life in extreme cold conditions.
- Students pose science questions drawn out of the context of researching life in extreme cold.

PRINT

RESOURCES

http://science.nasa.gov/headlines/y2000/ast03may_1m.htm
Article about extremophiles and implications for life on Mars

http://www.inel.gov/featurestories/9-99extremes.shtml
Article about extremophiles, Robert Evans, INEEL Research Communications
October 1999

http://www.sciencedaily.com/releases/1998/06/980626083315.htm
Viable extremophiles in ice near Lake Vostok
http://www.macatawa.org/~oias/snowflak.htm
Bacteria may play a role in the Snow Cycle

http://www.awi-bremerhaven.de/Eistour/eisbildung-e.html
The Alfred Wegener Institute: Germany's leading institute for polar research
How Sea Ice Can Harbor Life; Ice algae

http://space.com/scienceastronomy/antarctic_life_021216.html
Article about the implications for life on mars Robert Roy Britt space.com
16 December 2002

http://news.nationalgeographic.com/news/2004/11/1115_041115_antarctic_lakes.html
Article: Does Life Exist in Antarctic Lake Buried Under Miles of Ice? John Roach
National Geographic News,
November 15, 2004

http://www.eng.auburn.edu/~wfgale/usda_course/section0_5_page_2.htm
A very understandable explanation of approaches to store food (irradiation, refrigeration, freezing)

Images

Link to image gallery